No.

Tana Water Services Board
The Republic of Kenya

BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY SYSTEM IN EMBU AND SURROUNDING AREA
IN
THE REPUBLIC OF KENYA

May 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

NJS CONSULTANTS CO., LTD.

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Preface

In response to a request from the Government of the Republic of Kenya, the Government of Japan decided to conduct a basic design study on "The Project for Improvement of Water Supply System in Embu and surrounding area" and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Kenya a study team from 13th September 2009 till 1st November 2009.
The team held discussions with the officials concerned of the Government of Kenya, and conducted field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Kenya in order to discuss a draft basic design, and as this result, the present report was finalized.

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

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Kenya for their close cooperation extended to the team.

May 2010

Izumi TAKASHIMA
Vice-President
Japan International Cooperation Agency

May 2010

Letter of Transmittal

We are pleased to submit to you the basic design study report on "The Project for Improvement of Water Supply System in Embu city and surrounding area" in the Republic of Kenya.

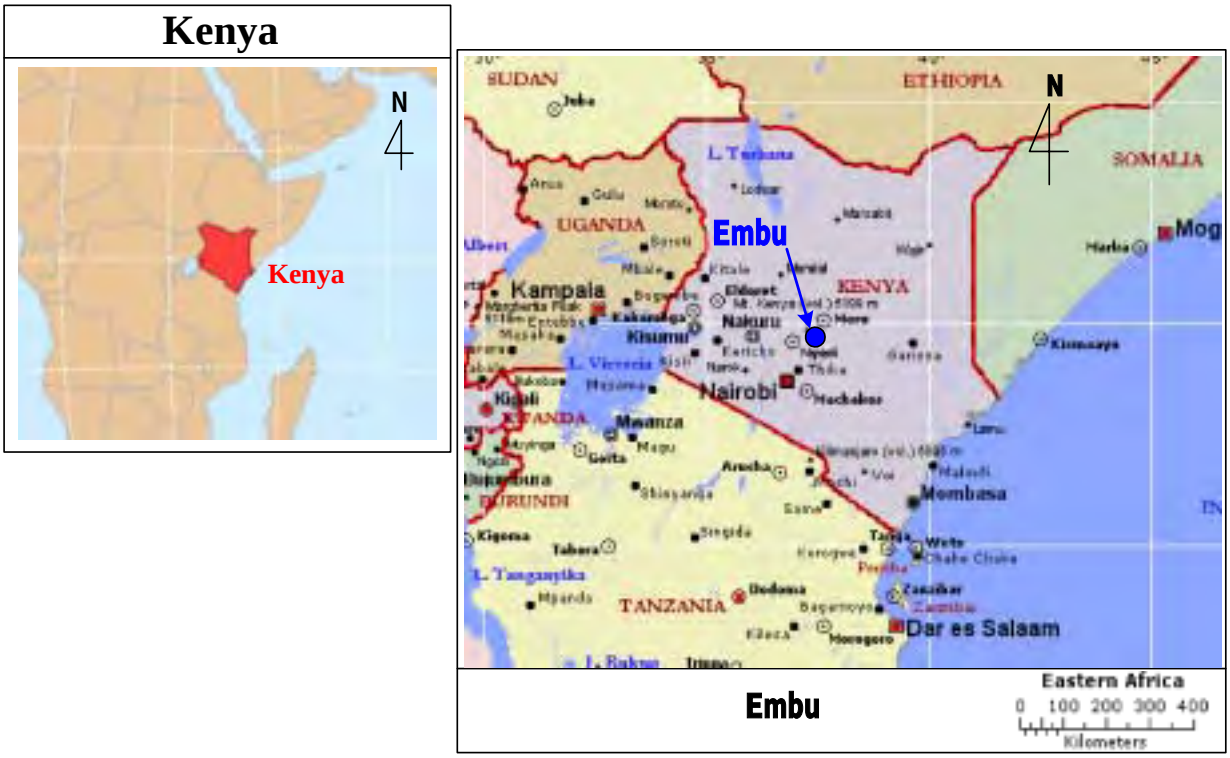
This study was conducted by NJS Consultants Co., Ltd., under a contract to JICA, during the period from September 2009 to May 2010. In conducting the study, we have examined the feasibility and rationale of the project, with due consideration to the present situation of Kenya and formulated the most appropriate basic design for the project under Japan's Grant Aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Keiji MATSUOKA
Project Manager
Basic Design Study Team on The Project for Improvement of Water Supply System in Embu and surrounding area in the Republic of Kenya
NJS Consultants Co., Ltd.

Location Map / Perspective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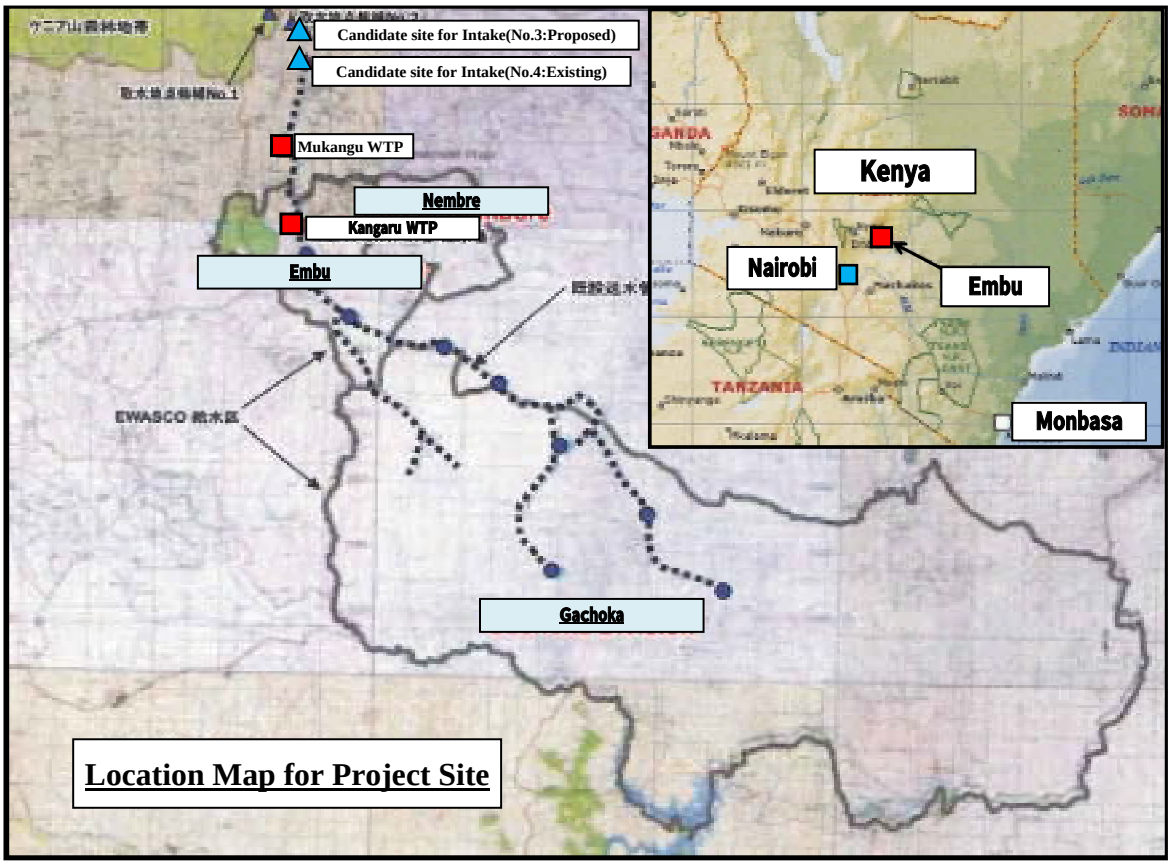
Candidate site for Intake(No.3:Proposed)
Candidate site for Intake(No.4:Existing)
Mukangu WTP
Nembre
Kangaru WTP
Embu
EWASCO 給水区
Gachoka
Location Map for Project Site
Kenya
Nairobi
Embu
Monbasa

Figure-1

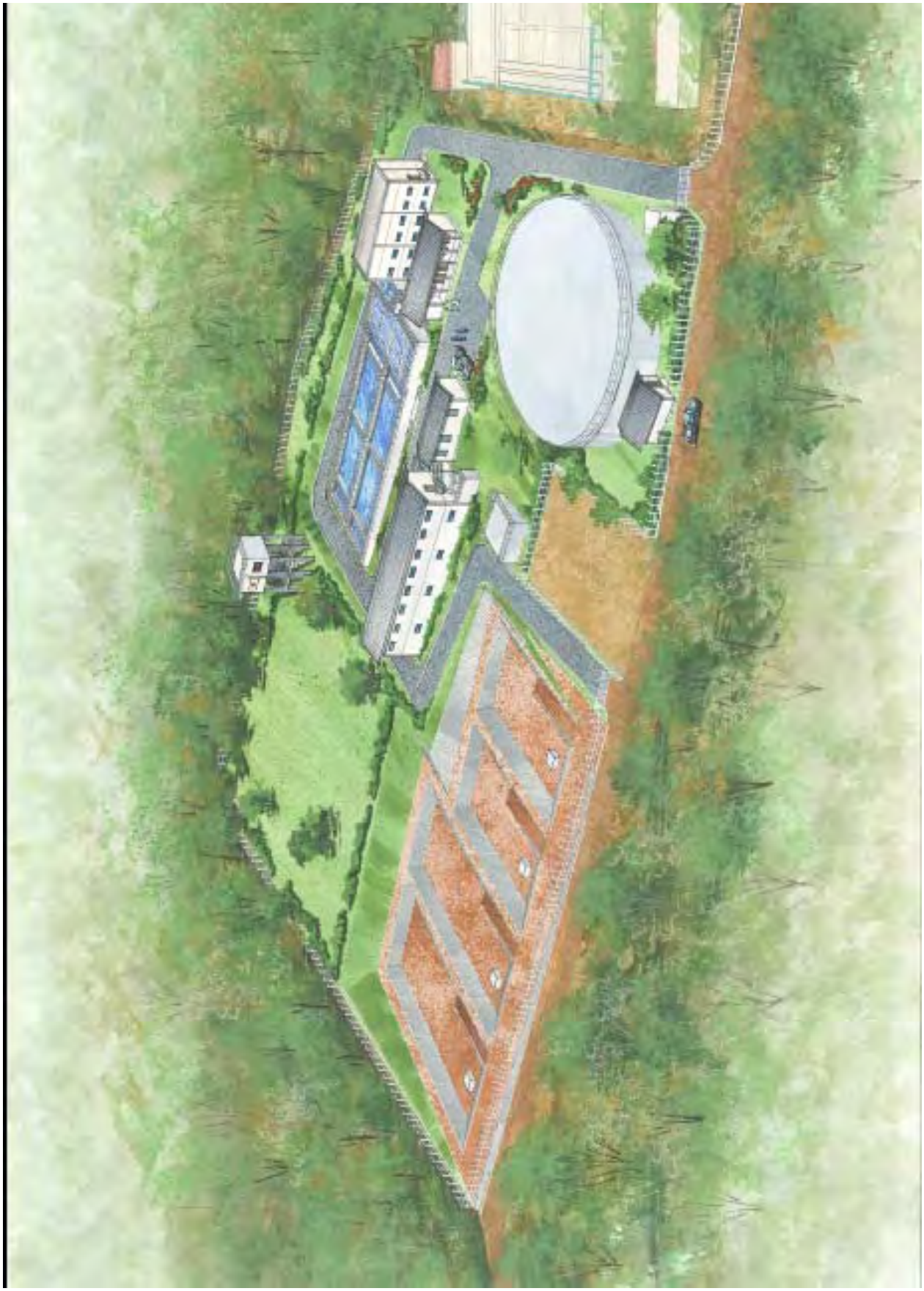

Figure-2

Summary

Summary

1． Summary of Study and Contents of the Project

In response to a request from the Government of the Republic of Kenya (hereinafter referred to as "GOK"), the Government of Japan (hereinafter referred to as "GOJ") decided to conduct a Preparation Study on the Project for Improvement of Water Supply System in Embu and the Surrounding Areas in the Republic of Kenya (hereinafter referred to as "the Study") with the support of the Japan International Cooperation Agency (hereinafter referred to as "JICA"). Accordingly, JICA sent a Basic Design Study Team (hereinafter referred to as "the Team") from September 13th to November 1st (state year).

For the Basic Design Study, the Team undertook the project design based on the results of the discussion with the GOK, as well as on the survey and meetings with the stakeholders, as shown below:

1) The water system will be simple and energy efficient, using gravity to distribute water to the service area.
2) The plant facilities will be designed to respond to the projected water demand by 2015 as its target year, and in accordance with the Practical Manual for Water Supply Services in Kenya, October 2005, MoWI.
3) The plan of the water supply system is shown below:

a) Intake Facilities

The new intake facilities will utilize the existing intake weir and mouths. The system will have two grit chambers with an intake capacity sufficient for the volume transmitting to the Mukangu WTP1 and WTP2, and a fine screen to remove screenings.

b) Raw Water Transmission Main

The transmission main (Ductile iron pipe: dia.500mm ×5.9km) will be installed along the public road by gravity to avoid the steep decline of the existing route. Ductile iron pipes were selected because of low reliability of uPVC pipes, over 355mm dia. of which being made to order.

c) Mukangu Water Treatment Plant (WTP)

The Mukangu 2 WTP will be a new WTP. Its design capacity is 11,000m^3/day, which is the requirement by 2015, and which already considers the capacity of the existing Mukangu 1 WTP. A treatment process for the WTP satisfies the values of WHO drinking water quality guidelines and can be easily operated and maintained manually, or with a minimum automation control. On the other hand, a micro-hydro-power generation facility will be introduced utilizing inflow gravity energy because of the bad energy supply condition in the Embu Area.

d) Clear Water Transmission Pipe

A gravity clear water transmission pipe (uPVC Pipe: dia.315mm x 5.2km) was designed from Mukangu WTP to Kangaru Reservoir Area.

e) Clear Water Reservoirs

There are two clear water reservoirs used to distribute water to high elevation areas in the Mukangu distribution area – a 3000m^3 reservoir located at the Mukangu WTP with a elevation of 1622m-1612m, and a 6000m^3 of reservoir is located in Kangaru Reservoir Site with elevation of 1507m-1504m.

f) Distribution Pipes

As requested by EWASCO, a total length of 71 kms of major distribution networks was surveyed. Of this, 10.8 kms were selected as the target of the project for pipe installation works. The rest of the 60.3km of pipe materials, including necessary pipe for pressure regulation tanks, will be set as procurement items.

g) Constriction Works

Since the construction of similar grant projects was implemented in nearby areas, such as Nieri and Meru Municipalities, local contractors can be utilized for construction work with a similar scale.

h) Procurement of Materials for Construction

There is a construction boom in South Africa for the FIFA World Cup Tournament, which presently affects the procurement of construction materials in Kenya. However, this boom will end by around June 2010, and will have little effect when the construction of the project commences. Electrical equipment and instrumentation such as power supply and power generators, as well as pipe materials which may not be available in Kenya can be from procured from Japan or other countries.

i) Soft Components

EWASCO has been operating a common type of WTPs in Kenya, composed by a circle coagulation sedimentation basin and a rapid filter. It seems, however, that the method of operation was improperly done, bringing to question the skill of the operations staff. There is a need, therefore, of a consultant team, to impart the proper knowledge on operation and maintenance to the local staff, including data arrangement and utilization, through a Soft Component project, utilizing on-the-job-training, or other training methodologies.

Table 1 Contents of Project

(1) Facilities

Name	Specifications/Contents	Note
Intake Facilities	To utilize existing intake weir and mouth, Installation of a fine screen, a spill way and two grit chambers	Refurbishing
Raw Water Transmission Main	Dia. 500mm×length 5.9 km（Ductile iron pipe）	New
Water Treatment Plant(WTP)	Design capacity 11,000m^3/day Receiving well, distribution chambers, receiving tank for Mukangu 2, mixing tanks, flocculation tanks, sedimentation tanks, rapid filters with pipe gallery and building, an elevated tank, a drainage washed water tank, sludge lagoons, a generator/chemical building, a control/electrical building, a chlorine room, a lift pump room, pipelines in the site, site works, mechanical facilities, hydro-power generator, electrical facilities	New
Clear Water Transmission Pipe	Dia.315mm×5.2km（uPVC Pipe）	New
Clear Water Reservoirs	6,000m^3×1（In Kangaru Reservoir Site） 3,000m^3×1（In MukanguWTP）	New
Distribution Pipes	Distribution Main: Dia.400-250mm, Length10.8km（Ductile iron pipe and uPVC pipe）	New

（2）Procurement Facilities

Name	Specifications/Contents
Materials Procurement	Distribution Main：Dia.225-355mm,Length 26.2km ：Dia.63～160mm, Length 34.1km Composed mainly of uPVC pipes, but ductile iron pipes will be used for road crossing lines and exposed lines Accessories: Flow meters (8 units), fitting, gate valves, air valves, drainage valves For Pressure regulation tanks: float valves and other valves
	Calibrator of Water Meter 1unit
	Portable super-sonic flow meter
	Water Analysis apparatus（pH/turbidity/residual chlorine meters, jar testers, measuring cylinders, a balance scale, a refrigerator, a deionizer, a work bench, a spectrophotometer, an incubator, an autoclave, a microbial taster, colony counter and UV equipment）
	Three (3) ton truck: 1 unit

(3) Soft Component

Name	Specifications/Contents
Soft Components	Training for O&M of WTP
	Training for Quality control of WTP

２． Project Period and Estimated Costs

The total period for the project is approximately 32 months, including the soft component, broken down into the following: 21 months for procurement and construction works, 4.5 months for detailed design, and two months for the bidding procedure. The total project cost is estimated to be 2,910 million Japanese Yen

(Japanese side 2,602million Yen{including contingency}, Kenyan side: 308 million yen).

3. Study on Adequacy of the Project

This project generally aims to improve water supply service in Embu Municipality and its surrounding areas, aligned with the targets set by the Kenyan Government in its "Kenya VISION 2030". For this project, water production capacity will be increased in order to provide water service to 87 percent of the population by 2015. A new WTP will be constructed, in addition to the construction of raw/clear water transmission mains and 70 kms of distribution pipelines, including the procurement of pipe material. The latter exceeds whole length of distribution mains owned by EWASCO. The Project also plans provide training for necessary staff in O&M and quality control for WTP through the Soft Components.

There is a JICA technical assistance project aimed at reducing non-revenue water (NRW) of EWASCO, which presently exceeds 50% of production. The implementation of this project will positively affect parts of the supply area of EWASCO, and is seen to increase revenue water by three-fold in 2015. EWASCO, therefore, will not have to raise water tariff because of this "surplus" in revenue water, even imputing a 10% annual inflation rate, additional costs for water production, water leakage protection, and expansion of sewage.

The implementation of the project will provide the following benefits:

1) The water production capacity will be boosted from 12,000m^3/d to 21,000m^3/d;
2) Along with the increase of water production comes the expansion of service coverage in terms of both service area and population. It is expected that the service ratio will go up from 41% to 87 in 2015;
   The financial condition of EWASCO will greatly improve resulting from the increase in water production and the expansion of distribution pipes, coupled with the reduction of NRW through JICA Technical Assistance Project in Kenya.
3) The planned construction of the reservoirs and expansion of distribution pipes will bring about sufficient water supply to support the expansion and improvement of water service in areas where there is no service, or where service is bad. In this connection, the following must be complied with:
   - Completion of the Project including the installation of 10.8km of distribution main,
   - The installation of 60.3km of pipe materials by EWASCO, which will be procured by the Project, and
   - The installation of 152.8km of distribution pipes in Gachoka Area by EWASCO under the Kenyan budget, proposed by EWASCO,
4) The leakage ratio will decrease following the installation of new distribution pipes. For 2009, the computed accountable ratio for 63 kms of distribution mains is 44%. If the leakage ratio of the 71 kms of new distribution mains is assumed to be 100%, the accountable ratio is calculated to be around 75%. Continuous effort toward leakage prevention should be sustained.
5) Water quality will greatly improve with the assistance of the project on operation and maintenance of the WTP and through other Soft Component measures.

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	Calibrator of Water Meter 1unit
	Portable super-sonic flow meter
	Water Analysis apparatus（pH/turbidity/residual chlorine meters, jar testers, measuring cylinders, a balance scale, a refrigerator, a deionizer, a work bench, a spectrophotometer, an incubator, an autoclave, a microbial taster, colony counter and UV equipment）
	Three (3) ton truck: 1 unit

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２． Project Period and Estimated Costs

The total period for the project is approximately 32 months, including the soft component, broken down into the following: 21 months for procurement and construction works, 4.5 months for detailed design, and two months for the bidding procedure. The total project cost is estimated to be 2,910 million Japanese Yen

Indirect effects can also be gained from the Project:

1) Through the Project, safe and adequate water will be provided to the service area, contributing to the reduction of water borne diseases (diarrhea, malaria, bilharziasis, parasite, typhoid) and morbidity caused by unclean water.
2) The Project will supply piped water to each household ensuring more productive use of time by women and children who used to fetch water from sources of doubtful quality.
3) Safe and adequate water and reliable water service will enhance the growth of the economy in Embu and its surrounding areas, particularly in commercial and agricultural activities.
4) The Project will improve the financial position of EWASCO enabling it to implement the following activities:
   - Continuous research/repair for water leakage prevention,
   - Expansion of water service pipes to areas such as Gachoka Area where water service condition is quite bad,
   - Expansion of sewage service areas.

This project is expected to have a great effect on the improvement of the people. The current organization and skill of EWASCO as the counterpart is relatively excellent, as evidenced by the their completion of Mukangu 1 WTP. As of the present time, the need remains for training on the operation and maintenance of the WTP, which will be addressed by the Soft Component of the Project.

In order to operate and manage the project more effectively and efficiently, the following items are required:

- Secure the budget for the implementation of the Kenyan Portion,
- Internal coordination in GOK, in connection with the procedure of the project implementation
- Encourage the project staff to participate in the training programs for to improve their technical know-how,
- Installation of pipe materials and expansion of the new water supply networks.
- The setting and collection of reasonable water tariff based on actual consumption.

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the Project for Improvement of Water Supply System
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Abbreviation

ADF :	African Development Fund
CAAC :	Catchment Area Advisory Committees
DANIDA :	Danish International Development Agency
DWO :	District Water Office
EWASCO :	Embu Water and Sanitation Company
GTZ :	Deutsche Gesellschaft fur Technische Zusammenarbeit
IFAD :	International Fund for Agricultural Development
JICA :	Japan International Cooperation Agency
KfW :	Kreditanstalt fur Wiederaufbau
KOICA :	Korean International Cooperation Agency
MENR :	Ministry of Environment and Natural Resources
MEWASS :	Meru Water and Sewerage Services Registered Trustees
MWI :	Ministry of Water and Irrigation
NEMA :	National Environmental Management Agency
NGO :	Non-governmental Organization
NIB :	National Irrigation Board
NWCPC :	National Water Conservation and Pipeline Corporation
NWSC :	Nairobi City Water and Sewerage Company
PSRS :	Public Service Reform Secretariat
SIDA :	Swedish International Development Agency
TWSB :	Tana Water Services Board
WAB :	Water Appeals Board
WHO :	World Health Organization
WRUA :	Water Resources User Association
WSB :	Water Services Board
WSP :	Water Service Provider
WSRB :	Water Services Regulatory Boards
WSTF :	Water Services Trust Fund
WRMA :	Water Resources Management Authority

[General]

BD :	Basic Design
BPT :	Break Pressure Tank
BS :	British Standard
CEO :	Chief Executive Officer
C/P :	Counterpart
DIN :	Deutche Industrie Normen

ECMA :	Environmental Management and Co-ordination Act
EIA :	Environment Impact Assessment
EIAAR :	Environmental Impact Assessment and Audit Regulation
GPS :	Global Positioning System
GOJ:	the Government of Japan
GOK:	the Government of the Republic of Kenya
IEE :	Initial Environment Examination
ISO :	International Organization for Standardization
MDG:	Millennium Development Goal
MKEPP :	Mount Kenya East Pilot Project
OJT :	On-the-job Training
ROW :	Right-of-way
SPA :	Water Service Providers Agreement
SWAP :	Sector Wide Approach to Planning
TOL :	Temporary Occupation Licenses
WASSIP :	Water Supply and Sanitation Service Improvement Project

[Unit]

BOD :	Biochemical oxygen demand
℃ :	Celcius
COD :	Chemical oxygen demand
Hz :	Herz
km :	Kilometer
Ksh :	Kenyan Shilling
L :	Liter
LCD :	Liter per Capita per Day
m :	Meter
mg/L :	Milligram per liter
mm :	Millimeter
mL :	Milliliter
NTU :	Nephelometric Turbidity Units
pH :	Hydrogen ion exponent
SS :	Suspended Solid
TDS :	Total Dissolved Solid
uPVC :	Ultra-Polyvinyl Chloride
V :	Volt

Chapter 1 Background of the Project

1. Background of the Project

1-1 Current Situation in the Target Service Area

Water service works in Embu Municipality, the target service area of this Project is currently managed by Embu Water and Sanitation Company (EWASCO), based on a contract with Tana Water Service Board (TWSB). The total area of water service area managed by EWASCO is 900 km^2, huge area consists of Embu Municipality and the surrounding areas including a part of Nembure District and whole Gachoka District.

The water service area is limited. Except for the central city area, the remaining service area is located along with the major roads where water service pipes are installed. The water sources of this area are generally small-scaled and unstable and therefore, many people spend hours for water fetching during dry seasons. As major cause of insufficient water supply for users is the shortage in water production, EWASCO is now tackling with the construction of a new water treatment plant (WTP) and it will be completed shortly. However, even if this WTP generates treated water in full capacity, total water production is still insufficient against the estimated water demand.

Accordingly, WTP expansion is urgently needed and installation of water distribution pipes for the districts needs water supply service is also essentially needed. In addition, as EWASCO is still new organization, the improvement in efficient management of the system, tariff system development, financial management and etc. is the subject to maintain a sound functional management of water supply system.

1-2 Condition of Relevant Infrastructures

(1) Road

The main road runs through the city center to Kangaru Reservoir to be constructed newly under this project is paved with specifications equivalent to national highway. While the road located 6 km away from Kangaru Reservoir connecting to Mukangu WTP where most of construction work will be executed, is still unpaved. Furthermore, the road located 6 km away from Mukangu WTP connecting to the Intake Facility is also unpaved. Although these roads are relatively wider than other local roads and there is no obstruction for heavy vehicles such as dump tracks and trailers, as surface soil of unpaved roads have been heavily scraped by traffic, adequate dust countermeasures shall be taken during construction stage. Periodical road repair works are also needed to cope with the damage generated by the heavy traffic.

(2) Electriciy

Distribution power voltage at the project site is 11kV-50Hz to be supplied by the main power distribution cable for Embu Municipality. The load voltage is 3 phase 415V and single phase 240V. There is no inconvenience in adoption of Japanese standard equipment. Power charge system at proposed Mukangu WTP is shown on Table 1-1.

Table 1-1 Power charge system at proposed Mukangu WTP

METHOD CI1	Electricity is provided on 11kV through by meters for industrial commercial use.
a) Fixed charge	KSh 2,500.00
b) Per consumption	KSh 4.73 /kWh
c) Per contract	KSh 400 /kVA

The power failure frequency is 5 or 6 times per week in Embu Municipality. Majority of power failure duration is 20 minutes but it sometimes takes few hours. Rational power interruption is executed for 8 hours every month for maintenance purpose. Power failure was observed almost everyday during this field survey. Since pumps and chemical dissolving devices are planned to be installed in Mukangu WTP, power generator shall be equipped for stable water treatment.

(3) Sewerage

Only a part of Embu Municipality is served by sewerage system. Total area of target sewerage service area in future plan is 1,115 ha but the current service area is only 269 ha, covering approximately 24% of the proposed area and total length of exiting sewer is approximately 12 km. Sewage treatment plant is located in southern part of the city, adjacent to the urban area. As sewage treatment is executed by Stabilization Pond, foul odor and flies are generated. Since this situation is unfavorable for city living environment, EWASCO is now planning to construct a new sewage treatment plant with capacity of 5,000m^3/d in city suburban area by applying World Bank Loan. As phase 2 (long term) plan, EWASCO prepared a plan to construct another sewage treatment plant to cover the whole sewerage service area in Embu Municipality.

As current sewerage service area is limited, total sewage amount discharged to the treatment plant is only 700 m^3/d. Infiltration type septic tanks are utilized in most of households and they are not connected to sewer system. Sewerage coverage area will be gradually increased by executing of abovementioned project, but since Embu Municipality is located at the most upstream of the watershed, the municipality wants to treat all the generated sewage. Therefore, expanding of sewerage system and sewage treatment plant shall be executed in harmony.

(4) Solid Waste Disposal

Solid waste collection and disposal are executed by Embu city government. The bill for waste disposal is charged together with water bill. 21 tons of solid waste per day is generated in average and it is conveyed and disposed on Kakunga dumpsite located 7 km away from the city center. At present, collection area only covers city center. Garbage is also conveyed to the same site without separating. The site area is 15 acre but the only 2 acre is utilized for waste disposal.

1-3 Natural Condition

(1) Topography

Embu Municipality, the center of the study area is located in the East skirt of Mt. Kenya (elevation 5,199m), the highest mountain in Kenya. Elevation of the city plateau area is ranging between 1,200m to 2,000m above Sea Level. The land has slope from North to South with average of 4.3 % containing rivers and canyons eroded by river flows. This topographic feature works as disadvantage in development and expansion of the city area. Small tributary rivers of Kathita River, Matakari River and Kamiugu River are flowing into Rupikangi River and Kapikangi River.

(2) Geology

The soil is composed with many types of volcanic rocks accumulated above the basement rock belongs to Precambrian period. Major soil in the urban area is covered with red volcanic soil weathered by lava flow generated in Mt. Kenya but a part of seepy area is covered with black clay soil.

Soil bearing capacity in construction site of water treatment plant and reservoir was confirmed by on-site test and N value was investigated by standard penetration test to select the optimum construction method. The survey results show that soil in construction site of water treatment plant and reservoir is mainly composed of red clay and silty clay and the bearing capacity at the depth exceeding 2 m is approximately 200kPa (20 t/m^2)

（See Appendix 3-1）

(3) Meteorological phenomena

The annual rainfall is 1,200mm. There are two rainy seasons, one is long term rainy season (March to May) and another is short-term (November to December). Some areas have been suffered by flood caused during rainy season. Average temperature in July and August is ranging from 13 degrees Celsius to 18 degrees Celsius, the lowest temperature in a year . Average temperature in January and February is ranging from 22degrees Celsius to 28 degrees Celsius, the highest temperature in a year. Municipality area can be divided into 4 agro-ecological zones by their longitude, amount of rainfall and temperature. Recently annual average rainfall amount is decreasing by draught. Table1-2 and figure1-1 show monthly average rainfall amount in last 3 years (2006-2009).

Table 1-2 Monthly average amount of rainfall last 3 years (2006-2009)

(Unit: mm)

Location/Month	Jan.	Feb	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Embu	66.4	8.6	124.1	246.1	140.7	16.9	25.5	25	29.5	259.4	223.8	116.5

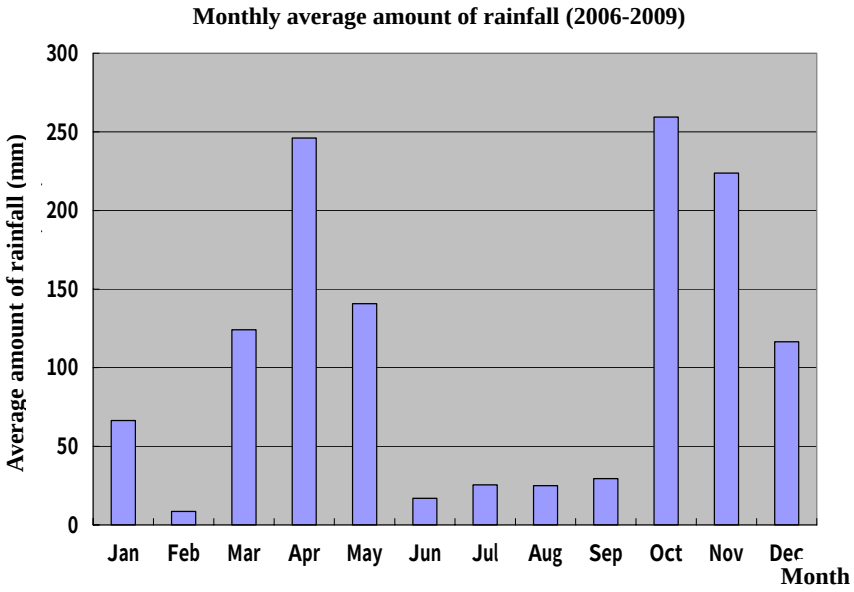

Figure 1-1 Monthly average amount of rainfall last 3 years (2006-2009)

(4) Water quality at water resource

Rupingagi River, the water resource of Embu, is one of the rivers coming from Mt. Kenya. The catchment area at Intake No.4 is 120.3 km^2. Table 1-3 shows the result of raw water quality analysis by EWASCO in 2007.

Table 1-3 Result of Raw Water Quality Analysis by EWASCO (2007)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Turbridity	Average	20.5	6.7	13.8	24.2	13.8	5.3	8	27.3	6.1	14.2	8.5	11.1	12.8
	Max.	173	45.5	187	394	119	12.5	92.6	364	37.2	198	49.1	49.2	394
	Min.	4.1	2.6	2.8	2.9	3.8	3	3	2	2	2.6	3	4.2	2
	# of sample	15	38	50	64	63	70	120	92	98	124	97	33	864
pH	Average	7.3	7.3	7.3	7.2	7.1	7.4	7.5	7.4	7.4	7.3	7.3	7.4	7.3
	Max.	8.3	7.9	7.8	7.6	7.5	7.8	7.9	8.2	7.8	7.8	7.5	8.9	8.9
	Min.	6.7	6.8	6.7	6.9	6.8	7	6.7	6.7	6.9	6.1	6.8	6.7	6.1
	# of sample	10	31	46	46	53	57	108	99	68	24	22	21	585
Temp. (℃)	Average	17.3	17.9	18.8	18	18.3	17.4	17.3	17.2	18.1	18.2	17.7	17.9	17.7
	Max.	19	21.9	21.4	25.1	21.4	20.4	22.8	21.8	24.1	23.6	20.5	24.4	25.1
	Min.	16.5	16	15.9	15.4	15.8	15.5	15	14.9	15.3	15.6	15.2	15	14.9
	# of sample	10	31	45	46	53	57	106	98	67	24	19	18	574

Table 1-4 and Table 1-5 show the result of water quality analysis. Approximately 10,000 m^3/d of water flowing from Mukangu Water Treatment plant was not treated at the time because chemical mixing tanks and sedimentation tanks were under repair and rapid sand filters were under construction.

Table 1-4 Result of Water Quality Analysis (Measured on Oct. 15th, 2009)

Item	Unit	Intake No.3	Intake No.4	Kangaru WTP（Inlet）	Kangaru WTP （treated）
pH	pH Scale	6.54	6.61	7.18	7.53
Suspended solid	mg/1	58	86	62	72
Total hardness	mg$CaCO_3$/1	34.24	34.24	34.24	34.24
Total alcalinity	mg$CaCO_3$/1	0.15	0.38	0.41	0.49
Cyanide	mg/1	<1	<1	<1	<1
Copper	mg/1	<0.01	<0.01	<0.01	<0.01
Mercury	mg/1	<0.01	<0.01	<0.01	<0.01
Iron	mgFe/1	0.22	0.32	0.45	0.46
Lead	mg/1	<0.01	<0.01	<0.01	<0.01
COD	mg/1	10	90	20	30
Turbidity	N.T.U	4.68	6.85	5.18	5.62
Conductivity	μS/ cm	0.02	0.03	0.07	0.07

Table 1-5 Result of Water Quality Analysis (Measured on Oct. 15th, 2009)

Item	Unit	Mukangu WTP（Inlet）	Kangaru WTP (Reservoir)	EWSCO Faucet	Gachoka Faucet
pH	pH Scale	6.82	7.07	7.20	7.34
Suspended solid	mg/1	96	214	238	306
Total hardness	mgCaCO3/1	34.24	34.24	51.36	34.24
Total alcalinity	mgCaCO3/1	0.16	0.25	0.33	0.41
Cyanide	mg/1	<1	<1	<1	<1
Copper	mg/1	<0.01	<0.01	<0.01	<0.01
Mercury	mg/1	<0.01	<0.01	<0.01	<0.01
Iron	mgFe/1	0.34	0.53	0.83	1.02
Led	mg/1	<0.01	<0.01	<0.01	<0.01
COD	mgO2/l	70	30	40	50
Turbidity	N.T.U	8.17	17.20	17.80	22.30
Conductivity	μS/ cm	0.03	0.04	0.05	0.07
Chloride	mg/l	1	3	3	4
Color	Degree	<10	10	<10	10
Zinc	mg/l	<0.01	<0.01	<0.01	<0.01
Coliform	Cfu/100ml	25	1	13	1
EColiform	Cfu/100ml	13	0	5	1
Cadmium	mg/l	<0.01	<0.01	<0.01	<0.01
Arsenic	mg/l	<0.01	<0.01	<0.01	<0.01
nitrate salt	mg/l	0.23	0.21	0.32	0.47
Residual Chlorine	mg/l	0	0.025	0.025	0.025

Rupinggi River water has low turbidity and visually clear in dray weather. While its turbidity exceeds 100 during wet weather but it rapidly recovers after raining.

Numbers of Coliform and E. Coliform of raw water exceed WHO standard values (Coliform: less than 1, E. Coliform: less than 10). They deceased at Kangaru reservoir and again increased at faucet in Embu (EWASCO). After raining, these values are lowered. Value of suspended solid and turbidity tend to increase as distance from water treatment plant enlarges. As rainfall effects largely on raw water quality, water quality flowing treatment facility, distribution facility is also affected by rainfall.

1-4 Socio-Environment Consideration

(1) Water right

EWASCO applied to Water Resources Management Authority (WRMA) the water right to extend water intake amount from 20,000 m^3/d to 30,000 m^3/d. WRMA approved the water right on December 18th 2009.

(2) EIA

EWASCO applied EIA for National Environment Management Agency (NEMA) for this project and the EIA license for this project was issued on December 1st on 2009.

The following items were confirmed during the survey.

1) Land acquisition for new treatment plant and involuntary resettlement of resident

The preliminary study team pointed out that 1 acre land located next to the existing Mukangu water treatment plant provided by EWACO would not be sufficient for the proposed water treatment plant. EWASCO has already acquired the adjacent private land (there is a house on site.) by land exchange. Proposed raw water transmission pipe route and clear water transmission pipe route basically runs in parallel to the existing pipeline. However, the length of raw water transmission pipe, planed to be installed 2.5 km through private lands (farms and slopes), is decreased and the pipe is to be installed along with the public road. Distribution pipeline is to be laid on the existing roads. As there is no inhabitant, no involuntary resettlement of resident will be caused.

2) Sludge and wastewater disposal generated in Water Treatment Plant

Sludge generated in sedimentation tank in water treatment plant will be dried at sludge lagoons in new treatment plant and then, dried sludge is dumped without any environment issues at waste disposal site owned by Embu Municipality. Backwash water amount in rapid sand filter is adjusted at washed water tank and settled at sludge lagoon. After the settlement, water infiltrates into the ground or flows into a small river at West side of the plant. There is no environmental issue to discharge it because effluent water quality is under the effluent standard.

3) Influence on commercial activity by project implementation

Raw water transmission pipe, clear water transmission pipe and distribution network pipe for this project are to be laid on the side of the road or agricultural land and the compensation for farm crops at the relevant area shall be fully executed. In case of pipe installation at edge of eaves on houses or retailing stores, influence for commercial activity is anticipated such as temporary traffic jam or car parking in front of store might not available. However, such small-scaled construction is basically done by manual excavation, construction time is limited and therefore, abovementioned impact can be minimized.

4) Cultural Assets near the project site

There is no cultural assets around the project site.

Chapter 2 Contents of the Project

2. Contents of Project

2-1 Basic Design

2-1-1 Design Policy

(1)Policy

The plant facilities will be designed to address the projected water demand in 2015 as a target year, in accordance with the Practical Manual for Water Supply Services in Kenya, October 2005, MoWI.

(2) Natural Conditions

Precipitation in Embu Municipality is more or less 1,000mm on average these past years, having a long rainy season from March to May, short rainy season from October to December, and dry seasons from January to February and June to September. In the preparation of construction schedule, 10 mm/day or more of rainfall is to be considered as a cause of delay.

(3) Socio-Economic Conditions

Normally, the public offices are closed in Kenya on Saturday and Sunday but the Labor Laws stipulate 45-hours of work in a week (8 hours on week days and 5 hours on Saturday). Kenya has national holidays more than 10 days in a year, and in case of duplication with Sunday and holiday, Monday is to be day off. Ramadan should also be considered in the preparation of construction schedule, for Islamic people.

(4) Laws, Institution and Standards

In the town area, pipelines are not allowed to be laid under paved road, so it should be installed outside the rainwater ditch. At the points where national or trunk roads cross in the town area, the Road Department standards require to place concrete pipes to protect the pipelines. In case that pipes run inside private lands, an agreement should be sought from the land owner, and whatever damage is incurred for the installation should be duly compensated to the owner. Some of these issues may be encountered in the installation of water transmission and distribution lines under the project, thus EWASCO is requested to undertake measures to settle the issues reasonably.

EWASCO has already acquired the EIA from National Environment Management Authority (NEMA). The implementation plan will be prepared to adhere to the contents of the EIA report, with particular focus on environmental considerations.

As mentioned in the standards of NEMA, the study should include restoring storage or open spaces, as well as having preventive measures against dust, noise, turbid water and surplus soil etc.

(5) Utilization of Local Contractors and Products

As similar water supply projects have been implemented near Embu Municipality, local contractors have shown capability to undertake water supply-related construction work. For simple work labors, the Government of Kenya recommends the labor concentrated method rather than using big construction machines. In fact, EWASCO has had experience in manually laying water transmission pipelines from the water intake to Mukangu WTP, and having constructed the Mukangu Water Treatment Plant manually. Under

such circumstances, there is no problem with use and supply of local labor.

In terms of construction materials, such as cement, crushed stone, brick, timber, gasoline and oil etc., these can be procured in Kenya. Electrical instrument and materials, and equipment for hydropower development may be more difficult to obtain, so importing these form Japan or other countries can be considered.

(6) Capacity Building on Operation and Maintenance

The total number of staff at EWASCO is now about 80, including the staff of technical and management divisions. They operate the circular chemical sedimentation tanks and rapid filtration tanks under local standards in Kenya, in addition to the first Mukangu WTP, which is operated through chemical injection process. However, improvements can still be made on design and operation matters, which suggests the importance of capacity building, particularly on institutional strengthening and engineering, (operation and maintenance) through OJT and soft components, such as proper data collection and compilation, which is required for future planning.

(7) Quality Level of Facility and Materials to be Utilized

The system for the treatment plant satisfies the WHO guidelines on drinking water quality, and at the same time, minimizes the consumption of power by manually operating the system, rather than automatic control. Two micro hydropower development plants are to be installed by the use of water heads between the water intake and Mukangu WTP, and another between Mukangu WTP and Kangaru WTP.

(8) Construction Method, Procurement Manner, and Construction Period

The contractor to be hired should take into account the natural and other physical conditions of the area, as well as the socio-economic conditions to ensure the timely completion of the project. It should also organize its construction teams based on the quality of its workers and should undertake the work using safe construction methods.

2-1-2 Basic Plan

Fig. 2-1 shows the pattern diagram of water supply system adopted under the project.

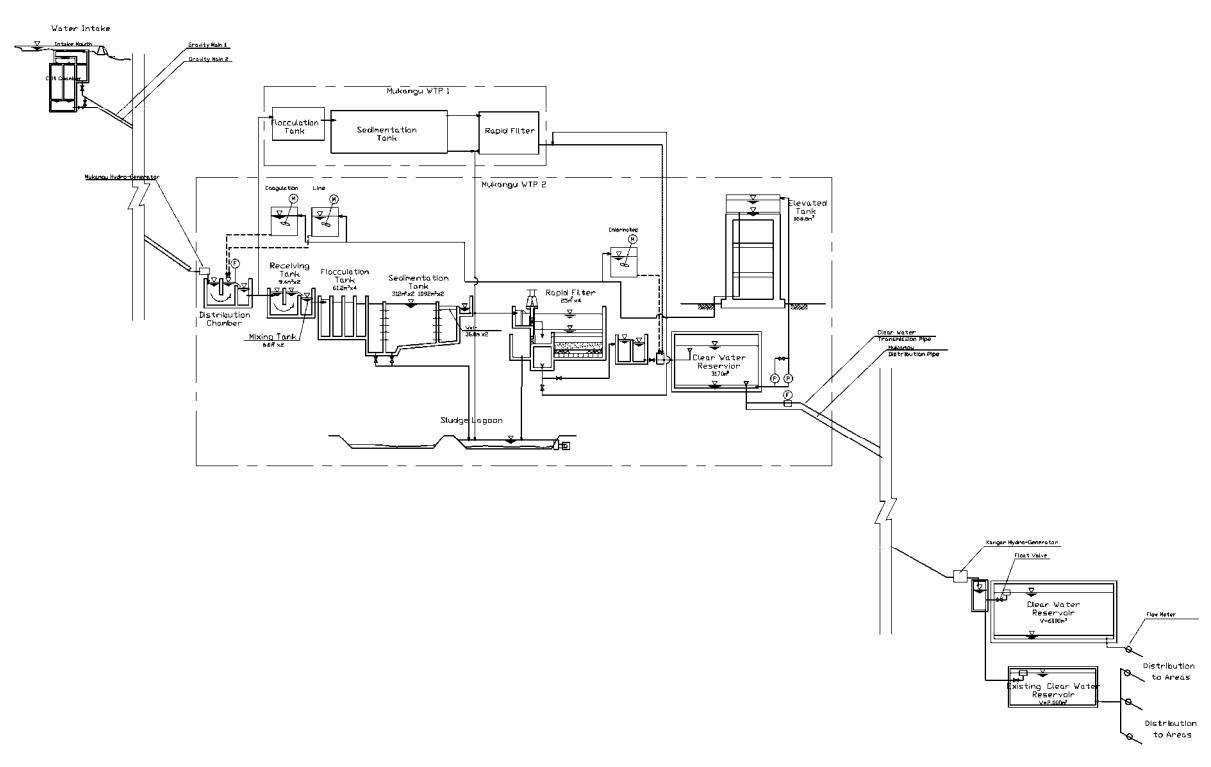

Figure 2-1 Flow Diagram of Water Supply System

2-1-2-1 Water Demand Projection

(1) Target Areas

The target areas comprise Embu Municipality and its surrounding areas, which include Nembure, Ena East, Gatunduri, Ena West, Kithegi and Kithimu of Nembure District, and Gacabari, Kiambere, Riacina, Kianjiru, Kirima, Mbita, Nyangwa, Kithunthiri, Mavuria, Gichiche, Gachoka, Gachichiri, and Kiamringa fo Gachoka District.

(2) Population and Water Demand Projection

1) Population Projection

i) Demographical Movement

Population census is taken every ten years after it was started in 1969. The result of the 2009 census will be available in December 2009. The study has, therefore, been carried out using the 1999 census data for the population projection in 2015.

Embu Municality was founded by British settlers in 1906. Having been the trading center in Eastern Kenya, it is now the provincial headquarters of the Eastern province. According to the census data of 1989 and 1999, the increasing rate of population in Embu town ship is 3.7% and 4.4% respectively; 1.7% in nearby Nembure district (Kithimu and Gaturi South), and 2.9% in Gachoka district (Kimabere, Kiamjiru, Mavuria, Mbeti South). Nembure district is adjacent to Embu municipality; but due to poor water supply, people relocate to Embu instead. The improvement of water supply in Embu will mean an increase of population in the area.

Embu District Statistical Office, Ministry of Planning and National Development suggests to utilize 1.7% of increment ratio in Embu municipality and 2.3% in Gachoka and Embure districts for population projection.

Population in the target areas is mentioned in the table below, Table 2-1, based upon the census data implemented in the past.

Table 2-1 Demographical Movement in the Project Target Areas

Location	1999	1989	1979	1969
Embu	Population	Population	Population	Population
Mbethi North	*15,526*	*10,554*	*7,019*	*11,159*
(Population Gowth Rate)	***4.4%***	***4.7%***		
Municipality	*36,920*	*26,614*	*15,986*	*3,928*
(Population Gowth Rate)	***3.7%***	***5.8%***		
Sub-total	**52,446**	**37,168**	**23,005**	**15,087**
(Population Gowth Rate)	**3.9%**	**5.5%**		
Nembure				
Gaturi South	*12,857*	*14,094*	*11,377*	*5,450*
Kithimu	*17,251*	*11,714*	*8,713*	
Sub-total	**30,108**	**25,808**	**20,090**	**5,450**
(Population Gowth Rate)	**1.7%**	**2.8%**		
Gachoka				
Kiambere	*10,810*	*7,429*	*4,648*	*3,471*
Kianjiru	*17,457*	*13,002*	*9,766*	*7,042*
Mavuria	*17,140*	*14,573*	*10,027*	*7,198*
Mbeti South	*13,695*	*10,556*	*6,724*	*4,068*
Sub-total	**59,102**	45,560	**31,165**	21,779
(Population Gowth Rate)	**2.9%**	**4.3%**		
Total	**141,656**	**108,536**	**74,260**	**42,316**

（Ref：Census Data of 1969, 1979, 1989 and 1999）

Table 2-2 Population Projection in 2009

District/Location/Sub-Location	1999			Population Increment Ratio (1989~1999)	2009
	Population	House-holds	Family Menber		Population
Embu (エンブ) 県					
Embu (エンブ) 市					
Mbethi North(ベティ北)	**15,526**	**3,578**	**4.3**	1.70%	**18,100**
Gatituri (ガティツリ)	5,416	1,238	4.4		
Itabua (イタブア)	6,283	1,449	4.3		
Kiangima (キアンガマ)	3,827	891	4.3		
Municipality (タウンシップ)	**36,920**	**11,148**	**3.3**	1.70%	**43,000**
Dallas/Stadium (ダラス)	16,993	5,902	2.9		
Kamiu (キミウ)	11,357	3,260	3.5		
Njukiri (ジュキリ)	5,092	1,157	4.4		
Nthambo (ヌトンボ)	3,478	829	4.2		
Sub-Total	**52,446**	**14,726**	**3.6**		**61,100**
Nembure郡					
Gaturi South (ガチュリ南)	**12,857**	**2,793**	**4.6**	2.30%	**36,900**
Ena East (エナ東)	2,969	642	4.6		
Gatuduri (ガトゥンデュリ)	5,330	1,145	4.7		
Nembure (ネンブレ)	4,558	1,006	4.5		
Kithimu (キシム)	**17,251**	**3,661**	**4.7**		
Ena West(エナ西)	1,796	406	4.4		
Kithegi (キテギ)	5,789	1,241	4.7		
Kithimu (キシム)	9,666	2,014	4.8		
Sub-Total	**30,108**	**6,454**	**4.7**		
Mbeere (ベーレ) 県					
Gachoka (ガチョカ) 郡					
Kiambere (キアンベレ村)	**10,810**	**2,208**	**4.9**	2.30%	**72,500**
Gacabari (ガカバリ)	2,124	416	5.1		
Kiambere (キアンベレ)	4,886	981	5.0		
Riacina (リアシナ)	3,800	811	4.7		
Kianjiru (キアンジル)	**17,457**	**3,722**	**4.7**		
Kirima (キリマ)	5,894	1,275	4.6		
Mbita (ベティ)	3,333	682	4.9		
Nyangwa (ニャンガワ)	8,230	1,765	4.7		
Mavuria (マブリア)	**17,140**	**3,654**	**4.7**		
Kithunthiri (キスンティリ)	5,848	1,256	4.7		
Mavuria (マブリア)	5,947	1,191	5.0		
Gichiche (ガチチェ)	5,345	1,207	4.4		
Mbeti South (ベティ南)	**13,695**	**3,321**	**4.1**		
Gachoka (ガチョカ)	5,344	1,149	4.7		
Gachuriri (ガチュリリ)	4,536	1,337	3.4		
Kiamuringa (キアムリンガ)	3,815	835	4.6		
Sub-Total	**59,102**	**12,905**	**4.6**		
Gross Total	**141,656**	**34,085**	**4.2**		**170,500**

（Ref. Census in 1999）

ii) Population Projection in 2015

The increase of the population in Embu municipality has been observed during the past years, and one of the most important reasons is immigration from the adjacent towns/districts. The Embu District Statistical Office and also EWASCO predict that this trend will continue, even without significant environmental improvement such as water supply. The population projection for 2015 in the project areas,asssumes and adopts increasing ratios as in 2009.

Table 2-2 presents the summary for the year 2009.

Population projection in 2015 is presented in Table 2-3, and is shown visually in Fig.2-2 visually.

Table 2-3 Population Projection in 2015

District/Location/Sub-Location	1999 Population	Population Increment Ratio (1989~1999)	2009 Population	2015 Population
Embu (エンブ) 県				
Embu (エンブ) 市				
Mbethi North(ベティ北)	**15,526**			**19,993**
Gatituri (ガティツリ)	5,416	1.70%	**18,100**	6,974
Itabua (イタブア)	6,283			8,091
Kiangima (キアンガマ)	3,827			4,928
Municipality (タウンシップ)	**36,920**			**47,542**
Dallas/Stadium (ダラス)	16,993			21,882
Kamiu (キミウ)	11,357	1.70%	**43,000**	14,624
Njukiri (ジュキリ)	5,092			6,557
Nthambo (ヌトンボ)	3,478			4,479
Sub-Total	**52,446**		**61,100**	**67,535**
Nembure郡				
Gaturi South (ガチュリ南)	**12,857**			**18,084**
Ena East (エナ東)	2,969			4,176
Gatuduri (ガトゥンデュリ)	5,330			7,497
Nembure (ネンブレ)	4,558	2.30%	**36,900**	6,411
Kithimu (キシム)	**17,251**			**24,263**
Ena West(エナ西)	1,796			2,526
Kithegi (キテギ)	5,789			8,142
Kithimu (キシム)	9,666			13,595
Sub-Total	**30,108**			**42,347**
Mbeere (ベーレ) 県				
Gachoka (ガチョカ) 郡				
Kiambere (キアンベレ村)	**10,810**			**15,204**
Gacabari (ガカバリ)	2,124			2,987
Kiambere (キアンベレ)	4,886			6,872
Riacina (リアシナ)	3,800			5,345
Kianjiru (キアンジル)	**17,457**			**24,553**
Kirima (キリマ)	5,894			8,290
Mbita (ベティ)	3,333			4,688
Nyangwa (ニャンガワ)	8,230	2.30%		11,575
Mavuria (マブリア)	**17,140**		**72,500**	**24,107**
Kithunthiri (キスンティリ)	5,848			8,225
Mavuria (マブリア)	5,947			8,364
Gichiche (ガチチェ)	5,345			7,518
Mbeti South (ベティ南)	**13,695**			**19,262**
Gachoka (ガチョカ)	5,344			7,516
Gachuriri (ガチュリリ)	4,536			6,380
Kiamuringa (キアムリンガ)	3,815			5,366
Sub-Total	**59,102**			**83,126**
Gross Total	**141,656**		**170,500**	**193,008**

The calculation on the increasing trend in population is presented in Figure 2.2. The assumption made is 1.7% for Embu municipality and 2.3% for Nembure and Gachoka districts as shown by the straight line.

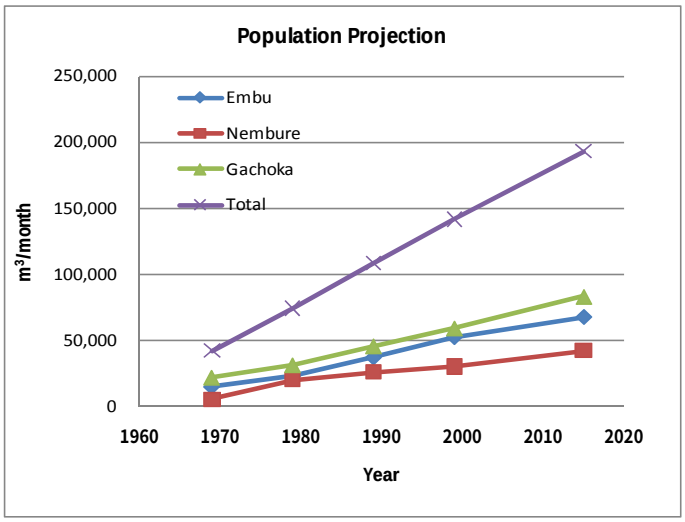

Figure 2-2 Demographical Movement from 1969 to 2015

iii) Population Planned to be Supplied by Water

By the target year of 2015, 100% of the population in the Embu Municipality and 80% in Nembure and Gachoka districts will be supplied with water, according to the plans of TWSB and EWASCO. Target population to be supplied by water by sub-location is found in Table 2-3.

2) Water Demand Projection

i) Domestic Water

Present Status

EWASCO is in the midst of constructing a first water treatment plant (1st WTP) at Mukangu which includes rehabilitation of the sediment tanks and the new construction of filtration tanks. The construction was expected to have been completed in the middle of 2009, but due to the lack of budget, the completion is delayed up to the middle of December 2009. Under such circumstances, water supplied from Mukangu WTP to the service areas through Kangaru WTP is processed only by chlorine, treatment. Such water supply shows high turbidity in rainy days, but has high transparency in the dry weather.

As Fig.2-3 shows, transmission and distribution route starts from Mukangu WTP. One route stretches to Kangaru WTP, and another to Njikiri/Nthambo service areas, which are located before and are higher than the Embu township level. From Kangaru WTP, the distribution line goes through the township; but at the Itabua junction, the line is divided into two – to Kiamuringa and to Gachgoka sub-location. At present, water is supplied only to Embu Municipality, and Gachoka, Kiamuringa, Mbita, Nyangwa and Kithumthiri in Gochoka district.

A pipeline further west from Kanyariri was installed under the ENA Water Supply System. But owing to the inadequate water production at 1,600 m^3/day, the supply was limited only to Siakago from Ena WTP, while the rest of the coverage areas, further west of Siakago, have been handed over to EWASCO together with the

pipeline. The pipeline on the western side from Kanyariri is rather old and leaky, thus EWASCO is working on the rehabilitation of the pipeline and on the expansion of the distribution line further to the west from Karii. During the study period, the pipeline between Kiritiri and Karii was under rehabilitation, and there was no water available to be supplied further west of Muchonoke, Kianjiru district, where water supply is now restricted to three days. In fact, the Gachoka district has a difficult time getting domestic water supply due to the inadequate water production capacity.

The longitudinal gradient of the distribution line peaks at Kiamulinga, and is lowest at Kanyariri. It once again ascends to the water reservoir at Nyangwa. Note that the water reservoir at Gikiiro is also one of the highest points, and is one of the most important reservoirs to supply water further west where distribution can more easily flow by gravity. There is, however, a full pavement road going to Kitiriri through Gachoka sub-location, but the distribution line cannot go this way since this road goes over the critical height needed to supply water to Kitiriri between Mutugu and Muthusu.

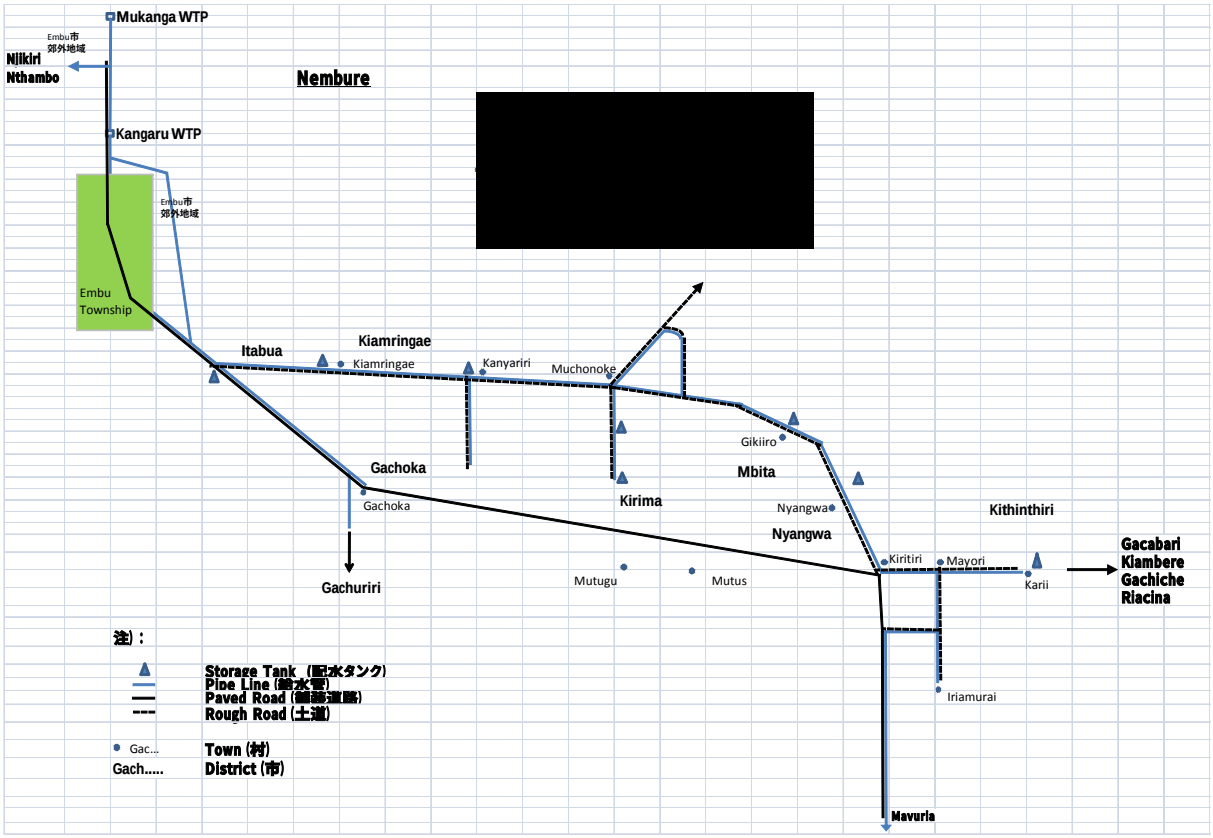

Figure 2-3 Water Distribution Diagram outside of Embu Municipality

Per Capita Demand of Domestic water Use

The "Practical Design Manual in 2005" mentions that Per Capita Demand in urban areas is 250 lcd for high income, 150 lcd for medium income and 100 lcd for low income households. These figures are recommended to be adopted as it takes into account the socio-economic conditions and living standards of the areas. If one allows for industrial development, or even improved lifestyles in Embu Province, it may be more practical to adjust the figures as was made by a previous Grant Program in Kenya taken from the data analysis. In Embu municipality, based on water consumption in Sections 21 to 34 (for a total of 3,400 households), the average billed water consumption is 113 lcd. In the rural areas, per capita demand is 60 lcd in the high-potential area, 50 lcd in the medium potential area, and 40 lcd in the low potential area, under the "Practical Design Manual in 2005". But on a site visit to Nembure and Gachoka, slight modification should be made, since per capita demand in the high and medium potential areas and the low with water faucets in common are 55 lcd and 25 lcd, respectively.

Table 2-4 Condition for Per Capita Demand of Domestic Water Use

Municipality/ District	Classification	Per Capita Demand (litter/day.capita)	Water Supply Ratio (%) ・
Embu Municipality	High Income	150 lcd	To supply to 100% of population: Proportion of income (High:32%, Medium:37%, Low:32%)
	Medium Income	100 lcd	
	Low Income		
Surrounding Areas	Each Faucet	55 lcd	To supply to 80% of population: Proportion by service type(Faucet in houses: 77%, Public faucet:23%)
	Faucet in Common	25 lcd	

Billed Water Ratio

Based upon the data of EWASCO from September 2008 to August 2009, billed volume, or accountable ratio is 44% of water production, meaning that unaccounted water ratio is as high as 56%, which obviously comes from leakages and illegal connections.

In 2007, the total length of the preliminary transmission line is 63 kms; while the length to be laid under this project is approximately 71 kms. With both the on-going rehabilitation of the pipelines, as well as the completion of the project, it is safe to adopt 75 percent as the accountable ratio, which means a loss of 25 percent from the production volume.

Water Demand Projection

Water demand projection in 2015 is presented in Table 2-5, based on the conditions previously mentioned above.

Table 2-5 Per Capita Demand of Domestic Water Use(without Loss)

District/Location /Sub-Location	2015							
	Population Projection	Classification in Population			Water Demand by classification (m^3/day)			Domestic Use (m^3/day)
		High (31%)	Medium (37%)	Low (32%)	High (150lcd)	Medium (100lcd)	Low (100lcd)	
Embu								
Mbethi North	**19,993**	**6,198**	**7,397**	**6,398**	**930**	**740**	**640**	**2,309**
Gatituri	6,974	2,162	2,580	2,232	324	258	223	805
Itabua	8,091	2,508	2,994	2,589	376	299	259	935
Kiangima	4,928	1,528	1,823	1,577	229	182	158	569
Municipality	**47,542**	**14,738**	**17,591**	**15,213**	**2,211**	**1,759**	**1,521**	**5,491**
Dallas/Stadium	21,882	6,783	8,096	7,002	1,018	810	700	2,527
Kamiu	14,624	4,533	5,411	4,680	680	541	468	1,689
Njukiri	6,557	2,033	2,426	2,098	305	243	210	757
Nthambo	4,479	1,388	1,657	1,433	208	166	143	517
Sub-Total(A)	**67,535**	**20,936**	**24,988**	**21,611**	**3,140**	**2,499**	**2,161**	**7,800**
Nembure		Population for Tapped Water	Population for Water Place		Tapped Water (55lcd)	Water Place (25lcd)		
Gaturi South	**18,084**	**11,140**	**3,327**		**613**	**83**		**696**
Ena East	4,176	2,572	768		141	19		161
Gatunduri	7,497	4,618	1,379		254	34		288
Nembure	6,411	3,949	1,180		217	29		247
Kithimu	**24,263**	**14,946**	**4,464**		**822**	**112**		**934**
Ena West	2,526	1,556	465		86	12		97
Kithegi	8,142	5,015	1,498		276	37		313
Kithimu	13,595	8,375	2,501		461	63		523
Sub-Total(B)	**42,347**	**26,086**	**7,792**		**1,435**	**195**		**1,630**
Gachoka		Population for Tapped Water	Population for Water Place		Tapped Water (55lcd)	Water Place (25lcd)		
Kiambere	**15,204**	**9,366**	**2,798**		**515**	**70**		**585**
Gacabari	2,987	1,840	550		101	14		115
Kiambere	6,872	4,233	1,264		233	32		264
Riacina	5,345	3,293	983		181	25		206
Kianjiru	**24,553**	**15,125**	**4,518**		**832**	**113**		**945**
Kirima	8,290	5,107	1,525		281	38		319
Mbita	4,688	2,888	863		159	22		180
Nyangwa	11,575	7,130	2,130		392	53		445
Mavuria	**24,107**	**14,850**	**4,436**		**817**	**111**		**928**
Kithunthiri	8,225	5,067	1,513		279	38		316
Mavuria	8,364	5,152	1,539		283	38		322
Gichiche	7,518	4,631	1,383		255	35		289
Mbeti South	**19,262**	**11,865**	**3,544**		**653**	**89**		**741**
Gachoka	7,516	4,630	1,383		255	35		289
Gachuriri	6,380	3,930	1,174		216	29		246
Kiamuringa	5,366	3,305	987		182	25		206
Sub-Total(C)	**83,126**	**51,206**	**15,295**		**2,816**	**382**		**3,199**
(B)+(C)	**125,473**	**77,291**	**23,087**		**4,251**	**577**		**4,828**
Total	**193,008**	**167,913**						**12,628**

ii) Other Water Use

For the other uses of water, the projections have been made with 2005 data, using the following assumptions:

- That the population increase in Embu Municipality and the other project target areas are 1.7% and 2.3% respectively. As for water consumption in school, public offices and hospitals and commercial areas, this is calculated proportionately with the population.

- That the water consumption of the high, medium and low-income groups was based on EWASCO water consumption data by category that shows 31%, 37% and 32%, respectively.
- That the data on the number of livestock is from the "Livestock Department Office in Embu", and is estimated at 2% of the increasing rate on a basis of cattle.
- That the number of schools is obtained from the Embu Province Education Office, and rate of increase is in proportion to the increase of the population.
- That the number of industries, business establishments, and central government and local administration is based proportionately on the increase in the population.
- That per capita demand is computed based upon the actual consumption.

The computation of water demand projection without water loss is presented in Table 2-6, by Sub location, as a minimum administrative unit.

Table 2-6 Whole Water Demand Projection

Year	2015 Target Year)				
CONSUMER TYPE	**Served Ratio (%)**	**Pop.in Service Area**	**Served Pop.**	**LCD**	**m^3/day**
A. Domestic Use					
DOMESTIC: HIGH INCOME	**100**	**20,936**	**20,936**	**150**	**3,140**
DOMESTIC: MEDIUM INCOME	**100**	**24,988**	**24,988**	**100**	**2,499**
DOMESTIC: LOW INCOME	**100**	**21,611**	**21,611**	**100**	**2,161**
DOMESTIC: RURAL(Tapped Water)	**80**	**96,614**	**77,291**	**55**	**4,251**
WATER KIOSKS	**80**	**28,859**	**23,087**	**25**	**577**
SUB TOTAL [A] (m^3/day)		**193,008**	**167,913**		**12,628**
B. Hospital & Schools					
EMBU HOSPITAL (BEDS)		**683**		**200**	**137**
DISPENSARIES		**19**		**5,000**	**93**
OUT-PATIENTS		**734**		**20**	**15**
BOARDING SCHOOLS: STUDENTS		**3,628**		**50**	**181**
PRIMERY SCHOOLS: STUDENTS		**20,725**		**25**	**518**
Sub Total [B] (m^3/day)					**944**
C. Large Users					
INDUSTRIAL (ACTUAL)					**141**
COMMERCIAL (ACTUAL)					**435**
LOCAL AUTHORITIES					**44**
GOK INSTITUTIONS (ACTUAL)					**272**
OTHERS (ACTUAL)					**1,088**
SUB TOTAL [C] (m^3/day)					**1,980**
D. Livestock			**Conversion**		
CATTLE		**33,329**	**33,329**		**1,666**
GOATS/SHEEP		**65,351**	**4,357**		**218**
PIGS		**114**	**23**	**50**	**1**
DONKEYS		**624**	**125**		**6**
RABBITS		**3,459**	**35**		**2**
POULTRY		**114,054**	**1,141**		**57**
SUB TOTAL [D] (m^3/day)					**1,950**
Provided through the water supply system (%	**20**				**390**
SUB TOTAL [A]+[B]+[C]+[D] (m3/day)					**15,942**
EFFECTIVE RATIO (%)	**75**				
DEMAND ESTIMATED (m^3/day)					**21,257**

iii) Planned Distribution Volume

The planned water distribution volume computed with water loss by sub-location is shown in Table 2-7. The projected total distribution volume without water loss is 21,257m^3/day, but if one takes into account water loss from reverse washing and other production loss, then the total volume is 23,000 m3/day, as shown in Table 2-7.

Table 2-7 Planned Water Distribution Volume With Water Loss

Sub-location	Distribution Volume (w. uncounted Volume) (m^3/day)	Sub-location	Distribution Volume (w.Uncounted Volume) (m^3/day)
Embu		**Gachoka**	
Mbethi North	**4,091**	Kiambere	**901**
Gatituri	1,427	Gacabari	177
Itabua	1,655	Kiambere	407
Kiangima	1,008	Riacina	317
Municipality	**9,727**	Kianjiru	**1,456**
Dallas/Stadium	4,477	Kirima	491
Kamiu	2,992	Mbita	278
Njukiri	1,342	Nyangwa	686
Nthambo	916	Mavuria	**1,429**
Sub-Total(A)	**13,818**	Kithunthiri	488
Nembure	0	Mavuria	496
Gaturi South	**1,072**	Gichiche	446
Ena East	248	Mbeti South	**1,142**
Gatunduri	444	Gachoka	446
Nembure	380	Gachuriri	378
Kithimu	**1,438**	Kiamuringa	318
Ena West	150	**Sub-Total(C)**	**4,928**
Kithegi	483		
Kithimu	806	**Total**	**21,257**
Sub-Total(B)	**2,511**		

2-1-2-2 Water Intake and Raw Water Transmission Main

(1) Possible Water Intake Volume

1) Discharge Data of the Rupinganzi River

The Water Resources Management Agency (WRMA) of the Ministry of Water and Irrigation (MoWI) is in charge of water intake control. The Agency has a gauging station at water intake candidate No.2; however, this station is not functioning at present. The catchment area of the gauging station is 79.3km^2 and the one at the water intake is 120.3km^2. Water discharge at the intake will be converted in proportion to the catchment areas. The discharge data covers the years 1970 up to 1996 only. Since 2000, however, the discharge has not been measured due to inadequate budget.

Table 2-8 Annual Lowest Discharge of the Rupinganzi River

Table 2-8 shows the annual lowest discharges from 1970 to 1996. Using the "Hazen method", water discharges have been calculated by each return period as presented in Table 2-9.

The conversion of the water intake in proportion to the catchment area is shown in Table 2-9. (Ref. 8-4)

No.	年	年最低流量(m^3/s)
1	1977	0.074
2	1978	0.127
3	1980	0.197
4	1994	0.275
5	1979	0.408
6	1988	0.455
7	1987	0.555
8	1992	0.555
9	1975	0.581
10	1976	0.582
11	1986	0.662
12	1971	0.777
13	1974	0.777
14	1984	0.777
15	1972	0.921
16	1970	0.998
17	1973	0.998
18	1985	1.017
19	1969	1.244
20	1981	1.28
21	1983	1.28
22	1991	1.49
23	1993	1.71
24	1998	1.862
25	1989	2.179
26	1995	2.179
27	1996	2.179
28	1982	2.346
29	1990	3.507
	1997	
	1999	

(Ref: WRMA Rupingazi Discharge Data 4DC03)

Table 2-9 Lowest Water Discharge by Each Return Period

Return Period	Annual Lowest Discharge（m^3/s）	
	Gauging Station	Water Intake
5 year	0.43 (37,200 m^3/day)	0.65 (56,360m^3/day)
10 years	0.31 (26,800 m^3/day)	0.47 (40,632 m^3/day)
25 years	0.21 (18,100 m^3/day)	0.32 (27,525m^3/day)
50 years	0.15 (13,000m^3/day)	0.23 (19,661m^3/day)

2) Water Intake on Rupinganzi River

At present, the Gandori-Ginda Water Union draws 9,000m^3/day from the Rupinganzi River, and EWASCO is also entitled to draw water up to 20,000m^3/day. So considering that there is no other water intake plan upstream, there might be an issue in terms of which agency or organization has prior rights over water. Accordingly, drinking water enjoys first priority.

The water intake required in 2015 is 23,000m^3/day, for which EWASCO has already applied for the water right of 30,000 m^3/day. The Team, therefore, employed 30,000m^3/day (0.35 m^3/second) as the water intake volume under the project.

River discharge of a 10-year return period can cover the intake volume of 30,000m^3/day (0.35m^3/sec.). A shortage of water intake volume of less then 30,000m^3/day briefly occurred for 122 days in 1977, 28 days in 1978 and 29 days in 1980, as shown in Fig. 2-4.

Normally, however, the river discharge is adequate, as shown in Fig.2-4. When droughts do occur, the shortage of river discharge appears in the months of February and March.

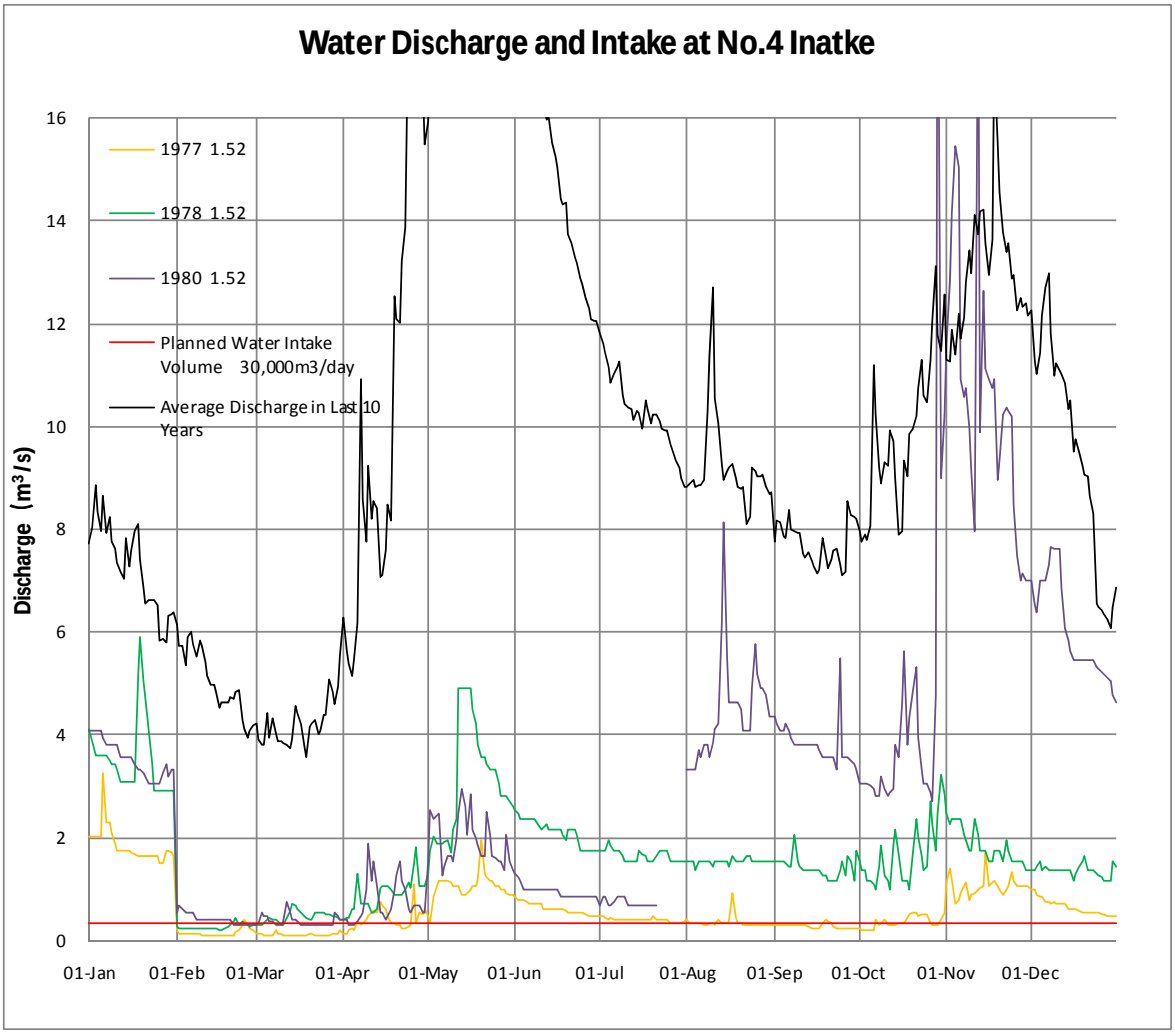

Figure 2-4 Discharges of 10 Years Average/Drought years and Intake Volume At No.4 Intake

(2) Use of Existing Water Intake

There is an existing 13m long water intake weir, used for Mukangu WTP1. Two water intake mouths, 1.15m wide and 1.35m high each, are installed approx. 2~5 m upstream of the weir on the right side of the river. The existing intake facility does not have a grit chamber, and river water flows down by gravity to Mukangu WTP with the discharge being regulated by a gate valve. The existing intake mouth or cavity below the weir top elevation is 1.15m^2(1.15m x 0.5m x 2), which is adequate for the water intake requirement of 30,000m^3/day at 0.3m/sec. This space/cavity is twice the size than the minimum requirement, thus the present intake mouth can be used for the Mukangu WTP2 as well.

(3) Intake Facilities

The concept design of the intake facilities is shown on Fig. 2-5. The new intake facilities use the existing intake weir and mouths, the rest of which will be installed adjacent to and in parallel with the existing system. The system will have two grit chambers with the capacity sufficient for the intake volume of both Mukangu WTP1 and WTP2. The water intake that passes through the intake chambers is to be regulated by a spillway, and will go into the grit chambers. These chambers have a gate valve on each side, at both entrance and exit,

which enables it to empty sediment sand. While flow regulation could be possibly made at the facilities, it should be done basically at Mukangu WTP, where discharge is measured on a real-time basis. A rough screen will be installed at the intake mouth and a fine screen at the intake chamber.

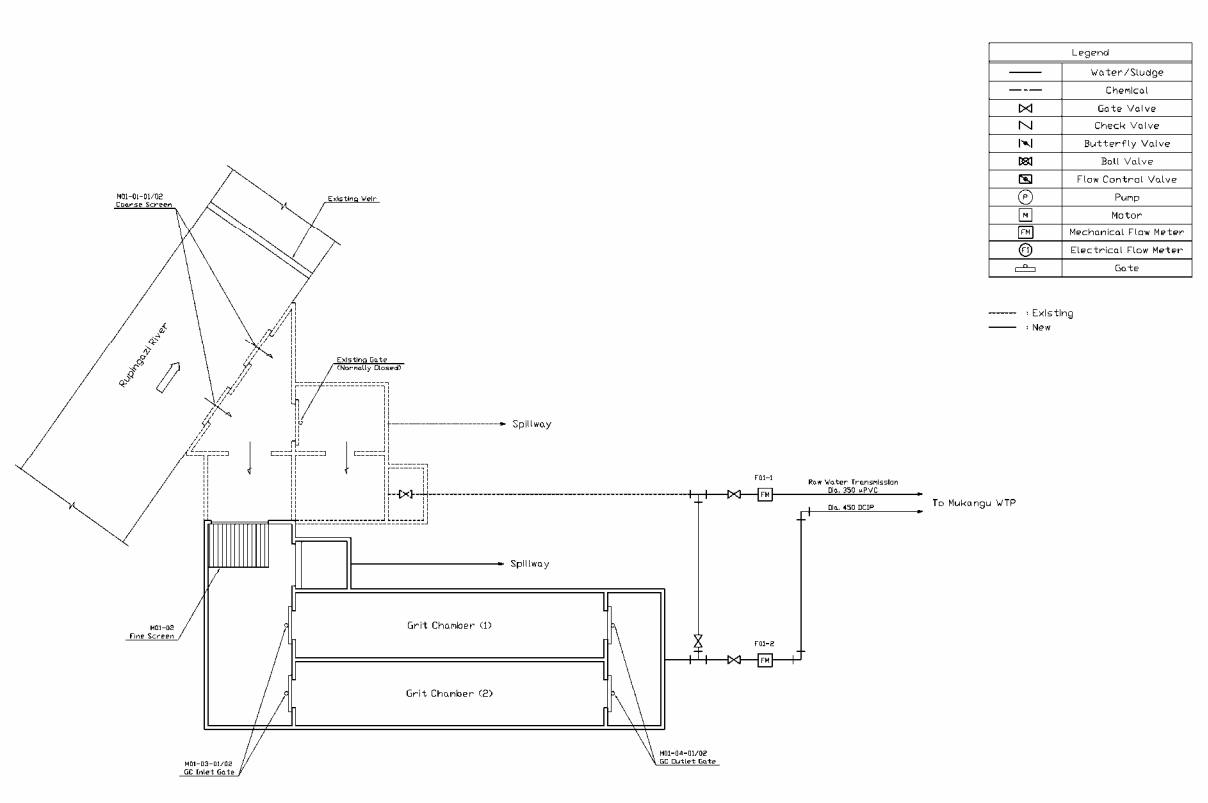

Figure 2-5 Flow Chart of Intake Facilities

(4) Raw Water Transmission Main

1) Route of Raw Water Transmission Main

The route for new raw water transmission main was initially planned to be alongside the existing raw water transmission main, as shown on Fig.2-6 because of its hydraulic advantage. However, since the route is too steep, it may be difficult to transport pipe materials, and even dangerous to install the pipes. Another route along the public road through the peak point was selected, where water can also be transmitted or can flow by gravity. The raw water transmission main goes through the private land about 200m after the intake facilities, and then will cross unto the public road, on to the pipe bridge until reaching the road right of way to Mukangu WTP. The total length of the raw water transmission main is 5,870m and the peak of the route is 1,655m MSL

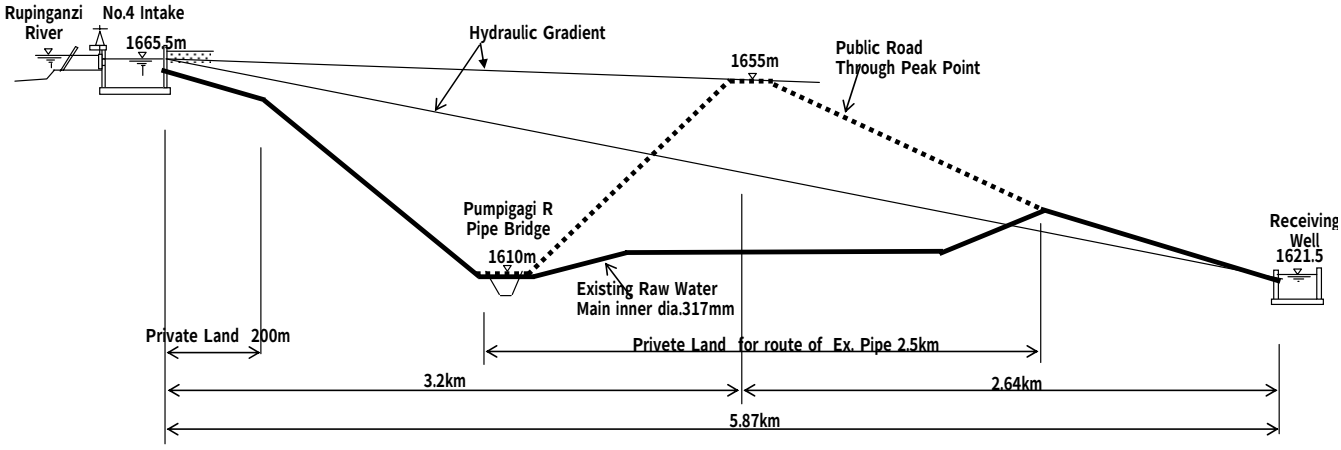

Figure 2-6 Profile of Raw Water Transmission Main

2) Determination of Pipe Size

EWASCO has applied for water right of 30,000m^3/day, in addition to the water right of 20,000m^3/day that it has previously obtained. The application has been approved last December 2009 by the Authority. This volume is considered suitable for reasons shown below.

The annual population growth rate was set at 2.1%. EWASCO, on the other hand, increased the rate of per capita water demand by two percent given the improvement of water quality and quantity after the completion of the Project. With the increased projections, the intake volume after seven years is calculated to be $23,000 \times (1.041)^7 = 30,470m^3$/day, meaning to say that seven years from target year, 30,000m^3/day becomes the water intake volume, which is more or less equal to the amount cited in the application for water intake right.

The new raw water transmission main should have a capacity of 30,000m^3/s, to match with the existing pipe line which has a 317mm inside dia., as well as to cope with the application for water right.

Water amounting to 23,000m^3/sec is the projected water intake volume in 2015. This is used for the design of power generation, together with the water head of 30m. Table 2-10 shows elevation data between the intake and Mukangu WTP:

Table 2-10 Elevation Data of Raw Water Transmission Main

Item	Peak Point			Mukangu WTP	
Distance	3,200	m		5,870	m
Elevation	Intake(m)	Peak(m)	Difference (m)	WTP(m)	Difference (m)
	1,665.5	1,655.0	10.5	1,621.5	44

Table 2-11 shows flow capacities of the water transmission main, subjected to head losses of 44m and 14m, and using uPVC pipe with an inside dia of 317mm (outside dia. of 355mm). Table 2-12 shows discharge capacities depending upon the remaining water head, which allows the use of the existing pipeline. Q1' shows the required flow capacity of the new pipeline, provided that the existing pipeline can flow water with the water head of 44m. Q2' shows the required flow capacity which can enable the generation of electrical power with water head of 30m with a head loss of 14m.

Table 2-11 Required Flow Capacity on Each Condition

Pipe Dia. (mm)	Water Head	Flow Capacity	
	m	m^3/s	m^3/d
317	44	0.1248	10,780
317	14	0.0672	5,805

By Hazen William Equation, with "C" Value of 130

Table 2-12 Required Flow Capacity

Code	Conditions	Flow Capacity	
		m^3/day	m^3/sec
Q1	Water Right	30,000	0.347
Q2	Planned Water Intake	23,000	0.266
Q1'	With the Use of Existing Pipeline (Remained Water Head:0m)	19,220	0.222
Q2'	With the Use of Existing Pipeline (Remained Water Head:30m)	17,195	0.199

The computed head loss of each pipe size on Q1' and Q2' is shown in Table 2-13, which also shows the maximum flow capacity, provided that the remaining water head at the peak is "0" and 30m at Mukangu WTP.

Table 2-13 Head Loss and Max. Flow Capacity

Pipe Size (mm)	Head Loss(m)		Max. Flow Capacity			
			Remained Water Head at the Peak: 0m		Remained Head at Mukangu WTP: 30m	
	Q1'	Q2'	m^3/sec	m^3/day	m^3/sec	m^3/day
350	50.1	40.7	0.220	19,000	0.148	12,800
400	26.1	21.3	0.261	22,500	0.182	15,700
450	14.7	12.0	0.310	26,800	0.224	19,300
500	**8.8**	**7.2**	0.369	**31,900**	0.274	**23,600**

A New Raw Water Main adopts ductile pipe with "C" Value of 120.

Table 2-13 shows that a sound pipe size is 500mm dia. for it to accommodate discharge flows of at least 30,000m^3/day, while maintaining the water head of 30m and the flow capacity of 23,000m^3/day.

3) Selection of Pipe Type

The difference in elevation between the intake and Mukangu WTP is 44m. Though water pressure in pipe is not that high, the project will use ductile pipes to attain needed reliability for the raw water transmission main and to avoid accidents in the case of the existing uPVC Pipe of 10 Bar Resistant, 317mm inside dia. which burst right after pipe laying.

In Kenya, local ready-made uPVC pipes are available only up to 355mm dia. Sizes of bigger diameters can, however, be ordered, although of questionable reliability and quality. Thus, ductile pipes will be utilized for pipes with sizes larger than 355mm dia.

For pipelines that cross streams or rivers, it is best to use a cast iron pipe with a steel frame support for easy maintenance. The brief concept of the pipe bridge is shown on Fig. 2-7.

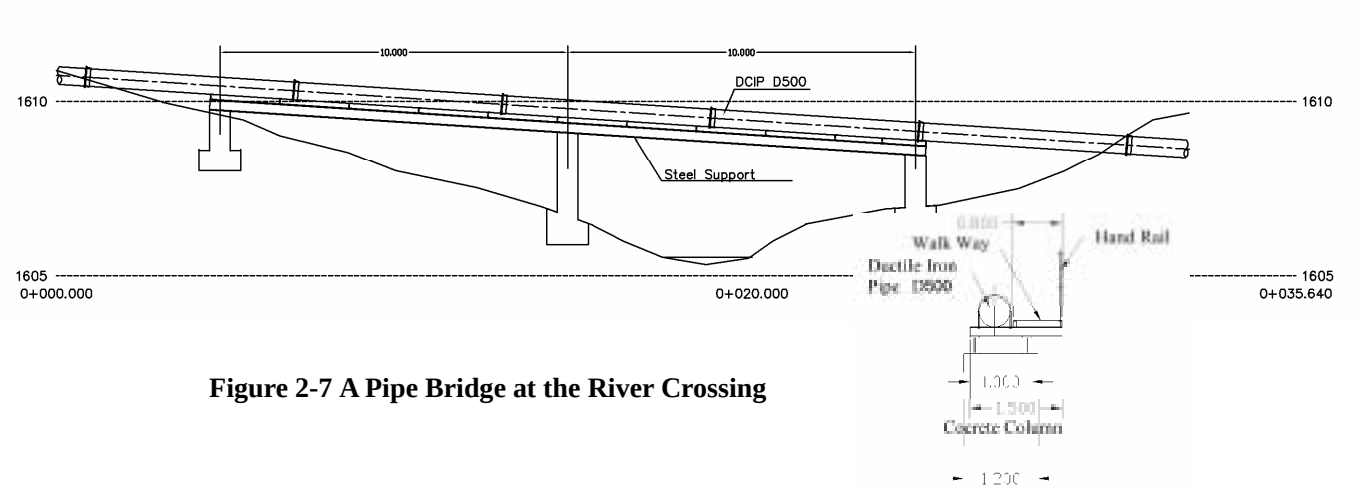

Figure 2-7 A Pipe Bridge at the River Crossing

(5) Summ**ary** of Facilities

Table 2-14 Summary Table of Water Intake and Raw Water Transmission Main

Facility Name	Contents and Dimensions	Remarks
1.Intake Weir （Replace of Intake Mouth Mesh）		
「Civil Facilities」		
Main Body	Weir and Intake Mouth	Use of Existing Ones
「Equipment」		
Screen	Replace of Intake Screens	Removal of Wooden Chips and Leaves
2.Intake Chamber （New）		
「Civil Facilities」		
Inflow Chamber （RC）	2.0mW×4.3mL×1.0mDepth× 1	
Inflow pit （RC）	2.0mW×6.1mL×2.0mDepth× 1	
「Equipment」		
Screen	Installation of Fine Screen : 1.5m×1.8m	Removal of Fine Particles
3.Spillway （New）		
「Civil Facilities」		
Weir(RC)	1.0m Wide	Spillway gate
Pit(RC)	1.5m W x 1.5mL x 2.0H	For Spillway route
	Hume Pipe:1000mm Dia.： 30mLong	Pipe for Spillway
4.Grid Chamber （New）		
「Civil Facilities」		
Main Body(RC)	Grit Chamber: 2.0mWx11.0mL x 2.2m D	2 Tanks
	Discharge pit:2.0mWx4.3mL x 2.2m D	1 Tanks
	Drain Pipe： 30m long	
「Equipment」	A Gate Valve on each side of grit chambers	
	A Drain Valve for sediment drain	
5.Raw Water Transmission Main （New）		
「Civil Facilities」		
Water Transmission Pipe line	Intake Facilities～Mukangu WTP2	
	Pipe Size500mm× Length 5.87km	
	<Contents>	
	L= 5,87 m Ductile Cast Iron Pipe	
	L=20 m Steel Frame Support	Steel Frame Support

2-1-2-3 Plan for Water Treatment Facilities

(1) Planned Water Treatment Volume

For the target year of 2015, the planned water demand is 21,000m^3/day. The present capacity of the existing Mukangu WTP1 is 10,000m^3/day, with the balance of 11,000m^3/day being the required treatment capacity of the Mukangu WTP2 under the project. Allowing for the production loss of 8%, for backwashing etc., the capacities of WTP1 and WTP2 are determined to be 11,000m^3/day and 12,000m^3/day, respectively. The total production capacity is, therefore, set at 23,000m^3/day.

(2) Flow Diagram of Water Treatment Plant (WTP2)

Fig. 2-8 shows the treatment system prepared under the study. It is a fact that the power supply condition in Embu Municipality is very unreliable, necessitating for a power generator for Mukangu WTP. A micro-hydropower generator was designed utilizing the excessive water head from the raw water main at the design flow rate as shown in Fig. 2-8. This type of generator is more expensive than common diesel generators; but the advantages far outweigh the disadvantages. Not only can it supply power continuously in the case of power failure, it is also more durable than diesel generators. A comparison of the micro-hydropower generator with the diesel generator is shown below:

When the micro-hydropower generator is installed, annual savings from fuel is one million Yen. This generator has twice the life of a diesel generator. The cost comparison for 20 years of estimated lifetime can be computed as shown below:

The difference of construction cost: 32mil. Yen (micro-hydropower generator: 42mil.Yen - Diesel generator:10mil.Yen =32mil. Yen

The difference of the operation cost: 34mil. Yen (Saving electricity cost {1 mil.Yen/y x 20y=20mil. Yen} + Diesel fuel cost{0.2mil./y x 20y=4mil. Yen + Replacement cost of diesel generator {10mil. Yen x 1times = 10mil. Yen})

WTP2 employs the same treatment process as WTP1. This is the chemical precipitation, rapid filtration system, injection of flocculants (Aluminum Sulfate) and coagulant agent (Soda Ash), floc formation, chemical precipitation tanks and rapid filtration system. As for sanitation, bleaching powder solvent is injected at the exit of the filtration tanks.

Since raw water quality is rather good, only reverse washing is employed, not surface washing nor air washing. Water is supplied from an elevated water tank with pressure for reverse washing.

Sludge from the chemical precipitation pond is to be processed directly in the sludge lagoon, and water used for reverse washing is to go into the same after temporary accumulation in the drainage tank. Supernatant water of sludge lagoon is released from the WTP to the river located on the western side of the WTP. Dried sludge is carefully discarded outside.

The Mukangu WTPs were designed to minimize power consumption as shown on Fig.2-8, and is simple to operate and maintain. The only difference is harnessing the remaining water head from the raw water, and with the introduction of a micro-hydropower generation equipment, power can now be generated to operate WTP2.

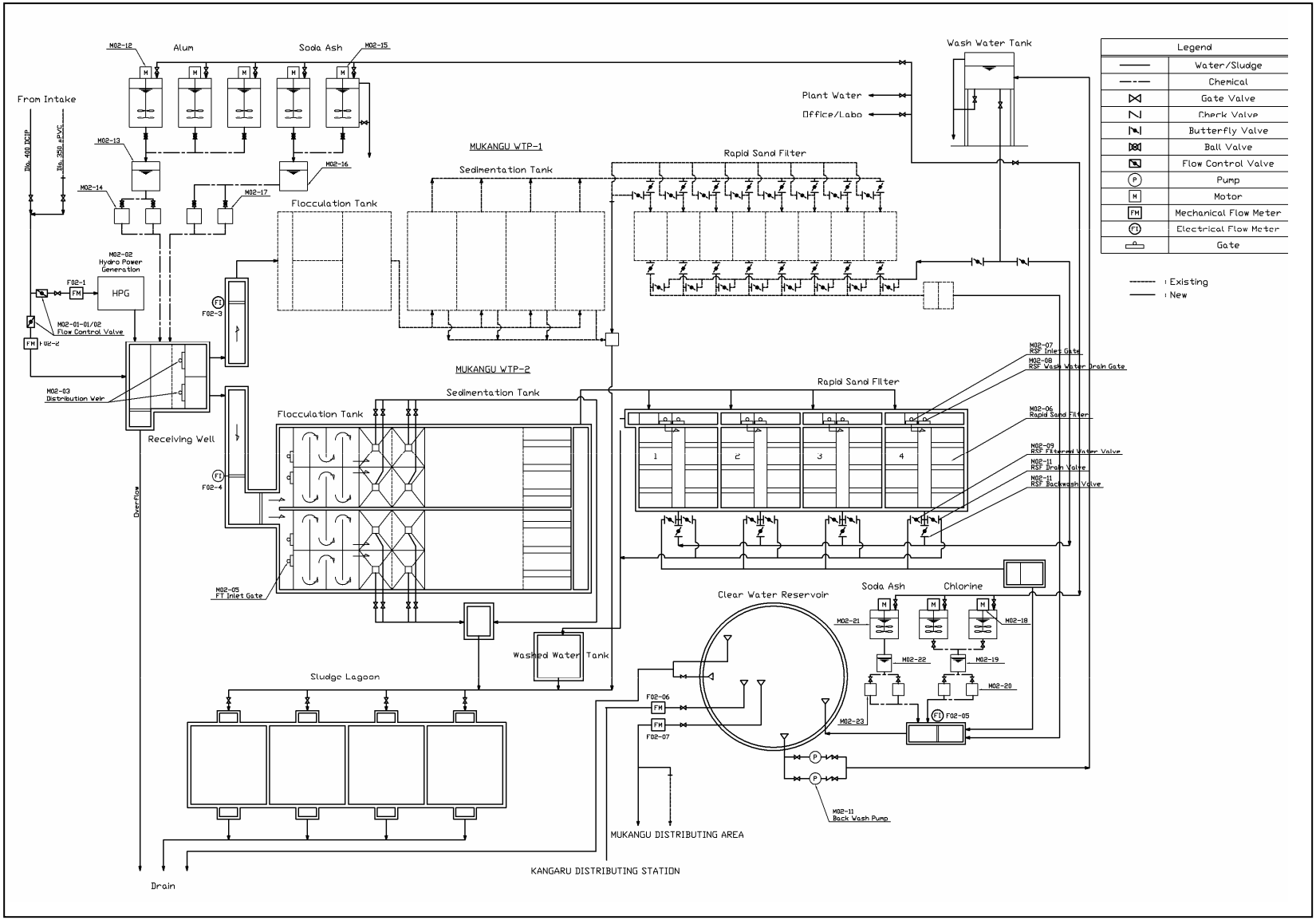

Figure 2-8 Treatment Flow of Mukangu WTP

Table 2-15 Components of Mukangu WTP

Facilities and Equipment	Contents
Rapid Mixing Tank	To harness mixing energy of water from a weir; detention time is 1.5minutes
Floc Formation Tanks	To harness horizontal circumvent flow for mixing water; detention time is 30 minutes
Coagulant Sedimentation Tanks	Vertical flow grit chamber; Detention time is 3.5 hours; Sludge is conducted to a sludge lagoon with gravity by manual valve operation, and with manual labor to gather half dried sludge and carry it out.
Rapid Filtration Tanks	Gravity filtration tank; Filtration speed is 120m/day; Waste water used for reverse washing is conducted into a drainage tank for temporary storage, then, to sludge lagoon; A pump is needed to supply water to a elevated tank; A elevated tank is used also for reverse washing of WTP1 filter tank.
Chemical Injection Facilities	Chemicals (Aluminum Sulfate, Soda Ash, Chlorine powder,) are injected with gravity flow; A mixer is used for chemical mixing;
Sludge Lagoon	Sludge from the sediment tank and from the process of reverse washing is dried herein.

(3) Chemical Dosing Rate

1) Basic Conditions

a. Chemicals to be used：

・Aluminum Sulfate (Solid sulfide aluminum, Oxidized aluminum:17%, 100kg/bag）

・Soda Ash（Na_2CO_3 97%、50kg/bag）

・Chlorine Ash（Chloride concentration, 65%）

b. Raw Water Turbidity

Table 2-16 shows raw water turbidity at No.4 Intake of the Rupinganzi River. The water quality is good and the average turbidity is less than 10NTU in dry season, but in the rainy season, water shows high turbidity of more than 100NTU.

Table 2-16 Raw Water Turbidity （At No.4 Intake of the Rupinganzi River）

（Unit：NTU）

Turbidity	2007 January～ December	2008 September～ December	2009 January～ September	2009 Sampled on June 16	2009 Sampled on October 15
Average	12.8			(7.0)	(8.2)
Minimum	2.0	3.2	1.2		
Maximum	394	76.6	361		
Source	EWASCO	EWASCO	EWASCO	JICA	Under the present study

( ) only one data

2) Aluminum sulfate and Soda Ash

a. Operation of Existing Kangaru WTP

Raw water for Kangaru WTP is from the Kapingazi River. It is this raw water that is being used as data, and its quality is much worse than water from the Rupinganzi River.

Table 2-17 Chemical Injection Ratio of Existing Kangaru WTP

（Raw Water from the Kapingazi River）

Operation Period		Aluminum Sulfate Injection Ratio （mg/L）	Soda Ash （mg/L）
From January 2005 ~ December 2005	Average	13.74	8.02
	Minimum	8.95	6.01
	Maximum	20.82	11.86
January 2006 ~ October 2006	Average	15.13	6.71
	Minimum	12.25	5.88
	Maximum	21.31	12.01

Data from EWASCO

b. Operation Records of Nyeri WTP

The Team has visited Nyeri WTP during the field investigation. The operation records are as follows:

Raw Water Turbidity: 18~20NTU in October; annual average of 5~7 NTU; 500NTU as Maximum on a rainy day; turbidity is rather high than the one of Mukangu WTP.

Injection Ration of Aluminum Sulfate;

20~24mg/L is the set dosing on a fine day, and 50mg/L on a rainy day.

Soda Ash：No entrance injection and 8mg/L of exit injection of limestone.

c. Experimental Equation for Aluminum Sulfate Injection Ratio in Japan

$\alpha = 6 + a\sqrt{T}$

α：Injection Ratio of Aluminum Sulfate（Solid）（mg/L）

T：Turbidity(NTU)

a：Coefficient by Turbidity

T= Less than 20　a=2.0

T=20～10-0　a=1.6

T= More than 100　a=1.4

Use recorded turbidities of the year of 2007 in the equation:

Average　In case that T=12.8　α=13.2

maximum　In case that T=394　α=33.8

d. Concept of Soda Ash Injection

Soda ash Injection ratio should be equivalent to the volume of alkali consumption of solid aluminum sulfate.

Soda ash injection ratio of 0.492(solid aluminum sulfate) is equivalent to solid aluminum sulfate of approx. 0.5. This is employed as an entrance injection of limestone; while half is also injected as an exit injection of limestone.

e. The Results of Beaker Test

In order to confirm the coagulation effects, the Team carried out beaker tests; and the results are shown below:

Table 2-18 Results of Beaker Coagulation Tests

Date	Sample	Raw Water Characteristics			Dosing Rate (mg/L)		Flocculation Condition		
		Temperature (℃)	pH	Turbidity (NTU)	Aluminum Sulfate	Soda Ash	Flocculation Speed	Size	Settling Speed
Oct 19th ,2009	Rupinganzi River	17.9	7.4	26.7	15	7.5	No floc	—	—
					20	10	Slow	Small	Slow
					25	12	Fast	Medium	Fast
					30	15	No floc	—	—

Based on the test results, flocculation could not be confirmed without the injection of soda ash.

f. Design Injection Ratios of Aluminum Sulfate and Soda Ash

Based on the foregoing data, the following injection ratios are adopted:

Table 2-19 Design Injection Ratio of Aluminum Sulfate and Soda Ash

Turbidity (NTU)	Injection Ration of Aluminum Sulfate(mg/L)		Soda Ash Injection Ratio (Aluminum Sulfate×1/2)	Design Volume of Water Treatment (m3/day)	Consumption (Kg/day)	
	Solid Aluminum Sulfate*	Conversion to Oxidized Aluminum			Solid Aluminum Sulfate	Soda Ash
Less Than 20	20	3.4	10	23,000	460	230
20～50	30	5.1	15	23,000	690	345
50～100	40	6.8	20	23,000	920	460
More than 100	50	8.5	25	23,000	1,150	575

*Concentration：Oxidized Aluminum 17%

3) Chlorine Injection Ratio

EWASCO has made it a regulation to inject chlorine, with at least 0.2mg/L as a residual in tap water. Recent records of the chlorine injections from January 2008 are as follows:

Table 2-20 Chlorine Injection Records of EWASCO

Operation Period		Chlorine Powder (mg/L)	Conversion to Effective Chlorine (mg/L)
January 2008～ December 2008	Average	2.32	1.51
	Minimum	1.64	1.07
	Maximum	2.64	1.72
January 2009～ September 2009	Average	2.67	1.53
	Minimum	2.20	1.46
	Maximum	3.16	2.05

By EWASCO, *Chlorine Powder: Effective Chlorine of 65%

Based upon the above record, the following injection ratio has been prepared:

Table 2-21 Design Injection Ration of Chlorine Powder

Effective Chlorine Injection Ratio (mg/L)	Chlorine Powder Injection Ratio (mg/L)	Design Volume of Water Treatment (m^3/day)	Consumption Vol. (kg/day)
1.0	1.54	23,000	35.4
2.0	3.08	23,000	70.8
3.0	4.62	23,000	106.3

* Chlorine Powder: Effective Chlorine of 65%

(4) Micro Hydro-Power Generation Facilities

One set of micro hydropower development unit is to be installed at the entrance of WTP using the. pump turbine type that is based upon the applied discharge and water head.

P = 9.8 x He x Q x E

P：Plant Output (kW)

He：Effective water head（approx. 30m）

Q：Discharge（23,000m^3/day=0.266m^3/sec）

E：Combined efficiency（approx.0.7）

P = 9.8 x 30 x 0.266 x 0.7 = 54.7kW

Design Output is 50kW.

(5) Components of WTP Facilities

The components of WTP Facilities are shown in Table 2-22.

Table 2-22 Components of WTP Facilities

Facilities	Contents and Dimensions	Remarks
「Civil and Building」		
1. Receiving Well (RC)	3.0mW×6.3mL×3.0mD×1=66.2m^3	
2. Distribution Chambers (RC)	1.5mW×3.5mL×3.0mD×2=31.5m^3	
3.Receiving tank for Mukangu 2 (RC)	1.5mW×3.2mL×3.0mD×2=28.8m^3	Weir W=0.8m, Dropped H=0.5m
4. Mixing Tanks (RC)	1.5mW×2.0mL×3.0mD×2=18.0m^3	
5. Flocculation Tanks (RC)	3.85mW×7.0mL×2.5mD×2×2=269.5m^3	Detour flow type
6. Sedimentation Tank (RC)	8.0mW×31.0mL×3.5mD×2=1736.0m^3	Transverse Flow Type
7. Rapid Filtration Tank (RC)	2.5mW×5.0mL×2×4=25m^3×4 Gravel layer：0.6m Sand layer：0.7m Water collector at the bottom：One lot of perforated pipe×2×4 Pipe Gallery: 4.8mW×26.9mL=129.1m^2 Filter Building: 5.15mW×27.1mL=139.6m^2	With gravity, Filtration Speed：120m/day With only Back Wash
8. Washing Water Tank (RC)	7.5mW×7.5mL×3.0mD×1=168.8m^3	For reverse washing of WTP 1&2,and cleaning misc. inside WTPs
9. Drainage Tank for Washed Water (RC)	7.5mW×7.5mL×2.0mD×1=112.5m^3	For velocity alleviation of washed water flowing into sludge lagoon
10. Clear Water Reservoir (RC)	32.0m Dia.×4.0mD×1 =3,160m^3	Include a chamber for pump room and electrical apparatus
11. Sludge Lagoons (Rock Bank with Sand Layer at the Bottom)	(12.0mW×32.5mL+ 12mW×22.5m L) ×1.0mD×each 2 Ponds=1.320m^2	
12. A building for chemical injection and hydropower generation unit (RC and Rock Wall)	6.4mW×18.0mL=115.2m^2(2 Stories) Chemical Injection Room:6.4×11.9m Chemical Storage Room:6.4×14.6m Power Generation Room:6.4×6.0m With Receiving Well	Chemical Storage: 90 days for Aluminum sulfate solution tanks：3.6m^3×3tanks Soda ash solution tanks：3.6m^3×2tanks
10. A Control Building (Rock Wall)	4.8mW×15.0mL= 72.0m^2 Electrical room：4.8×7.2m Control room：4.8×4.8m(With Toilet and Washing Room)	
11. Chlorination Injection Room (Rock Wall)	6.0mW×10.8mL=64.8m^2	Chemical Storage: 90 days Chlorine powder solution tanks：3.6m^3×2tank Later stage soda ash solution tank：3.6m^3×1 tank
12. Pump Room (RC & Rock Wall)	5.0mW×7.5mL=35.0m^2	Pumps：2 sets including standby
13. Plumbing inside of the plant	Plumbing in the plant：One lot	
14. Landscape	Landscaping & restoration: One lot	
15. Misc. Works	Misc. works ：One lot	

Facilities	Contents and Dimensions	Remarks
「Mechanical Facilities」		
1. Hydropower Generation Unit	Reverse Pump Turbine with Generator Output: Approx. 50kWh x 1Unit	With PDB, Dummy Load and Accessories
2. Distributable and Movable Weir	Cast Iron Made Manually Movable Weir W 1000mm×St400mm×2Units	
3. FT Inflow Gate	Cast Iron Made Manual Operation Square Gate W300 mm×H 300 mm×4Units	
4. RSF Inflow Gate	Cast Iron Made Manual Operation Round Gate Dia.250mm×4Units	
5. RSF Waste Water Drainage Gate	Cast Iron Made Manual Operation Square Gate W500mm×H500mm x 4 基	
6. RSF Filtered Water Valve	Manual butterfly valves Dia.250mm×4units, with Switching Tables	
7. RSF Valves for Reverse Washing	Manual butterfly valves Dia.400mm×4units, with switching tables	
8. Aluminum Sulfate Injection Facilities	Powered mixers for chemical mixing x 3units、 Storage tank×1unit、 Gravity flow injectors with manual control ×2 units (one standby unit)	
9. Early Stage Soda Ash Injection Facilities	Powered mixers for chemical mixing x 2units、 Storage tank×1unit、 Gravity flow injectors with manual control ×2units（one standby unit）	
10. Over head hoist for Chemicals	Powered chain hoist, 0.25Ton×1unit	
11. Chlorine Injection Unit	Powered mixers for chemical mixing× 2units、 Storage tank× 1unit、 Gravity flow injectors with manual control ×2units（one standby unit）	
12. Later Stage Soda Ash Injection Facilities	Powered mixers for chemical mixing x 1units、 Storage tank ×1unit、 Gravity flow injectors with manual control ×2units（one standby unit）	
13. Pumps for Reverse Washing	Cross Shaft One Side Suction Spiral Pump 2.7m^3/min.×25m×22kW×2Units(One Standby)	
14. Drainage Pump	Portable, engine driven submersible pump; 1unit	
15. Mechanical Flow Meters	Field instructive turbine flow meters: 4 sets	For inflow water, and water and outgoing water
16. Mechanical Leveling Apparatus	Field instructive scale, 2Units	Water tank for washing water
17. Internal Plumbing and Valves	For chemical storage, Pump room	

Facilities	Contents and Dimensions	Remarks
「Electrical Facilities」		
1. Transformer	11kV／415V、100kVA	
2. Power Distribution Board	Indoor Self-standing Steel Panel　ACB 225AF	
3. PDB for Power Generator	Indoor Type Self standing Steel Panel ACB 225AF	
4. Power Control Panel	Indoor Self-standing Steel Panel MCC type	
5. UPS	5kVA 240V	
6. Control Panel for Chemical Injection	Indoor Self-standing Steel Panel	
7. Outdoor Control Panel	Outdoor Self-standing Type	
8. Inflow Flow Meter	Supersonic Type	
9. Clean Water Flow Meter	Supersonic type	
10. Water Level Controller of Distribution tank	Anchorage type	
11. Level Switch	Electrode Type	
12. Instrument Board	Indoor Self-Standing Type	
13. Monitoring Bay	Indoor Wall hanging Type	

2-1-2-4 Water Transmission and Distribution Pipelines

Two distribution tanks will be constructed to supply potable water to Embu Municiplality and its surrounding areas by gravity flow. One distribution tank of 3,000m_3/day will be constructed at Mukangu WTP and another of 6,000m^3/s will be put up at Kangaru WTP.　The Kangaru WTP will have a storage capacity of around 8,400m^3, together with the existing tank of 2,400m^3. The following is the plan for the water transmission line from Mukangu water distribution reservoir at 1,612m MSL (Mean Sea Level) to Kangaru Distribution Tanks at 1,508m MSL, by using gravity flow.

(1) Route of Transmission Pipeline

The route of the new water transmission line will run parallel with the existing transmission line between Mukangu WTP2 and Kanagaru distribution reservoir. Most of the pipe line will run alongside the public road, but approximate 200m of the outflow parts from Mukangu STP will run through low private land till the connection points of the existing clear water transmission main in order to avoid too deep excavation due to the large level difference between the new transmission main and the load surface in front of the WTP.　At right before Kangaru WTP, it will be made to pass through a government farm land to avoid installing the pipeline under the national road as the existing transmission main.

(2) Selection of Pipe Material and Size

As Table 2-23 shows, the distance between Mukangu distribution reservoir (LWL 1,612.8m) and Kanagru receiving reservoir (WL 1,507.6 MSL).is approx. 5.2km, while and height difference is 105.2m

The present pipe size between Mukangu WTP and Kangaru distribution reservoir is 315mm dia., which is of PVC material, that can withstand pressure of 6~12.5 bars (Class B, Class C and Class D) in different sections. The pipeline branches into two distribution lines in the middle of the course.

Table 2-23 Distance and Difference of Elevation

Distance	5,200m		
Elevation Difference	Mukangu (m)	Kangaru (m)	Difference (m)
	1,612.8	1,507.6	105.2

As Fig. 2-9 shows, the construction of the new Mukangu WTP2 will require a pipeline branch of 315mm dia. at the point, around 0.6km away from Mukangu WTP, which will provide water for the expansion of service area in Nembure. Two cases were studied for the branching as follows:

Case1: The existing water transmission line is converted to a distribution line, and the new pipe line from Mukangu WTP will be converted into the transmission line.

Case2: The existing transmission line will remain as is, and the new distribution lines will be installed instead.

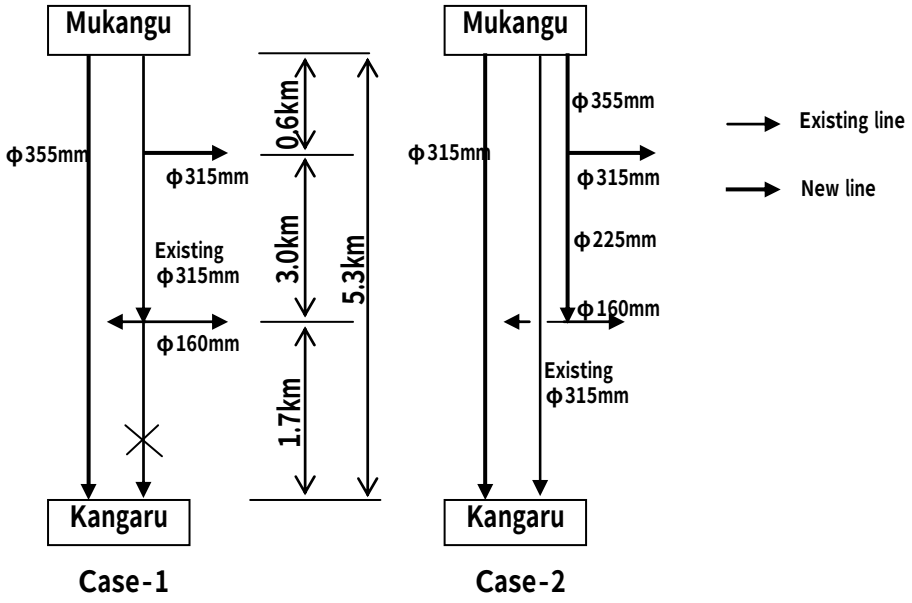

Figure 2-9 Plan of Transmission Line

A study has been made on Cases 1 and 2 for determining the right size of pipe. The flow capacity of the existing transmission main is shown in Table 2-24. Using the existing transmission main will necessitate the computation of the suitable capacity for the new transmission main, the calculations of which are shown in Table 2-25.

Table 2-26 shows, as a result of calculation based upon the foregoing conditions, that, for Case 1 regardless of the existing pipeline, the minimum requirement is PVC pipe of 355mm dia. As for Case 2, taking into account the capacity of the existing pipe line, the pipe with a 315mm inside dia. (272mm outside dia.) will be able to maintain the required water head at the Kangaru. Since the proposed pipe size is315mm dia., no study has been made for smaller pipe sizes.

Based on the above, Case 2 is superior to Case 1, due to the following reasons:

1) Use of existing pipeline,

2) The pipe size of 315mm dia. withstanding 16 bar is consistent to the proposal and is capable of handling the required water volume flow,

3) The recommended pipe material and pipe size has been known to maintain appropriate pressure throughout the networks, and

Table 2-24 Flow Capacity f Existing Pipeline

Inner Pipe Size (mm)	Head Loss	Flow Capacity	
	m	m^3/Sec.	m^3/Day
272	105.2	0.1325	11.445

Table 2-25 Required Capacity of New Transmission Line

Code	Conditions	Flow	
		m^3/day	m^3/sec.
Q	Flow Volume to Kangaru distribution tank	15,000	0.174
Q1	Use of the existing pipeline	3,555	0.041

Table 2-26 Maximum Water Flow Volume

Pipe Size (mm)	Max. flow (Case2)			
	Case 1		Case 2	
	m^3/sec.	m^3/day	m^3/sec.	m^3/day
272	0.144	12,400	**0.276**	**23,800**
307	**0.197**	**17,050**	0.330	28,500

(3) Summary of Facility Components

Table 2-27 Summary of Transmission Facilities

Facilities	Contents and Size	Remarks
Transmission Pipe		
「Civil Facility」		
Transmission Pipe	New WTP~ New Distribution Tank	New Construction
	PVC Pipe, Dia. 315mm × Appro.5.2kmLong	
	<Contents>	
	L=5,300m PVC Pipe	

2-1-2-5 Plan for Distribution Facilities

(1) Distribution System

Fig. 2-10 shows the layout of distribution pipeline which is proposed by EWASCO. Distribution starts from Mukangu WTP (1,612.8m ASL, LWL of the distribution reservoir) and the Kangaru distribution reservoir (1,502.3m ASL, LWL of new distribution reservoir). The Mukangu WTP will supply water to the new areas of Kiangima, Ena east, Gatunduri, Nembure, Ena West, Kithegi, Kithumu in addition to Nthambo

where supply of adequate water is already enjoyed through the branching out of the existing transmission line in between Mukangu and Kangaru WTPs, and also in Kathangari, Njukiri, Gaturi and Itabua, which partially is supplied with water. These areas are rather close to Embu Township and are located in the eastern part of the township. Of these areas, Kangaru WTP will be unable to supply water by gravity to Kathangari, Kiangima, and Gatunduri, Ena East and Ena West, which are in the northern part of the project area. The demand of water supply in these sub-locations is 7,000m^3/day including water lost to leakage and etc. The remaining 14,000 m^3/day is to be supplied from Kangaru distribution reservoir to Nthambo, Njukiri, Gaturi, Kamu, Dallas/Stadium, Itabua etc., which might duplicate with Mukangu WTP supply areas. Water volume from Kangaru distribution reservoir accounts for 66% of the whole production, but not in terms of its proportion in the service area, as shown on Fig. 2-11. Much of the project areas is covered under Kangaru distribution reservoir, including Gachoka District. The farthest part under the project is 10km away, but the distribution line further extends to 45km into Gachoka districts from the Kangaru. The water demand for Gachoka district is supplied through distribution lines towards Mbeere and Donbosco. There are still areas and sub-locations where there is neither water supply nor transmission lines, such that water supply is eagerly awaited.

Figure 2-10 Distribution Lines Proposed by EWASCO

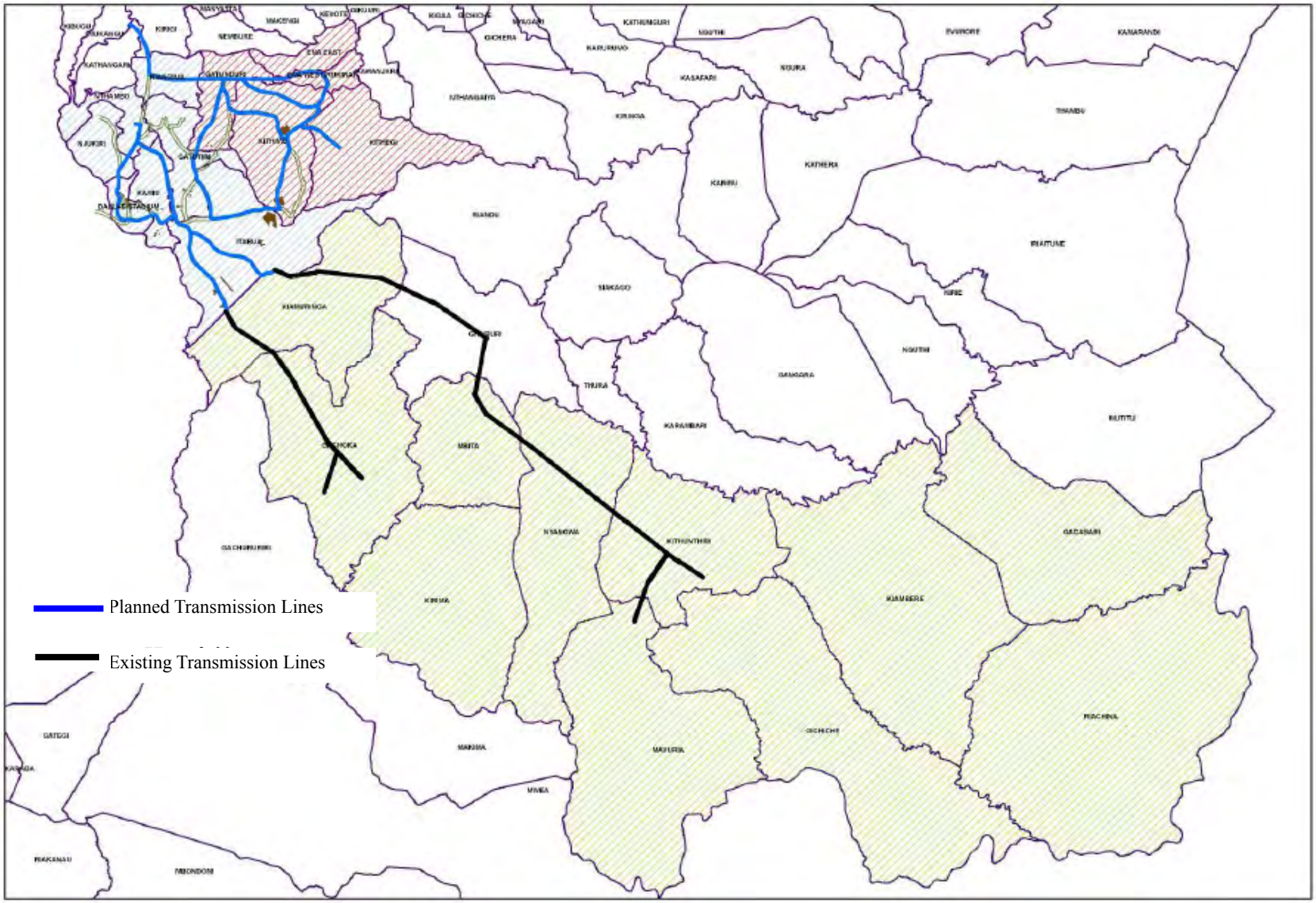

Figure 2-11 Existing Water Transmission Line of EWASCO

(2) Distribution Reservoir

The "Practical Manual for Water Supply Services" in Kanya, stipulates that the storage capacity of a water reservoir should be big enough to storage water for 12 hours for systems using gravity flow. This method of determining the storage capacity of a distribution reservoir is similar to the Japanese Standards for small-scale water supply systems.

＜Calculation in Japan to determine the storage capacity＞

The calculation is made on the assumption that hourly maximum consumption will be kept until the entire daily requirement is transmitted.

Hourly Maximum Proportion	α	
Hourly volume of Maximum Daily Water Consumption	q_0	(m^3/h)
Hourly Maximum Water Consumption	$\alpha \cdot q_0$	(m^3/h)
Maximum Daily Water Supply	$Q_0=24q_0$	(m^3/d)
Duration of Maximum Hourly Consumption	$t=Q_0/(\alpha \cdot q_0)=24q_0/(\alpha \cdot q_0)=24/\alpha$	(h)

$Vmax=\alpha \cdot q_0 \cdot t - q_0 \cdot t$ The balance between the distribution volume within t-hours and the transmitted

$=(\alpha-1) \cdot q_0 \cdot 24/\alpha$

$=24(1-1/\alpha)\, q_0$

In the project design, the hourly maximum proportion is assumed to be 2.0. This figure is generally used and is seen to be reasonable for the project judging from the hourly flow fluctuation data used for the design of the distribution pipe networks. Vmax should be large enough to store water for 12 hours.

Since the planned distribution volume (or production volume) is 21,000m^3/day, the required capacity of water storage reservoir is 10,500m^3 for the 12-hour storage. Allowing for the existing five tanks with a storage capacity of 2,382 m^3, the new storage capacity will be required to be approx. 9,000m^3. The project area is divided into two – the Mukangu distribution area where the flow volume is allocated to be 7,054m^3/day and Kangaru distribution area, where the flow volume is allocated to be 7,054m^3/day, as shown in Table 2-28.

Given the allocation of flow volumes between the two areas, the water reservoir of 3,000m^3 will be constructed at Mukangu WTP and another 6,000m^3 at Kangaru WTP, which will provide proportionate storage capacities of 3,000m^3 : (6,000m^3 + 2,382m^3=)8,382m^3 being equivalent to "0.26: 0.74". Detention times will be 10.2 hours at the Mukangu and 14.4 hours at the Kangaru. While it may appear that a slight imbalance in storage capacity exists, this could be disregarded owing to the fact that clean water is sent to the Kangaru through Mukangu distribution reservoir, and the imbalance is quite negligible on production.

(3) Distribution Line

1) Distribution Network

In planning the layout of distribution networks, the basic concept is to take into serious consideration the proposed distribution networks by EWASCO, as mentioned on Fig. 2-10, and connect to the existing pipeline,

if so required, in order to form new networks.

Table 2-28 Water Demand Projections in Each Distribution Areas

Area/District	Demand Projection in 2015				Actual Demand (m^3/day)	Sub-Total (Including NRW)	Total Adusted to be 21,000m^3/d	Division of Dis. Area	
	Domestic (m^3/d)	B. Hospital/ School (m^3/d)	C. Large Users (m^3/d)	D. Livestock (m^3/d)				Mukangu Demand (m^3/d)	Kangaru Demand (m^3/d)
Embu									
Mbethi North	**2,309**	**173**	**586**		**3,068**	**4,091**	**4,041**	**4,041**	0
Gatituri	805	60	204		1,070	1,427	**1,410**	1,410	-
Itabua	935	70	237		1,242	1,655	**1,635**	1,635	-
Kiangima	569	43	144		756	1,008	**996**	996	-
Municipality	**5,491**	**410**	**1,394**		**7,295**	**9,727**	**9,610**	**530**	**9,079**
Dallas/Stadium	2,527	189	642		3,358	4,477	**4,423**	-	4,423
Kamiu	1,689	126	429		2,244	2,992	**2,956**	-	2,956
Njukiri	757	57	192		1,006	1,342	**1,325**	530	795
Nthambo	517	39	131		687	916	**905**	-	905
Sub-Total(A)	**7,800**	**583**	**1,980**		**10,363**	**13,818**	**13,651**	**4,571**	**9,079**
Nembure						0			
Gaturi South	**696**	**52**		**56**	**804**	**1,072**	**1,059**	**1,059**	
Ena East	161	12		13	186	248	**245**	245	-
Gatunduri	288	22		23	333	444	**439**	439	-
Nembure	247	18		20	285	380	**375**	375	-
Kithimu	**934**	**70**		**75**	**1,079**	**1,438**	**1,421**	**1,421**	
Ena West	97	7		8	112	150	**148**	148	-
Kithegi	313	23		25	362	483	**477**	477	-
Kithimu	523	39		42	604	806	**796**	796	-
Sub-Total(B)	**1,630**	**122**		**132**	**1,883**	**2,511**	**2,480**	**2,480**	
Gachoka						0			
Kiambere	**585**	**44**		**47**	**676**	**901**	**891**		**890**
Gacabari	115	9		9	133	177	**175**	-	175
Kiambere	264	20		21	306	407	**402**	-	402
Riacina	206	15		17	238	317	**313**	-	313
Kianjiru	**945**	**71**		**76**	**1,092**	**1,456**	**1,438**		**1,439**
Kirima	319	24		26	369	491	**486**	-	486
Mbita	180	13		15	208	278	**275**	-	275
Nyangwa	445	33		36	515	686	**678**	-	678
Mavuria	**928**	**69**		**75**	**1,072**	**1,429**	**1,412**		**1,412**
Kithunthiri	316	24		26	366	488	**482**	-	482
Mavuria	322	24		26	372	496	**490**	-	490
Gichiche	289	22		23	334	446	**440**	-	440
Mbeti South	**741**	**55**		**60**	**856**	**1,142**	**1,128**		**1,128**
Gachoka	289	22		23	334	446	**440**	-	440
Gachuriri	246	18		20	284	378	**374**	-	374
Kiamuringa	206	15		17	239	318	**314**	-	314
Sub-Total(C)	**3,199**	**239**		**258**	**3,696**	**4,928**	**4,869**		**4,869**
(B)+(C)	**4,828**	**361**		**390**	**5,579**	**7,439**	**7,349**	**7,051**	**13,949**
Total	**12,628**	**944**	**1,980**	**390**	**15,942**	**21,257**	**21,000**		**21,000**

Pipe network analysis was done by using Water CAD software by Haestad Method, inputting elevation

data, water demand as mentioned on Table 2-28, pipe line length, type of pipe, C-value (for the Equation of Hazen William) and pipe diameter at each contact point, then, computing for water pressure, water flow and velocity at each point. The most appropriate pipe size was selected, after inputting various pipe sizes and materials, and also after the pressure was evaluated, and flows computed.

2) Pipe Type and Size

PVC pipes are to be used for all requested pipe sizes less than 355mm out-dia., while ductile pipes will be used for pipes sizes of more than 350mm inside-dia. as well as on crossing points between the road and river. As for pipe types, PVC pipes of withstanding 16 bar shall be used for all pipes requiring pressure resistance in Meru Municipality, to avoid mistakes in installation and repair works. This countermeasure has been evaluated to be effective in minimizing water leakage. This has proven to be effective also at Embu Municipality which uses PVC pipe withstanding 16 bar for the portions where pressure resistance is needed.

The results of computation for the distribution areas utilizing Water CAD are shown on Fig. 2-12 for the Kangaru distribution area and Fig. 2-13 for the Mukangu distribution area. This result implies that pressure is loaded within the reasonable range (1.0～6.0Bar; Kenya Practice Manual for Water Supply Services, ASTM D1785) and the velocity (0.6～2.5m/sec.) at all the points. The distribution pipes to be selected are shown on Fig.2-12 and 13, in terms of size and type. For 10.8km out of 71.1km of pipelines as indicated on Fig. 2-13, the installation work will be carried out under the project, while the rest of the 60.3kms will be installed by EWASCO together with the associated accessories which will be supplied by GOJ within due time. The following is the list of installation materials, the Water CAD input data, and its outputs.

3) Ancillary Facilities

- 10 sets of flow meters (except for meters installed in Mukangu and Kangaru Site) are to be installed in the pipe line network, as shown on Fig. 2-10, for the purpose of getting the information on distribution of flow volumes, leakage etc.
- Gate valves are to be installed at each branch of the distribution line, and at the points required for maintenance purposes, and should be installed in the manner that Non Revenue Water (NRW) is easily monitored.
- Break pressure tanks/Pressure reducing valves (PRVs) are to be installed at the places as shown on the Fig. 2-12 and 13, to control water pressure in the pipes with less than 6 bar.

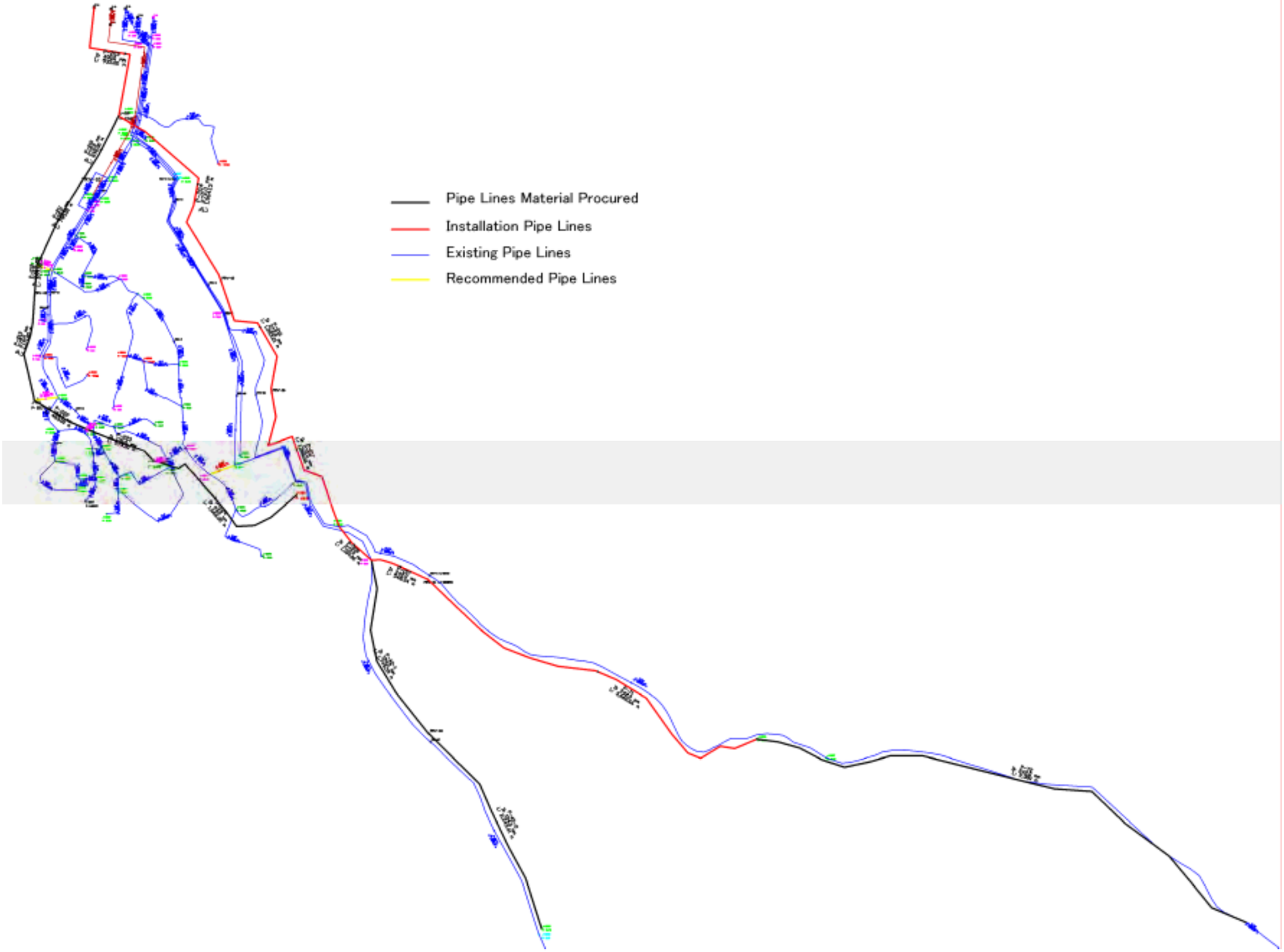

Figure 2-12 Computation by Water CAD for Kangaru Distribution Areas

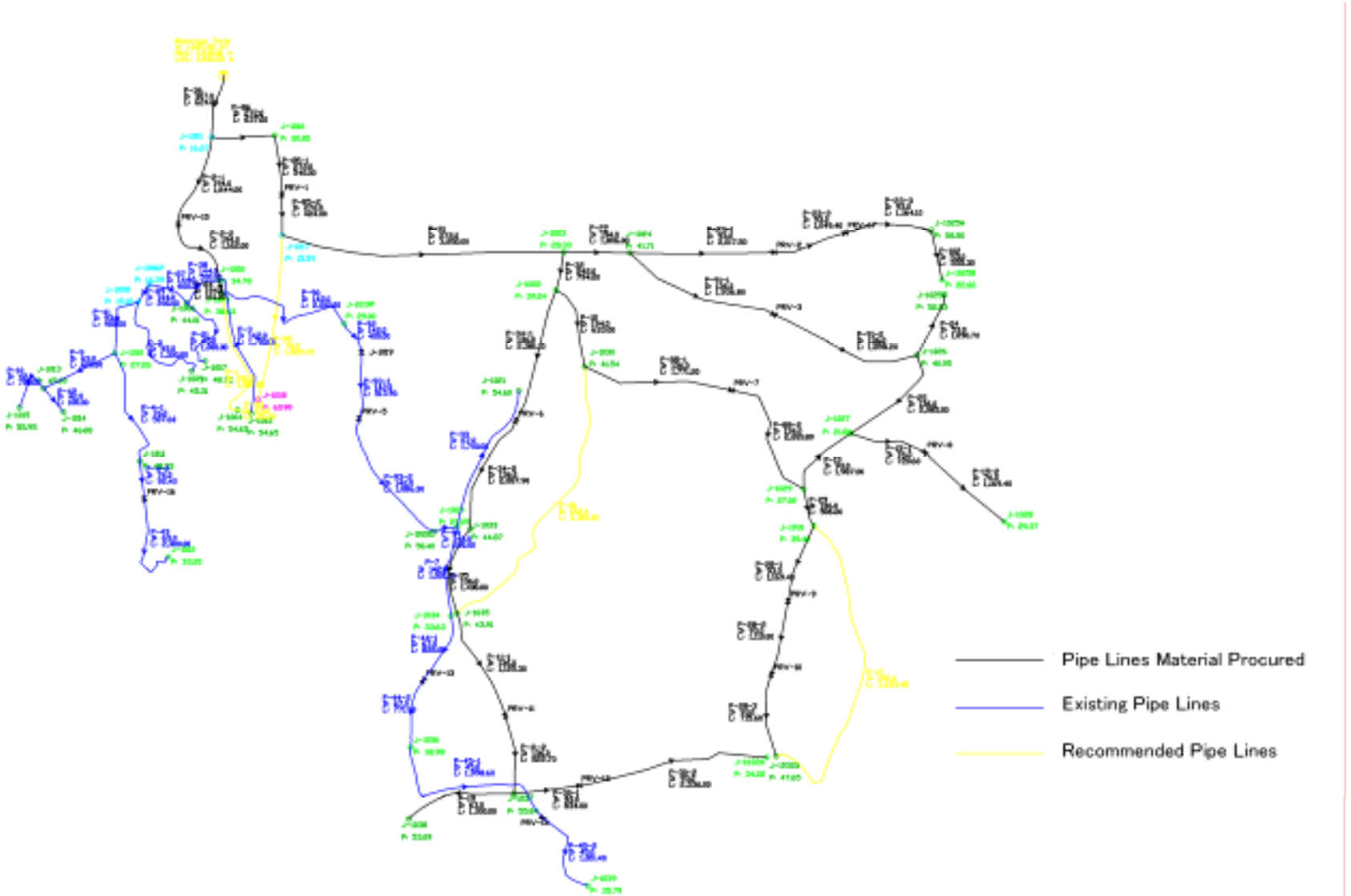

Figure 2-13 Computation by Water CAD for Mukangu Distribution Areas

4) Laying of Distribution Pipes Under the Project

In order to increase the positive effects of the project, the primary distribution pipeline of 10.8km will be installed under the project. The selection was made based on the following criteria:

a) The selection focuses on sending clean water to areas critically requiring water supply in Gachoka District, as shown in Fig 2-10. The proposed area has an existing pipeline, but the volume of clean water supplied to the low lying areas is inadequate, and is restricted on only thrice a week. Thus the installation of the proposed pipeline will enable the supply of adequate water to the low lying areas of Gachoka, while further extension of the pipe line to the west will provide additional benefits.

b) The proposed line is will supply water to a populated area, although it is a bit far from the township

(4) Components of Distribution Facilities

Table 2-29 Component of Distribution Facilities

Facilities	Contents & Dimensions	Remarks
1. Kangaru Water Distribution Reservoir		
「Civil Facilities」		
Clear Water Reservoir (RC)	Dia. 39.5m× 5mD×1= 6,000m^3	New Construction
「Mechanical & Electrical Facilities」		
R-6 Water Level Control valve	Water Level Control Valve Dia.300mm×One unit	
R-5 Water Level Control Valve	Water Level Control Valve Dia.150mm×One Unit	
Mechanical Flow Meter	Field Turbine Flow Meter , 1 sets	For Out Flow
Mechanical Flow Meter	Field Scale, One Set	Distribution Reservoir
Power Distribution Board	Steel Made In-House Self-Standing Type: 240V	
UPS	3kVA 240V	
Water Level for Distribution Reservoir	Anchorage Type, 2 Sets	
Instrument Board	In house Self-Standing Type	
Remote Control Equipment	Base Unit, Hand Set, One Set	
PDB for Power Generation	Steel Made In-house Self Standing Type: ACB 225AF	
Transformer for Power Grid	11kV／415V、100kVA	
4. Distribution Pipe		
「Civil Facilities」		
Main Distribution Pipe	Ductile Cast Iron Pipe, Dia.400 mm × Approx. 0.9km Long	New Construction
	uPVCPipe:Dia.355mm～250mm×Approx.9.8km Long	
	Total : 10.7km	

2-1-2-6 Procurement Plan

The procurement plan study was made with the proposed procurement list by EWASCO as follows:

(1)Materials for Distribution Pipe Installation

A land survey was carried out to obtain the data of distances and elevations etc. in the areas where the distribution pipes will be installed and where the materials are to be supplied under the project. Water CAD was used to analyze both the data and he network. _Based on the result, it is recommended that 10.8km of pipelines should be installed, and materials should be supplied for the 60.3km.

As indicated earlier, PVC pipes will be required for all pipes with sizes less than 355 mm dia., particularly in the areas where materials are to be supplied. Ductile pipes will be utilized at the points where the road and

the river cross. The pipe types will be pressure-resistant against 16 bar. Table 2-30 shows the list of piping materials to be supplied.

Table 2-30 Material List of Piping to be supplied

Classification	Contents		
Cast Iron	Dia.(mm)	Pipe Type	length
	φ355～225	uPVC Pipe, Ductile Cast Iron Pipe	Approx.26.2km
	φ160～63	uPVC Pipe, Ductile Cast Iron Pipe	Approx.34.1km
Accessories	Flow Meter, Special Shaped Pipe, Gate Valve, Air Valve, Drain Valve etc.		
Break Pressure Tank	Float Valve, Other Valves		

(2) Calibrator of Water Meter

For accurate fees to be collected from the water users, it is important that water meters measure consumption correctly. EWASCO uses water meters that are made in China. Water meters can be checked by visual inspection, and through calibration, which will check the meter's preciseness. The calibration will reveal whether the meter is accurate, or should be replaced, repaired or adjusted. Water meter calibrators are not available in Kenya, so it is proposed that one set of calibrator be secured from Japan, together with a standard tank, a rotor meter, a test table and other associated accessories.

Training will be conducted on the use of the calibrator in the Soft-Component portion of the project.

(3) Water Quality Test Equipment and Materials

At Kangaru WTP, which is the future Kangaru distribution reservoir, there are two laboratories, one used by EWASCO and another by MoWI. These laboratories conduct the following tests: (i) turbidity tests of raw water and clean water, (ii) pH tests, (iii) residual chlorine tests, and (iv) coliform population tests. Furthermore, tests items required by the Water Quality Laboratory in Nairobi, MoWI, are conducted twice a year.

After the completion of Mukangu WTP1 and WTP2, EWASCO is duly required to conduct more tests to cover wider range of water quality, in addition to the basic requirements of Jar-test, turbidity and residual chlorine. For this reason, EWASCO proposed basic test devices such as Jar testers, measuring cylinders, a balance scale, a refrigerator, and a deionizer etc., as well as a work bench, a spectrophotometer, an incubator, an autoclave, a microbial taster, and UV equipment etc., in their proposal. As for the spectrophotometer, the one made by HACH made was introduced at Meru WTP, because of its superiority on the number of test items. But since this requires complicated preparation and very expensive reagents (360,000Ksh for 50 times test reagents of chorine, fluorine, iron/manganese, nitric acid, nitrous acid nitrogen, phosphorus, sulfur, Calcium and total hardness), advanced skill is required in using this apparatus. Therefore, it is recommended that a Japanese-made spectrophotometer be procured for the Mukangu1 WTP, as recommended by the person-in-charge of the laboratory, since it is easier to operate, and that detergents are available locally for this type of spectrophotometer.

(4) Equipment for Operation and Maintenance

As for operation and maintenance equipment, it is proposed that a three (3) ton truck, a portable super-sonic flow meter and one set of radio communication equipment be procured. EWASCO has a few pickup trucks but no bigger truck. As EWASCO will be installing the pipes by administration, a three-ton truck is needed.

At Meru WTP, a flow meter is used to find leakage by measuring the flow volume at estimated points, resulting to a drastic reduction of non-revenue water volume in Meru. EWASCO should adopt this same system of utilizing the flow meter as a means to reduce non-revenue water.

EWASCO's facilities comprise a water intake, the Mukangu WTP, the Kangaru water distribution reservoir (WTP), the EWASCO head office, the Gachoka branch office and the 45-kms distribution pipeline. Because of the area being covered by EWASCO, radio communications equipment is being requested, although this may be too expensive to cover at this time.

2-1-3 Drawings for Basic Design

Table 2-31 The List of Drawings for Basic Design

No.	Drawing Name	Note
1)	Location Map	
2)	Flow Sheet and Hydraulic Profile of System	
3)	Intake Flow Sheet	
4)	Intake Facilities Layout Plan	
5)	Intake Facilities Plan and Section	
6)	Plan for Raw Water Transmission Main	
7)	Pipe Bridge of Raw Water Transmission Main	
8)	Mukangu WTP 2 Yard Layout Plan	
9)	Mukangu WTP 2 Flow Sheet	
10)	Mukangu WTP 2 Sedimentation Tanks with Related Tanks Plan and Section	
11)	Mukangu WTP 2 Rapid Filters Plan and Section	
12)	Mukangu WTP 2 Clear Water Reservoir Plan and Section	
13)	Mukangu WTP 2 Elevated Water Tank and Washed Water Drainage Tank Plan and Section	
14)	Mukangu WTP 2 Sludge Lagoons Plan and Section	
15)	Mukangu WTP 2 Generator/Chemical Building Plan and Section	
16)	Mukangu WTP 2 Control/Electrical Building Plan and Section	
17)	Mukangu WTP 2 Chlorine Dosing House Plan and Section	
18)	Mukangu WTP 2 Lift Pump House Plan and Section	
19)	Mukangu WTP 2 Pipe Layout Plan	
20)	Plan for new Clear Water Transmission Main	
21)	Kangaru Reservoir Site Flow Sheet	
22)	Kangaru Clear Water Reservoir Plan and Section	
23)	Kangaru Reservoir Site Layout with Pipes	
24)	Plan for Distribution Pipes (from Kangaru to Majimbo)	
25)	Plan for Distribution Pipes (from Majimbo to Mbreere)	
26)	Electrical Instrument Flow	
27)	Single Flow Diagram for Mukangu and Kangaru	

The drawings are shown in attached Appendix-7.

2-1-4 Implementation Plan and Procurement Policy

2-1-4-1 Implementation Plan and Procurement Policy

The executing agency on the Kenyan side is Tana Water Service Board (TWSB) which is under the control of MoWI. In the Embu province, TWSB entrusted the works for the water supply to EWASCO on a basis of trust agreement. Fig 2-14 shows the organization chart for the project execution.

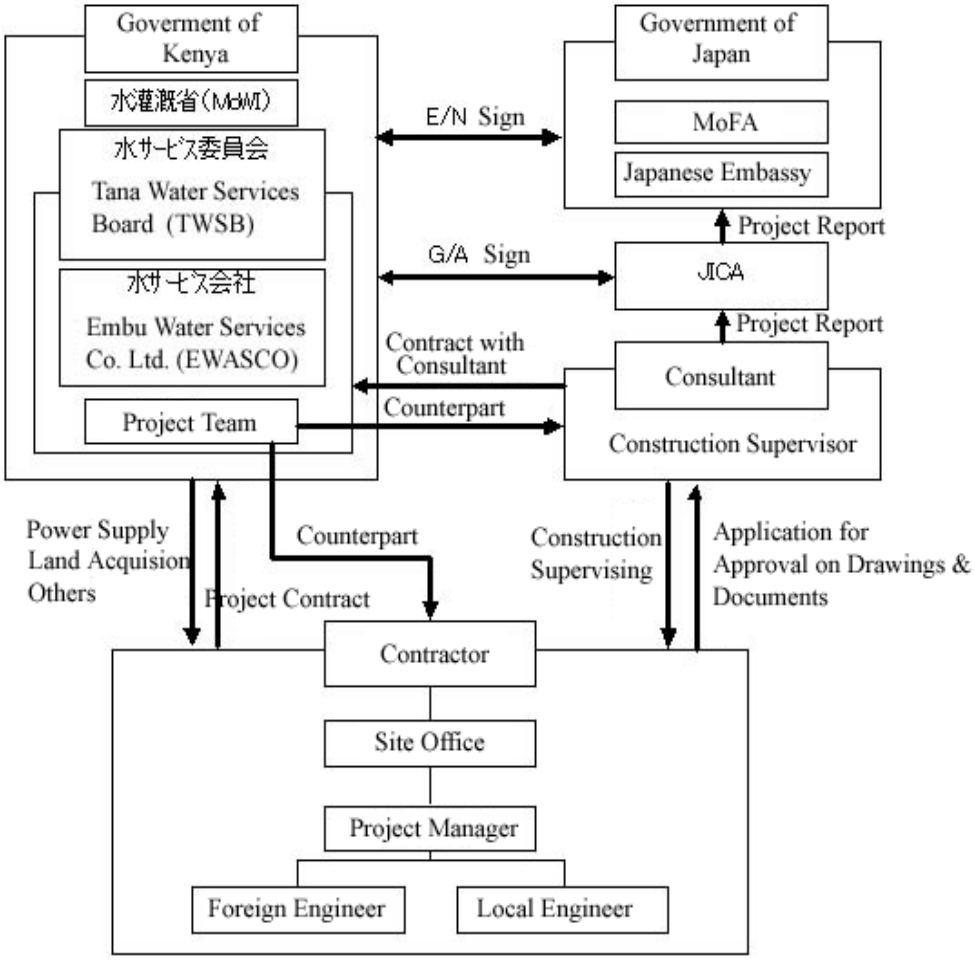

Figure 2-14 Project Executing Organization

The project will be managed from the detailed design stage up to completion of construction by the team set up in TWSB/EWASCO especially for the project. The work assignments are as follow:

a. To function as the “front desk” of the project,
b. To coordinate with the concerned divisions of the Kenyan government,
c. To coordinate with external organizations in connection with the project,
d. To finalize the design, to prepare tender documents, as a counterpart of the consultant, and
e. To coordinate the additional survey and experiment, as the need arises,

NJS Consultants will carry out the project within the time schedule, including detail design, tender preparation and construction supervision. For this purpose, the consultant will assign a regular construction supervisor on site, who will acts as a representative of the consultant, and at the same time, dispatch

specialists in the fields of civil, mechanical, water supply, and electrical etc., in accordance with the progress of the project.

Main component of the project is civil, mechanical and electrical installation, so that a Japanese contractor who has had adequate track record in the similar projects, is recommended. The selection of the contractor should be made through an open competitive bidding procedure, and discussion should be made with TWSB to determine the required qualification of the bidders and the selection criteria, in the process of tender preparation.

During the construction, the Japanese contractor will dispatch regular construction engineers on site. In Kenya, it is acceptable for the contractor to entrust a part of the project components to local contractors, since the construction skill is relatively well developed in Kenya.

2-1-4-2 Remarks about Implementation and Procurement

The construction works are composed of the rehabilitation of water intake, a new water treatment plant, a new distribution reservoir, raw water transmission main, clean water transmission pipe line, distribution pipe line. At, Mukangu WTP2, a control building will be constructed to accommodate the minimum requirements of electrical control system for pumping facilities, water treatment and transmission, etc. As for the location of a site office and material storage space, enough spaces to place them are necessary, at water intake, Mukangu WTP and Kangaru WTP. This will be determined upon consultation with TWSB and EWASCO.

It will not be difficult to hire local labor, and the same is true with the use of local contractors who have the necessary construction materials and equipment. The contractor can also assign certain components of the construction work to capable local contractors.

Found below are comments / remarks with respect to general matters and safety management:

<u>General Matters</u>

a. Saturdays and Sundays are normally the days off from work. In addition, the days after the Ramadan are considered off days for Muslims..
b. Embu township is located northeast of Nairobi, on the way to Kenya. Being the center of trading, and provincial capital of Eastern Kenya Province, labor and construction materials are readily available.
c. The only means of transporting goods is through land (truck). The railway hasn't reached Embu yet.
d. The average annual precipitation is more or less 1,000mm. The long rainy season is from April to July, and the short rainy season is from October to December. Dry seasons are from January to March, and from August to September. In general, rain does not much affect to the field work, even during the rain season, since it rains mainly in the early morning and evening not much in daytime. In the preparation of the construction schedule, rain fall less than 10mm/day will be ruled out.
e. The construction of intake facility should be completed before March, to avoid construction work during the long rainy season of April, May and June. During the rainy season, temporary drainage should be provided since topsoil in the project area becomes muddy.
f. The contractor should take into account rock excavation at Mukangu WTP in laying water transmission pipes and distribution pipes.

g. Slope protection should be taken into account where the pipes are to be laid to avoid erosion sand oil disturbance during the rains .
h. In the township, the laying of pipes is not allowed under the road,. Pipes should be laid in the empty space outside the side drain. In case where the pipes will have to be laid in private land, TWSB/EWASCO will be fin charge of getting the approval, and of paying due compensation.
i. To conform to Road Department regulation, pipes should be placed in a concrete pipe for protection at the crossing point of national road and town road.
j. When constructing at the crossing of the national road, following proper construction processes will mean avoiding road closure.
k. No ready-mixed concrete plant is available in Embu. Proper quality control should be made in the job site when mixers are used.
l. Foreign specialist should be dispatched during the pump installation and the trial operation, and during weld examination etc.
m. During the rehabilitation of the water intake, special care should be made in avoiding the flow of turbid water into existing water treatment system.
n. Application should be made for the exemption from Value Added Tax (VAT) on imported goods and import tax. In case of local procurement, application should also be made to get the refund on any tax paid.
o. EWASCO has already acquired the EIA December 2009 submitted to NEMA on August 3. Environment-friendly methods of construction should be adopted in the preparation of the implementation plan. NEMA regulations state that the contractor should take into account better environmental recovery with reinstatement and countermeasure against dust, noise, turbid water and surplus soil.
p. Power failures are frequent, and last for long period of time. The contractor should have a suitable power generator on stand-by for construction work.
q. Price increase in Kenyan market and in labor cost is announced by the relevant agency.
   (1) In the past, 8% in 2005, 8% in 2006, 7% in 2007, and 8% in 2008 are recorded,
   (2) JETRO issues increase ratios of commodity goods.

Safety Control

The contractor will collect information from the Japanese Embassy and JICA office on the local security conditions in Embu and the surrounding areas, and apply comprehensive safety countermeasures during project implementation, allowing for the following:

a. Regularly receive advices from TWSB/EWASCO for safety and smooth implementation of the project,
b. In order to secure the security for the staff participating the Project, the Team will keep in touch closely with the donor for security information etc.
c. All the hotels in Embu Township are locally owned. There is no particular security issue in and

around Embu township, however it is better that foreigners live in the hotel during the implementation of the project for better security.

d. Cars should be marked with the logo indicating it is a Japanese Government Supported Project.

e. , The Basic Operating Guideline (BOG) should be publicized to make one aware of proper safety measure in case of an unexpected incident.

Others

a. Procurement of Cement

Cement used for reinforced concrete is monopolized by one company.

Cement that has less strength is produced by a company located in Mombasa. Sales are strictly in cash.

b. Procurement of Rebar

Due to the FIFA 2010 to be held in South Africa, the demand of rebar is very high and is difficult to obtain. However, this will ease during the start of the Project.

c. Procurement of Casting Form

Casting forms can be procured in Kenya.

d. Procurement of Sand （Fine Aggregate）

Batch plant dust is also used as fine concrete aggregate in Kenya. If this dust is used for mixing concrete, grain size distribution should be carefully checked, including the proper manner to remove fine particles, in order to maintain good quality concrete.

e. Transportation Cost

Transportation of materials to Embu will depend on land transportation impacting directly on fuel costs for the construction project.

f. Significant Exchange of Kenyan Shilling

Recently, since the value of Kenyan Shilling has been largely fluctuated (1.2～1.8 Yen/Kshs), it needs to be observed carefully.

2-1-4-3 Sharing of Responsibility in Implementation, Procurement and Installation

Table 2-32 and Table 2-33 show the sharing of responsibilities between GOP and the Government of Kenya, on the implementation of the project, which follows the policy of “Grant Aid Program” of GOP;

Table 2-32 Share of Responsibilities on the Project Implementation

Items	Contents	Kenyan Government	Japanese Government
Rehabilitation of Weir and New Construction of Water Intake and Raw Water Main	Procurement of Equipment and Materials		○
	Rehabilitation and Construction		○
Construction of WTP, Distribution Tanks and Distribution Pipeline	Procurement of Equipment and Materials		○
	Construction		○
	Installation		○
	Land Acquisition	○	
	Installation of External Fence	○	
	Installation of Power Line	○	
Micro hydropower generation unit and other associated accessories	Procurement of Equipment and Materials		○
	Installation and Adjustment		○
Common	Improvement of Access Road （on site）	○	
	Attaining required approvals	○	

Table 2-33 Share of Responsibilities between Kenyan Government and Japanese Government

(General Items)

No.	Items	Japan (Grant Aid)	Kenya
1	Land acquisition		●
2	Opening of construction site		●
3	Installation of gate and fence on site		●
4	Construction of access road to the site		
	1) Inside of WTP Site	●	
	2) Outside of WTP Site		●
5	Construction of facilities（Including hydropower development facilities	●	
6	Service facilities of power supply		
	Power distribution to individual household		●
	Connection to the existing power grid		●
7	Construction of power and water supply, drainage and other associated facilities		
	1) Power Supply		
	a. Power line to the WTP site		●
	b. WTP Interanl wiring on site	●	
	c. Power distribution board and transformer	●	
	2) Potable water supply		
	a. Connection to the WTP internal pipe from transmission line		●
	b.WTP Internal Piping	●	
	3) Stormy water drain		
	a. Piping from WTP to the public sewerage system		●
	b. WTP internal plumbing for toilet, waste water, stormy water etc.	●	
	5) Telephone		
	a. Wiring to the WTP office from outside		●
	b. WTP internal wiring	●	
	5) Faurniture		
	a. Household furniture		●
	b. Office furniture	●	
8	Commission in connection to B/A		
	1) Commission for A/P process		●
	2) Other commission for payment		●
9	Discharge and custom clearance for imported goods		
	1) Freight Charge for imported goods	●	
	2) Tax excemption procedure and smooth custom clearance		●
	3) Inland trasportation from the port to the WTP site	●	
10	Cooperation for the foreign staff to enter and stay in Kenya, for the execution of the project.		●
11	Tax exemption for imported materials and Japanese staff, such as custom duty, internal tax and any levy be imposed to Japanese staff.		●
12	Cost of operation and maintenance of equipment granted under the project		●
13	Cost of installation for the equipment which is not covered by grant procurement		●

(B/A : Bank Arrangement、 A/P : Authorization to pay)

2-1-4-4 Plans for Construction Supervising and Procurement

The project will commence upon the signature of both governments on the "Exchange Notes(E/N)" for the Project on Grant Aid Program, through the Cabinet Approval of the Government of Japan after the completion of the Basic Design.

1) Detailed Design

Based on the Exchange of Notes, TWSB will hire the consultants for detailed design works for the project. After the GOJ verification of the detailed design contract, the consultants will perform detailed site survey and prepare the detailed design, cost estimates and tender documents in Japan.

2) Tendering and Evaluation

All the tender documents are subject to TWSB approval. After the approval, the consultants will immediately proceed with tendering.

a. To allow one week for bidders to prepare an application for prequalification
b. To evaluate prequalification submissions from the bidders immediately
c. To allow one and half months for pre-qualified bidders to prepare bidding documents after providing tender documents to each pre-qualified bidder.
d. To recommend the lowest qualified bidder for LVNWSB as a successful bidder and assist LVNWSB in contract negotiation.

3) Construction Supervision

Construction works include civil works, plumbing works, mechanical/electrical works. Besides a resident civil engineer, the consultants will dispatch civil engineers for plumbing and structures, as well as mechanical and electrical engineers to the construction site as needed, as construction works requires supervision by the above specialists. The consultants will hire local engineers to support their works.

The resident engineer of the consultants will maintain close contact with TWSB and the contractors throughout project implementation. The resident engineer will submit progress reports to MoWI, TWSB, the JICA Kenya Office and to the JICA headquarters at the agreed interval.

2-1-4-5 Quality Control Plan

Consultant shall instruct the Contractor to perform the analyses and tests etc. related to the facility construction works as shown in Table 2-34 and these shall reflect results on quality control.

Table 2-34 Test Methods on Quality Control

Work Items	Control Points	Method	Applicable Criteria
Pipe Materials	- Strength/Dimension - Appearance/Dimension	- Verification on Report of Shop Inspection & Tests - Visual Inspection/Dimensional Measurement - Gauge	Criteria of Japan
Plumbing Conditions	- Torque - With or Without Water Leakage - Painting	-Torque Wrench (Tension Wrench) - Hydrostatic Test - Film thickness meter/Visual Inspection	Criteria of Japan
Foundation	Ground Bearing Capacity	Plate Bearing Test	Criteria of Japan
Concrete	- Aggregate/Cement/Water - Ready Mixed Concrete - Concrete Strength	- Physical/Chemical Tests - Grain Size Analysis - Slump/Air Content/Chloride Content - Compressive Strength Test	
Reinforcing Steel Bar	Strength	- Tensile Strength - Bar Arrangement (Scheduling) Inspection	Criteria of Japan 440 - 600N/mm^2 Products made in Kenya 545 - 595N/mm^2
Structural Output		Dimension Inspection	
Water Proofing Works	- Material Quality - Coating Film/Adhesive Force - Coating Conditions - With or Without Water Leakage	- Verification on Certificate of Quality - Film Thickness Test/Tension Test - Visual Inspection - Stretch Test	Criteria of Japan
Electrical/Mechanic Equipment	- Installation Precision - Capability	- Measurement on Installation Location - Loading Running Test	Criteria of Japan

2-1-4-6 Procurement Plan

1) Supplier

As to the procurement of construction materials and equipment, the countries eligible on Grant Aid shall be the recipient country and/or Japan. Equipment and materials required for the Project shall be procured from the domestic market wherever possible. However, if equipment and materials cannot be procured from the domestic market, or if those available in the domestic market do not meet the quality specification, or provide stable prices or terms at the time of purchase, then procurement will be from Japan and/or a third country taking the cost-benefit performance, ease in O&M and self-sustainability. Third Countries mean southern African countries near Kenya and/or EU nations.

a. Civil Materials

Among the main civil engineering and building works, common construction materials such as cement, gravel, sand, brick, timber (squared timber & board), petrol and oil etc. can be procured in Kenya. However, it is necessary to take appropriate measures for the stable procurement of the forms guaranteed with the specified quality

b. Pipe Materials

Ductile iron pipes have been produced in Kenya before, however, it has been observed that there are currently no available products being distributed that meet the required quality. Ductile iron pipe will be used mostly for piping work for the new WTP which requires a lot of fittings. Therefore, ductile iron pipes may be better procured from Japan, including those produced by Japanese manufacturers, other than those coming from the third countries, because of reliability of quality and ease of procurement.

As for steel pipes, several local manufacturers are currently producing the pipes with coating on inside and outside. uPVC pipes for water works are also available in Nairobi. Therefore, such pipes shall be procured in Kenya. However, the high-pressure steel pipe for the transmission mains shall be procured from Japan.

c. Mechanical/Electrical Equipment

Mechanical/electrical equipment is required by the Project. In addition, such equipment for the facilities of new WTP is of limited quantity. Therefore, Japanese mechanical/electrical equipment with higher reliability shall be adopted as compared to those available from third countries whose products are of lesser reliability and quality.

d. Filter Sand

Filter sand to be used as rapid sand filter of the WTP should have high-level specifications in terms of effective size, specific gravity and coefficient of uniformity. During the field study, it was confirmed that filter media being supplied in Kenya doesn't have any quality issues and can be utilized .

e. Construction Machinery

There are some unknown factors regarding the failure and/or breakdown in the availability of construction machinery in the lease market in Kenya. Even with this situation, domestic field procurement will still be applicable to general construction machinery.

Table 2-35 summarizes the procurement category on construction equipment and materials.

Table 2-35 Procurement Plan

Construction Equipment & Materials		Expected Country of Origin		
Category	Item	Kenya	Japan	3rd Country
Materials for Civil Engineering Works	Cement	○		
	Reinforcing Steel Bar	○		
	Form	○		
	Sand, Gravel, Brick	○		
	Diesel Oil and Petrol etc.	○		
Piping Materials	Ductile Iron Pipe		○	○
	Steel Pipe	○		
	uPVC Pipe	○		
Mechanic/Electrical Equipment and Others	Pumps		○	
	Chlorine Feeding Facilities		○	
	Filtering Sand	○		
Construction Machinery (by Lease)	Construction Equipment	○		

2) Delivery and Storage Yard

The delivery and storage site for procured materials shall be set up as a field base where EWASCO will prepare within the Embu Municipality. Since the base must be guarded to prevent robbery, the space may be relatively limited. Thus these materials especially pipes should be delivered divided several times.

2-1-4-7 Operational Guidance Plan

Prior to the turn-over of the facilities, the start-up and commissioning program will be carried out in order to verify the function and operation of the equipment, such as micro-power generator, pump equipment and chemicals dosing equipment installed at the WTP. In this program, the Contractor will provide the required guidance/trainings mainly on how to operate the equipment and in troubleshooting. Training will initially be conducted to the technical staff of EWASCO as an operational guidance.

Table 2-36 Initial Operational Guidance

Facility	Contents	Remarks
WTP	Hydro-power generator: Operation methods, function test Surface wash pump: Function test, ON-OFF operation, Set-up of pumping rate, Daily check Chemicals dosing equipment: Set-up of dosing rates, Hand mixer operation, Daily check Electrical facilities: Function test, Daily check	
Clear Water Reservoirs	Water level indicator: Function test, Daily check	
Raw Water / transmission/distribution pipelines	Valves: Function test, valve operation, Daily check	
Intake weir	Gate/valves: Function test, operation, Daily check	

2-1-4-8 Soft Components Plan

The project is to expand the capacity of water supply system of Mukangu WTP, to cope with the increasing demand of water supply in Embu Municipality and its surrounding area. The expansion will cover water intake, raw water transmission main, water treatment system and distribution system. As for the water treatment system, Mukangu WTP1 is now under construction, which has a production capacity of 10,000m^3/day. WTP2, under the project, will be constructed adjacent to WTP1, capacity of which is

11,000m^3/day. Kangaru WTP, which has a capacity of 2,500m^3/day with six small production lines, will be abandoned, because the quality of raw water is worsening, the capacity of each production lines are too small, and the equipment are significantly deteriorated and obsolete. The total capacity will be 21,000m^3/day, upon the completion of WTP2.

Kangaru WTP is a combined system of sedimentation and filtration, which is commonly used in Kenya. Both Mukangu WTP1 and WTP2 adopt a transverse circulation system. Present staff are not used to the new system and need to have due training to be familiarized with the operation and maintenance. Presently, there are only five O&M staff, and additional staff will be needed for the operation upon the completion.

In terms of water quality, at present, only limited number of tools is available, and these measure only temperature, turbidity and residual chlorine. The project will supply water quality analytical equipment, which will enable the required monitoring of water quality, in order to maintain proper operation and maintenance of WTP, and to ensure the quality of clean water. This also requires staff training to be familiar with proper handling of the equipment.

It is also important to shape a decent organization for operation and maintenance, for the purpose of proper O & M and water quality control. In line this, the project will support the following, as a part of soft components, for smooth start up of the project operation.

① Technical guidance for the operation and maintenance of water supply system, mainly focusing on water treatment plant, and

② Technical guidance for water quality

As acknowledged, non-revenue water is one of the most important items in operation and maintenance of water supply system, since the start of this project, “Technical Cooperation Project” under JICA. However, field counter measures against non-revenue water is a huge undertaking and cannot be made a part of this project.

2-1-4-9 Implementation Schedule

Project implementation schedule is as follows: 21 months for procurement and construction works, 4.5 months for detailed design, such that the overall project period will be approximately 31 months, including the soft components. For construction works, the water treatment plant will need at least 18 months to construct. The project is to be implemented on a bond dependent budget basis, so the logical project period is assumed to be approximately three years. Fig. 2-15 shows draft implementation schedule.

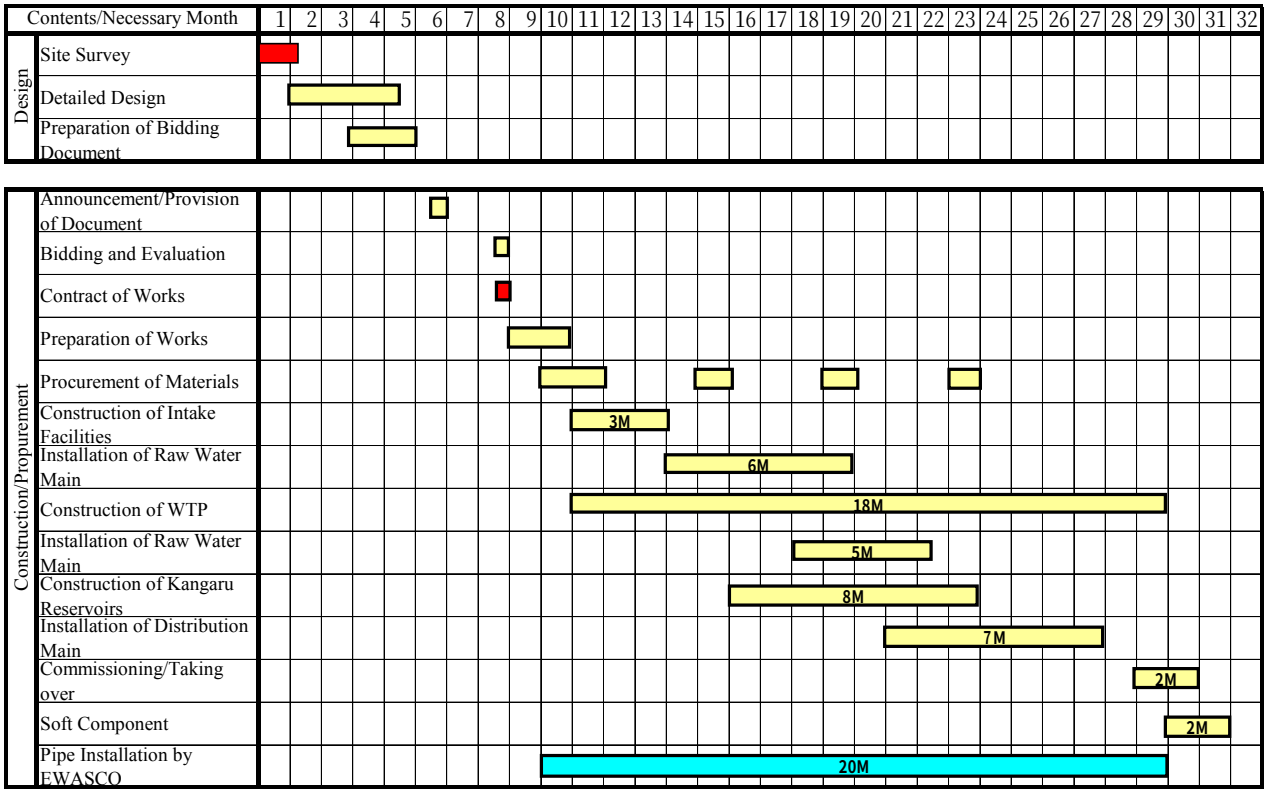

Figure 2-15 Draft Implementation Schedule

2-2 Responsibilities of the Governments of Kenyan

In the implementation of the project, the government of Kenya and EWASCO will take full charge of the items mentioned in clause 2-1-4-3. The following are details of the obligation of the Government of Kenyan and EWASCO:

a. Land Acquisition

   Land adjacent to the existing Mukangu WTP1 for WTP2：One

   Easement for Raw Water Main, Transmission Line and Distribution Line

b. Fencing

   Peripheral of Mukangu WTP：One

c. Installation of Power Feeder Line to the construction sites

   Mukangu WTP：One

   Kangaru Water Distribution Reservoir：One

d. Improvement of Access Road to the sites

e. Installation of Transmission Pipes；φ355mm～63mm　60.3km

f. Expansion of Distribution Pipes in Gachoka District; φ225mm or/less 152.8km

g. Demolition of Kangaru WTP Facilties

h. Installation of Drainage Pipes at Mukangu WTP

i. Others

Establishment for installation right for pipes at private land, land rental for contractor's site, procurement material storage site and bank transfer costs

All of the above works are important for the Project, particularly 'e' and 'f' which are essential in attaining the target service ratio of 87%. EWASCO proposed 'f' and they assured to complete the installation of a total of 223 kms of pipelines within the duration of project implementation mobilizing a large labor force of over 1000 in the areas. To realize the above works, budgetary allocation to EWASCO by GOK in addition to this Grant Project is essential.

As a result of the implementation of the works per the Kenyan side, the target service rate will be attained and each consumer will be connected to the system by 2015.

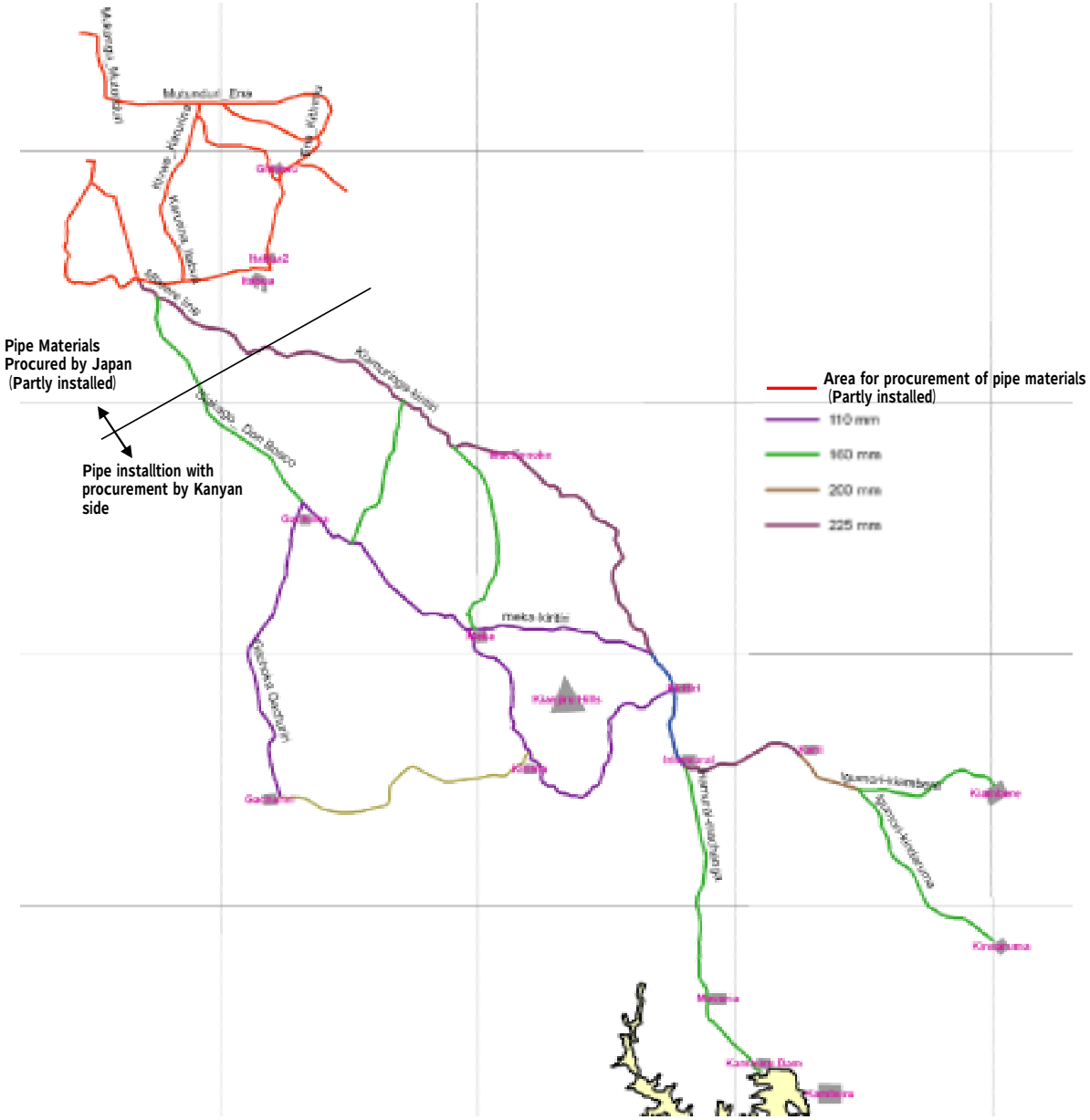

Figure 2-16 Areas of Material Provision by the Project and Implementation by Kenyan-side including Materials

2-3 Plan for Operation and Maintenance of the Project

(1) Organization Structure for Operation and Maintenance

The total number of staff in EWASCO is 77, including management staff and operation and maintenance staff. There are 27 technical staff, which include the manager for the maintenance of transmission and distribution line, and 15 staff for water treatment including a supervisor. In the division of operation and maintenance, there are 22 regular workers, 15 plumbers and seven laborers. This direct employment of workers infers that private sector is not well developed in the field of plumbing for water supply in Embu Municipality and in the immediate vicinities. In the water treatment division, there are eight and seven staff who operate Kanagru WTP and Mukangu WTP, respectively, the latter being operated by chemical

precipitation.

Upon completion of the project, the plant capacity will increase to 21,000m^3/day from 12,000m^3/day. The number of households who can enjoy tapped water will also increase to 39,900 (computed by covered population of 167,913/4.3) in 2015 from only 7,972 in September 2009.

In terms of the operation of WTP, provided that same level of quality control is expected, total loads on the operation of both Mukangu and Kangaru WTPs will be almost same with new Mukangu WTP1 and WTP2, due to simplified and rationalized operation at the Mukangu WTPs site. But this does not mean that correct and proper management is done. On the contrary, a new operational framework is needed for the new WTP1 and WTP2.

As for the billing and fare collection system, the system is computerized. For the present, the consumers pay their water bills at the EWASCO office. EWASCO is aware that with the big increase in water consumers by 2015, the tellers may not be able to handle the number of the over-the-counter payments. Payment by account transfer is now being discussed in EWASCO, in order to reduce the work load of the paying tellers. The Team would like to suggest improved operation and maintenance system of the project, based upon the study of the present organization, and as recommended by the Meru Water Service Board.

The total number of staff required in 2015 is 102. Fig.2-17 shows the organization chart, made with the following assumptions:

1） To introduce the direct deposit payment method not only for a more efficient water fee collection, but also to minimize hiring of new employees in the account section;

2） Expansion of distribution system should be encouraged in Gachoka District where water supply is very critical, and at the same time, rehabilitation of distribution pipeline should also be encouraged to reduce non-revenue water. For both purposes, increase in staff complement may be allowed to the extent that use of the private sector work force be taken into account; and

3） Staff transfer be made from the Kanagru WTP to the Mukangu WTOs.

With these efforts to minimize recruitment, the staff is estimated to increase by 10 and will total 102 by 2015.

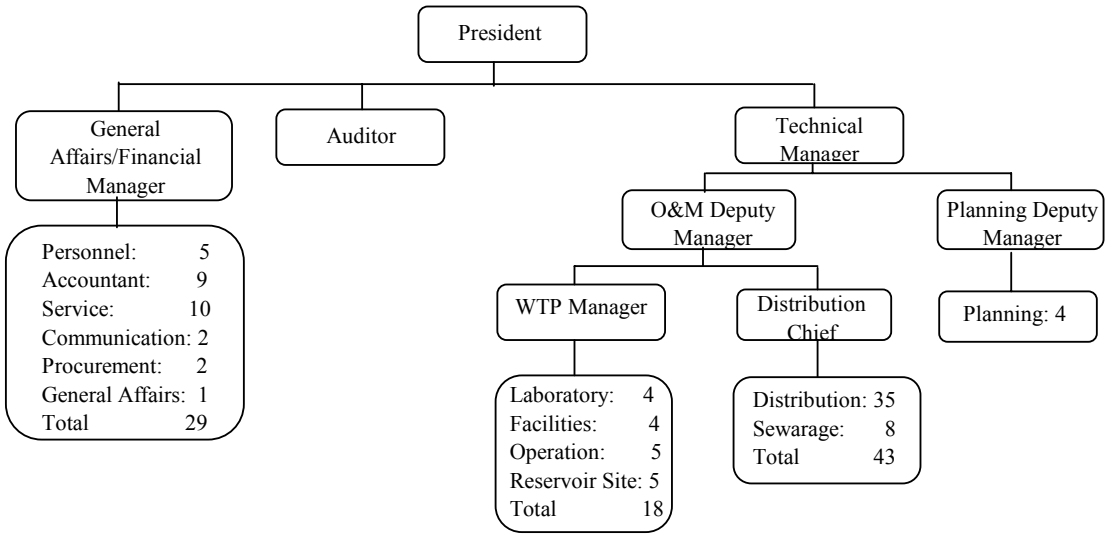

Figure 2-17 Draft of Proposed Organization Chart in 2015

(2) Annual Staff Increase from Completion of the Project till 2015

Table 2-37 suggests the annual increase of staff and their assignment from the completion of the project up to 2015. This indicates the need to recruit a technical manager before January 2011, to coordinate and manage the project during the implementation phase. Upon completion of the project by December 2012, extra technical staff should be employed to operate and maintain the new WTP.

Table 2-37 Annual Increment of Staffs from 2009 till 2015

Assignment/Year	2009	2010	2011	2012	2013	2014	2015
	At Present		Construction Start		Completion of Plant Construction		Target Year
Manager	14	14	15	15	15	15	15
General Affairs and Financial Division	19	19	19	19	19	19	23
Water Treatment Div.	7	7	7	7	16	16	18
Distribution Div.	30	30	30	30	30	30	35
Sewerage Div.	6	6	6	6	6	6	8
Planning Div.	1	1	1	1	1	1	3
Total	77	77	78	78	87	87	102
（Plan of Distribution Expansion）							
Covered Households)	7,972	8,210	8,460	8,710	31,920	35,910	39,900
Installed Water Meters	7,972	8,210	8,460	8,710	31,920	35,910	39,900
Revenue Water Volume (m^3/day)	4,500	4,730	4,970	5,220	12,600	14,180	15,750

2-4 Preliminary Cost Estimation of the Project

2-4-1 Preliminary Cost estimation of the Project

The project cost will approximately be 2.45 billion Yen, secured under the Japanese Grant Aid Program. The work allocation between both governments is described in the precedent clause, together with the cost allocation of the project between both governments. The estimated cost does not mean the upper limit of the project cost agreed in E/N.

(1) Costs borne By GOJ

Total Project Cost : Approx. 2.602 billion Yen

Table 2-38 Cost to be borne by GOJ

Items		Project Cost（mil.Yen）
Facilities	- Rehabilitation of Existing Intake - Construction of New WTP2 - Construction of new distribution reservoir - Installation of raw water main, transmission line and distribution line	1,838
D.D, C.S, and Soft Components		242
Procurement of equipment and Materials		244
Contingency		278
Total		2,602

(2) Costs Borne by GOK

Table 2-39 Construction Work Costs borne by GOK

No.	Items	Contents	Quantity	unit	Unit Price (1000Kshs)	Costs (1000Kshs)	Costs (1000JY)
1	Mukangu WTP Fence and Others	Gates: 2	1	Unit		200	246
		Fence	250	m	1.5	375	461
		Road	100	ditto	20.0	2,000	2,456
		Drainage pipes	400	ditto	2.5	1,000	1,228
2	Kangar Reaservoir Site	Dimolition of Existing Structures	1	Unit		1,000	1,228
		Others works	1	ditto		200	246
3	Electricity Connection	Mukangu WTP	1	ditto		150	184
		Kangar Site	1	ditto		150	184
4	Installation for provided Materials	Dia.355-220mm	26,200	m	0.6	15,720	19,304
		Dia. less than160mm	34,100	ditto	0.55	18,755	23,031
		Pressure Breaking Tank	15	Units	500.0	7,500	9,210
5	Distribution Net Work Expansion	Dia.less than225mm	152,800	m	1.3	198,640	243,930
6	Land Easement	1ha	1	ha	2,500	2,500	3,070
7	Land Easement	1ha	1	ha	1,250	1,250	1,535
6	BankTansfer Charge	0.05%of total +20000Yen	1	Unit		1,076	1,321
	Total					245,690	307,633

(3) Conditions for Cost Estimation

At the time of Cost Estimation November 2009

Exchange Rates （Before the end of Preliminary Design ：Average of May - September, 2009）

Yen／US$	1 US $ ＝	Yen 91.09	Decided rate for Cabinet Council in April
Yen／Ksh	1 Kshs ＝	Yen 1.228	Average of May - September, 2009

2-4-2 Operation and Maintenance Costs

(1) Operation and Maintenance Costs

The operation and maintenance costs of the project exclude depreciation cost. There is a need to add costs for sludge disposal, communication, billing and accounting system, in addition to tho general O&M items. An annual inflation rate of 10% is applied to the costs on the target year of 2015, based on the recent inflation trends.

EWASCO is planning to borrow the costs for the improvement of sewerage system from WB. The loan amount is estimated to be 200 Million Kshs with an annual interest of 14%. The repayment is scheduled in 10 years with flat repayment. The flat repayment is calculated as follows:

200,000,000 Kshs × {(1+0.14)^10×0.14}/{(1+0.14)^10-1}÷10＝38,343,000Kshs

Taking into account the loan repayment, the operation and maintenance costs in 2015 is shown on Table 2-40. It predicts a significant increase of O&M costs from 82.4 Million Kshs/year, (which is the actual cost now) to 254 Million Kshs/year in 2015, with hydropower generation, increased by 3.3 times.

Table 2-40 Operation and Maintenance Costs of the Project

Items	Calculation	O&M Costs（Kshs/Year）	
		2015	2008/09 (Past Record)
Employment Cost	・Total 102 Staff 34,700 Kshs/MM×12M×102Men＝45,778,000Kshs/year	45,778,000	32,047,729
Chemicals	・Aluminum Sulfate（Average Injection Rate 25ppm） 38 Kshs/kg×22,000m3/日×25kg/1,000m3×365days＝7,628,000Kshs/Year ・Soda Ash（Average Injection Rate10ppm） 20 Kshs/kg×22,000m3/day×10kg/day×365day＝1,606,000Kshs/year ・Bleaching Powder（Average Injection rate：As effective chlorine, 1ppm） 160 Kshs/kg×22,000m3/day×1/0.6kg/day×365day＝2,141,000Kshs/Year	11,376,000	2,074,686
Power Consumption	・With hydropower generation at Mukangu WTP Base Cost：16,054Kshs/month×12months＝193,000Kshs/year ・Without hydropower generation at Kanagu distribution reservoir Base Cost：16,054Kshs/month×12months＝193,000Kshs/year Power consumption：17,616 Kshs/month×12months＝211,000 Kshs/year	597,000	0
Communication	60 times a day（Within 1minute、30 minutes once auto transmission, 12 times for receipt confirmation） 60times×5 Kshs＝300Kshs/day 300 Kshs/day×365days＝110,000Kshs/year	110,000	
Sludge Disposal	・Dried sludge production：0.328tDS/day/0.4(water contents60%)×365day/year =300tons/year 300tons/year×2,000 Kshs/ton＝600,000Kshs/year	600,000	
Rehabilitation	Assume 3 times higher than the costs of now for counter measure for water leakage, expansion of water supply pipeline 5,130,492Kshs/year×3=15,391Kshs/year	15,391,000	5,130,492
Others	47,988,224Kshs/year	47,988,000	47,988,224
Total in 2009 Price		121,840,000	87,241,131
Total in 2015	×(1.10)^6=×1.7716 (6 years of 10% of annual inflation)	215,847,000	
Repayment for Sewage debt		38,343,000	
Gross Total in 2015		254,190,000	

(2) Estimation of Fare Receipt

Fare collection is estimated to 271,604,000 Kshs, as described below, from water supply volume and number of connections as estimated in the target year of 2015.

- Water Supply Volume: 15,750m^3/day (water loss is assumed 25% out of planned water supply of 21,000m^3/day
- Covered population : 167,500 (4.2 persons/household)
- Covered households : 39,900(high income 2,100families, low income 4,400 families)

Based on EWASCO records from 2008 to 2009, the annual fare collected from water supply and sewerage service is 89,295,000Kshs/year. The number of water supply connections is 7,912. Of this number, 1,787 are connected to the sewerage system. A sewerage user pays 50% higher than a user of water. The annual revenue water volume is 1,667,126m^3/year from 2008 to 2009. The amount of fare collected and the cost

(m^3) of tapped water is computed as follows:

7,912/(1,787×1.5+(7,912-1,787))×89,294,000 Kshs＝80,233,000Kshs

80,233,000Kshs/1,667,126＝48 Kshs/m^3

At present, water is supplied to densely populated areas that have a high consumption per household. The areas where water supply is to be expanded will have a smaller consumption compared to the present coverage area. If EWASCO employs an escalated tariff structure for water fare (more consumption, higher unit cost), the unit cost of tapped water is assumed to be lower by 10%. The amount of fare collection is computed as follows:

15,750m^3/day×48Kshs/m^3×(1-0.1)×365day/year＝248,346,000Kshs/year

Number of sewerage users is also expected to increase from 1,787 to 2,800, then, the fare collection is computed as follows:

(89,294-80,233) x 1,000 Kshs×(1,787+2,800)/1,787＝23,258,000 Kshs

Ninety-seven percent of the income of EWASCO comes from potable water and sewerage fare collection. Disregarding the remaining three percent, the gross income of EWASCO in the target year of 2015 can be computed as shown below.

248,346,000+23,258,000 Kshs＝271,604,000 Kshs

Based upon the income plan as mentioned above, the balance of revenue and expenditure by 2015 is shown on Table 2-41. At the start of loan repayment in 2012 for sewerage improvement, there will be a negative balance or temporary deficit. But after 2013, due to the increment of potable water production and revenue water ratio, the balance will turn to surplus income. Fig. 2-18 shows the balance, provided that water production will be maintained until 2020. Annual inflation ratio is assumed at 10%, which will cause the imbalance between revenue and expenditure, and will compel a price increase. But, it is not logical to say that water supply will be maintained as the population will surely increase. It is more likely that expansion of water treatment plant will be needed after 2015.

Table 2-41 Balance Projection of Revenue and Expenditure

Items(1000Kshs/Year)	2008/09	2010	2011	2012	2013	2014	2015
Charge Revenue	89,294	93,849	98,560	106,971	201,160	223,511	271,604
Expenditure	87,241	91,603	96,183	139,335	213,179	232,605	254,190
Balance（Revenue-Expenditure)	2,053	2,246	2,377	-32,364	-12,019	-9,094	17,414
Water Charge	80,233	84,324	88,559	92,939	201,160	223,511	248,346
Sewage Charge	9,071	9,525	10,001	14,032	18,063	22,095	23,258
Repayment for Sewage Debt	0	0	0	38,343	38,343	38,343	38,343
Revenue Water Volume(m^3/year)	1,667	1,752	1,840	1,931	4,599	5,176	5,749

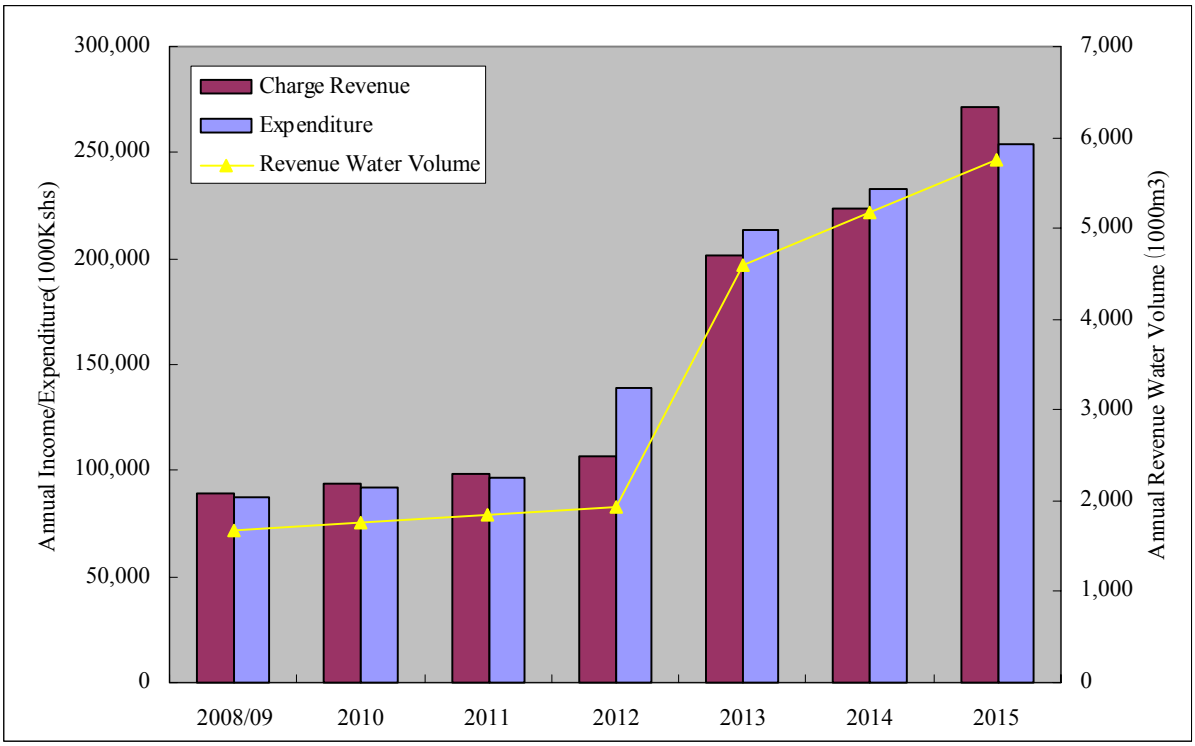

Figure 2-18 Comparison of Fare Collection and Estimated Expenditure upon the Project Completion

One hundred percent of all households connected by piped water have already been installed meters in EWASCO distribution areas. Based on the results of Socio-Economic Survey, people living in three districts of Embu, Nembure and Gachoka had adequate "Willingness To Pay", especially in the Gachoka Area, where the people had high willingness. In Gachoka area, since there is no proper water source, the water supplied to the people is also used for irrigation and feeding to their livestock, a reason why water charges are high. In their desire to have piped water, the people often connect pipes to their houses on their own from the nearby distribution line without EWASCO doing the necessary connection work.

Table 2-42 Results of Socio-Economic Survey (In the case of Domestic)

Place	Embu	Nembure	Gachoka
Number of Samples (Users)	102 (90)	50 (32)	120 (36)
Average Income	10,400 Kshs/month	15,400 Kshs/month	9,000 Kshs/month
Willingness to Pay (WTP)	325 Kshs/ month	382 Kshs/ month	1,304 Kshs/ month

(3) Timing of Facilities Renovation

The durability of facilities is in conformity with the Kenyan Standards, which are 30 years for structures, 30 years for pipes, and 10 years for electrical and mechanical facilities.

2-5 Remarks on the Implementation of the Project

2-5-1 Capacity of Mukangu WTP1

Mukangu WTP1 will have a capacity at least of 10,000m^3/day. Mukangu WTPs, however, needs to produce 21,000m^3/day, which is the 2015-projected water demand.. The capacity of Mukangu WTP2 has been determined based upon those figures. During the field survey, some doubt was raised in terms of treatment process, and modifications may be required. EWASCO has promised to do any modification, if the situation requires so, in January to February 2010, during the dry season. This should be followed up, in order to maintain the required capacity.

2-5-2 Installation of Distribution Pipes

Under the project, pipes and associated materials for the 60.3km distribution pipeline will be granted to EWASCO, and EWASCO is obligated to install them with the collateral fund from the Government of Kenya. This portion of works includes the provision of Break Pressure Tanks which has to be completed before the end of the project. In order to achieve 87% population coverage, pipes and materials which have been donated are not adequate for the 152.8km proposed by EWASCO. It is necessary to seek the budget from the Kenyan side to complete the pipeline installation. EWASCO reported that they have been able to install 10kms of pipeline per month, and with this development, it may be possible to complete the installation of the entire pipeline as targeted. Nevertheless, careful follow-up will be needed.

Chapter3 Study on Adequacy of the Project

3. Study on Adequacy of the Project

3-1 Effects of the Project

The project is expected to bring the following beneficial effects to improve the quality of life of the residents in Embu Municipality:

Table 3-1 Effects under the Implementation of the Project

Present status and issues	Counter Measures under the project	Effects of the project
A：Direct Effects		
• Water production capacity is very low against demand • At present, covered population is only 41% • Water supplied, through WTP1, is done with chlorine injection only, and is highly turbid. Not suitable as drinking water • Water borne disease is rampant	• Construct a new WTP2, and increase the production capacity from 10,000m^3/day to 21,000m^3/day. • Construct new water distribution reservoirs（3000m^3 at Mukangu WTP, and 6000m^3 at Kangaru Site • Install 10.8 km distribution pipeline and supply material for the water distribution line of 60.3 km	• Increase the production capacity to 21,000m^3/day. • Increase of water production volume enables to extend service to additional areas. • Enable to supply water for 168,000 population. (Covered population increase from 41% to 87%) • Clean water supply will reduce morbidity of water borne disease (diarrhea, Malaria, birhalziasis, Parasite, typhoid）
• Water supply system from both Mukangu and Kangaru WTPs is not well balanced in supplying the population. • In the remote areas, water head is significantly high, where pipes are old, thereby causing pipes to leak. • Appropriate water quality control is not done yet.	• Construct new distribution reservoirs and install new water supply pipelines, the supply networks are to be divided based on the capacity of the reservoir and its elevation. • Rehabilitate water supply pipeline in remote areas by using the collateral local fund • Improve water quality control at WTPs. • Install materials procured by the Project and additional expansion by Kenyan-side • Support for operation and maintenance be made through Soft Component	• Have a secure, stable and efficient water supply. • Rehabilitation of pipelines in the remote areas will reduce water leakage. • Water quality will substantially improve
• Clogging is often observed in the flow meter resulting to inaccurate fare collection. • Non revenue water ratio is high, and the improvement is highly anticipated • No proper data collection and compilation for future improvement of the system	• Supply a water meter calibrator • Give guidance in the operation of the water meter calibration in Soft Components • Develop campaign for water meter connection, removal of illegal connection, and support of proper data collection.	• Revenue will increase as a result of water supply increase • Reduction of non revenue water and water meter installation campaign will help EWASCO financial stability • Proper and organized data collection will provide EWASCO with important information with which to base future improvements.
• The billing and collection system can be better managed.	• Provide training on the development and management of an efficient system for billing and fare collection in Soft Component portion of the project.	• A simplified billing and collection system contributes to efficiency and better service to customers.
B：Indirect Effects		
• Unsafe water causes high morbidity because of widespread water borne diseases.	—	• Clean and safe water supply contributes to health and productivity, and reduces morbidity caused by water borne diseases such as cholera and diarrhea.
• Lack of piped water supply is a burden to women and children who are tasked with fetching water for their domestic needs.	—	• Safe and potable piped water supply allows women and children to use their time more productively.

3-2 Issues and Suggestions

In order to achieve the target of the project and maximize its beneficial effects, the Kenyan side is expected to initiate the following actions:

3-2-1 Issues and Suggestions to be Undertaken by the Kenyan Side

(1) Before the Commencement of the Project Implementation

The Kenyan side should secure the budget for their particular scope of works, such as land acquisition for WTP and distribution reservoirs, fencing/construction of access road of those, power supply, installation of pipe materials procured by the Project, expansion of water supply pipeline in accordance with the schedule of the project implementation.

Organization and support for the project team, as well as all budgetary arrangements should be on schedule during and after project implementation. Required permits and approvals in connection with the project implementation should be obtained on time so as not to affect the construction schedule.

(2) During the Project Implementation

The project team should be established at the detailed design stage to effectively start technology transfer. This team should also be an active participant in the soft component portion of the project so that what is learned can be fully applied in the management as well as in the operation and maintenance of the system.
To reiterate, the Kenyan side should fulfill its obligations in a timely manner with respect to such areas as fencing/construction of access road, power supply, installation of procured pipe materials by the Project, expansion of water supply pipeline, and the availability of the budget.

(3) After the completion of the Project Implementation

After project completion, water service connections should be provided to the consumers from the distribution pipes, including installation of water meters supported by the Kenyan budget. Water fees should be collected so that the water supply system becomes a viable institution. Power generated by the mini hydropower unit in Mukangku WTP should also be effectively utilized.

3-2-2 Technical Cooperation and Coordination with Other Donors

The government of Kenyan has proposed to GOJ a technical cooperation project for the Reduction of non-revenue water. It is proposed that TWSB be included as a member of the committee/board.

3-3 Adequacy of the Project

The implementation of the project under the Grant Aid Program of Japan, is done because of the following reasons:

- The number of beneficiaries totals 168,000 persons in Embu Municipality and its surrounding areas.
- Water supply, which is a basic social and human need, will improve in terms of quality and quantity.
- Facilities, which are to be improved and expanded, are similar to the existing ones and there is no technical incompatibility to the capacity of EWASCO to manage it successfully.
- The project, when completed, will provide additional revenues to EWASCO without necessarily having to raise water tariffs.
- Micro hydropower generation in Mukangu WTP will produce power for the plant not only during power failures, but will also be a power resource. It is recommended that this be incorporate into the existing power grid line, even if its power contribution is small.
- The project will not produce any negative effects during and after the construction period.
- The project is aligned with the sector development targets of Kenya.
- The project can be implemented under the Grant Aid Program of Japan, without any negative issue.

3-4 Conclusion

The project, under the Grand Air Program of Japan and with the participation and involvement of the Government of Kenya, will surely improve the quality of life to the project beneficiaries. Not only will they be free of waterborne diseases because of safe water supply; they also will have more productive time in their hands because of adequate and reliable piped water service. The project will also contribute to uplifting the level of expertise in management, in operation and maintenance, and in revenue generation for EWASCO through the soft component of the project. Through this project, EWASCO can give better and sustainable water supply to its growing number of customers.

Appendices

Appendices

Appendix 1　Member List of the Study Team

1. Basic Design

Name	Assignment	Position
Keiko YAMAMOTO,Ms	Leader of the Study Team	Senior Advisor, JICA
Yoichi INOUE, Mr.	Study Coordinator	Representative, JICA Kenya
Keiji MATSUOKA,Mr	Leader of the Consultant Team / Water Supply Planning / Environmental and Social Consideration	NJS Consultants Co., Ltd.
Hiroki FUJIWARA, Mr.	Water Treatment Facility Design / Operation and Maintenance Planning	NJS Consultants Co., Ltd.
Shigeru TAKARA, Mr.	Intake Facility Planning	NJS Consultants Co., Ltd.
Nadika AKWATTA, Mr.	Pipeline Design	NJS Consultants Co., Ltd.
Teru MIURA, Mr.	Electrical Facility	NJS Consultants Co., Ltd.
Kazuhiko NAKAMURA, Mr.	Construction and Procurement Planning	NJS Consultants Co., Ltd.

No.2: Explanation on Draft Report

Name	Assignment	Position
Kyosuke KAWAZUMI , Mr.	Leader of the Study Team	Deputy Director, JICA Kenya
Yoichi INOUE, Mr.	Study Coordinator	Representative, JICA Kenya
Keiji MATSUOKA,Mr	Leader of the Consultant Team / Water Supply Planning / Environmental and Social Consideration	NJS Consultants Co., Ltd.
Kazuhiko NAKAMURA, Mr.	Construction and Procurement Planning	NJS Consultants Co., Ltd.

Appendix 2 Study Schedule

No.1: Basic Design Study

Days	Date	Week day	Activity	Team Member							
				Ms. Yamamoto	Mr. Inoue	Mr. Matsuoka	Mr. Fujiwara	Mr. Takara	Mr. Miura	Mr. Akwatta	Mr. Nakamura
1	13th Sep.	Sun	Move (Japan-Dubai)			○		○		○	○
2	14th Sep.	Mon	Move (Dubai-Nairobi)To visit JICA			○		○		○	○
3	15th Sep.	Tue	To visit/MoWI&Tana		○	○		○		○	○
4	16th Sep.	Wed	Field Survey/data		○	○		○		○	○
5	17th Sep.	Thu	Field Survey/data			○		○		○	○
6	18th Sep.	Fri	Field Survey/data			○		○		○	○
7	19th Sep.	Sat	Field Survey/data			○		○		○	○
8	20th Sep.	Sun	Arragement of data			○		○		○	○
9	21th Sep.	Mon	Start of Basic design/Site Survey			○		○		○	○
10	22th Sep.	Tue	Data Collection/Basic Design			○	○	○		○	○
11	23th Sep.	Wed	Data Collection/Basic Design			○	○	○		○	○
12	24th Sep.	Thu	Data Collection/Basic Design			○	○	○		○	○
13	25th Sep.	Fri	Meeting with EWASCO			○	○	○		○	○
14	26th Sep.	Sat	Move of Team Leader/Data Arragement	○		○	○	○		○	○
15	27th Sep.	Sun	Data Arragement/Inner Meeting	○	○	○	○	○		○	○
16	28th Sep.	Mon	To visit Japanese Embassy/MoWI	○	○	○	○	○		○	○
17	29th Sep.	Tue	To visit EWASCO/Site Inspection	○	○	○	○	○		○	○
18	30th Sep.	Wed	Inner Meeting	○	○	○	○	○		○	○
19	1st Oct.	Thu	MM Discussion	○	○	○	○	○		○	○
20	2nd Oct.	Fri	MM Signture	○	○	○	○	○		○	○
21	3rd Oct.	Sat	Basic Design/Drawing up Reports			○	○	○	○	○	○
22	4th Oct.	Sun	Basic Design/Drawing up Reports			○	○	○	○	○	○
23	5th Oct.	Mon	Basic Design/Drawing up Reports			○	○	○	○	○	○
24	6th Oct.	Tue	Meeting with EWASCO			○	○	○	○	○	○
25	7th Oct.	Wed	Basic Design/Drawing up Reports			○	○	○	○	○	○
26	8th Oct.	Thu	Survey of Pipeline Route			○	○	○	○	○	○
27	9th Oct.	Fri	Inspection of Distribution Area			○	○	○	○	○	○
28	10th Oct.	Sat	Basic Design/Drawing up Reports			○	○	○	○	○	○
29	11th Oct.	Sun	Holiday			○	○	○	○	○	○
30	12th Oct.	Mon	Social Condition Survey/Drawing up			○	○	○	○	○	○
31	13th Oct.	Tue	To visit Meru			○	○	○	○	○	○
32	14th Oct.	Wed	Basic Design/Drawing up Reports			○	○	○	○	○	○
33	15th Oct.	Thu	Sampling of Water/Drawing up			○	○	○	○	○	○
34	16th Oct.	Fri	Basic Design/Drawing up Reports			○	○	○	○	○	○
35	17th Oct.	Sat	Basic Design/Drawing up Reports			○	○	○	○	○	○
36	18th Oct.	Sun	Holiday, All day Black-			○	○	○	○	○	○
37	19th Oct.	Mon	Start of Soil Survey			○	○	○	○	○	○
38	20th Oct.	Tue	Drawing up Reports			○	○	○	○	○	○
39	21th Oct.	Wed	Meeting with EWASCO/Start of Soil Survey			○	○	○	○	○	○
40	22th Oct.	Thu	Drawing up Reports/Exploration of Trasmission line			○		○	○	○	○
41	23th Oct.	Fri	Discussion for T-N			○		○	○	○	○
42	24th Oct.	Sat	Finish of Soil Survey			○		○	○	○	○
43	25th Oct.	Sun	Drawing up Reports			○		○	○	○	○
44	26th Oct.	Mon	Drawing up Reports			○		○	○	○	○
45	27th Oct.	Tue	Signiture of T-N			○		○	○	○	○
46	28th Oct.	Wed	Drawing up Reports			○		○	○	○	○
47	29th Oct.	Thu	Reporting to JICA and Japanese Embassy			○		○	○	○	○
48	30th Oct.	Fri	Clearing up Office			○		○	○	○	○
49	31th Oct.	Sat	Move to Nirobi-Dubai			○		○	○	○	○
50	1st Dec	Sun	Dubai-Japan			○		○	○	○	○

No.2: Explanation on Draft Final Report

Days	Date	Week day	Activity	JICA		Consultant	
				Mr. Kawazumi	Mr. Inoue	Mr. Matsuoka	Mr. Nakamura
1	10th Feb.	Wed	Move (Japan-Dubai)			○	○
2	11th Feb.	Thu	Move (Dubai-Nairobi)			○	○
3	12th Feb.	Fri	To visit EWASCO, Explanation of design in the sites		○	○	○
4	13th Feb.	Sat	Explanation of DFR to EWASCO and TWASB		○	○	○
5	14th Feb.	Sun	Move to Nirobi			○	○
6	15th Feb.	Mon	To visit JICA and Japanese Embassy, explanation to MoWI			○	○
7	16th Feb.	Tue	Discussion for M/D			○	○
8	17th Feb.	Wed	Diginiture of M/D			○	○
9	18th Feb.	Thu	Move to Nirobi-Dubai			○	○
10	19th Feb.	Fri	Dubai-Japan			○	○

Appendix 3 Site Survey Results

Appendix 3-1 Soil Survey

1. Contents of the Report

   A-5 ～ A-12

2. Location Map

   Mukangu WTP/ Kangaru Reservoir Site:A-34

   Test Pit: A-13～14

3. Drawings for Bore Hole logs

   A-15～A-17

1. Conversion Table between N Value and Undrained Shear Strength

   A-18～A-19

2. Drawing of Test Pit Logs

   A-20～A-24

6. Section of Boring Logs

   A-25～A-27

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REPORT

OC/1501/SI/gg/09

Client : NJS Consultants Co. Ltd

Improvement of Embu Water Supply Geotechnical Investigations

1. Introduction

We were appointed by NJS Consultants Co. Ltd to undertake a geotechnical investigation at the sites of the existing Mukangu Treatment Works and Kangaru Water Storage Facility which forms part of the Embu Water & Sewage Co Ltd. As it is understood our Client was recently commissioned by the Japanese International Co-operation Agency (JICA) to undertake a detailed study of the existing facilities, supported by a detailed design for upgrading and future expansion.

As part of this study, we were engaged to drill a series of boreholes to a specified depth of 10 metres; four of which were located at Mukangu Treatment Works and a further two boreholes at the site of Kangaru Water Storage Facility, both within the Embu District.

In addition to the above exercise we were required to excavate a total of 10No. Trial Pits, to a specified depth of 2.0 metres, at intervals along the route of the existing water pipeline with the aim of establishing the nature of the soils strata.

In accordance with the instructions issued by the Client we were not required to recover samples from either the boreholes or the trial pits and the testing required was to comprise solely of the determination of the insitu SPT values within each of the boreholes drilled and at a frequency of every one metre.

In this regard, we had proposed that it would be advantageous to recover both undisturbed and disturbed samples during the drilling operations purposely to allow for possible subsequent laboratory testing, however this was considered unnecessary by our Clients representative onsite and the classification of the material types should be based on specialist experience presumably within our laboratories.

Our brief in respect of the trial pit investigations was purely to excavate each hole to a depth of 2 metres and provide a description of the materials encountered, together with photographic records.

As a supplementary part of this investigation we were requested to analyse the quality of both treated and untreated water taken from various processing points within the existing Water Treatment Works. In this regard, samples were recovered from various locations as defined by NJS Consultants and in the presence of their representative and personnel from EWASCO, the local water authority. The results of this latter investigation are presented as a supplementary report.

2. Characteristics of the Area

2.1 : Climatic Conditions & Hydrology

The town of Embu is situated approximately 120Kms north-east of Nairobi and within relatively close proximity to Mount Kenya National Park. It is characterised as typical tropical highlands, midlands, and other features including hills and valleys, with wide variations in altitude. Altitudes from the highlands range from 1,500 to 4,500 at the foothills of Mount Kenya with the midlands ranging from 1,200 to 1,500 metres above sea level.

Plate No.1 : Map of Kenya (Embu)

The mean maximum temperatures range from 24 to 36^{0}C , whilst the mean minimum temperatures ranges from 10 to 14^{0}C. Rainfall distribution is controlled by the north-south movement of tropical convergence zone. This gives rise to, basically, two seasons with the dry season normally commencing in January and February followed by the rainy season which commences from March to the end of May; the latter is described as the "long rains". Conversely, the dry season invariably starts from about June to mid October and, thereafter, the wet season from mid-October to the end of December. It will be appreciated that the weather patterns all over the World are changing dramatically, thus the forecast that could have earlier been made can, occasionally be in doubt, mainly as a result of global warming and the like.

The average rainfall is about 1495mm in the region where the terrain is above, which it thought to result from the high capacity of indigenous forest to store water, thereby making most of the water courses and streams perennial. The forest belt between, say, 2,300 to 3,350 metres has the highest water yield per unit area and, equally yields the greatest proportion of surface discharge.

Plate No. 2: Water Runoff from Mount Kenya

The main drainage channels are rivers Kabingazi, Ripinazi, Thuci, and Ena which drain into the south and east respectively; several branches of these rivers form denritic patterns distributed over the region.

2.2 : Geology of Embu Region

The geology of the soils within the Embu region basically falls within a number of categories with the more common type comprising well drained red clayey loam to red/brown highly compacted clayey soils. Most of these soil type tend to be friable when moist and both sticky and plastic when wet, and exhibiting

a very high workability. It is not unusual to find such deposits interlaid with gravel and the occasional rock fragments which in variably are cemented by a surrounding clay matrix.

Land use is a very significant factor in the formation of the upper geological strata and the maintenance of the soil structure. For example, the soil structure under napier grass, tea, and fallow areas are relatively well formed with relatively stable aggregates, whilst land under under maize and coffee tend to be weak and massive, breaking into dust. When wet such soils become puddled with reduced water permeability which is invariably a result of intensive cultivation.

Because of different impacts of different land use types, the soil particles are variously arranged into particles of different sizes and grades giving rise to variation in the absorption and porosity characteristics, and total water retention characteristics. However, these trends can occasionally change periodically due to the dynamic nature of the pore geometry, caused by changes in the management regimes.

Below this upper geological strata, mainly comprising red loamy soils which sometimes comprises substantial depths lays various strata of igneous type rocks originating from the volcanic lava flows that occurred in the region thousands of years earlier. An example of the earlier volcanic reactions and the subsequent uplifts and laying down of magma may be characterised by Mount Kenya and the surrounding environs; all of which are reported to have been derived from the tectonics of the Mozambique Belt east of the Rift Valley. Studies carried out in recent years have tended to progressively reveal the complexity of the geology, structure, and tectonics of the Mozambique Belt in this region.

Previously the geology of the Central Region was thought to comprises predominantly of pelitic and semi-pelitic schists and gneisses, magmatites and amphiboles. Further north in the Chanlers Falls and Archers Post areas this segment is dominated by paragneisses and schists, marbles, and calc-silicate rocks, granulites and metamorphosed mafic and ultramafic rocks.

Complex foldings exhibiting at least three fold generations and which occasionally have formed elliptical domes and basin structures are widespread. The entire segment, however, has several Neoproterozoic faults thrusts and shear zones some of which are of regional dimensions.

The general geology within the close vicinity of Embu can be categorized as falling within the basement system of granite and igneous rocks and invariably comprises moderately dissected undulating peneplain. Within certain portions and especially in the western part the formation is described as being slightly dissected and very gently undulated peneplain.

The overlying soil structure are developed on undifferentiated basement system rocks and are categorised, in most instances, as well drained dark red and occasionally yellow red stony loamy to clay consistency .

These soil types can be highly erodible, especially in areas which have been overgrazed or denuded, and are known to occasionally exhibite high expansive characteristics.

3. Geotechnical Investigations

Following receipt of instructions to commence works two drilling rigs, complete with the required drilling components, were mobilised to site on the 19th October 2009 and during a period of six days extending to the 24th October 2009 a total of 10No. boreholes were drilled at the two locations defined by the Client. It may be noted, it had been intended to commence drilling at the Mukangu Treatment Works, basically as this was thought to be the most difficult location in the event of the onset of rains and our belief that the exposed strata, particularly the red coffee soils may pose problems in gaining access to the four locations defined by the Client.

It had been envisaged from our initial reconnaissance of the Works that one may encounter some minor problems in gaining access to the various parts of the site, however, on arrival we were somewhat taken aback to find the main access had been blocked by excavations by another contractor working on site and as a means of draining some open excavations. In actual fact, the access had been disrupted to an extent there was no passage for vehicular traffic despite the fact that during our initial inspection of the Works the access was reasonable good.

Plate No.3 : Drilling in Progress at Mukangu Water Treatment Plant

The resultant affect was that one had little alternative but to demobilise the equipment and transfer to the second site which was located some distance away, within the Kanguru Water Storage Facility.

During the course of the drilling operations SPT values were recorded at 1 metre intervals down to the base of each borehole; the values of which are presented in Appendix B of this report.

From review of the soils being recovered during the drilling operation the material can be described as soft to very stiff clays of differing bearing values.

Set out in Appendix A of this report are the Borehole Logs describing the materials encountered in each of the holes, together with the respective SPT ("N") values recorded at the time of drilling.

As discussed in the introduction to this report we were required to excavate a series of trial pits along the existing pipeline and in areas where there may be some modification to the existing line.

The investigation comprised excavating each of the trial pits to a specified depth of 2.0 metres in areas pre-defined by the Client. Reference to Appendix D and Appendix E of this report gives details of the materials encountered in each of the trial pits excavated, together with photographic records of the trial pits inspected.

4. Discussion

Reference to the data presented shows the material encountered in each of the boreholes is reasonably similar in composition and tends to vary between firm/stiff to very stiff reddish brown loamy type clays. Notwithstanding, it will be noted the soils encountered at the bottom of the boreholes drilled at Kangaru showed to mainly comprise a greyish/brown clay .at depths of 9.5 and 10.45 metres, respectively.

The results of insitu SPT tests carried out during the drilling of these two boreholes yielded "N" values ranging between 8-32 and 4-62.
Similar tests undertaken on each of the four boreholes drilled at Mukangu Water Treatment Works tended to be a little more consistent with values ranging between say 12-36 if one discards the occasional low and high values.

The density index calculated from the data obtained indicates minimum values as low as 15% with higher value of >85% and an average in the ranged of 40-65%.

In order to understand the data obtained the estimated bearing values have been calculated from each of the individual "N" values recorded from which it can be seen the bearing capacity of the soil encountered at Kangaru ranges from 107KN/M^2 to 427KN/M^2, and 53KN/M^2 to 826KN/M^2, respectively.

Similar analyses carried out on the data obtained from the boreholes drilled at Mukangu shows the estimated bearing value to range between 240KN/M^2 to 440KN/M^2, 53KN/M^2 to 480KN/M^2, 173KN/M^2 to 400KN/M^2, and 107KN/M^2 to 560KN/M^2. Nevertheless, we would prefer to believe a more conservative estimate for design purposes should probably be in the order of 200KN/M^2, although we are still of the opinion this would be far better confirmed by supportive laboratory testing of soil samples recovered from the intended founding level and one metre below.

It should be borne in mind Kenya has recently undergone an extensive period of dry weather thus the soil structure is relatively dry and considering such soils are known to degrade by the presence of excess moisture this should be taken into account especially in any long-term considerations. This is supported to some extend purely by the fact it was not possible to define the level of the water table, basically as the strata observed throughout the full depth of the boreholes was comparatively dry.

The characteristics of the soils encountered fall within a "Classification" of MH and/or A-7-5. Reference to the Unified Soils Classification System describes such soils as inorganic clays and silts of medium compressibility, whereas reference to ASTM D-2487 defines the soils as "fair to poor" for use as a load bearing material.

Typical dry densities of the soils encountered are invariably low, generally in the order of 1200- 1400Kgs/M^3 with relative optimum moisture contents in the range of 32 to 38%. These are values based on a laboratory compaction carried out in accordance with BS.1377 (standard) compaction or the equivalent AASTHO T.99 method. In general, the swell characteristics of the red soils can be quite variable and, on occasions can be quite high; a typical value is in the order of 2.5%. It is with this in mind, that we believe it is rather unwise to rely solely on typical values and ideally any serious consideration to the quality and nature of soils is better confirmed by laboratory tests.

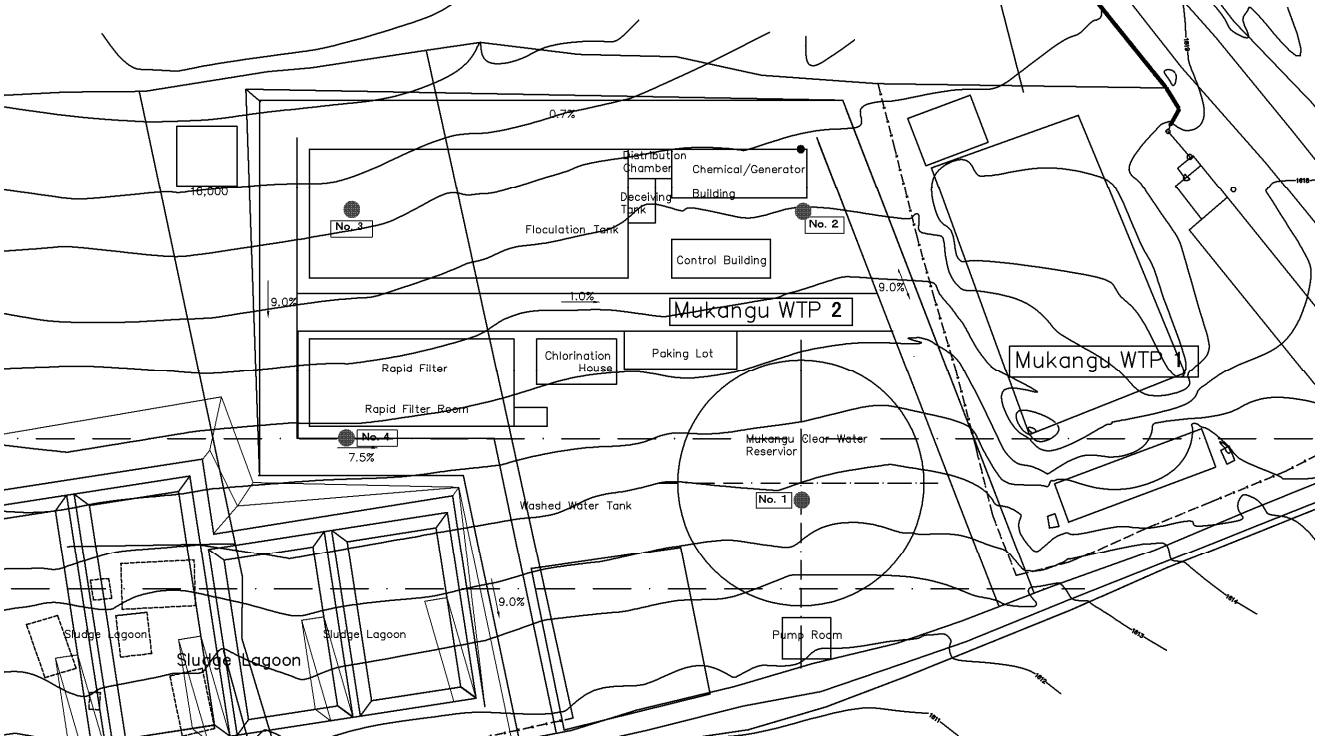
From a review of the trial pit logs produced during the pipeline investigation it is apparent most of the strata encountered, at depths as little as 0.5 metres, appears to comprise clayey gravels or soils containing rock fragments; most of which should prove to be reasonable load bearing material. We would reiterate, however, this assessment has been made purely on a visual basis, therefore, it would be rather difficult to be conclusive.

This completes the investigations outlined in the instructions given by the Client, however, despite the fact there was no requirement for any additional testing, other than those undertaken on site, we have attempted to provide additional information based on our experience of similar soils encountered in this region. Notwithstanding, we can only reiterate our views that it would be advisable to confirm the nature of the soils at the proposed foundation levels in order to establish the safe bearing values and the level of potential settlement before concluding the foundation type and size.

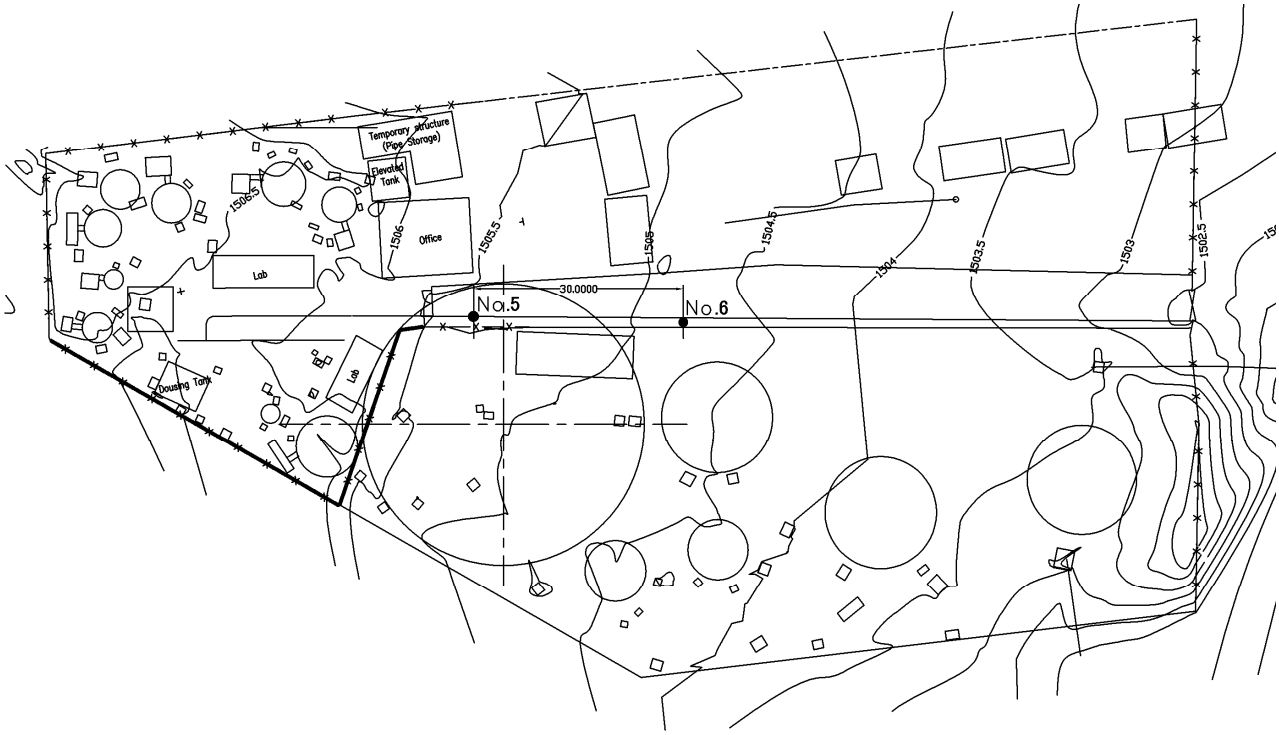
In conclusion, should you require further information or, indeed, clarification of the data presented in this report , please do not hesitate in contacting us.

for Geoff Griffiths & Associates

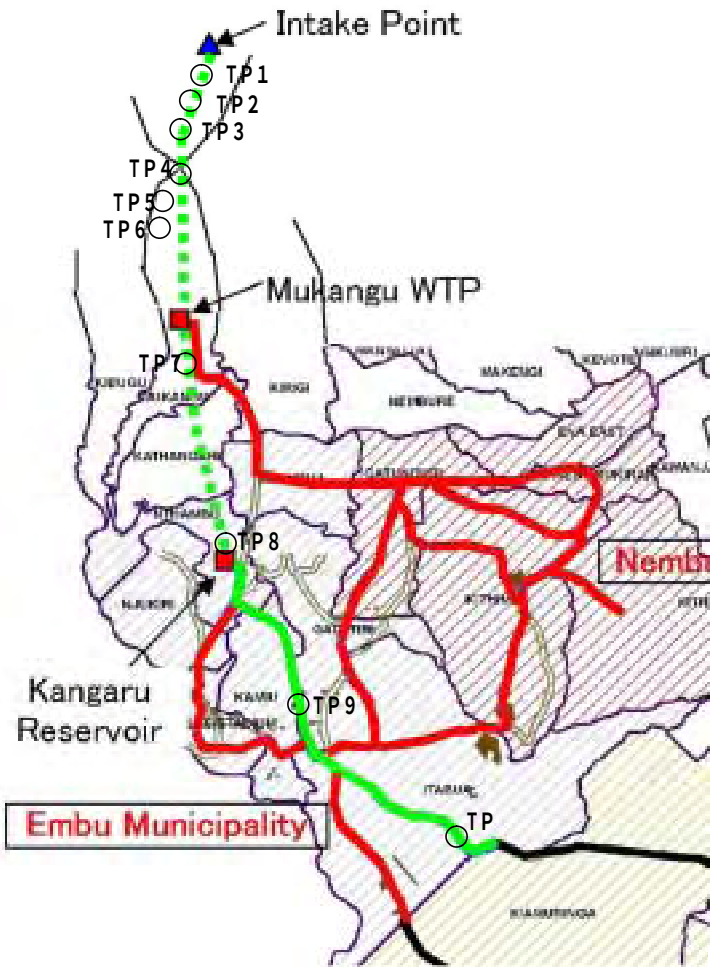
7th November 2009



Boring Location in Mukangu WTP



Boring Location in Kangaru Reservoir Site



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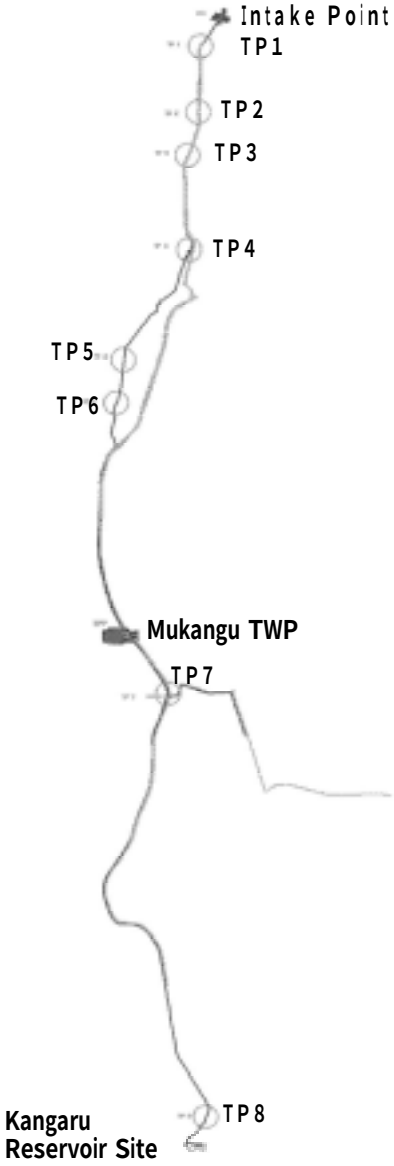
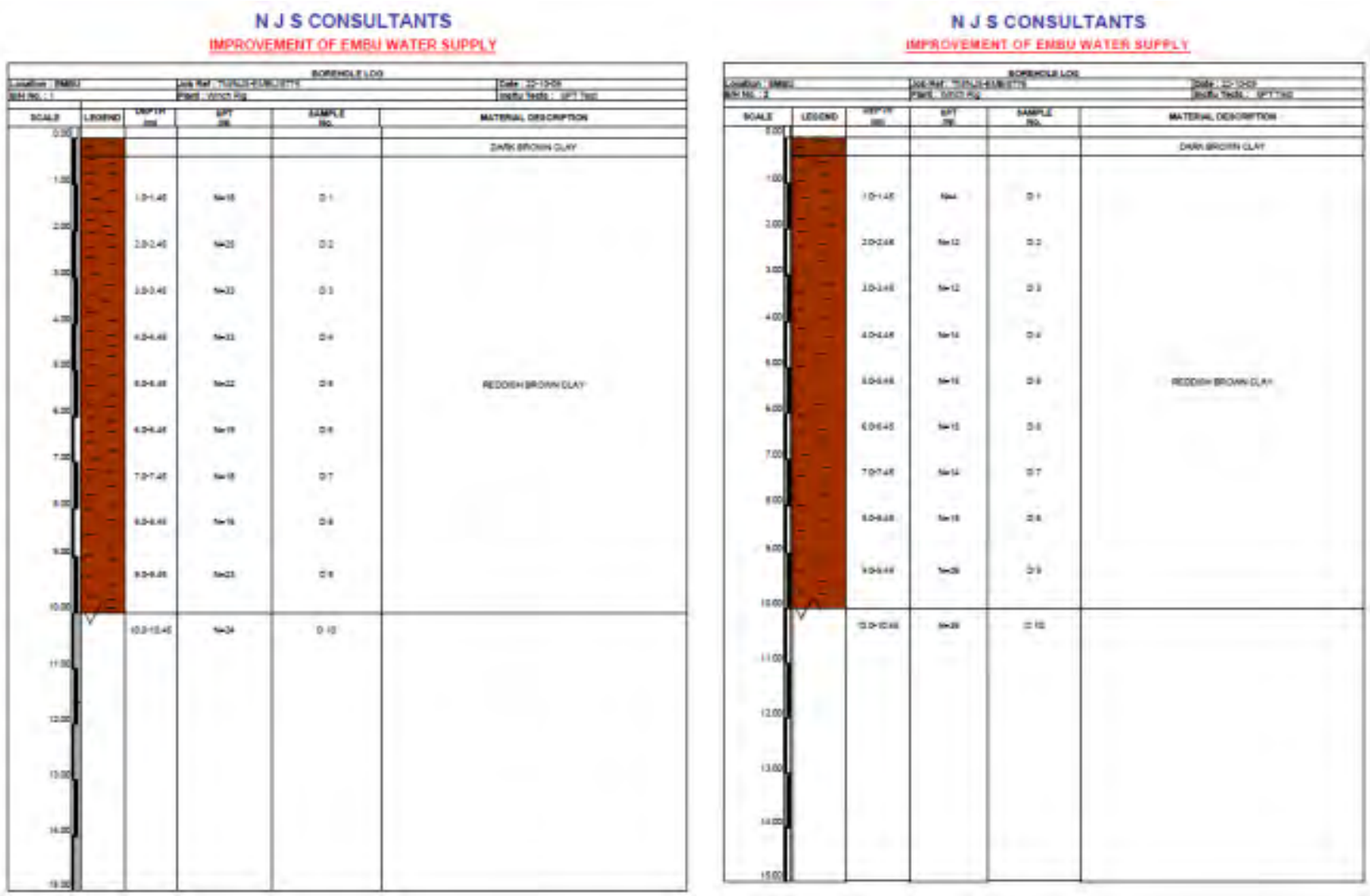
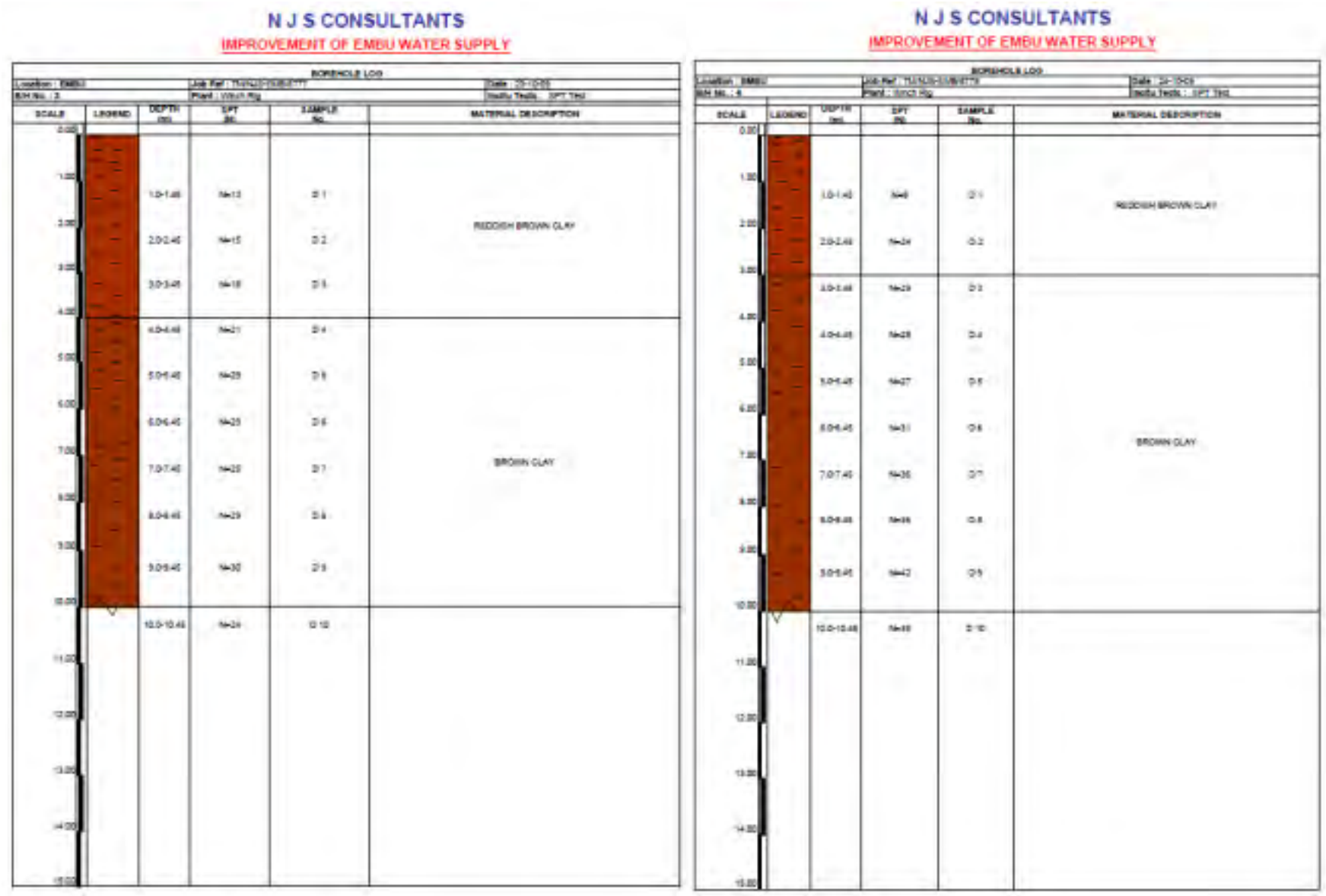


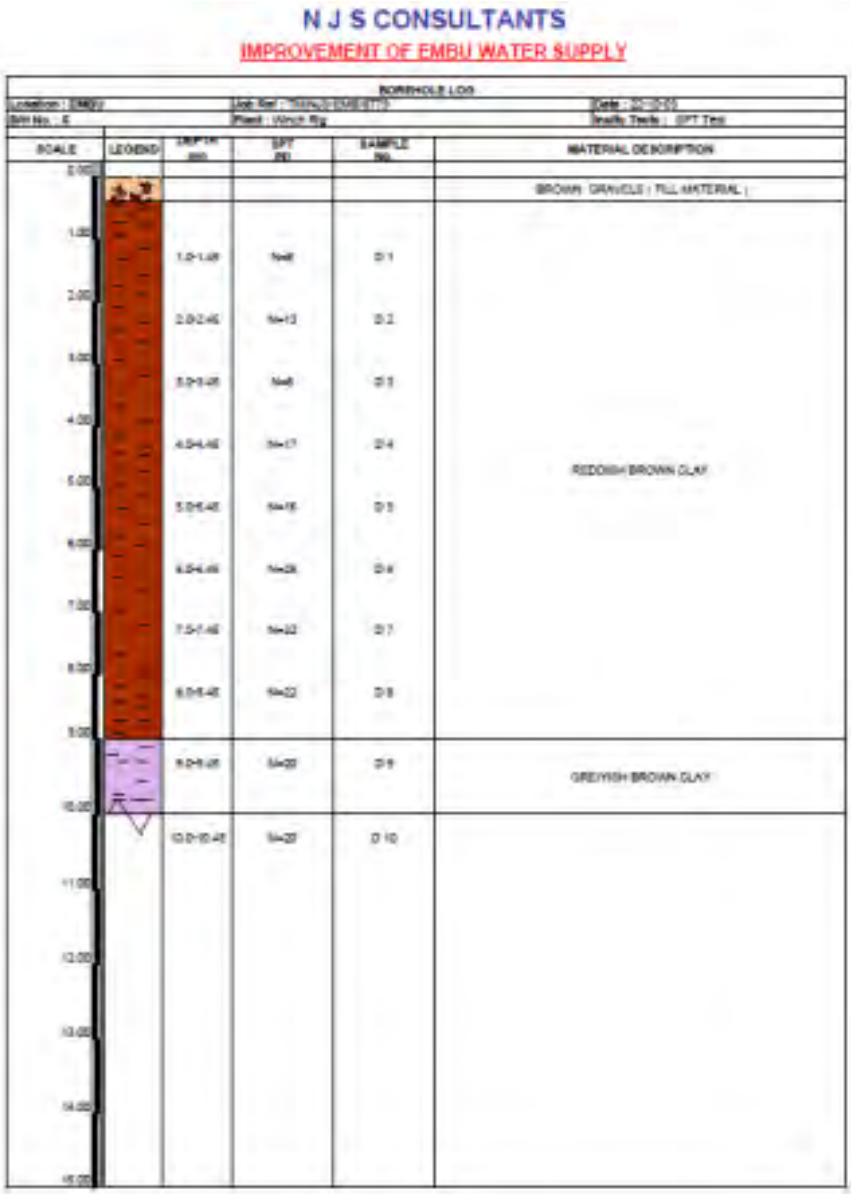
Detail Location TP 1—8

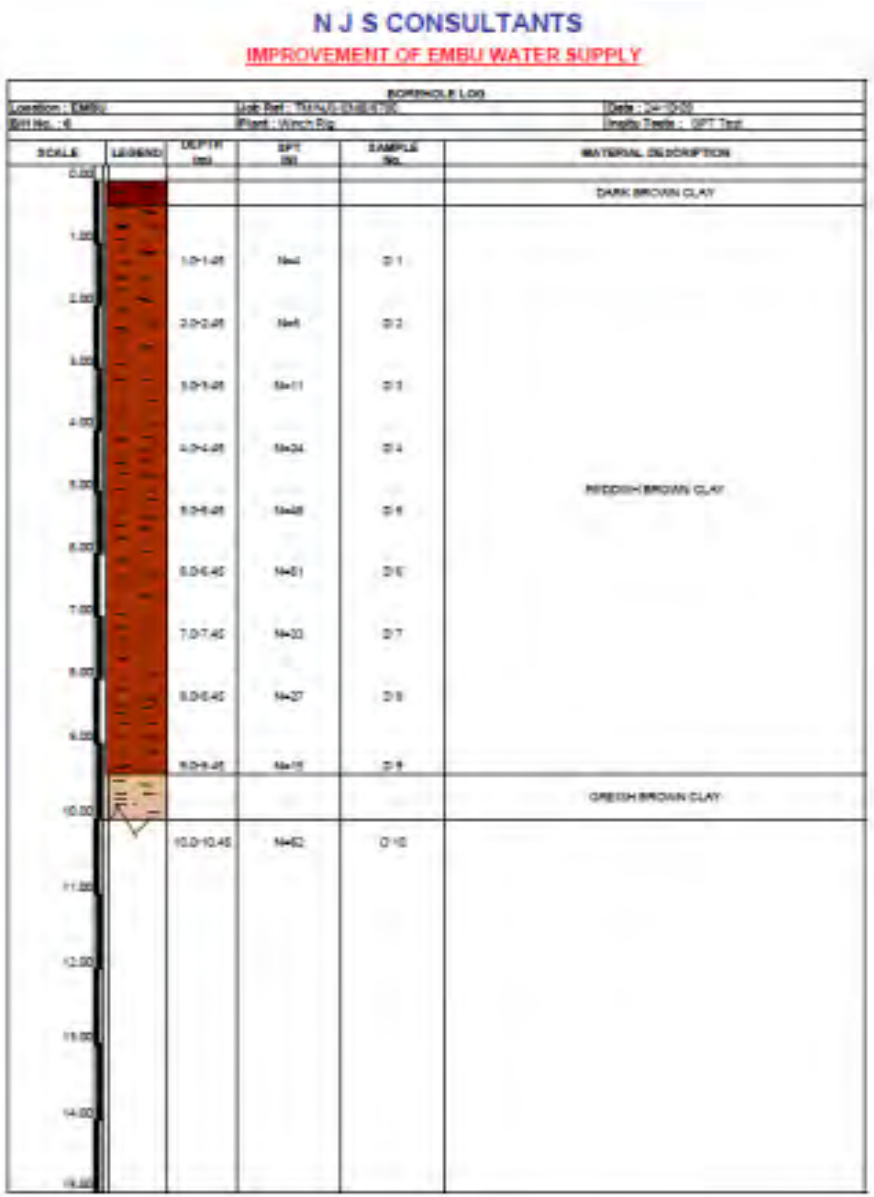


No.1, No.2 Bore Hole Logs



No.3, No.4 Bore Hole Logs





No.4, No.5 Bore Hole Logs

Kenya

N J S CONSULTANTS

IMPROVEMENT OF EMBU WATER SUPPLY

SPT VALUES

Site : MUKANGU

Date of Test : 20-10-09

TEST LOCATION	DEPTH (m)	SPT N-Value	Relative Density		APPROXIMATE UNDRAINED SHEAR STRENGTH (KN/M²)
			Description	Density Index (Id)	
Borehole No. 1	1.45	18	VERY STIFF CLAY	47%	240
	2.45	25	VERY STIFF CLAY	58%	333
	3.45	33	HARD CLAY	68%	440
	4.45	33	HARD CLAY	68%	440
	5.45	22	VERY STIFF CLAY	53%	293
	6.45	19	VERY STIFF CLAY	49%	253
	7.45	18	VERY STIFF CLAY	47%	240
	8.45	16	VERY STIFF CLAY	44%	213
	9.45	23	VERY STIFF CLAY	55%	307
	10.45	24	VERY STIFF CLAY	56%	320
Borehole No. 2	1.45	4	SOFT CLAY	15%	53
	2.45	12	STIFF CLAY	38%	160
	3.45	12	STIFF CLAY	38%	160
	4.45	14	STIFF CLAY	41%	187
	5.45	15	STIFF CLAY	43%	200
	6.45	15	STIFF CLAY	43%	200
	7.45	14	STIFF CLAY	41%	187
	8.45	15	STIFF CLAY	43%	200
	9.45	26	VERY STIFF CLAY	59%	347
	10.45	36	HARD CLAY	71%	480

N J S COSULTANTS

IMPROVEMENT OF EMBU WATER SUPPLY

SPT VALUES

Site : MUKANGU

Date of Test : 23-10-09

TEST LOCATION	DEPTH (m)	SPT N-Value	Relative Density		APPROXIMATE UNDRAINED SHEAR STRENGTH (KN/M²)
			Description	Density Index (Id)	
Borehole No. 3	1.45	13	STIFF CLAY	40%	173
	2.45	15	STIFF CLAY	43%	200
	3.45	16	VERY STIFF CLAY	44%	213
	4.45	21	VERY STIFF CLAY	52%	280
	5.45	29	VERY STIFF CLAY	64%	387
	6.45	29	VERY STIFF CLAY	64%	387
	7.45	25	VERY STIFF CLAY	58%	333
	8.45	29	VERY STIFF CLAY	64%	387
	9.45	30	VERY STIFF CLAY	65%	400
	10.45	24	VERY STIFF CLAY	56%	320
Borehole No. 4	1.45	8	FIRM CLAY	28%	107
	2.45	24	VERY STIFF CLAY	56%	320
	3.45	29	VERY STIFF CLAY	64%	387
	4.45	28	VERY STIFF CLAY	62%	373
	5.45	27	VERY STIFF CLAY	61%	360
	6.45	31	VERY STIFF CLAY	66%	413
	7.45	36	VERY STIFF CLAY	71%	480
	8.45	36	VERY STIFF CLAY	71%	480
	9.45	42	VERY STIFF CLAY	77%	560
	10.45	35	VERY STIFF CLAY	70%	467

No.1～No.4 Conversion Table between N Value and Undrained Shear Strength

N J S COSULTANTS

IMPROVEMENT OF EMBU WATER SUPPLY

SPT VALUES

Site : KANGARU

Date of Test : 24-10-09

TEST LOCATION	DEPTH (m)	SPT N-Value	Relative Density		APPROXIMATE UNDRAINED SHEAR STRENGTH (KN/M^2)
			Description	Density Index (Id)	
Borehole No. 5	1.45	6	FIRM CLAY	26%	107
	2.45	13	STIFF CLAY	40%	173
	3.45	6	FIRM CLAY	26%	107
	4.45	17	VERY STIFF CLAY	46%	227
	5.45	16	VERY STIFF CLAY	44%	213
	6.45	25	VERY STIFF CLAY	58%	333
	7.45	32	HARD CLAY	67%	427
	8.45	22	VERY STIFF CLAY	53%	293
	9.45	20	VERY STIFF CLAY	50%	267
	10.45	20	VERY STIFF CLAY	50%	267
Borehole No. 6	1.45	4	SOFT CLAY	15%	53
	2.45	6	FIRM CLAY	22%	80
	3.45	11	STIFF CLAY	37%	147
	4.45	24	VERY STIFF CLAY	56%	320
	5.45	46	VERY HARD CLAY	81%	613
	6.45	51	VERY HARD CLAY	>85%	680
	7.45	33	HARD CLAY	68%	440
	8.45	27	VERY STIFF CLAY	61%	360
	9.45	15	VERY STIFF CLAY	43%	200
	10.45	62	VERY HARD CLAY	>85%	826

No.5～No.6　Conversion Table between N Value and Undrained Shear Strength

N J S CONSULTANTS.

IMPROVEMENT OF EMBU WATER SUPPLY

TRIAL PIT LOG

Location : EMBU WATER SUPPLY	Job Ref : TM/NJS-EMB/6781	Date of Test : 22.10.09
TRIAL PIT No.1	Method of Excavation : Hand	Insitu Tests :

SCALE	LEGEND	DEPTH (m)	MATERIAL DESCRIPTION
0.00			
0.50			DARK BROWN LEAN CLAY
1.00			
1.50			BROWN CLAY WITH GRAVEL INCLUSIONS
2.00			

N J S CONSULTANTS

IMPROVEMENT OF EMBU WATER SUPPLY

TRIAL PIT LOG

Location : EMBU WATER SUPPLY	Job Ref : TM/NJS-EMB/6782	Date of Test : 22.10.09
TRIAL PIT No.2	Method of Excavation : Hand	Insitu Tests :

SCALE	LEGEND	DEPTH (m)	MATERIAL DESCRIPTION
0.00			
0.50			REDDISH BROWN SILTY CLAY
1.00			
1.50			ROCK BOULDERS IN A CLAY MATRIX
2.00			

TP1/TP2 Test Pit Logs

N J S CONSULTANTS

IMPROVEMENT OF EMBU WATER SUPPLY

TRIAL PIT LOG

Location : EMBU WATER SUPPLY	Job Ref : TM/NJS-EMB/8783	Date of Test : 22.10.09
TRIAL PIT No.3	Method of Excavation : Hand	Insitu Tests :

SCALE	LEGEND	DEPTH (m)	MATERIAL DESCRIPTION
0.00			
			REDDISH BROWN SILTY CLAY
0.50			
			ROCK BOULDERS IN A CLAY MATRIX
1.00			
1.50			
2.00			

N J S CONSULTANTS.

IMPROVEMENT OF EMBU WATER SUPPLY

TRIAL PIT LOG

Location : EMBU	Job Ref : TM/NJS-EMB/8784	Date of Test : 22.10.09
TRIAL PIT No.4	Method of Excavation : Hand	Insitu Tests :

SCALE	LEGEND	DEPTH (m)	MATERIAL DESCRIPTION
0.00			
			DARK BROWN CLAY SOIL
0.50			
			DARK BROWN CLAY WITH GRAVELS
1.00			
			ROCK BOULDERS
1.50			
2.00			

TP3/TP4 Test Pit Logs

N J S CONSULTANTS

IMPROVEMENT OF EMBU WATER SUPPLY

TRIAL PIT LOG

Location : EMBU WATER SUPPLY	Job Ref : TM/NJS-EMB/8785	Date of Test : 22.10.09
TRIAL PIT No.6	Method of Excavation : Hand	Insitu Tests :

SCALE	LEGEND	DEPTH (m)	MATERIAL DESCRIPTION
0.00			
0.50			YELLOWISH BROWN CLAYEY SAND WITH GRAVELS
1.00			
1.50			ROCK BOULDERS
2.00			

N J S CONSULTANTS

IMPROVEMENT OF EMBU WATER SUPPLY

TRIAL PIT LOG

Location : EMBU WATER SUPPLY	Job Ref : TM/NJS-EMB/8785	Date of Test : 22.10.09
TRIAL PIT No.8	Method of Excavation : Hand	Insitu Tests :

SCALE	LEGEND	DEPTH (m)	MATERIAL DESCRIPTION
0.00			
0.50			REDDISH BROWN SILTY CLAY
1.00			
1.50			BROWN GRAVELS WITH ROCK BOULDERS
2.00			

TP5/TP6 Test Pit Logs

N J S CONSULTANTS

IMPROVEMENT OF EMBU WATER SUPPLY

TRIAL PIT LOG

Location : EMBU WATER SUPPLY	Job Ref : TM/NJS-EMB/8787	Date of Test : 22.10.09
TRIAL PIT No.7	Method of Excavation : Hand	Insitu Tests :

SCALE	LEGEND	DEPTH (m)	MATERIAL DESCRIPTION
0.00			
			DARK BROWN LOAMY CLAY (SUB-SOIL)
0.50			
			REDDISH BROWN CLAY
1.00			
1.50			
2.00			

N J S CONSULTANTS

IMPROVEMENT OF EMBU WATER SUPPLY

TRIAL PIT LOG

Location : EMBU WATER SUPPLY	Job Ref : TM/NJS-EMB/8788	Date of Test : 22.10.09
TRIAL PIT No.8	Method of Excavation : Hand	Insitu Tests :

SCALE	LEGEND	DEPTH (m)	MATERIAL DESCRIPTION
0.00			
			DARK BROWN CLAY
0.50			
			REDDISH BROWN SILTY CLAY
1.00			
1.50			
2.00			

TP7/TP8 Test Pit Logs

N J S CONSULTANTS

IMPROVEMENT OF EMBU WATER SUPPLY

TRIAL PIT LOG

Location : EMBU WATER SUPPLY	Job Ref : TM/NJS-EMB/8799	Date of Test : 24.10.09
TRIAL PIT No.9	Method of Excavation : Hand	Insitu Tests :

SCALE	LEGEND	DEPTH (m)	MATERIAL DESCRIPTION
0.00			
			DARK BROWN LOAMY CLAY
0.50			
1.00			
			REDDISH BROWN SILTY CLAY
1.50			
2.00			

N J S CONSULTANTS

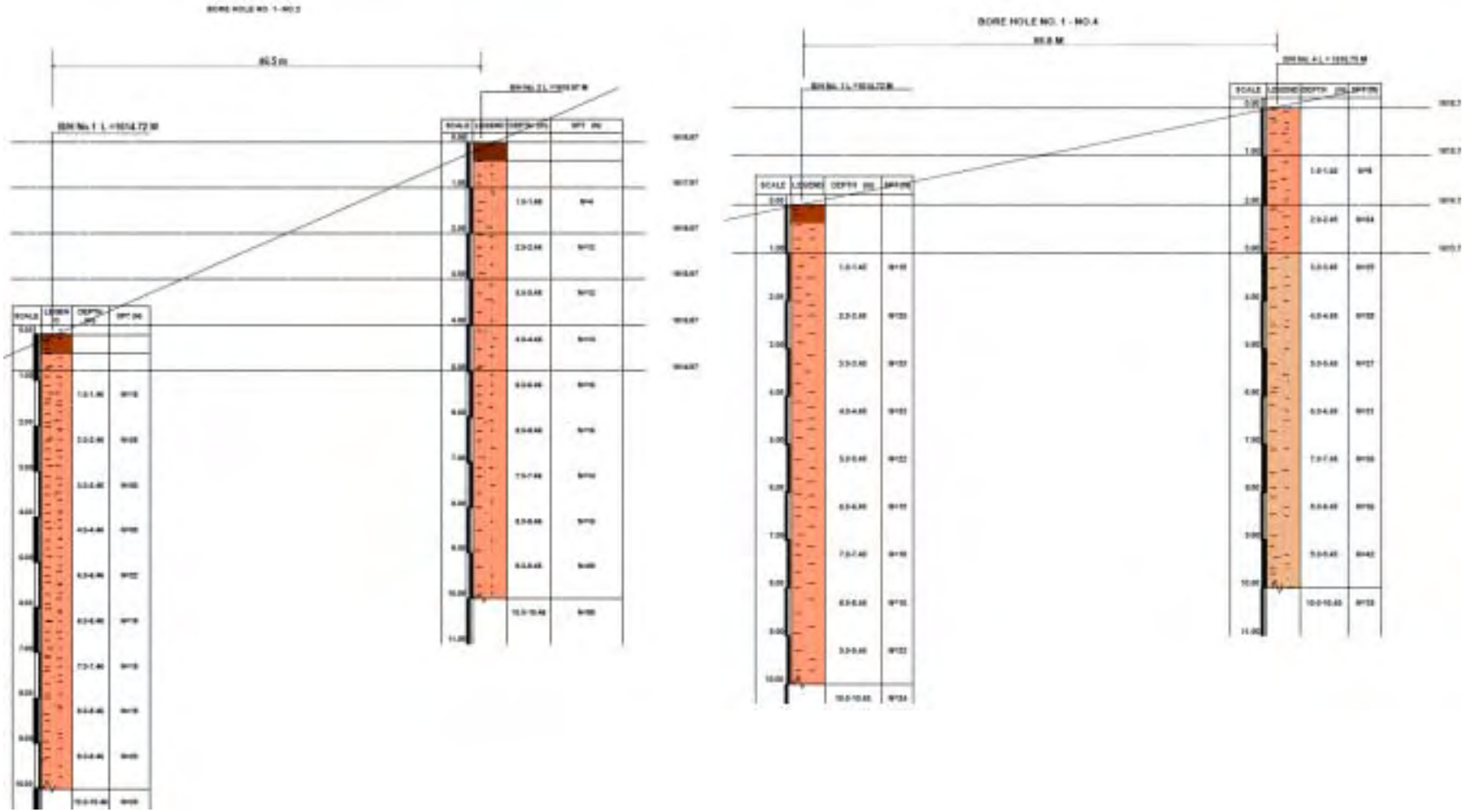
IMPROVEMENT OF EMBU WATER SUPPLY

TRIAL PIT LOG

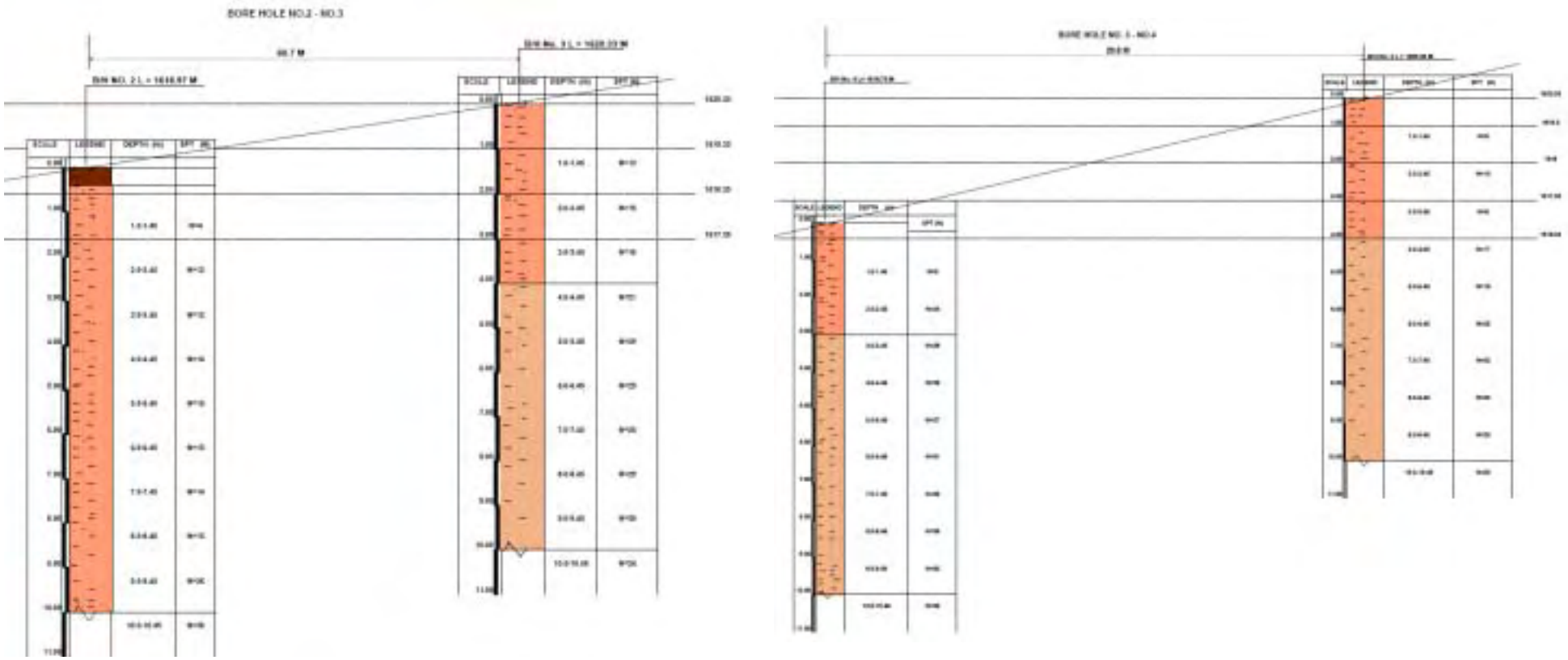
Location : EMBU WATER SUPPLY	Job Ref : TM/NJS-EMB/8790	Date of Test : 24.10.09
TRIAL PIT No.10	Method of Excavation : Hand	Insitu Tests :

SCALE	LEGEND	DEPTH (m)	MATERIAL DESCRIPTION
0.00			
			DARK BROWN CLAY
0.50			
1.00			
			REDDISH BROWN CLAY
1.50			
2.00			

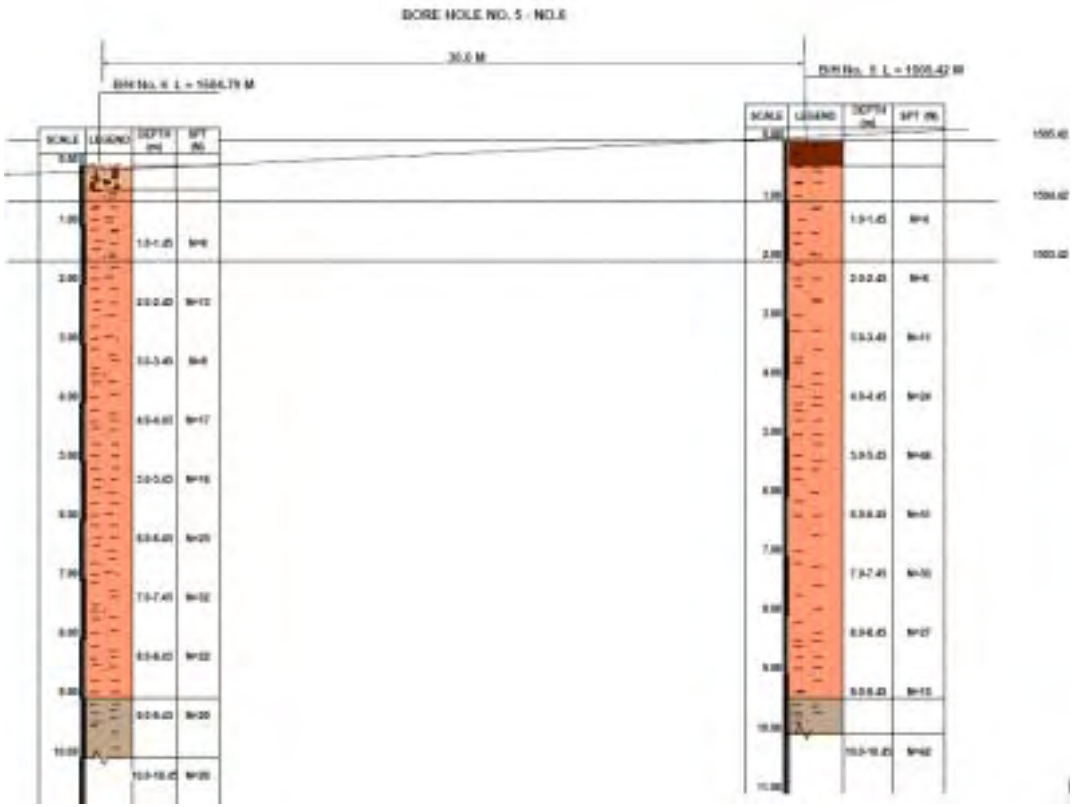
TP9/TP10 Test Pit Logs



Section of Bore Holes for No.1-No.2 and No.1-No.4



Section of Bore Holes for No.2-No.3 and No.3-No.4



Section of Bore Holes for No.5-No.6

Appendix 4 Other Data and Information

Appendix 4-1 Basic Data for Water Demand Projection

(1) Water Production Volume of EWASCO

Table 4-1-1 shows daily production volume and Fig. 4-1-1 shows graphs for monthly production volume.

(2) Water Consumption Data for each category Consumers of EWASCO

Table 4-1-2 shows water consumption data for each category consumers and Fig. 4-1-2 shows that per units.

Table 4-1-1 Daily water Production volume 2007/1～2009/9

Month	Jan			Feb			Mar			Apr			May			Jun		
Day/Year	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
1	6,984	7,673	9,857	9,807	10,775	11,696	8,385	10,631	9,858	8,163	10,025	13,227	7,707	10,229	11,083	6,076	10,414	7,589
2	7,098	8,136	11,539	10,159	10,875	11,303	9,132	10,178	10,505	8,298	10,323	11,744	7,708	10,273	11,214	8,113	11,439	11,956
3	7,410	8,824	10,998	9,961	10,940	11,696	8,749	9,888	9,448	7,726	10,339	14,255	8,175	10,283	11,770	7,882	10,614	10,891
4	7,565	8,460	11,242	9,514	9,460	11,115	8,114	10,802	11,334	8,656	12,987	9,886	3,721	9,555	12,041	7,338	10,992	11,784
5	6,780	8,145	10,279	9,871	11,858	11,186	8,389	9,627	9,930	8,324	7,935	12,772	5,182	9,885	11,161	7,332	10,679	12,132
6	6,690	9,645	10,421	9,881	8,438	11,103	8,207	7,477	9,815	7,913	10,342	12,940	3,351	10,624	11,652	7,257	10,273	10,778
7	6,721	11,904	11,559	8,503	10,532	10,814	8,068	9,407	11,961	8,068	9,232	10,956	8,326	7,695	11,302	7,688	10,913	11,438
8	6,477	12,082	10,615	9,395	10,154	11,126	8,193	10,891	9,021	8,495	10,831	12,981	7,425	7,586	11,518	7,016	10,206	11,513
9	6,447	6,388	9,586	8,980	9,957	10,271	8,411	9,204	9,898	8,577	8,318	10,579	7,471	9,485	10,848	6,713	11,091	11,486
10	8,650	8,201	10,883	8,808	10,104	11,028	7,900	10,280	9,918	2,126	9,851	11,039	6,984	9,108	10,006	7,206	9,987	10,509
11	8,335	10,981	9,615	4,760	10,157	11,099	8,293	11,101	10,994	8,361	9,953	10,874	7,394	9,796	10,715	6,397	10,002	11,882
12	10,114	10,029	9,104	8,332	10,715	10,754	7,818	10,526	9,789	8,108	10,469	10,550	7,435	9,379	9,900	7,199	10,464	10,809
13	9,612	10,342	7,441	5,679	10,035	10,911	10,003	11,173	7,644	7,706	10,520	9,905	7,445	6,864	11,800	7,629	9,870	9,219
14	8,818	10,923	8,573	6,939	10,380	10,713	10,225	10,822	10,575	6,996	8,389	10,903	7,508	7,934	6,886	6,460	11,399	10,608
15	9,118	10,669	7,428	7,812	10,387	10,102	10,592	11,138	11,200	5,902	5,631	11,434	7,362	8,377	9,879	7,312	9,670	11,799
16	9,144	11,246	6,954	8,663	10,509	9,064	10,620	10,787	10,353	5,221	7,937	11,371	6,538	3,428	8,779	6,227	10,524	11,143
17	9,421	9,189	10,853	8,167	10,611	10,859	10,310	10,261	10,432	4,237	5,748	9,910	6,588	7,927	10,101	7,929	10,189	11,656
18	8,962	10,955	11,202	6,781	10,358	10,981	10,294	10,054	11,264	7,511	7,713	10,722	7,050	9,273	10,138	7,308	11,633	10,125
19	9,383	9,507	10,531	7,096	10,567	10,285	10,544	11,318	13,519	7,768	9,643	11,005	7,996	8,877	9,275	7,140	10,686	11,613
20	9,686	8,163	11,183	4,182	10,486	9,201	9,488	10,171	9,095	6,799	10,064	8,987	7,624	9,753	9,034	6,728	10,922	11,064
21	8,947	10,865	11,214	5,183	10,293	10,241	8,479	9,393	11,677	3,448	10,211	10,416	7,427	10,349	8,980	6,884	10,548	11,159
22	8,477	11,646	10,387	10,570	9,696	9,576	8,770	6,781	9,877	5,299	9,283	10,060	6,213	10,858	8,771	6,867	10,877	8,342
23	8,416	8,631	9,143	10,252	8,920	9,754	8,636	9,218	11,951	9,029	9,920	6,762	7,398	9,425	8,789	7,538	11,330	10,833
24	8,563	9,861	10,873	10,106	9,108	12,390	9,197	10,726	10,316	10,311	8,686	11,042	7,067	9,369	7,812	6,785	9,853	8,739
25	8,125	10,939	12,154	9,893	8,969	10,455	8,482	7,109	10,693	9,589	5,638	12,585	6,865	11,118	7,567	7,446	11,693	8,739
26	8,085	10,582	10,634	9,851	8,790	9,752	7,407	6,661	10,296	9,943	7,000	11,149	7,415	10,170	8,511	6,093	10,942	12,346
27	8,165	8,781	9,648	8,900	9,996	10,310	8,902	9,628	10,483	8,822	10,216	10,751	6,740	10,247	11,586	7,765	10,490	11,850
28	8,441	9,625	7,156	8,630	10,510	11,539	8,566	9,790	11,690	9,005	9,639	10,074	7,083	10,044	10,441	7,022	10,705	11,378
29	8,984	11,097	9,464		10,465		8,079	6,861	13,660	8,961	10,624	11,034	6,622	10,210	9,534	7,202	10,206	11,523
30	5,447	10,982	11,288				8,220	9,515	12,931	8,360	9,623	10,494	6,608	9,747	12,329	6,711	10,461	9,613
31	3,230	10,529	10,505				7,720	9,698	12,335				5,576	6,981	11,988			
Daily Av.	8,010	9,839	10,075	8,453	10,139	10,690	8,845	9,713	10,725	7,591	9,236	11,014	6,903	9,189	10,175	7,109	10,636	10,817
Month	Jul			Aug			Sep			Oct			Nov			Dec		
Day/Year	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
1	7,707	9,426	10,607	7,783	10,330	9,333	6,755	11,001	10,817	6,082	8,618		8,800	9,281		7,787	10,272	
2	7,086	10,695	12,317	7,235	10,559	10,910	6,829	11,484	10,651	7,854	9,165		8,068	8,617		8,165	9,535	
3	7,687	11,083	11,957	6,602	11,169	10,864	6,807	10,620	11,058	7,166	8,235		7,965	8,578		8,039	9,528	
4	7,057	8,590	11,489	7,506	10,414	10,191	7,763	10,642	12,077	6,914	5,438		6,732	7,048		7,753	8,179	
5	7,738	9,094	11,615	8,103	9,051	10,430	8,101	9,803	10,677	6,705	8,698		8,988	9,006		8,466	10,281	
6	6,887	9,758	11,955	8,068	10,064	9,708	7,750	11,748	10,019	6,223	9,745		9,192	8,818		8,101	9,186	
7	5,822	10,183	12,393	7,725	8,722	11,616	8,004	11,012	10,786	6,759	10,564		4,173	7,716		7,928	9,624	
8	7,204	10,450	11,722	8,094	9,742	10,652	7,281	10,657	9,439	5,130	11,160		8,156	7,655		8,582	9,366	
9	7,516	11,040	12,208	8,169	10,094	11,440	7,377	11,330	7,969	5,933	9,940		8,948	10,344		7,933	9,429	
10	7,415	10,460	11,453	7,408	10,725	10,544	7,266	10,686	11,668	7,236	10,843		9,416	11,381		8,401	2,234	
11	7,254	10,613	11,890	8,266	11,887	11,137	6,385	8,561	12,597	6,954	11,175		9,032	11,442		6,341	3,611	
12	6,078	10,510	9,647	8,187	8,951	9,342	7,559	11,294	10,153	8,845	9,958		9,554	11,459		8,244	9,964	
13	6,699	10,195	10,383	8,334	9,733	12,313	7,263	11,017	10,022	9,024	10,320		9,171	11,054		8,796	10,790	
14	7,330	10,096	10,507	8,132	10,139	10,578	6,892	11,366	9,304	9,371	9,312		8,481	10,258		8,866	10,746	
15	6,440	9,889	11,895	7,885	10,464	9,845	7,641	8,840	8,644	7,540	11,057		8,976	10,073		7,866	10,645	
16	6,558	9,816	10,584	7,323	10,426	10,908	7,175	10,573	9,956	7,808	10,202		8,098	9,566		6,271	10,608	
17	6,479	11,023	11,539	7,583	9,927	11,620	7,476	10,896	8,681	8,479	9,230		9,350	11,155		7,383	11,004	
18	6,300	9,920	12,320	6,122	10,334	11,634	7,016	9,135	9,745	7,768	8,743		9,473	10,837		10,804	9,854	
19	6,742	10,015	9,331	6,177	10,328	10,862	6,841	11,352	3,748	7,225	9,708		9,545	10,516		8,597	10,245	
20	6,414	10,310	9,042	8,301	10,351	10,901	7,138	9,971	6,552	8,307	10,263		8,503	10,531		10,141	9,942	
21	7,548	10,344	8,718	7,439	9,934	11,860	7,134	10,119	11,262	8,656	10,383		7,765	10,575		9,997	10,036	
22	7,979	11,040	8,919	8,396	10,466	10,440	7,220	10,935	9,849	8,207	10,352		7,759	10,389		10,324	8,875	
23	6,318	5,239	9,372	8,307	10,216	10,870	7,576	10,160	9,667	8,228	10,217		8,126	9,889		8,741	9,734	
24	7,481	6,129	9,041	8,189	10,463	10,571	8,070	6,574	9,253	9,768	10,383		7,326	9,949		7,315	11,003	
25	6,610	9,392	9,269	7,364	10,323	10,994	7,546	3,049	11,086	9,207	10,937		6,926	10,071		10,940	8,655	
26	6,647	10,357	8,520	7,146	10,160	10,893	7,771	8,407	10,720	8,751	10,319		9,695	10,084		9,690	9,532	
27	7,090	10,008	8,717	7,509	10,616	10,643	8,055	10,321	8,225	7,741	11,127		8,299	9,503		11,298	10,198	
28	7,049	10,245	8,790	7,398	10,126	10,733	7,544	11,298	10,666	8,744	9,628		7,386	9,192		8,351	11,146	
29	6,391	10,363	7,463	7,282	10,312	10,492	6,577	10,339	9,369	8,765	8,975		7,359	9,809		9,711	10,470	
30	5,394	10,959	8,282	7,219	10,235	10,248	7,504	10,419	10,621	8,540	10,159		8,432	9,759		8,391	10,593	
31	7,119	9,773	8,646	6,835	10,656	11,005				8,530	9,924					7,767	10,898	
Daily Av.	6,904	9,904	10,342	7,616	10,223	10,761	7,344	10,120	9,843	7,821	9,832	0	8,323	9,819	0	8,613	9,554	0

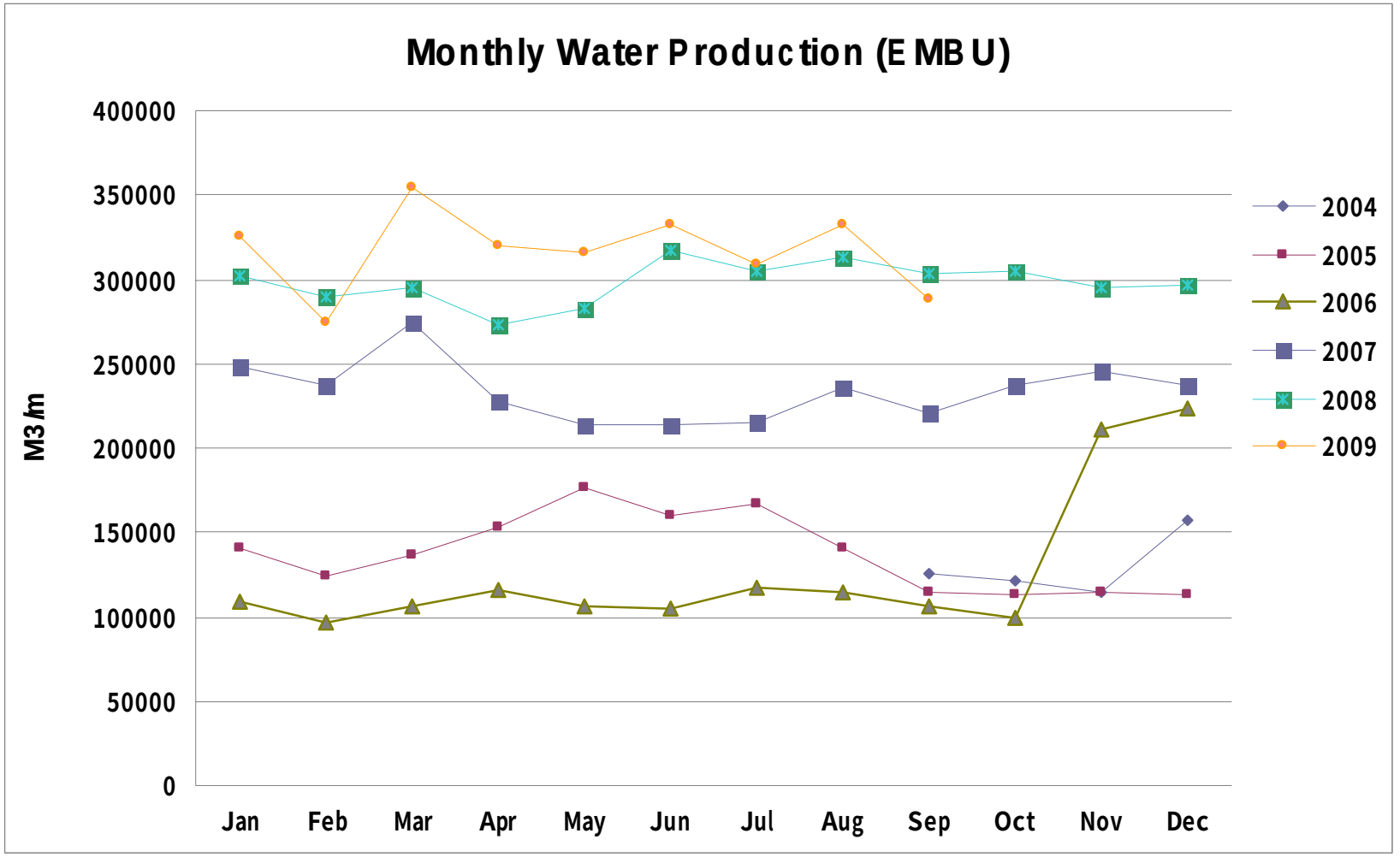


Fig. 4-1-1 Monthly Water Production Volume

Table 4-1-2 Daily Water Consumption for each Consumer Categories

Month	7月		8月		9月		10月		11月		12月	
Item	Contracted No.	Water Consumption	Contracted No.	Water Consumption	Contracted No.	Water Consumption	Contracted No.	Water Consumption	Contracted No.	Water Consumption	Contracted No.	Water Consumption
Commerce					214	**10,346**	228	**16,089**	234	**11,473**	243	**13,672**
Industry					231	**6,850**	222	**3,499**	230	**3,296**	229	**4,984**
Home					2,423	**39,375**	2,574	**52,635**	2,751	**43,064**	2,899	**66,550**
School					20	**4,141**	20	**4,060**	20	**4,042**	19	**2,184**
Public Org.					52	**2,509**	57	**2,664**	51	**2,148**	51	**4,646**
Hospital					10	**7,980**	11	**6,843**	11	**5,626**	11	**3,146**
University					8	**3,320**	9	**3,961**	9	**4,696**	8	**3,646**
Local Gov.					8	**1,898**	8	**1,868**	8	**1,797**	8	**1,654**
Others					2,324	**42,621**	2,140	**34,465**	2,190	**39,949**	2,161	**43,309**
Total	5,180	**81,145**	5,210	**60,843**	5,290	**119,040**	2,140	**126,084**	5,504	**116,091**	5,629	**143,791**
Month	1月		2月		3月		4月		5月		6月	
Item	Contracted No.	Water Consumption	Contracted No.	Water Consumption	Contracted No.	Water Consumption	Contracted No.	Water Consumption	Contracted No.	Water Consumption	Contracted No.	Water Consumption
Commerce	256	**9,098**	262	**12,529**	261	**12,087**	261	**14,122**	266	**10,985**	279	**13,754**
Industry	227	**2,593**	301	**4,230**	203	**2,394**	207	**3,892**	204	**3,836**	198	**3,466**
Home	2,959	**37,883**	3,071	**43,626**	3,195	**41,590**	3,377	**48,166**	3,446	**46,490**	3,781	**52,796**
School	21	**2,039**	22	**3,232**	24	**4,271**	26	**4,358**	27	**2,804**	30	**4,730**
Public Org.	46	**2,677**	48	**2,764**	49	**2,296**	48	**3,004**	52	**3,245**	54	**4,478**
Hospital	11	**4,047**	11	**6,436**	13	**7,897**	12	**7,287**	10	**9,223**	11	**7,065**
University	9	**1,372**	8	**2,761**	8	**4,076**	8	**4,618**	6	**4,621**	9	**5,176**
Local Gov.	8	**1,076**	8	**846**	8	**1,315**	8	**1,214**	8	**3,061**	8	**1,100**
Others	2,083	**28,671**	1,926	**29,744**	2,014	**30,727**	1,884	**42,297**	1,917	**31,576**	1,851	**30,785**
Total	5,620	**89,456**	5,657	**106,168**	5,775	**106,653**	5,831	**128,958**	5,936	**115,841**	6,221	**123,350**

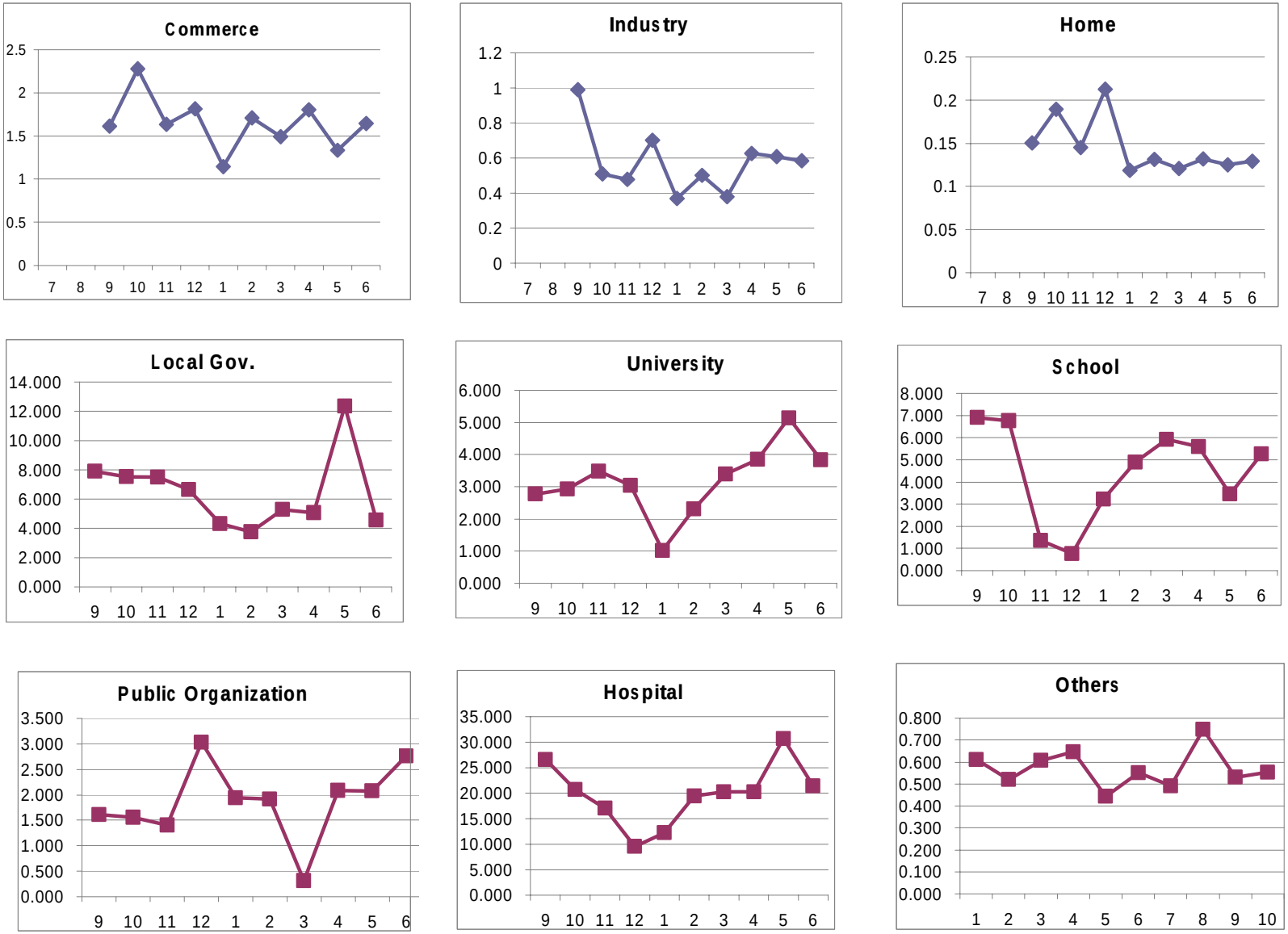


Fig. 4-1-2 Water Consumption per Units for each Consumer Categories

Appendix 4-1 Rupinganzi River Flow Record

Table 4-2-1-and 4-2-2 shows measured flow rate at Rupingazi River Observation station. Fig.4-2-1 shows a logarithm return probability sheet to estimate return period flow.

Table 4-2-1 Flow Rate of Rupinganzi River（1）

Month	Jan										Feb									
Date/Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1		1.423	3.660	1.813	3.379	2.247	1.423	1.332	1.332	2.714		1.423	1.244	1.077	2.079	1.332	0.998	0.885	0.127	0.176
2		1.423	5.219	1.713	3.379	2.024	1.516	1.159	1.332	2.543		1.423	2.247	1.159	2.024	1.332	0.998	0.848	0.099	0.159
3		1.423	4.736	1.612	3.243	1.917	1.470	1.159	1.332	2.362		1.244	1.332	1.159	2.024	1.246	0.998	0.848	0.099	0.159
4		1.470	4.253	1.516	3.806	1.813	1.423	1.159	1.332	2.362		1.244	1.332	1.077	1.998	1.159	0.921	1.077	0.099	0.159
5		1.516	1.244	1.711	4.494	1.917	1.334	1.159	1.332	2.362		1.423	1.244	2.362	1.971	1.423	0.998	0.998	0.099	0.159
6		2.024	1.244	1.516	4.253	1.865	1.244	1.159	2.156	2.362		1.516	1.244	2.543	1.917	1.516	0.848	1.711	0.099	0.159
7		1.813	1.244	1.516	3.816	1.813	1.332	1.159	1.516	2.362		1.513	1.202	2.724	1.917	1.332	0.849	0.848	0.099	0.159
8		1.516	1.516	1.516	3.379	1.813	1.244	1.332	1.516	2.305		1.424	1.159	3.379	2.024	1.244	0.849	0.848	0.099	0.159
9		1.917	1.516	1.470	3.176	1.917	1.244	1.244	1.380	2.247		1.332	1.423	3.379	1.917	1.244	0.813	0.848	0.099	0.159
10		2.247	1.470	1.423	2.978	1.711	1.159	1.159	1.244	2.247		1.332	1.159	3.362	1.917	1.202	0.777	0.848	0.074	0.159
11		2.548	1.423	1.470	2.978	1.711	1.244	1.246	1.159	2.190		1.332	1.159	3.804	2.083	1.159	0.777	0.848	0.074	0.159
12		2.849	1.423	1.423	3.520	1.711	1.202	1.332	1.159	2.024		2.132	1.077	2.978	2.248	1.332	0.777	0.848	0.074	0.159
13		2.480	1.332	1.423	3.243	1.711	1.159	1.244	1.159	2.024		1.612	1.077	2.155	2.134	1.332	0.777	0.848	0.074	0.159
14		1.917	1.332	1.423	3.382	1.711	1.159	1.077	1.159			1.244	1.077	1.332	2.363	1.244	0.709	0.848	0.074	
15		3.379	1.711	1.423	3.520	1.917	1.077	1.077	1.159			1.244	1.077	1.244	2.304	1.332	0.709	0.848	0.074	
16		2.362	1.917	1.378	4.177	1.711	1.077	0.998	1.132			1.244	1.077	2.362	2.861	1.244	0.709	0.848	0.074	
17		1.711	2.321	1.332	3.806	1.711	1.077	0.998	1.104			1.332	0.998	1.423	3.243	1.244	0.709	0.998	0.074	
18		1.638	2.724	1.244	3.109	1.612	1.159	0.998	1.077			1.244	0.998	1.423	2.862	1.244	0.709	0.812	0.074	
19		1.564	1.711	1.244	3.110	1.711	1.159	0.998	1.077			1.244	0.998	1.244	2.481	1.159	0.709	0.848	0.074	
20		1.516	1.423	1.244	3.660	1.614	1.159	0.998	1.077			1.244	0.998	1.161	2.978	1.159	0.709	0.848	0.074	
21		1.423	1.423	1.244	3.223	1.516	1.077	0.998	1.077			2.134	0.998	1.077	2.304	1.077	0.644	0.848	0.074	
22		2.024	1.332	1.244	2.786	1.516	1.077	0.921	1.077			2.134	0.998	1.077	2.421	0.998	0.644	0.813	0.113	
23		2.978	1.332	1.244	2.662	1.516	1.077	0.921	1.077			2.134	0.921	1.423	2.024	1.077	0.644	0.777	0.143	
24		2.134	1.424	1.244	2.724	1.516	1.077	0.921	1.077			2.024	0.921	1.378	1.917	1.077	0.644	0.777	0.195	
25		1.923	1.516	1.244	2.540	1.423	0.998	0.921	1.077			1.516	0.921	1.332	1.998	1.077	0.709	0.998	0.272	
26		1.711	1.516	1.159	2.480	1.423	0.998	0.921	0.998			1.332	0.921	1.244	2.079	1.077	0.709	0.960	0.193	
27		1.612	2.480	1.118	2.362	1.423	0.998	0.921	0.998			1.077	0.921	1.161	1.813	0.998	0.709	1.038	0.160	
28		1.516	1.516	1.077	2.333	1.423	0.998	0.921	1.159			1.104	0.921	1.077	1.612	0.998	0.777	0.998	0.127	
29		1.516	1.423	1.077	2.304	1.423	0.921	0.921	1.159					1.077				1.018		
30		1.516	1.332	1.077	2.247	1.332	0.921	0.921	1.118											
21		1.423	1.288	1.077	2.134	1.332	0.998	0.921	1.077											
Daily/Ave.		1.887	1.936	1.362	3.168	1.677	1.161	1.071	1.214	2.316		1.471	1.130	1.800	2.197	1.209	0.779	0.917	0.108	0.160
Month	Mar										Apr									
Date/Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1		1.132	0.921	1.332	1.612	0.921	0.709	1.038	0.099	0.193	1.762	2.600	1.077	0.887	1.181	2.134	0.875	0.644	0.099	0.272
2		1.159	0.921	1.423	1.612	0.998	0.743	1.378	0.099	0.193	1.711	2.362	0.921	0.898	1.118	1.917	0.921	0.644	0.099	0.283
3		1.159	0.848	3.804	1.516	0.998	0.777	0.778	0.099	0.212	2.368	2.600	0.998	0.910	1.159	2.600	0.921	0.644	0.129	0.294
4		1.077	0.848	1.516	1.516	0.998	0.676	0.676	0.074	0.231	2.039	5.052	0.960	0.921	1.118	2.247	0.676	0.613	0.159	0.413
5		0.998	0.848	1.338	1.516	0.998	0.709	0.848	0.074	0.263	1.711	4.216	0.921	0.921	1.159	1.516	0.582	0.582	0.143	0.415
6		0.998	0.848	1.159	1.423	0.921	0.777	1.813	0.074	0.294	1.678	3.379	0.848	0.921	1.159	1.516	0.646	0.582	0.252	0.861
7		0.998	0.848	1.077	1.470	0.921	1.711	1.445	0.074	0.272	1.645	8.033	0.848	1.077	1.077	1.424	0.709	0.790	0.193	0.467
8		1.257	0.848	0.998	1.516	0.921	0.921	1.077	0.129	0.272	1.612	3.804	1.159	1.077	1.038	1.332	0.848	0.848	0.233	0.467
9		1.516	0.777	1.077	2.307	0.921	0.921	0.921	0.099	0.252	1.564	4.724	1.592	0.963	0.998	2.247	0.998	1.770	0.272	0.467
10		1.917	0.848	1.077	1.612	0.960	0.921	0.848	0.099	0.193	1.612	5.052	2.024	0.848	1.038	2.024	1.516	1.612	0.311	0.467
11		1.244	0.921	1.244	1.518	0.998	0.848	0.743	0.074	0.193	1.516	3.379	2.024	3.025	0.998	1.612	2.134	2.201	0.349	0.363
12		1.711	0.921	1.121	1.424	0.921	0.777	0.676	0.074	0.291	1.423	3.052	2.024	2.198	0.998	1.765	0.998	2.789	0.388	0.363
13		1.244	0.921	0.998	1.470	0.848	0.709	0.644	0.074	0.388	1.519	2.724	2.024	4.330	1.612	1.917	0.923	1.814	0.365	0.413
14		1.159	0.849	1.077	1.470	0.848	0.709	0.677	0.074		1.614	2.480	1.917	4.253	1.711	1.989	0.848	2.481	0.495	
15		1.159	0.777	2.600	1.470	0.777	1.813	0.709	0.074		1.516	2.362	1.423	1.244	1.871	2.062	2.707	3.109	0.440	
16		1.159	0.848	2.247	1.332	0.777	1.331	0.644	0.074		1.470	2.247	3.804	1.517	2.030	2.134	4.565	2.513	0.413	
17		1.516	0.848	1.244	1.332	0.813	0.848	0.644	0.074		1.423	2.134	3.109	1.789	2.361	3.379	5.219	1.917	0.322	
18		1.244	0.848	1.077	1.288	0.848	0.848	0.709	0.074		1.765	2.024	2.736	1.332	19.924	2.978	6.650	1.611	0.231	
19		1.077	0.848	1.038	1.244	0.848	0.777	0.709	0.074		1.423	2.024	2.362	2.842	9.096	3.109	5.561	1.304	0.231	
20		0.998	0.777	0.998	1.288	0.921	0.777	0.644	0.087		1.687	2.024	3.804	2.648	5.848	2.849	5.063	0.998	0.193	
21		1.244	0.777	0.998	1.244	0.848	0.709	0.613	0.099		1.951	5.561	2.978	1.291	2.600	2.665	4.565	0.884	0.193	
22		1.244	0.777	0.998	1.202	0.848	0.644	0.582	0.074		1.516	5.737	2.247	1.077	2.662	2.480	4.887	0.812	0.159	
23		1.244	0.848	0.921	1.244	0.848	0.613	0.582	0.074		1.423	8.663	2.024	1.038	2.724	2.026	5.561	1.038	0.159	
24		1.077	0.998	0.921	1.244	0.963	0.582	0.644	0.074		1.332	13.954	3.243	0.998	2.786	2.772	5.914	2.849	0.186	
25		2.024	0.998	0.921	1.266	1.077	0.582	0.644	0.074		1.244	12.144	3.524	0.960	4.566	3.518	4.407	2.466	0.212	
26		2.247	0.998	0.921	1.288	0.921	0.644	0.812	0.074		1.244	8.941	3.804	0.921	4.644	2.247	3.243	2.082	0.715	
27		3.486	0.998	0.921	1.288	0.998	0.644	0.777	0.074		1.244	5.737	3.951	0.921	2.662	2.134	2.477	2.136	0.231	
28		4.724	0.923	0.921	1.244	1.711	0.690	0.743	0.099		1.244	5.389	4.101	0.998	2.362	2.289	1.711	1.762	0.365	
29		4.230	0.848	0.848	1.202	2.134	0.736	0.709	0.099		1.244	8.663	2.724	0.998	2.554	2.445	1.516	1.470	0.340	
30		3.737	0.921	0.848	1.202	1.917	0.783	0.676	0.099		1.244	7.425	4.101	1.236	2.745	2.600	1.423	1.332	0.413	
21		3.243	1.159	0.868	1.244	2.026	0.829	0.644	0.127											
Daily/Ave.		1.717	0.883	1.243	1.407	1.047	0.831	0.808	0.085	0.250	1.558	4.950	2.309	1.501	2.927	2.264	2.635	1.543	0.276	0.427
Month	May										June									
Date/Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	1.380	7.425	5.318	1.473	2.496	2.725	1.378	1.221	0.323	1.009	2.134	4.889	4.605	4.649	5.226	3.352	3.472	3.052	0.553	1.673
2	1.516	7.425	6.535	1.711	2.247	2.849	1.332	1.109	0.233	1.159	2.134	4.724	4.486	4.409	4.977	3.727	3.425	2.725	0.523	1.636
3	3.660	8.939	7.752	3.465	1.865	2.024	1.244	0.998	0.560	1.332	2.134	4.724	4.253	4.565	4.772	4.101	3.379	2.480	0.523	1.562
4	5.155	10.452	5.478	2.826	1.813	1.711	1.244	1.210	0.709	1.244	2.134	5.052	4.253	5.111	4.566	3.660	3.109	2.304	0.523	1.562
5	6.650	9.763	4.026	2.501	2.600	1.614	1.244	1.825	0.777	1.244	2.134	4.565	4.253	5.657	4.486	2.978	2.849	2.362	0.495	1.562
6	3.243	11.162	6.609	5.914	4.368	1.516	1.711	1.118	0.777	1.244	2.024	4.565	4.177	4.409	4.330	1.612	2.849	2.248	0.467	1.562
7	3.109	9.538	9.986	5.739	6.171	1.332	1.917	1.118	0.777	1.266	2.134	4.409	4.101	4.177	4.253	1.516	2.724	2.134	0.467	1.562
8	3.109	9.316	9.538	5.563	5.475	1.291	1.516	1.332	0.760	1.288	2.026	4.253	4.409	3.804	4.101	1.516	2.662	2.024	0.467	1.562
9	5.914	9.096	7.379	4.147	4.486	1.378	1.159	2.123	0.743	1.118	1.917	4.253	3.878	3.660	3.951	1.516	2.600	4.179	0.467	1.490
10	3.518	9.317	5.220	4.736	3.381	1.288	1.159	2.914	0.709	1.423	1.917	4.101	3.804	3.660	3.878	1.516	2.600	2.363	0.467	1.418
11	3.314	9.538	4.330	3.956	7.026	1.516	1.159	4.693	0.709	1.567	1.917	4.101	3.880	4.077	3.804	1.612	2.480	2.024	0.413	1.454
12	3.109	9.096	4.486	3.806	3.379	1.565	1.159	2.602	0.709	3.225	1.917	4.101	3.660	4.494	3.804	1.612	2.600	2.024	0.413	1.490
13	4.101	8.451	6.670	5.389	4.139	1.614	2.978	3.307	0.582	3.225	1.917	3.951	4.387	4.102	3.660	1.516	2.480	1.868	0.413	1.418
14	3.951	9.096	5.742	3.818	4.898	1.378	2.600	5.151	0.582		1.813	3.951	5.114	3.589	3.660	1.423	2.480	1.711	0.413	
15	4.253	8.663	5.914	2.247	3.660	1.711	3.660	2.849	0.613		1.813	3.951	4.117	3.518	3.660	1.423	2.364	1.711	0.413	
16	5.737	7.625	6.285	2.247	3.451	1.662	10.686	6.380	0.644		1.813	3.951	3.878	3.311	3.951	1.470	2.247	1.711	0.413	
17	3.804	7.138	6.655	2.304	3.449	1.516	6.840	9.910	0.709		1.711	4.887	3.518	3.379	3.806	1.516	2.480	1.711	0.413	
18	3.732	6.650	7.239	3.311	4.034	1.516	5.396	4.409	0.709		1.711	4.565	3.379	3.244	3.660	1.711	2.362	1.662	0.413	
19	3.660	6.650	7.931	3.043	2.978	1.516	3.951	3.385	0.778		1.711	4.101	3.379	3.109	3.804	1.612	2.480	1.917	0.388	
20	3.109	6.650	7.938	2.480	4.200	1.516	3.660	2.786	1.297		1.711	3.951	6.646	3.043	3.660	1.516	2.247	2.514	0.363	
21	2.724	7.228	8.456	2.666	5.421	1.423	5.219	4.273	0.848		1.711	3.804	9.913	2.978	3.379	1.423	2.600	3.110	0.363	
22	2.724	7.228	7.625	2.851	11.676	2.480	15.041	5.219	0.813		1.711	3.732	4.644	2.914	3.589	1.423	2.922	2.916	0.363	
23	2.600	7.228	6.860	2.480	11.404	2.079	4.887	5.891	0.777		1.711	3.660	3.951	2.914	3.660	1.470	3.243	2.024	0.363	
24	2.480	6.483	6.094	3.391	11.283	1.917	3.804	6.563	0.777		1.711	3.660	3.804	2.849	3.556	1.516	3.243	1.971	0.363	
25	2.540	5.737	5.825	4.724	4.726	1.813	3.558	3.878	0.709		1.711	3.660	3.518	3.080	3.451	1.612	3.379	2.193	0.363	
26	2.600	5.737	5.561	9.582	7.425	2.311	3.311	4.112	0.709		1.711	3.518	3.518	3.311	10.423	1.516	3.660	1.813	0.340	
27	2.362	6.094	5.825	4.565	10.648	2.808	3.109	3.244	0.644		1.917	3.660	3.554	3.661	9.367	1.516	3.951	1.713	0.316	
28	2.247	5.737	5.563	4.687	13.871	3.660	3.109	3.660	0.644		1.813	3.518	3.589	2.978	4.101	1.612	4.565	1.612	0.316	
29	2.247	5.737	5.389	4.808	7.138	3.243	2.978	3.660	0.613		1.813	3.381	3.379	2.786	3.660	1.711	3.772	1.612	0.316	
30	2.134	5.219	5.057	5.435	6.004	3.043	3.243	3.520	0.582		1.813	3.243	3.243	2.914	3.660	2.156	2.978	1.612	0.316	
21	2.134	5.054	4.724	4.888	5.475	2.978	3.518	3.379	0.582											
Daily/Ave.	3.317	7.725	6.387	3.895	5.522	1.968	3.476	3.479	0.690	1.565	1.878	4.096	4.243	3.678	4.362	1.895	2.940	2.177	0.414	1.535

Table 4-2-2 Flow Rate of Rupinganzi River（2）

Month	July										Aug									
Date/Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	1.612	3.243	3.451	3.109	3.452	2.600	2.978	1.612	0.316	1.146	2.024	3.243	3.243	2.024	2.724	3.518	3.109	1.564	0.272	1.017
2	1.612	3.243	3.589	2.917	3.243	2.362	2.724	1.612	0.316	1.146	1.917	3.155	3.243	2.024	2.600	3.518	3.518	1.516	0.231	1.017
3	1.711	3.109	3.243	2.724	3.660	2.362	2.600	1.612	0.294	1.146	1.882	3.066	3.243	2.024	2.362	3.243	3.314	1.516	0.231	1.017
4	1.711	3.379	3.243	2.724	3.518	2.849	2.600	1.612	0.272	1.280	1.848	2.978	3.243	1.917	3.243	3.311	3.109	1.516	0.231	0.893
5	1.612	3.449	3.243	2.724	3.518	2.724	2.849	1.612	0.294	1.213	1.813	2.724	3.243	1.917	2.922	3.379	2.849	1.516	0.231	1.017
6	1.612	3.518	3.661	2.600	3.379	3.243	2.849	1.564	0.272	1.146	1.813	2.600	3.109	1.917	2.600	3.243	2.724	1.423	0.231	1.017
7	1.612	3.243	3.449	2.914	3.379	5.536	2.849	1.516	0.272	1.146	2.849	2.362	3.243	1.917	2.724	3.243	2.849	1.423	0.212	1.017
8	1.612	3.109	3.243	2.978	3.179	7.828	2.787	1.516	0.272	1.146	4.253	2.362	3.176	1.917	2.724	3.243	2.849	1.378	0.193	1.017
9	1.612	3.109	3.311	2.851	2.978	8.241	2.724	1.516	0.272	1.082	2.724	2.140	3.109	1.917	2.600	3.379	2.724	1.332	0.231	1.017
10	1.813	2.978	3.109	2.724	2.724	7.425	2.600	1.516	0.272	1.017	2.917	1.917	3.311	1.813	2.978	3.379	2.662	1.332	0.231	0.955
11	1.813	2.978	3.109	2.724	2.724	6.193	3.524	1.771	0.272	1.017	3.109	2.600	3.243	1.813	4.101	3.379	2.600	1.332	0.212	1.017
12	1.612	2.978	3.109	2.851	2.724	6.094	2.849	2.026	0.272	1.017	2.724	2.724	3.176	1.813	3.740	3.379	2.600	1.288	0.272	1.017
13	1.588	2.978	3.109	2.480	2.724	6.650	2.787	2.481	0.272	1.017	2.724	2.662	3.243	1.813	3.379	3.243	3.109	1.159	0.231	1.017
14	1.564	2.978	3.109	2.540	2.600	5.935	2.724	2.024	0.272		2.600	2.600	3.109	1.813	3.243	3.243	2.724	1.159	0.231	
15	1.612	2.849	3.043	2.362	2.540	5.219	2.849	2.024	0.272		2.849	2.600	3.109	1.711	3.379	2.978	2.600	1.386	0.231	
16	1.612	2.849	3.311	2.451	2.480	4.887	3.379	1.971	0.272		3.243	2.789	3.109	1.711	3.379	2.978	2.600	1.612	0.252	
17	1.516	2.724	3.243	2.540	2.600	4.887	3.951	1.813	0.272		3.243	2.978	3.176	1.813	3.379	3.379	2.600	1.516	0.616	
18	1.516	2.724	3.312	2.421	2.480	5.052	3.109	1.762	0.272		3.243	3.109	3.109	2.480	3.379	3.244	2.600	1.378	0.294	
19	1.825	2.724	3.381	2.540	2.362	5.052	2.978	1.711	0.272		3.243	3.379	2.976	1.917	3.311	3.109	2.849	1.332	0.231	
20	2.134	2.724	3.176	2.724	2.362	4.565	2.851	1.612	0.316		3.243	2.978	2.976	1.865	3.243	3.109	2.600	1.332	0.231	
21	2.134	2.724	3.372	2.480	2.362	4.645	2.724	1.612	0.272		3.109	2.849	3.109	1.813	3.243	2.978	2.724	1.332	0.212	
22	1.917	2.600	3.379	2.247	2.543	4.724	2.600	1.612	0.272		3.109	2.724	3.044	1.917	3.109	3.243	2.600	1.332	0.193	
23	1.917	2.600	3.311	2.247	2.724	5.052	2.849	1.612	0.272		3.109	2.218	2.978	1.813	2.978	2.978	2.600	1.332	0.193	
24	1.917	2.480	3.243	2.247	2.480	4.407	3.109	1.516	0.272		3.176	1.711	3.109	1.813	3.043	3.243	2.570	1.332	0.193	
25	1.917	2.480	3.277	2.247	2.480	4.101	3.660	1.470	0.272		3.243	4.887	3.109	1.711	3.243	3.176	2.540	1.614	0.193	
26	2.024	2.540	3.311	2.134	2.362	3.804	3.518	1.423	0.231		2.978	4.565	2.914	1.711	3.111	3.109	2.480	1.470	0.193	
27	2.079	2.600	3.381	2.134	2.362	3.804	3.314	1.516	0.231		2.978	1.711	2.979	1.711	2.978	3.243	2.480	1.564	0.193	
28	2.134	2.600	3.243	2.024	2.362	3.732	3.109	1.612	0.231		2.978	1.813	3.804	1.711	2.978	2.849	2.480	1.516	0.193	
29	2.362	2.724	3.243	2.024	3.011	3.660	2.978	1.564	0.231		2.978	1.813	3.457	1.516	2.978	2.849	2.600	1.424	0.193	
30	2.134	3.109	3.176	2.024	3.660	3.660	2.600	1.612	0.231		3.379	2.596	3.109	0.998	3.109	2.724	2.600	1.332	0.193	
21	2.024	3.804	3.243	2.024	3.109	3.660	2.724	1.612	0.252		3.179	3.379	2.978	1.917	3.379	2.683	4.169	1.424	0.193	
Daily/Ave.	1.802	2.940	3.278	2.507	2.841	4.676	2.960	1.679	0.270	0.468	2.854	2.749	3.161	1.831	3.102	3.180	2.788	1.409	0.233	1.003
Month	Sep										Oct									
Date/Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	2.978	3.379	2.849	1.612	3.243	2.641	5.737	1.919	0.193	1.017	2.134	2.600	3.804	2.662	3.660	2.247	3.660	1.159	0.159	
2	2.978	3.243	2.724	1.516	3.046	2.600	2.480	1.711	0.193	1.017	2.079	2.724	3.109	2.600	3.518	2.247	2.247	1.159	0.143	
3	2.849	3.379	2.849	1.470	2.849	2.362	3.109	1.711	0.193	1.017	1.917	2.724	2.678	2.421	2.849	2.134	1.917	1.826	0.127	
4	2.849	3.379	2.724	1.423	2.978	2.480	2.849	1.516	0.193	1.017	1.917	2.486	2.247	2.247	2.724	2.134	1.917	2.492	0.127	
5	2.849	3.379	2.724	1.423	2.849	2.600	3.243	1.470	0.193	0.986	2.082	2.247	3.804	2.134	2.724	1.917	2.448	3.379	0.127	
6	2.978	3.379	2.724	2.481	2.724	2.600	2.600	1.423	0.193	0.955	2.247	2.247	2.724	2.602	2.724	1.917	2.978	3.311	0.127	
7	2.882	3.379	2.724	4.333	2.724	3.243	2.540	1.288	0.193	0.955	2.247	2.362	2.600	3.660	2.543	1.917	2.024	2.665	0.272	
8	2.786	3.379	2.600	2.079	2.724	3.452	2.480	1.244	0.193	1.349	2.136	2.362	4.407	3.041	2.362	2.024	2.172	2.193	0.193	
9	2.851	3.379	2.480	1.813	2.724	3.660	2.362	1.244	0.193	1.017	2.729	2.247	2.724	2.421	2.362	2.024	2.320	1.711	0.233	
10	2.786	3.379	2.480	1.713	2.724	3.518	2.480	1.159	0.193	0.955	2.922	2.480	2.543	2.134	2.362	1.917	2.602	1.567	0.272	
11	3.661	3.379	2.724	1.612	2.480	3.660	2.724	1.159	0.193	0.893	3.379	2.930	2.362	2.024	2.362	1.813	2.480	1.423	0.193	
12	2.786	3.379	2.602	1.516	2.480	3.660	2.849	1.118	0.193	0.893	2.729	3.379	2.247	2.024	2.362	1.813	2.441	1.378	0.193	
13	2.724	3.379	2.480	11.037	2.421	3.379	2.600	1.077	0.176	0.893	2.079	3.243	2.600	1.917	13.688	1.779	2.401	1.288	0.193	
14	2.724	3.379	2.978	2.481	2.480	3.109	2.481	1.077	0.159		1.971	2.978	2.480	5.052	11.839	1.745	2.362	1.159	0.193	
15	2.724	3.109	2.480	2.307	2.362	2.979	2.362	1.077	0.159		2.423	3.243	2.134	10.680	9.990	1.711	2.480	1.332	0.231	
16	2.724	3.518	2.480	2.480	2.392	2.849	2.480	1.077	0.159		4.052	11.404	2.024	16.307	9.538	1.711	2.600	1.332	0.231	
17	2.662	3.660	2.362	2.451	2.421	2.600	2.480	1.077	0.159		2.363	3.804	2.252	16.090	2.978	1.612	2.480	2.034	0.231	
18	2.600	2.978	2.362	2.421	2.600	2.600	3.660	1.077	0.216		2.134	3.457	2.480	18.996	12.649	1.713	1.516	2.735	0.286	
19	2.480	2.978	2.362	2.362	2.362	2.662	2.600	1.038	0.272		2.191	3.109	2.480	16.464	10.220	1.813	2.532	1.612	0.340	
20	2.362	2.978	2.362	3.109	2.362	2.978	2.362	0.998	0.244		2.247	3.917	2.480	15.076	9.491	2.075	3.549	1.564	0.352	
21	2.362	2.978	2.247	3.530	2.247	3.109	2.248	1.077	0.216		2.304	4.724	2.480	13.688	8.762	2.338	4.565	1.516	0.363	
22	2.362	2.724	2.247	2.362	2.849	2.795	2.134	1.159	0.187		2.190	3.379	2.600	11.731	8.033	2.600	3.176	1.332	0.316	
23	2.247	2.724	2.362	3.243	3.475	2.480	2.024	1.159	0.159		2.429	3.109	2.247	9.774	7.625	2.480	4.565	1.332	0.328	
24	2.247	2.978	2.247	3.530	4.101	2.480	2.024	5.748	0.159		2.190	2.978	3.099	6.752	7.425	4.407	3.518	1.625	0.340	
25	2.540	2.724	2.362	3.816	3.660	2.362	2.024	2.134	0.159		2.247	4.015	3.951	6.278	2.480	2.978	3.379	1.917	0.343	
26	2.362	2.724	2.362	3.110	3.660	2.247	1.917	1.837	0.159		2.136	5.052	2.362	7.427	2.247	2.978	3.379	2.622	0.231	
27	2.362	2.851	2.362	2.724	3.518	2.247	2.247	1.541	0.159		2.024	4.565	3.109	7.430	2.134	2.914	3.379	1.564	0.193	
28	2.305	2.978	2.247	3.740	3.804	2.362	2.425	1.244	0.159		2.247	3.243	3.109	6.840	2.097	2.849	3.109	1.424	0.193	
29	2.247	2.978	3.660	3.816	3.660	2.362	2.602	1.159	0.159		1.917	3.109	3.379	7.875	2.061	2.600	4.969	1.202	0.193	
30	2.247	2.600	3.951	2.724	3.660	2.362	3.660	1.159	0.159		2.540	2.978	3.379	8.909	2.024	1.917	4.724	1.077	0.279	
21											2.304	2.849	2.961	13.871	2.312	1.711	3.662	1.077	0.365	
Daily/Ave.	2.650	3.155	2.604	2.808	2.919	2.815	2.659	1.456	0.185	0.997	2.339	3.418	2.802	7.456	5.166	2.195	2.953	1.742	0.238	
Month	Nov										Dec									
Date/Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	2.024	3.327	2.543	11.415	2.600	2.024	2.600	1.077	0.743		2.247	2.849	2.247	6.936	3.243	2.024	1.711	2.606	0.644	
2	1.998	3.804	2.480	9.316	2.480	2.600	2.452	1.038	0.921		2.190	2.724	2.024	6.650	2.922	2.024	1.917	2.606	0.644	
3	1.971	3.660	3.255	8.771	2.247	2.849	2.304	1.159	0.778		2.134	3.379	1.917	6.510	2.600	1.917	2.247	2.190	0.582	
4	2.026	3.243	2.914	11.648	2.247	2.849	3.379	1.567	0.467		2.134	2.724	1.917	6.369	2.724	1.917	2.134	2.134	0.567	
5	1.917	3.660	2.786	12.690	2.247	2.849	2.600	2.953	0.523		2.079	2.849	1.972	6.094	2.600	2.600	1.917	1.974	0.552	
6	2.480	3.804	2.724	13.731	4.724	2.247	1.917	6.094	0.616		2.024	2.548	2.026	5.914	2.600	2.724	2.600	1.813	0.495	
7	2.786	4.253	2.632	9.990	4.253	2.134	1.917	6.965	0.709		2.024	2.247	2.134	5.825	2.480	3.109	2.452	1.711	0.495	
8	3.804	3.748	2.540	9.933	5.052	3.109	1.917	7.835	0.743		2.024	2.247	2.134	5.737	2.487	2.855	2.304	1.711	0.467	
9	3.264	3.243	3.740	9.876	3.660	3.660	1.865	2.794	0.523		1.971	2.247	2.140	5.737	2.480	2.600	1.917	1.612	0.495	
10	2.724	2.978	2.662	10.576	3.379	3.806	1.813	2.423	0.582		1.917	2.134	2.134	5.521	2.480	1.813	1.917	1.612	0.467	
11	2.662	2.600	2.851	9.316	3.972	3.951	2.600	2.248	0.613		1.917	2.024	2.024	5.304	2.480	1.813	1.711	1.917	0.467	
12	2.247	2.978	2.600	9.654	4.565	4.887	2.978	2.079	0.644		1.865	2.024	2.098	5.178	2.480	1.713	1.814	2.249	0.467	
13	2.247	2.600	2.362	9.991	3.518	3.379	3.707	1.711	0.677		1.813	2.024	2.173	5.052	2.480	1.612	1.917	2.582	0.467	
14	2.978	3.243	2.421	14.408	3.379	3.109	2.600	1.567	0.709		1.813	2.024	2.247	4.887	2.480	1.711	2.082	2.914	0.413	
15	2.362	2.984	2.480	11.772	3.379	3.109	2.024	1.423	1.121		1.813	2.362	2.190	4.724	2.362	1.662	2.247	2.786	0.413	
16	2.609	2.724	2.362	10.105	3.518	2.849	2.640	1.332	0.709		1.813	2.134	1.971	4.565	2.362	1.612	2.024	2.662	0.413	
17	2.855	3.243	2.247	9.876	5.914	3.400	3.255	1.378	0.743		1.711	1.917	2.556	4.809	2.362	2.724	2.134	1.711	0.413	
18	2.247	3.804	2.247	11.404	5.161	3.951	2.851	1.423	0.777		1.762	2.024	1.917	5.053	2.362	2.480	1.711	1.711	0.388	
19	2.481	2.724	2.134	11.166	4.407	3.243	2.247	1.516	0.709		1.711	2.024	2.384	4.888	2.480	1.813	1.612	1.614	0.363	
20	2.485	2.600	2.116	10.928	4.101	2.978	2.247	1.516	0.646		1.662	1.919	2.851	5.138	2.362	1.813	1.711	1.516	0.363	
21	3.311	2.600	2.097	10.924	3.660	2.724	2.134	1.639	0.582		1.613	1.813	2.855	4.486	2.362	1.711	1.614	1.564	0.363	
22	3.379	2.922	2.079	9.539	3.660	2.480	1.917	1.762	0.644		1.564	1.813	2.725	4.177	2.441	1.662	1.516	1.711	0.363	
23	5.212	3.243	2.248	9.650	3.518	2.362	2.291	2.481	0.709		1.516	1.813	3.051	3.951	2.521	1.612	1.516	1.612	0.363	
24	7.044	3.109	2.421	8.771	3.518	2.362	2.665	1.971	0.887		1.516	1.711	3.051	3.896	2.600	1.516	1.423	1.564	0.363	
25	3.806	3.518	2.855	8.451	3.314	2.362	2.079	2.134	0.777		1.516	1.711	2.768	3.842	2.560	1.516	1.423	1.506	0.351	
26	2.978	3.518	2.304	8.504	3.109	2.362	1.917	2.481	0.709		1.516	1.711	2.484	3.787	2.520	1.516	1.423	1.448	0.340	
27	2.662	2.600	2.247	8.557	3.109	2.247	2.024	3.109	0.709		1.516	1.711	2.201	3.732	2.480	1.516	1.423	1.390	0.328	
28	2.600	3.243	2.305	7.931	3.109	2.134	1.423	3.473	0.709		1.493	1.711	1.917	3.589	2.134	1.516	1.378	1.332	0.316	
29	2.247	3.281	2.363	7.525	3.518	2.247	1.813	3.837	0.709		1.470	1.711	1.971	3.379	2.134	1.470	1.332	1.332	0.316	
30	2.247	3.319	2.602	7.034	3.243	2.024	1.762	3.255	0.709		1.423	1.612	2.079	3.379	2.248	1.423	1.516	1.332	0.316	
21											1.516	2.247	1.917	3.379	2.362	1.423	1.516	1.332	0.316	
Daily/Ave.	2.855	3.219	2.521	10.115	3.619	2.876	2.331	2.541	0.703		1.783	2.129	2.260	4.919	2.490	1.917	1.812	1.863	0.429	

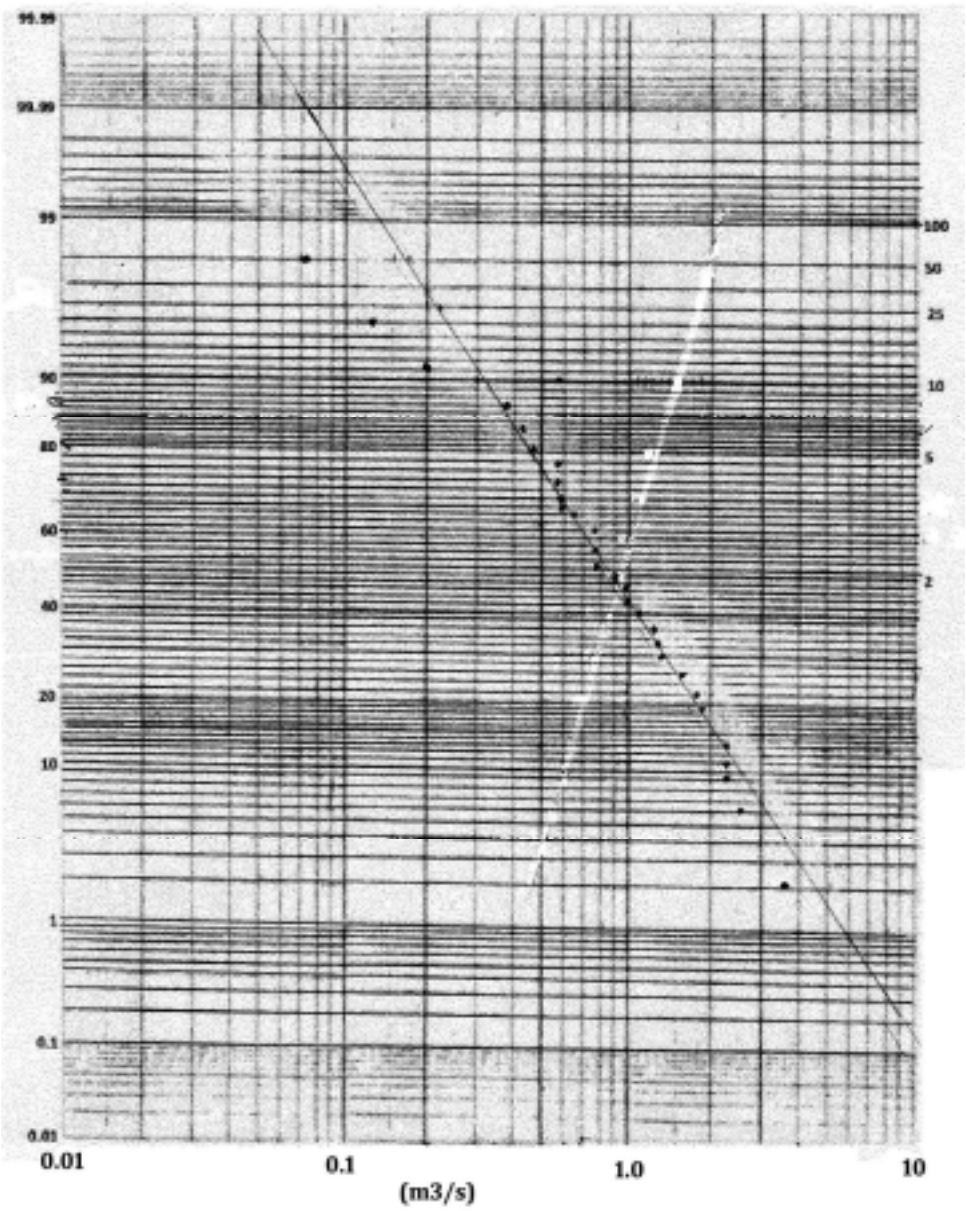


Fig. 4-2-1 Rupinganzi River Return Period

Return Period Flow Rare of Rupiganzi River

Return Period (year)	Flow Rate (m^3/sec)
5	0.43
10	0.31
25	0.21
50	0.15

Appendix 4-3 Capacity Calculation of Mukangu WTP

Mukangu WTP Capacity Calculation

Items	m3/d	m3/h	m3/m	m3/s
Productio	11,000	458.3	7.64	0.127
Intake	12,000	500.0	8.33	0.139

Note : Filter Washing Water5%+Drainage from Sed. T 2%＝7%

1.Recieving T				
	Retention Time(RT)		1.5	min <
	Number		2	tanks
	Necessary Volume		6.25	m3/tank
	Water Depth		3	m
	Size	W1.5×L3.2×H2.5m		
	Actual Volume		12	m3/tank
	Actual RT		2.88	min
2. Mixing T Rapid Mixing	Number		2	tank
	Mixing Time		1-5	min
		Drop From weir		50cm
		Weir Width		60cm
		Over flow depth		10cm
	Necessary Volume		4.2-20.8	m3/tank
	Size	W1.5×L2.0×H2.0m		
	Actual Volume		6.00	m3/tank
	Actual RT		1.44	min
Flocculation	Number		2	tanks
	RT	20～40(30)		min Aprox.30min
	Necessary Volume		125.0	m3/tank
	Water Depth		2.5	m
	1st Stage Width		1.5	m
	2nd Stage Width		2.0	m
	1-S Length		6.8	m
	2-S Length		7.1	m
	Actual Volume		122.0	m^3/tank
	Actual RT		29.3	min
3. Sedimantation Tank	Number		2	tanks
Parallel Flow	Flow Rate per T tank		4.17	m3/min
	Effective Depth		3～4	m
	Depth of Settled Sludge		30	Over cm
	Surface Load		15～30	mm/min
	Kenyan Manual 1.0m3/m2/h=17mm/min			
	Necessary Surface		245.1	m^2 Fron Manual
	Size	W8.0×L31×H3.5m		
	Flow Velocity of Tank		0.174	m/min (<0.4m/min)
	Actual Surface Load		16.8	mm/min
	Weir Length		24.8	m/tanks
	Weir Load of Overvflow		242	m3/m/d (<500m3/m/d)
	Surface Area		248	m2
	Effective Water Depth		3.5	m
	Volume		868	m3
	RT		3.472	hr
4.Rapid Filter	Filteration Velocity		120	m/d
By Gravity	Necessary Filter Area		100	m2
	Numberr		4	tanks
	Filter Area		25	m2/tank
	Size	W2.5m×L5.0m×2		
	Filteration Speed		120	m/d Using Whole Tanl
			160	m/d One Tank Washing
	Washing Water Volume			
	Back wash speed		42	m3/m2/h
			0.7	m3/m2/min
	From Manual (In the case of Sand Effective Dia.)			
	Washing Duration		6	min (4-6min)

	Gravel Layer				
	2-2.8mm		15	cm	
	5.6-8.0mm		10	cm	
	16-23mm		10	cm	
	38-54mm		25	cm	by Manual
	Sand Layer				
	Effective Diameter		0.7	mm	
	Equalization Ccoefficient		1.5	less	
	Thickness of the Layer		0.7	m	
	Water Collection Basin	By Porous Pipes			
Washing Water	For Washing of Mukangu1 & Mukangu2		157.5	m3	
Tank(Elevated	Number		1	tank	
	Size	W7.5×L7.5×H3m			
	Actual Volume		168.8	m3	
Washed Water	For Mukangu2 Back Wash		105	m3	
Drainage Tank	Number		1	tank	
	Size	W7.0×L7.0×H2.5m			
	Actual Volume		122.5	m3	
5.Clear Waqter Reservoir	Number		2	tanks	
& Pump Pit	Necessary Volume		3,158	m3/tank	3,000＋157.5m3
	Effective Depth		4	m	
	Size	Dia.32m×WH4m			
	Actual Volume		3,217	m3/tank	
	Actual RT		3.7	hr	Q=21,000m3/d

6.Sludge lagoon

Tubidity av.=10, Injection rate of $Al_2(SO_4)_3$=20mg/L

Daily Generated sludge as dried solid

=23000*(10+20*0.15*1.42)*10^(-3) 328 kg/d

Condition	By Turbidity		
	Turbidity:soild=1:1	10	mg/L
	By $Al_2(SO_4)_3$		
	Contents ratio of Al_2O_3	15	w t %
	Al_2O_3 is converted to be 1.42times of solid		
	Injection Ratio of $Al_2(S$	20	mg/L

Settled sludge of the sedimentation tank and Washed drainage water are throw in the sludge lagoons. The supernatant of sludge lagoon is discharged daily then the sludge load of each lagoon become 35kgDS(dried solid: 0.7m of sludg with 5% of density). The sludge can be dried within 3 months to be 60% of wa contens, and it can be disposed as soil.

Necessary area of the lagoon is calculated as below:

Necessary Area		
328*(1+3)*30/35=	1125	m2
Size and Number	W12m×L21.5m×2+W12m×L31.5m×2=1272m2	