JAPAN INTERNATIONAL COOPERATION AGENCY

MANDALAY CITY DEVELOPMENT COMMITTEE

DEPARTMENT OF DEVELOPMENT AFFAIRS
MINISTRY OF PROGRESS OF BORDER AREAS AND
NATIONAL RACES AND DEVELOPMENT AFFAIRS

THE STUDY ON WATER SUPPLY SYSTEMS IN MANDALAY CITY AND IN THE CENTRAL DRY ZONE IN THE UNION OF MYANMAR

FINAL REPORT

Vol. I

EXECUTIVE SUMMARY

JULY 2003

KYOWA ENGINEERING CONSULTANTS CO., LTD.
PACIFIC CONSULTANTS INTERNATIONAL CO., LTD.

THE STUDY ON WATER SUPPLY SYSTEMS IN MANDALAY CITY AND IN THE CENTRAL DRY ZONE IN THE UNION OF MYANMAR

COMPONENT OF THE FINAL REPORT

Vol. I EXECUTIVE SUMMARY

Vol. II MAIN REPORT

Vol. III SUPPORTING REPORT

Vol. IV DATA & DRAWINGS

Foreign Exchange Rate:

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(As of November 2002)

PREFACE

In response to a request from the Government of the Union of Myanmar, the Government of Japan decided to conduct the study on Water Supply Systems in Mandalay City and in the Central Dry Zone and entrusted the study to Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Masayuki Taguchi of Kyowa Engineering Consultants Co., Ltd. to Myanmar, four times between May 2001 and July 2003. In addition, JICA set up an advisory committee headed by Mr. Yoshiki Omura, Development Specialist, JICA, between March 2001 and August 2003, which examined the study from specialist and technical points of view.

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

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

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Myanmar for their close cooperation extended to the team.

July, 2003

Takao KAWAKAMI
President
Japan International Cooperation Agency

July 2003

Mr. Takao KAWAKAMI
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit to you the final report entitled "the Study on Water Supply Systems in Mandalay City and in the Central Dry Zone in the Union of Myanmar ".

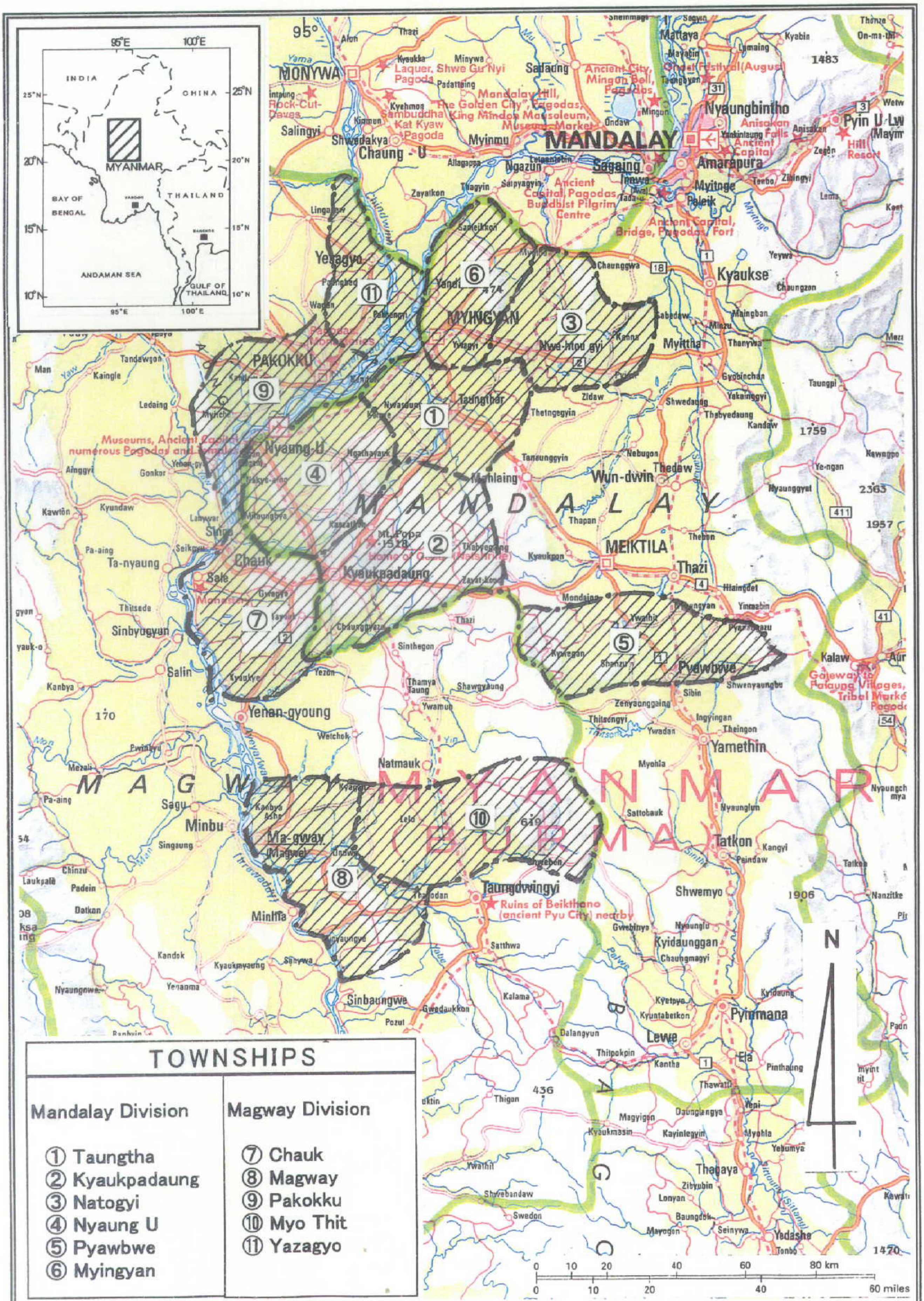
The Study outputs are broadly grouped into two components. One is the Master Plan Study for arrangement of the water supply system that meets water demand projected for the target year 2020 for Mandalay City. The other is the Study on project for improvement of water supply condition for 110 villages situated in the Central Dry Zone.

The report consists of the Executive Summary, Main Report, Supporting Report, and Data and Drawings. The Executive Summary summarizes the results of all the studies. The Main Report contains the results of survey, analysis implemented at each step of the Study. The Supporting Report includes details of investigations and analyses for formulating the contents of the Master Plan, other related plans and studies.

All members of the Study Team wish to express grateful acknowledgement to the personnel of your Agency, Ministry of Foreign Affairs and Embassy of Japan in Myanmar, and also to the officials concerned of the Government of Myanmar for all assistances extended to the Study Team. The Study Team sincerely wishes that the results of the Study would contribute to the future water supply project in particular and to social and economic development of the Union of Myanmar.

Sincerely,

Masayuki Taguchi
Team Leader



LOCATION MAP OF THE STUDY AREA

THE STUDY ON WATER SUPPLY SYSTEMS IN MANDALAY CITY
AND IN THE CENTRAL DRY ZONE
IN
THE UNION OF MYANMAR

FINAL REPORT

Vol. I EXECUTIVE SUMMARY

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Abbreviations and Units

List of Abbreviations

ADB	Asian Development Bank
BAJ	Bridge Asia Japan (a Japanese NGO)
BPS	Booster Pumping Station
CDZ	the Central Dry Zone
DIP	Ductile Iron Pipe
DAC	Development Assistance Committee (of OECD)
DDA	Department of Development Affairs, Ministry of Progress of Border Area and National Races and Development Affairs.
E.	East (of longitude)
EC	Electrical Conductivity
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
GAD	General Affairs Department: the predecessor of DDA
GIS	Geographic Information System
GL	Ground Level
HWL	High Water Level
JICA	Japan International Cooperation Agency
KOICA	Korea International Cooperation Agency
Lat.	Latitude
Long.	Longitude
LWL	Low Water Level
MCDC	Mandalay City Development Committee
Mt.	Mountain
N.	North (of latitude)
NDWQS	National Drinking Water Quality Standard
NGO	Non-government Organization
OJT	On-the-job Training
OPEC	Organization of Petroleum Exporting Countries
pH	Hydrogen power
S.	South (of latitude)
S-N	Direction from South to North
SW-NE	Direction from Southwest to Northeast
TDS	Total Dissolved Solid
UNDP	United Nation Development Programme
UNICEF	United Nation Children's Fund
WHO	World Health Organization

WRUD	Water Resources Utilization Department, Ministry of Agriculture and Irrigation
WSD	Water Supply and Sanitation Department, MCDC
WTP	Water Treatment Plant
ϕ	Diameter of Pipe

Units

cm/s	centimeter per second
cm/month	centimeter per month
gal(s)	gallon(s) (Imperial, 4.54596 liters)
gpd	gallon per day
gph	gallon per hour
ha	hectare
hr(s)	hour(s)
HP	horse Power
km	kilo meter
Ks	Kyats (Local currency unit in Myanmar)
kW	kilo watt
kV	kilo volt
lit(s).	liter(s)
lpcd	liter per capita per day
LPS	liter per second
l/d	liter per day
l/m	liter per month
l/min/m	liter per minute per meter
l/s	liter per second
m^3	cubic meter
m^3/d	cubic meter per day
min	minute(s)
mg/l	milligram per liter
mgpd	million gallons per day
mm/d	millimeter per day
mm/y	millimeter per year
m/sec	meter per second
NTU	nephelometric turbidity unit
Pc(s)	piece(s)
US$	United States Dollar
µS/cm	microsiemens per centimeter at 25 degrees Celsius
O	ohm: unit of electrical resistance

SUMMARY

CHAPTER I INTRODUCTION

1.1 Study Objectives

The aim of the Study is to work out the Master Plan for the following components:

1) Water Supply System in Mandalay City

A Master Plan for improvement of water supply in Mandalay City up to the target year 2020 would be formulated in consideration of water demand increase of the entire administrative area, potential evaluation on groundwater in the present water sources, etc.

2) Village Water Supply Plan in the Central Dry Zone

A water supply improvement plan for 110 villages situated in Mandalay and Magway Divisions in the Central Dry Zone (CDZ) would be formulated based on available hydrogeological data, results of field surveys such as electric resistivity survey, electromagnetic survey, test wells drilling conducted in the targeted villages.

1.2 Study Area

The study area consists of the whole administrative area of the Mandalay City and the rural area comprising six Townships in the Mandalay Division and five Townships in Magway Division in the CDZ.

1.3 Progress of the Study

The Study period was from May 2001 to July 2003. The field survey was conducted in two phases. In the Phase 1 survey, which was commenced in May 2001, collecting the existing data such as geography, geology, socio-economy, and various field works to investigate the conditions of the water supply systems, hydrogeological prospecting, water use condition, etc. had been conducted until March 2002. The Phase 2 survey, which was commenced in May 2002, had included working out the Master Plan on the water supply system for Mandalay City, and drilling of test wells in the CDZ. Draft Final Report was prepared by March 2003 in Japan based on analyses of those survey results. In June 2003, the Study Team brought the report and explained its contents to the officials concerned of Myanmar. The Myanmar side commented on the report in July 2003, and the Study Team reviewed the comments and compiled this Final Report.

CHAPTER II WATER SUPPLY IMPROVEMENT PLAN IN MANDALAY CITY

2.1 Outline of Mandalay City

Mandalay City is the second largest city in Myanmar and developing as the center of various activities such as in politics, economy, culture, religion, historic remains, etc. in the Upper Myanmar. Mandalay City consists of five Townships with a population of 802,000 (estimation as of 2000) within the entire administrative area of 117 km^2.

2.2 Present Water Supply System

(1) Water Supply Service Level

The present water supply system is managed by the Water Supply and Sanitation Department of Mandalay City Development Committee (MCDC). The existing water supply system had been constructed during 1983 and 1992 with the financial assistance of ADB, OPEC and Myanmar Economic Bank. At present the water is distributed to approximately 0.4 million population or 50 % of the total population, and covers 65 km^2 or 60% of the whole city area. The system consists of production wells, reservoirs, booster pumping stations, and pipelines of conveyance and distribution network. The key indicators of the present system are as follows:

- Production volume of groundwater: 109,000 m^3/d
- Distribution volume : 96,000 m^3/d
- Revenue water volume : 39,000 m^3/d
- Non-revenue water volume : 57,000 m^3/d
- Water tariff : Ks 10 per m^3 (up to 30 m^3/month), Ks 15 per m^3 (over 30 m^3/month)
  Collecting in every three months.

(2) Existing Water Supply Facilities

1) Water Production Facilities: 28 deep tube wells with more than 100 m deep. Water is distributed through the booster pumping stations.

2) Disinfection Facilities: Having been out of order after an accident of chlorine gas leakage in 1994.

3) Booster Pumping Stations (BPS): two stations are in operation.

BPS1: A ground reservoir (Q=23,000 m^3).
Electric motor-drive (410 kW) pumps-3 sets

Engine-drive (880 HP) pump-1 set

BPS2: Location- about 2.5 km southeast from BPS1. Water is transferred from BPS1 and distributed to the southern service area through BPS2.
Electric motor-drive pumps; (110kW)-2 sets + (55 kW) -1 set

4) Distribution Reservoirs

Mandalay Hill Reservoir: A ground reservoir (Q=12,500 m^3) built in 1991.

This reservoir had not been used for about 10 years due to insufficient water pressure of the distribution pipeline. The reservoir is now functioning with groundwater received from No. 28 tube well constructed by MCDC in 2002.

Steel elevated tank (Q=500 m^3)- 2 sets

5) Pipeline

Transmission Pipeline (from the proposed production tube wells to BPS1):
Ductile iron pipe (φ400-900 mm), L=6,774 m

Distribution Pipeline:
Main Pipeline*): Ductile iron pipe, φ200-800 mm, L 87km
Internal Network*): Ductile iron pipe, φ100-150 mm, L=201 km

Public Water Supply Point with a small tube well: 54 points in the southern area beyond the present water service area.
System: φ4 inch (φ100mm) tube well of a depth ranging from 20m to 40m, an airlift pump, a ground reservoir with 5,000 gallons capacity.

2.3 Water Source of Mandalay City

As the surface water resource, the Ayeyarwaddy River flowing along the west side of the city and the Dotehtawaddy River, a tributary of the Ayeyarwaddy River, flowing in the south of the city were evaluated comparatively. Moreover, the potential of groundwater in the whole city area were analyzed based on the present groundwater use condition, results of the hydrogeological survey, test well drillings, monitoring of the existing tube wells, etc.

(1) Surface Water Resources

It was concluded that the Ayeyarwaddy River has an advantage over the Dotehtawaddy

*) "Main Pipeline" and "Internal Network" generally mean "Primary Main" and "Secondary Main" respectively

River as a source of Mandalay City water supply for the target year 2020 from the following points of view:

1) The flow volumes of both the rivers are quite enough for the future water demand of Mandalay City. However, the Dotehtawaddy River water contains higher dissolved solids, sediment, total solids, turbidity, etc. than the Ayeyarwaddy River. It means that the water of the Dotehtawaddy River needs higher treatment cost than that of the Ayeyarwaddy River.

2) The Ayeyarwaddy River is situated near the city. However, the Dotehtawaddy River is located over 20 km far from the city center. That means the higher construction cost will be needed for the water conveyance main pipe in the case of the Dotehtawaddy River.

(2) Groundwater Resources

Based on the available hydrogeological data, electrical resistivity prospecting was conducted. Monitoring of groundwater level and water quality of the existing tube wells had been conducted for one year. Moreover, a test well (φ6", 180 m deep) and five monitoring wells (φ4", 60-120 m) had been constructed, and a series of pumping test was conducted by using those newly drilled tube wells. Based on the result of the above field works, hydrogeological condition of Mandalay City was grasped and a groundwater simulation was conducted to analyze groundwater potential exploitable in the future.

As a result, it was concluded that an additional safe pumpage to be exploited in the future was estimated at 26,000 m^3/day in the northwestern area along the Ayeyarwaddy River near the present well field and 22,000 m^3/day in the southern area including the industrial zone. From the viewpoint of hydrogeology of the area and the exploitable safe pumpage, it was judged that groundwater development in the northwest area would be more beneficial than developing groundwater in the southern area for the city water supply.

2.4 Water Demand Projection in Mandalay City

Daily average water demand of Mandalay City in future is estimated to increase from 120,000 m^3/day in 2000, to 264,000 m^3/day in 2015, and 305,000 m^3/day in 2020. There is already a water shortage of about 24,000 m^3/day on daily average base as of 2001. Therefore it is quite obvious that necessity for countermeasures is mounting to solve urgently this water shortage. The water demand estimated is shown in Fig. 2.4.1.

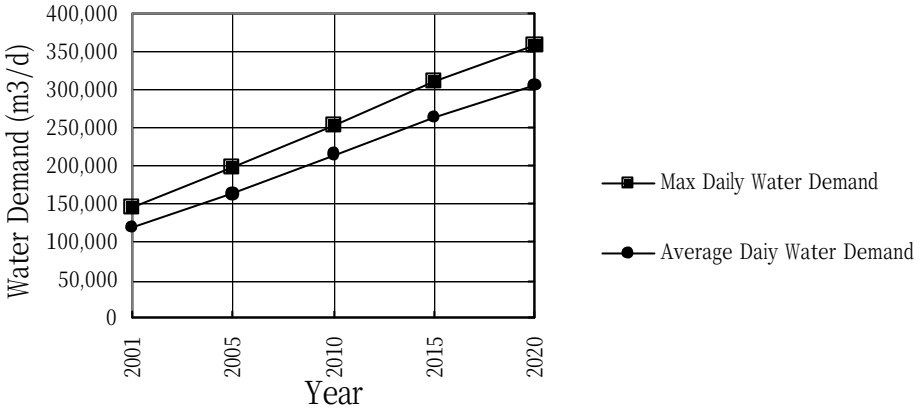


Fig. 2.4.1 Water Demand Projection

2.5 Phase-in Construction Plan for the Proposed Project

The project was planned to be implemented in the following two phases as the water demand would be increasing in future. The phase-in program for the proposed project is shown in Fig. 2.5.1

Phase I: Expansion of Exiting Water Supply Facilities Project

2004 to 2005: Urgent project (Groundwater development & existing facilities improvement.)

2005: Expansion of the existing distribution pipeline network supplied by BPS1

Phase II: Surface Water System Development Project

1st Step: 2006 to 2008: Intake Facilities& Treatment Plant (WTP 100,000m^3/day capacity)

2nd Step: 2009 to 2010: Intake Facilities & Treatment Plant (WTP 50,000m^3/day capacity)

3rd Step: 2014 to 2015: Intake Facilities & Treatment Plant (WTP 50,000m^3/day capacity)

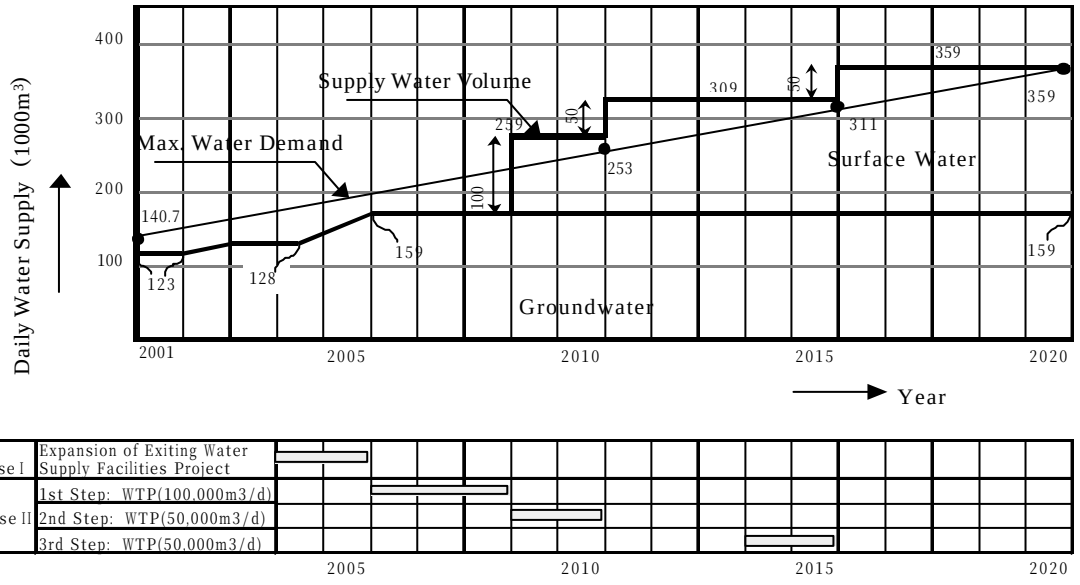


Fig. 2.5.1 Phase-in Construction Plan for Proposed Project

2.6 Master Plan of Water Supply System

For making the best use of the existing facilities and supplying adequate water in accordance with the water demand increase, the following design criteria were adopted for formulating the Master Plan:

The final target year of Master Plan :	2020
Total Population in Mandalay City:	1,098,800 persons
Water Served population:	988,900 persons
Domestic Water Consumption per capita per day:	180 lpcd
Water consumption for other purpose:	36 lpcd
Effective Water Ratio:	70 %
Average Daily Water Supply Volume	305,000 m^3/day
a) Groundwater system after improvement:	135,000 m^3/day
(Including a water volume of 22,500 m^3/day to be increased by Urgent Project)	
b) Proposed system of Ayeyarwaddy River water:	170,000 m^3/day
Maximum Daily Water Supply Volume:	359,000 m^3/day
a) Groundwater system after improvement:	159,000 m^3/day
b) Proposed system of Ayeyarwaddy River water:	200,000 m^3/day
Peak Hourly Water Supply Volume:	22,437 m^3/hr
a) Groundwater system after improvement:	9,937 m^3/hr
b) Proposed system of Ayeyarwaddy River water:	12,500 m^3/hr

(1) Proposed Project Components

The following projects were proposed in Master Plan.

1) **Phase I**: Expansion of Exiting Water Supply Facilities Project

i) Urgent Project

a) Proposed Groundwater Development Project

* Deep Tube Wells: Five tube wells will be drilled along the Ayeyarwaddy River.
  - The additional water production: 22,500 m^3/day (on a daily average basis)
  - Well materials for: 300mm diameter, 150m deep – 5 sets
* Submersible motor pumps:
  - In the north area, 200mm diameter x 75 l/s x 110 kW – 2 sets
  - In the south area, 200mm diameter x 75 l/s x 90 kW – 3 sets
* Water conveyance pipe: 300 to 500 mm diameter, DIP mortar lining L= 6,140m

b) Improving the existing facilities

* Installation of booster pumps in BPS1: 400 mm x 30 m^3/min x 45 m –2 sets
* Replacement of a booster pump in BPS2: 200 mm x 7.5 m^3/min x 50 m –1 set
* Construction of a ground reservoir in BPS1: Capacity 12,500m^3 – 1 pc.
* Installation of disinfection facilities in BPS1: (calcium hypochlorite) - 1 set
* Electromagnetic Water Flow meters with related pipelines –2 sets.

c) Implementing Plan for Urgent Project

The project is recommended to be implemented in combination with two types of project categorized in the type of equipment and material procurement and in the type of facilities construction.

MCDC has a drilling machine donated through the ADB-funded project and has constructed more than 30 deep tube wells by that machine to date. MCDC has been maintaining the machine, however, the tools and accessories for drilling works have been used out by more than 20 years working. Therefore the proposed five new tube wells can be constructed by MCDC, if materials of well casing & screen and adequate drilling tools and accessories for the MCDC-owned drilling rig would be procured. MCDC can also manage pipe-laying works of the proposed water conveyance pipeline if materials are procured. On the other hand, involvement of a contractor under the supervision of a reliable consultant is recommended for construction and installation of facilities such as a ground reservoir, disinfection facilities, booster pumps, because MCDC has no adequate capacity and know-how to manage the construction work and installation of those facilities and equipment by itself.

ii) Expansion of the existing distribution pipeline network supplied by BPS1

BPS1's service area will be partly reinforced through expansion of the existing distribution network.

The proposed expansion area; about 2,200 ha.

The proposed length of new pipeline; 50,980 m.

The proposed Diameter of pipeline; from 100 mm to 600 mm.

2) **Phase II**: Surface Water System Development Project

After the urgent project, a surface water supply system is needed.

The designed treated water volume is 200,000 m^3/day to meet the water demand in 2020. The designed intake water volume is 220,000 m^3/day.

The following facilities will be constructed by phase-in program.

i) Outline of the Proposed Facilities

- Intake Facilities

From the following three alternative Intake sites, Alternative 1 was selected by a careful comparative analysis from the advantageous points of views such as water quality, the river flow volume, geographical feature, distance from the city, and easiness for combination with the existing facilities, etc.

Alternative 1: on the Ayeyarwaddy River near the west end of 22nd street.
Alternative 2: on the Ayeyarwaddy River near the west end of 41st street.
Alternative 3: on the Dotehtawaddy River right bank.

The land will be reclaimed in the foreland of the river. Structure; Intake Gate type. Pumps; five sets (one standby) as the full line-up.

- Water Conveyance Pipeline

The pipeline is proposed to be laid under the circular road for 5.6 km distance between the Intake Facilities and the WTP.
The pipe specification; 1,350 mm diameter of ductile cast iron.

- Water Treatment Plant (WTP)

Treatment system; Coagulation & Sedimentation + Rapid Sand Filter
Location; About two km distant west from Mandalay Hill
The land will be reclaimed in the foreland of the river.

2.7 Construction Plan and Cost

(1) Cost for the Proposed Projects

The proposed projects are planned to be implemented by the phase-in program. The project cost is estimated as shown in Table 2.7.1. The total cost for the proposed Urgent Project was estimated at US$ 7.11 million (the cost for procurement of equipment is US$ 4.86 million, for construction of facilities was US$ 2.08 million, in which local portion was US$ 0.17million). The total cost for the Phase I Project including the Urgent Project was estimated at US$ 12.96 million. The total cost for the Phase II project, which includes construction of Intake & Treatment Plant, was estimated at US$ 126.67 million (for the direct cost was US$ 107.35

million, and for indirect cost was US$ 19.32 million). Grand total of all the proposed projects was estimated at US$ 139.63 million.

Table 2.7.1 Phase-in Construction of Proposed Projects

Phase-in Program / Facilities		Phase I: Expansion of Existing Water Supply Facilities Project		Phase II: Surface Water System Development Project		
		Urgent Project (2004 to 2005)	Expansion of Existing Distribution Pipe Net work by BPS1 (2005)	1st Step Project (2006 to 2008)	2nd Step Project (2009 to 2010)	3rd Step Project (2014 to 2015)
Water Distribution Capacity		26,500m^3/day	-	100,000m^3/day	50,000m^3/day	50,000m^3/day
Intake	Civil Works	Deep well x 5 sets	-	220,000m^3/day	-	-
	Pumps / Conveyance Pipeline	4.5m^3/min x 5 sets	-	38.2 m^3/min x 3sets, φ 1350 mm, L=5.6 km	38.2 m^3/min x 1set	38.2 m^3/min x 1set
WTP	Grit Chambers	-	-	1 lines	1 lines	-
	Sedimentation, Filters	-	-	2 lines	1 line	1 line
	Clear Water Reservoirs	-	-	1 basin	1 basin	-
	Transmission Pipeline	φ300 to 500mm L=6.14 km		φ1000 to 1200mm, L=2.86 km	φ1000 mm, L=2.9 km	
	Buildings	-	-	To be Completed	-	-
Distribution Facilities	Reservoir, Pump, etc.	12,500 m^3 x 1 unit 30m^3/minx2 sets Disinfection 1 set	-	17,000 m^3 x 1 unit	25,000 m^3 x 1 unit	-
	Distribution Pipe Network	φ600 to 900 mm, L=0.62 km	φ100 to 600 mm, L=51.0 km	φ100 to 600mm, L=67.4 km	φ100 to 1200mm, L=170.8 km	φ100 to 800 mm, L=120.8 km
Project Cost (in US $1000)	By Project	7,115	5,849	55,447	46,949	24,275
	By Phase	12,964		126,672		
	Grand total	139,636				

(2) Operation and Maintenance Cost for Proposed Facilities

The operation and maintenance cost for the Urgent Project was estimated at US$ 5,469 a month. For the Phase II project, the same cost after the completion of the 1st Step project (100,000 m^3/day capacity) was estimated at US$ 54,742 a month, the same for the 3rd Step (200,000 m^3/day capacity) was US$ 102,038 a month.

2.8 Financial and Economic Analyses

The Financial Internal Rate of Return (FIRR) of the overall proposed project was estimated at 8.0 % when the tariff was set at 0.15 US$/$m^3$ in the initial stage and raised annually at 4%. Then those of FIRRs for the sub-projects such as Urgent Project, Expansion of Existing Pipe Network supplied by BPS1, and the Surface Water System Development Project (Phase II Project), were estimated at 13.0 %, 14.3 % and 7.1 %, respectively.

The economic rate of return (EIRR) of the overall proposed project was estimated at 8.1 %, then those of EIRRs for the sub-projects, Urgent Project, Expansion of Existing Pipe Network supplied by BPS1, and the Surface Water System Development Project were 12.3 %, 13.8 %, and 7.3 %, respectively.

2.9 Technology Transferred in the Study

Through the study, the following groundwater development technologies have been mainly transferred to MCDC staff. 1) reporting on drilling work, well logging, pumping test, 2) groundwater monitoring, 3) formulation of well database, and 4) operation of computer software for groundwater simulation.

2.10 Conclusions and Recommendations

The proposed projects for Mandalay City consist of the following two components and sub projects;

Phase I Project; Expansion of the existing water supply system by developing groundwater and improving the related facilities.

1) Urgent Project (Groundwater Development + Improving the Existing Facilities)
2) Expansion of the Existing Distribution Pipeline Network supplied by BPS1

Phase II Project; Construction of a new water treatment system using the water of the Ayeyarwaddy River and expanding the distribution facilities to the whole city.

1) 1st Step; Intake Facilities& Treatment Plant (WTP 100,000m3/day capacity)
2) 2nd Step; Intake Facilities & Treatment Plant (WTP 50,000m3/day capacity)
3) 3rd Step; Intake Facilities & Treatment Plant (WTP 50,000m3/day capacity)

At present, the daily water supply volume is insufficient by about 24,000 m3/day against the total water demand. Urbanization toward the eastern and the southern areas beyond the present water service area is progressing. And development of the industrial zone also causes an increase in population in the southern area. Therefore expansion of the water service area toward the southern area and exploitation of new water sources to cover the area are coming up as the problems to be solved urgently by MCDC.

The proposed Urgent Project intends to improve the present water supply condition by drilling

five new tube wells, constructing a ground reservoir and installation of new booster pumps in BPS1, installation of disinfection facilities, etc. These facilities are not new to MCDC except the disinfection facilities using calcium hypochlorite. Therefore, the proposed groundwater supply system is evaluated as appropriate and reasonable from the technical point of view. The proposed Urgent Project is expected to reduce effectively the present problems of the water supply system in MCDC.

The proposed surface water treatment system is indispensable for Mandalay City in the future. As operation of such large scaled system is new to MCDC, it is strongly recommended for MCDC to take up the proper preparation works in technological and institutional management for introducing the new water supply system. The operation and maintenance technology should be transferred to MCDC staff in the inauguration stage of the facilities on the contract basis under the supervision of a reliable consultant. It is also recommended to let the main staff participate in suitable training programs provided by donor organizations.

Water tariff increase is indispensable for implementing the proposed projects and for repayment of the loan to be financed for the project. In the financial analysis, the FIRR of the overall project was estimated at 8.0 % when the tariff was set at US$ 0.15 per m^3 (about 6.8 times higher than the present tariff) in the initial stage and raised by 4% yearly.

The project robustness is verified, if MCDC introduces the tariff revision and a certain amount of subsidy, beside of the loan, is available from a foreign and/or the central government.

For implementing of this project, it is strongly recommended that MCDC shall make strict management of the project cost and the time-schedule, and the financial control with monitoring of the trend of economic development in Mandalay City.

It is concluded that the proposed projects in this study are essential for economic and social development of the second largest city in Myanmar. To secure the stable implementation of the proposed project, the following actions are recommended for MCDC to take:

- To enhance administrative capability of Water and Sanitation Department.
- To introduce a self-supporting accounting system for water supply activities.
- To introduce computer oriented management for data processing and compiling various operation & maintenance records, inventory control of the facilities, stocks of materials and spare parts, designing or drawings, database control, etc.

- To establish a groundwater monitoring system.
- To acquire technology on operation of water treatment plant.
- To revise a water tariff
- To reform Water and Sanitation Department
- To initiate the study on management of sewage and wastewater to be increased by the implementation of the proposed project.

CHAPER III WATER SUPPLY IMPROVEMENT PLAN IN THE CENTRAL DRY ZONE

3.1 Geography

The Central Dry Zone (CDZ) is situated almost in the middle of the country. The zone is also located in the basin lying between Chine Hills on the west and Shan Plateau on the east. Its ground elevation ranges between 45m and 70 m above mean sea level. As the average annual rainfall is from 500 mm to 1000 mm, the zone is categorized as the semi-arid zone in Myanmar. The Study area covers six Townships in Mandalay Division and five Townships in Magway Division. The total study area is 16,500 km^2 and has 3.2 million population and 80 % of them live in the rural area.

3.2 Hydrogeological Situation

(1) Hydrogeological Structure

The CDZ is covered with Tertiary sedimentary rocks, which may be grouped under three broad units, namely the Eocene rocks, Pegu Group and Irrawaddy Formation. The Study area is covered, particularly with the last two and Quaternary unconsolidated sediments.

Groundwater in the aquifers of Pegu Group and Irrawaddy Formation is mainly fissure water in rocks and that of Quaternary unconsolidated sediments is stratum water. The potential and quality of groundwater varies depending on the aquifers which groundwater originates.

Pegu aquifer is generally not so suitable for drinking due to high salinity content. Irrawaddy aquifer normally presents an allowable T.D.S level, however, water in some aquifers are not potable due to high minerals content.

3.3 Water Use Conditions

Traditional water source for the villages is the rainwater stored in rain-fed ponds. Women and children are mainly involved in fetching water from the pond to their houses in the village. A villager carries water by cans or buckets hung from a pole on her shoulders several times a day. Several ceramic pots with about one meter diameter are placed beside a house and the water is stored in these pots. In the middle of the dry season, the pond water lowers and becomes dark in color due to soil content, however, the villagers try to use the pond until it gets empty. After the pond water dries out, villagers go to tube wells or other water sources

a few miles far from the village to bring back water by bullock cart in barrels.

International aid organizations and NGOs have drilled thousands of tube wells in the rural area and water shortages were solved in many villages. However, there are still hundreds of villages, which are facing difficulties in getting domestic water in sufficient quality and quantity, such as having to travel a long distance to the water source, high content of salinity or minerals in the well water, etc. especially in dry season. People in these villages eager to have a deep tube well in their village and use sufficient volume of water at their convenient time and at an affordable price.

A village having tube well(s) has organized a water committee by participation of villagers to operate the well pump, collect tariff, and manage other related activities. The water is drawn up from the tube well normally by an engine-driven pump or a submersible motor pump with a generator set. The water committee charges generally Ks 10 to Ks 25 per 50 gallons of water to its own villagers but about the double price to outsiders.

3.4 Present Situation of Village Water Supply

Various village water supply projects have been implemented from 1980's by NGOs and international aid agencies like UNDP or UNICEF in cooperation with WRUD as the counterpart of the Myanmar side. On the occasion of transferring the administrative competence on rural water supply from WRUD to DDA in 2001, DDA became the sole department responsible for both urban and rural water supply in Myanmar except Yangon City and Mandalay City.

DDA placed its priority on improving water supply conditions in the rural area and formulated "10 Year Project for Rural Water Supply 2000-2010", which includes three Divisions located in the CDZ. The beneficiaries of the project are shown in Table 3.4.1.

Table 3.4.1 Populations of Targeted Divisions in "10 Year Project"

Division	No. of Townships	No. of Villages	No. of Household	Estimated Population in Years	
				2000	2010
Mandalay	26	5,550	789,069	3,903,805	4,666,227
Magway	25	4,792	557,119	2,977,279	3,558,748
Sagain	34	5,460	716,384	3,913,874	4,678,262
Total	85	15,802	2,062,572	10,794,958	12,903,237

In the "10 Year Project", DDA intends to solve problems in the villages, where the water is not secured in quantity and in quality, by adopting various countermeasures to obtain water

from sources such as deep wells, shallow wells, dug wells, reservoir improvement, river water, and others in accordance with the natural conditions surrounding the target villages.

3.5 Groundwater Survey in the Study Area

(1) Monitoring of Existing Wells and Geophysical Survey

Groundwater monitoring was conducted in the Study area for one year. About 10 to 15 of the existing tube wells were selected in each Township as the monitoring wells and the officer of each Township cooperated to take records of the groundwater level and basic water quality tests of each monitoring well in accordance with instruction of an expert of the Study Team. In cooperation with engineers of DDA, the Study Team had conducted electric resistivity surveys in 110 target villages to trace the probable depth and stretch of the aquifer and to analyze possibility of groundwater development in each village.

(2) Selection of Test Well Drilling Site

For selecting 22 villages for test well drilling sites, the Study Team evaluated several factors such as accessibility of drilling machine to the village, supposed water quality, yield of water, aquifer type, electric resistivity result, and socioeconomic conditions including water supply difficulties in 110 target villages.

The final decision was made through discussion with Study Team and officers concerned of DDA.

(3) Test Well Drilling

Test well drilling was conducted by deployment of three DDA-own drilling rigs and one new drilling rig having a 300 m deep drilling capacity, which was newly provided by JICA for this Study. JICA had repaired three DDA-own drilling rigs by dispatching an expert and necessary spare parts. The drilling work of the test wells had been implemented from June 2002 until February 2003, and 23 tube wells have been drilled altogether with 21 deep tube wells whose depths are mostly 200 to 300m, and 2 shallow wells with a depth of 60 m.

Since these test wells were intended to be used as production wells, 21 sets of well pumps were procured. However, out of these 21 well pumps, only 17 sets of well pumps were installed as the remaining four sets could not be installed due to the following reasons:

- In Kangyikon N village, Nyaung-U Township, an aquifer could not be confirmed.
- In Magyithonepin village, Pakokku Township, water yield was too little to use.

- In Thayetpin village, Chauk Township, the static water level (315 m deep) was deeper than the specified pump heads.

- Yonbingon village, Pyawbwe Township, a pump was not necessary because it is an artesian well.

Two sets of airlift pumping system, which consists of an air compressor, an engine and pipes, were procured and installed into the two shallow wells. DDA has constructed a ground reservoir, a pump house, and a pipeline for each tube well on its own responsibility.

3.6 Groundwater Potential and Policy of Improving Water Use Conditions

(1) Groundwater Potential

Based on various surveys done in this Study, groundwater to be developed in the target villages is mainly fissure water saturated in fractured or weathered zone in the rocks in Irrawaddy Formation and Pegu Group, those are found widely in the Study area.

The result of the field survey shows that groundwater is available generally for the rural water supply purpose. However, as the fissure aquifer generally distributes in a limited zone in width and in depth, the following attention shall be paid in developing groundwater in the Study area:

- To grasp hydrogeological features of the targeted area by analyzing data of the existing tube wells and other hydrogeological data.

- To conduct a geophysical survey carefully, and

- To design tube well structure based on the above analyses and well logging data.

(2) Policy of Improving Water Use Conditions

There are some deep tube wells surrounding the target villages in CDZ. Such tube wells are irreplaceable water sources for not only villagers who own them but also many people who live in the surrounding villages as well. The tube wells are operated and maintained by water committees formed by the villagers and the committees charge the users for the water consumption. In the villages, yet without any tube wells, people have some basic knowledge on how to manage the facilities and eager to have a tube well in their village. They also wish to manage the facilities and to share its operational cost.

Population of most of the villages in the study area ranges within some hundreds and two or three thousands. They are isolated from each other by several miles of distance. From

the groundwater potential point of view, the groundwater development project adopting point-source water supply systems is judged to be the most suitable for improving water use conditions in the villages.

3.7 Component of Proposed Project

(1) Objectives of Proposed Project

The objectives of the proposed project are to provide villages hygienic and healthy living circumstance by supplying safe and enough water and thereby to reduce burden of the villagers in fetching water from outside the village for several hours in the dry season. It is expected that villagers could increase their income by making good use of the time saved by decreasing water fetching work.

(2) Status of Proposed Project

Target of the proposed project is 110 villages, which belong to six Townships in Mandalay Division and five Townships in Magway Division. There are 21,700 of households and 117,100 of population in these 110 villages in 2001. The population is expected to increase up to 137,500 in 2010. The proposed project covers a significant part of "10 Year Project", which is being implemented by DDA.

(3) Groundwater Development Project

According to the result of the field reconnaissance, there is no river or spring to be useful through the year as the alternative water source near the target villages. Therefore, groundwater is the most reliable and applicable water source, if it could be economically exploited. The results of hydrogeological survey and test well construction indicate that it would be possible to obtain enough groundwater to cater the water demand of almost all the targeted villages on condition that the tube well has a depth from 200 m to 300 m. However, it is suggested to analyze carefully the results of hydrogeological surveys of electrical & electromagnetic resistivity and well logging so as not to miss even a small indication of aquifer through the survey.

1) Proposed Well Facilities

Depth of the proposed wells is designed at a range from 200 m to 300 m based on the results of the hydrogeological analysis. The total number of the proposed deep wells is 120 as shown in Table 3.7.1.

Table 3.7.1 Numbers of Proposed Tube Wells

Division	Name of Township	Depth of Tube Well: 200m	Depth of Tube Well: 300m	Total
Mandalay	Taungtha	12	1	13
	Kyaukpadaung	5	4	9
	Natogyi	14	-	14
	Nyaung-U	8	3	11
	Pyawbwe	8	-	8
	Myingyan	9	2	11
Magway	Chauk	1	11	12
	Magway	9	-	9
	Pakokku	11	1	12
	Myothit	13	-	13
	Yesagyo	8	-	8
	Total	98	22	120

Depending on results of the test well construction, a helical rotor type pump, which has a higher applicability to a large change of groundwater level than the ordinary submersible motor pump, is recommendable to be adopted in the proposed project. A set of reservoir, pump house, and a connecting pipeline is necessary for each tube well. These facilities shall be constructed by the local authorities. The water will be supplied through the faucets installed on the reservoir.

2) Project Implementation and Period

In order to expedite the implementation of "10 Year Project" of DDA, for planning purpose the proposed project is scheduled to commence in fiscal year 2004 and to continue for five years.

DDA cannot afford to deploy its-own drilling rigs for the proposed project due to the current workload of the "10 Year Project". JICA provided a drilling rig with a drilling capacity of 300 m depth for this Study. This machine can be used for the proposed project if necessary accessories and tools will be newly supplemented. Consequently two more drilling rigs with a drilling capacity of 200 m to 300 m deep are needed in order to drill the total proposed wells within five years.

It is strongly recommended that equipment and tools for rehabilitation and repair of the tube well shall be provided and the related technology shall also be transferred to DDA so that a large number of damaged tube wells so far left unused can be restored. It can secure more sustainability in implementation of the project.

GAD (General Affairs Department: the predecessor of DDA) had completed two groundwater development projects for 11 towns in the CDZ, which were granted by Japan

in 1983 and in 1986. At present DDA is carrying out a rural water supply project in Northern Shan State, which was granted by Japan in 2001. Therefore it can be said that DDA is capable to implement construction work of the proposed project if the necessary equipment and materials are supplied, on the same basis of those former projects.

3) Equipment and Material Procurement Plan and Cost Estimation

Equipment and materials required for the proposed project is as shown in Table 3.7.3.

Table 3.7.3 Equipment and Materials to be Procured from Foreign Countries

	Categories	Name of Machine	Specifications	Quantity
1	Well Drilling	1) Truck Mounted Drilling Rig	300 m deep capacity	2 Set
2	Tools and Accessories	1) for the above Drilling Rig	300 m deep capacity	2 Set
		2) for Drilling Rig (JICA Provided in 2001, including consumed ones during the test well drilling under this Study for DDA-owned rigs)		1 Set
3	Supporting Equipments	1) Air Compressor		3 Sets
		2) Long body Cargo Trucks	4WD, 6 ton loading capacity with 3t crane	2 Sets
		3) Medium size Cargo Trucks	4WD, 3 ton loading capacity	2 Sets
		4) Water Bowser (Tanker)	$8m^3$, 4WD	3 Sets
		5) Pick-up truck	4WD、W-Cabin	4 Sets
		6) Mobile Workshop	With equipment and tools	1 Set
		7) Truck mounted well Repairing Equipment		1 Set
		8)Pumping Test Equipment	φ100mm, 800lit/min φ80mm, 400lit/min	3 Sets
4	Well Materials	Well Casing φ12”		3,600m
		Well Casing φ6”		22,270m
		Screen φ6”	SUS,	3,930**m**
		Centerizer		1 Set
		Bentonite, CMC		1 Set
5	Well Pump	Helical Rotor Pump with Diesel Engine	1000gal/hr～5000gal/hr	121 Sets
6	Others	Well logging equipment	Capable to logging is up to 400 m deep/	1 Set
		Water quality equipment		1 Set

The project cost for purchasing equipment and materials from the foreign countries was estimated at US$ 9.0 million. The cost for construction of facilities such as tube wells, pump houses, ground reservoirs, pipelines to be managed by the local Government was estimated at US$ 350 thousand.

4) Operation and Maintenance Plan

Village committees have been formulated in all the target villages and they have been taking various actions for operating the existing facilities such as ponds, dug wells or shallow wells and for improving hygienic conditions of the villages. The proposed water supply facilities are not new to the villagers and can be managed by the water committee to be organized by the villagers. Since each of the villages belongs to one of Township Development Committees, which are under the jurisdiction of DDA, the villages can obtain necessary assistances from the Township in case of any problems arising after the project commencement. Township officers are expected to be involved in various educational programs for improving the water supply and hygienic conditions in the villages and also in training the villagers for operation and maintenance of the facilities.

DDA has the full responsibility to maintain the drilling equipment, supporting equipment, tools and accessories. It is necessary to use workshops equipped with adequate equipment and skilled technicians during the implementation of the proposed project. However, DDA has no properly arranged workshop at present to repair and maintain the equipment. There are several well-equipped workshops, that belong to other ministries or governmental departments, located in the CDZ. Therefore it is strongly recommended that the central government should sufficiently coordinate between such ministries and departments for utilizing their workshops during implementation of the proposed project.

3.8 Financial and Economic Analyses

An average water tariff was recommended to be set between Ks 20 and Ks 25 per 50 gallons for the target villages, assuming that it should cover the operation cost and basic repair cost for the facilities, and also taking the villagers' affordability to pay for water into account.

In case that the proposed project would be implemented without any subsidies, water tariff was estimated at around Ks 80 per 50gallons in order that the FIRR of the proposed project should be kept more than 7.0 %. It was judged that this water tariff was too high for the villagers to accept and the proposed project should be implemented with substantial subsidy from foreign and/or the central governments. Assuming that the procurement cost of the initial construction cost and a half of the replacement cost of pump, which was scheduled in 16 years after the initial installation, were subsided, FIRR was worked out at 7.0 % with the water tariff of Ks 20 per 50gallons.

The EIRR was worked out at 5.7 % by assuming the following benefits:

- To reduce water fetching time in dry season and to make a good use of surplus time for waged work
- To increase water consumption due to water charge reduction in dry season.
- To reduce medical expense because of improvement of hygienic conditions by using safe water.

3.9 Technology Transferred in the Study

All the field works had been carried out by the Study Team in cooperation with and with participation of the staff of DDA. The status of technology transfer performed in the Study were as follows:

(1) Test Well Drilling

Drilling of 23 test wells was conducted in cooperation with 4 drilling teams of DDA during eight months under supervision of two Japanese experts of the Study Team. Through this work drilling team has mastered various applicable skills and technologies to be adopted for drilling tube wells of more than 200 m depth.

(2) Hydrogeological Prospecting

JICA provided a set of electrical resistivity sounding equipment and a set of electromagnetic sounding equipment through the Study. DDA had no such hydrogeological sounding equipment. The electric resistivity sounding technology was transferred through four-month actual survey work in the entire 110 target villages conducted in cooperation with DDA staff. Electromagnetic sounding technology was also transferred through one-month training with lectures and actual fieldwork in 15 villages. DDA could manage the hydrogeological soundings and the data analyzing of the soundings. It is expected that DDA will manage drilling work more successfully by adopting these sounding technologies.

(3) Formulation of Well Database

As data of the existing tube wells had not been compiled properly, collecting and analyzing the relevant data was found difficult during the Study. A well database covering the 11 targetted Townships was formulated by using a GIS software in cooperation with several engineers of DDA. Now DDA's engineers in charge can operate and adequately modify the database. DDA can use the database efficiently for promoting the rural water supply development project by accumulating more data in the database.

3.10 Conclusions and Recommendations

The proposed project is expected to cover the important part for the implementation of the "10 Year Project for Rural Water Supply in the CDZ" managed by DDA. The proposed project aims to supply safe and enough water by constructing tube wells to a population of 137,000 (estimated for year 2010) living in 110 villages. The project also intends to reduce or remove the burden of water fetching work on the villagers and to provide them with public health and hygienic circumstances.

The result of financial and economic analyses show that the proposed project is not feasible if implemented as a project on loan basis. However, since the project aims at improvement of living conditions in the villages by supplying safe and sufficient water, the implementation of the project can be justified from the view point of Basic Human Needs.

DDA has no adequate financial sources to import a lot of equipment and materials. Moreover, though there are some well-trained drilling technicians who have nearly 20 years experiences and a few hydrogeologists with practicable knowledge as specialists. DDA has to recruit more staffs and train them for the implementation of the project. At present, as the machine maintenance system of DDA is not sufficient, it is recommended to use several large and middle scale workshops equipped with machines and tools, which belong to other ministries or departments. It is highly recommended that the central government have to take an important role to coordinate between DDA and the related ministries or departments for using those workshops during the construction period of the project.

A water committee will be an implementing body at village level for managing the facilities to be constructed by the proposed project. Although the autonomy of water committee should be respected in financial and management of the facilities, taking weakness of financial and technological capacity of the villages into consideration, DDA's involvement in the water supply management will be positively appreciated for enhancing sustainability of the proposed project. Therefore, it is strongly recommended that DDA organizes a new section specialized in rural water supply projects and appoint special staff and dispatch them to the Township offices. This section should monitor the conditions of facilities, activities of water committees, water quality, etc., and perform repair work, train on operation and maintenance of the facilities, and advise water committees properly. Allocation of the budget for such activities is also an indispensable responsibility by the Township offices.

For securing sustainability of the project, it is also highly recommended that specialists working in the same area under various NGOs or international aid organizations cooperate with DDA and support the villages so that each village can be encouraged to improve their living conditions.

EXECUTIVE SUMMARY

CHAPTER I INTRODUCTION

1.1 Background of the Study

The Union of Myanmar is situated between lat. 10 ° to 28 ° N. and long. 92 ° to 101 ° E. Myanmar has a total area of 678,000km^2 and an estimated population of 46.4 millions in 1997.

Since 1988, only UNICEF and UNDP have been involved in improving water supply and sanitary conditions in the rural area under suspension of DAC member countries' official assistance to the Union of Myanmar. There are lots of difficulties for citizens to access safe and enough water in the whole country. The problems can be roughly summarized as follows:

- Insufficient water resources in quantity and in quality
- Deterioration of the water supply facilities
- Inadequate technological and financial capacity of the organizations concerned
- Unsuitable administrative system of water supply sector

In March 2000, under this circumstance the Government of the Union Myanmar requested the Government of Japan to implement the study on water supply sector in the Union. In response to the request, JICA dispatched preliminary study teams in July and November 2000 to confirm intention of the Government of Myanmar and to make up the outline of the study content, hereinafter referred to as "the Study". Consequently, the Government of the Union of Myanmar and the JICA preliminary study team agreed that the study should consist of the following two components, and the scope of works of the Study was also agreed through a basic site reconnaissance,

1) The study on improvement plan of water supply system in Mandalay City
2) The study on water supply plan in the Central Dry Zone

In accordance with the Scope of Works agreed in November 2000, JICA dispatched a full-scale study team, hereinafter referred to as "the Study Team", in May 2001.

1.2 Study Objectives

In accordance with the above Scope of Works, the Study Team worked out the following components:

1) Improvement Plan of Water Supply System in Mandalay City

A Master Plan up to the target year 2020 for improvement of water supply in Mandalay City would be formulated in consideration of population increase of the entire administrative area of the city, potential evaluation on groundwater in the present water sources, etc.

2) Water Supply Plan in the Central Dry Zone

A water supply improvement plan for villages situated in Mandalay and Magway Divisions in the Central Dry Zone shall be formulated based on available hydrogeological data, results of field surveys such as electric resistivity survey, electromagnetic survey, test wells drilling to be conducted in the targeted villages.

1.3 Study Area

The study area consists of 1) the Mandalay City administrative area, about 117 km^2, where about 800,000 populations inhabit and 2) the rural area comprising six Townships in the Mandalay Division and five Townships in Magway Division in the Central Dry Zone. The population and area of each study area are as follows.

Table 1.3.1 Mandalay City Study Area

Township	Area (km^2)	Population (as of July, 2000)
Aung Mya Thar Zan	28.57	215,774
Chan Aye Thar Zan	13.08	205,385
Ma Ha Aung Myay	14.81	187,798
Chan Mya thar Zi	25.12	144,543
Pyi Gyi Thar Gon	35.64	48,207
Total	117.22	801,707

Table 1.3.2 Central Dry Zone Study Area (Estimation as of Oct. 2000)

Division	Township	Area (km^2)	Population		
			Urban	Rural	Total
Mandalay	Taungatha	1,298	68,113	168,080	236,193
	Kyaukpadaung	1,940	95,137	234,767	329,904
	Natogyi	1,410	68,741	169,631	238,372
	Nyaung U	1,492	82,153	202,727	284,880
	Pyawbwe	1,750	83,443	205,910	289,353
	Myingyan	958	105,161	259,501	364,662
Magway	Chauk	1,080	42,563	222,988	265,551
	Magway	1,790	52,091	272,904	324,995
	Pakokku	1,790	58,182	304,816	362,998
	Myo Thit	1,970	27,990	146,642	174,632
	Yezagyo	970	47,769	250,263	298,032
Total		16,448	731,343 (23.1%)	2438,229 (76.9%)	3,169,572 (100%)

1.4 Progress of the Study

In May 2001, the 1st Field Survey was begun and in September 2001, Progress Report was prepared, which reported about the progress of the 1st Field Survey, some parts of the 2nd Field Survey and some results gained through the field surveys.

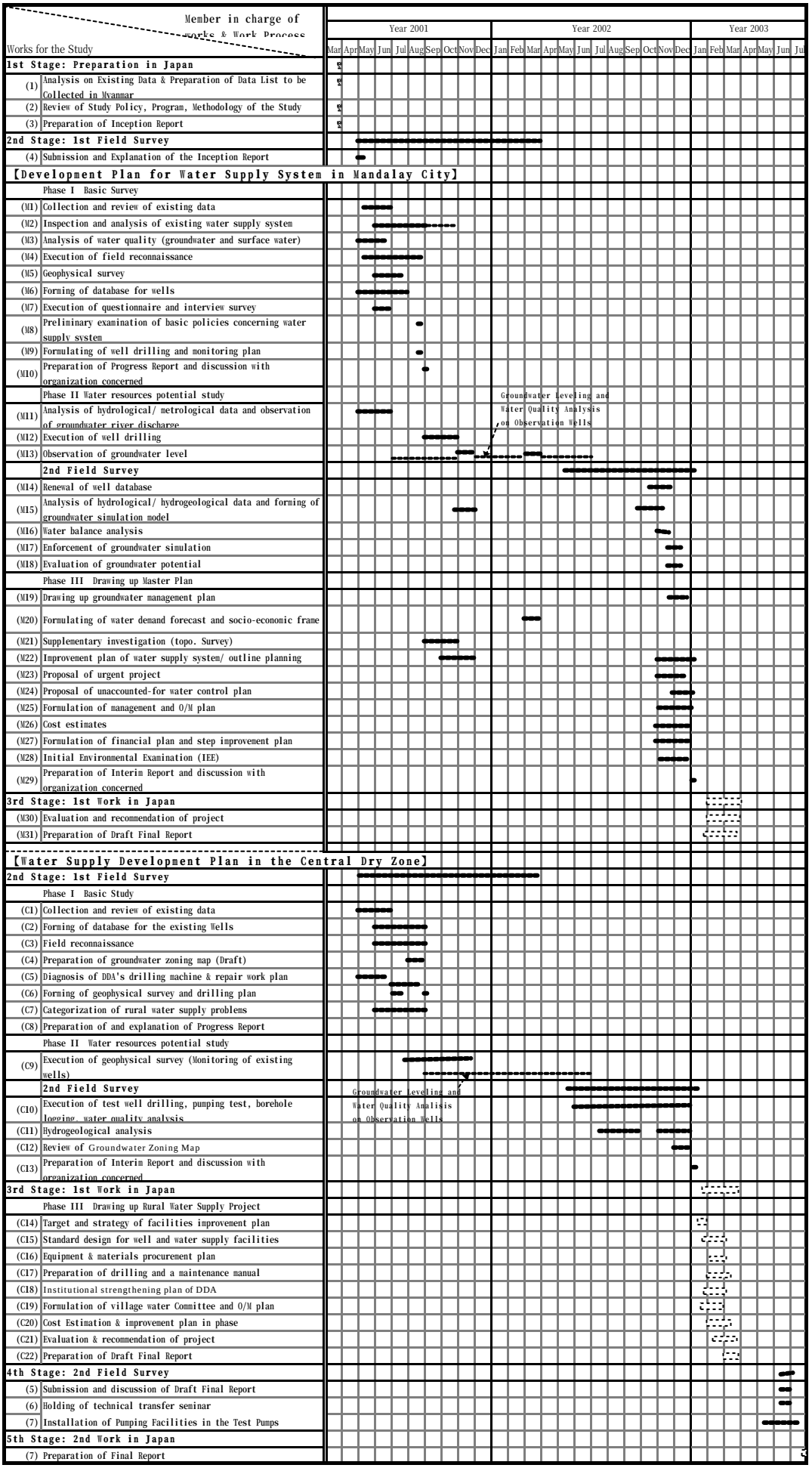
In September 2001, a new drilling rig, spare parts for repairing the existing drilling rigs, tools and well materials etc., which JICA would procure and provide to the Study in order to construct test wells in the Central Dry Zone, could not arrive on time.

In November 2001, it became clear that the equipment and materials for the Test Well Drilling would deliver to Myanmar in the next fiscal year, then JICA decided to change the study schedule and dispatched a mission headed by Mr. Senichi Kimura, Director, Second Development Study Division of Social Development Study Department, JICA to explain the change of study schedule to the officials of the Myanmar and Myanmar side kindly agreed it. In February 2002, a mission was dispatched to Myanmar in order to summarize the results gained through the 1st Field Survey and to confirm the site conditions and problems, which might affect to resume the 2nd Field Survey in the next fiscal year. On the occasion of arriving of various spare parts for repairing DDA-own three existing drilling rigs in January 2002, an expert for the repairing work was dispatched to Myanmar from January to March. The repair work was carried out successfully in cooperation with some of DDA mechanics and technicians.

In May 2002, JICA dispatched again the Study Team to conduct the 2nd field survey. The Study Team had implemented various surveys and analyses in Mandalay City and in the Central Dry Zone and the Study Team had summarized the results in the Interim Report. In January 2003, the Study Team submitted the report to the Myanmar side and explained about the contents. The team had continued the analysis of the result of the field survey and conducted further study and prepared the Draft Final Report in Japan. In June 2003, a mission was dispatched for submission and explanation of the Draft Final Report to the Myanmar side. This Final Report was prepared through some reviews and revisions based on comments made and sent by the Myanmar side.

The Work progress is shown in Figure 1.4.1.

Table 1.4.1 Progress of the Study



CHAPTER II WATER SUPPLY IMPROVEMENT PLAN IN MANDALAY CITY

2.1 Outline of Mandalay City

Mandalay City is the second largest city in Myanmar and the biggest center of various fields such as politics, economy, culture, religion, historic remains, etc. in the Upper Myanmar. Mandalay City consists of five Townships with 802 thousand of population (as of the end of 2000) within a total area of 117 km^2.

2.2 Present Water Supply System

(1) Water Supply Service Level

The present water supply system is managed by the Water Supply and Sanitation Department (herein after referred to as "WSD"), sector of Mandalay City Development Committee (herein after referred to as "MCDC"). The system consists of production wells, water reservoirs, booster pumping stations, conveyance pipeline and distribution pipe network. These main facilities were constructed during 1983 and 1992 by financial assistances of ADB, OPEC and Myanmar Economic Bank. At present the system covers only a northern half of the city, it has not enough water volume nor pressure to expand the coverage to southern and eastern peripheral area where population are increasing. The water is distributed approximately 50 % or 0.4 million of the population, and covers 60 % or 65 km^2 of the city area. These water supply facilities are shown in Fig 2.1.1. The key indicators of the existing water supply system are as follows:

- Production volume of groundwater: 109,000 m^3/day
- Distribution volume : 96,000 m^3/day
- Billed water volume : 52,000 m^3/day
- Revenue water volume : 39,000 m^3/day
- Non-revenue water volume : 57,000 m^3/day
- Water tariff: Ks 10 per m^3 up to 30 m^3/month, Ks 15 per m^3 over 30 m^3/month, Collecting in every three months,

(2) Existing Water Supply Facilities

1) Water Production Facilities

There are altogether 28 tube wells (as of July 2002) for the water supply system in Mandalay City. Among them, 25 tube wells are located along the east bank of the