Republic of the Union of Myanmar

DATA COLLECTION SURVEY ON WATER RESOURCES POTENTIAL FOR THILAWA SPECIAL ECONOMIC ZONE AND ADJOINING AREAS

FINAL REPORT

(MAIN REPORT)

SEPTEMBER 2014

JAPAN INTERNATIONAL COOPERATION AGENCY

SANYU CONSULTANTS INC.

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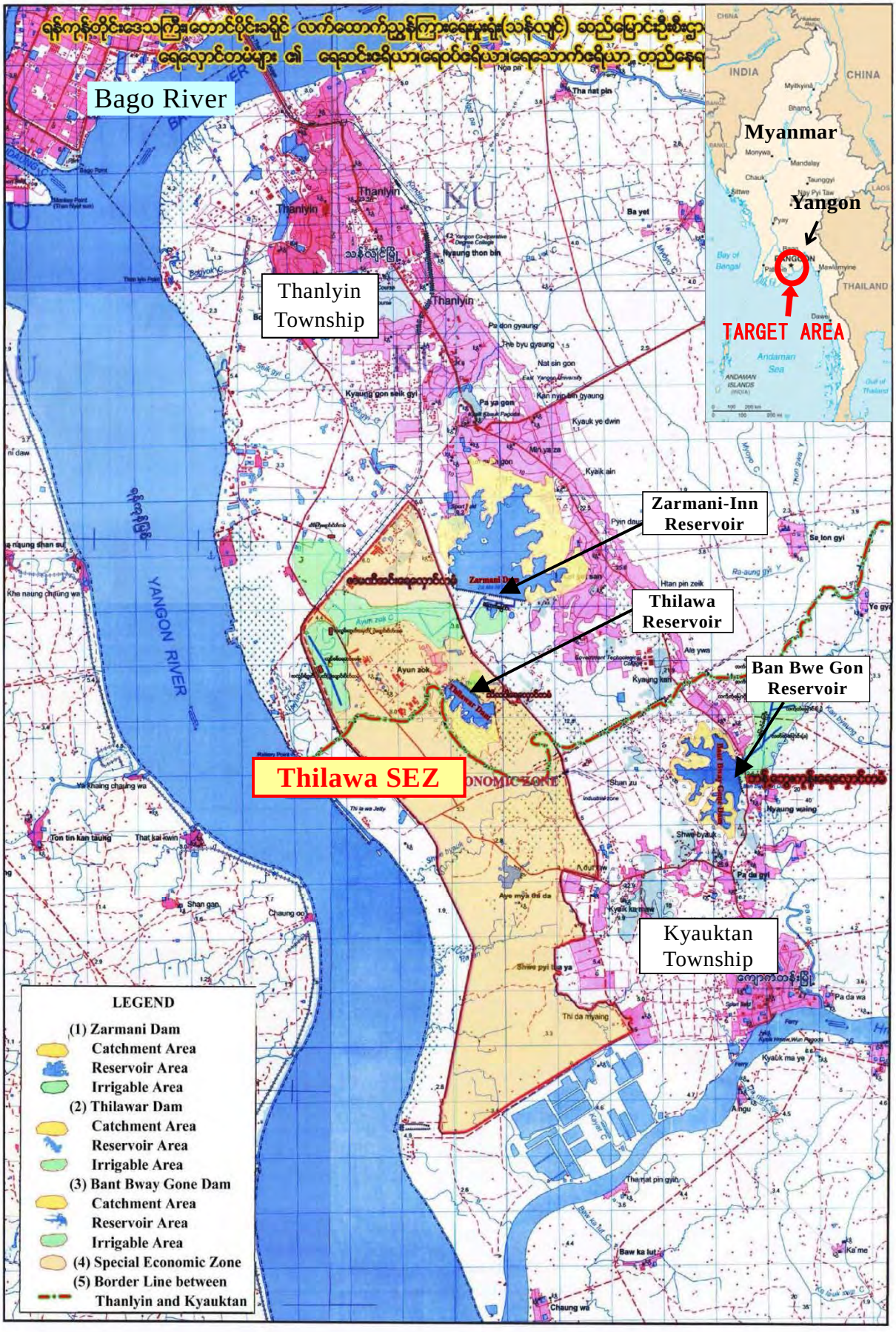
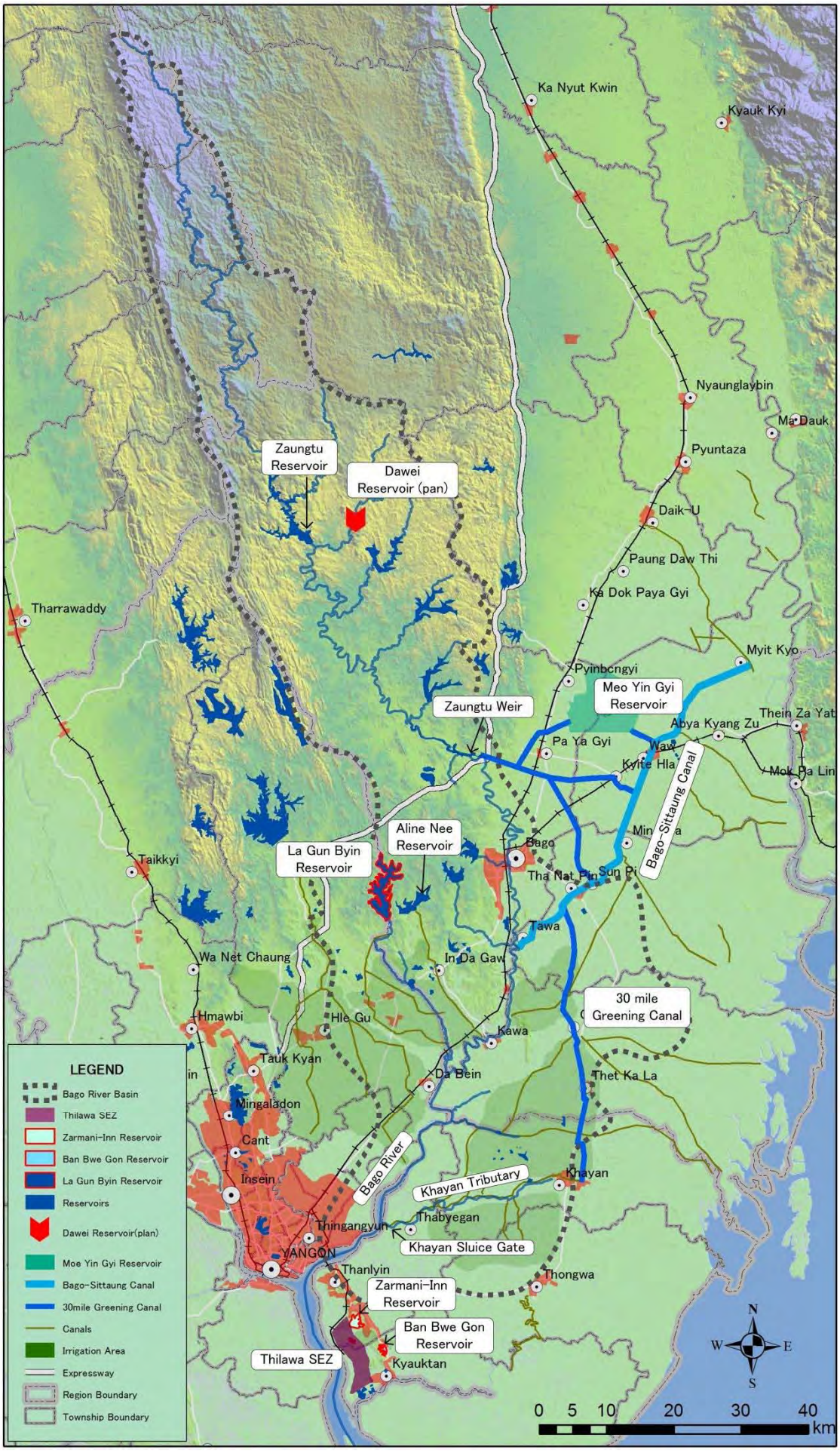


Location Map – Area around Thilawa SEZ- (1/2)



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Measures Unit

Measures Unit

cm	centimeter	℃	centigrade
cu.m	cubic meter	cms (m^3/sec)	cubic meter per second
hr	hour	km^2	square kilometer
km	kilometer	TCM	thousand cubic meter
lit.	liter	MCM	million cubic meter
m	meter	MGD	million gallon per day
mg/lit.	milligram per liter	meq/lit.	milli-equivalent per liter
m/s	meter per second	ppm	parts per million
lit/sec	liter per second	%	percent
m^3/d, m^3/day	cubic meter per day		

	ton	1 t	=	1,000 kg
	inch	1 in.	=	0.0254 m
	mile	1 mi.	=	1,609 m
	hectare	1 ha	=	10,000 m^2
			=	2.471 acres
	acre feet	1 acre-ft	=	1,233 m^3
	gallon (UK)	1 gal.	=	4.546 liter (UK)
	kilogram	1 kg	=	1,000 gram
	viss	1 viss	=	1.64 kg
	feet	1 ft	=	0.3048 m
	acre	1 ac	=	4,048 m^2
	cubic feet	1 cu-ft	=	28.31 liter
	cubic inch	1 cu-in	=	0.01638 liter
Currency	Aug2014	1 Kyat	=	0.107 JPY
		US$1.00	=	102.40 JPY

Acronyms and Abbreviations

ID	Irrigation Department (Ministry of Agriculture and Irrigation)
DA	Department of Agriculture (Ministry of Agriculture and Irrigation)
EC	Electric Conductivity
FC	Foreign Currency
FY	Fiscal Year
GOM	Government of Myanmar
HHWL	Highest High Water Level
HWL	High Water Level
IEE	Initial Environmental Examination
JICA	Japan International Cooperation Agency
Kyat	Myanmar Kyat
LWL	Low Water Level
MCTSEZ	Managing Committee Thilawa Special Economic Zone
METI	Ministry of Economy, Trade and Industry (Japan)
MOAI	Ministry of Agriculture and Irrigation
MOC	Ministry of Construction
MOEC	Ministry of Environment Conservation
MOEP	Ministry of Electric Power
MOF	Ministry of Forestry
MOFA	Ministry of Foreign Affairs
MOFR	Ministry of Finance and Revenue
MOI	Ministry of Industry
MONPED	Ministry of National Planning & Economic Development
MOPBANRD	Ministry of Progress of Border Areas, National Races and Development
MOTC	Ministry of Transpotation and Communication
MWL	Mean Water Level
N/A	Not Available
NGO	Non-Governmental Organization
SCTSEZ	Supporting Committee Thilawa Special Economic Zone
SEZ	Special Economic Zone (Thilawa Special Economic Zone)
TDEM	Time Domain Electro-magnetic Method
TS	Town Ship (eg. Thanlyin TS: Thanlyin Town Ship)
VES	Vertical Electric Sounding
YCDC	Yangon City Development Committee

CHAPTER 1

BACKGROUND AND OBJECTIVES OF THE STUDY

CHAPTER 1 BACKGROUND AND OBJECTIVES OF THE STUDY

1-1 Background of the Study

In the Republic of the Union of Myanmar (Myanmar), the political system led by military forces has continued for a long period. After General Thein Sein from the military assumed the post of Prime Minister in October, 2007, political reform began. Then, after H.E. U Thein Sein assumed the position of President in March, 2011, the approach forward toward a democratic system and market-oriented economic reform remarkably improved.

The corresponding change of the international community over the democratic political system and market-oriented economic reform in Myanmar has changed rapidly, with a typical example being the US government's cancellation of the economic sanction in May, 2012 to forge ahead in the new market under consideration of the "Last frontiers in the Asian Region".

Myanmar President Honorable H.E. U Thein Sein, who officially visited Japan and its Prime Minister, Mr. Yoshihiko Noda, signed the "Memorandum of Intent on the Cooperation for the Development of the Master Plan for the THILAWA" on 21 April, 2012 to make a master plan together for the THILAWA Special Economic Zone (Thilawa SEZ) which is located near Yangon City. The memorandum, promoting the direct investment of Japan in Myanmar, can contribute to high economic growth and provide job opportunities by developing industries in Myanmar and can contribute toward shared benefits between the two countries.

Thilawa SEZ is located 23 (twenty three) km southeast of Yangon City. The Master Plan consists of an industrial complex, commercial facilities, housing etc. in an area of 2,400 ha and can be called a "Smart Community Development". The Japanese Government intends to make this a joint project with a large number of Japanese business groups having private capital and has pledged in the memorandum to support the project financially. Consequently, the development of Thilawa SEZ is expected to progress steadily as a future cornerstone for the two counties' economic development.

Basic conditions required to effectively utilize the capital of the Japanese private sector include full preparation for electrical energy, roads, port facilities, storage facilities, and especially, a safe water supply system, including an intake facility, conveyance networks, and water supply networks, which are essential to providing a sustainable water supply system for Thilawa SEZ. It is essential to deal with the water resources development in a well-planned, under consideration for the harmony with environment and evaluation for the water quality and cost-performance. For the sustainable water supply to the Thilawa SEZ, in case of the utilization of the surface water, since existing reservoirs have already set the water right, amount of the available water resources are not secured. In the progress of the development of the Yangon urban area, the survey area also will be developed. The future water requirement can be assumed to increase.

Here are the means of the data collection survey on the water resources potential for the Thilawa Special Economic Zone and Adjoining Areas.

1-2 Objectives of the Study

The Data Collection Survey on the Water Resources Potential for the Thilawa Special Economic Zone and Adjoining Area intends to collect basic information on water resources necessary for making a future development plan of Thilawa SEZ and the surrounding areas.

Intended data are available surface water and groundwater. The water resources potential of those resources should be assumed by scientific approach and should be examined for the cost of developing the water resources to meet the required purpose individually.

The following are outcomes anticipated as a result of the Survey:

- Present and future potential of groundwater resources are assessed from a viewpoint of utilization through 3D groundwater numerical modeling;
- Present and future potential of surface water resources are assessed from a viewpoint of utilization after understanding abundance, quality and demand of surface waters;
- Based on the above two potentials of ground and surface water resources, concrete plans are made for costs, amount of exploitable water resources, water quality, etc.; and
- A database for water resources development, which shows exploitable amount, quality and developing costs, is created.

CHAPTER 2

BASIC DATA COLLECTION AND ANALYSIS

CHAPTER 2 BASIC DATA COLLECTION AND ANALYSIS

2-1 Basic Data of Nature, Society, Economy and Environmental & Social Considerations

2-1-1 Target Area of the Study

Myanmar is composed of seven (7) regions and seven (7) states as an administrative classification. The Thilawa Special Economic Zone (Thilawa SEZ) is located in Yangon.

Yangon Region is composed of 45 townships. The study area is located in Thilawa SEZ and adjoining areas and is defined specifically as Thanlyin Township, Kyauktan Township, Thongwa Township and Kayan Township as the target area of the study for the existing shallow wells.

From the aspect of the study for the surface water resources, the target area of the study includes Bago Region (next to Yangon Region) because the main candidate for surface water resources was assumed to be the Bago River.

(Region)

1. Ayeyarwady Division
2. SagaingDiveision
3. Tanintharyi Division
4. Bago Division
5. Magway Division
6. Mandalay Division
7. Yangon Division

(State)

1. Kachin State
2. Kayah State
3. Kayin State
4. Shan State
5. Chin State
6. Mon State
7. Rakhine State

Figure 2-1-1 Administrative Sectional Map of Myanmar

2-1-2 Nature

Myanmar is located from the northern latitude of 10 degrees to the northern latitude of 28 degrees, stretching 900km east to west and 2,000km north to south and is situated in the climate zone of tropical monsoons.

The nation's land has features from a coastal line to the highest mountain, Hkakabo Razi Mt (5,581m). It is changing from flat ground to undulating ground.The climate of the county has three (3) seasons, as follows:

Late October – May	Dry Season
April and May	Summer Season
June – Mid-October	Monsoon Season

The characteristic feature of the monthly mean temperature is comparatively high in Yangon City; on the other hand, rainfall morphology shows the feature of the concentrated rainfall wave. Ninety-six percent (96%) of the annual rainfall in Yangon City falls in the rainy monsoon season.

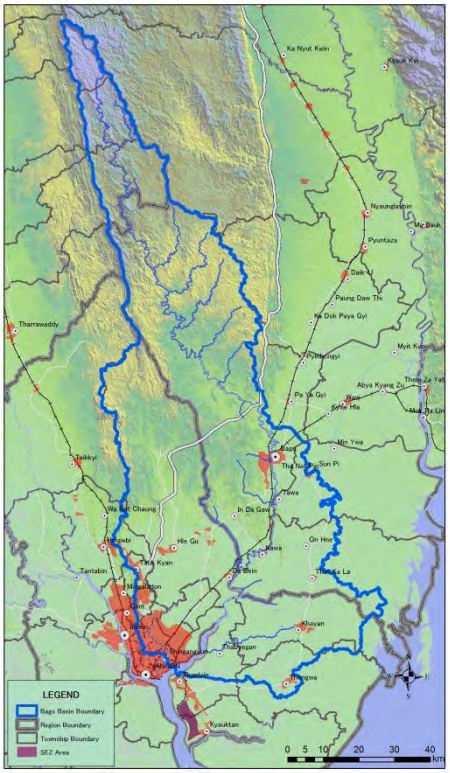


Figure 2-1-2 Target Area of the Study for the Surface Water

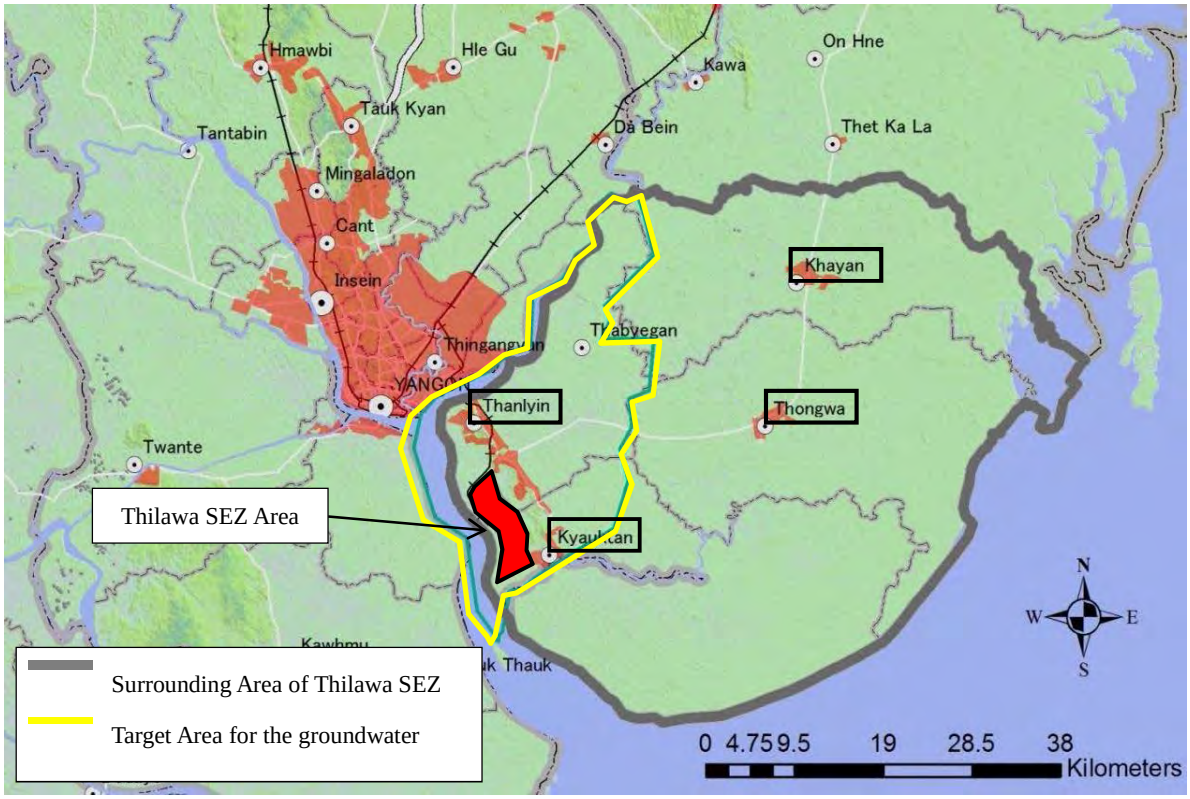
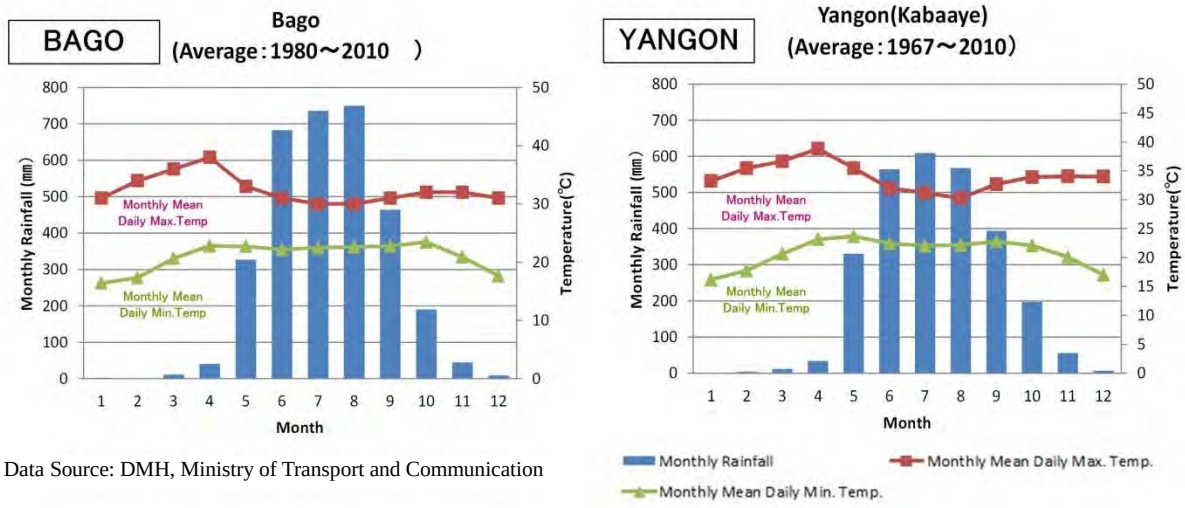


Figure 2-1-3 Target Area of the Study for the Groundwater

This rainfall morphology is the main reason to verify the possibility of cultivating farms througout the year. At the same time, it provides water resources for irrigated farming.

Effective usage of the water resources ensures the possibility to realize the creation of the living standard in rural areas through agricultural promotion



Data Source: DMH, Ministry of Transport and Communication

Figure 2-1-4 Monthly mean temperature and rainfall

2-1-3 Society

The society of Myanmar consists of eight (8) numbers of the major tribes (Burma, Kachin, Kayah, Kayin, Chin, Mon, Rakhine), each name being used to name each of the states. The total number of states is 135. The population of the Burma tribe comprises about 70% of the total population of the 62.42 million in Myanmar. Myanmar is multiracial country.

90% of the population is Buddhist, and the strongest religious conflict is between Buddhists and Muslims. Furors resulting in deaths have occurred in the local areas sporadically.

To know the degree of social development from an international standpoint, the human development index published by the UNDP in 2011 shows a value of 0.483, which situates Myanmar as 149th out of 187 countries. At the same time, the value of the index for Japan was 0.901. The index was estimated according to the average life expectancy, literacy rate, school enrollment ratio and GDP and is also used to classify the countries into: advanced country; developing country; and least developed country. Myanmar is classified under the least developed country category.

On the other hand, from the aspect of the standard of education, the adult literacy rate of the citizens show more than 90% and the youth literacy rate shows more than 95%, which is the same level as Vietnam. As far as literacy rate then, Myanmar can be understood as a rich country. The traditional system of education in Myanmar which is done in and through temples, like TERAKOYA in Japan, is expanding widely.

2-1-4 Economy

(1) Scale of the National economy

The Gross Domestic Production (GDP) was announced as 39,846,693,000,000 Kyat in the Statistical Year Book 2011 which is a value equivalent to one hundred and thirty parts of the Japanese GDP of 512 trillion Yen in 2010. It can be understood that the scale of Myanmar's national economy has one hundred and thirty parts of the Japanese national economy at this moment.

(2) Industrial Structure

According to the above-mentioned Statistical Year Book, the industrial scale in the GDP (2011) is shown below:

Table 2-1-1 Sharing Ratio by item of Industries in GDP

(Unit ; million Kyat)

Industry	Amount	Ratio	Industry	Amount	Ratio
Agriculture	11,082,206	27.8%	Construction	1,839,334	4.6%
Livestock & Fishery	3,392,044	8.5	Transportation	4,837,735	12.1
Forestry	158,340	0.4	Communication	323,544	0.8
Energy	66,229	0.2	Financial Institution	37,715	0.1
Mining	303,517	0.8	Social & Administarative Services	788,177	2.0
Processing & Manufac.	7,896,966	19.8	Rental & Other Services	738,480	1.9
Electric Power	422,525	1.1	Trade	7,959,882	20.0
			Total	39,846,693	100.0%

(Statistical Yearbook 2011)

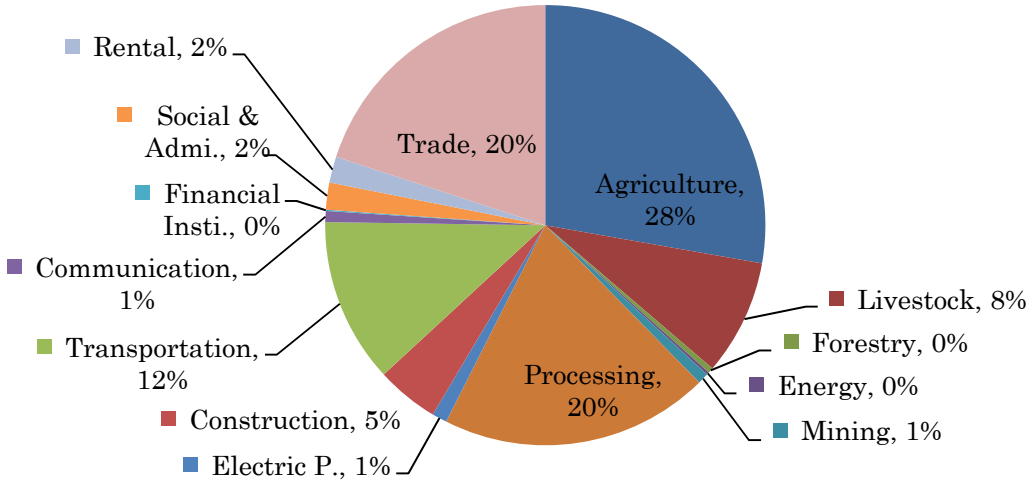


Figure 2-1-5 Industrial Structure in GDP

Agriculture shares 27.8% among all industries in the GDP of Myanmar, which means that Agriculture is the main industry in the country. Here, the strong intention of the Government of Myanmar is shown with its request to the Government of Japan to introduce the competitive industrialized processing and manufacturing industries with a Private-Public Initiative for the Thilawa Special Economic Zone.

(3) International Competitiveness

According to the above-mentioned Statistical Year Book of 2011, the balance of trade in 2010-2011 was 8,861 million USD (Export), 6,413 million USD (Import) and 2,448 million USD (Balance in black figure).

By item of the export, Natural Gas and Precious Metals exceed Agriculture in amount of export. The garment industry, which is a light industry, shares only 4.3% of the total amount of export. Here, the Government of Myanmar promotes its strong intention to establish the Industrial Nation by the processing industry and the manufacturing industry mainly through the invitation of foreign investment to the Special Economic Zone.

Table 2-1-2 Industrial Export Amount

(Unit: million USD)

Item	Amount	Ratio	Item	Amount	Ratio
Agriculture	1,228	13.9%	Animal Product	13	0.1%
Fisheries	287	3.2	Timber	594	6.7
Base metals	42	0.5	Precious metals	2,028	22.9
Natural Gas	2,523	28.5	Garments	379	4.3
Others	1,767	18.9	Total	8,861	100%

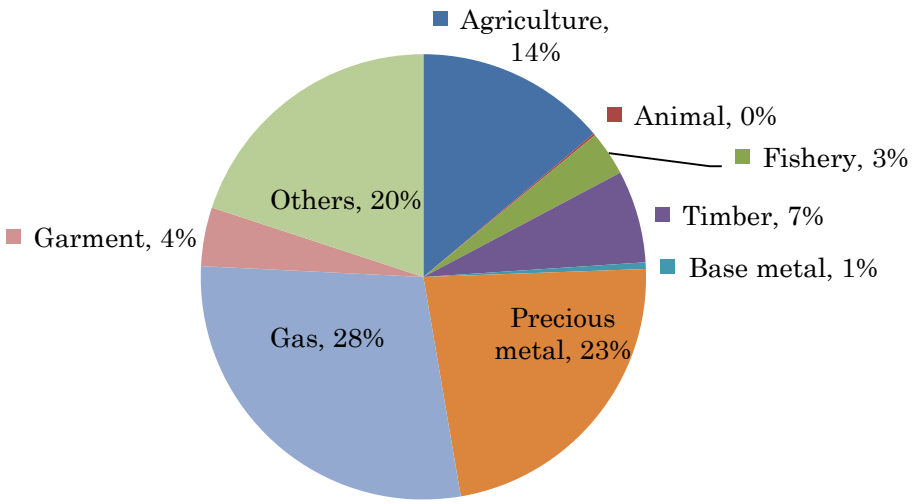


Figure 2-1-6 Industrial Export Ratio

2-1-5 Environmental and Social Consideration

(1) Historic steps and changes in Myanmar with Environmental and Social Considerations

The Environment Conservation Law was enacted in March 2012 in Myanmar. Before establishing the Law, there was no related law regarding the environmental protection. The laws, which were established by the ministries individually on the each fields, perform the roles of the environmental protection on the each fields. The National Commission for Environmental Affairs (NCEA) is defined as a lead ministry in the Government. The NCEA was established in 1990 as a Government

office to manage the environmental education and environmental policy under the Ministry of Foreign Affairs. The National Environmental Policy was established by the NCEA in 1994 to make clear the direction for the environmental conservation. At later time, the Myanmar Agenda 21 was established in 1997. The NCEA was placed under the Ministry of Forestry, nowadays, was placed under the Ministry of Environmental Conservation and Forestry (MOECF). Now, MOECF is lead ministry for the environmental conservation.

(2) Related law on the environment

The related laws on the environmental fields are shown below.

- The Forest Law : State Law and Order Restoration Council Law No. 8/92 (1992)
- The Protection of Wildlife and Conservation of Natural Areas Law: The State Law and Order Restoration Council Law No. 6/94 (1992)
- The Myanmar Marine Fisheries Law: The State Law and Order Restoration Council Law No. 9/94 (1990)
- The Freshwater Fisheries Law: The State Law and Order Restoration Council Law No. 1/91 (1991)
- The Law Amending the Myanmar Marine Fisheries Law: The State Law and Order Restoration Council Law No. 16/93 (1993)
- The Law Amending the Law Relating to the Fishing Rights of Foreign Fishing Vessels: The State Law and Order Restoration Council Law No. 15/93 (1993)
- The Law Relating to Aquaculture: The State Law and Order Restoration Council Law No. 24/89 (1989)
- The Pesticide Law: The State Law and Order Restoration Council Law No. 10/90 (1990)
- The Myanmar Mines Law: The State Law and Order Restoration Council Law No. 8/94 (1994)
- The Conservation of Water Resources and River Law: State Peace and Development Council Law No. 8/2006 (2006)
- The Environment Conservation Law: The Pyidaungsu Hluttaw Law No. 9/2012 (2012)

2-2 Organization of the Administration and Legal Frame on the Water Utilization

2-2-1 Organization of the Administration on the Water Utilization

In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MOLTT) take charge of management of the Class A River, and the Regional Government take charge of management of the Class B River. The Water Utilization Administration is defined as below.

- The MOLTT has right to give a permission of the water right to the water users which is the public property.
- The MOLTT has responsibility to insure the effective utilization of the river water, and to smooth management of the water utilization by various users in the river basins.
- In terms of above-mentioned issues, for the integrated management of the rivers in low water level, the MOLTT shall set the required water discharge volume to keep the normal function of the river flow. The MOLTT shall carry our following activities.
    - ・Forecasting the future water requirement
    - ・Estimation of the available water resources volume for developing
    - ・Permission of the Water Right

In Myanmar, the Ministry of Transport take charge of management the shipping traffic under the Department of Transport. It is a part of the function of the transportation system. In terms of the Water Resources, Department of Water Resources and Improvement of River System has responsibility for improvement of the river water way and improvement of the dike regarding the Ayeyarwady River, the Salween River, Sittang River and Chindwin River.

The National Plan of the water resources development for the irrigation water, industrial water and domestic water is approved by the National Water Resources Committee. The Department of the Water Resources and Improvement of the River System, Ministry of the Transport, is in charge of the management of the committee. It is not functioning actually in this situation by the result of the interview with the officials concerned in October 2013. The vice president is the chairman of the committee and the vice chairman is the minister of the Ministry of Transport. The Director General of the Department of the Water Resources and the Improvement of the River System is the secretary of the committee. The Water Policy is under discussing by the Committee and it will be established by 2015. Discussion schedule on the Water Right is not defined yet by the interview with high ranking officer of the Irrigation Department.

Accordingly, for making the real river development plan and irrigation development plan, the main ministry has responsibility to handle the project implementation by getting the budget of the Union Government through the making the consensus among the regional government related the project. Based on the above-mentioned definition by the Government of Japan, the leading ministry for the administration of the water utilization can be assumed to be the Irrigation Department, Ministry of Agriculture and Irrigation.

2-2-2 Policy

The making activities for the draft of the Water Utilization Policy consist of the River Administration Policy by the Department of the Water Resources and Improvement of the River System and the Water Development and Water Utilization regarding the groundwater and surface water by the Irrigation Department. But present situation, there is no permanent committee among the both ministry. There was no friction among both ministries, because the ministry of the transport has concentrated on the main river as already mentioned. There is no five-year plan for the water utilization as a fundamental principle by both ministries at this moment. The data collection survey team has already requested to the ministries regarding the annual budgetary plan. Unfortunately, the information has not reached yet.

2-2-3 Legal Frame

It is clear that the Law of the Water Right in Myanmar has not established yet, by the interview with high ranking officer of the Irrigation Department.

The data collection survey team has an intension to collect information by the interview with the planning Sector in the Irrigation Department, Ministry of Agriculture and Irrigation.

An acceptance of the water resources development by the ministry level, the National Water Resources Committee has a right to conduct the acceptance. The Directorate of Water Resources and Improvement of River System was appointed as the main agency, but it is not functional. The National Water Resources committee is discussing the Water Policy for making the law by end of 2015. According to the interview from the high-ranked officer, the schedule for the discussion still was not determined.

The respective water right regarding the reservoirs, small reservoirs and groundwater development are not managed based on the real law. For the transitional periods, the ministry of the electric power or ministry of the agriculture and irrigation are managing under the cabinet meeting of the union government. After development of the water resources, the operation and maintenance will be transfered to the ministry level or regional government level. According to the interview with the Irrigation Department, from making the project master plan to the implementation the project of the surface water resource, the Irrigation department has responsibility. For the groundwater development, the Water Resource Utilization Department has responsibility on this matter.

2-3 Outline of Topography and Geology

2-3-1 Topography

(1) Topographic Units and Survey Area

Mountains cover Myanmar in the east and west as well as in the northern edge. Lowlands spread

in the central part. The Irrawaddy and the Sittang Rivers flow southward in the lowland into the Andaman Sea as shown in Figure 2-3-1. Between the two rivers, Pegu Yoma (Pegu Hill) runs from north to south to divide the lowland. The southern end of Pegu Yoma is the Yangon Ridge on which Yangon City is located, and also the Thanlyin-Kyauktan Ridge which stretches southeastwards over the Bago River as shown in Figure 2-3-2.

The Bago River originates in the south of Pegu Yoma. It flows first southeastwards to near Bago City, and turns to south keeping its flow in lowland to Yangon city.

The Bago River originates in the south of Pegu Yoma. It flows first southeastward to near Bago City, and then turns to the south, keeping its flow in the lowland to Yangon City.

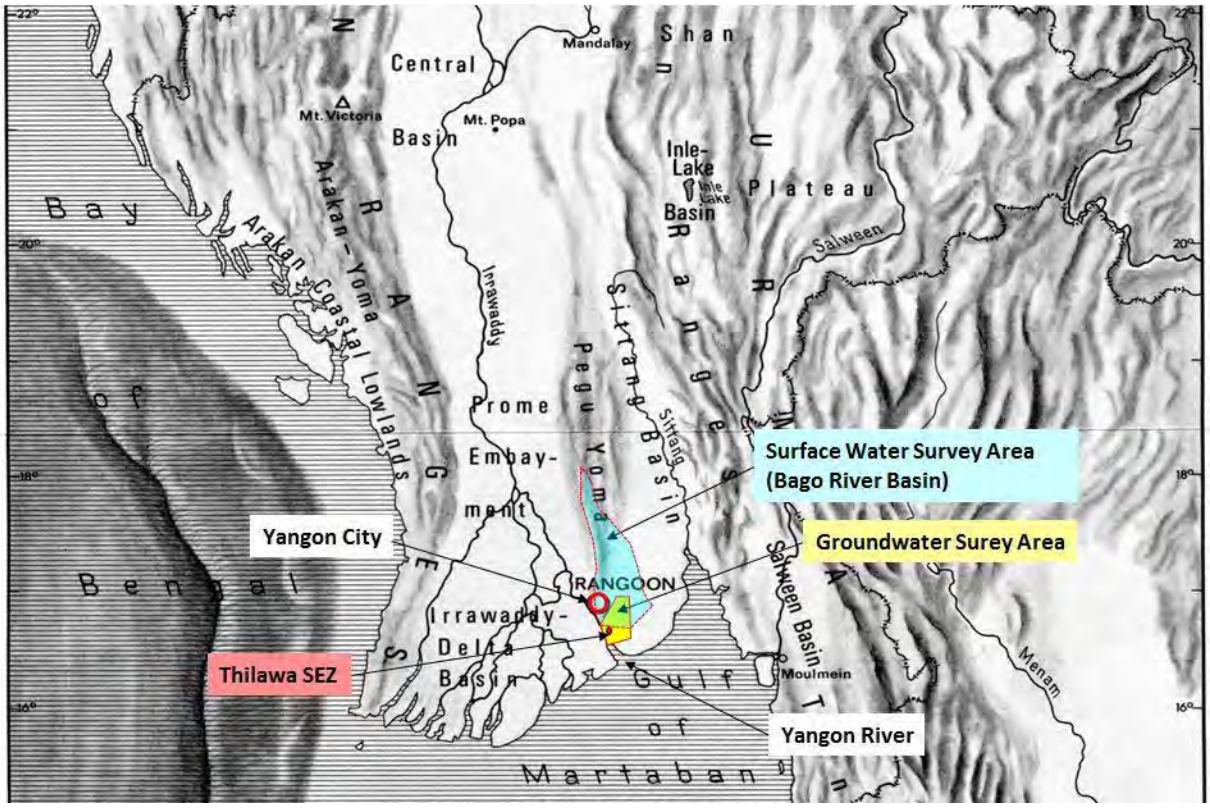
The groundwater investigation of the present survey targets the area of the Thanlyin-Kyauktan Ridge and the lowland plain next to it to the east (called respectively as the “hill” and “plain” hereafter), which is surrounded by the Bago, Yangon and Hmawwun Rivers as shown in Figure 2-3-2 and Figure 2-3-3.

The surface water investigation targets the Bago river Basin in addition to this area.

(2) Ground Elevation and Gradient

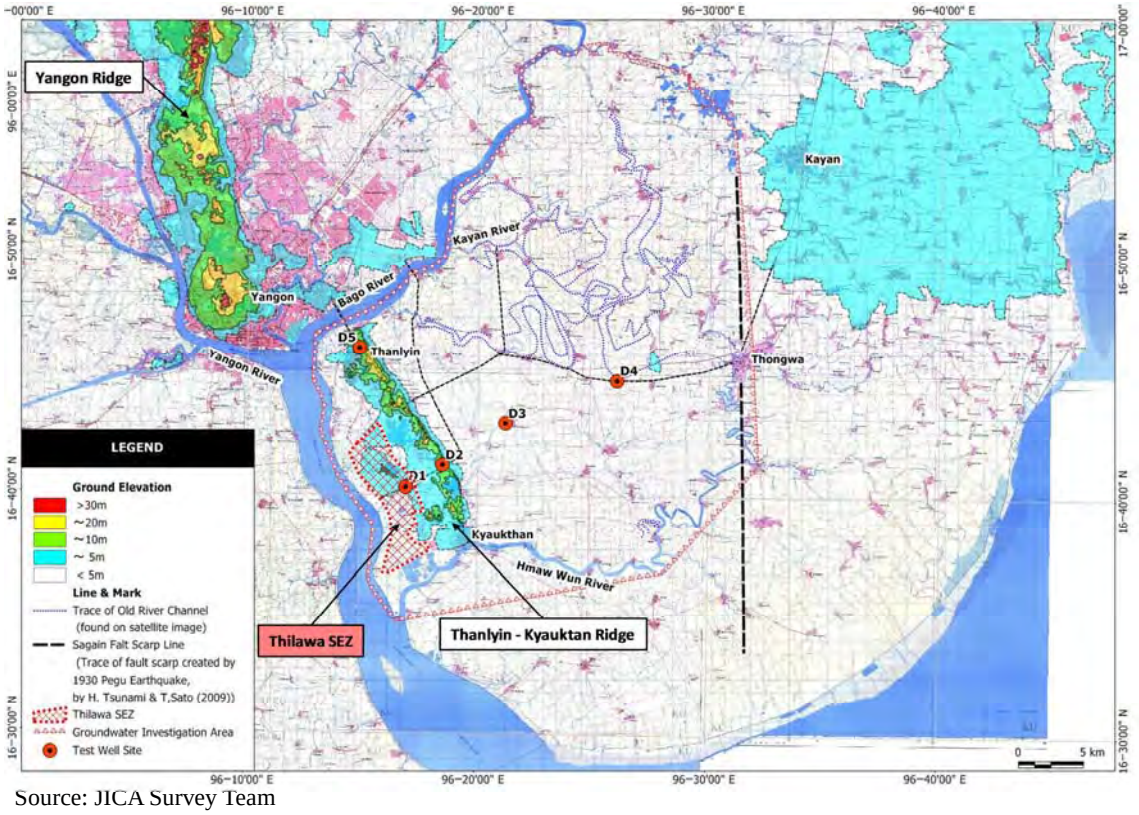
The southern part of Bago Yoma is a low relief hill with a fine valley system whose elevation ranges mostly from 10 to 200 m and partly along the ridge from 400 to 600 m.

The Thanlyin-Kyauktan Ridge is also a low relief hill with 5 to 25 m in elevation stretching in NNW - NNE direction, where shallow valleys develop in the western part. The plain out of the ridge is very low and flat. The elevation is 0.7 to 3.5 m in the eastern plain and around 10 m in Bago City. Therefore the riverbed gradient is very small and the Bago River is still tidal even at Bago City which is located about 60 km upstream of Yangon. All creeks and canals in the investigation area are basically tidal. However the tidal effect is considerably reduced by the sluice gates which were constructed mainly at the exit of the creek by the Irrigation Department, MoAI.



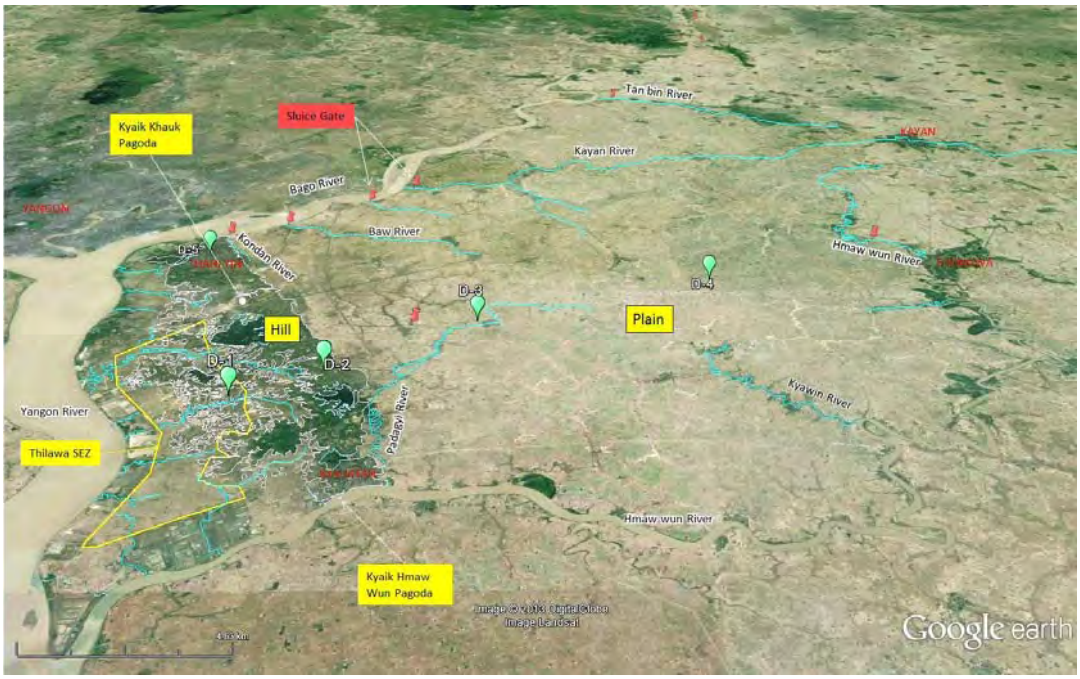
Source：Excerpt from Bender(1983); retouched.

Figure 2-3-1　Topographic Units in the Southern Myanmar and Location of Survey Area



Source: JICA Survey Team

Figure 2-3-2　Topography and Elevation in and near the Groundwater Investigation Area



Source: Google Earth satellite image; retouched.

Figure 2-3-3 Bird's-eye View of Topography of Groundwater Investigation Area

2-3-2 Geology

(1) Regional Geology

Figure 2-3-4 shows the regional geology and Table 2-3-1 shows a stratigraphic table around the survey area.

Pegu Yoma consists mainly of the Pegu Group. The Irrawaddy Formation distributes along its periphery. The Pegu Group comprises weakly- to moderately-consolidated sedimentary rocks of Tertiary Oligocene to Miocene age. They are considered to be marine deposits. The upper part mainly consists of an alternation of sandstone and mudstone; the middle part, of sandstone; and the lower part, of shale. The Irrawaddy Formation is made up of continental deposits comprising weakly-consolidated medium- to coarse-grained sandstone and conglomerate intercalated with weakly- to moderately-consolidated muddy rocks. The lowland out of the ridge is covered with unconsolidated silt, clay and sand of Quaternary age. These sediments were conveyed by river flow, so that their formation is named 'Alluvium' here.

In Pegu Yoma, some anticlines are identified. In the Yangon Ridge and the Thanlyin-Kyauktan Ridge, an anticline is inferred. A famous active lateral fault called the Sagain Fault runs along the linear boundary between Pegu Yoma and the Sittang plain. The Bago Earthquake occurred in 1930 on the fault with an epicenter located to the north of Thongwa in the eastern edge of the investigation area. The linear fault scarp created by the earthquake is traceable even at present.

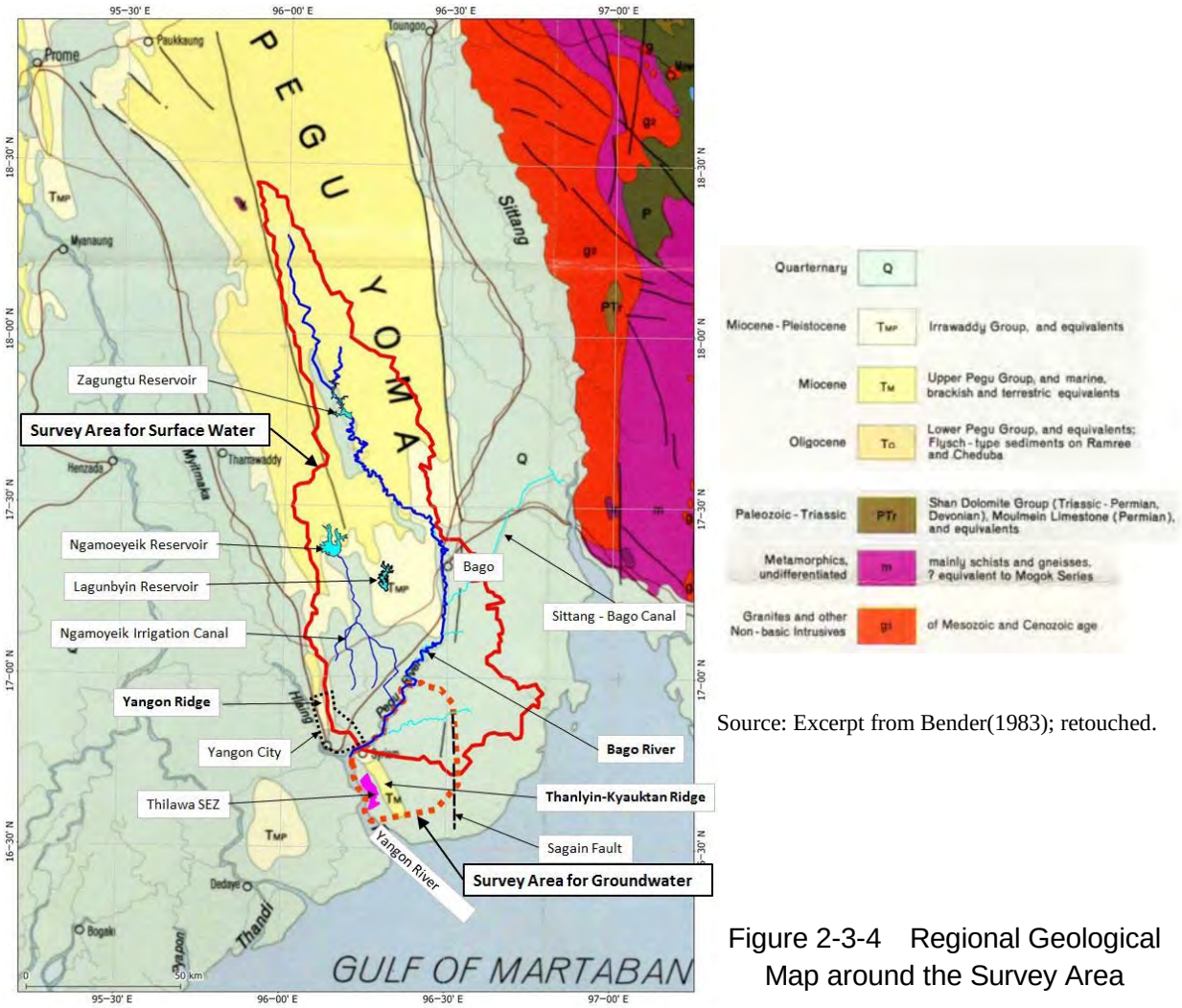
Note: A digital revised version of geological map of Myanmar was made by the Myanmar Geoscience Society in

2011. Though it could not be obtained, as far as seeing the diminished printout, Geology distribution around the investigation area is mostly the same as Bender(1983).

Table 2-3-1 Stratigraphic Sequence in Eastern Irrawaddy Delta, Pegu Yoma and Sittang Basin

Age	Formation		Lithology	Approx. Maximal Thickness (m)
Quaternary	Alluvium		Sand, silt, clay	
Pliocene-Miocene?	Irrawaddy Group		Medium- to coarse-grained sandstone, gravel, conglomerate; thick-bedded, cross-bedded, massive	1,200
Angular unconformity				
Miocene ～Oligocene?	Pegu Group	Upper	Alternation of fine- to medium-grained sandstone and mudstone	1,000
		Middle	Fine- to medium-grained sandstone with little shale	900
		Lower	Sandy shale and shale intercalated with some fine-grained sandstone	850

Source: Bender(1983); partly changed on age and added with Alluvium.



Source: Excerpt from Bender(1983); retouched.

Figure 2-3-4 Regional Geological Map around the Survey Area

(2) Geology of Thanlyin-Kyauktan Ridge

Figure 2-3-5 shows the geological map and Table 2-3-2 shows stratigraphic table of Thanlyin-Kyauktan Ridge. Figure 2-3-5 was compiled based on geological maps by Win Naing et a l. (1991) and Aye Thanda Bo (2001), topographical analysis of a satellite image, and outcrop reconnaissance.

According to existing geological maps including regional ones, geologic units distributed in the area are the Irrawaddy Formation in the north and the Pegu Group in the south. They contact each other on an inferred fault running near Kyaik Kauk Pagoda in Thanlyin. Another fault is inferred along the eastern edge of the hill, because it shows a clear lineament. Considering the Bouguer abnomly map shown in Figure 2-3-6, it is probable for a fault to run along the western edge of the hill.

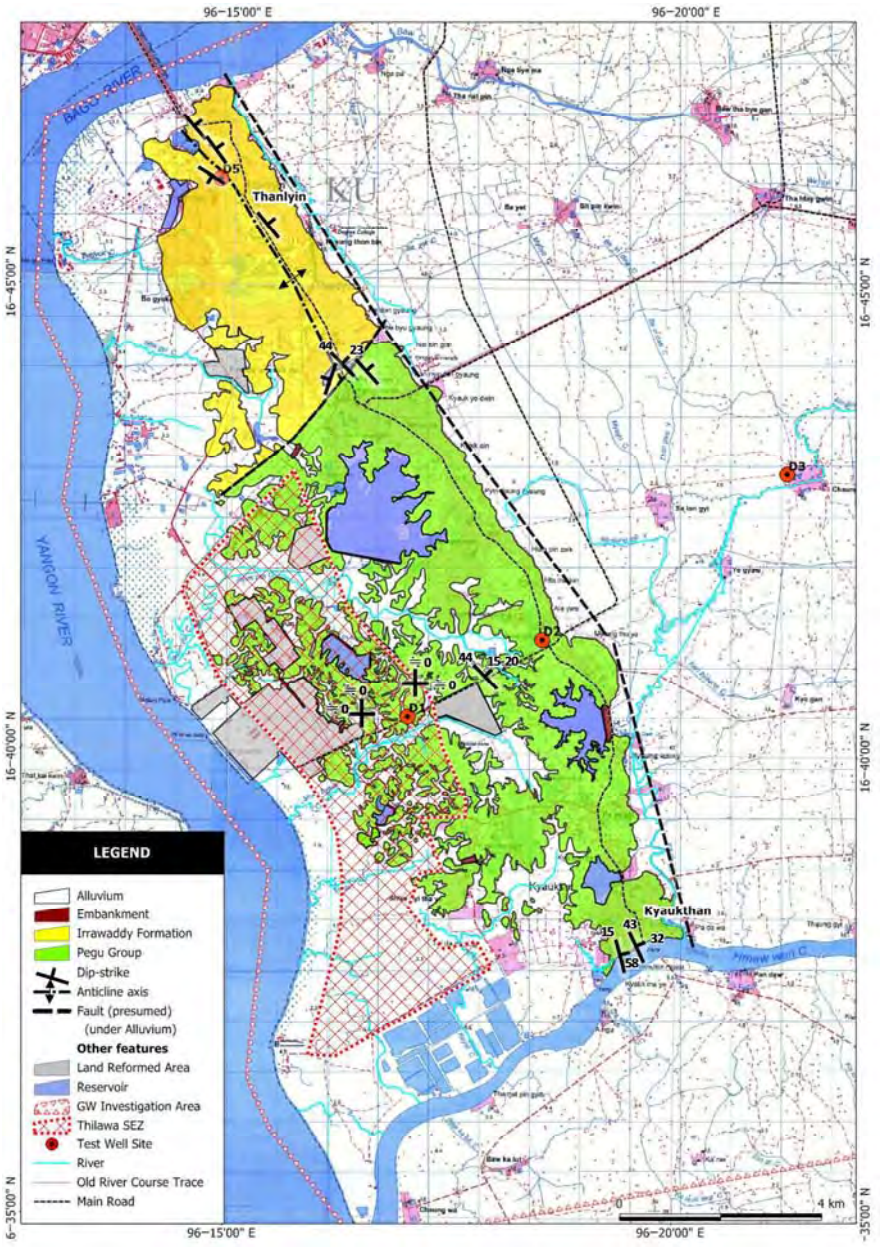
The Irrawaddy Formation consists of semi-consolidated medium- to coarse-grained sandstone with mudstone layers. The Pegu Group comprises an alternation of shale (or mudstone) and fine- to medium-grained sandstone with ferruginous bands. According to the core boring and test well drilling results by the present survey (later described in detail), sandstone of the Irrawaddy Formation distributes down to approximately 100m from the ground and mudstone prevails below this depth. In the southern area where the Pegu Group distributes, the ground is covered mainly with mudstone. However sandstone prevails in the core sample obtained at an eastern edge of the central part of the hill. The ferruginous bands were found in the core above 100m from the ground.

It is generally difficult to grasp the bedding condition in the hill, because outcrops are rarely distributed. However, dip and strike can be measured at some outcrops in a small valley, developed land and wall of dug well. An anticline axis is inferred along the ridge in the Irrawaddy Formation. In the central part of the Pegu-Group-covering area, it is inferred from the drilling result by the present survey that as a whole, layers dip gently to the east and, and near the eastern edge of the hill, they dip more. Along the riverside of the Hmawwun River, there is a continuous outcrop of the Pegu Group. The layers there dip with as much as 30 to 60 degrees to the east..

In the surface of the hill, the lateritic soil develops. Generally a few meters of the surface are reddish brown or brownish in color and contain spherical or sphere-connected ferruginous concretions in the middle and lower portions. In the test well site in Thanlyin where the Irrawaddy formation distributes, lateritic weathering is as remarkable as that the layer is brownish down to 25 m below ground and a thick tabular iron vein 5cm thick was found. In the Pegu-Group-covering area, lateritic weathering reaches about five meters. Such a surface layer of the hill was used as fill material for the embankment in SEZ and the nearby development area. This material is generally not permeable, because its mother rock is mainly mudstone and it contains much silt and clay as well as the concretions.

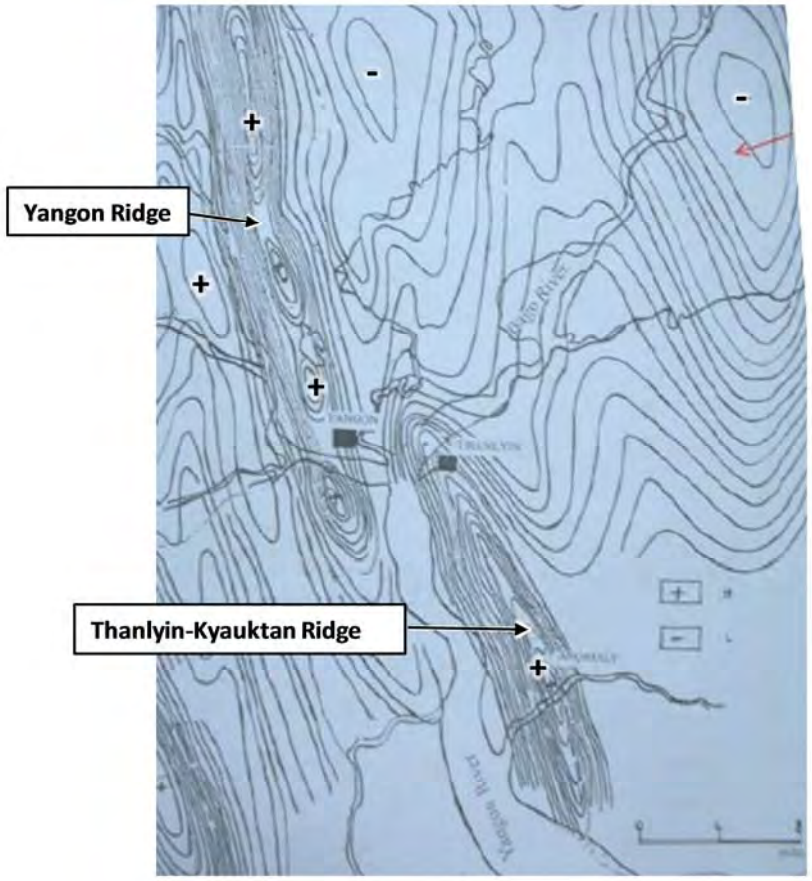
Table 2-3-2 Stratigraphic Table of Thanlyin-Kyauktan Ridge (Win Naing et al., 1991)

Geologic Age	Geologic Units	Symbol	Lithology	Lithology (detail)
Recent	Alluvium	A	Sands and Clayes	Yellowish grey, bluish grey, brownish grey coloured sands and clyas.
Pliocene	Irrawaddy Formation	I	Sand rocks interbedded with Clays and Mudstones	Medium to coarse grained sand rocks interbeded with clays and mudstones.
Oligocene ? to Miocene	Pegu Group	P	Alternationof Shale and Sandstone with ferrugenous bands	Alternation of shales and well consolidated argillaceous, bluish grey to brownish grey coloured, fine to mediumgrained micaceous sandstone with ferrugenous band.



Source: Compiled based on geological maps by Win Naing et al. (1991) and Aye Thanda Bo (2001), topographical analysis of satellite image and outcrop reconnaissance. Inferred faults indicated only for majors.

Figure 2-3-5 Geological Map of Thanlyin-Kyauktan Rigde



Source: Original – MOGE; Excerpt from Thint Lwin Swe (2008), retouched.

Figure 2-3-6 Bouguer Anomaly near Yangon and Thanlyin-Kyauktan Ridges

2-4 Socioeconomic Situation in the Project Area

2-4-1 Area and Population

(1) Area

The survey area is composed of 4 townships: Thanlyin, Kyautan, Thongwa and Kayan. The largest township is Kyautan (84,371.0 Ha), followed by Thongwa (83,547.0 Ha) (Table 2-4-1). The survey area belongs to the Yangon Southern district; the survey area covers 53.0% of the district (266,526.4 Ha of 503,091.5 Ha in total).

The largest land use category in the survey area is agricultural land. According to the SLRD data, the largest percentage of it is in Kyautan with 74.5% (62,882.9 Ha), followed by Kayan with 71.9% (44,063.0 Ha). Even in the lowest percentage township, Thanlyin, 66.4% (24,762.3ha) of all its area is agricultural land. 71.0% (357,336.9 Ha) of the total area is categorized as agricultural land in the Yangon Southern district. After agricultural areas, the second largest is water. 13.6% to 22.7% of the areas among the survey townships were covered by water and 18.1% (91,253.5 Ha) of the Yangon

southern district is a water area.

Industrial area is larger around the Yangon city area townships. The townships where Thilawa SEZ planned site, Thanlyin and Kyautan are larger than other townships, the areas are 2,108.0 Ha (5.7%), 794.4 Ha (0.9%), respectively. Percentage of Building land of Thanlyin is the largest with 10.6% (3,936.0 Ha) of all survey townships. There are two bridges which connected to Yangon city area in Thanlyin, so workers can commute conveniently. It might be thought that there is a function of commute town for workers in Yangon City.

Table 2-4-1 Area and Land Use in 2012/13

Township Name	**Thanlyin**		**Kyautan**		**Thongwa**		**Kayan**		**Yangon Southern District**	
Land Category	Ha	(%)	Ha	(%)	Ha	(%)	Ha	(%)	Ha	(%)
Agricultural Land	24,762.3	66.4	62,882.9	74.5	58,804.5	70.4	44,063.0	71.9	357,336.9	71.0
Forest & Natural Area	51.4	0.1	225.4	0.3	-	-	308.8	0.5	3,999.1	0.8
Road & Railway	803.7	2.2	1,097.5	1.3	1,221.7	1.5	591.2	1.0	5,463.7	1.1
Water Area	5,064.6	13.6	12,087.2	14.3	18,961.6	22.7	10,254.7	16.7	91,253.5	18.1
Industrial Land	2,108.0	5.7	794.4	0.9	20.2	0.02	32.0	0.1	3,275.1	0.7
Building Land	3,936.0	10.6	3,840.9	4.6	3,346.8	4.0	3,360.1	5.5	24,757.1	4.9
Other	565.3	1.5	3,442.7	4.1	1,192.2	1.4	2,707.3	4.4	17,006.1	3.4
Total Area	37,291.3	100.0	84,371.0	100.0	83,547.0	100.0	61,317.1	100.0	503,091.5	100.0

Source: Yangon Southern District, Settlement and Land Record Department

(2) Population

The age-distribution population for each survey townships are shown in Figure 2-4-1. Thanlin shows a large population among the younger generation (less than 15 years old), but the tendency was not shown in other townships. Based on the viewpoint of demographic transition, Thanlyin could be categorized as stage two (meaning high birth rate and low death rate), whereas others could be categorized as stage three (meaning low birth rate and low death rate). Demographic transition will change with modernization, and developing countries are categorized as first stage (meaning high birth rate and high death rate), usually. However, the survey townships were categorized by a higher stage, the same as a developed country. On the other hand, due to the low sanitation standard and lack of medical technology, the population segment over 70 years old was lower than others, relatively. According to that, it might be said that the area is a low birth rate and high death rate area. Primitive agricultural area societies usually have high birth rates for work power, but that tendency was not seen in the area.

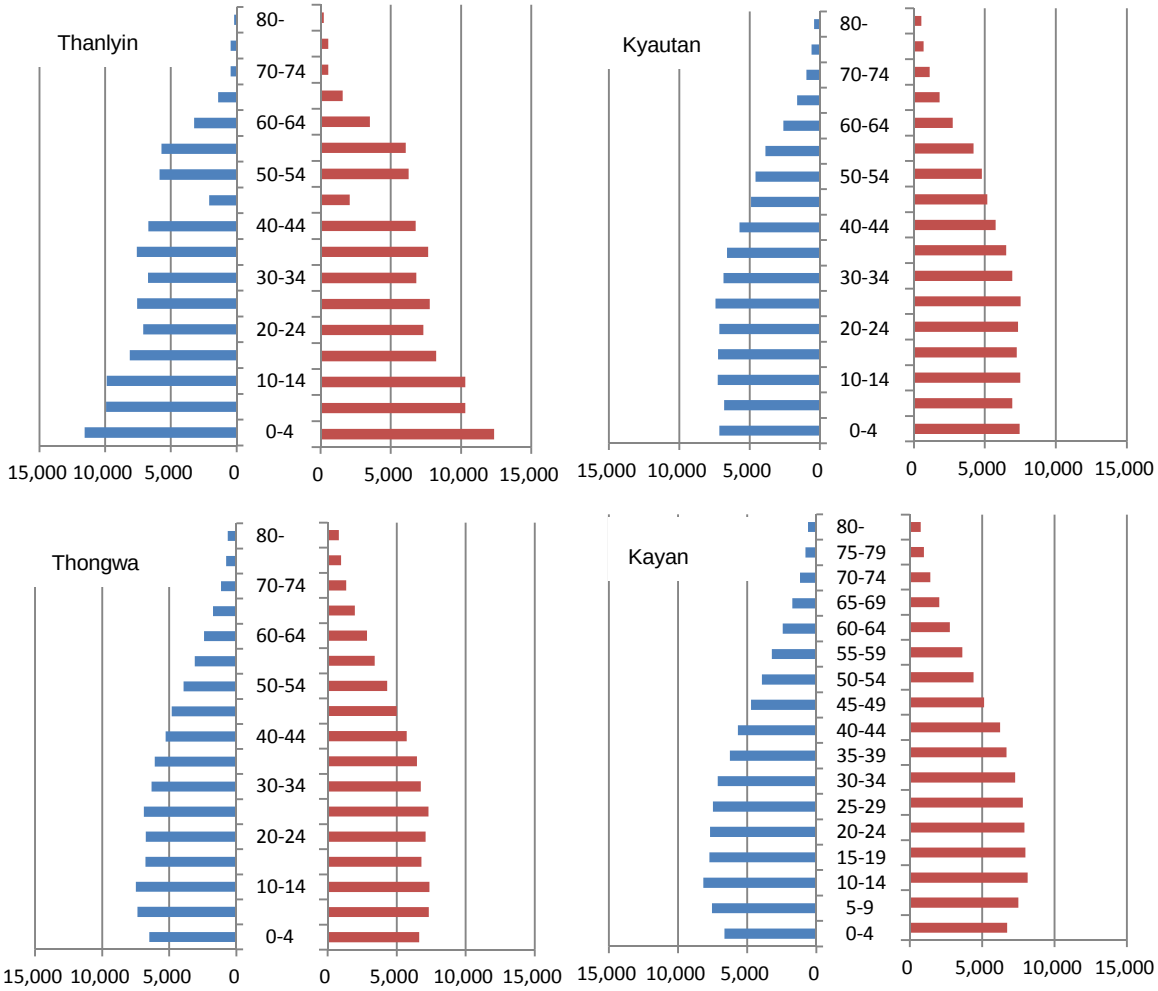


Figure 2-4-1 Population Age Distribution in 2012 by Township

Table 2-4-2 summarized the number of households, the population (under 18 years old, over 18 years old), the number of members per household, and the population density. The largest population is in Thanlyin: 208,435 (under 18 years old: 53,903; over 18 years old: 154,532), followed by Thongwa: 162,884 (under 18 years old: 53,493; over 18 years old: 109,391). The number of members per household and the population density are also the largest in Thanlyin; the numbers are 4.6 and 558.9, respectively. Population density especially is more than double that of the other townships. As mentioned above, Thanlyin is located near Yangon City, and the township is a commuter town; therefore, its population density is significantly higher than that of the others. The other townships' population density is lower than that of the Yangon southern district.

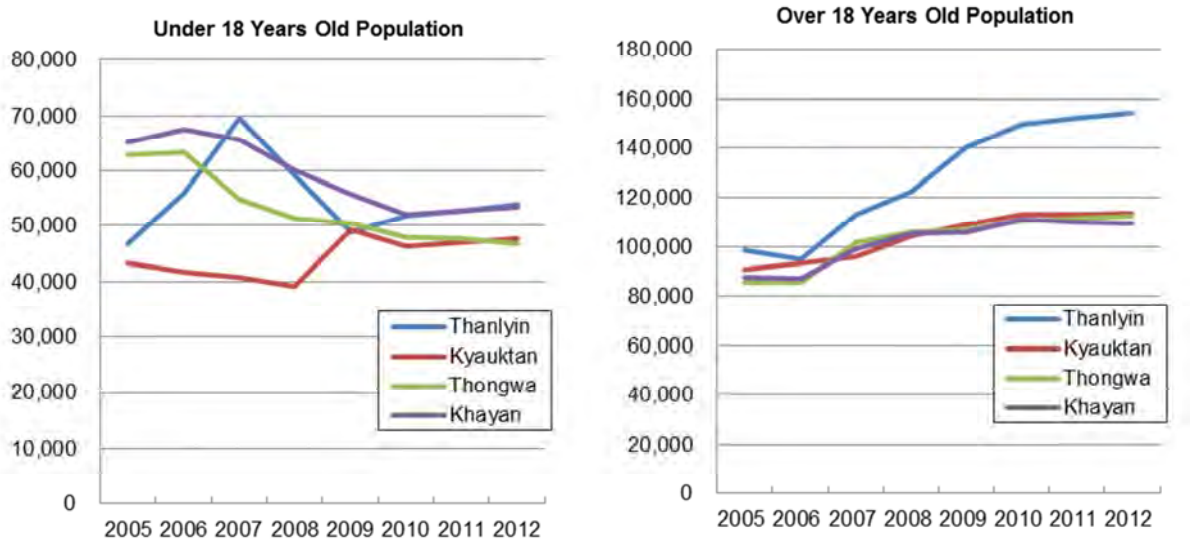
Table 2-4-2 No. of House Hold and Population in 2012/13

Township Name	No. of Ward	No. of Village Tract	No. of House Hold	Population			No. of Member / House Hold	Population Density (Person/km^2)
				Under 18	Over 18	Total		
Thanlyin	17	28	45,143	53,903	154,532	208,435	4.6	558.9
Kyauktan	17	56	39,084	47,740	113,284	161,024	4.1	190.9

Thongwa	12	53	38,611	53,493	109,391	162,884	4.2	195.0
Khayan	12	64	36,478	46,825	112,379	159,204	4.4	259.6
Yangon Southern District	110	375	308,184	410,672	917,692	1,328,364	4.3	264.0

Source: Township General Administration Department

Population dynamics which are divided between those less than 18 years old and those over 18 years old from 2008 to 2012 are shown in Figure 2-4-2. Except for Kyautan, all of the townships' under 18-year old populations declined during this period. Thanlyin's briefly increased in 2007 but then decreased. On the other hand, the populations over 18-years old increased in all townships. The increase rate is especially higher in Thanlyin than in the others. The increase is not related to the under 18-year old population; it might be single person or non-child families migrating from outside. This township could be the commuter town for Yangon City, beginning from 2007.



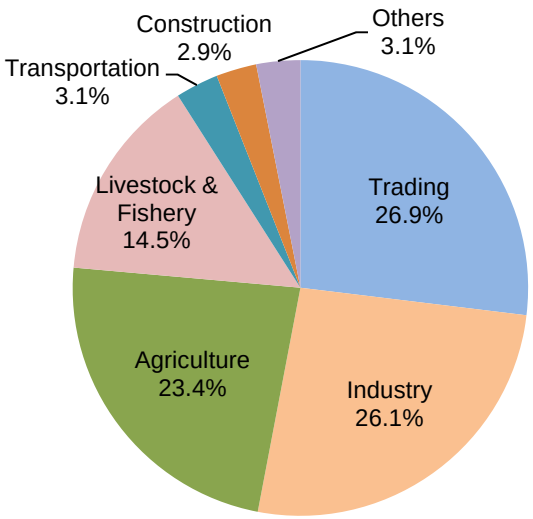
Source: Township General Administration Department

Figure 2-4-2 Population Trend during 2005 to 2012

2-4-2 Industry, Economy, Employment

(1) GDP

The economy in the four townships which cover the survey area is mainly composed of trading, industry, agriculture, and livestock & fishery. The following Figure 2-4-3 shows the GDP in the 2012/13 fiscal year for the four townships. The trading sector shares 26.9% of the total GDP for the four townships, showing the biggest share. The industry sector comes second with 26.1% of the GDP. The agriculture sector comes third with 23.4 %, followed by the livestock & fishery sector with 14.5%. The primary industry sector, agriculture and livestock & fishery, shares 37.9% of the GDP. Considering the results of the field survey and land use condition, the percentage of priority industry might be higher than the figure.



Source: Township General Administration Department

Figure 2-4-3 GDP Share in 4 Townships

(2) Employed Workforce

The following table shows the employment situation in four townships of the survey area. The unemployment rate is the highest with 31.5% in Kyautan, followed by Thanlyin with 17.2%. The percentage of Thongwa (2.4%) and Kayan (5.0%) are lower than the percentage of the Yangon southern district (14.5%). As is well-known, temporary wage work is common in the Southeast Asian countries; the number of employed persons will change seasonally, such as in the farming season; however, the data did not mention the data collecting period. Therefore, it might be considered that the data reflecting the low unemployment rate areas were taken during the busy farming period while others were probably taken during the farming off-season.

Table 2-4-3 No. of Workers and Unemployment Rate in 2012/13

Township Name	No. of Workers	No. of Employed Person	No. of Unemployed Person	Unemployment Rate (%)
Thanlyin	139,440	115,420	24,020	17.2
Kyautan	113,459	77,694	35,765	31.5
Thongwa	110,882	107,533	2,649	2.4
Kayan	91,977	87,379	4,598	5.0
Total	**455,758**	**388,026**	**67,032**	**14.7**
Yangon Southern District	891,829	761,537	129,592	14.5

Source: Yangon Southern District, General Administration Department

The table above shows the number of workers in the different industry sectors. Although the data source is the Yangon southern district general administration office, which provides official data, Thanlyin's number is quite small and Khayan's number is large, considering the over 18 years old population. The percentage of agricultural workers shares 0.8% to 34.9% of the total. According to the area of agricultural land use and the results of the field survey, the percentage is considered small. Landless farmers are involved in farmland activities as temporary workers, so temporary workers should usually be considered as agriculture workers.

In addition, the share of the primary industry sector is 59.8% (Agriculture: 34.9%; Livestock: 0.7%; Temporary workers: 24.2%), in Thanlyin, 73.9% (Agriculture: 20.4%; Livestock: 20.8%; Temporary workers: 32.7%), and in Kyautan, 50.4% (Agriculture: 21.8%; Livestock: 10.0%; Temporary workers: 18.6%) in the Yangon southern district. The percentage of the primary industry sector is relatively large compared to other sectors. However with the percentages of the primary industry sector in Kyautan being 37.0% (Agriculture: 12.0%; Livestock: 12.0%; Temporary workers: 13.0%) and Thongwa being 10.2% (Agriculture: 0.8%; Livestock: 0.7%; Temporary workers: 8.7%), as well as a large number of others (Kyautan: 34.3%; Thongwa: 39.5%), these figures might include a significant number of agricultural workers.

Table 2-4-4 No. of Worker by Township by in 2012

Township Name	Thanlyin		Kyautan		Thongwa		Kayan		Yangon Southern District	
	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Government Employee	6,335	33.5	1,720	1.7	2,579	2.5	1,864	1.3	23,683	3.3
Labor	813	4.3	14,500	13.9	31,472	30.1	9,837	6.6	101,963	14.1
Agriculture	6,596	34.9	12,538	12.0	843	0.8	30,270	20.4	157,272	21.8
Livestock	130	0.7	12,500	12.0	721	0.7	30,872	20.8	72,453	10.0
Trader	216	1.1	13,500	13.0	15,324	14.6	16,386	11.1	100,093	13.8
Industrial Worker	20	0.1	100	0.1	3,255	3.1	3,378	2.3	11,545	1.6
Temporary Worker	4,569	24.2	13,585	13.0	9,150	8.7	48,446	32.7	134,130	18.6
Others	235	1.2	35,765	34.3	41,287	39.5	7,067	4.8	121,829	16.9
Total	18,914	100.0	104,208	100.0	104,631	100.0	148,120	100.0	722,968	100.0

Source: Yangon Southern District, General Administration Department.

(3) Factories and the employees

Table 2-4-5 summarizes the number of factories and workers in the project area. The largest number of factories and workers is in Thanlyin with 47 factories and 6,327 workers (male: 2,536; female: 3,791), followed by Kyautan with 15 factories and 2,503 workers (male: 1,882; female: 621).

There are no factories in Thongwa and Kayan. Thanlyin is located on the left banks of the Bago and Yangon Rivers where there are ports. Therefore, several factories are located around those ports.

Table 2-4-5 No. of Factories and Laborers in 2013

Township Name	No. of Factories	No. of Labor		
		Male	Female	Total
Thanlyin	47	2,536	3,791	6,327
Kyautan	15	1,882	621	2,503
Thongwa	-	-	-	-
Kayan	-	-	-	-
Total	62	4,418	4,412	8,830
Yangon Southern District	72	4,503	4,640	9,143

Source: Yangon Southern District, Department of Labor

2-5 Present Situation of the Water Utilization of the Survey Areas

The subjects to be considered of the present situation of the water utilization of the survey areas are classified into following three items.

- Water for Agriculture
- Water for Industry
- Water for Domestic use

The developing level of the survey areas are still low, the irrigation system and water supplying system are almost not yet implemented. The other side, the survey areas are expected as the one of the future Greater Yangon City Area.

2-5-1 Present Situation of the Agriculture in the Target Area

Agriculture shares the first priority in the structure of the GDP of 27.8% in Myanmar, and even as it is going toward a manufacturing industry nation in the future, agriculture is the main industry at this moment. Since the natural resources of the Earth and the Water are essential components for agriculture, agricultural field is the biggest user for the water resource.

Fundamental information for the grasp of the agricultural field is summarized below. The data for the agricultural fields of the Thanlyin Township, the Kyauktan Township, the Thongwa Township and the Kayan Township which are target areas of the survey have not yet been collected by the formal administrative organ. The survey team collected the related data from the respective townships by conducting interviews. The data are summarized below.

(1) Present situation of the agricultural foundation

Table 2-5-1 Fundamental information for the grasp of the agricultural field

	Thanlyin	Kyauktan	Thongwa	Kayan	Total	Yangon Southern District
Administrative Area (km^2)	372.9	843.7	835.5	613.2	2,665.3	5,030.9
Population less than 18 years	53,903	47,740	53,493	46,825	201,961	410,825
Population greater than 18 years	154,532	113,284	109,391	112,379	489,586	917,692
Total of Population	208,435	161,024	162,884	159,204	691,547	1,328,364
Farming household	6,463	12,290	14,214	12,127	45,094	80,827
Farmer engaged	6,596	12,538	843	30,270	50,247	157,272
Cultivated area (ha)	24,762	62,883	58,805	44,063	190,513	357,337
Sown area (ha)	46,652	96,904	110,396	84,549	338,501	491,350
Monsoon Paddy(ha)	24,802	63,144	59,783	44,825	192,554	321,336
Summer Paddy (ha)	642	21	0	81	744	25,108

Source: Yangon Southern District, Settlement and Land Record Department
Yangon Southern District, General Administration Department
Yangon Southern District, Department of Agriculture

(2) Present Water Demand for Irrigation

To grasp the water demand for irrigation, the water supply for the monsoon paddy isn't needed because of the rainwater falling throughout the season; however, the water supply for the summer paddy needs irrigation water throughout the season. The real water demand volume on the survey area has not been grasped by the Irrigation Department, which has the responsibility for this issue country-wide. Therefore, the following estimation formula will be applied, which is used for the making a preliminary plan for the water resource development study in the Irrigation Department.

1) Pre-condition for the sown area of the summer paddy

The summer paddy can be cultivated by sustainable irrigation water throughout the season. The sown area of summer paddy is appropriated as 744 (ha) in the four townships.

2) Estimation formula for the irrigation water demand volume

The Irrigation Department is applying the following formula to grasp the irrigation water demand.

Water Demand Volume (acre-feet/year) = 6 (acre-feet/acre) × Irrigated area (acre)

For making the water resource development plan for the irrigation project, in the Irrigation Department, the required annual irrigation water volume shall be estimated based on the unit consumptive use water depth of six (6) feet.

The converted formula from acre-feet to ha-m^3 is shown below.

Water Demand Volume (m^3/year) =18,295 (m^3/ha) × Irrigated area (ha)

3) Irrigation Water demand volume

The irrigation water demand volume can be estimated below.

	Thanlyin	Kyauktan	Thongwa	Kayan	Total
Cultivated area (ha)	24,762	62,883	58,805	44,063	190,513
Summer Paddy (ha)	641	21	0	81	744
Water demand volume (10^6 m^3)	11.7	0.4	0	1.5	13.6

The water demand volume is considerably small because of a sowing area for the summer paddy of 744 (ha). This means that future water demand, because of an increasing of the sowing area of the summer paddy, will be increased by an incentive for farmers through the implementation of the irrigation project.

2-5-2 Present Situation of the Industry in the Target Area

Industry consists of the manufacturing and processing and shares 19.8% of the structure of the GDP in Myanmar. It is the third priority following Agriculture and Trade.

Fundamental information is provided for the Industry sector of the Thanlyin Township, the Kyauktan Township, the Thongwa Township and the Kayan Township, the target areas of the survey. The data are summarized below.

Table 2-5-2 Fundamental Information for the Industry Sector

	Thanlyin	Kyauktan	Thongwa	Kayan	Total
Population	208,435	161,024	162,884	159,204	691,547
Number of Factories	47	15	-	-	62
Number of Workers	6,327	2,503	-	-	8,830
Annual used water volume (10^6m^3)	unknown	unknown	unknown	unknown	unknown

The data on the water resources in Japan, summarized by the Ministry of the Land Infrastructure

2-5-3 Present Situation and Future image of the Domestic Use in the Target Area

There are 12,400 shallow wells which are used for living purposes. At first, people store the rainwater during the monsoon season, and then the groundwater will be used to cover any volume shortage of the domestic use water. Even the public water supply system can be used, which peoples will use for limited purposes and in limited volume amounts.

There are some number of the small ponds for the domestic use water and agricultural water in the part of the agricultural activities. There are some families to use the rain water by using the roof and gutters with the roof. These water resources are used for the subsidized water in the rainy season.

The public water supply system is used in the Thanlyin Township and Kyauktan Township under management of the regional development committee, the penetration rate is still few percent. There is a plan to provide the water from the Yangon City Development Committee (YCDC) in these areas in future, but it should prepare the bridge or crossing facilities to cross the Bago River. To realize this plan, it takes much cost. It should pass the barriers to reach the implementation. The salt intrusion in to the river discharge around these area are confirmed, it is difficult to obtain the safety and sustainable water though the Bago River. The population density is still low except a part of the areas, due to the low effect of the cost/benefit ration, regional development is still low.

2-6 Agriculture in the Project Area

2-6-1 Agricultural Land Use

Table 2-6-1 shows agricultural land use in the project area and in the Yangon southern district. More than 96% of all agricultural land is lowland in the project area. Thanlyin has a slightly larger percentage of gardens compared with the others; it is located near Yangon city in a relatively hilly portion. Compared to the Yangon southern district, the project area could be characterized as a dominant are of paddy cultivation.

Table 2-6-1 Agricultural Land Use in the Project Area

Township Name	Thanlyin		Kyautan		Thongwa		Kayan		Yangon Southern District	
Land Category	**Ha**	**(%)**	**Ha**	**(%)**	**Ha**	**(%)**	**Ha**	**(%)**	**Ha**	**(%)**
Lowland	23,917.8	96.6	62,131.0	98.8	58,181.3	98.9	43,615.4	99.0	320,270.1	89.6
Shoal and Riverbank Field	-	-	-	-	-	-	-	-	474.7	0.1
Garden	673.8	2.7	486.0	0.8	384.9	0.7	433.4	1.0	34,760.1	9.7
Nipa Field	170.8	0.7	265.9	0.4	238.4	0.4	14.2	0.03	1,832.0	0.5
Total Agricultural Land	**24,762.3**	**100.0**	**62,882.9**	**100.0**	**58,804.5**	**100.0**	**44,063.0**	**100.0**	**357,336.9**	**100.0**

Source: Yangon Southern District, Settlement and Land Record Department

2-6-2 Planted Area, Production and These Trend in Recent Years

(1) Planted Area and Production

The monsoon paddy takes the largest harvested area with the second being green gram in the project area in 2012/13, and the order is the same as in the Yangon southern district. Though the harvested area of the Yangon southern district is 25,107.9 Ha, the total harvested area of the project area is only 743.3 Ha (Thanlyin: 642.2 Ha; Kyautan: 20.6 Ha; Kayan: 80.5 Ha).Due to the lack of irrigation facilities, the summer paddy area is smaller than that of other townships in the Yangon southern district.

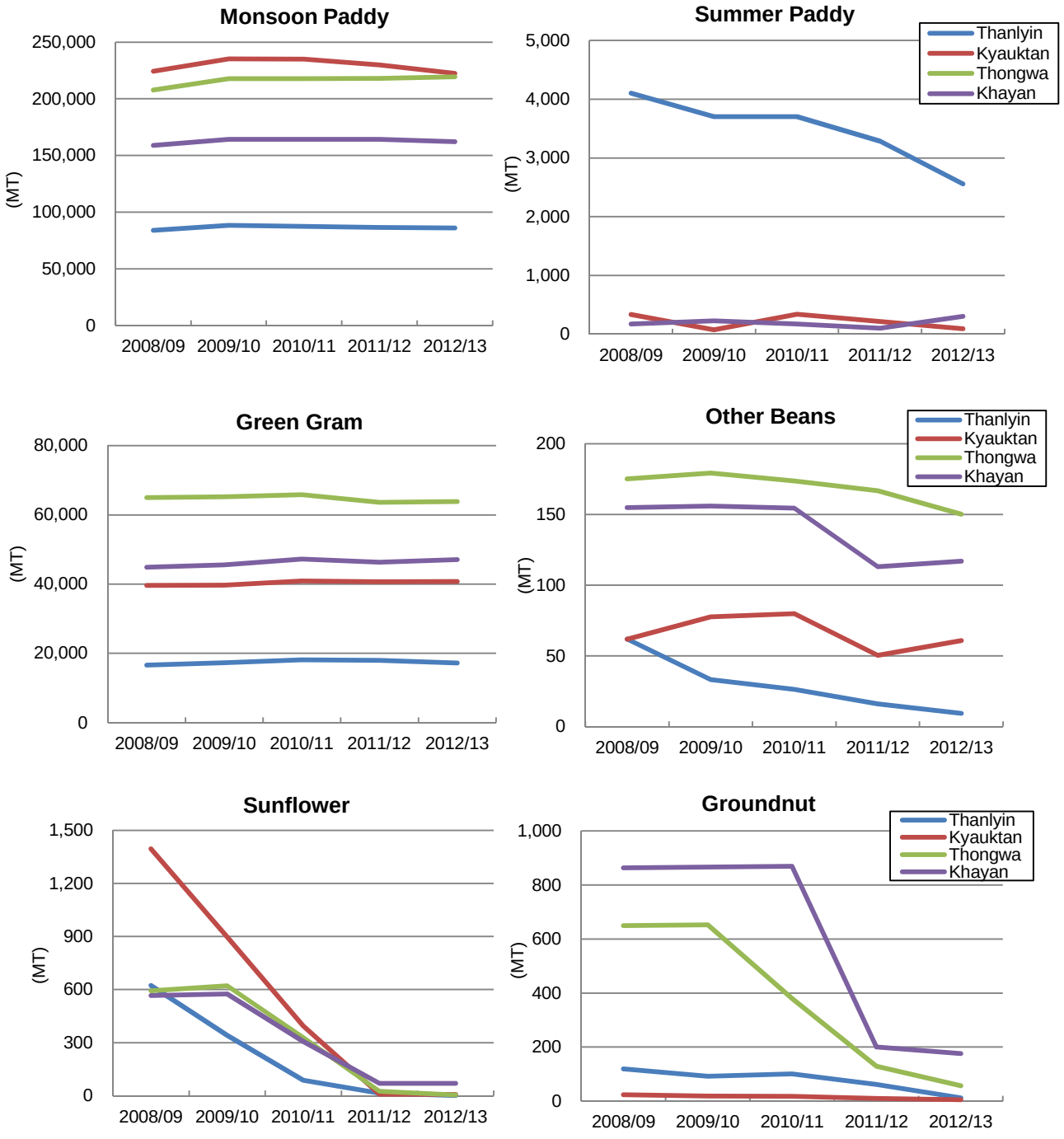
Table 2-6-2 Harvested Area and Production by Crop in 2012/13

Township Name	Thanlyin		Kyauktan		Thongwa		Khayan		Yangon Southern District	
Crop Name	(Ha)	(MT)	(Ha)	(MT)	(Ha)	(MT)	(Ha)	(MT)	(Ha)	(MT)
Monsoon Paddy	24,802.0	86,077.8	63,144.0	222,323.1	59,782.6	219,348.4	44,824.6	162,096.8	321,335.7	1,119,597.8
Summer Paddy	642.2	2,558.7	20.6	91.7	-	-	80.5	301.8	25,107.9	108,224.2
Groundnut	11.7	11.7	3.6	5.1	41.3	57.2	124.6	176.0	191.0	257.6
Sunflower	4.0	1.0	21.0	7.7	19.8	5.0	175.6	69.8	250.5	94.6
Black Gram	-	-	-	-	-	-	6.9	5.7	118.2	96.4
Green Gram	21,180.1	17,183.4	32,949.1	40,769.3	50,418.2	63,838.2	39,187.0	47,087.1	143,925.8	169,075.8
French Bean	-	-	-	-	-	-	-	-	52.6	47.9
Other Beans	11.7	9.4	765.7	60.8	134.0	150.2	149.7	116.9	367.9	338.2

Source: DOA, Yangon Southern District

The trends of crop production by each crop from 2008 to 2013 are shown in Figure 2-6-1. During this time, the production of the monsoon paddy and green gram were approximately constant in all townships, but the summer paddy production decreased in Thanlyin. The sunflower production also decreased, becoming quite small in 2011/12. Production of groundnut, which was widely produced in Thongwa and Kayan, decreased in 2010/11 to approximately a quarter of what was produced in 2009/10 and 2012/13.

According to the result of an interview with DOA officers, farmers could not select planting crops freely even if the farmer had a right of land to use before 2010. It is considered that low profit crops such as summer paddy, sunflower and groundnut were not very attractive for farmers; a profitable crop, green gram, was produced stably though. However, the production of green gram did not increase from 2010; in other words, low profit crop production was not changed to profitable crops. It is considered that the place where sunflower and groundnut were planted has lower water potential; therefore, the place was not suitable for green gram cultivation. It also might be considered that even if the farmer has land, temporary work is more attractive than unstable and low profit crop production. Therefore, the number of temporary workers is high in the project area.



Source: Yangon Southern District, Department of Agriculture

Figure 2-6-1 Trend of Crop Production from 2008 to 2013

(2) Planted Area and Production under Irrigation

Irrigated areas in the four survey townships and the Yangon southern district in 2011/12 are shown in Table 2-6-3. The percentages of irrigated areas in Thanlyin, Kyautan, Thongwa and Khayan were 15.6% (3,851.0Ha in 24,762.3Ha); 3.2% (2,023.4Ha in 62,882.9Ha); 23.8% (14,016.3Ha in 58,804.5Ha); and 34.1% (48,912.0Ha in 357,336.9Ha), respectively. The percentages were higher than the percentage in the Yangon southern district (13.7%), except Kyautan.

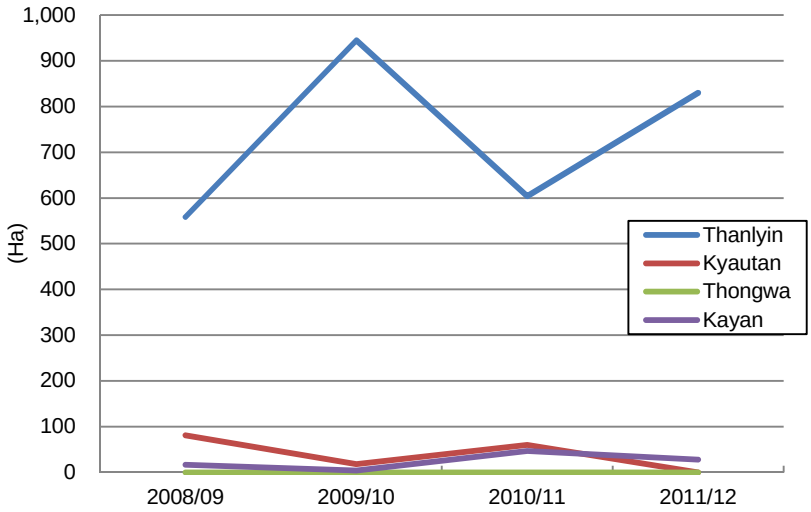
The summer paddy area in the four townships was 857.5Ha; it takes up no more than 6% of the Yangon southern district (14,310.9Ha). The variation of the summer paddy harvested area from 2008/09 to 2012/13 is shown in Figure 2-6-2. It was changed about 300Ha in Thanlyin from 2008 to 2012, but it did not clearly show large changes among other townships. Therefore, the small number of summer paddy planted areas was not related with the policy change after 2010, which allowed the farmers to decide on the crops they wanted to grow in their own fields. The summer paddy which required much irrigation water was not a major crop grown in the project area.

The total irrigated area in the four townships is relatively larger in the Yangon southern district; however the amount of distributable water is small. Hence, most of the irrigable area planted pulses which required small amount of water rather than summer paddy. Actually, triple crop farming is possible in a year in the area. It is considered that if abundant irrigation water is provided by an irrigation facility in the project area, it makes it possible to increase and stabilize crop production.

Table 2-6-3 Irrigated Areas in 2011/12

Township Name	**Thanlyin**		**Kyautan**		**Thongwa**		**Kayan**		**Yangon Southern District**	
Crop Name	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)
Summer Paddy	830.0	21.6	-	-	-	-	27.5	0.2	14,310.9	29.3
Green Gram	2,967.6	77.1	2,023.4	100.0	13,856.4	98.9	14,793.7	98.3	33,767.4	69.0
Sunflower	-	-	-	-	-	-	-	-	327.8	0.7
Groundnut	53.4	1.4	-	-	89.0	0.6	141.6	0.9	284.1	0.6
Cow pea	-	-	-	-	-	-	62.3	0.4	69.6	0.1
Black gram	-	-	-	-	-	-	4.0	0.03	50.2	0.1
Vegetable	-	-	-	-	70.8	0.5	13.4	0.1	102.0	0.2
Total	3,851.0	100.0	2,023.4	100.0	14,016.3	100.0	15,042.6	100.0	48,912.0	100.0

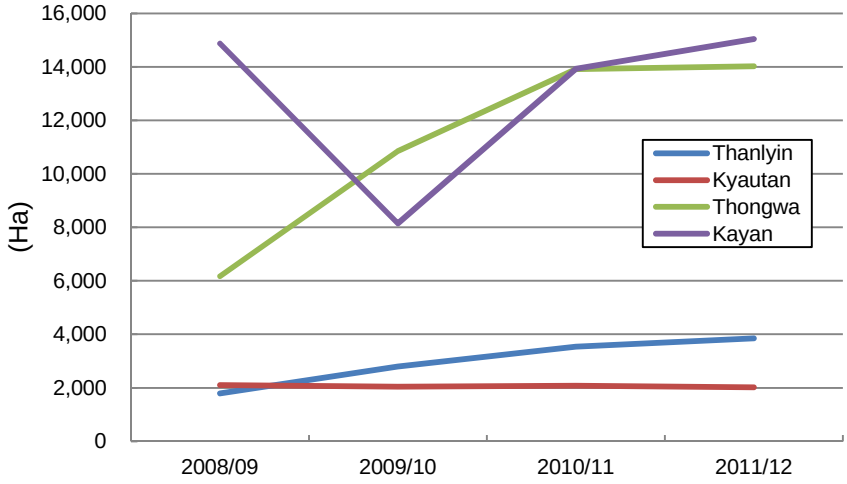
Source: DOA, Yangon Southern District, Department of Agriculture



Source: Yangon Southern District, Department of Agriculture

Figure 2-6-2 Trend of Summer Paddy Harvested Area from 2008 to 2012

The irrigated area was increasing in Thanlyin, Thongwa and Kayan from 2008 to 2012 (Figure 2-6-3). The increase might have been caused by the 30-mile greening project which the irrigation department (ID) pushes forward continuously. That project is not completed yet due to the increase of the canal length or its connection to the existing canal; the water in the canal can be used for the winter crop supplementary.



Source: Yangon Southern District, Department of Agriculture

Figure 2-6-3 Trend of Total Irrigated Area from 2008 to 2013

2-6-3 Agricultural Tools and Machineries

The number of owned agricultural materials and machines by townships are shown in Table 2-6-4. It is an error that the number of hand tractor in Thanlyin is 0, obviously. In whole, the numbers of traditional tools, harrows (40,471), ploughs (53,331) and bull carts (24,240) are larger than those of tractors (1,316) and hand tractors (4,722). This suggests that the way of agricultural operation is still traditional in the area; therefore, agricultural mechanization is expected which might contribute to agricultural labor-saving and labor provision for the industrial sector in Yangon City.

Table 2-6-4 No. of Agricultural Materials in 2012/13

	Thanlyin	Kyauktan	Thongwa	Khayan	Total
Traditional Harrow	6,941	10,008	12,498	11,024	40,471
Traditional Plough	8,150	12,785	18,619	13,777	53,331
Bull Cart	4,513	5,551	7,151	7,025	24,240
Tractor	169	199	567	381	1,316
Water Pump	332	68	63	848	1,311
Hand Tractor	0	1,624	1,934	1,164	4,722
Planting Machine	0	0	10	0	10
Harvester	3	3	3	0	9
Thresher	50	44	35	275	404

Source: Yangon Southern District, General Administration Office

2-7 Water Right and Organization of the Water Utilization

2-7-1 Water Right

There is no Law of the Water Right in Myanmar therefore, there is no definition of the Water Right not only for the surface water resource but also the groundwater. Since there is no Law of the water resource development, the decision making and responsibility of the project plan and implementation of the project belong to the ministry individually. The procedure for giving the permission regarding the water utilization facilities, which are the bridge, dredging, river improvement, embankment of the dike and construction of the weir, are not defined by the Law. The construction of those facilities are implemented by the regional government with the budget given by the Union Government, the implementation agencies asking the cabinet for the budget allocation of the each implementation plan individually. Substantially, the Implementation Ministry has responsibility for the projects, the water right also belonging to the Ministry individually.

The groundwater development consist of the shallow wells for personal use, public water supply system and irrigation water resource development in the Central Dry Zone. Even these development

plan is not controlled by the any kinds of the law. The developer has to entry the basic data on the ledger at the township office without regard to the capacity of the developed groundwater resource. It has no water right administratively.

2-7-2 Water Users Association

There is no institution for the collection of the water utilization fee due to the fact that the Water Users Association has not been organized under the management by the ministry of agriculture and irrigation which is largest organization for the water resource in Myanmar. There is the rationale on the present situation of the maintenance systems for the main canals and the secondary canals by the Irrigation Department.

But the maintenance fee for the tertiary canals and the terminal level canals are not collected from the beneficiaries anymore; therefore, the maintenance fee is lacking from the annual budget and all facilities have become superannuated.

In a similar way, the City Development Committee (CDC) has a responsibility to manage the domestic water supply system instead of the Water Users Association. It mean that the domestic water supply system is not managed by the self-support accounting.

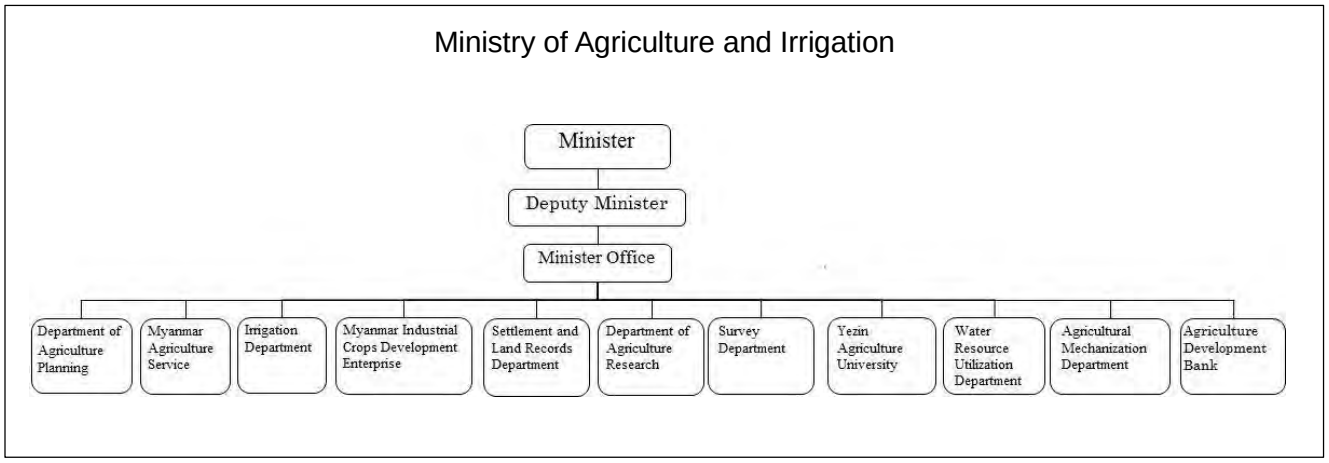
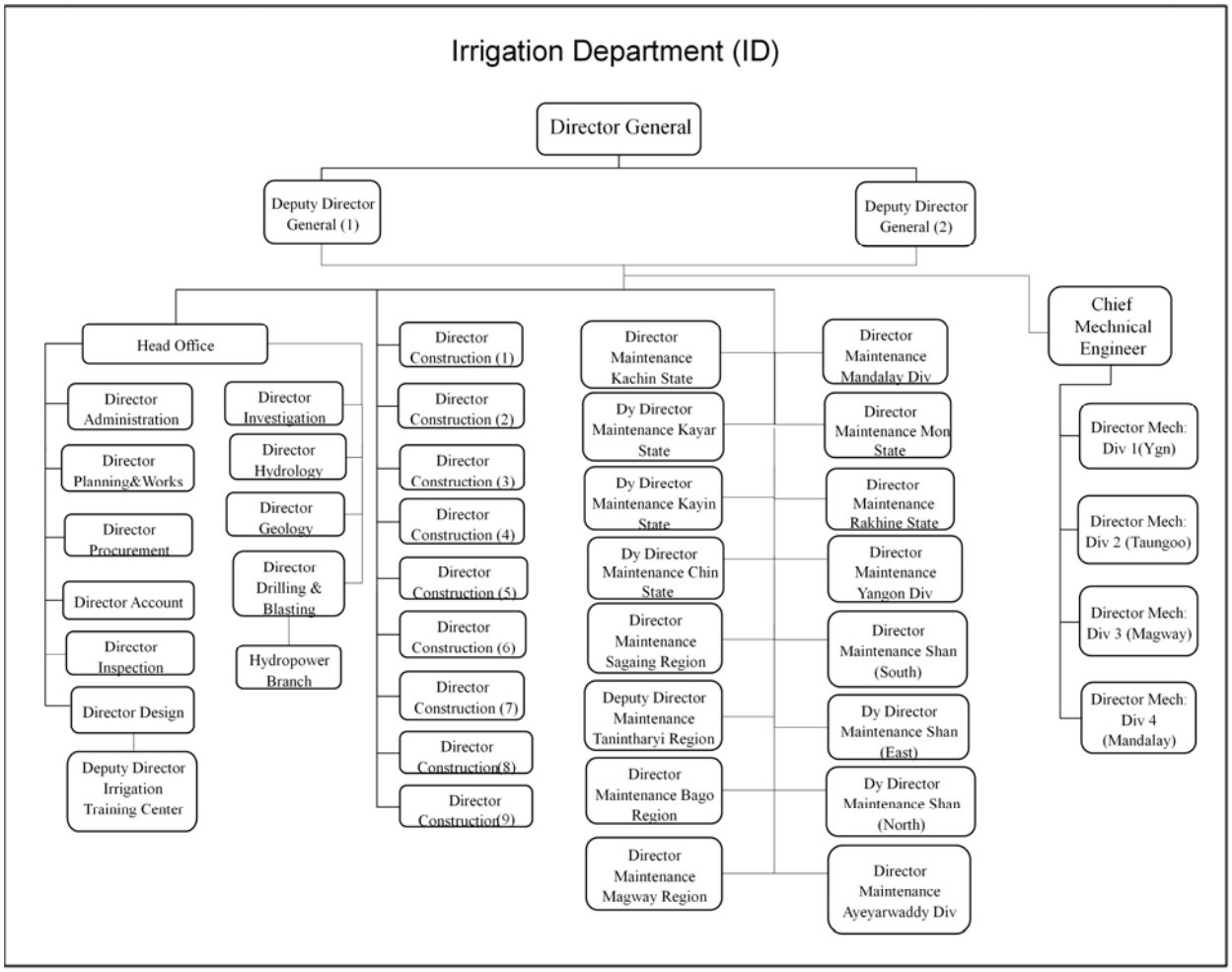


Figure 2-7-1 Organization chart of the related ministries -1



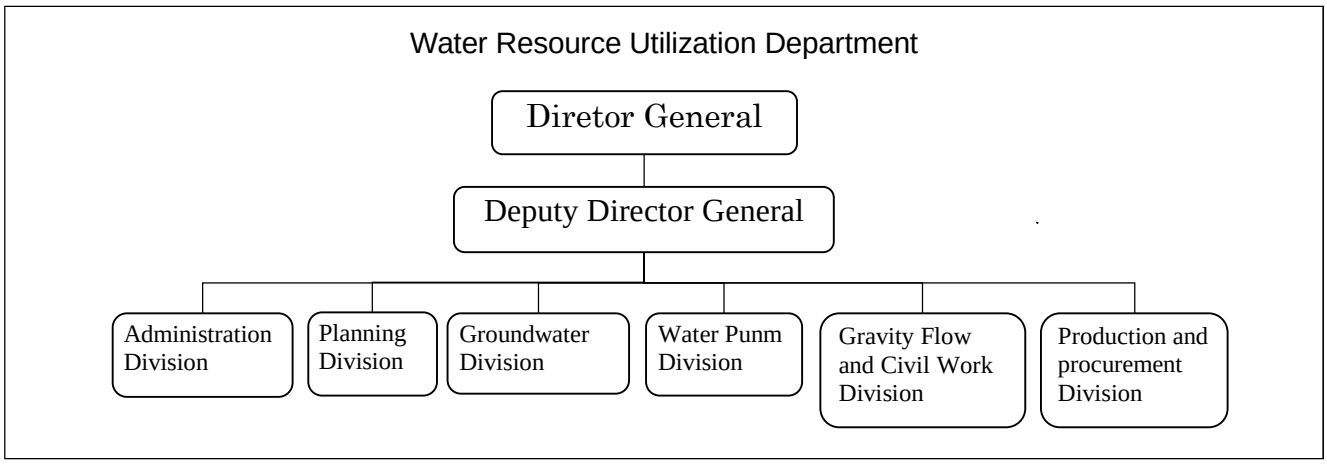
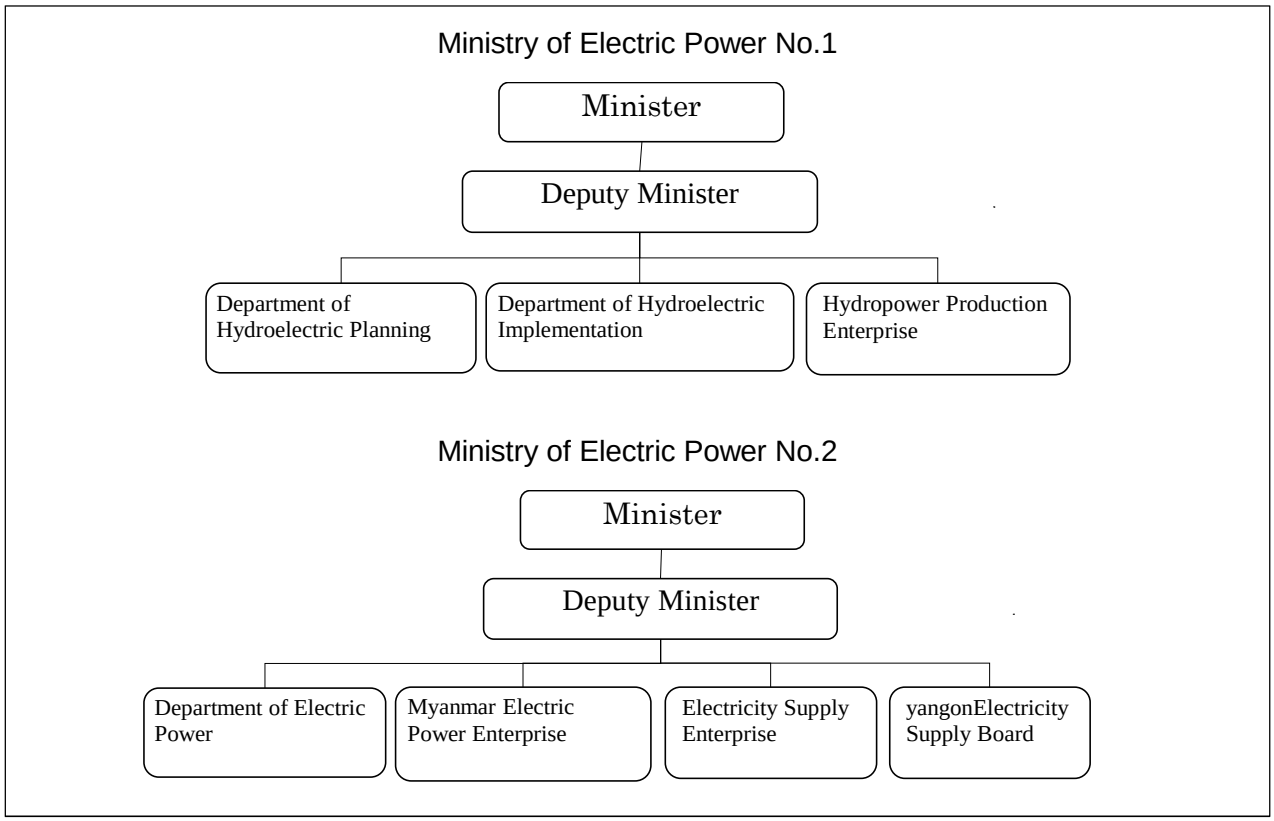


Figure 2-7-2 Organization chart of the related ministries -2



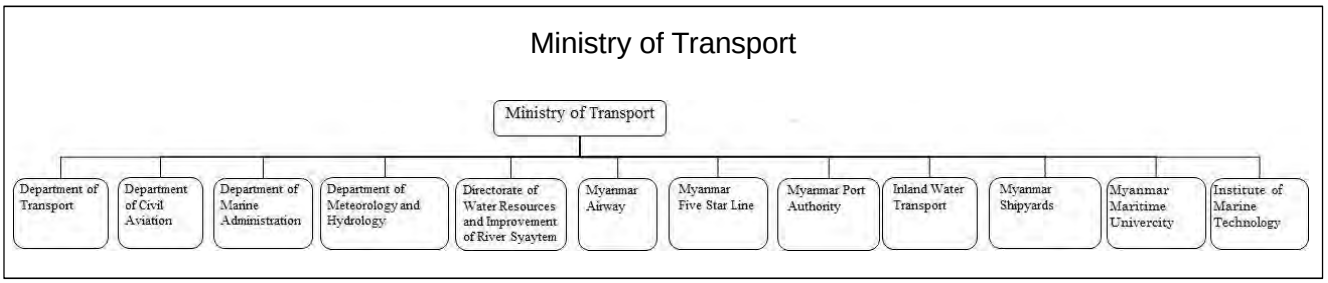


Figure 2-7-3 Organization chart of the related ministries -3

CHAPTER 3

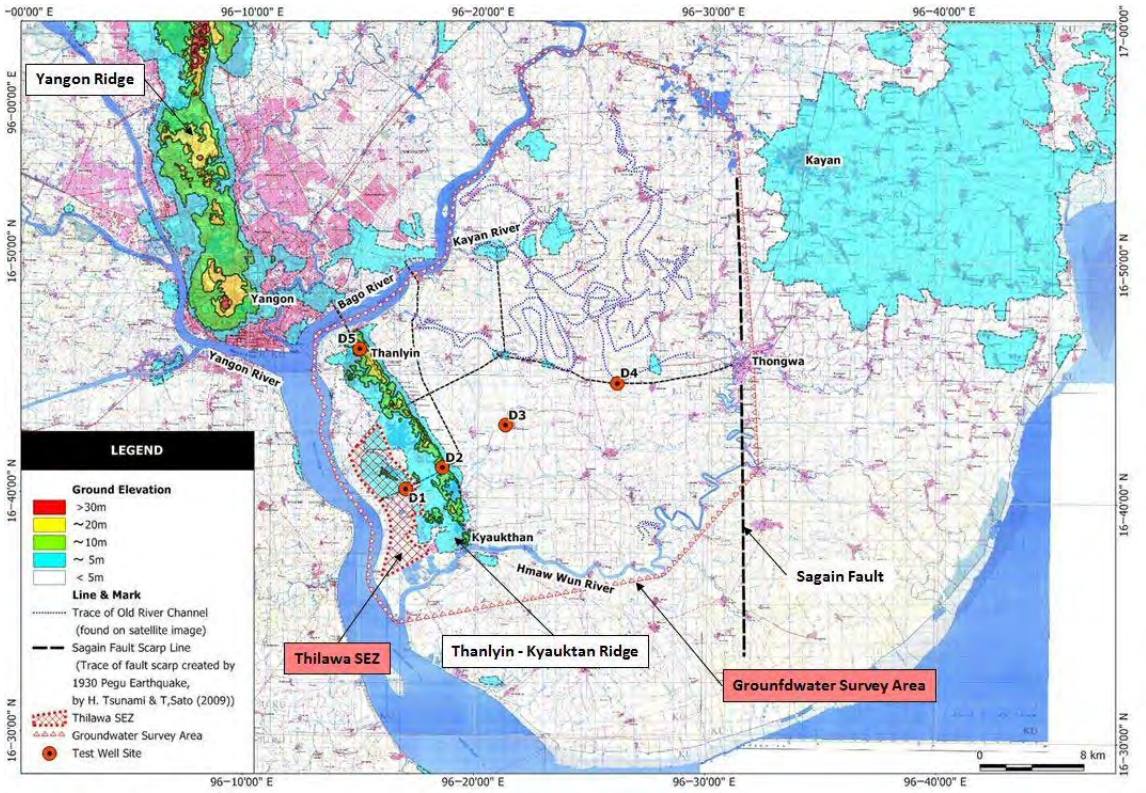
SURVEY AND ANALYSIS OF GROUNDWATER

CHAPTER 3 Survey and Analysis of Groundwater

3-1. Outline

3-1-1 Purpose

A survey and analysis of groundwater was carried out to estimate the groundwater development potential in the area shown in Figure 3-1-1-1 for the Thilawa SEZ and the adjoining area.



Source: JICA Survey Team

Figure 3-1-1-1 Groundwater Survey Area and Topography

3-1-2 Definition of Groundwater Development Potential

Here the "groundwater development potential" means a groundwater amount which can be sustainably supplied for the Thilawa SEZ and the adjacent area without socially unallowable environmental impact. Generally, to estimate the groundwater development potential, first the following four items are assessed, and then, comprehensively considering the results, the amount is fixed:

(1) Water Budget

A development amount must be lower than the groundwater recharge in a target area. If there is existing groundwater use, the amount of the present usage must be withheld from the amount. In addition, it must be considered that it is impossible to take all excess water in a water budget, because

some parts of groundwater would flow out of the area. Therefore, a part of the groundwater recharge could be developed.

(2) Water Quality

The water quality of the developed water must fit the purpose of usage, or the treatment cost of the water to be used must be economical enough to be acceptable.

(3) Hydraulic Ability

The hydraulic ability of the aquifer must be high so as to allow collecting water into intake facilities effectively and economically.

(4) Environmental Impact

The environmental impact of the water development must be as small as the negative impact to make it negligible, or the negative impact must be reduced with a mitigation measure so as to be acceptable.

Ordinarily, small groundwater development is planned only with well capacity and water quality. But the well capacity shows only the hydraulic ability of the aquifer. For a larger scale development, the water budget and environmental impact must be considered as well. For the development in an area where groundwater is already being used, its environmental impact on the existing usage often limits the potential.

3-1-3 Topography

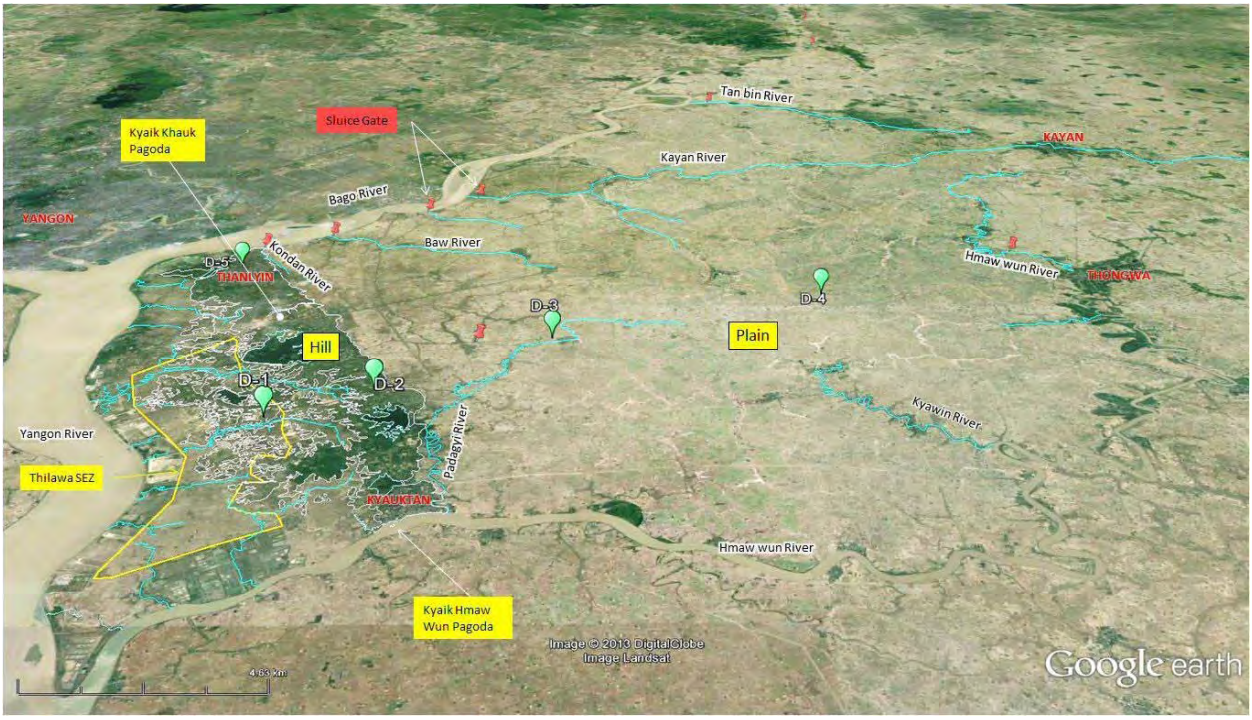
As shown in Figure 3-1-3-1, the target area consists of a low-relief hill and a flat plain surrounded by the Bago, Yangon and Hmaw Wun Rivers, and Tan Bin Creek. The total area is about 930 km^2.

The hill occupies the western side of the area with the towns of Thanlyin and Khauktan on it. The ground elevation ranges from about 5 m to 25 m. The Thilawa SEZ is located on the western flank. The hill is sometimes called the “Thanlyin-Kyauktan Ridge”

The plain covers most of the area extending to the east. The ground elevation ranges mainly from 1m to 4m. There are many creeks and canals connected to each other. Because sluice gates are installed at the exit of the main creeks along the Bago River, and a main water divide of the plain runs along the road which connects Thanlyin and Thongwa, the northern part of the plain is protected against saline water intrusion into creeks in the dry season, though it is not perfect. In the southern part, the creeks remain tidal and salty water is moving through them.

In the northern part of the survey area, the old river channels of the Bago River are easily traceable on the satellite image as shown in Figure 3-1-1-1.

Along the eastern side of the survey area, the Sagain Fault, a famous active fault, runs.



Source: Google Earth satellite image; retouched.

Figure 3-1-3-1 Bird's-eye View of Groundwater Survey Area

3-1-4 Geology

Figure 3-1-4-2 shows the geological map and Table 3-1-4-1 shows the stratigraphic table of the Thanlyin-Kyauktan Ridge. The map was compiled based on geological maps by Win Naing et al. (1991) and Aye Thanda Bo (2001), topographical analysis of a satellite image, and outcrop reconnaissance.

According to existing geological maps including regional ones, geologic units distributed in the area are the Irrawaddy Formation in the north and the Pegu Group in the south. They contact each other on an inferred fault running near Kyaik Kauk Pagoda in Thanlyin. Another fault is inferred along the eastern edge of the hill, because it shows a clear lineament. Considering the Bouguer anomaly map shown in Figure 3-1-4-1, it is probable for a fault to run along the western edge of the hill.

The Irrawaddy Formation consists of semi-consolidated medium- to coarse-grained sandstone with mudstone layers. The Pegu Group comprises an alternation of shale (or mudstone) and fine- to medium-grained sandstone with ferruginous bands. According to the core boring and test well drilling results by the present survey (later described in detail), sandstone of the Irrawaddy Formation distributes down to approximately 100 m from the ground and mudstone prevails below this depth. In the southern area where the Pegu Group distributes, the ground is covered mainly with mudstone. However sandstone prevails in the core sample obtained at an eastern edge of the central part of the hill. The ferruginous bands were found in the core above 100 m from the ground.

It is generally difficult to grasp the bedding condition in the hill, because outcrops are rarely distributed. However, dip and strike can be measured at some outcrops in a small valley, developed land and wall of

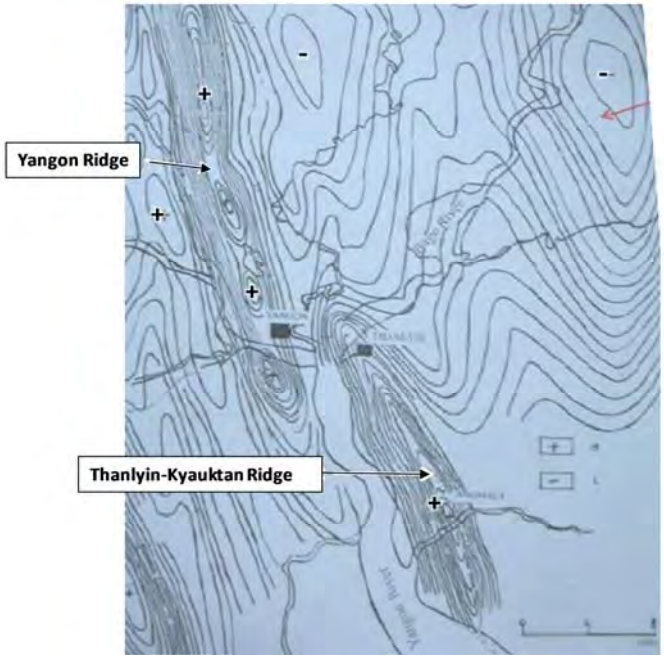
dug well. An anticline axis is inferred along the ridge in the Irrawaddy Formation. In the central part of the Pegu-Group-covering area, it is inferred from the drilling result by the present survey that as a whole, layers dip gently to the east and, and near the eastern edge of the hill, they dip more. Along the riverside of the Hmaw Wun River, there is a continuous outcrop of the Pegu Group. The layers there dip with as much as 30 to 60 degrees to the east.

In the surface of the hill, the lateritic soil develops. Generally a few meters of the surface are reddish brown or brownish in color and contain spherical or sphere-connected ferruginous concretions in the middle and lower portions. In the test well site in Thanlyin where the Irrawaddy formation distributes, lateritic weathering is as remarkable as that the layer is brownish down to 25 m below ground and a thick tabular iron vein 5 cm thick was found. In the Pegu-Group-covering area, lateritic weathering reaches about five meters. Such a surface layer of the hill was used as fill material for the embankment in SEZ and the nearby development area. This material is generally not permeable, because its mother rock is mainly mudstone and it contains much silt and clay as well as the concretions.

The plain is underlain by unconsolidated Quaternary alluvial deposits. The thickness is 50m ~ 70m. It consists mainly of fine alternation of very fine sand, silt and clay (clayey deposits), and a basal sand layer with granules lies on the bottom. Less consolidated Tertiary deposits underlie the layer unconformably.

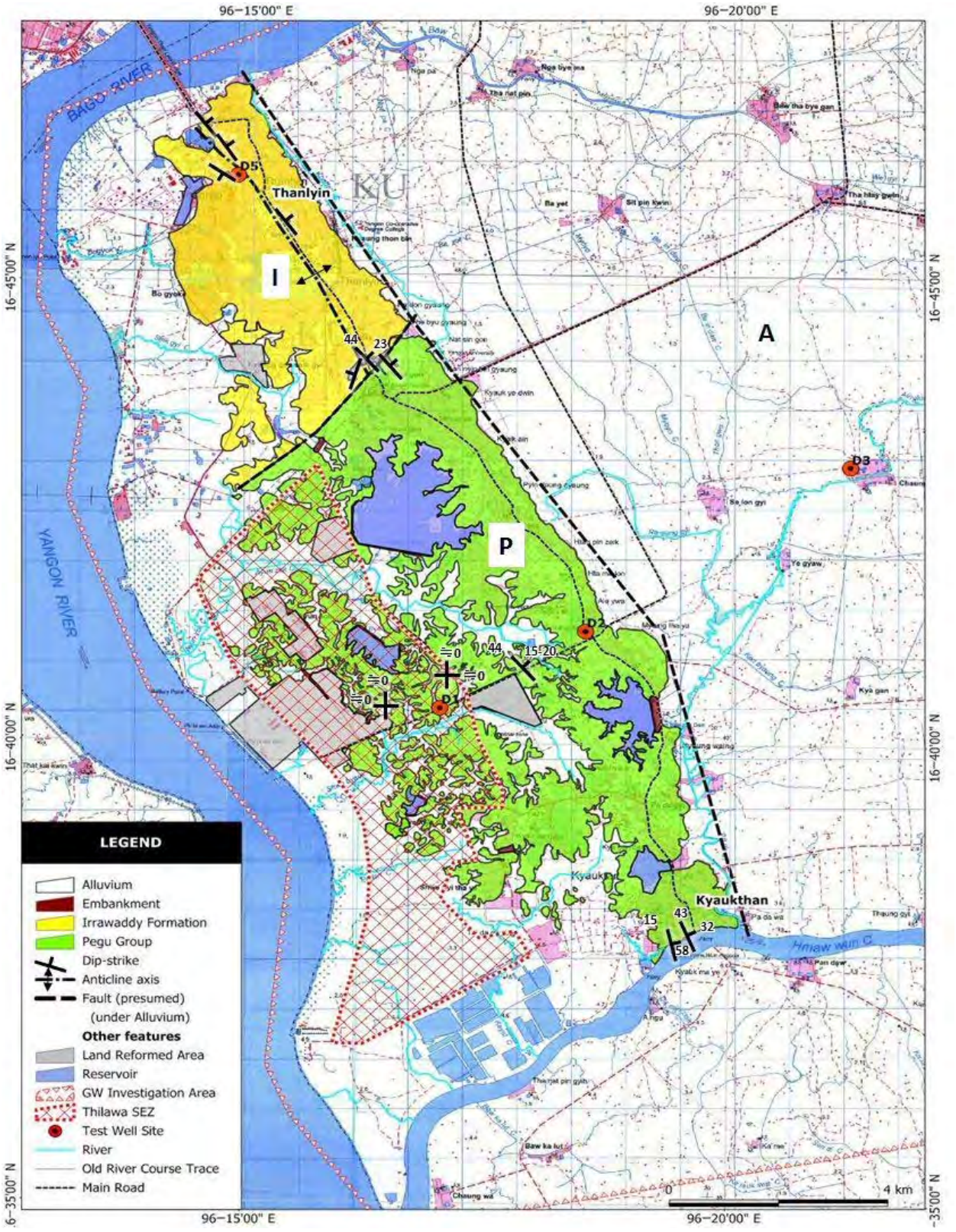
Table 3-1-4-1 Stratigraphic Table of Thanlyin-Kyauktan Ridge (Win Naing et al., 1991)

Geologic Age	Geologic Units	Symbol	Lithology	Lithology (detail)
Recent	Alluvium	A	Sands and Clays	Yellowish grey, bluish grey, brownish grey coloured sands and clyas.
Pliocene	Irrawaddy Formation	I	Sand rocks interbedded with Clays and Mudstones	Medium to coarse grained sand rocks interbeded with clays and mudstones.
Oligocene ? to Miocene	Pegu Group	P	Alternationof Shale and Sandstone with ferrugenous bands	Alternation of shales and well consolidated argillaceous, bluish grey to brownish grey coloured, fine to mediumgrained micaceous sandstone with ferrugenous band.



Source: Original – MOGE; Excerpt from Thint Lwin Swe (2008), retouched.

Figure 3-1-4-1 Bouguer Anormaly near Yangon and Thanlyin-Kyauktan Ridges



Source: Compiled based on geological maps by Win Naing et al. (1991) and Aye Thanda Bo (2001), topographical analysis of satellite image and outcrop reconnaissance. Inferred faults indicated only for majors.

Figure 3-1-4-2 Geological Map of Thanlyin-Kyauktan Ridge

3-2. Groundwater Survey

3-2-1 Outline

To estimate the groundwater development potential of a region, we must survey the target items shown in Table 3-2-1-1. The following methods are applied for the present survey:

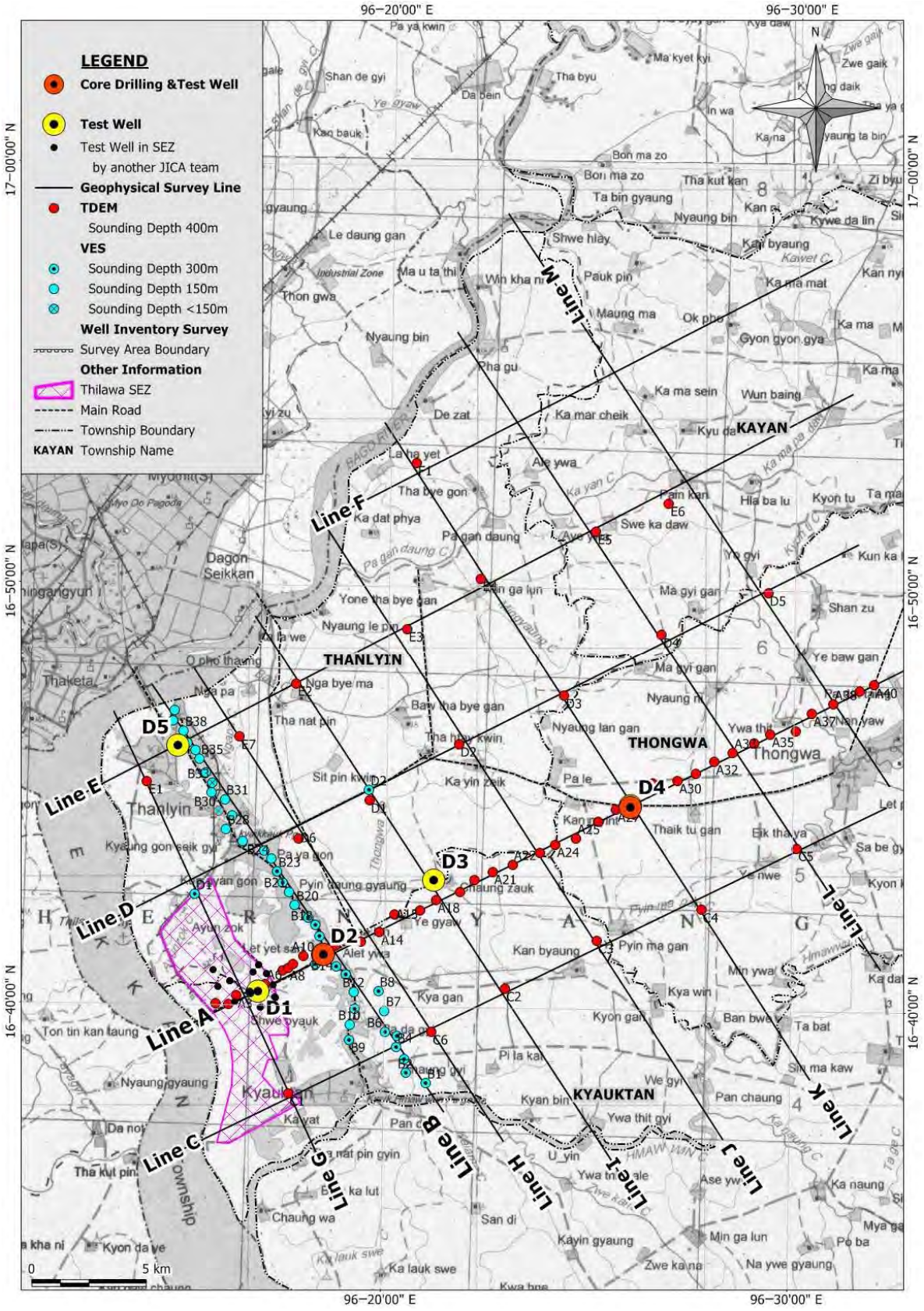
1) Review of Existing Reports
2) Well Inventory Survey
3) Geophysical Survey
4) Core Boring
5) Test Well
6) Pumping Test
7) Water Quality Survey and Test
8) Outcrop Reconnaissance
9) Groundwater Head Monitoring

Figure 3-2-1-1 shows the main locations and area of the survey.

Table 3-2-1-1 Survey Items Related to GW Potential and Methods Applied in this Survey

Target Item of Survey		Explanation	Method of Survey Applied
Water Budget	Aquifer distribution	A place of movement and storage	Well inventory suevey (14,691 facilities), geophysical survey (VES 43 points, TDEM 60 points), core boring (2 points), test well (5 sites, 16 wells), outcrop recconnassance, topographic analysis with sattelite image.
	Groundwater table	1) A result of water budget. 2) The gradient shows GW movement direction.	Observation of GW level: Automatically & hourly - 16 wells GW level measurement at dug wells
	Groundwater recharge	Input of water budget	Collection of metrological and hydrological data (rainfall, evapotranspiration, tide level, etc.), confirmation of water body location, creation of landcover map with sattellite image.
	Groundwater runoff	Output of water budget	Estimation of GW use amount through well inventory survey.
Water Quality		Requirement from development purpose	Water quality measurement/analysis: 200 exhisting wells - Twice a year, in-situ measurement 16 test wells - sampled during pumping test and monthly, in-situ and in laboratory analysis. 13 test wells - Isotopic analysis
Hydraulic Ability		Controling rechrage and water moving rate. Affects economy of development.	Pumping test at test well (16 wells) and existing wells (3 wells). Well capacity data in existing reports
Environmental Impact Assessment	Impact provider	Water development plan	(Amount and facilities allocation to be assumed)
	Impact receiver	Water use and land use	Water use facilities inventory survey. Landuse survey.
	Field of impact transmissin	Aquifer	(See the methods for water budget and hydraulic ability)

Source: JICA Survey Team



Source: JICA Survey Team

Figure 3-2-1-1 Main Locations of Groundwater Surveys

3-2-2 Review of Existong Reports and Data

3-2-2-1 Existing Reports and Data

Two study reports shown in Table 3-2-2-1 were reviewed. The general geology, well logs and water quality data on the reports are useful to understand the outline of hydrogeology in the area.

Table 3-2-2-1 Existing Hydrogeological Study Reports

Citation Abbreviated	Win Naing et al. (1991)	Aye Thanda Bo (2001)
Author	Aung Aung Tin, Win Naing and Maung Maung	Aye Thanda Bo
Year	1991	2001
Title	Hydrogeology of Thanlyin - Kyauktan Area	Urban Geology of Thanlyin Area
Publication	Diploma Article, Applied Geology Department, Yangon University	Diploma Article, Department of Engineering Geology, Yangon Technological University
Target Area	Thanlyin-Kyauktan Ridge and nearby area	Thanlyin
Study Oulline	・Collection of 6 well logs and 36 tube well data ・Water quality analysis at 44 wells(dug and tube well) ・Collection of information on water supply and treatment in Kyauktan ・Creation of hydrogeological maps	・Collection of 9 engineering boring logs (with soil tst data), 8 investigation drilling logs and 7 well logs ・Summarization of water use and water quality ・Geo-engineering consideration on land use and foundation
Main Figures Presented	Geological map	Geological map
	Location map of well	Water quality map (main ions, iron ion)
	Map of water supply system of Kyauktan	Hydrogeological map
	Water table depth map	Land Use Map
	Hydrogeological map	Geotechnical classification map of foundaion
	Ion balance charts	

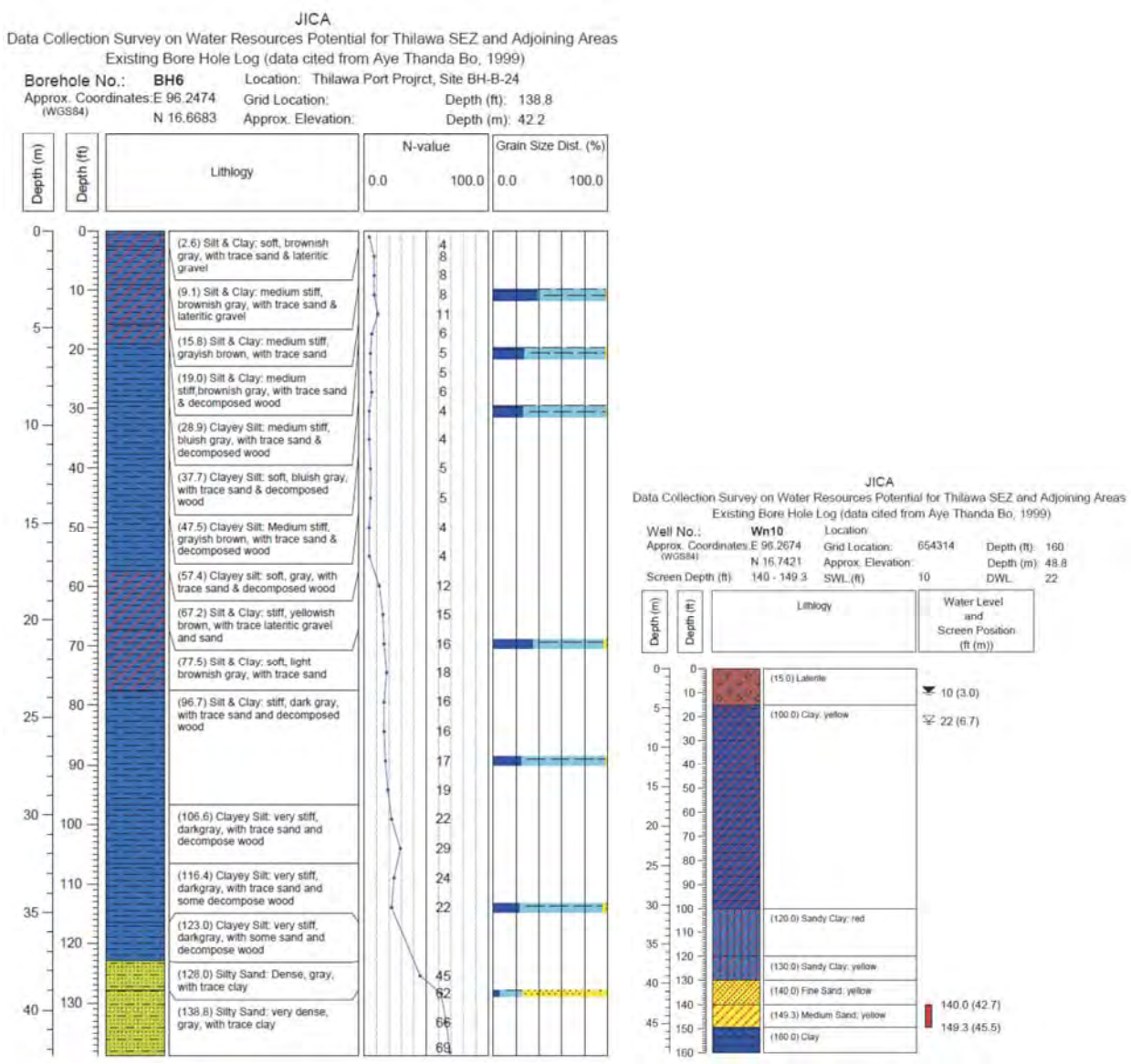
Source: JICA Survey Team

Each township administration has a well inventory, which provides an outline of groundwater use in the township, including the number of wells and the condition of the public water supply. This inventory became a base for a detailed exhaustive well survey carried out by the present survey.

Only these are the obtainable comprehensive reports and data. Since there are many wells in the area, well-construction contractors might have information on well log and aquifer location. But it is difficult to collect such information in fact, because they are private and rarely leave documents.

3-2-2-2 Geologic and Well Logs

Table 3-2-2-2 shows a list of all geologic and well logs collected from the above-mentioned reports and obtained through the JICA survey including the present one. Figure 3-2-2-2 to Figure 3-2-2-4 show their locations. All the logs are attached in the ”Supporting Data”. Figure 3-2-2-1 shows an example.



Geologic Log Well Log

Source: Original data by Aye Thanda Bo (2001): Compiled by JICA study team.

Figure 3-2-2-1 Example of Geologic and Well Logs

Table 3-2-2-2 List of Geologic and Well Logs

No.	Kind	Name	Depth (m)	Depth (ft)	Reference Location	Longitude	Latitude	Source
1	C	D2	272	892.4	Thilawa SEZ Supporting Committee Compound	96.30803	16.68694	JICA-1
2	C	D4	248	813.6	No.6 Express Road between Kan Myin and Thaik Tu Gan, Thongwa	96.43456	16.74736	JICA-1
3	TW	D-1-0	52	170.6	SEZ Class A	96.28331	16.67314	JICA-1
4	TW	D-1-1	85	278.9	SEZ Class A	96.28339	16.67319	JICA-1
5	TW	D-1-2	150	492.1	SEZ Class A	96.28322	16.67317	JICA-1
6	TW	D-1-3	330	1082.7	SEZ Class A	96.28328	16.67314	JICA-1
7	TW	D-2-0	56	183.7	Thilawa SEZ Supporting Committee Compound	96.30764	16.68681	JICA-1
8	TW	D-2-1	97	318.2	Thilawa SEZ Supporting Committee Compound	96.30794	16.68672	JICA-1
9	TW	D-2-2	150	492.1	Thilawa SEZ Supporting Committee Compound	96.30786	16.68686	JICA-1
10	TW	D-2-3	330	1082.7	Thilawa SEZ Supporting Committee Compound	96.30811	16.68658	JICA-1
11	TW	D-3-1	80	262.5	Chaung Zauk	96.35294	16.71714	JICA-1
12	TW	D-3-2	180	590.6	Chaung Zauk	96.35278	16.71711	JICA-1
13	TW	D-3-3	330	1082.7	Chaung Zauk	96.35264	16.71711	JICA-1
14	TW	D-4-1	85	278.9	No.6 Express Road between Kan Myin and Thaik Tu Gan, Thongwa	96.43511	16.74739	JICA-1
15	TW	D-4-2	146	479.0	No.6 Express Road between Kan Myin and Thaik Tu Gan, Thongwa	96.43511	16.74742	JICA-1
16	TW	D-5-1	65	213.3	Thanlyin Center	96.24714	16.76911	JICA-1
17	TW	D-5-2	100	328.1	Thanlyin Center	96.24700	16.76911	JICA-1
18	TW	D-5-3	350	1148.3	Thanlyin Center	96.24708	16.76911	JICA-1
19	TW	TW3	198.1	650	SEZ Class A	96.26307	16.68047	JICA-2
20	TW	TW4	198.1	650	SEZ Class A	96.26503	16.67393	JICA-2
21	TW	TW5	204.2	670	SEZ Class A	96.27952	16.67967	JICA-2
22	TW	TW6	198.1	650	SEZ Class A	96.26977	16.67615	JICA-2
23	TW	TW7	195.1	640	SEZ Class A	96.27813	16.67202	JICA-2
24	TW	TW8	198.1	650	SEZ Class A	96.27200	16.66782	JICA-2
25	TW	TW9	198.1	650	SEZ Class A	96.28752	16.67463	JICA-2
26	TW	TW10	198.1	650	SEZ Class A	96.28852	16.67010	JICA-2
27	W	PW1	91.4	300	SEZ Class A	96.27837	16.6712	JICA-2
28	W	PW2	91.4	300	SEZ Class A	96.28857	16.6698	JICA-2
29	W	PW3	91.4	300	SEZ Class A	96.28253	16.6658	JICA-2
30	W	PW4	91.4	300	SEZ Class A	96.26985	16.6762	JICA-2
31	E	BH.A	30.5	100	SEZ near Zamani Inn Reservoir	96.2682	16.6978	JICA-2
32	E	BH.B	30.5	100	SEZ near Thilawa	96.2682	16.6590	JICA-2
33	E	BH.C	30.5	100	SEZ near Ship Breaking Yard	96.2687	16.6128	JICA-2
34	W	No2	72.5	238	Aungmingalar-4, Thanlyin	96.2474	16.7680	Ref1
35	W	No6	116.7	383	Prguzy, Tynalyin	96.2479	16.7583	Ref1
36	W	No14	114.3	375	Tin Smelting and Refinery Plant.1, Thanlyin	96.2650	16.7315	Ref1
37	W	No23	62.5	205	Shwegon 2, Kyauktan	96.3230	16.6506	Ref1
38	W	No24	67.1	220	Singan 3, Kyauktan	96.3310	16.6393	Ref1
39	W	No34	88.4	290	Hospital 16, Kyauktan	96.3268	16.6370	Ref1
40	E	BH1	64.3	211.0	YGN-TLN Bridge BH1	96.2434	16.7828	Ref2
41	E	BH2	20.4	67.0	Glass Factory Extension BH-1	96.2311	16.7197	Ref2
42	E	BH3	24.8	81.5	Thanlyin-Thilawa-Padagyi Road, Bridge No.2/1	96.2468	16.6978	Ref2
43	E	BH4	21.8	71.5	Thanlyin-Thilawa-Padagyi Road, Brige Site, Mile Post 2/4 &2/5 BH-1	96.2660	16.6721	Ref2
44	E	BH5	24.8	81.5	Thanlyin-Thilawa-Padagyi Road, Brige Site, Mile Post 5/4 BH-1	96.2743	16.6615	Ref2
45	E	BH6	42.3	138.8	Thilawa Port Project, Site BH-B-24	96.2474	16.6683	Ref2
46	E	BH7	35.4	116.1	Thilawa Ship Breaking Yard Projrct, Site S-15	96.2610	16.6133	Ref2
47	E	BH8	36.2	118.8	Thilawa Port Project, Site BH-B-13	96.2526	16.6630	Ref2
48	En	Bn5	11.0	36		96.2304	16.7147	Ref2
49	En	Bn6	20.1	66		96.2336	16.7115	Ref2
50	En	Bn7	19.8	65		96.2432	16.7097	Ref2
51	En	Bn8	16.8	55		96.2429	16.7050	Ref2
52	En	Bn9	16.5	54		96.2662	16.7171	Ref2
53	En	Bn10	16.5	54		96.2654	16.7216	Ref2
54	En	Bn11	16.8	55		96.2658	16.7316	Ref2
55	En	Bn12	13.7	45		96.2660	16.7351	Ref2
56	W	Wn1	54.9	180		96.2693	16.7464	Ref2
57	W	Wn10	48.8	160		96.2674	16.7421	Ref2
58	W	Wn11	44.2	145		96.2685	16.7465	Ref2
59	W	Wn4	45.7	150		96.2215	16.7567	Ref2
60	W	Wn37	42.7	140		96.2327	16.7493	Ref2
61	W	Wn46	42.7	140		96.2404	16.7739	Ref2
62	W	Wn52	45.7	150		96.2483	16.7641	Ref2
63	E	Bmmu	18.3	60	Myanmar Maritime University	96.2660	16.7029	Ref4

Note ·C: Core boring
TW: Test Well
W: Well
E: Geoengineering boring with geotechnical data
En: Geoengineering boring with no geotechnical data

Source: JICA-1 The present JICA Study Team.
JICA-2 Nippon Koei Inc. (2013)
Ref1 Aung Aung Tin, Win Naing and Maung Maung (1991)
Ref2 Aye Thanda Bo (2001)
Ref3 Kunio Watanabe, Htike Htike and Hidehiko Kazama (2004)

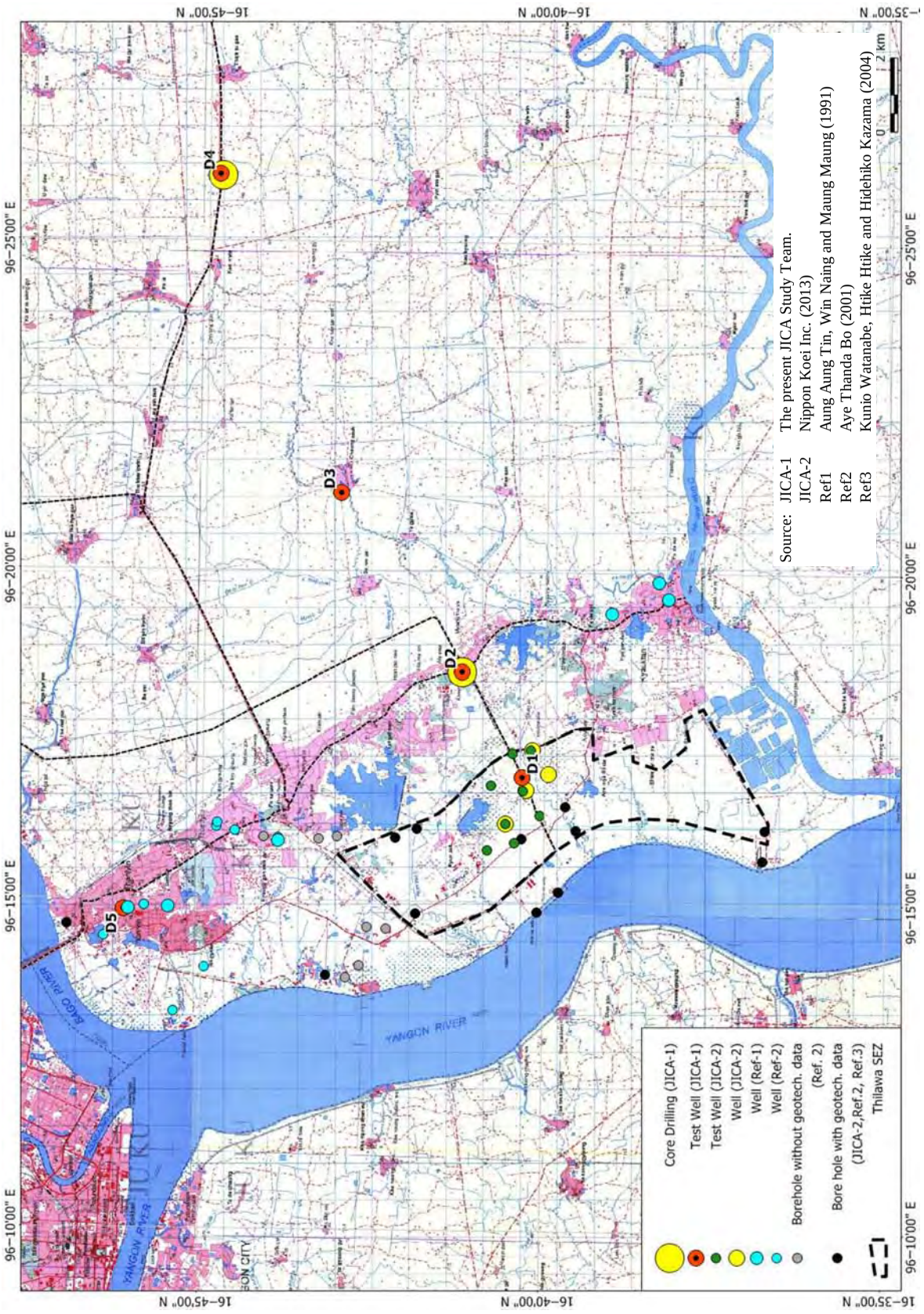
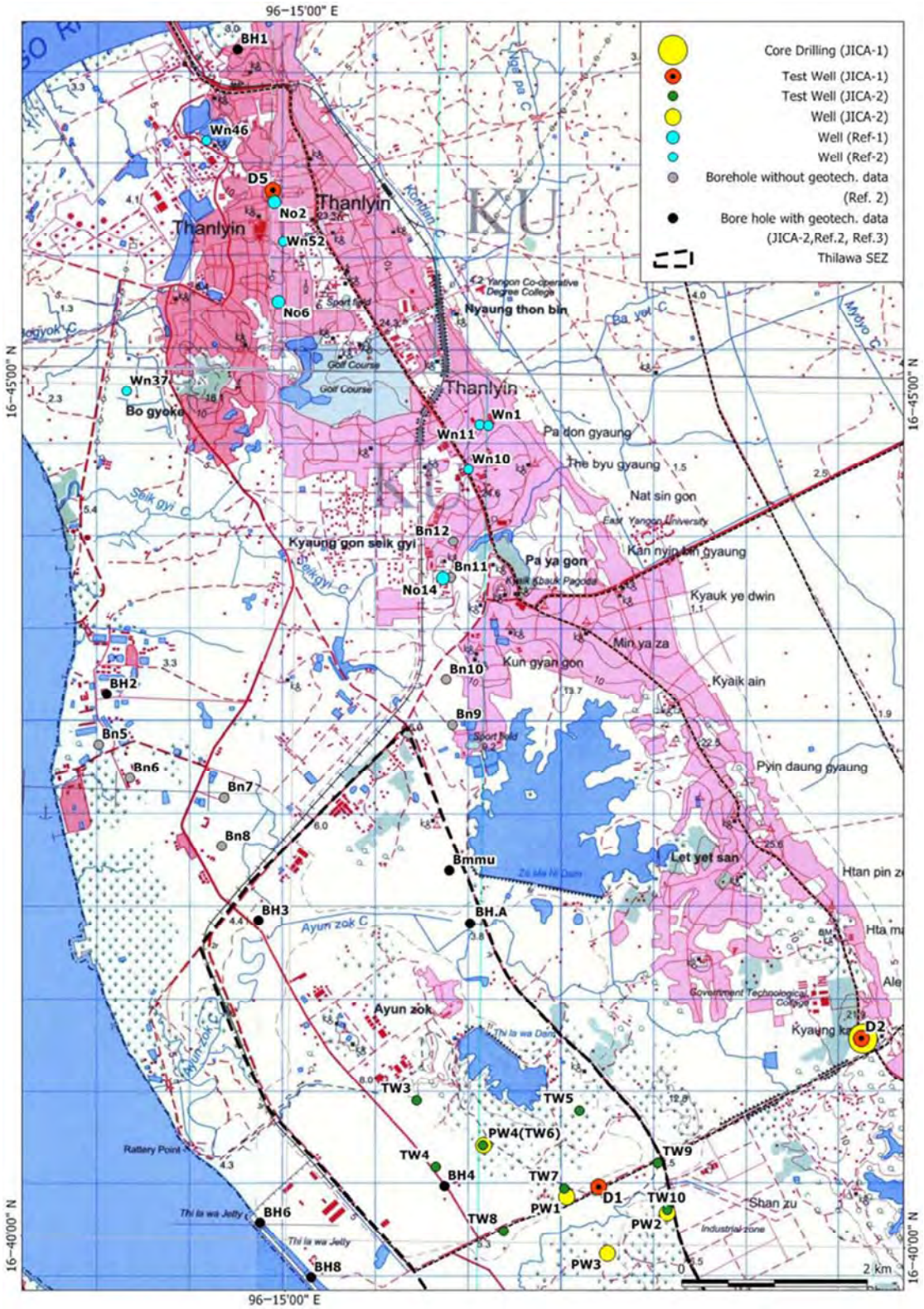
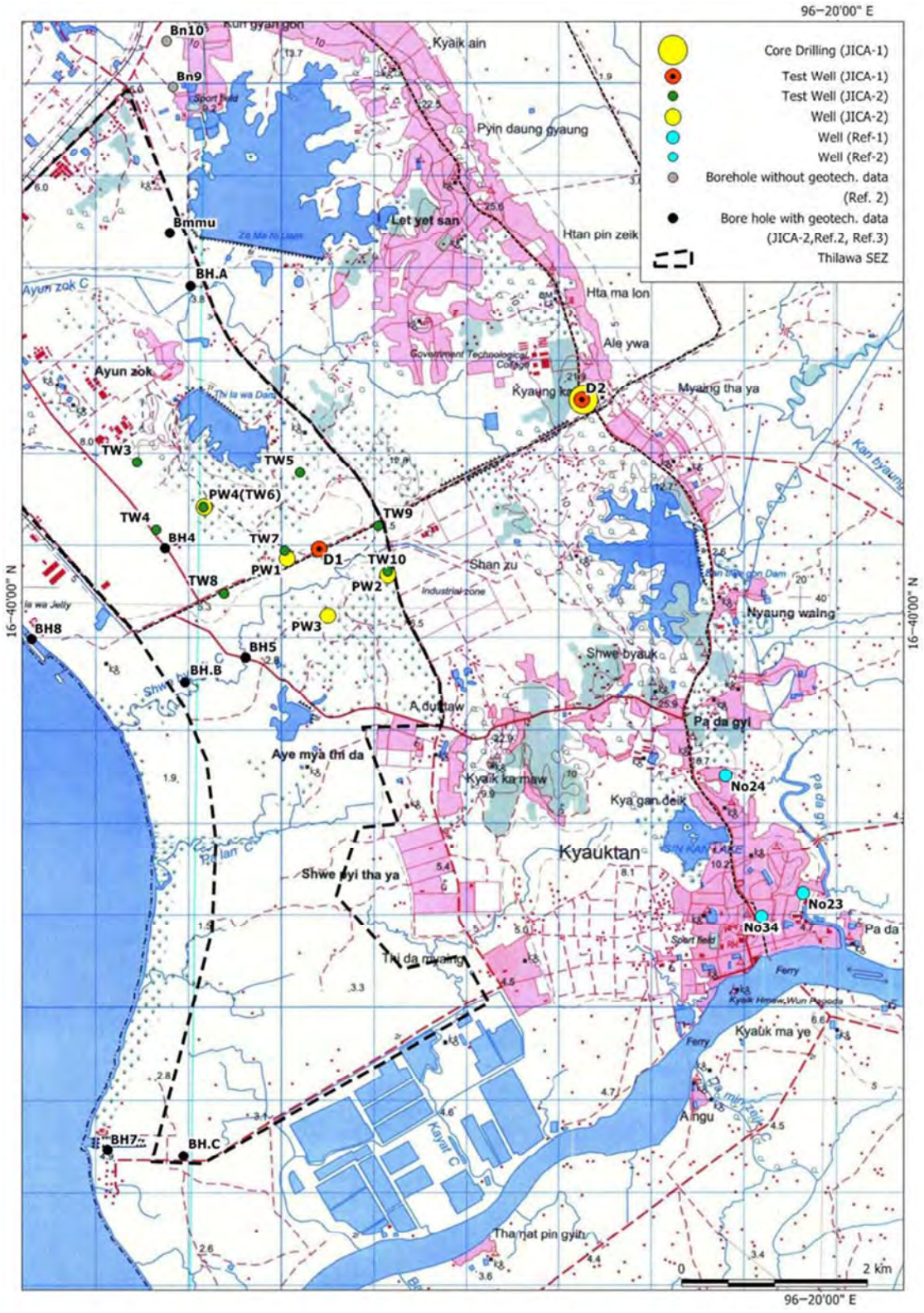


Figure 3-2-2-2 Location of Geologic and Well Logs (Whole Area)



Source: JICA-1 The present JICA Study Team.
JICA-2 Nippon Koei Inc. (2013)
Ref1 Aung Aung Tin, Win Naing and Maung Maung (1991)
Ref2 Aye Thanda Bo (2001)
Ref3 Kunio Watanabe, Htike Htike and Hidehiko Kazama (2004)

Figure 3-2-2-3 Location of Geologic and Well Logs (Northern Area)



Source: JICA-1 The present JICA Study Team.
JICA-2 Nippon Koei Inc. (2013)
Ref1 Aung Aung Tin, Win Naing and Maung Maung (1991)
Ref2 Aye Thanda Bo (2001)
Ref3 Kunio Watanabe, Htike Htike and Hidehiko Kazama (2004)

Figure 3-2-2-4 Location of Geologic and Well Logs (Southern Area)

3-2-2-3 Aquifer Depth and Hydraulic Ability

(1) Aquifer Depth

Aye Thanda Bo (2001) summarizes the aquifer features in the Thanlyin area as Table 3-2-2-4. According to this, there are two aquifers, upper and lower. The upper aquifer is located around 30 to 40 m underground and the lower one is 60 to 70 m and 80 to 100 m underground.

Win Naing et al. (1991) presented deep well data as shown in Table 3-2-2-5. Figure 3-2-2-5 and Figure 3-2-2-6 show value distribution of the data. In the table, the wells in Thanlyin are presumed to be located in the Irrawaddy Formation and those in Kyauktan are in the Pegu Group. The screen depth of the wells in Thanlyin mostly corresponds to the aquifer depth of the lower one. The wells in Kyauktan have similar screen depth to those in Thanlyin, though the formation is different.

According to the result of the well inventory survey explained later, the frequency of well depth shows a large peak at an interval between 30 and 40 m, as well as a small peak between 90 and 100 m. These peaks fit with the above-mentioned two aquifers' depths. However, the aquifer depth may vary, as there are a considerable number of wells whose depths are between and beyond the two peaks.

(2) Hydraulic Ability

Based on Table 3-2-2-4 and Table 3-2-2-5, the capacity and specific capacity of the wells is summarized in Table 3-2-2-3. The yield of a well is presumed to be a few hundred m^3/day maximum.

Table 3-2-2-3 Outline of Aquifers in the Thanlyin and Kyauktan Areas by Existing Reports

Aquifer		Depth	Well Capacity	Specific Capacity	Remarks
		m	m^3/day	m^3/day/m	
Irrawaddy Formation (Thanlyin Area)	Upper	30 - 40	44 - 65	3 - 24	2" well
	Lower	60 - 70 80 - 100	216 - 648	12 - 156	8-10" well
Pegu Group (Kyauktan Area)		50 - 100	72 - 864	2.4 - 31	4" well

Note: Table 3-2-2-4 and Table 3-2-2-5 combined.

Table 3-2-2-4 Outline of Aquifers in the Thanlyin Area (Aye Thanda Bo, 2001)

Aquifer		Depth	Thickness	Well Capacity	Specific Capacity	SWL
		m	m	m^3/day	m^3/day/m	m
Irrawaddian	Upper	30 - 40	3 - 6.1	44 - 65	3 - 24 for 2" well	1 - 4.6
	Lower	59 - 73 79 - 102		436 - 655	28 - 54 for 10" well	1 - 2.1

Source: Main text description of Aye Thanda Bo(2001).

Table 3-2-2-5 Deep Well Data in the Thanlyin and Kyauktan Areas (Win Naing et al., 1991)

Area	No	Location	Well Dia-meter	Well Depth	Depth to Aquifer			Aquifer Thick-ness	Static Level	Draw-down	Capacity		Specific Capacity	
			in	m	m			m	m	m	m^3/hr	m^3/day	m^3/hr /m	m^3/day /m
Thanlyin	1	Thanlyin East	10	136	121	-	136	15	-	-	20	490	-	
	2	Aungmingalar-4	10	73	59.1	-	72.5	13	17	36	23	550	0.6	15
	3	Aungmingalar-5	10	94	50.3	-	59.4	9	24	40	18	440	0.5	11
					79.2	-	94.5	15						
	4	Aungmingalar-6	10	104	56.4	-	62.5	6	23	37	18	440	0.5	12
					91.4	-	104	12						
	5	Municipal	10	90	71.6	-	89.9	18	12	23	24	580	1.1	25
	6	Peguzu	10	110	27.1	-	34.1	7	-	-	25	610		
					97.2	-	110	13						
	7	MPE Thanlyin	10	84	37.2	-	83.8	47	-	-	27	650		
	8	Housing Project	8	118	110	-	116	6	23	44	25	590	0.6	13
	9	Marble Factory	4	43	36.6	-	42.7	6	11	21	14	330	0.6	15
	10	Marble Factory	4	43	33.5	-	39.6	6	9	20	15	350	0.7	18
	11	Thilawa Port	2	54	50.9	-	53.9	3	5	-	8	200		
	12	Trade School-2	8	70	57.9	-	64	6	9	29	18	440	0.6	15
					65.8	-	68.9	3						
	13	Trade School-1	6	107	85.3	-	88.4	3	11	27	23	550	0.8	20
					96	-	99.1	3						
					102	-	105	3						
	14	Tin Plant.1	8	114	95.1	-	99.1	4	4	7	45	1090	6.5	156
					102	-	112	10						
	15	Tin Plant.2	8	107	86.9	-	89	2	5	9	41	980	4.6	111
					95.1	-	105	10						
	16	Glass Factory-1	8	76	41.1	-	47.2	6	5	14	36	870	2.7	64
					66.8	-	75.9	9						
	17	Glass Factory-2	8	85	73.2	-	85.3	12	3	12	19	450	1.6	39
	18	Glass Factory-6	8	82	70.1	-	82.3	12	4	30	9	220	0.3	7
	19	Glass Factory-7	8	88	73.2	-	88.4	15	6	29	27	650	0.9	23
	20	Glass Factory-8	8	85	61	-	73.2	12	15	32	18	440	0.6	14
					79.2	-	85.3	6						
	21	Glass Factory-9	8	98	79.2	-	97.5	18	11	26	32	760	1.2	29
	22	Glass Factory-10	8	110	97.5	-	110	12	9	13	36	870	2.8	67
Kyauktan	23	Shwegon 2	4	61	51.2	-	57.3	6	1	17	23	550	1.3	31
	24	Singan 3	4	67	50	-	56.1	6	11	38	3	70	0.1	2
	25	Singan 4	4	107	80.8	-	83.8	3	5	31	25	610	0.8	19
					85.3	-	88.4	3						
	26	Shwegon 5	4	70	51.8	-	57.9	6	2	28	30	720	1.1	26
	27	Shwegon 6	4	67	53.3	-	59.4	6	3	35	14	330	0.4	9
	28	Shwegon 7	4	70	51.8	-	57.9	6	2	35	18	440	0.5	12
	29	Shwegon 8	4	73	57.9	-	64	6	3	38	9	220	0.2	6
	30	Shwegon 9	4	67	53.3	-	59.4	6	4	28	13	310	0.5	11
	31	Hospital, 10	4	88	73.2	-	82.3	9	8	41	7	160	0.2	4
	32	Shwegon 11	6	79	61.9	-	71	9	5	31	23	550	0.7	17
	33	Shwegon 12	4	146	79.2	-	91.4	12	5	28	14	330	0.5	12
	34	Hospital 16	4	104	84.4	-	93.6	9	6	34	11	270	0.3	8
	35	Police Station 15	4	55	23.8	-	29.9	6	3	28	5	110	0.2	4
	36	Regiment (90) 3	6	79	53.3	-	59.4	6	11	24	15	360	0.6	15

Note: Original unit: feet & gallon

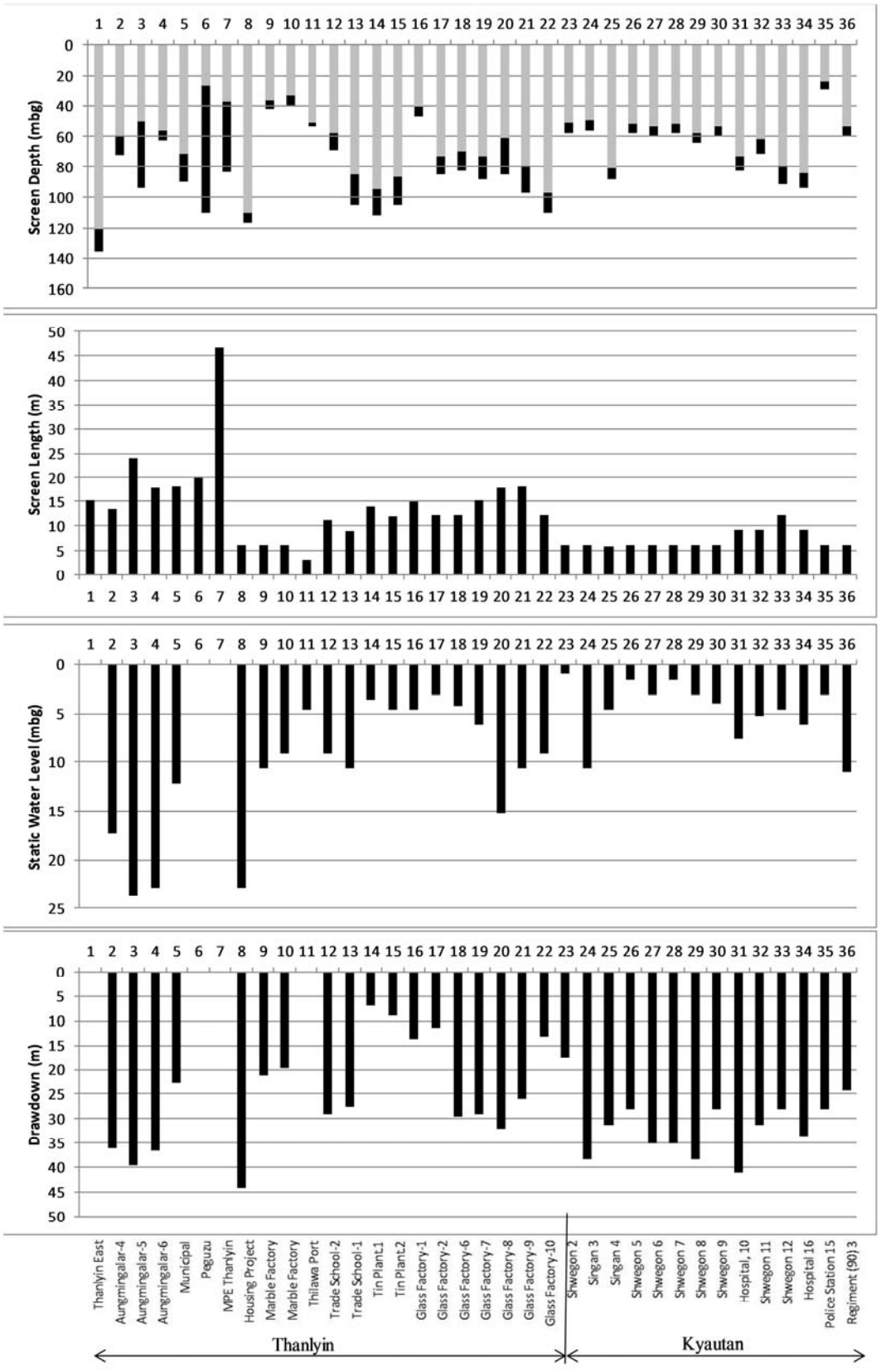


Figure 3-2-2-5 Value Distribution of Deep Well Data in the Thanlyin and Kyauktan Areas (Win Naing el al., 1991) (1/2)

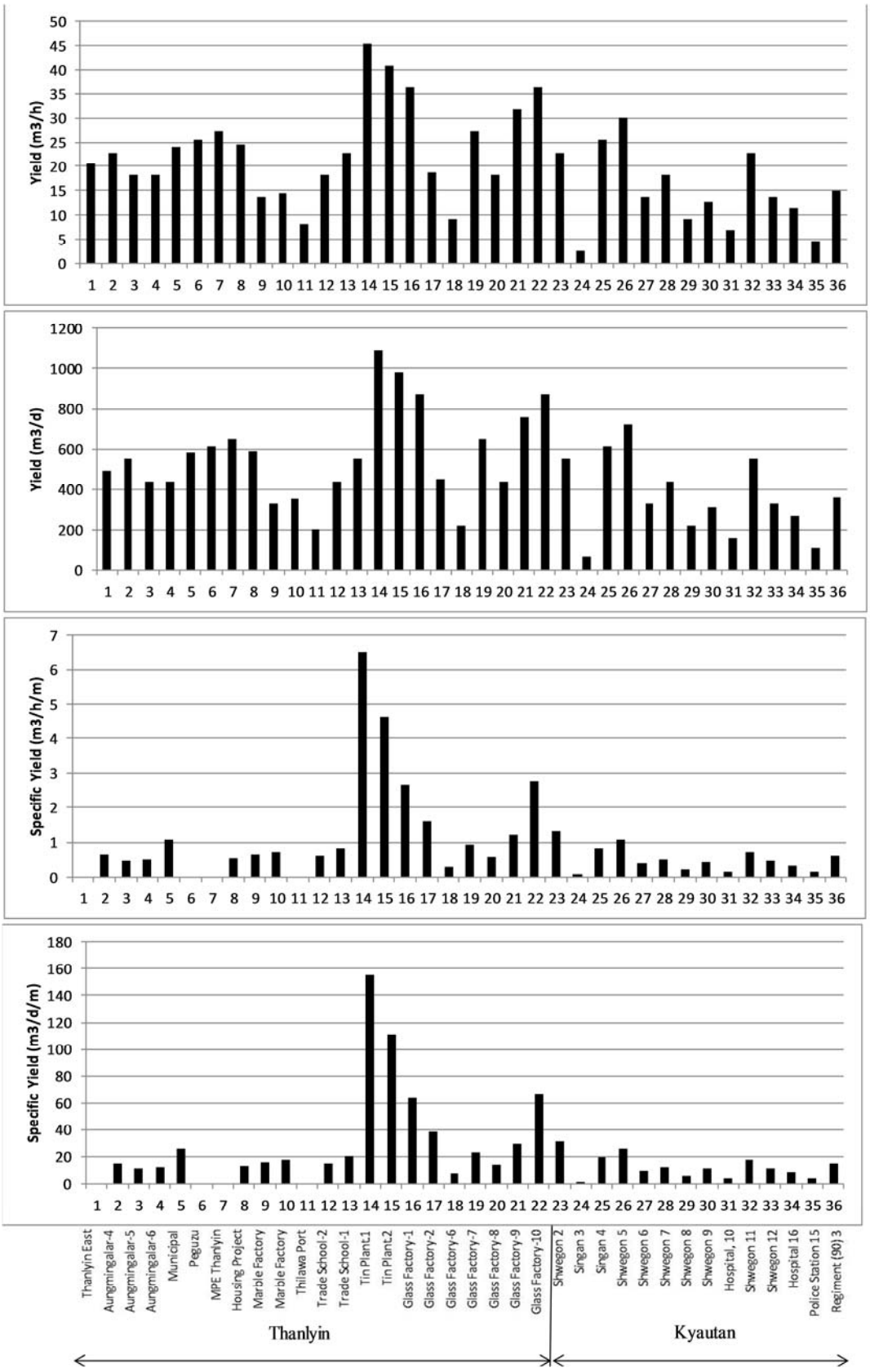


Figure 3-2-2-6 Value Distribution of Deep Well Data in the Thanlyin and Kyauktan Areas (Win Naing el al., 1991) (2/2)

3-2-2-4 Water Quality

Win Naing et al. (1991) carried out water quality analysis of wells located in the Thanlyin-Kyauktan ridge and nearby area. Table 3-2-2-6 and Figure 3-2-2-7to Figure 3-2-2-9 show its results.

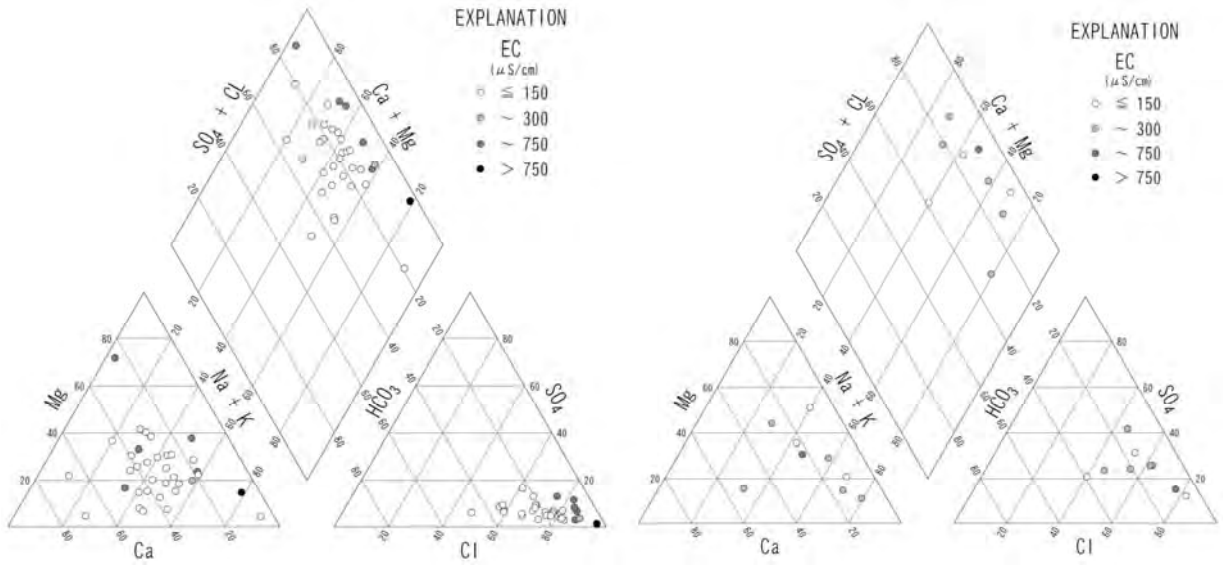
In groundwater in the area, chloride and sodium ions occupy a large proportion among the main anions (Figure 3-2-2-7). Therefore, chloride ion concentration and electric conductivity (EC) have a good relationship, and it is presumed that approx. 750 μS/cm of EC correspond to 200 mg/l of chloride concentration beyond which people possibly feel water is salty (Figure 3-2-2-9). A large content of the two ions may be derived from sea salts. Saline water intrusion is reported in Alluvium near the river at the northeastern and western edges of Thanlyin hill.

It is generally said that if iron concentration exceeds 0.3 mg/l, water gets color, and beyond 0.5 ㎎/l～1.0 mg/l, people feel a metallic taste. Groundwater in the area often has an iron concentration exceeding such guideline values (Figure 3-2-2-8). The pH ranges widely from 5.2 to 8.7 (Table 3-2-2-6).

Data in the eastern plain is rare. According to what has been heard, the aquifer is salinized down to 100 m below the ground near Thongwa town.

Table 3-2-2-6 Water Quality Analysis Result of Wells in the Thanlyin and Kyauktan Areas (Win Naing et al., 1991)

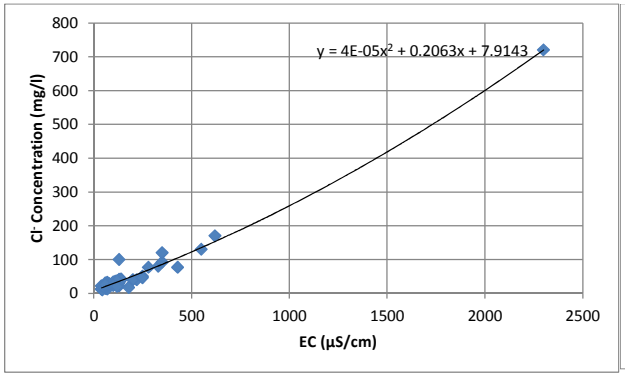
Sample No.	Location	Well Type	pH	EC (μS/cm)	TDS (ppm)	Major Anions				Major Cations				Remarks
						CO_3 (ppm)	HCO_3 (ppm)	CL (ppm)	SO_4 (ppm)	Ca (ppm)	Mg (ppm)	Na&K (ppm)	Fe (ppm)	
1	Nan oo kaung	Hand dug	7.62	130	70		18	31	4	7.21	2.4	10.01	0.03	
2	Taukthordwin	Hand dug	7.54	110	70		16	36	4	5.61	2.88	122.2		
3	Thanlyin downtown	Hand dug	6.52	330	200		12	80	8	4	6.72	17.03		
4	Nyaungthonbin	Hand dug	7.53	60	30		12	23	4	2.4	2.4	8.8		
5	Natsingon	Hand dug	6.16	50	30		14	19	1.68	4.8	0.96	5.23	3	
6	Okkyin	Hand dug	8.68	2300	1600	8	20	720	12	19.23	24.96	263	2.09	
7	Aungthukha	Hand dug	7.23	620	400		22	170	32	46.49	9.6	39.4	0.34	
8	Daragah	Hand dug	6.78	430	280		12	77	10	15.23	8.64	16.1		Dried in summer
9	Thanpigon	Hand dug	6.71	350	220		18	92	4	8.01	6.24	29.8		
10	Pegusu	Hand dug	6.13	280	180		12	77	4	8.01	4.32	24.7		
11	Myothit	Hand dug	5.21	100	60		12	23	6	12.02	2.4	2.45		
12	Western ward	Hand dug	5.76	130	80		18	34	6	6.4	5.28	9		Sometimes dried in summer
13	Sanchcinhmi	Hand dug	8.32	550	350	8	18	130	30	23.24	40.8	3.8		
14	Singon	Hand dug	6.03	140	90		14	41	4	4	2.88	14.85		
15	Kyaukyedwin	Hand dug	6.89	60	40		16	15	3	5.61	2.88	3.1	0.6	
16	Chanmyeithaga	Hand dug	6.9	130	80		16	41	4	6.41	4.56	12.6	0.7	
17	Aungdnantha	Hand dug	6.31	140	90		14	42	3	5.61	4.32	12.2	0.3	
18	Shegon	Hand dug	8.04	70	45		12	12	2.6	5.61	2.64	5.1	0.8	Dried in summer
19	Kyaukyedwin	Hand dug	8.48	40	26	4	12	12	2	4.8	0.96	7.5	0.9	
20	Lehyetsang	Hand dug	6.17	60	36		14	14	2.14	4.8	1.44	10	0.6	
21	Pyindaunggyaung	Hand dug	6.55	40	24		12	12	1.68	4	0.48	6.9		
22	Kyaukyedwin	Hand dug	7.73	45	30		10	10	2.14	4.8	0.48	5.3	1.5	Dried in summer
23	Ale ywa	Hand dug	7.31	130	84		14	22	8	12.02	0.48	5.4		
24	Kyaungkan	Hand dug	7.21	40	26		12	22	3.42	4.8	1.67	8.5		Dried in summer
25	Myayayo	Hand dug	7.19	140	96		12	40	3.62	6.41	3.36	11.9		
26	Shanzu	Hand dug	8.03	50	32		14	19	2.12	5.61	0.48	6.6		
27	Alat ywa	Hand dug	8.43	80	50		10	28	3.21	7.21	2.85	7.5		Dried in summer
28	Nyaungwaung	Hand dug	8.72	80	50		12	27	2.26	6.41	1.44	8.1	2	
29	Banbwegon	Hand dug	7.93	70	45		12	32	3.12	5.61	2.54	11.8		Dried in summer
30	Shwebyauk	Hand dug	7.72	110	70		10	32	1.84	4.8	2.88	7.6	2.08	Dried in summer
31	Kuaikkamau	Hand dug	6.72	60	36		12	30	2.42	4	3.36	5	0.75	
32	Pdanpetaya	Hand dug	6.69	60	36		12	22	1.22	5.61	1.92	5.1	0.65	
33	Aduttaw	Hand dug	6.55	100	60		10	34	1.48	4.8	1.92	11		
34	Padagyi	Hand dug	5.2	60	36		8	26	1.44	4	1.92	5.1	1.34	
35	Glas factory	Hand dug	6.35	120	70		10	37	4.24	6.41	5.28	6.9	2.62	
36	Shwegon	Tube well	6.49	250	150		16	50	28	4.01	5.28	20.6	5	well no. 2/6378
37	Singam	Tube well	6.58	100	50		40	24	16.8	2.4	8.16	12.4	0.5	well no. 4/6379
38	Shwegon	Tube well	6.83	220	140		26	40	23.84	16.08	2.88	11.8	4.5	well no. 42/6380
39	Shwegon	Tube well	6.75	200	130		20	40	49.92	4.8	2.88	27	3.09	well no. 5/6381
40	Shwegon	Tube well	7.27	180	100		20	17	12	4.81	3.36	47	6	well no. 7/6383
41	Shwegon	Tube well	6.75	250	150		16	46	26	8.81	8.64	11	5	well no. 9/6385
42	Hospital	Tube well	6.29	120	70		10	20	16	4.008	3.89	9.1	2.54	well no. 10/6386
43	Regiment(90)	Tube well	6.15	130	100		12	100	20	4.81	5.76	37.2	4.25	well no. 13/6389
44	Police station	Tube well	7.59	350	220		22	120	32	14.42	12	36	4.5	well no. 15/6391



Dug Well　　Tube Well

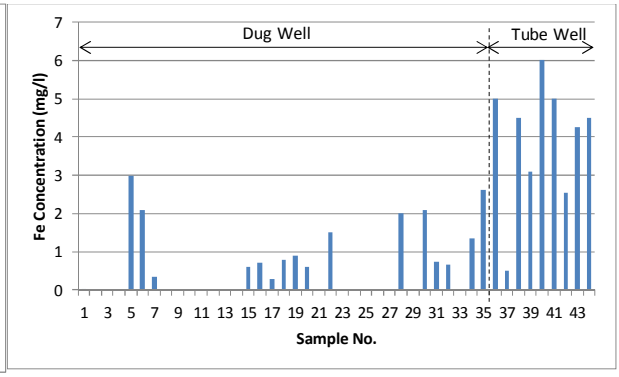
Data source: Win Naing el al.(1991) Graph redrawn by JICA study team,

Figure 3-2-2-7 Tri-linear Diagram of Main Ions of Well Water near Thanlyin-Kyuaktan Ridge



Data source: Win Naing el al.(1991)

Figure 3-2-2-9 Relationship between Electric Conductivity and Chloride Concentration



Data source: ditto.

Figure 3-2-2-8 Iron Concentration of Well Water

3-2-3 Well Inventory Survey

3-2-3-1 Outline

The well inventory survey, that is, a well survey (including ponds) based on existing inventories, was carried out over a period of four months from Oct. 2012 to Jan. 2013. The work was entrusted to the National Engineering and Planning Services Co., Limited (NEPS). The survey purposed to infer the ability of an aquifer around Thilawa's Special Economic Zone (SEZ) and the adjacent area through grasping the present groundwater use in the areas, as well as to obtain basic information for estimating groundwater development potential around SEZ in future. The outline of the survey is as follows.

(1) Target Area

The target area consists of 92 village groups in 4 townships: Thanlyin, Kyauktan, Kayan and Thongwa. Figure 3-2-3-1 shows the location of the village groups.

- Thanlywin Township (29 village groups)
- Kyauktan Township (25 village groups)
- Kayan Township (17 village groups)
- Thongwa Township (21 village groups9

(2) Procedure and Time of Survey

The survey first picked up fundamental information of wells from existing inventories and input it onto a questionnaire shown in Table 3-2-3-1. Then the field survey was carried out on all the wells to obtain data lacking on the questionnaire. It was completed at the end of December 2012, so the information collected represents that as of the end of 2012. Finally, the information was input into a database.

Procedure of Inventory Survey

- Collection and check of existing inventories
- Input of fundamental information to questionnaire
- Field survey of facilities on the inventory
- Input of survey results to database

(3) Field Survey and Number of Facilities

The field survey was carried out by teams from the first week of October, after the rainy season had just ended, and continued until the end of December. The registration information of facilities was collected from existing inventories in each township, and then the surveyors visited all the facilities and conducted hearings with the owners, making necessary measurements. Among the registered 15,252 facilities, approx. 4% could not be found due to maybe having been abandoned or collapsed, but 14, 691 facilities were identified and confirmed as still being used. Table 3-2-3-2 shows the number of facilities by township, and Figure 3-2-3-2 shows their location.

Many wells, as many as 90%, distribute in Thanlyin and Kyauktan where many houses are constructed whereas approx. only 6% distribute in Kayan and Thongwa where paddy fields dominate. Such distribution of wells meets almost all the needs of the population of the villages.

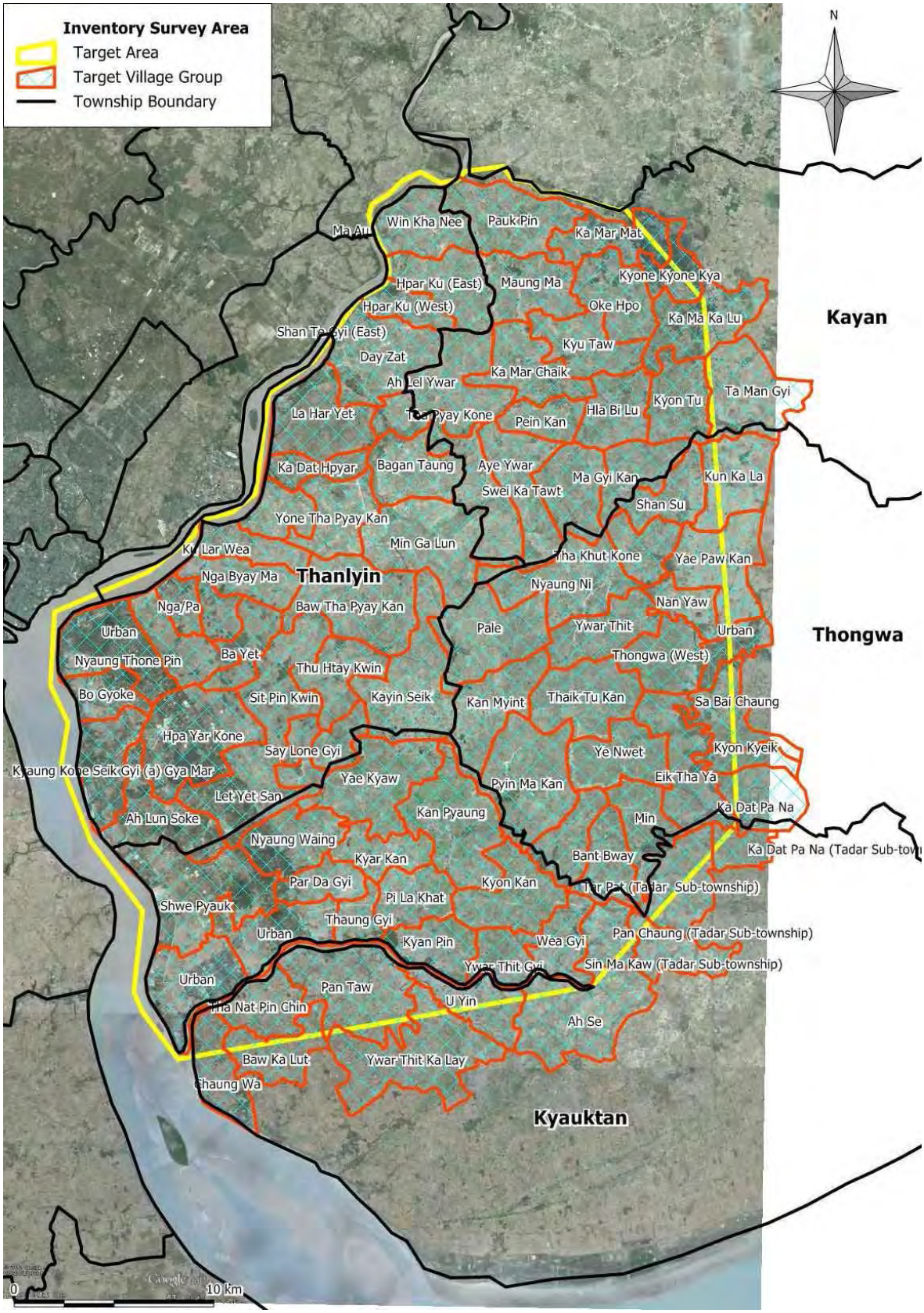


Figure 3-2-3-1 Target Village Group

Table 3-2-3-1 Questionnaire

Inventory Survey for Water Points

Questionnaire Sheet No ----------

Name of Facility	Facility Name					(Remarks)
	Facility ID					
	Water point ID					
Location	Facility Location					(Remarks)
	Lat (WGS84)	D	M	S		
	Lon (WGS84)	D	M	S		
	Address of Owner					
Purpose	Purpose	drinking	domestic	agriculture	industry	Others (Fishery,Building O/M etc)
	Agriculture Use	for paddy field	for dry field	for arboriculture	for green house	Others (Street Greenery,Gardening etc)
Dependence	Dependence	with SW sources	groundwater	emergency water		Others (degree of dependence etc)
Status of Use	Frequency of Use	full time	times in month	times in week	No use	Others (seasonal and emergency use etc)
	Used Hours	hr/day	hr/week	hr/month	hr/year	Others ( )
	Test for Pumping	done	not done			Others ( )
	Date of Test	Y	M	D		
	Pumping Rate	l/min				
	Measured Applied	measuring meters	using measures			Others ( )
Facility Type	Kinds of Facility	shallow well	deep well	collecting channel spring		Others ( )
	Kinds of Well	dug well	driving well	tube well		Others ( )
Facility Structure	Facility Structure	open hole	stone arrangement	concrete lining	steel casing	Others ( )
	Structure Drawing	done	not done	Contractor Name		
	Dimension	m x m x m				
	Depth of facility	m				
	Configuration	circular		square		Others ( )
	Screen Position(1)	from top of casing	m	m		
	Screen Position(2)	from top of casing	m	m		
	Screen Position(3)	from top of casing	m	m		
Aquifer	Geological Log	done	not done	Contractor Name		
	Type of Aquifer	Alluvium	Tertiary Formation	Pre-Tertiary	Volcanics	Others ( )
	Aquifer Test	done	not done	Contractor Name		
	Well Yield	l/min/m				
	Transmissivity	m^2/day				
	Storage Yield					
Pump	Pump Type	electrical pump	hand pump			Others ( )
	Pump Loc	from top of casing	m			
Groundwater Obstacles	GW Obstacles	Observed	Not Observed			
	Status of Obstacles	decreasing amount	increasing amount	wording quality	Rising up well	Others (seawater intrusion & etc)
	Reason of obstacles					Others (not specified reason & etc)
Future Use	Future Use	continue current use	increasing use	decreasing use	stop use	Others (not planned & etc)

Remarks:

Table 3-2-3-2 Number of Facilities Surveyed

Township	Number of Village Groups	Number of Facilities Registered on Inventory	Number of Facilities Identified in Field Survey
Thanlyin	29	10,849	10,786 (73%)
Kyauktan	25	3,028	3,025 (21%)
Kayan	17	1,146	651 (4%)
Tho ngwa	21	229	229 (2%)
SUM	92	15,252	14,691 (100%)

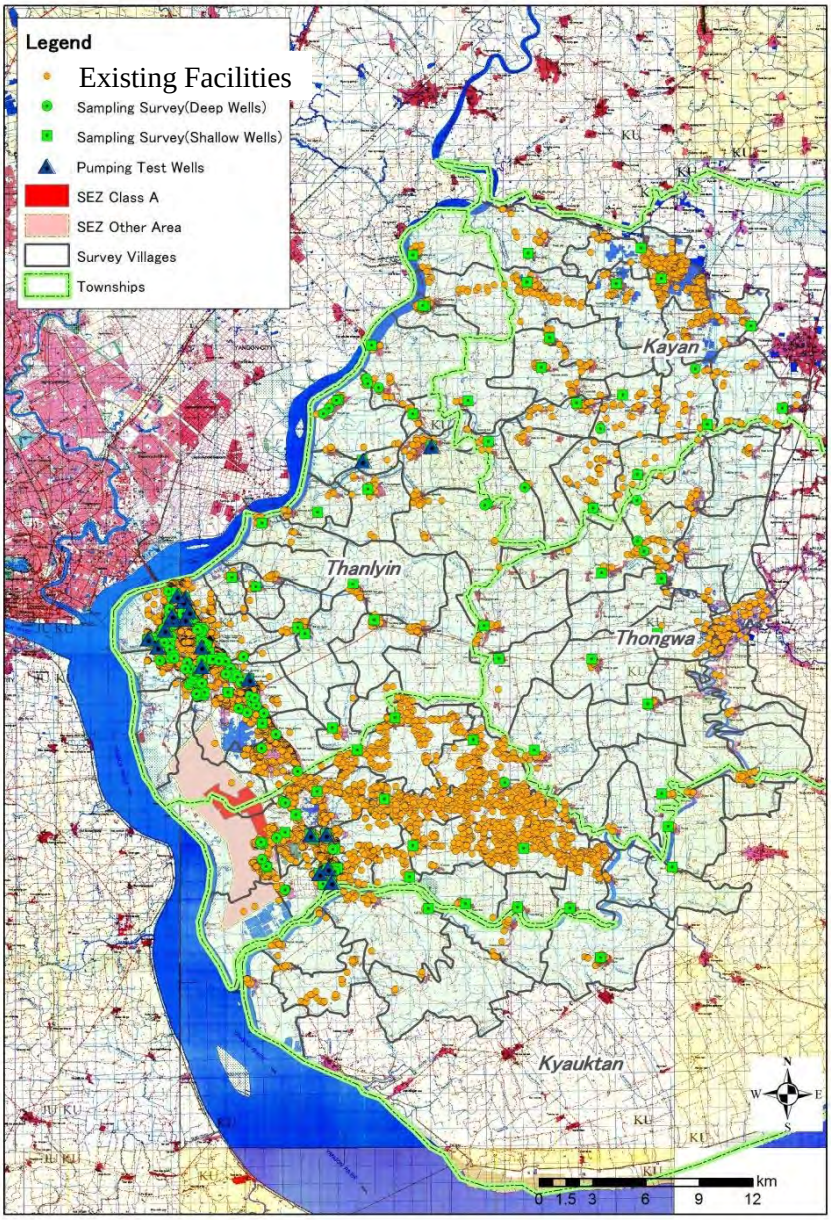


Figure 3-2-3-2 Location of Facilities

(4) Type and Use of Facilities

Dug wells, tube wells and ponds are found as water source facilities. Dug and tube wells are used for domestic and water supply, whereas ponds are multi-purpose, such as for fishery, domestic and water supply as well as being used partly for agriculture.

Figure 3-2-3-3 shows examples of the facilities. At the public facilities, a submergible or air lift pump is used. Pumped water is often delivered through a pipe system. At domestic wells, a bucket, hand pump, or airlift pump is used. At ponds, water is used often by gravity flow in the wet season but mainly by

pumping in the late dry season because of the much-decreased water level.

Dug well with bucket
(Thanlyin)

Dug well with hand pump
(Thanlyin)

Tube well with airlift pump
(Thanlyin)

Pond
(Thongwa, taking water with bucket for domestic use)

Figure 3-2-3-3 Example of Facilities

(5) Well Selection for Areal Observation Well and Pumping Test Well

1) Areal Observation (Monitoring) Well

Among about 12,000 wells in the investigation area, each 100 of the shallow and deep wells were selected for areal monitoring on groundwater quality. Here it is defined that a “shallow well” is one shallower than approx. 30 m, and a “deep well” is one deeper than approx. 30 m. The condition of selection is:

- Selected wells should distribute uniformly in the whole investigation area
- Water can be sampled and, if possible, the water level can be measured as well.

All wells were classified as either shallow or deep wells, and the candidates were selected in each village group. The results are shown in Figure 3-2-3-4 (right).

2) Pumping Test Well

Pumping tests at existing wells were planned in order to widely grasp hydraulic parameters of aquifers in the investigation area. Twenty (20) candidate wells for the test were selected as shown in Figure 3-2-3-4 (left) from among the above-mentioned monitoring wells, considering a selection condition that pumping for the test would be allowed by the owner.

The selected wells are concentrated in the urbanized area of the Thanlyin and Kyauktan townships. This spatial imbalance is not avoidable because a tube well is generally closed, making it difficult to measure the water level, and a dug well distributes in a limited area. After confirmation of the sites and facility conditions by visiting them, three wells were finally selected, and the tests were carried out (see "2-13 Pumping Test at Existing Wells").

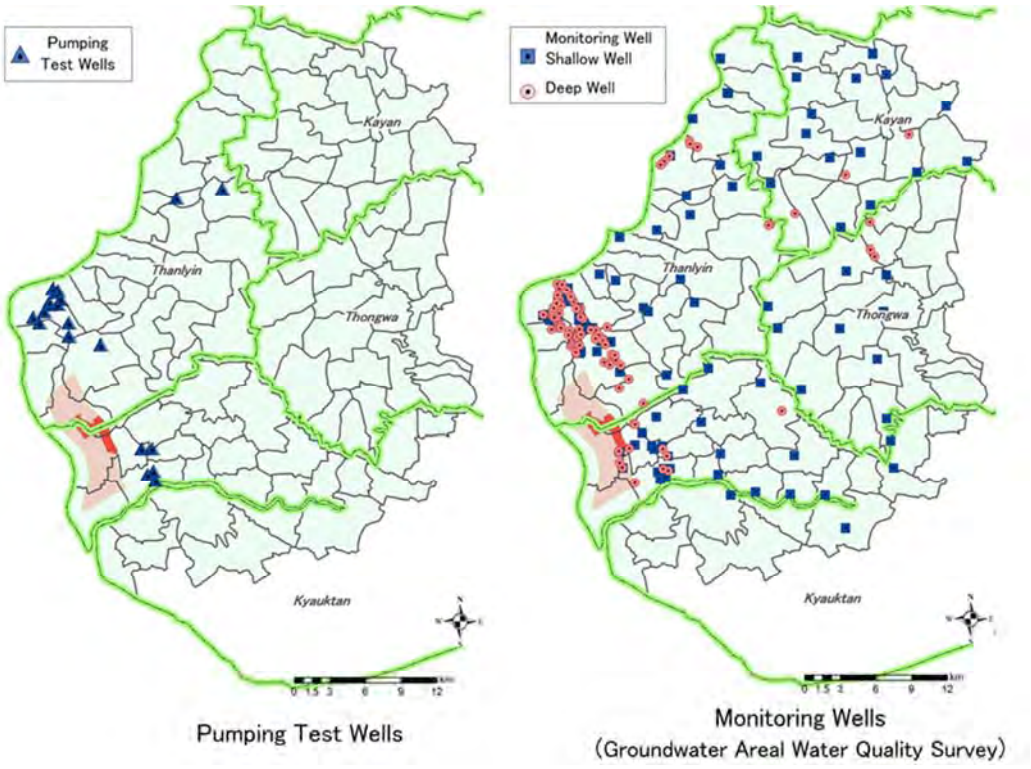


Figure 3-2-3-4 Location of Candidate Wells for Monitoring and Pumping Test

3-2-3-2 Detailed Survey Results

(1) Distribution of Water Source Facilities and Water Use Amount by Township

1) Well

Wells in the investigation area are classified into two kinds: "Tube Well" and "Dug Well". The tube well is drilled by a boring machine, and screen and casing with small diameter are installed. The dug well is excavated manually with digging tools and cased with nothing or lithic material like brick and stone. Figure 3-2-3-5 and Table 3-2-3-3 show number and estimated discharge of these wells by

township. Figure 3-2-3-7 and Figure 3-2-3-8 show spatial distribution of the wells.

There are 8,028 tube wells, among which, 90% are in Thanlyin, 8 % in Kyauktan and 1% in Thongwa and Kayan. There are 4,381 dug wells, among which, 75% are in Thanlyin and 25% in Kyauktan. No working dug well is present in Thongwa or Kayan. As understood with the distribution maps, most wells are located at the Thanlyin-Kyauktan Ridge and its nearby area, and in the eastern plain, only tube wells are scattered.

The discharge was estimated as follows: the first, daily discharge of a well was calculated as the well capacity multiplied by the daily pumping hours. The daily discharge was summed up for all data-known wells. In the end, the sum was corrected with the ratio of data-known wells to all wells. The estimated total discharge in the area is approx. 17,000 m^3/day, in which, Thanlyin gives 81% (approx. 13,500 m^3/day) and Kyauktan, 15% (approx. 2,500 m^3/day). Thongwa and Kayan discharge only 1% (215 m^3/day) and 3% (586 m^3/day) respectively. Most discharge of groundwater is made at the Thanlyin-Kyauktan Ridge and its nearby area. In the eastern plain, the discharge is estimated to be approx. 1,800 m^3/day (11%).

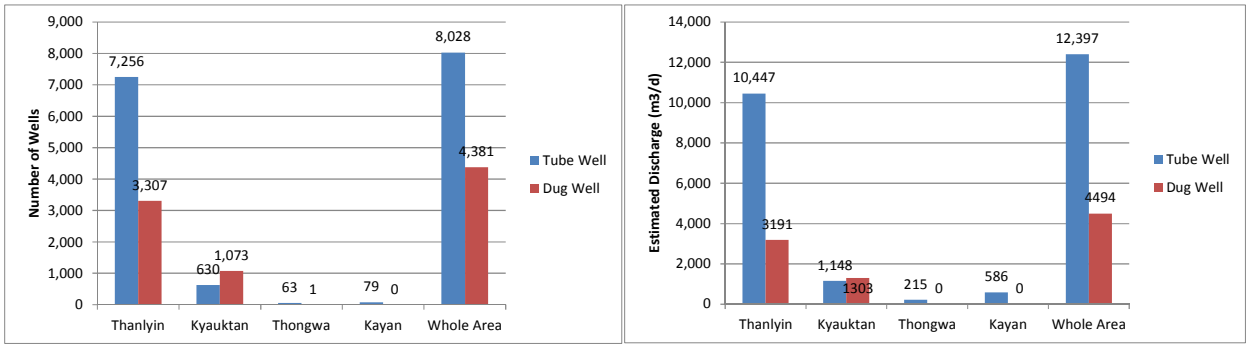


Figure 3-2-3-5 Number and Discharge of Wells in the Survey Area

2) Pond

As shown in Figure 3-2-3-6 and Table 3-2-3-4, there are 2,280 ponds in the investigation area, and most of them are located in the plain as shown in Figure 3-2-3-9. The total capacity is 13.5 MCM. Kayan has a larger capacity of ponds. Kyauktan has a large number of ponds, but this is due to including small ponds which were not targeted in the other Townships.

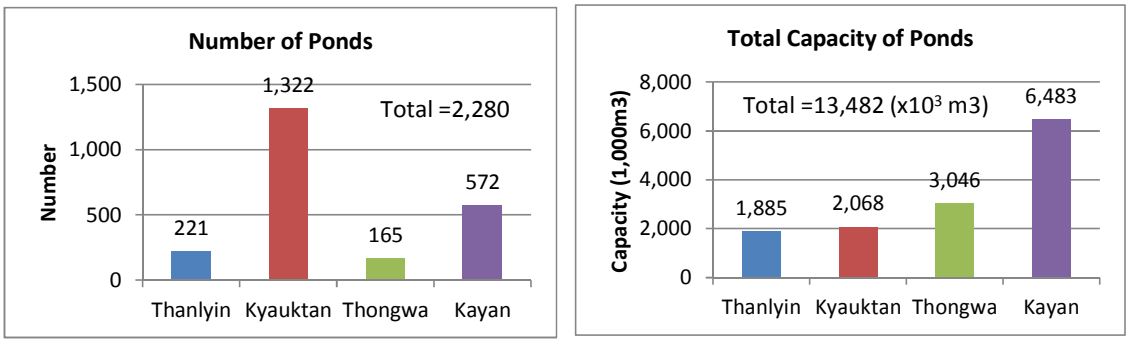


Figure 3-2-3-6 Number and Capacity of Ponds in the Survey Area

Table 3-2-3-3 Number and Estimated Discharge in the Survey Area

Kind of Well	Item		Thanlyin	Kyauktan	Thongwa	Kayan	Whole Area
Tube Well	Number of wells	In use	7,113	551	59	70	7,793
		Out of use	143	79	4	9	235
		Total	**7,256** 90%	**630** 8%	**63** 1%	**79** 1%	**8,028** 100%
	Discharge	Data Count	6,212	398	53	70	6,733
		DataTotal (m^3/day)	9,124	829	193	586	10,733
		Max. (m^3/day)	72.0	29.7	40.8	24.8	72
		Min. (m^3/day)	0.01	0.01	0.50	0.60	0.01
		Average (m^3/day)	1.46	2.08	3.65	8.37	1.59
		Estimated Total Dschrage (m^3/day)	**10,447** 84%	**1,148** 9%	**215** 2%	**586** 5%	**12,397** 100%
Dug Well	Number of wells	In use	3,178	1,029	0	0	4,207
		Out of use	129	44	1	0	174
		Total	**3,307** 75%	**1,073** 24%	**1** 0%	**0** 0%	**4,381** 100%
	Discharge	Data Count	1,530	47	0	0	1,577
		DataTotal (m^3/day)	1,536	60	0	0	1,596
		Max. (m^3/day)	64.8	19.2	0	0	65
		Min. (m^3/day)	0.00384	0.03	0	0	0.00
		Average (m^3/day)	1.00	1.27	0	0	1.01
		Estimated Total Dschrage (m^3/day)	**3191** 71%	**1303** 29%	**0** 0%	**0** 0%	**4494** 100%
All Wells	Number of wells	In use	10,291	1,580	59	70	12,000
		Out of use	272	123	5	9	409
		Total	**10,563** 85%	**1,703** 14%	**64** 1%	**79** 1%	**12,409** 100%
	Diacharge	Estimated Total Dschrage (m^3/day)	**13,639** 81%	**2,451** 15%	**215** 1%	**586** 3%	**16,891** 100%

Note: The target area of Kyauktan, Thongwa and Kayan limited to the groundwater investigation area.
Source: Inventory survey by JICA Survey Team.

Table 3-2-3-4 Number and Capacity of Ponds in the Survey Area

Item		Thanlyin	Kyauktan	Thongwa	Kayan	Total
Number		**221** 10%	**1,322** 58%	**165** 7%	**572** 25%	**2,280** 100%
Capacity (m^3)	Total	**1,885,033** 14%	**2,067,556** 15%	**3,045,956** 23%	**6,483,244** 48%	**13,481,789** 100%
	Maximum	178,204	28,285	251,957	117,344	251,957
	Median	5,448	680	10,206	7,785	-
	Minimum	307	5	68	384	5
Length (m)	Maximum	244	91	376	402	402
	Median	51	18	61	80	-
	Minimum	14	1	6	14	1
Width (m)	Maximum	411	122	274	209	411
	Median	40	18	46	51	-
	Minimum	12	1	6	4	1
Depth (m)	Maximum	7.6	10.4	7.6	6.1	10
	Median	2.4	2.1	3.1	1.5	-
	Minimum	0.6	0.3	1.3	1.2	0.3
	Average	2.7	2.3	3.4	1.9	2.3

Note: Small ponds in Thanlyin, Thongwa and Kayan maybe not counted.

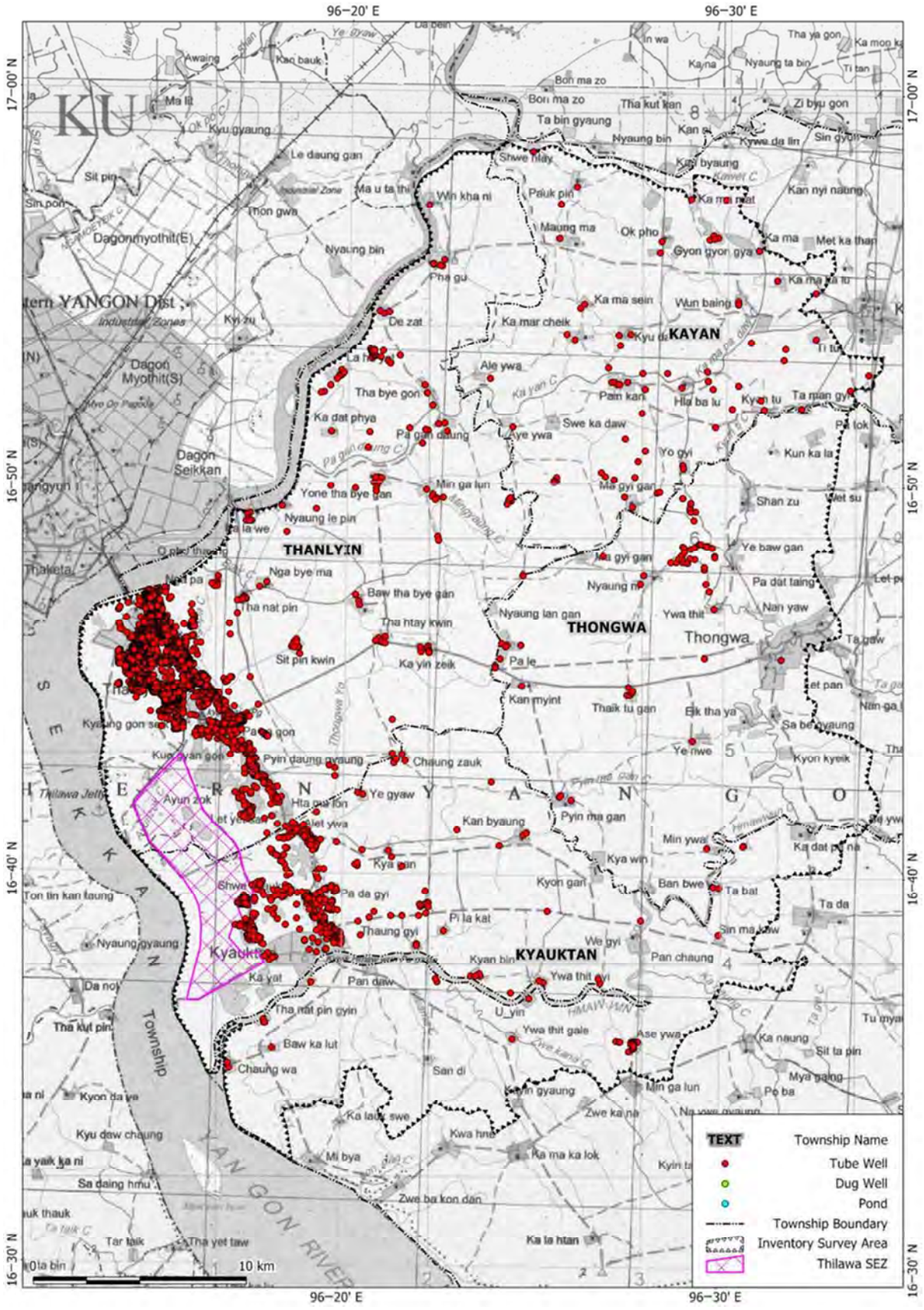


Figure 3-2-3-7 Distribution of Tube Wells in the Survey Area

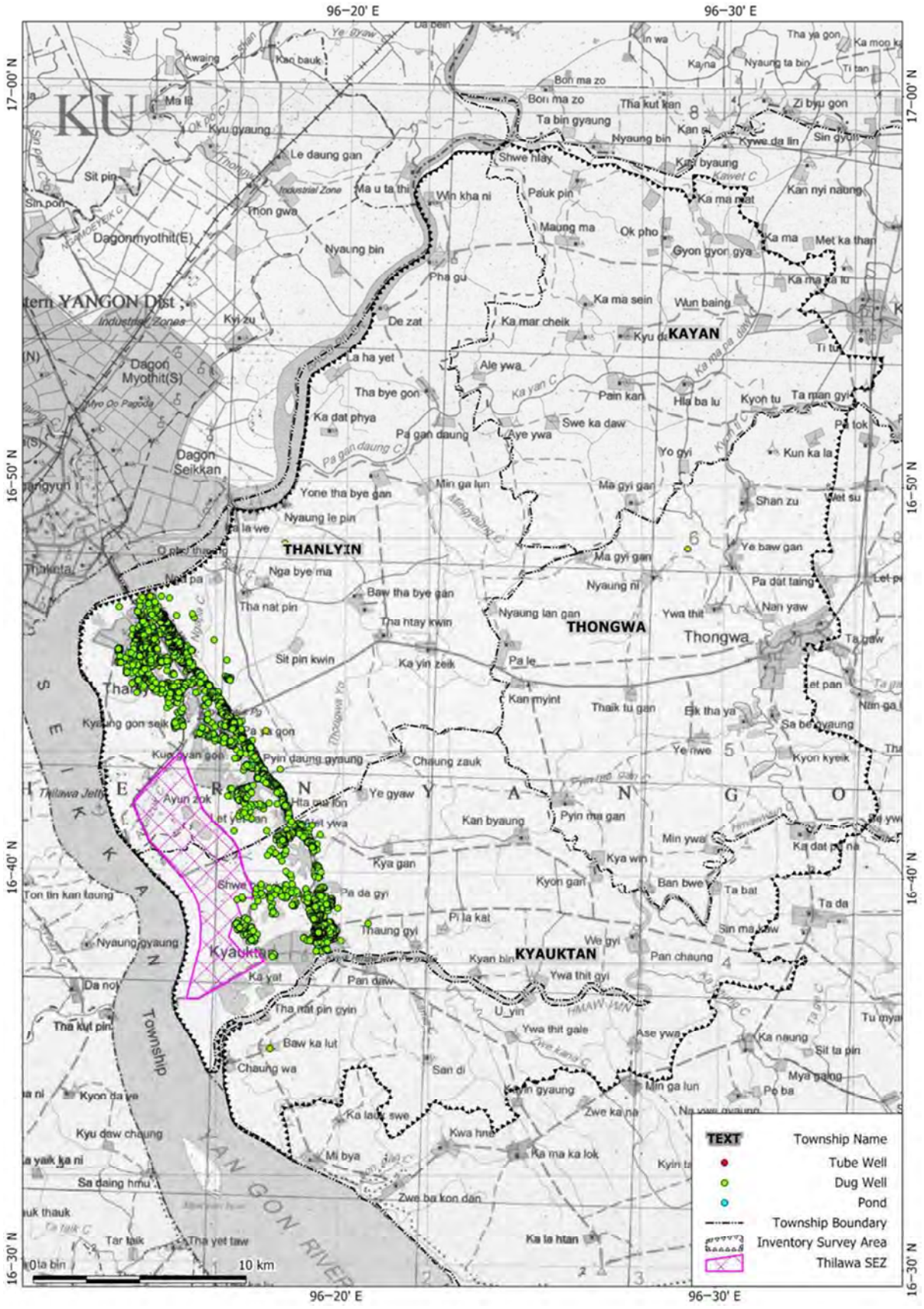


Figure 3-2-3-8 Distribution of Dug Wells in the Survey Area

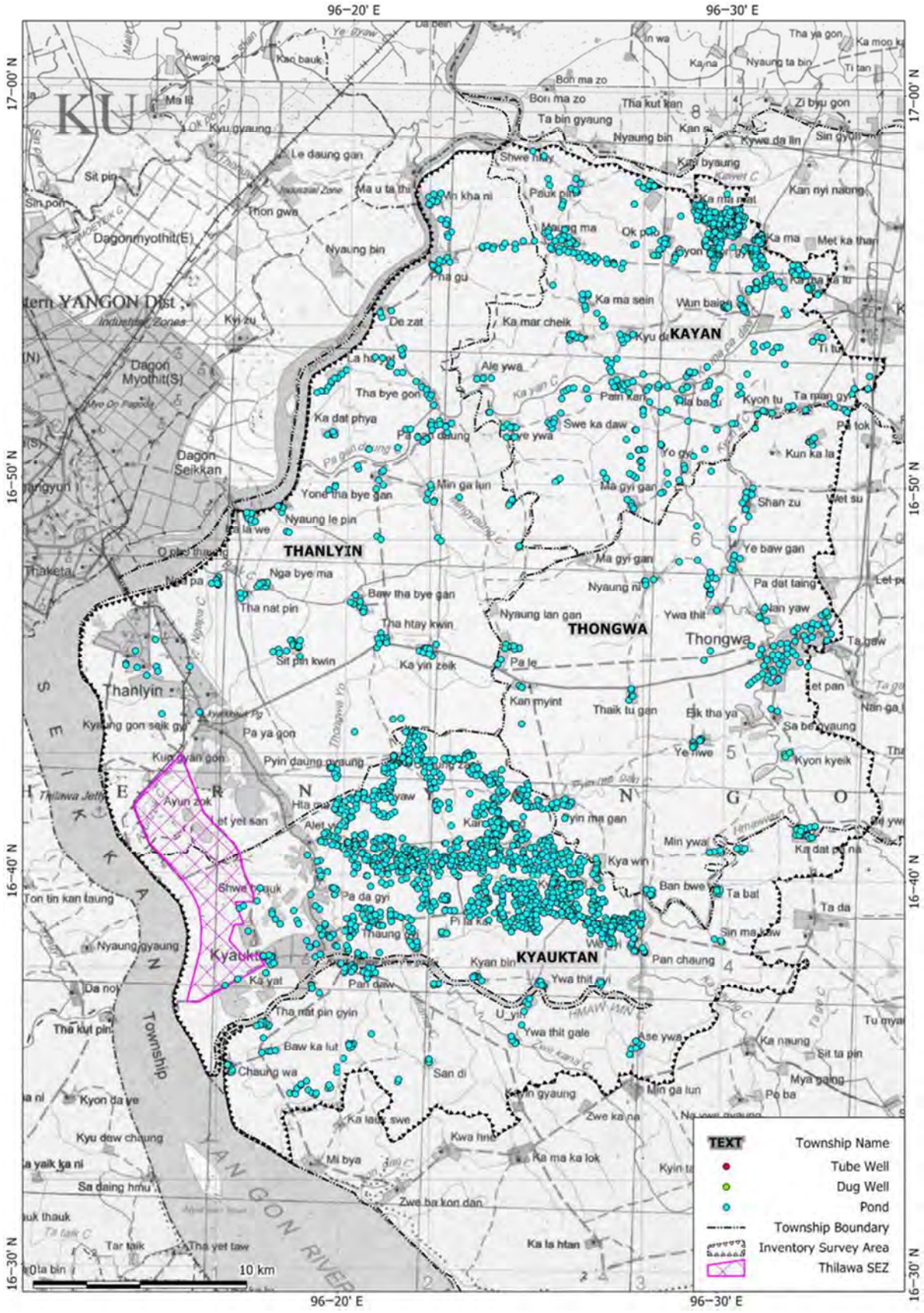


Figure 3-2-3-9 Distribution of Ponds in the Survey Area

(2) Attributes of Tube Well

1) Installation Year

As shown in Figure 3-2-3-10, the tube wells increased their number after 1995. 1,501 wells were installed during 2011 and 2012 mostly in the Thanlyin Township. They must be increasing even now.

2) Depth

Figure 3-2-3-11 and Figure 3-2-3-16 to Figure 3-2-3-19 show the value and spatial distribution of depth of the tube wells. The depth differs much between Thanlyin and Kyauktan which have hills and in Thongwa and Kayan which are located in the plain. In the former townships, the depth value has a peak frequency at 30~40 m intervals and distributes continuously to a hundred and a few tens of meters decreasing in number. On the contrary, in the latter townships, the depth value distributes less than 20m and greater than 100~110 m, but does not distribute between these ranges. This implies that there is no available aquifer between 20 m and 110 m underground in the plain. It is notable that one smaller frequency peak is found at around 100 m in Thanlyin and Kyauktan.

3) Diameter

As shown in Figure 3-2-3-12, the diameter of the tube well is mostly 2" (0.05 m). A well with over 4" (0.10 m) diameter distributes only in Thanlyin.

4) Daily Pumping Hours

As shown in Figure 3-2-3-13, the daily pumping hours of the tube well are mostly less than one hour and rarely exceed three hours. In Kayan, a well is used longer. This may be because it is used mainly for public water supply, and its capacity is relatively small compared with the requirement.

5) Capacity

As shown in Figure 3-2-3-14, the capacity of the tube well has peaks of frequency around intervals of 20~40 l/min, 60~70 l/min and 200~300 l/min. In Kayan, it ranges completely in and below 20~30 l/min. In other townships, there are also found larger capacity values such as 200~400 l/min.

6) Daily Discharge

As shown in Figure 3-2-3-15, the daily discharge of the tube well has a large frequency less than one (1) m^3 and is mostly less than a few m^3/day. The average is 1.5 m^3/day in Thanlyin, 2.1 m^3/day in Kyauktan, 3.7 m^3/day in Thongwa and 8.4 m^3/day in Kayan. A reason why the value is larger in Thongwa and Kayan may be because the water is mainly used for public supply.

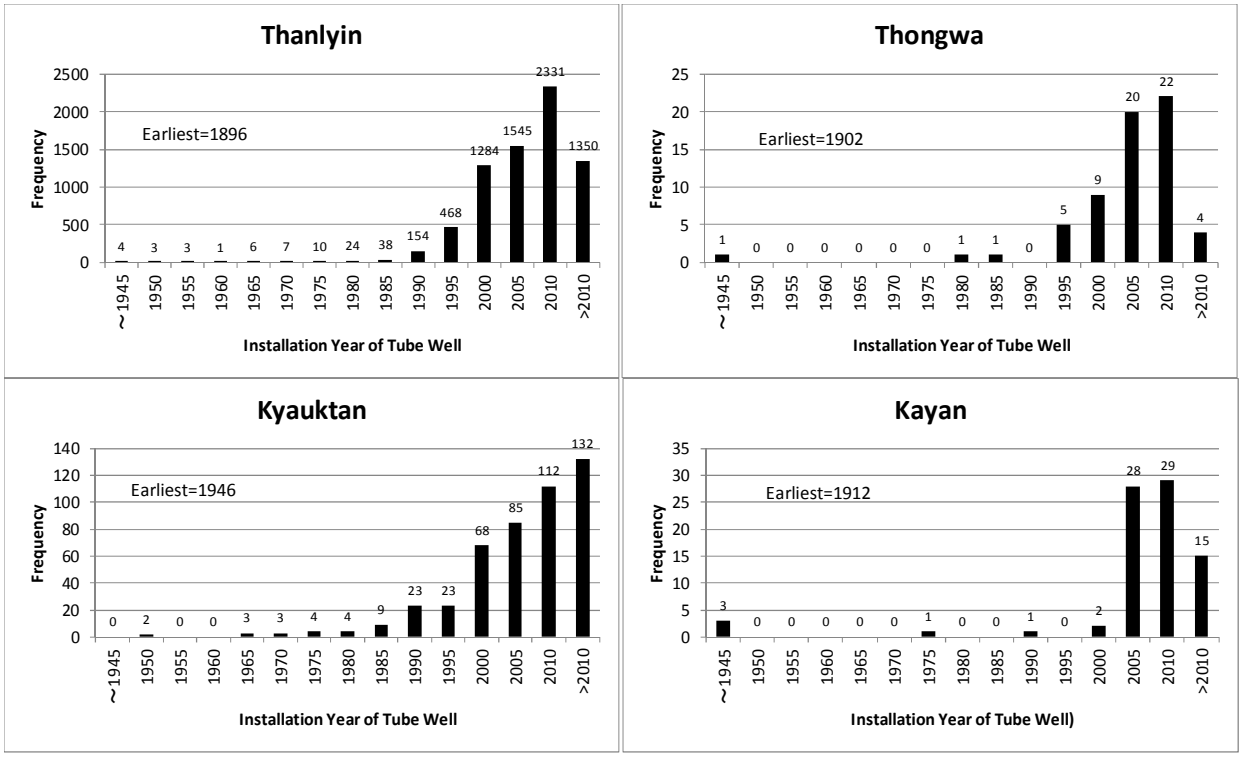


Figure 3-2-3-10 Installation Year of Tube Well (as of Dec., 2012)

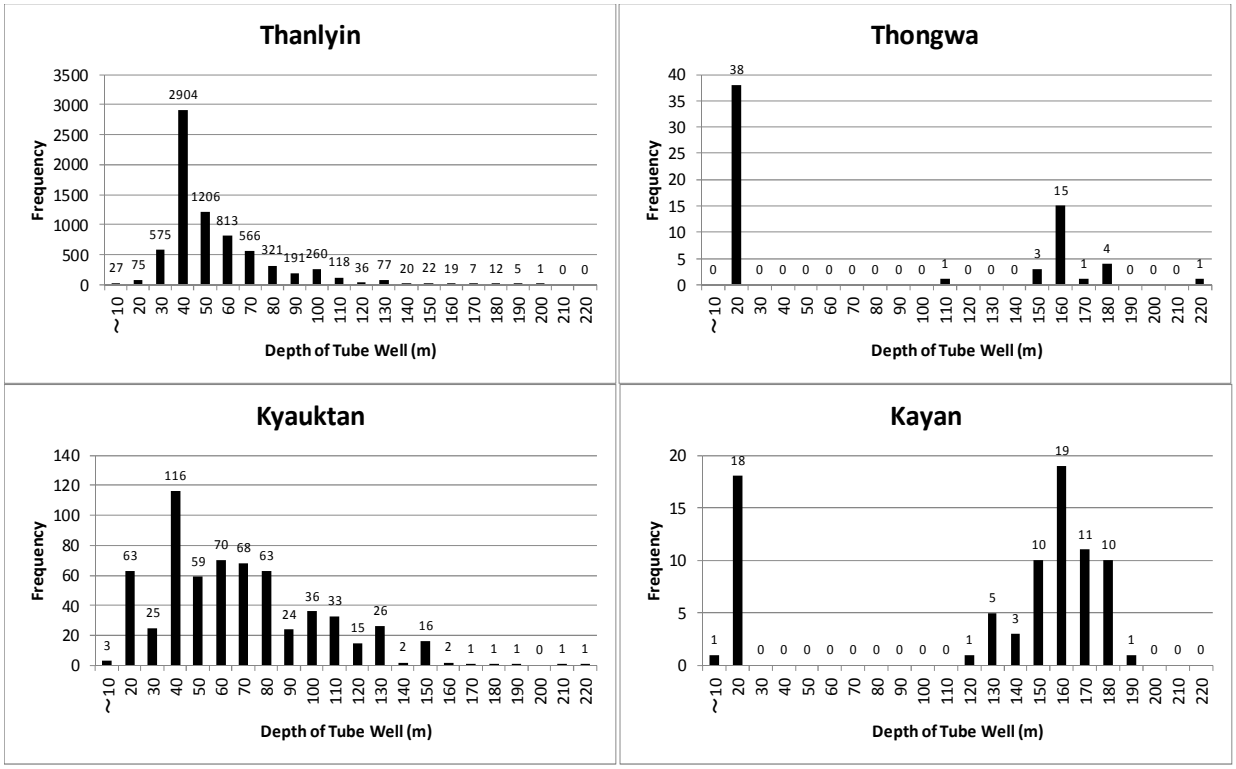


Figure 3-2-3-11 Depth of Tube Well

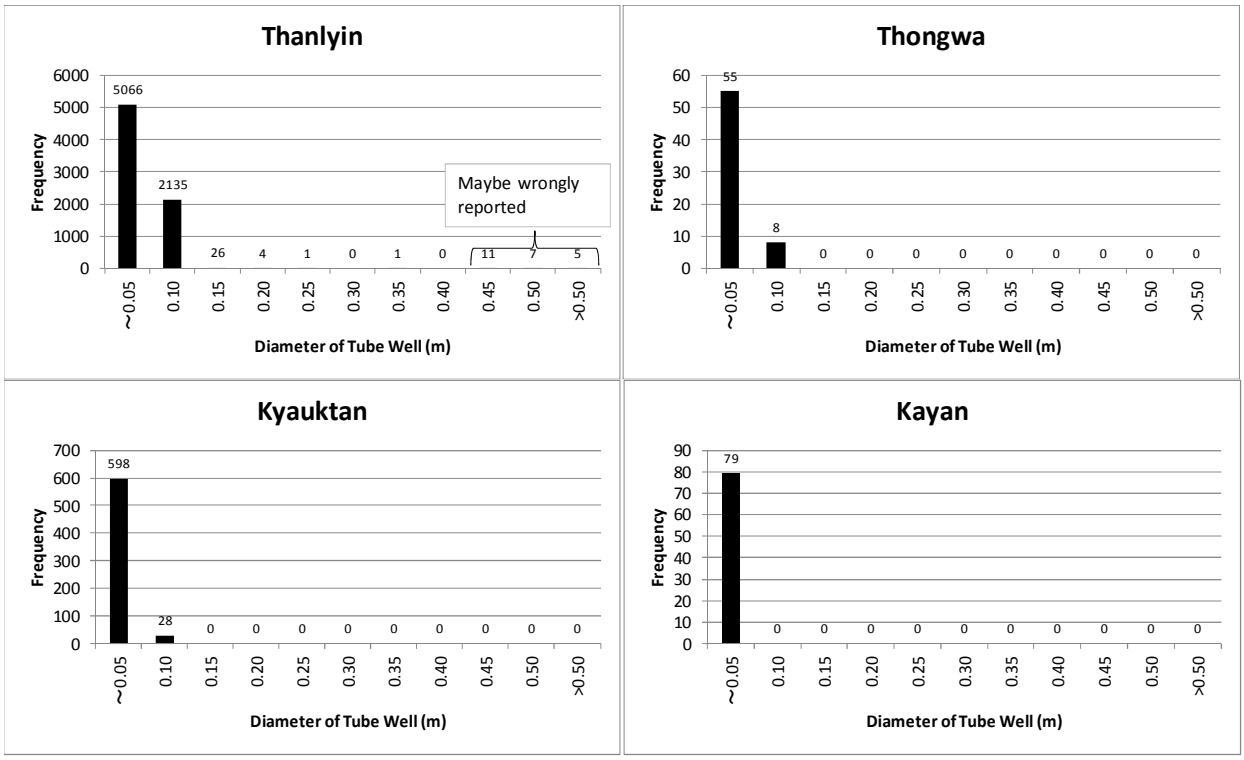


Figure 3-2-3-12 Diameter of Tube Well

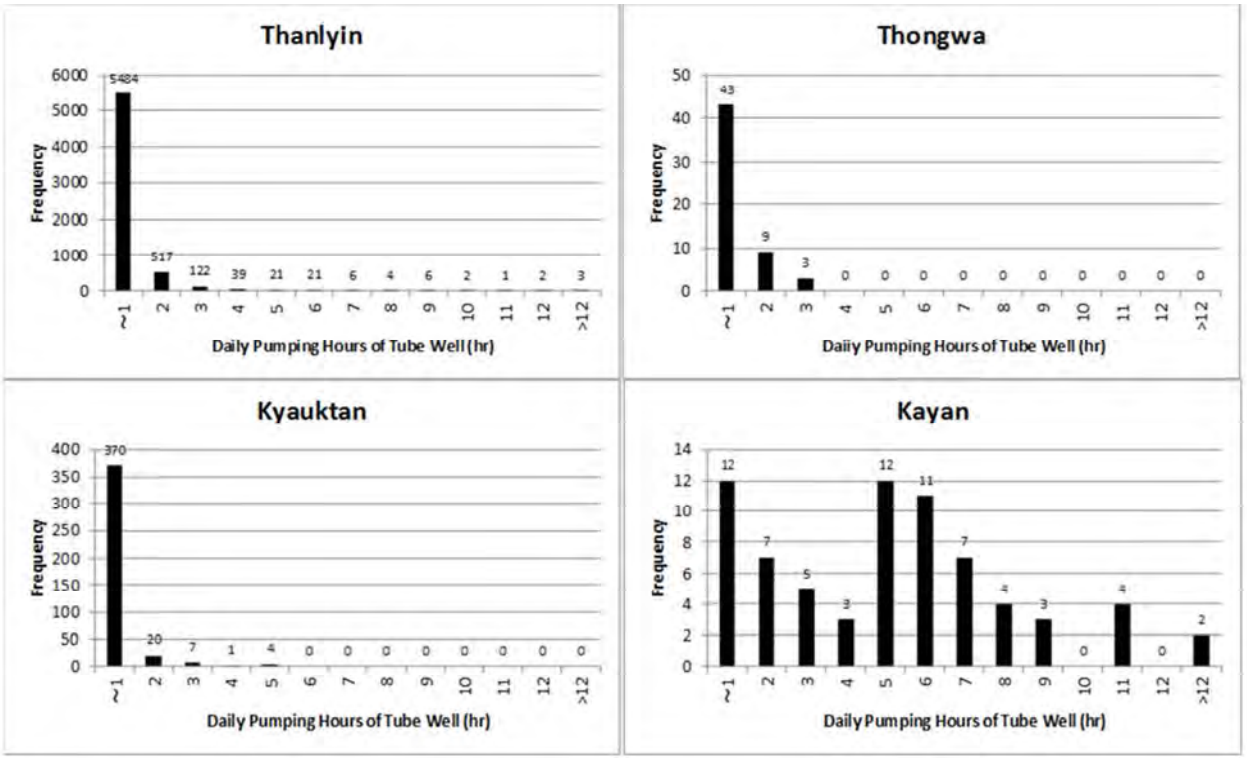


Figure 3-2-3-13 Daily Pumping Hours of Tube Well

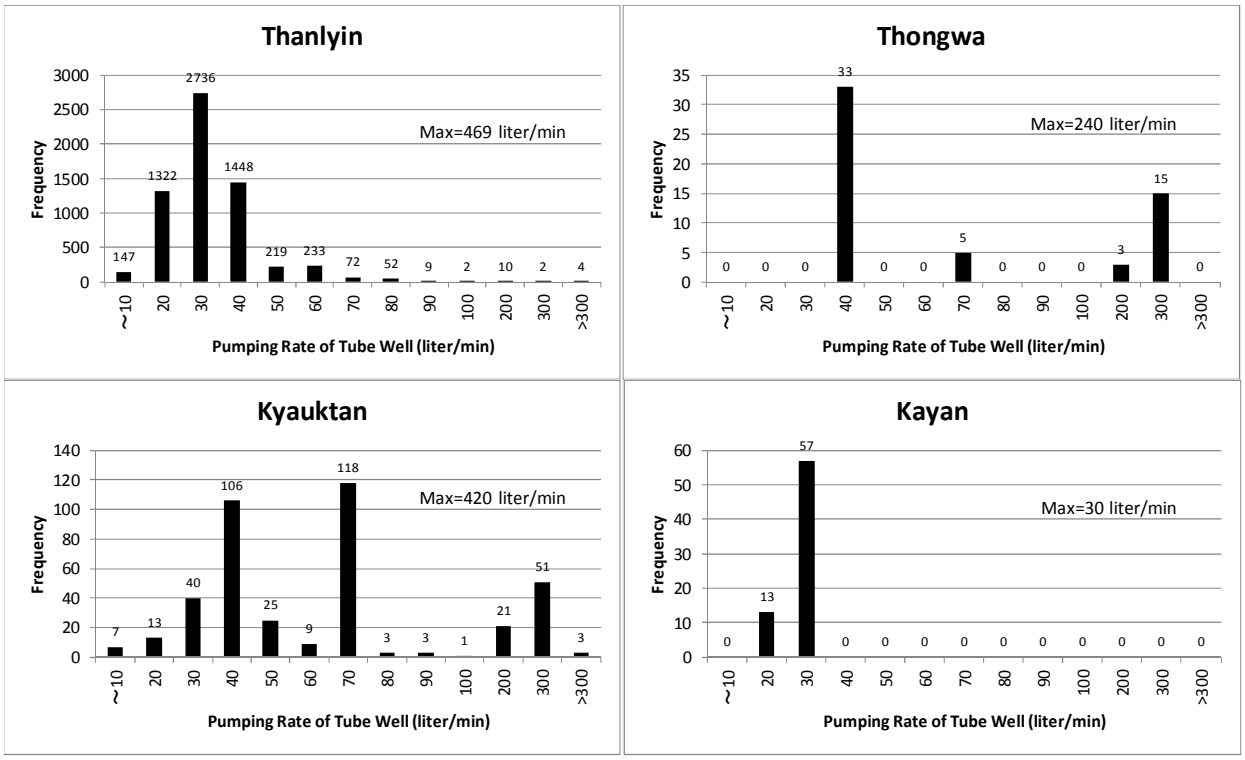


Figure 3-2-3-14 Capacity of Tube Well

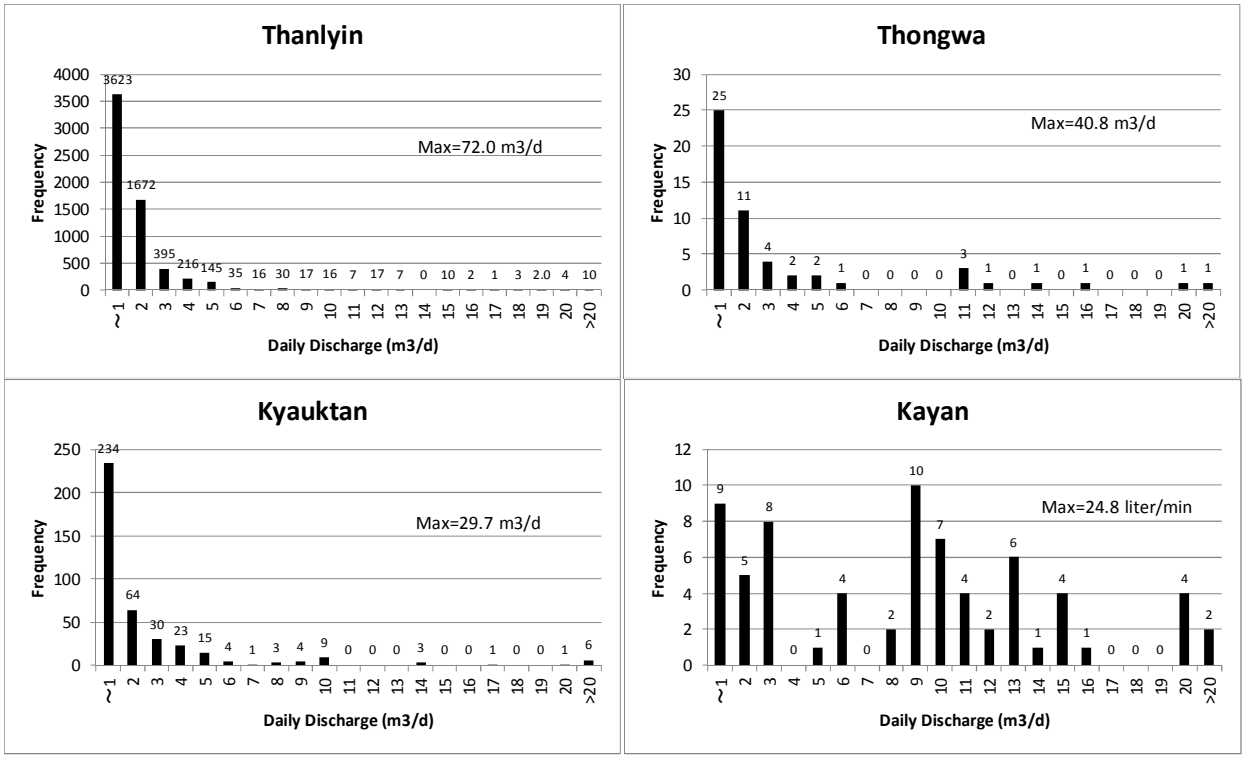


Figure 3-2-3-15 Daily Discharge of Tube Well

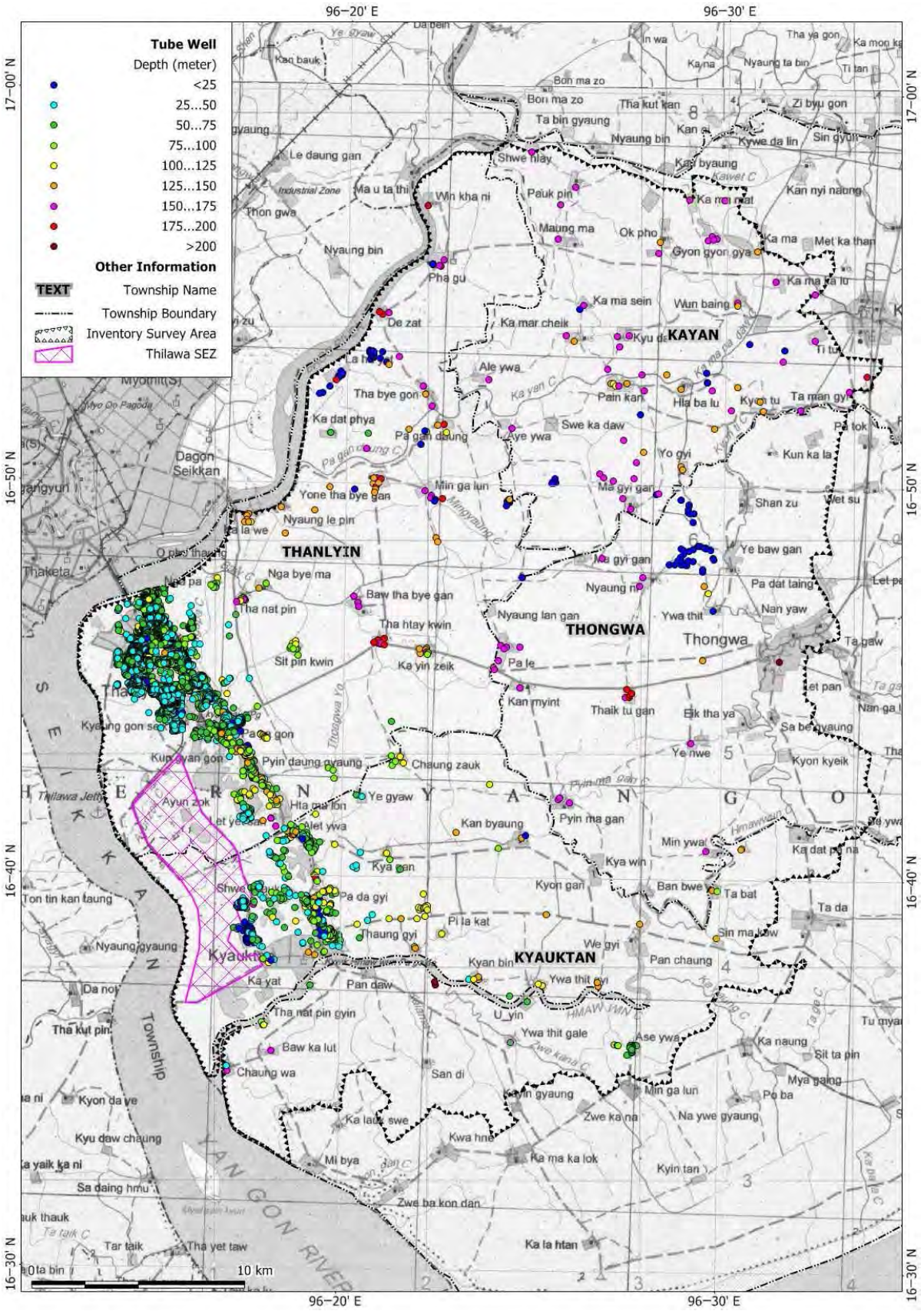


Figure 3-2-3-16 Spatial Distribution of Tube Well Depth (Whole Area)

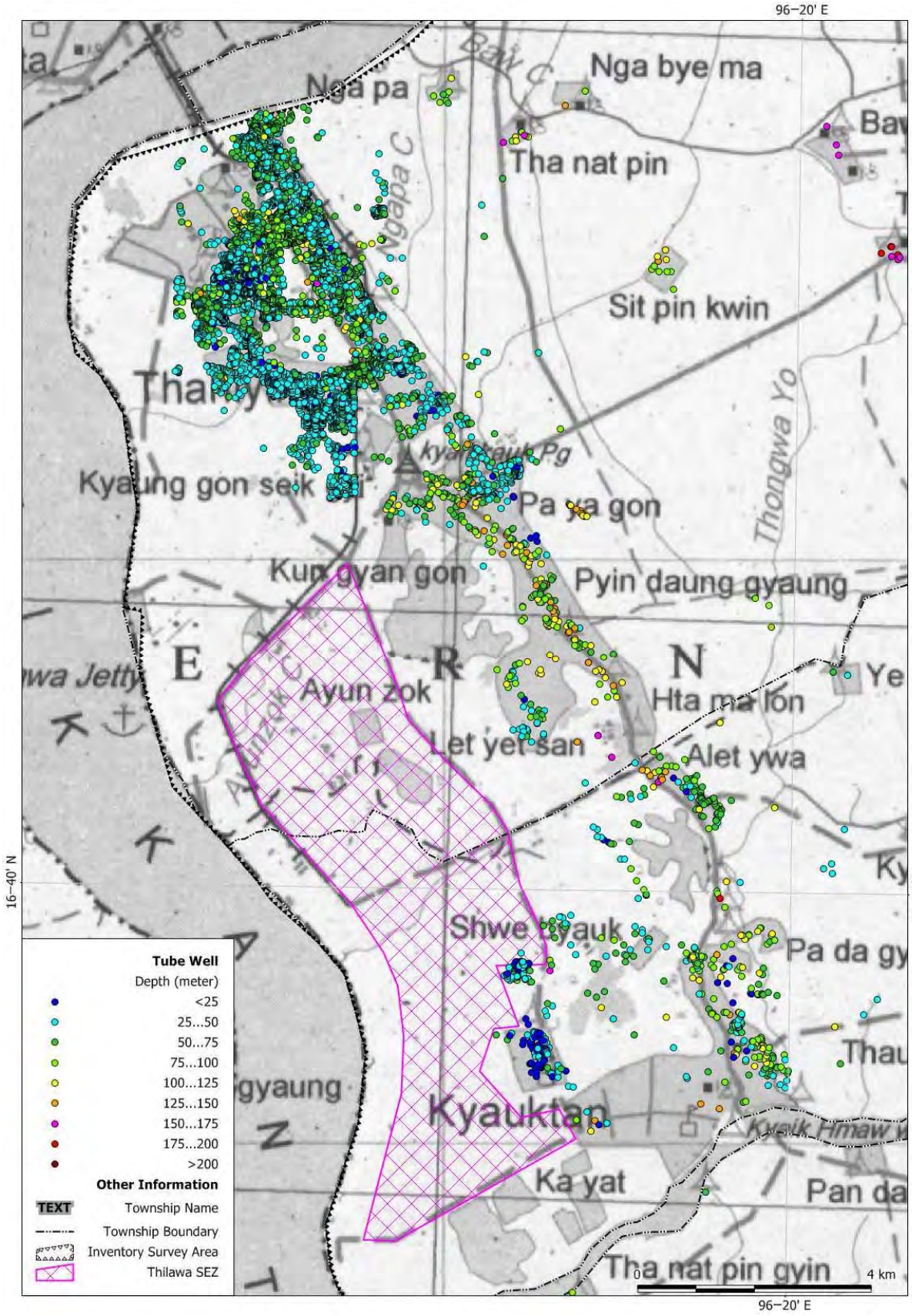


Figure 3-2-3-17 Spatial Distribution of Tube Well Depth (in and near the Hill)

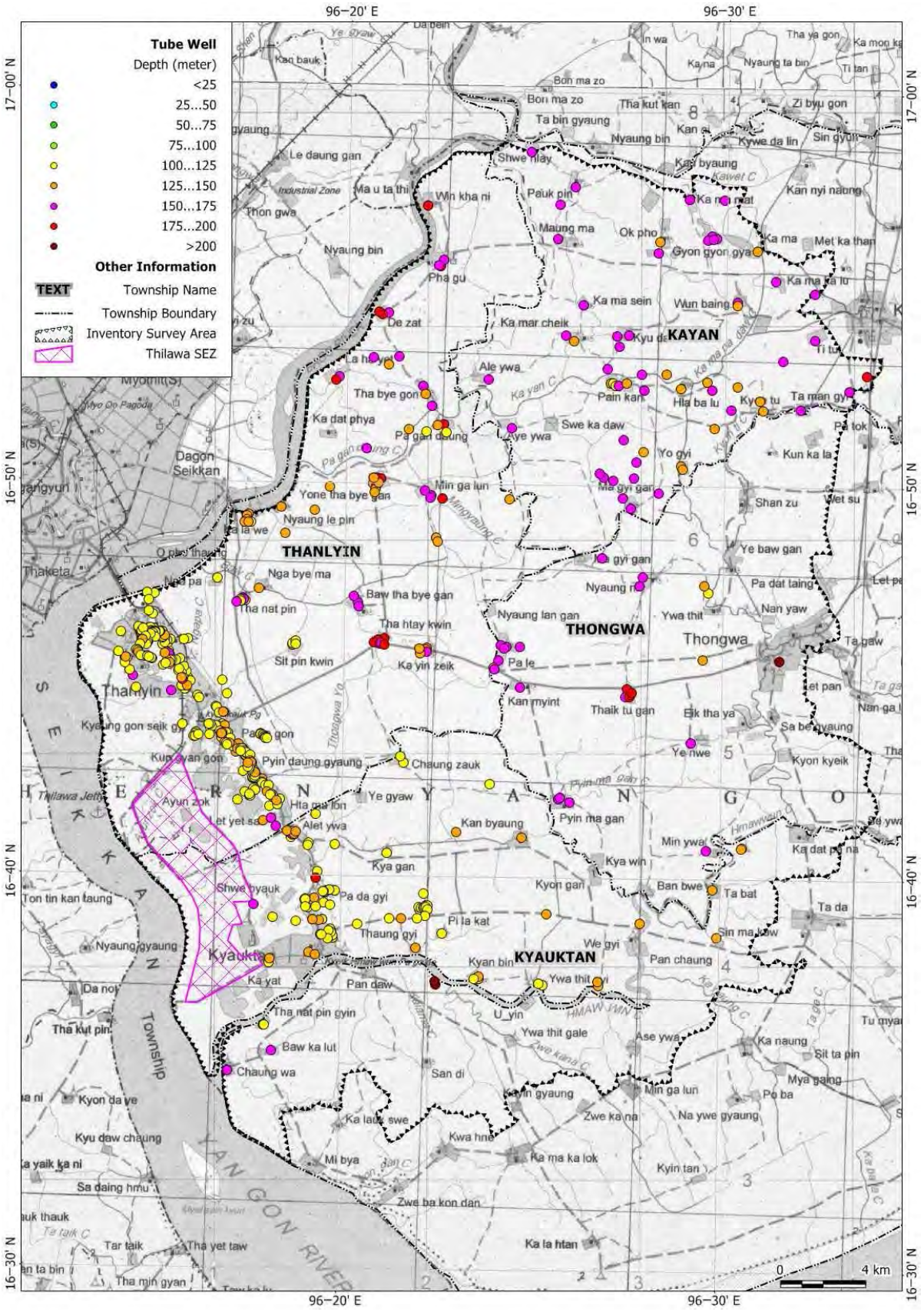


Figure 3-2-3-18 Spatial Distribution of Tube Well Depth greater than 100m (Whole Area)

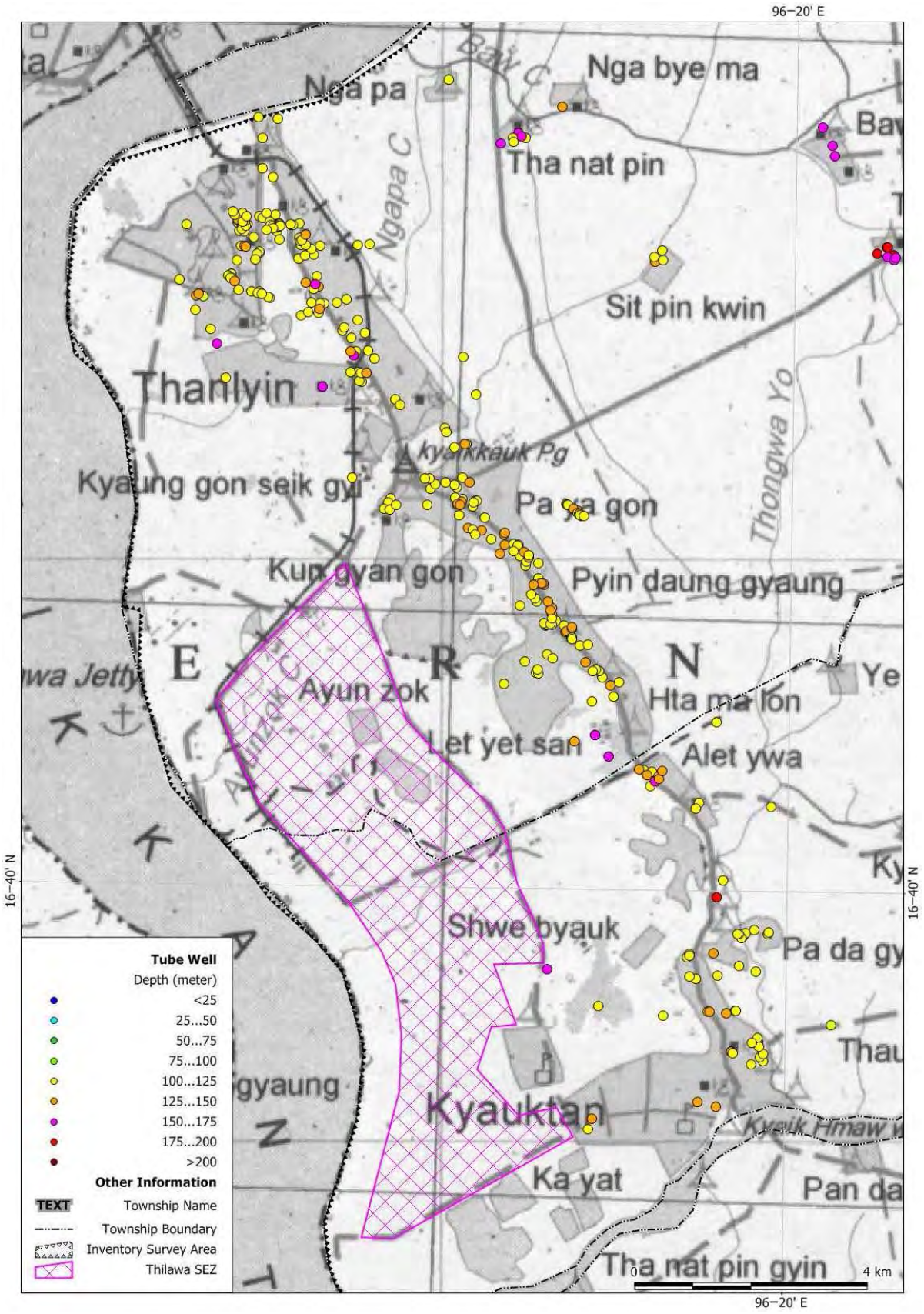


Figure 3-2-3-19 Spatial Distribution of Tube Well Depth greater than 100 m (in and near the Hill)

(3) Attributes of Dug Well

1) Construction Year

As shown in Figure 3-2-3-20, the dug wells also much increased their number after 1995 and they must be increasing even now.

2) Depth

Figure 3-2-3-21, Figure 3-2-3-27 and Figure 3-2-3-28 show value and spatial distribution of depth of dug wells. They distribute only in the Thanlyin-Kyauktan Ridge and its nearby area. Their depth is mostly less than 10 m. Some wells with depths greater than 15m are found in the hill.

3) Diameter

As shown in Figure 3-2-3-22, the diameter of the dug well is mostly 0.75 to 2 m.

4) Daily Pumping Hours

As shown in Figure 3-2-3-23, the daily pumping hours are mostly less one (1) hour. 50% of the wells have no data. They may use a bucket to take water.

5) Capacity

As shown in Figure 3-2-3-24, the pump capacity of the dug well is mainly 10 to 30 l/min.

6) Daily Discharge

As shown in Figure 3-2-3-25, the daily discharge of the dug well mainly distributes in less than one (1) m^3/day and mostly falls in less than a few m^3/day. A well without the data provably discharges less than one (1) m^3/day, because water is taken with a bucket.

7) Groundwater Table Depth

A well could be dug down to a few meters below the groundwater table. As shown in Figure 3-2-3-26, the water table depth in the dug well falls mostly within 8 m.

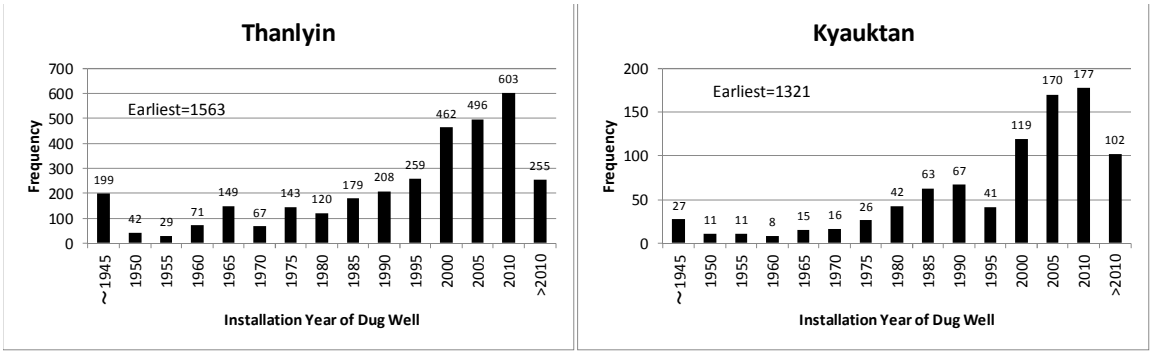


Figure 3-2-3-20 Installation Year of Dug Well

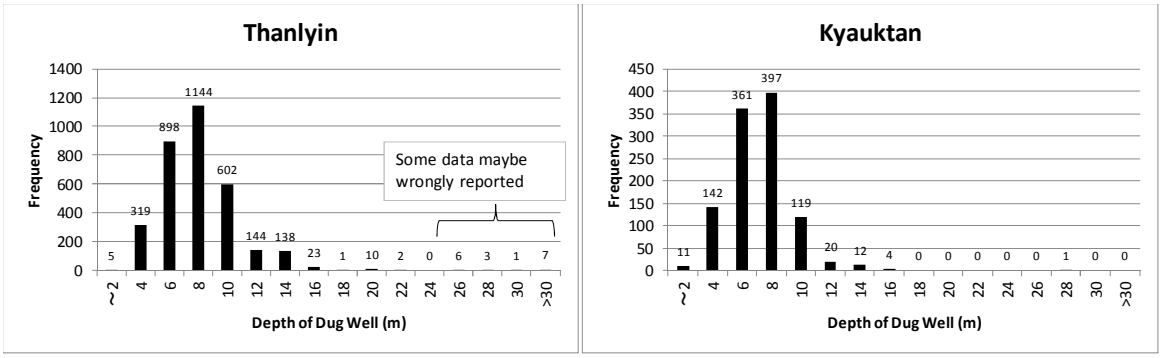


Figure 3-2-3-21 Depth of Dug Well

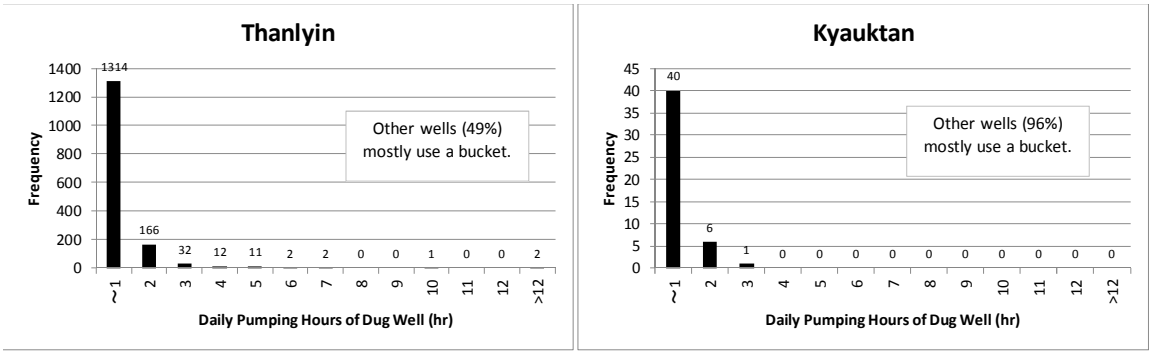


Figure 3-2-3-22 Diameter of Dug Well

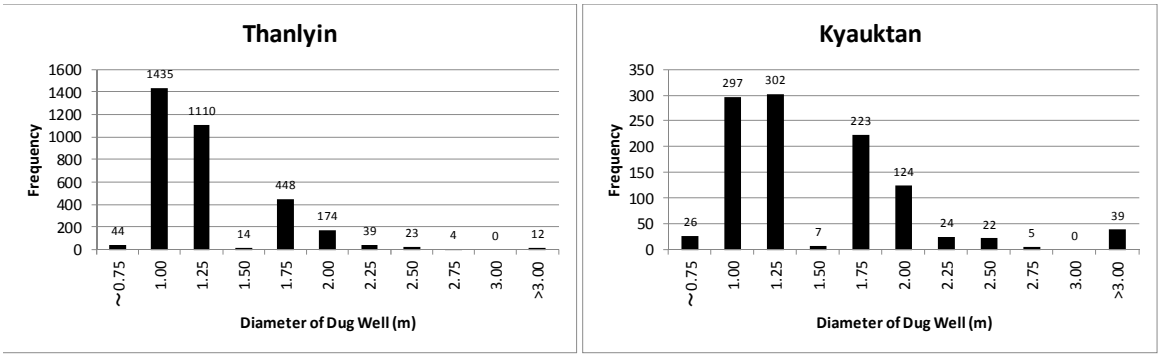


Figure 3-2-3-23 Daily Pumping Hours of Dug Well

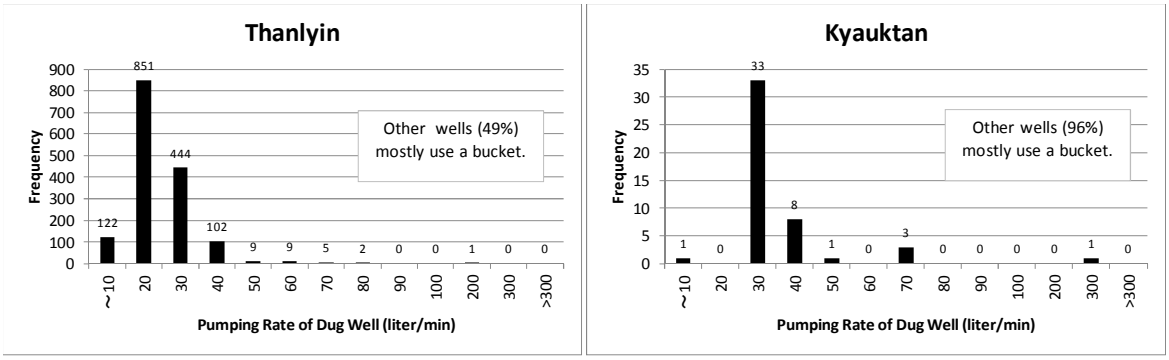


Figure 3-2-3-24 Pumping Capacity of Dug Well

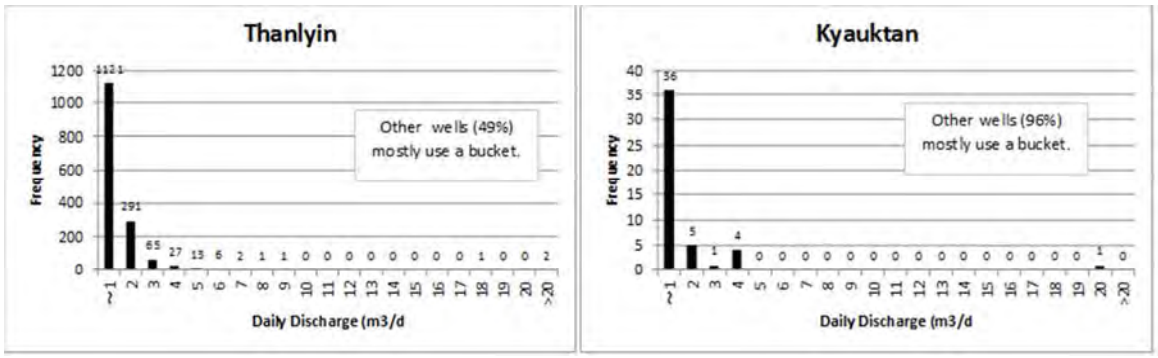


Figure 3-2-3-25 Daily Discharge of Dug Well

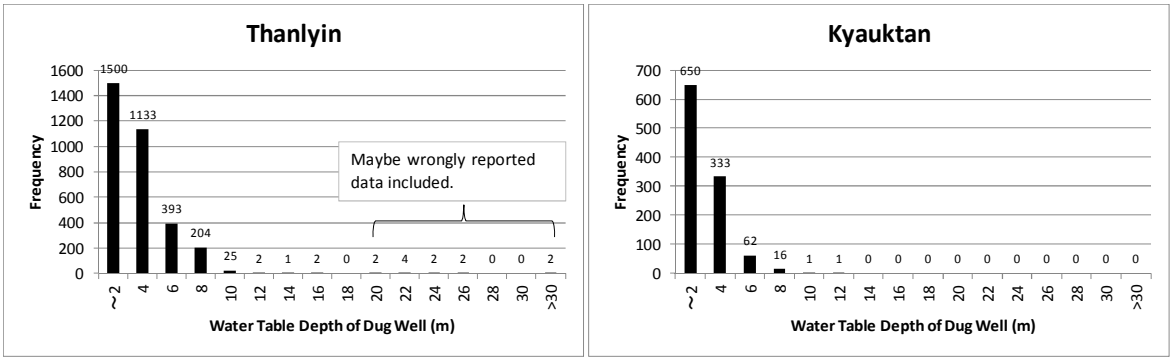


Figure 3-2-3-26 Groundwater Table Depth of Dug Well

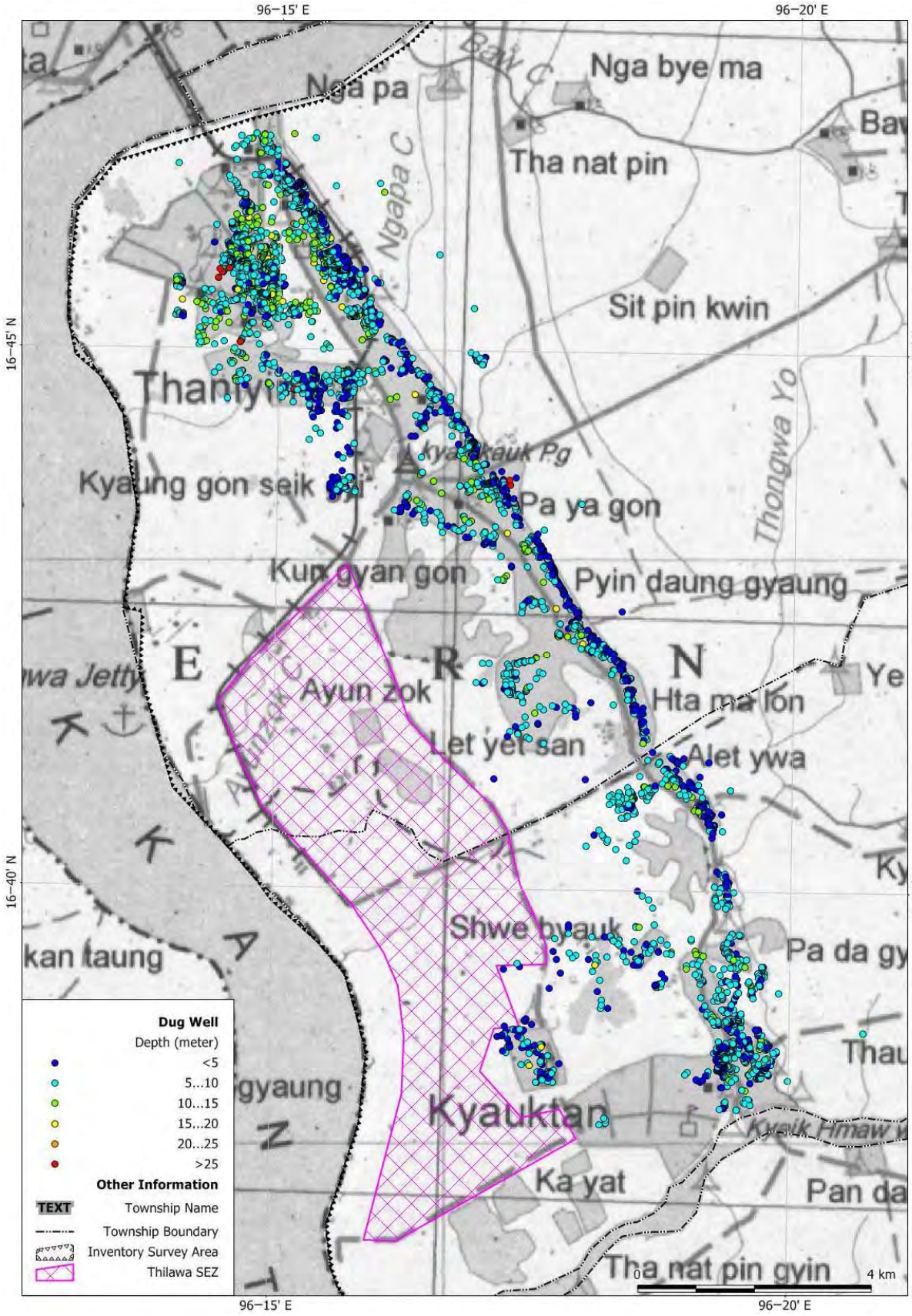


Figure 3-2-3-27 Spatial Distribution of Dug Well Depth (In and near the Hill)

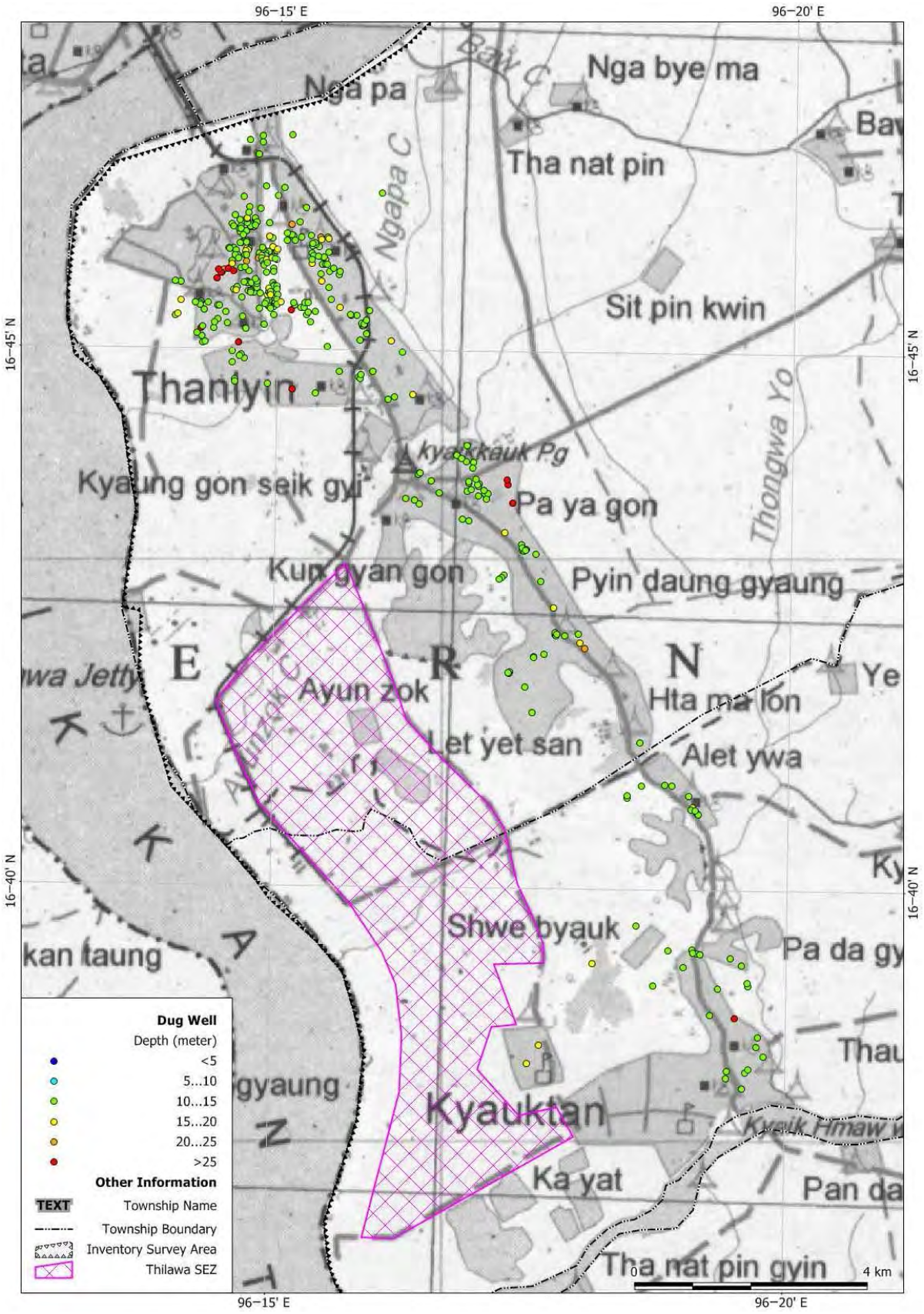


Figure 3-2-3-28 Spatial Distribution of Dug Well Depth greater than 10 m (In and near the Hill)

(4) Pond

1) Construction Year

As shown in Figure 3-2-3-29, the pond was constructed years ago, and it is understood that the pond was a main water source facility in the region. In Kayan, many ponds were added in the 1980's and 1990's.

2) Length and Width

A pond has a rectangular or square configuration in the plan. As shown in Figure 3-2-3-30 and Figure 3-2-3-31, the length and width of the pond ranges mostly from 20 to 80 m. In Kyauktan, ponds smaller than 20 m long/wide dominate. However, in the other three townships, such small-scaled ones are probably not included in the inventory as shown in Figure 3-2-3-35. In Kayan and Thongwa, large-scaled ponds greater than 100 m are found. Such large ones are rarely found in Kyauktan.

3) Depth

As shown in Figure 3-2-3-32, the depth of the pond is about 1 to 5 m. The average is 2.3 m as shown above in Table 3-2-3-4. In Thongwa, it is 3.4 m and deeper than in the other townships.

4) Capacity

As shown in Figure 3-2-3-33, the capacity of the pond mainly varies from a few to 15 thousand m^3. In Kyauktan, the dominant capacity is less than 1,000 m^3. As shown in Figure 3-2-3-34, a large capacity pond is found more in Kayan and Thongwa.

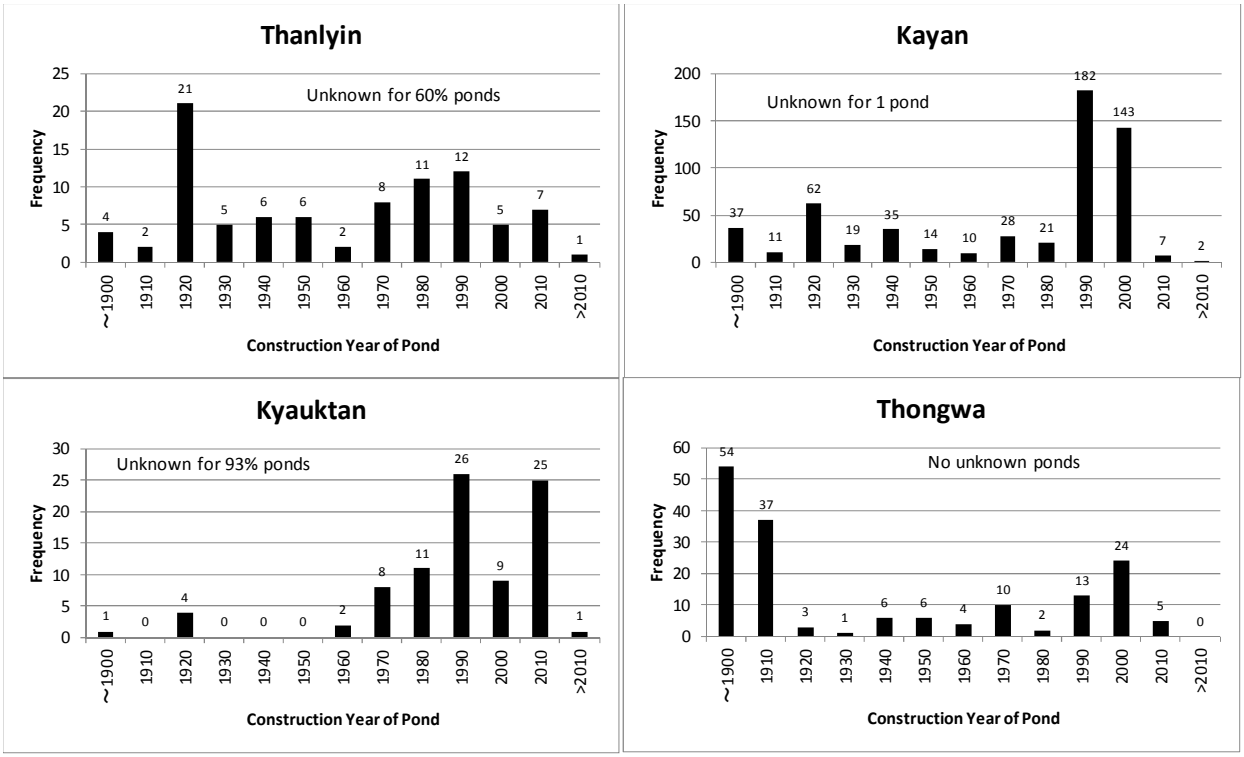


Figure 3-2-3-29 Installation Year of Pond

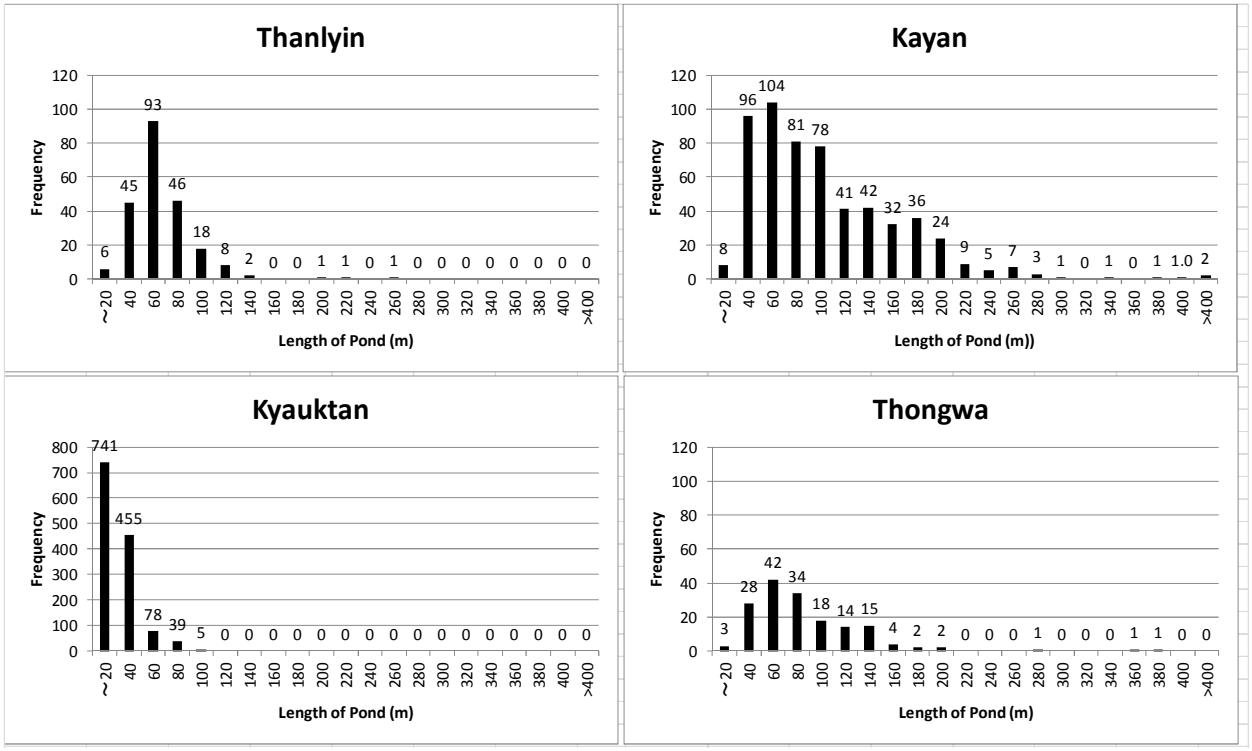


Figure 3-2-3-30 Length of Pond

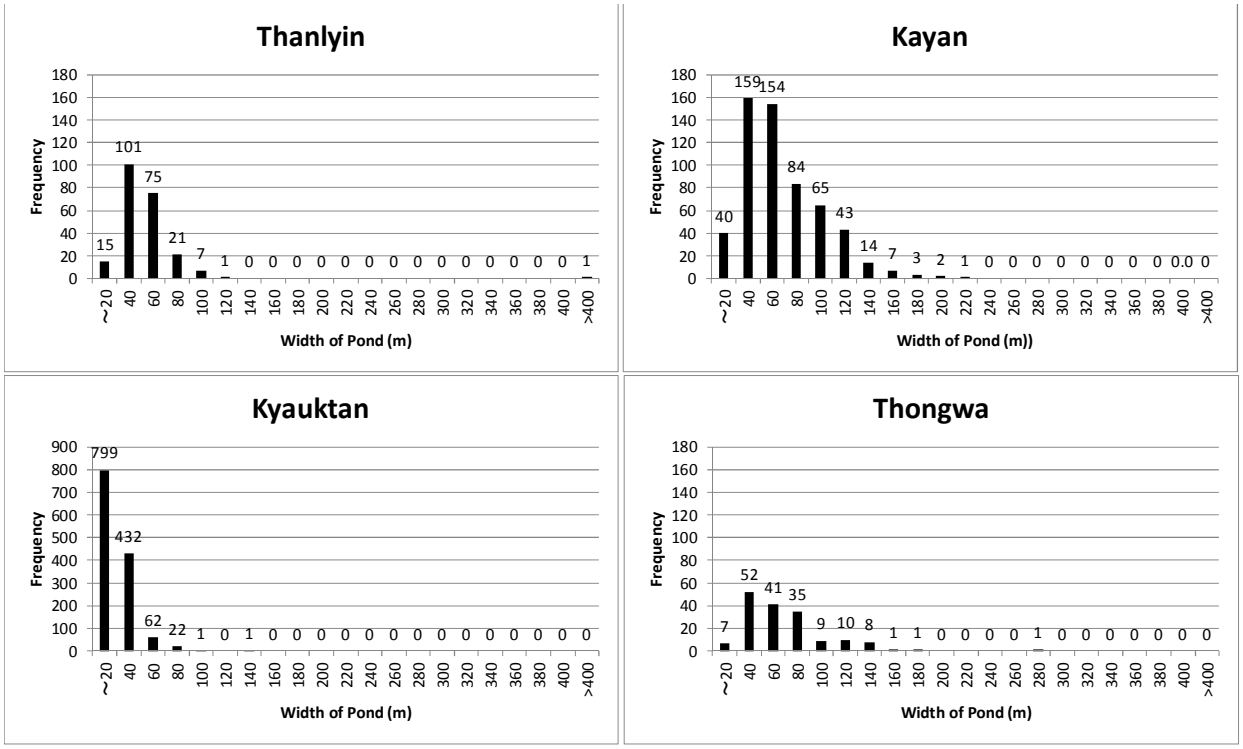


Figure 3-2-3-31 Width of Pond

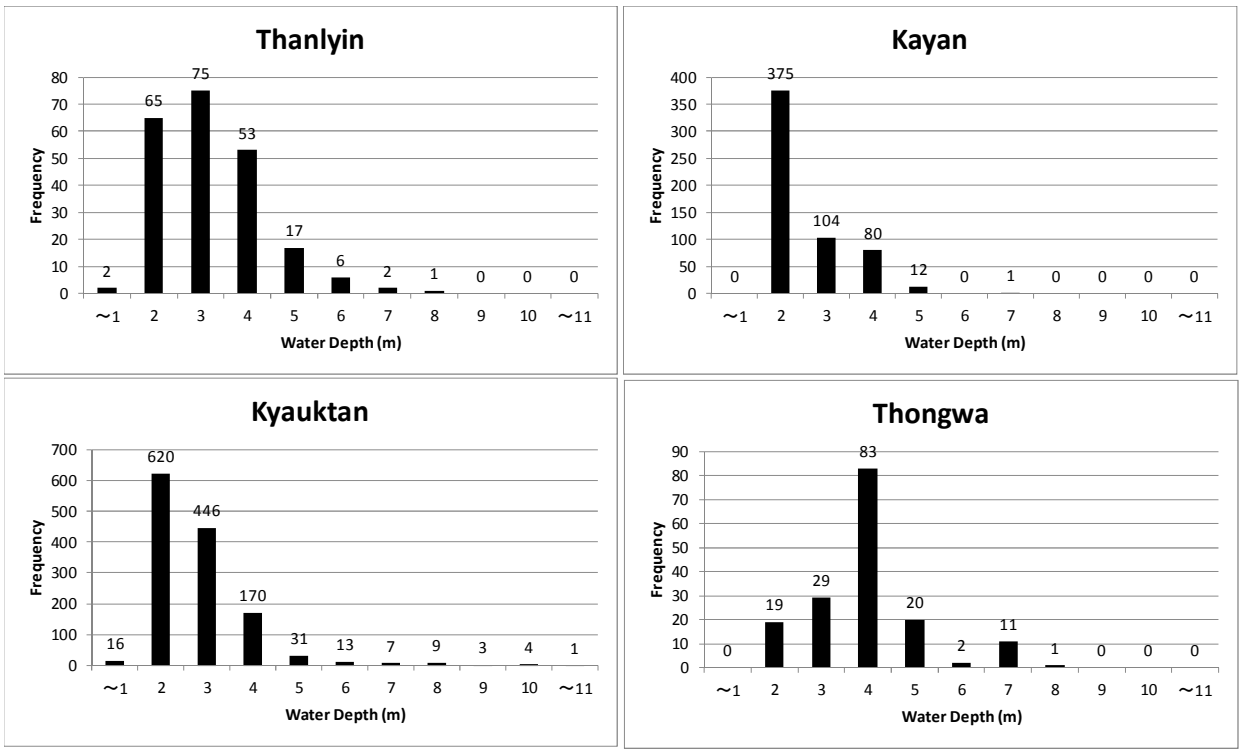


Figure 3-2-3-32 Depth of Pond

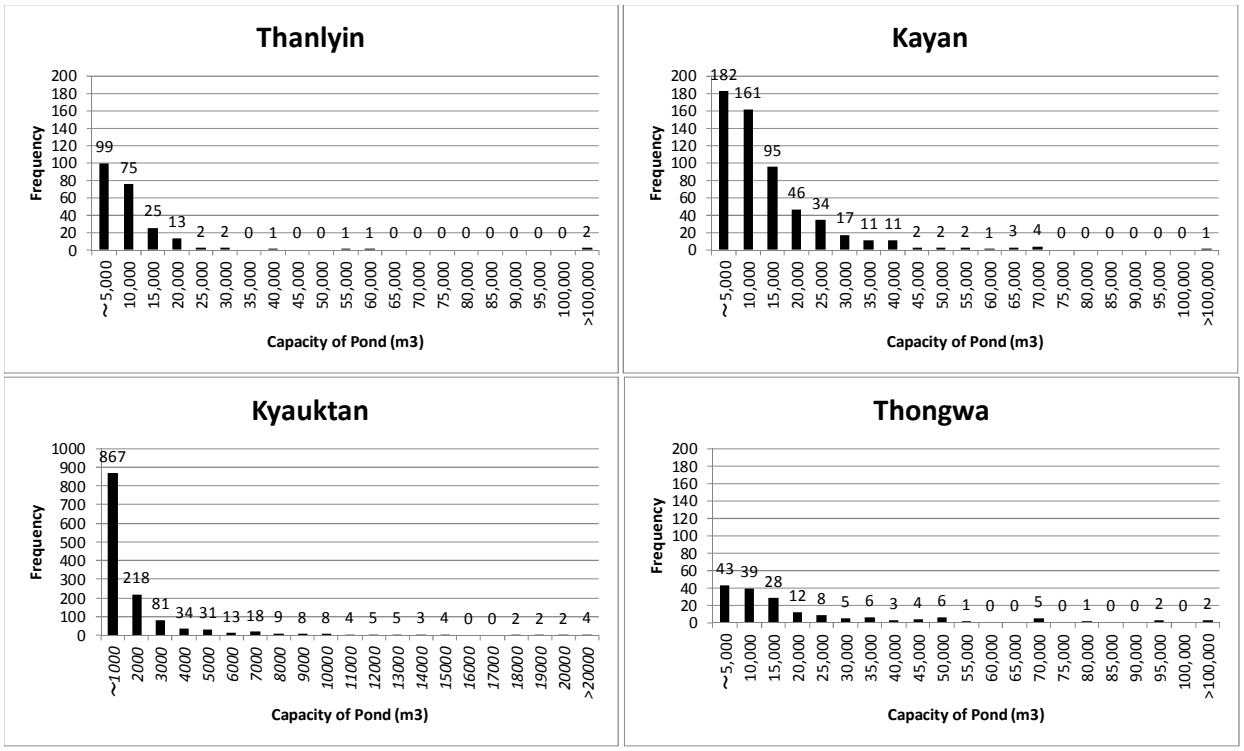


Figure 3-2-3-33 Capacity of Pond

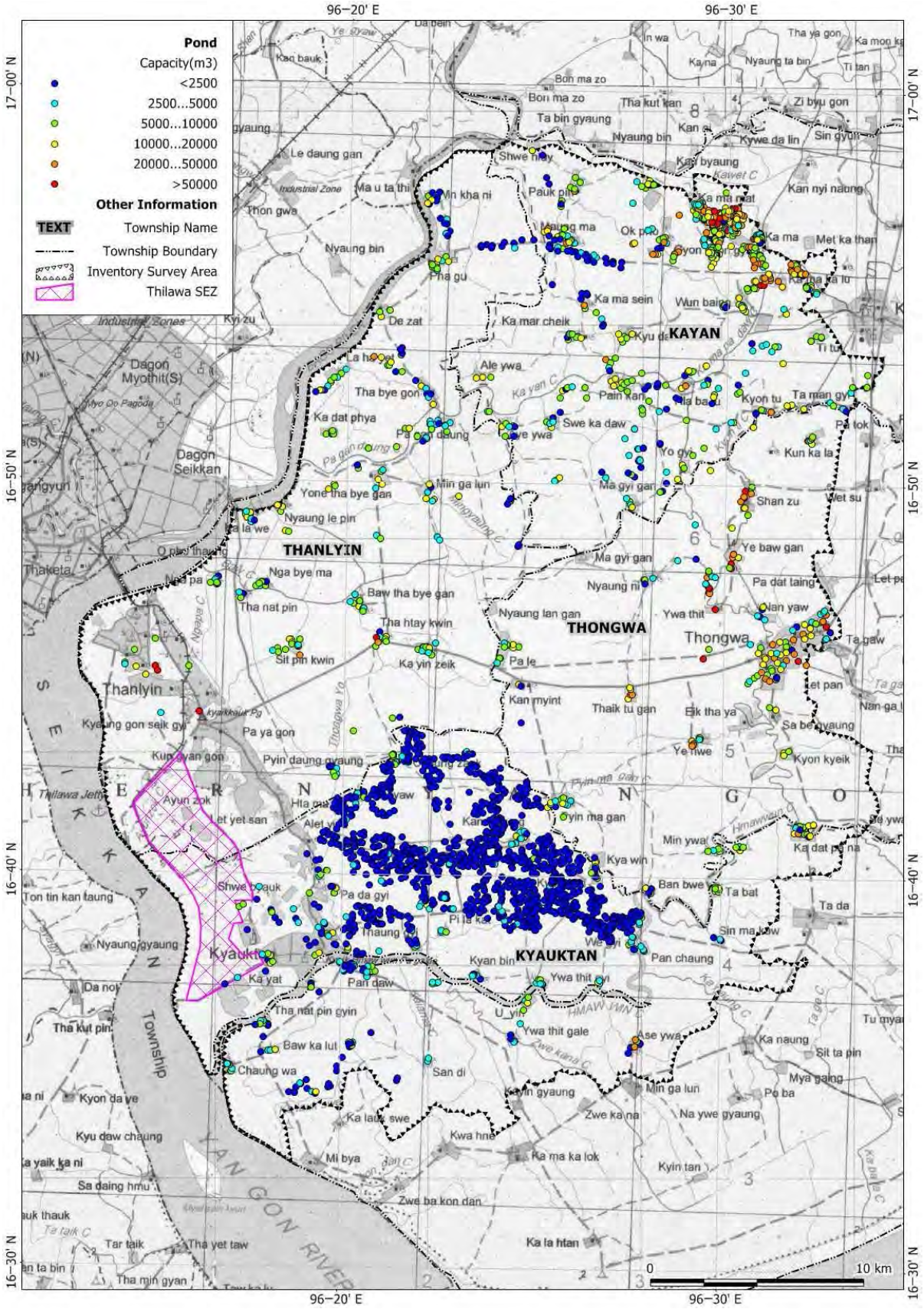


Figure 3-2-3-34 Spatial Distribution of Capacity of Pond

Figure 3-2-3-35 Example of Pond Distribution in Thongwa Township

3-2-4 Geophysical Survey

A geophysical survey was made with two types of surveys aiming at 1) the confirmation of seawater intrusion and 2) clarifying the spatial geological structure. The details of the survey result are described below.

3-2-4-1 Confirmation Survey for Seawater Intrusion

Seawater intrusion was confirmed by a (quasi-) 2D survey with the TDEM (Time Domain Electro-Magnetic) method. The survey line is located in SEZ, settling the SEZ western border to 1.7 km inland (eastside) of the middle of SEZ. On the survey line, 85 measuring points are placed at 20 meter intervals with 100 meters of detective depth. In addition, the 1D survey was also made at the proposed drilling point planned by another JICA survey (Preparatory Study of Thilawa SEZ Infrastructure Development).

As a result of the survey (refer to Figure 3-2-4-1)[1], the conductive layer (low resistivity) was found on the western side (Yangon River) and traced inland (Thilawa Reservoir) with the form of wedging into the deeper horizon.

Since the conductive layer shows as very low, less than 10 ohm-m, it is correlative with the saline

[1] Figure 3-2-4-1 shows 10Ω - m of resistivity with heavy line. It can correspond to 1,000 μS/cm of EC and plunges the deeper horizon to the east.

blackish aquifer or clay layer. This layer extends nearly all the western half of SEZ.

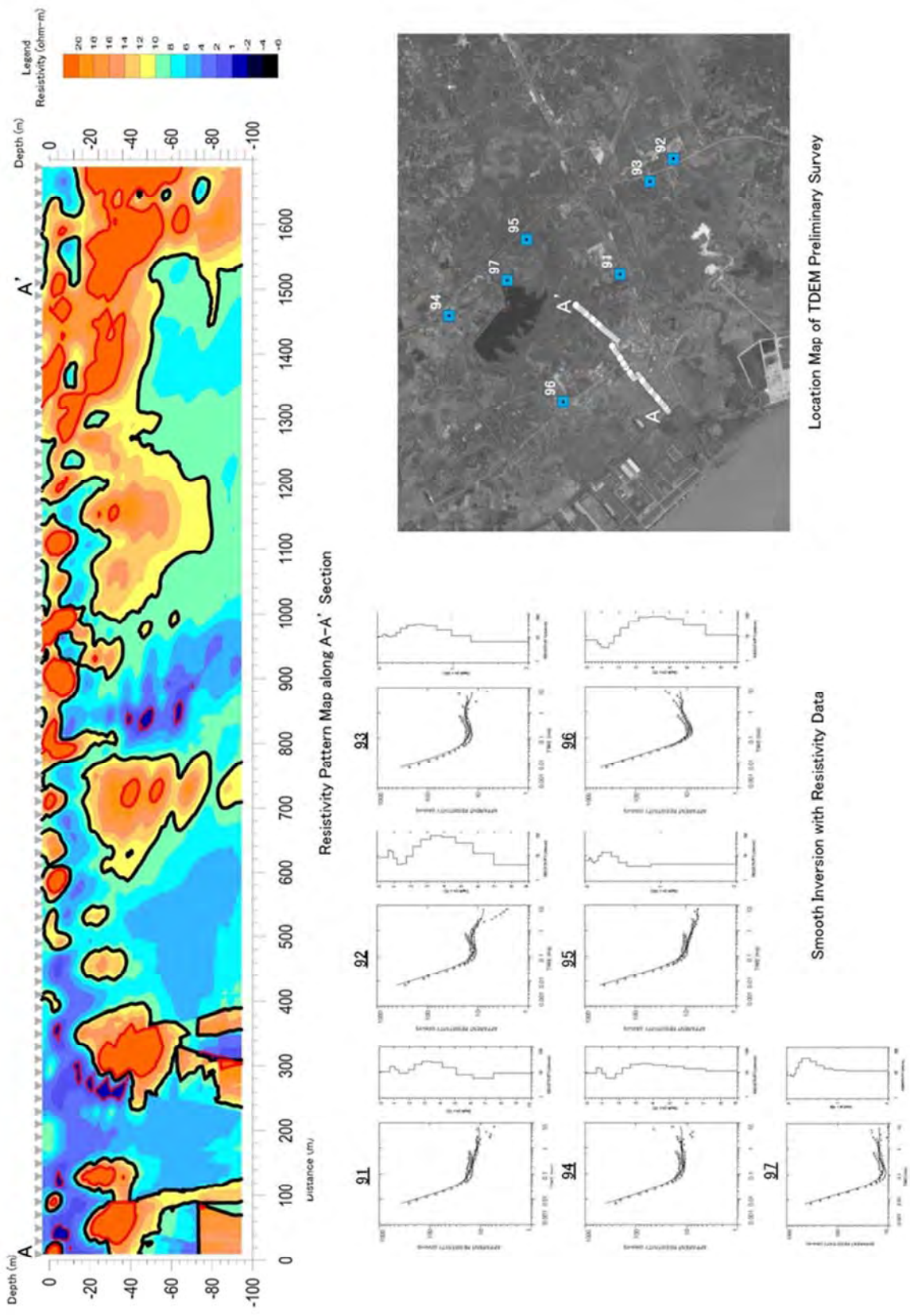


Figure 3-2-4-1 Summary of Survey for Seawater Intrusion

3-2-4-2 Structural Survey

Aquifer structure was detected by two methods of Electrical Survey (Vertical Electrical Sounding: VES) and TDEM. On the field, VES points are placed on a vacant space able to maintain the necessary distance of a measurement line to avoid obstacles of roads and houses. As for TDEM, the points are settled on the (electro-magnetic) noise-free spaces far from power line, transformers and conductive circuit (iron fences, bars, pipes, etc.). Finally, 43 points of VES and 60 points of TDEM are measured as shown in Figure 3-2-1-1 (presented above).

(1) Measurement and Analysis

As mentioned above, the VES and TDEM survey are applied for the structural survey. By checking the Electro-magnetic noise on the field, VES was carried out on the B-B' Line crossing the populated area which has a high intensity of noise while TDEM was made on the A-A' Line running in the rural area under a low noise condition. The process of analysis is as follows:

1) VES Survey

A VES Survey was carried out with a Schlumberger array, using 500m and 1000m of survey line, which is capable to detect 150 m and 300 m deep. The survey result was arranged into ρ-a curve (apparent resistivity-depth curve) for conforming the data reliability and providing smooth inversion analysis. Taking specific resistivity of 15 to 20 layers by the smooth inversion, the layered analysis was followed to fix the resistivity layered models. The analytical result of drilling points (D-2, D-5) are shown in Figure 3-2-4-2.

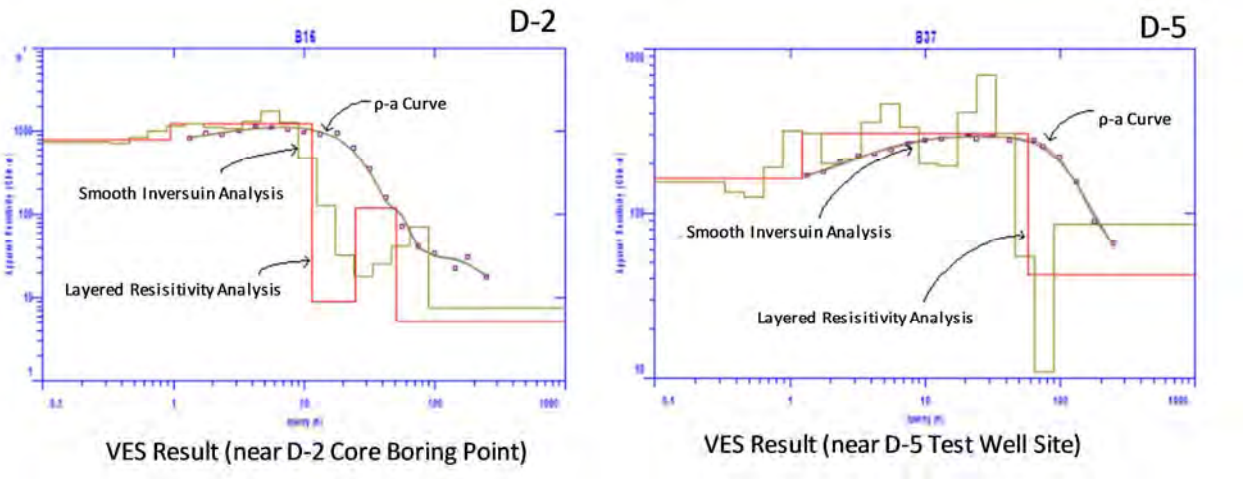


Figure 3-2-4-2 Analytical Result of VES

2) TEDM Survey

Since the SEZ is covered by conductive soils so the induced eddy current is rapidly consumed within the shallow horizon, it is hard to penetrate the deeper necessary horizons. To meet the planned

depth, the loop size is change to the larger and coil is used in the more sensitive configuration2. For the analysis, the same as the VES procedure, a series of ρ-a curve, smooth inversion and layered analysis were carried out to recognize the aquifer positions and their structure. The analytical result of the drilling point (D-4) and well pints (D-3, 4) are shown below.

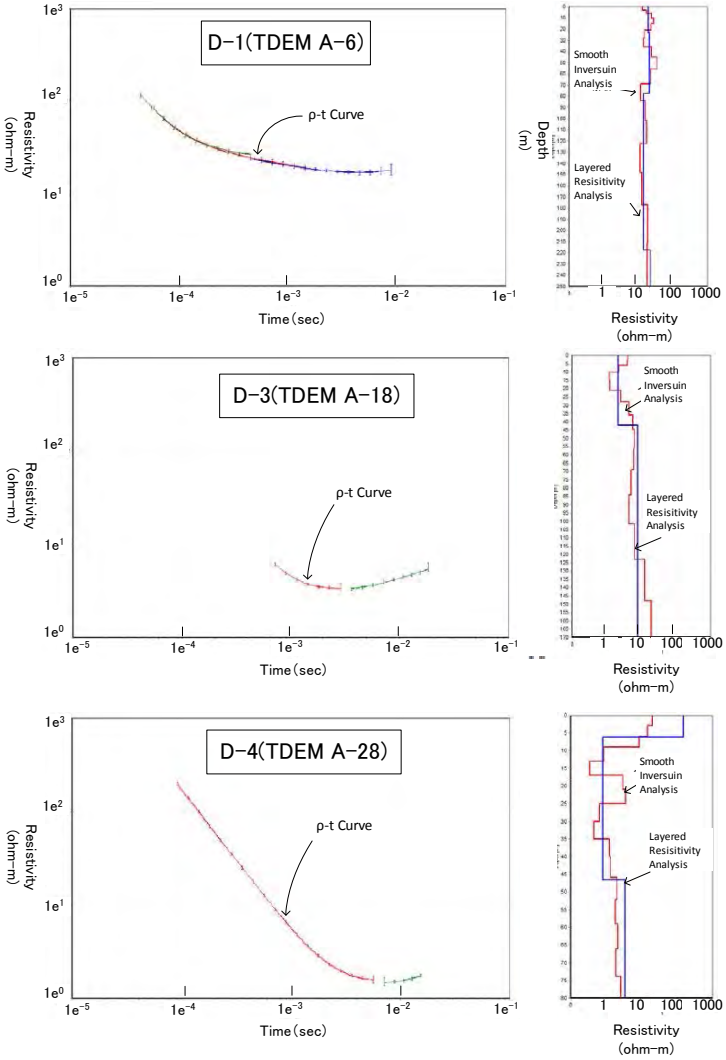


Figure 3-2-4-3 Result of TDEM Survey (e.g.)

D-1 Drilling: Resistivity contrast is not so clear, but relatively high and low resistivity repeatedly appeared. High resistive layers are found at several horizons of 40 m to 60 m, around 100 m and below 170 m. These are all indicated as about 50 ohm-m which can be considered as an aquifer. As for low resistivity, the saline condition indicated by several ohm-m or less was not detected in all the layers. At least, up to 300m deep, the aquifer is supposed to be filled by freshwater.

D-3 Test well: The low resistivity layer less than 10 ohm-m is detected up to 120 m deep. In particular, a superficial zone shallower than 20 m contains very low resistivity of 1 ohm-m to be co-related to the saline layer. The aquifer is expected below 150 m deep.

D-4 Test well Point: The resistivity is low as it is less than 10 ohm-m in the section of 20m to 100 m deep. For the deeper section than the 100 m, the resistivity turns into an increase and is correlated to sandy formation. Especially at 150 m deep, the aquifer is expected to have fresh water.

[2] TDEM survey is carried out with the following instruments and specification.
TDEM System: ABEM WalkTEM, Transmitter Loop:200m x 200m,Observation Configuration: Central Loop (place censor set at the center of Tx loop),Censor coil: :RC-5(Area=5m^2, LM/IM Mode) /Rc-200(Area=200m^2, HM mode),Transmitter Output: I=0.8A (LM Coil used), I=5.8A (HM Coil used), Turn-off time: 3.1μsec (LM Mode, IM Mode), 18.0μsec (HM Mode)

(2) Resistivity Profile

The resistivity survey, either VES or TEDM, aims to estimate the geological structure by the measurement of the earth's "resistivity". Along with this purpose, the 1-D (vertical) survey was conducted for obtaining the specific resistivity at 103 points made up of 60 TDEM points and 43 VES points. These results were then arranged in the A-A' line (East-West line, 40 TDEM points) and B-B' line (South-North Line, 41 points), and used for delineating the resistivity profiles. In the interpretation for them, the resistivity continuities (or discontinuities) are traced in the profiles and are correlated with the geological boundaries and faulting systems (refer to Figure 3-2-4-4 and Figure 3-2-4-5). The interpretation for resistivity profiles are described below.

A-A' Profile (Section): The line was arranged in the east-west direction and was 33 km long. Its western margin (A) was set at the center of SEZ and the eastern end (A') was placed at the center of Thongwa T/S. The resistivity values measured show the wide range from 1 ohm-m (> 1,000 μS/cm) to several 100 ohm-m (< 10 μS/cm) and their resistivity structure is traced in the horizontal (east-west) direction especially in the upper horizon. The conductive layer, indicating the less than 5 ohm-m, lies on the Thanlyin-Kyauktan Hill and extends over 25 km to the east with the increment of its depth. So, the layer thickness is thinner at the western side and became thicker towards the east by which the maximum thickness of 100 meters is at the eastern end of line. In addition, the very low resistivity layer indicated as a saline layer is also in place inter-bedded at the superficial zone. With the comparative interpretation between the resistivity pattern and geologic structure, this conductive layer is correlative with the alluvial layer mainly composed of the clayey deposits with the saline sands.

The lower layer below the Alluvial layer is relatively resistive and is divided into four (4) layers of: (1) Slightly Low (5-10 ohm-m); (2) Medium (10-50 ohm-m); (3) Slightly High (50-100 ohm-m); and (4) High (over 100 ohm-m). In comparison with the theoretical standard, if an unknown effect from pore-water is eliminating, they are respectively correlative with: (1)Mudstone; (2) Muddy Alternation; (3) Alternation; (4) Sandy Alternation; and (5)Sandstone. The Sandstone is observed at Thanlyin-Kyauktan Hill (4km-6km section) and the western border of Thongwa T/S (14 km-22 km section). On the other hand, Mudstone is detected at the eastern border of Thongwa T/S (30 km-33 km section). At the eastern end of the A-A' line, there is a dissentious zone which is close to the assumable position of the (concealed) Sagaing Faults.

B-B' Profile (Section): The line lies in the east-west direction and is 26 km long. Its southern end (B) is at the Hmaw Wun River of SEZ while the northern end (B') reaches the Bago River. The resistivity has a range from the several ohm-m (several 1,000 μS/cm) to the several 100 ohm-m (around 10 μS/cm) and generally shows higher resistivity than that of the A-A' section. The horizontal (north-south) continuity is clear as the high resistivity zone (>100 ohm-m) at the cross-point with the A-A' section. It extends toward the north with the increases of its depth up to 200 meters max. With the comparison to

the surface geologic structure, the zone can be corresponded to the Irrawaddy Group.

The lower horizon overlain by the Irrawaddy Group is characterized by medium resistivity (10-50 ohm-m) and can correlate to the Pegu Group. The boundary between Irrawaddy and the Pegu Group has in general the gentle undulation dipping as low as 1 to 2 degree of the apparent dipping, even though it partly involves a structural disturbance being a steep or even reverse angle.

At the Thanlyin T/S, located at the northern end of the line, the high resistivity (assuming as the Irrawaddy Group) is traced with a thick zone, while the low resistivity exits at the other end of the line near the Hmaw Wun River. At this riverside, very low resistivity is observed and traced vertically to the deeper horizon. Its resistivity contrast may be derived from the existence of faulting systems (at 2 km and 9 km of section).

As a result of the analysis for the resistivity classification of the A-A' and B-B' sections, both the Medium resistivity (10-50 ohm-m showing as 'Yellowish Green' in Figure 3-2-4-4 and Figure 3-2-4-5) and Slightly High resistivity (50-100 ohm-m showing as 'Yellow' in Figure 3-2-4-4 and Figure 3-2-4-5) are correlative with a productive aquifers.

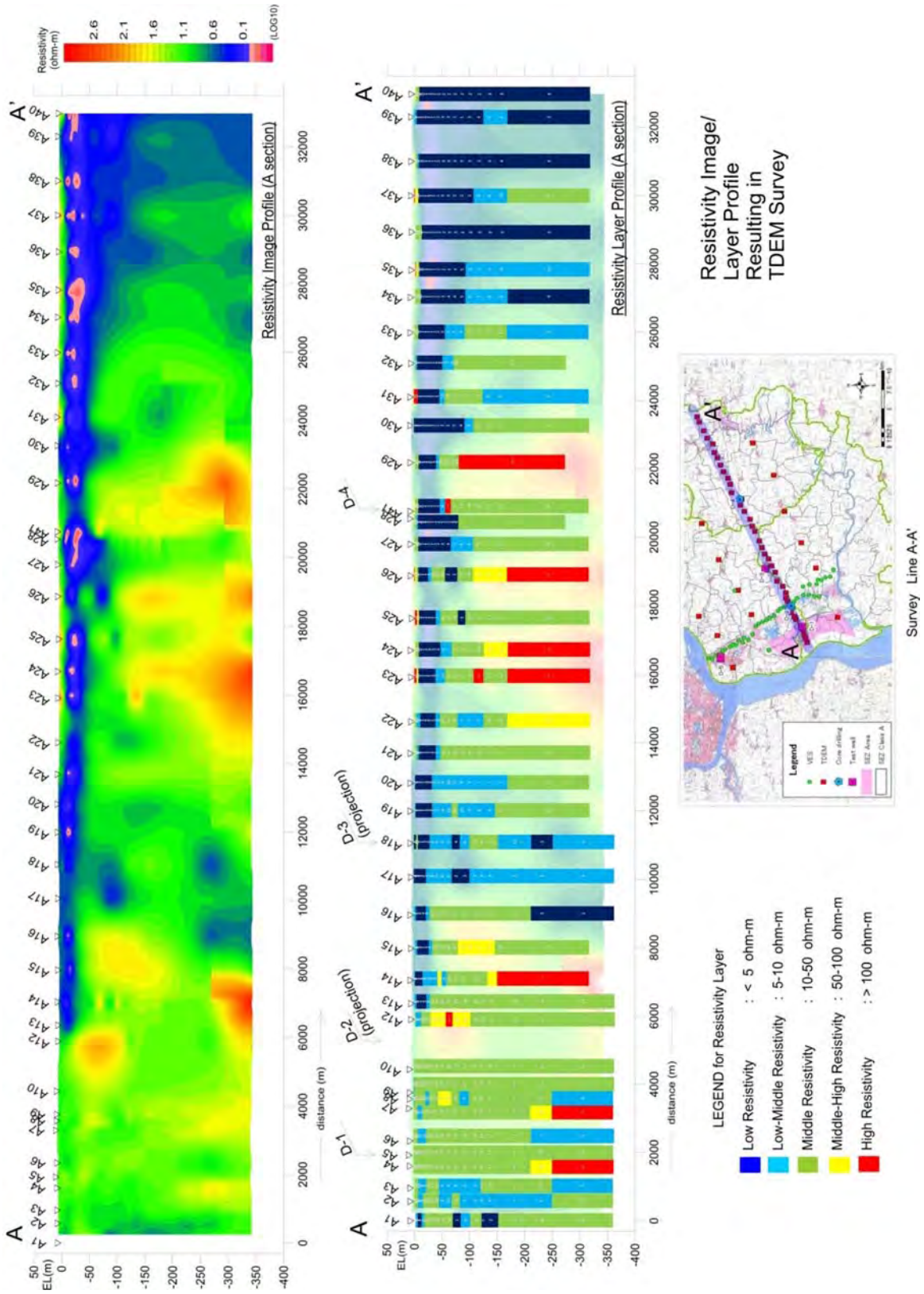


Figure 3-2-4-4 Resistivity Profile (A Line)

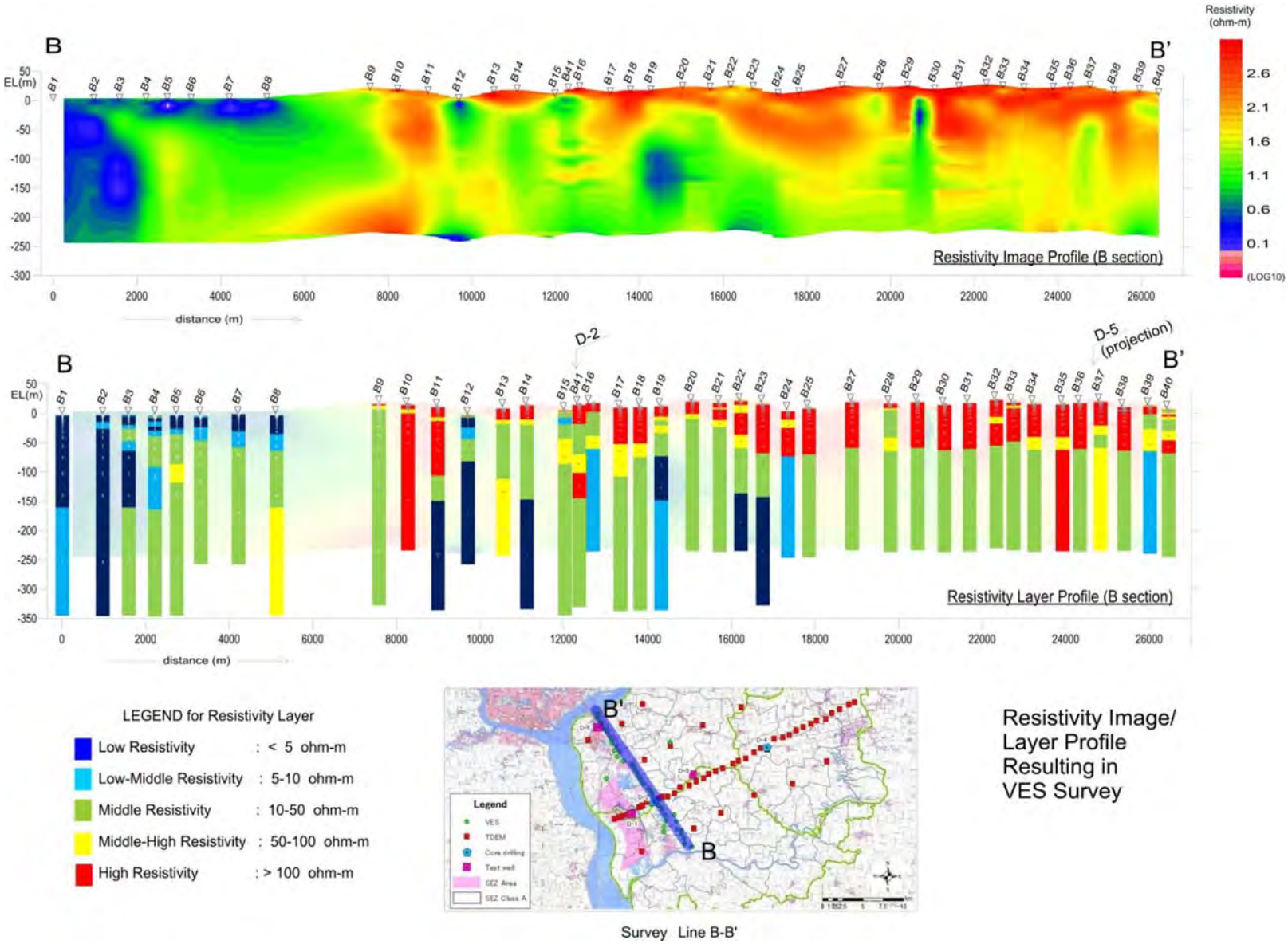


Figure 3-2-4-5 Resistivity Profile (B Line)