MINISTRY OF CONSTRUCTION
REPUBLIC OF THE UNION OF MYANMAR

PREPARATORY SURVEY FOR THE PROJECT FOR STRENGTHENING CONNECTIVITY OF INTERNATIONAL HIGHWAY IN MEKONG REGION

FINAL REPORT

PHASE-II SURVEY REPORT (PRELIMINARY FEASIBILITY STUDY)

DECEMBER 2016

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
INTERNATIONAL DEVELOPMENT CENTER OF JAPAN
CTI ENGINEERING CO., LTD.
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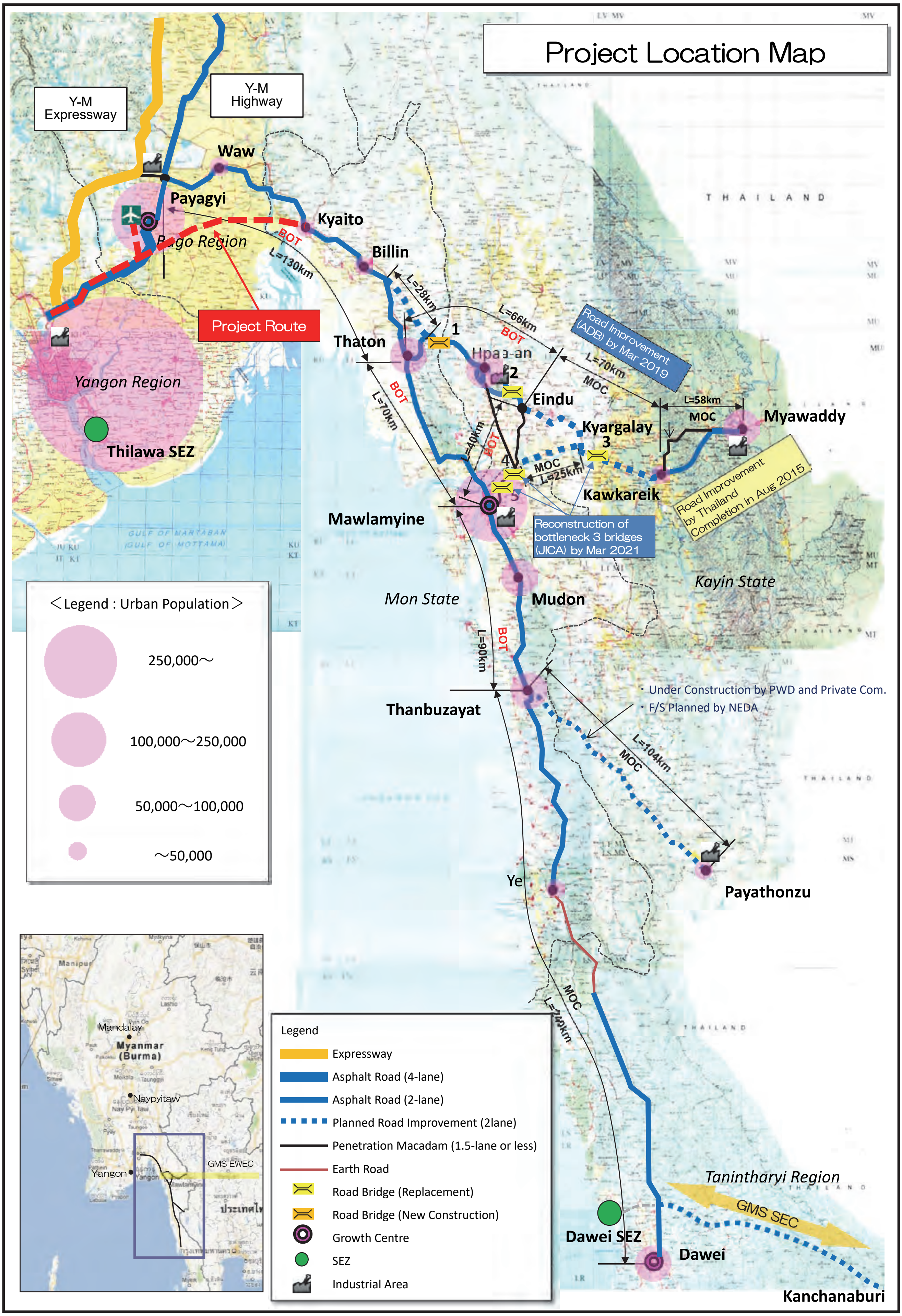
Currency Equivalents

USD 1.00 = MMK 1183.0 = JPY 109.2 (July 2016)
*MMK: Myanmar Kyat


Project Location Map
Y-M Expressway
Y-M Highway
Waw
Payagyi
Bago Region
Kyaito
BOT
L=130km
Billin
L=28km
Project Route
Thaton
1
L=66km
BOT
Hpaa-an
2
Road Improvement (ADB) by Mar 2019
L=70km
MOC
Eindu
L=58km
MOC
Myawaddy
Yangon Region
Thilawa SEZ
BOT
L=70km
L=40km
BOT
Kyargalay
3
4
MOC
L=25km
Road Improvement by Thailand Completion in Aug 2015
Kawkareik
5
Mawlamyine
Reconstruction of bottleneck 3 bridges (JICA) by Mar 2021
GULF OF MARTABAN
Mon State
Mudon
Kayin State
BOT
L=90km
Thanbuzayat
・Under Construction by PWD and Private Com.
・F/S Planned by NEDA
L=104km
MOC
Payathonzu
Ye
MOC
L=74km
＜Legend : Urban Population＞
250,000～
100,000～250,000
50,000～100,000
～50,000
Mandalay
Myanmar (Burma)
Naypyitaw
Yangon
GMS EWEC
Legend
Expressway
Asphalt Road (4-lane)
Asphalt Road (2-lane)
Planned Road Improvement (2lane)
Penetration Macadam (1.5-lane or less)
Earth Road
Road Bridge (Replacement)
Road Bridge (New Construction)
Growth Centre
SEZ
Industrial Area
Tanintharyi Region
GMS SEC
Dawei SEZ
Dawei
Kanchanaburi
THAILAND

Perspective of the Project (New Sittaung Bridge)

Perspective of the Project (New Sittaung Bridge)

Perspective of the Project (Improvement of National Highway No.1 / Viaduct Section)

Perspective of the Project (Improvement of National Highway No.1 / At-grade Section)

Table of Contents

List of Tables

Page

List of Figures

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Concrete
ADB	Asian Development Bank
AH	Asian Highway/ ASEAN Highway
AIDS	Acquired Immune Deficiency Syndrome
AK	AyeKo family
ASEAN	Association of South East Asian Nations
ASTM	America Society for Testing and Materials
AT	Atran
ATM	Automatic Teller Machine
B/C	Cost-Benefit Ratio
BOD	Biochemical Oxygen Demand
BOT	Build-Operate-and-Transfer
CC	Concrete Caisson
CPCP	Cast in Place Concrete Pile
DCA	Department of Civil Aviation
D/D	Detailed Design
DEM	Digital Elevation Map
DMH	Department of Meteorology and Hydrology
ECD	Environmental Conservation Department
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMP	Environmental Management Plan
EWEC	East-West Economic Corridor
EXIM	Export and Import
FAO	Food and Agriculture Organization
F/S	Feasibility Study
GDP	Gross Domestic Product
GIS	Geographic Information System
GMS	Greater Mekong Sub-region
GPS	Global Positioning System
GRDP	Gross Regional Domestic Product
GZ	Gyaing Zathapyin
HFL	Highest Flood Level
HIA	Hanthawaddy International Airport
HIV	Human Immunodeficiency Virus
HSR	High Speed Rail
HWL	High Water Level
ID	Irrigation Department, MOAI
IDF	Intensity-Duration-Frequency
IEE	Initial Environmental Examination
IMF	International Monetary Fund
ITD	Italian-Thai Development
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
JICA GL	JICA Guideline for Environmental and Social Considerations
JRA	Japan Road Association
LCC	Life Cycle Cost
LRFD	Load and Resistance Factor Design
MIMU	Myanmar Information Management Unit
MOAI	Ministry of Agriculture and Irrigation
MOC	Ministry of Construction
MOECAF	Ministry of Environmental Conservation and Forestry
MOT	Minister of Transport
MPA	Myanmar Port Authority
MSL	Mean Sea Level
MYT-Plan	The National Transport Development Plan
NEDA	Neighboring countries Economic Development cooperation Agency
NSC	North-South Corridor
NSEC	North-South Economic Corridor
OD	Origin-Destination
ODA	Official Development Assistance
OP	Operational Policies
PAHs	Project Affected Households
PAPs	Project Affected Persons
PC	Pre stressed Concrete
PCU	Passenger Car Unit
PHC	Pretensioned spun High strength Concrete
PPP	Public Private Partnership
PW	Public Works
RAP	Resettlement Action/Land Acquisition Plan
RC	Reinforced concrete
ROW	Right of Way
SC	Steel Composite piles
SEZ	Special Economic Zone
SLRD	Settlement and Land Records Department
SLSC	Standard Least Squares Criterion
SOI	Survey of India
SPC	Special Purpose Company
SPP	Steel Pipe Pile
SPSP	Steel Pipe Sheet Pile
SPT	Standard Penetration Test
STD	Sexually Transmitted Disease
TFR	Total Fertility Rate
TIN	Triangulated Irregular Network
TM	Thematic Mapper
TSP	TrisodiumPhosphate
UN	United Nations
UNDP	United Nations Development Program
UNESCAP	United Nations Economic and Social Commission for Asia and Pacific
UNHCR	United Nations High Commissioner for Refugees
UNOSAT	United Nations Operational Satellite Applications Programme
UTM	Universal Transverse Mercator
VOC	Vehicle Operation Cost
WB	World Bank
WGS	World Geodetic System
YUEX	Yangon Urban Expressway
YUTRA	Project for Comprehensive Urban Transport Plan of the Greater Yangon

CHAPTER 1 INTRODUCTION

1.1 Introduction

1.1.1 Survey Background

After the transition to democracy in March 2011, the Republic of the Union of Myanmar (hereinafter "Myanmar") made efforts to accelerate its economic growth through the development of its infrastructure, with the intention of upgrading it to international standards before Myanmar's integration into ASEAN in 2015.

The Ministry of Construction ("MOC") has been developing roads and bridges with its own budget and private funds; however, the reach of this development work to remote areas was insufficient due to fiscal limitations. Particularly, in the southeast where Myanmar shares a border with Thailand, one of its economically close partners, the development of the international road network is an urgent task. In this connection, improvement of the East-West Corridor ("EWC")[1] including the Greater Mekong Sub-region ("GMS"), is of the highest priority and is a key national infrastructure undertaking of Myanmar. In this context, the JICA Survey Team has proposed the most prioritized projects such as the replacement of three bottleneck bridges and construction of "Thaton Bypass" and "Kyargalay Bypass" in the Phase-I Survey, to ensure smooth traffic flows and safety that will be able to cope with the continued economic development of Myanmar.

However, focusing on future development for the EWC, it is expected that further road development is necessary on the section between Payagyi and Thaton, where future traffic demand is estimated to be more than 40,000 PCU by traffic mixture from the eastern and southern regions of Myanmar after the completion of the scheduled road improvement projects on the GMS EWEC[2]. It is also supposed to result in social problems such as heavier traffic congestion and a lower level in traffic safety.

Under the above expected situation, "New Bago – Kyaito Road Construction" and "Improvement of National Highway No.1" have been proposed for the next priority projects by the JICA Survey Team through a series of discussions with MOC and JICA. The JICA Survey Team commenced the Phase-II survey from January 2016 to prepare the basic information for the next step of the study such as a Feasibility Study ("F/S").

1 The section of Yangon, Mawlamyine and Myawaddy and the section of Mawlamyine and Dawei are defined as the EWC in this report in order to distinguish from the section between Mawlamyine and Myawaddy, which is recognized as a part of the GMS EWEC.

2 The GMS East-West Economic Corridor, Eindu to Kawkareik Road Improvement Project (ADB) and the East-West Economic Corridor Improvement Project (JICA)

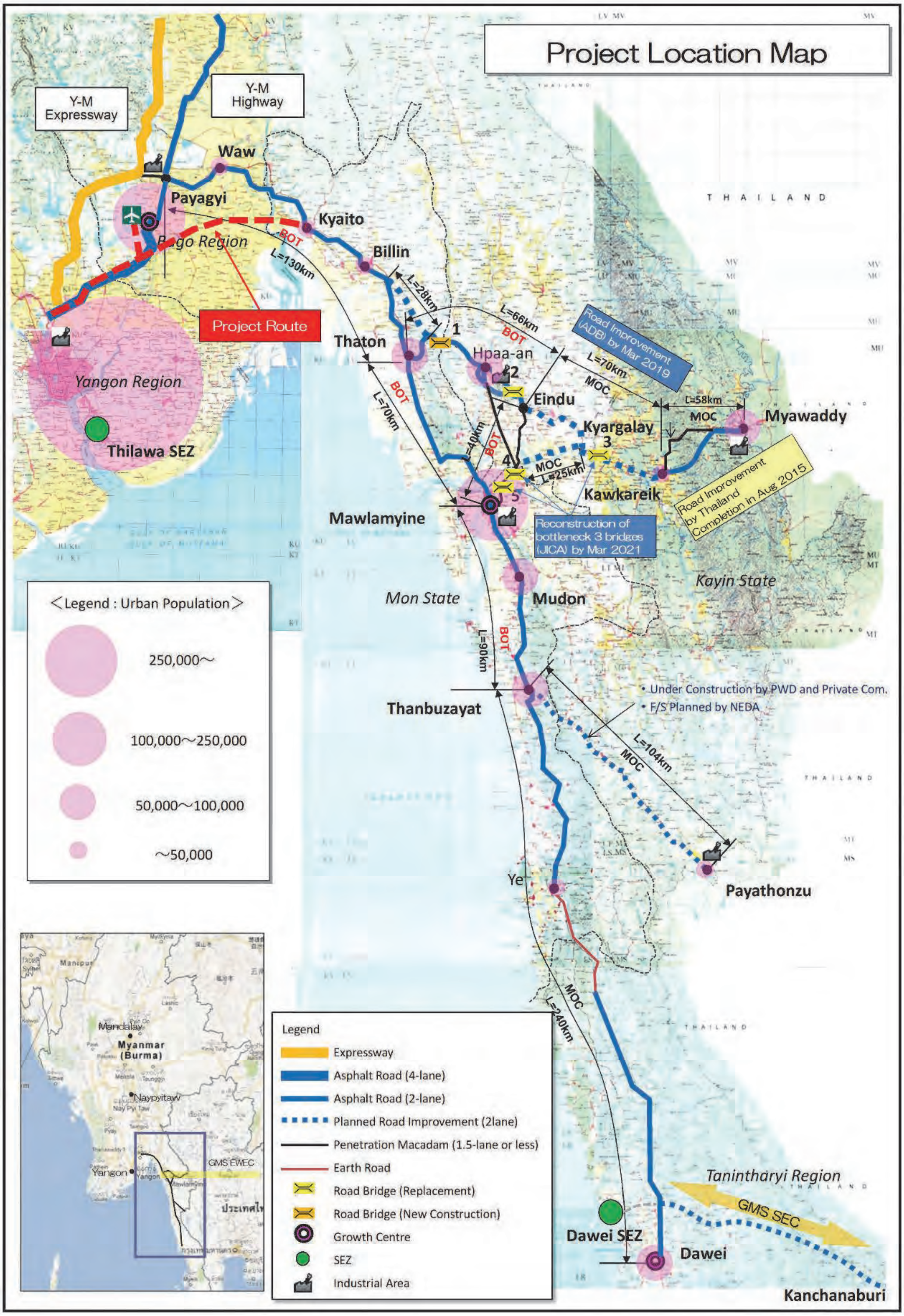
1.1.2 Survey Objectives

The objective of this second phase survey is to conduct a Pre-Feasibility Study for “New Bago – Kyaito Road Construction Project” and “Improvement of National Highway No.1 Project” including Hanthawaddy International Airport (HIA) access road in order to collect and prepare basic information for the next detailed study such as F/S. The outputs of the survey are :

- Preliminary road alignment and structure study for the proposed project
- Preliminary environmental and social considerations
- Preliminary cost estimation and economic analysis and evaluation
- Preliminary implementation programme

1.1.3 Survey Area

The survey area covers the southeastern part of Myanmar and the Bago Region. The project location map shown in Figure 1.1.1.

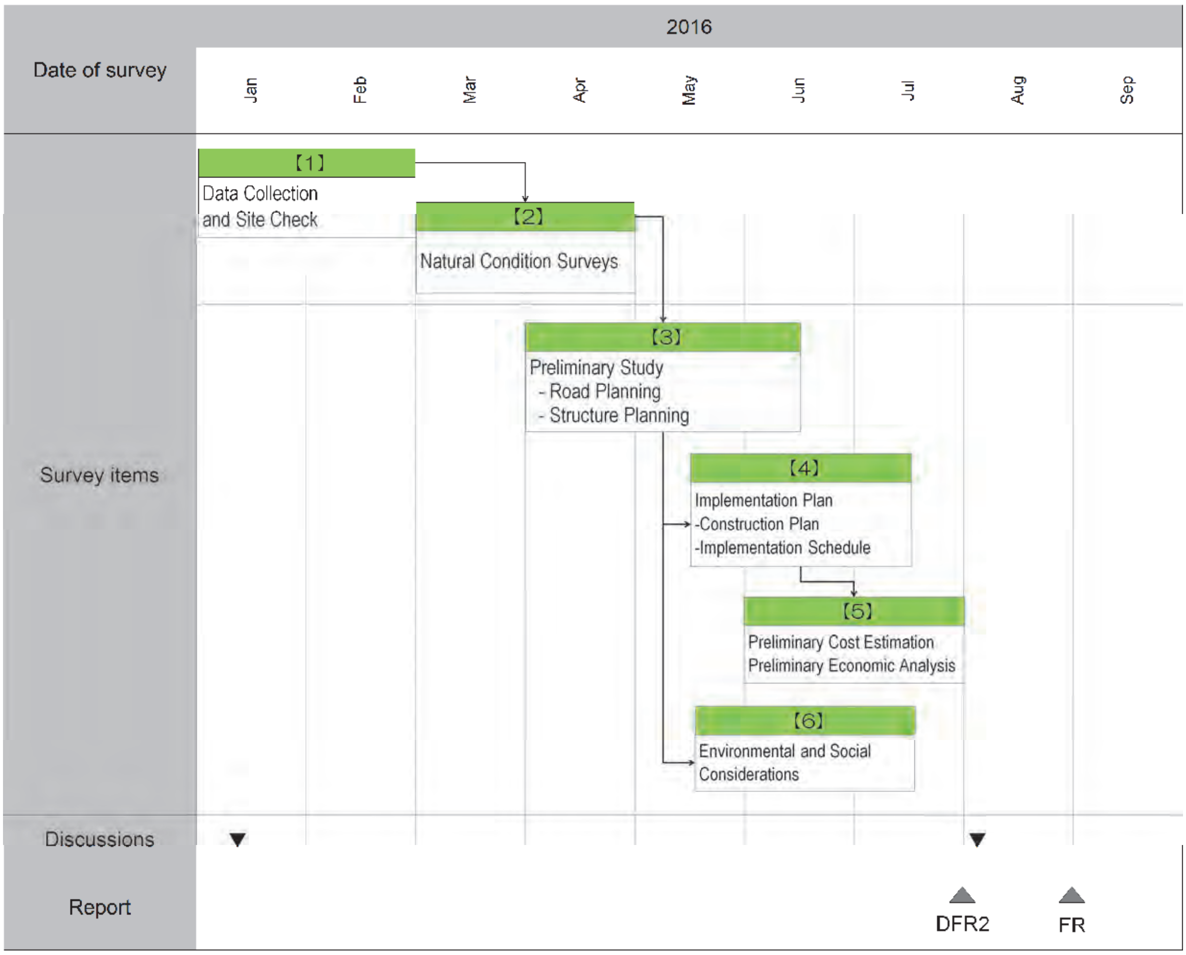


Source: JICA Survey Team

Figure 1.1.1 Project Location Map (Phase-II Survey)

1.2 Schedule and Flow of the Survey

The schedule and flow of the Phase II Survey is shown in Figure 1.2.1. The survey was conducted from January 2016 to the end of July 2016.



Source: JICA Survey Team

Figure 1.2.1 Flow and Schedule for the Phase II Survey

CHAPTER 2 VERIFICATION OF NECESSITY/ APPROPRIATENESS OF THE PROJECT FORMULATION

2.1 Introduction

In this Chapter, the conditions surrounding the project are studied in order to justify the necessity and appropriateness for the formulation of the project.

2.2 Understanding the Surrounding Conditions for the Project

Upon understanding the surrounding conditions for the project including the existing/related development plan in the southeast region of Myanmar covering the development plan in the Bago region, the preliminary study was conducted to identify the necessity and appropriateness for the implementation of the project.

2.2.1 Required Functions on the East-West Corridor

The project road which composes of several road links as a part of a stretch on the GMS- EWEC linking from Mawlamyine to Myawaddy bordering with Thailand, the GMS-West Economic Corridor linking from Mawlamyine to Tamu through Bago and Nay Pyi Taw as well as an arterial road extending to Dawei through Mawlamyine in the southern region of country. Thus, the project road (EAST-WEST CORRIDOR[3]) is required to assess the functions as vital links pursuant to both international and national networks.

(1) The Role of the EWC in the International Road Network

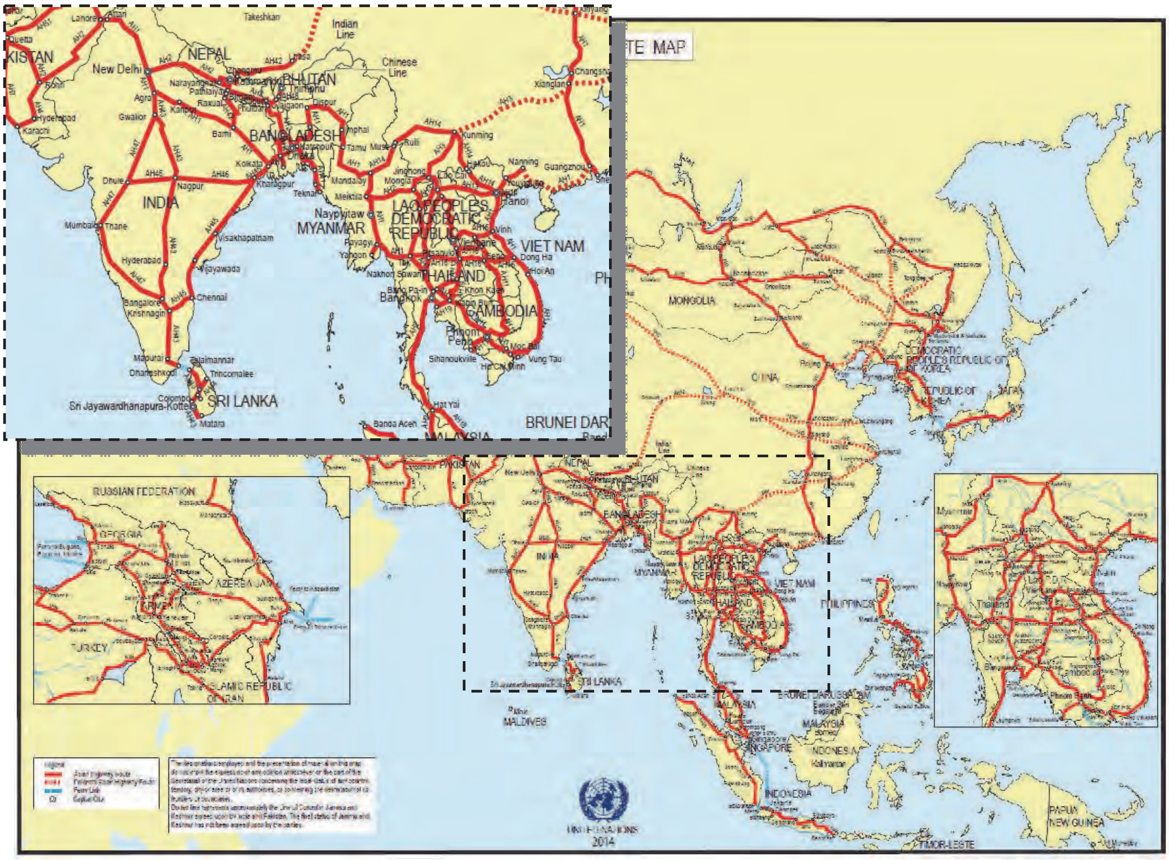
Asian Highways

Asian Highways is the international highway network initially established by UNESCAP in 1959, with its approximately 140,000 km length of road networks covering 32 countries. There are four Asian Highways , totally 3,018km in length, passing through Myanmar: AH1, AH2, AH3 and AH14 linking the neighbouring countries of China, India and Thailand. The section of Myawaddy – Mawlamyine – Yangon, approximately 400km in length, is a part of the EWC.

[3] In the GMS Economic Corridor Framework, the section between Mawlamyine and Myawaddy is recognized as the GMS –EWEC. Thus.to distinguish from the GMS EWEC, in this report, the section of Yangon – Mawlaymyine – Myawaddy and Mawlamyine – Dawei is defined to be the East – West Corridor following the Development Corridor Framework in the Program for the National Transport Development Plan in the Republic of the Union of Myanmar

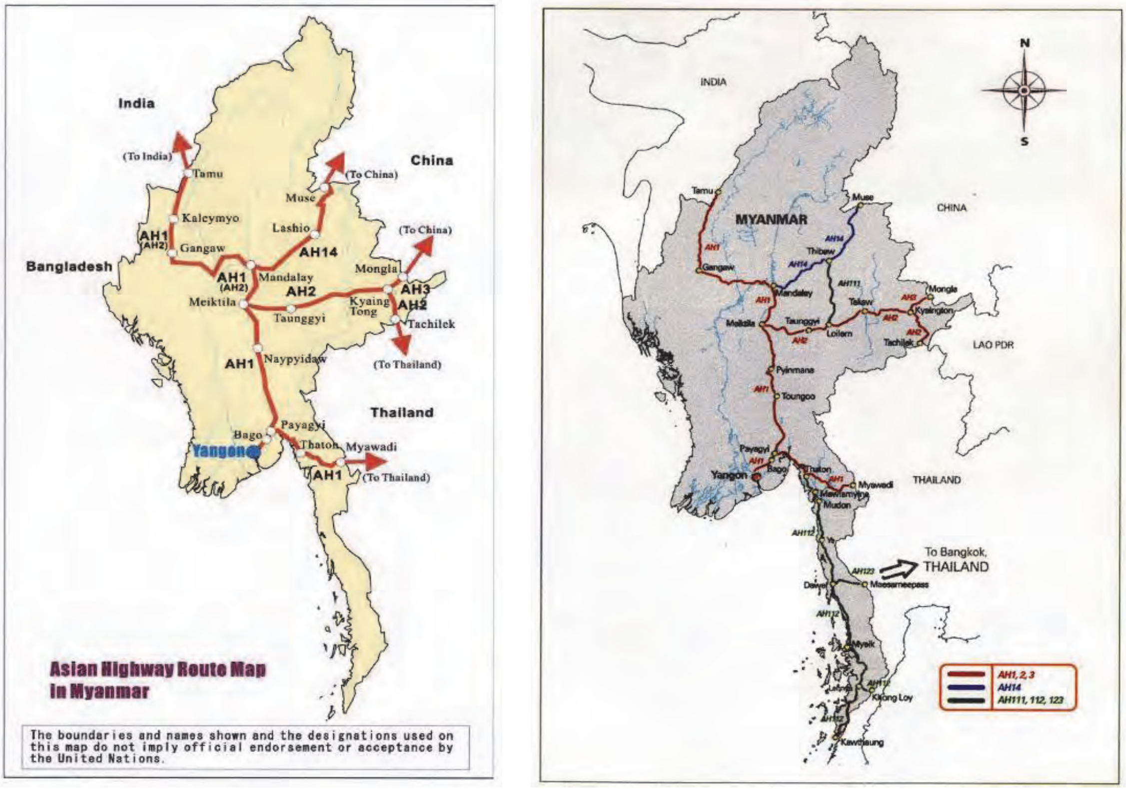
<u>ASEAN Highways</u>

ASEAN highway network comprises 23 routes involving some 38,400km over ASEAN countries and is under development for the purpose of the establishment efficient, integrated, safe and environmentally sustainable regional land transport corridors linking all ASEAN Member States and countries beyond. There are seven routes within Myanmar designated as parts of the ASEAN Highway Network. These consist of four routes that coincide with the Asian Highway Network (AH1, AH2, AH3 and AH 14), and another three additional routes (AH 111, AH 112 and AH 123, with a total length of a further 1,525km). Therefore, the total length of ASEAN designated routes in Myanmar is approximately 4,543km. The section between Thaton and Dawei on AH112, approximately 400km in length, is also a part of the EWC.



Source: UNESCAP

Figure 2.2.1 ASIAN Highway Route Map

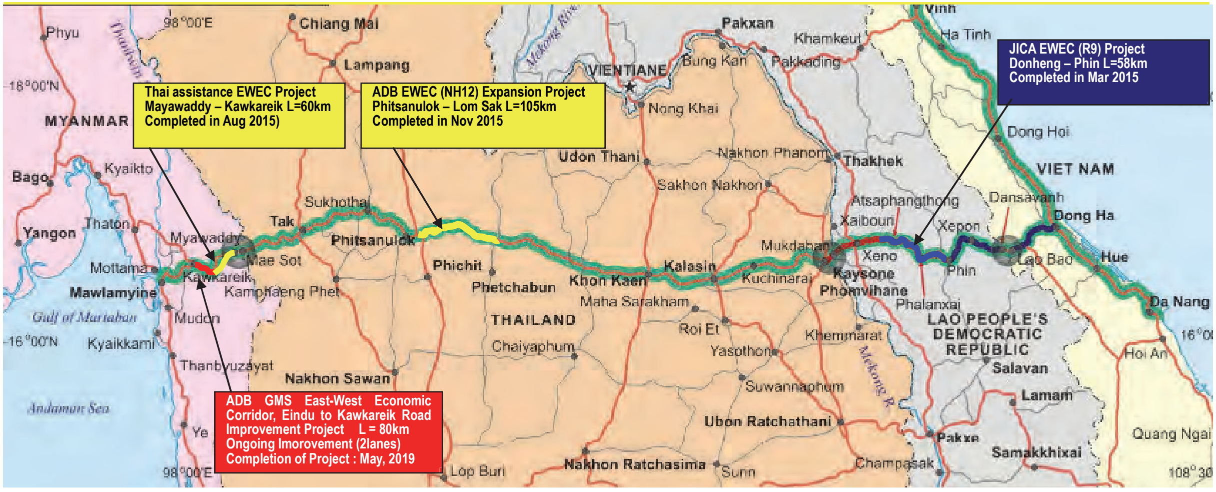


Source: MOC

Figure 2.2.2 ASIAN Highway and ASEAN Highway Route Map in Myanmar

<u>GMS Economic Corridor</u>

The GMS Economic Corridor consists of seven corridors and five corridors (North-South Economic Corridor, East-West Economic Corridor, Southern Economic Corridor, Northern Economic Corridor and Western Economic Corridor) pass through Myanmar, as shown in Figure 2.2.4. The GMS EWEC extends 1,320km between Da Naung, Viet Nam and Mawlamyine, Myanmar and the section between Myawaddy and Mawlamyine, approximately 170km in length, passes through Myanmar. Most of the road sections in the EWEC are in good condition or are already being improved. For example, the ADB-funded GMS Highway Expansion Project 1, co-financed by the Thai Government, is upgrading a 178 km section of the EWEC in Thailand; specifically a 105 km section of Highway No.12 running from Phitsanulok to Lom Sak was completed in Nov 2015. Also, a JICA Grant Aid project for upgrading 58 km of road in Savannkahet Province of Lao PDR was completed in March 2015. In Myanmar, the construction of a 28km length of bypass between Kawkareik and Myawaddy, funded by the Thai Government, was completed on 30th August 2015, providing a new route to go around the Dawna mountain range. In addition, the road improvement of between Eindu and Kawkareik is planned to be completed in March 2019 with the aid by ADB and the existing bottleneck bridges are expected to be replaced to the new bridges until March 2023, with the aid by JICA. However, the remaining sections of the EWEC in Myanmar still need substantial improvement if they are to become part of a fully functioning transport corridor.



Source: Prepared by the JICA Survey Team based on the material obtained from ADB website

Figure 2.2.3 GMS East West Economic Corridor

Abovementioned, the East-West Corridor is a multiple corridor associated with Asian Highway No.1 (Tham - Mandalay - Napyitaw - Yangong - Payagi - Thaton - Myawaddy), GMS-EWEC (Mawlamyain - Myawaddy), GMS-WC (Mawlamyain - Bago - Naypyitaw - Tam), and Asean HW No.112 (Thaton - Dawei - Kotong). Especially, the section between Yangon and Myawaddy is also significant for trading between the southeast countries and west countries.

Source: ADB

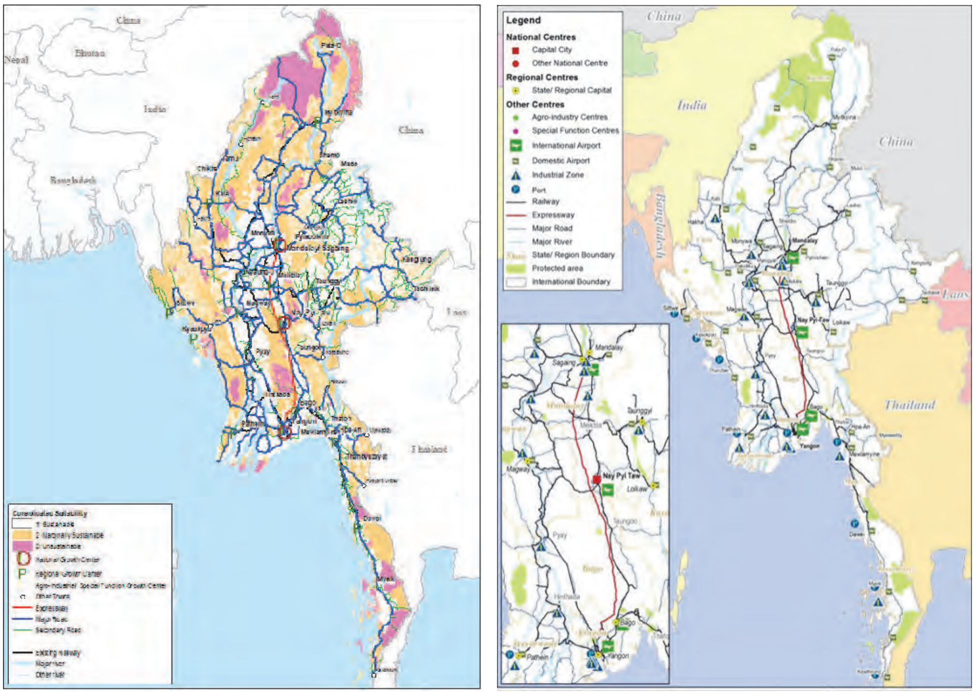
Figure 2.2.4 GMS Economic Corridor

(2) The Role of the EWC in Myanmar

The role of the East -West Corridor in Myanmar is stated in the previous JICA Study called the "National Transport Master Plan" prepared in September 2014 (hereinafter referred to "MYT-Plan"). The improvement of the East-West Corridor is expected to be completed during the time period between 2014 and 2020 in order to comprehensively enhance transport networks via aviation, roads, railways, ports, and inland waterways. The investments for those transport infrastructures are required to ensure the sustainable economic development of Myanmar.

Currently, there is no existing cross-sectoral transportation policy at the national level, across the government agencies of Ministry of Transport, Ministry of Railway, Ministry of Transport, and Ministry of Construction, etc. Each government agency is involved in the establishment of their own long-term development plans and projects list. However those plans and lists are prepared without quantitative analysis and priorities of the benefits generated by the infrastructure thus subject to the urgent establishment of a comprehensive national transport plan. In this context, the MYT-Plan launched the development plan for ten economic corridors connecting the regional hubs to form the axis of national transport networks. (Fig 2.2.5).

Among these corridors, the East-West Corridor connects the regional hubs such as Bago and Mawlamyine, etc., with the capital city of Yangon. Also, the linkages of the major land developments, such as Hanthawaddy New International Airport (Bago), special economic zone and port development plan (Dawei), industrial park development plan (Mawlamyine), etc. are expected to enhance economic activities along the corridor for which the priority is followed after the north-south corridor (Figure 2.2.5 A) between Yangon - Mandalay, provided in the second highest traffic demand (Figure 2.2.5 B).

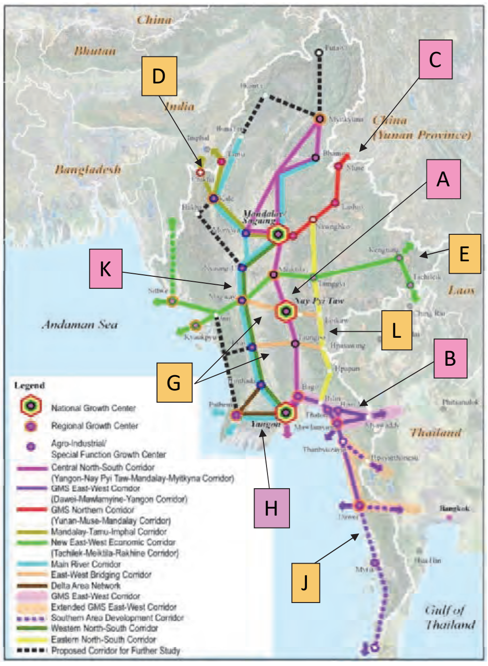


Source: The Survey Program for the National Transport Development Plan

Figure 2.2.5 National and Regional Growth Centres (Left) and Hubs for Land Development (Right)

Population and GDP

The population of beneficiaries along the EWC has nearly reached 28% of the national population and its density of economic activity is equivalent to 35% of the GDP in Myanmar. These figures are given as second highest following the North-South Corridor (NSC).



Source: The MYT Plan

Figure 2.2.6 Development Corridor

Cargo and Passenger Transportation

The cargo transport volume of the EWC, which is equivalent to 12% of the total cargo volume in Myanmar, is placed as the third highest volume following the highest given at the section between Yangon and Mandalay (45%), and second highest given at the section between Mandalay - Muse (13%) along the NSC (Fig 4 left). The number of passenger trips of the EWC is equivalent to 12% of the total number of passenger trips in Myanmar and is placed for the second largest following that of the NSC between Yangon - Mandalay (50%).

Traffic Demand and Capacity

The current infrastructure of the EWC is not provided with sufficient capacity to accommodate the undermentioned traffic volume which is being increased rapidly at present. There is also no redundancy and alternative corridor that incurs the highest congestion in the country (in giving congestion degrees 1.8 times at passenger car and 2.0 times at cargo), which is required as a high priority to improve the road network.

Development Corridor	Section	Code	2012 Population (,000)	% of National Population	2012 GRDP (Kyat billion)	% of National GDP
A. Central North-South Corridor	Yangon-Nay Pyi Taw	A1	11,714	41%	13,170	50%
	Nay Pyi Taw-Mandalay	A2	6,323		4,457	
	Mandalay - Myitkyina	A3	7,035		5,548	
B. East - West Corridor	Yangon - Hpa-An - Myawaddy	B1	14,052	28%	14,543	35%
	Mawlamyine - Dawei	B2	2,753		2,039	
C. Northern Corridor	Mandalay - Musa	C1	6,042	10%	4,503	10%
D. Mandalay - Tamu Corridor	Mandalay - Tamu	D1	3,722	14%	6,392	15%
E. Second East - West Corridor	Tachilek - Meiktila - Kyaukpyu	E1	10,636	17%	6,938	15%
G. East - West Bridging Corridor	Hpasawing - Pyay	G1	2,664	12%	1,727	11%
	Loikaw - Magway	G2	4,767		3,214	
H. Delta Area Network	Yangon - Pathein	H1	3,992	21%	10,076	27%
	Pathein - Hinthada	H2	3,766		2,551	
J. Southern Area Development Corridor	Thanbyuzayat - Hpayathonesu	J1	2,537	8%	1,182	8%
	Dawai - Thai Border	J2	811		781	
	Dawei - Kawthaung	J3	1,756		1,579	
K. Western North-South Corridor	Yangon - Pyay - Magway	K1	12,810	33%	14,388	42%
	Magway - Mandalay	K2	7,096		5,458	
L. Eastern North - South Corridor	Bilin - Loikaw	L1	3,896	12%	2,550	9%
	Loikaw - Nawnghko	L2	3,247		1,900	

Source: The Survey Program for the National Transport Development Plan

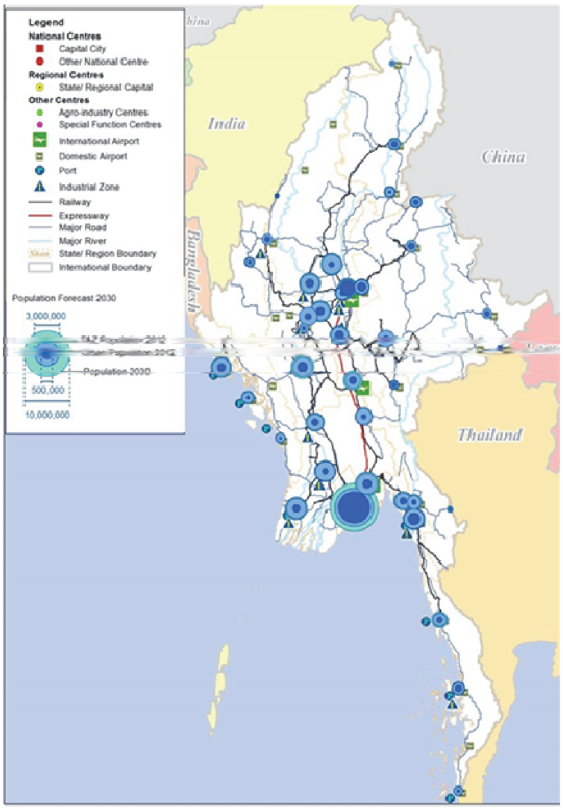


Figure 2.2.7 Population and GDP for Each Corridor (Left) and Future Population for National and Regional Growth Centers (Right)

Table 2.2.1 Cargo Transportation (Left) and Passenger Transportation (Right) for Each Corridor

Development Corridor	Section	Code	2013 Freight demand (million ton-km)	% of traffic demand along corridor	Modal Share (ton-km) in 2013		
					Road	Rail	River
A. Central North-South Corridor	Yangon-Nay Pyi Taw	A1	23.3	27%	93%	7%	0%
	Nay Pyi Taw- Mandalay	A2	15.4	18%	92%	8%	0%
	Mandalay - Myitkyna	A3	2.6	3%	67%	13%	20%
B. East - West Corridor	Yangon - Hpa-An - Myawaddy	B1	10.0	12%	95%	5%	0%
	Mawlamyine - Dawei	B2	0.4	0%	92%	8%	0%
C. Northern Corridor	Mandalay - Muse	C1	11.1	13%	98%	2%	0%
D. Mandalay - Tamu Corridor	Mandalay - Tamu	D1	1.4	2%	75%	7%	18%
E. Second East - West Corridor	Tachilek - Meiktila - Kyaukpyu	E1	2.4	3%	97%	3%	0%
G. East - West Bridging Corridor	Hpasawing - Pyay	G1	0.1	0%	100%	0%	0%
	Loikaw - Magway	G2	1.0	1%	100%	0%	0%
H. Delta Area Network	Yangon - Pathein	H1	1.4	2%	52%	0%	48%
	Pathein - Hinthada	H2	0.2	0%	97%	3%	0%
J. Southern Area Development Corridor	Thanbyuzayat - Hpayarthonesu	J1	0.0	0%	-	-	-
	Dawai - Thai Border	J2	0.0	0%	100%	0%	0%
	Dawei - Kawthaung	J3	0.1	0%	100%	0%	0%
K. Western North-South Corridor	Yangon - Pyay - Magway	K1	8.8	10%	61%	6%	33%
	Magway - Mandalay	K2	2.1	2%	12%	8%	80%
L. Eastern North - South Corridor	Bilin - Loikaw	L1	0.2	0%	100%	0%	0%
	Loikaw - Nawnghko	L2	0.1	0%	97%	3%	0%

Development Corridor	Section	Code	2013 Traffic demand (million person-km)	% of traffic demand along corridor	Modal Share				
					Air	Car	IWT	Rail	Bus
A. Central North-South Corridor	Yangon-Nay Pyi Taw	A1	21.6	30%	1%	13%	0%	6%	80%
	Nay Pyi Taw- Mandalay	A2	14.4	20%	0%	15%	0%	14%	70%
	Mandalay - Myitkyna	A3	6.8	5%	8%	10%	10%	60%	13%
B. East - West Corridor	Yangon - Hpa-An - Myawaddy	B1	7.8	12%	0%	23%	0%	14%	64%
	Mawlamyine - Dawei	B2	0.5	1%	0%	22%	0%	10%	68%
C. Northern Corridor	Mandalay - Muse	C1	4.0	5%	0%	41%	0%	21%	38%
D. Mandalay - Tamu Corridor	Mandalay - Tamu	D1	1.9	4%	2%	22%	0%	11%	65%
E. Second East - West Corridor	Tachilek - Meiktila - Kyaukpyu	E1	4.1	6%	5%	26%	0%	10%	58%
G. East - West Bridging Corridor	Hpasawing - Pyay	G1	0.0	0%	0%	0%	0%	0%	100%
	Loikaw - Magway	G2	2.1	0%	17%	0%	0%	46%	37%
H. Delta Area Network	Yangon - Pathein	H1	3.9	5%	1%	24%	14%	0%	61%
	Pathein - Hinthada	H2	0.6	1%	0%	24%	0%	17%	59%
J. Southern Area Development Corridor	Thanbyuzayat - Hpayarthonesu	J1	0.0	0%	0%	100%	0%	0%	0%
	Dawai - Thai Border	J2	0.0	0%	0%	46%	0%	0%	54%
	Dawei - Kawthaung	J3	0.9	1%	87%	9%	0%	0%	4%
K. Western North-South Corridor	Yangon - Pyay - Magway	K1	6.2	5%	0%	22%	0%	23%	55%
	Magway - Mandalay	K2	1.8	2%	1%	9%	0%	45%	45%
L. Eastern North - South Corridor	Bilin - Loikaw	L1	0.0	0%	0%	0%	0%	0%	100%
	Loikaw - Nawnghko	L2	0.2	0%	0%	17%	0%	79%	4%

Source: The Survey Program for the National Transport Development Plan

Accordingly, the East–West Corridor is recognized as a significant corridor to support the logistics for the development of the country's economy followed by the NSEC. The infrastructure of the East–West Corridor should be improved according to the development plan based on the development strategies as follows:

Development Strategies

- Improvement of connectivity between Myanmar and Thailand (in expediting trade via land transport)
- Contribution to the industrial development along the offshore region between Yangon and Mawlamyine
- Secure connectivity between the East–West Corridor and new traffic nodes (Hanthawaddy airport, etc.) between
- Efficient usage of existing transport facilities
- Supply of a reliable transport system for freight services

Development Plan

- Widening and improvement of road facilities along the current corridor network
- Construction of bypasses for shortening travelling time without passing through the major cities
- Improvement of crossing facilities to meet the current traffic load
- Provision of roadside stations which contribute to community development
- Provision of one-stop services to facilitate the border crossing between Myanmar and Thailand

2.2.2 Current Condition on the East – West Corridor

In this section, the current condition and road development plan in the Southeastern Myanmar including Bago region are described.

(1) Bago (Yangon-Mandalay Expressway Entrance) – Thaton Section

Shwe Than Lwin Highway Co., Ltd is currently involved in the operation and maintenance for the road section under the BOT contract. It is observed that the road surface in a two-lane asphalt pavement is kept in a relatively good condition. In recent days, the soft shoulder has been gradually changed to asphalt concrete that contributes to road safety improvement (Photo-3). However, heavy vehicles (large freight cargo) (Photo-1) are travelling through the urban area which is a concern causing chronic congestion and degradation of road safety in the future.

Meanwhile, there are so many existing houses and commercial facilities on the roadside. Thus, a large number of resettlements is predicted when widening the road over the limited ROW. Particularly, Thaton, which has about 35 million people, which is the second highest population in the southeast region, is a confluence of major roads such as AH1 and AH112. It is therefore obvious for social issues to appear such as increased congestion and accidents along with the growth in traffic demand. It is therefore expected to implement the project for construction of Kyargalay Bypass proposed in the Phase-I survey as soon as possible in order to bypass Thaton.

Photo-1 Road Condition at Bago

Photo-2 Road Condition on Bago – Payagyi Section

Photo-3 Road Condition on Payagyi – Thaton Section (near Payagyi)

Photo-4 Road Condition at Waw

Photo-5 Road Condition at Kyaito

Photo-6 Road Condition at Thaton

Source: JICA Survey Team

Figure 2.2.8 Current Situation on Bago (Yangon-Mandalay Expressway Entrance) – Thaton Section

(2) Thaton – Myawaddy Section

Of this section, the Thaton - Eindu section is maintained by BOT (Shwe Than Lwin Highway Co., Ltd) and the other section is controlled by the MOC. Currently, the road surface of a two-lane machadam paved road (soft shoulder) is kept in relatively good condition. In town areas, such as Eindu and Kawkareik, some roadside houses and local shops invade the road area over the boundary of ROW while other sections have been basically ensured. In August 2015, the bypass of Donna mountain range was completed by the support of the Thai government. The road was most the difficult mountainous section along GMS-EWEC and required an unavoidable one-sided traffic every other day. Now the complete two lane road allows mutual traffic flows at around 40km in length that dramatically improved the traffic conditions for this section.

Meanwhile, the new bypass is a full 10m width two-lane AC road with a design speed of 50km/h. However, there are some sections where passing through the mountainous area which cannot meet the ASEAN highway road design criteria. The longitudinal gradient are given more than 12% and successively smaller radius of S curves are applied while some warning boards and reminder signs are installed to warn the driver for safety along the road (Photo-12). The Survey Team observed an accident with the vehicle left on the roadside by its driver during the field survey. For the traffic demand to increase in the future and to ensure the traffic safety, improvements should be considered, such as improvement on road alignment which are subsequently required.

In addition, Gyang-Kawkareik Bridge, which is located on the west side of Kawkareik town (Photo-9), has insufficient structural capacity thus the operation of the bridge has been restricted with the weight limit of traffic up to 24t (as of January 2016). Large vehicles with the gross weight of more than 24t is thereby forced to divert for crossing the river via the temporary pontoon bridge located on the upstream side (Photo-10). This bottleneck of bridges will be replaced by the support of Japan ODA until March 2021. On the other hand, for the section between Eindu and Kawkareik, the road improvement project will be conducted until March 2019 by the financial support of ADB. By the completion of these projects, the section between Eindu - Kawkareik will be improved for completely asphalt paved roads.

Photo-7 Road Condition on Thaton – Eindu Section

Photo-8 Road Condition on Eindu – Kawkareik Section

Photo-9 Gyaing Kawkareik Bridge (Existing)

Photo-10 Pontoon Bridge

Photo-11 Kawkareik – Thin Gan Nyi Naung Bypass

Photo-12 Kawkareik – Thin Gan Nyi Naung Bypass

Photo-13 An Accident Truck Left on the Roadseide

Source: JICA Survey Team

Figure 2.2.9 Current Situation on Thaton –Myawaddy Section

(3) Eindu – Mawlamyine, Hpa-an – Mawlamyine Section

As for this section, the operation and maintenance is currently carried out under BOT contract (AyeKo Family (AK) company) (except the bridges). The road is a one half to two lanes width macadam paved road and is being currently upgraded to two lanes without a paved shoulder at the section between Zathapyin and Eindu (Photo-18, as of January 2016). Both the Gyaing/Zathapyin Brdige and Atran Bridge have an insufficient structural capacity, and are thereby restricted for carrying traffic loads up to 20t and the traffic consisting of more than the weight of 20t are diverted to the road via Hpa-an and Thaton. The replacement of these bottleneck bridges will be conducted by the support of Japan ODA and its completion is expected in March 2021. Moreover, the Kyargalay bypass, which was proposed to be utmost shortened travelling distance to Mawlamyaing at the original end point of GMS EWEC passing through the section between Kyagaly and Zathpyin in the Phase-1 of this study, is expected to realize the implementation as soon as possible.

Photo-14 Atran (AT) Bridge

Photo-15 AT Road Condition on AT Bridge-GZ Bridge

Photo-16 Gyaing Zathapyin (GZ) Bridge

Photo-17 Branch Point for Hpa-an or Eindu

Photo-18 Road Condition on Zathapyin – Eindu Section

Photo-19 Road Condition on Zathapyin – Hpa-an

Source: JICA Survey Team

Figure 2.2.10 Current Situation on Eindu-Mawlamyine and Hpa-an-Mawlamyine Section

(4) Thaton – Mawlamyine – Dawei Section

Among these sections, the road between Thaton and Thanbyuzayat is maintained by the BOT contract (Shwe Than Lwin Highway Co.Ltd) and the maintenance of other sections are controlled by the MOC. Currently, the section between Thaton and Thanbyuzayat is improved with a two lanes macadam paved road (but partially upgraded to hot mix asphalt concrete pavement) and the road surface is kept in a relatively good condition. The section to the south also progresses with asphalt paving other than approximately 10km mountainous section from Ye and is secured at one half to two lanes width. As undermentioned, while the development of the Dawei special economic zone is still ongoing, it will be not required to upgrade the pavement from the current macadam surface because the traffic condition is assumed not to drastically be changed.

Photo-20 Road Condition on Thaton - Mawlamyine

Photo-21 Road Condition on Mawlamyine - Thanbyuzayat

Photo-22 Thanbyuzayat- Ye

Photo-23Ye - Dawei

Source: JICA Survey Team

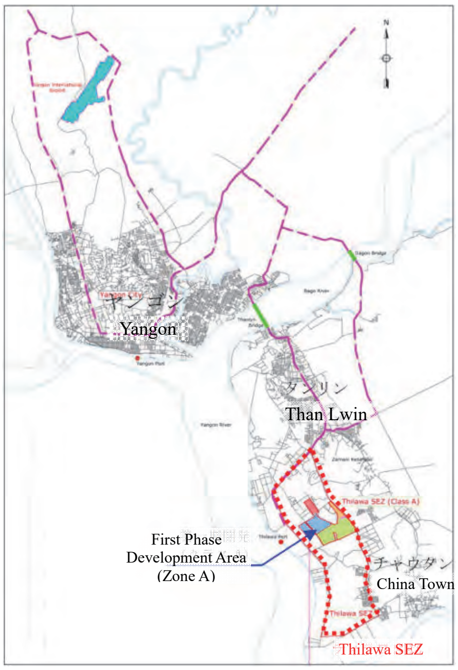
Figure 2.2.11 Current Situation on Thaton – Mawlamyine – Dawei

2.2.3 Related Development Plans

In this section, the outline and the progress of other development projects related to the project are summarized for justification of the necessity and appropriateness for the formulation of the project.

(1) Thilawa Special Economic Zone (SEZ) Development Plan

Myanmar has achieved dramatic economic development, and the Thilawa SEZ is expected to be a major trade and industrial centre to support both the national and international logistics. The SEZ is located about 23km from Yangon city centre, out of 2,400 ha, 400ha (A zone) has been developed by domestic and foreign investment. The operation opened in September 2015 and other infrastructures are currently being constructed by the assistance of Japan ODA. According to the JICA Study Report "Preparatory survey on Yangon port in Thilawa area and logistics depot development in the Republic of the union of Myanmar ", the total freight volume of the Thilawa SEZ in 2025 is estimated to be approximately 2.86 million tons per year and those supplies will be distributed across the country from Yangon.

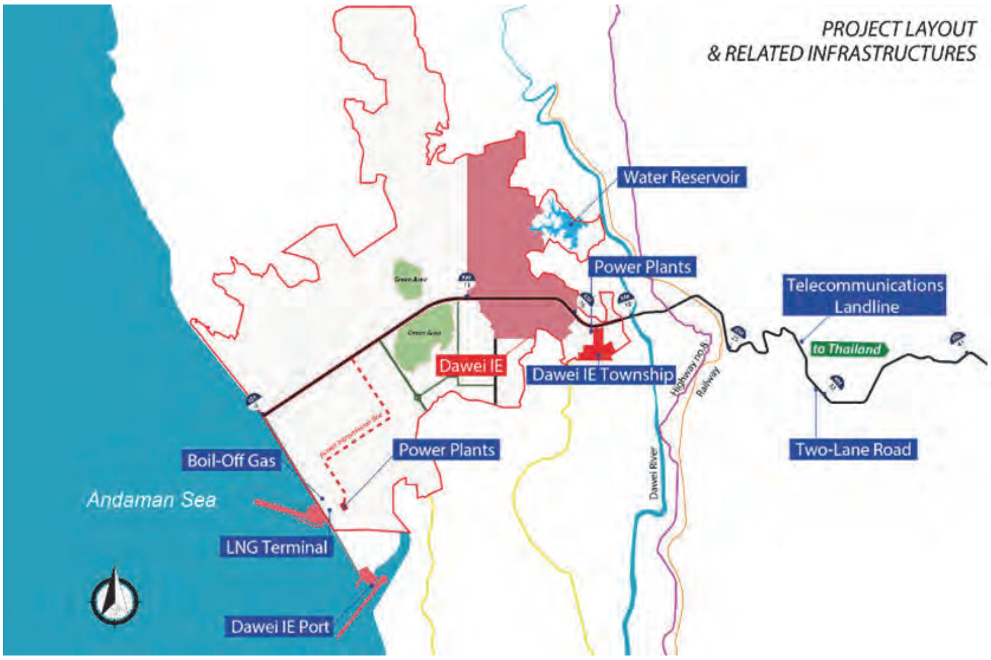


Source: The Preparatory Survey for the Project for Development of Infrastructure for Thilawa Special Economic Zone

Figure 2.2.12 Location of Thilawa SEZ

(2) Dawei Special Economic Zone (SEZ) Development Plan

Along with the development of Thilawa SEZ, Dawei SEZ is also expected as being major trade and economic centre to support the economic growth of Myanmar. The development plan of Dawei SEZ including the Dawei deep-sea port was initiated by Italian-Thai Development (ITD) under the BOT scheme since 2010. However, the operation of BOT scheme was entrapped and undergone due to financial shortage. Afterwards, in order to expedite the implementation of project, the special purpose entities (SPC) in which both the governments of Myanmar and Thailand were associated together, set up and held a main stake for the joint implementation in 2013. In August 2014, the bidding of the initial phase of construction was announced by the Dawei SEZ Management Committee and the ITD company consortium has got the order of construction work. On the other hand, in October 2015, with the support of the Economic Development Cooperation Agency (NEDA), Thailand, Roland Berger, Inc. produced a master plan for Dawei SEZ development. According to the plan, the initial phase (2015-2020) comprises nine sub-projects as given in Figure 2.2.13. The second phase (2020-2025) comprises the sub-projects including the construction of a four-lane paved road connecting between Thailand and the SEZ and the deep sea port. By its successful completion, the operation of these infrastructures will contribute to boost the local economy in even more expecting the activation of the economy of the south eastern region of the country. However, influence by the development plan is uncertain since the initial phase of construction is behind the schedule.



Source: http://www.daweiindustrialestate.com/

Figure 2.2.13 Dawei SEZ Development Plan (Initial Phase)

(3) Bago Industrial Park Plan

In Myanmar, there are the existing or scheduled 22 industrial areas in the whole country in addition to the four areas in Yangon region. Among these, a project, which is to develop an industrial park of more than 400 acres in the suburb of Bago city (which is called the "i-Land project"), has been initiated by private investment. In the Bago industrial area, the area will be developed with necessary infrastructures including a stable power supply system and capable water supply, central sewage treatment facilities and communication network. In addition to these basic infrastructure, the facilities including restaurants, food court, supermarket, accommodation and residential facilities, 24 hours medical care system in 365 days a year, all days security patrol, police station, fire station, gas station, bank with ATM, community centre, meeting facilities, job placement offices, vocational training centres, cargo delivery service, import and export customs clearance services start-up support, governmental services of business license and employment VISA, etc., and various services such as supporting applications for work permits, will be provided.

In the case of the investment for the establishment of manufacturing business in the area, according to the foreign capital investment law, the various privileges and preferable treatments including a five-year tax exemption, exemption of import duties in accordance with, such as raw materials and manufacturing equipment, tax-free up to 50% of export earnings, beneficial short term depreciation and amortization will be provided in the industrial area. As such, a large European beer factory, etc. has started operation in advance. In February 2016, a soft opening was already launched in the aim of full-scale operation in the near future.

In fact, the Bago region is located within a 100km distance of Yangon and has about 4.9 million people corresponding to 9.45% (sixth place) of total the population of Myanmar. Thus, it is advantageous for the procurement of reasonable labour forces compared with other neighbouring countries. These conditions are so attractive for foreign firms as to intimate higher interest for further development of this region in the future.

Source: http://www.i-landmyanmar.com

Figure 2.2.14 Bago Industrial Park Development Plan Implemented by Private Firms

(4) Development Plan for New Hanthawaddy International Airport

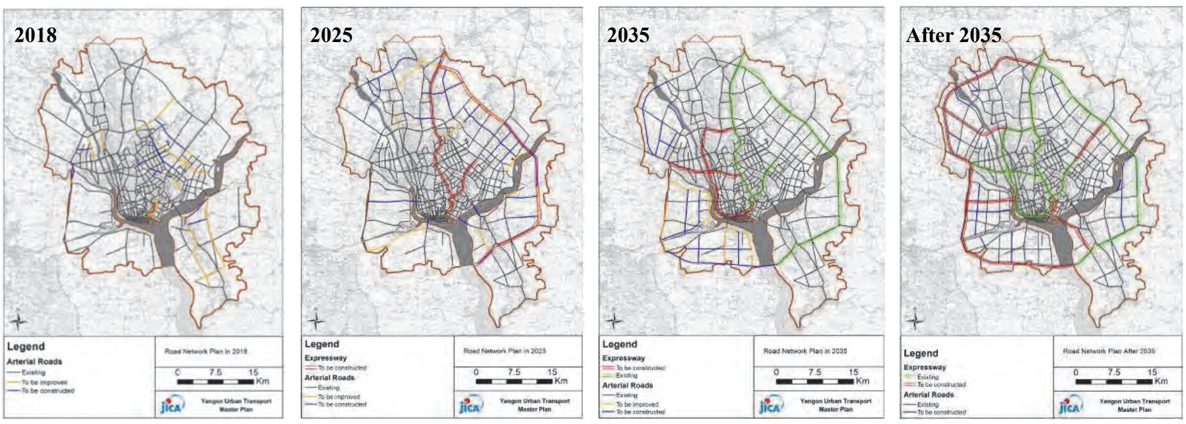
The construction of New Hanthawaddy International Airport which is located about 70km north west of Yangon is scheduled in the Bago region. It is expected to play a role as a new international airport to replace with the current Yangon International Airport. In October 2014, three consortium firms have established a special purpose company (SPC) and obtained a concession license from the Civil Aviation Authority (DCA) in Myanmar. The new airport is expected to start its operation through a PPP scheme from the target year of 2022. According to the preparatory survey undertaken by JICA, the annual number of passengers in 2025 is estimated at about 11 million people at the opening of airport and also estimated at about 53 million people in 2050. It is predicted that most of the passenger demand will be derived from the Yangon area. Thus, the development of infrastructure such as roads and a railway network via high-speed access linking between the Yangon area and the airport is essential.

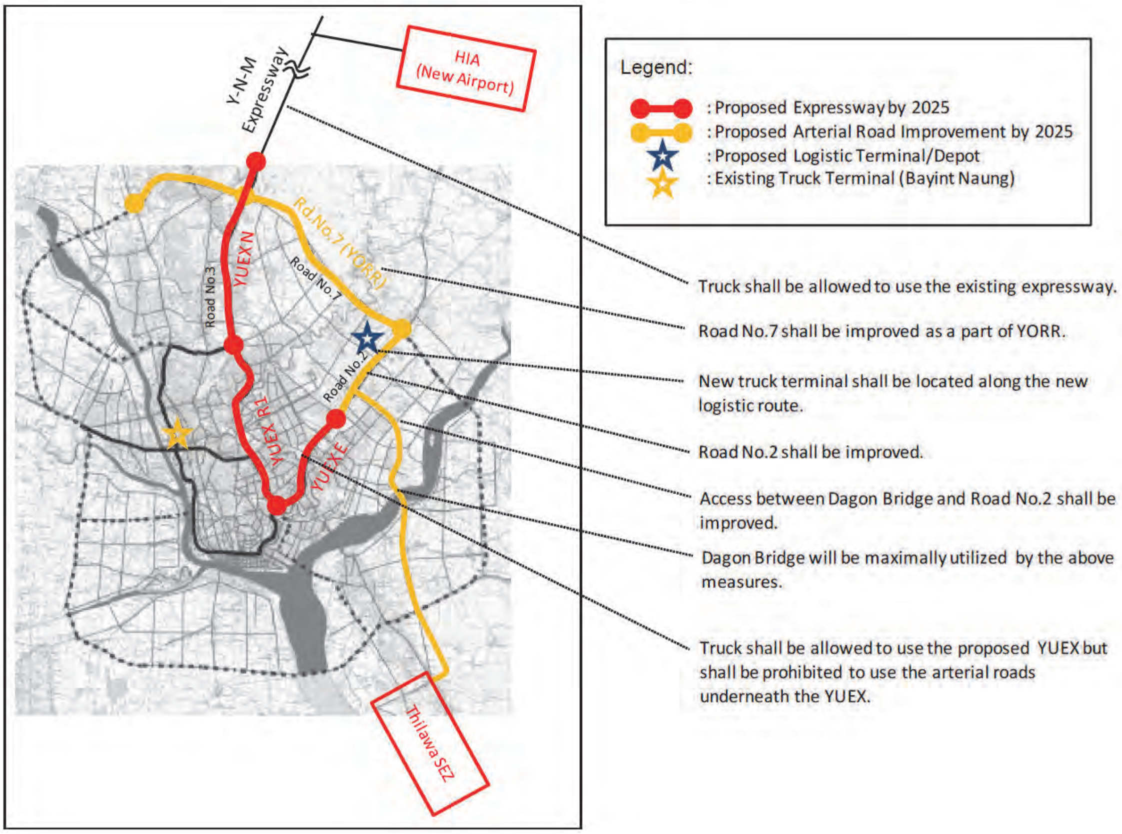
Source: Preparatory Survey on Myanmar Hanthawaddy International Airport Project

Figure 2.2.15 Project Location of New Hanthawaddy International Airport

(5) Yangon Urban Expressway Plan (YUEX)

For rapidly increased traffic demand in the Yangon area, it is proposed to build a reliable road network under the JICA Study of "Project for comprehensive urban transport plan of the greater Yangon (YUTRA)". YUTRA suggests the phasing development of urban expressway ring roads (inner and outer ring) necessary to transit the traffic on radial roads by connecting with each other. Of the phasing development, the construction of the inner ring road (East) is required in the midterm plan for its realization by the target year of 2025. The ring road (East) will be a major economic corridor linking between Myanmar Nay Pyi Taw, Mandalay, the Yangon centre and the Thilawa SEZ which will be a vital hub for the economy of the Yangon area. Thus, several studies on the related projects for inner ring road (East) have been conducted upon the urgency recommended by YUTRA.

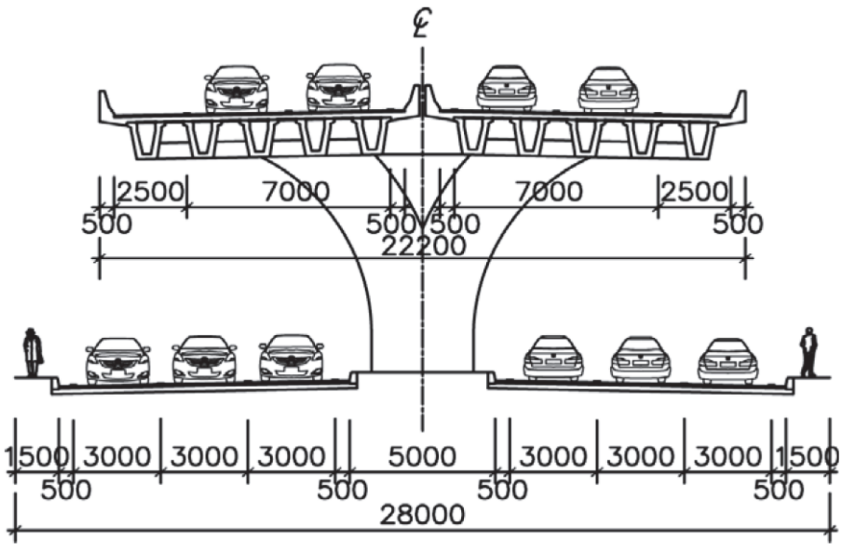




Source: The Project for the Strategic Urban Development Plan of the Greater Yangon

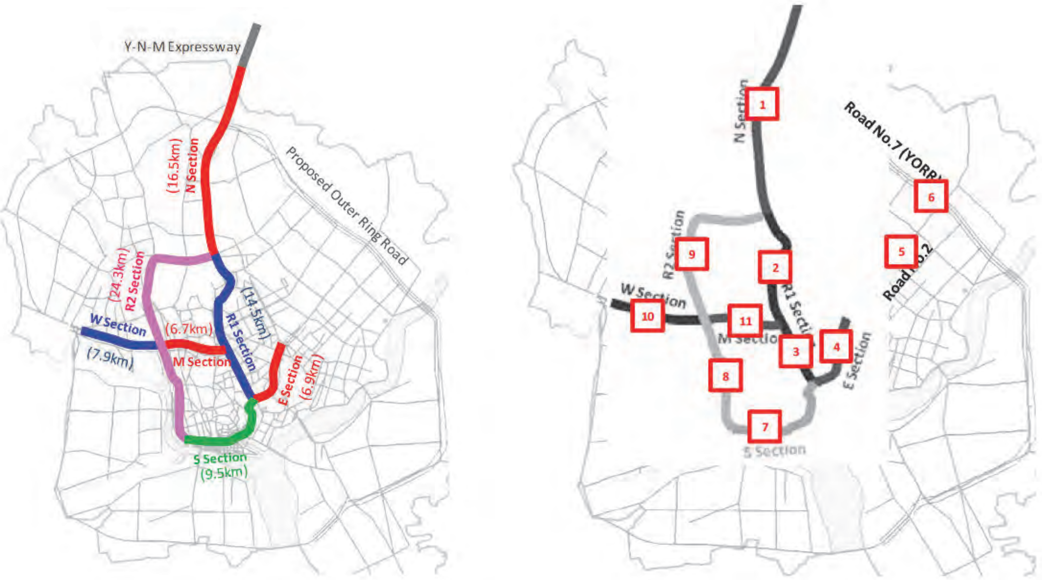
Figure 2.2.16 Location Map of Yangon Urban Expressway (Inner Ring Road)

The inner ring road is proposed to be an elevated road structure (viaduct) in order to pass through the densely populated Yangon city. As given in Figure 2.2.17, the expressway is elevated and the aerial highway is at grade in the land. The number of lanes is shown in Figure 2.2.18. The Project cost is estimated to be about 48 billion yen according to the study report.



Source: The Data Collection Survey on the Project for Construction of Yangon Urban Expressway (YUEX)

Figure 2.2.17 Typical Cross Section for YUEX (Viaduct Section)



Type of Roads	Required Number of Lanes (both dir.) at YUEX sections										
	1	2	3	4	5	6	7	8	9	10	11
Expressway	4	4	2	2	0	0	2	3	2	2	3
Arterial	2	4	3	4	2	2	2	2	4	4	3

Source: The Data Collection Survey on the Project for Construction of Yangon Urban Expressway (YUEX)

Figure 2.2.18 Number of Lanes on YUEX (Inner Ring Road)

2.2.4 Traffic Demand Forecast

The future traffic demand estimated for East-West Corridor given is summarized in Table 2.2.2. The traffic demand of the East-West Corridor is predicted to increase dramatically by its road improvements and surrounding development plan, along with the projects for the improvement of GMS- EWEC. Meanwhile, by its improvement of the roads, it would be a concern for traffic congestion and would significantly increase the risk of traffic safety. Especially, the concern tends to be remarkable at Thaton where the traffic from the Thai border merges with the traffic from the south of Myanmar, about thirteen times the traffic demand will be increased from the current situation in 2035 after about 20 years that will be incurred largely over the current traffic capacity.

Table 2.2.2 Traffic Demand Forecast on the EWC and Required Number of Lanes

Traffic Demand Forecast	2014 (PCU)	2025(PCU)	2035(PCU)	Required No. Lanes ( ) Current No. Lanes
Y-M Exp. connect - Bago	N/A	44,400-52,700	127,200-147,200	10 (4-6)
Bago - Payagyi	N/A	37,300	118,900	8 (2-4)
Payagyi-Thaton	5,800	14,400-33,400	52,900-79,900	6 (2)
Thaton -Mawlamyine	4,000	11,900	36,000-52,900	4 (2)
Thaton -Myawaddy	3,400	4,500-7,900	10,000 - 28,400	2 (2)
Mawlamyine - Dawei	1,000	2,800-5,500	6,900-11,500	2 (1.5-2)

Source: JICA Survey Team

2.3 Key Subjects and Necessity/ Appropriateness of the Project

2.3.1 Key Subjects for the Improvement of East – West Corridor

In consideration of the traffic demand, current road conditions and the related development plans along the East–West Corridor as described in the previous sections, the East–West Corridor will connect the Yangon region with Thailand and other trade centres and commercial hubs which strengthen the tie between the domestic markets of Myanmar and other asian regions. In this context, the role of the East–West Corridor will be more enhanced as a major logistics corridor. Under such circumstances, the following key subjects are identified.

Subject-1 Ensuring the redundancy (sustainability)

In order to realize a "safe and reliable transport network and services focus on the country logistics" of which is proposed in the development strategy for the East–West Corridor in the MYT-Plan, it is highly required to ensure the redundancy (substitutability) of the road network. Redundancy is the means not only to reduce traffic congestion but also provide an alternative function to divert the traffic for alleviating/reducing the social disruption and economic loss in emergency events caused by natural disasters or serious accidents. The Yangon - Mandalay Expressway consists of the north-south corridor that has already provided an alternative route for the national road (Yangon - Mandalay road). However, the East–West Corridor has very few sections having alternative routes. Particularly, the section between Bago and Thaton where the traffic is highly concentrated is meaningfully required for redundancy on the East–West Corridor.

Subject-2 Improvement of connectivity between Myanmar and Thailand

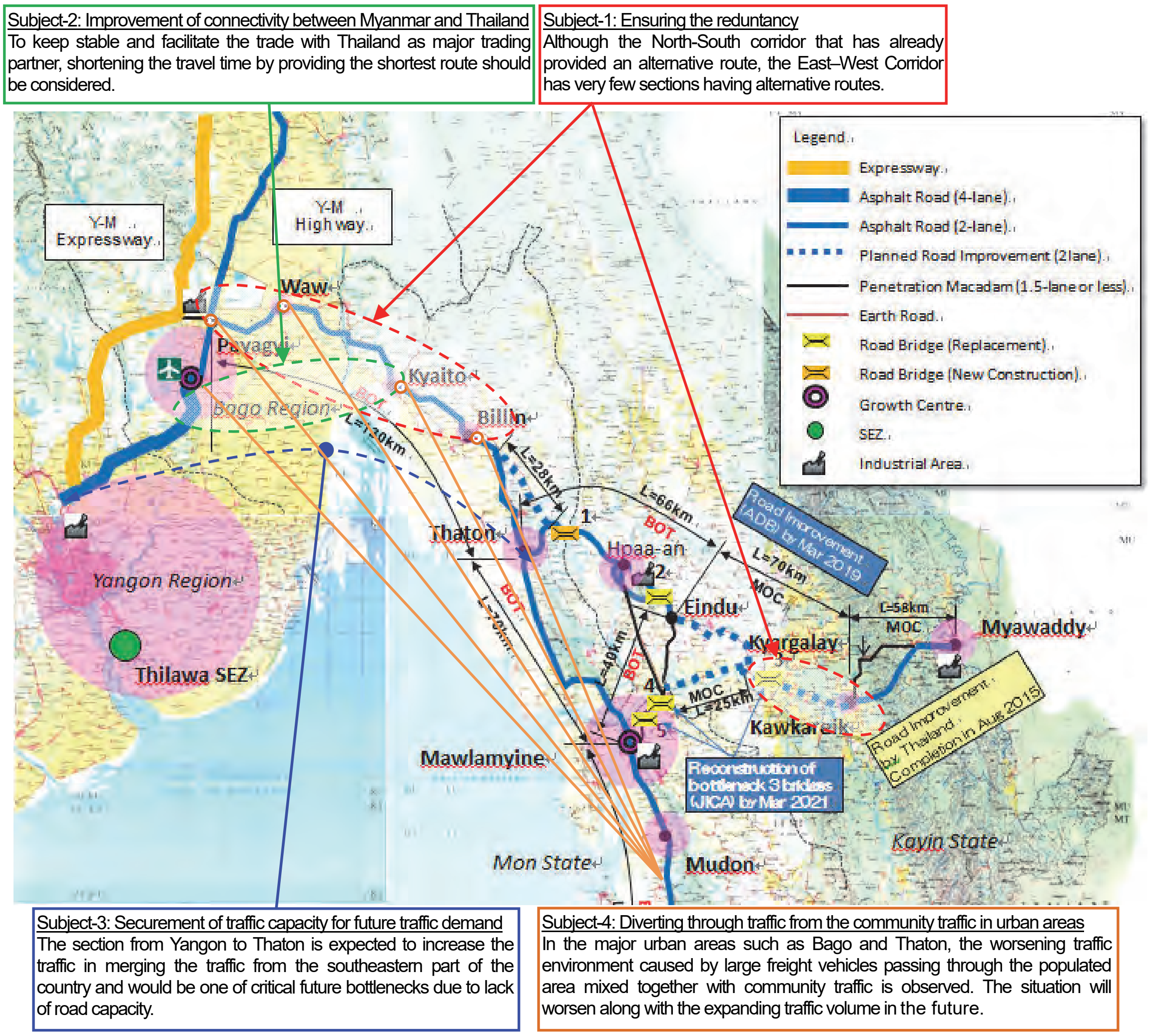
"The improvement of connectivity between Myanmar and Thailand", which is the one of the development strategies of the East-West Corridor proposed in the MYT-Plan, is an essential term to keep stable and facilitate the trade with Thailand as major trading partner. To do so, to shortening the travel time by providing the shortest route should be considered, in addition to the increase of traffic capacity for the existing road to alleviate the congestion and avoid lowering the travel speed.

Subject-3 Securement of traffic capacity for future traffic demand

As mentioned in 2.2.4, the East-West Corridor has not reserved sufficient traffic capacity between Mawlamyine and Yangon to accommodate the future traffic demand. For the section between Thaton and Myawaddy as a part of the GMS EWEC, it has specifically initiated road improvements corresponding to the future traffic demand by the support of international organizations, however other sections of the East-West Corridor are not scheduled yet due to the conflict with the BOT contract. The section from Yangon to Thaton is expected to increase the traffic in merging the traffic from the southeastern part of the country and would be one of critical future bottlenecks due to lack of road capacity. Accordingly its improvement is highly required.

Subject-4 Diverting through traffic from the community traffic in urban areas

In the major urban areas such as Bago and Thaton, the worsening traffic environment caused by large freight vehicles passing through the populated area mixed together with community traffic is observed. The situation will worsen along with the expanding traffic volume in the future. It is necessary to construct the bypass to divert the large freight vehicles to prevent them from passing through the populated areas. That will be a measure to ideally improve the traffic environment in these areas. Particularly, it should be considered to improve the section between Thaton and Bago taking into account the rapidly increase of traffic volume in the near future.



Source: JICA Survey Team

Figure 2.3.1 Key Subjects for the Improvement of East – West Corridor

2.3.2 Necessity/ Appropriateness of the Project

As described above, taken into account the current status, the future development and other relevant plans along with the East-West Corridor, 1) ensuring redundancy (substitutability), 2) improvement of connectivity between Myanmar and Thailand, 3) secure traffic capacity for the future traffic demand, and 4) improvement of traffic safety by separating the through traffic from community traffic in urban areas should be the key subjects to future challenges. As described in Figure 2.3.1, the future traffic is predicted to merge between Thaton and Bago, connecting Yangon central region and southeastern part of Myanmar, and urgent countermeasure is highly required. And it could be considered for the means to solve all these subjects with its achievements via; "improvement of National Highway No.1 (Yangon-Mandalay road)," and "construction of New Bago – Kyaito Road". Table 2.3.1 and Table 2.3.2 show the effect to be expected by those achievements and Table 2.3.3. shows the preliminary study on route justification for the section between Bago and Kyaito. The East-West Corridor is an international highway as well as a crucial logistics road to support the economic development of Myanmar.

In this context, the implementation of these projects will be able to avoid the future critical bottlenecks and to provide an integral connectivity via shortest way by high speed travelling between Yangon, the largest economy in Myanmar, the new transport hub (New Hanthawaddy

International Airport) and Thailand, a major trading partner. Also, the road section will formulate a safe and reliable road network by providing alternative routes (substitutability). It will contribute to promote roadside development and also is expected to have the secondary effect of creating employment opportunity by activating the regional economy. These are well synchronized in conformity with the development strategy of the East-West Corridor under the MYT-Plan; “improvement of connectivity between Yangon and Thailand (land freight transport)", "contribution to the industrial development for the coastal regions extended between Yangon and Mawlamyine", “New connectivity with new transport hub (Hanthawaddy International Airport, etc.)", "provision of safe and reliable transport network/services focused on cargo", thus indicates a physically viability and necessity.

Table 2.3.1 Expected Project Effect (New Bago – Kyaito Road)

Key Subjects	Expected Project Effect						
1) Redundancy	Secured by the Completion of the Project						
2) Improvement of Connectivity between Myanmar and Thailand	2014	2027 (2nd year after the completion)			2035		
	Without	Without	With		Without	With	
	Existing	Existing	Existing	New Rd.	Existing	Existing	New Rd.
Ave. Travel Time (hr)*1	2.0	4.5	2.7 (-1.8)	1.1 (-3.4)	8.2*3	4.0 (-4.2)	1.6 (-6.6)
Ave. Travel Speed (km/h)*2	52.4	23.6	39.5	63.5	12.9	26.0	44.3
Congestion Factor (V/C)*4	0.28	1.54	0.58	0.46	3.93	1.35	0.99
3) Road Capacity	2-Lane	2-Lane	2-Lane	4-Lane	2-Lane	2-Lane	4-Lane
			6-Lane (Total)			6-Lane (Total)	
4) Traffic Safety	Accident risk :High	Improved by separation of through traffic and local traffic					

*1 The average travel time is calculated by the average travel speed and the section length
*2 The average travel speed (km/h) in traffic analysis model is utilized
*3 At the peak time in 2035, travel time would be 17.5 hour
*4 Traffic Volume (V) is divided by Traffic Capacity (C)
Source: JICA Survey Team

Table 2.3.2 Expected Project Effect (Improvement of NH1)

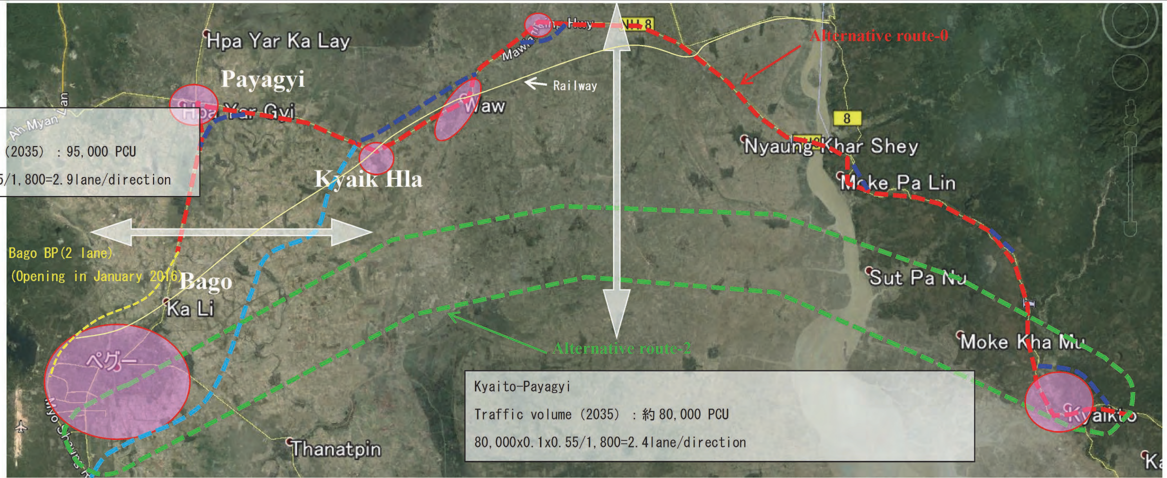
Key Subjects	Expected Project Effect						
1) Redundancy	Already Secured by Y-M Expressway						
2) Improvement of Connectivity between Myanmar and Thailand	2014	2027 (1st year after the completion)			2035		
	Without	Without	With		Without	With	
	NH1 (Sub-Arterial)	NH1 (Sub-Arterial)	NH1		NH1 (Sub-Arterial)	NH1	
			(Sub-Arterial)	(Expressway)		(Sub-Arterial)	(Expressway)
Ave. Travel Time (hr) *1	0.6	1.0	0.7 (-0.3)	0.6 (-0.4)	1.8	0.9 (-0.9)	0.9 (-0.9)
Ave. Travel Speed (km/h) *2	56.6	37.0	53.3	60.4	19.9	40.7	39.5
Congestion Factor (V/C)*3	0.12	0.94	0.28	0.60	1.94	0.71	1.14
3) Road Capacity	4-Lane	4-Lane	4-Lane	4-Lane	4-Lane	4-Lane	4-Lane
			8-Lane (Total)			8-Lane (Total)	
4) Traffic Safety	Accident risk :High	Improved by separation of through traffic and local traffic					

*1 The average travel time is calculated by the average travel speed and the section length
*2 The average travel speed (km/h) is based on the traffic analysis model for traffic demand forecast
*3 At the peak time in 2035, travel time would be 17.5 hour
Source: JICA Survey Team

Table 2.3.3 Preliminary Route Justification of Bago-Kyaito Section

	Alternative route -0	Alternative route -1, route -1'	Alternative route-2
Alternative	Widening of existing NH-8 to 4 lanes(Bago-Payagyi: 6 lanes) Length: 86.3km	Widening of existing NH-8 to 4 lanes(Bago-Payagyi: 6 lanes) and development of BP for town area Route -1:Widening: 54.4 km, BP: 27.6km Route -1': Widening: 37.6 km, BP: 54.4km	Development of 4 lane road connecting between Kyaito – Bago shortly Length: 71 km

Map



	Alternative route -0	Alternative route -1, route -1'	Alternative route-2
Road Safety	－ Risk of traffic accident is high, since existing road does not satisfy geological criteria on horizontal curve － There is a possibility of significant reduction of traffic safety by a mix of the increased regional traffic and inter regional heavy traffic	－ Low speed operation due to applying deign speed 60 km/h of rolling terrain although the geometric criteria is satisfied ＋ Reduction of traffic safety due to increase of traffic volume can be reduced because of separation between regional traffic and inter regional heavy traffic by construction of BP	＋ Traffic safety is high because design criteria of design speed 80 km/h are satisfied ＋＋Reduction of traffic safety due to increase of traffic volume can be reduced because of separation between regional traffic and inter regional heavy traffic by construction of BP
Redundancy	－ Capacity of alternative route is limited in case of unusable road due to traffic accident and disaster	＋ Capacity of alternative route is limited (only BP section) in case of unusable road due to traffic accident and disaster	＋＋it can reduce social and economic loss because alternative route of existing national road can be utilized in case of unusable road due to traffic accident and disaster
Shortening of Travel Time (Bago – Kyaito)	－ No shortening：3.4 hours (travel speed 28-33 km/h)	－ Route-1: 3.3 hours, 0.1 hours shortening(travel speed 28-33km/h) ＋ Route-1':2.8 hours, 0.7 hours shortening(travel speed 28-33km/h)	＋＋1.7 hours, 1.8 shortening (travel speed 42km/h)
Impact on Development and Local Community	－ Almost same as current condition	－ Almost same as current condition	＋ Income increase for former can be expected because of Improvement of accessibility from local area to urban are ＋ creation of regional employment and economic impact is expected with acceleration of roadside development
Impact on Environmental and Resettlement	－ Large impact of resettlement in Urban area and city － Large impact to around area during construction due to noise, vibration and traffic restriction	＋ Low impact of resettlement in urban area and city by construction of BP, some impact along existing road	＋＋Lowest impact on resettlement because of construction of BP to avoid to pass urban/town area － Large scale of land acquisition of paddy field and plantation area is required
Project Cost	Road: 86.3km×0.3 billion Yen/km=26 billion Yen Bridge: 6 billion Yen Total: approximately 32 billion Yen (1.00)	Road 54.4km×0.3billion Yen/km=16 billion Yen、27.6km×0.5 billion Yen/km=14 billion Yen Bridge 6 billion Yen Total: Route-1 approximately 36 billion Yen(1.13), Route-1' approximately 44 billion Yen(1.38)	Road：71km×0.5 billion Yen/km=35 billion Yen Bridge: 21 billion Yen Total: approximately 56 billion Yen(1.75)
Evaluation	Although project cost is lowest, social impact is high and redundancy is not enough as a main logistic road	Although project cost is moderate, redundancy and effect of shortening travel time is limited	**(Recommended)** Social impact due to construction is lowest and redundancy as a main logistic road and impact of roadside development, economic impact of shortening travel time are expected.

Source: JICA Survey Team

CHAPTER 3 TRAFFIC DEMAND FORECAST

3.1 Socio-economic Framework

3.1.1 Population Growth

JICA Survey Team on "The Survey Program for The National Transport Development Plan" projected the national population until 2040. The Survey Team utilized a "comfort method," and prepared three alternative population growth scenarios in accordance with the difference of Total Fertility Rate (TFR). The Survey Team selected the middle scenario, in which the TFR drops from 2.31 in 2015 to 1.71 in 2040. The population in this scenario will amount to 73.80 million in 2040.

Table 3.1.1 shows changes in region/state population from 2012 to 2040. The Survey Team distributed the population to regions/states, while considering magnitude/probability of regional economic development including industrial, agricultural and tourism development projects across the country.

Table 3.1.1 Population by region/state from 2012 to 2040

Unit: 000 persons

Region/State	2012	2020	2030	2040
Kachin State	1,616	1,820	1,935	1,973
Kayah State	365	424	450	460
Kayin State	1,855	2,151	2,401	2,496
Chin State	571	630	656	666
Sagaing Region	6,654	7,029	7,179	7,236
Tanintharyi Region	1,755	2,051	2,301	2,396
Bago Region	6,125	6,691	7,261	7,507
Magway Region	5,730	6,013	6,113	6,151
Mandalay Region	7,423	7,949	8,370	8,617
Mon State	3,193	3,489	3,846	3,998
Rakhine State	3,370	3,666	4,016	4,130
Yangon Region	7,170	8,739	10,445	11,015
Shan State	5,779	6,128	6,378	6,473
Ayeyarwaddy	8,205	8,685	8,864	8,902
Naypyitaw Council Territory	1,164	1,434	1,684	1,779
Total	60,976	66,900	71,900	73,800

Source: Population Department, Ministry of Immigration and Population (2012) and JICA Survey Team on "The Survey Program for the National Transport Development Plan"

3.1.2 Economic Development

The JICA Survey Team on "The Survey Program for The National Transport Development Plan" also projected GDP growth until 2035. Observing the government's economic growth target, experiences of other Asian countries and limited population growth prospect, the Study Team set the GDP growth rate from 2015 to 2035 at 7.2%. As a result, the National GDP in real terms will increase 3.4 times between 2012 and 2030, or from 46,915 billion Kyat to 160,498 billion Kyat .

Table 3.1.2 indicates GRDP changes by regions/states until 2030. The three region/states of the study are projected to achieve more rapid economic growth than the national average and raise their GRDP share in the national GDP, considering the magnitude/probability of regional economic development including industrial, agricultural and tourism development projects across the country.

Table 3.1.2 Projection of GRDP by Region/State until 2030

Unit: billion Kyat

Region/State	2012	2020	2030
Kachin State	1,097	1,858	3,467
Kayah State	172	345	667
Kayin State	829	1,503	3,583
Chin State	154	253	542
Sagaing Region	5,508	7,731	12,320
Tanintharyi Region	1,679	2,646	5,863
Bago Region	4,027	6,581	14,124
Magway Region	4,631	6,582	9,660
Mandalay Region	5,186	9,915	22,782
Mon State	2,063	3,560	7,580
Rakhine State	1,856	3,420	7,676
Yangon Region	10,294	21,705	47,162
Shan State	3,373	4,929	9,185
Ayeyarwaddy Region	5,465	7,772	12,597
Naypyitaw Concil Territory	581	1,280	3,290
Total	46,915	80,080	160,498

Source: JICA Survey Team on "The Survey Program for the National Transport Development Plan"

3.2 Traffic Demand Forecast

3.2.1 Approach and Methodology

(1) Overview of Traffic Demand Forecast in MYT-Plan

The comprehensive traffic demand forecast was utilised in the JICA-supported Survey Program for The National Transport Development Plan (hereinafter referred to as the MYT-Plan). The conventional four-step traffic demand model was developed based on the result of traffic surveys (traffic count survey, roadside OD interview survey, terminal interview survey and transport operators survey) and secondary information, such as population and economic indicators.

During the modelling in traffic demand forecast, the Study Area (the whole country) was divided into 71 traffic analysis zones. A traffic generation and attraction model was developed with a formula encompassing the population and GRDP as explanatory factors. The traffic distribution model was developed by a gravity model with zonal impedances (time and cost) as explanatory factors.

The traffic demand forecast was carried out by the intermediate and target years of 2020 and 2030 in the MYT-Plan. The OD matrix was prepared by seven different types of vehicles (passenger car, bus, small 2-axle truck, large 2-axle truck, 3-axle truck, 4 and over axle truck and trailer). The future road network (free flow speed and traffic capacity) was developed, considering the number of lanes, topography and pavement type.

(2) Approach and Methodology of Traffic Demand Forecast in the Study

Basically, the same approach and methodology of the traffic demand forecast applied to the MYT-Plan is adopted for the traffic demand forecast in the Study, considering the following implications. First, the traffic demand forecast is carried out by 2035 (the target year of the Study). Secondly, the OD matrix is calibrated by the Traffic Survey conducted in the Phase-I Survey.

3.2.2 Traffic Demand taken into account in the Study

The demand forecast of the Study takes into account the following traffic demand which influences the traffic along the East West Corridor (EWC).

Export and import cargo between Thailand and Myanmar: For EXIM cargo between Thailand and Myanmar, the modal share and route share models are newly developed, considering the sea and land transport between Thailand and Myanmar, and the route share between the EWC and the newly improved Three Pagoda Pass. As described later, sea transport cargo will be shifted to land transport cargo, and the cargo volume equivalent to 2,880 trucks in 2035 will be transported through EWC and/or Three Pagoda Pass.

Hanthawaddy International Airport: Considering maturity of the project and impact to the traffic along the EWC, traffic demand generated from newly developed Hanthawaddy International Airport is separately estimated in the Study. As described later, 12,100 PCU in 2025 and 25,800PCU in 2035 is estimated as traffic demand of Hanthawaddy International Airport and 70% of which is generated to/from Yangon district, and 12% is generated to/from the Study Area, including Bago.

Dawei Deep-sea Port and surrounding development project: Since the traffic from newly developed Dawei Deep-sea Port and surrounding development projects is generated along the Southern Economic Corridor (between Thailand, Vietnam and South Asia) and is expected to have less impacts on the EWC, the traffic demand forecast in the Study will not take into account the traffic generated from development projects in Dawei.

Traffic demand from various other development plans: Socio-economic factors of the development plans, such as future population and GRDP, is developed, taking account the features of these plans and accordingly, traffic demand generated from SEZ, EPZ, and Industrial Parks is implicitly estimated. Also, traffic demand generated from each development plans is relatively small. (For instance, the Bago Industrial Park, discussed in Chapter 2, is expected to generate traffic equivalent to 800 trucks per day) Accordingly, the traffic demand forecast in the Study will not separately estimate the traffic generated from these development plans.

3.2.3 Traffic Demand Forecast

(1) Projection of EXIM Cargo Volume between Thailand and Myanmar

1) Future EXIM Cargo Volume between Thailand and Myanmar

Considering population size and industrial development potential, the Study assumes that Myanmar will develop its economy similar to that of Vietnam. Looking at the GDP and EXIM volume of Vietnam in the last decade (2000 – 2011), the elasticity of the EXIM cargo volume against GDP is estimated at 1.29 on the average for import commodities and 2.37 on the average for export commodities[4] and is summarized in Table 3.2.1.

[4] Elasticity of the import of Commodity_9 (Cement and Construction Material) is referred to that projected by Thai EXIM data and estimated at 1.865 since extra-ordinal projection is observed using the Vietnam EXIM data.

Table 3.2.1 Elasiticity of the Commodity-wise EXIM Cargo Volume against GDP

Commodity	EXIM ton - GDP elasticity (Constant Price 2005)	
	Import	Export
1_Live Animal & Animal Products	2.92	-0.56
2_Fish and Aquatic Products	1.36	-0.94
3_Vegetable and Fruits	2.62	0.08
4_Grain and Grain Products	1.48	1.80
5_Other Agricultural Products (ex. Plantation Product)	2.52	1.57
6_Foodstuff, Beverage and Animal Food	2.52	1.30
7_Petroleum, Oil and Gas	0.17	3.77
8_Coal, Ore, Stone and Sand	2.18	3.40
9_Cement, Construction Material (incl. steel - frame)	1.87	2.15
10_Fertilizer (incl. Urea)	0.10	2.51
11_Garment, Textiles and fabric	1.25	1.22
12_Wood and Wood Products	4.12	1.83
13_Paper and Printed Matter	1.46	1.92
14_Metal and Metal Products (excl. construction material)	1.80	3.04
15_Industrial Material, Chemicals	1.49	1.77
16_Household articles, miscellaneous	1.34	0.44
17_Machinery and Parts, Transportation	0.67	1.50
Total	1.29	2.37

Source: JICA Survey Team

Assuming Myanmar's GDP growth of 7% per annum until 2035, the same growth rate applied to the MYT-Plan, and using the elasticity GDP estimated above, the commodity-wise import volume from Thailand to Myanmar is estimated to increase by 9% p.a. on the average (GDP growth rate of 7.0% * 1.29) and reach 28 million tons, with export volume from Myanmar to Thailand estimated to increase by 17% p.a. (7% * 2.37) and reach 17 million tons in total by 2035.

2) Modal Share of EXIM Cargo between Thailand and Myanmar

The modal split model of the EXIM cargo between sea and land transport was developed assuming that most EXIM cargo is transported between the industrial zones in Ayutthaya and Yangon. The generalized cost of both sea and land transport is calculated by multiplying the time value of the cargo and travel time, and then adding the transport cost. The time value of the cargo is estimated by multiplying the cargo value and interest rate (i.e., cargo value*10% (borrowing interest rate at commercial banks in Myanmar)/365 days/24 hours).

Table 3.2.2 Commodity-wise Time Value of EXIM Cargo between Thailand and Myanmar

Commodity	Value (USD/Ton)	Time Value (USD/Hour/Ton)
1_Live Animal & Animal Products	2,569	0.03
2_Fish and Aquatic Products	1,939	0.02
3_Vegetable and Fruits	727	0.01
4_Grain and Grain Products	1,315	0.02
5_Other Agricultural Products (ex. Plantation Product)	6,495	0.07
6_Foodstuff, Beverage and Animal Food	1,627	0.02
7_Petroleum, Oil and Gas	1,051	0.01
8_Coal, Ore, Stone and Sand	250	0.00
9_Cement, Construction Material (incl. steel - frame)	77	0.00
10_Fertilizer (incl. Urea)	467	0.01
11_Garment, Textiles and fabric	6,189	0.07
12_Wood and Wood Products	608	0.01
13_Paper and Printed Matter	1,253	0.01
14_Metal and Metal Products (excl. construction material)	1,361	0.02
15_Industrial Material, Chemicals	1,710	0.02
16_Household articles, miscellaneous	6,293	0.07
17_Machinery and Parts, Transportation	11,117	0.13

Source: JICA Survey Team

As seen in the above figure, a modal share of sea transport and cost difference between land and sea transport can be explained by applying an exponential function and therefore the following formula (log-function) is adopted to estimate the modal share between sea and land transport.

$$Log(Psea) = a \times Log(\alpha \times (Tland - Tsea) + (Cland - Csea)) + b$$

Subject to Psea (Share of Sea Transport), α (Time Value per ton), Tland/Tsea (Transport Time by Land/Sea Transport), Cland/Csea (Transport Cost by Land/Sea Transport), a/b (parameters)

Table 3.2.3 shows the result of regression analysis of the above formula and parameters estimated through the analysis. Both regression and t-value[5] of the parameters suggest the modal split model of sea and land transport between Thailand and Myanmar can be judged as adequate.

Table 3.2.3 Result of Regression Analysis and Parameters Estimated

R^2	0.83
a	4.09（t=5.78）
b	-18.5 (t=－6.21)

Source: JICA Survey Team

The following table and figure compares the actual modal share and projected modal share of the sea transport between Thailand and Myanmar by commodity.

Table 3.2.4 Commodity-wise Comparison of Actual Modal Share and Projected Modal Share of Sea Transport between Thailand and Myanmar

Commodity	Actual Modal Share of Sea Transport	Estimated Modal Share of Sea Transport
1_Live Animal & Animal Products	34%	31%
2_Fish and Aquatic Products	5%	37%
3_Vegetable and Fruits	50%	52%
4_Grain and Grain Products	49%	44%
5_Other Agricultural Products (ex. Plantation Product)	0%	8%
6_Foodstuff, Beverage and Animal Food	36%	41%
7_Petroleum, Oil and Gas	59%	47%
8_Coal, Ore, Stone and Sand	75%	59%
9_Cement, Construction Material (incl. steel - frame)	87%	61%
10_Fertilizer (incl. Urea)	96%	55%
11_Garment, Textiles and fabric	15%	9%
12_Wood and Wood Products	56%	53%
13_Paper and Printed Matter	69%	45%
14_Metal and Metal Products (excl. construction material)	43%	44%
15_Industrial Material, Chemicals	63%	40%
16_Household articles, miscellaneous	17%	9%
17_Machinery and Parts, Transportation	0%	1%

Source: JICA Survey Team

3) Future Land-based Transport EXIM Cargo between Thailand and Myanmar

Both road network improvement of the EWC, and transport and trade facilitation between Thailand and Myanmar (Ayutthaya and Yangon) are expected to reduce transport cost (a reduction of 150 USD between Ayutthaya and Yangon) and transport time (a reduction of 35 hours). Assuming that sea transport service will remain the same, a maximum of 15% of the EXIM cargo volume is estimated to divert from sea to land transport due to the improvement of the road transport network and service.

As a result, 6.6 million tons (2,880 trucks per day[6]) in 2035 are estimated to shift from sea to land transport due to the improvement of the road transport network and service between Thailand and Myanmar.

[5] When the t-value exceeds 1.96, the parameter is considered valid with 95% of accuracy.

[6] Based on the result of OD Interview Survey, the average loading volume of the trucks is 8.8 tons. Operation of the trucking service is assumed at 260 days per year. Thus, 3.8 million tons (diverted from sea to land transport in 2030)/8.8 tons/truck /260 working days = 1,660 trucks/day.

Table 3.2.5 Commodity-wise Future EXIM Cargo Volume shifted from Sea Transport to Land Transport between Thailand and Myanmar

	2030 EXIM Volume with Thai ('000ton)	2030 Trade Volume shifted from Sea to Land Trasnport ('000ton)	2035 EXIM Volume with Thai ('000ton)	2035 Trade Volume shifted from Sea to Land Trasnport ('000ton)
1_Live Animal & Animal Products	252	26	497	52
2_Fish and Aquatic Products	30	3	19	2
3_Vegetable and Fruits	167	24	276	39
4_Grain and Grain Products	18	2	23	3
5_Other Agricultural Products (ex. Plantation Product)	83	3	121	5
6_Foodstuff, Beverage and Animal Food	4,298	530	7,567	933
7_Petroleum, Oil and Gas	240	32	199	27
8_Coal, Ore, Stone and Sand	6,601	999	15,281	2,313
9_Cement, Construction Material (incl. steel - frame)	10,814	1,675	15,626	2,420
10_Fertilizer (incl. Urea)	34	5	42	6
11_Garment, Textiles and fabric	87	4	104	5
12_Wood and Wood Products	2,127	306	3,664	528
13_Paper and Printed Matter	84	11	114	15
14_Metal and Metal Products (excl. construction material)	688	88	1,070	138
15_Industrial Material, Chemicals	677	82	872	106
16_Household articles, miscellaneous	84	4	103	5
17_Machinery and Parts, Transportation	63	0	62	0
Total	26,349	3,797	45,641	6,596

Source: JICA Survey Team

(2) Projection of Passenger Demand of Hanthawaddy Airport

1) Airport Passengers

JICA conducted a comprehensive demand forecast in the course of the PPP Study on Hanthawaddy Airport Development Project. The result of the JICA's demand forecast shows by the year 2025, it is estimated that Hanthawaddy Airport will service approximately 10.2 million international passengers annually. This is further estimated to increase to around 5.2 million domestic passengers and 29.1 million international passengers annually by 2040[7]. This is included within the framework of the transport model as a special generator.

The new airport for Yangon, Hanthawaddy is located approximately some 70 kilometres from the central Yangon station and only twenty minutes from Yangon via a proposed high speed rail service[8]. However, this rail service was not considered in this analysis, since realization of the rail project is still unknown.

2) Person Movements

<u>**Total Person Trips**</u>

The new airport is included in the model for this project as a special generator. When consideration is given not only to passenger demand but also the employment and phenomenon of greeters or well wishes, the total number of daily airport person trips associated with passenger flow is expected in excess of 125,000 trips[9] by 2035. There are two types of air passengers travelling namely the domestic and the international passenger. In addition, the number of trips must also include an allowance for the airport workforce.

The total trips attracted to the new airport must be distributed across the region to determine the

7 The source of the estimates for passenger forecast and employment at Hanthawaddy airport is taken from the recently prepared Interim Report of the " Preparatory Survey for Hanthawaddy International Airport Project in the Republic of Myanmar".

8 In an earlier project, there was consideration for a high speed rail link to Hanthawaddy airport. This proposed HSR link is not considered in this technical note.

9 The reference is from the High Speed Rail Review in Myanmar under preparation by JICA.

non-airport end of trips to and from the airport. The domestic trips are distributed to Yangon and the Bago hinterland in proportion to the zonal urban population. In the case of international passengers, they are distributed across the country also in proportion to the zonal urban population with the proviso that the economics of the zone must not be dissimilar to that of the traffic zones in the Yangon region[10].

Modal Distribution

The person trips to the airport must then be assigned to the mode of travel. The person trips were then allocated between the various modes using the overall project mode split model. Without a high speed rail link to the new airport nearly 90% of all travel to the airport will be via the road sector. These airport trips are then incorporated into the overall regional travel matrix prior to the assignment of the travel matrix to the network. The total trips are tabulated in Table 3.2.6.

Table 3.2.6 Daily Person Trips via the Road Sector

Year	Person Trips by the Road Sector		Vehicle Trips (pcu)[11]
	Bus	Car	
2025	20,600	34,200	12,200
2035	43,100	72,700	25,800

Source: Compiled by JICA Survey Team

(3) Traffic Assignment and Projection of Traffic Volume

The OD matrix is revised by adding the additional vehicular traffic diverted from sea transport to land transport (2,880 trucks per day in 2035) and traffic demand, mainly passenger demand, of Hanthawaddy Airport (25,800 PCU per day in 2035). The revised OD matrix is assigned to the future network[12].

The following table and figures show the projected traffic volume by the project section and result of the traffic assignment. As a result of the traffic assignment, the EWC is expected to accommodate relatively larger traffic and function as an international and regional corridor even in the future.

Table 3.2.7 Projected Traffic Volume by Designated Project Section (Unit: PCU/day)

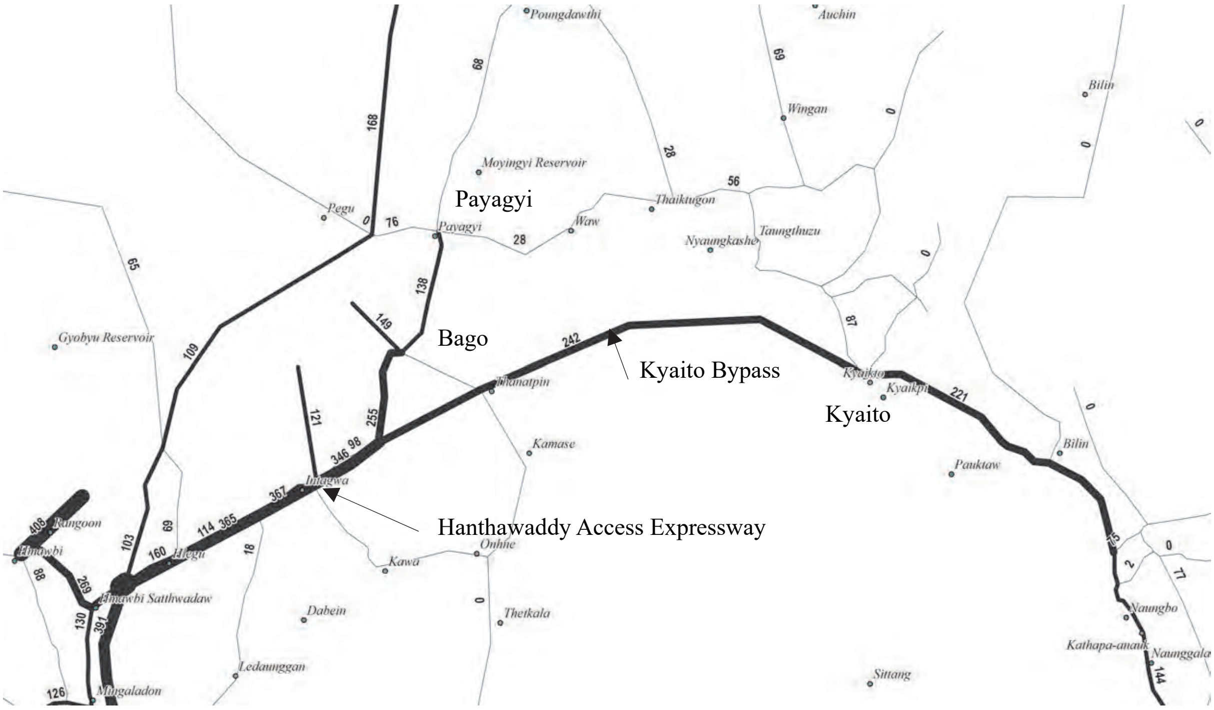
Section	YR 2025	YR 2035
Payagyi - Kyaito (Existing Road)	2,800-8,700	10,500-16,400
Payagyi – Bago (Existing Road)	13,800-25,500	54,400-77,500
New Bago - Kyaito Road	24,200	63,500
NH-1 (Bago – YM Express Connect)	9,800-16,000	44,700-47,900
Hanthawaddy Access Expressway	34,600-36,700	82,500-99,300

Source: JICA Survey Team

[10] Nay Pyi Taw is considered as an exception to this rule. In the future, Hanthawaddy Airport is to be considered the gateway to the Union.

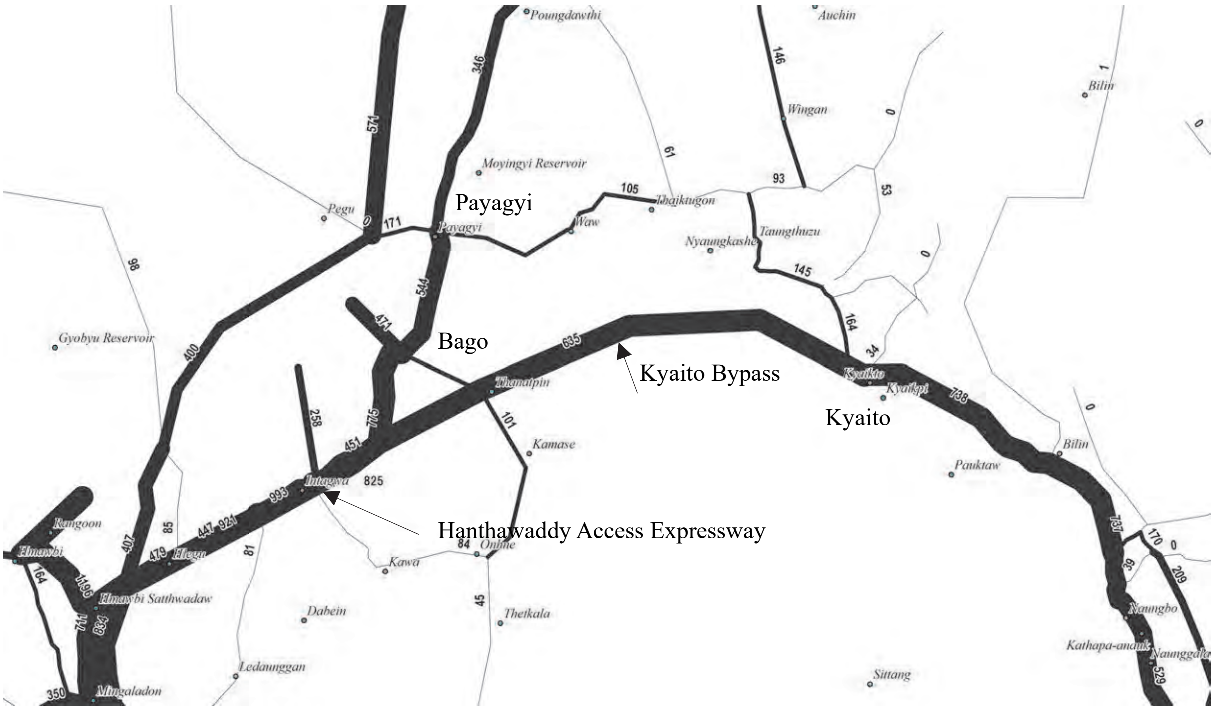
[11] In this case the overall regional assignment parameters were incorporated in the estimation of the vehicle flow with an occupancy of 3.13 and 34 for cars and buses respectively.

[12] The road section under the BOT (between Payagyi and Mawlamyine) is assumed to be widened to 4 lanes and East-West Economic Corridor, Three Pagoda Pass and the road section between Mawlamyine and Dawei are to be improved to 2 lane roads.



Source: JICA Survey Team

Figure 3.2.1 2025 Projected Traffic Volume by Designated Section (Unit: 100 PCU/day)



Source: JICA Survey Team

Figure 3.2.2 2035 Projected Traffic Volume by Designated Section (Unit: 100 PCU/day)

CHAPTER 4 NATURAL CONDITION SURVEYS

4.1 Topographical Survey

A digital topographic map was produced from aerial photographs in order to understand ground profiles, levelling and ground surface properties. An outline of the survey and results are described in the sections below.

4.1.1 Scope of Work

The following works were conducted to create the basic map data in the Project Area such as the New Bago-Kyaito Road, National Highway No.1 (NH1) and Hanthawaddy International Airport Access Road (HIA).

- Aerial Photo Acquisition
- Satellite Image Acquisition
- GPS survey
- Leveling Survey
- Aerial Triangulation, Georeferencing and Geometric Correction
- Orthophoto production
- Digital topographic map production

4.1.2 Parameters

Datum and Coordinate System

All mapping deliverables shall be in the following coordinate system:

- Ellipsoid : WGS84 (World Geodetic System 84)
- Projection : Universal Transverse Mercator (UTM) Projection
- Zone : Zone number N47
- Central Meridian origin : 99 degrees west of Meridian international
- Latitude origin : Equator
- Scale factor at origin : 0.9996
- False coordinates : (0,500,000) at equator
- Vertical : BM height adopted by Myanmar Survey Department

- Unit of measurement : metre
- EPSG : 3247 (WGS84 UTM coordinates.47)

4.1.3 Target Area

The mapping survey total area of whole project is 57 km^2. The following table shows outline of target area in each area.

Table 4.1.1 Outline of Target Area for Topographic Survey

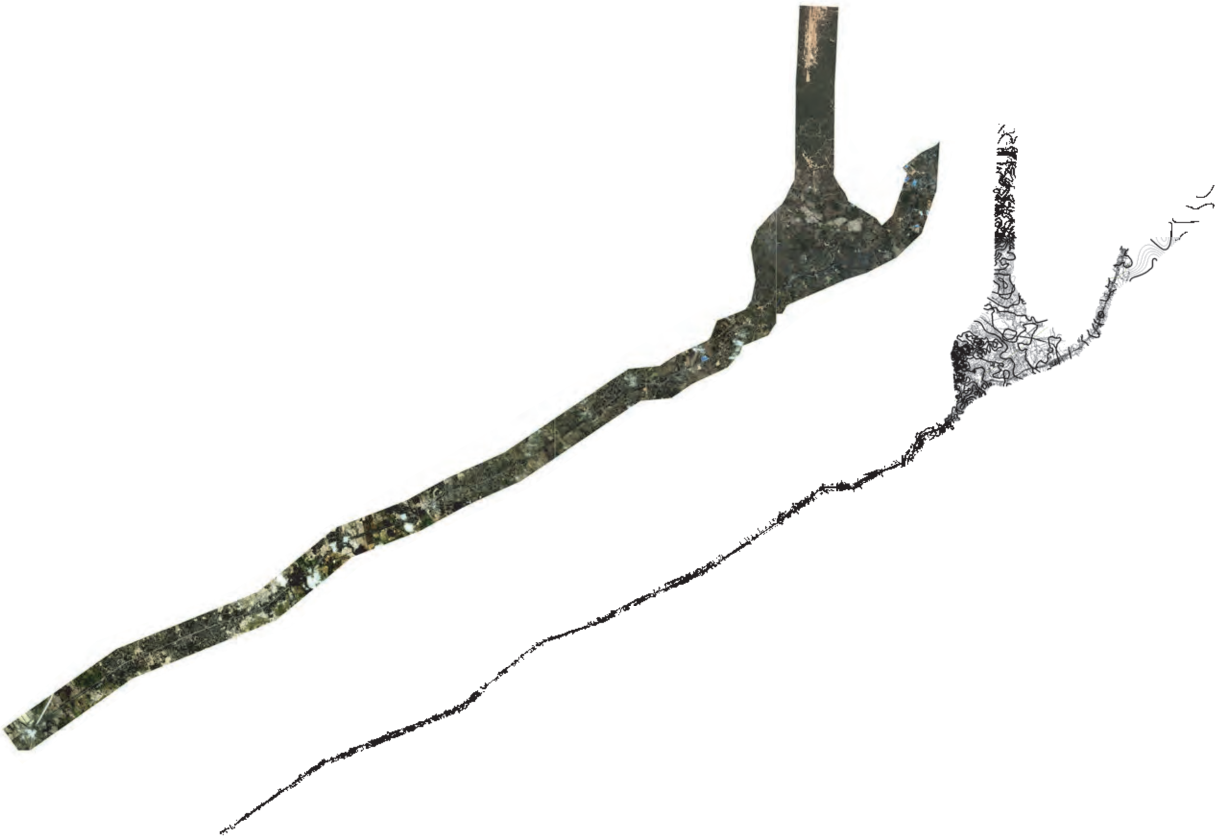
Area Name	Area (Sqkm)	Outline of Area
Bago –Kyaito Road	15.6	・ Aerial Photo Acquisition(2014 Archive) ・ Satellite Image Acquisition(2014 Archive) ・ GPS Survey ・ Leveling Survey ・ Post processing of Aerial Photo Data ・ Aerial Triangulation ・ Orthophoto production ・ Digital topographic mapping scale 1:5,000 ・ Some areas of aerial photos are cloudy based on the Aerial Photo. It is necessary to select satellite image archive data to recover the cloudy area.
NH1	16.4	・ Aerial Photo Acquisition(2014 Archive) ・ Orthophoto production ・ Digital topographic mapping scale 1:10,000
HIA Access Road	25	・ Satellite Image Acquisition(2014 Archive) ・ Orthophoto production ・ Digital topographic Mapping scale 1:10,000 ・ This area is cloudy area based on the Aerial Photo. So the satellite image archive data should be selected.

Source: JICA Survey Team

4.1.4 Results of Survey

Source: JICA Survey Team

Figure 4.1.1 Orthophoto and Digital Topographic Map (New Bago-Kyaito Road Site)



Source: JICA Survey Team

Figure 4.1.2 Orthophoto and Digital Topographic Map (NH1 Site)

4.2 Geological Survey

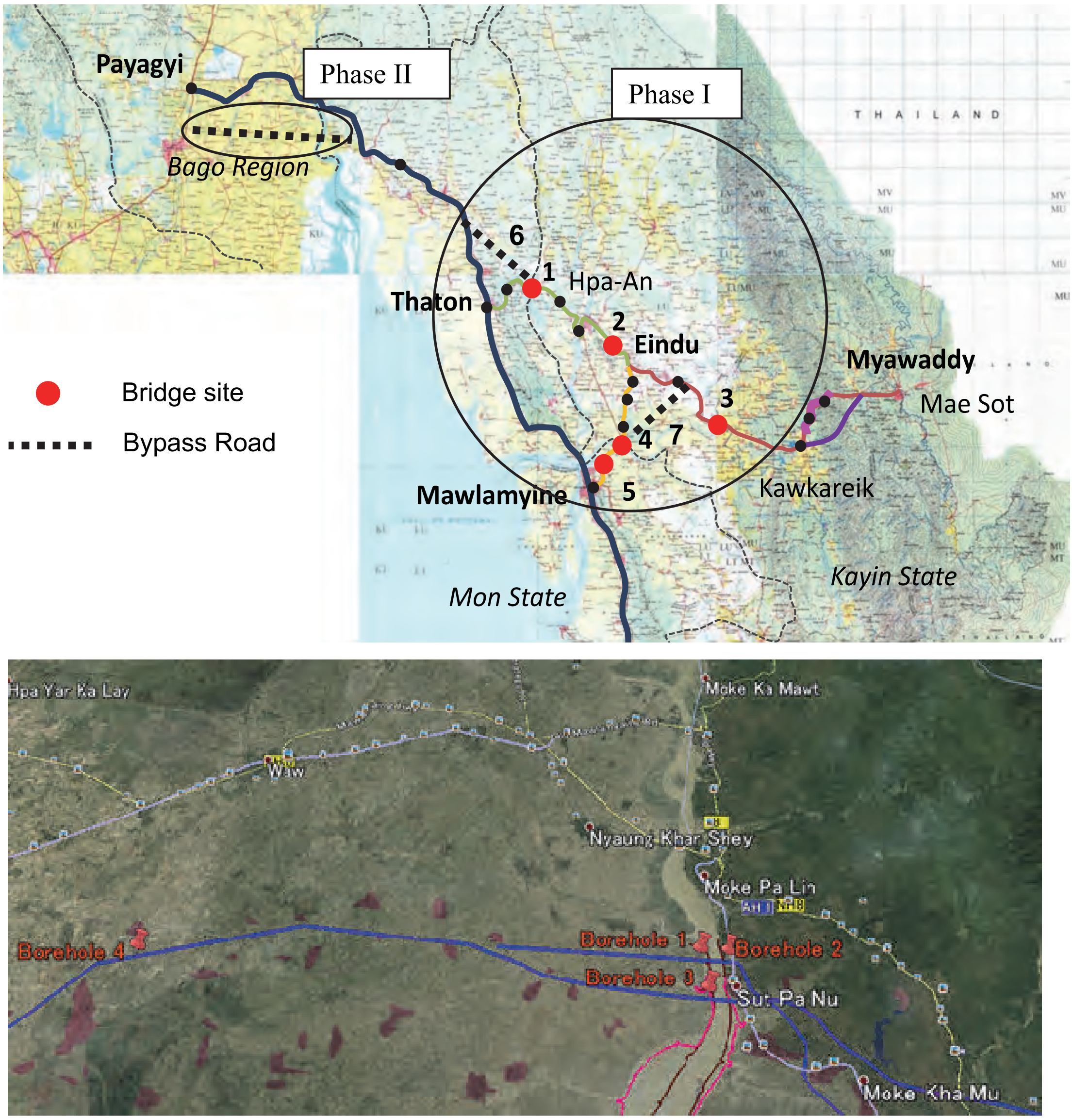
4.2.1 Scope of Work

The objective of the Survey is to provide preliminary data regarding the geological formation and geological properties along the Project site. The collected data and information are incorporated into the implementation of preliminary road and bridge designs of the Project.

Geological Surveys are undertaken by a sub-contractor selected in accordance with JICA procedure. A detailed survey result is described in a report submitted by the sub-contractor. In this Section, the summary of the geological survey is described.

(1) Survey Area

Geological Surveys for Phase II (Kyaitto – Bago Bypass Road) are carried out for four points as shown in Figure 4.2.1 and Table 4.2.1.



Source: Prepared by JICA Survey Team based on Google Earth

Figure 4.2.1 Location Map of Survey Area

Table 4.2.1 Location of Survey Areas for Phase II

Bor.No	Purpose	Depth	Remarks
1	Bridge	46m	Sittaung River Side
2	Bridge	60m	Sittaung River Side
3	Bridge	31m	Sittaung River Side
4	Soft Soil	30m	Paddy Field

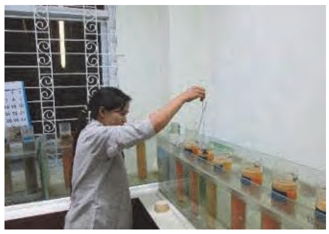
Source: JICA Survey Team

(2) Survey Components

The following work was performed during Geological Investigation. The method followed was America Society for Testing and Materials (ASTM). The detailed method is described in the sub-contractor's report.

- Setting up Boring Stage on Land
- Boring (Including Water level measuring and water sampling)
- Drilling with in-situ test (SPT) and sampling
- Sampling (Undisturbed, Disturbed sampling)
- Laboratory Test
    - Unit weight for undisturbed sample
    - Natural moisture contents
    - Atterberg limits (Liquid Limit/Plastic Limit) for cohesive soil
    - Grain size analysis (sieve + hydrometer)
    - Specific gravity
    - Unconfined Compression Test
    - Consolidation Test
    - Water quality Test






4.2.2 Results of Survey

(1) Soil Profile

The objective of the present investigation is to identify the general stratification of the ground and the nature of the soil. There are a total of four boring points which were planned to be investigated by the requirement. The field investigation included soil boring with the performing of the test associated with Standard Penetration Test (SPT), Disturbed Soil Sampling, Undisturbed Soil Sampling, Water Level Measuring and Water Sampling.

The locations of the investigated points were designated by the design engineer. The coordinates and elevation of all investigated holes were measured by hand GPS. The coordinates and elevation of all boring points are shown in Table 4.2.2. Moreover, the plan map showing geotechnical investigated points are indicated in Figure 4.2.2.

Table 4.2.2 Coordinate Data of Borehole Points

No.	BH No.	Easting (E)	Northing (N)	Elevation (m) Hand GPS
1	BH-01	275530.000	1924805.000	8.00
2	BH-02	276632.000	1924814.000	9.00
3	BH-03	275873.000	1922917.000	9.00
4	BH-04	249007.000	1922257.000	8.00

Source: JICA Survey Team

Source: Prepared by JICA Survey Team based on Google Earth

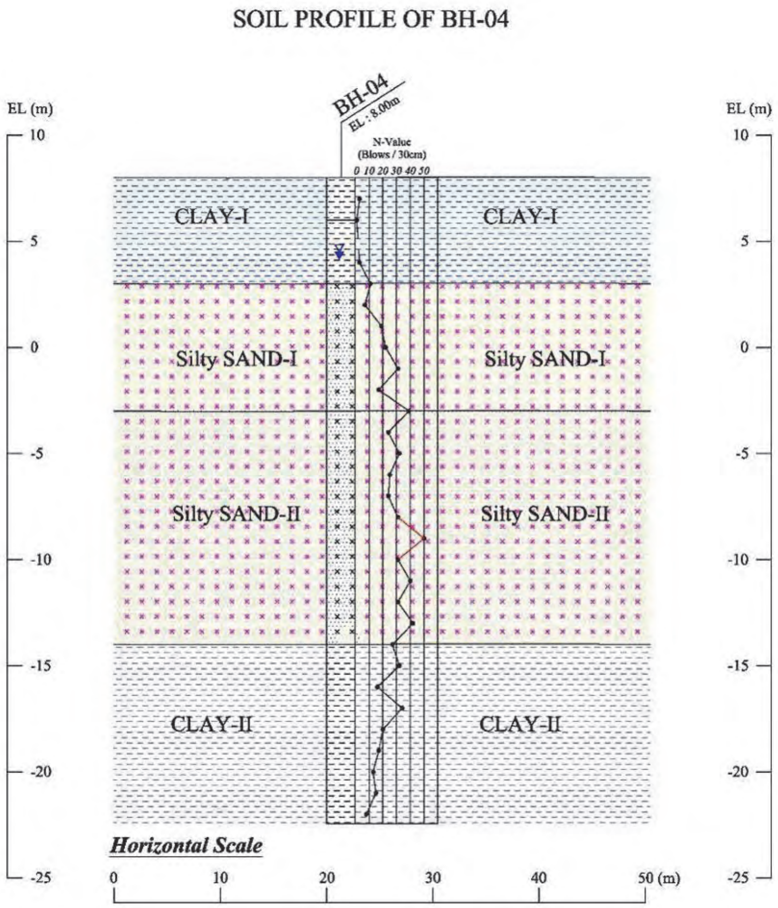
Figure 4.2.2 Location Map of Soil Investigation Points

The soil profile is divided in two portions, BH 04 and Sittaung River side (BH 03, BH 01 and BH 02) as shown in Figure 4.2.3 and Figure 4.2.4 respectively.

There are four boreholes; depths are 30.0m in minimum and 60.0m in maximum from ground level with the performance of Standard Penetration Tests. In this operation, a total of nine different layers have been recognized. The soil layers are classified in accordance with their physical properties and/or their relative density. The nine different layers observed in project area are described from top to bottom as follows.

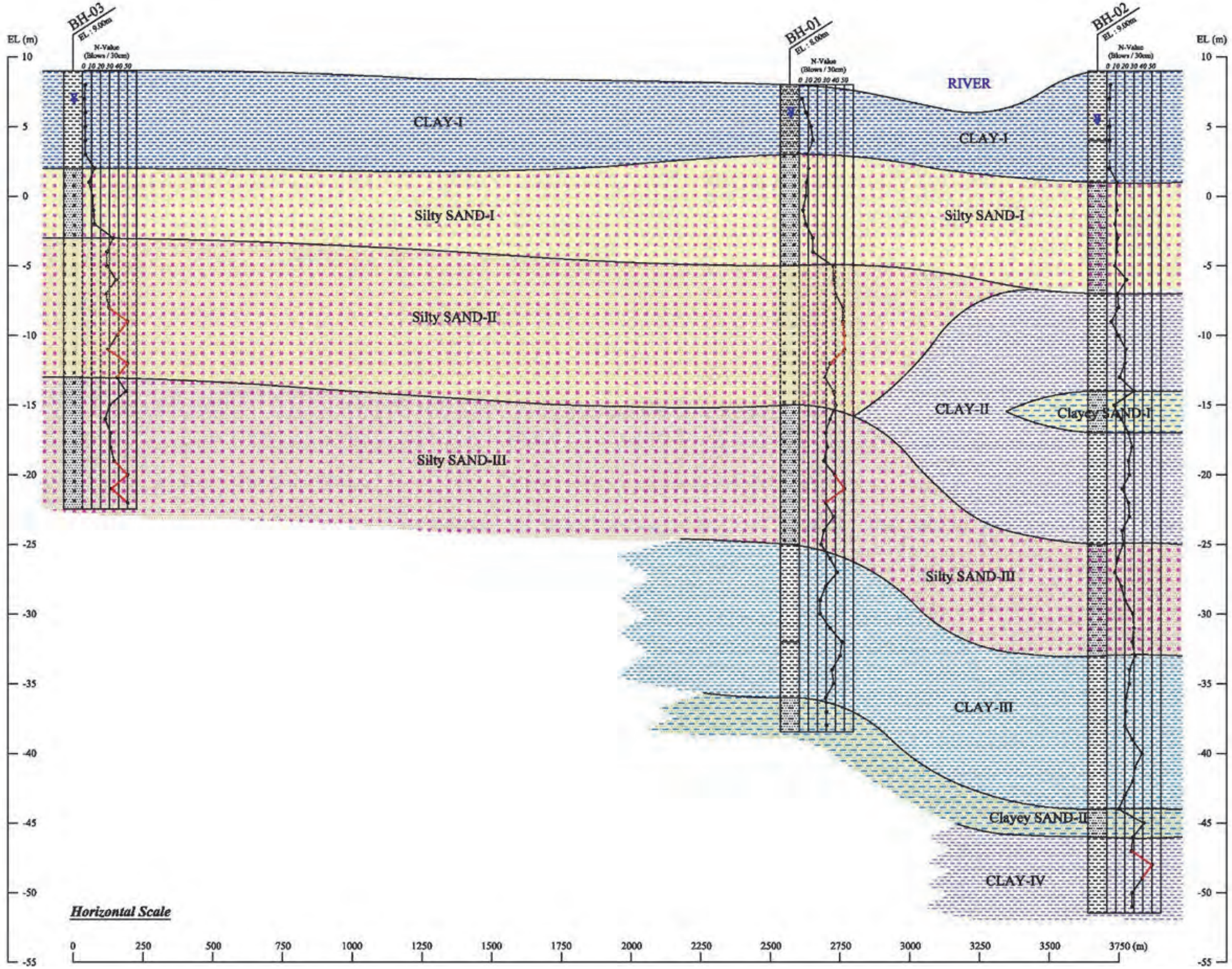
① Silty SAND-I
② Silty SAND-II
③ CLAY-II
④ Clayey SAND-I
⑤ Silty SAND-III

⑥ CLAY-III
⑦ CLAY-I
⑧ Clayey SAND-II
⑨ CLAY-IV



Note) Boring logs are shown in Appendix 4
Source: JICA Survey Team

Figure 4.2.3 Soil Profile of BH 04



Note) Boring logs are shown in Appendix 4
Source: JICA Survey Team

Figure 4.2.4 Soil Profile along Sittaung River (BH03, BH01, BH02)

(2) Soil Property

A summary of the soil test results are shown in Figure 4.2.5. Natural water content, Specific Gravity, Fine Content, and Unconfined Compression Test results are compiled in a graph as a depth distribution figure layer by layer. The test items are shown in Figure 4.2.5.

Table 4.2.3 Quantity of Laboratory tests

BH-No.	Physical Properties Test							Engineering Properties Test		Chemical Properties Test
	Natural Moisture Content Test	Specific Gravity Test	Particle Size Analysis Test		Atterberg's Limit Test		Unit Weight	Unconfined Compression Test	One Dimensional Consolidation Test	Water Quality Test
			Sieve Analysis Test	Hydrometer Analysis Test	Liquid Limit Test	Plastic Limit Test				
BH-01	15	15	15	15	4	4	-	-	-	1
BH-02	15	15	15	15	13	13	3	1	3	1
BH-03	9	9	9	9	-	-	-	-	-	1
BH-04	11	11	11	11	4	4	1	-	1	1
Total	**50**	**50**	**50**	**50**	**21**	**21**	**4**	**1**	**4**	**4**

Source: JICA Survey Team

Each test result is summarized as follows:

① Natural Moisture Content (Wn %)

Natural water content (Wn) for CLAY-I, CLAY-II, CLAY-III ranges from 23% to 34%, Wn for Silty SAND-I, II, III ranges from 11% to 30%, Wn for Clayey SAND-I, II ranges from 15% to 20%, CLAY-IV is 27%.

② Specific Gravity（ρs）

Specific gravity（ρs） ranges from 2.6 to 2.7 in spite of difference of soil type, Sand, Clay, Gravel etc.

③ Liquid Limit, Plastic Limit test

The detailed soil classification based on this test result is CL and CH.

④ Particle Size Analysis Test

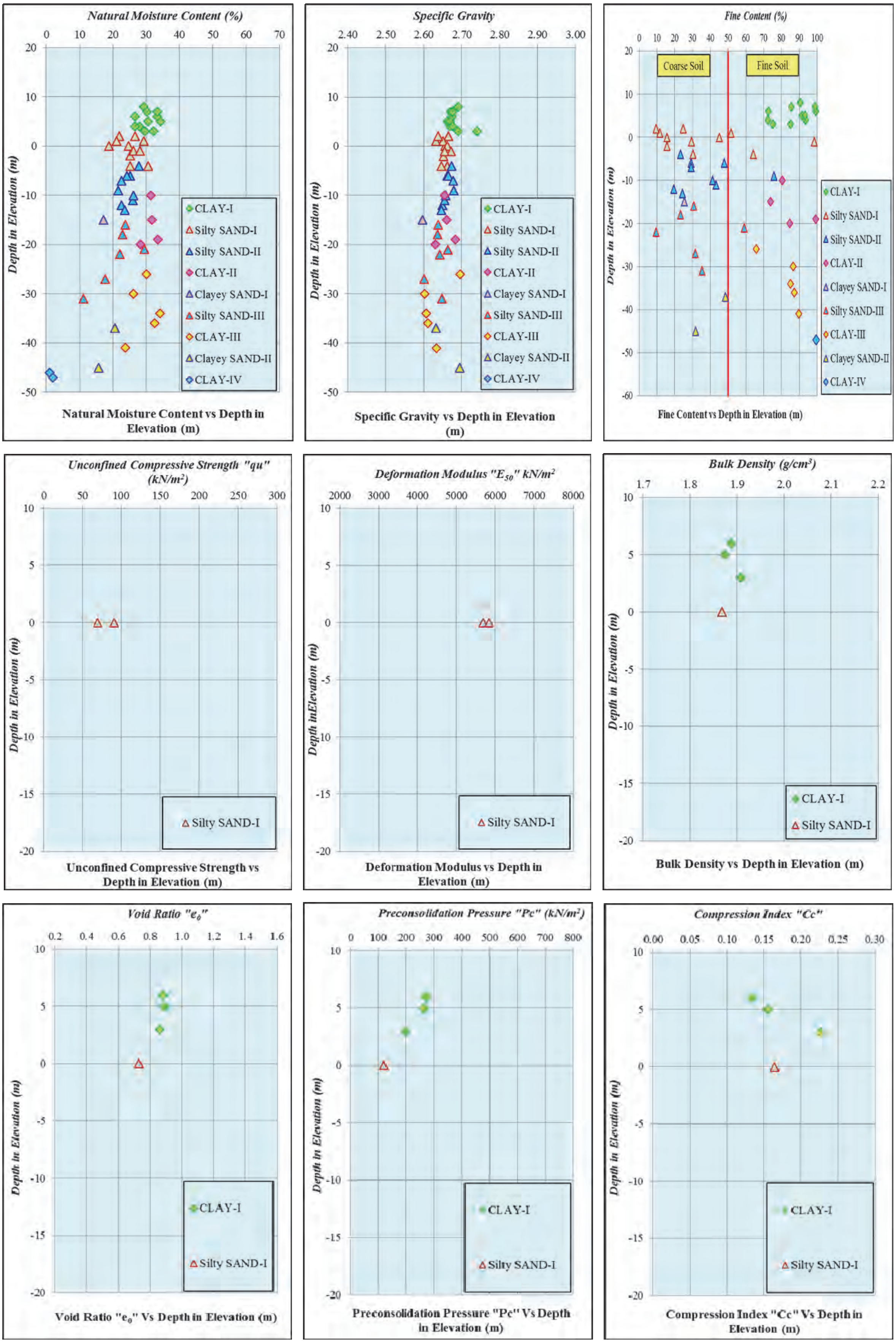
For CLAY-I, II, III, IV, fine content ratio (<0.075mm) ranges almost over 70%. For Silty SAND-I, II, III, fine content ratio ranges almost 10% to 50%. Also for Clayey SAND-I, II, fine content ratio ranges almost 10% to 50% as well as one of Silty SAND-I, II, III.

⑤ Unconfined Compression Strength Test (qu kN/m^2)

Only one sample is available for the Unconfined Compression test because there are many sand mixing with Clay samples. For Silty SAND-I, the Unconfined Compression Strength (qu) is $80kN/m^2$ on average. Bulk density is $1.87(g/cm^3)$.

⑥ Consolidation Test

For CLAY-I, Pre-consolidation Yield Stress (Pc) ranges from $196kN/m^2$ to $270kN/m^2$. For Silty SAND-I, Pc is $120kN/m^2$. It indicates the soil is over-consolidated condition. Compression Index (Cc) for CLAY-I ranges from 0.13 to 0.22, comparatively low. The Cc for Silty SAND-I is 0.16.



Source: JICA Survey Team

Figure 4.2.5 Summary of Soil Test Results

(3) Considerations

1) Soil Condition of Foundation of Ground

According to the soil investigation results, soil condition of each layer is summarized as shown in Table 4.2.4.

Table 4.2.4 Soil Condition of Each Layer

Layer Name	Soil Condition
CLAY- I	This layer is well observed in all boreholes. The thickness of this layer is a minimum 5.0m and a maximum 7.0m. The colour of this layer is brown to grey and the water content is 26% to 34%, not so high. SPT N-value range of this layer 1/30 to 15/30 blows, and it can be described as very soft to stiff in consistency. This Clay layer mixes with sand abundantly.
Silty SAND-I	The second sub-soil layer, Silty SAND-I layer is also well observed at all investigated boreholes. The thickness of this layer is a minimum 5.0m and a maximum 8.0m. The colour is brownish grey. The grain size of the sand is fine to medium grained. Moreover, clay patches and trace of mica mineral are included in this layer. SPT N-value range is varying from 4/30 to 31/30 blows. As a result of this, the relative density of this layer is very loose to dense.
Silty SAND-II	This layer is observed except BH-02. The thickness of this layer is about 10.0m. The colour is brownish grey. The grain size of the sand is fine grained. Moreover, a trace of mica mineral is included in this layer. SPT N-value range of this layer is 25/30 to over 50 blows and it can be described as medium dense to very dense.
CLAY- II	This layer is well observed at BH-02 and BH-04. The thickness of this layer of BH-02 is a minimum 7.0m and a maximum 8.0m. But, the thickness of this layer of BH-04 cannot be estimated because of this layer is terminated in this layer. The colour of this layer is mottled grey and red and grey colour in some boreholes. SPT N-value of it is 8/30 to 34/30 blows. The consistency of this layer is firm to hard.
Clayey SAND-I	It is only observed at BH-02. Thickness of this layer is about 3.0m and the colour of this layer is brownish yellow. The grain size of the sand is fine to medium grained. Moreover, fine gravel is included in this layer. SPT N-value is 8/30 to 30/30 blows. As a result of this, the relative density of it is loose to medium dense.
Silty SAND-III	It is well observed in this project area except BH-04. The thickness of this layer is a minimum 8.0m and a maximum 10.0m. The colour of it is brownish gray. The grain size of the sand is fine to medium grained. SPT N-value of this layer is 9/30 to over 50 blows and it can be described as loose to very dense.
CLAY-III	It is only observed at BH-01 and BH-02. The thickness of this layer is about 11.0m. The colour of this layer is mottled grey and red. Moreover, a trace of fine grained sand and fine gravel is included in this layer. SPT N-value range of this layer is 13/30 to 41/30 blows and it can be described as stiff to hard in consistency.
Clayey SAND-II	It is only observed at BH-01 and BH-02. The thickness of this layer is about 2.0m at BH-02 and cannot be estimated at BH-01 because of this layer is terminated in this layer at BH-01. The colour of this layer is brownish grey. The grain size of the sand is fine to coarse grained sand. Moreover, fine gravel is included in this layer. SPT N-value range of it is 13/30 to 41/30 blows. According to the investigation results, the relative density of this layer is medium dense to dense.
CLAY-IV	It is observed only at BH-02. The thickness of this layer cannot be estimated because this layer is the last layer. But, the thickness of this layer is more than 5.0m. The colour of this layer is mottled grey and red. Moreover, trace of fine gravel and fine sand are included in this layer. SPT N-value range of it is 27/30 to 29/30 blows and it can be described as very stiff in consistency. At the depth of GL- (57.00 ~ 59.00) m in this layer, dense, yellowish brown colour of SAND layer is inserted.

Source: JICA Survey Team

2) Soil Condition of Foundation of Ground

Structure foundations generally require an N-value of at least over 30 to 50 for the Sand/Gravel layer, and an N-value of at least over 15 to 20 for the Clay/Silt layer. For the soil condition in the Project Area, Clay I and Silty SAND-I layer cannot be expected to be suitable bearing layers without some soil treatment.

Layers distributed under the Silty SAND-I layer, such Silty SAND-II layer and Silty SAND-III layer can be expected as a bearing layer. However, the decision of the bearing layer should be made carefully because the N-value ranges widely vary in some portions.

Since the depth of the bearing layer is around over 20m, the suitable foundation type is generally recommended as the pile foundation. A suitable structure foundation type shall be selected taking into consideration various conditions, such as design, economical point of view, work efficiency, local characteristics and ground conditions.

Since the ground water level rises close to ground level during the rainy season, foundation work should be avoided during the rainy season.

3) Soft Soil Problem

Soft soil generally causes stability and settlement problems due to fill load and structure load on the ground foundation.

For the survey area, the Clay-I layer might be called soft soil because the N-value is less than four except BH-01. This layer is well observed in whole area. The thickness of this layer is from 5.0m to 7.0m. The colour of this layer is brown to grey and the water content is 26% to 34%, not so high. This layer is mixed with quite a bit sand content.

An expected settlement amount for Clay-I layer is just 24cm in case of 6m fill on the ground according to a settlement examination based on soil laboratory test results. Water content is comparatively low, bulk density is high and much of the sand content is mixed. Therefore, the settlement problem does not seriously occur in the area. And also, negative friction will not be generated for the pile foundation. However, the number of boreholes is not enough for the understanding of the soft soil distribution in the survey area. More soil investigation needs to be carried out to confirm soft soil distribution conditions in more detail.

CLAY-I is almost soft and Silty SAND-I layer is very loose to loose according to the N-value. Therefore, for Clay-I and Silty SAND-I layer, the safety of slope failure for the filling work on the ground shall be examined carefully. Moreover, for this loose Silty SAND-I layer, the possibility of liquefaction shall be considered for the design.

4.3 Hydrological Survey

4.3.1 General

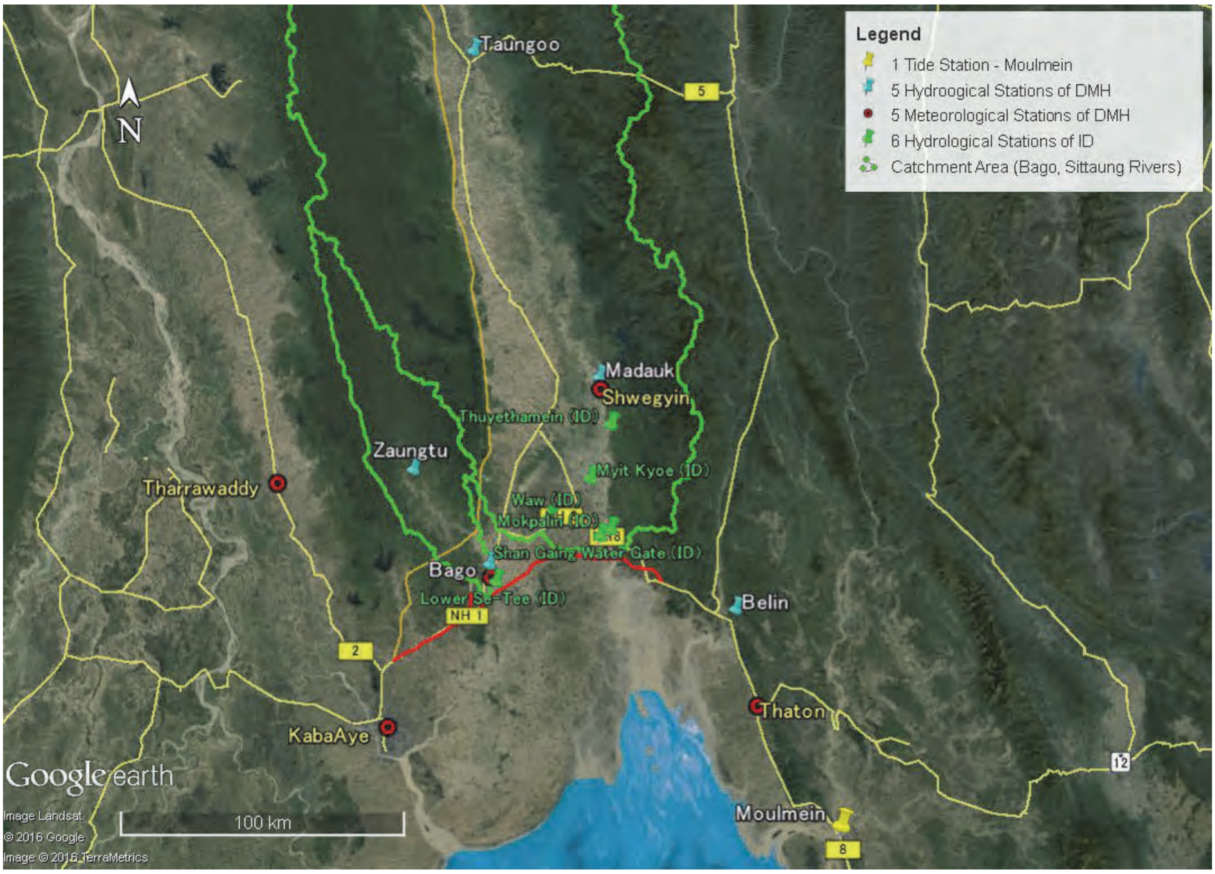
The climate of the targeted area in this study is typically classified as a tropical monsoonal type (Am) with a lower humidity than in most parts of South East Asia, according to Köppen climate classification system. (At the upper river basin of the Study Areas are classified as a tropical wet and dry or savanna climate; Aw.)

The rainy season is typically tropical southwest monsoon, and it has cloudy, rainy, hot and humid summers from June to September. On the other hand, the dry season is northeast monsoon, and it is less cloudy, has scant rainfall, mild temperatures, and lower humidity during winter from December to April. The targeted area is one of the areas of relatively higher precipitation in Myanmar as shown in Figure 4.3.7, and floods occur in the targeted area frequently. Also, at the lower reach to its junction with the Bago-Sittaung Canal from the river mouth of the Sittaung River, the tidal bore occurs twice per month, and therefore the bank erosion or deposition and the shifting of river course are serious.

The locations of existing seventeen meteorological, hydrological and tide stations are shown in Figure 4.3.1.

There are five observation stations of climatic data in and around the target area which have been operated by the Department of Meteorology and Hydrology (DMH) under the Ministry of Transport (MOT), as shown in Table 4.3.1. Also, eleven existing gauging stations (of water level/discharge data) are managed by the DMH and the Irrigation Department (ID) under the Ministry of Agriculture and Irrigation (MOAI) in and around target catchment basins as shown in Table 4.3.2. Of these stations, six stations of ID are not observed in the discharge records. Also, of these hydrological stations, the stations which are located within 100km from the sea are affected by the tidal action during the dry season. However, the discharge records at these stations during the rainy season can be utilized for flood probability calculation.

Regarding the tide data, it is observed by the Myanmar Port Authority (MPA) under MOT. However, the location of the tide station is far from the Study Area, and the nearest tide-station is located in the Moulmein (Mawlamyine) Port of Mon State, and the distance from the station to Sittaung River mouth is 104km.



Source: JICA Survey Team, Google Earth Map

Figure 4.3.1 Location Map of Meteorological, Hydrological and Tide Stations

Table 4.3.1 Inventory of Meteorological Stations

Meteorological Station	Code (WMO)	Coordinates		Height (m)	Period of Records						Remarks
		Latitude	Longitude		Temperature	Relative Humidity	Rainfall	Sunshine	Evaporation	Wind	
1. Kaba Aye (Yangon)	48097	16-54	96-10	20.00	1968-	1968-	1968-	1977-	1975-	1968-	
2. Bago	48093	17-20	96-30	9.00	1965-	1965-	1965-	-	-	1965-	
3. Tharrawady	48088	17-38	95-48	15.00	1965-	1965-	1965-	-	-	1965-	
4. Shwegyin (Madauk)	48089	15-55	96-52	12.00	-	-		-	-	-	
5. Bilin	-	17-11	97-17	16.15	-2013	-2013	-2013	-	-	-2013	

Source: JICA Survey Team

Table 4.3.2 Inventory of Hydrological and Tide 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. Sitttaung River / Taungoo	7040	18-55	96-28	14660	44.28	Pile Gauge	1965-	○	○	DMH	
2. Sitttaung River / Madauk	7060	17-55	96-51	26758	10.80	Pile Gauge	1965-	○	○	DMH	
3. Bago River / Zaungutu	6220	17-38	96-14	1,927	9.80	Pile Gauge	1987-	○	○	DMH	
4. Bago River / Bago (Pegu)	48093	17-20	96-30	2,580	9.00	Pile Gauge	1970-	○	○	DMH	
5. Bilin River / Belin	7210	17-49	95-41	2518	9.97	Mixed Gauge	1965-	○	○	DMH	
6. Sittaung River / Thuyethamein	-	17.7667	96.8833	-	-	Manual	-	○	-	ID	
7. Sittaung Tributary / Myit Kyoe	-	17.5992	96.8140	-	-	Manual	-	○	-	ID	
8. Sittaung River / Mokpalin	-	17.4396	96.8779	-	-	Manual	-	○	-	ID	
9. Sittaung-Bago Canal / Shan Gaing Gate	-	17.4190	96.8432	-	-	Manual	-	○	-	ID	
10. Sittaung-Bago Canal / Waw	-	17.4767	96.6780	-	-	Manual	-	○	-	ID	
11. Sittaung-Bago Canal / Lower Se-Tee	-	17.2768	96.4935	-	-	Manual	-	○	-	ID	
12. Mawlamyine Port / Moulmein	747(PSMSL) 141(GLOSS)	16-29	97-37	-	-	Steel Plate	1954-	○	-	Navy / MPA	

Source: JICA Survey Team

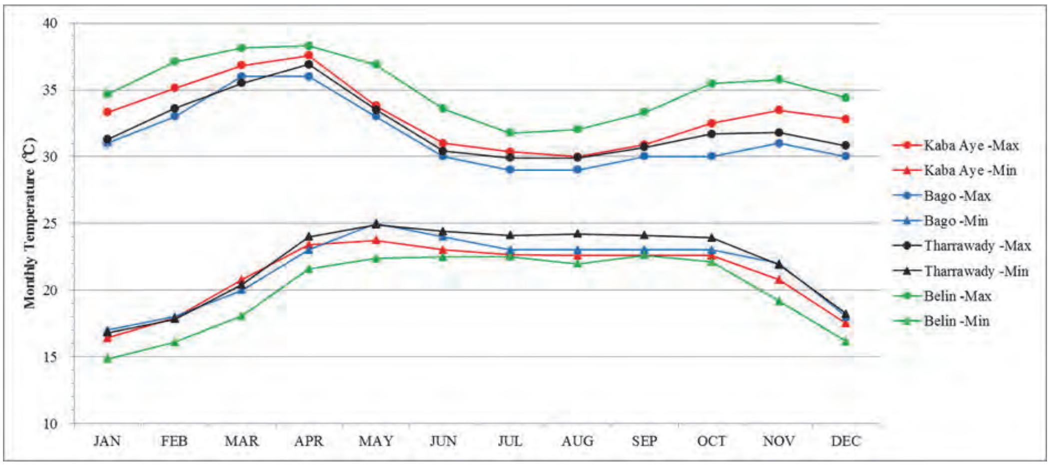
4.3.2 Meteorological Conditions

(1) General Weather Conditions

1) Temperature

The temperature data of four stations shows almost a similar trend. The monthly mean temperature at the coastal area of Martaban Gulf has a range between around 24℃ and 30℃. According to the collected data, the mean monthly maximum temperature 30-37℃ (maximum is April) and the mean minimum temperature 16-24℃ (minimum is January) at the targeted area were recorded respectively.

The mean monthly maximum and minimum temperature at the four stations is shown in Figure 4.3.2 and Table 4.3.3.



Source: JICA Survey Team, DMH

Figure 4.3.2 Mean Monthly Maximum and Minimum Temperature

Table 4.3.3 Mean Monthly Maximum and Minimum Temperature

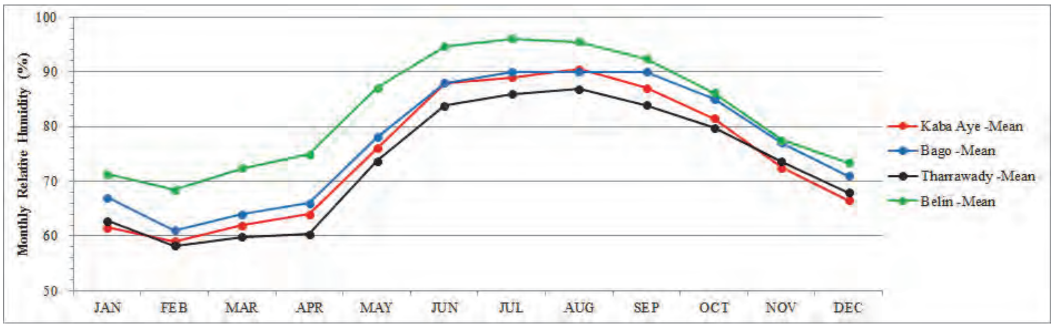
Station		Item	Monthly Temperature in ℃													Remarks
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average	
1	Kaba Aye	Max	33.3	35.1	36.8	37.6	33.8	31.0	30.3	30.0	30.9	32.5	33.5	32.8	33.1	1991-2008
		Min	16.4	17.9	20.8	23.4	23.7	23.0	22.6	22.6	22.6	22.6	20.8	17.5	21.2	1991-2008
2	Bago	Max	31.0	33.0	36.0	36.0	33.0	30.0	29.0	29.0	30.0	30.0	31.0	30.0	31.5	17 yrs*
		Min	17.0	18.0	20.0	23.0	25.0	24.0	23.0	23.0	23.0	23.0	22.0	18.0	21.6	17 yrs*
3	Tharrawady	Max	31.3	33.6	35.5	36.9	33.5	30.4	29.9	29.9	30.7	31.7	31.8	30.8	32.2	30 yrs*
		Min	16.8	17.8	20.4	24.0	24.9	24.4	24.1	24.2	24.1	23.9	21.9	18.2	22.1	30 yrs*
5	Belin	Max	34.7	37.1	38.1	38.3	36.9	33.6	31.8	32.0	33.3	35.5	35.8	34.4	35.1	2004-2013
		Min	14.8	16.1	18.1	21.6	22.4	22.5	22.5	22.0	22.6	22.1	19.2	16.1	20.0	2004-2013
Average			24.4	26.1	28.2	30.1	29.1	27.4	26.7	26.6	27.2	27.7	27.0	24.7	27.1	
Average Max.			32.6	34.7	36.6	37.2	34.3	31.2	30.3	30.2	31.2	32.4	33.0	32.0	33.0	
Average Min.			16.3	17.4	19.8	23.0	24.0	23.5	23.1	22.9	23.1	22.9	21.0	17.5	21.2	

Source: DMH except for *. The data of * is; http://www.weatherbase.com/weather/

2) Relative Humidity

The relative humidity has been observed twice a day (at 9:30 and 18:30). Although the rainy season is hot-humid, the relative humidity during winter from December to April is low. The mean monthly relative humidity in the targeted area ranges between 62 and 91%.

The mean monthly relative humidity at 4 stations is shown in Figure 4.3.3 and Table 4.3.4.



Source: JICA Survey Team, DMH

Figure 4.3.3 Mean Monthly Relative Humidity

Table 4.3.4 Mean Monthly Relative Humidity

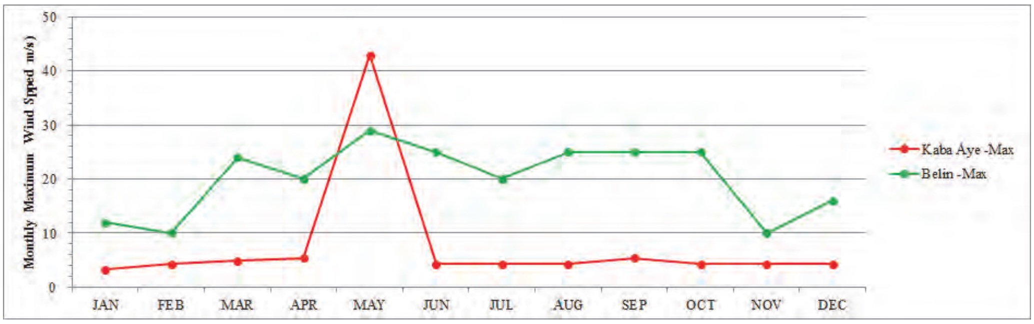
Station		Item	Monthly Relative Humidity in %													Remarks
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average	
1	Kaba Aye	Mean	61.5	59.0	62.0	64.0	76.0	88.0	89.0	90.5	87.0	81.5	72.5	66.5	74.8	1991-2000
2	Bago	Mean	67.0	61.0	64.0	66.0	78.0	88.0	90.0	90.0	90.0	85.0	77.0	71.0	77.3	12 yrs*
3	Tharrawady	Mean	62.8	58.2	59.8	60.3	73.7	83.8	85.9	86.8	83.9	79.8	73.6	67.9	73.0	112 yrs*
5	Belin	Mean	71.3	68.4	72.4	74.9	87.1	94.6	96.1	95.5	92.4	86.1	77.5	73.4	82.5	2004-2013
Average			65.7	61.7	64.6	66.3	78.7	88.6	90.3	90.7	88.3	83.1	75.2	69.7	76.9	

Source: DMH except for *. The data of * is; http://www.weatherbase.com/weather/

3) Wind Speed and Direction

The monthly maximum wind speed at each station is not stable at a range between 3 and 43 m/s throughout the year. The wind direction in the targeted area depends on the influence of the southwest monsoon during the rainy season and the northeast monsoon during the dry season. The maximum wind speed of the targeted area is caused by low-pressure waves (the remnants of typhoons and tropical storms of the South China Sea), and the Bay of Bengal cyclones have never hit the southern coast in Mon State and Tanintharyi Division in Myanmar.

The monthly maximum wind speed at two of the stations is shown in Figure 4.3.4 and Table 4.3.5.



Source: JICA Survey Team, DMH

Figure 4.3.4 Monthly Maximum Wind Speed

Table 4.3.5 Monthly Maximum Wind Speed

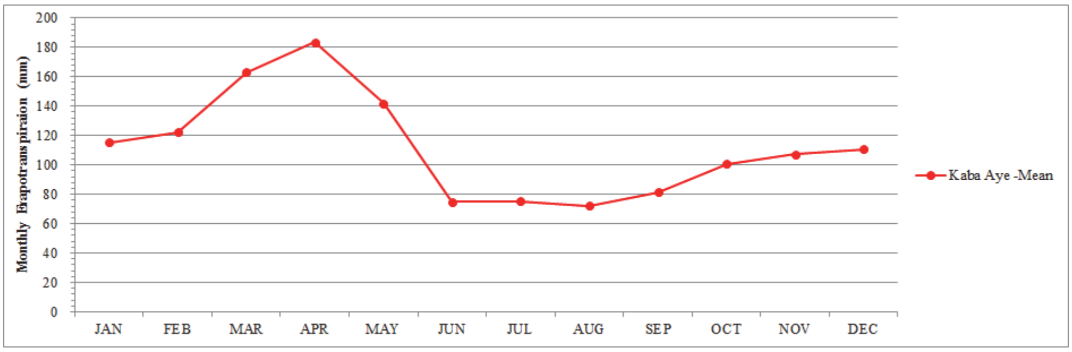
Station		Item	Monthly Maximum Wind Speed in m/s													Remarks
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average	
1	Kaba Aye	Max	3.2	4.3	4.8	5.4	42.9	4.3	4.3	4.3	5.4	4.3	4.3	4.3	7.6	1999-2008
5	Belin	Max	12	10	24	20	29	25	20	25	25	25	10	16	20.1	2004-2013

Source: DMH

4) Evapotranspiration

The evapotranspiration is not observed at other stations except Kaba-Aye (Yangon). The annual mean evapotranspiration is 1173-1582mm, and it accounts 49% of the annual rainfall.

The mean monthly evapotranspiration at Kaba-Aye Station is shown in Figure 4.3.5 and Table 4.3.6.



Source: JICA Survey Team, DMH

Figure 4.3.5 Mean Monthly Evapotranspiration (1981-2000)

Table 4.3.6 Mean Monthly Evapotranspiration (1981-2000)

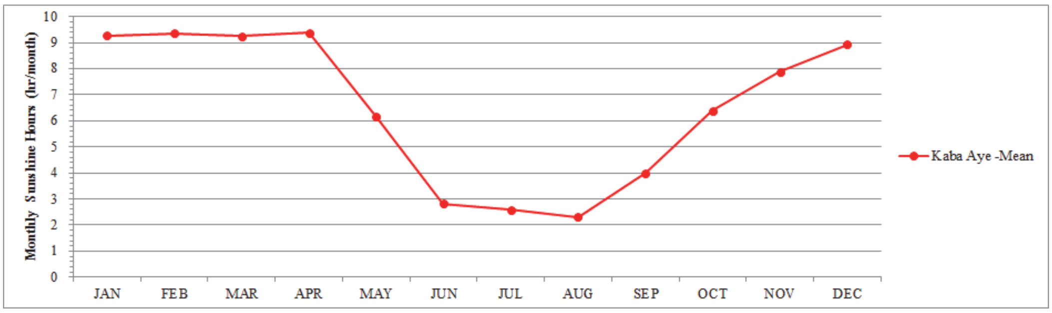
	Station	Item	Monthly Evapotranspiration in mm/month													Remarks
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total	
1	Kaba Aye	Mean	115.4	122.1	162.9	183.6	141.9	74.9	75.3	72.4	81.5	100.7	107.2	110.6	1348.6	1981-2000 (1984missing)

Source: DMH

5) Sunshine Hours

The sunshine hours are observed at Kaba-Aye Station only. The annual mean sunshine hours is 6.5 hours/day. The sunshine hours are shorter during the rainy season, and its pattern is shown the opposite of monthly rainfall fluctuation.

The mean monthly sunshine hours at Kaba-Aye Station is shown in Figure 4.3.6 and Table 4.3.7.



Source: JICA Survey Team, DMH

Figure 4.3.6 Mean Monthly Sunshine Hours (1977-2000)

Table 4.3.7 Mean Monthly Sunshine Hours (1977-2000)

	Station	Item	Monthly Sunshine Hours in hr													Remarks
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total	
1	Kaba Aye	Mean	9.3	9.4	9.2	9.4	6.2	2.8	2.6	2.3	4.0	6.4	7.9	8.9	78.3	1977-2000

Source: DMH

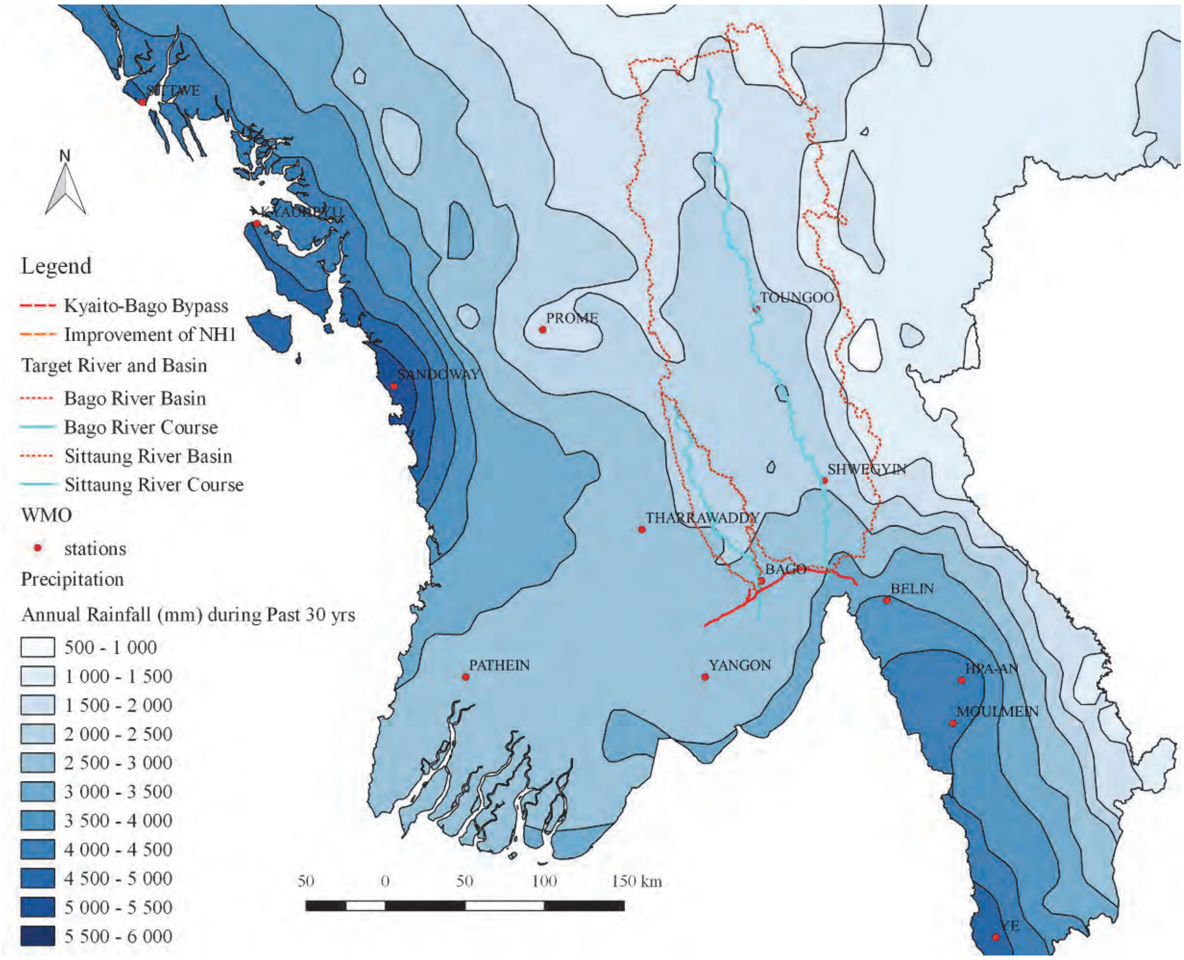
(2) Rainfall

1) Annual Rainfall and Seasonal / Long-term Fluctuation

The targeted area is one of the areas having the highest abundant precipitation in Myanmar. (The areal distribution of average annual rainfalls which is observed based on annual rainfalls during past 30 years of weather station operation in and around the coastal area of the Martaban Gulf, is shown in Figure 4.3.7.) The annual mean rainfall ranges from 2,745mm at Kaba-Aye to 5,480mm at Belin. Also the annual rainfall fluctuates between each station significantly. (e.g. between 2,127 and 3,592mm at Kaba-Aye of Yangon city.)

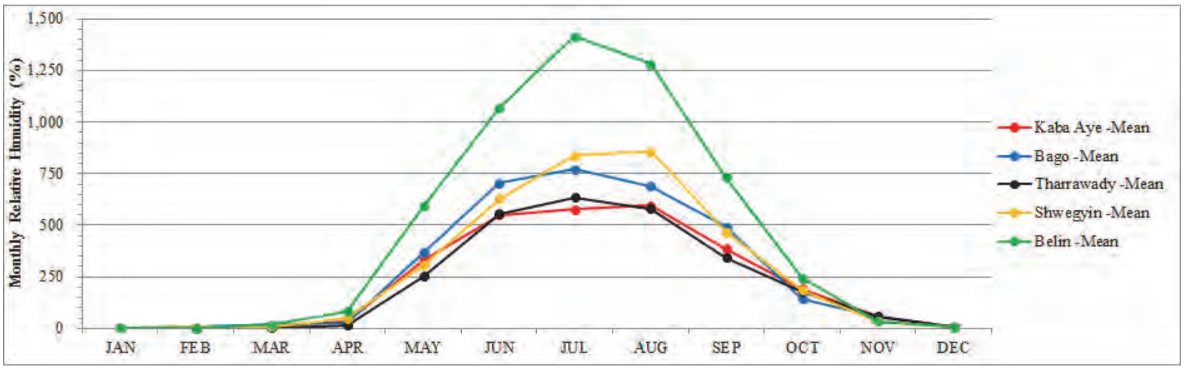
Seasonal variation of the monthly total is similar in each station. Regarding the seasonal fluctuation of rainfall, 95% or more of annual rainfall is brought by the rainy season from May to October, with the highest amount of rainfall in July or August.

The mean monthly rainfall at five of the stations is shown in Figure 4.3.8 and Table 4.3.8.



Source: JICA Survey Team, Digital Agricultural Atlas (FAO, http://dwms.fao.org/atlases/myanmar/index_en.htm)

Figure 4.3.7 Areal Distribution (Isohyet) of Annual Rainfall in Southern Myanmar



Source: JICA Survey Team, DMH

Figure 4.3.8 Mean Monthly Rainfall (1968-2015)

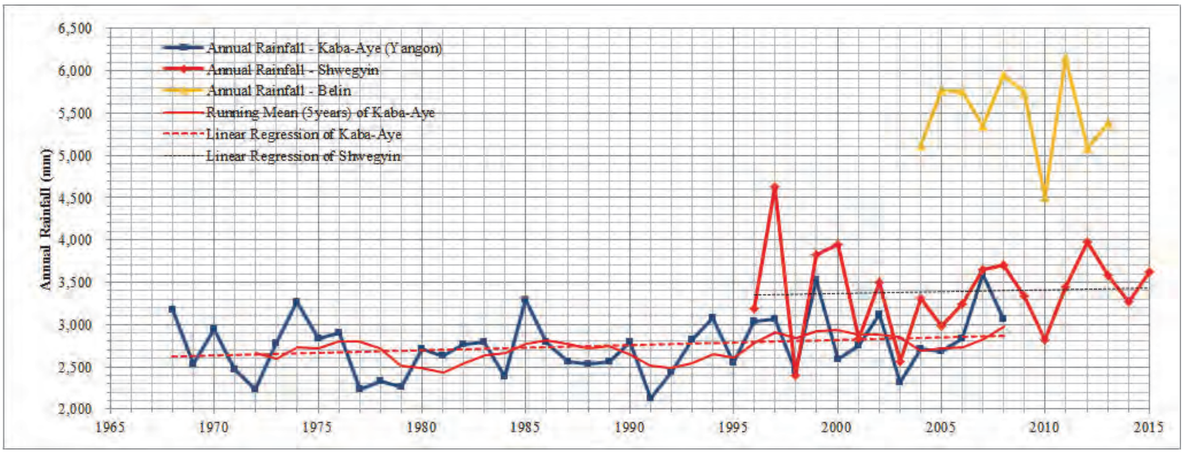
Table 4.3.8 Mean Monthly Rainfall (1968-2015)

Station		Item	Monthly Rainfall in mm													Remarks
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total	
1	Kaba Aye	Mean	4	3	13	32	331	550	576	596	387	192	59	6	2,747	1968-2008
2	Bago	Mean	2	6	19	29	369	704	771	688	492	144	54	10	3,288	1996-2005
3	Tharrawady	Mean	4	1	3	16	251	555	635	581	342	180	56	7	2,633	112 yrs*
4	Shwegyin	Mean	3	5	8	50	306	629	839	857	466	186	34	7	3,390	1996-2015
5	Belin	Mean	2	1	19	83	593	1,069	1,415	1,282	733	242	34	7	5,480	2004-2013

Source: DMH except for *. The data of * is; http://www.weatherbase.com/weather/

Figure 4.3.9 shows the long-term fluctuation of annual rainfall at three stations. Although the cycle of wet and drought periods is not clear, the rainfall of 2010 was not so much at every station.

However, regarding Kaba-Aye (Yangon) and Shwegyin Stations, it is indicated that the limited rise trend of annual rainfall is going on in recent years.



Source: JICA Survey Team, DMH

Figure 4.3.9 Fluctuation of Annual Rainfall

2) Exceedance Probability and Intensity Curve of Rainfall

The annual maximum daily rainfall (extremal value) data at four meteorological stations was collected, for studying the road profile for "New Kyaito - Bago Road Construction" and "Improvement of NH1". The 24 hour rainfalls of 2-500 year probabilities are calculated by using these extreme values, as shown in Table 4.3.9 and Figure 4.3.10.

The probability calculation adopts the Gumbel distribution method that is most commonly used.

Among of these four stations, the result of Belin Station was rejected, because the distribution of the precipitation sample is estimated that it is relatively uniform and the correlation is low. The remaining results of three stations are shown a relatively good correlation, even if there is a difference in the number of samples.

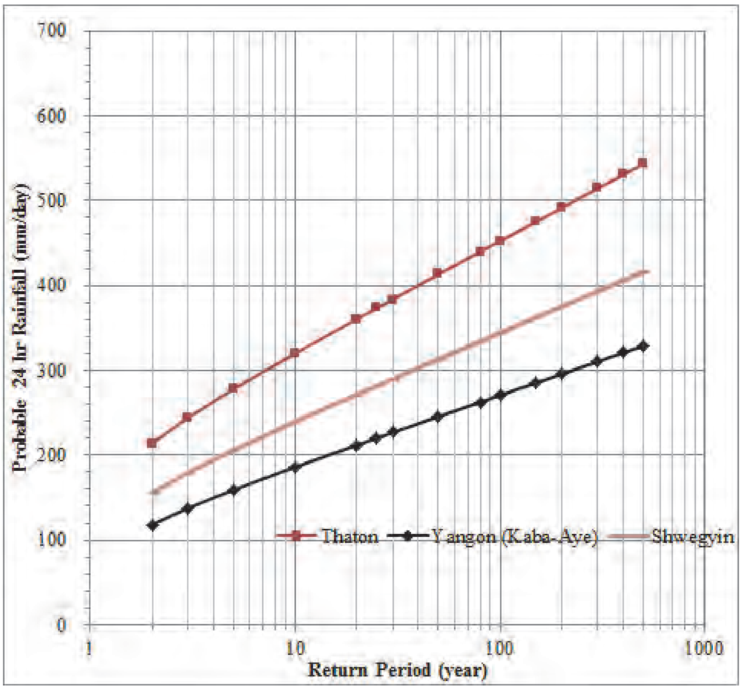
The difference of probability values of the three stations is big, and the regional deviation is also big. Therefore, the maximum probability values of each road alignment are set by using its distribution map. For reference, the spatial distribution map of 50-years probability rainfall is plotted in Figure 4.3.11. (The probability rainfalls of each road are estimated by reading the maximum probability values on the alignment of the TIN (Triangulated Irregular Network) of GIS software.)

As the next step, the correlation between the intensity of short time rainfall duration and 24 hour rainfall is estimated in reference to Mononobe's equation. The relationship of IDF (Intensity-Duration-Frequency), namely the rainfall-intensity is shown in Table 4.3.10, Table 4.3.11 and Table 4.3.12.

Table 4.3.9 Calculation Results of Probable Daily Rainfall at Four Precipitation Stations

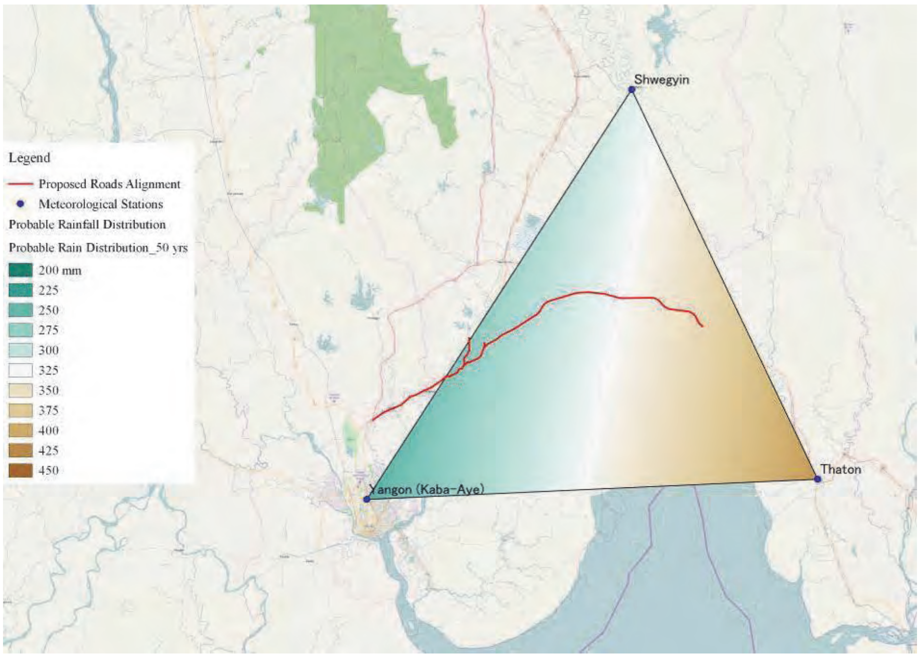
Return Period (Probability) (Year, %)		Dairy Rainfall: R_{24} (mm/day)			
		Yangon (Kaba-Aye)	Shwegyin	Belin	Thaton
2	50.0%	118.2	155.3	175.0	213.7
3	33.3%	137.5	179.2	181.7	243.9
5	20.0%	159.0	205.9	189.1	277.6
10	10.0%	186.0	239.4	198.5	319.8
20	5.0%	211.9	271.5	207.4	360.4
25	4.0%	220.2	281.7	210.3	373.3
30	3.33%	226.8	289.9	212.6	383.7
50	2.0%	245.5	313.0	219.1	412.9
80	1.25%	262.5	334.2	225.0	439.6
100	1.0%	270.6	344.2	227.8	452.2
150	0.667%	285.3	362.4	232.8	475.1
200	0.5%	295.7	375.2	236.4	491.4
300	0.33%	310.3	393.4	241.5	514.3
400	0.25%	320.7	406.2	245.1	530.5
500	0.2%	328.7	416.2	247.9	543.1
Data No.		45 (years)	20 (years)	10 (years)	10 (years)
Probable Distribution Method		Gumbel distribution	Gumbel distribution	Gumbel distribution	Gumbel distribution

Source: JICA Survey Team



Source: JICA Survey Team

Figure 4.3.10 Correlation of Probable Daily Rainfall at Three Precipitation Stations



Source: JICA Survey Team

Figure 4.3.11 Spatial Distribution of Probability Daily Rainfall (Case of 50-years Flood)

Table 4.3.10 Calculation Results of IDF (Intensity-Duration-Frequency) at Kaba-Aye Station

Return Period (Probability) (Year, %)		Dairy Rainfall: R_{24} (mm/day)	Rainfall intensity each rainfall duration (mm/hr): It = $R_{24}/24*(24/t)^m$, m=2/3											Remarks
Yangon (Kaba-Aye)		24 hour	24	12	8	6	3	2	1.5	1	0.75	0.5	It= $A/t^{2/3}$	
		1,440 min.	1,440	720	480	360	180	120	90	60	45	30		
2	50.0%	118.2	4.9	7.8	10.2	12.4	19.7	25.8	31.3	41.0	49.6	65.0	A= 40.978	
3	33.3%	137.5	5.7	9.1	11.9	14.4	22.9	30.0	36.4	47.7	57.7	75.7	A= 47.669	
5	20.0%	159.0	6.6	10.5	13.8	16.7	26.5	34.7	42.1	55.1	66.8	87.5	A= 55.122	
10	10.0%	186.0	7.8	12.3	16.1	19.5	31.0	40.6	49.2	64.5	78.1	102.4	A= 64.483	Road Drain
20	5.0%	211.9	8.8	14.0	18.4	22.2	35.3	46.3	56.1	73.5	89.0	116.6	A= 73.462	
25	4.0%	220.2	9.2	14.6	19.1	23.1	36.7	48.1	58.3	76.3	92.5	121.2	A= 76.339	Culvert
30	3.33%	226.8	9.5	15.0	19.7	23.8	37.8	49.5	60.0	78.6	95.3	124.8	A= 78.627	
50	2.0%	245.5	10.2	16.2	21.3	25.8	40.9	53.6	65.0	85.1	103.1	135.1	A= 85.110	Bridge
80	1.25%	262.5	10.9	17.4	22.8	27.6	43.8	57.3	69.4	91.0	110.2	144.5	A= 91.004	
100	1.0%	270.6	11.3	17.9	23.5	28.4	45.1	59.1	71.6	93.8	113.6	148.9	A= 93.812	Main Bridge
150	0.667%	285.3	11.9	18.9	24.7	30.0	47.6	62.3	75.5	98.9	119.8	157.0	A= 98.908	
200	0.5%	295.7	12.3	19.6	25.6	31.0	49.3	64.6	78.2	102.5	124.2	162.7	A= 102.513	
300	0.33%	310.3	12.9	20.5	26.9	32.6	51.7	67.8	82.1	107.6	130.3	170.8	A= 107.575	
400	0.25%	320.7	13.4	21.2	27.8	33.7	53.5	70.0	84.8	111.2	134.7	176.5	A= 111.180	
500	0.2%	328.7	13.7	21.7	28.5	34.5	54.8	71.8	87.0	114.0	138.0	180.9	A= 113.954	

Source: JICA Survey Team

Table 4.3.11 Calculation Results of IDF (Intensity-Duration-Frequency) at Shwegyin Station

Return Period (Probability) (Year, %)		Dairy Rainfall: R_{24} (mm/day)	Rainfall intensity each rainfall duration (mm/hr): It = $R_{24}/24*(24/t)^m$, m=2/3											Remarks
Shwegyin		24 hour	24	12	8	6	3	2	1.5	1	0.75	0.5	It= $A/t^{2/3}$	
		1,440 min.	1,440	720	480	360	180	120	90	60	45	30		
2	50.0%	155.3	6.5	10.3	13.5	16.3	25.9	33.9	41.1	53.8	65.2	85.5	A= 53.840	
3	33.3%	179.2	7.5	11.9	15.5	18.8	29.9	39.1	47.4	62.1	75.3	98.6	A= 62.125	
5	20.0%	205.9	8.6	13.6	17.8	21.6	34.3	45.0	54.5	71.4	86.5	113.3	A= 71.382	
10	10.0%	239.4	10.0	15.8	20.7	25.1	39.9	52.3	63.3	83.0	100.5	131.7	A= 82.995	Road Drain
20	5.0%	271.5	11.3	18.0	23.5	28.5	45.3	59.3	71.8	94.1	114.0	149.4	A= 94.124	
25	4.0%	281.7	11.7	18.6	24.4	29.6	47.0	61.5	74.5	97.7	118.3	155.0	A= 97.660	Culvert
30	3.33%	289.9	12.1	19.2	25.1	30.4	48.3	63.3	76.7	100.5	121.8	159.5	A= 100.503	
50	2.0%	313.0	13.0	20.7	27.1	32.9	52.2	68.4	82.8	108.5	131.5	172.3	A= 108.511	Bridge
80	1.25%	334.2	13.9	22.1	29.0	35.1	55.7	73.0	88.4	115.9	140.4	183.9	A= 115.861	
100	1.0%	344.2	14.3	22.8	29.8	36.1	57.4	75.2	91.1	119.3	144.6	189.4	A= 119.327	Main Bridge
150	0.667%	362.4	15.1	24.0	31.4	38.0	60.4	79.1	95.9	125.6	152.2	199.4	A= 125.637	
200	0.5%	375.2	15.6	24.8	32.5	39.4	62.5	81.9	99.3	130.1	157.6	206.5	A= 130.075	
300	0.33%	393.4	16.4	26.0	34.1	41.3	65.6	85.9	104.1	136.4	165.2	216.5	A= 136.384	
400	0.25%	406.2	16.9	26.9	35.2	42.6	67.7	88.7	107.5	140.8	170.6	223.5	A= 140.822	
500	0.2%	416.2	17.3	27.5	36.1	43.7	69.4	90.9	110.1	144.3	174.8	229.0	A= 144.288	

Source: JICA Survey Team

Table 4.3.12 Calculation Results of IDF (Intensity-Duration-Frequency) at Thaton Station

Return Period (Probability) (Year, %)		Dairy Rainfall: R_{24}	ration (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	It= $A/t^{2/3}$	
Thaton		1,440 min.	1,440	720	480	360	180	120	90	60	45	30		
2	50.0%	213.7	8.9	14.1	18.5	22.4	35.6	46.7	56.5	74.1	89.7	117.6	A= 74.086	
3	33.3%	243.9	10.2	16.1	21.1	25.6	40.7	53.3	64.5	84.6	102.4	134.2	A= 84.555	
5	20.0%	277.6	11.6	18.4	24.1	29.1	46.3	60.6	73.4	96.2	116.6	152.8	A= 96.239	
10	10.0%	319.8	13.3	21.2	27.7	33.6	53.3	69.8	84.6	110.9	134.3	176.0	A= 110.868	Road Drain
20	5.0%	360.4	15.0	23.8	31.2	37.8	60.1	78.7	95.3	124.9	151.4	198.3	A= 124.944	
25	4.0%	373.3	15.6	24.7	32.4	39.2	62.2	81.5	98.8	129.4	156.8	205.4	A= 129.416	Culvert
30	3.33%	383.7	16.0	25.4	33.3	40.3	64.0	83.8	101.5	133.0	161.1	211.2	A= 133.021	
50	2.0%	412.9	17.2	27.3	35.8	43.4	68.8	90.2	109.2	143.1	173.4	227.2	A= 143.144	Bridge
80	1.25%	439.6	18.3	29.1	38.1	46.2	73.3	96.0	116.3	152.4	184.6	241.9	A= 152.401	
100	1.0%	452.2	18.8	29.9	39.2	47.5	75.4	98.8	119.6	156.8	189.9	248.9	A= 156.769	Main Bridge
150	0.667%	475.1	19.8	31.4	41.2	49.9	79.2	103.8	125.7	164.7	199.5	261.5	A= 164.708	
200	0.5%	491.4	20.5	32.5	42.6	51.6	81.9	107.3	130.0	170.4	206.4	270.4	A= 170.359	
300	0.33%	514.3	21.4	34.0	44.6	54.0	85.7	112.3	136.1	178.3	216.0	283.0	A= 178.298	
400	0.25%	530.5	22.1	35.1	46.0	55.7	88.4	115.9	140.4	183.9	222.8	291.9	A= 183.914	

Source: JICA Survey Team

4.3.3 Hydrological / Hydraulic Conditions

In order to predict the flow rate/water level during the flood season, it is necessary to collect and correlate the collectable data/conditions concerning the hydrological/hydraulic of the related rivers surrounding the targeted area.

(1) Rivers and Characteristics of River Flow

1) Riverine System

In and around the target area, two big river basins (Bago and Sittaung River basins) exist, and there are the Sittaung-Bago Canal that connects the rivers, and many drainage/irrigation creek systems. The related drainage/irrigation network in the target area is shown in Figure 4.3.12.

➢ <u>Sittaung River</u>

The Sittaung (formerly, the Sittang or Sittoung) is a river in central-south Myanmar in Bago Division. The Sittaung River is the fourth largest river of Myanmar with the entire length of about 420km. It originates near Yamethin, and it discharges into the Gulf of Martaban of the Andaman Sea. The source of Sittaung River is 460m above mean sea level. The broad Sittaung River valley lies between the forested Bago Mountains on the west and the steep Shan Plateau on the east. The Sittaung River is navigable for 40 km year-round and for 90 km during the three rainy months. Transport is used to float timber, particularly teak, south for export. Its lower course is linked by canal to Bago River, which makes the basins during the wet season very inter-related. The number of dams and reservoirs are increasing, and currently, there are seventeen dams and also thirteen reservoirs in the Sittaung River basin for multi-purpose uses, such as irrigation, flood control and hydropower generation.

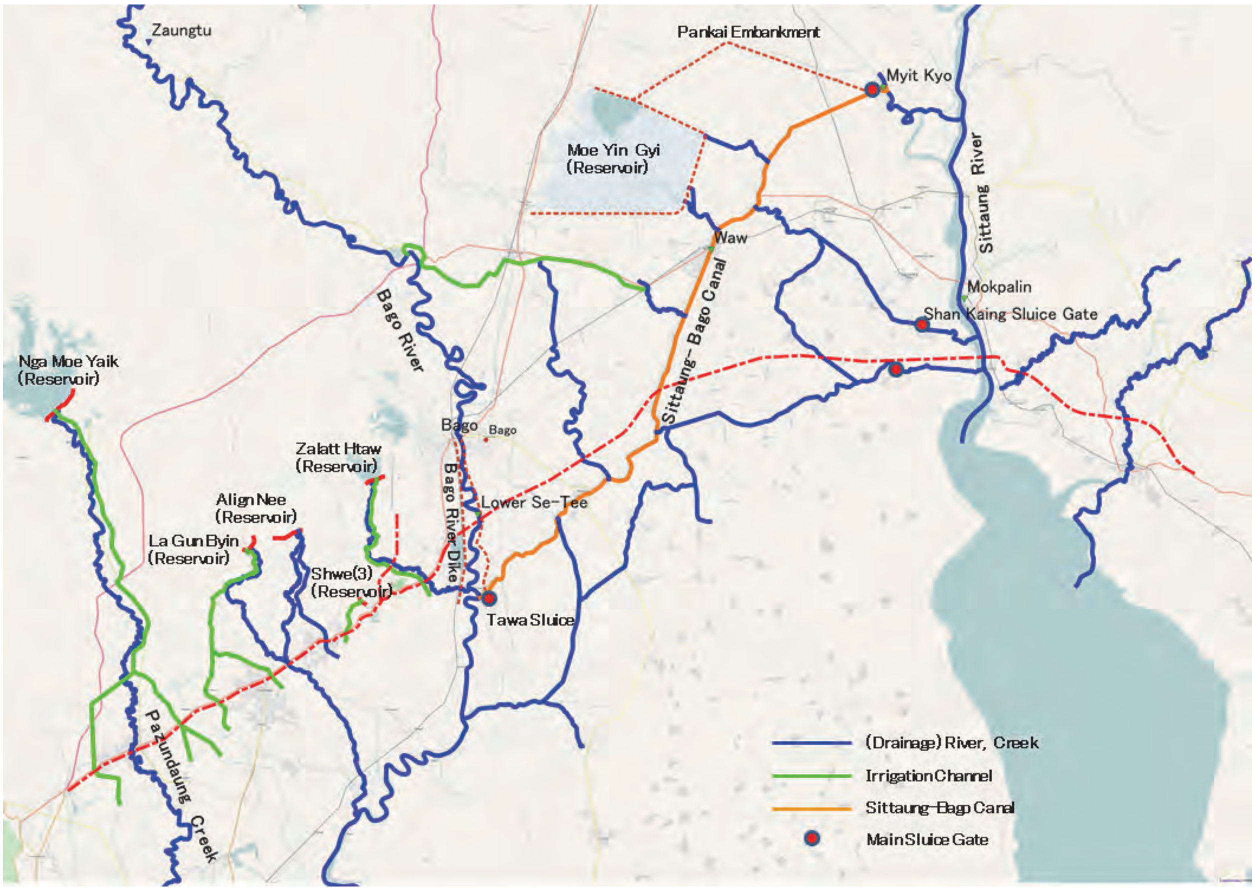
➢ <u>Bago River</u>

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 Yangon River. From the confluence point with the Hlaing River (located in Yangon), it is called the Yangon River.

The total length from its source to its mouth at the confluence of Yangon River is about 260km. Bago River at Bago gauging station is clearly influenced by tidal level during the period of low flows. In the Bago River basin, thirteen reservoirs and one dam are situated for multi-purpose uses.

➢ <u>Sittaung-Bago Canal</u>

The Sittaung-Bago canal was constructed in 1878 primarily for navigational (timber transport) purposes, and it is aimed to connect Bago River with the Sittaung River to avoid the tidal bore on the lower reach of Sittaung River. The canal leaves the Bago River at Tawa and continues for 61km to enter the Sittaung River at Myit-kyo, and it provided the only route from Yangon to Taungoo. The Sittaung-Bago Canal was renovated in 2014 and now protects residents from flooding and is an important water supplier for local irrigation. The canal has one interconnected reservoir and six sluices. Also, there are a large number of sluices of which most are not clearly documented, because they were constructed by local residents. Sluices regularly regulate the in- and outflow of tributaries. A tidal effect is seen on both ends from the canal. According to the literature of Myo Lin of TU Delft (2015), it is described that 'During a heavy rainfall event, the operation of the reservoir and sluices is very complex due to the effect of inland flow and high tide.' This causes continuous complexity for decision making with the uncertainty of the system tidal and rainfall components.

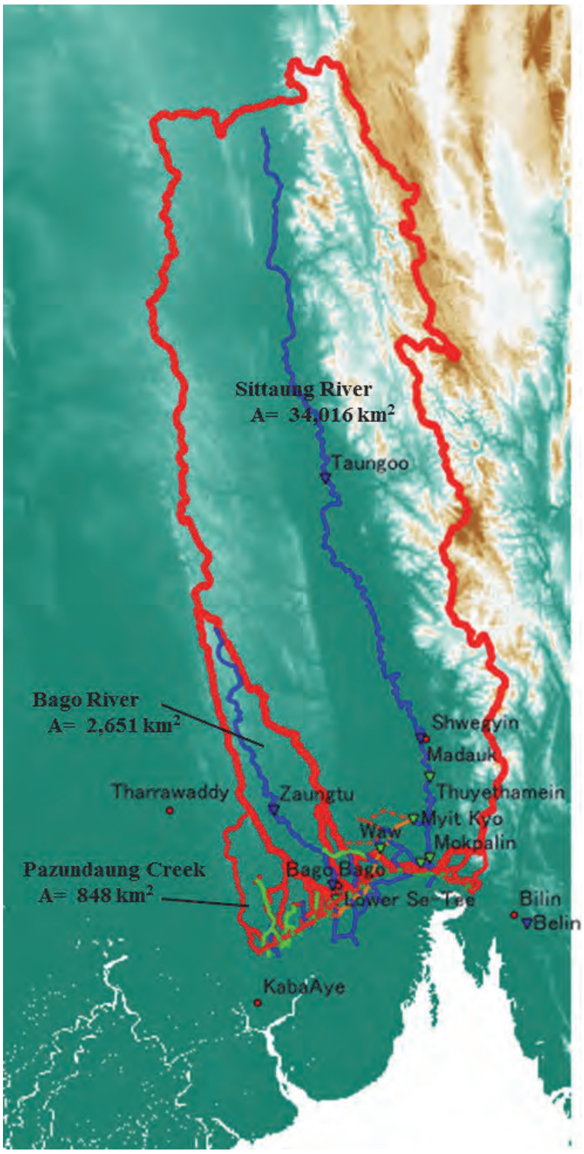


Source: JICA Survey Team

Figure 4.3.12 Drainage and Irrigation Channel Network around Proposed Roads

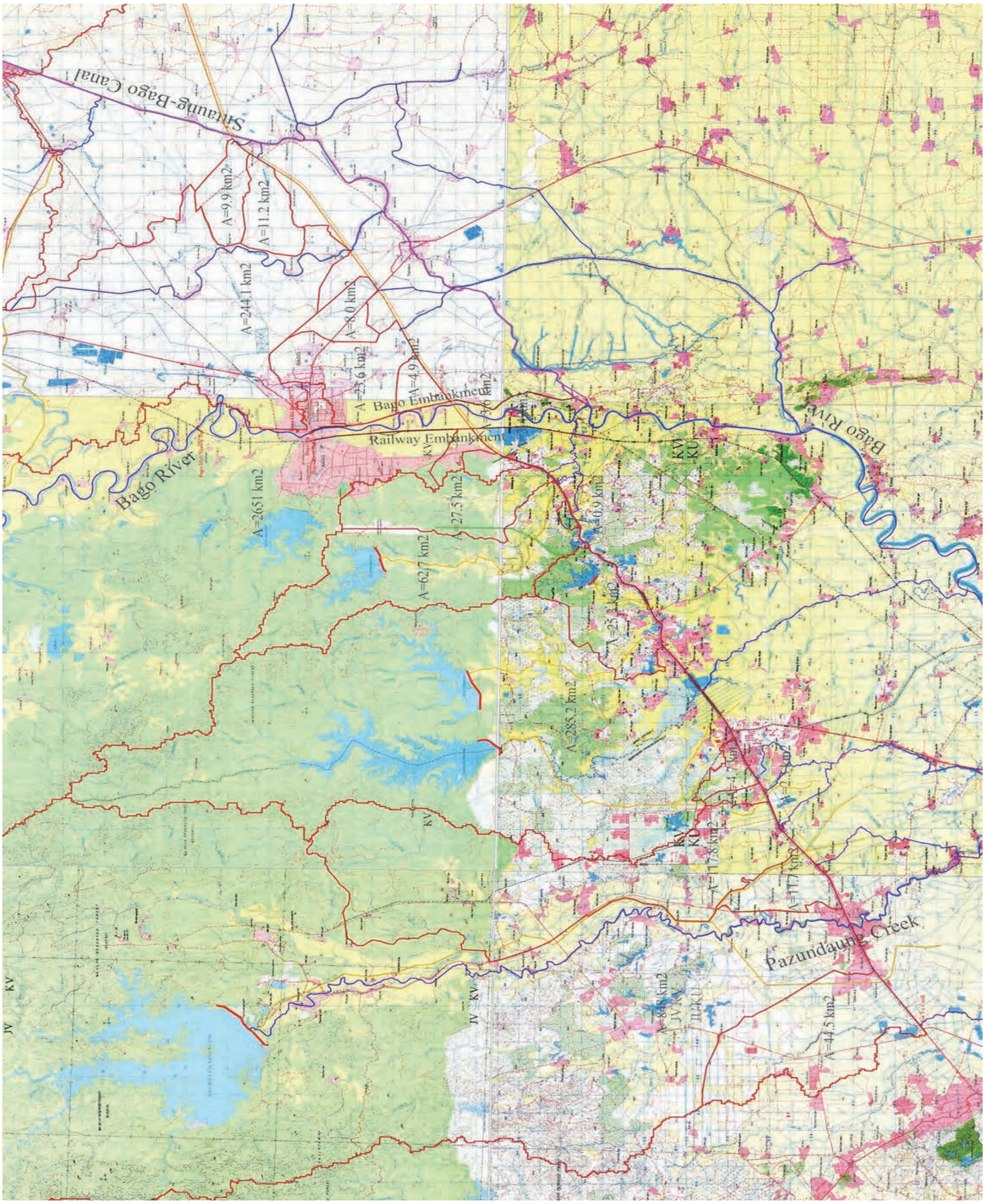
2) Catchment Areas of Related Rivers Crossing the Proposed Roads

The related rivers or creeks at the proposed roads are identified by the topographic map and the hearing investigation as shown in Figure 4.3.13, Figure 4.3.14 and Figure 4.3.15, and their catchment areas are measured. The proposed roads traverse across several types of terrain such as swampy, waterways, paddy field zones, low-lying and hilly areas. However, most of the targeted area is low-lying areas and paddy field areas, and the drainage and irrigation channels consist with the intricate network mutually. The lateral drainage facilities (such as bridges and culverts) of roads are to be provided by the design discharge which is calculated from its catchment area. This time, the detailed topographic survey is not conducted, and its topographic information is not detailed. Therefore, a furthermore detailed survey shall be performed in the future study, for clarifying the channel and its catchment area information.



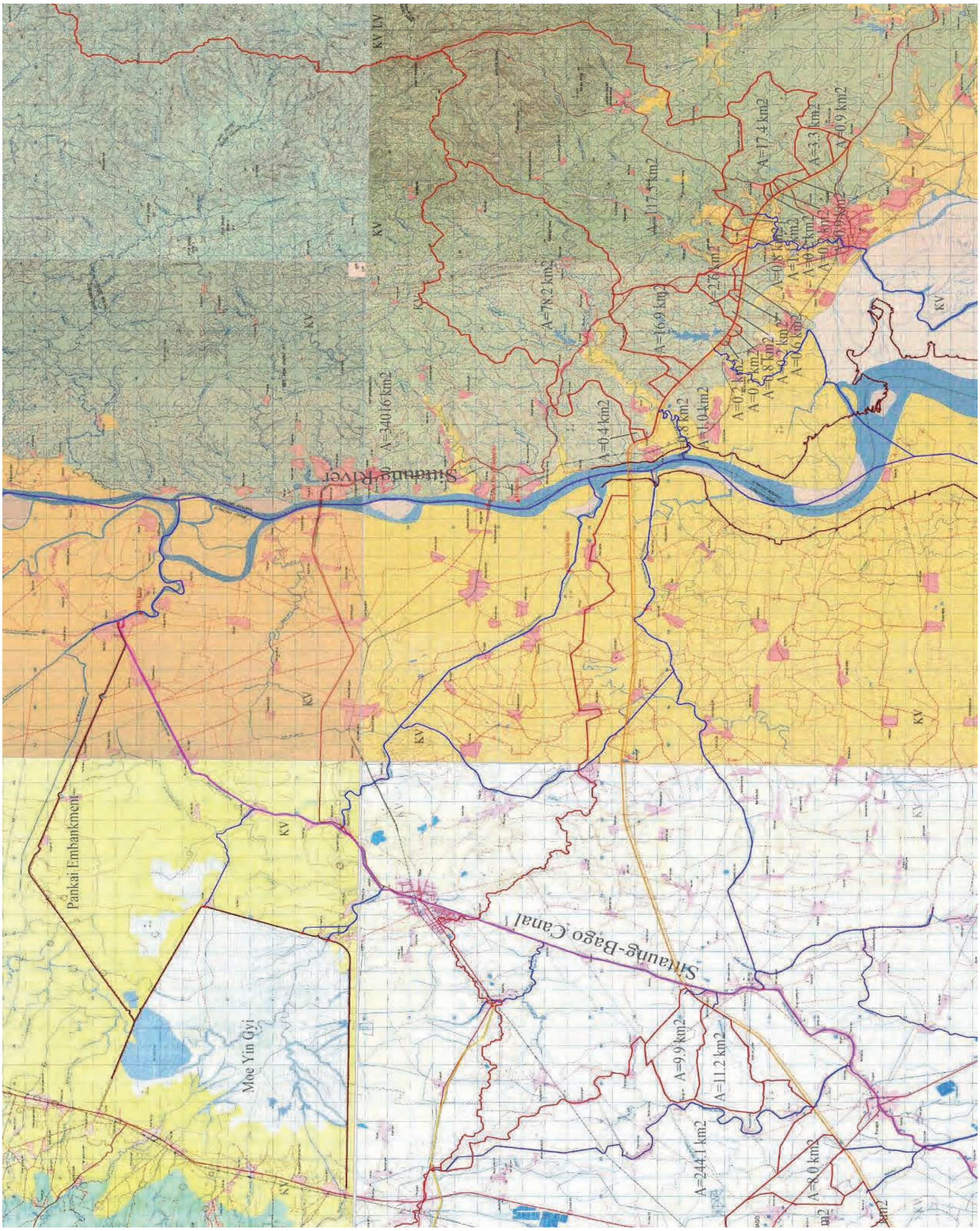
Source: JICA Survey Team based on the data from Topographic Map (Irrigation Dept.) and ASTER-GDEM

Figure 4.3.13 Catchment Area Map (1)



Source: JICA Survey Team based on the data from Topographic Map (Irrigation Dept.)

Figure 4.3.14 Catchment Area Map (2)



Source: JICA Survey Team based on the data from Topographic Map (Irrigation Dept.)

Figure 4.3.15 Catchment Area Map (3)

3) Flow Regime of Main Rivers

The discharge-duration curve, which is often used in Japan, is examined in order to understand the potential surface water characteristics of the river through 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 as follows;

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

The coefficient of the river regime is the ratio of the minimum flow and the maximum flow rate at optional points of the river, and shows the stability of the river flow quantitatively. The magnitude of the coefficient of the river regime indicates the magnitude of flow fluctuation, and if it is large, it indicates that the full year water intake is difficult and the flood damage is easy to occur. (For example, in the Europe, 18 - Basel of the Rhine River, 4 - Vienna of the Danube river, 34 - the Seine River. In Japan, 930 - the Tone River, 870 - the Kiso River, 5060 - the Yoshino River.)

The flow regime which was calculated at the three stations of Bago (Bago River) and Taungoo/Madauk (Sittaung River) during ten years (2005-2014), is summarized in Table 4.3.13 / Table 4.3.14 / Table 4.3.15 and Figure 4.3.16 / Figure 4.3.17 / Figure 4.3.18. And several unit discharges at the three stations are shown in Table 4.3.16.

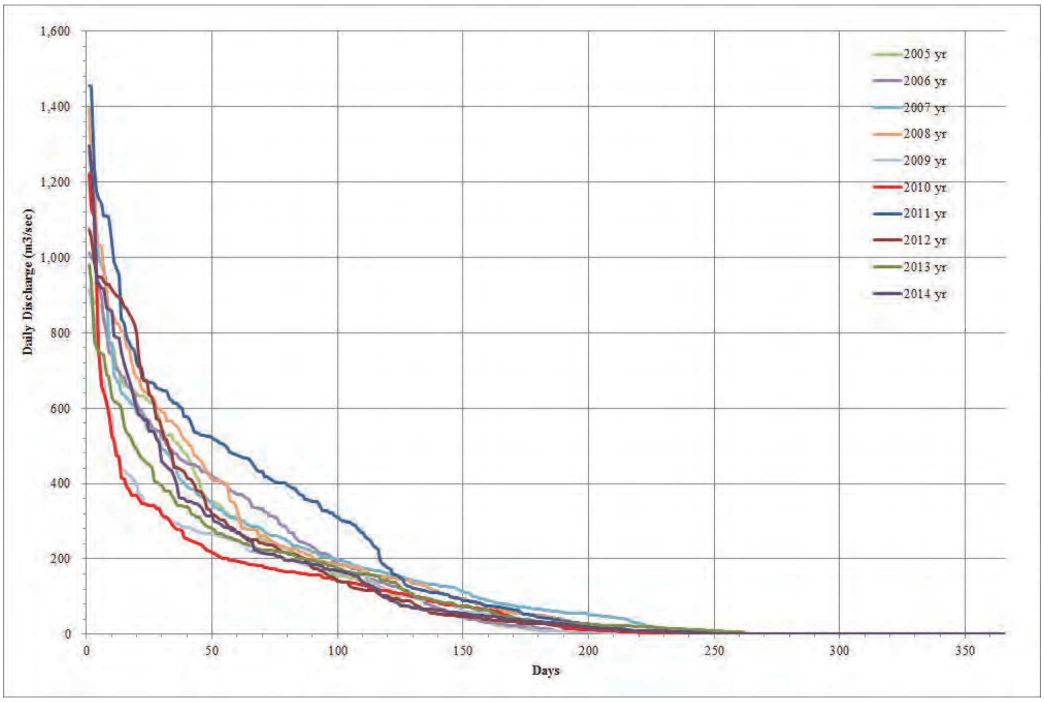
Although there is a certain level of flow fluctuation in the rainy season, the coefficient of the river regime of both rivers is relatively small and similar, for having the morphology of delta-specific. The flow-rate during the dry-season is relatively stable for both rivers. (Regarding the Bago Station, it is influenced by the tide to the gauging-station during the dry season.)

(At the lower reach to its junction with the Bago-Sittaung Canal from the river mouth of the Sittaung River, the tidal bore occurs twice per month. Therefore a further hydrological survey/study or river morphological study will be needed for understanding the magnitude, the damage situation and the generating mechanism of the tidal bore.)

Table 4.3.13 Flow Regime (2005-2014) at Bago of Bago River

Year	Annual Maximum Discharge	Plentiful Discharge	Ordinary Discharge	Low Discharge	Drought Discharge	Annual Minimum Discharge	Coefficient of River Rregime	Remarks
	1-day	95-day	185-day	275-day	355-day	365-day	Max/Min	
2005	911.0	174.0	11.0	0.0	0.0	0.0	∞	
2006	1010.0	214.0	11.0	0.0	0.0	0.0	∞	
2007	1281.0	206.0	62.0	0.0	0.0	0.0	∞	
2008	1395.0	192.0	46.0	0.0	0.0	0.0	∞	
2009	918.0	170.0	9.0	0.0	0.0	0.0	∞	
2010	1223.0	150.0	27.0	0.0	0.0	0.0	∞	
2011	1455.0	327.0	41.0	0.0	0.0	0.0	∞	
2012	1074.0	163.0	25.0	0.0	0.0	0.0	∞	
2013	980.0	189.0	31.0	0.0	0.0	0.0	∞	
2014	1297.0	174.0	30.0	0.0	0.0	0.0	∞	
Average	1154.4	195.9	29.3	0.0	0.0	0.0	-	
Maximum	1455.0	327.0	62.0	0.0	0.0	0.0	-	
Minimum	911.0	150.0	9.0	0.0	0.0	0.0	-	

Source: JICA Survey Team, DMH



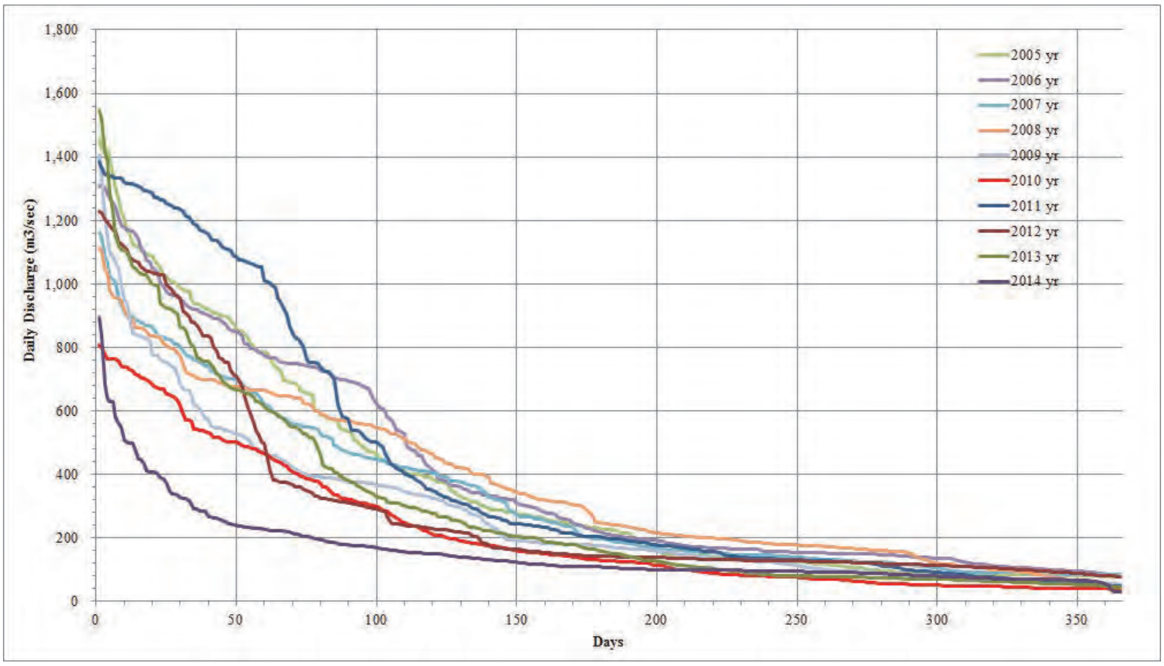
Source: JICA Survey Team, DMH

Figure 4.3.16 Discharge-Duration Curve (2005-2014) at Bago of Bago River

Table 4.3.14 Flow Regime (2005-2014) at Toungoo Station of Sittaung River

Year	Annual Maximum Discharge	Plentiful Discharge	Ordinary Discharge	Low Discharge	Drought Discharge	Annual Minimum Discharge	Coefficient of River Rregime	Remarks
	1-day	95-day	185-day	275-day	355-day	365-day	Max/Min	
2005	1459.0	491.0	222.0	101.0	81.0	76.0	19.20	
2006	1308.0	679.0	209.0	149.0	92.0	85.0	15.39	
2007	1163.0	460.0	188.0	125.0	85.0	85.0	13.68	
2008	1111.0	559.0	241.0	163.0	57.0	50.0	22.22	
2009	1406.0	375.0	170.0	93.0	57.0	52.0	27.04	
2010	807.0	310.0	127.0	60.0	41.0	37.0	21.81	
2011	1385.0	528.0	196.0	120.0	52.0	48.0	28.85	
2012	1229.0	302.0	142.0	121.0	85.0	73.0	16.84	
2013	1548.0	356.0	151.0	74.0	52.0	46.0	33.65	
2014	893.0	177.0	107.0	89.0	64.0	29.0	30.79	
Average	1230.9	423.7	175.3	109.5	66.6	58.1	22.95	
Maximum	1548.0	679.0	241.0	163.0	92.0	85.0	33.65	
Minimum	807.0	177.0	107.0	60.0	41.0	29.0	13.68	

Source: JICA Survey Team, DMH



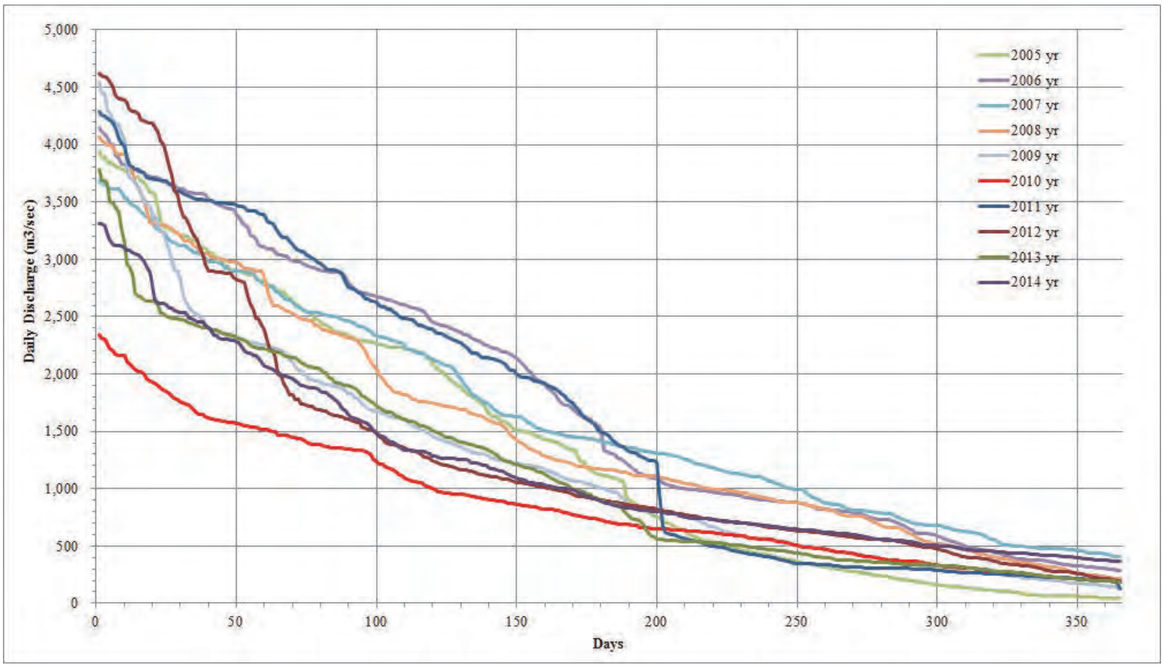
Source: JICA Survey Team, DMH

Figure 4.3.17 Discharge-Duration Curve (2005-2014) at Toungoo of Sittaung River

Table 4.3.15 Flow Regime (2005-2014) at Madauk Station of Sittaung River

Year	Annual Maximum Discharge	Plentiful Discharge	Ordinary Discharge	Low Discharge	Drought Discharge	Annual Minimum Discharge	Coefficient of River Rregime	Remarks
	1-day	95-day	185-day	275-day	355-day	365-day	Max/Min	
2005	3932.0	2291.0	1092.0	258.0	54.0	44.0	89.36	
2006	4144.0	2709.0	1292.0	755.0	319.0	291.0	14.24	
2007	3681.0	2416.0	1383.0	805.0	441.0	408.0	9.02	
2008	4069.0	2239.0	1160.0	740.0	243.0	206.0	19.75	
2009	4543.0	1742.0	969.0	408.0	166.0	139.0	32.68	
2010	2338.0	1335.0	699.0	408.0	207.0	185.0	12.64	
2011	4287.0	2699.0	1404.0	311.0	202.0	129.0	33.23	
2012	4617.0	1538.0	882.0	563.0	233.0	189.0	24.43	
2013	3783.0	1811.0	862.0	363.0	199.0	187.0	20.23	
2014	3309.0	1583.0	853.0	575.0	383.0	364.0	9.09	
Average	3870.3	2036.3	1059.6	518.6	244.7	214.2	26.5	
Maximum	4617.0	2709.0	1404.0	805.0	441.0	408.0	89.4	
Minimum	2338.0	1335.0	699.0	258.0	54.0	44.0	9.0	

Source: JICA Survey Team, DMH



Source: JICA Survey Team, DMH

Figure 4.3.18 Discharge-Duration Curve (2005-2014) at Madauk of Sittaung River

Table 4.3.16 Mean Several Unit Discharge per Drainage Area at 2005-2014

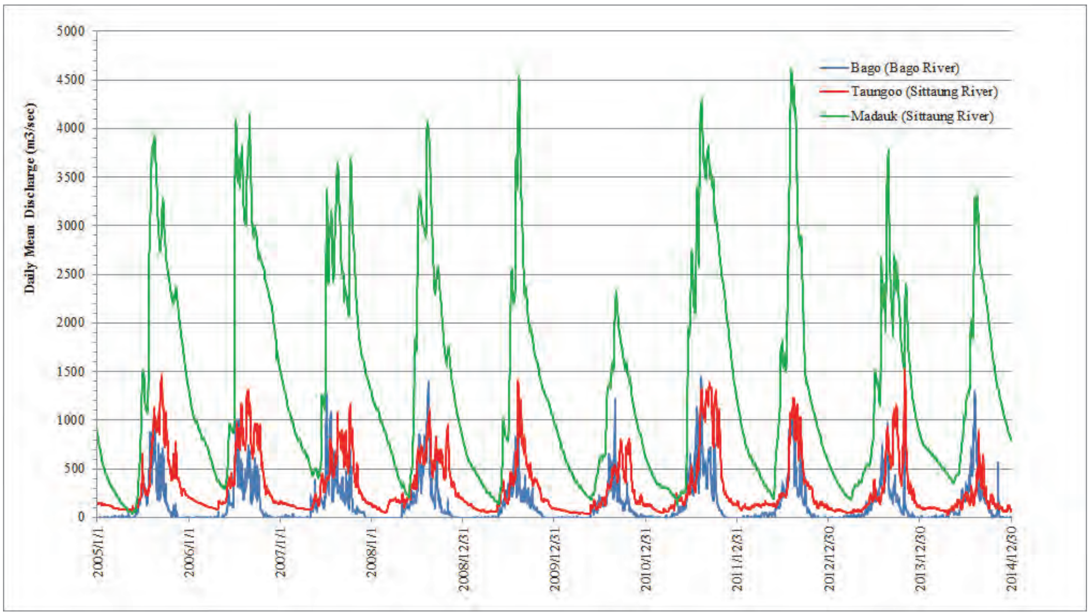
Station	Annual Maximum Discharge	Plentiful Discharge	Ordinary Discharge	Low Discharge	Drought Discharge	Annual Minimum Discharge	Coefficient of River Rregime	Remarks
	1-day	95-day	185-day	275-day	355-day	365-day	Max/Min	
Bago Station	0.44744	0.07593	0.01136	0.00000	0.00000	0.00000	-	CA= 2580km2
Toungoo Station	0.08396	0.02890	0.01196	0.00747	0.00454	0.00396	26.5	CA= 14660km2
Madauk Station	0.14464	0.07610	0.03960	0.01938	0.00914	0.00801	22.9	CA= 26758km2

Source: JICA Survey Team

4) Yearly, Monthly and Daily Flow Pattern

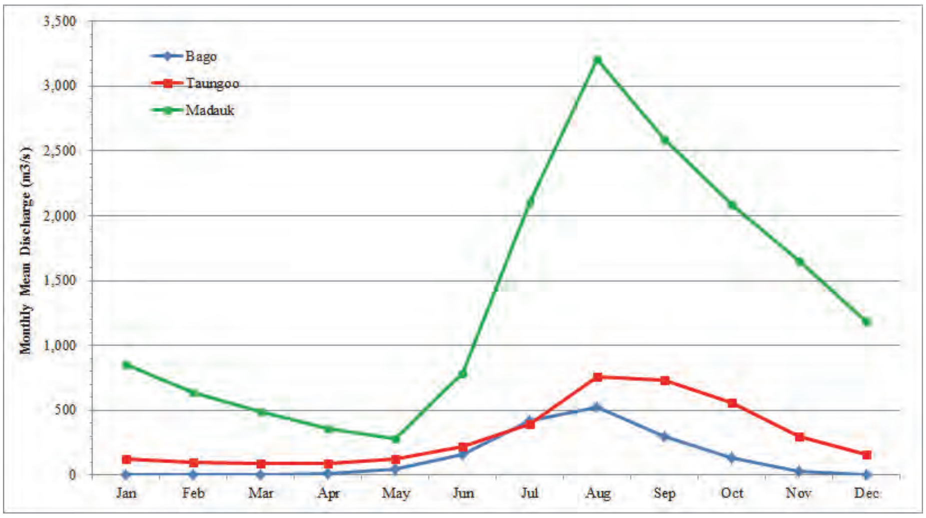
The mean daily flow patterns from the data of the recent ten years at the two rivers' three gauging stations are shown in Figure 4.3.19. Also, the mean monthly flow patterns from them are shown in Figure 4.3.20. The peak discharge occurs in around August.

And Figure 4.3.21 shows the fluctuation of annual maximum discharge at three stations during the past 45 (30) years. The historical maximum discharge occurred in 2011 at Bago, in 2013 at Taungoo and in 1997 at Madauk.



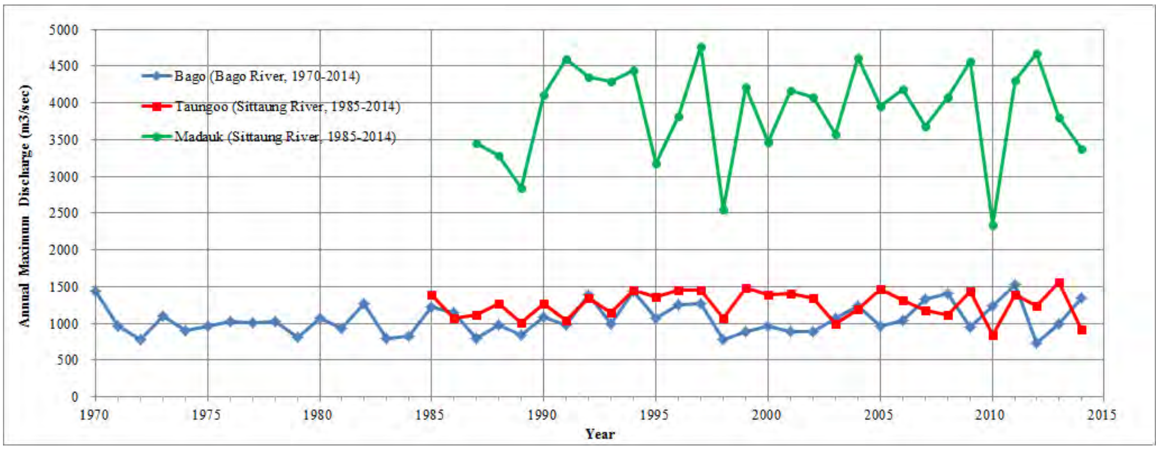
Source: JICA Survey Team, DMH

Figure 4.3.19 Daily Flow Pattern at Bago and Sittaung Rivers (Bago, Taungoo, Madauk) during 2005-2014



Source: JICA Survey Team, DMH

Figure 4.3.20 Mean Monthly Flow Pattern at Bago and Sittaung Rivers (Bago, Taungoo, Madauk) during 2005-2014



Source: JICA Survey Team, DMH

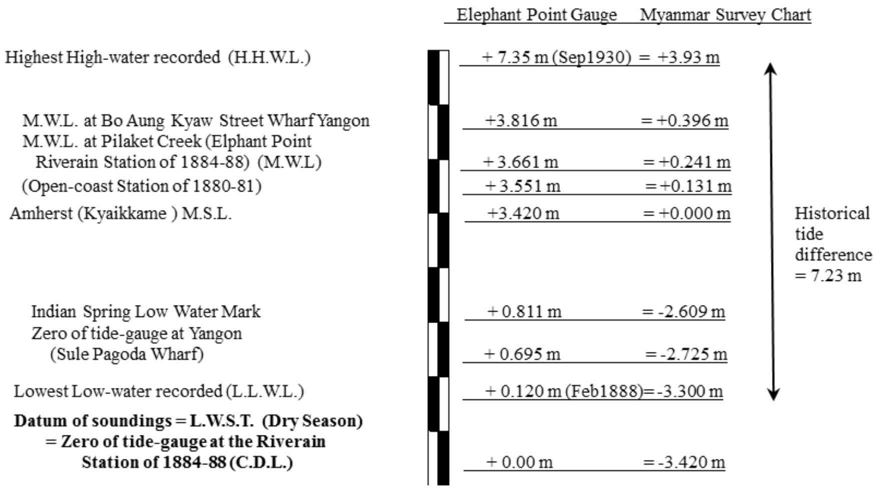
Figure 4.3.21 Fluctuation of Annual Maximum Discharge at Bago and Sittaung Rivers (Bago, Taungoo, Madauk)

(2) River and Tidal Levels

1) Tidal Level

The nearest tide-gauge station of the study area is the Mawlamyine (formerly, Moulmein) Port (located near the Andaman Sea). However, its tide chart diagram is difficult to obtain, therefore, the chart diagram at the Elephant Point as the same tidal station, is shown in Figure 4.3.22. From it, the difference between historical highest and lowest tide levels is observed as 7.23m.

And, zero of Myanmar Survey Datum, namely, zero meter of topographic survey is measured based on M.W.L.(Mean Water Level) at Amherst (Kyaikkhame) tidal station. Hence, historical high-tide at Elephant Point becomes +3.93m of Myanmar Survey Datum from this Figure.

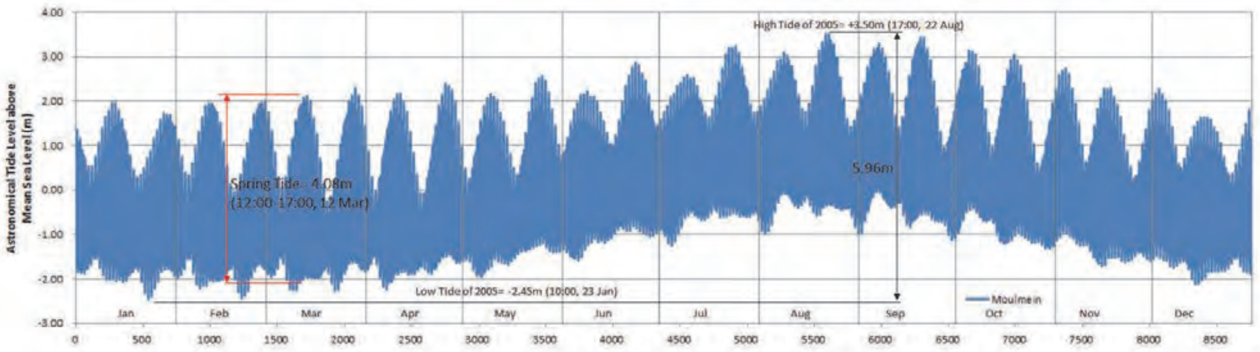


Source: MPA

Figure 4.3.22 Tide Level of Elephant Point (Chart Diagram)

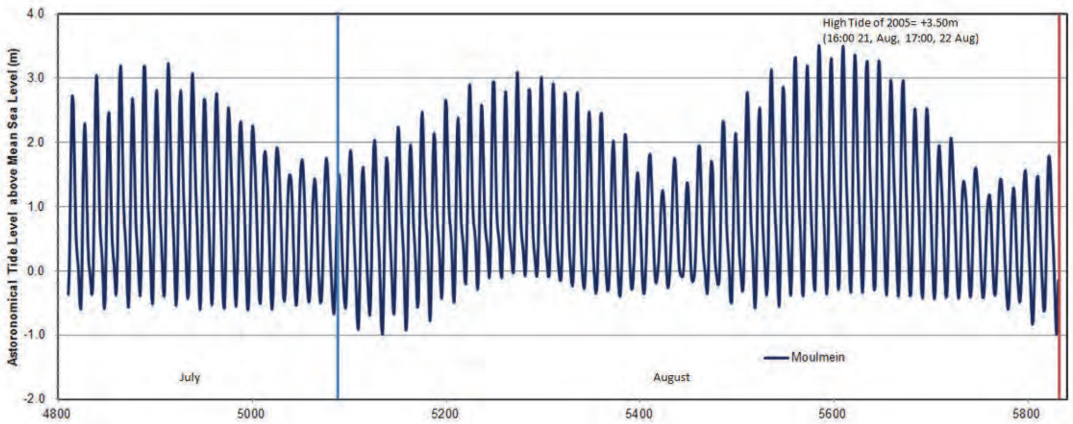
On the other hand, the hourly data of the calculated astronomical tide at Mawlamyine Port are available from the web site of the University of Tokyo. The astronomical tide levels at Mawlamyine during 2005 are shown in Figure 4.3.23 and Figure 4.3.24. The season of highest tide as seen in this Figure is in August to September of the rainy season. In reality, since the rising of water-level by the discharge from the river and the cyclone's barometric fluctuations are added to this astronomical tide, the actual water level at the inland river during the rainy season is higher. In addition, at the river-mouth of Sittaung River, the sudden increase in the water level will additionally appear by the influence of the tidal bore.

As seen above, the water level of the Sittaung River during the rainy-season is closely related to the normal tidal change and the tidal bore.



Source: Earthquake Research Institute, the University of Tokyo

Figure 4.3.23 Fluctuation of Annual Astronomical Tide at Moulmein Station (2005)



Source: Earthquake Research Institute, the University of Tokyo

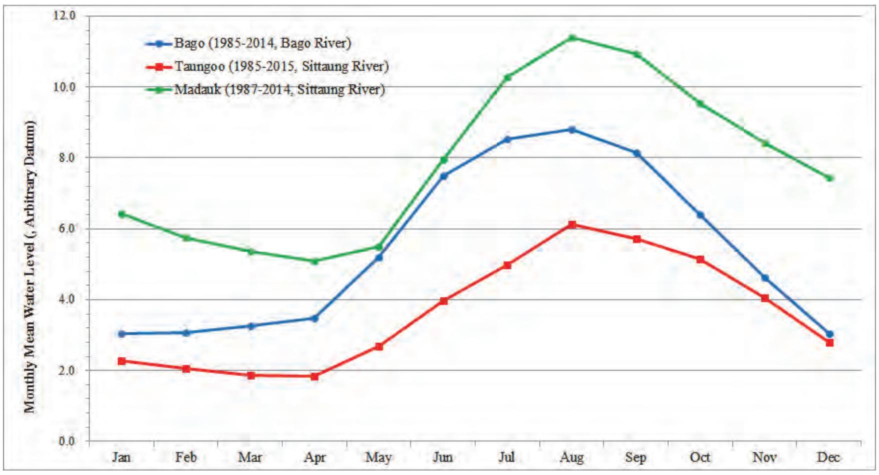
Figure 4.3.24 Fluctuation of (Astronomical) High Tide at Moulmein Station (July-August 2005)

2) Water Levels of Related Rivers

The mean monthly water levels during the recent 28-30 years at DMH's three gauging stations are shown in Figure 4.3.25. And Figure 4.3.26 shows the fluctuation of annual maximum water levels at the three stations.

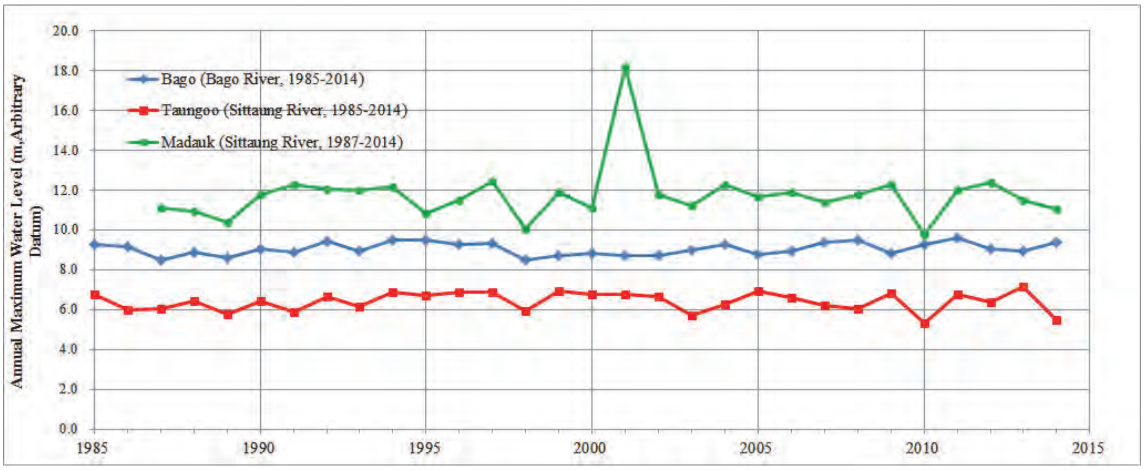
Also, the daily maximum water levels during 2-5 years at four gauging stations of ID (Irrigation Department) are shown in Figure 4.3.27.

Although these water levels are the data of arbitrary datum and are not the national datum for topographic survey, the daily and monthly pattern shows almost the same trend as the discharge pattern. It's striking that the rising of water level occurs twice a month at Shan Gaing station in the vicinity of Sittaung River-mouth. This cause may be estimated to be affected by the tidal bore.



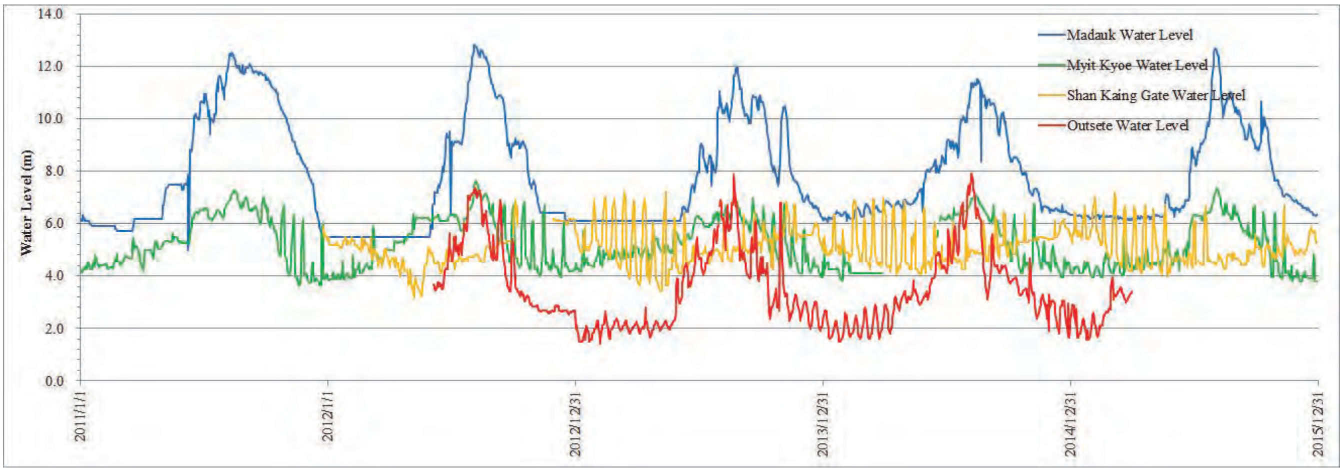
Source: JICA Survey Team, DMH

Figure 4.3.25 Monthly Mean Water Level at Bago and Sittaung Rivers (Bago, Taungoo, Madauk)



Source: JICA Survey Team, DMH

Figure 4.3.26 Fluctuation of Annual Maximum Water Level at Bago and Sittaung Rivers (Bago, Taungoo, Madauk)



Source: JICA Survey Team, Irrigation Department

Figure 4.3.27 Daily Maximum Water Levels at Gauging Stations of the Irrigation Department (Madauk, Myit Kyoe, Shan Gaing and Outsetee)

(3) Historical River Course Shifting of the Sittaung River

Historical satellite images have been used to evaluate the characteristic features of channel shifting and to estimate the river bank erosion. As satellite images at different times are available for the study reach, the analysis of the stability of the study river reach using satellite images is presented in this section.

The planform analysis of the proposed bridge was conducted using Landsat Thematic Mapper (TM) images and Goggle Earth images. Nine images of the years 1973, 1980, 1989, 1996, 2000, 2004, 2006, 2010 and 2014 were used for the analysis. The change in planform over the 42 year period is shown in Figure 4.3.28, and a zoomed view over the bridge site is shown in Figure 4.3.29 Also, the historical-changes of them are shown in Figure 4.3.30 from topographic maps of the SOI (Survey of India) of 1942[1].

It can be seen in Figure 4.3.31and Figure 4.3.32 that the river reach has experienced significant erosion or deposition over the last 42 years. Initially, as the alignments of the new Sittaung Bridge, three alternatives were considered. From Figure 4.3.32 zoomed in, the significant changes can be seen in the right bank side at the alignment of Alternative-1, both bank sides at Alternative-2 and the left bank side at Alternative-3. (The shifted amounts of banks are shown in Figure 4.3.33 and Table 4.3.17.) However, the right bank change of Alternative-1 progressed from 1973 to 1989, and since then, it is relatively stable compared with Alternative-2 and -3. In addition, in the right bank side of Sittaung River, many sluices were constructed until recently, and it is estimated that the erosion of right bank side will not progress so significantly. Notwithstanding, the long-term prediction of erosion and deposition, it may be difficult realistically. (Although the key factor of erosion/deposition can estimate as day-to-day active tidal-flow and semi-monthly tidal bore, the numerical analysis or modelling of the tidal bore will have difficulty.)

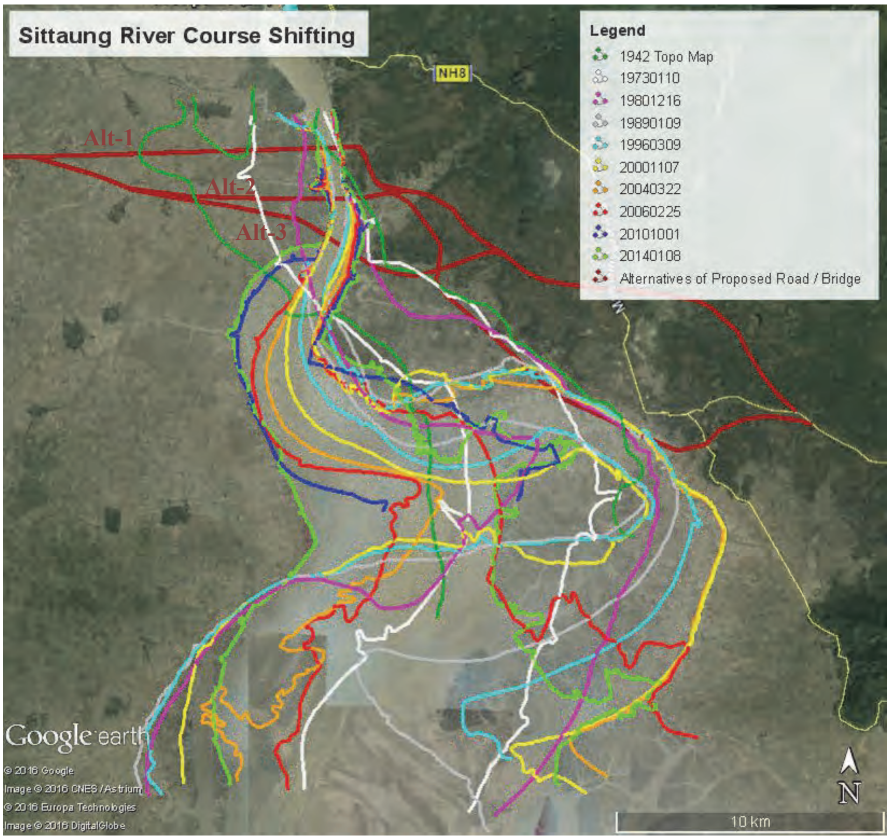
As the good choice among the three alternatives in this pre-feasibility study, the alignment of Alternative-1 will be recommended as noted above. However, a variety of studies shall be examined additionally.

➢ <u>About Tidal Bore at Sittaung Estuary</u>

A tidal bore is a tidal phenomenon in which the leading edge of the rising-tide forms waves of water that travel up a river or narrow bay against the direction of the river or bay's tidal-current.

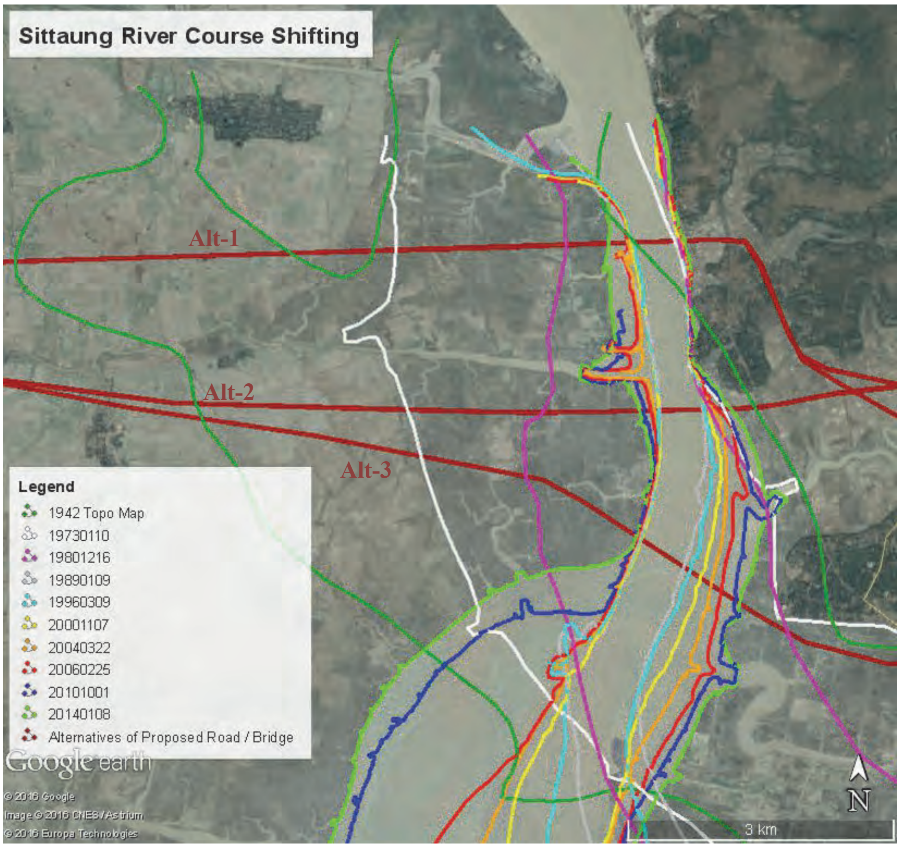
The tidal bore occurs usually in areas with a large tidal range (typically more than 6m between high and low water), and it occurs in where flood-tides are funnelled into a shallow, narrowing river via a broad bay. The funnel-like shape not only increases the tidal range, but it can also decrease the duration of the flood-tide, down to the point where the flood appears as a sudden increase in the water level. A tidal bore takes place during the flood-tide and it never occurs during the ebb-tide. According to the interview survey to residents, the tidal bore occurs twice per month, and the maximum wave height of the tidal bore has been witnessed as the height of 2.5m at the existing Sittaung Bridge (6.8km upstream of the proposed bridge).

[1] "Alt-1" to "Alt-3" in Figure 4.3.28, 4.3.29, 4.3.31 and 4.3.32 show the alternatives for comparative study on optimum bridge crossing point over the Sittaung River, as examined in 6.2 in this report.



Source: JICA Survey Team, Google Earth

Figure 4.3.28 Shifting of Bank Lines around the Proposed Sittaung Bridges during Past 17 years

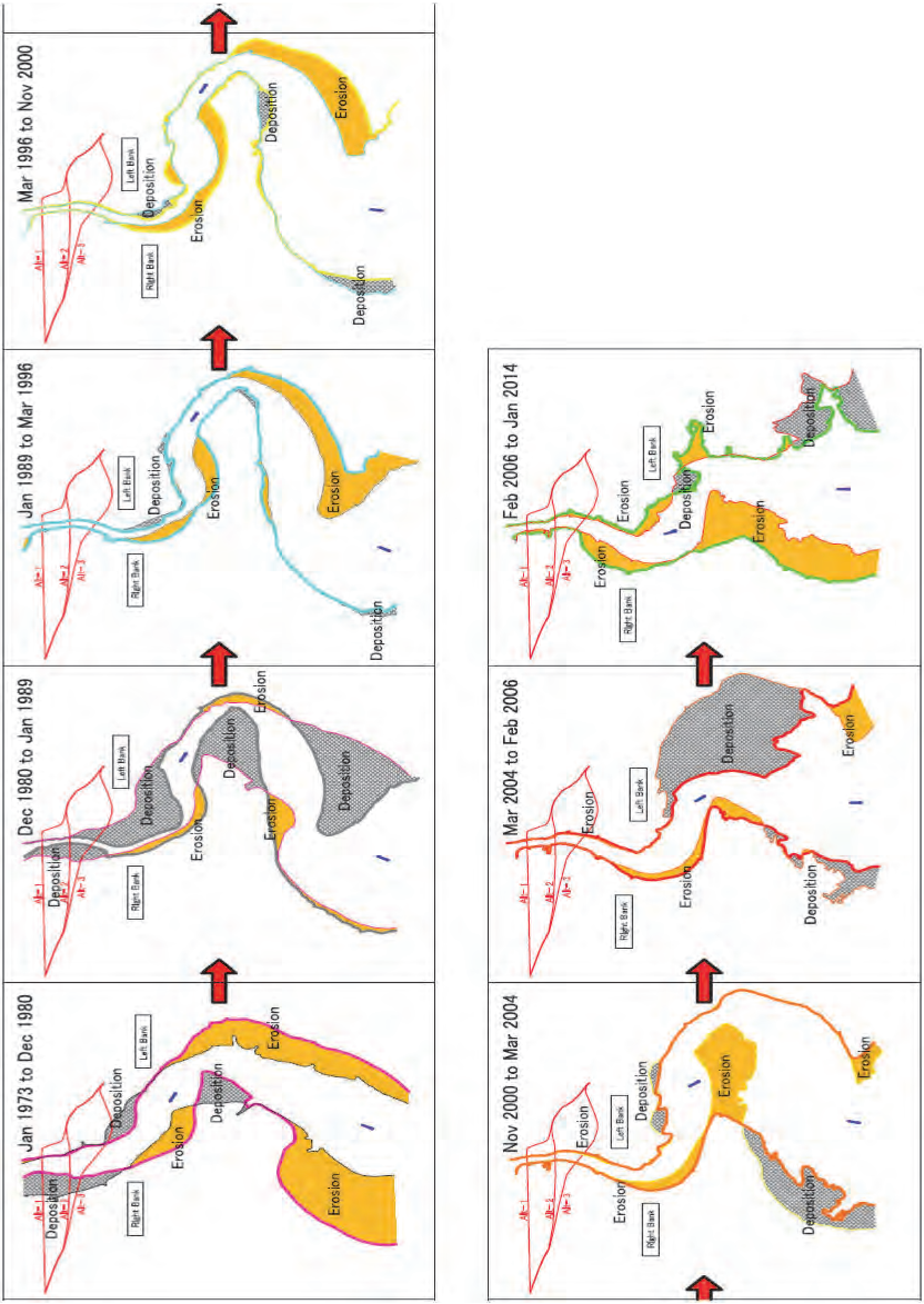


Source: JICA Survey Team

Figure 4.3.29 Zoomed View of Shifting of Bank Lines around Proposed Sittaung Bridge

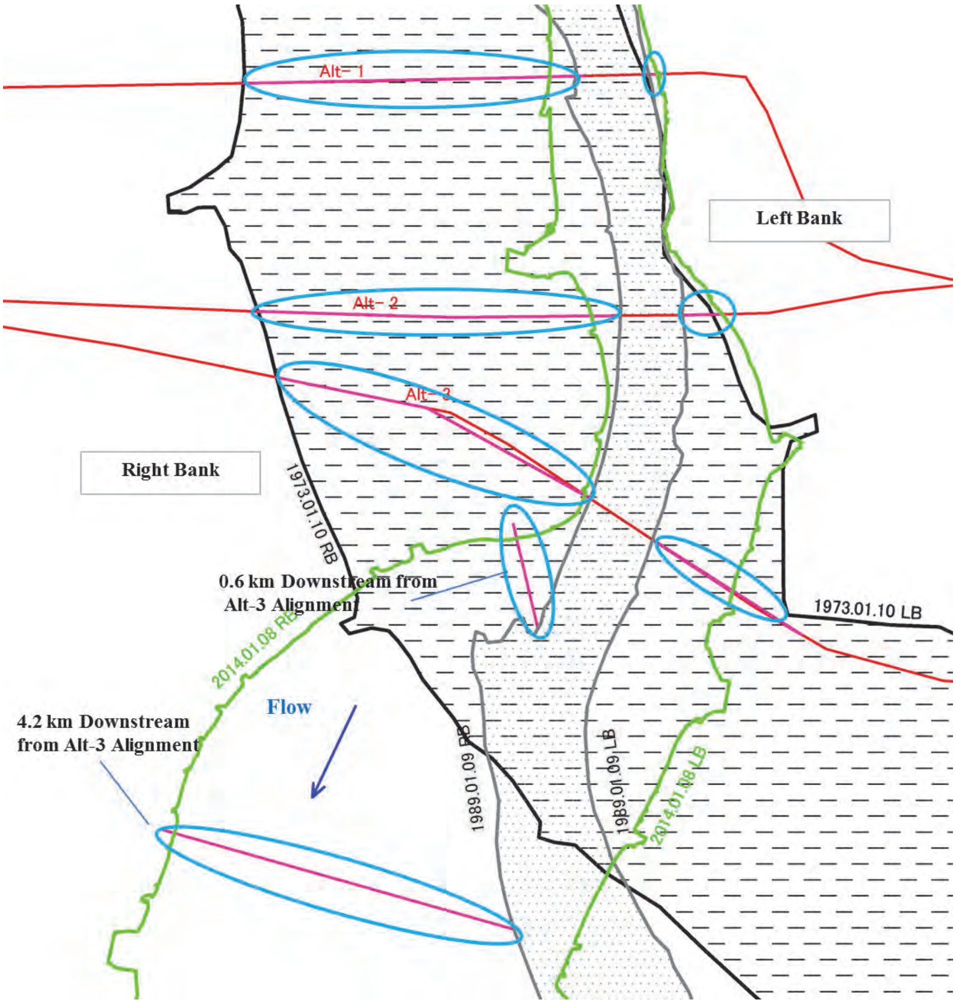
Source: Survey of India, 1942

Figure 4.3.30 Topographic Map at 1942 (Survey of India) around Proposed Sittaung Bridge



Source: JICA Survey Team

Figure 4.3.31 Past Erosions and Depositions of Bank Lines around Proposed Sittaung Bridge



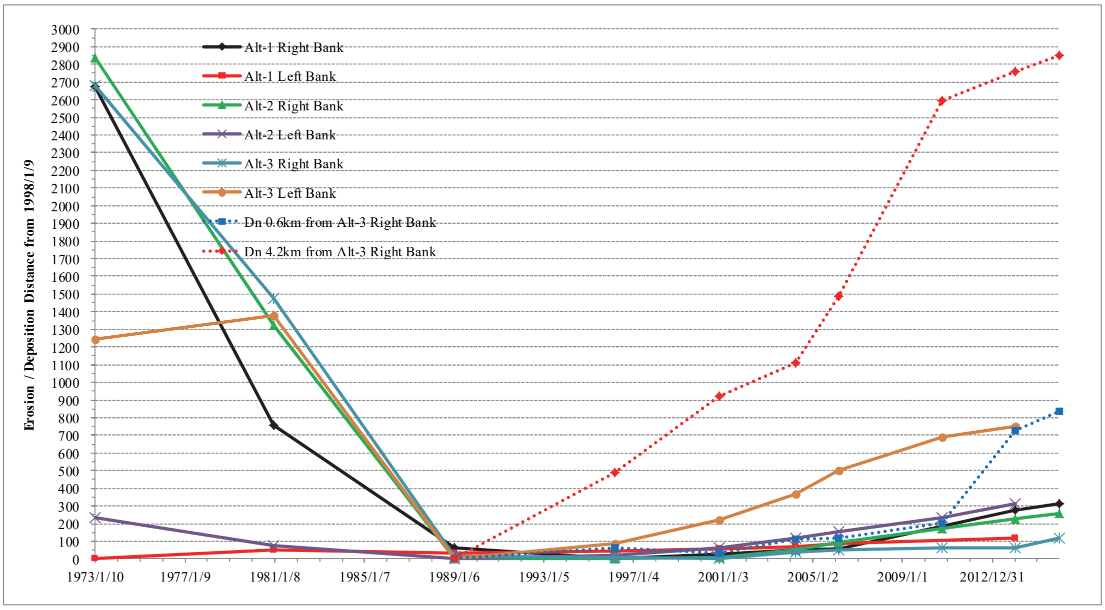
Source: JICA Survey Team

Figure 4.3.32 Past Erosion / Deposition of each Period around Proposed Sittaung Bridge

Table 4.3.17 Past Erosion / Deposition Rate of each Period around Proposed Sittaung Bridge

Date	Increment Days	Alt-1 Right Bank		Alt-1 Left Bank		Alt-2 Right Bank		Alt-2 Left Bank		Alt-3 Right Bank		Alt-3 Left Bank		Dn 0.6km from Alt-3 Right Bank		Dn 4.2km from Alt-3 Right Bank		Remarks
		Increment Distance (m)	Erosion Rate* (m/year)	Increment Distance (m)	Erosion Rate* (m/year)	Increment Distance (m)	Erosion Rate* (m/year)	Increment Distance (m)	Erosion Rate* (m/year)	Increment Distance (m)	Erosion Rate* (m/year)	Increment Distance (m)	Erosion Rate* (m/year)	Increment Distance (m)	Erosion Rate* (m/year)	Increment Distance (m)	Erosion Rate* (m/year)	
1973/1/10	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-					
1980/12/16	2897	-1913.48	***-241.08***	50.28	*6.34*	-1515.78	*-190.98*	-162.37	*-20.46*	-1204.63	*-151.77*	133.01	*16.76*					
1989/1/9	2946	-692.01	*-85.74*	-15.69	*-1.94*	-1322.08	*-163.80*	-73.82	*-9.15*	-1457.64	*-180.60*	-1378.55	*-170.80*	0.00	-	0.00	-	
1996/3/9	2616	-65.77	*-9.18*	9.19	*1.28*	4.28	*0.60*	21.38	*2.98*	-6.18	*-0.86*	85.13	*11.88*	60.77	*8.48*	488.22	*68.12*	
2000/11/7	1704	28.06	*6.01*	10.95	*2.35*	3.26	*0.70*	41.52	*8.89*	-10.59	*-2.27*	137.34	*29.42*	-25.11	*-5.38*	431.10	*92.34*	
2004/3/22	1231	26.20	*7.77*	16.57	*4.91*	46.25	*13.71*	56.33	*16.70*	42.08	*12.48*	144.30	*42.79*	79.60	*23.60*	189.77	*56.27*	
2006/2/25	705	5.72	*2.96*	15.38	*7.96*	40.75	*21.10*	37.57	*19.45*	11.30	*5.85*	135.75	*70.28*	0.41	*0.21*	377.73	*195.56*	
2010/10/1	1679					80.07	*17.41*	76.62	*16.66*	12.04	*2.62*	185.14	*40.25*	90.43	*19.66*	1110.31	***241.37***	
2014/1/8	1195	215.17	*27.33*	34.34	*4.36*	50.93	*15.56*	78.11	*23.86*	1.16	*0.36*	60.53	*18.49*	519.49	*158.67*	164.64	*50.29*	
2015/12/19	710	39.74	*20.43*			30.19	*15.52*			53.26	*27.38*			113.14	*58.16*	89.93	*46.23*	

Source: JICA Survey Team



Note. The up-hill grade of lines on the graph shows the magnitude of erosion rate, and the declined lines shows the magnitude of deposition rate. The zero meter on the graph indicates as the distance of when the riverbank line is closest to river-center.

Source: JICA Survey Team

Figure 4.3.33 Past Erosion / Deposition Rate of each Period around Proposed Sittaung Bridge

Source: "Tidal Bores, Aegir, Eagre, Mascaret, Pororoca: Theory and Observations" (Author: Hubert Chanson)

Figure 4.3.34 19th Century Gravure of the Sittaung River Tidal Bore

Source: "RFA Myanmar news TV Update on 27 January 2016, Village Losing Land by Erosion from Sittaung River" (https://www.youtube.com/watch?v=7isxqOg2lUM)

Figure 4.3.35 Video Picture of Sittaung River Tidal Bore

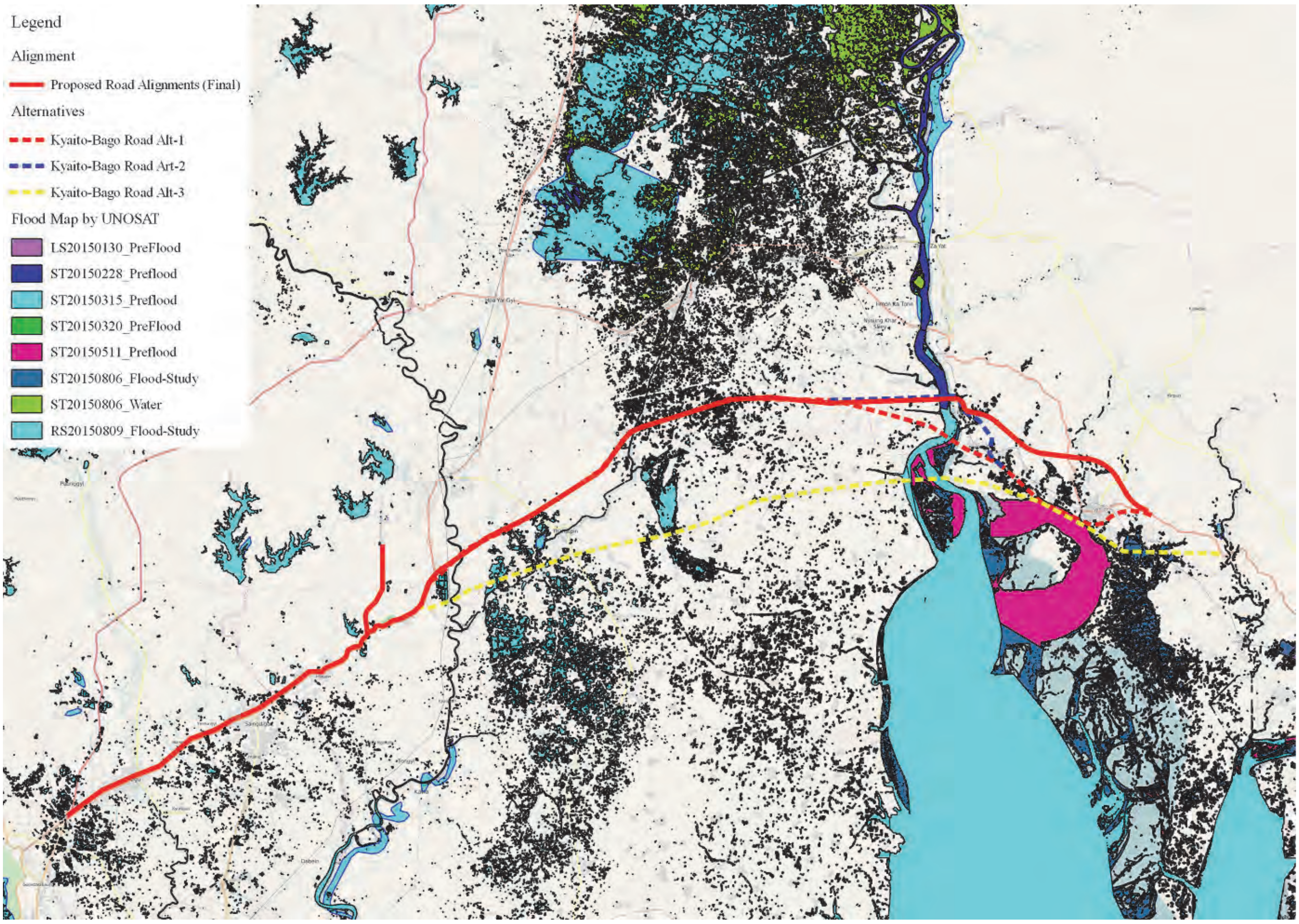
(4) Flood Conditions

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

- ✓ Riverine floods in the river delta or the lowland;
- ✓ 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 (such as blocked drains);
- ✓ Flooding due to a storm surge in the coastal areas.

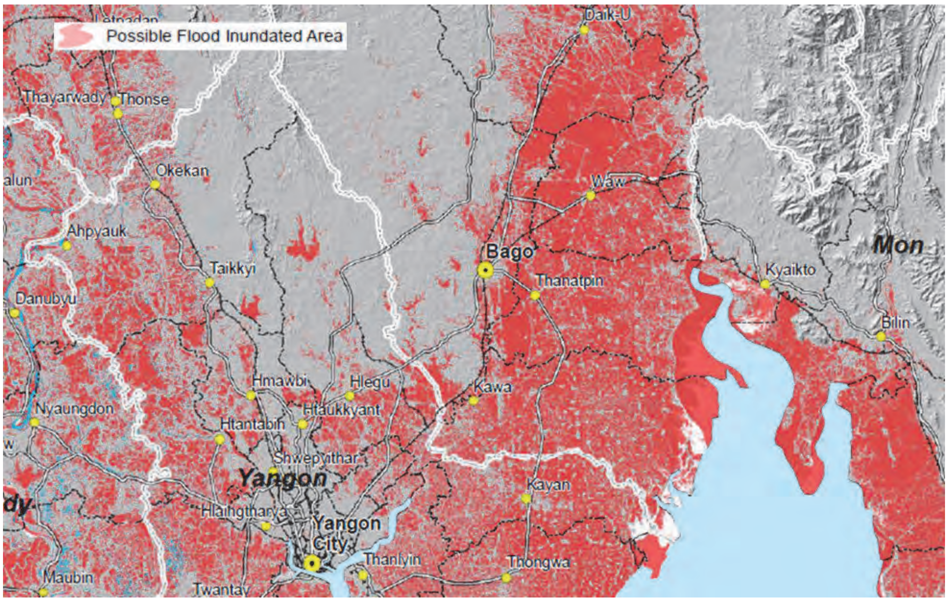
In the Sittaung riverine systems, floods are caused by rainfall associated with low-pressure waves (the remnants of typhoons and tropical storms of South China Sea) moving from east to west. Riverine floods are most common among all, and they happen when the monsoon troughs or low-pressure waves or storm-surges superimposes on the general monsoon pattern resulting in intense rainfall over the lowlands of the river catchment areas.

According to DMH reference, the flood frequency during 1966-2009 along the Sittaung River is 88 events in 44 years at Madauk of Sittaung River. As recent flood events, the inundation hazardous areas based on satellite images at the time of 30 January to 09 August of 2015 is shown in Figure 4.3.36. Also, Figure 4.3.37 shows the flood hazard map by MIMU, and it is suggested that most of the target area is a flood-prone area.



Source: GIS data of UNSAT (UNITAR's Operational Satellite Applications Programme)

Figure 4.3.36 Inundation Hazardous Areas based on Satellite Image at the time of 30 January to 09 August of 2015



Source: MIMU (Myanmar Information Management Unit)

Figure 4.3.37 Hazard Map around Sittaung River Basin

4.3.4 Estimation of Probable Floods and Water Levels

(1) Probability Floods and Water Level at Gauging Stations

1) Probability Floods at Gauging Stations

Past annual maximum discharges (extremal values) of 3 stations (Bago, Taungoo, Madauk) for the design discharge are collected. (Although two gauging stations are influenced by the tide, it is considered that the accuracy against flow rate in the rainy season is no problem, since the flow of rainy season is only one-way from upstream to downstream.)

The probability discharges are calculated according to the following points;

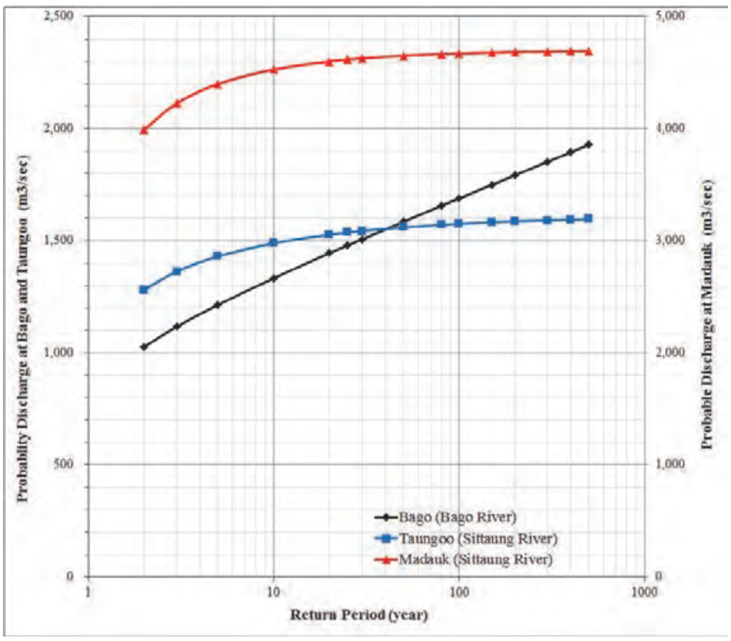
- ✓ To select the appropriate model for probability distribution from the six methods; Exponential distribution, Gumbel distribution, Square Root - Exponential type maximum distribution, Generalized extreme value distribution, Log Pearson type Ⅲ distribution (Real space method) and Log Pearson type Ⅲ distribution (Logarithmic space method).
- ✓ In this study, the distribution model is selected in reference to SLSC (Standard Least Squares Criterion) value or adequacy of probability value, etc. (SLSC value is 0.04 or less is desirable.)
- ✓ Calculation return periods are for 2, 3, 5, 10, 20, 25, 30, 50, 80, 100, 150, 200, 300, 400 and 500 years.

The results of probability discharge at three discharge stations are shown in Table 4.3.18 and Figure 4.3.38.

Table 4.3.18 Probability Flood Calculation at Bago, Taungoo and Madauk Stations

Station Name			Bago	Taungoo	Madauk	Remarks
River Name			Bago - Yangon	Sittaung	Sittaung	
Station ID			48093	7040	7060	
Long. (X)			96.5000	96.4667	96.8500	
Lat. (Y)			17.3333	18.9167	17.9167	
Catchment Area (km2)			2,580	14,660	26,758	
Data No. of Extreme Value			45	30	30	
Probable Discharge (m3/s)	(Year)	(%)				
	2	50%	1027	1281	3991	
	3	33.3%	1117	1363	4227	
	5	20%	1214	1430	4399	
	10	10%	1333	1489	4529	
	20	5%	1445	1528	4601	
	25	4%	1479	1537	4617	
	30	3.33%	1507	1544	4628	
	50	2%	1585	1560	4652	
	80	1.25%	1656	1571	4667	
	100	1%	1689	1576	4672	
	150	0.667%	1750	1583	4680	
	200	0.5%	1793	1587	4685	
	300	0.333%	1853	1591	4689	
	400	0.25%	1895	1594	4692	
	500	0.2%	1929	1596	4694	
Probable Discharge per Drainage Area (m3/s/km2)	(Year)	(%)				
	2	50%	0.39806	0.08738	0.14915	
	3	33.3%	0.43295	0.09297	0.15797	
	5	20%	0.47054	0.09754	0.16440	
	10	10%	0.51667	0.10157	0.16926	
	20	5%	0.56008	0.10423	0.17195	
	25	4%	0.57326	0.10484	0.17255	
	30	3.33%	0.58411	0.10532	0.17296	
	50	2%	0.61434	0.10641	0.17385	
	80	1.25%	0.64186	0.10716	0.17442	
	100	1%	0.65465	0.10750	0.17460	
	150	0.667%	0.67829	0.10798	0.17490	
	200	0.5%	0.69496	0.10825	0.17509	
	300	0.333%	0.71822	0.10853	0.17524	
	400	0.25%	0.73450	0.10873	0.17535	
	500	0.2%	0.74767	0.10887	0.17542	
X-COR(99%)			0.986	0.990	0.995	
P-COR(99%)			0.994	0.991	0.485	
SLSC(99%)			0.030	0.036	0.024	
Probabilistic Distributed model			3-parameter log-normal distribution (Quantile method)	Generalized extreme value distribution	Log Pearson type III distribution (Real space method)	

Source: JICA Survey Team based on the data from DMH



Source: JICA Survey Team based on the data from DMH

Figure 4.3.38 Probability Flood Calculation at Bago, Taungoo and Madauk Stations

2) Probability Water Levels at Gauging Stations

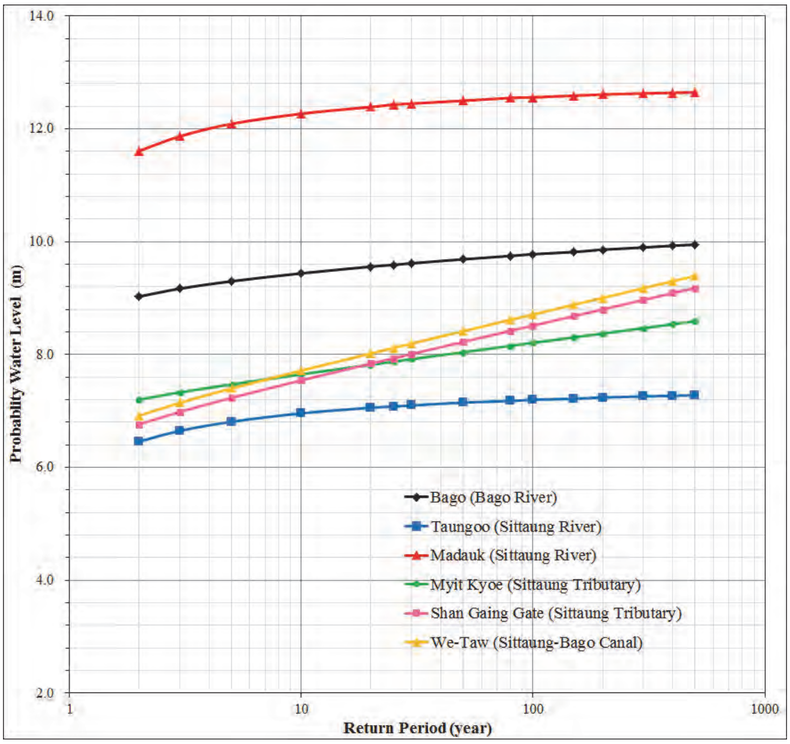
In a similar way, the past annual maximum water levels (extremal values) of three stations (Bago, Taungoo, Madauk) of DMH and three stations (Myit-Kyoe, Shan Gaing, Waw) of ID are used, as the reference for the design water-level. (Regarding the observed water levels of other stations of ID, the observed-year is little, and it is not used for the probability calculation.) In this regard, the offset for heights is needed, because the datum of observed water-level at all stations collected are the arbitrary datum.

The results of probability water-level at the above six stations are shown in Table 4.3.19 and Figure 4.3.39.

Table 4.3.19 Probability Water Level Calculation at Six Stations

Observation Organization			DMH			Irrigation Departmrnt			Remarks
Station Name			Bago	Taungoo	Madauk	Myit Kyoe	Shan Gaing Gate	Waw	
River Name			Bago - Yangon	Sittaung	Sittaung	Sittaung	Sittaung	Sittaung-Bago	
Station ID			48093	7040	7060	-	-	-	
Long. (X)			96.5000	96.4667	96.8500	96.8140	96.8432	96.6780	
Lat. (Y)			17.3333	18.9167	17.9167	17.5992	17.4190	17.4767	
Catchment Area (km2)			2,580	14,660	26,758	-	-	-	
Data No. of Extreme Value			28	30	29	5	5	11	
Probable Water Level (m)	(Year)	(%)							
	2	50%	9.03	6.46	11.61	7.20	6.77	6.92	
	3	33.3%	9.17	6.65	11.87	7.33	6.99	7.15	
	5	20%	9.30	6.81	12.09	7.47	7.23	7.40	
	10	10%	9.44	6.96	12.27	7.65	7.54	7.72	
	20	5%	9.56	7.06	12.39	7.82	7.84	8.02	
	25	4%	9.59	7.08	12.43	7.88	7.94	8.12	
	30	3.33%	9.62	7.10	12.45	7.92	8.01	8.20	
	50	2%	9.69	7.15	12.50	8.04	8.23	8.42	
	80	1.25%	9.75	7.18	12.55	8.16	8.42	8.62	
	100	1%	9.78	7.20	12.56	8.21	8.52	8.71	
	150	0.667%	9.82	7.22	12.59	8.31	8.68	8.89	
	200	0.5%	9.86	7.24	12.61	8.38	8.80	9.01	
	300	0.333%	9.90	7.26	12.63	8.47	8.97	9.18	
	400	0.25%	9.93	7.27	12.64	8.54	9.09	9.30	
	500	0.2%	9.95	7.28	12.65	8.59	9.18	9.40	
X-COR(99%)			0.985	0.990	0.996	0.989	0.923	0.923	
P-COR(99%)			0.988	0.989	0.998	0.983	0.961	0.964	
SLSC(99%)			0.037	0.030	0.022	0.035	0.126	0.118	
Probabilistic Distributed model			Log Pearson type Ⅲ distribution (Real space method)	Log Pearson type Ⅲ distribution (Real space method)	Log Pearson type Ⅲ distribution (Logarithmic space method)	Gumbel distribution	Gumbel distribution	Gumbel distribution	

Source: JICA Survey Team based on the data from DMH and Irrigation Department



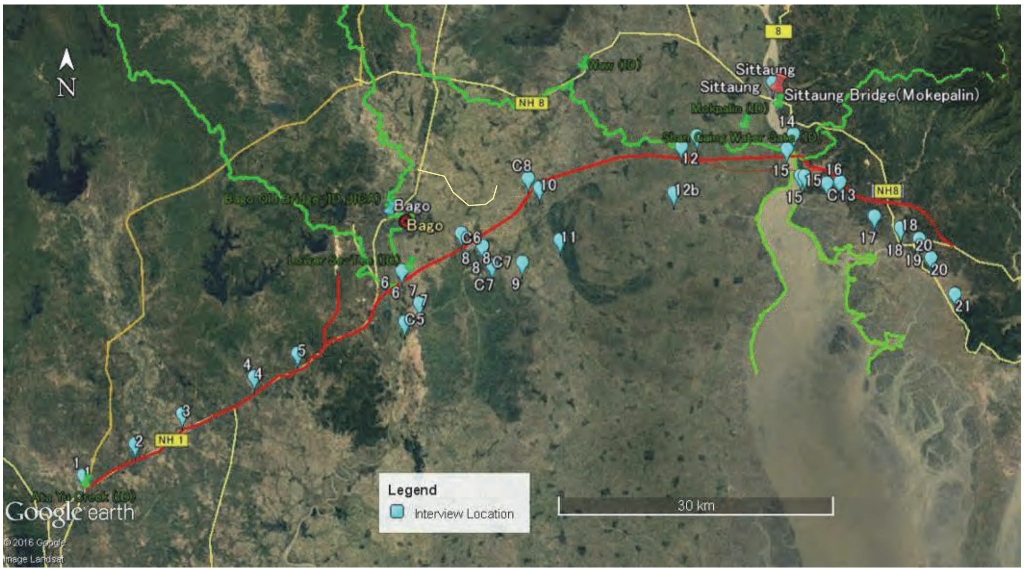
Source: JICA Survey Team based on the data from DMH and Irrigation Department

Figure 4.3.39 Probability Water-level Calculation at Six Stations

(2) Interview Survey Result

The water level in the water-level gauging station is not the elevation of topographic survey datum, and it is the arbitrary elevation value. Therefore, in order to analogize the correlation between the flood-level at sites and the probability value at the gauging station, the interview survey for actual flood levels to inhabitants was conducted.

Locations of the interview to local residents are shown in Figure 4.3.40.



Source: JICA Survey Team

Figure 4.3.40 Hydrological Interview Survey Locations

(3) Design Floods and Water Levels at Proposed Bridges and Roads

1) Design Floods at the Proposed Culverts and Bridges

There are many methods and procedures for the flood estimation in general. In this study, two estimation methods are examined, and the size of the catchment area of each method is limited as shown in following points;

- ✓ Catchment Area < 200 km^2 ⇒ Rational Formula
- ✓ Catchment Area ≥ 200 km^2 ⇒ Specific Discharge (Probability discharge per unit drainage area, modified by "Creager curve")

The design discharges (probability floods) at proposed bridges are applied big one among the above mentioned two methods, and the specific discharge is calculated by multiplying the proportion of the catchment area of each catchment area to the probability discharges of each gauge stations upstream. (Method by the "modified specific discharge by Creager curve".) The catchment areas of culverts are small, and the design discharge is calculated by the only rational formula which is most commonly used.

The magnitude of the design discharge is adopted 100-years flood for the main two bridges and 50-years flood for small bridges on the proposed roads. The design flood for culverts adopts 20-years flood (> 1 km^2) and 10-years flood (<1 km^2) by the magnitude of catchment area.

The design discharges are shown in Figure 4.3.20 and Figure 4.3.21.

Table 4.3.20 Design Discharges at Proposed Culverts and Bridges (1)

ID	Chainage	Drainage Area (Irrigation Area)	Design Scale	Specific Discharge (A>20km^2)		Rational Formula (A<200km^2)						Design Discharge	Culvert Type	Remarks
				Discharge per drainage-area	Design Discharge	Concentration Time	Flow Length	Mononobe's A	Rainfall Intensity	Runoff Coefficient	Design Discharge		(Bridge Length)	
		A (km^2)		($m^3/s/km^2$)	(m^3/s)	(hr)	(m)	-	(mm/hr)	-	(m^3/s)	(m^3/s)	(m)	
< NH1 Improvement >														
Brd-1	-Km00+386	44.5	50yrs	3.92157	174.5	3.83	12,904	96.196	39.266	0.60	291.2	291.2	(-)	Freeboard= 0.8
C-1	Km02+730	(4162)	Irrigation	-	-	-	-	-	-	-	6.37	6.4	II	
Brd-2	Km06+313	848.0	50yrs	1.14127	967.8	-	A>200 km2	-	-	-	-	967.8	(150.0)	Freeboard= 1.0
Brd-3	Km10+078	11.7	50yrs	-	-	2.05	6,475	96.196	59.639	0.60	116.4	116.4	(90.0)	Freeboard= 0.6
C-2	Km10+997	(8938)	Irrigation	-	-	-	-	-	-	-	12.72	12.7	II	
Brd-4	Km12+667	117.8	50yrs	2.77173	326.5	10.17	35,712	96.196	20.493	0.60	402.3	402.3	(120.0)	Freeboard= 0.8
C-3	Km14+785	(1689)	Irrigation	-	-	-	-	-	-	-	3.91	3.9	Ib	
C-4	Km14+798	2.3	25yrs	-	-	1.09	3,012	86.449	81.793	0.60	31.5	31.5	II	
C-5	Km15+914	4.7	25yrs	-	-	1.08	2,974	86.449	82.318	0.60	64.1	64.1	III	
C-6	Km19+713	(505)	Irrigation	-	-	-	-	-	-	-	1.64	1.6	Ic	
Brd-5	Km21+459	310.5	50yrs	1.84600	573.3	-	A>200 km2	-	-	-	-	573.3	(150.0)	Freeboard= 1.0
C-7	Km25+232	(1800)	Irrigation	-	-	-	-	-	-	-	4.25	4.3	II	
C-8	Km27+015	(243)	Irrigation	-	-	-	-	-	-	-	1.10	1.1	Ib	
C-9	Km34+018	0.9	10yrs	-	-	0.58	1,178	73.274	105.678	0.60	16.0	16.0	Ic	
C-10	Km35+377	(724)	Irrigation	-	-	-	-	-	-	-	1.10	1.1	II	
Brd-6	Km35+757	62.7	50yrs	3.49563	219.2	7.84	27,309	96.196	24.384	0.60	254.8	254.8	(90.0)	Freeboard= 0.8
C-11	Km36+416	27.5	25yrs	4.23895	116.8	3.73	12,515	86.449	35.967	0.60	165.1	54.4	III	
Brd-7	Km36+597	27.5	50yrs	4.54275	125.1	3.73	12,515	96.196	40.023	0.60	183.8	123.2	(90.0)	Freeboard= 0.6
C-12	Km39+165	3.4	25yrs	-	-	0.85	2,154	86.449	96.463	0.60	54.0	54.0	III	
<Kyaikto-Bago Bypass>														
C-12	Km00+727	3.4	25yrs	-	-	0.85	2,154	86.449	96.463	0.60	54.0	54.0	III	
C-13	Km02+185	3.6	25yrs	-	-	1.20	3,436	86.449	76.364	0.60	45.8	45.8	II	
Brd-8	Km04+330	2651.2	**100yrs**	0.65826	1745.1	-	A>200 km2	-	-	-	-	1745.1	(200.0)	Freeboard= 1.0
C-14	Km07+019	4.9	25yrs	-	-	1.28	3,699	111.916	95.059	0.60	78.0	78.0	III	
C-15	Km08+879	-	-	Restoration to original form									III	
Brd-9	Km09+320	23.6	50yrs	4.74508	112.1	2.45	7,930	124.045	68.205	0.60	268.6	268.6	(90.0)	Freeboard= 0.8
C-16	Km10+463	-	-	Restoration to original form									III	
C-17	Km10+750	-	-	Restoration to original form									II	
C-18	Km11+185	-	-	Restoration to original form									II	
C-19	Km11+646	-	-	Restoration to original form									III	
C-20	Km11+720	-	-	Restoration to original form									III	
C-21	Km11+764	-	-	Restoration to original form									III	
C-22	Km11+782	-	-	Restoration to original form									III	
C-23	Km12+111	-	-	Restoration to original form									III	
C-24	Km12+918	-	-	Restoration to original form									II	
C-25	Km14+019	-	-	Restoration to original form									II	
Brd-10	Km14+389	244.1	50yrs	2.05330	501.1	-	A>200 km2	-	-	-	-	501.1	(120.0)	Freeboard= 1.0
C-26	Km15+284	-	-	Restoration to original form									II	
C-27	Km16+439	-	-	Restoration to original form									II	
C-28	Km17+490	-	-	Restoration to original form									Ic	
C-29	Km17+673	-	-	Restoration to original form									Ib	
C-30	Km18+566	-	-	Restoration to original form									II	
C-31	Km19+279	-	-	Restoration to original form									II	
C-32	Km19+544	-	-	Restoration to original form									Ib	
C-33	Km20+115	-	-	Restoration to original form									III	
C-34	Km21+184	-	-	Restoration to original form									III	
Brd-11	Km21+343	11.2	50yrs	-	-	1.98	6,212	124.045	78.789	0.60	146.6	146.6	(90.0)	Freeboard= 0.6
Brd-12	Km22+747	9.9	50yrs	-	-	2.19	6,995	124.045	73.489	0.60	121.8	121.8	(90.0)	Freeboard= 0.6
Brd-13	Km23+162	-	50yrs	from Typical Cross Section								-	(90.0)	Freeboard= 1.0
C-35	Km24+496	-	-	Restoration to original form									III	
C-36	Km25+446	-	-	Restoration to original form									Ic	
C-37	Km25+545	-	-	Restoration to original form									III	
C-38	Km26+230	-	-	Restoration to original form									III	

Source: JICA Survey Team

Table 4.3.21 Design Floods at Proposed Culverts and Bridges (2)

ID	Chainage	Drainage Area (Irrigation Area)	Design Scale	Specific Discharge (A>20km^2)		Rational Formula (A<200km^2)						Design Discharge	Culvert Type	Remarks
				Discharge per drainage-area	Design Discharge	Concentration Time	Flow Length	Mononobe's A	Rainfall Intensity	Runoff Coefficient	Design Discharge		(Bridge Length)	
		A (km^2)		(m^3/s/km^2)	(m^3/s)	(hr)	(m)	-	(mm/hr)	-	(m^3/s)	(m^3/s)	(m)	
C-39	Km27+075	-	-	Restoration to original form									II	
C-40	Km27+562	-	-	Restoration to original form									II	
C-41	Km27+641	-	-	Restoration to original form									Ic	
C-42	Km27+693	-	-	Restoration to original form									Ib	
C-43	Km29+119	-	-	Restoration to original form									Ia	
C-44	Km29+134	-	-	Restoration to original form									Ia	
C-45	Km30+479	-	-	Restoration to original form									Ib	
C-46	Km30+922	-	-	Restoration to original form									Ib	
C-47	Km32+560	-	-	Restoration to original form									II	
C-48	Km33+671	-	-	Restoration to original form									III	
C-49	Km35+343	-	-	Restoration to original form									Ib	
C-50	Km35+964	-	-	Restoration to original form									Ib	
C-51	Km36+874	-	-	Restoration to original form									Ia	
C-52	Km37+340	-	-	Restoration to original form									III	
C-53	Km37+838	-	-	Restoration to original form									II	
C-54	Km38+390	-	-	Restoration to original form									III	
C-55	Km38+583	-	-	Restoration to original form									Ib	
C-56	Km40+182	-	-	Restoration to original form									Ic	
C-57	Km41+457	-	-	Restoration to original form									Ib	
C-58	Km41+683	-	-	Restoration to original form									Ib	
C-59	Km41+746	-	-	Restoration to original form									Ic	
C-60	Km41+912	-	-	Restoration to original form									Ib	
C-61	Km42+681	-	-	Restoration to original form									Ib	
C-62	Km43+122	-	-	Restoration to original form									Ia	
C-63	Km43+655	-	-	Restoration to original form									Ic	
C-64	Km43+834	-	-	Restoration to original form									Ia	
C-65	Km44+519	-	-	Restoration to original form									Ia	
C-66	Km46+131	-	-	Restoration to original form									Ib	
C-67	Km47+398	-	-	Restoration to original form									III	
C-68	Km48+488	-	-	Restoration to original form									Ia	
C-69	Km48+655	-	-	Restoration to original form									III	
C-70	Km49+287	-	-	Restoration to original form									III	
Brd-14	Km50+877	34015.6	**100yrs**	0.1746020	5939.2	-	A>200 km2	-	-	-	-	5939.2	(2000.0)	Navigation Clearance= 6.1
C-71	Km52+769	0.4	10yrs	-	-	0.41	592	95.526	171.835	0.60	10.2	10.2	Ic	
Brd-15	Km54+636	78.2	50yrs	3.23169	252.9	8.67	30,294	124.045	29.403	0.60	383.4	383.4	(120.0)	Freeboard= 0.8
C-72	Km55+954	0.8	10yrs	-	-	0.50	886	95.526	152.444	0.60	20.9	20.9	Ic	
C-73	Km57+059	1.0	10yrs	-	-	0.62	1,319	95.526	131.875	0.60	21.6	21.6	Ic	
Brd-16	Km58+849	16.9	50yrs	-	-	1.75	5,390	124.045	85.512	0.60	241.4	241.4	(90.0)	Freeboard= 0.8
C-74	Km59+349	0.2	10yrs	-	-	0.38	453	95.526	183.394	0.60	4.6	4.6	Ib	
C-75	Km60+067	0.3	10yrs	-	-	0.36	408	95.526	187.640	0.60	8.5	8.5	Ic	
C-76	Km61+146	0.8	10yrs	-	-	0.51	925	95.526	150.226	0.60	20.3	20.3	Ic	
C-77	Km61+842	0.2	10yrs	-	-	0.37	445	95.526	184.184	0.60	7.2	7.2	Ib	
C-78	Km63+776	0.6	10yrs	-	-	0.68	1,564	95.526	122.991	0.60	12.0	12.0	Ic	
C-79	Km64+128	2.6	25yrs	-	-	1.22	3,488	111.916	98.074	0.60	42.3	42.3	II	
Brd-17	Km64+542	117.5	50yrs	2.77445	326.0	8.06	28,120	124.045	30.855	0.60	604.2	604.2	(120.0)	Freeboard= 1.0
C-80	Km65+388	0.8	10yrs	-	-	0.59	1,207	95.526	136.534	0.60	18.0	18.0	Ic	
C-81	Km65+752	1.1	25yrs	-	-	0.71	1,651	111.916	140.791	0.60	26.6	26.6	II	
Brd-18	Km66+410	17.4	50yrs	5.15361	89.4	2.96	9,767	124.045	60.129	0.60	173.9	173.9	(90.0)	Freeboard= 0.6
C-82	Km67+392	0.2	10yrs	-	-	0.43	646	95.526	167.833	0.60	6.8	6.8	Ib	
C-83	Km67+733	0.2	10yrs	-	-	0.41	564	95.526	174.070	0.60	5.4	5.4	Ib	
C-84	Km68+074	0.9	10yrs	-	-	0.69	1,593	95.526	122.046	0.60	19.1	19.1	Ic	
C-85	Km70+502	3.3	25yrs	-	-	0.88	2,269	111.916	121.836	0.60	66.6	66.6	III	
C-86	Km71+794	0.9	10yrs	-	-	0.48	817	95.526	156.482	0.60	22.4	22.4	Ic	

Note. Time of concentration is calculated by assumed velocity of flow channel. Assumed V= 1.0 m/s.
Necessary Bridge Opening Width is calculated by Lacey's equation, in order to prevent contraction scour.
The specific discharge is performed the corrections to the weighting of the catchment area by "Creager curve".

Culvert Type

Type	B (φ) (m)	H (φ) (m)	Cell No.	Slope (%)	Area (m2)	Wetted perimeter (m)	Velocity (m/s)	Discharge capacity (m3/s)	Remarks	BoQ
C90-1	0.90	0.90	1	0.60%	0.55	1.99	2.18	1.19	80% depth	0
C150-1	1.50	1.50	1	0.30%	1.52	3.32	2.16	3.28	80% depth	0
Ia	1.50	1.50	1	0.30%	1.80	3.90	2.18	3.93	80% depth	7
Ib	2.00	2.00	1	0.30%	3.20	5.20	2.64	8.45	80% depth	19
Ic	3.00	3.00	1	0.30%	7.20	7.80	3.46	24.92	80% depth	17
II	3.00	3.00	2	0.30%	7.20	7.80	3.46	49.85	80% depth	20
III	6.00	4.50	1	0.20%	21.60	13.20	4.14	89.43	80% depth	24

Source: JICA Survey Team

2) Design Water Levels at Proposed Bridges and Roads

The correlation between the flood-level at sites and the probability value at the gauging station is estimated based on the undermentioned assumptions:

- The probability water levels calculated from the observed data of DMH and ID are arbitrary datum elevation, and they are not the elevation above mean-sea-level, namely, the elevation above national topographic survey datum. From them, the relative water-level relationship/difference can only be grasped.
- The flood level at each proposed bridge/road sites in the Sittaung River Basin is associated with the distance from river-mouth near the Moulmein Port. The annual maximum spring tide at Moulmein Port is 3.50m (on survey datum, namely MSL). At the existing Sittaung Bridge, the maximum wave height of the tidal bore has been witnessed as the height of 2.5m on flood tide, by local residents.
- The coordinates of the interview location was measured by handy GPS. However, the interviewed water levels are based on various inhabitant's memories, it is uncertainly. Also, in this study, a detailed topographic survey is not conducted. Therefore, interviewed water levels are estimated as the values on commonly utilisable elevations such as google earth or satellite DEM (digital elevation map).

In this study, the flood level are estimated by the relationship between the interviewed historical high flood levels and distance from river-mouth to the interviewed location, and the information of the calculated probability flood levels and flood-level of existing bridge drawing and the past literature. Although some errors are included, the design high water-levels at each bridge on proposed roads are shown in Table 4.3.22. (The design scale is 50-years flood for normal bridges and 100-years flood for New Sittaung Bridge).

Table 4.3.22 Design High Water Level at Proposed Bridges

Bridge ID	Road Chainage	River Name	Catchment Area (km^2)	Design Discharge		Design High Water Level (m)		Freeboard / Navigation Clearance (m)	Remarks
				Return Period	Discharge (m3/s)	100 yrs	50 yrs		
< NH1 Improvement >									
Brd-1	-Km00+386	Ata Yu Creek	44.5	50yrs	291.2	-	7.39	0.8	
Brd-2	Km06+313	Pazundaung Creek (River)	848.0	50yrs	967.8	-	8.96	1.0	
Brd-3	Km10+078	(unknown)	11.7	50yrs	116.4	-	8.84	0.6	
Brd-4	Km12+667	(unknown)	117.8	50yrs	402.3	-	9.52	0.8	
Brd-5	Km21+459	Le Gun Byin Creek	310.5	50yrs	573.3	-	7.68	1.0	
Brd-6	Km35+757	Zeletaw Creek	62.7	50yrs	254.8	-	10.57	0.8	
Brd-7	Km36+597	Split flow by Culvert Width 8.3746	27.5	50yrs	123.2	-	10.47	0.6	
<Kyaikto-Bago Bypass>									
Brd-8	Km04+330	Bago River	**2,651**	100yrs	**1,745**	10.85	(10.72)	1.0	
Brd-9	Km09+320	Mokkala Creek (W=31.4m)	23.6	50yrs	268.6	-	9.67	0.8	
Brd-10	Km14+389	Kamapa Yan Creek (W=46.4m)	244.1	50yrs	501.1	-	9.54	1.0	
Brd-11	Km21+343	Maung Makawyo (W=37.4m)	11.2	50yrs	146.6	-	9.40	0.6	
Brd-12	Km22+747	(unknown)	9.9	50yrs	121.8	-	9.40	0.6	
Brd-13	Km23+162	Sittaung-Bago Canal (W=75m)	-	50yrs	-	-	9.41	2.0	
Brd-14	Km50+877	Sittaung River	**34,016**	100yrs	**5,939**	8.76	(8.66)	6.1	Navigation Clearance
Brd-15	Km54+636	Ka Lun Chaung	78.2	50yrs	383.4	-	9.02	0.8	
Brd-16	Km58+849	(unknown)	16.9	50yrs	241.4	-	9.12	0.8	
Brd-17	Km64+542	Kadat Chaung	117.5	50yrs	604.2	-	8.75	1.0	
Brd-18	Km66+410	Tagal Chaung	17.4	50yrs	173.9	-	8.90	0.6	

Source: JICA Survey Team

(4) Hydrological Assessment of Proposed Bridges and Roads

1) Hydraulic Design Criteria of Bridges

In order to design the opening of the bridge waterway, the following design criteria for hydraulics are required.

- ✓ The backwater does not significantly increase the flood damage to properties upstream of the bridge.
- ✓ The velocity through the bridge does not damage the road facility or increase the damages to downstream properties.
- ✓ The existing flow distribution is maintained to the extent practicable.
- ✓ The pier and abutment are designed to minimize the flow disruption.
- ✓ Potential local scour is within acceptable limits.
- ✓ Clearance at the structure is adequately designed to safely pass any anticipated debris. (The elevation of the bottom of the bridge girder is higher than "Highest high water level + Navigation channel height".)

The design return period, the clearance from the bridge girder to high water level shall be compliant with authorized standards by the organizations concerned. (In case of a navigation waterway, the clearance between the bridge bottom girder and the water surface is secured with the existing bridge clearance at least. In other cases, the freeboard on the hydraulics is in compliance with Japanese Technical Criteria for River Works.)

In this study, the design return period is adopted as a 100 year return period for main bridges and a 50 year period for small bridges of bypass roads.

2) Hydraulic Design Criteria of Culverts and Road Embankments

The design scale (return period) for drains, culverts and road embankments is applied to the following.

- ✓ Drains (for road drainage), Small culverts (A<1km2) ----- 10 year return period
- ✓ Culverts (A≥1km2) ----- 25 year
- ✓ Road embankments ----- 50 year

Lateral road drainage is mainly through culverts and bridges. The size of the flood opening is determined by the catchment area parameters and consideration of existing nearby structures.

The hydraulic design requires the consideration of the following points:

- ✓ Head loss due to contraction at the entry of the culvert.
- ✓ Head loss at the inlet, through the culvert and outlet due to the roughness.
- ✓ Tailwater level and downstream condition

The embankment of roads is made from the earth and sand material, and it is very weak to overtopping and bumping. Therefore the planner must consider the safety countermeasures such as clearance. The freeboard of roads will be applied for the criteria same as the river embankment. Protection for the embankment shall be ensured using the suitable protection works. In addition, all high flood levels shall be shown in the design drawings in order to check whether the high flood level influences the road embankment.

(5) Hydrological Recommendations

From the above hydraulic study, several challenges and conclusions has been extracted. As for hydraulic issues of the proposed hydraulic structures, following respects are left as future challenges.

- ✓ The detailed topographic, bathymetric and hydrological surveys are not conducted in this study. In order to clarify the river morphology/characteristics, tidal motions (flood-/ebb tide) and the unique hydraulic phenomenon (tidal bore), these detailed surveys shall be conducted. The flow-rate around estuaries is the sum of tidal-flow and river own flow, and generally, the river's own flow (by rainfall of upstream) is smaller than tidal flow (of flood-/ebb tide by tidal motion). Especially, the tidal influence distance from the estuary of Sittaung River is long, and a large-scale survey will be needed.
- ✓ In this study, the hydraulic analysis including the bridge-scour have not conducted in detail, and also the river-training works around the piers/abutments are not studied. Hence, the study of appropriate bed protection and revetment works shall be conducted at the next design stage. Especially, because hydraulic phenomena of the Sittaung estuary section are highly unusual, detailed hydraulic studies will be needed.
- ✓ In order to secure the accuracy of the elevation values and probability values, the checking of the difference between "datum of gauging stations" and "topographic survey datum" shall be performed in next design stage.
- ✓ The rainfall intensity formula at the current stage is predicted from the 24 hour rainfall volume, and the rainfall data for a short time has not been used. (It was difficult to collect.) If there is many short-term rainfall data, the rainfall intensity curve equation should be modified.
- ✓ This study area is a low-lying area and flood area, and the channel-network for irrigation/drainage is very complicated. Therefore, a more detailed survey shall be performed in the future study in the range of all of the catchment area of drainage structures.