REPUBLIC OF THE UNION OF MYANMAR
MINISTRY OF CONSTRUCTION
PUBLIC WORKS

THE PREPARATORY SURVEY FOR THE PROJECT FOR CONSTRUCTION OF BAGO RIVER BRIDGE

FINAL REPORT

AUGUST 2014

JAPAN INTERNATIONAL COOPERATION AGENCY

ALMEC CORPORATION
ORIENTAL CONSULTANTS CO., LTD
NIPPON KOEI CO., LTD.

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N
BHUTAN
INDIA
CHINA
BANGLA DESH
MYANMAR
VIET NAM
Nay Pyi Daw
LAOS
Yangon
THAILAND
CAMBODIA
Dagonmyothit(South)
Thingangyun
Dagonmyothit (Seikkan)
Kywe gu zeik
Existing Yangon-Thanlyin Bridge
Thaketa
BAGO RIVER
Proposed Location of Bago River Bridge
Thanlyin
Nyaung thon bin
Bo gyoke
SCALE
0
1
2 km
Kyaung gon seik gyi
Pa ya gon
PROJECT LOCATION MAP

The Preparatory Survey for
The Project for Construction of Bago River Bridge

Final Report

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List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ADB	Asia Development Bank
ARP	Abbreviated Resettlement Plan
ASEAN	Association of Southeast Asian Nations
B/C	Cost Benefit Ratio
BOD	Biological Oxygen Demand
BOT	Build-Operate-Transfer
BRT	Bus rapid transit
BSW	Bo Aung Kyaw Wharf
CBD	Central business district
CBR	California Bearing Ratio
CDL	Chart Datum Level
CNG	Compressed natural gas
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
CPLAD	City Planning and Land Administration Department
CS	Consultant Service
CT	Contractor
D/D	Detailed Design
DF/R	Final Report
DMH	Department of Meteorology and Hydrology, Ministry of Transport
DWIR	Department of Water Resources and Improvement of River System
DWT	Dead weight tonnage
ECD	Environmental Conservation Department
EIA	Environmental impact assessment
EIRR	Equity internal rate of return
EMP	Environmental Management Plan
E/S	Engineering Service
ESAL	Equivalent Single Axle Loads
FERD	Foreign Economic Relations Department
FHWA	Federal Highway Administration
F/R	Final Report
GAD	General Administration Department
GDP	Gross Domestic Product
GIS	Geographic Information System
GOM	Government of Myanmar
HEC	Hydraulic Engineering Circular
HEC-RAS	Hydrologic Engineering Center – River Analysis System
HHWL	The highest high water level
HWL	High Water Level
IC/R	Inception report
ID, MOAI	Irrigation Department, Ministry of Agriculture and Irrigation
IEE	Initial environmental examination
I/P	Implementation Program
IT/R	Interim Report

ITS	Intelligent Transport Systems
IUCN	International Union for Conservation of Nature
IWT	Inland Water Transport
JICA	Japan International Cooperation Agency
JICAGL	JICA Guideline
JICA-SUDP	Project for Strategic Urban Development Plan of the Greater Yangon
JPY	Japanese Yen
JSHB	Japanese Standard for Highway Bridge
LARAP	Land Acquisition and Resettlement Action Plan
LLWL	Lowest Low Water Level
LOA	Length Overall
MEPE	Myanmar Electric Power Enterprise
MES	Myanmar Engineering Society
MFSL	Myanmar Five Star Line
MGS	Myanmar Geosciences Society
MITT	Myanmar International Terminal Thilawa
MMK	Myanmar Kyats
MN	Myanmar Navy
MNPED	Ministry of National Planning and Economic Development
MOC	Ministry of Construction
MOE	Ministry of Energy
MOECF	Ministry of Environment Conservation and Forestry
MOF	Ministry of Fishery
MOGE	Myanmar Oil and Gas Enterprise
MOH	Ministry of Health
MOHA	Ministry of Home Affairs
MOI	Ministry of Industry
MOT	Ministry of Transport
MPA	Myanmar Port Authority
MPPE	Myanmar Petroleum Product Enterprise
MR	Myanma Railways
MSL	Mean Sea Level
MWL	Mean Water Level
MYT-Plan	The Survey Program for the National Transporation Development Plan in the Republic of the Union of Myanmar
NGO	Non-Governmental Organization
NO2	Nitrogen Dioxides
NPV	Net Present Value
NTU	Unit of Turbidty
ODA	Official Development Assistance
O&M	Operation and Maintenance
PAPRD	Project Appraisal and Program Reporting Department
PAPs	Project Affected Persons
PCD	Pollution and Cleaning Department
PCU	Passenger Car Unit
PD	Planning Department
PG/R	Progress Report
PM	Particulate Matter

PPGD	Playgrounds, Parks and Gardening Department
PVD	Prefabricated Vertical Drain
PW	Public Works
ROW	Right of Way
S/C	Steering Committee
SCF	Standard Conversion Factor
SEZ	Special Economic Zone
SIA	Social Impact Assessment
SLRD	Settlement and Land Record Department
SO2	Sulfer Dioxides
SPT	Standard Penetration Test
STDs	Sexually Transmitted Diseases
SUDP	The Strategic Urban Development Plan of the Greater Yangon, JICA (2013)
TEU	Twenty-foot equivalent units
T-N	Total Nitrogen
T-P	Total Phosphorus
TOD	Transit Oriented Development
TS	Township
TTC	Travel Time Costs
UMRT	Urban Mass Rapid Transit
USD	US Dollar
V/C	Volume to Capacity
VOC	Vehicle Operation Cost
VOT	Value of Time
WB	World Bank
WHO	World Health Organization
YCDC	Yangon City Development Committee
YRDC	Yangon Region Development Committee
YUTRA	Project for Comprehensive Urban Transport Plan of the Greater Yangon

Chapter 1

Introduction

1. Introduction

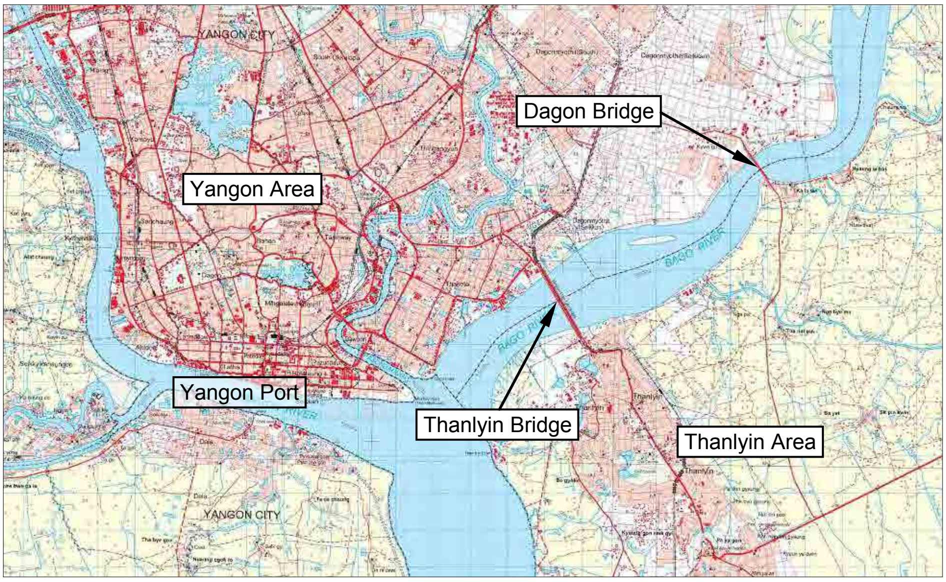
1.1 Project Background

Myanmar is a country of abundant natural resources, and has a great potential to attain rapid economic growth in the coming years. Yangon is the former capital, the main center of Myanmar's economic activities, and the largest city of Myanmar having about 5 million populations, which is 12% of the national population (2010). The Port of Yangon, the largest international port of Myanmar, is located on the left bank of the Yangon River, next to Yangon downtown area.

During the fiscal year of 2010~2011, the scale of the economy of Yangon Region was 23% of the national gross domestic product (GDP). The Myanmar government is now undertaking the fifth five-year plan for 2011~2012 to 2015~2016 fiscal years, which sets a GDP growth target of 6.7% for the 2012~2013 fiscal year. Due to the recent rapid growth of economy, Yangon shows excessive centralization of daily economic activities which generates transport demands that are larger than ever, and which reveals the insufficient capacity of the present transport infrastructure to cope with further economic growth/development.

At the same time, the Greater Yangon Region is expanding outward, including Thanlyin area and Dala area. Both areas are separated from Yangon by the Yangon River and the Bago River, respectively. At the moment, there is no bridge between Yangon and Dala area, and Dala Bridge is proposed to be constructed soon. Between Yangon and Thanlyin area, there are two bridges, namely, Thanlyin Bridge and Dagon Bridge, as shown in Figure 1.1. Thanlyin Bridge, completed in 1993, is a road cum rail bridge. It has a dual 1-lane roadway section. Thanlyin Bridge prohibits heavy vehicle traffic over 32 t. Dagon Bridge, completed in 2007, is a dual 3-lane bridge, and therefore has enough traffic capacity. However, Dagon Bridge is located distant from Yangon Central Area (around 14 km) and around 6.4 km upstream of Thanlyin Bridge. Due to this distance from Yangon central area, Dagon Bridge seems to be underutilized for daily traffic, in spite of its ample traffic capacity.

Thanlyin area is a developing area. The further development of Myanmar International Terminals Thilawa (MITT) is planned with Japanese assistance under the Project for Development of Yangon Port (Thilawa area). MITT is intended to share cargo handling with the Port of Yangon, and to be the backbone of Myanmar's future development. The further development of MITT is also expected to ease the traffic congestion caused by Yangon Port activities in Yangon central area. Next to MITT, Thilawa Special Export Zone (SEZ) is planned to provide the industrial area and to be implemented soon. Private developments such as the construction of commercial and residential areas and the construction of recreation center are also quite active. Due to these developments, it is anticipated that Thilawa area will have around 500,000 daytime population in the near future. Consequently, it is believed that the traffic between Yangon area and Thanlyin area will increase. The current traffic capacity of the two existing bridges cannot accommodate the future traffic demand generated in the area, and will soon become a serious bottleneck.



Source: JICA Survey Team

Figure 1.1 Two Existing Bridges on the Bago River

Therefore, the construction of a new bridge, i.e., Bago River Bridge, is urgently required.

At the moment, the Project for the Strategic Urban Development Plan of the Greater Yangon (SUDP) and the Project for Comprehensive Urban Transport Plan of the Greater Yangon (YUTRA) are conducted under Japanese assistance. These projects already pointed out the insufficient transport infrastructure between Yangon area and Thanlyin area. Being aware of the necessity of bridge between these two areas, the SUDP proposed a bridge at Bago Point as an integral part of the future transport network of Greater Yangon. YUTRA is still in its early stage and not able to identify the future traffic demand or the required additional number of lanes between the two areas. However, YUTRA is anticipating the requirement of more lanes to cope with the future traffic demand, which would result in the construction of one or more bridges.

The existing Thanlyin Bridge was constructed as a bridge for freight train with road section attachments. When the role of Dagon Bridge is understood as a bridge for freight transport of the region, then it can be said that there is no commuter purpose infrastructure in terms of road transport and railway transport between Yangon area and Thanlyin area. To cope with the increased traffic demand (mainly commuter traffic) between Yangon area and Thanlyin area, it is believed essential to take into consideration the construction of commuter train system, in order to avoid the excessive burden to roadway transport system.

In case of deploying the commuter railway system between Yangon area and Thanlyin area, it would be advisable to adopt the double-decked road cum rail bridge with the shortest length, from the transport engineering viewpoint. Instead of two separate bridge constructions, one for road and the other for railway, the application of double-decked bridge will reduce the construction cost.

Apart from the bridge type selection between road bridge and road cum rail bridge, the construction of Bago River Bridge will surely guarantee the expected economic growth in Thanlyin area, accelerate Thilawa SEZ development, and greatly contribute to the economic development of Myanmar.

Hence, Bago River Bridge needs to be constructed urgently.

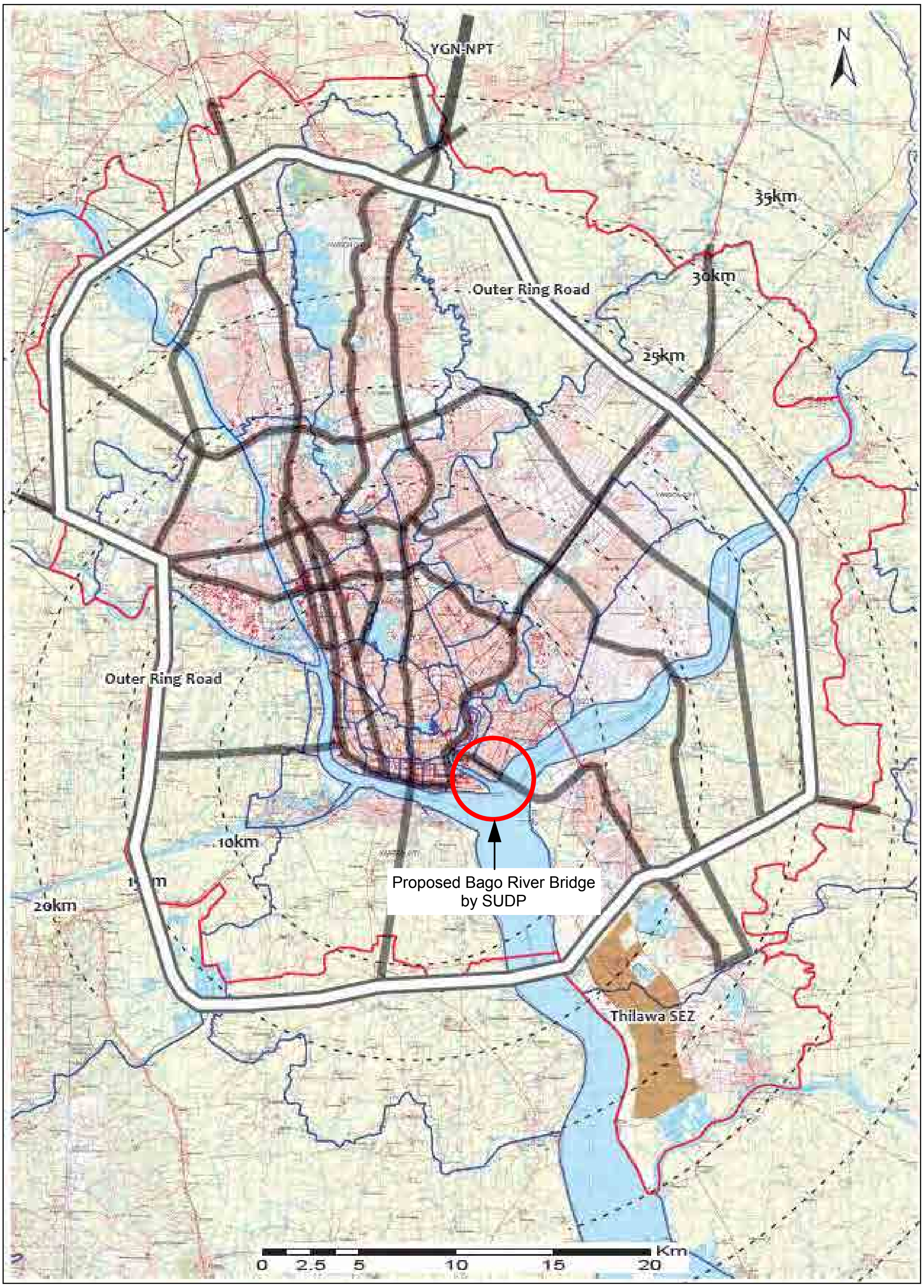
1.2 Project Objective

As stated in the Minutes of the Meeting between Public Works (PW), Ministry of Construction (MOC), and Japan International Cooperation Agency (JICA), signed on May 15, 2013, the objective of this Preparatory Survey is to conduct a feasibility study on the new construction of Bago River Bridge and approach road to the bridge.

1.3 Related Studies

The first phase of SUDP was conducted under Japanese assistance. The Final Report I was submitted in April 2013. In this report, SUDP reported the forecasted cross sectional traffic demand on the Bago River in 2040 as four times of the current volume, which would require a traffic capacity equivalent to 20 traffic lanes. It is noted that the current number of lanes is eight, of which Thanlyin Bridge has two lanes and Dagon Bridge has six lanes. Then, SUDP proposed the construction of Bago River Bridge to cope with the forecasted cross sectional traffic demand on the Bago River.

At the moment, YUTRA is conducted under Japanese assistance. YUTRA already pointed out the insufficient transport infrastructure between Yangon area and Thanlyin area. YUTRA is still in its early stage and not able to identify the future traffic demand or the required additional number of lanes between the two areas. However, YUTRA is anticipating the requirement of more lanes to cope with the future traffic demand, which would result in the construction of one or more bridges.



Remarks: SUDP proposed Bago River Bridge at Bago Point with the following reasons:

1. SUDP proposed the waterfront development along the Yangon River.
2. SUDP anticipated the serious traffic congestion in the downtown area of Yangon by Bago River Bridge at Monkey Point, which is not suitable for the waterfront development.

Source: SUDP Study Team (Figure 3.4.14)

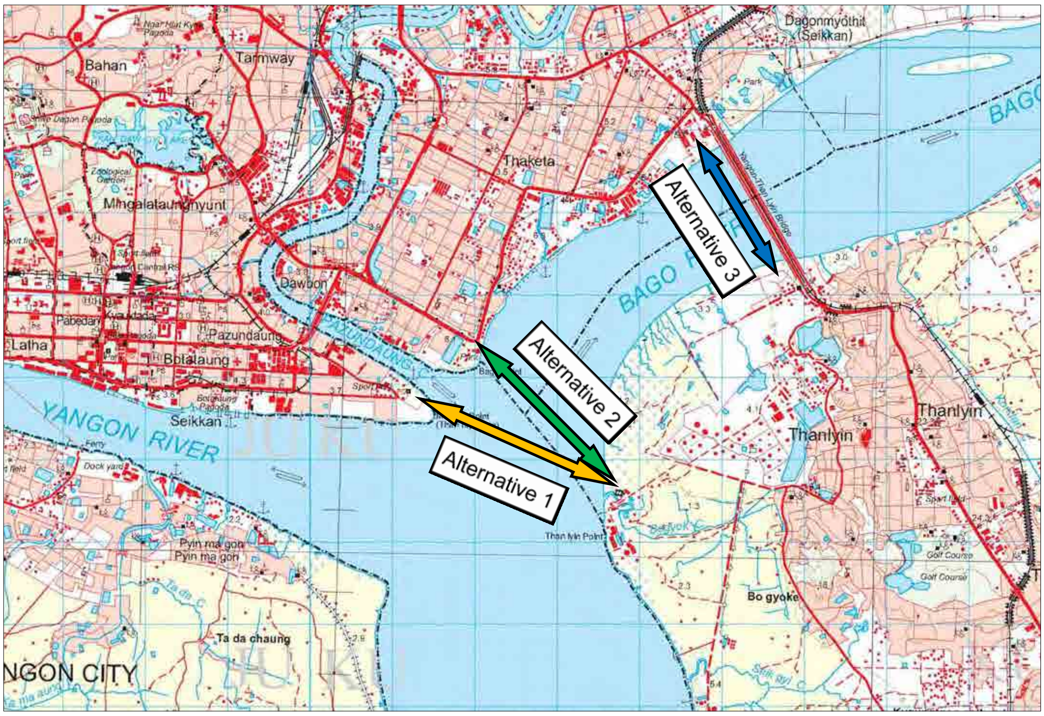
Figure 1.2 Proposed Conceptual Plan of Road Network by SUDP

1.4 Previously Proposed Three Bridge Locations

In the Preparatory Study for Urban Development Programme in the Greater Yangon under Japanese assistance, the initial study on Bago River Bridge was conducted. This initial study proposed three alternative locations for Bago River Bridge, which were selected considering the existing road at the Yangon side which has a possibility to form the link with the proposed approach road to Bago River Bridge. The three locations and the assumed existing roads at Yangon side which will link with the proposed approach road to the bridge are as follows:

Alternative Route	Yangon Side Existing Road
Alternative 1: Monkey Point Route	Strand Road
Alternative 2: Bago Point Route	Yamonnar Road
Alternative 3: Proximity to the Existing Thanlyin Bridge Route	Shukhinthar-Mayopat Road

Figure 1.3 shows the three alternative locations for Bago River Bridge.



Source: JICA Survey Team

Figure 1.3 Three Alternative Locations for Bago River Bridge

Chapter 2

Schedule of Preparatory Survey

2. Schedule of the Preparatory Survey

2.1 Time Schedule of the Preparatory Survey

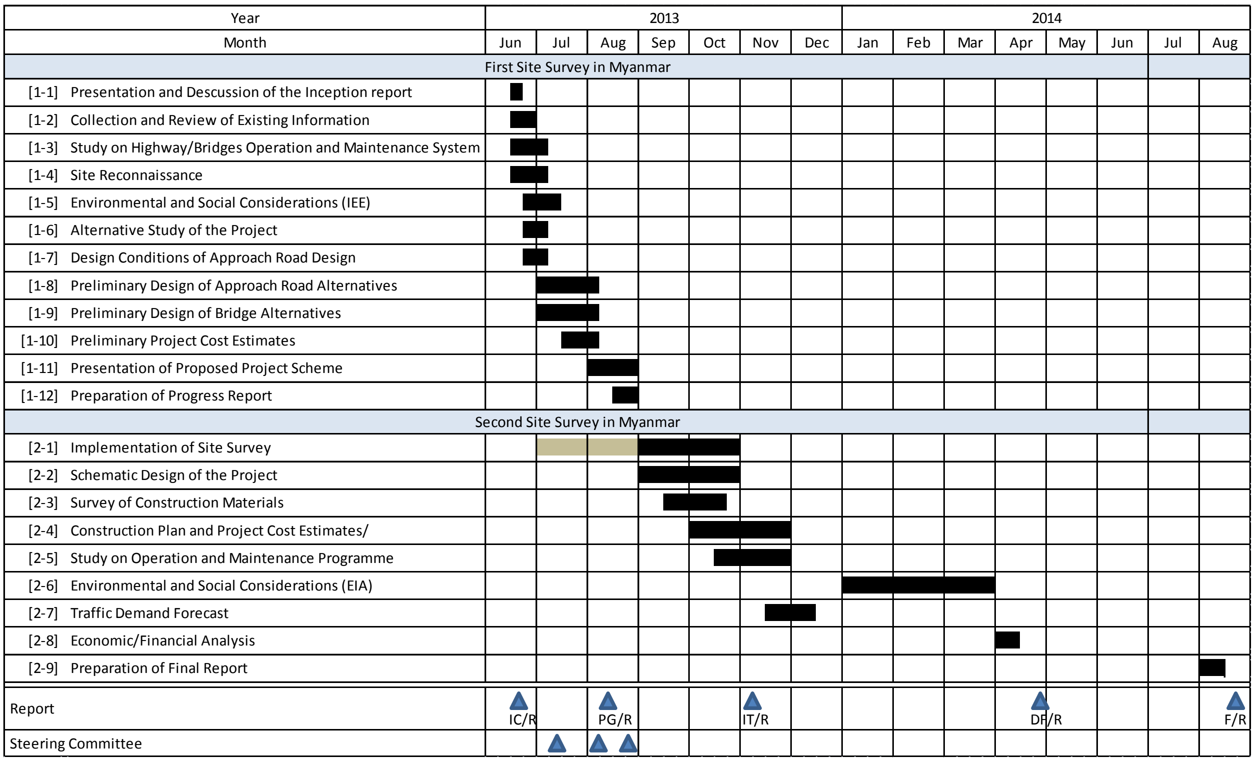
Table 2.1 shows the proposed time schedule of the Preparatory Survey. It was planned that this Preparatory Survey is to be carried out in two phases as follows:

1st Phase: To conduct the alternative study and propose the most appropriate project scheme covering the bridge location and bridge type.

2nd Phase: To carry out the feasibility study of the Project, upon mutual agreement on the proposed project scheme.

As shown in the “Report” row in Table 2.1, the inception report was submitted in early July and the progress report was submitted in the end of August. During the 2nd Phase, the interim report, Final report, and then the final report will be submitted.

Table 2.1 Time Schedule of the Preparatory Survey



Source: JICA Survey Team

2.2 Members of the JICA Survey Team

The JICA Survey Team is composed of 11 members, as shown in Table 2.2:

Table 2.2 List of JICA Survey Team Members for the Preparatory Survey

No.	Name	Position/Assignment
1.	Takashi Shoyama	Team Leader/Comprehensive Urban Transport Plan
2.	Eiichi Yokota	Road Planning/Road Design
3.	Toshio Ichikawa	Bridge Planning/Bridge Design 1
4.	Tomoyuki Konishi	Bridge Planning/Bridge Design 2
5.	Ryo Tanahashi	Construction Planning/Cost Estimation 1
6.	Tomokuni Hayakawa	Construction Planning/Cost Estimation 2
7.	Hironobu Kuroe	Hydrologic Characteristic Analysis
8.	Takeshi Maeda	Geological Condition Data
9.	Mazhar Iqubal	Traffic Demand Forecast
10.	Rie Tajima	Economic and Financial Analysis
11.	Testujiro Tanaka	Social and Environmental Considerations

Source: JICA Survey Team

2.3 Progress of the Preparatory Survey

The major milestones of the Preparatory Survey are as follows:

(1) Presentation of Inception Report (IC/R) and Discussion on the Contents of IC/R

On July 2, 2013, the JICA Survey Team visited the Ministry of Construction (MOC), Nay Pyi Taw and made the presentation of IC/R to the concerned personnel of PW. IC/R introduced the time schedule of the Preparatory Survey, work items to be carried out in Myanmar, and proposed design considerations, such as design criteria, typical cross sections, and navigation clearance, for Bago River Bridge and approach road design.

In the course of the presentation of the time schedule, the JICA Survey Team said that the bridge location, among the three alternatives shown in Figure 1.3, shall be finalized by at least mid-August. PW agreed to this and requested for the JICA Survey Team to provide the materials for the comparison and final selection of the bridge location. The JICA Survey Team agreed to PW's request. The minutes of the meeting is attached in Appendix 1.

(2) Presentation of Study of Three Alternative Locations for Bago River Bridge and Discussion on the Contents

Following the presentation of IC/R, the JICA Survey Team carried out the preliminary design of Bago River Bridge and approach roads to the bridge, along with the initial environmental examination (IEE). The working results were prepared as the report of the Study of Three Alternative Locations for Bago River Bridge.

On August 6, 2013, the JICA Survey Team visited MOC, Nay Pyi Taw, and made the presentation of the report. In this meeting, PW invited representatives of concerned organizations. After the presentation of the report by the JICA Survey Team, each representative including PW provided comment on the bridge location. Taking into consideration the various comments given by the representatives of concerned organizations, PW selected Alternative 3, i.e., Proximity of the Existing Thanlyin Bridge Route, as the location of Bago River Bridge.

The JICA Survey Team proposed the bridge type of continuous steel box girder with steel plate deck for Alternative 3 route from the viewpoint of construction cost. PW requested for the JICA

Survey Team to make further study on the bridge type which may include the application of longer span bridge, taking into account the safety requirement for vessel operating route, and the importance of technology transfer of bridge construction into Myanmar. The JICA Survey Team agreed to do so. The Technical Notes for the meeting is attached in Appendix 2.

(3) Presentation of Alternative Study of Bridge Type for Bago River Bridge

The JICA Survey Team prepared the alternative study report of the bridge type which includes the comparison of the following six alternative bridge types:

Alternative-A: Continuous Steel Box Girder with Steel Plate Deck Girder + Continuous Steel I-Girder with Precast PC Deck Slab

Alternative-B: Nielsen Arch Bridge + Continuous Steel I-Girder with Precast PC Deck Slab

Alternative-C: Continuous PC Box Girder + Continuous Precast PC Box Girder (Span by Span)

Alternative-D: Extradozed Bridge + Continuous Precast PC Box Girder (Span by Span)

Alternative-E: Steel Cable Stayed Bridge + Continuous Steel Box Girder with Steel Deck Slab + Continuous Precast PC Box Girder (Span by Span)

Alternative-F: Extradozed Bridge + Continuous Steel Box Girder with Steel Deck Slab + Continuous Precast PC Box Girder (Span by Span)

This alternative study report evaluated each alternative bridge type applying the scoring system stated in the report. Alternative-E bridge type attained the highest score.

On the occasion of the 3rd Steering Committee Meeting of YUTRA held on August 16, 2013 in Yangon, the JICA Survey Team submitted the report to PW and recommended to apply the Alternative-E bridge type, which was evaluated with the highest score. PW verbally agreed to adopt the bridge type of Alternative-E for Bago River Bridge. This verbal agreement was confirmed through the MOC's formal decision in Nay Pyi Taw. The Technical Notes for the selection of bridge type is attached in Appendix 3.

The alternative study of bridge type is introduced in Subchapter 6.2.

(4) Natural Condition Surveys

Upon the final decision on the bridge location and bridge (superstructure) type of Bago River Bridge, the following natural condition surveys were conducted:

- Topographic Survey
- Geological Survey

Topographic survey and geological survey were contracted with local contractors at the end of August. However, due to the delay of permission to conduct the survey, both topographic survey and geological survey were completed at the beginning of November.

(5) Environmental and Social Considerations Survey

Environmental and social considerations surveys were conducted from October 2013. The following natural condition surveys were conducted:

- Ecosystem Survey
  - Terrestrial component
  - Aquatic component
  - Fish resources

- Water Quality Survey
- Sediment Quality Survey
- River Velocity Survey
- Air Quality Survey
- Ambient Noise Survey

The stakeholder meeting was conducted on 24 January 2014 with concerned personnel of PW, related organization and PAPs.

(6) Design for Feasibility Study, Cost Estimation, Traffic Demand Forecast and Economic Evaluation

Based on the natural condition survey, the JICA Survey Team conducted the preliminary design of the Bago River Bridge and its approach roads. Cost estimation was conducted for the purpose of the economic evaluation based on the traffic demand forecast carried out in the YUTRA Project.

(7) Presentation of the Draft Final Report and Discussion on the Contents

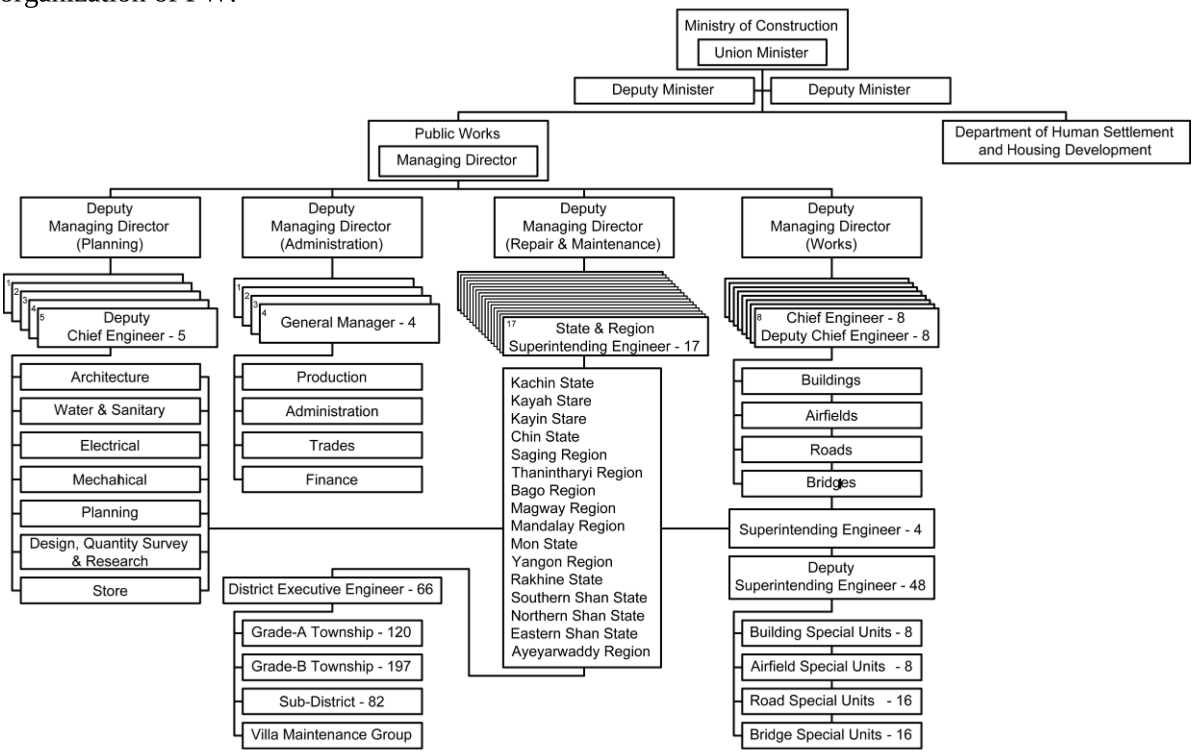
On July 31, 2013, the JICA Survey Team visited MOC, Nay Pyi Taw, and made the presentation of the Draft Final Report to the concerned personnel of PW staff headed Managing Director U Kyaw Linn. The contents of the report were mainly approved without some description of the report.

Chapter 3

Organization of Public Works

3. Organization of Public Works (PW)

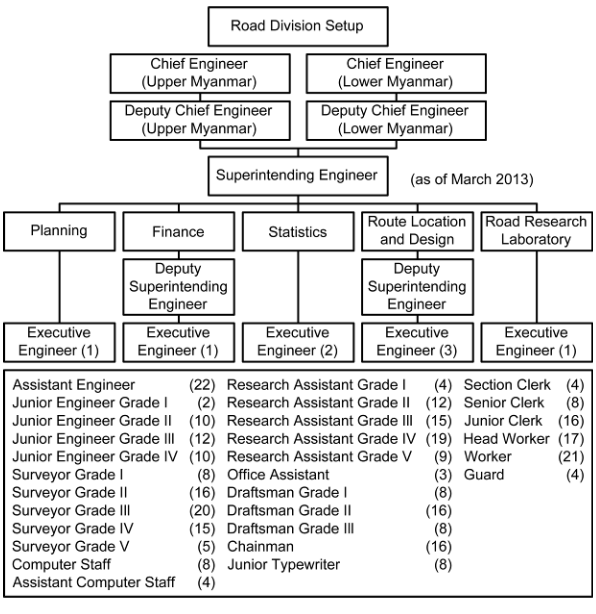
The executing agency of the Bago River Bridge is PW which belongs to MOC Figure 3.1 shows the organization of PW.



Source: PW

Figure 3.1 Organization of Public Works

As seen in Figure 3.1, PW consists of four departments under the Managing Director. The Department of Works has four divisions, namely: Building, Airfield, Road, and Bridge. Figure 3.2 shows the organizational chart of the Road Division.



Source: PW

Figure 3.2 Organizational Chart of the Road Division, PW

The PW's counterpart division of the Project for Construction of Bago River Bridge is the Bridge Division. Although the organizational information of the Bridge Division was not obtained, it is anticipated that the Bridge Division also has the organization structure similar to that of the Road Division. Table 3.1 shows the staff number of the Road Division and Bridge Division. The Bridge Division has 106 officials and 854 employees as of August 2013.

Table 3.1 List of Employees in MOC as of August 2013

Name of Department	Government Official	Government Employee	Total
Road (Site)	189	1,220	1,409
Road (Head Office)	36	193	229
Bridge (Site)	83	790	873
Bridge (Head Office)	23	64	87
Total	331	2,267	2,598

Source: MOC

Table 3.2 shows the summary of equipment and the number of equipment possessed by PW. These huge numbers of equipment are deployed to various states and regions. Table 3.3 shows the equipment distribution status.

Table 3.2 Summary of Equipment in PW, as of August 2013

No.	Name of Equipment	Total Units	Remarks
1	Bulldozer	243	
2	Motor Grader	147	
3	Excavator	146	
4	Loader	155	
5	Road Roller	727	
6	Soil Compactor	29	
7	Vibratory Roller	135	
8	Crane	125	
9	Drilling Rig	22	
10	Vibro Hammer	23	
11	Rock Drill	22	
12	Asphalt Concrete Plant	16	
13	Air Compressor	129	
14	Generator	141	
15	Dump Truck	908	
16	Truck	272	
17	Tyre Roller	30	
18	Asphalt Concrete Paver	9	
19	Agitator Truck	47	
20	Stone Crusher	116	
	Grand Total	3,442	

Source: PW

Table 3.3 Distribution of Existing Equipment in PW (State and Region)

Sr.	Type of Equipment	Kackin State	Kayar State	Kayin State	Chin State	Sagaing Division	Tanantharyi Division	Bago Division	Magwe Division	Mandalay Division	Mon State	Rakhaing State	Yangon Division	Shan State (South)	Shan State (North)	Shan State (East)	Ayarwadi Division	Mechanical Department	Total	Remark
1	Bull Dozer (Large)	11	2	5	6	26	5	7	10	12		10	3	1	4	11	6	12	131	
2	Bull Dozer (Median)	4	1	2	5	13	5	2	6	5		4	1	9	2	10	6	10	85	
3	Bull Dozer (Small)	3	1		2	3	1	3	1	2			2	4	1		1	3	27	
4	Motor Grader	12	2	4	8	24	10	5	10	11	2	8	3	8	7	11	9	13	147	
5	Excavator	8	2	4	5	14	7	5	10	10	1	9	9	7	7	13	21	14	146	
6	Loader	14	2	4	11	13	9	7	10	11		13	2	8	5	14	8	24	155	
7	Scraper																	1	1	
8	Road Roller	41	12	26	31	86	40	48	57	63	17	65	31	48	35	35	73	19	727	
9	Tyre Roller	1				2		4	3	4		1	1	1		1	4	8	30	
10	Sheep Foot Roller	1				3	1	5		1			5				5	1	22	
11	Vibrating Roller	6	2	1	2	16	6	6	8	14		5	4	6	8	5	13	33	135	
12	Compactor			2		7		3	4	5		1	3	1			1	2	29	
13	Crane	6	3	1		11	1	5	19	6	1	7	19	4	1	6	10	25	125	
14	Bored Pile Drilling Rig	1	3			1	1	1	1			2	5	1		2	1	3	22	
15	Vibro Hammer	1	1			2	1	2	2			3	5	1		1	1	4	24	
16	Reversed Circulation Drill											2	2					2	6	
17	Desander																	4	4	
18	Pile Driving Machine					1			1	1		2					1	19	25	
19	Asphalt Concrete Plant							3	1				4					8	16	
20	Asphalt Concrete Paver							1		1			1					6	9	
21	Decander							5		1			2				1	2	11	
22	Distributor				1	2	2		2		1	4	2	2	1	1	3	10	31	
23	Concrete Batching Plant							3	5	6		2	4			2	1	3	26	
24	Concrete Mixer	15			3	13	2	19	20	2	1	10	19	1			17	29	151	
25	Concrete Cutter							3										3	6	
26	Concrete Agitator Truck					1		5	8	9		2	14			4	3	1	47	
27	Concrete Pump and Pump Truck									1			2					11	14	
28	Concrete Paver									2								2	4	
29	Concrete Texturing M/C									2								1	3	
30	Concrete Breaker Gun					2		1	2								1	3	9	
31	Stone Crusher	9	1		3	5	1	7	7	4	2	7	7	2	2	3	4	52	116	
32	Rock Drill					1			1									20	22	
33	Screening & Washing M/C							2				2	1					1	6	
34	Air Compressor	3	2	1	1	4		3	5	7		12	9	6	1	2	2	71	129	
35	Electric Generator	8	2	2	1	8	1	8	18	6		5	16	1	2	4	15	44	141	
36	Welding Machine	6			1	2		3	2			1	2			2	1	25	45	
37	Stressing Jack										2		6				1	3	12	
38	Cement Pump							5											5	
39	Cement Bulk Carrier							1		1								2	4	
40	Tipper	73	2	23	45	109	39	66	71	66	7	64	37	48	47	57	63	91	908	
41	Truck	21	4	2	10	23	2	15	12	23	6	9	22	17	7	9	13	77	272	
42	Water Bowzer	4		3	1	8	4	5	5	14	1	4	4	2	1	7	5	8	76	
43	Oil Bowzer				2	4		3	6	6		4	3	1	2	2	2	1	36	
44	Wheel Tractor	7				1		6	4		1	1						13	33	
45	Transporter							1	1									16	18	
46	Service Truck				2			1					2	1			1		7	
47	Barge					1			6	2		3	10				9	4	35	
48	Tug Boat								2			1	1						4	
49	Z- Craft					1											1		2	
50	Anchor Boat								1										1	
	Total	255	42	80	140	407	138	269	321	298	42	263	263	180	133	202	303	704	4040	

Source: PW

Detailed equipment list, including model number, capacity, procured year, and maker name, is presented in Appendix 4.

Judging from the number of staff in the Road/Bridge Division and wide variation of equipment owned by PW, it is believed that PW has ample experience and capacity to carry out the appropriate maintenance activities for the completed infrastructures. However, in case of infrastructures built with technology that is new to Myanmar, such as steel cable-stayed bridge and/or steel box girder bridge with steel deck slab, it would be necessary to transfer the maintenance know-how to Myanmar.

Chapter 4

Design Criteria applied to the Project Design

4. Design Criteria Applied to the Project Design

In order to carry out the Project design of Bago River Bridge and its approach roads, design criteria shall be established. The current considerations regarding bridge design, road design, and navigation clearance are discussed in the following subchapters.

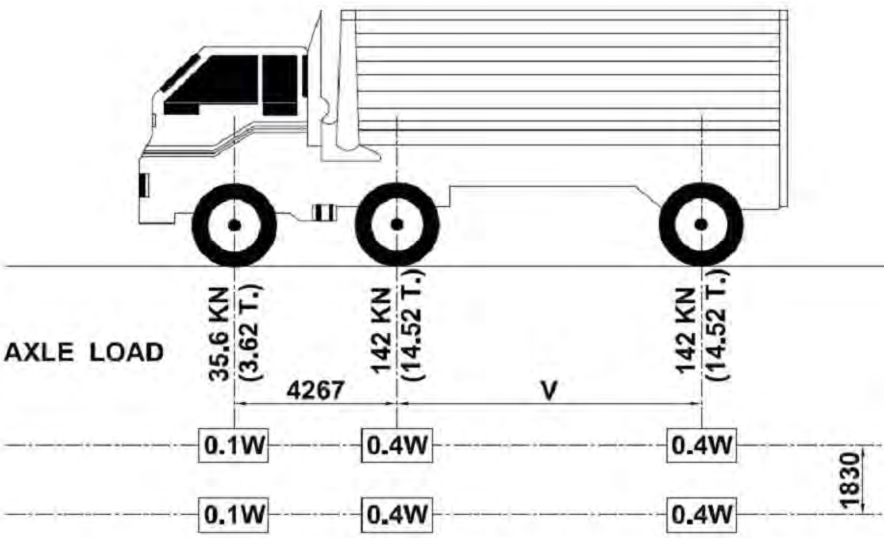
4.1 Design Criteria for Structural Design

4.1.1 Structural Guidelines

With respect to the structural guidelines, specialized structural design criteria associated with complex bridge types are compiled with the Japanese Standard for Highway Bridge (JSHB-2002) associated with developing preliminary bridge concepts. The only cords related to the application of live loading system are applied from AASHTO standard and other design loads such as earthquake, temperature, and wind are studied and applied or modified with JSHB considering local conditions. The general structural limitations and restrictions for Bago River Bridge such as span length restrictions, typical bridge cross sections, location of abutment, and restrictions on distance to adjacent structures on land or water are individually identified and verified.

4.1.2 Design Criteria

(1) Live Loading System (AASHTO Standard)



Note: V =Variable spacing from 4.267 m to 9.144 m to be used is that which produces maximum stresses
Source: JICA Survey Team

Figure 4.1 Standard Highway Bridge Loading (HS20-44)

AASHTO standard also specifies the track as a single concentrated load and a uniform load as follows:

- Concentrated Load 8.16 T (104 kN) for Moment
  11.80 T (116 kN) for Shear
- Uniform Load 0.95 T/m (9.38 kN)

(2) Seismic Design

The Sagaing Fault is seismically active and running as a north-south trending fault extending to the Sagaing Hill. Along the Sagaing Fault, major earthquakes had occurred in the past as shown in Figure 4.1.

Table 4.1 List of Major Earthquakes near Yangon along the Sagaing Fault

No.	Date	Epicenter (Lat. N, Long. E)	Richter Magnitude	Remarks
1.	March 6, 1913	17° 00′, 96° 50′	7.0	Near Bago
2.	July 5, 1917	17° 00′, 96° 50′	7.0	Near Bago
3.	May 5, 1930	17° 00′, 96° 50′	7.3	Near Bago, 500 people killed in Bago and 50 in Yangon
4.	Dec. 5, 1930	18° 00′, 96° 50′	7.3	Near Pyu

Source: JICA Survey Team

The proposed bridge site, which is located near the south end of the Sagaing Fault, will be affected by earthquakes. Myanmar Geosciences Society (MGS) has prepared the earthquake zoning map of the Yangon area as shown in Figure 4.2 based on the characteristic earthquake of 7.3 Mw on firm rock that occurred on May 5, 1930. According to the zoning map, ground motion near the bridge site is around 0.135~0.145 gal (maximum: 0.15) which is rather lower than a Level-1 earthquake with ground motion of 200 gal (0.20) in JSHB.

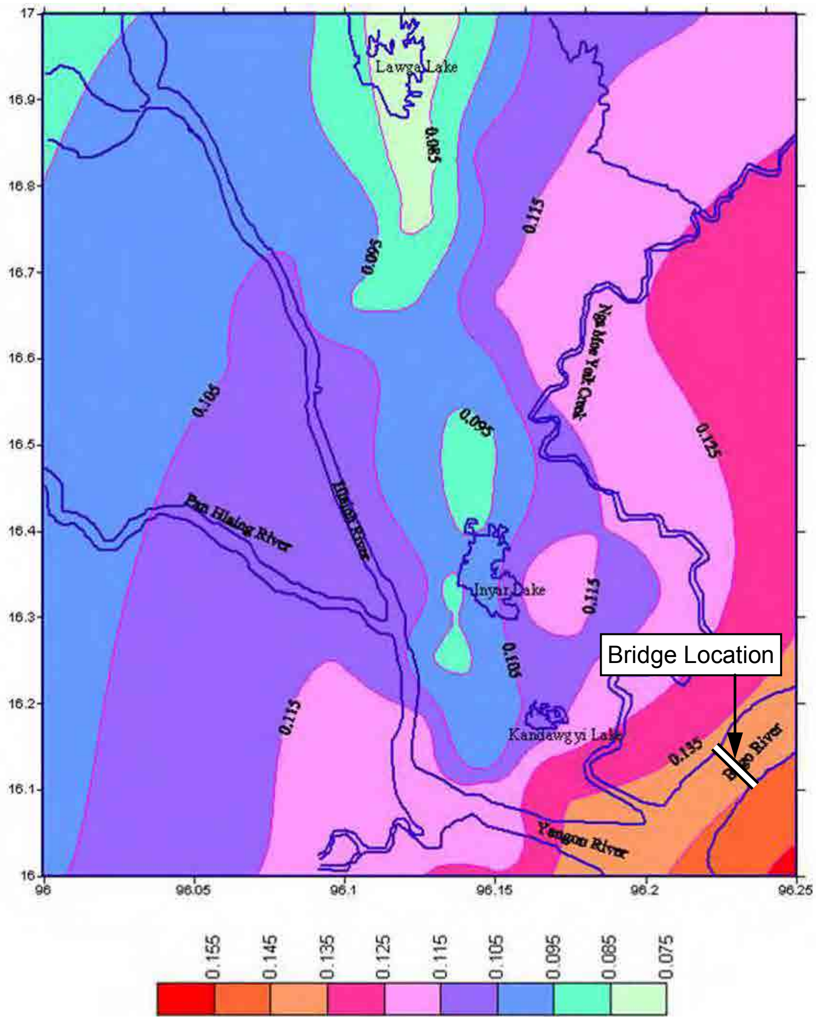
Seismic design for this study is carried out using acceleration response spectra for Level-1 earthquake ground motion in JSHB. The verification of Level-1 seismic design is carried out through the seismic coefficient method in Japan. When plastic behaviour of a reinforced concrete column is expected in the seismic design, structure details shall conform with JSHB (Part-V Seismic Design) in order to ensure the plastic deformation performance.

(3) Temperature

Maximum temperature in Yangon was recorded at 37.6 °C and the minimum was 16.6 °C based on the data of Kaba-Aya Observatory Station from 1999 to 2008. Temperature range for design shall be 15 °C to 40 °C with a mean temperature of about 25 °C (temperature rise of 10 °C, temperature fall of 15 °C) for ordinary bridge and from 15 °C to 50 °C with a mean temperature of about 25 °C (temperature rise of 10 °C, temperature fall of 25 °C) for steel plate deck.

(4) Wind

The biggest cyclone Nargis with winds up to 54 m/s swept through the neighbouring bridge location on May 2, 2008. There is a wind record with maximum wind speed of 49 m/s in Yangon, which is almost equal to the scale of the large typhoon in Japan. Therefore, wind load acting on the superstructure can be applied with the cord of JSHB. Design reference wind speed is set as 40 m/s at a height of 10 m in JSHB. If suspension bridge, cable-stayed bridge, and other flexible bridges are applied for the main bridge, more detailed study such as wind tunnel test is necessary to examine the stability due to wind in the detailed design.



Source: Tint Lwin Swe, Earth Sciences and its Applications

Figure 4.2 Earthquake Zoning Map of Yangon Area (Tint Lwin Swe, 2004)

4.2 Design Criteria for Road Design

Road design shall be carried out based on the appropriate geometric design criteria for horizontal/vertical alignment design. Also, the geometric design criteria for horizontal/vertical alignments are governed by the design speed. It is understood that Asian Highway and ASEAN Highway are planned to traverse in Myanmar. Table 4.2 shows the extract of ASEAN Highway Standards which is based on the Asian Highway Standards by ESCAP 1995.

Table 4.2 Extract of ASEAN Highway Standards

Highway classification		Primary (4 or more lanes) (control access)			Class I (4 or more lanes)		
Terrain classification		**L**	**R**	**M**	**L**	**R**	**M**
Design speed (km/h)		100-120	80-100	60-80	80-110	60-80	50-70
Width (m)	Right of way	(50-70) ((40-60))			(50-70) ((40-60))		
	Lane	3.75			3.50		
	Shoulder	3.00		2.50	3.00		2.50
Min. horizontal curve radius (m)		390	230	120	220	120	80
Type of pavement		Asphalt/cement concrete			Asphalt/cement concrete		
Max. superelevation (%)		(7) ((6))			(8) ((6))		
Max. vertical grade(%)		4	5	6	5	6	7
Min. vertical clearance (m)		4.50 [5.00]			4.50 [5.00]		
Structure loading (minimum)		HS20-44			HS20-44		
Highway classification		**Class II (2 lanes)**			**Class III (2 lanes)**		
Terrain classification		**L**	**R**	**M**	**L**	**R**	**M**
Design speed (km/h)		80-100	60-80	40-60	60-80	50-70	40-60
Width (m)	Right of way	(40-60) ((30-40))			30-40		
	Lane	3.50			3.00[3.25]		
	Shoulder	2.50		2.00	1.50[2]		1.0[1.5]
Min. horizontal curve radius (m)		200	110	50	110	75	50
Type of pavement		Asphalt/cement concrete			Double bituminous treatment		
Max. superelevation (%)		(10) ((6))			(10) ((6))		
Max. vertical grade(%)		6	7	8	6	7	8
Min. vertical clearance (m)		4.50			4.50		
Structure loading (minimum)		HS20-44			HS20-44		

Note:

1. Abbreviation: L = Level Terrain M = Mountainous Terrain R = Rolling Terrain
2.( ) = Rural (( )) = Urban
3. [ ] = Desirable Values
4. The right of way width, lane width, shoulder width and max. superelevation rate in urban or metropolitan area can be varied if necessary to conform with the member countries design standards.

Source: The Association of Southeast Asian Nations
(http://www.asean.org/communities/asean-economic-community/item/annex-b-asean-highway-standards)

Referring to Table 4.2, it is proposed to apply the "Class I" classification to the Project, with the terrain classification of "L" and the design speed of 80 km/h. The number of carriageway shall be determined by the traffic demand. However, considering the crowded traffic condition of the existing Thanlyin Bridge and the estimated future traffic demand forecasted by relevant studies, it is believed that the application of dual 2-lane bridge would be reasonable.

4.3 Design Navigation Clearance

The design height of the bridge is controlled by the design vessels navigating on the Bago River. According to the obtained information, it is clear that Yangon Port is accessible to vessels of 167 m LOA, 9 m draft, and 15,000 DWT. However, the maximum scale of vessel which may navigate on the Bago River is not known.

According to the Study on Ship Height by Statistical Analysis (November 2006) by the National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport, Japan, it was reported that the navigation clearance for cargo vessels of around 15,000 DWT is about 30 m or more, as shown in Table 4.3.

Table 4.3 Height above Water Level: Cargo Vessel

DWT	Coverage		
	50%	75%	95%
	Height (m)		
1,000	18.8	20.9	23.9
2,000	21.4	23.5	26.6
3,000	22.9	25.0	28.1
5,000	24.8	27.0	30.0
10,000	27.5	29.6	32.6
12,000	28.1	30.3	33.3
18,000	29.7	31.8	34.9
30,000	31.6	33.7	36.8
40,000	32.7	34.8	37.9
55,000	33.9	36.0	39.1
70,000	34.8	36.9	40.0
90,000	35.8	37.9	40.9
120,000	36.8	39.0	42.0
150,000	37.7	39.8	42.9

Where: Number of analyzed cargo vessel is 568.
Coverage is the applicable ratio against the population (568).

Source: JICA Survey Team

It is believed that a 15,000 DWT vessel will not navigate through the Bago River. However, considering an emergency case when an out-of-control vessel drifts from the Yangon River to the Bago River under a storm, the proposed height of the new bridge, which may be located near the confluence of the Yangon River and the Bago River, shall have enough vertical clearance.

In case the new bridge location is proposed nearby the existing Thanlyin Bridge, the minimum requirement of navigation clearance shall be the same with that of the existing bridge.

Taking into consideration the above, the design navigation clearance for Bago River Bridge at each alternative route was proposed as shown in Table 4.4.

Table 4.4 Proposed Navigation Clearance for Each Alternative Route

Alternative Route	Navigation Clearance
Alternative 1: Monkey Point Route	35 m
Alternative 2: Bago Point Route	35 m
Alternative 3: Proximity to the Existing Thanlyin Bridge Route	Same with the existing Thanlyin Bridge (around 10.2 m)

Source: JICA Survey Team

Chapter 5

Study of Three Alternative Locations for Bago River Bridge

5. Study of Three Alternative Locations for Bago River Bridge

As aforementioned, three locations were proposed for Bago River Bridge. In order to select the most appropriate location for the Project, the preliminary design for the bridge and approach roads at each alternative location was carried out in order to compare the advantages and disadvantages between each alternative route.

5.1 Design Conditions for Alternative Study

This alternative study was carried out under the following conditions:

1. The objective of preliminary design is as stated in Subchapter 1.2.

2. The proposed approach road is to be connected to the existing road.

   In Thanlyin side, the existing road linked to the proposed approach road is expected to be improved/upgraded as dual 2-lane road from the link point with approach road up to Thilawa SEZ area.

3. Design speed for the bridge and approach roads is 80 km/h. Design criteria follows the ASEAN Highway Standards. However, the maximum vertical grade of $i = 4.0\%$ was applied, referring to the Japanese Road Structure Ordinance, taking into consideration the presence of low power vehicles.

4. The proposed Bago River Bridge at Alternative 1 (Monkey Point Route) was assumed as a road cum railway bridge. The maximum vertical grade of the railway section is controlled by the design criteria of railways, i.e., $i_{max} = 10$‰ (1.0%).

5. Assumed navigation clearance of Bago River Bridge was:

   - 35 m for Alternative 1 and Alternative 2

   - The same height (around 10.2 m) as with the existing Thanlyin Bridge for Alternative 3

6. The Yangon side route of Alternative 1 and Alternative 2 will traverse the built-up area. In order to minimize the social environmental impacts on the area, there would be several variations in the horizontal alignment as shown in Figure 5.1.

   For Alternative 1, Northern Route along Pazundaung Creek and Southern Route along the Yangon River are considered as variations. For Alternative 2, the loop type ramp is considered to minimize the adverse social environmental impacts along Yamonnar Road.

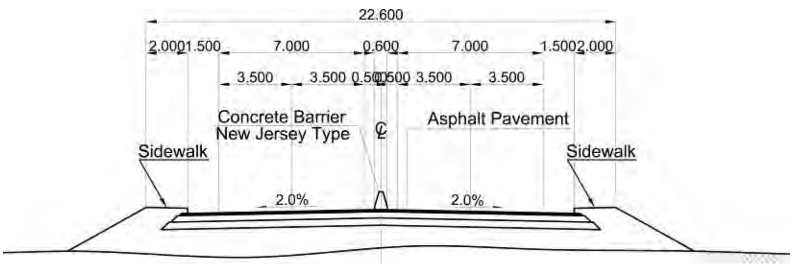
   However, for the purpose of this study, simplified alignments as shown in Figure 5.3 were applied as the preliminary design.

7. Typical cross sections applied in this study are given in Figure 5.2. It was judged as appropriate to have dual 2-lane of 3.5 m wide carriageway with inner/outer shoulder. For cost savings purpose, the width of the outer shoulder of the bridge section was reduced to 0.50 m from the 1.50 m of the earthwork section.

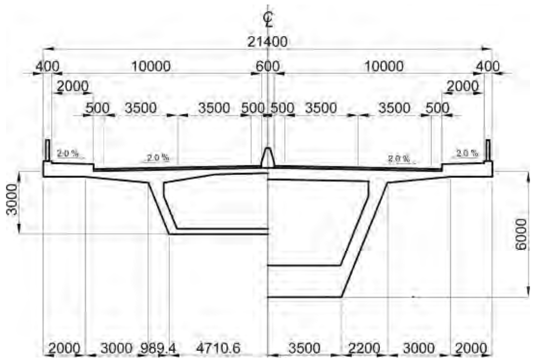
Source: JICA Survey Team

Figure 5.1 Several Route Arrangements for Alternative 1 and Alternative 2

8. The Preparatory Survey for the Project for Construction of Bago River Bridge scheduled the conduct of the investigation of natural conditions, such as topographic survey and geological survey, after the selection of bridge location. Therefore, the preliminary design for this alternative study was carried out utilizing aerial photography and 3D terrain data provided by Google Earth. It is noted that there is a certain limitation in the accuracy of the ground elevation. It must be understood that the profile alignment design shows only the design concept, and the work quantity calculations related especially to earthwork would not have a significant meaning.



(a) Earthwork Section

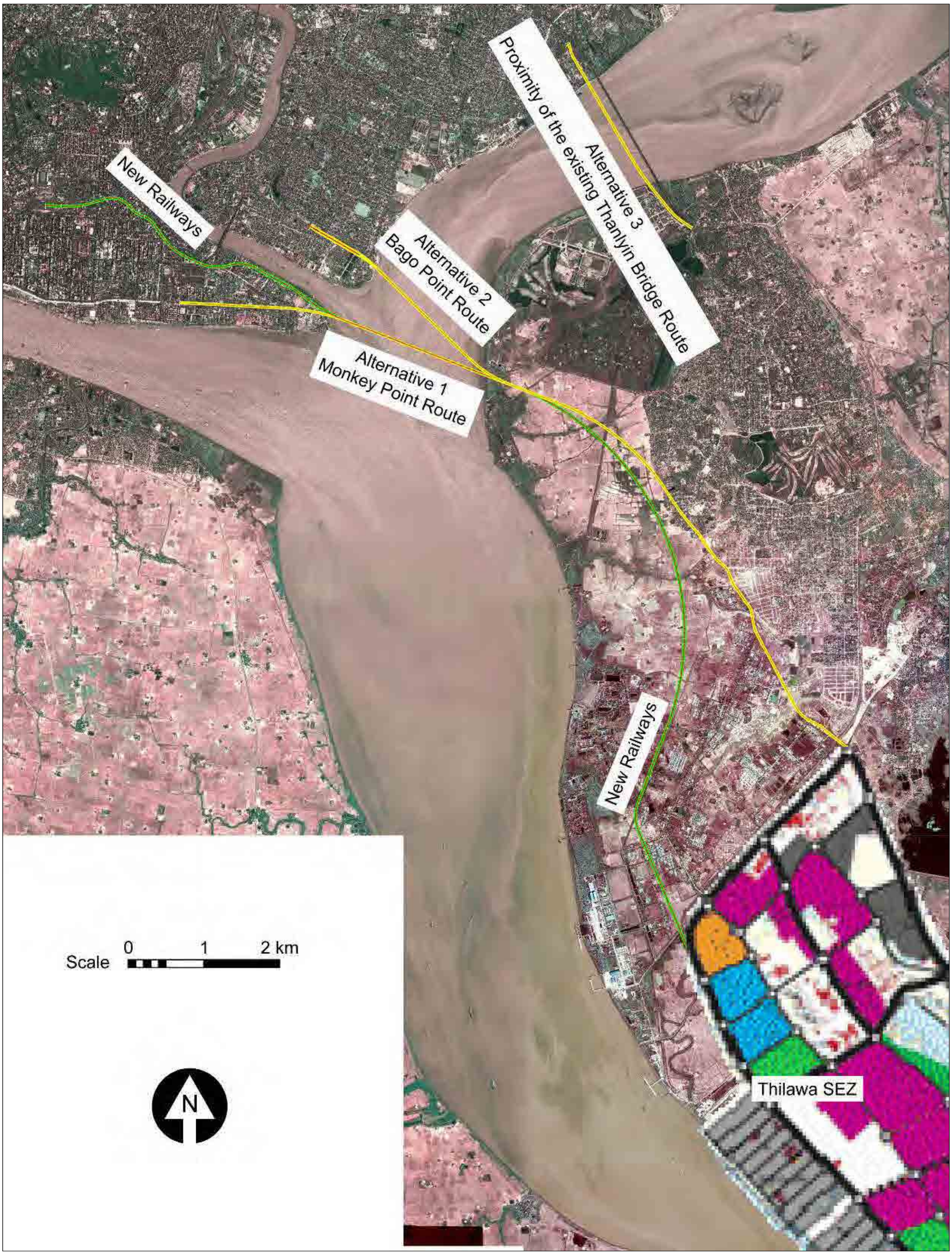


(b) Bridge Section

Note: Superstructure type is for illustration purposes only.

Source: JICA Survey Team

Figure 5.2 Typical Cross Sections Applied in the Alternative Study



Source: JICA Survey Team

Figure 5.3 Alignment Layout of Three Alternative Routes

5.2 Comparison of Three Alternative Locations for Bago River Bridge

5.2.1 Outline of Project Route

The Project consists of approach road + Bago River Bridge + approach road. Since the Project road is proposed as a dual 2-lane road, if the existing road, links to the Project approach road, is a dual 1-lane road, it is expected that the existing road will be improved to a dual 2-lane road under another project.

Table 5.1 Project Route Outline of Three Alternatives

	Alternative 1 Monkey Point Route	Alternative 2 Bago Point Route	Alternative 3 Proximity to the Existing Thanlyin Bridge Route
Existing road linked to the Project			
Right bank	Strand Road	Yamonnar Road	Shukhinthar-Mayopat Road Thanlyin Chin Kat Road
Left bank	Local road running outskirts of Bo Gyoke Village	Local road running outskirts of Bo Gyoke Village	Kyaik Khauk Pagoda Road
Total Length	11,330 m	10,178 m	2,974 m
Total Project Length	7,120 m	5,968 m	2,974 m
Approach Road (Right bank)	190 m	458 m	419 m
Bridge	5,650 m	3,081 m	1,909 m
Approach Road (Left bank)	1,280 m	2,429 m	646 m
Improvement of Existing Road	4,210 m	4,210 m	-

Remark: Information of Monkey Point Route gives the road section length of road cum railway bridge.

Source: JICA Survey Team

In Alternative 1 and Alternative 2, the improvement of existing road would be required from the link point with the Project approach road up to the outskirts road of Thilawa SEZ.

As it was informed that Kyaik Khauk Pagoda Road will be improved to a dual 2-lane road under Thilawa SEZ Project (northern half by MOC and southern half by Thilawa SEZ Project), the improvement of the existing road is not considered in Alternative 3.

Plan and profile designs of each alternative route for this study are given in Appendix 5.

5.2.2 Land Use Condition along the Project Route

The JICA Survey Team has started the initial inventory survey regarding the land use and assessment of the scale of involuntary resettlement for each of the three alternatives. However, it would not be appropriate to conduct the detailed inventory survey at this stage in order not to give the unnecessary adverse impact on the related communities.

Hence, the following descriptions were not yet confirmed by valid evidence, and may contain wrong information. In case the descriptions are not appropriate, the correct/right information shall be provided to the JICA Survey Team.

Table 5.2 Land Use Condition along the Project Route

Required Land for the Project	Alternative 1 Monkey Point Route	Alternative 2 Bago Point Route	Alternative 3 Proximity to the Existing Thanlyin Bridge Route
Right Bank of the Bago River	The project route starts from Strand Road, and crosses over the Navy land. When the southern route is applied, the project route will pass the south of Than Lyet Soon Road, cross over the Ministry of Energy land, YCDC Sewage Treatment Plant area and Navy land. When the northern route is applied, then the project route will pass over the existing railways area, built-up area along Lower Pazundaung Road and jetty area of Navy land.	The project route starts from Yamonnar Road and crosses over the Asian Bowling Club, or fringe of Shu Khin Tar Amusement Park. In order to provide the project approach road, it is necessary to widen the existing Yamonnar Road, which has continuous and dense private premises on both sides. In order to minimize the social and environmental impact, it would be possible to deploy the loop type approach road. In case of loop type approach road, it is noted that the length of around 800 m shall be provide in the loop section, due to the high elevation of the Bago River Bridge.	The project route starts from the intersection between Shukhinthar-Mayopat Road and Thanlyin Chin Kat Road. From this starting point to the Bago River, the project road traverses Myanmar Railways land, touching to the existing narrow road beside the PW's compound.
Left Bank of the Bago River	The project route lands on the fringe of Star City land and passes the land of the Ministry of Energy (MOE) or old oil refinery plant area. The land of MOE is large and the southern area seems to be used for cultivation. After traversing MOE land, the project route links to the existing local road. The proposed railways alignment diverts from the road alignment, and traverses MOE land and then Navy land up to the merging point with the existing railways.	The alignment of Alternative 2 is the same as the alignment of Alternative 1.	The proposed Bago River Bridge and its approach road runs on Myanmar Railways land parallel to the border of private developer's land, having Excel River View Hotel inside, and then links to Kyaik Khauk Pagoda Road.

Source: JICA Survey Team

5.2.3 Foreseen Natural/Social Environmental Impact

The following environmental impacts are the outputs of preliminary site reconnaissance and assessment of available aerial photography. Therefore, the descriptions below are neither the final conclusion nor the results of definitive field assessment. Environmental impacts are evaluated by using the following components:

(1) Social environment: involuntary resettlement (land acquisition, resettlement, etc.), cultural heritage and/or religious sites, fishery activities.

(2) Natural environment: endangered/valuable plants and animals, protected area, row of trees along the road.

(3) Environmental pollution: air pollution and noise.

Table 5.3 Foreseen Social and Environmental Impact

Item	Alternative 1 Monkey Point Route	Alternative 2 Bago Point Route	Alternative 3 Proximity to the Existing Thanlyin Bridge Route
Right Bank of the Bago River Administration	Botahtaung Township, Pazundaung Township	Thaketa Township, Dawbon Township	Thaketa Township
Social Environment a) Involuntary resettlement (land acquisition / resettlement, etc.)	Assuming the elevated approach road to the bridge, ROW for piers should be secured under the road structure. Thus, number of Project Affected Persons (PAPs) is expected from more than 200 to less than 50, depending on the alignment. However, estimation of the number of PAPs is difficult at present because the road alignment is not yet finalized. (1) The route passes the Than Lyet Soon Road and Strand Road The expected number of PAPs is more than 200. In addition, mostly affected land and structures are those of government properties.	Number of PAPs is expected to be more than 200 in order to secure the necessary land for ROW of at-grade road along Yamonnar Road. However, estimation of the number of PAPs is difficult at present because the road alignment is not yet clear. Land and structures (plots, commercial buildings, shops, houses, government offices, etc.) belonging to Dawbon Township (southern side of the road) are expected to be more affected. By contrast, those that belong to Thaketa Township (northern side of the road) are expected to be less affected.	Number of PAPs are expected to be less than 10 in order to secure the necessary land around the intersection of Thanlyin Chin Kat Road and Shukhinthar Myo Pat Road and along the approach road to the proposed Bago River Bridge. However, estimation of the number of PAPs is difficult at present because the road alignment is not yet clear.

Item	Alternative 1 Monkey Point Route	Alternative 2 Bago Point Route	Alternative 3 Proximity to the Existing Thanlyin Bridge Route
	(2) Southern route: pass along the Yangon River bank The alignment passes through compounds of Navy, Sewage Treatment Plant, Ministry of Energy and jetty, and connected to Strand Road. The expected number of PAPs is less than 50. (3) Northern route: pass along the river bank of Pazundaung Creek The alignment crosses the existing railway line, traverses built-up areas, and connects to Strand Road. The number of PAPs is more than 200.		
b) Cultural, heritage and/or religious sites	No cultural or heritage sites. One monastery and mosque distributed along Than Lyet Soon Road.	No cultural heritage or religious sites.	No cultural heritage or religious sites.
Natural Environment a) Endangered/valuable plants and animals	No species are found at present.	No species are found at present.	No species are found at present.
b) Row of trees along the roads	Cutting and/or replanting 30 to 100 trees including Indian Almond and Ashok species is required depending on the alignment.	Cutting and/or replanting about 100 trees including Indian Teak, Almond, and Ashok species is required depending on the alignment.	Cutting and/or replanting about 20 trees is required depending on the alignment.
c) Protected area	No protected areas such as designated park and natural reserves are found.	No protected areas such as designated park and natural reserves are found.	No protected areas such as designated park and natural reserves are found.
Environmental pollution a) Air pollution	Considerable impact on air quality is expected because the route is located in a densely urban built-up area.	Some impact on air quality is expected because the route is located in an urban built-up area.	Little impact on air quality is expected because the route is located in a suburban area.
b) Noise pollution	Considerable impact on ambient noise is expected because the route is located in a densely urban built-up area.	Some impact on ambient noise is expected because the route is located in an urban built-up area.	Little impact on ambient noise is expected because the route is located in a suburban area.

Item	Alternative 1 Monkey Point Route	Alternative 2 Bago Point Route	Alternative 3 Proximity to the Existing Thanlyin Bridge Route
Left Bank of Bago River Administration	Thanlyin Township	Thanlyin Township	Thanlyin Township
Social Environment a) Involuntary resettlement (land acquisition / resettlement, etc.)	Necessary land to secure ROW is mostly distributed in the compound of the Ministry of Energy and in a farmland. Number of PAPs is expected to be less than 50. However, estimation of the number of PAPs is difficult at present because the road alignment is not yet clear.	Necessary land to secure ROW is mostly distributed in the compound of the Ministry of Energy and in a farmland. Number of PAPs is expected to be less than 50. However, estimation of the number of PAPs is difficult at present because the road alignment is not yet clear.	No PAPs are expected because land for ROW is within the compound of the railway department.
b) Cultural, heritage and/or religious sites	No cultural, heritage or religious sites.	No cultural heritage or religious sites.	No cultural heritage or religious sites.
Natural Environment a) Endangered/valuable plants and animals	No species are found at present.	No species are found at present.	No species are found at present.
b) Row of trees along the roads	Cutting and/or replanting of about 30 trees is required depending on the alignment.	Cutting and/or replanting of about 30 trees is required depending on the alignment.	Cutting and/or replanting of about ten trees is required depending on the alignment.
c) Protected area	No protected areas such as designated park and natural reserves are found.	No protected areas such as designated park and natural reserves are found.	No protected areas such as designated park and natural reserves are found.
Environmental pollution a) Air pollution	Negligible impact on air quality is expected because the route is located in rural area.	Negligible impact on air quality is expected because the route is located in rural area.	Some impact on air quality is expected because the route is located in residential area.
b) Noise pollution	Negligible impact on ambient noise is expected because the route is located in rural area.	Negligible impact on ambient noise is expected because the route is located in rural area.	Some impact on ambient noise is expected because the route is located in residential area.
Fishery Activities in the River Fishery activities	Impact on fishery activities is expected to be small, but not clear.	Impact on fishery activities is expected to be small, but not clear.	Impact on fishery activities is expected to be small, but not clear.

Source: JICA Survey Team

5.2.4 Influence on the Adjacent Road Network/Traffic Environment

Along with the development of Thanlyin area/Thilawa area, when Bago River Bridge is completed and starts its operation, almost all traffic between Yangon area and Thanlyin area will use Bago River Bridge. Traffic volume is anticipated to increase, keeping pace with the regional activity and growth. Hence, the implementation of Bago River Bridge will incur serious traffic problem especially in Yangon area if there is no improvement in the existing road and road network, traffic management/control, or improvement of traffic mode and other countermeasures to realize the desirable transport system in Yangon area.

It is understood that, at the moment, YUTRA and SUDP are conducted under Japanese assistance. These projects are aiming to realize the well-balanced future Yangon, avoiding the excessive centralization of every activity in Yangon central area, and providing the appropriate road network and appropriate countermeasures of traffic management, with the provision of medium-/long-term plan proposal.

Therefore, it is believed that the magnitude of contribution or adverse influence of Bago River Bridge over the regional transport environment shall be evaluated in line with the abovementioned two projects' analysis. However, for example, YUTRA is now carrying out the traffic survey to collect the current traffic information. After finishing the data collection/data arrangement and data calibration, YUTRA will start the future traffic demand forecast and future traffic distribution analysis over the planned road network. YUTRA is scheduling these future traffic demand forecast and future traffic analysis in late autumn 2013. At present, it is not possible to address the influence on the adjacent road network/traffic environment by the Bago River Bridge construction in the medium/long term.

The descriptions in Table 5.4 give the anticipated influence of Bago River Bridge implementation over the current traffic environment in the short term.

Table 5.4 Influence on the Adjacent Road Network/Traffic Environment

	Alternative 1 Monkey Point Route	Alternative 2 Bago Point Route	Alternative 3 Proximity to the Existing Thanlyin Bridge Route
Right Bank of the Bago River	Increased traffic by Bago River Bridge implementation will cause serious traffic problems. Due to the convenience of Bago River Bridge route up to Thilawa area, almost all car drivers intending to move between Yangon area and Thilawa area will use Bago River Bridge. Hence, the traffic volume in Yangon downtown area will increase and generate serious traffic jam. However, heavy vehicles bringing goods into/out of Yangon Port may also use Bago River Bridge, instead of passing through Yangon downtown area. It is judged that this detouring manoeuvre of heavy vehicles in Yangon Port area will relieve the current crowded traffic conditions in Yangon downtown area. Heavy vehicle's freight route is expected as: Yangon Port⇔Bago River Bridge⇔Thanlyin area⇔Dagon Bridge. Although it is a long distance, heavy vehicle drivers may prefer this route due to time saving. It would be also possible to enforce this detour route to heavy vehicles by providing administrative regulations.	From the traffic engineering viewpoint, this Bago Point Route would be the best route if the related road network has ample traffic capacity and traffic management is operated desirably. However, Yamonnar Road, to which Bago River Bridge approach road will link, is already a busy road. It seems Yamonnar Road is now receiving saturated traffic volume. Yamonnar Road has an intersection with Maha Bandula Road - Min Nandar Road. During peak time, this intersection shows serious traffic congestion now. When Bago River Bridge is completed and traffic volume is increased in this area, the traffic conditions would be worsened. In order to avoid such situation, providing an independent road, from Bago River Bridge to Yangon area, would be one of the options. However, this independent road construction will need an additional bridge over Pazundaung Creek, and will result in shifting the traffic congestion into Yangon downtown area.	The Bago River Bridge approach road is proposed to connect with the intersection with Shukhinthar-Mayopat Road and Thanlyin Chin Kat Road. The intersection would be a 5-leg irregular shape. The appropriate traffic control by traffic signal shall be provided in this intersection. Increased traffic by Bago River Bridge implementation will use Shukhinthar-Mayopat Road or Thanlyin Chin Kat Road which links to Ayer Wun Main Road. In between Bago River Bridge and Yangon central area, there is a certain extent of road network. It is anticipated that the increased traffic would be distributed among this road network, and would not cause excessive traffic problems in Yangon central area in a concentrated manner.

	Alternative 1 Monkey Point Route	Alternative 2 Bago Point Route	Alternative 3 Proximity to the Existing Thanlyin Bridge Route
Left Bank of Bago River	As the road network in this area is not developed yet, no serious influence would be incurred over the area. The existing narrow local road shall be upgraded to a dual 2-lane road, in order to connect Bago River Bridge traffic to Thilawa SEZ area. If the local road is upgraded, the dual 2-lane Bago River Bridge and dual 2-lane local road will link to Thilawa SEZ area. It is believed that the traffic condition in this area will be improved. It is essential to provide the traffic safety measures to local communities, as local people may not have enough living experience with high speed vehicle traffic.	Same as the situation in Alternative 1.	As mentioned before, it is expected that Kyaik Khauk Pagoda Road will be upgraded to a dual 2-lane road. Connecting the dual 2-lane Bago River Bridge and dual 2-lane Kyaik Khauk Pagoda Road, it is expected that the traffic condition up to Thilawa SEZ area will be improved.
Railways	Bago River Bridge at Alternative 1 route would be constructed as a road cum railway bridge. The railways will apply a commuter train system. As Thilawa SEZ is forecasting 200,000 to 400,000 daytime population, it is judged as an appropriate plan to construct the new railways between Yangon area and Thilawa area. The deployment of railway system will prevent the concentration of vehicle transportation and contribute to the harmonized transport modal development. The construction of new railways shall be justified with its feasibility. However, at this moment, it is not possible to confirm the sound feasibility of railway system. YUTRA will conduct the analysis in autumn this year.	No railways.	No railways.

Source: JICA Survey Team

5.2.5 Possible Superstructure Type

Possible superstructure types for each alternative route were provided for study purpose as given in Table 5.5. Considering its economical construction cost, the continuous box girder with steel plate deck was adopted for the Alternative 3 route. Elevation plans and typical cross sections of each bridge type are provided in Appendix 6.

Table 5.5 Possible Superstructure Types for Each Alternative Route

Possible Superstructure Type	Alternative 1 Monkey Point Route	Alternative 2 Bago Point Route	Alternative 3 Proximity to the Existing Thanlyin Bridge Route
Road cum Railway Bridge	Steel Plate Girder Bridge + Double-decked Truss Bridge + Double-decked Cable-stayed Bridge	-	-
Road Bridge	Case – 1: No structure for railways except the section over the Bago River Steel Plate Girder Bridge + Double-decked Truss Bridge + Double-decked Cable-stayed Bridge Case - 2 Steel Plate Girder + Continuous Box Girder with Steel Plate Deck + Cable Stayed Bridge	Steel Plate Girder + Continuous Box Girder with Steel Plate Deck + Cable Stayed Bridge	Continuous Box Girder with Steel Plate Deck or Nielsen Arch Bridge or Extradozed Bridge or PC Box Girder Bridge

Source: JICA Survey Team

5.2.6 Cost Estimates

This alternative study was prepared based on the preliminary design of bridge and approach roads. Therefore, work quantities were not estimated properly. Further, as the JICA Survey Team is still in the early stages of the survey period in Myanmar, reasonable construction cost inventory was not obtained yet. However, in order to know the project scale in terms of the construction cost, the cost estimates of the main bridge was conducted. Reference was made to unit construction costs in Japan in 2010 and unit construction costs of Hinthata Bridge, as given in Appendix 7.

Table 5.6 Preliminary Cost Estimates

	Alternative 1 Monkey Point Route	Alternative 2 Bago Point Route	Alternative 3 Proximity to the Existing Thanlyin Bridge Route
Bridge Length	8,550 m/5,650 m	3,081 m	1,909 m
Assumed Bridge Type Road cum Railway Bridge	Steel Plate Girder Bridge + Double-decked Truss Bridge + Double-decked Cable-stayed Bridge	-	-
Road Bridge	Case – 1 (No structure for railways except the section over the Bago River) Steel Plate Girder Bridge + Double-decked Truss Bridge + Double-decked Cable-stayed Bridge Case - 2 Steel Plate Girder + Continuous Box Girder with Steel Plate Deck + Cable Stayed Bridge	Steel Plate Girder + Continuous Box Girder with Steel Plate Deck + Cable Stayed Bridge	Continuous Box Girder with Steel Plate Deck
Approximate Construction Cost Road cum Railway Bridge	JPY 40,010,000,000	-	-
Road Bridge	Case – 1 JPY 31,500,000,000 Case – 2 JPY 22,000,000,000	JPY 18,000,000,000	JPY 10,200,000,000

In addition to the bridge construction cost, the following works are required.			
Approach roads	L = 1,470 m	L = 2,887 m	L = 1,065 m and Improvement of Intersection
Improvement of existing road	L = 4,210 m	L = 4,210 m	-

Source: JICA Survey Team

5.2.7 Comparison of Alternative Routes from the Transport Planning Point of View

When comparing alternative routes from purely transport planning point of view, advantages/disadvantages of each route will be described as given in Table 5.7.

Table 5.7 Comparison of Alternative Routes from the Transport Planning Point of View

Aspect	Alternative 1 Monkey Point Route	Alternative 2 Bago Point Route	Alternative 3 Proximity to the Existing Thanlyin Bridge Route
Capacity to Transport Demand	- Enough (to be examined)	- Enough (to be examined)	- Enough (to be examined)
Road Network	- Shortest distance between Yangon central business district (CBD) and Thilawa	- Consistent with the network planned by SUDP - Consistent with the planned reconstruction of Thaketa Bridge	- Not changed
Railway Network	- Possible new line connecting Yangon CBD and Thilawa	- New line proposed by SUDP	- Utilize existing railway system
Traffic Congestion	- May worsen traffic congestion in Yangon CBD	- May worsen traffic congestion in Yamonnar Road and adjacent road network	
Urban Development	- May hinder waterfront development planned by SUDP		

Note: Green - Advantage
Red - Disadvantage

Source: JICA Survey Team

5.3 Other Information Related to the Project

5.3.1 Port Limit

Myanma Port Authority (MPA) defines the "port limit" on the Yangon River, the Bago River, and Pazundaung Creek as shown in Figure 5.4. The downstream area from these port limits is under the jurisdiction of MPA. It is noted that, on the Bago River, the location of the existing Thanlyin Bridge is assigned as the port limit. Hence, the design of Bago River Bridge for Alternative 1/Alternative 2 routes shall follow MPA's design control.

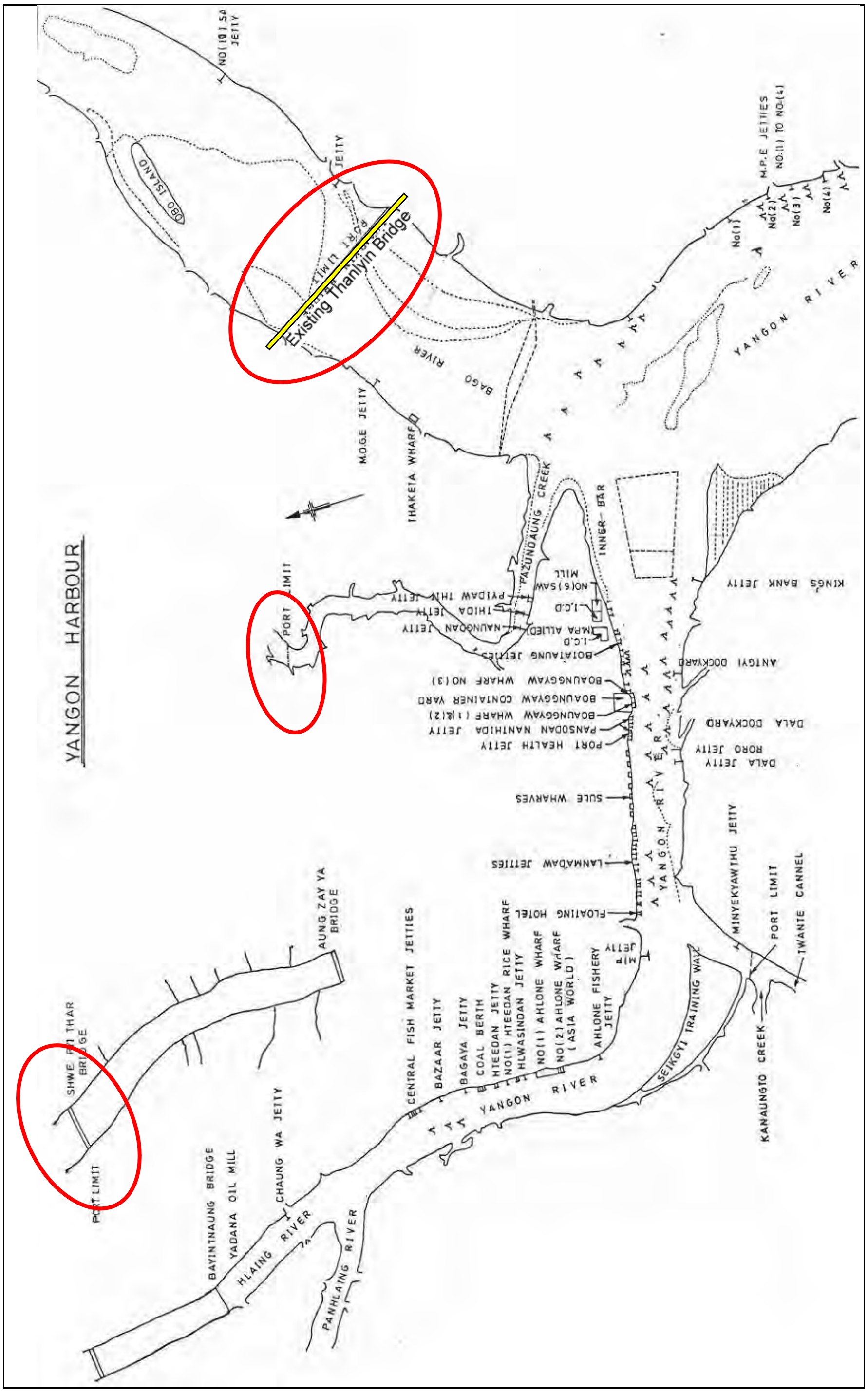


Figure 5.4 Location of Yangon Port Limit shown in Red Oval

Source: JICA Survey Team

5.3.2 Vessel Operating Route at the Existing Thanlyin Bridge Area

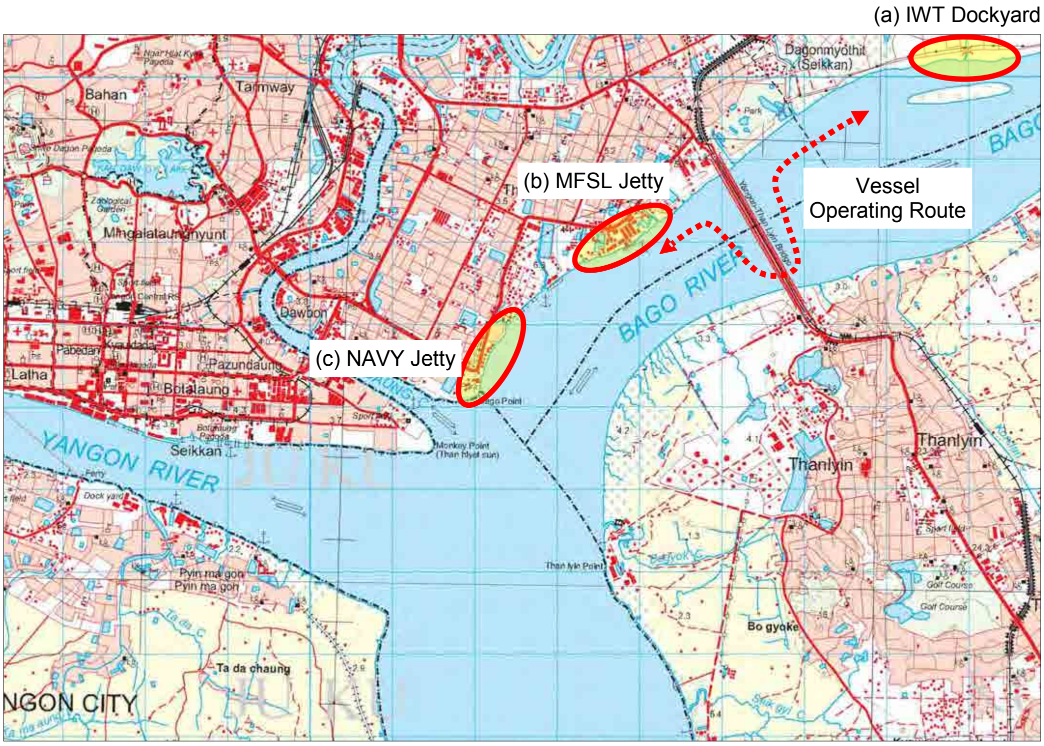
The Inland Water Transport (IWT) was informed about the facilities (jetty and dockyard) along the Bago River at the meeting with the JICA Survey Team on July 5, 2013, as follows:

(a) Dockyard of IWT for small boats (200 ft) upstream of the existing Thanlyin Bridge;

(b) Jetty for Myanma Five Star Line (MFSL), and

(c) Jetty for the Navy between the existing Thanlyin Bridge and the Bago River mouth.

Further, IWT specified the vessel operating route under the existing Thanlyin Bridge to the dockyard of IWT as shown in Figure 5.5.



Source: JICA Survey Team

Figure 5.5 Vessel Operating Route at the Existing Thanlyin Bridge Area

In case the Alternative 3 location is selected for Bago River Bridge, the pier arrangement shall be carefully studied taking into consideration the vessel operating route, in consultation with IWT.

5.3.3 Comment of Myanma Port Authority

The JICA Survey Team visited MPA on July 5, 2013 to consult on the design controls of Bago River Bridge. Mr. Cho Than Maung, Managing Director of MPA, attended the meeting and gave his comment as given in the scanned copy of the meeting record in Figure 5.6.

Date & Time		5th July, 2013. 11:30-12:30
Visit Details	Organization	Myanma Port Authority (MPA)
	Participants	Mr. Cho Than Maung (MPA, Managing Director) Daw San Phyu Phyu Sue (Public Works)
	Location of the Meeting	Myanma Port Authority No.10, Pansodan Street, Yangon
	TEL	951-391269
	E-mail	mpamd@mptmail.net.mm
Participants from JICA Project Team		Toshio ICHIKAWA, Tomokuni HAYAKAWA, Hiroaki UEYAMA, Ryo TANAHASHI (NK), Tomoyuki KONISHI(OC)
Main Topics		1. Navigation Clearance 2. Operating Route by MPA 3. Considerations of Alternatives
Results of Discussion (Agreement, Request, Need to be investigated)		Alternative 1 and 2 is not acceptable by MPA. Navigation clearance for 2nd Thanlyin Bridge Plan and New Thaketa Bridge can be same as existing bridge.
Documents	Submitted	•
	Obtained	•

Note: Please fill in the table above in English.

Highlights

- **Navigation Clearance for 2nd Thanlyin Bridge Plan**

  Navigation clearance for Alternative 3 (2nd Thanlyin Bridge plan) can be same as existing Thanlyin Bridge.

- **Operating Route by MPA**

  Operating route by MPA is shown in Figure 1. The vessels are operated along the deeper area, and now the Area *1 which is shallow and prone to deposit sediment has been dredged by MPA to maintain the route. Without the maintenance of work, vessels entering Yangon Port will be very limited.

- **Considerations of Alternatives (comments by MPA)**

  The location of Alternative 1 (Monkey Point Plan) is exactly on the operating route by MPA. Hence, it is surely impossible to accept the plan by MPA.

  The location of Alternative 2 (Bago Point Plan) is not constrained by the operating route by MPA. But the Bridge at Bago Point surely will affect the river flow and make the current speed less than before, and it causes to deposit more sediment downstream. It is also big problem for the operating route maintenance work. Hence, it is also impossible to accept the plan by MPA. It is required to have detailed hydraulic analysis for feasibility study.

- **Navigation Clearance along the Operation Route by MPA**

  Regulation for maximum ship operated by MPA is "167 LOA", "15,000t".

  Navigation Clearance is officially required 60m from High Water Level (H.W.L) for the future plan.

- **Navigation Clearance for New Thaketa Bridge**

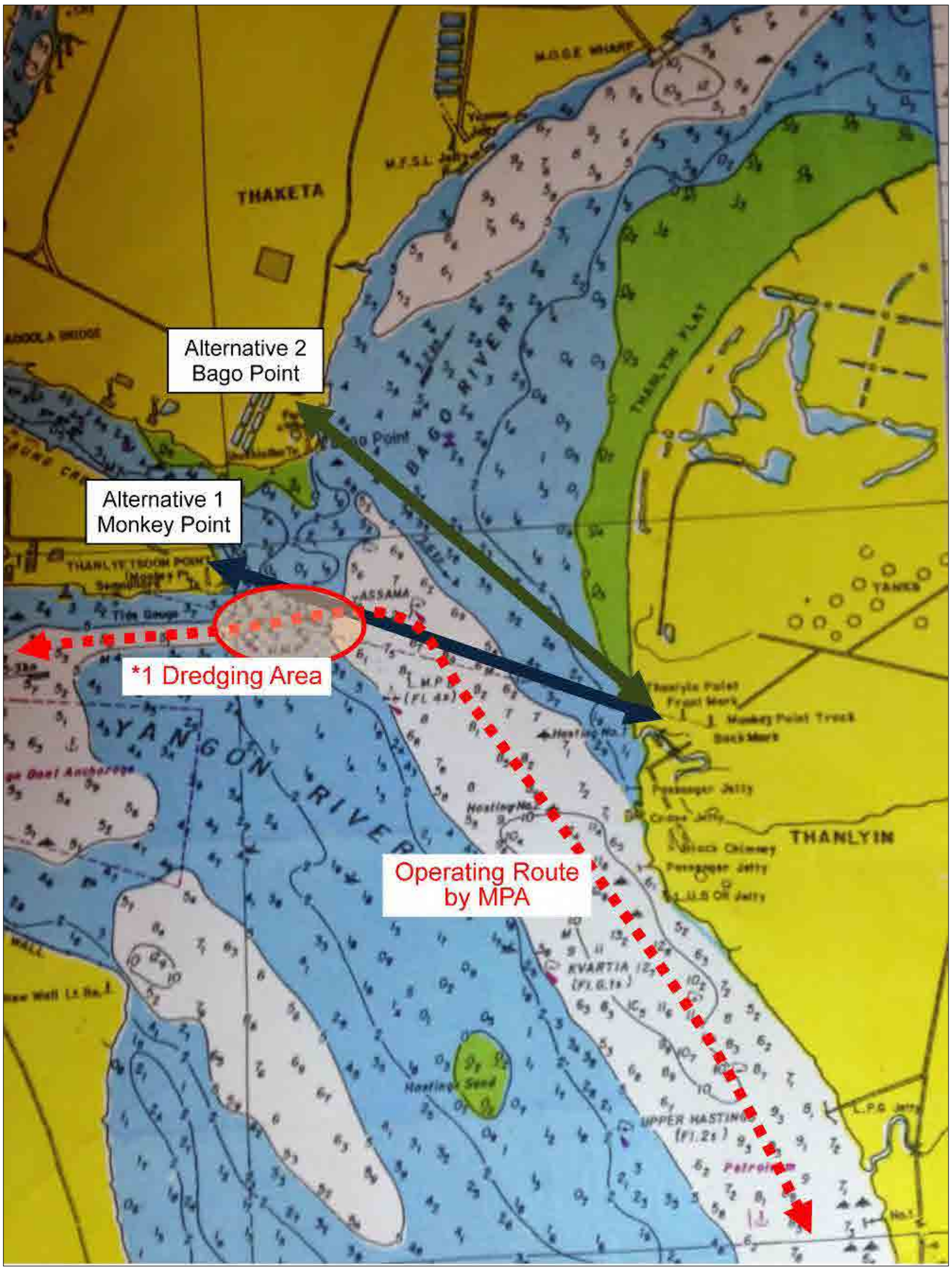
  Pazun Daung Creek is not river, and there is no big vessel crossing the existing Thaketa Bridge. Navigation clearance for New Thaketa Bridge can be same as existing Thaketa Bridge. But it is required to consider the location of piers for safety of small boat operating under the bridge.

- **Comments by MPA**

  MPA requested that the important decision shall also be reported to MPA beforehand.

Source: JICA Survey Team

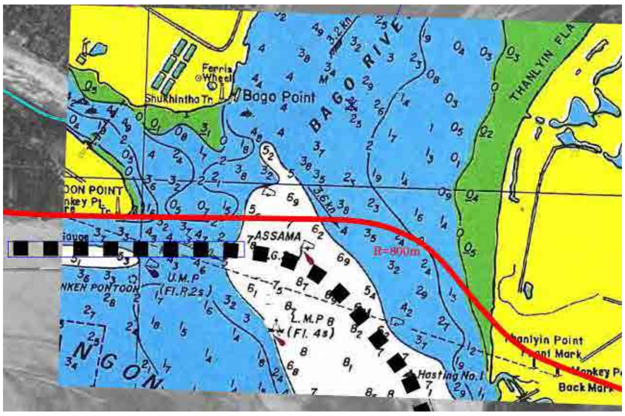
Figure 5.6 Scanned Copy of Meeting Record with MPA (1/2)



Source: JICA Survey Team

Figure 5.7 Scanned Copy of Meeting Record with MPA (2/2)

As indicated in Figure 5.8, it would be worth to propose the curved bridge alignment over the Bago River in order to avoid traversing just above the vessel operation route.



Source: JICA Survey Team

Figure 5.8 Proposed Alignment of Curved Bridge at Monkey Point Route

5.4 Selection of Bago River Bridge Location

As reported in Subchapter 2.3 (2), a meeting was held on August 6, 2013 at the conference room of the Ministry of Construction, Nay Pyi Taw to present the Study of Three Alternative Locations for Bago River Bridge given in Subchapter 4.2 of this report.

As a conclusion of the meeting, the location of Alternative 3, Proximity to the Existing Thanlyin Bridge Route, was selected for Bago River Bridge.

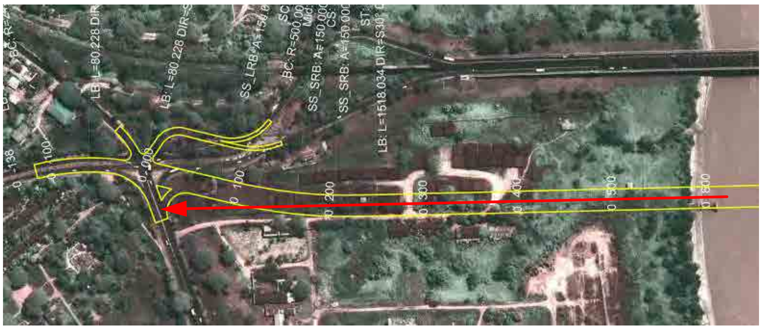
Chapter 6

Preliminary Design of Bago River Bridge

6. Preliminary Design of Bago River Bridge

6.1 Alignment Design

The Bago River Bridge at Alternative 3 (Proximity to the Existing Thanlyin Bridge Route) was proposed to run parallel to the existing Thanlyin Bridge at the downstream side due to land availability and desirable connection arrangement to the existing roads. If the straight alignment, parallel to the existing bridge, is applied from the beginning point, the project road will start from Shukhinthar-Mayopat Road nearby the existing intersection, as shown with the red arrow in Figure 6.1. This is not recommended from the viewpoint of traffic safety. It is believed that the project road shall be designed along with the remodelling of the existing intersection as given in the yellow line of Figure 6.1. In the course of the intersection design, it is required to secure the access to the National Races Village.



Source: JICA Survey Team

Figure 6.1 Plan at Yangon Side

The alignment at Thanlyin side is relatively simple. In between the existing Thanlyin Bridge and private development land, the project road will traverse and link to the existing Kyaik Khauk Pagoda Road. Intersections with the existing approach roads to the Thanlyin Bridge would be required.

Source: JICA Survey Team

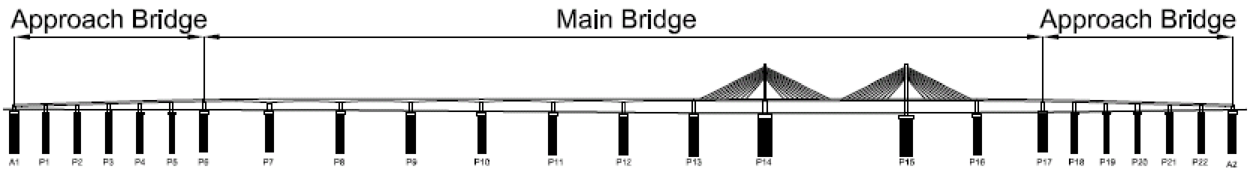
Figure 6.2 Plan at Thanlyin Side

The vertical grade of the approach road section is 2.50% in the preliminary design. It is noted that a grade steeper than 2.50%, up to 4.00%, is still allowable referring to the design standards.

6.2 Study of Superstructure Type

6.2.1 Selection of Superstructure Type

The bridge in this feasibility study is mainly composed of a main bridge and approach bridge on both sides as shown in Figure 6.3. The main bridge maintains the navigational requirement and the approach bridge is a connection to the main bridge from the highway. The types of the main bridge are each evaluated based on the engineering criteria such as span length, navigation requirement, structural stability, constructability, construction cost, maintenance, new technology, and aesthetic point. The key criteria to examine the viability among them are span length, structural stability, and new technology. Other items such as construction cost, constructability, maintenance, aesthetic point, and navigation are also comprehensively examined for the selection of bridge type. Regarding new technology of bridge, the PW strongly requested the JICA Survey Team to add alternative types of bridges with combination of various bridge types such as long-span steel cable bridge and continuous box girder with steel deck plate in the meeting held in the MOC on August 6, 2013.



Source: JICA Survey Team

Figure 6.3 Composition of Bridge

(1) Main Span

The span of the main bridge is determined as the same span of the existing Thanlyin Bridge in the above meeting held on August 6, 2013 in consideration of the navigational requirements including the adjacent existing bridge and river conditions. The span arrangement is 104 m + 10@112 m + 104 m, with total length of 1,328 m. IWT also proposed that the navigation span used at present should be wider at the existing navigation channel because the river boat pilots use the channel to pass diagonally under the bridge. PW requested the JICA Survey Team to add the alternative bridge type with 224 m span at the navigation channel that may be a new type of bridge and contribute to the development of Myanmar bridge construction.

Six alternative types are comprehensively selected based on the engineering criteria, and requests of PW and IWT, as follows:

1) Alternative-A: Continuous Steel Box Girder with Steel Deck

2) Alternative-B: Continuous PC Box Girder

3) Alternative-C: Nielsen Arch

4) Alternative-D: Extradozed Bridge

5) Alternative-E: Combination with Steel Cable Stayed and Continuous Steel Box Girder with Steel Deck

6) Alternative-F: Combination with Extradozed Bridge and Continuous Steel Box Girder with Steel Deck

Drawings of the alternative bridge (superstructure) types of the main bridge are presented in Appendix 8 (Six (6) Alternative Bridge Types for Superstructure Type Selection).

(2) Approach Bridge

The cross section of the approach bridge is adopted in the outline of the cross section from the main bridge to keep a consistent depth of the main bridge. Therefore, span length of the approach bridge is 40 m ~ 60 m applied in consideration of girder depth restriction and economical viewpoint. The length of the approach bridge may be different for every superstructure type of the main bridge. The following two bridge types for the approach bridge are selected in matching with the main bridge and new bridge technology in Myanmar.

1) Precast Continuous PC Box Girder (Span by Span)

2) Steel I-Girder with Precast PC Slab

Drawings of approach bridge (superstructure) types are presented together with the main bridge in Appendix 8 (Drawings of Alternative Bridge Type).

6.2.2 Evaluation Criteria

For the selection of the most appropriate bridge type, the JICA Survey Team has prepared the evaluation criteria as shown in Table 6.1 and Table 6.2, using score (point) ranking to evaluate priority of each category.

Table 6.1 Evaluation Criteria of Alternative Study

N o.	Category	Evaluation Criteria	Maximum Score (Point)
1	Technical Viability (30 points)	Structural Stability	20
2		Constructability	10
3	Economic Viability (25 point)	Construction Cost	20
4		Maintenance	5
5	Other Viability (45 points)	New Technology	20
6		Landscape	10
7		Navigation	10
8		Environment	5
		Total Points	100

Source: JICA Survey Team

Table 6.2 coring System for Evaluation of Alternative Bridge Type

Description		Structural Stability	Construct-ability	Construction Cost		Maintenance	New Technology	Landscape	Navigation	Environment
Grade	Rate	(20)	(10)	(20)	Ratio	(5)	(20)	(10)	(10)	(5)
Good	100%	20	10	20	1.00 ~ 1.10	5	20	10	10	5
Fair	50%	10	5	10	1.10 ~ 1.20	3	10	5	5	3
Poor	30%	6	3	6	1.20 ~ 1.30	2	6	3	3	2
Bad	0%	0	0	0	Over 1.30	0	0	0	0	0

Source: JICA Survey Team

6.2.3 Evaluation Results and Recommendation

Evaluation for each alternative bridge type is presented in Table 6.4 to Table 6.9, and the results of the selection are shown in Table 6.3.

Table 6.3 Results of Selection of Bridge Type

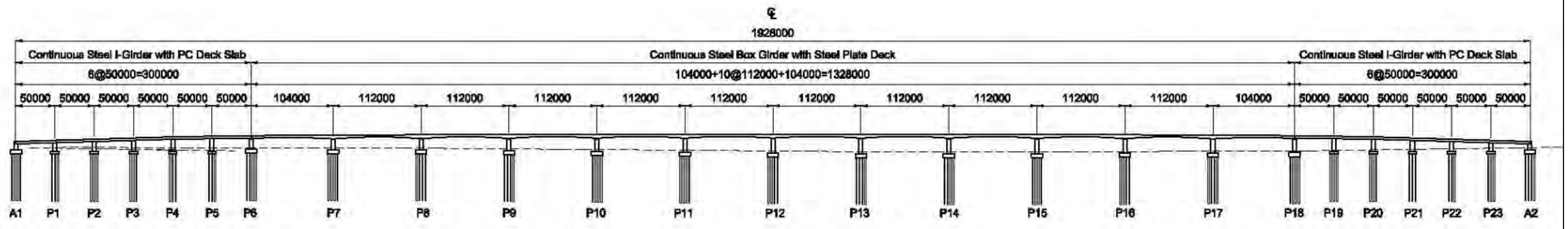
Category		Alternative					
		A	B	C	D	E	F
Structural Stability	(20)	20	10	10	10	20	10
Constructability	(10)	10	5	5	5	5	3
Construction Cost	(20)	20	6	20	10	6	6
Maintenance	(5)	3	3	3	3	3	3
New Technology	(20)	6	10	6	10	20	20
Landscape	(10)	3	5	3	5	10	10
Navigation	(10)	5	5	5	5	10	10
Environment	(5)	5	5	5	5	5	5
Total Score		72	49	57	53	79	67
Priority Order		2	6	4	5	1	3

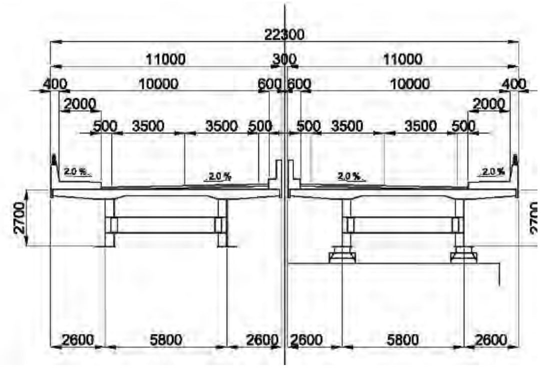
Note: Figure in ( ) shows the maximum score.

Source: JICA Survey Team

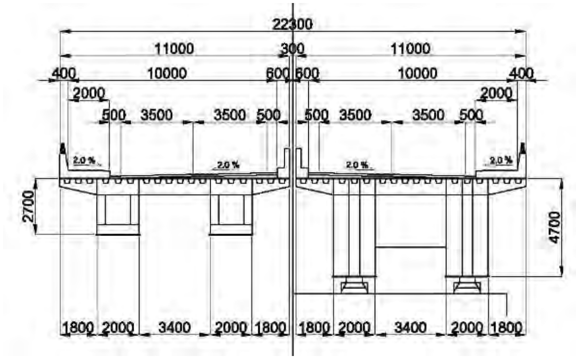
The above table shows the results of bridge type selection among the six alternatives. Alternative-A is the lowest cost type of bridge but Alternative-E has the highest score in the comprehensive engineering assessment considering the preferences of PW, IWT, MPA, and other relative authorities. In consideration of the compilation of new bridge technologies in Myanmar, opinions of river boat pilots, and aesthetic viewpoint, Alternative-E (Combination with Cable-Stayed Bridge and Continuous Steel Box Girder with Steel Plate Deck) is also recommended as the most suitable bridge type.

Table 6.4 Alternative-A: Continuous Steel Box Girder with Steel Plate Deck





Continuous Steel I- Girder with Precast PC Deck Slab

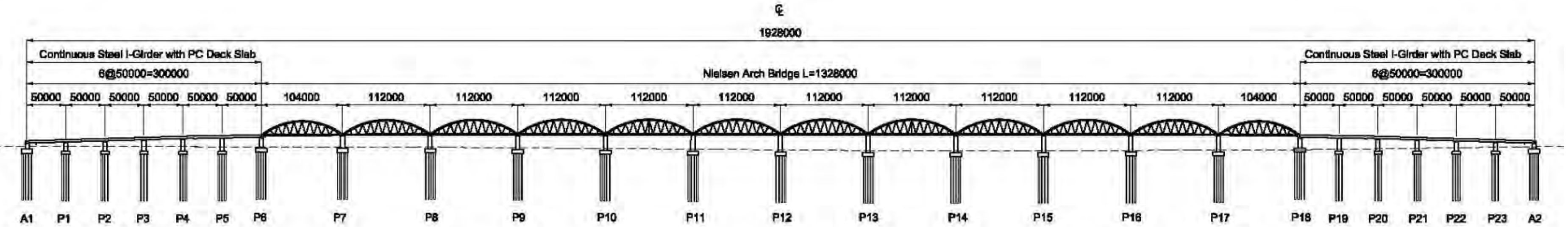


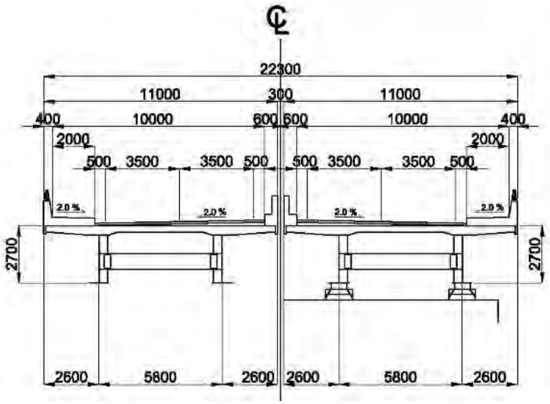
Continuous Steel Box with Steel Deck

Category	Evaluation Criteria	Max. Point	Description	Evaluation	
Technical Viability	Structural Stability	20	Multi-continuous spans are structurally strong against earthquake resistance and results in smooth driving.	Good	20
	Constructability	10	Light and short steel members are advantageous for erection. Construction period is 24 months.	Good	10
Economic Viability	Construction Cost	20	μ =1.00 | Economical bridge type because steel fabrication cost is considerably low in comparison with Japan.	Good	20
	Maintenance	5	Periodical maintenance for painting on steel is only required.	Fair	3
Other Viability	New Technology	20	Steel and precast PC deck slabs are only new approaches.	Poor	6
	Landscape	10	This type of bridge is relatively visually simple and associated with the existing Thanlyin Bridge.	Poor	3
	Navigation	10	Navigation clearance is secured but careful sailing is required due to the adjacent existing Thanlyin Bridge.	Fair	5
	Environment	5	Almost no impact.	Good	5
Evaluation			Recommended in case of minimum cost		72

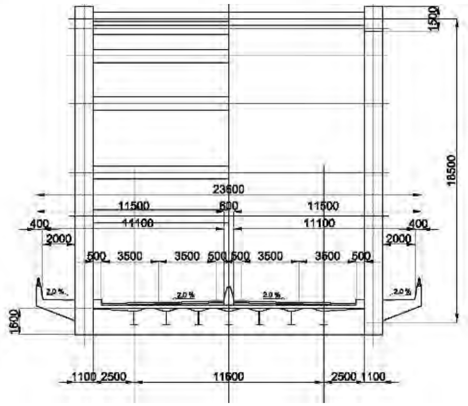
Source: JICA Survey Team

Table 6.5 Alternative-B: Nielsen Arch Bridge





Continuous Steel I- Girder with Precast PC Deck Slab

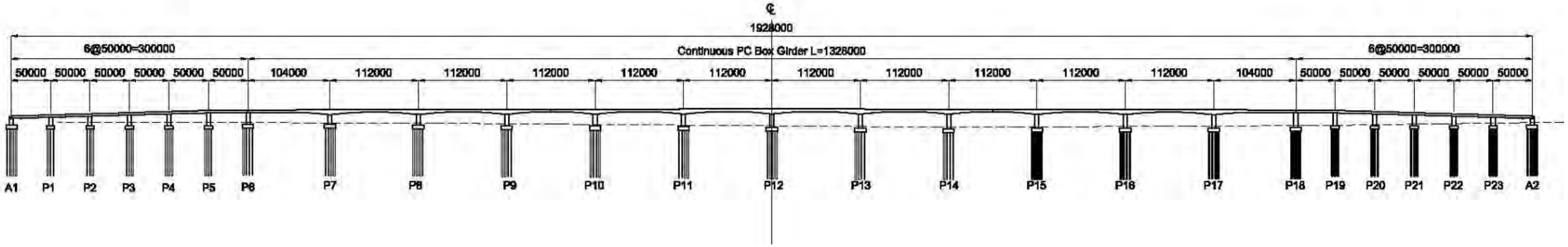


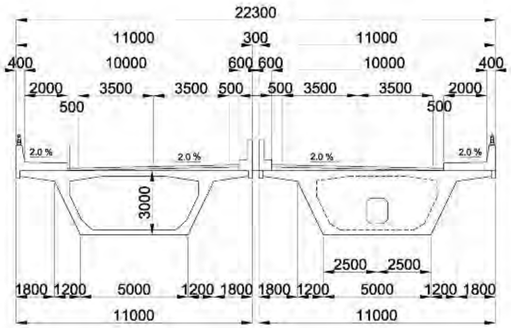
Nielsen Arch

Category	Evaluation Criteria	Max. Point	Description		Evaluation	
Technical Viability	Structural Stability	20	Multi-simple spans are structurally weak against earthquake resistance and make noise when passing at expansion joints.		Fair	10
	Constructability	10	Lift-up barge erection method using tidal movement can be applied. Construction period is 26 months.		Fair	5
Economic Viability	Construction Cost	20	μ=1.21	112 m span is not economical span for Nielsen arch in comparison with continuous steel box girder.	Poor	6
	Maintenance	5	Periodical maintenance for painting on steel is only required.		Fair	3
Other Viability	New Technology	20	Nielsen arch using cables is new technology but too small scale (Span 112 m) for technology transfer.		Fair	10
	Landscape	10	This type is an aesthetical bridge but has relatively visual complexity associated with the existing Thanlyin Bridge.		Fair	5
	Navigation	10	Navigation clearance is secured but careful sailing is required due to the adjacent existing Thanlyin Bridge.		Fair	5
	Environment	5	Almost no impact.		Good	5
Evaluation			Not recommended			49

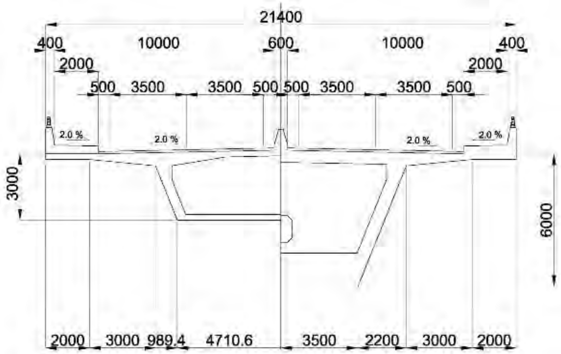
Source: JICA Survey Team

Table 6.6 Alternative-C: Continuous PC Box Girder





Precast Continuous PC Box (Span by Span)

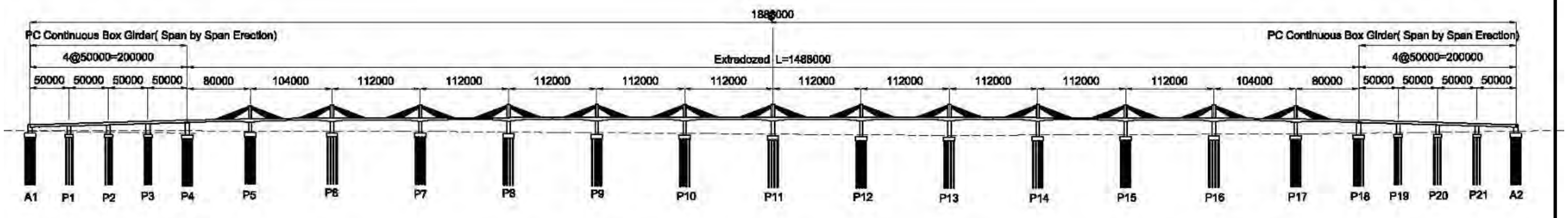


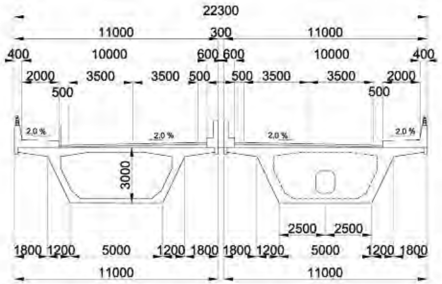
Continuous PC Box

Category	Evaluation Criteria	Max. Point	Description	Evaluation	
Technical Viability	Structural Stability	20	Multi-continuous spans are structurally strong against earthquake resistance but cause deflection problem at center joints.	Fair	10
	Constructability	10	Pre-cast concrete cantilever method is a reliable and safe method in the river. Construction period is 26 months.	Fair	5
Economic Viability	Construction Cost	20	μ=1.05 Concrete bridge has relatively high cost because procurement of the materials is difficult and costly.	Good	20
	Maintenance	5	Maintenance is almost free except expansion joints at center hinges.	Fair	3
Other Viability	New Technology	20	Pre-cast PC box girder is new erection method but not enough for technology transfer.	Poor	6
	Landscape	10	This type of bridge has relatively visual simplicity associated with the existing Thanlyin Bridge.	Poor	3
	Navigation	10	Navigation clearance is secured but careful sailing is required due to the adjacent existing Thanlyin Bridge.	Fair	5
	Environment	5	Almost no impact.	Good	5
Evaluation			Not recommended		57

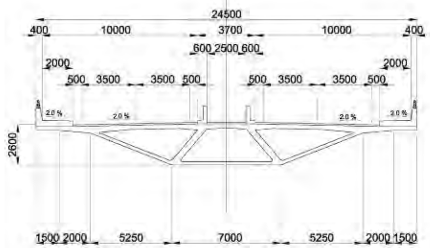
Source: JICA Survey Team

Table 6.7 Alternative-D: Extradozed Bridge

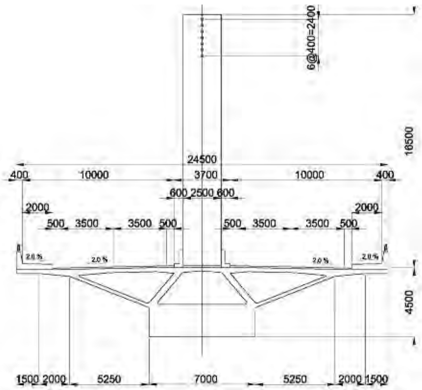




Precast Continuous PC Box (Span by Span)



Extradozed Bridge (At Center)

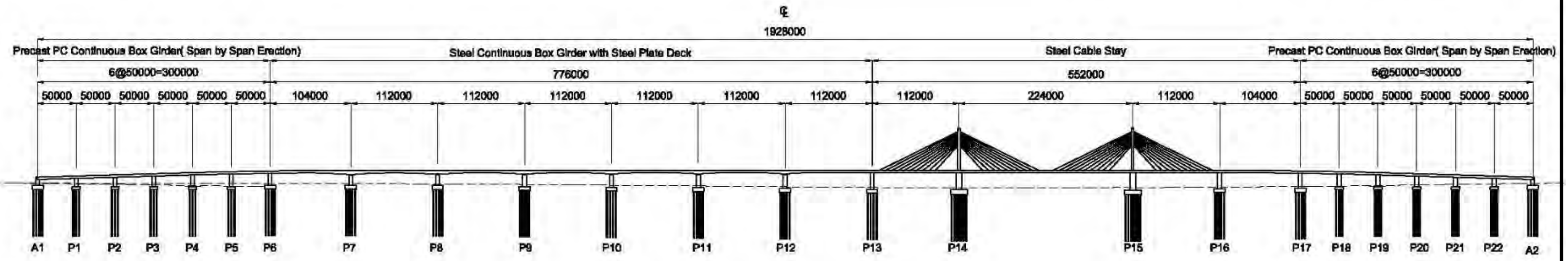


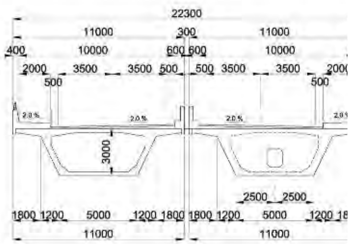
Extradozed Bridge (At Pier)

Category	Evaluation Criteria	Max. Point	Description		Evaluation	
Technical Viability	Structural Stability	20	Multi-continuous spans are structurally strong against earthquake resistance but cause deflection problem at center joints.		Fair	10
	Constructability	10	Cast-in-place concrete cantilever method using outer cables is applied. Construction period is 30 months.		Fair	5
Economic Viability	Construction Cost	20	μ=1.15	Concrete bridge has relatively high cost because procurement of the materials is difficult and costly.	Fair	10
	Maintenance	5	Maintenance is almost free except expansion joints at center hinges.		Fair	3
Other Viability	New Technology	20	Extradozed bridge using cables is new technology but too small scale (Span 112 m) for technology transfer.		Fair	10
	Landscape	10	This type is an aesthetical bridge but has relatively visual complexity associated with the existing Thanlyin Bridge.		Fair	5
	Navigation	10	Navigation clearance is secured but careful sailing is required due to the adjacent existing Thanlyin Bridge.		Fair	5
	Environment	5	Almost no impact.		Good	5
Evaluation			Not recommended			53

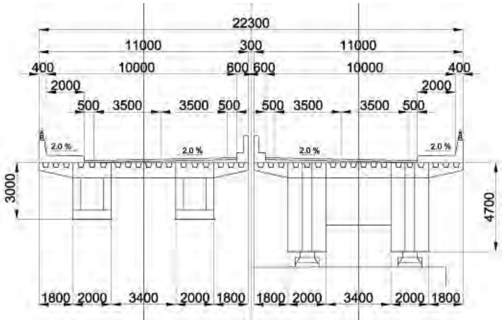
Source: JICA Survey Team

Table 6.8 Alternative-E: Combination with Steel Cable Stayed Bridge and Continuous Steel Box Girder with Steel Plate Deck

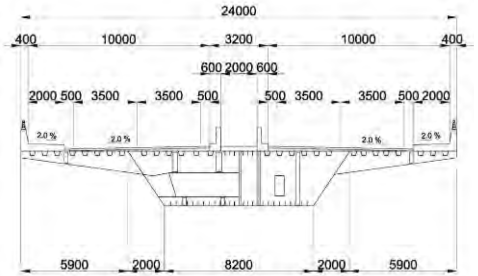




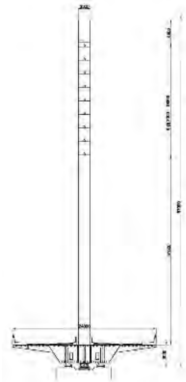
Precast Continuous PC Box (Span by Span)



Continuous Steel Box with Steel Deck Slab



Cable Stay Bridge

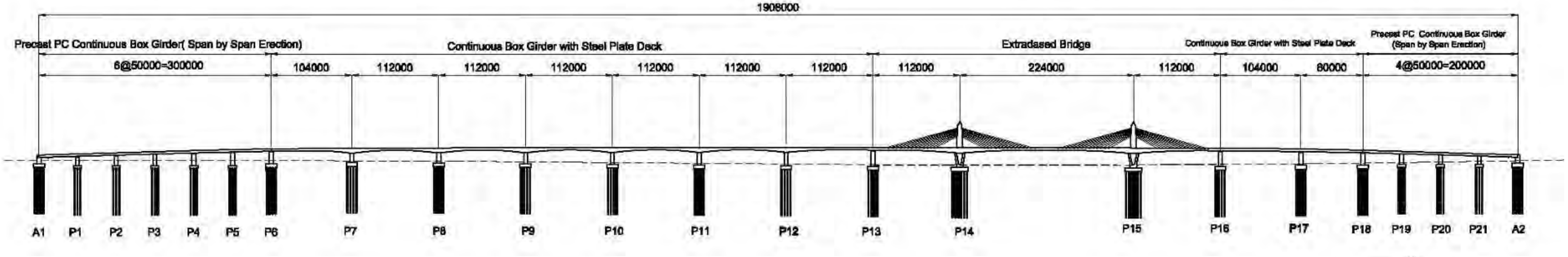


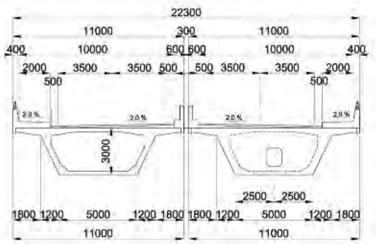
At Tower

Category	Evaluation Criteria	Max. Point	Description		Evaluation	
Technical Viability	Structural Stability	20	Steel cable stay and continuous steel box girders have strong earthquake and wind resistance.		Good	20
	Constructability	10	Erection of cable stay and steel bridges is performed from barge-mounted crane. Construction period is 28 months.		Fair	5
Economic Viability	Construction Cost	20	μ=1.23	Cable-stayed bridge is rather costly but is an economical type for long span of 224 m.	Poor	6
	Maintenance	5	Periodical maintenance for painting on steel is only required.		Fair	3
Other Viability	New Technology	20	Steel cable stay and box girder with steel deck slab and precast PC box girder (Span by Span) are new technologies.		Good	20
	Landscape	10	Excellent view and symbolic structure due to high towers and its cables.		Good	10
	Navigation	10	Wide navigation clearance is secured when sailing from and toward the adjacent existing Thanlyin Bridge.		Good	10
	Environment	5	Almost no impact.		Good	5
Evaluation			Comprehensively Recommended			79

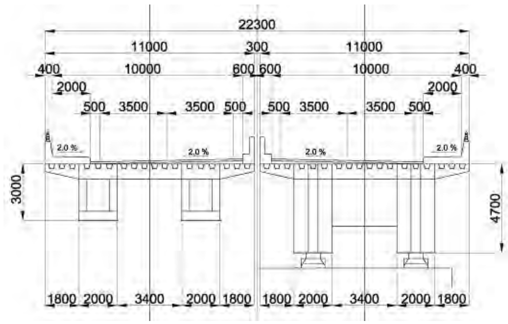
Source: JICA Survey Team

Table 6.9 Alternative-F: Extradozed Bridge and Continuous Steel Box Girder with Steel Plate Deck

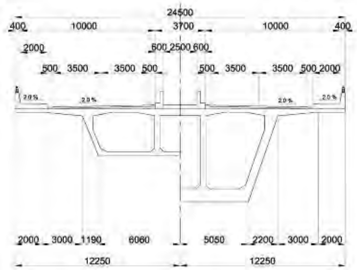




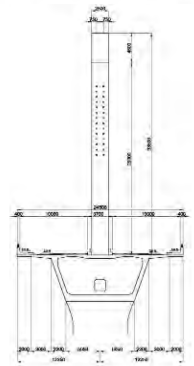
Precast Continuous PC Box (Span by Span)



Continuous Steel Box with Steel Deck Slab



Extradozed Bridge



Pylon

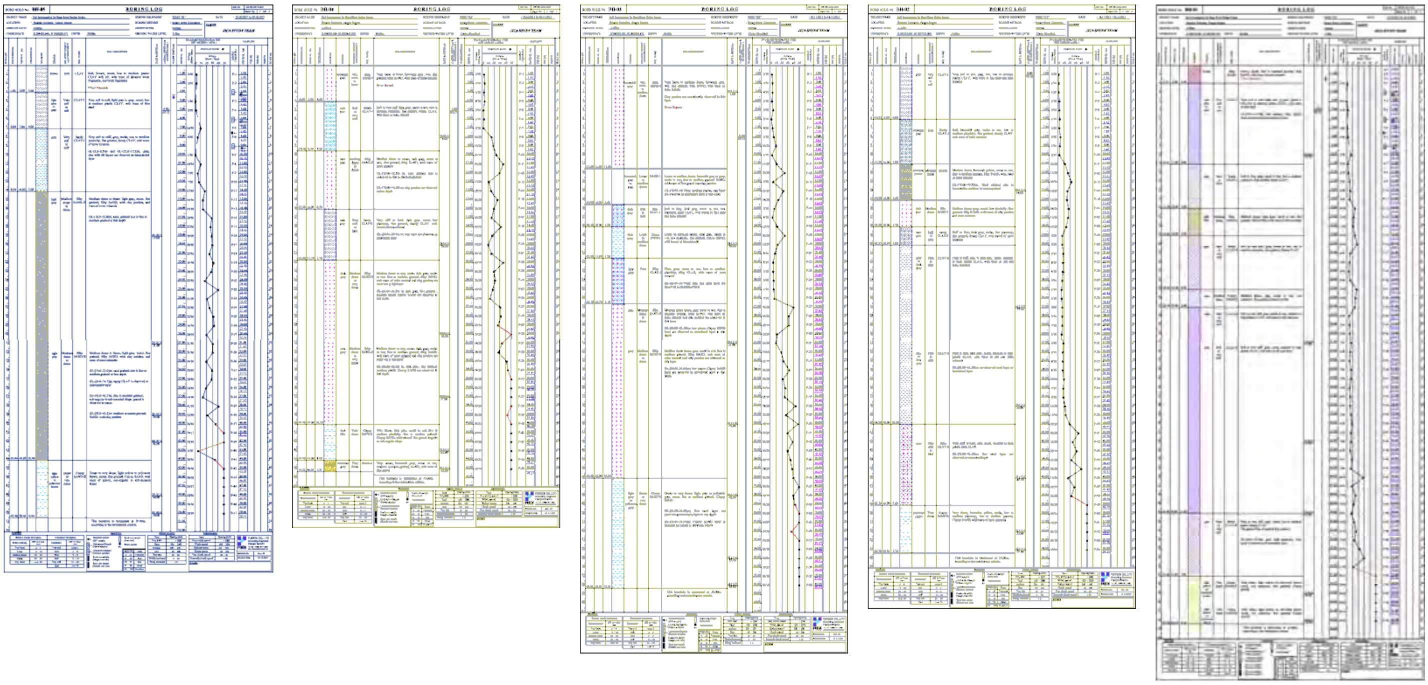
Category	Evaluation Criteria	Max. Point	Description	Evaluation	
Technical Viability	Structural Stability	20	Extradozed bridge alternated with steel bridges is applied for this span arrangement but not suitable.	Fair	10
	Constructability	10	Extradozed bridge with long span (224 m) is technically the most difficult option. Construction period is 32 months.	Poor	3
Economic Viability	Construction Cost	20	μ=1.28 Extradozed bridge is costly because center span of 224 m is out of the economical span (120 m~200 m).	Poor	6
	Maintenance	5	Periodical maintenance for painting on steel part is required.	Fair	3
Other Viability	New Technology	20	Extradozed, precast PC box girder (span by span) and steel box girder with steel deck slab are new technologies.	Good	20
	Landscape	10	Extradozed bridge has excellent view but inferior to cable-stayed bridge as a symbolic structure due to low pylons.	Good	10
	Navigation	10	Wide navigation clearance is secured when sailing from and toward the adjacent existing Thanlyin Bridge.	Good	10
	Environment	5	Almost no impact.	Good	5
Evaluation			Not recommended		67

Source: JICA Survey Team

6.3 Study of Substructure

6.3.1 Study on Foundation Type

The geological investigation conducted at five locations (three locations in the river and two locations on the land). According to the investigation results, it is assumed that the dense sand supporting layer is existing at around EL=-40~-50 m.

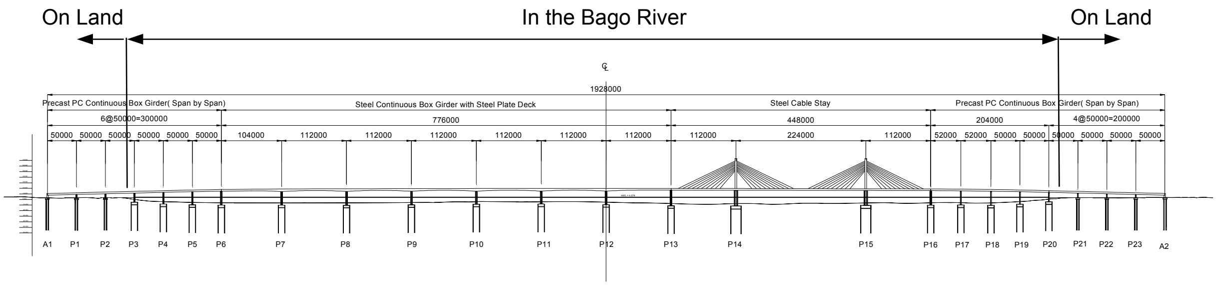


(A1) (P7) (P11) (P15) (A2)

Source: JICA Survey Team

Figure 6.4 Geotechnical Investigation Result

The study of foundation type is conducted in two patterns, i.e., one in the river and another on the land, as the general condition is greatly different.



Source: JICA Survey Team

Figure 6.5 Area In the Bago River and On Land

a) Foundation In the Bago River

The following is a summary of conditions to be studied for the foundation of the river crossing bridge:

- The maximum water depth for proposed bridge sites is more than 10 m.
- Sufficient attention must be paid to scouring in the vicinity of the foundation.
- The foundation must be able to support a large vertical load.
- The supporting layer will be at relatively deep location (EL -40~-50 m).

Table 6.10 shows the selection table of foundation type (from Japan Road Bridge Specifications).

Table 6.10 Applicability Criteria of Foundation Types for Main Bridge

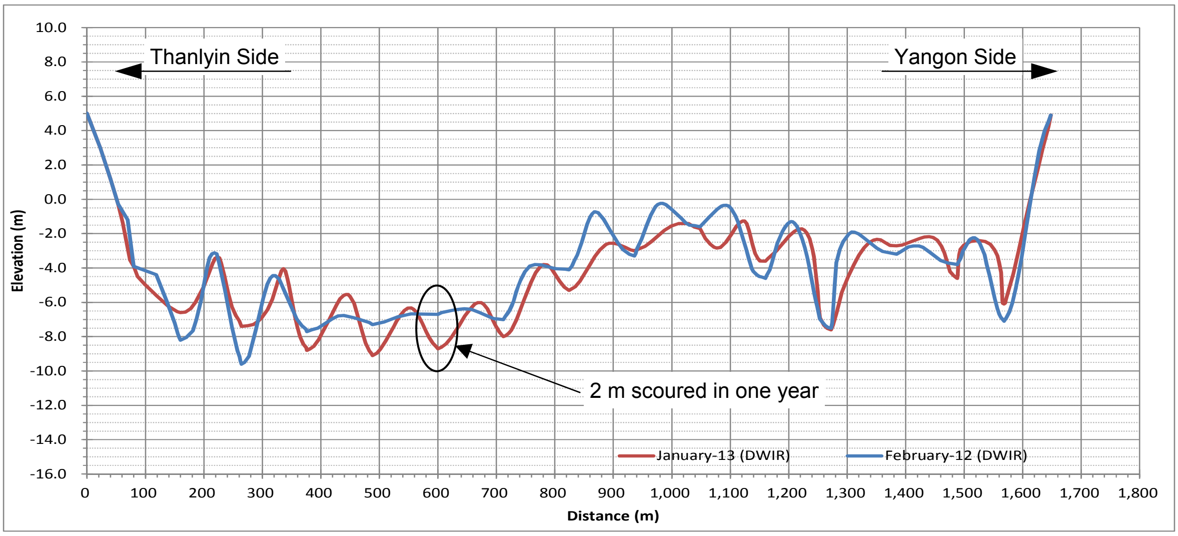
Applicable Condition \ Foundation Type			Cast- in-place Concrete Pile	PHC / SC Pile	Steel Pipe Pile	Diaphragm wall	Steel Pipe Sheet Pile	Caisson
Condition of Construction	Temporary Jetty	Depth < 5 m	△	○	○	×	○	△
		Depth > 5 m	△	△	○	×	○	△
	Environment	Vibration Noise	○	×	×	○	△	○
		Impact on Adjacent Structure	○	×	△	○	△	△
	Loading	Normal	○	○	○	○	○	○
		Large	○	×	○	○	○	○
Ground Condition	Depth of Supporting Layer	< 5 m	△	×	×	×	×	×
		5~15 m	○	○	○	△	△	○
		15~25 m	○	○	○	○	○	○
		25~40 m	○	○	○	○	○	○
		40~60 m	○	△	○	○	○	○
		>= 60 m	△	×	△	△	△	△
	Soil Condition	Clay (20 =< N)	○	○	○	○	○	○
		Sand/Gravel (30 =< N)	○	○	○	○	○	○

Note: ○: Suitable, △: Possible, ×: Impossible Source: Japan Bridge Standard

According to the above table, four foundation types (cast-in-place concrete pile, steel pipe pile, steel pipe sheet pile, and caisson) can be applied to the bridge over the river. However, the steel pipe pile will require temporary cofferdam. Thus, steel pipe sheet pile will be cheaper and more reasonable than steel pipe pile. Accordingly, three foundation types (cast-in-place concrete pile, steel pipe sheet pile, and caisson) can be considered as the foundation type of the bridge over the river.

When the foundation is to be constructed more than 10 m deep from the water surface, in accordance with the above conditions, the size of the temporary cofferdam would be large. Therefore, a foundation that allows the use of a temporary cofferdam also for the main part of the bridge or that omits the temporary cofferdam is considered advantageous.

According to the present result of river crossing survey at Thanlyin Bridge in February 2012 and January 2013, maximum 2 m scouring can be seen at the pier location in only a year (see Figure 6.6). Therefore, it is necessary to pay close attention to scouring.



Source: DWIR

Figure 6.6 River Crossing Survey Results at Thanlyin Bridge

Cast-in-place concrete pile will be a multi-pile type since the depth of the water is very deep. Therefore, it is greatly easy to receive influence of scouring.

Table 6.11 shows the foundation type alternatives in the river. In addition, the three piers (P12, P14, and P18) which are representatives in each type of superstructure, a comparison between cast-in-place concrete pile and steel pipe sheet pile was carried out (refer to Table 6.12~Table 6.14).

Source: PW

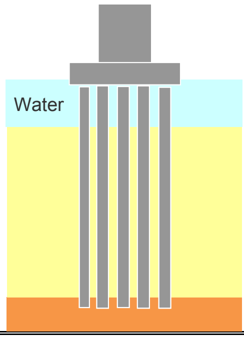
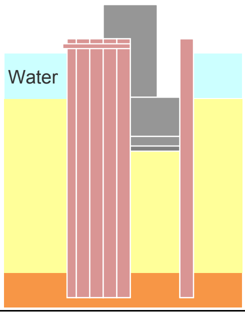
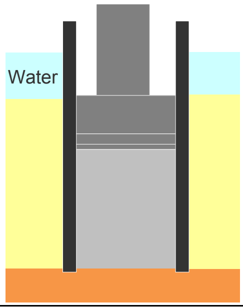
Photo 6.1 Scouring around Cast-in-place Pile Foundation

As a result of the comparison mentioned above, steel pipe sheet pile foundation is considered the optimal solution in terms of its applicability to deep-water construction and anti-scouring properties.

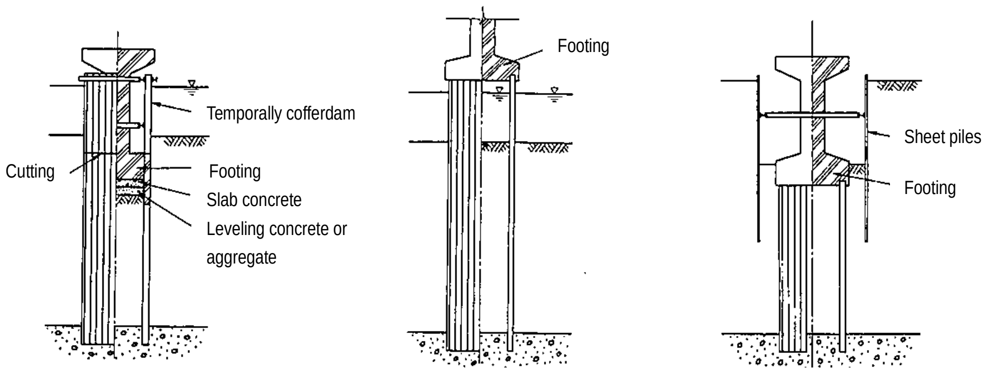
As illustrated in Figure 6.7, steel pipe sheet pile foundations can be categorized into three types based on construction method, i.e.: (1) temporary cofferdam-combined method, (2) build-up method, and (3) cofferdam method. Because the temporary cofferdam-combined method is commonly used for general bridges, it was applied to the project site based on economic, construction timeframe, and safety considerations.

In addition, as for the foundation shape, round shape or oval shape will be adopted in consideration of the river flow (refer to Figure 6.8).

Table 6.11 Foundation Type Alternatives for the Main Bridge

	Cast-in-place Concrete Pile	Steel Pipe Sheet Pile	Concrete Caisson
Foundation Type			
Workability on Water	**Inferior** - Temporary cofferdam is separately required. - Permanent casing is required. - Loading test is required.	**Superior** - Temporary cofferdam is not separately required. - Loading test is not required.	**Moderate** - Temporary cofferdam is not separately required. - Loading test is not required.
Work Period	**Moderate** - Driving of many piles takes time.	**Superior** - After driving steel pipe, construction is fast and safe.	**Moderate** - It takes time for excavation.
Against Ship Collision	**Inferior** - Because multi-pile structure.	**Superior** - Because rigid and massive structure.	**Superior** - Because rigid and massive structure.
Against Scouring	**Inferior** - Because multi-pile structure.	**Superior** - Because rigid and massive structure.	**Superior** - Because rigid and massive structure.
Safety of Works	**Moderate** - Temporary cofferdam is separately required.	**Superior** - Temporary cofferdam is not separately required.	**Superior** - Temporary cofferdam is not separately required.
Cost	**Superior**	**Moderate**	**Moderate**
Experience in Myanmar	**Many** - No new technology	**None** - New technology and technical transfer can be done	**Some** - No new technology.
Evaluation	- Although the construction cost is cheapest among the alternatives, it is inferior for ship collision and scouring. "Not Recommendable"	- Although the construction cost is inferior to cast-in-place concrete pile, it is superior in other aspects. - Also, technical transfer will be done since there is no experience yet with this type in Myanmar. **"Recommendable"**	- Although the construction cost is inferior to cast-in-place concrete pile, it is superior in some aspects. - Some aspects are inferior to steel pipe sheet pile. "Not Recommendable"

Source: JICA Survey Team

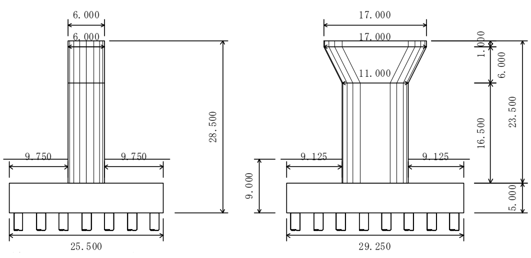
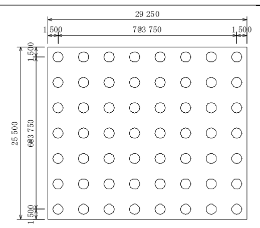
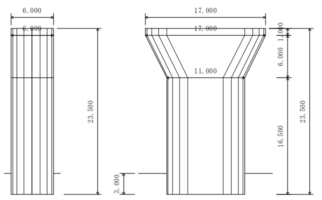
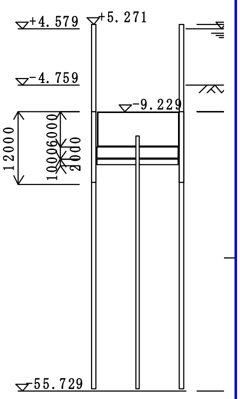
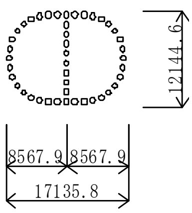


i) Foundation & temporary cofferdam method ii) Vertical pile method iii) Cofferdam method

Source: Japanese Association for Steel Pipe Piles

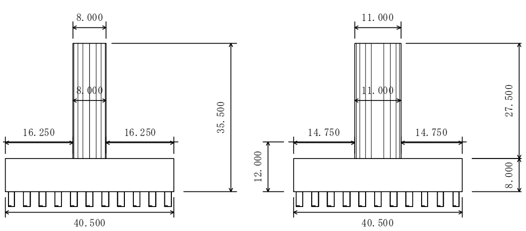
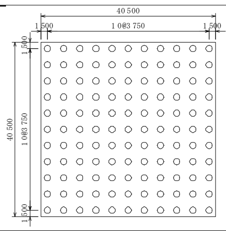
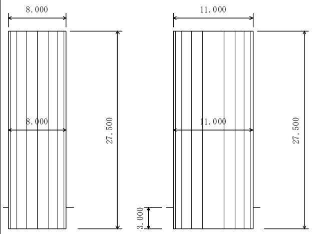
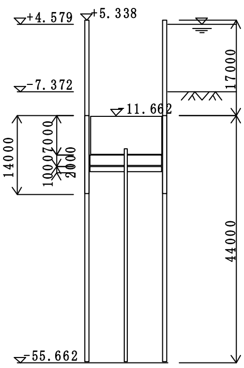
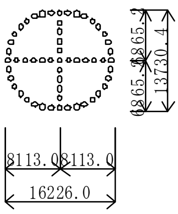
Figure 6.7 Cofferdam Method for Steel Pipe Sheet Pile Foundation

Table 6.12 Comparison of Foundation Type In the River (P12: Box Girder with Steel Plate Deck Section)

	Cast-in-Place Concrete Pile (φ1500)	Steel Pipe Sheet Pile (φ1000)
Foundation	 Plan 	  Plan 
Description	■Pier Column ･6m x 11m ･Main re-bar : D32 ･Seismic time ■Foundation ･Cast-in-place concrete pile, φ1500-56, L=40.0m	■Pier Column ･6m x 11m ･Main re-bar : D32 ･Seismic time ■Foundation ･Steel pipe sheet pile, φ1000-44, L=61.0m
Cost ratio	1.10	1.00
Evaluation	△ (Construction term will be very long since there are so many piles)	○

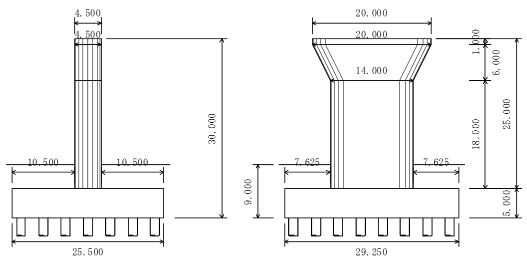
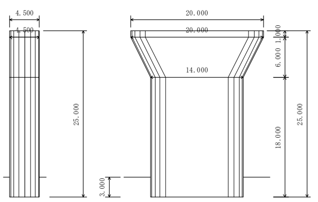
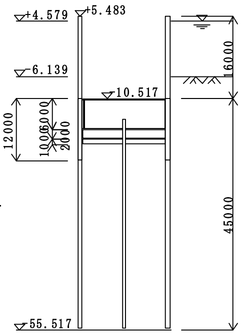
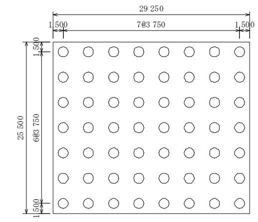
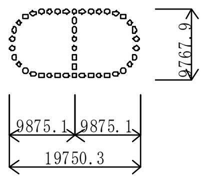
Source: JICA Survey Team

Table 6.13 Comparison of Foundation Type In the River (P14: Cable-stayed Bridge Section)

	Cast-in-Place Concrete Pile (φ1500)	Steel Pipe Sheet Pile (φ1000)
Foundation	 Plan 	  Plan 
Description	■Pier Column ･8m x 11.0m ･Main re-bar : D32 ･Seismic time ■Foundation ･Cast-in-place concrete pile, φ1500-121, L=33.5m	■Pier Column ･8m x 11.0m ･Main re-bar : D32 ･Seismic time ■Foundation ･Steel pipe sheet pile, φ1000-55, L=61.0m
Cost ratio	1.80	1.00
Evaluation	△ (Construction term will be very long since there are so many piles)	○

Source: JICA Survey Team

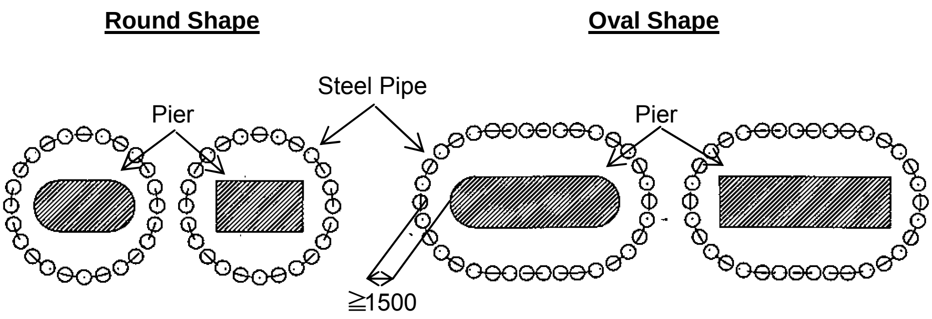
Table 6.14 Comparison of Foundation Type In the River (P18: PC Box Girder Section)

	Cast-in-Place Concrete Pile (ϕ1500)		Steel Pipe Sheet Pile (ϕ1000)	
Foundation				
	Plan		Plan	
Description	■Pier Column ・4.5m x 14.0m ・Main re-bar : D32 ・Seismic time ■Foundation ・Cast-in-place concrete pile, ϕ1500-56, L=40.0m		■Pier Column ・4.5m x 14.0m ・Main re-bar : D32 ・Seismic time ■Foundation ・Steel pipe sheet pile, ϕ1000-44, L=61.0m	
Cost ratio	1.10		1.00	
Evaluation	△ (Construction term will be very long since there are so many piles)		○	

Source: JICA Survey Team

As for the foundation shape, round shape or oval shape will be adopted in consideration of the river flow.

Generally, the smallest shape of steel pile sheet pile foundation is decided by the shape of piers. In case of concrete piers, the distance between the inside of the sheet pile and pier shall be kept more than 1.5 m in consideration of the size of falsework, thickness of inter-filling concrete, working space, and formwork of pier.



Source: JICA Survey Team

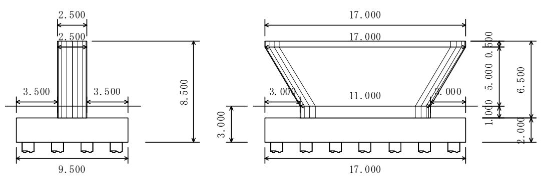
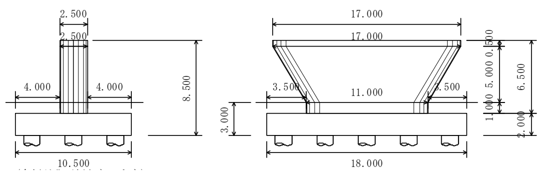
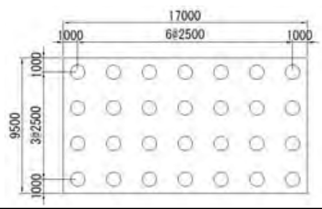
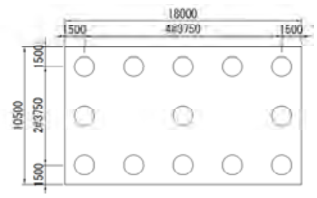
Figure 6.8 Possible Shape of Steel Pipe Sheet Pile Foundation

b) Foundations on Land

As for the foundation type on land, piers and abutment are constructed on existing ground surfaces. A multi cast-in-place pile foundation using bored piles will be selected for its easy constructability and procurement of materials/equipment as well as the availability of experience in Myanmar.

Although several construction methods for the cast-in-place pile foundation (e.g., all casing, reverse, earth drilling method, etc.) could be considered, the reverse method using casing pipe, which is widely used in Myanmar, will be adopted.

Table 6.15 Comparison of Cast-in-place Concrete Pile on Land (P1: PC Box Girder Section)

	Cast-in-Place Concrete Pile (φ1000)	Cast-in-Place Concrete Pile (φ1500)
Foundation		
	Plan 	Plan 
Description	■Pier Column ・2.5m x 11m ・Main re-bar : D32 ・Seismic time ■Foundation ・Cast-in-place concrete pile, φ1000-28, L=40.5m	■Pier Column ・2.5m x 11m ・Main re-bar : D32 ・Seismic time ■Foundation ・Cast-in-place concrete pile, φ1500-13, L=41.0m
Cost ratio	1.004	1.000
Evaluation	△ (Construction term will be very long since there are so many piles)	○

Source: JICA Survey Team

6.3.2 Adverse Effect of New Bridge Foundation on Existing Bridge Foundation

When the new bridge is constructed in the neighbourhood of the existing bridge, the construction sometimes gives some adverse effects on the existing bridge due to ground movement.

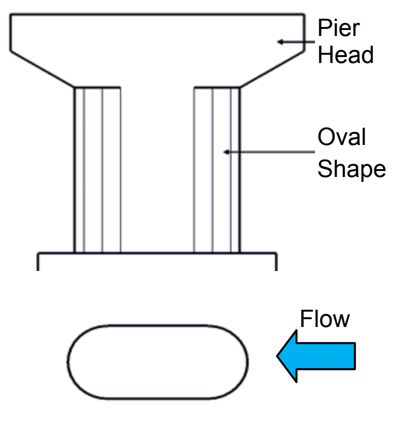
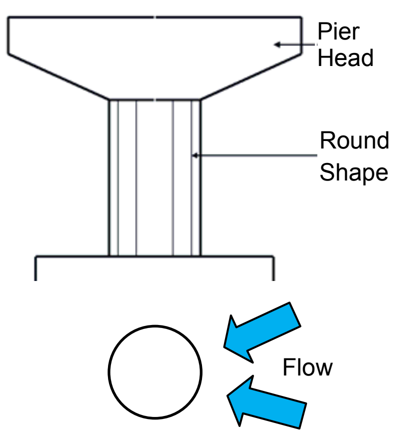
However, it can be judged that the adverse effects to the existing Thanlyin Bridge by the construction of the new bridge will not occur at all since the new bridge is approximately 140 m away from the existing Thanlyin Bridge.

6.3.3 Study on Substructure Type

The substructure would be constructed by reinforced concrete.

As for the substructure shape, round shape or oval shape will be adopted in consideration of the river flow. Besides, the direction of substructure should be the same direction as the river flow.

Table 6.16 Substructure Type Alternatives for Main Bridge

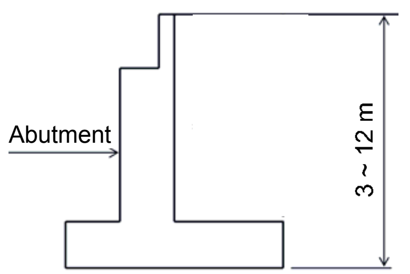
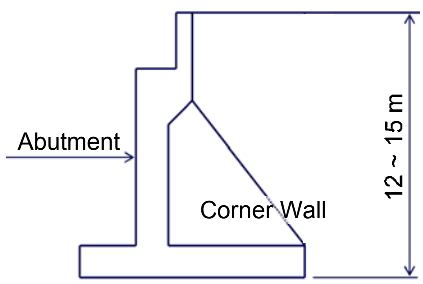
	Oval	Round
Substructure Type		
Feature	It is applied to the river bridge. Oval shaped pier is set parallel to the water flow in order to keep smooth water flow.	It is applied to the river bridge. When the direction of the river flow is not fixed such as in the river junction, it is applied.

Source: JICA Survey Team

6.3.4 Study on Abutment Type

Although few abutment types can be considered, reverse T shape will be applied in consideration of cost and constructability.

Table 6.17 Abutment Type Alternatives

	Reverse T Type	Counterfort Type
Abutment Type		
Feature	It is very common and has an economical shape.	It is difficult to construct corner wall. It is not a common shape. Although box type is also considered, it is not an economical shape.

Source: JICA Survey Team

Chapter 7

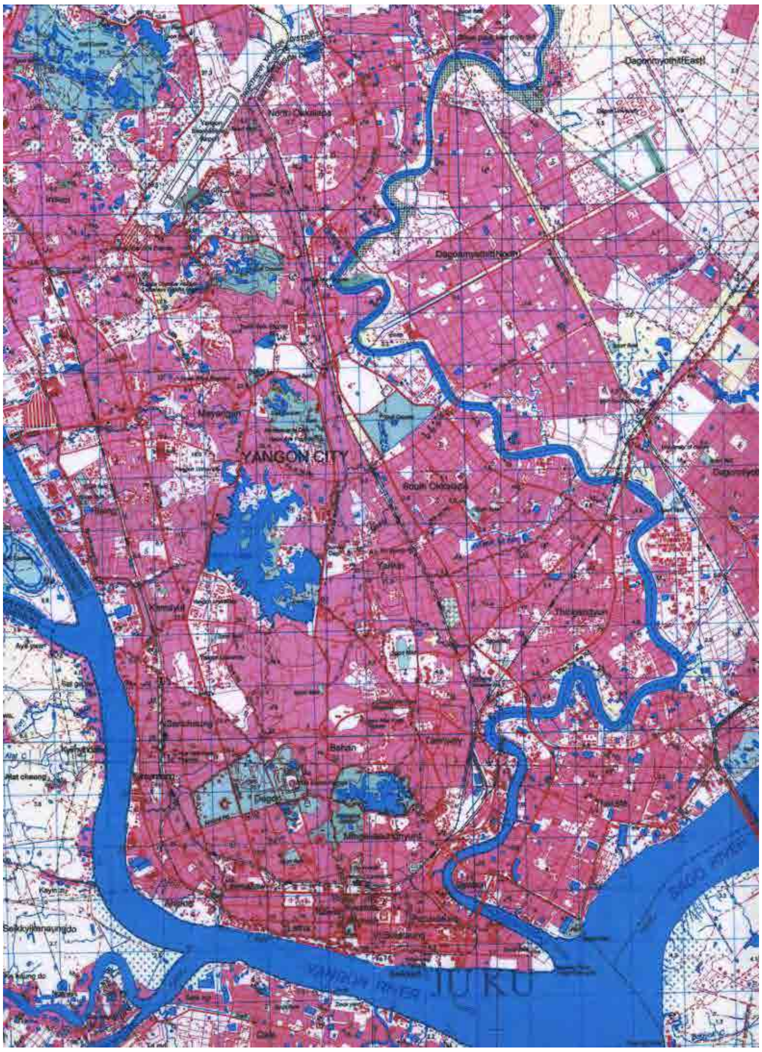
Natural Condition Surveys

7. Natural Condition Surveys

7.1 Topographic Survey

7.1.1 Summary of the Yangon Urban Area

The Yangon urban area is situated between latitudes 17°06’ N and 16°35’ N, and between longitudes 95°58’ E and 96°24’ E, and is located in the east side of the Aveyarwaddy River delta area. There is a range of mountains and hills about 25-30 m above sea level called the Bago Yoma that stretches from north to south in the central delta. The altitude of the low-lying area is very low and parts of this area often experience flood during the rainy season. A map of Yangon City is shown in Figure 7.1.



Source: Japan International Cooperation Agency (JICA) and Survey Department Ministry of Forestry in the Union of Myanmar, 2004

Figure 7.1 Map of Yangon City

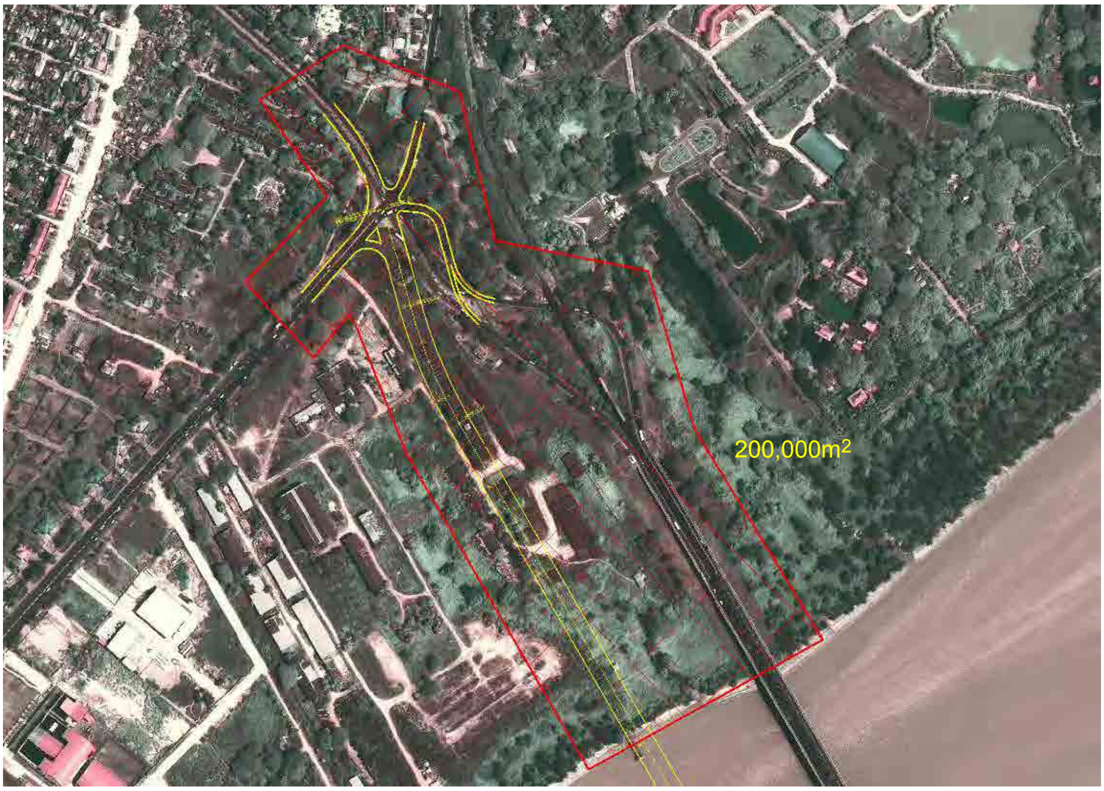
7.1.2 Topographic Survey

The topographic survey commenced on August 29, 2013 and was completed on November 30, 2013.

The topographic survey is divided into the following nine subcomponents:

1) Mobilization and demobilization,
2) Benchmark installation,
3) Control point installation,
4) Plane survey by total station,
5) Profile leveling survey for road centerline,
6) Profile leveling survey for road cross section,
7) Profile leveling survey for river axial direction,
8) Profile leveling survey for river cross section, and
9) Mapping and reporting.

All these surveys were carried out on the Kyak Khauk Pagoda Road for the design of Bago River Bridge including its approach road. The areas where the topographic survey was conducted are shown in Figures 7.2 to 7.7.

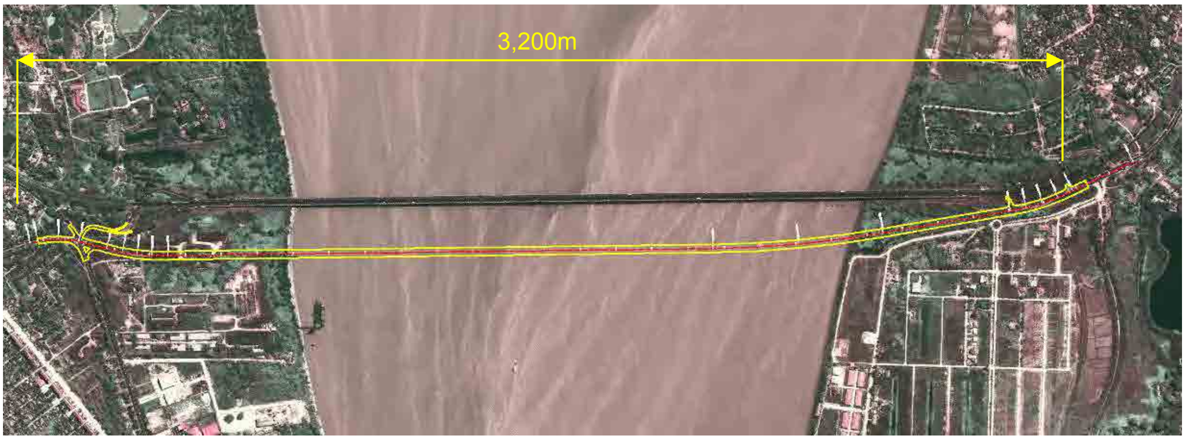


Source: JICA Survey Team

Figure 7.2 Area of Plane Survey (1/2)

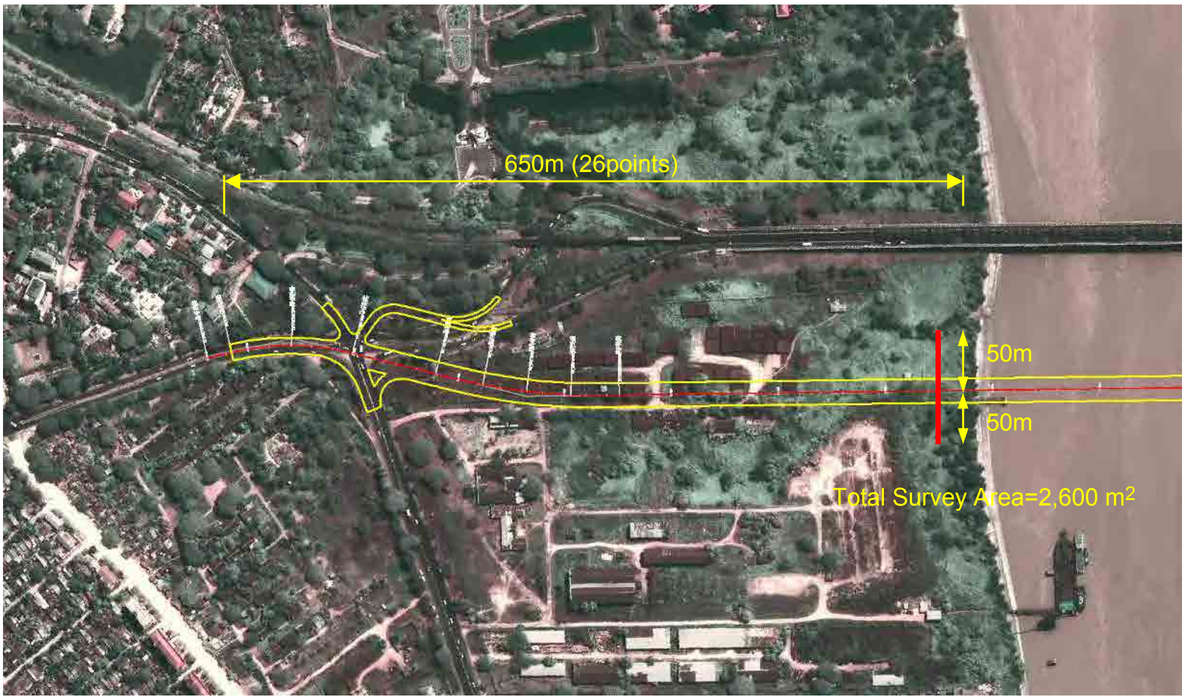
Source: JICA Survey Team

Figure 7.3 Area of Plane Survey (2/2)



Source: JICA Survey Team

Figure 7.4 Area of Profile and Cross Section Survey for Road (1/3)

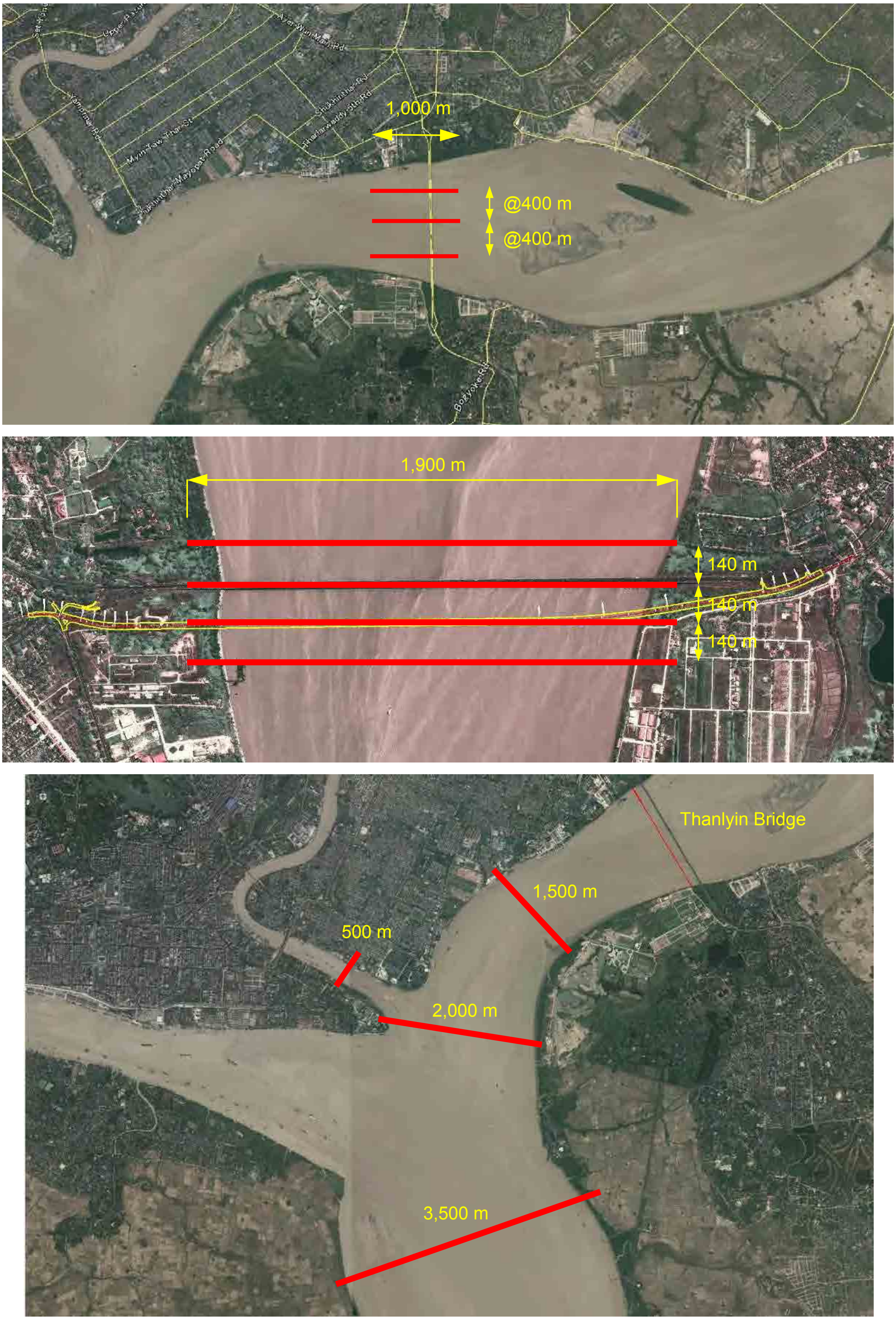


Source: JICA Survey Team

Figure 7.5 Area of Profile and Cross Section Survey for Road (2/3)

Source: JICA Survey Team

Figure 7.6 Area of Profile and Cross Section Survey for Road (3/3)

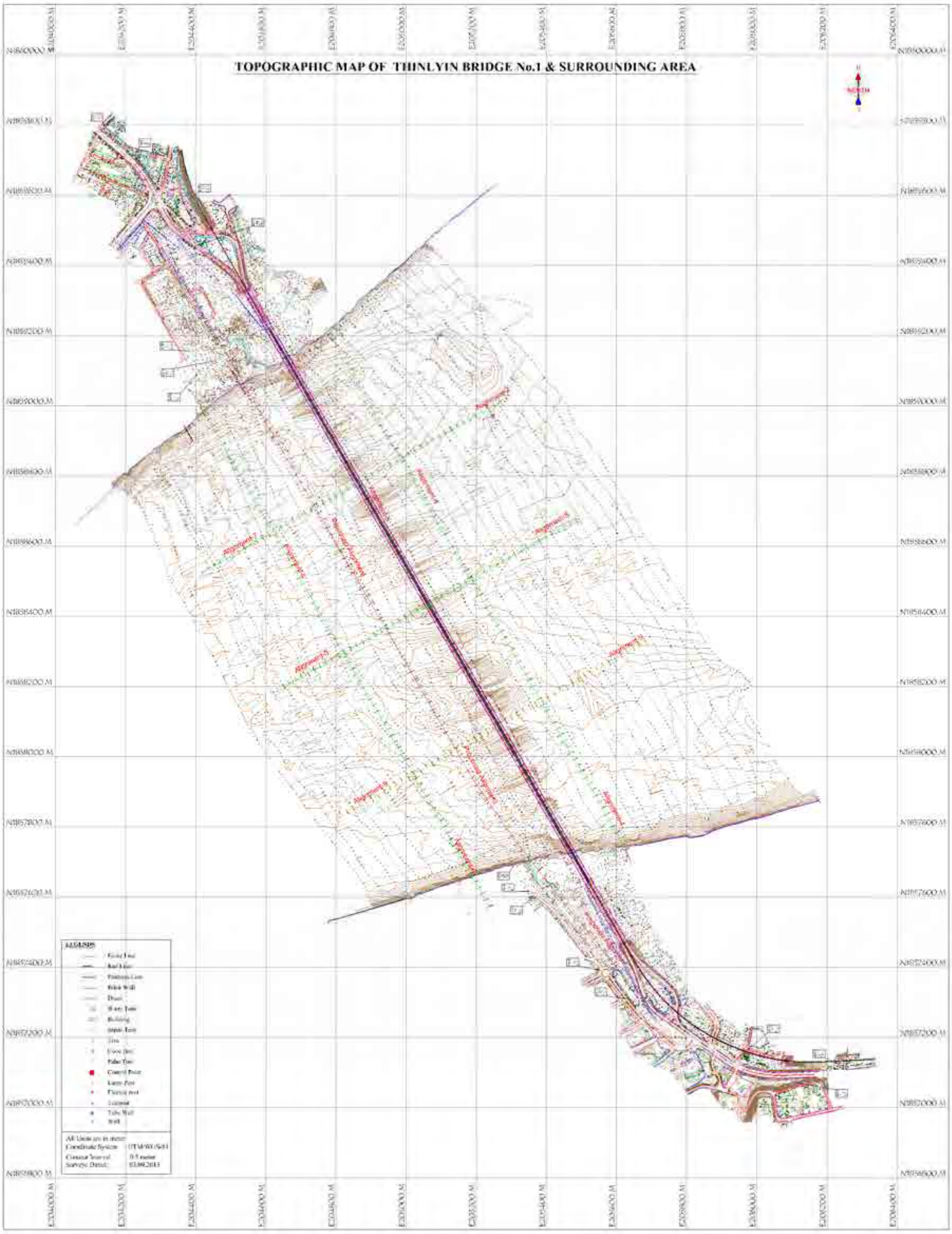


Source: JICA Survey Team

Figure 7.7 Area of Cross Section Survey for the River

7.1.3 Survey Result

Figure 7.8 shows the result of the plane survey.



Source: JICA Survey Team

Figure 7.8 Plane Survey Result

7.2 Geological Survey

7.2.1 Summary of Geological Condition

The geological condition of the surface in Yangon is divided in three categories, as follows (refer to Figure 7.9):

- Alluvium,
- Irrawaddy formation, and
- Pegu group.

Generally, the Yangon area is covered by alluvium. The Irrawaddy Formation comprises the bedrock along the Bago Yoma, the Arzamigone Sandstone in the north of the Shwedagon Pagoda, and Danyingone Clay in the east of the Arzamigone Sandstone. The Pegu Group comprises the Besapet Alternation, Thadugan Sandstone, and Hlawga Shale distributed in the north of the Yangon area.

(a) Alluvium

Recent Alluvium

Top soil has been covered with river deposits in recent years, which blankets all over the project area. It has brown to gray, mottled brown, and yellow colors, and the main constituents frequently found are clay and organic matters, which come from decayed plant roots and wood. The formation of these materials is caused by flood action and yields moderate to high water content.

Older Alluvium

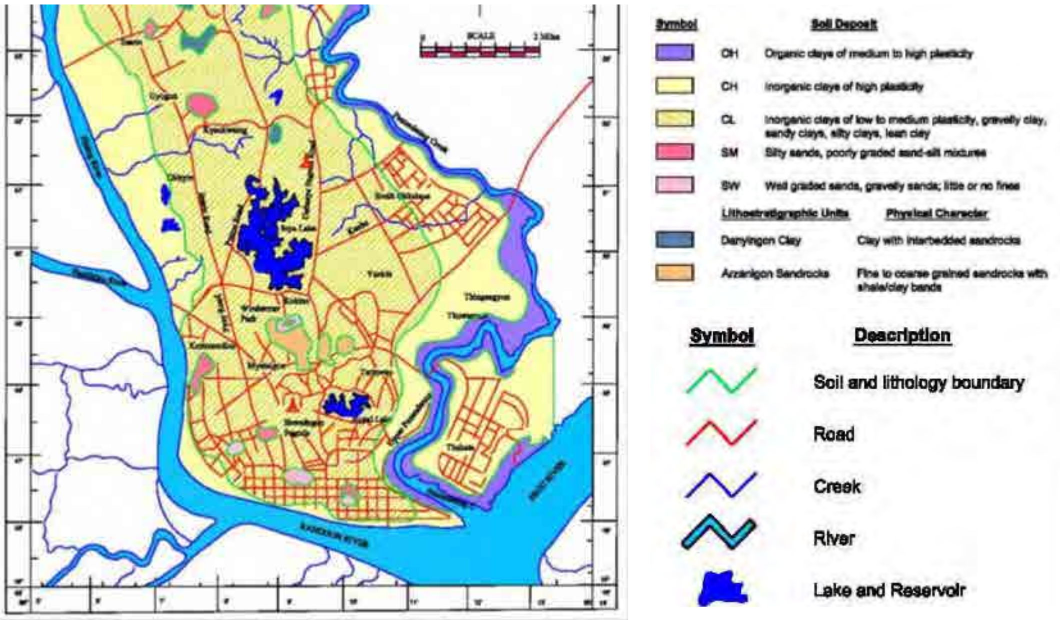
The older alluvial deposits consist of medium to very dense and poorly graded sand with silt, mainly yellowish brown in color,. In all borehole locations, trace amounts of gravel were found. Moreover, water content is low to moderate in those layers.

(b) Irrawaddy Formation

This formation is composed of yellowish fine sand of the Irrawaddian Group. The outcropping areas can be seen in Danyingone, Arzarnigone, Southern Twin Te, and the left bank of Yangon-Than Hlyn across the Pegu River.

(c) Pegu Group

This formation is mainly composed of sand and shale interbeds. Outcropping areas are found along the anticlinal ridges of the Danyingone and Than Hlyn areas. Most of them are composed of reddish brown oxidized lateritic soil.



Source: Geology of Burma, 1983, Dr. Friedrich Bender

Figure 7.9 Geological Structure

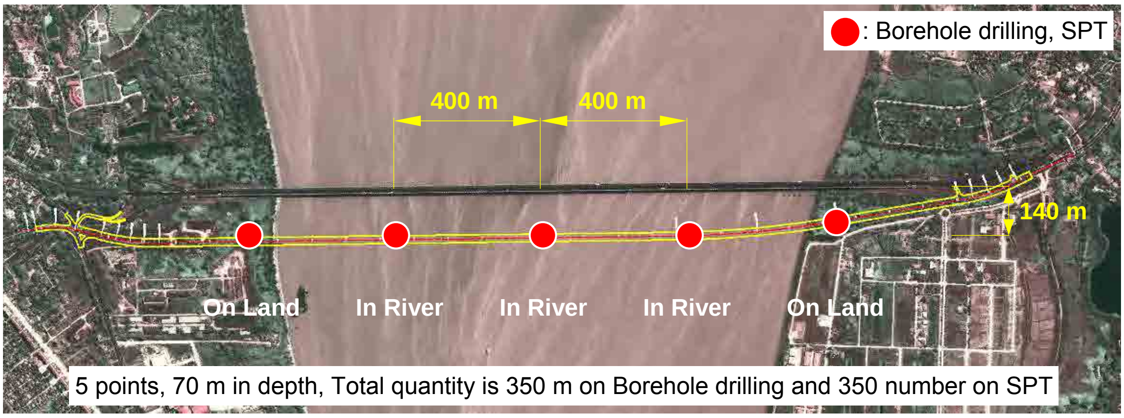
7.2.2 Geological Survey

The geological survey commenced on August 29, 2013 and was completed on November 30, 2013.

This survey is divided into five subcomponents:

1) Mobilization and demobilization,
2) Borehole drilling on land and in the river,
3) Standard penetration test (SPT),
4) Laboratory test, and
5) Reporting.

The locations where the survey was conducted are shown in Figure 7.10.



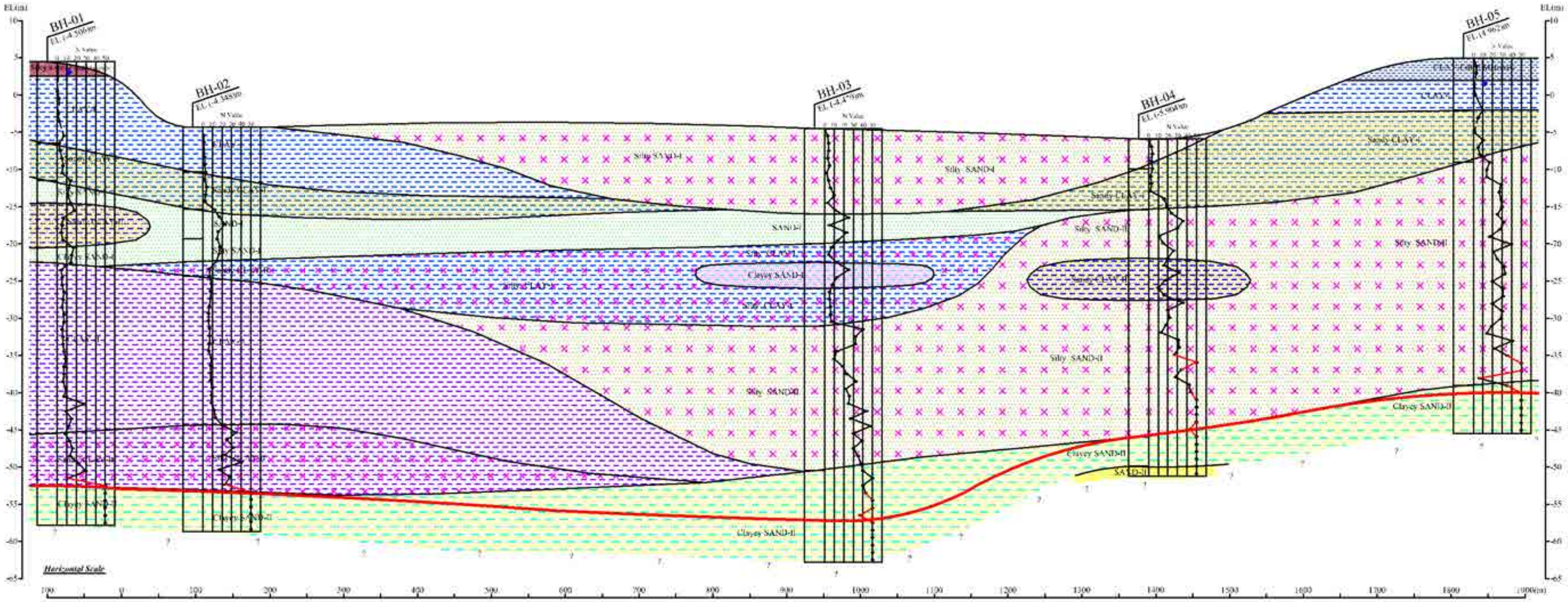
Source: JICA Survey Team

Figure 7.10 Position of Survey

The contents of the laboratory test are the following:

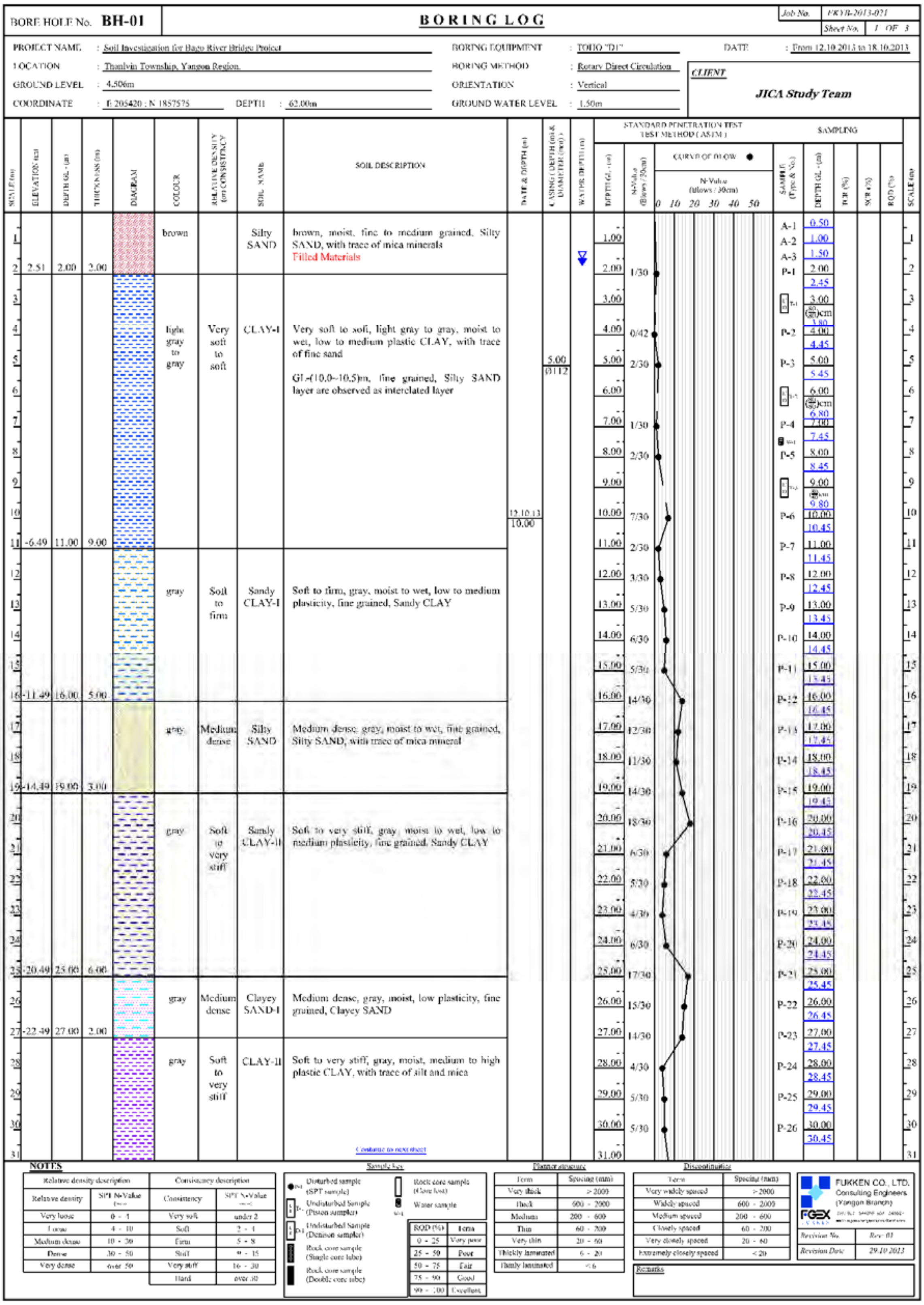
- Natural moisture content test,
- Specific gravity test,
- Particle size analysis,
- Atterberg limit test,
- Unit weight, and
- Unconfined compression test.

Figure 7.11 shows the soil profile of the Project area based on the boring logs of BH-01 to BH-05 (samples logs are shown in Figures 7.12 to 7.16).



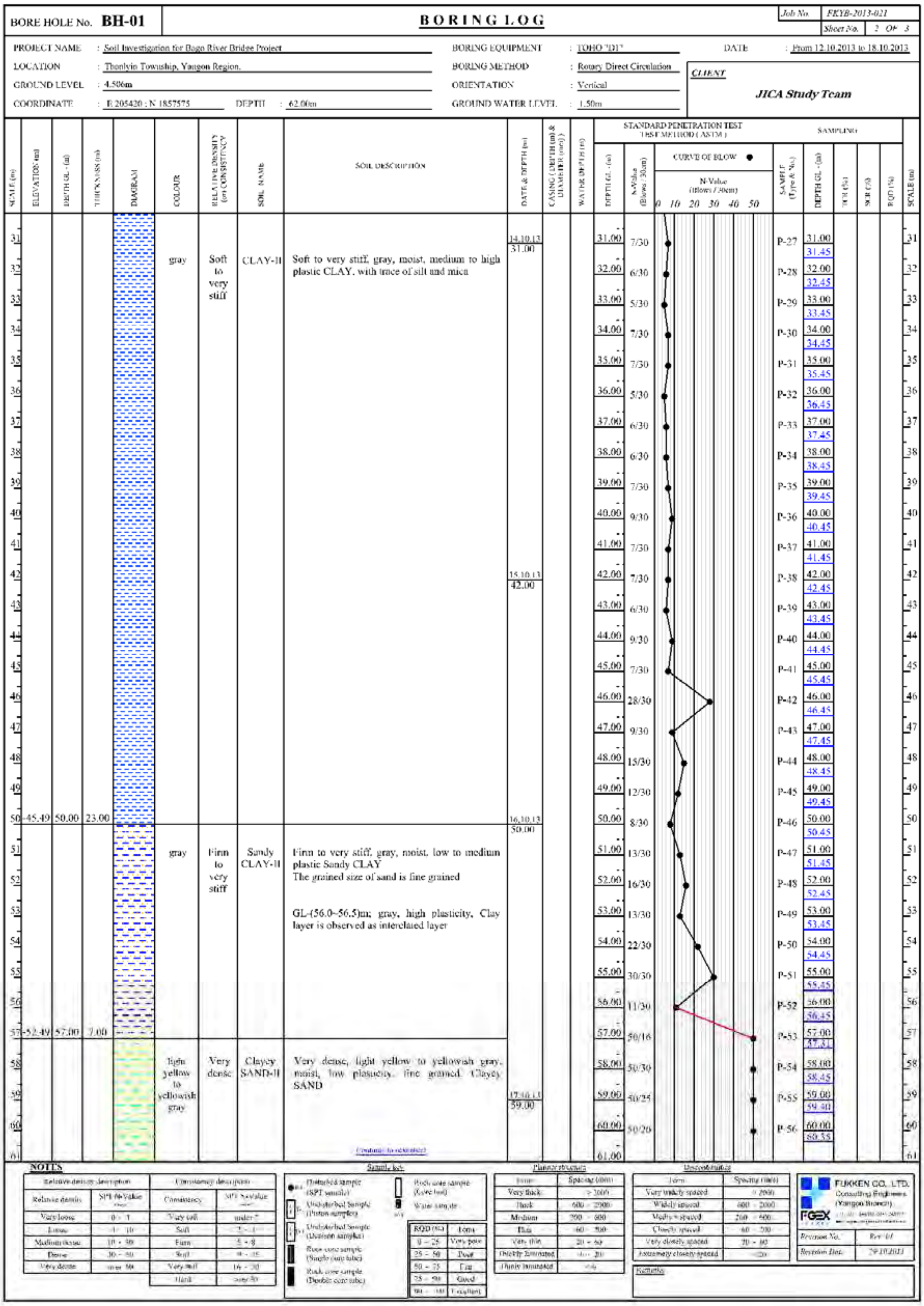
Source: JICA Survey Team

Figure 7.11 Soil Profile of the Project Area



Source: JICA Survey Team

Figure 7.12 Boring Log (BH-01) 1/3



Source: JICA Survey Team

Figure 7.13 Boring Log (BH-01) 2/3

BORE HOLE No. **BH-01**	**BORING LOG**	Job No.	FKYB-2013-021
		Sheet No.	3 OF 3

PROJECT NAME	: Soil Investigation for Bago River Bridge Project	BORING EQUIPMENT	: TOHO "D1"
LOCATION	: Thanlyin Township, Yangon Region.	BORING METHOD	: Rotary Direct Circulation
GROUND LEVEL	: 4.506m	ORIENTATION	: Vertical
COORDINATE	: E 205420 ; N 1857575 DEPTH : 62.00m	GROUND WATER LEVEL	: 1.50m

DATE : From 12.10.2013 to 18.10.2013

CLIENT: ***JICA Study Team***

SCALE (m)	ELEVATION (m)	DEPTH GL - (m)	THICKNESS (m)	DIAGRAM	COLOUR	RELATIVE DENSITY (or CONSISTENCY)	SOIL NAME	SOIL DESCRIPTION	DATE & DEPTH (m)	CASING (DEPTH (m) & DIAMETER (mm))	WATER DEPTH (m)	STANDARD PENETRATION TEST (TEST METHOD (ASTM)) DEPTH GL - (m)	N-Value (Blows / 30cm)	CURVE OF BLOW ● N-Value (Blows / 30cm) 0 10 20 30 40 50	SAMPLING SAMPLE (Type & No.)	DEPTH GL - (m)	TCR (%)	SCR (%)	RQD (%)	SCALE (m)
61					light yellow to yellowish gray	Very dense	Clayey SAND-II	Very dense, light yellow to yellowish gray, moist, low plasticity, fine grained, Clayey SAND				61.00	50/16		P-57	61.00 / 61.31				61
62	-57.83	62.34	5.34						18.10.13 / 62.00			62.00	50/19		P-58	62.00 / 62.34				62
63								This borehole is terminated at 62.00m, after confirmation.				63.00								63
64												64.00								64
65												65.00								65
66												66.00								66
67												67.00								67
68												68.00								68
69												69.00								69
70												70.00								70
71												71.00								71
72												72.00								72
73												73.00								73
74												74.00								74
75												75.00								75
76												76.00								76
77												77.00								77
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87												87.00								87
88												88.00								88
89												89.00								89
90												90.00								90
91												91.00								91

NOTES

Relative density description		Consistency description	
Relative density	SPT N-Value	Consistency	SPT N-Value
Very loose	0 - 4	Very soft	under 2
Loose	4 - 10	Soft	2 - 4
Medium dense	10 - 30	Firm	5 - 8
Dense	30 - 50	Stiff	9 - 15
Very dense	over 50	Very stiff	16 - 30
		Hard	over 30

Sample Key

- Disturbed sample (SPT sample)
- Undisturbed Sample (Piston sampler)
- Undisturbed Sample (Denison sampler)
- Rock core sample (Single core tube)
- Rock core sample (Double core tube)
- Rock core sample (Core loss)
- Water sample

RQD (%)	Term
0 - 25	Very poor
25 - 50	Poor
50 - 75	Fair
75 - 90	Good
90 - 100	Excellent

Planner structure

Term	Spacing (mm)
Very thick	> 2000
Thick	600 - 2000
Medium	200 - 600
Thin	60 - 200
Very thin	20 - 60
Thickly laminated	6 - 20
Thinly laminated	< 6

Discontinuities

Term	Spacing (mm)
Very widely spaced	> 2000
Widely spaced	600 - 2000
Medium spaced	200 - 600
Closely spaced	60 - 200
Very closely spaced	20 - 60
Extremely closely spaced	< 20

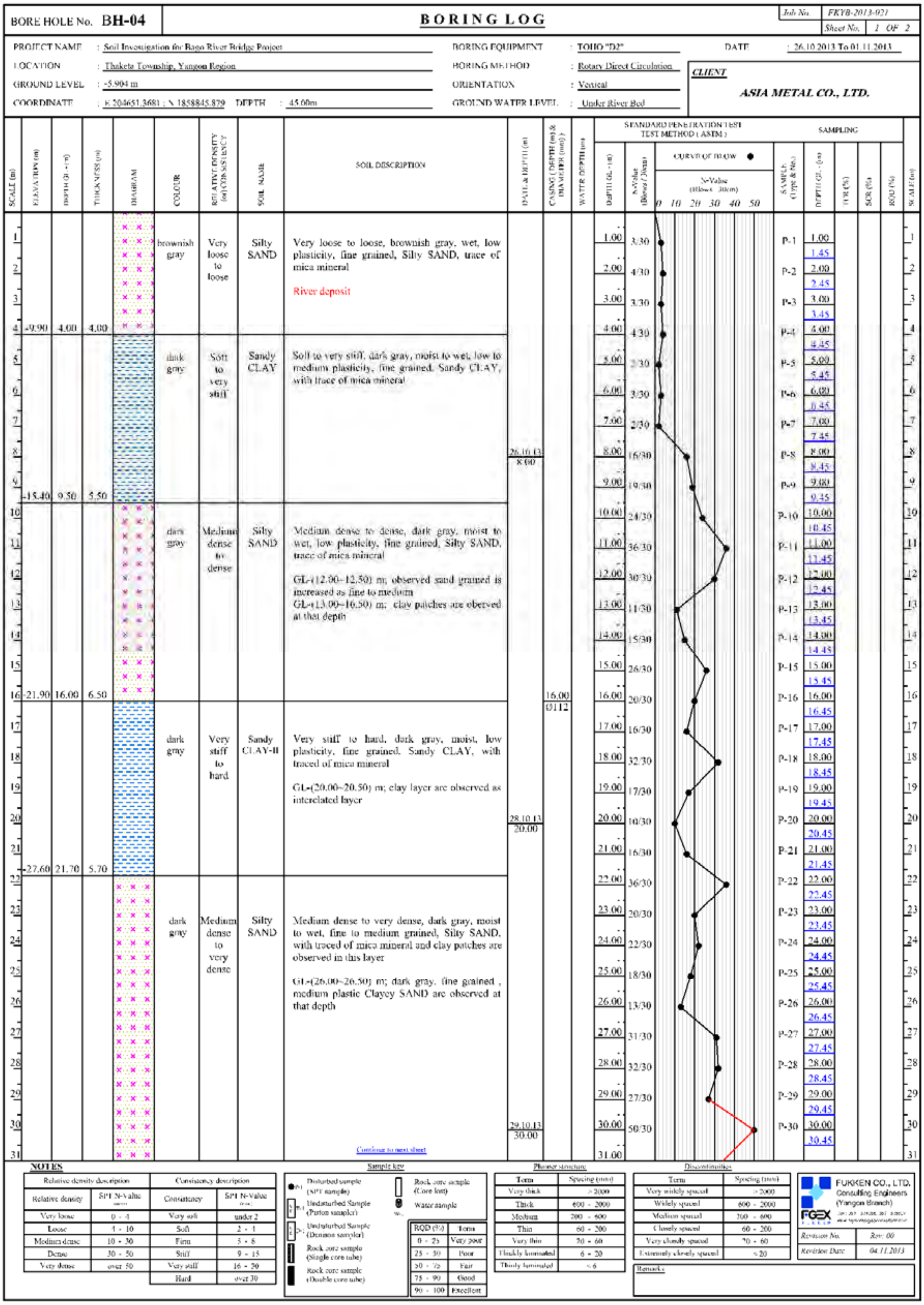
Remarks

FUKKEN CO., LTD. Consulting Engineers (Yangon Branch)

Revision No.	Rev: 01
Revision Date	29.10.2013

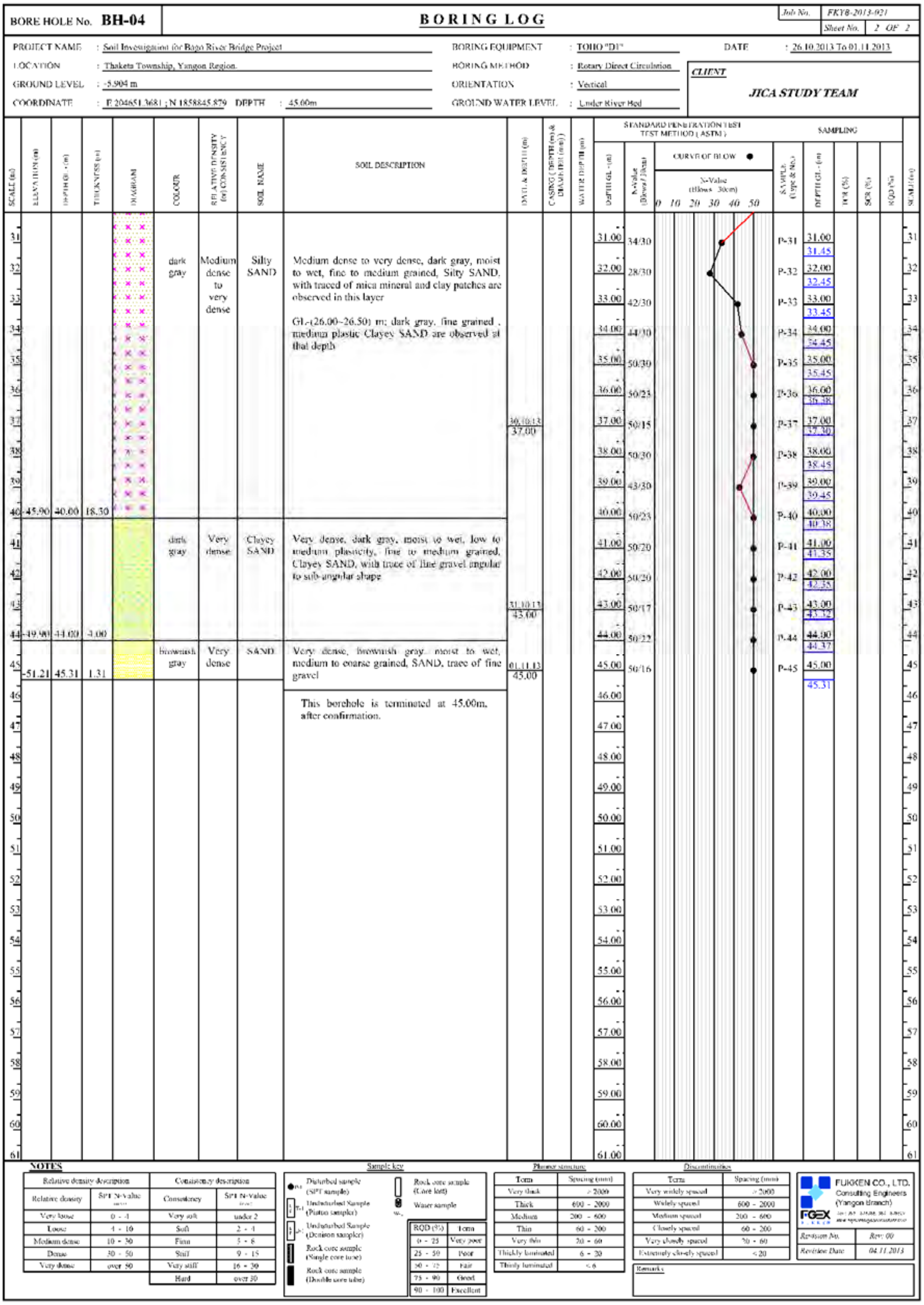
Source: JICA Survey Team

Figure 7.14 Boring Log (BH-01) 3/3



Source: JICA Survey Team

Figure 7.15 Boring Log (BH-04) 1/2



Source: JICA Survey Team

Figure 7.16 Boring Log (BH-04) 2/2

7.2.3 Geotechnical Design Parameters

Geotechnical parameters can be directly evaluated in many ways such as in situ and laboratory tests. Some of the design parameters could not be evaluated directly from field tests or laboratory tests due to the unfavorable nature of deposits or investigation methods. However, some parameters would be derived from other instrumental testing of past events, and some mechanical and physical properties obtained from field and laboratory tests. In evaluating ground stability, shear strength parameters are significant. The geotechnical design parameters required for foundation design analysis are listed in Table 7.1.

Table 7.1 Soil Parameters Recommended by J.H.C

Soil Type		Condition of Soil		Bulk Density γt (tf/m^3)	Internal Friction Angle φ (°)	Cohesion Cu (tf/m^2)	Remarks (Soil Name)
Fill Material	Gravel Gravelly Sand	Compacted		2.0	40	0	(GW), (GP)
	Sand	Compacted	Well graded	2.0	35	0	(SW), (SP)
			Poorly graded	1.9	30	0	
	Silty Sand Clayey Sand	Compacted		1.9	25	Less than 3	(SM), (SC)
	Silt, Clay	Compacted		1.8	15	Less than 5	(ML), (CL) (MH), (CJ)
	Kanto Loam	Compacted		1.4	20	Less than 1	(VH)
Natural Ground	Gravel	Densely or well graded		2.0	40	0	(GW), (GP)
		Less dense and poorly graded		1.8	35	0	
	Gravelly Sand	Dense one.		2.1	40	0	(GW), (GP)
		Less dense		1.9	35	0	
	Sand	Densely or well graded		2.0	35	0	(SW), (SP)
		Less dense and poorly graded		1.8	30	0	
	Silty Sand Clayey Sand	Dense		1.9	30	Less than 3	(SM), (SC)
		Less dense		1.7	25	0	
	Sandy Silt Sandy Clay	Stiff		1.8	25	Less than 5	(ML), (CL)
		Firm		1.7	20	Less than 3	
		Soft		1.6	15	Less than 1.5	
	Silt Clay	Stiff		1.7	20	Less than 5	(CH) (MH), (ML)
		Firm		1.6	15	Less than 3	
		Soft		1.4	10	Less than 1.5	
	Kanto Loam	---		1.4	5	Less than 3	(VH)

Source: JICA Survey Team

Table 7.2 shows the soil parameters extracted from several correlations and formulas proposed. The geotechnical design parameters recommended for future analysis are described in Table 7.3.

Table 7.2 Soil Parameters for Geotechnical Analysis Extracted from Several Formulas

No.	Soil Name	N-value	Cohesion (Cu)			Angle of Friction			Soil Unit Weight				Modulus of Elasticity (kN/m^2)	Poisson's Ratio
		(Average)	kN/m^2			(degree)			γ_{sat}	γ'	γ_{sat}	γ'		
		N	by SPT	by Lab	by JHC	by SPT	by Lab	by JHC	Lab Test		by JHC			
1	Silty Sand-Filled Materials	2	0	N/A	<30	21	N/A	19	20	10	19	9	1400	0.4
2	Clay-Filled Materials	3	20	N/A	N/A	0	N/A	N/A	19	9	N/A	N/A	2000	0.4
3	Silty Sand-River Deposit	4	0	N/A	0	24	N/A	25	19	9	17	7	2800	0.5
4	Clay-I	1	7	18	<15	0	19	10	17	7	14	4	1800	0.5
5	Sandy Clay-I	5	33	25	<30	0	N/A	20	18	8	17	7	2500	0.4
6	Silty Sand-I	14	0	N/A	0	32	N/A	25	20	10	17	7	9800	0.4
7	Sand-I	19	0	N/A	0	34	N/A	30	19	9	18	8	13300	0.4
8	Silty Clay-I	6	40	N/A	<30	0	N/A	15	18	8	16	6	4000	0.4
9	Clayey Sand-I	8	0	N/A	0	28	N/A	25	19	9	17	7	5600	0.5
10	Clay-II	8	53	N/A	<30	0	N/A	15	19	9	16	6	5333	0.5
11	Silty Clay-II	27	180	N/A	<50	0	N/A	20	18	8	17	7	18000	0.4
12	Sandy Clay-II	14	93	N/A	<50	0	N/A	25	19	9	18	8	9333	0.4
13	Silty Sand-II	30	0	N/A	0	39	N/A	25	20	10	17	7	21000	0.3
14	Clayey Sand-II	48	0	N/A	<30	46	N/A	30	20	10	19	9	33600	0.2
15	Sand-II	50	0	N/A	0	47	N/A	35	21	11	20	10	35000	0.2

Source: JICA Survey Team

Table 7.3 Geotechnical Design Parameters Recommended for Future Analysis

No.	Soil Name	N-Value	Cohesion	Angle of Friction	Soil Unit weight		Modulus of Elasticity (kN/m^2)	Poisson's Ratio
		(Average)	Cu	ϕ	kN/m^3			
		N	kN/m^2	(degree)	γsat	γ'		
1	Silty Sand-Filled Materials	2	0	20	20	10	1400	0.4
2	Clay-Filled Materials	3	20	0	19	9	2000	0.4
3	Silty Sand-River Deposit	4	0	20	19	9	2800	0.5
4	Clay-I	1	15	0	17	7	1800	0.5
5	Sandy Clay-I	5	30	0	18	8	2500	0.4
6	Silty Sand-I	14	0	30	20	10	9800	0.4
7	Sand-I	19	0	30	19	9	13300	0.4
8	Silty Clay-I	6	40	0	18	8	4000	0.4
9	Clayey Sand-I	8	0	25	19	9	5600	0.5
10	Clay-II	8	50	0	19	9	5333	0.5
11	Silty Clay-II	27	180	0	18	8	18000	0.4
12	Sandy Clay-II	14	90	0	19	9	9333	0.4
13	Silty Sand-II	30	0	40	20	10	21000	0.2
14	Clayey Sand-II	48	0	45	20	10	33600	0.2
15	Sand-II	50	0	45	21	11	35000	0.2

Source: JICA Survey Team

In this chapter, the geotechnical design parameters are determined only for shallow footing. For bridge construction, pile foundation will be applied, and the geotechnical design parameters will be directly applied from standard penetration test results. Moreover, the geotechnical design parameters identified from SPT will be directly applied for liquefaction potential analysis.

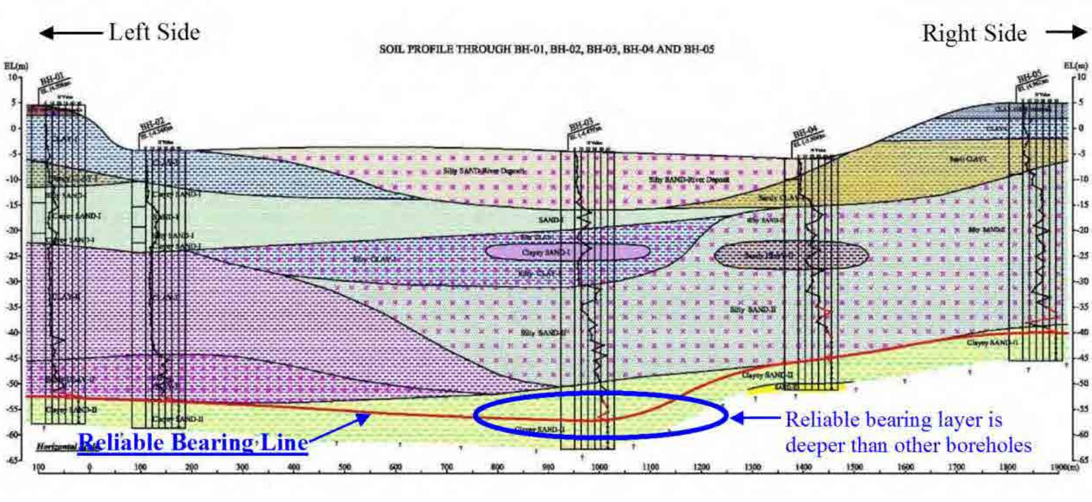
7.2.4 Summary of Soil Investigation

According to the investigation results, the left side of the Bago River (BH-01 and BH-02) and the right side of the Bago River (BH-04 and BH-05) have different soil conditions because of river dynamism. Clayey soil layers are well observed in the left side of the river, while granular soil layers are more observed in the right side of the river. Although there is a difference in soil deposition, the top soil layer (Clay-I) and reliable bearing layer (Clayey Sand-II) of BH-01 and BH-02 are the same.

In the left side boreholes (BH-01 and BH-02), clayey soil layers are deposited from ground surface to EL -50 m to EL -55 m. Among the clayey soil, the Clayey Sand and Silty Sand layers are observed as intercalated layers.

As for the right side boreholes (BH-04 and BH-05), the top soil layer of BH-05 is of clayey soil with a thickness of 14 m. The top soil layer of BH-04 is of silty sand (river bed), which is 4.0 m thick, and is underlain by a sandy clay layer. The frictional soil layer, which is 30.0 m thick, is underlying the clayey soil layer. Moreover, clayey soil layers are observed as lens forms within the silty sand layer. The reliable bearing layer (Clayey Sand-II) is underlying the Silty Sand-II layer. According to the investigation results, the Sand-II layer is observed under the Clayey Sand-II layer. This Sand-II layer is only observed in BH-04.

The borehole in the center of the river (BH-03) has the same soil conditions with the right side boreholes, except for the absence of upper clayey soil layer and thick clayey soil lens forms. However, the reliable bearing layer in BH-03 is deeper than those of the other boreholes. In Figure 7.17, the reliable bearing layer, which has an SPT N-value of more than 50, for the proposed Bago River Bridge is indicated with a red line.



Source: JICA Survey Team

Figure 7.17 Ground Condition and Reliable Bearing Layer

Chapter 8

Hydrological Assessment of Bago River

8. Hydrological Assessment of the Bago River

In order to design the new bridge, it is necessary to collect and correlate all the basic meteorological and hydraulic data.

8.1 Meteorological Conditions

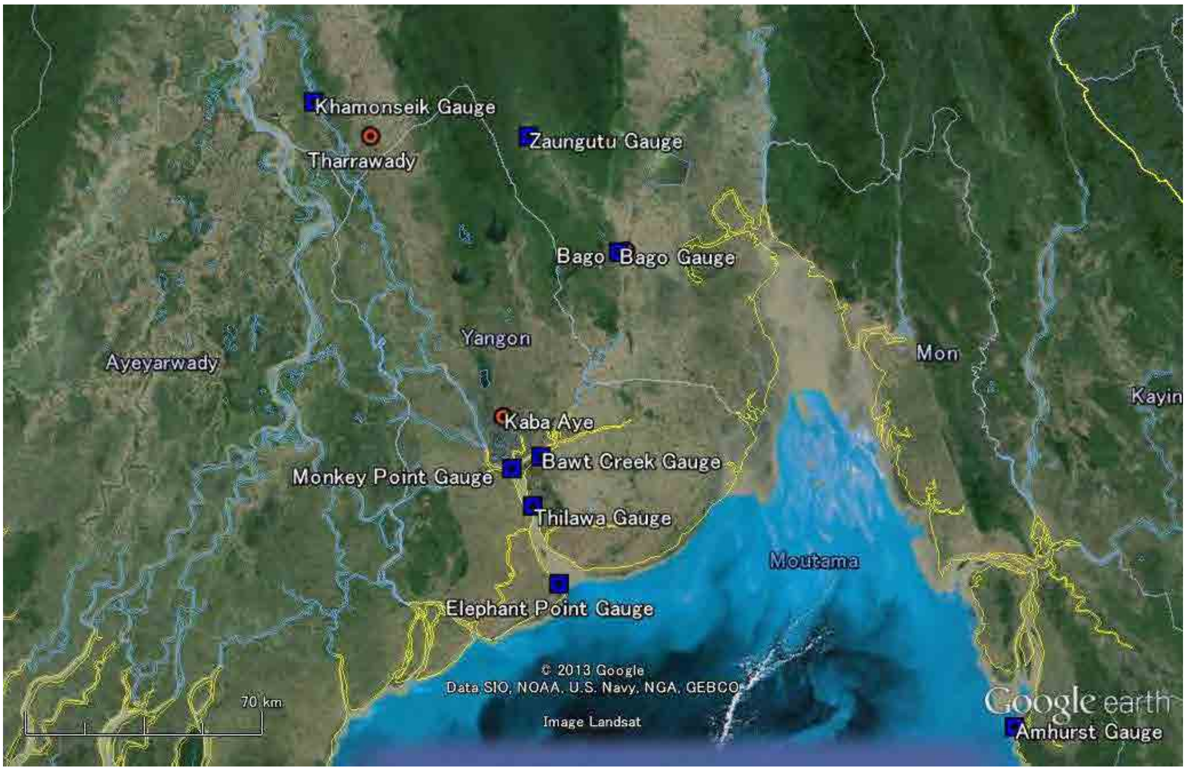
Yangon City has a tropical monsoon climate. Rainfall is highly seasonal, being concentrated in the hot humid months of the southwest monsoon (May to October). By contrast, the northwest monsoon (December to March) is relatively cool and dry. In some occasions, severe cyclones cross the Myanmar coast in the months of April to May.

There are three meteorological stations in and around Greater Yangon, which were installed and have since been operated by the Department of Meteorology and Hydrology (DMH) of MoT, as shown in Table 8.1. The locations of meteorological and hydrological stations are shown in Figure 8.1.

Table 8.1 Inventory of Meteorological Stations

Meteorological Station	Code (WMO)	Coordinates		Height (m)	Period of Records						Remarks
		Latitude	Longitude		Tempera-ture	Relative Humidity	Rainfall	Sunshine	Evapora-tion	Wind	
1. Kaba Aye (Yangon)	48097	16-54	96-10	20	1968~	1968~	1968~	1977~	1975~	1968~	
2. Bago	48093	17-20	96-30	9	1965~	1965~	1965~	-	-	1965~	
3. Tharrawady	48088	17-38	95-48	15	1965~	1965~	1965~	-	-	1965~	

Source: DMH

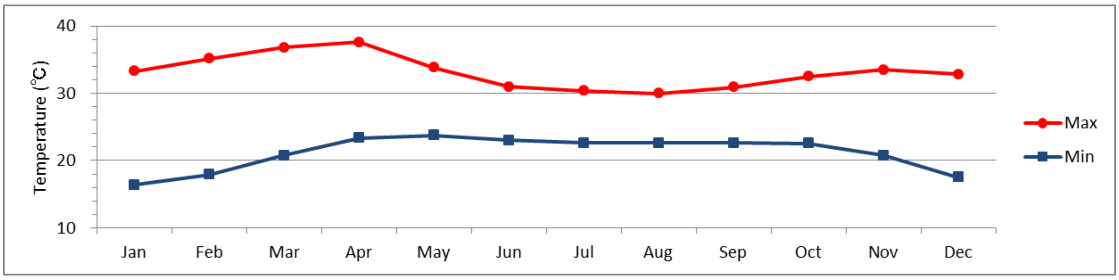


Source: DMH, MPA, ID (Google Earth)

Figure 8.1 Location Map of Meteorological and Hydrological Stations

8.1.1 Temperature

The monthly mean temperature ranges between 24.8 °C and 30.3 °C in and around Yangon City. According to the collected data for the past 18 years, the mean monthly maximum temperature is 37.6 °C (April) while the mean minimum temperature is 16.4 °C (January) within the Yangon region.

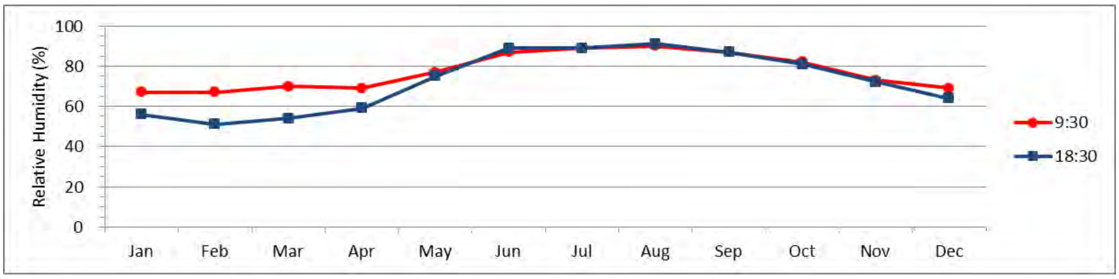


Source: JICA Survey Team based on the data from DMH

Figure 8.2 Mean Monthly Maximum and Minimum Temperatures at Kaba-aye Station (1991-2008)

8.1.2 Relative Humidity

Relative humidity is observed twice a day (at 9:30 and 18:30). As seen in Figure 8.3, difference in humidity between the morning and evening is quite small. Mean monthly relative humidity in Yangon City ranges between 51 and 91%.

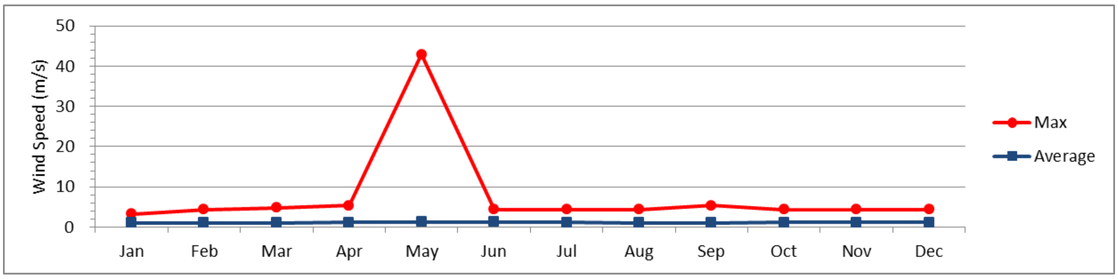


Source: JICA Library (The Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, 2002), DMH

Figure 8.3 Mean Monthly Maximum and Minimum Relative Humidity at Kaba-aye Station (1991-2008)

8.1.3 Wind Speed and Direction

The mean monthly wind speed is stable at 1.0-1.2 m/s throughout a year. Wind condition in Yangon area depends on the influence of the southwest monsoon during the rainy season. The highest maximum wind speed of 42.9 m/s was recorded during the passage of Cyclone Nargis in May 2008.

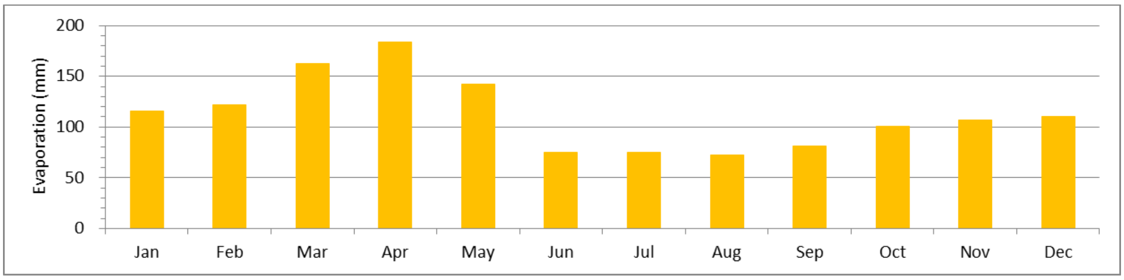


Source: JICA Survey Team based on the data from DMH

Figure 8.4 Maximum Wind Speed and Mean Monthly Wind Speed recorded at Kaba-aye Station (1999-2008)

8.1.4 Evaporation

The annual mean evapotranspiration in Yangon area is 1,349 mm, which is 50% of the annual rainfall.

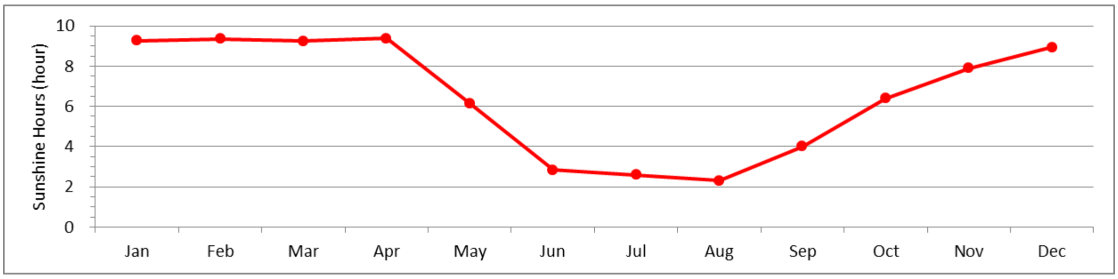


Source: JICA Survey Team based on the data from DMH

Figure 8.5 Mean Monthly Evaporation at Kaba-aye Station (1981-2000)

8.1.5 Sunshine Hours

The annual mean sunshine hours are about 6.5 hours/day in Yangon area. Sunshine hours during the rainy season are shorter than the other seasons, showing different patterns of fluctuation.



Source: JICA Survey Team based on the data from DMH

Figure 8.6 Mean Monthly Sunshine Hours at Kaba-aye Station (1977-2000)

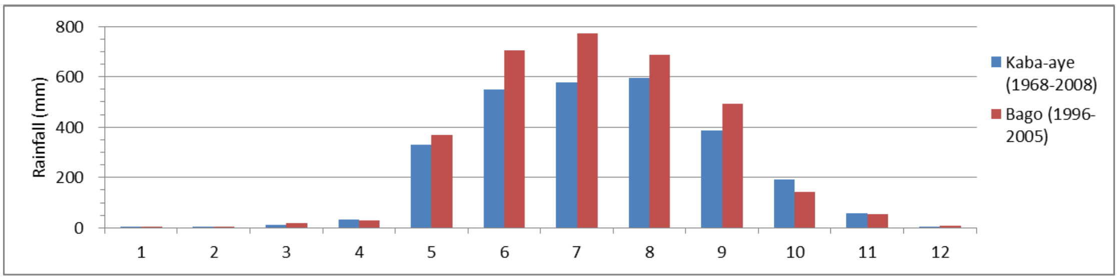
8.1.6 Rainfall

(1) Annual Rainfall and Seasonal Fluctuation

Seasonal variation of monthly total is similar in Yangon City (Kaba-aye) and Bago City. Regarding seasonal fluctuation of rainfall, about 96% of annual rainfall is brought by the rainy season from May to October, with the highest amount of rainfall in July or August.

The annual mean rainfall is 2,745 mm in Yangon City and 3,288mm in Bago City. Annual rainfall in Yangon City fluctuates between 3,592 mm and 2,127 mm. According to the collected data/documents, the following characteristics in Yangon area can be observed:

- ✓ Bago, located in the eastern side of Yangon area, has the highest annual rainfall volume; and
- ✓ Tharrawady, located in the northwestern side of Yangon area, has the lowest annual rainfall. Annual rainfall gets progressively smaller towards the north (upstream) side of the Hlaing River.

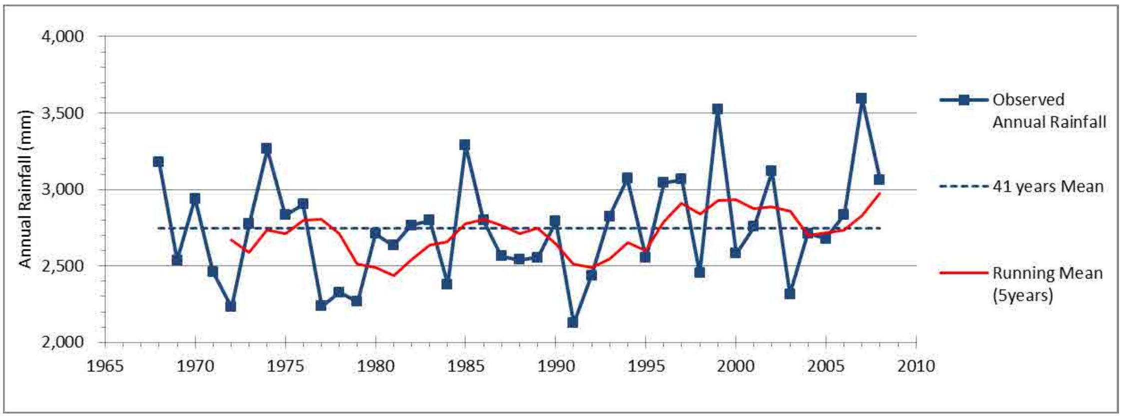


Source: JICA Survey Team based on the data from DMH

Figure 8.7 Mean Monthly Rainfall in and around Greater Yangon

(2) Long-term Fluctuation of Annual Rainfall

Figure 8.8 shows the long-term fluctuation of annual rainfall by using a five-year running mean at Kaba-aye. Although the cycle of wet and dry periods is not clear, the aforementioned figure gives a clear presentation of such periods. It is indicated that a limited rising trend of annual rainfall is going on in recent years.



Source: JICA Survey Team based on the data from DMH

Figure 8.8 Annual Rainfall and Five-Year Running Mean Rainfall at Kaba-aye Station (1968-2008)

(3) Exceedance Probability and Intensity Curve of Rainfall

Kaba-aye, Bago, and Tharrawady Stations have been measuring the annual maximum daily rainfall data (extreme value) for over 40 years. The 24-hour rainfalls of 2- to 500-year probabilities are calculated by using the extreme values measured from the three stations. Also, the correlation between intensity of short-time rainfall duration and 24-hour rainfall is estimated using Mononobe's equation.

Probable rainfalls and intensity curve are shown in Table 8.2 to Table 8.4 and Figure 8.9 to Figure 8.11.

Table 8.2 Correlation between intensity of short-time rainfall duration and 24-hour rainfall at Kaba-aye Station (Mononobe's equation, 1968-2012)

Return Period (Probability) (Year, %) Kaba-aye Station		Daily Rainfall R_{24} (mm/day)	Rainfall Intensity of each Rainfall Duration (mm/hr): It = $R_{24}/24*(24/t)^m$, m=2/3												Remarks
		24 hour	24	12	8	6	3	2	1.5	1	0.75	0.5	0.333	0.167	
		1,440 min.	1,440	720	480	360	180	120	90	60	45	30	20	10	
2	50.0%	115.5	4.8	7.6	10.0	12.1	19.3	25.2	30.6	40.0	48.5	63.6	83.3	132.2	
3	33.3%	134.2	5.6	8.9	11.6	14.1	22.4	29.3	35.5	46.5	56.4	73.9	96.8	153.6	
5	20.0%	156.0	6.5	10.3	13.5	16.4	26.0	34.1	41.3	54.1	65.5	85.9	112.5	178.6	
10	10.0%	184.6	7.7	12.2	16.0	19.4	30.8	40.3	48.8	64.0	77.5	101.6	133.1	211.3	
20	5.0%	213.2	8.9	14.1	18.5	22.4	35.5	46.6	56.4	73.9	89.5	117.3	153.7	244.1	
25	4.0%	222.5	9.3	14.7	19.3	23.4	37.1	48.6	58.9	77.1	93.4	122.4	160.5	254.7	
30	3.33%	230.2	9.6	15.2	20.0	24.2	38.4	50.3	60.9	79.8	96.7	126.7	166.0	263.5	
50	2.0%	252.0	10.5	16.7	21.8	26.5	42.0	55.0	66.7	87.4	105.8	138.7	181.7	288.5	
80	1.25%	272.5	11.4	18.0	23.6	28.6	45.4	59.5	72.1	94.5	114.4	150.0	196.5	311.9	
100	1.0%	282.3	11.8	18.7	24.5	29.6	47.1	61.7	74.7	97.9	118.6	155.4	203.6	323.2	
150	0.667%	300.6	12.5	19.9	26.1	31.6	50.1	65.6	79.5	104.2	126.2	165.4	216.8	344.1	
200	0.5%	313.8	13.1	20.8	27.2	32.9	52.3	68.5	83.0	108.8	131.8	172.7	226.3	359.2	
300	0.33%	332.8	13.9	22.0	28.8	34.9	55.5	72.7	88.0	115.4	139.8	183.1	240.0	381.0	
400	0.25%	346.6	14.4	22.9	30.0	36.4	57.8	75.7	91.7	120.2	145.6	190.7	249.9	396.8	
500	0.2%	357.4	14.9	23.6	31.0	37.5	59.6	78.1	94.6	123.9	150.1	196.7	257.7	409.1	
		Calculation formula of probable rainfall = Iwai's quantile method													

Source: JICA Survey Team based on the data from DMH

Table 8.3 Correlation between intensity of short-time rainfall duration and 24-hour rainfall at Bago Station (Mononobe's equation, 1965-2012)

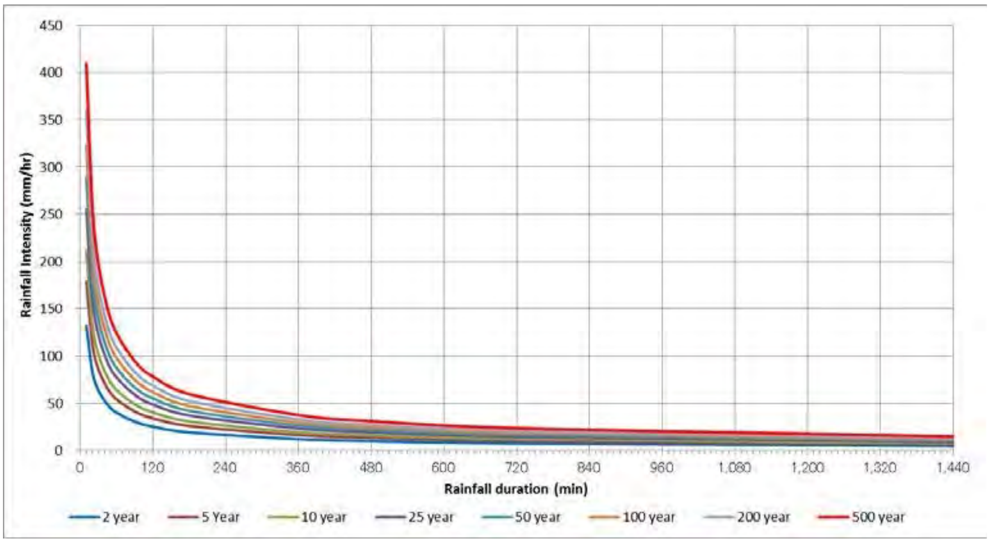
Return Period (Probability) (Year, %) Bago Station		Daily Rainfall R_{24} (mm/day)	Rainfall Intensity of each Rainfall Duration (mm/hr): It = $R_{24}/24*(24/t)^m$, m=2/3												Remarks
		24 hour	24	12	8	6	3	2	1.5	1	0.75	0.5	0.333	0.167	
		1,440 min.	1,440	720	480	360	180	120	90	60	45	30	20	10	
2	50.0%	129.7	5.4	8.6	11.2	13.6	21.6	28.3	34.3	45.0	54.5	71.4	93.5	148.5	
3	33.3%	146.8	6.1	9.7	12.7	15.4	24.5	32.1	38.8	50.9	61.7	80.8	105.9	168.0	
5	20.0%	166.5	6.9	11.0	14.4	17.5	27.8	36.4	44.1	57.7	69.9	91.6	120.1	190.6	
10	10.0%	192.1	8.0	12.7	16.6	20.2	32.0	42.0	50.8	66.6	80.7	105.7	138.5	219.9	
20	5.0%	217.4	9.1	14.4	18.8	22.8	36.2	47.5	57.5	75.4	91.3	119.6	156.8	248.9	
25	4.0%	225.6	9.4	14.9	19.6	23.7	37.6	49.3	59.7	78.2	94.7	124.2	162.7	258.2	
30	3.33%	232.3	9.7	15.4	20.1	24.4	38.7	50.7	61.5	80.5	97.6	127.8	167.5	265.9	
50	2.0%	251.4	10.5	16.6	21.8	26.4	41.9	54.9	66.5	87.2	105.6	138.4	181.3	287.8	
80	1.25%	269.2	11.2	17.8	23.3	28.3	44.9	58.8	71.2	93.3	113.1	148.1	194.1	308.2	
100	1.0%	277.8	11.6	18.4	24.1	29.2	46.3	60.7	73.5	96.3	116.7	152.9	200.3	318.0	
150	0.667%	293.7	12.2	19.4	25.5	30.8	49.0	64.1	77.7	101.8	123.3	161.6	211.8	336.2	
200	0.5%	305.1	12.7	20.2	26.4	32.0	50.9	66.6	80.7	105.8	128.1	167.9	220.0	349.3	
300	0.33%	321.4	13.4	21.3	27.9	33.7	53.6	70.2	85.0	111.4	135.0	176.9	231.8	367.9	
400	0.25%	333.2	13.9	22.0	28.9	35.0	55.5	72.8	88.2	115.5	139.9	183.4	240.3	381.4	
500	0.2%	342.5	14.3	22.7	29.7	36.0	57.1	74.8	90.6	118.7	143.8	188.5	247.0	392.1	
		Calculation formula of probable rainfall = Iwai's quantile method													

Source: JICA Survey Team based on the data from DMH

Table 8.4 Correlation between intensity of short-time rainfall duration and 24-hour rainfall at Tharrawady Station (Mononobe's equation, 1965-2012)

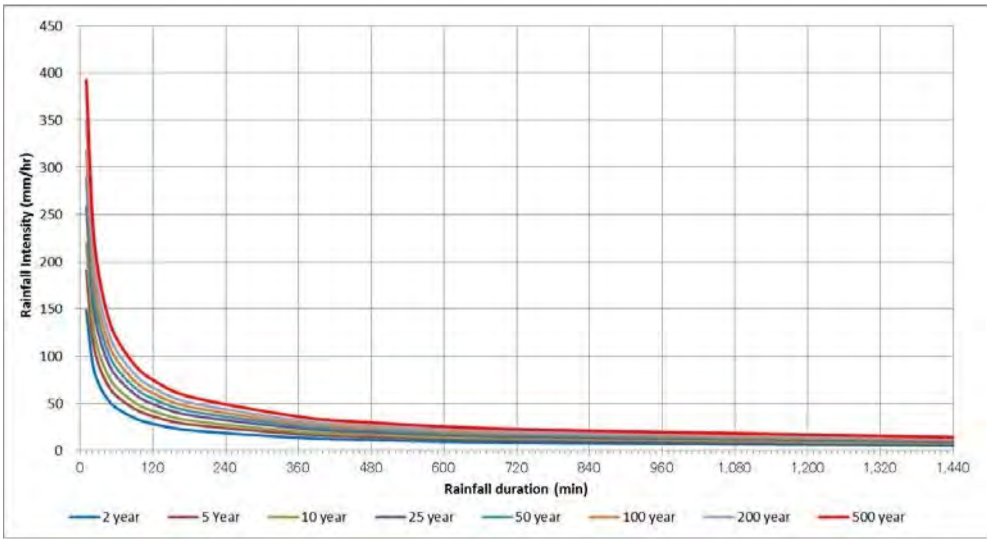
Return Period (Probability) (Year, %) Tharrawady Station		Daily Rainfall R_{24} (mm/day)	Rainfall Intensity of each Rainfall Duration (mm/hr): It = $R_{24}/24*(24/t)^m$, m=2/3												Remarks
		24 hour	24	12	8	6	3	2	1.5	1	0.75	0.5	0.333	0.167	
		1,440 min.	1,440	720	480	360	180	120	90	60	45	30	20	10	
2	50.0%	105.6	4.4	7.0	9.2	11.1	17.6	23.1	27.9	36.6	44.3	58.1	76.2	120.9	
3	33.3%	121.5	5.1	8.0	10.5	12.8	20.3	26.5	32.1	42.1	51.0	66.9	87.6	139.1	
5	20.0%	140.3	5.8	9.3	12.2	14.7	23.4	30.6	37.1	48.6	58.9	77.2	101.2	160.6	
10	10.0%	165.4	6.9	10.9	14.3	17.4	27.6	36.1	43.8	57.3	69.5	91.0	119.3	189.3	
20	5.0%	190.8	8.0	12.6	16.5	20.0	31.8	41.7	50.5	66.1	80.1	105.0	137.6	218.4	
25	4.0%	199.2	8.3	13.2	17.3	20.9	33.2	43.5	52.7	69.1	83.7	109.6	143.6	228.0	
30	3.33%	206.1	8.6	13.6	17.9	21.6	34.4	45.0	54.5	71.5	86.6	113.4	148.6	235.9	
50	2.0%	225.7	9.4	14.9	19.6	23.7	37.6	49.3	59.7	78.2	94.8	124.2	162.8	258.4	
80	1.25%	244.4	10.2	16.2	21.2	25.7	40.7	53.4	64.7	84.7	102.6	134.5	176.2	279.8	
100	1.0%	253.4	10.6	16.8	22.0	26.6	42.2	55.3	67.0	87.8	106.4	139.5	182.7	290.1	
150	0.667%	270.2	11.3	17.9	23.4	28.4	45.0	59.0	71.5	93.7	113.5	148.7	194.8	309.3	
200	0.5%	282.4	11.8	18.7	24.5	29.7	47.1	61.7	74.7	97.9	118.6	155.4	203.6	323.3	
300	0.33%	300.0	12.5	19.8	26.0	31.5	50.0	65.5	79.4	104.0	126.0	165.1	216.3	343.4	
400	0.25%	312.8	13.0	20.7	27.1	32.8	52.1	68.3	82.8	108.4	131.4	172.1	225.6	358.1	
500	0.2%	322.9	13.5	21.4	28.0	33.9	53.8	70.5	85.4	111.9	135.6	177.7	232.9	369.6	
		Calculation formula of probable rainfall = Iwai's quantile method													

Source: JICA Survey Team based on the data from DMH



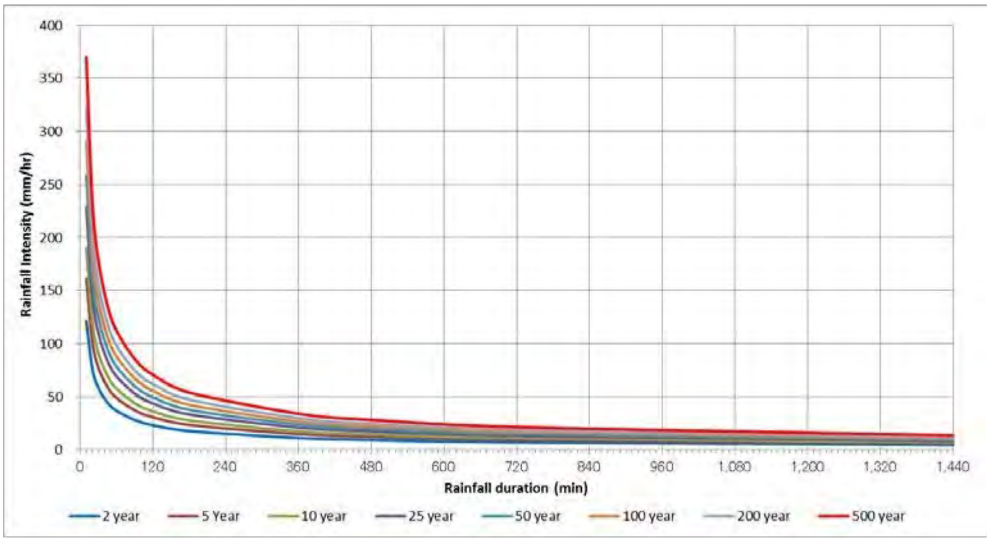
Source: JICA Survey Team based on the data from DMH

Figure 8.9 Rainfall Intensity Curve at Kaba-aye Station



Source: JICA Survey Team based on the data from DMH

Figure 8.10 ainfall Intensity Curve at Bago Station



Source: JICA Survey Team based on the data from DMH

Figure 8.11 Rainfall Intensity Curve at Tharrawady Station

On the other hand, the short intensity rainfall data prepared by the Irrigation Department of MoAI is shown in Table 8.5. There are differences in the values shown between Table 8.2 and Table 8.5 due to differences in data/theory used. These differences shall be clarified by collecting and studying the annual maximum rainfall data for short periods again.

Table 8.5 Short Intensity Rainfall Data at Kaba-aye Station

Return Period Rainfall Intensity	5 year	10 year	20 year	50 year
60 min. rainfall	63.5	71.1	78.7	104.6
75 min. rainfall	52.1	63.9	69.9	77.5
120 min. rainfall	40.6	45.7	49.5	55.9

Source: Study on Drainage System of Mingalar Taung Nyunt Area, Nov. 2002, Fukken Co. Ltd.

8.2 Hydrological and Hydraulic Conditions

In order to predict the flow rate and water level during flood season, it is necessary to collect and correlate the hydrological and hydraulic conditions of the Yangon (Hlaing) River, the Bago River, and the Pazundaung Creek surrounding Yangon City. This survey was examined in reference to previous reports (e.g., JICA report) with the collected information from relevant organizations in Myanmar.

Six existing gauging stations (water level/discharge) are managed by the Department of Meteorology and Hydrology (DMH) and Myanma Port Authority (MPA) in the Hlaing, Bago, and Yangon River basins. Of these stations, three stations of MPA do not record discharge measurements. Also, Bago Station of DMH is influenced by tidal levels during the dry season (October to May); therefore, discharge records during this period are not available. However, discharge records at Bago Station during the rainy season can be utilized for flood probability calculation.

DMH has its own discharge rating tables, which have been changed several times by use of discharge measurement records taking into account the flow conditions. The inventory of river/tidal gauge stations is shown in Table 8.6.

Table 8.6 Inventory of River/Tidal Gauging Stations

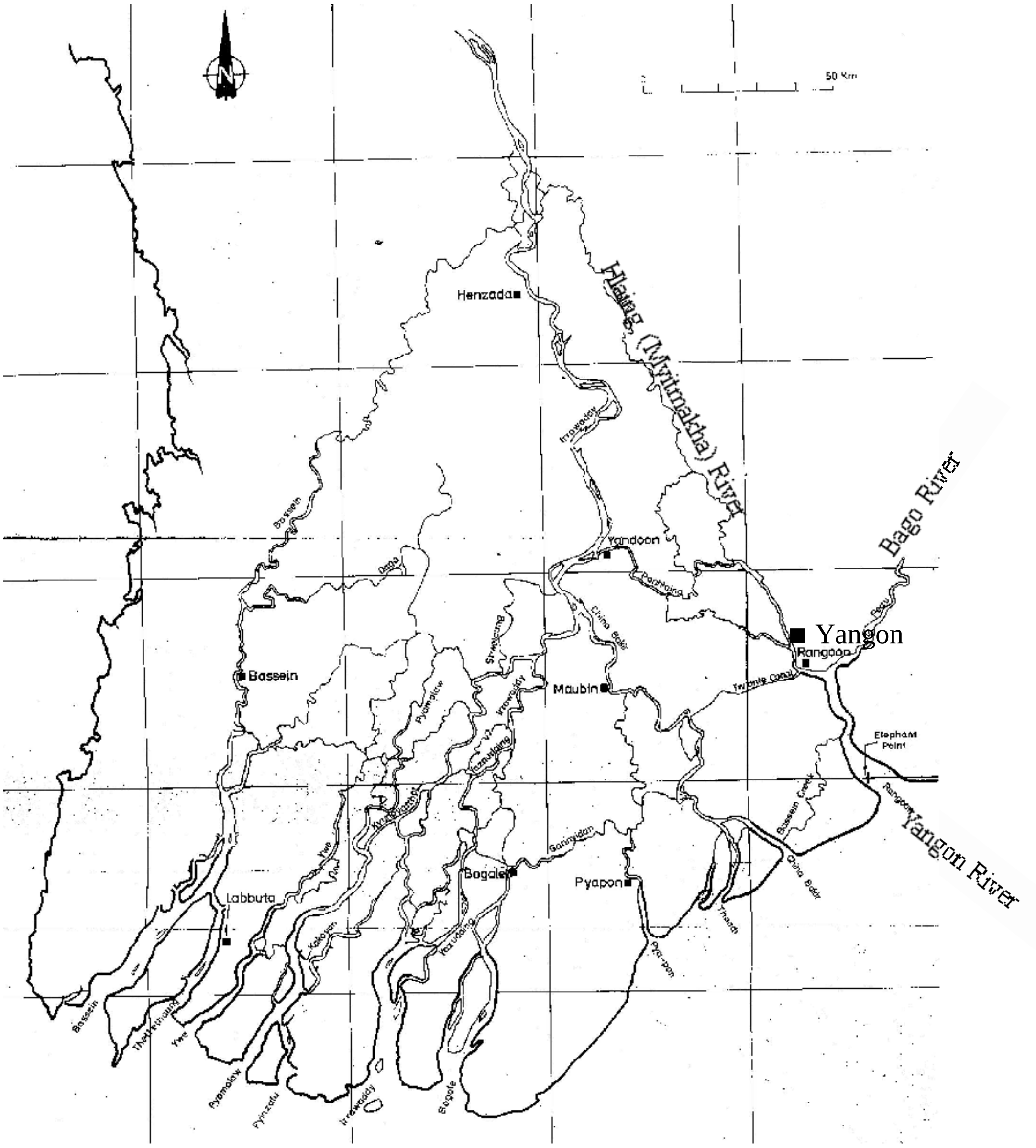
River/Gauging Station	Code	Coordinates		Catchment Area (km^2)	Height (m)	Type of Gauge	Period of Record	Water (Tide) level	Discharge	Observed by	Remarks
		Latitude	Longitude								
1. Hlaing River/Khamonseik	6020	16-35	95-30	5,840	14.465	Pile Gauge	1987~	○	○	DMH	
2. Bago River/Zaungutu	6220	17-38	96-14	1,927	9.8	Pile Gauge	1987~	○	○	DMH	
3. Bago River/Bago (Pegu)	48093	17-20	96-30	2,580	9	Pile Gauge	1970~	○	○	DMH	
4. Hlaing River/Yangon Port	210	16-46	96-11	-	-	Steel Plate (Automatic)	-	○	-	MPA	Other 2 stations at Yangon port
5. Yangon River/Thilawa Point	-	16-40	96-15	-	-	Steel Plate (Automatic)	-	○	-	MPA	
6. Yangon River / Elephant Point	-	16-28	96-19	-	-	Steel Plate (Manual)	-	○	-	MPA	

Source: DMH, MPA

8.2.1 Rivers and Characteristics of River Flow

The Yangon Riverine system is located at the eastern end of Ayeyarwady (Irrawaddy) Delta as shown in Figure 8.12.

In Yangon City, the Yangon River is formed by the junction of the Panhaling and Hlaing rivers at a point about 13 km (8 miles) upstream of Monkey Point. The Panhlaing River is a distributary of the Ayeyarwady River, while the Hlaing River is a true river rising in the Bago Yomas and having a drainage area of about 12,950 km^2 (5,000 mi^2). The Pazundaung Creek, named the Ngamoyeik Creek in the northern part of the city, joins the Yangon River at Monkey Point, the southeastern extremity of the city. The Pazundaung Creek has a drainage area of about 1,487 km^2 (574 mi^2). The Bago River, with a drainage area of 5,180 km^2 (2,000 mi^2), also joins the Yangon River just east of the city, the point where the Yangon River flows south some 45 km (28 mi) into the Gulf of Bengal. The catchment area at the mouth of the Yangon River is 25,640 km^2 (9,900 mi^2).



Source: A one dimensional analysis of the tidal hydraulics of deltas (Nicholas Odd, Report OD 44, July 1982, Hydraulics Research Station, UK), from the MoAI Library

Figure 8.12 Ayeyarwady (Irrawaddy) Delta and Yangon River

(1) Hlaing/Yangon River

The Hlaing River, also known as Myitmakha River, has its source near Paunk Kaung. It flows from north to south approximately parallel to the Ayeyawady River; first joining the Bawle River in Taikkyi Township, then the Kotekowa River in Hmawbi Township, and finally the Penhlaing River near Hsinmalaik. When it reaches Yangon, it flows into the sea as the Yangon River.

At Schwelaung Village, the Hlaing River meets the Thenet River, a branch of the Ayeyarwaddy (Irrawaddy) River. The inflow of water from the Ayeyarwaddy River goes into the Hlaing River through the Thenet River during high water level period during the rainy season.

The total length from its source to its mouth at the confluence of the Yangon River is about 330 km (205 miles). As it flows directly into the sea, tidal flow affects a distance of about 100 km (62 miles) upstream (around Tharrawaddy of the Myitmaka River).

(2) Bago River

The Bago River has its source near Thikkyi in the Bago Yoma. It flows down the east-facing slope of the Bago Yoma from north to south approximately parallel to the Sittang River. When it reaches Bago, it turns to the southwest and flows into the sea as the Yangon River.

The total length from its source to its mouth at the confluence of the Yangon River is about 260 km (162 miles). The Bago River at the Bago Gauging Station is clearly influenced by tidal level during the low-flow period.

(3) Characteristics of River Flow

1) Characteristics of Upstream Part in Related River (Freshwater Area)

The discharge-duration curve, which is often used in Japan, was examined in order to understand the potential surface water characteristics of the river throughout the year. The flow regime shows the annual flow condition using the daily discharge at each hydrological station, and is indicated by the daily discharge and the number of exceeded days. The annual flow regime shows the following:

- ✓ High discharge (95th daily discharge from the greatest),
- ✓ Normal discharge (185th daily discharge from the greatest),
- ✓ Low discharge (275th daily discharge from the greatest), and
- ✓ Drought discharge (355th daily discharge from the greatest).

The flow regime that was computed at Zaungtu and Khamonseik stations for a period of 14 years (1987-2000) is summarized in Table 8.7 and Figure 8.13. As seen in the aforementioned table and figure, the coefficient of river regime differs extremely by river. Although the low flow of the Hlaing River at Khamonseik and the flow of the Bago River at Zaungtu are not steady, their coefficients of river regime are very large. Moreover, it was found that the flow regime of the Bago River at Zaungtu does not have a sustainable quantity of base flow. Also, the magnitude of coefficient of river regime indicates that the flow fluctuation is large; and a large value indicates that the full year water intake is difficult and flood damage can easily occur.

Table 8.7 Flow Regime (1987-2000) of the Hlaing and Bago Rivers

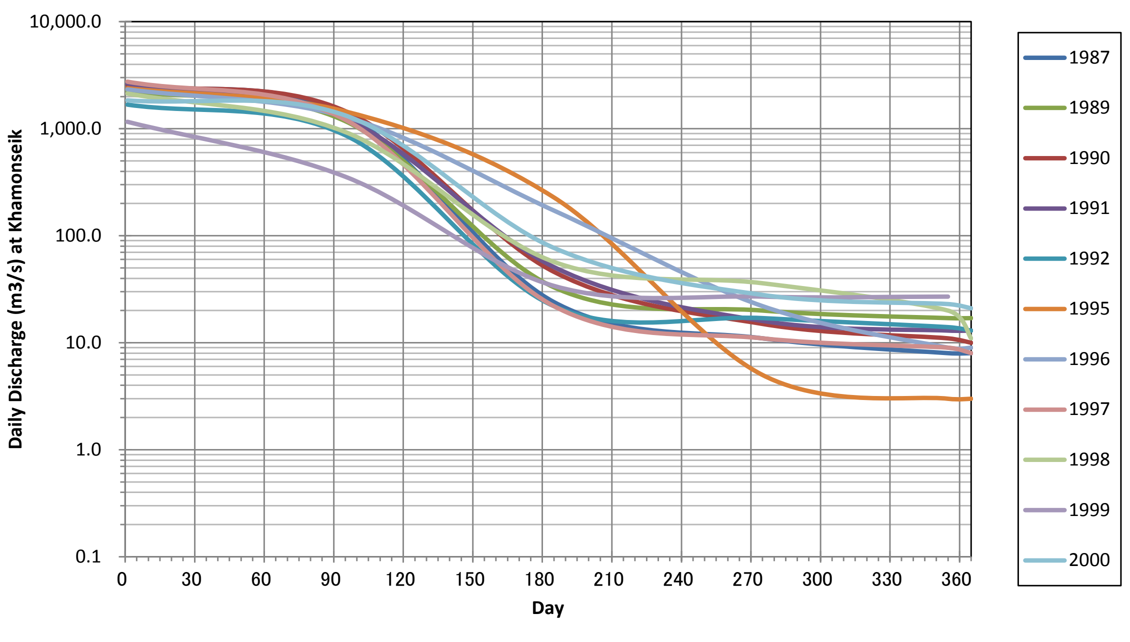
River: Bago Station: Zaungtu

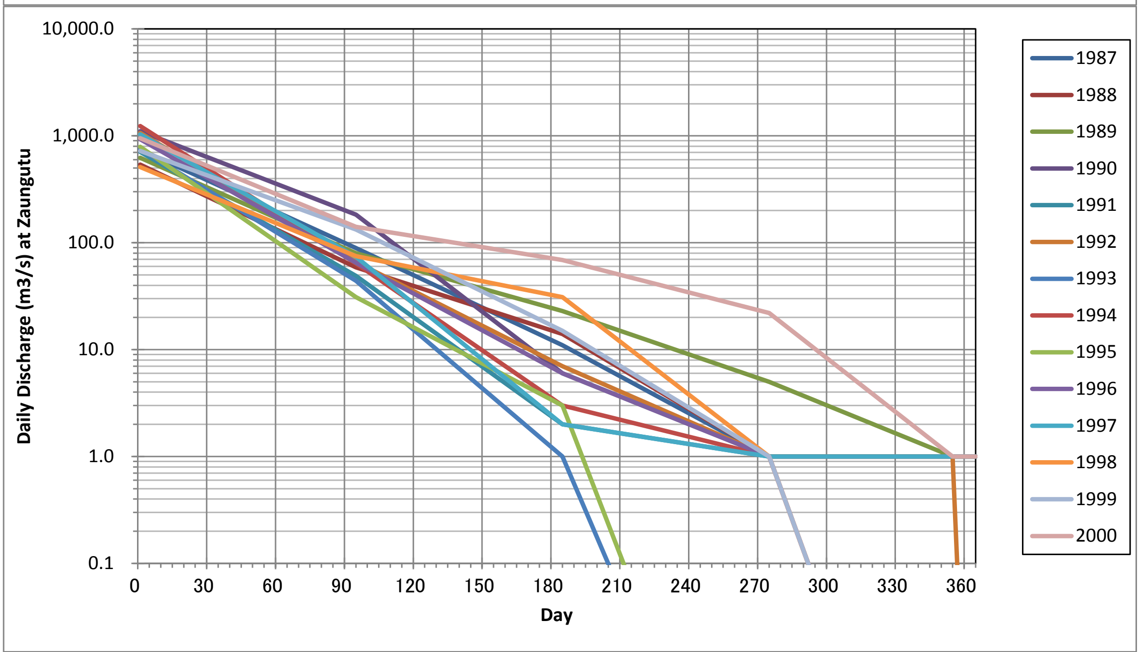
Year	Daily Discharge (m^3/s)							Coefficient of River Regime	Remarks
	Max.	High Discharge	Normal Discharge	Low Discharge	Drought Discharge	Min.	Mean		
		95th day	185th day	275th day	355th day				
1987	741	89	11	1	1	1	72	741.0	
1988	538	59	14	1	1	1	56	538.0	
1989	623	80	23	5	1	1	64	623.0	
1990	1,108	183	6	1	1	1	122	1,108.0	
1991	708	49	2	1	1	1	59	708.0	
1992	1,069	66	7	1	1	0	67	-	
1993	752	44	1	0	0	0	54	-	
1994	1,237	64	3	1	0	0	71	-	
1995	790	31	3	0	0	0	60	-	
1996	933	65	6	1	0	0	64	-	
1997	1,034	74	2	1	1	1	73	1,034.0	
1998	510	75	31	1	0	0	63	-	
1999	722	133	15	1	0	0	82	-	
2000	951	141	69	22	1	1	103	951.0	
Mean	837	82	14	3	1	1	72	837.0	

River: Hlaing Station: Khamonseik

Year	Daily Discharge (m^3/s)							Coefficient of River Regime	Remarks
	Max.	High Discharge	Normal Discharge	Low Discharge	Drought Discharge	Min.	Mean		
		95th day	185th day	275th day	355th day				
1987	2,577	1,366	24	11	8	8	612	322.1	
1988	-	-	-	-	-	-	-	-	
1989	2,260	1,177	33	20	17	17	520	132.9	
1990	2,570	1,460	46	15	11	10	687	257.0	
1991	2,652	1,238	51	16	13	13	656	204.0	
1992	1,680	869	22	17	14	13	426	129.2	
1993	-	-	-	-	-	-	-	-	
1994	-	-	-	-	-	-	-	-	
1995	2,390	1,452	228	5	3	3	703	796.7	
1996	2,330	1,290	172	22	9	9	602	258.9	
1997	2,752	1,214	22	11	9	8	609	344.0	
1998	2,133	932	57	36	20	11	574	193.9	
1999	2,026	1,161	356	34	27	27	656	75.0	
2000	1,842	1,332	77	28	23	21	573	87.7	
Mean	2,292	1,226	99	20	14	13	602	176.3	

Source: JICA Library (The Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, 2002), DMH





Source: JICA Library (The Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, 2002), DMH

Figure 8.13 Flow Regime (1987~2000) of the Hlaing and Bago Rivers

In reference to the previous JICA report (recorded in 1987-2000), the mean monthly flow pattern at Khamonseik and Zaungtu stations are shown in Table 8.8 and Figure 8.14. As seen in Figure 8.14, the monthly discharge shows an increase during the rainy season, with the peak runoff occurring in August.

Table 8.8 Mean Monthly Flow Pattern at Khamonseik and Zaungtu Stations (1987-2000)

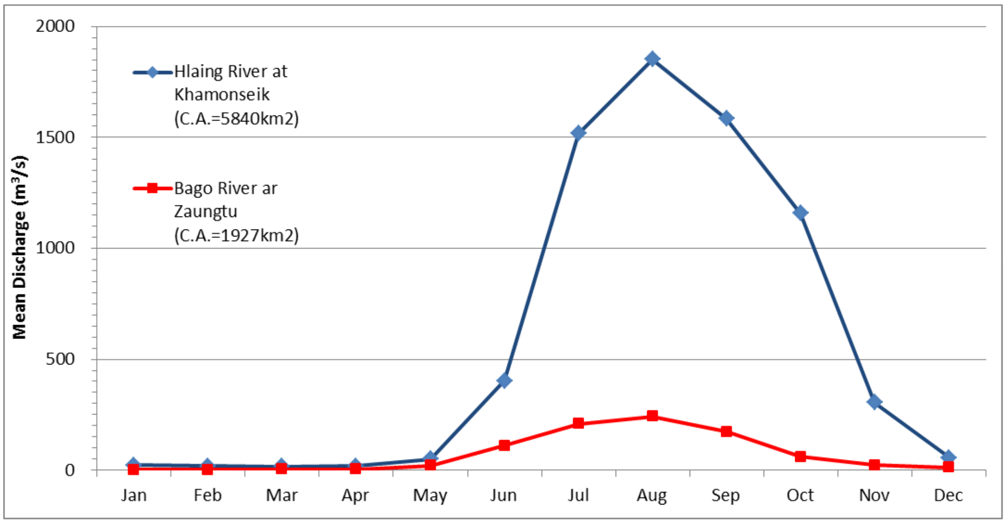
Hlaing River at Khamonseik (C.A.=5840 km²) (Unit: m³/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987	13	11	10	9	12	374	1177	2071	2039	1460	88	24	7287
1988	16	15	-	44	-	448	1156	1661	1930	871	305	87	-
1989	28	21	20	18	18	144	1022	1722	1174	1413	569	32	6183
1990	22	15	12	11	59	777	2155	2148	1420	1405	118	24	8166
1991	19	16	15	13	68	348	1738	2323	1419	1314	495	34	7801
1992	23	20	18	19	17	32	1195	1461	887	1016	365	14	5068
1993	13	11	13	16	17	451	1625	1902	2211	-	-	-	
1994	-	-	-	-	5	260	1245	1352	1228	641	49	9	-
1995	7	5	4	3	126	552	2129	1978	1534	1538	330	151	8358
1996	37	13	13	34	130	239	1608	2059	1656	1027	313	50	7179
1997	11	10	9	10	16	238	1599	2109	1470	1650	83	22	7228
1998	36	34	39	24	69	520	1584	1837	1789	630	240	38	6842
1999	35	33	29	28	65	602	1409	1796	1806	1014	834	186	7837
2000	39	29	26	23	61	664	1588	1499	1610	1073	184	48	6844
Average	23	18	17	19	51	404	1516	1851	1584	1158	306	55	7003

Bago River ar Zaungtu (C.A.=1927 km²) (Unit: m³/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987	2	1	1	3	3	90	253	213	193	54	47	3	863
1988	1	1	1	2	6	96	173	179	61	82	53	15	670
1989	12	17	23	1	19	82	144	247	157	56	6	2	766
1990	1	1	1	1	110	275	352	361	263	75	13	3	1456
1991	1	1	1	1	1	42	213	306	78	34	14	3	695
1992	1	1	1	2	8	37	174	283	203	78	11	2	800
1993	1	0	0	0	3	109	96	257	160	14	2	1	644
1994	1	1	3	1	14	168	287	208	116	16	0	32	846
1995	0	0	0	0	16	128	229	146	182	7	11	2	721
1996	1	3	1	1	12	93	209	214	160	50	12	2	759
1997	1	1	1	1	4	106	219	327	157	46	4	2	868
1998	1	1	1	0	9	63	180	166	144	109	44	30	747
1999	7	1	1	1	40	112	162	324	236	84	10	1	979
2000	1	2	11	28	37	134	233	157	323	139	91	75	1231
Average	2	2	3	3	20	110	209	242	174	60	23	12	860

Source: JICA Library (The Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, 2002), DMH



Source: JICA Library (The Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, 2002), DMH

Figure 8.14 Mean Monthly Flow Pattern at Khamonseik and Zaungtu Stations (1987-2000)

2) Characteristics of Related Tidal River (Tidal Area of Mixed Tide)

As mentioned above, the lower reaches of the Yangon Riverine system are tidal rivers that are affected by tidal variability more than 100 km from the estuary.

The tidal range around Yangon Port is about 5.1 m and 2.5 m at spring tide and neap tide, respectively. The spring tide from the estuaries to Yangon Port is accompanied by a flow of up to 3.0 m/s. Velocities around Yangon Port according to the nautical chart are about 1.6-1.8 m/s.

In addition to "upland flow (river's own flow) arising from the catchment area" and "tidal flow based on tidal motion", there are "density current at the river mouth due to the difference in salinity between seawater and river water", "density flow by difference in concentration of suspended solids", "heat convection" and "wind-driven current", among others, in the river tidal compartment. The scale of these flows varies greatly in both time and space, and as it shows a complex phenomenon, its prediction is difficult. However, because these flows are assumed as a well-mixed type tide under great tidal variability, it is considered that the effects of stratified flow and density flow under actual streaming motion are smaller at the time of rising tide and ebb tide. Thus, in this survey, the hydraulic analysis is performed only by simulating the river flow (upland flow) and tidal flow.

In addition, tide is based on celestial motion, it is represented as the sum of many periodic components, and tidal flow (rising tide and falling tide) in tidal rivers also shows periodic fluctuations. Furthermore, the average velocity in one tidal cycle at one point in a tidal compartment is not zero. The average flow associated with oscillatory tidal motion like this is defined as the tide-induced residual current resulting from the asymmetry of tidal motion.

Therefore, the simulation period desired is the relatively long period from the neap tide to the spring tide, and not only a one tidal cycle. Also, all riverine systems which affect tidal motion are desirable as the simulation range.

On the other hand, a large amount of sediments has been flowing out of the vast basin of the Yangon Riverine system. Sediments are deposited on the estuarine regions from Yangon Port. Hence, the river channel and bed of the tidal reach in the Yangon River have not changed much. According to Myanmar Rivers Reference (1996, DWIR of MoT), the estimated annual sediment transport is 37 million tons for the Yangon River based on the size and character of its drainage area. In the vicinity of Yangon Port, MPA has been dredging the sediment deposits in order to secure the navigation channel.

3) Aggradations and Degradations of Rivers

The collected bathymetric survey data are listed in Table 8.9. From these data, cross-sectional data of related rivers were prepared by the JICA Survey Team. These cross section data are useful in checking and understanding the change in cross-sectional and longitudinal profiles, such as aggradations and degradations of rivers.

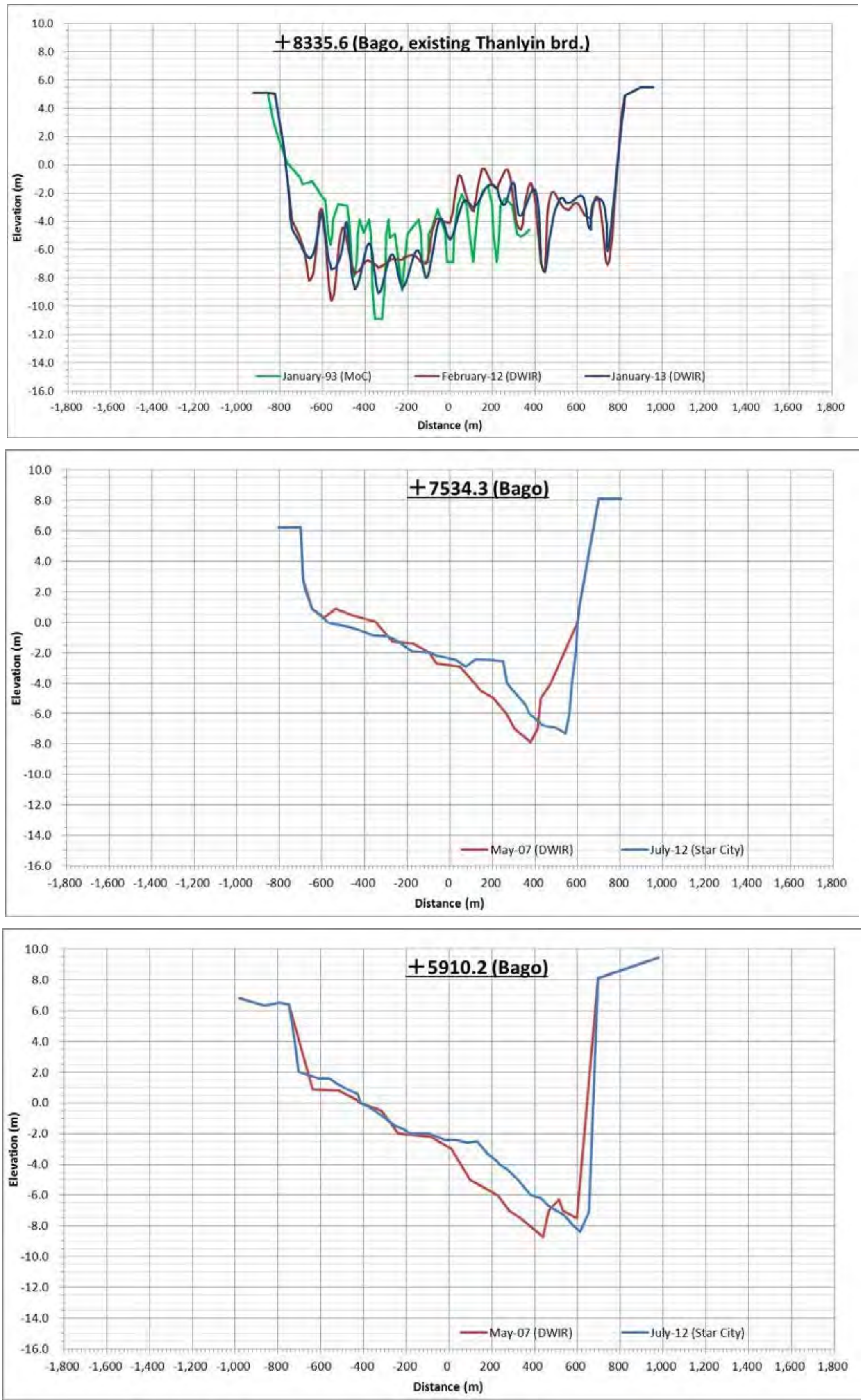
Table 8.9 Bathymetric Survey Data List

Organization	Reach	Survey Date	Remarks
MPA - nautical chart	Yangon River mouth –Bago River, Pazundaung Creek, Hlaing River to the Port limit	Sep. 2007	
MPA - bathymetric survey	Inner bar (Monkey Point)	Feb. 2010, Feb., Jun., and Jul. 2013	Partial data
MPA - bathymetric survey	Liffy reach of the Yangon River	Apr. 2011	Partial data
MPA - bathymetric survey	Monkey Point to Bo Aung Kyaw Wharves of the Hlaing River	Feb. 2010	
DWIR - bathymetric survey	Upstream of Thanlyin to upstream of Dagon Bridge	Jan. 2013	
DWIR - bathymetric survey	Confluence of Hlaing to Thanlyin Bridge	May 2007	
Thanlyin Estate Development Ltd. (Star City) – bathymetric survey	Monkey Point to Thanlyin Bridge of the Bago River	Jul. 2012	
JICA Survey Team	Confluence of Hlaing to upstream of Thanlyin Bridge, Pazundaung Creek	Aug. 2013	This Survey

Source: JICA Survey Team

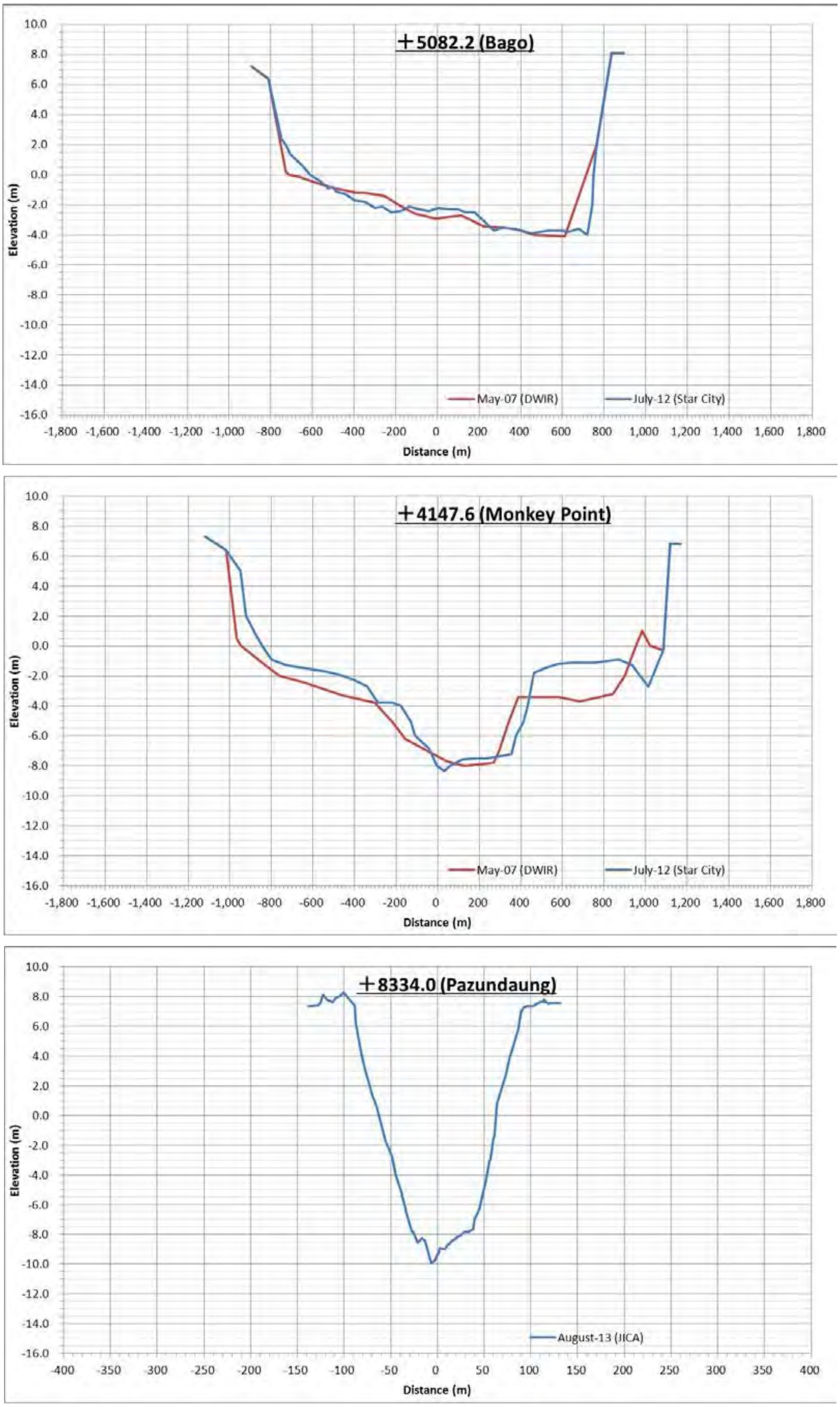
The fluctuations of cross-sectional profiles of rivers in recent years are shown in Figure 8.15 and 8.16.

- ✓ At Station No. 7534 and No. 5910, the profiles indicate a trend toward increasing erosion to the outer bending part of the Bago River caused by washout.
- ✓ At Station No. 8336 at Thanlyin Bridge of the Bago River and 8334 at Thaketa Bridge of the Pazundaung Creek, local scouring of bridges is progressing, and its depths are fluctuating on a large scale.
- ✓ At station No. 5082 at Bago Point, riverbed depth seems to be almost stable in recent years.
- ✓ At station No. 4148 at Monkey Point, riverbed height seems to be unstable due to the sedimentation of sand from the Hlaing River and Pazudaung Creek.



Source: JICA Survey Team based on the data collected from MPA, DWIR, Star City

Figure 8.15 Change of Cross-sectional Profiles of Rivers (1)

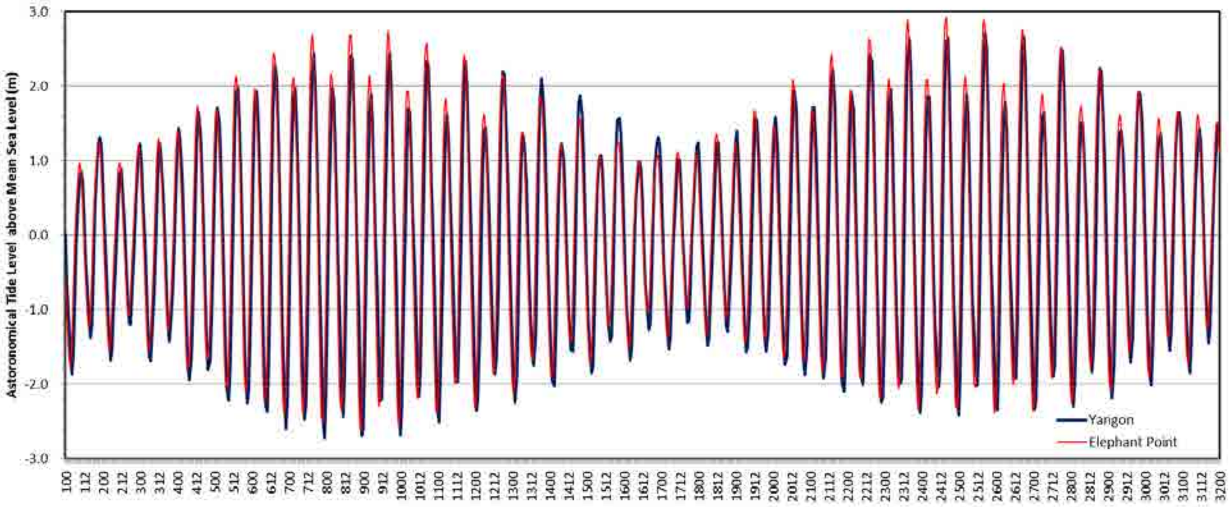


Source: JICA Survey Team based on the data collected from MPA, DWIR, Star City

Figure 8.16 Change of Cross-sectional Profiles of Rivers (2)

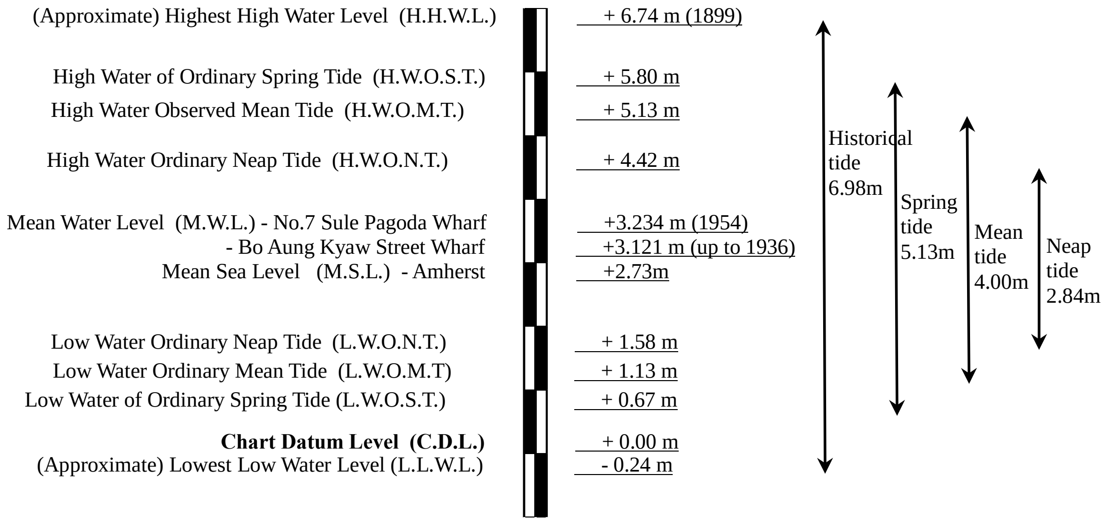
8.2.2 Tidal Level around Yangon Area

Hourly calculated data of astronomical tide at Yangon Port (located 36 km upstream from the mouth of the Yangon River) and at Elephant Point (located at the river mouth) are available from the website. Both station's astronomical tide level records in March 2005 are shown in Figure 8.17, while the tide chart diagram of Yangon Port is shown in Figure 8.18 (ground elevation of land survey is normally indicated as zero from the MWL+3.121m at Bo Aung Kyaw Street Whalf Station of MPA.) From the tide chart diagram, observed fluctuations of spring, average, and neap tides are 5.13 m, 4.00 m, and 2.84 m, respectively. According to MPA, the maximum storm surge (namely, the sea level departure from normal or the difference between astronomical tide and observed tide) at Yangon Port is reported to be 2.13 m. During the passage of Cyclone Nargis on May 3, 2008, MPA measured 2.13 m from flood mark after the storm. For comparison, the probable surge amplitudes (or sea level departure from normal) at Elephant Point as calculated by the Hydrology Branch of the Irrigation Department are shown in Table 8.10. Comparing with probable surge amplitude, it can be said that the storm surge during the passage of Cyclone Nargis at Yangon port is very high. In addition, the calculated tides in four and eight major constituent tides at Elephant Point are shown in Table 8.11 based on the existing study.



Source: Earthquake Research Institute, the University of Tokyo

Figure 8.17 Astronomical Tide at Elephant Point and Yangon Port (2005)



Source: MPA

Figure 8.18 Tide Level at Yangon Port

Table 8.10 Return Period and Surge Amplitude at Elephant Point

Return Period (year)	5	10	20	25	50	**100**	200
Surge (m)	0.889	1.046	1.196	1.244	1.391	**1.537**	1.682

Source: JICA Library (The Project for Preservation of Farming Area for Urgent Rehabilitation of Agricultural Production and Rural Life in Areas affected by Cyclone Nargis, 2011), MoAI,

Table 8.11 Amplitude of Major Tidal Constituents Actual Measurement in 1978-79 at Elephant Point (Past Computation Result of Harmonic Decomposition)

Latitude : 16 30'
Latitude : 96 18'

			Amplitude H		Phase G
			ft	m	degree
Major 8 Constitu-ents	Major 4 Constitu-ents	M2	5.743	1.750	99.18
		K1	0.673	0.205	20.53
		S2	2.299	0.701	141.96
		O1	0.305	0.093	40.86
		N2	1.097	0.334	90.91
		K2	0.625	0.191	141.96
		P1	0ss.223	0.068	20.53
		Q1	0.049	0.015	307.42
Sum of Major 4 Constituents				2.749	

Source: Irrawaddy Delta Hydrological Investigations and Delta Survey, Volume 3 – Analysis, Sir William Halcrow & Partners, January 1982, MoAI,

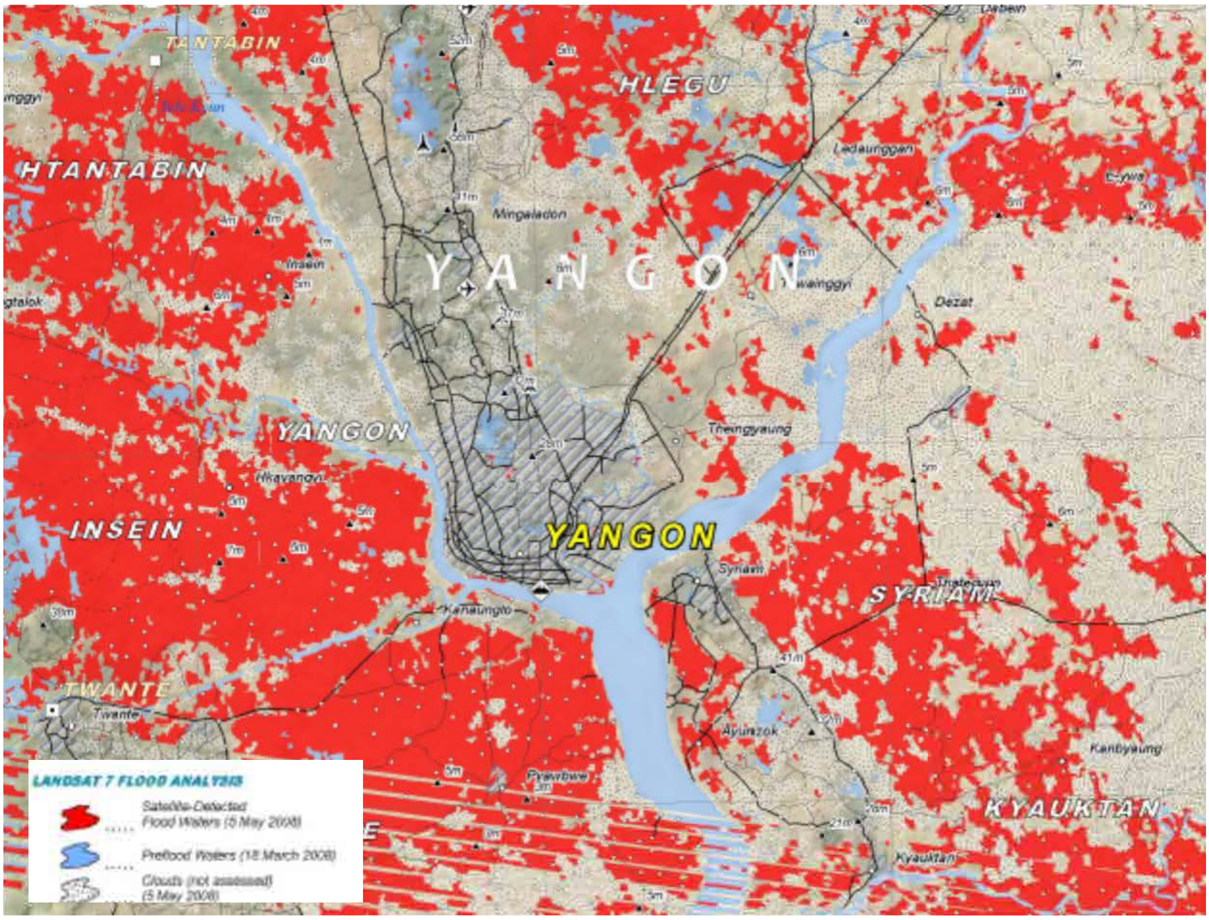
Note: In the abovementioned document, 32 major constituents were calculated by harmonic analysis.

8.2.3 Flood Conditions including Storm Surge

According to the Hazard Profile of Myanmar, 2009, flooding has always been one of the major hazards in Myanmar, accounting for 11% of all disasters and second only to fire. Floods around Yangon area can be classified into three types as follows:

- ✓ Riverine floods in the river delta;
- ✓ Localized floods in urban areas due to a combination of factors, such as cloudburst, saturated soil, poor infiltration rates, and inadequate or poorly-built infrastructure (e.g., blocked drains); and
- ✓ Flooding due to cyclone and storm surge in the coastal areas.

Floods that have caused the largest damage are due to cyclones and storm surges Figure 8.19 shows the flood inundation areas resulting from Cyclone Nargis, taken by satellite imagery on May 5, 2008. The Hazard Profile of Myanmar described that the damage brought by Cyclone Nargis caused 138,373 people dead or missing, killed 300,000 cattle, and destroyed over 4,000 houses and schools in more than 6,000 villages, with a total damage cost of MMK 13 trillion, including those in Ayeyarwady and Yangon areas.



Source: UNOSAT (www.unosat.org)

Figure 8.19 Flood Waters surrounding Yangon City (Cyclone Nargis, 5 May 2008)

8.2.4 Inland Water Transportation Condition

The Port of Yangon is a river port having 18 wharves and is the premier international port of Myanmar. The port lies along the Yangon Riverbank at the Yangon City side. General cargoes handled at the Port of Yangon are as follows:

- ✓ Main Export Commodities - timber, pulses, rice and rice products, yellow maize, and fishery products; and
- ✓ Main Import Commodities - construction materials, machinery and equipment, fertilizer, crude oil, palm oil, wheat grain, and cement.

General cargo handled at the Yangon Port in 2011-2012 was 20,408 thousand metric tons (imports at 12,590 and exports at 7,818), volume of handled container is 408,043 twenty-foot equivalent unit (TEU: imports at 207,540 and exports at 200,503).

Most of the abovementioned comes from the trading volume in the inner harbor of the Port of Yangon. In the proposed bridge sites of the Bago River and Pazundaung Creek, ships owned by some organizations only sail around the Tharkata Jetty at a rate of about once a day except for small ships and fishing boats. Also, there is a small shipyard upstream of the existing Thanlyin and Thaketa bridges, where some small ships crosses under them. Among the organizations that own vessels are Myanmar Five Star Line (MFSL), Myanmar Port Authority (MPA), Myanmar Navy (MN), Myanmar Oil and Gas Enterprise (MOGE) and Yuzana Company Limited. The largest ship, owned by MFSL, is as follows:

- ✓ Ship's name : M.V. Mongla
- ✓ Length Overall (LOA)/Beam : 92.45 m/15.8 m
- ✓ Depth : 7.8 m
- ✓ GRT/NRT : 3388 t/1421 t
- ✓ Hatches : 2
- ✓ Draft : 5.3 m
- ✓ DWT : 3,309 t
- ✓ Ship Height above Sea Level : 28 m (light draft)

On the other hand, the list of navigation channel limitation of related existing bridges is shown in Table 8.12.

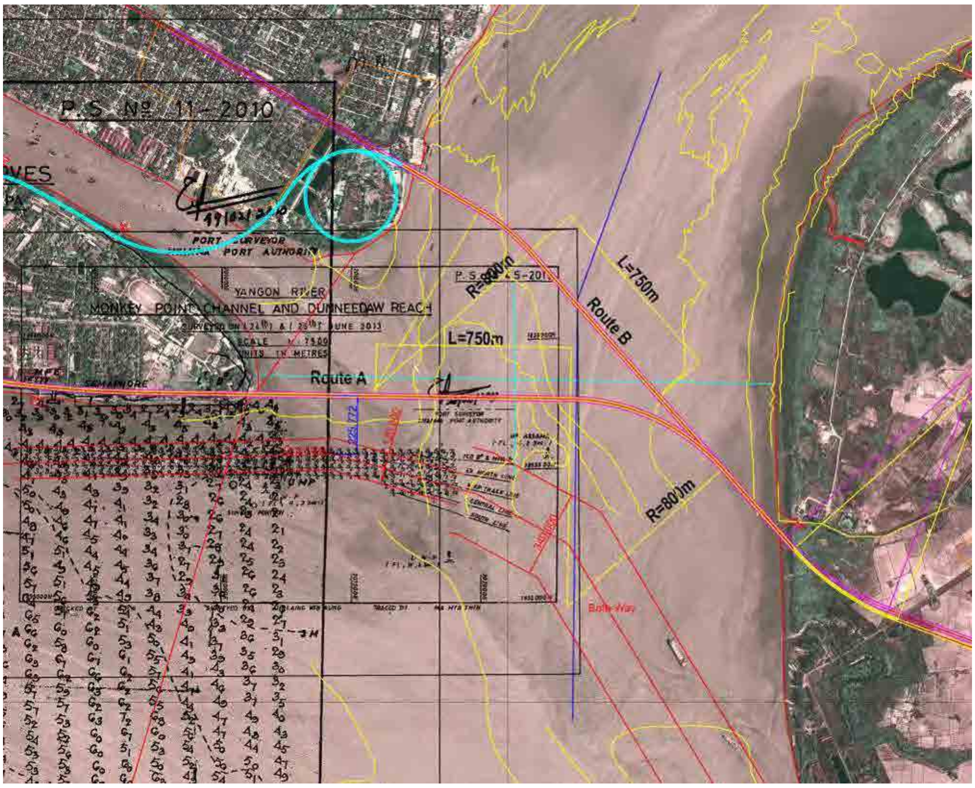
Table 8.12 Navigation Channel Limitation of Related Existing Bridges

Bridge Name	River Name	Clearance(m)	
		Width	Height
Maha Bandoola Bridge (Thaketa Township)	Pazundaung Creek	120.0	16.8
Thanlyin Bridge (Thanlyin Township)	Bago	106.1	10.2

Source: IWT

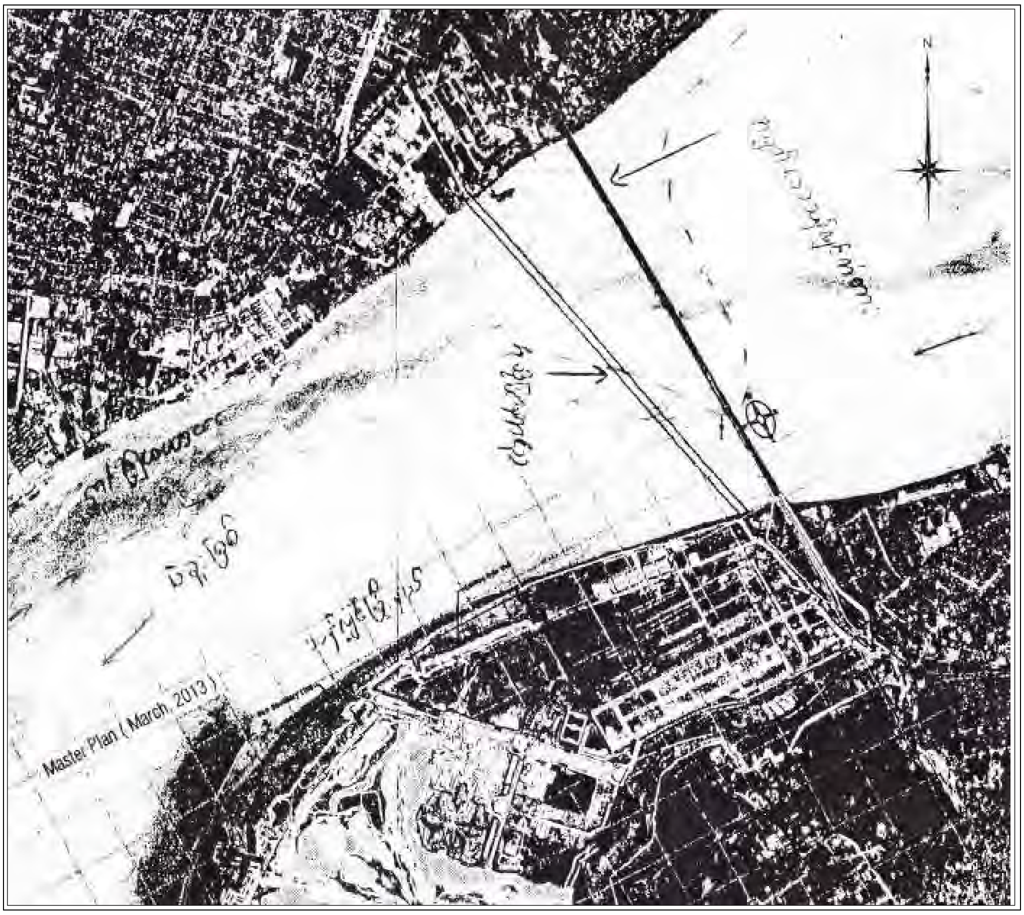
From the above, in the navigation channel of this proposed bridge site up to the Thaketa Jetty, the largest allowable ship weight is 3,309 t and necessary navigation channel height is 28 m at present. Navigation channel height for the Pazundaung Creek and the upstream part from Thaketa Jetty is about 10 m for small ships.

Based on an interview with MPA and IWT, the navigation fairways at Monkey Point and the Thanlyin Bridge are commonly navigated as shown in Figure 8.20 and Figure 8.21.



Source: JICA Survey Team based on the data from MPA

Figure 8.20 Navigation Fairway at Monkey Point (Yangon Port)



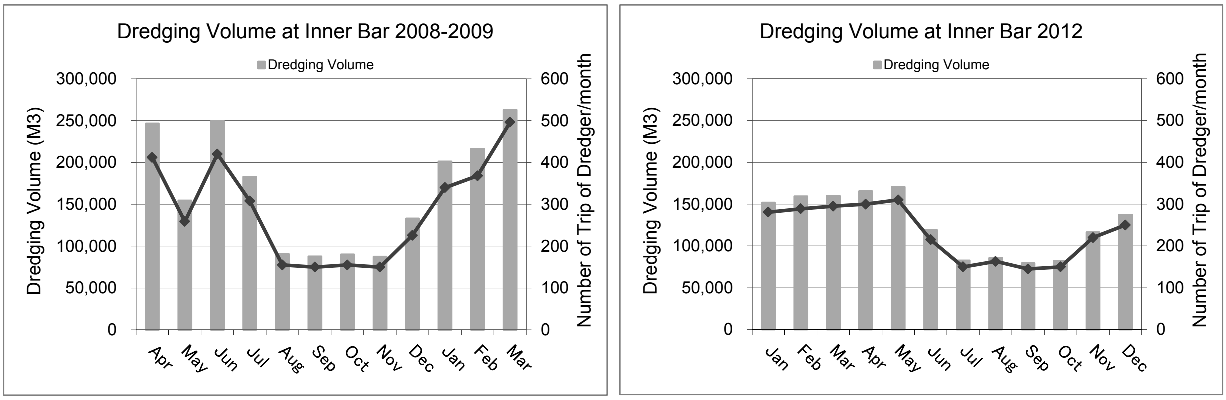
Source: IWT

Figure 8.21 Navigation Fairway at Thanlyin Bridge

8.2.5 Dredging Condition of Inner Bar of Yangon Port

MPA has conducted a bathymetric survey at the inner bar (Monkey Point) of their navigation channel every week. Based on the results, MP has dredged using its self-propelled suction hopper dredger (800-1,000 m^3, three ships), conducted during low tide. It takes about 30 min until the dredger is full. The dredging cycle includes a one-hour trip to the dumpsite that is 3.6 km (2.2 mi) away.

Dredging of mud and sand at the inner bar is performed by one ship during the rainy season. As sand increases during the dry season, dredging is then performed by two or three ships. Annual dredging soil volume for maintenance is 1.5-2.0 million m^3 per year, annual budget for dredging is secured at USD 950,000. Records of dredging volume and number of trips of dredgers are shown in Figure 8.22.



Source: JICA Survey Team based on the data from MPA

Figure 8.22 Dredging Volume and Dredger Trips at Yangon Port

8.3 Estimation of Probable Floods and Water Levels

8.3.1 Probable Floods at Gauging Stations

Past annual maximum discharges (extremal values) of Zaungtu, Bago, and Khamonseik gauging stations collected for the calculation of design discharges are shown in Table 8.13.

Table 8.13 Collected Data List for Annual Maximum Discharge

Station Name	River Name	Catchment Area (km^2)	Period of Record	Collected Data No.	Remarks
Zaungtu	Bago	1,927	1987~	25 (1987-2011)	
Bago	Bago	2,580	1970~	43 (1970-2012)	
Khamonseik	Hlaing	5,840	1987~	22 (1987-2011)	3-year missing observation

Source: DMH

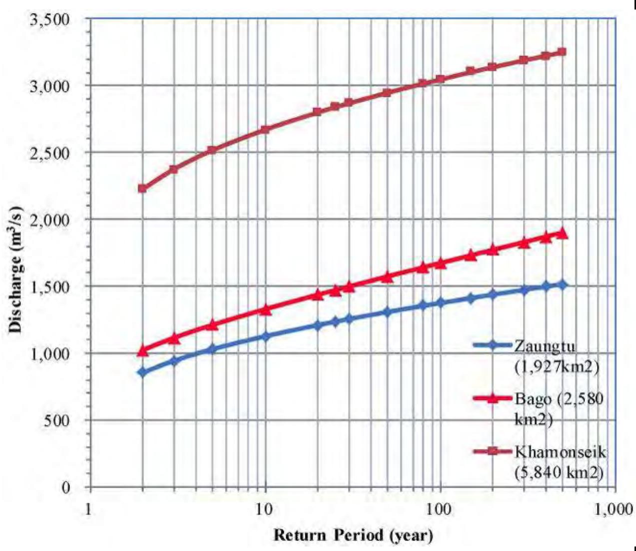
Probable discharges are calculated according to the following:

- ✓ To select the appropriate model for probability distribution from the three methods: Gumbel distribution, Iwai distribution and Lognormal distribution. In this survey, Iwai distribution of most common method is adopted.
- ✓ Calculations are for 2, 3, 5, 10, 20, 25, 30, 50, 80, 100, 150, 200, 300, 400 and 500 year return periods.

The results of probable discharge at Zaungtu, Bago, and Khamonseik gauging stations are shown in Table 8.14.

Table 8.14 Probable Flood Calculation at Zaungtu, Bago, and Khamonseik Gauging Stations

Return Period (Probability) (Year, %)		Probable Discharge Qmax (m^3/s)		
		Bago	Zaungtu	Khamonseik
		2,580 km^2	1,927 km^2	5,840 km^2
2	50.0%	1,024	855	2,227
3	33.3%	1,114	942	2,374
5	20.0%	1,211	1,030	2,517
10	10.0%	1,329	1,127	2,671
20	5.0%	1,437	1,210	2,800
25	4.0%	1,471	1,235	2,838
30	3.33%	1,498	1,255	2,868
50	2.0%	1,574	1,308	2,947
80	1.25%	1,642	1,354	3,015
100	1.0%	1,674	1,375	3,046
150	0.667%	1,732	1,412	3,101
200	0.5%	1,773	1,438	3,138
300	0.33%	1,830	1,473	3,188
400	0.25%	1,871	1,498	3,223
500	0.2%	1,902	1,516	3,249



Source: JICA Survey Team based on the data from

8.3.2 Probable Floods from River Flow for Design

The discharge at the proposed bridge sites are calculated by multiplying the proportion of of each catchment area to the probable discharges of each gauging stations upstream (or “specific discharge” method).

Probable discharges used for the hydraulic calculation are shown in Table 8.15. Incidentally, these discharges are runoff volumes from the river’s own flow, but excluding additional flow rates from the influence of the falling tide.

Table 8.15 Probable Floods from River Flows for this Design

Riverine System Name	Yangon River					Remarks
River Name	Bago River		Hlaing River		Pazundaung Creek	
Gauging Station Name	Bago		Khamonseik		(Bago)	
Catchment Area at Station (km^2)	2,580	-	5,840	-	-	
Catchment Area at Construction Site (km^2)	-	5,180	-	12,950	1,490	
Return period	Probability value	Discharge	Probability value	Discharge	Discharge	
1/2	1,024	2,056	2,227	4,938	591	
1/3	1,114	2,237	2,374	5,264	643	
1/5	1,211	2,431	2,517	5,581	699	
1/10	1,329	2,668	2,671	5,923	768	
1/20	1,437	2,885	2,800	6,209	830	
1/25	1,471	2,953	2,838	6,293	850	
1/30	1,498	3,008	2,868	6,360	865	
1/50	1,574	3,160	2,947	6,535	909	
1/80	1,642	3,297	3,015	6,686	948	
1/100	1,674	3,361	3,046	6,754	967	
1/150	1,732	3,477	3,101	6,876	1,000	
1/200	1,773	3,560	3,138	6,958	1,024	
1/300	1,830	3,674	3,188	7,069	1,057	
1/400	1,871	3,757	3,223	7,147	1,081	
1/500	1,902	3,819	3,249	7,205	1,098	
		Q1		Q3	Q2	
100 year discharge per unit drainage area ($m^3/sec/km^2$)	0.64884		0.52158			=specific discharge

	Bago River Q1	Pazundaung Creek Q2	Hlaing River Q3	Yangon River (Monkey P.) Q4	Yangon River-mouth Q5	Remarks
Catchment Area (km^2)	5,180	1,490	12,950	19,620	(25,640)	
10 year flood (m^3/s)	2,668	768	5,923	9,359	(12,112)	
30 year flood (m^3/s)	3,008	865	6,360	10,232	(13,189)	
50 year flood (m^3/s)	3,160	909	6,535	10,604	(13,642)	
100 year flood (m^3/s)	3,361	967	6,754	11,082	(14,222)	Design Discharge
500 year flood (m^3/s)	3,819	1,098	7,205	12,122	(15,471)	

Source: JICA Survey Team based on the data from DMH

8.3.3 Probable High Water Level at Tidal Gauging Station

Past annual maximum high water level records (extremal values) at Yangon Port stations for the calculation of design high water level are as shown in Table 8.16. From these values, probable high water levels are calculated as shown at the right side of the same table.

Table 8.16 Probable High Water Level and Observed High Water Level (1997-2013) at Yangon Port (Monkey Point)

Return Period (Probability) (Year, %)		Probable High Water Level (HWL) (m)		Remarks
		Yangon Port		
		13 years (1997-2013) (1998-2001 was not observed)		Collected Data No.
		MPA	Land Survey	Benchmark
2	50.0%	7.0	3.9	
3	33.3%	7.1	4.0	
5	20.0%	7.2	4.1	
10	10.0%	7.4	4.3	
20	5.0%	7.4	4.3	
25	4.0%	7.5	4.4	
30	3.33%	7.5	4.4	
50	2.0%	7.6	4.5	
80	1.25%	7.7	4.6	
100	1.0%	7.7	4.6	
150	0.667%	7.8	4.7	
200	0.5%	7.8	4.7	
300	0.33%	7.9	4.8	
400	0.25%	7.9	4.8	
500	0.2%	8.0	4.9	

Year	Observed Maximum Annual Water Level (m, MPA-based)	Remarks
	Yangon Port	
1997	7.04	
1998	Not observed	
1999	Not observed	
2000	Not observed	
2001	Not observed	
2002	7.00	
2003	6.80	
2004	7.30	
2005	7.20	
2006	7.20	
2007	7.20	
2008	6.80	
2009	6.70	
2010	6.61	
2011	6.90	
2012	7.00	
2013	7.30	

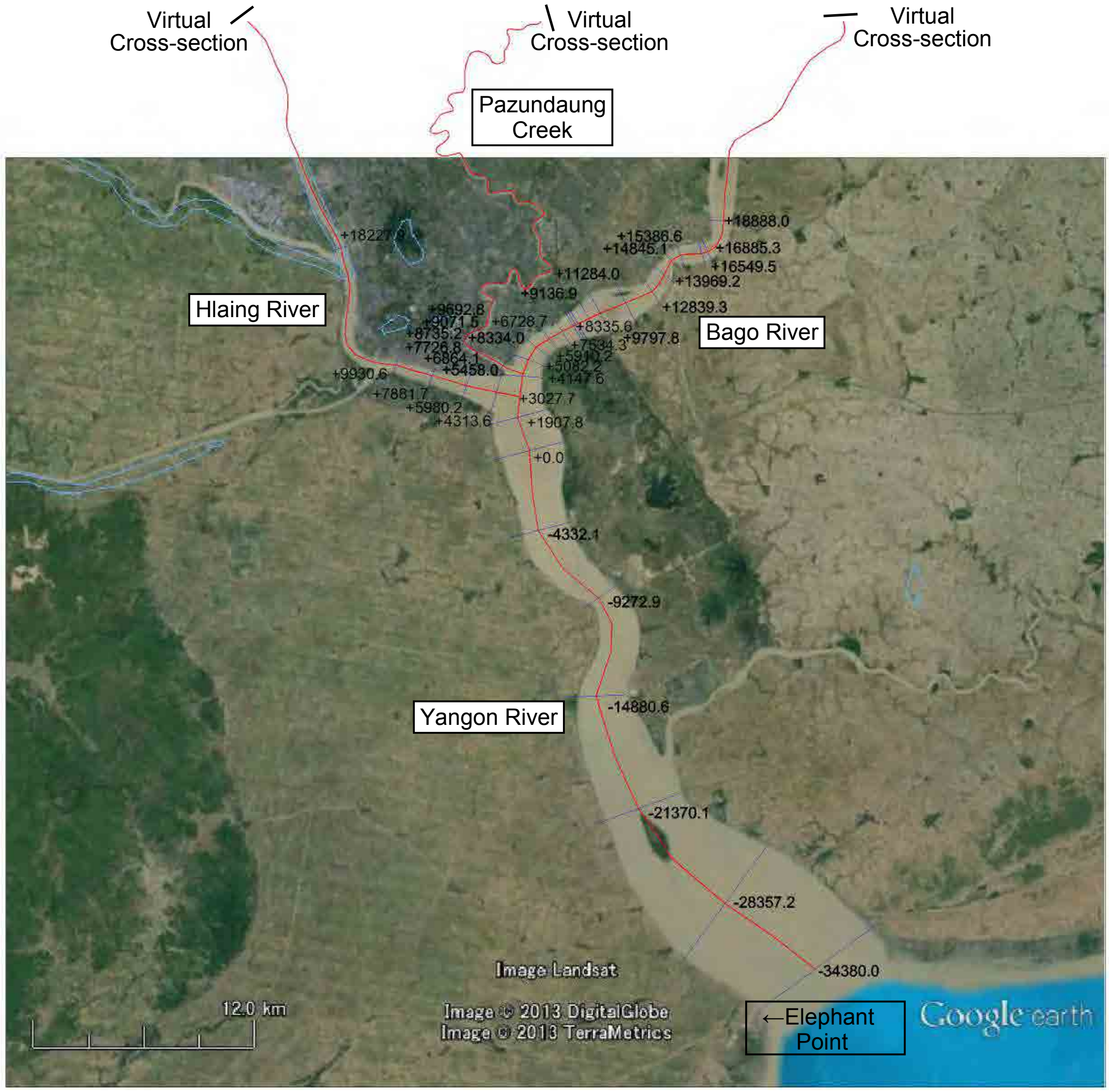
Note: Adopted probability distribution is the Gumbel distribution.

Source: JICA Survey Team based on the data from MPA

8.3.4 Hydraulic Calculation

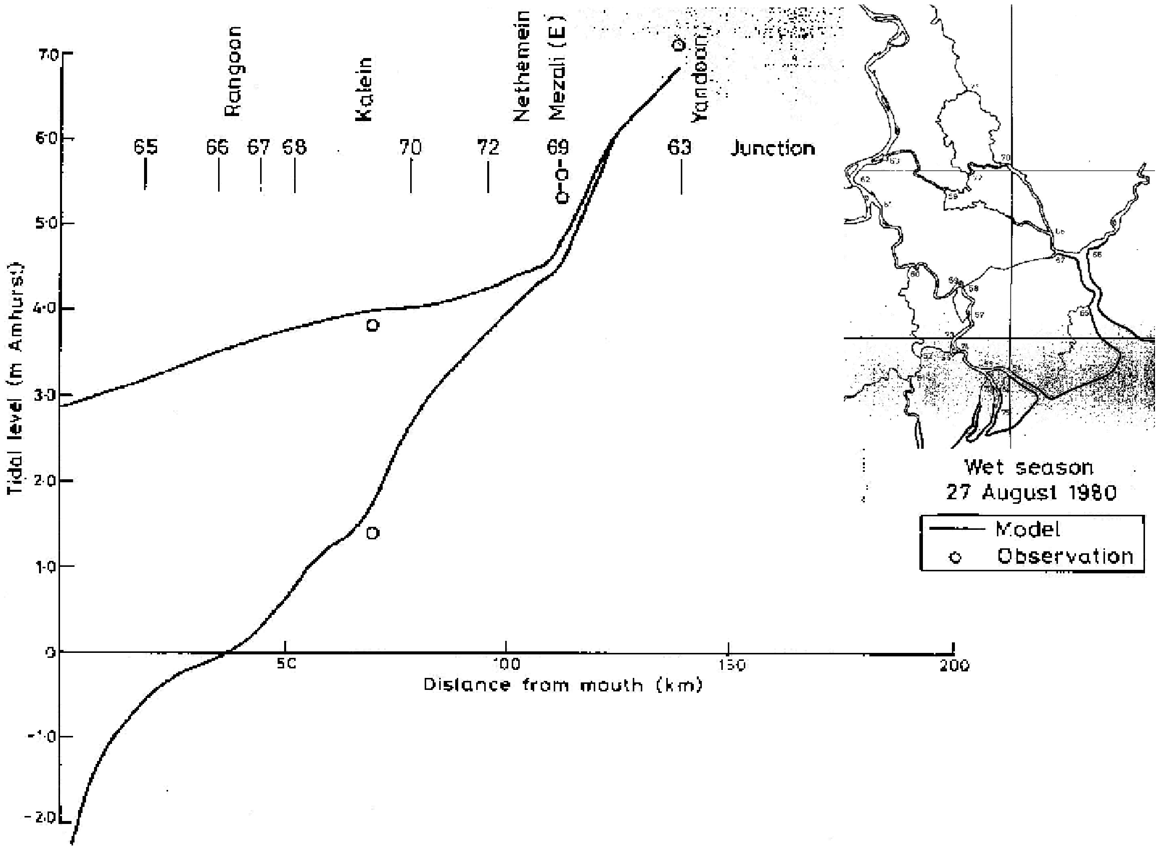
Hydraulic phenomena (rising tide, falling tide, etc. in addition to the river's own flood) at tidal compartments of the river are needed for simulating all of the tidal reaches. Therefore, the range of numerical calculation shall target all tidal areas of the Yangon Riverine system together with its tributaries such as the Bago River and Pazundaung Creek. The downstream boundary is assumed to be at Elephant Point (located at the river mouth of the Yangon River). The upstream boundary of tributaries is assumed in reference to past documents (Figure 8.24), river length is measured from the river route on the topographic map, and river cross section at the upstream end is assumed as the virtual cross-section. Distance from the river mouth to the upstream boundary is measured at 100 km or more.

The hydraulic calculation model of the Yangon Riverine system is shown in Figure 8.23.



Source: JICA Survey Team

Figure 8.23 Hydraulic Calculation Model of the Yangon Riverine System



Note: High Water Level around Yangon on the figure above is estimated at 6.23 m (=2.73 m+3.5 m). (Tide level on the figure above is based on Amherst station chart. Difference between Amherst and Yangon station chart is 2.73 m.)

Source: A One Dimensional Analysis of the Tidal Hydraulics of Deltas (Nicholas Odd, Report OD 44, July 1982, Hydraulics Research Station, UK), from MoAI Library

Figure 8.24 Past Simulation Example of High Water and Low Water Profiles at the Yangon River (during the wet season in August 1980)

1) Analysis Software

Hydraulic analysis was carried out to simulate the tidal and flood phenomena in the Yangon River using HEC-RAS (Hydrologic Engineering Center - River Analysis System), a software developed by the US Army Corps of Engineers, USA.

HEC-RAS has the capability to compute one-dimensional water surface profiles for both steady and unsteady flows. Sub-critical, supercritical, and mixed flow regime profiles can be calculated.

Water surface profiles are computed from one cross section to the next by solving the energy equation using the standard-step method. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion coefficients. HEC-RAS requires inputs for boundary conditions of upstream discharge and either downstream water level or known energy gradient.

Also, tidal waves are very dynamic. According to the user manual of this software, in order for the solution to be able to accurately model a tidal surge, the theta implicit weighting factor must be close to 0.6.

2) Hydraulic Analyses and Precondition

Hydraulic analyses were conducted through the following procedure:

- The roughness coefficient of the river channel is estimated by using the existing astronomical tide levels at two places during the dry season. The upstream water level of Yangon Port, which is calculated from the downstream astronomical tide for Elephant Point, is approximated as the astronomical tide waveform of Yangon Port by changing the roughness coefficient of tidal reaches. The 2005 tide table at Elephant Point and Yangon Port are given as known water level data.

- The calculation case at the time of flood (rainy season) was conducted by using the abovementioned roughness coefficient calculated from real tide level.

Also, preconditions of the calculation case are as follows:

- The cross sections for hydraulic calculation are given by using the bathymetric survey results (MPA Datum), nautical charts, and other data in reference to the above hydraulic model.

- The dry season downstream boundary for hydraulic calculation is given based on the tide level (from February 2 to 24, 2005, neap tide-spring tide-neap tide) at Elephant Point which varies from hour to hour; hence, the flow becomes unsteady. The dry season upstream boundary is given based on the steady low water runoff (275th day discharge).

- The rainy season downstream boundary for hydraulic calculation is given based on the tide level (from October 17 to 21, 2005, spring tide) at Elephant Point. The rainy season upstream boundary is given based on the 100-year flood as steady flow in each river.

- The flow rate to the upstream end is given as the proportional distribution of the catchment area at the upstream end with the total area. The flow rate of remaining catchment area is given as the uniform lateral inflow against the stream length.

3) Hydraulic Analyses and the Result

Two cases of hydraulic analysis were performed as shown in Table 8.17.

Table 8.17 Cases of Hydraulic Analysis

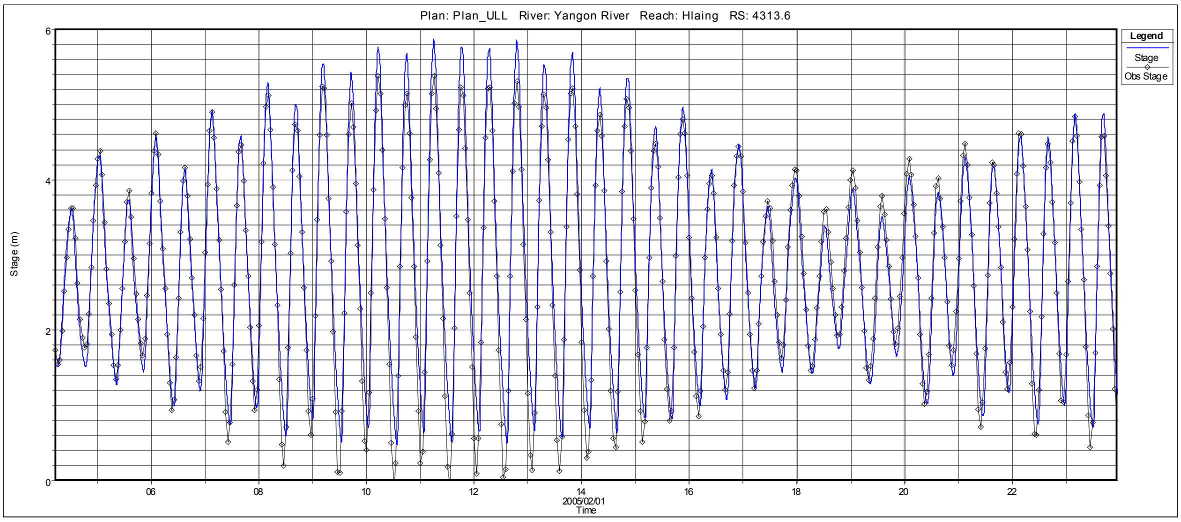
Case No.	Upstream Boundary Condition (m^3/s)				Downstream Boundary Condition of (Elephant Point)	Remarks (Objectives)
	Discharge	Hlaing	Bago	Pazun-daung	Period of Tidal Waveform	
1	Low water runoff	44	8	5	Feb 4– 24, 2005 (Annual minimum tide, Neap - Spring – Neap tide)	(For the calibration of roughness coefficient)
2	100-year flood	6,754	3,361	967	Oct 17 to 21, 2005 (Annual Maximum Tide, Spring tide)	(For the calculation of HWL)

Source: JICA Survey Team

Note: Discharge is indicated as the value at confluence of Hlaing, Bago and Pazundaung.

If the riverbed material is very small and the riverbed slope is very gentle such as those in the delta area, the roughness coefficient of river channel is generally very small and its coefficient is estimated to be about 0.015 according to past literatures[1]. From the results of the geotechnical survey in this study, the mean grain size of riverbed material in the Thaketa/Bago Bridge site is very small at 0.015-0.15 mm.

The roughness coefficients for Case 1 were set at 0.010, 0.015, 0.020, and 0.025. From the results of hydraulic calculation, the calculation case of surge amplitude that was properly synchronized with astronomical tide, where a roughness coefficient of 0.015 is applied, with a maximum margin of error of about 40 cm as shown in Figure 8.25.



Source: JICA Survey Team

Figure 8.25 Synchronization between Astronomical Tide and Calculated Tide at Yangon Port by Hydraulic Calculation (Roughness Coefficient: 0.015, Case 1)

From the results of low discharge calculation during the dry season, hydraulic calculation of high water level is calculated by using a roughness coefficient of 0.015. The results of hydraulic calculation for Cases 1 and 2 are shown in Table 8.18 and in Figure 8.26 to Figure 8.32.

Moreover, the estimation of high water level made an allowance for the elevation of water surface due to a decrease in atmospheric pressure caused by cyclones. The increment by waves is not considered in this survey. The elevation of water surface due to a decrease in atmospheric pressure is estimated through the following equation:

- Rising value of static water level by barometric depression;

$\eta_{PS} = 0.991 \cdot (1013 - p) = 0.991 \cdot (1013 - 962) = 50.54$ cm = 0.505 m

where; η_{PS}: Rising value of static water level by barometric depression (hPa)

p: Atmospheric pressure value which is decreased due to cyclone (hPa)

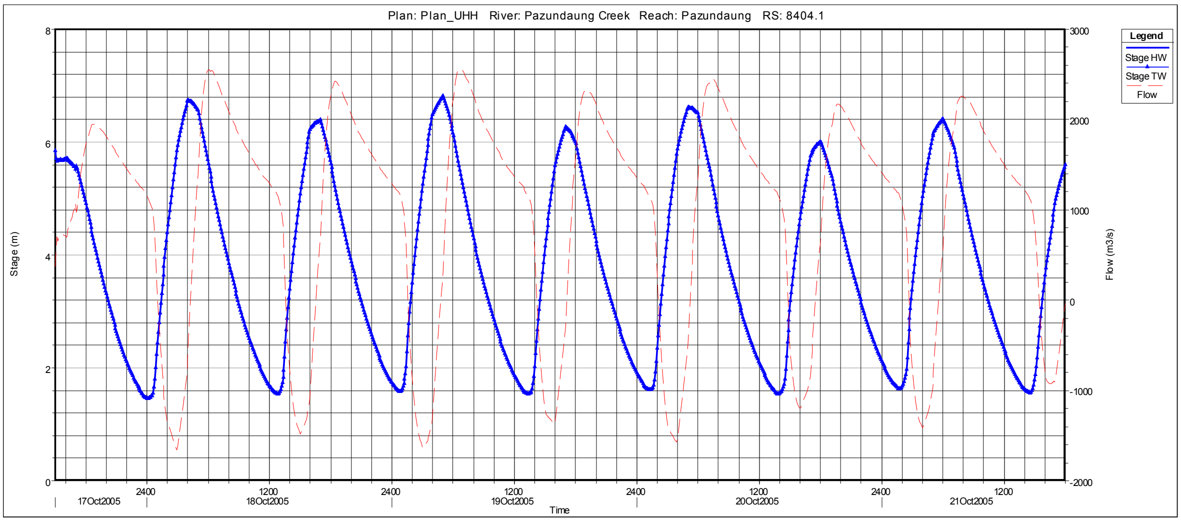
(2008 Cyclone Nargis: 962 hPa)

[1] Bed Form and Bed Variation During Floods of the TONE River Mouth, Journal of Japan Society of Civil Engineers, Ser. B1 (Hydraulic Engineering) Vol. 54(2010), Japan

Table 8.18 Results of Hydraulic Analyses

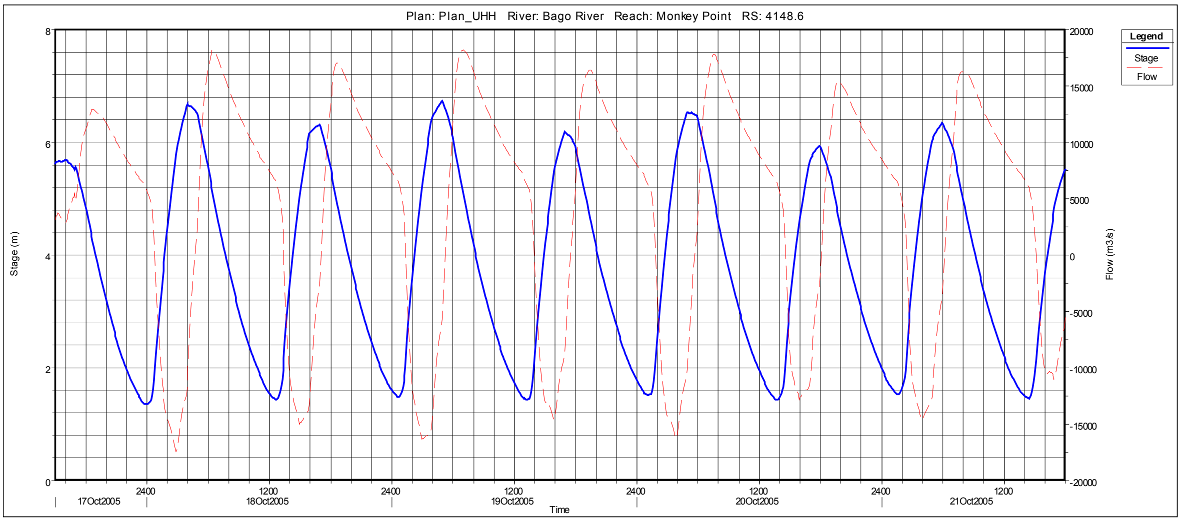
Item	Unit	New Bago Bridge			New Thaketa Bridge	Remarks
		Option 1	Option 2	Option 3		
		+4,148.6	+5,082.2	+8,144.4	+8,404.1	
< Hydraulic Calculation Results >				Case 1: Annual Minimum Tide and Flood		
High Water Level	m	5.86	5.86	5.88	5.87	at Low Discharge
Maximum Discharge	m^3/s	12,269.11	10,379.84	9,298.12	1,705.62	
Low Discharge	m^3/s	13.17	8.06	8.06	5.10	
Tidal flow	m^3/s	12,255.94	10,371.78	9,290.06	1,700.52	falling tide
Minimum Discharge	m^3/s	-18,511.03	-15,870.22	-14,428.05	-2,405.57	
100-year Flood	m^3/s	13.17	8.06	8.06	5.10	
Tidal flow	m^3/s	-18,524.20	-15,878.28	-14,436.11	-2,410.67	rising tide
< Hydraulic Calculation Results >				Case 2: Annual Maximum Tide and Flood		
High Water Level: (1)	m	6.74	6.74	6.79	6.81	at 100 year Flood
Water Level Departure from Normal by Cyclone: (2)	m	0.505	0.505	0.505	0.505	Cyclone Nargis: 962 hPa
High Water Level: (1)+(2)	m	7.25	7.25	7.30	7.32	
Maximum Discharge	m^3/s	18,291.25	15,502.38	14,397.53	2,556.37	
100-year Flood	m^3/s	4,327.74	3,360.98	3,360.98	966.77	
Tidal flow	m^3/s	13,963.51	12,141.40	11,036.55	1,589.60	falling tide
Minimum Discharge	m^3/s	-17,421.38	-15,468.58	-13,942.54	-1,657.47	
100-year Flood	m^3/s	4,327.74	3,360.98	3,360.98	966.77	
Tidal flow	m^3/s	-21,749.12	-18,829.56	-17,303.52	-2,624.24	rising tide
< Probability Calculation >						
Probable H.W.L.	m	7.7	7.7	7.7	7.7	
< Planned Value >						
Design Discharge	m^3/s	18,292	15,503	14,398	2,557	
Design H.W.L. (MPA-based)	m	7.7	7.7	7.7	7.7	
Design H.W.L. (Land Survey)	m	4.579	4.579	4.579	4.579	△3.121 m

Source: JICA Survey Team



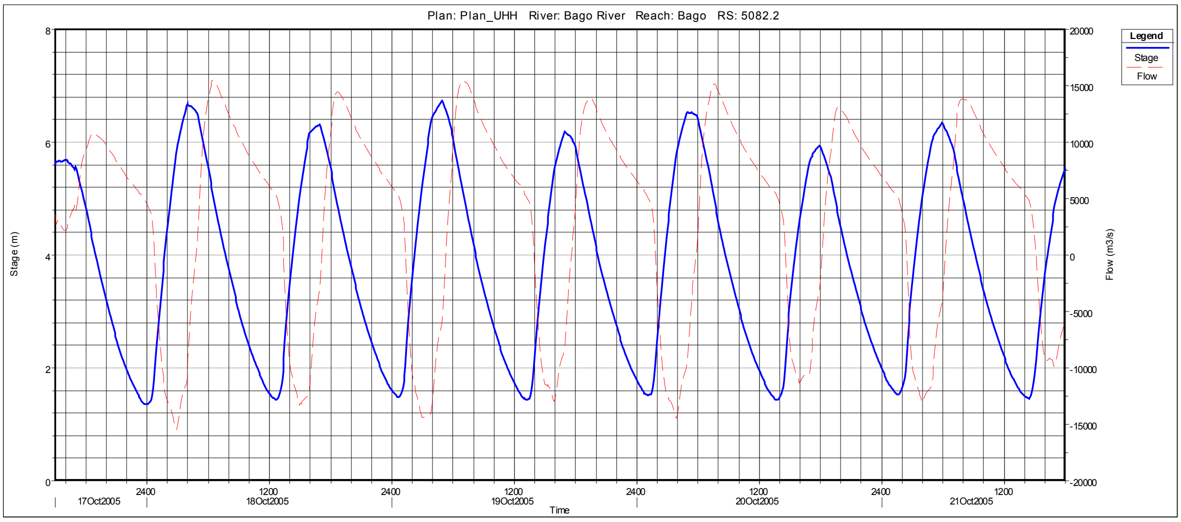
Source: JICA Survey Team

Figure 8.26 Tidally Dominated Water Level and Discharge Fluctuation (Rising and Falling Tide) at New Thaketa Bridge – Case 2



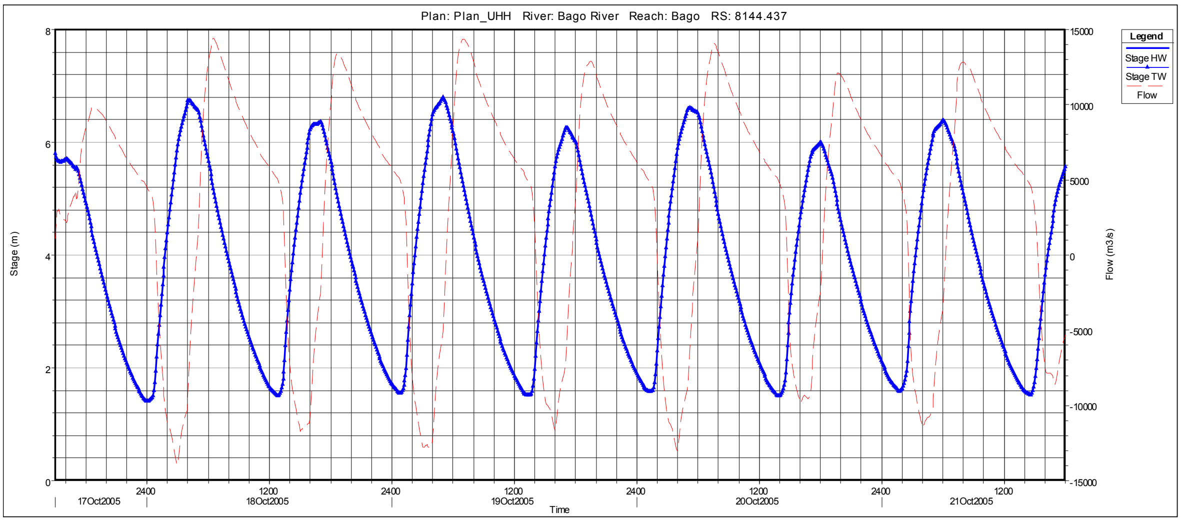
Source: JICA Survey Team

Figure 8.27 Tidally Dominated Water Level and Discharge Fluctuation (Rising and Falling Tide) at the New Bago Bridge (Option 1) - Case 2



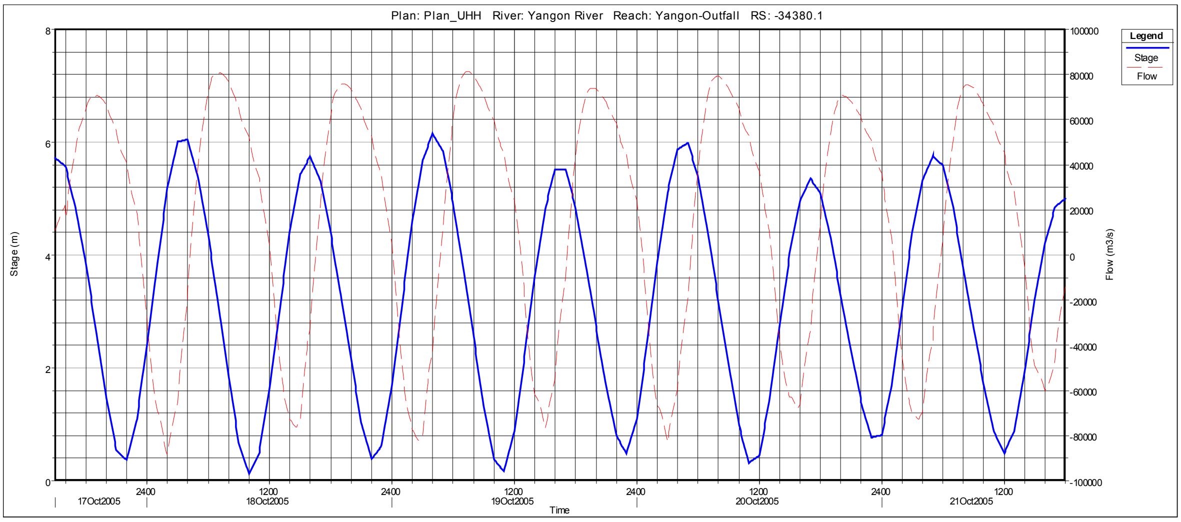
Source: JICA Survey Team

Figure 8.28 Tidally-dominated Water Level and Discharge Fluctuation (Rising and Falling Tide) at the New Bago Bridge (Option 2) - Case 2



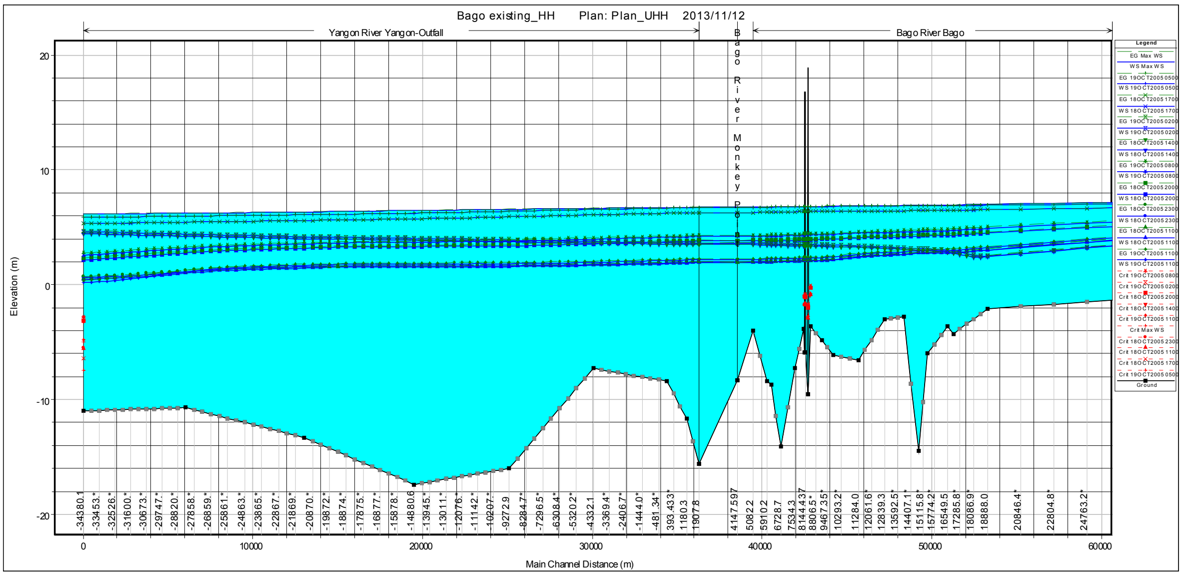
Source: JICA Survey Team

Figure 8.29 Tidally Dominated Water Level and Discharge Fluctuation (Rising and Falling Tide) at the New Bago Bridge (Option 3) – Case 2



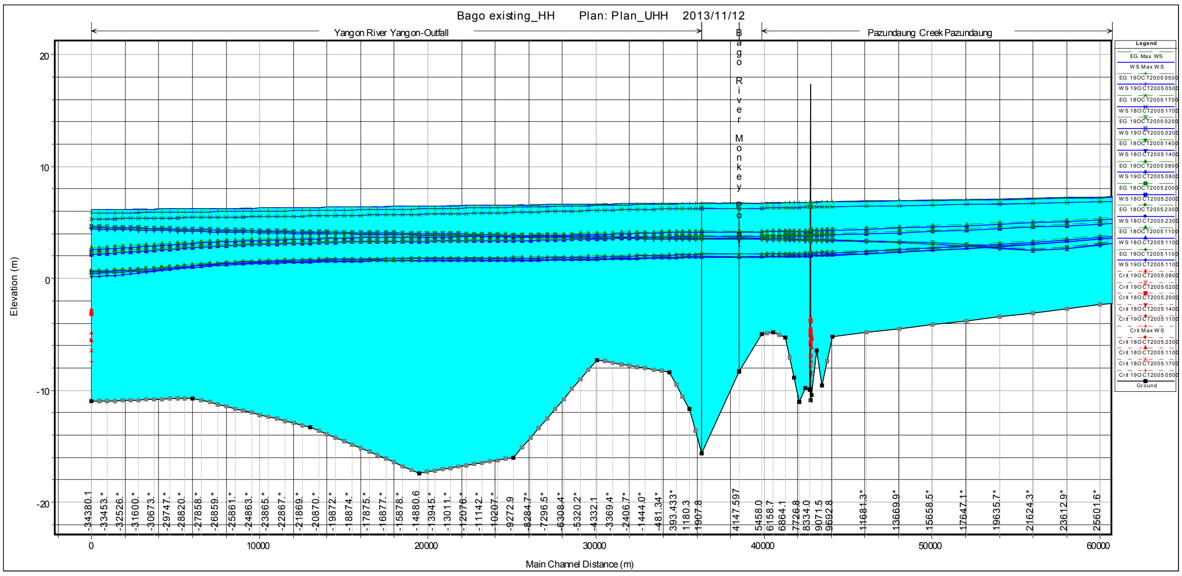
Source: JICA Survey Team

Figure 8.30 Tidally Dominated Water Level and Discharge Fluctuation (Rising and Falling Tide) at the Yangon River Mouth – Case 2



Source: JICA Survey Team

Figure 8.31 Longitudinal Profile of the Bago River to the Yangon River Reach – Case 2



Source: JICA Survey Team

Figure 8.32 Longitudinal Profile of the Pazundaung Creek to the Yangon River Reach – Case 2

(5) Design High Water Level and Discharge

From the above hydraulic analyses, the design high water level and discharge are determined as shown in the Table 8.20. As for discharge, most of the total discharge is decided by the component of tidal flow other than the river's own flow (upland flow) from the catchment area for large tidal variations. For the determination of the design high water level and discharge, the following aspects are left as future challenges:

- ➢ The number of data for observed annual maximum high water level at Yangon Port is just 13 years, which somewhat lacks reliability (i.e., problem on statistics analysis).

- The flows of rising and falling tide during the dry season were restaged well by using unsteady flow simulation. However, the observed data on past storm surge tide level and discharge during the rainy season is difficult to obtain as most of the data format are not organized in a manual. Hence, the calculation result of hydraulic analysis is difficult to calibrate against the observed data at the time of storm surge.

- The bathymetric survey data of tidal section is much less. However, all survey data of tidal area for the Yangon Riverine system, including all its tributaries, is difficult to obtain. Also, hydraulic analysis for the tidal area of the Yangon River, including all its tributaries, is difficult to perform for a road project as the workload required is enormous (e.g., problem on hydraulic analysis).

In view of the above issues, various studies and surveys shall be performed in the detailed design stage.

8.4 Hydrological Assessment of the Proposed Bridge Sites

8.4.1 Hydraulic Design Criteria of Bridge

In designing the opening of the bridge waterway, the following design criteria for hydraulics are required:

- Backwater shall not significantly increase flood damage to properties upstream of the bridge;

- Velocity through the bridge shall not damage the road facility or increase the damages to downstream properties:

- The existing flow distribution shall be maintained to the most practicable extent;

- The pier and abutment shall be designed to minimize the flow disruption;

- Potential local scour shall be within acceptable limits; and

- Clearance at the structure shall be adequately designed in order to provide safety for falling debris (the elevation of bottom of bridge girder must be higher than the highest high water level plus the navigation channel height.)

The design return period and the clearance from the bridge girder to the high water level shall be compliant with standards authorized by the organizations concerned.

In this survey, the design return period is 100 yearss. Also, the design standard is based on the HEC series of FHWA[2] as well-used international standards.

8.4.2 Assessment of Scouring

(1) Basic concept

Scour at bridge occurs due to the erosion caused by flowing water, excavation, and carrying away of materials from the riverbed and its banks. Scour process is cyclic in nature which complicates the determination of its magnitude. Scour can be deepest near flood peak; however, it is hardly visible as scour holes are covered with sediments during the receding stage of flood. In general, several floods may be needed in order to attain maximum scour under typical flow conditions at bridge crossings.

[2] Hydraulic Engineering Circular, Federal Highway Administration, USA

(2) Methodology of scour computation

In designing the bridge substructure, it is very important to evaluate the scour potential at piers and abutments and carefully studying site-specific subsurface information. Total scour at a bridge crossing is comprised of three components:

1. Long-term aggradation or degradation
2. Contraction scour
3. Local scour

1) Aggradation and Degradation

Aggradation and degradation are long-term changes in streambed elevation due to natural or man-induced causes. Aggradation involves the deposition of material eroded from the stream or watershed upstream of the bridge; whereas, degradation involves the lowering of streambed due to lack of sediment supply from upstream. Both are evaluated independently in the hydraulic model. Generally, streams are considered to have stable and balance of sediment transport if the configuration is not changed in the long term. In this survey, the river bed/course fluctuation analysis is not conducted. In the detailed design stage, this analysis shall be conducted and their results will be studied after surveying the past and current topographic data of rivers.

2) Contraction Scour

Contraction scour at a bridge crossing involves the removal of material from the streambed and banks across the channel width, resulting from a contraction of the flow area and an increase in discharge at the bridge.

In case of constructing a new bridge, common causes for contraction of flows are constriction (encroachment) of road embankment onto the floodplain and/or into the main channel or piers blocking a portion of flow. As a result, flow area decreases velocity and bed shear stress increase. Hence, more bed material is removed from the contracted reach than those transported into the reach. As bed elevation lowers, flow area increases while velocity reduces, reaching a state of relative equilibrium.

3) Local Scour

Local scour at piers or abutments involves the removal of bed material as a result of formation of vortices known as the horseshoe vortex and wake vortex at their base. The horseshoe vortex results from the pileup of water on the upstream surface of the obstruction and subsequent acceleration of the flow around the nose of the pier or abutment. The action of the vortex removes bed material around the base of the obstruction. In addition to the horseshoe vortex around the base of a pier, there are vertical vortices downstream of the pier, called the wake vortex. Both the horseshoe and wake vortices remove material from the pier base region. The intensity of wake vortices diminishes rapidly as the distance downstream of the pier increases. As a result, there is often deposition of material immediately downstream of a long pier.

Factors that affect the magnitude of local scour depth at piers and abutments are:

① Velocity of the approach flow,

② Depth of flow,

③ Width of the pier,

④ Discharge intercepted by the abutment and returned to the main channel at the abutment,

⑤ Length of the pier if skewed to flow,

⑥ Size and gradation of bed material,

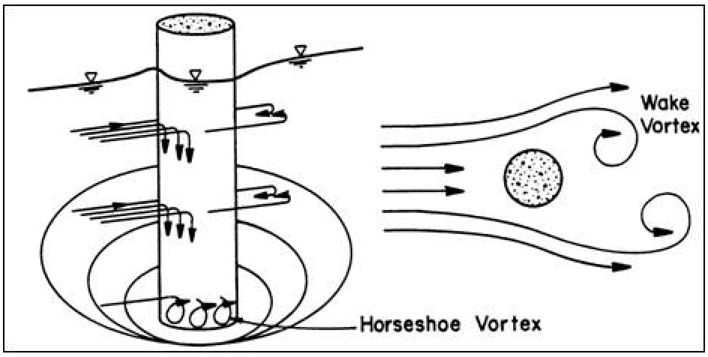
⑦ Angle of attack of the approach flow to a pier or abutment,

⑧ Shape of a pier or abutment,

⑨ Bed configuration, and

⑩ Ice formation or jams and debris.

A sample illustration of scour at a cylindrical pier is shown in Figure 8.33.



Source: Evaluating Scour at Bridges (2012 Fifth Edition), Hydraulic Engineering Circular No. 18 (HEC 18), FHWA, USA

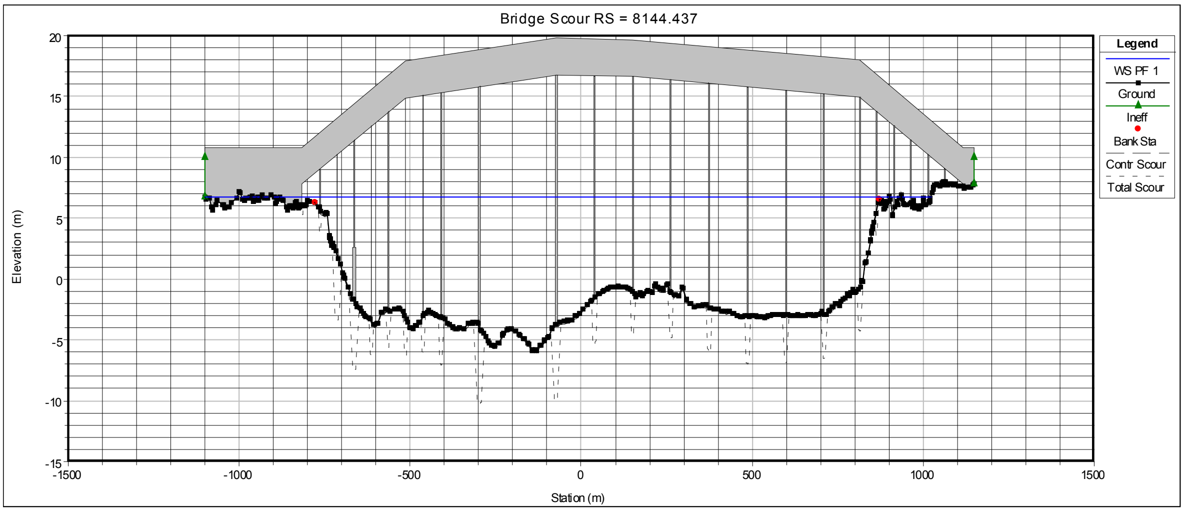
Figure 8.33 Simple Schematic Representation of Scour at a Cylindrical Pier

(3) Scour Estimation

All major streams intercepted by the proposed bridge alignment were modelled using HEC-RAS developed by Hydrologic Engineering Center, USA. The model reach covered a sufficient length from upstream to downstream of the bridge location. These models were simulated for 100-year return period discharges under existing conditions (or without the bridge) and incorporating the bridge. In Geometric Data window of HECRAS, all bridge data including deck/roadway and piers are given and the schematic diagram of the bridge are shown in Figure 8.34 to Figure 8.37.

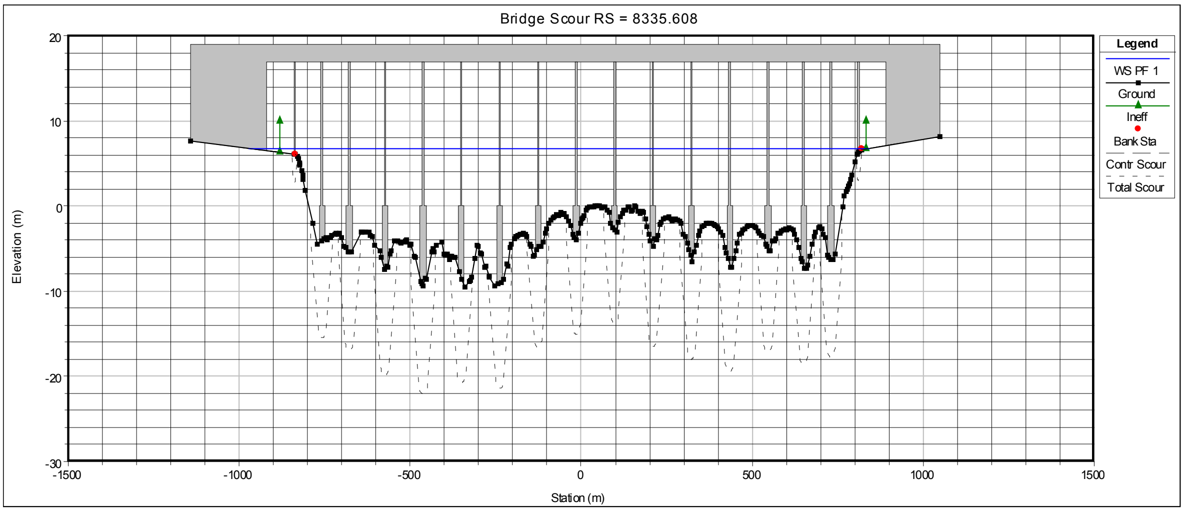
Scour estimation by steady flow analysis of HEC-RAS was conducted based on Hydrologic Engineering Circular No. 18 (HEC 18) of the Federal Highway Administration (FHWA), USA, by using the value of maximum discharge and high water level resulting from unsteady flow analysis.

The results of scour estimation are shown in Table 8.19.



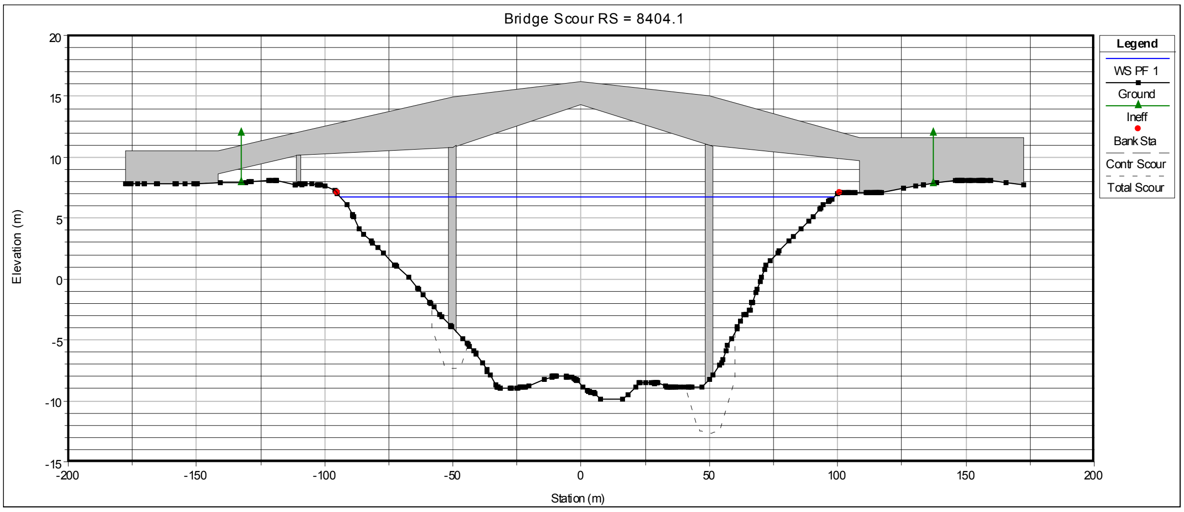
Source: JICA Survey Team

Figure 8.34 Scouring Computation Result at the New Bago Bridge (Option 3)



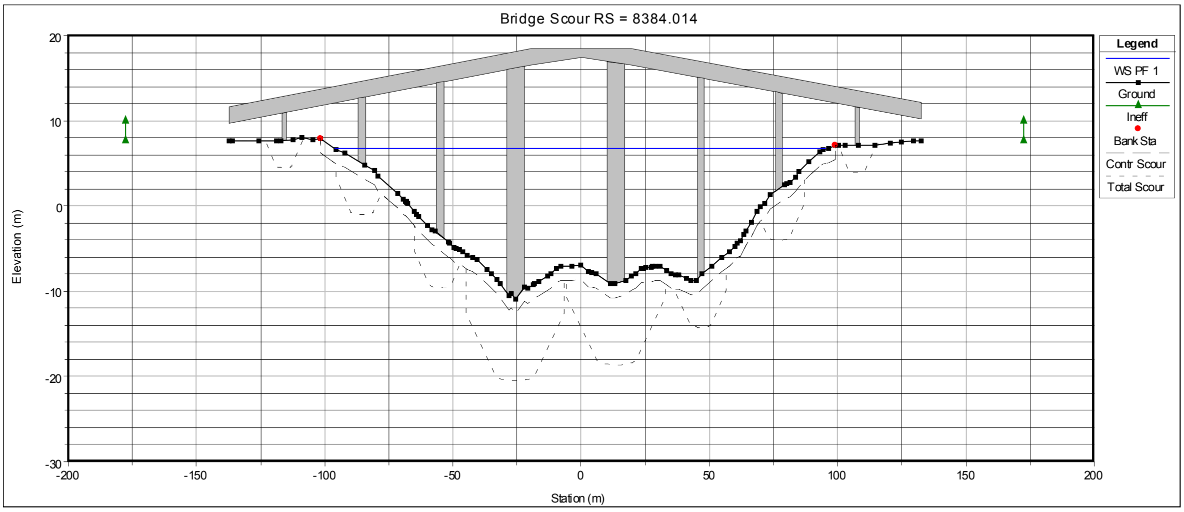
Source: JICA Survey Team

Figure 8.35 Scouring Computation Result at the Existing Thanlyin Bridge



Source: JICA Survey Team

Figure 8.36 Scouring Computation Result at the New Thaketa Bridge



Source: JICA Survey Team

Figure 8.37 Scouring Computation Result at the Existing Thaketa Bridge

Table 8.19 Results of Scouring Computation

Pier No.	New Bago Bridge			Existing Thanlyin Bridge			New Thaketa Bridge			Existing Thaketa Bridge		
	Total Scour (m)	Local Scour (m)	Contraction Scour (m)	Total Scour (m)	Local Scour (m)	Contraction Scour (m)	Total Scour (m)	Local Scour (m)	Contraction Scour (m)	Total Scour (m)	Local Scour (m)	Contraction Scour (m)
P1	2.08	1.88	0.2	3.31	3.31	0	0	0	0	3.25	3.25	0
P2	5.38	5.18	0.2	11.46	11.46	0	3.32	3.32	0	6.08	4.38	1.7
P3	5.81	5.61	0.2	11.64	11.64	0	4.38	4.38	0	6.08	4.38	1.7
P4	2.8	2.61	0.2	12.6	12.6	0	-	-	-	9.62	7.91	1.7
P5	3.08	2.88	0.2	12.81	12.81	0	-	-	-	9.62	7.91	1.7
P6	3.1	2.91	0.2	12.32	12.32	0	-	-	-	6.08	4.38	1.7
P7	3.1	2.9	0.2	12.39	12.39	0	-	-	-	6.08	4.38	1.7
P8	3.98	3.78	0.2	11.61	11.61	0	-	-	-	3.25	3.25	0
P9	6.4	6.2	0.2	11.1	11.1	0	-	-	-	-	-	-
P10	6.27	6.08	0.2	10.93	10.93	0	-	-	-	-	-	-
P11	3.95	3.75	0.2	11.73	11.73	0	-	-	-	-	-	-
P12	3.59	3.4	0.2	11.91	11.91	0	-	-	-	-	-	-
P13	3.74	3.54	0.2	12.51	12.51	0	-	-	-	-	-	-
P14	3.81	3.61	0.2	12.25	12.25	0	-	-	-	-	-	-
P15	3.96	3.76	0.2	11.64	11.64	0	-	-	-	-	-	-
P16	3.95	3.75	0.2	11.55	11.55	0	-	-	-	-	-	-
P17	3.67	3.47	0.2	3.17	3.17	0	-	-	-	-	-	-
P18	3.55	3.36	0.2	-	-	-	-	-	-	-	-	-
P19	2.16	1.97	0.2	-	-	-	-	-	-	-	-	-
P20	0.32	0.32	0	-	-	-	-	-	-	-	-	-
P21	0.28	0.28	0	-	-	-	-	-	-	-	-	-
P22	0.25	0.25	0	-	-	-	-	-	-	-	-	-
P23	0	0	0	-	-	-	-	-	-	-	-	-

Pier No. is indicated as the pier number on calculation.

Source: JICA Survey Team

From the above scouring computations, the scouring depths at each pier were estimated. As for hydraulic issues of the new and existing bridges, the following aspects are left as future challenges:

- ✓ Contraction scour occurs at the existing Thaketa and Thanlyin bridges. Particularly in the existing Thaketa Bridge, contraction scour of 1.7 m will occur due to the decrease of water flow area for the main channel and the pier section. Water flow area at the existing bridge decreases by 18% compared to the upstream cross-section. Regarding the bridge length of the new Bago Bridge, the value of contraction scour is small, and it may not cause any problem.

- ✓ Based on the results of computation, local scouring occurs at all bridges, and is more pronounced at the existing Thanlyin and Thaketa bridges. The riverbed around the piers of both existing bridges is not provided with bed protection works. Therefore, bed protection and refilling works using appropriate materials shall be immediately conducted for the existing piers.

- ✓ Also, for the two new bridges, the study of appropriate bed protection and revetment works shall be conducted during the detailed design stage. In addition, estimation of scouring is necessary to be further studied using other prediction formula including that of HEC during the detailed design stage.

8.4.3 Assessment of the Proposed Bridge

Hydraulic and navigation channel conditions at each proposed bridge site from above study are shown in Table 8.20.

Table 8.20 Assessment of Proposed Bridges

Item		Unit	Bago (Option 1)	Bago (Option 2)	Bago (Option 3)	Thaketa	Remarks
Design Water Level	Highest High Water Level (HHWL)	m	7.70	7.70	7.70	7.70	From probable H.W.L.
	Mean High Water Springs (HWL)	m	5.80	5.80	5.80	5.80	From MPA (observed W.L.)
	Mean Water Level (MWL)	m	3.121	3.121	3.121	3.121	From MPA (observed W.L.)
	Mean Low Water Springs (LWL)	m	0.67	0.67	0.67	0.67	From MPA (observed W.L.)
	Chart Datum Level (CDL)	m	0.00	0.00	0.00	0.00	From MPA (observed W.L.)
Design Discharge	(1)+(2)	m^3/s	18,291	15,502	14,398	2,556	From hydraulic calculation
	Upland Flow (River's Own Flow) (1)	m^3/s	4,328	3,361	3,361	967	Falling tide
	100-Year Flood (2)	m^3/s	13,964	12,141	11,037	1,590	Upland flow
Navigation Channel Limitation (Assuming Future Ships)	Maximum Ship Size	DWT	15,000		Ships crossing the bridges are small and there is no plan to expand. Hence, these conditions are the same as existing bridge condition. (Refer to Table 8.12)		
	Height	m	35[1)]				
	Width	m	288 m(=1.5×LOA[2)]), in case of Both-way)				
Navigation Channel Limitation (Assuming Current Ships)	Maximum Ship Size	DWT	3,309				
	Height	m	28[3)]				
	Width	m	139 m(=1.5×LOA[4)]), in case of Both-way)				

Source: JICA Survey Team

Note. 1) Determine the height with reference to "Study on Ship Height by Statistical Analysis - Standard of Ship Height of Design Ship (Draft) (National Institute for Land Infrastructure Management, Japan, 2006)".

2) Assumed as "Length overall (of a ro-ro ship) = 192.0 m ". Determine the height with reference to "Technical Standards for Port (Ports & Harbours Association of Japan, 1999)".

3) Height above water level (of a current ship) = 28 m. From an interview with MFSL.

4) Length overall (of a current ship) = 92.45 m. From an interview with MFSL.

Chapter 9

Design for Feasibility Study

9. Design for Feasibility Study

9.1 Study of Bridge Location and its Proximity to the existing Thanlyin Bridge

The proposed bridge location was selected downstream of the existing Thanlyin Bridge. The alignment of the bridge section is parallel to the existing bridge with a center to center offset of 140 m. This location was selected from three possible locations as illustrated in Figure 9.1.

These three locations were proposed under the following conditions:

- Approach roads of Bago River Bridge shall be connected with existing roads by the shortest length.
- No involuntary resettlement or minimum involuntary resettlement due to project implementation.
- No land acquisition or minimal acquisition of private lands.

It is noted that there are limited road networks in this area. The major roads are Shukhinthar-Mayopat Road and Thanlyin Chin Kat Road on the right bank of the Bago River, and Kyaik Khauk Pagoda Road on the left bank. Furthermore, National Races Village is located upstream of the existing bridge on the right bank of the Bago River, while two private development areas, including Star City, are located downstream of the existing bridge on the left bank side. Having these situations, three routes, namely Route A and Route B in the upstream and Route C in the downstream of the existing bridge, were studied. The horizontal alignment outlines of these routes are given in Table 9.1.

Source: JICA Survey Team

Figure 9.1 Three Possible Bridge Locations

Table 9.1 Brief Aspects of the Three Studied Routes

	Route A	Route B	Route C
Location	950 m upstream	140 m upstream	140 m downstream
Length	3,440 m	2,730 m	2,830 m
Exiting road to be connected			
Right bank	Local road traversing the north of National Races Village	Approach road of the existing Thanlyin Bridge	Intersection of Shukhinthar-Mayopat Road and Thanlyin Chin Kat Road
Left bank	Kyaik Khauk Pagoda Road	Kyaik Khauk Pagoda Road	Kyaik Khauk Pagoda Road
Outline of Alignment			
Right bank	Running the east fringe of National Races Village.	Starts from the approach road of the existing Thanlyin Bridge and traverses the west fringe of National Races Village.	Starts from the intersection, and traverses the Myanmar Railways-owned land.
Left bank	Approach road uses the existing Bogyoke Road alignment.	Traverses the west fringe of a private land and connects with the existing road.	Traverses a land owned by Myanmar Railways and connects with the existing road.

Source: JICA Survey Team

Features of these three routes are described as follows:

Route A

- On the right bank, the route connects to a local road at a T-shaped intersection. This is not appropriate for the Bago River Bridge Project which is expected to form a major road network.
- On the right bank, the route traverses a small dock area. In case Route A is selected, the operation of this small dock shall be abandoned.
- On the left bank, the route will utilize the existing Bogyoke Road alignment up to the link point with Kyaik Khauk Pagoda Road in a T-shaped intersection. This existing road is around 10 m wide, and runs through the center of the township area. In order to accommodate the dual two-lane approach road for Bago River Bridge, the widening of existing road is inevitable. Consequently, land acquisitions and involuntary resettlement would be generated.

Route B

- On the right bank, the route crosses under the existing railway and traverses the green space at the fringe of National Races Village. In case Route B is selected, it will be necessary to cut down many trees.
- On the left bank, the route passes through the western fringe of a private land, and connects to Kyaik Khauk Pagoda Road after it crosses under the existing railway.
- Thus, the route will cross under the existing railway twice. Although the railway crossing points are in the approach road section and the actual running speed at these points will not be fast, it is considered inappropriate to have two rather sharp bending portions when the design speed of the Project is 80 km/h.

Route C

- On the right bank, the route starts from the intersection between Shukhinthar-Mayopat Road and Thanlyin Chin Kat Road, and traverses a land owned by Myanmar Railways, which has no permanent houses or assets at the moment.
- On the left bank, the route also passes through a land owned by Myanmar Railways, which is empty at the moment, and connects to Kyaik Khauk Pagoda Road smoothly.
- Among the three routes, it was judged that Route C has smoothest horizontal alignment and is appropriate for the project design speed of 80 km/h.

Based on the above considerations, Route C was adopted as the bridge location adjacent to the existing Thanlyin Bridge.

9.2 Continuity with Thilawa SEZ Access Road

The existing Kyaik Khauk Pagoda Road will be upgraded to a dual two-lane road similar to Thilawa SEZ Access Road that starts from a point near the existing Thanlyin Bridge to the proposed Thilawa SEZ Area. Figure 9.2 shows the proposed horizontal alignment for Thilawa SEZ Access Road. It is believed that the new Bago River Bridge along with its approach roads shall be connected to Thilawa SEZ Access Road and form one continuous trunk road.

Figure 9.3 shows the horizontal alignment elements and coordinates of SEZ Access Road end section. Figure 9.4 shows the vertical alignment and proposed height of the same section.

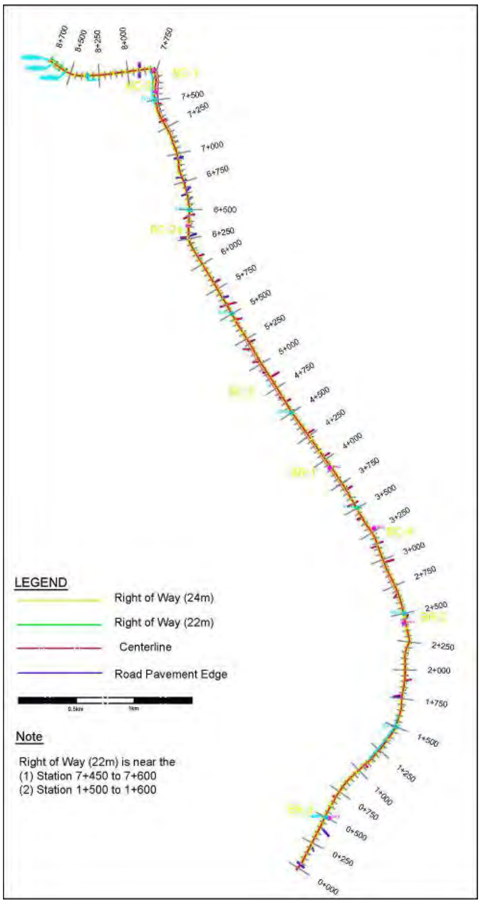
Based on these data, the data summary of the point to which the approach road for Bago Bridge connects is as follows:

- ✓ Station on SEZ Access Road: 8+700.000
- ✓ End Point Coordinates: (205789.549518, 1857219.291051)
- ✓ Horizontal Alignment Element: Straight Line
- ✓ Proposed Height: 5.380 m
- ✓ Vertical grade: -0.04%

Source: JICA Survey Team

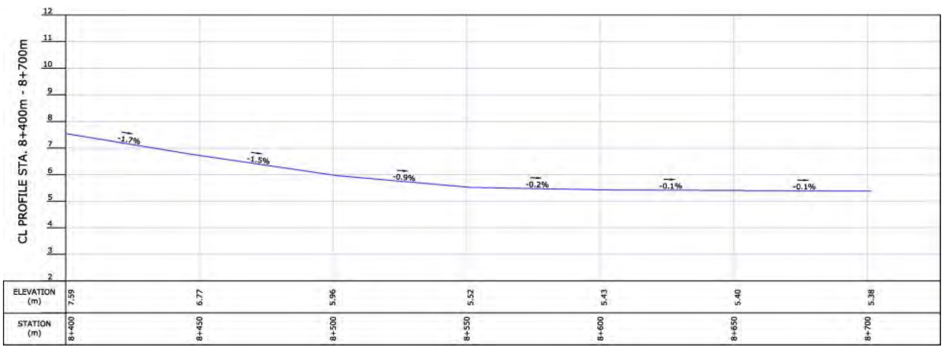
Figure 9.3 SEZ Access Road Horizontal Alignment

As shown in Figure 9.5, SEZ Access Road was proposed to have two typical cross sections for two different ROW width sections. It is noted that the outer shoulder and median widths are different from the proposed cross-sectional arrangement of the Project. It is required to provide a transition section in order to adjust these width differences.



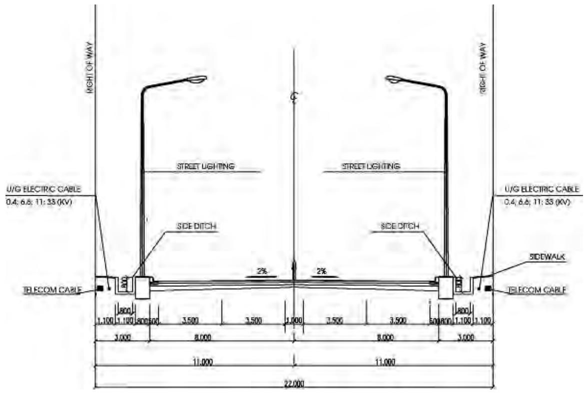
Source: JICA Survey Team

Figure 9.2 Horizontal Alignment of Thilawa SEZ Access Road

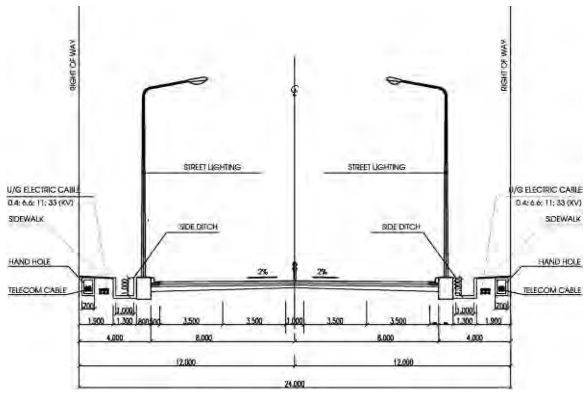


Source: JICA Survey Team

Figure 9.4 SEZ Access Road Profile



Typical Cross Section for 22 m ROW Section



Typical Cross Section for 24 m ROW Section

Source: JICA Survey Team

Figure 9.5 Typical Cross Section of SEZ Access Road

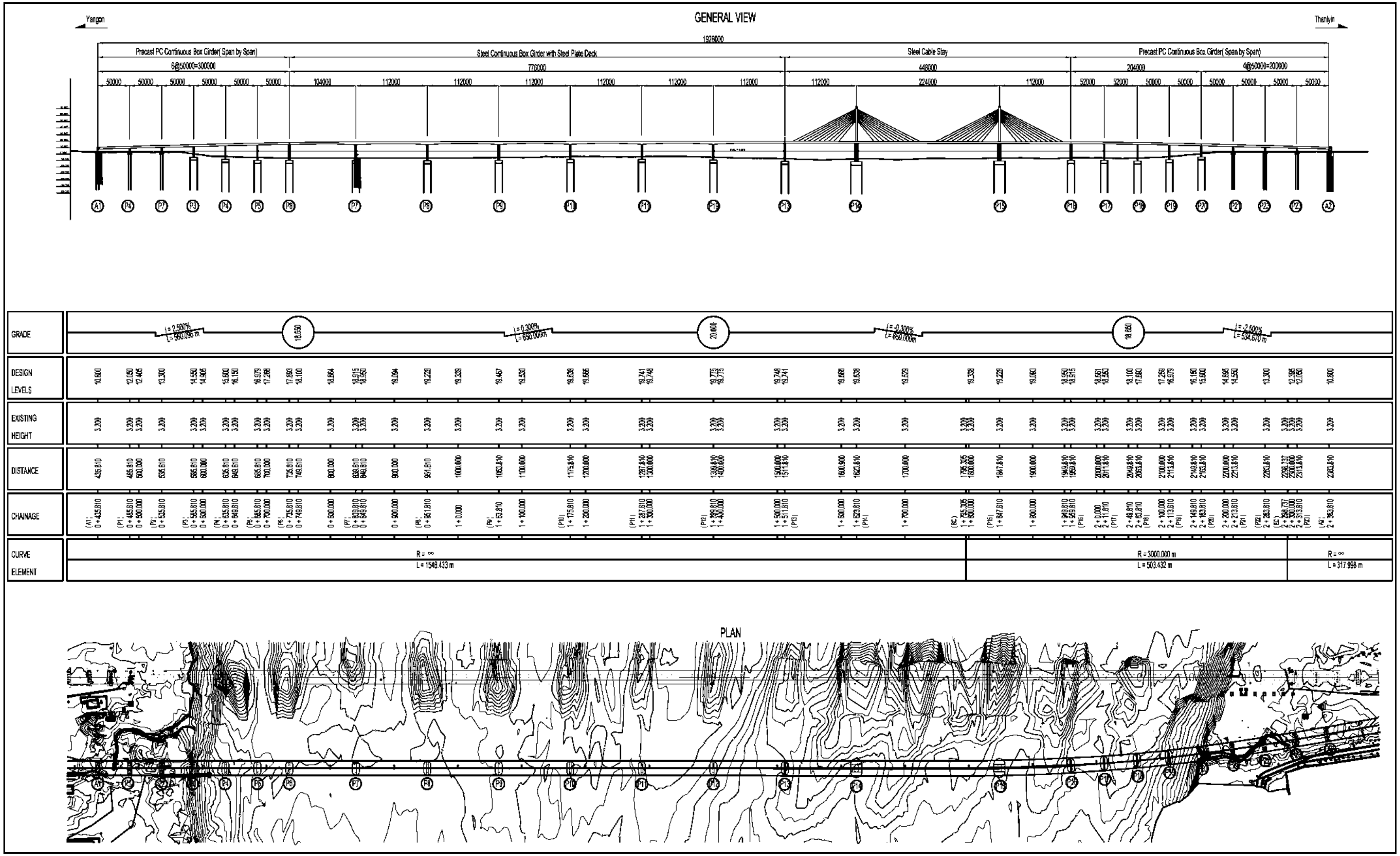
9.3 Structural Design

9.3.1 Design of Superstructures

The design of the superstructure is preliminarily performed for the recommended bridge from among the alternatives. The purpose of the preliminary design is to define the structural element sizes so that better estimates of cost and constructability could be obtained. The refinement of alternative study also allows the preliminary design to have a more efficient structure and to more accurately show those member sizes which are reflected in the drawing. Structural analysis are initially carried out for each of the recommended types of superstructure in order to assess the vertical reaction loads from the superstructure for the design of substructure and foundation and structural stability considering site specific loadings such as temperature, stream flow, wind and seismic loads. Types of superstructure applied for Bago River Bridge are a cable-stayed bridge and a continuous steel box girder with steel plate deck for the main bridge, and continuous PC box girder for the approach bridge as shown in Figure 9.6.

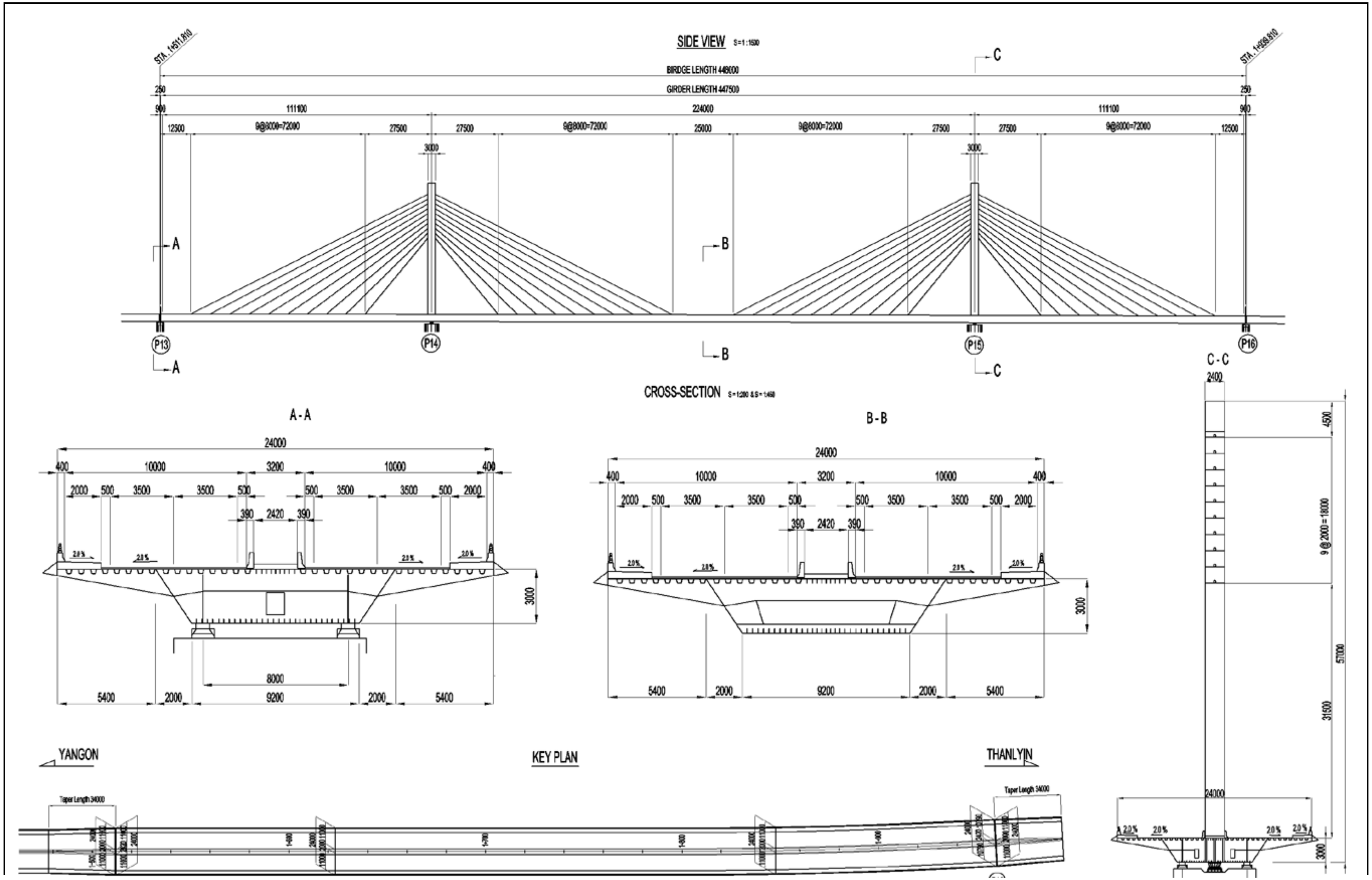
Steel Cable-stayed Bridge

Steel cable-stayed bridge having a total length of 448 m consists of the main channel bridge with a center span of 224 m and side span of 112 m on both sides of the main bridge as shown in Figure 9.6 and Figure 9.7. Configurations of the cable-stayed bridge are determined in the following studies:



Source: JICA Survey Team

Figure 9.6 General Plan of Bago River Bridge

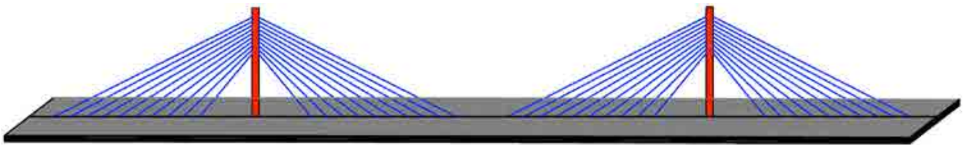


Source: JICA Survey Team

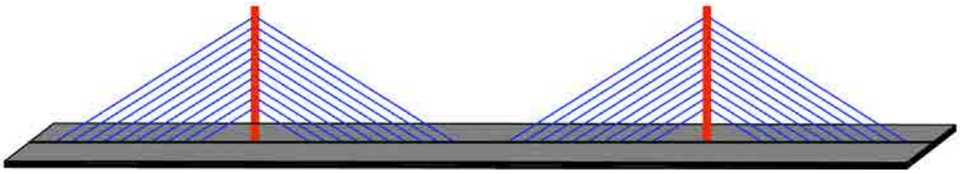
Figure 9.7 Configurations of Steel Cable Stayed

(1) Arrangement of Stay Cables

From the various longitudinal cable arrangements of steel cable-stayed bridges, two basic systems, namely parallel and fan-shaped systems as shown in Figure 9.8, are recommended. The parallel-shaped system may be preferred from an aesthetic point of view. However, it has a tendency to cause bending moment in the tower as it requires a higher tower than for a fan-shaped system. In addition, the lower cables are fixed at the lower part of the tower leg that do not function properly as stay cables. The quantity of steel and cable required for a parallel-shaped cable arrangement is slightly higher than for a fan-shaped arrangement. Therefore, the fan-shaped system is applied for Bago River Bridge in consideration of technical and economical points.



Fan-shaped System



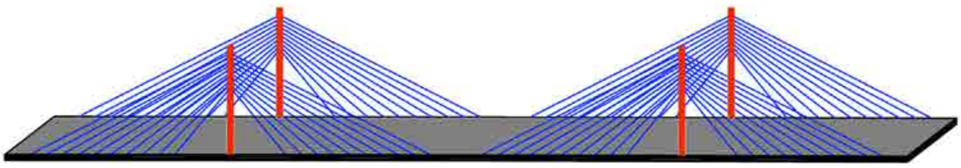
Parallel System

Source: JICA Survey Team

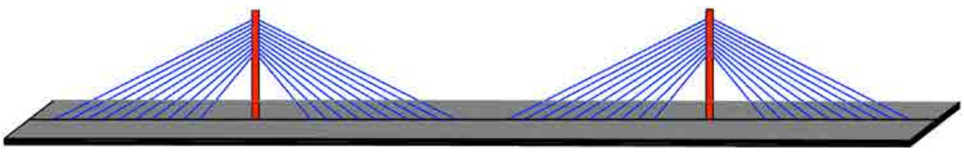
Figure 9.8 Stay Cable Arrangements

(2) Position of Stay Cables

There are two alternative layouts that may be adopted when using the fan-shaped system: the cable anchorages may be situated outside the deck structure (double plane system), or they may be built inside the main girder (single plane system) as shown in Figure 9.9. The single plain system is better than the double plain system for small cable-stayed bridges and will be applied for Bago River Bridge due to the following reasons:



Two Vertical Plane System



Single Plane System

Source: JICA Survey Team

Figure 9.9 patial Positions of Stay Cables

1) Single plane of stay cables along the longitudinal axis located in the wide central median of superstructure will not be affected by any traffic limit even in a curve alignment.

2) Single plane system creates a lane separation so that there can be a smooth natural continuation of the approach bridge to the cable-stayed bridge.

3) It is an economical and aesthetically acceptable solution, providing an unobstructed view from the bridge.

4) In addition, this system also offers the advantage of requiring relatively small piers, because pier size is determined by the width of the main girder.

In the case of a single plane system, the towers are generally fixed to one main box girder. With this arrangement, it is necessary not only to reinforce the box girder but also to provide strong bearings for the towers. The supports should also resist the horizontal forces caused by the increased friction forces in the bearings due to temperature.

(3) Taper Length

For the bridge is adopted the single plane system, the center strip shall be wider than the standard cross section and the taper shall be introduced to the carriageways. The shift length to lateral direction is 0.85m to each side. Application of the Japanese Road Specifications, the taper length is calculated as 34.0m.

L=VxdW/2=80x0.85/2=34.0

Here, L: taper length (m)

V: design speed (km/h)

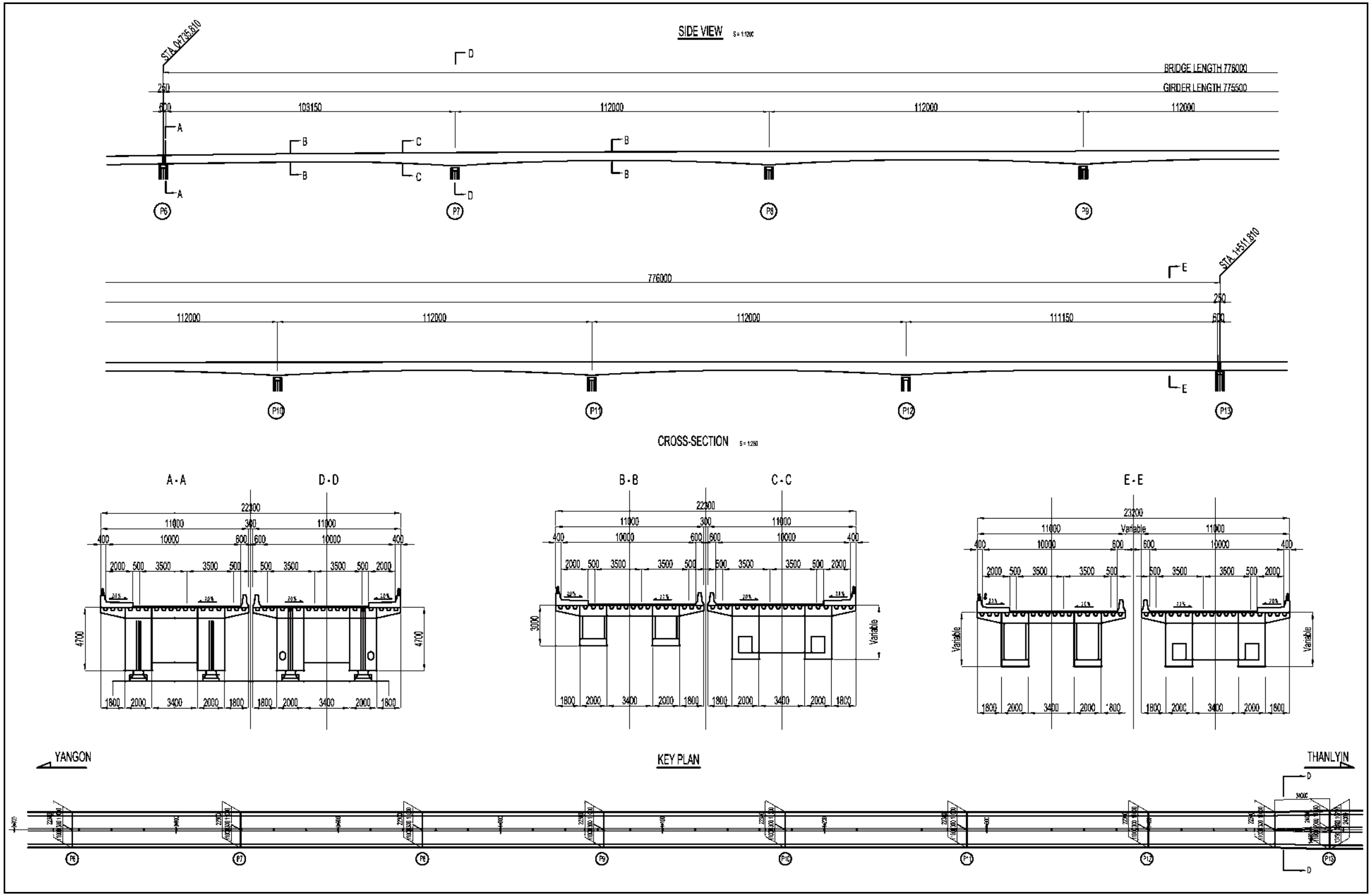
dW: shift length to lateral direction

<u>Continuous Steel Box Girder with Steel Plate Deck</u>

Continuous steel box girder bridge, having a total length of 776 m, consists of five main spans of 112 m each, a side span of 112 m in the Thanlyin side, and a side span of 104 m in the Yangon side as shown in Figure 9.6 and Figure 9.10. Configuration of the steel box girder with steel plate deck reinforced by ribs and its wearing surface are determined in the following studies:

(1) Continuous Steel Box Girder with Steel Plate Deck

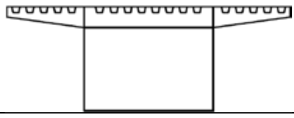
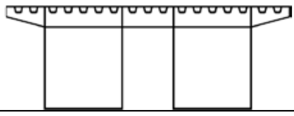
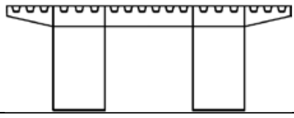
For relatively small spans in the 60-90 m range, it is convenient to use a reinforced concrete deck with steel box girder acting as a composite section as the main girder. On the other hand, for spans over 100 m, steel plate deck systems with crossbeams and longitudinal ribs have been widely used to reduce the weight and depth of girders. In the design of long-span bridges, dead load of steel plate deck is 30-40% lower than concrete deck slab. For the main spans of Bago River Bridge, three types of steel box girders with steel plate deck are considered as shown in Table 9.2. Twin narrow width rectangular box girder is applied for this type of main bridge in consideration of the fabrication capacity and welding techniques of Myanmar companies and transportation route to the site. In addition, small box girders will require smaller erection equipment and simplified fabrication steps.



Source: JICA Survey Team

Figure Figure 9.10 Configuration of Continuous Steel Box Girder with Steel Plate

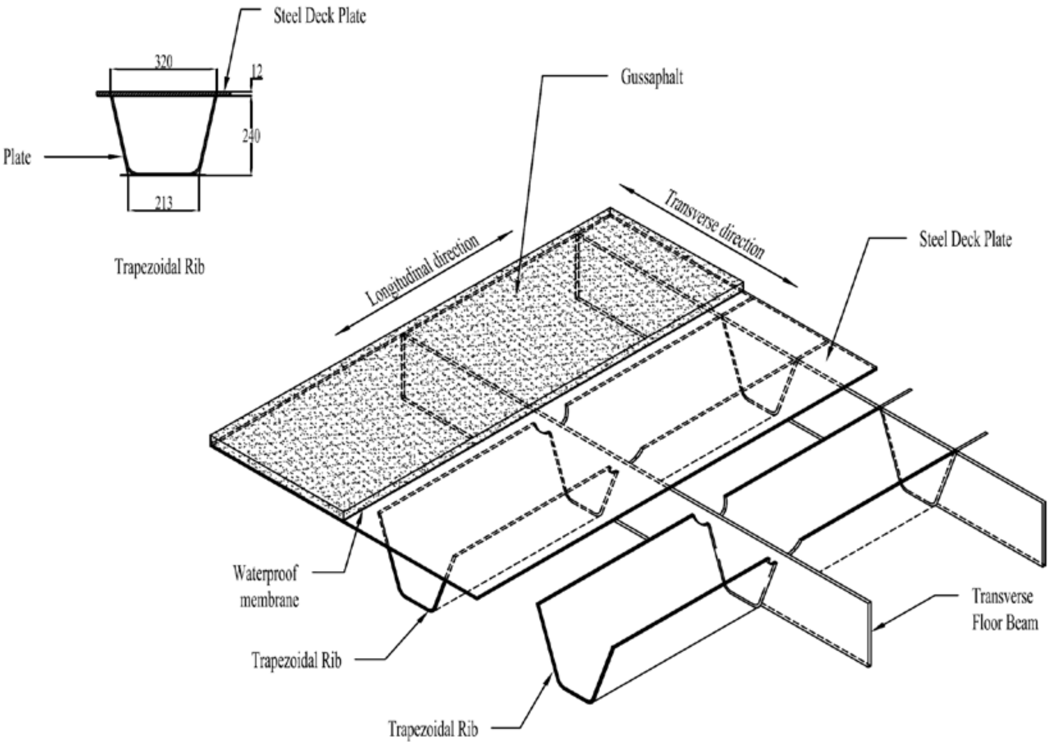
Table 9.2 Type of Main Girder of Steel Box Girder

Arrangement	Deck Cross Section	Comments
1. Single Rectangular Box Girder		Fabrication and transportation of box girders are difficult and erection will require larger equipment.
2. Twin Rectangular Box Girder		Since interval of box girder is narrow, it is reasonable for reinforced concrete slab but not economical for steel plate deck.
3. Twin Narrow Width Rectangular Box Girder		Fabrication and transportation of box girder are relatively easy and erection will requiresmaller equipment.

Source: JICA Survey Team

(2) Rib

The open- and closed-rib systems are the basic types of ribs. Ribs are normally welded to the transverse floor beams and steel deck plate as shown in Figure 9.11. The trapezoidal rib (called U-Rib in Japan) has been widely used and is the most practical for steel plate deck of long span steel box girders and cable-stayed bridges in Japan.

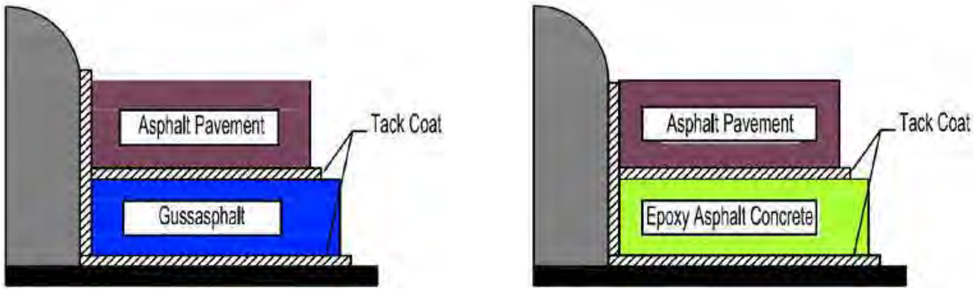


Source: JICA Survey Team

Figure 9.11 Details of Trapezoidal Rib connected to Steel Plate Deck and Floor Beam

(3) Wearing Surface on Steel Plate Deck

Typical structures of wearing surface on steel plate deck are: 1) guss asphalt and 2) epoxy asphalt concrete, which are commonly applied on base course to function as waterproofing layer, as shown in Figure 9.12. The structure of wearing surface used in Japan is 35 mm for guss asphalt and 25 mm for densely graded asphalt concrete.



1) Guss Asphalt 2) Epoxy Asphalt Concrete

Source: JICA Survey Team

Figure 9.12 Typical Structures of Wearing Surface on Steel Deck

The performances of both wearing surfaces on steel plate decks vary from poor to excellent depending largely on local climate, deck plate flexibility, and volume of heavy truck traffic. In general, comparing between guss asphalt and epoxy asphalt concrete, the performance and condition of the latter is better but the cost is higher. On the other hand, the application of guss asphalt is economical and simple using penetration asphalt as a binder heated to a high temperature of over 200°C and applied, usually by pouring and leveling by guss asphalt finisher or by hand. Moreover, it has been used widely and successfully for steel plate deck of long span bridges in Japan.

In this feasibility study, it is recommended that guss asphalt be applied over the base course of wearing surface on continuous steel box girder and steel cable-stayed bridge. However, further laboratory studies and field tests are necessary in order to determine the most appropriate wearing surface on steel deck bridge considering local climate and its cost.

Continuous PC Box Girder with Precast Segmental and Span by Span Method

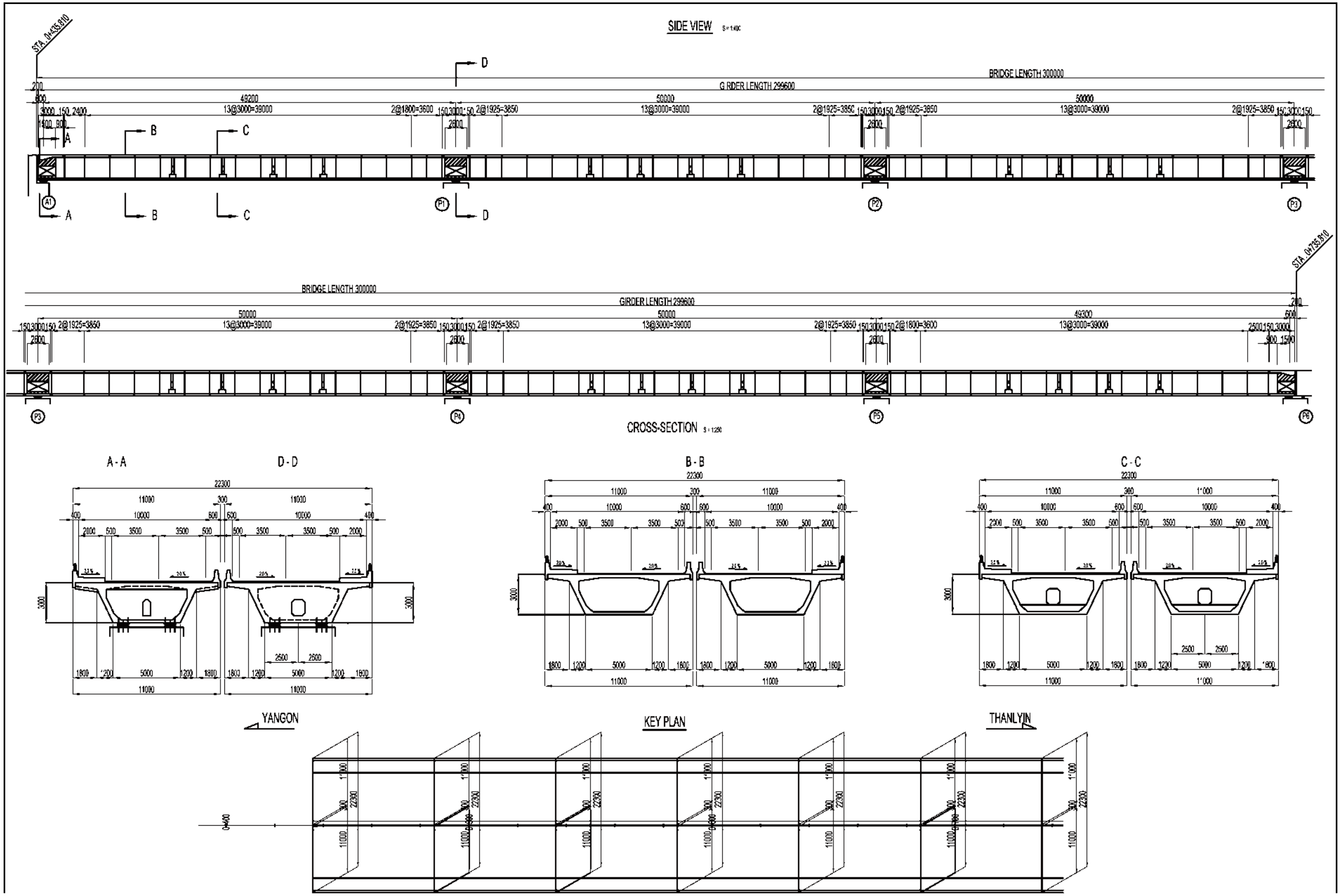
Continuous PC box girder bridge, having a total length of 704 m,consists of the approach bridge, six spans of 50 m each in the Yangon side and two spans of 52 m and six spans of 50 m each in the Thanlyin side, as shown in Figures 9.6, 9.13, and 9.14.

Continuous PC box girder for the approach bridge uses precast segmental construction, which is widely used in the world. The segmental method has the following advantages:

1) Concrete segments are produced under high quality control standards using a casting machine.

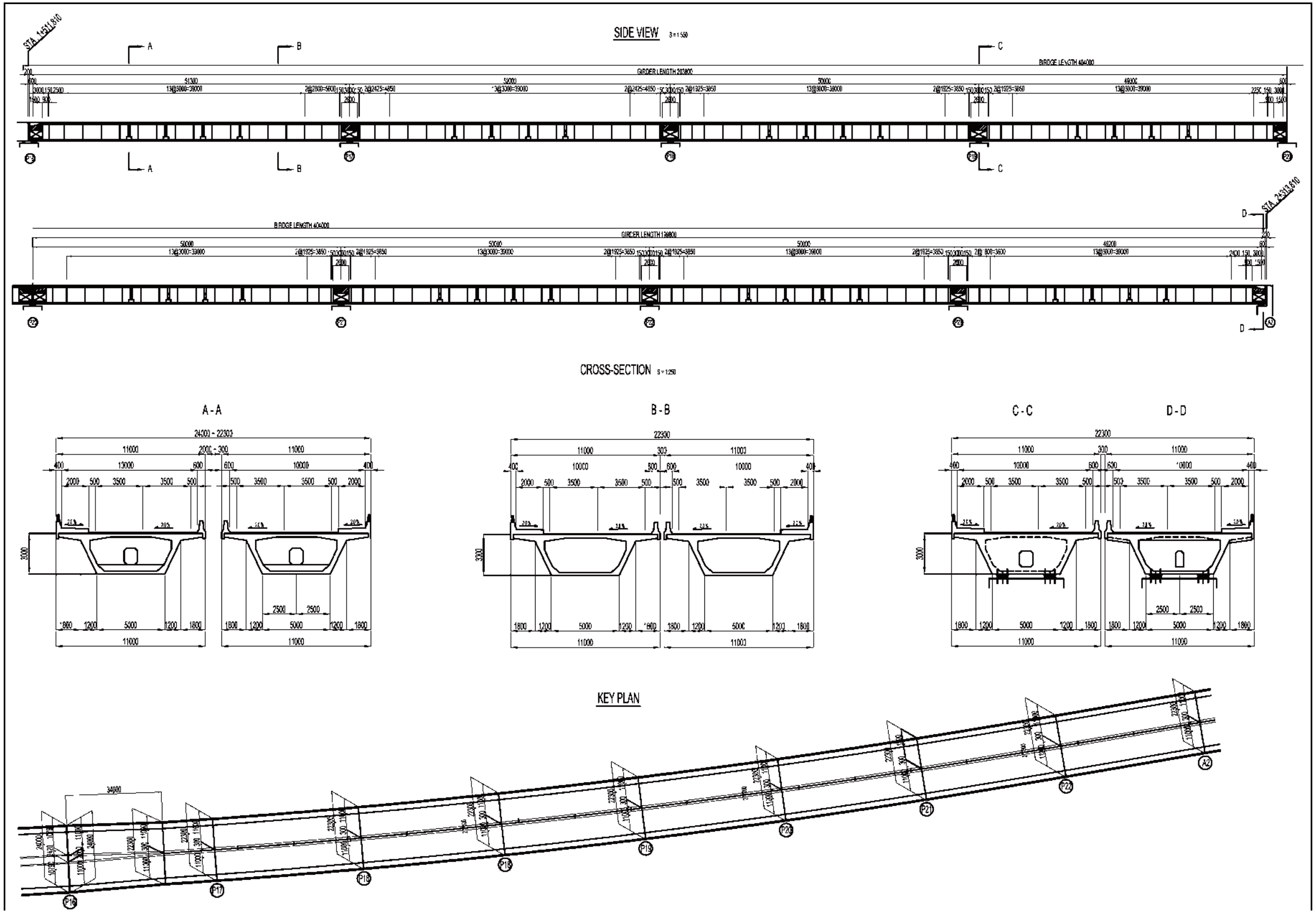
2) Site works can be minimized and construction period can be greatly shortened in comparison with cast in situ construction method.

3) This precast segment method is still new in Myanmar but possible to be applied widely not only for river bridges but also for viaducts in urban areas.



Source: JICA Survey Team

Figure 9.13 Configuration of Continuous PC Box Girder (1/2)



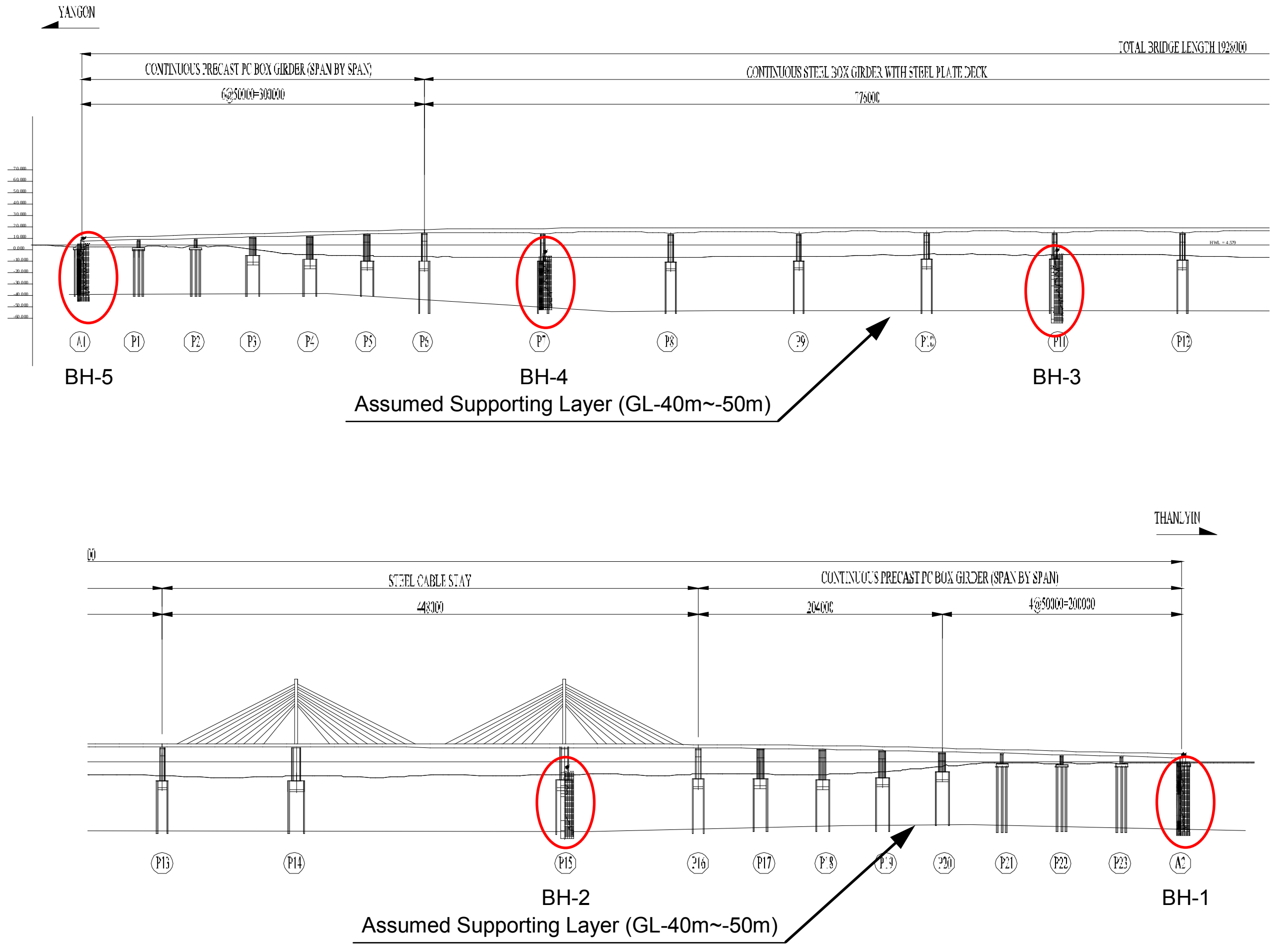
Source: JICA Survey Team

Figure 9.14 Configuration of Continuous PC Box Girder (2/2)

Single-cell box girder, which is used for the approach bridge in this design, provides the most efficient section for precast segment construction and its inclined webs improve aesthetics. Span-to-depth ratio for constant-depth PC box girders is between 16 and 20. However, box girders shallower than 2 m in depth has practical difficulties for stressing operations inside the box. As girder depth at the connection between cable-stayed bridge and continuous steel box girder is 3.0 m, girders of with a constant depth of 3.0 m is used for continuous PC box girder in order to maintain a constant horizontal line through the whole bridge length, and its span length of 50 m is in the economical range in this feasibility study. Span-by-span erection is selected for the segmental PC box girders because the erection equipment is widely used for spans shorter than 50 m and easily procured in neighbouring countries.

9.3.2 Design of Substructure and Foundations

As described above, geological investigation was carried out at five locations. The layer supporting the foundation is assumed as shown in Figure 9.15 based on the geological investigation results.



Source: JICA Survey Team

Figure 9.15 Assumed Supporting Layer

The outline design of foundation is carried out for the following four types in consideration of location (in and out the river) and type of superstructure:

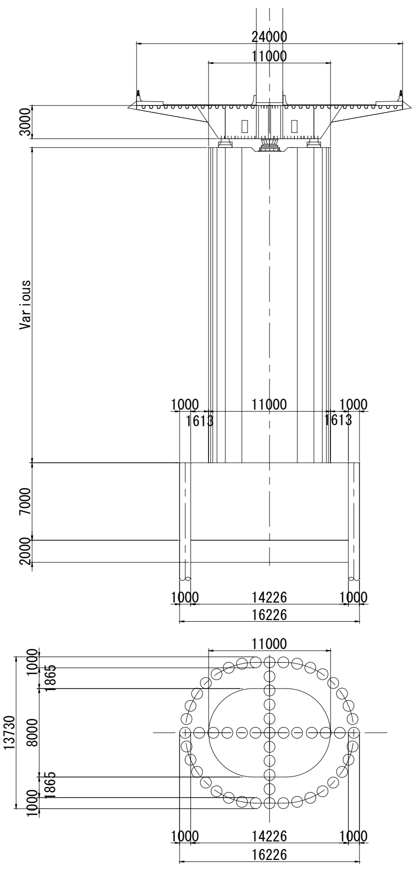
- Type 1: In the River (Section of Steel Stay Cable)
- Type 2: In the River (Section of Steel Box Girder with Steel Plate Deck)
- Type 3: In the River (Section of PC Box Girder)
- Type 4: On the Land (Section of PC Box Girder)

As described in Section 6.3.1, Study on Foundation Type, steel pipe sheet pile foundation is used for foundations in the rivers in consideration of deep-water construction, scouring, and technical transfer from Japan. Cast-in-place concrete pile is used for foundations on land.

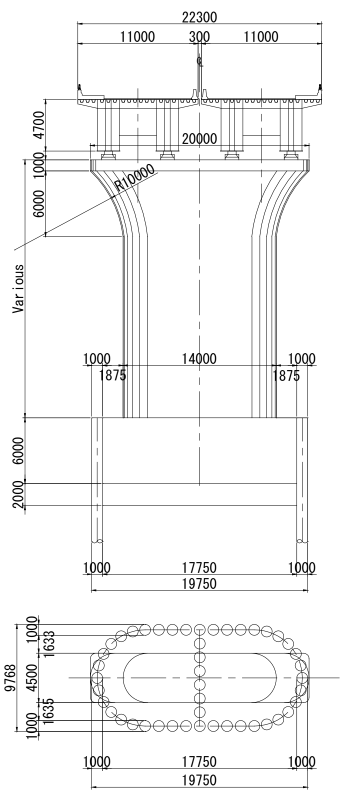
9.3.3 Design of Substructures

An oval or round shape for the substructure can be applied as described in Section 6.3.3, Study on Substructure Type. This bridge has a relatively wide width with four lanes; and in consideration of smooth river flow, oval-shaped piers shall be used.

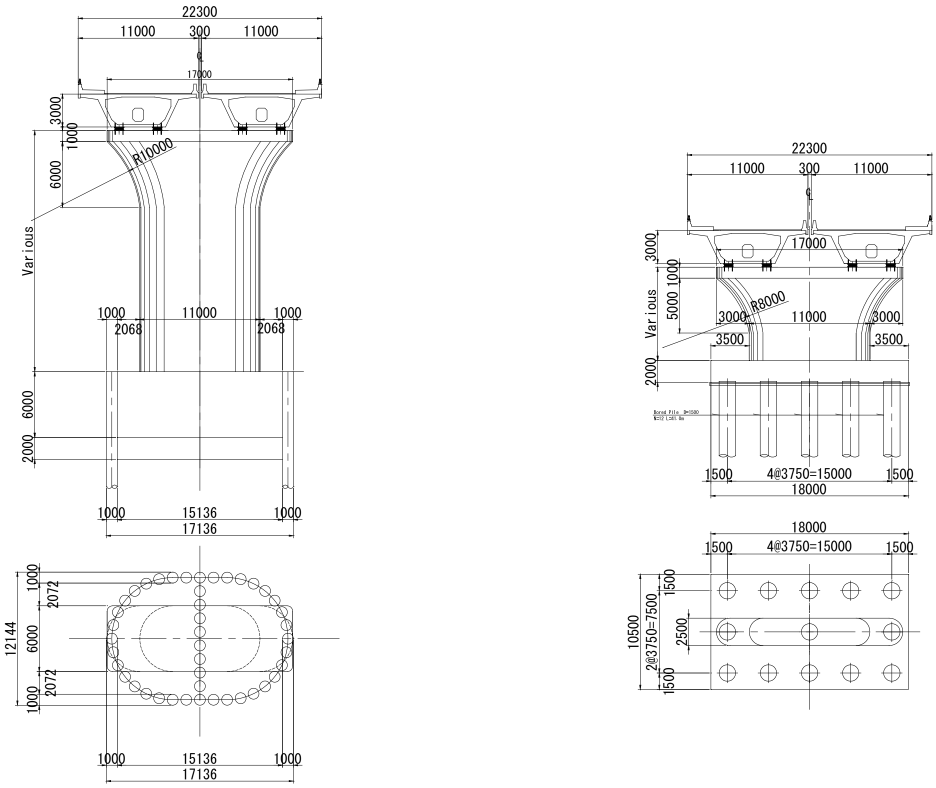
The shapes of substructure and foundation based on the outline design are shown in Figure 9.16.



Steel Cable-stayed Bridge Section
In the River



Steel Box Girder with Steel Plate Deck Section In
the River



PC Box Girder Section In the River PC Box Girder Section on the Land

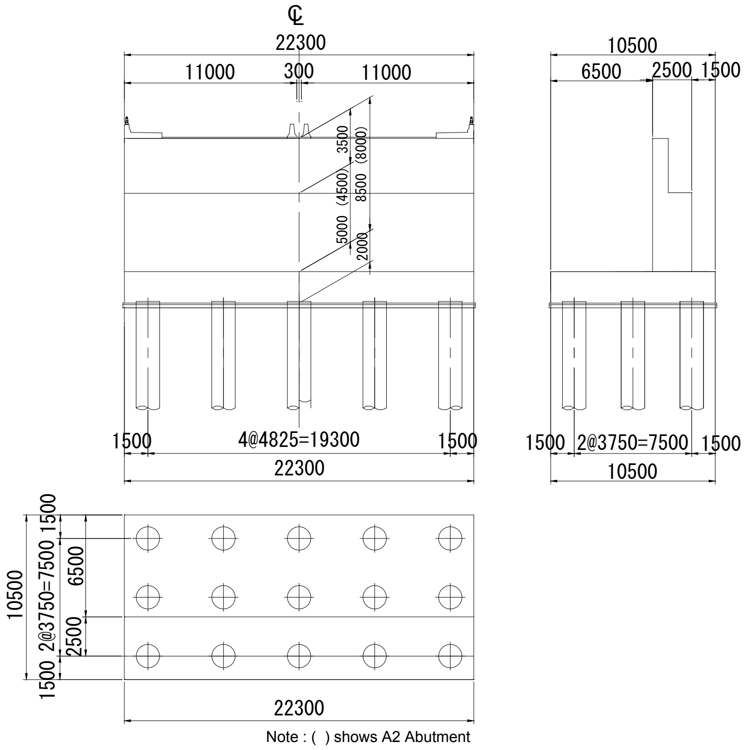
Source: JICA Survey Team

Figure 9.16 Substructure and Foundation Shapes

9.3.4 Design of Abutments

Inverted T shape is applied to the abutments in consideration of cost and constructability as described in Section, 6.3.4 Study on Abutment Type.

The shapes of abutment based on the outline design are shown in Figure 9.17.



Source: JICA Survey Team

Figure 9.17 Abutment Shapes

9.4 Highway Design

9.4.1 Alignment Design

The horizontal and vertical alignments were reviewed, adjusted, and finalized based on the draft output of the topographic survey. On the right bank, the route starts from the intersection between Shukhinthar-Mayopat Road and Thanlyin Chin Kat Road and traverses a land owned by Myanmar Railways. The horizontal alignment was adjusted so as not to affect the local road running along the western side of the Myanmar Railways-owned land. On the left bank, the route also traverses the Myanmar Railways-owned land and connects smoothly to Kyaik Khauk Pagoda Road. The end point of the alignment is the starting point of Thilawa SEZ Access Road.

Taking into consideration the drainage efficiency, the main bridge section has 0.30% vertical grade with a crest at the centre of the main bridge section. Vertical grades at both sides of this 0.30% section, approach bridges, and approach roads, were proposed at 2.50%.

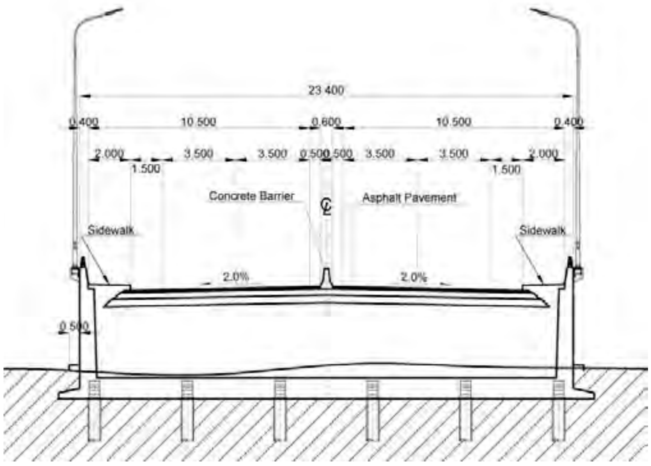
The plan and profile of Bago River Bridge are given in Appendix 9.

9.4.2 Cross Sectional Arrangement

The cross sectional elements are as follows:

Sectional Element	Width
Carriageway	2@3.50 m = 7.00 m
Inner shoulder	0.50 m
Outer shoulder	1.50 m
Median	0.60 m
Sidewalk	2.00 m

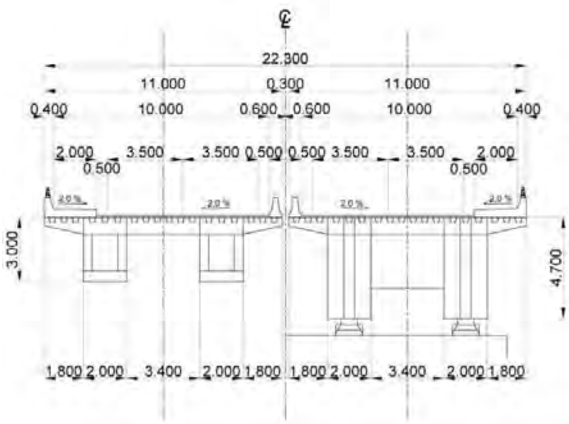
According to the information from the geological investigation, the existence of soft ground layer was confirmed at the riverbank area. Therefore, it is required to implement soft ground treatment works. As it is difficult to know the extent of the soft ground area in this Preparatory Survey stage, a concrete structure with concrete pile was proposed as shown in Figure 9.18.



Source: JICA Survey Team

Figure 9.18 Typical Earthwork Cross Section

In the bridge section, the width of outer shoulder was reduced to 0.50 m as shown in Figure 9.19.



Source: JICA Survey Team

Figure 9.19 Typical Bridge Cross Section (Steel Box Girder)

9.4.3 Necessity of Soft Ground Treatment

The geological investigations found the soft soils, with N-Value ranging from 0 to 5, exist at both the right and left banks of the Bago River. Therefore, it is needed to provide soft ground treatment for the construction of the approach road. Figure 9.20 shows the data extracted from the boring logs of BH-01 and BH-05, which were conducted on the land side. According to the geological investigation, the left bank of the Bago River has thicker soft soil layers of around 10-20 m.

For soft ground treatment, the following methods are usually applied:

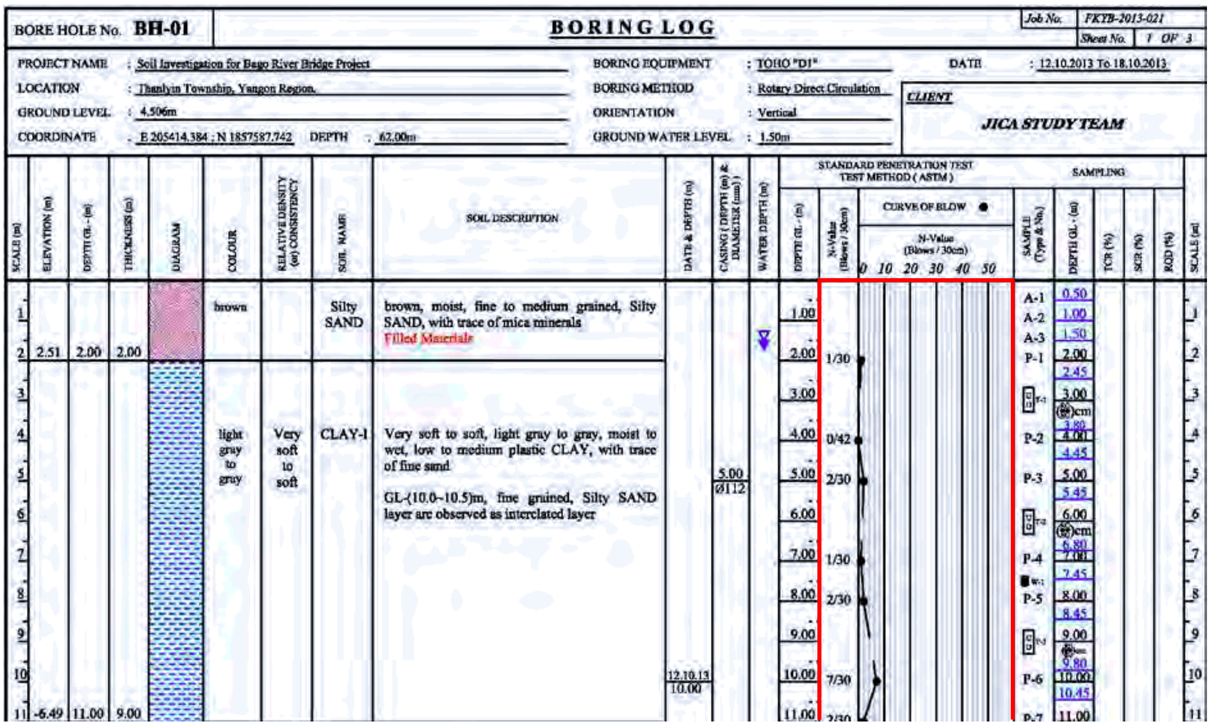
- ✓ Soil Replacement with Preloading
- ✓ Vertical Drain with Preloading

  The vertical drain system would be sand drain or prefabricated vertical drain (PVD).

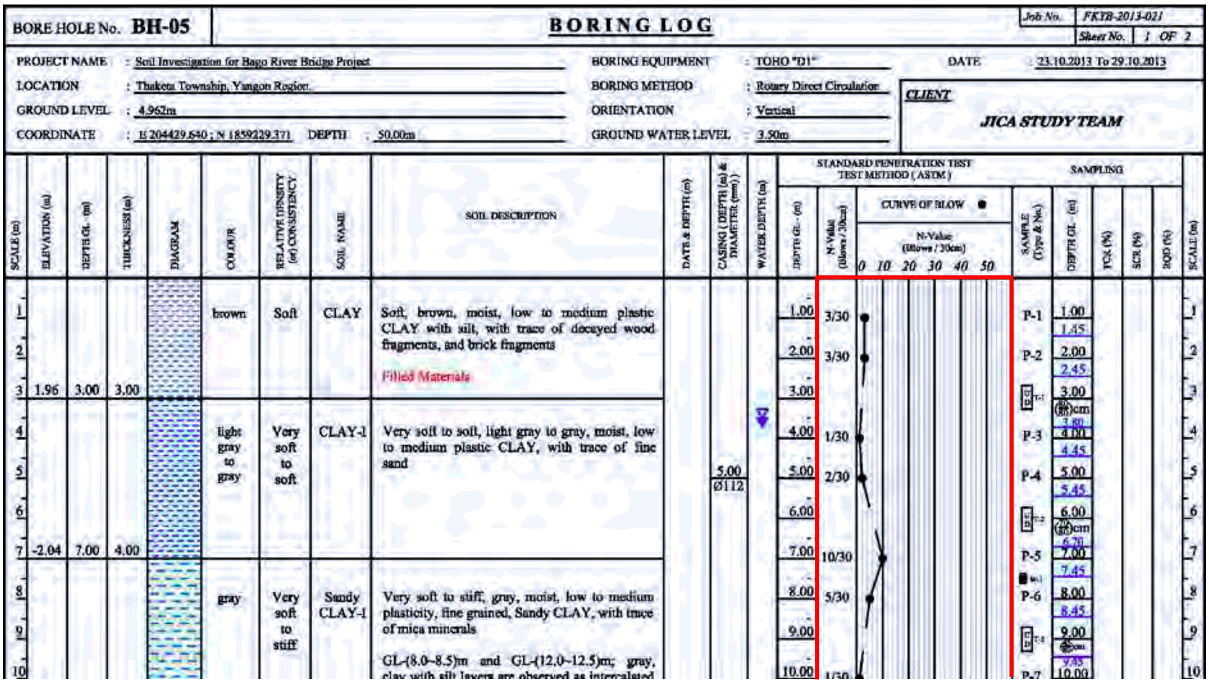
- ✓ Vacuum Consolidation with Preloading
- ✓ Soil Cement Columns
- ✓ Piled Foundation System (piles and a concrete slab)

The method shall be selected based upon the characteristics of soil, soft soil depth, soft soil areal extent, and others such as constraints of construction period and available budget. In this Preparatory Survey, it is not possible to select the improvement method as the details of spreading situation of soft soil layers are not available.

As shown in Figure 9.18, an inverted T-shaped retaining wall with continuous footing with piles was used for the design of the approach road section, which will require minimal land area for construction in the urban area and give safer stability against soft ground behaviour.



BH-01 Boring Log: Left Bank



BH-05 Boring Log: Right Bank

Source: JICA Survey Team

Figure 9.20 Extraction of Boring Log at Land Side

9.4.4 Study on Pavement Structure

The pavement structure of approach road section was studied using the AASHTO Guide for Design of Pavement Structures, 1993. In this guide, the pavement structure is designed by taking the vehicle's cumulative axle load in terms of equivalent single axle load (ESAL) during the design period. In this study, a design period of 20 years was used Table 9.3 shows the forecasted traffic volumes in 2018, 2025, and 2035 at Bago River Bridge conducted by YUTRA. The traffic volume given in the said table is the total sectional traffic volume on Bago River Bridge in passenger car unit (pcu) per day.

Table 9.3 Traffic Demand Forecast at Bago River Bridge Section

Unit: pcu/day

Year	Crossing Section	Motorcycle	Car	Taxi	Bus	Truck	Total
2018	Existing Thanlyin Bridge	841	12,446	9,195	534	4,583	27,600
	Bago River Bridge	Not constructed yet					
2025	Existing Thanlyin Bridge	Occupied by BRT					
	Bago River Bridge	1,089	19,103	9,319	2,530	4,610	36,651
2035	Existing Thanlyin Bridge	Occupied by BRT					
	Bago River Bridge	1,352	27,593	12,874	1,106	6,578	49,503

Source: JICA Survey Team

If the bridge construction is assumed to commence in late 2017, Bago River Bridge will be opened to the public in late 2019. Therefore, ESAL shall be estimated based on the traffic volume in 2020 to 2039. Table 9.4 shows the traffic volume in pcu from 2018 to 2039, applying interpolation and extrapolation of given values in Table 9.3, with total traffic volume from 2020 to 2039 in pcu/day.

Table 9.4 Traffic Volume from 2018 to 2039

Unit: pcu/day

Year	Motorcycle	Car	Taxi	Bus	Truck	Total
2018	841	12,446	9,195	534	4,583	27,600
2019	873	13,232	9,213	667	4,587	28,741
2020	906	14,067	9,231	833	4,591	29,929
2021	940	14,955	9,249	1,040	4,595	31,167
2022	975	15,899	9,267	1,299	4,599	32,456
2023	1,012	16,903	9,285	1,622	4,603	33,798
2024	1,050	17,970	9,303	2,026	4,607	35,196
2025	1,089	19,103	9,319	2,530	4,610	36,651
2026	1,113	19,819	9,625	2,329	4,777	37,769
2027	1,137	20,561	9,941	2,144	4,950	38,922
2028	1,162	21,331	10,267	1,974	5,129	40,110
2029	1,187	22,130	10,604	1,817	5,315	41,334
2030	1,213	22,959	10,952	1,673	5,507	42,595
2031	1,240	23,819	11,312	1,540	5,706	43,895
2032	1,267	24,711	11,684	1,418	5,912	45,234
2033	1,295	25,637	12,068	1,305	6,126	46,614
2034	1,323	26,597	12,464	1,201	6,348	48,036
2035	1,352	27,593	12,874	1,106	6,578	49,503
2036	1,382	28,627	13,297	1,018	6,816	51,014
2037	1,412	29,699	13,734	937	7,063	52,571
2038	1,443	30,811	14,185	863	7,319	54,175
2039	1,475	31,965	14,651	794	7,584	55,828
Total pcu/day from 2020 to 2039	23,973	455,156	223,312	29,469	112,735	846,797

Source: JICA Survey Team

PCU conversion rates of YUTRA are given in Table 9.5. Applying these rates, the total traffic volume in vehicles/day from 2020 to 2039 was calculated as shown in Table 9.6.

Table 9.5 PCU Conversion Rate

Vehicle Type	Motor Cycle	Car	Taxi	Bus	Truck
PCU Conversion Rate	0.25	1.00	1.00	1.75	1.75

Source: JICA Survey Team

Table 9.6 Total Traffic Volume from 2020 to 2039 (in vehicles/day)

Vehicle Type	Motor Cycle	Car	Taxi	Bus	Truck
Total vehicles/day from 2020 to 2039	95,892	455,156	223,312	16,839	64,420

Source: JICA Survey Team

A unit of ESAL is 18 kip, where kip stands for 1,000 pounds-force, which is equivalent to 4.4482216 kN. Therefore, 18 kips is equivalent to 80 kN, or 8.157 tonne-force. Table 9.7 shows equivalency factors (or load equivalency values) for converting axle load of each vehicle class into ESAL numbers.

Table 9.7 Equivalency Factor of Vehicles

Type of Vehicle	Equivalency Factor
Passenger Car	0.001
Bus	0.87
Rigid trucks 2-axles	0.98

Source: JICA Survey Team

As seen in Table 9.7, the equivalency factor for a passenger car is small; hence, the value for motorcycles is negligible. Therefore, motorcycles are excluded in the traffic volume for the estimation of ESAL.

ESAL number is calculated using the following formula:

$$ESAL = D_D \times D_L \times \hat{w}_{18}$$

where, D_D : a directional distribution factor = 0.5

D_L : a lane distribution factor = 0.8

$\hat{w}_{18}$: the cumulative two-directional 18 kip ESAL units

= Σ (cumulative two-directional traffic volume/day of each vehicle class × 365 days × equivalency factor)

Applying the traffic volumes in Table 9.4, ESAL number was calculated in Table 9.8 as 11,455,160.

Table 9.8 Calculation of $\hat{w}_{18}$

Vehicle Type	Car	Taxi	Bus	Truck	Total
Total vehicles/day from 2020 to 2039	455,156	223,312	16,839	64,420	
Total vehicles from 2020 to 2039 (vehicles/day×365 days)	166,131,940	81,508,880	6,146,235	23,513,300	
Equivalency Factor	0.001	0.001	0.87	0.98	
$\hat{w}_{18}$	166,132	81,509	5,347,224	23,043,034	$\hat{w}_{18}$ = 28,637,899
ESAL = $D_D \times D_L \times \hat{w}_{18} = 0.5 \times 0.8 \times \hat{w}_{18}$ = 11,455,160					

Source: JICA Survey Team

Based on this obtained ESAL number, the following pavement structure was estimated:

Asphalt concrete surface course: 4 cm
Asphalt concrete binder course: 6 cm
Base course: 30 cm
Subbase course: 35 cm

Assumptions in major input values for estimating the layer thickness of pavement structure were given in Table 9.9. Including an assumed CBR of 7% for subgrade, there are many uncertain variables at this stage. The pavement structure must be reviewed in the detailed design stage by utilizing the laboratory test results of available materials for the Project.

Table 9.9 Input Value Assumptions

Design Input Requirements		Value
Design Variables	Performance Period (years) Reliability	20 90
Performance Criteria	Design Serviceability Loss, ΔPSI	1.7
Material Properties	Roadbed Soil CBR Effective Roadbed Soil Resilient Modulus, MR (psi)	7% 1,500 × CBR
	Subbase Course Resilient Modulus, MR (psi)	15,000
	Base Course Resilient Modulus, MR (psi)	28,400
	Asphalt Concrete Surface Course Resilient Modulus, MR (psi)	300,000
	Asphalt Concrete Binder Course Resilient Modulus, MR (psi)	300,000
Pavement Characteristics	Drainage Coefficients for Base Course and Subbase Course, m2, m3	1.0

Source: JICA Survey Team

9.5 Construction Planning

9.5.1 Site Conditions

(1) Basic Construction Conditions

The location of the Bago River Bridge site is about 4 km upstream of the confluence of the Bago and Yangon rivers. The Yangon River flows into the Gulf of Martaban in the Andaman Sea (a part of the Indian Ocean) at 40 km downstream of the confluence.

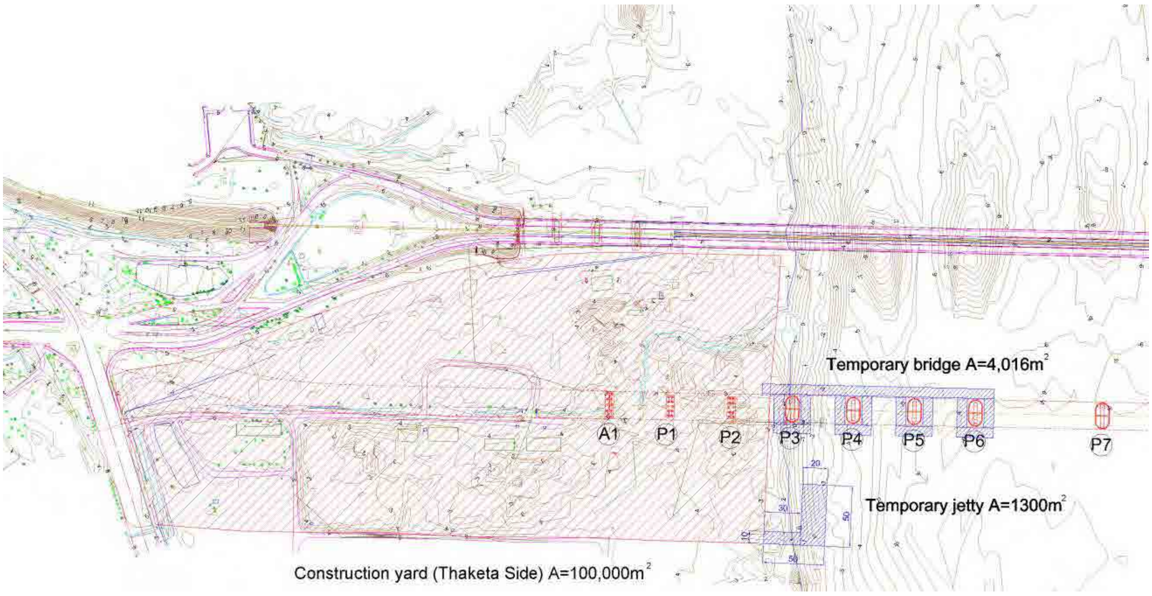
Most construction materials and machines will be transported by water. The Bago River is relatively shallow (about 6.5 m at MSFL Port), but freights can be reshipped by small barges at Thilawa Port near the location. Freights will be unloaded at the temporary jetty on the each bank of the Bago River.

Most of the construction site lies on public land, which has an ample space for construction and accommodating the precast segment fabrication yard. The major facilities of the construction yard is as shown in Table 9.10.

Table 9.10 Major Facilities of the Construction Yard

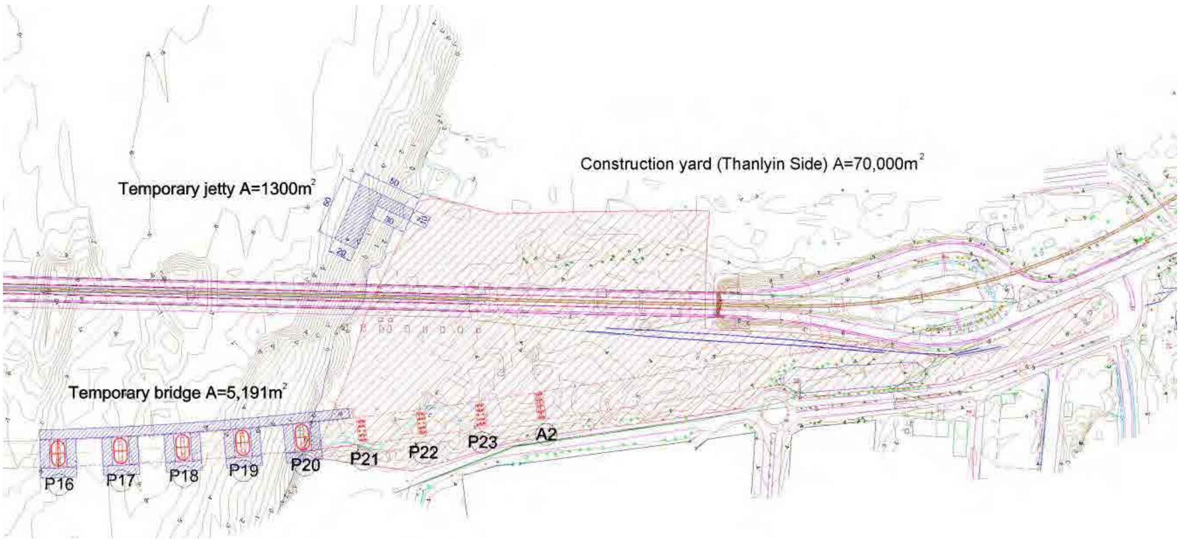
	Thaketa Side	Thanlyin Side
Facilities	Concrete and Asphalt Plant, Precast Segment Fabrication, Steel Box Girder Assembly, Stockyard, Office, Accommodation, etc.	Concrete and Asphalt Plant, Precast Segment Fabrication, Stockyard, etc.
Area (m^2)	100,000	70,000

Source: JICA Survey Team



Source: JICA Survey Team

Figure 9.21 Proposed Construction Yard in Thaketa Side (Right Bank)



Source: JICA Survey Team

Figure 9.22 Proposed Construction Yard in Thanlyin Side (Left Bank)

(2) Work Content

The works contain the following major items:

1) Temporary Works

(a) Temporary jetties
(b) Construction yard
(c) Office and accommodation
(d) Concrete and asphalt plant

2) Road Works

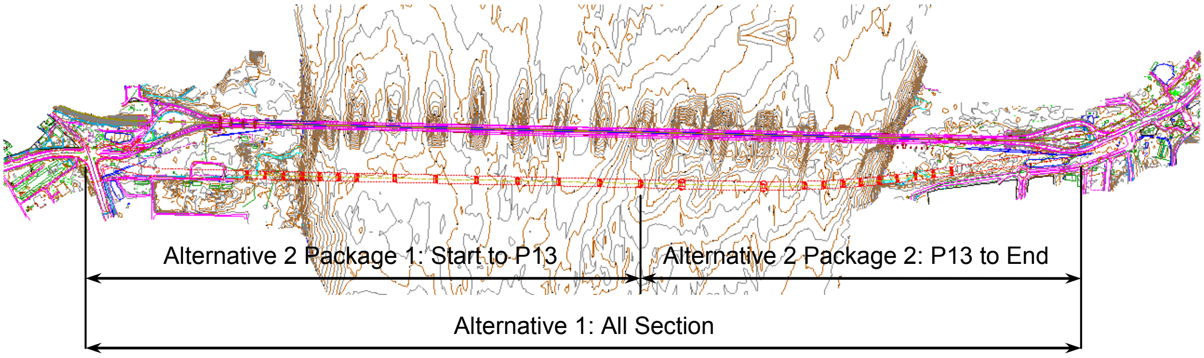
(a) Soft soil treatment works (piled slab)
(b) Embankment works
(c) Retaining wall
(d) Pavement works
(e) Ancillary works

3) Bridge Works

(a) Foundation works
(b) Substructure works
(c) Superstructure works
(d) Surface works
(e) Ancillary works

9.5.2 Construction Packaging Plan

In order to select the optimal construction package, the alternatives as shown in Figure 9.23 were studied and discussed in the sections below.



Source: JICA Survey Team

Figure 9.23 Plan of Construction Packaging Alternatives

Table 9.11 Construction Packaging Alternatives

	Alternative No.1	Alternative No.2	
	One Package	Package No. 1	Package No. 2
Location	All Sections	Right Bank Side: West Approach Road (L=539 m) Bridge (L=1,076 m, PC Box & Steel Box)	Left Bank Side: East Approach Road (L=647 m) Bridge (L=852 m, Cable Stay& PC Box)

Source: JICA Survey Team

(1) Alternative No.1: One Package

Another proposed alternative is to incorporate all construction works into one package.

Advantages:

a) Construction schedule can be managed comprehensively, which is good in terms of overall project implementation.

b) Problems concerning interference can be solved as part of the scope of one contractor.

c) The number of necessary temporary facilities such as offices and plants can be minimized.

Disadvantages:

a) As the contract amount is too large, many construction companies cannot afford to bid. There is a risk where no companies would intend to apply to bid.

(2) Alternative No.2: Two Packages

Another proposed alternative of construction contract packaging are as follows:

Package 1: Right Bank from KM 0 to KM 1+500, Pier P13
Package 2: Left Bank from KM 1+500 to KM 2+826, Project End.

Advantages:

a) Both packages have reasonable contract amounts in terms of road and bridge works.

b) The boundary of the packages at the west end of the cable-stayed bridge; hence, no major interference to the construction works is anticipated.

Disadvantages:

a) It is difficult to control the overall construction schedule as the completion of each package varies.

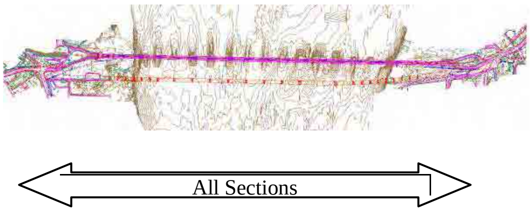
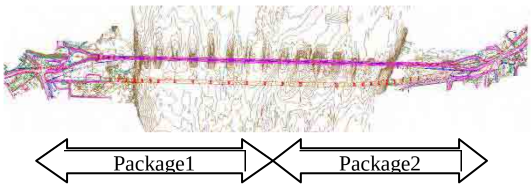
b) Some temporary facilities such as offices and plants should be duplicated.

c) Construction of P13 by Package 2 is critical for the construction of the end span of the steel box girder of Package 1.

(3) Recommendation

As shown in the comparison in Table 9.12, Alternative No. 1 with a single package is recommended than Alternative No. 2 with two packages.

Table 9.12 Comparison among Alternatives in Construction Packaging Plan

Evaluation Item	Alternative No. 1		Alternative No. 2	
Schematic Plan View				
No. of Packages	One (1)		Two (2)	
Manageability	Construction schedule can be managed comprehensively, which is good for overall project implementation.	○	It is difficult to control the overall construction schedule as the completion of each package varies.	△
Interference between packages	Problems concerning interference can be solved as part of the scope of one contractor.	○	The boundary of the packages is at the west end of the cable-stayed bridge; hence, there will be no major interference to the construction works although adjustment in construction schedule is necessary at the boundary.	△
Construction Cost	No major differences even if a few temporary facilities will be reduced.	○	No major differences even if a few temporary facilities will be duplicated.	○
Qualification of Bidders	The contract amount is larger and the length of the bridge is longer than many construction companies have accomplished. The requirements for pre-qualification should be decided after discussion with MOT and JICA.	△	No major problem in qualification of bidders as there are many construction companies having experience in similar works.	○
Attractiveness of packages	Attractive only for big general contractors because of the large contract amount.	○	Both packages have reasonable contract amounts in terms of road and bridge works.	○
Evaluation	Recommended		-	

Remarks: ○:Good, △:Fair
Source: JICA Survey Team

9.5.3 Temporary Facilities

Temporary facilities contain the following major items:

1) Temporary offices and plant yard
   - (a) Temporary office for contractor with contractors' accommodation.
   - (b) Concrete batching plant
   - (c) Asphalt plant
   - (d) PC segment fabrication yard
   - (e) Steel girder fabrication yard
   - (f) Material stockyard
   - (g) Machinery work shop

2) Temporary jetties
   - (a) Loading and unloading jetty

3) Temporary access
   - (a) Entrance access road from public road
   - (b) Temporary bridges

4) Navigation safety measures

Summary of temporary facilities are shown on the table below.

Table 9.13 Summary of Temporary Facilities

Description	Location	Quantity	Remark
Temporary Yard	Thaketa Side	100,000 m^2	
	Thanlyin Side	70,000 m^2	
Temporary Jetty	Thaketa Side	1,300 m^2	
	Thanlyin Side	1,300 m^2	
Temporary Access	Thaketa Side	4,016 m^2	
	Thanlyin Side	5,191 m^2	

Source: JICA Survey Team

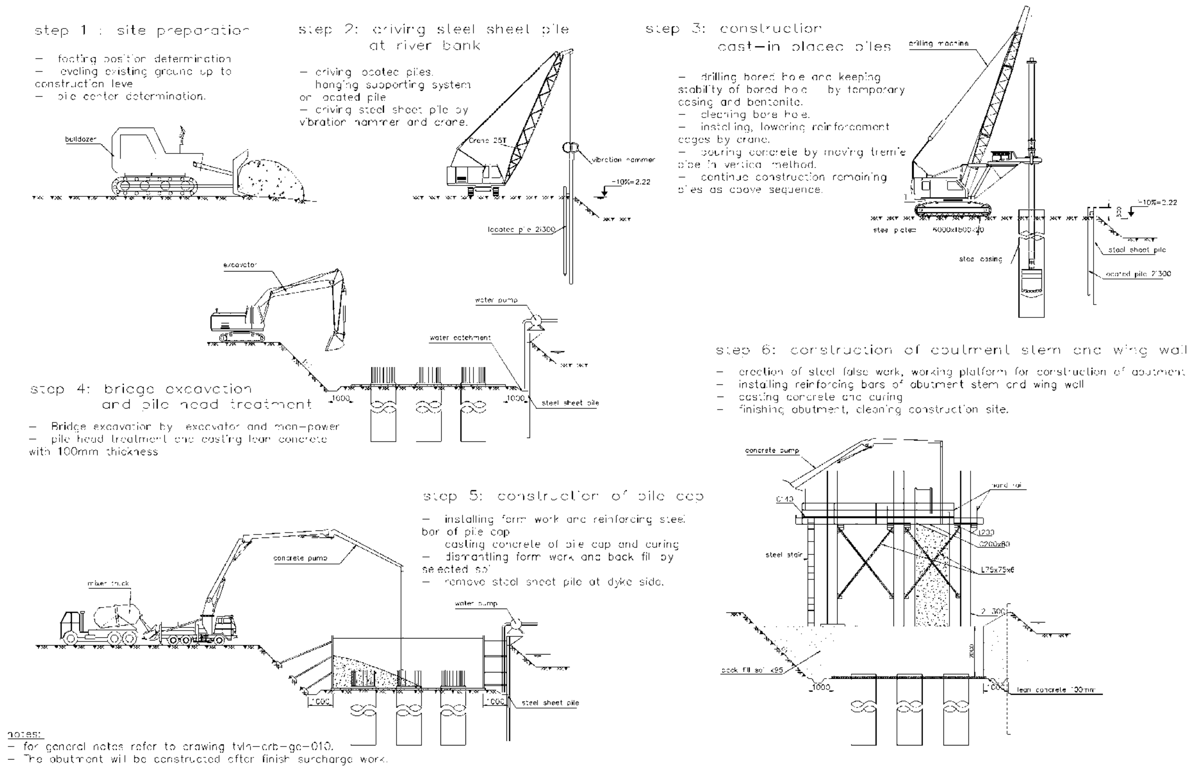
9.5.4 Construction Procedures

<u>Construction of Substructure</u>

A construction plan of the substructure is developed for each bridge type and commented in the following subsection.

(1) Abutment

Construction of the abutments starts with foundation work utilizing a temporary casing, a boring machine, etc., followed by pile cap concreting. After installation of scaffoldings and temporary support for the formworks, reinforcing work, and concrete casting for the abutment wall and its wing walls follow. A series of construction procedures is shown in Figure 9.24.

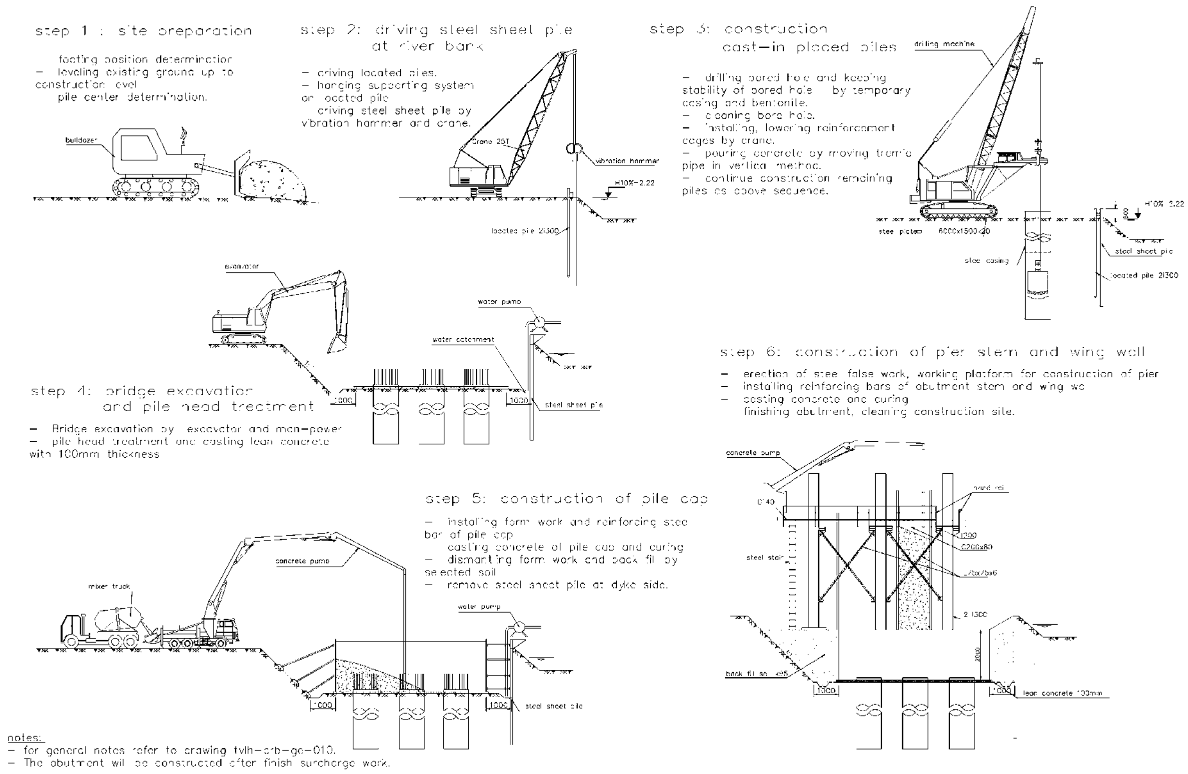


Source: JICA Survey Team

Figure 9.24 Construction Procedures for Abutment

(2) Pier on Land

Construction of the piers on land starts with foundation work utilizing a temporary casing, a boring machine, etc., followed by pile cap concreting. After installation of scaffoldings and temporary support for the formworks, reinforcing work, and concrete casting for the pier follow. A series of construction procedures is shown in Figure 9.25.

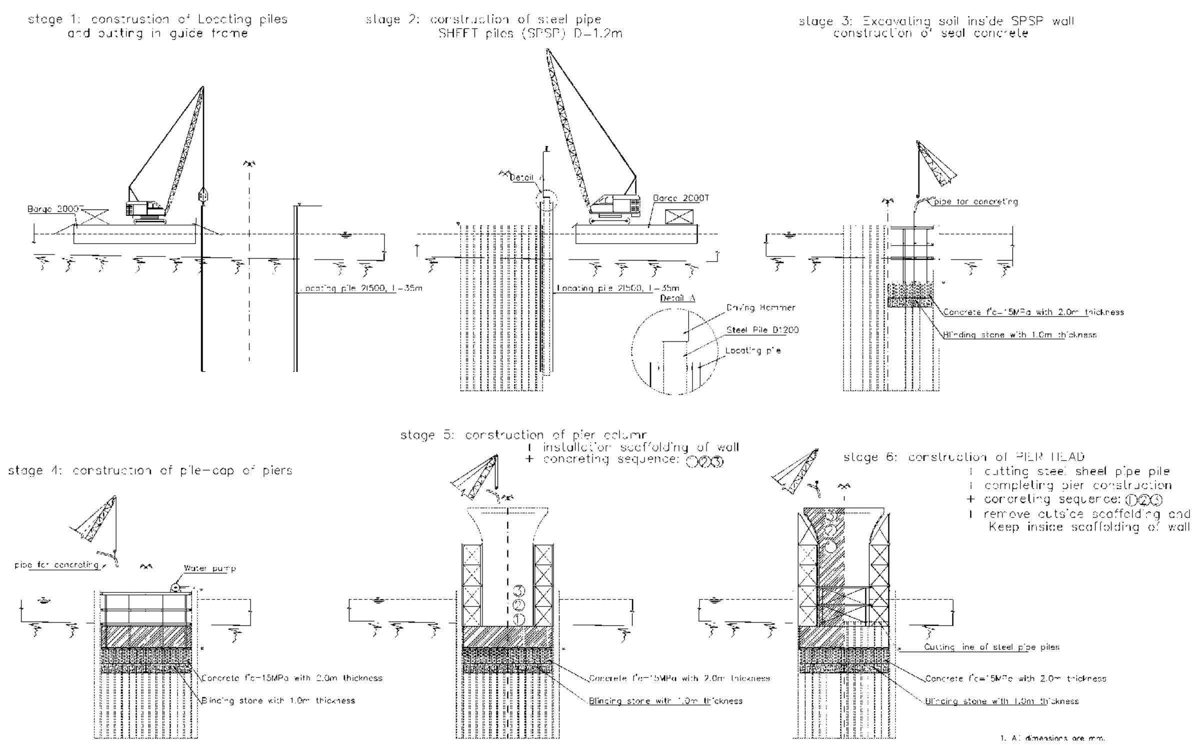


Source: JICA Survey Team

Figure 9.25 Construction Procedures for Pier on Land

(3) Pier in the River

Construction of the piers in the river starts with driving steel pipe sheet piles utilizing a silent pile driver with locating piles and a temporary guide frame, followed by excavation inside the cofferdam with temporary bracings. After casting the concrete pile cap, reinforcing work, and concrete casting for the pier follow. A series of construction procedures is shown in Figure 9.26.



Source: JICA Survey Team

Figure 9.26 Construction Procedures for Pier on River

Erection of Superstructure

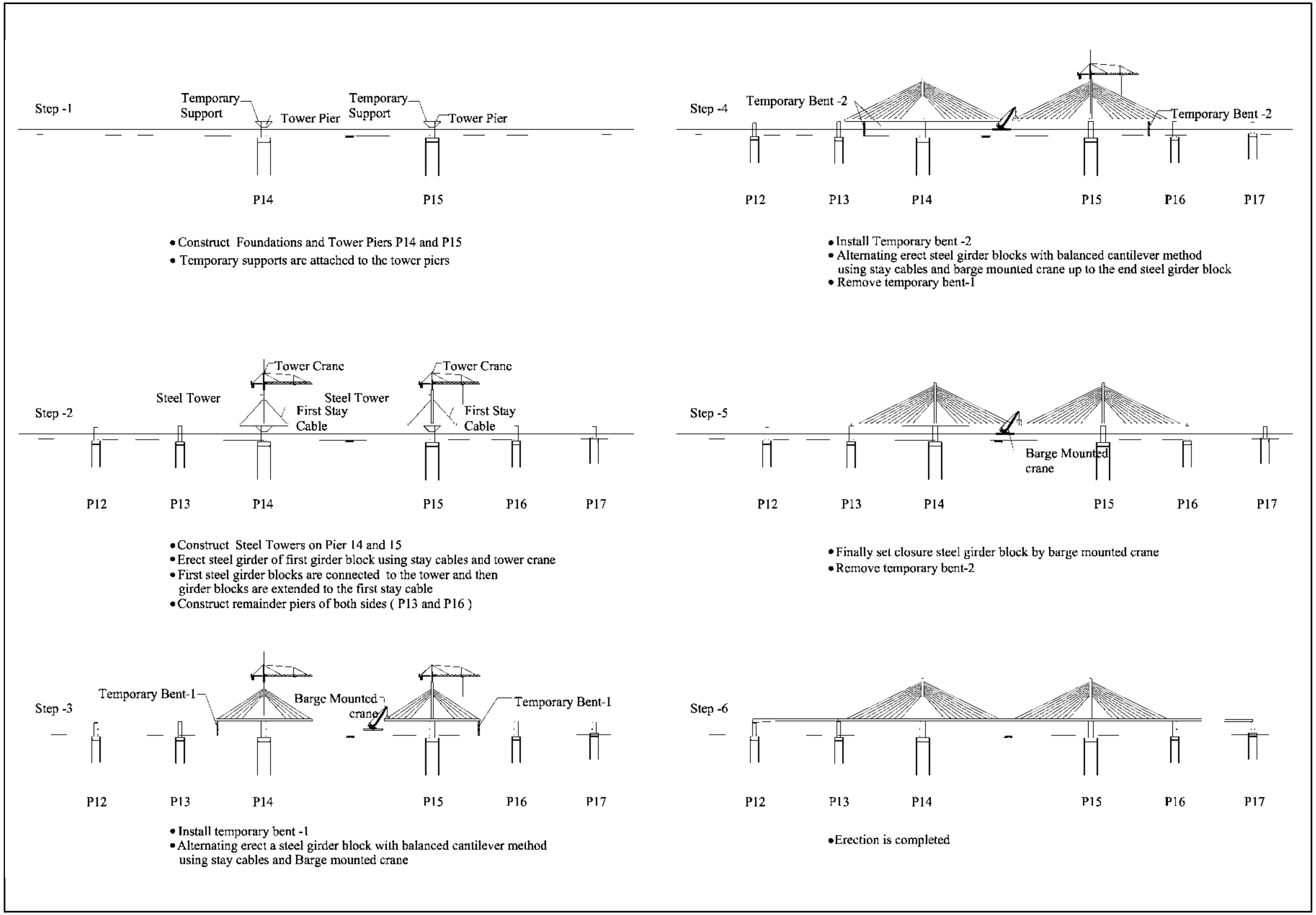
In consideration of general constructability relating to the erection of superstructure, it is important to maintain the main navigational channel free from any obstruction during construction, and minimize the number and period required for temporary bents in the Bago River. An erection plan of the superstructure was developed for each bridge type and commented in the following subsection.

It is anticipated that materials and equipment for erection of the superstructure will have to be loaded on barges and transported to the erection site on the river. There are a number of areas downstream of the site that would permit the loading and storage area for erection equipment and fabricated steel girder blocks. Consequently, temporary jetties are provided for loading and unloading on both river banks.

The major erection works for the superstructures will be performed using the balanced cantilever method by barge-mounted cranes or erection equipment, or using the span-by-span method by erection truss girder.

(1) Cable-stayed Bridge

Cable-stayed bridge erection is performed utilizing a permanent tower and stay cable that will support all loads during the assembly of the superstructure. After the majority of the tower construction is completed, the first steel girder blocks will be connected directly to the tower using temporary supports attached to the tower pier. Additional steel girder blocks will be erected on the temporary support and will extend alternately up to the installation of the first permanent stay cable. Then, alternating cantilever erection of steel girder blocks continues along with stay cable installation until the mid-span is reached. When two adjacent cantilever end steel girder blocks are completed, the closure block will be installed and the erection will be complete. A series of construction procedures is shown in Figure 9.27.



Source: JICA Survey Team

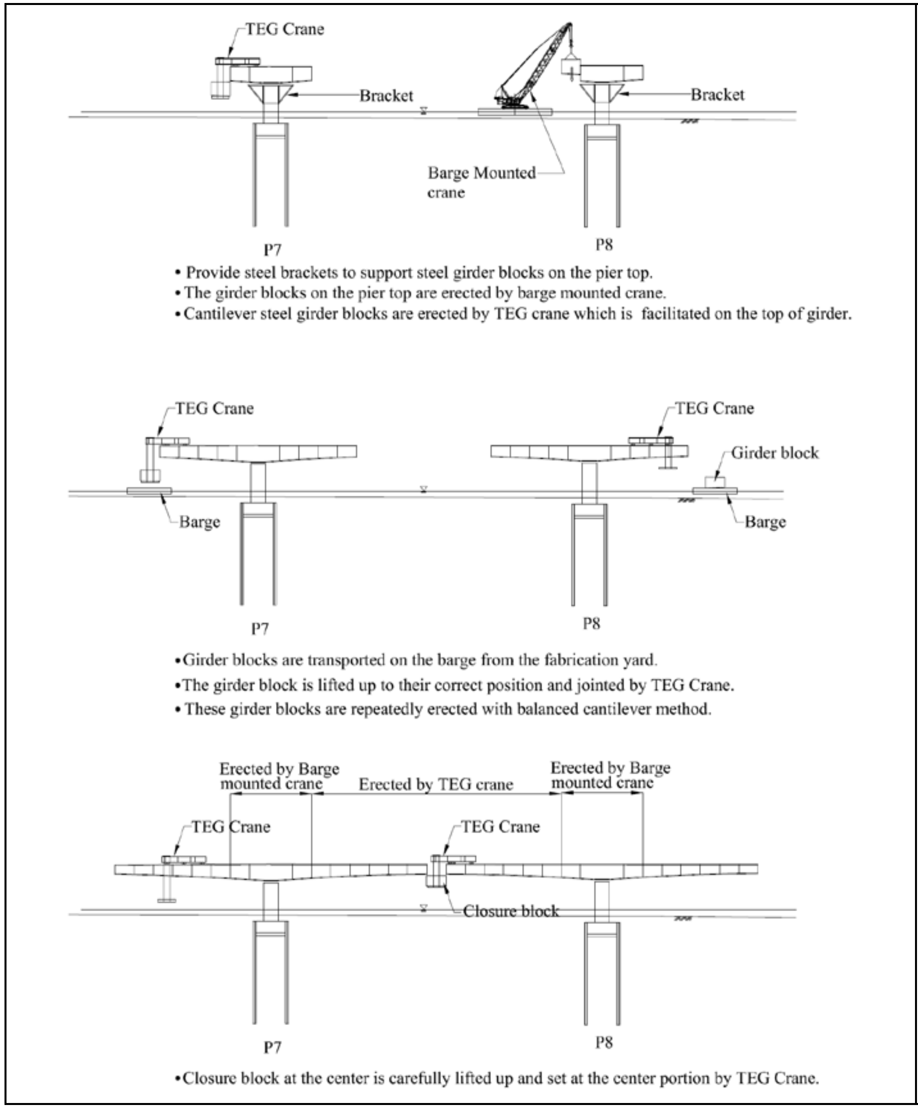
Figure 9.27 Construction Procedure of Steel Cable Stayed Bridge

(2) Continuous Steel Box Girders

The cantilever method of erection for continuous steel box girder starts with assembling the sections over a pier top using pier brackets. Once the initial steel box girder blocks are assembled on the pier top, new blocks are added to each end and erected by cantilever method using TEG erection equipment or travelling derrick in an alternating process until mid-span is reached. Cantilever erection will proceed simultaneously with the adjacent pier. When the two adjacent cantilever end steel girder blocks are completed, the closure block will be installed and the erection will be completed. A series of construction procedures is shown in Figure 9.28.

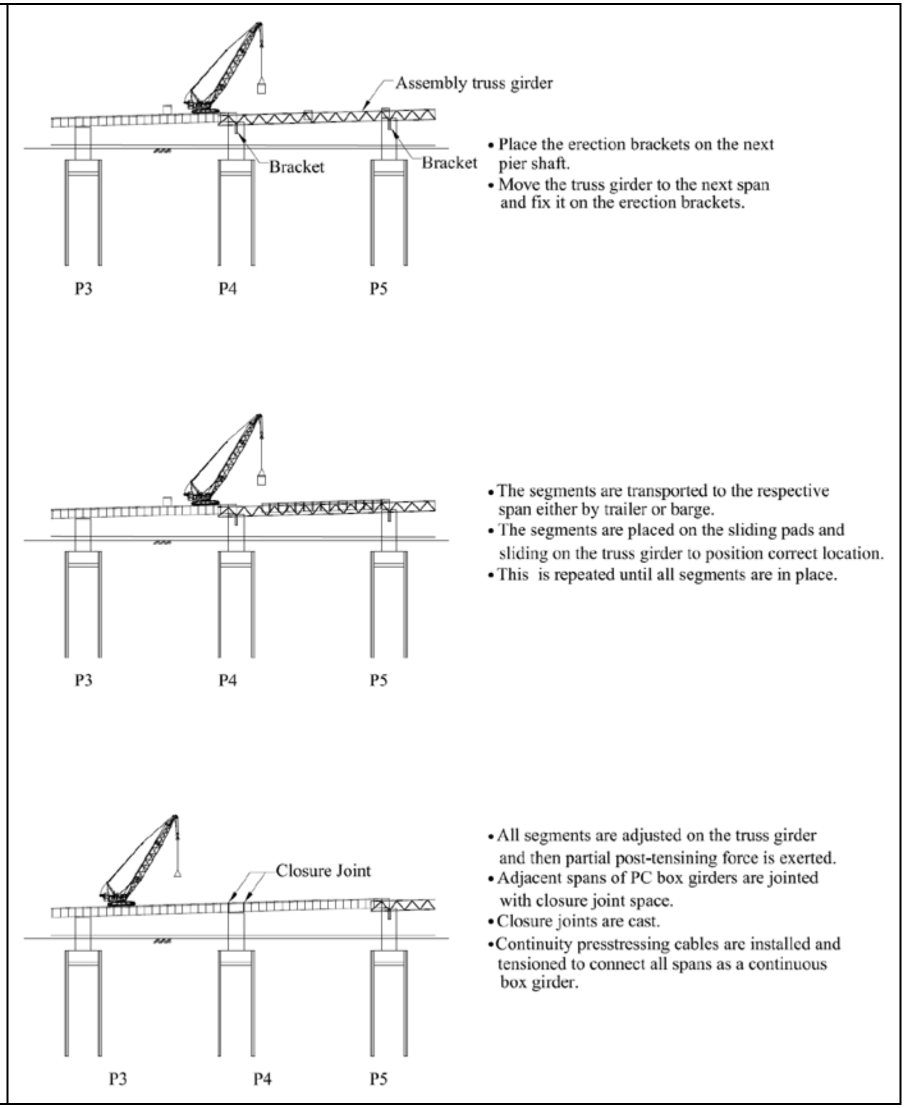
(3) Continuous PC Box Girder

All of the segments are precast at the casting yard and transported by trailer or barge to the site. All segments that make up one span are positioned and adjusted on the assembly truss girders, and then partial post-tensioning force is exerted. The adjacent spans of continuous box girders are adjusted and joined together with a closure space that avoids the short-line segmental match-casting geometric tolerances. The closure joint is then casted. After the closure concrete has hardened, continuous prestressing cables are installed in the box girder and tensioned to connect all spans as a continuous box girder. A series of construction procedures is shown Figure 9.29.



Source: JICA Survey Team

Figure 9.29 Construction Procedure of Continuous Steel Box Girder with Steel Deck Slab

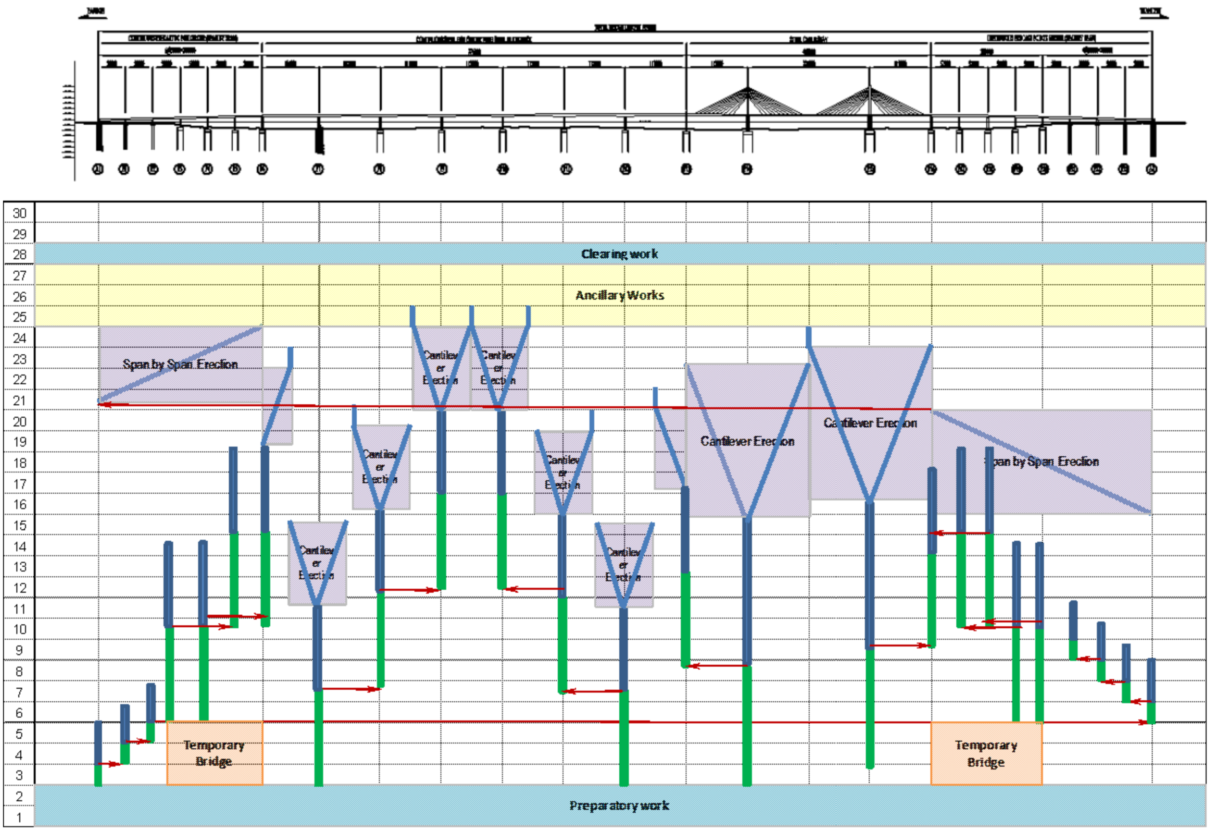


Source: JICA Survey Team

Figure 9.28 Construction Procedure of Continuous PC Box Girder with Span by Span

9.5.5 Construction Period

The total construction period is 28 months. The construction time schedule with overall construction sequence and major critical activities is shown in Figure 9.30.



Source: JICA Survey Team

Figure 9.30 Construction Schedule