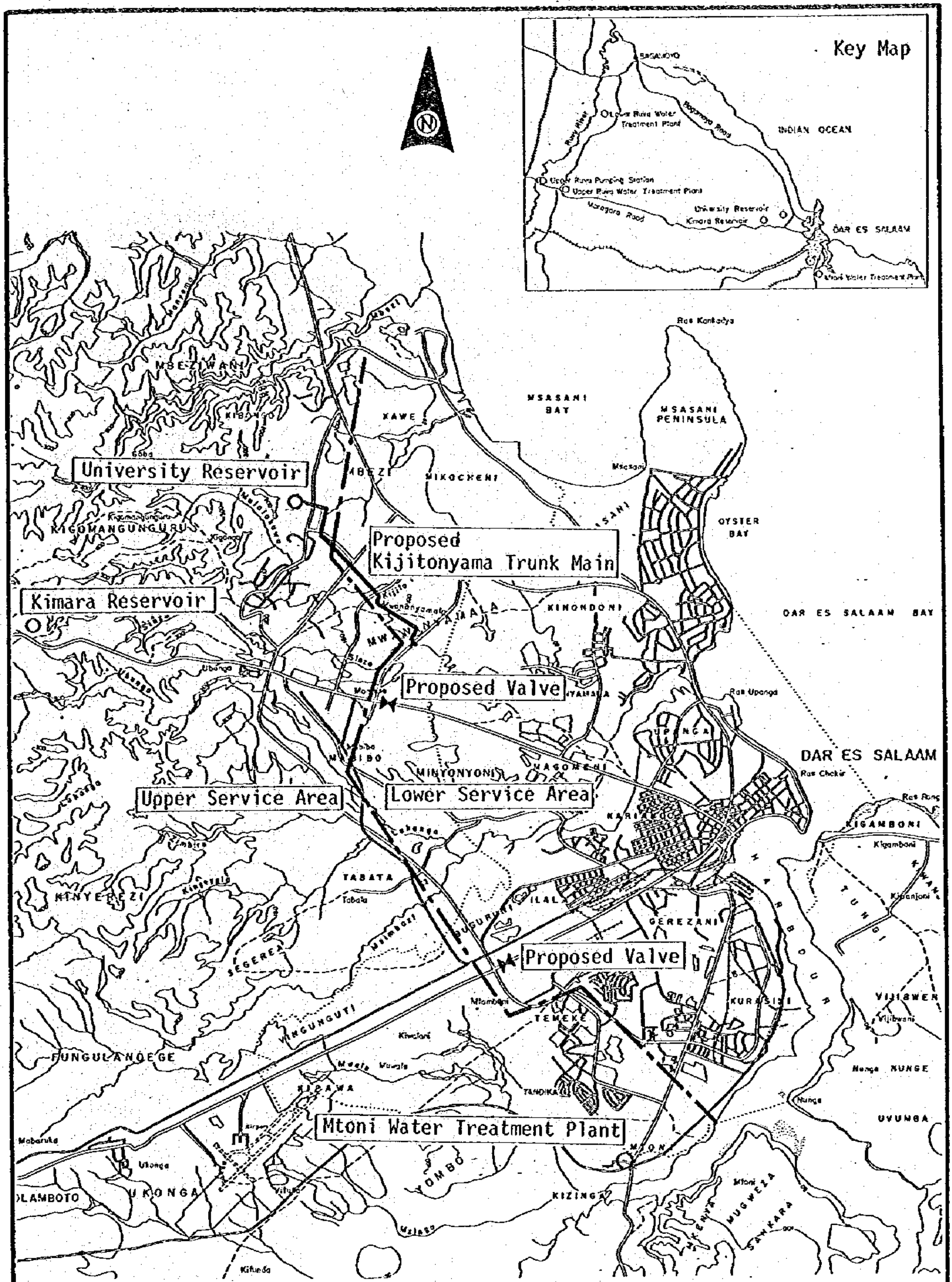
BASIC DESIGN STUDY REPORT ON DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT THE UNITED REPUBLIC OF TANZANIA

OCTOBER 1984

JAPAN INTERNATIONAL COOPERATION AGENCY



LOCATION MAP

DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT

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PREFACE

In response to the request of the Government of the United Republic of Tanzania, the Government of Japan decided to conduct a basic design study on the Dar es Salaam Water Supply Improvement Project and entrusted the study to the Japan International cooperation Agency. The JICA sent to Tanzania a study team headed by Mr. Hideyuki AOKI, Director, Design Division, Kanagawa Water Supply Authority from June 15 to July 11, 1984.

The team had discussions with the officials concerned of the Government of Tanzania and conducted a field survey. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the United Republic of Tanzania for their close cooperation extended to the team.

October 1984

Keisuke Arita

President

Japan International Cooperation Agency

SUMMARY

SUMMARY

The coverage of water supply system in Tanzania, according to a survey undertaken in 1983, shows 88% in urban areas but only 36% in the rural areas, with a national average of 39%. The served population for Dar es Salaam, the present study area, was approximately 1.11 million persons out of a total population of approximately 1.24 million in 1983.

The present condition of the Dar es Salaam water supply system is extremely unsatisfactory in spite of its long history and large coverage. At the time of the survey undertaken by the Study Team, actual delivered quantity was only 115,000 m^3/d against water demand of 230,000 m^3/d, which means only 50% of supply capacity was being distributed to the consumers. The reason for this poor supply service is due to the fact that the intake pumping facilities of the Lower Ruvu system, which provides approximately 79% of the supply for the entire service area, are not properly functioning. In addition, the Upper Ruvu system was also supplying only up to 50% due to deterioration of the old facilities in use. The municipal authorities therefore resorted to limiting daily water supply to the period from 5 a.m. to 2 p.m., resulting in each family trying to store enough water independently for use during the rest of the day.

It is expected that the deficiency of the Lower Ruvu system will soon be repaired, but there is no prospect for improvement of the inadequate Upper Ruvu system for the time being due to the extensive work, equipment and funds required. This presents a serious provlem inasmuch as this area covers public facilities inclusive of the university, international airport, and, in addition, quite a number of industrial facilities, which have been forced to lower their productivity due to the shortage of water supply, amounting to a loss of up 86.5 million shillings per annum, according to Government estimates. In addition, the quality of the piped water is high in turbidity with brownish colour, without evidence of free residual chlorine at house faucets, which indicated that the supplied water is not sanitary or safe for drinking purpose.

As a result, the Government of Tanzania submitted a request in December 1982 for improvement of the Dar es Salaam City water supply system to the Government of Japan which dispatched a preliminary study mission through the Japan International Cooperation Agency (JICA) in May 1983. In June 1984, a Study Team was dispatched to examine and assess the technical and economical viability of the project. The team held discussions with the Government authorities concerned, along with field surveys of the current condition of the system, which enabled the team to identify the problems facing the Government. Careful analysis of the findings thus gained was conducted in Tokyo after return to Japan, resulting in a five-point work programme covering steps considered to be most suitable.

This programme, which is recommended for immediate action from the points of urgency of need and effectiveness, is as follows:

1) Installation of Valves for Division of the Upper and Lower Service Areas

Considering that the water supply area of the City consists basically of high level and low level areas, connected by the distribution pipelines, the problem of inadequate and uneven supply of water in the Upper Service Area, stems from the natural tendency of water to flow down towards the Lower Service Area. In order to solve this problem, it has been confirmed that the entire distribution area should be divided into two parts along the border of + 30 m elevation, and connected by two sluice valves to be installed, one (ø315 mm) at Manzese and another (ø 300 mm) at Mtambani, which are the most suitable locations under the present condition of the distribution pipeline network which lacks adequate valves.

2) Installation of Kijitonyama Trunk Main

Calculation of distribution flow rate has confirmed that there will be places with insufficient water pressure at the upper part of the lower level area when the whole supply area is divided into two parts as described above. In order to cope with this problem,

it is considered necessary to newly lay 4.1 km. of ϕ 800 mm ductile cast iron pipeline from the University Reservoir to Mwananyamala, which is to be called the Kijitonyama trunk main.

3) Replacement of Low Lift and High Lift Pumps at Upper Ruvu System

The existing pumps for intake and tranamission have been used already for more than twenty years, and naturally require replacement in the same capacity, which are as follows:

a) Low Lift Pumps
22.8 m^3/min. x 70.2 m x 380 kw x 1 set.
11.4 m^3/min. x 70.2 m x 190 kw x 1 set.

b) High Lift Pumps
22.8 m^3/min. x 152.5 m x 800 kw x 1 set.
11.4 m^3/min. x 152.5 m x 400 kw x 1 set.

4) Replacement of Air Valves

Two transmission pipelines of ϕ 600 mm and ϕ 750 mm respectively, exist between the Upper Ruvu treatment plant and Kimara reservoir, each provided with air valves of ϕ 100 mm and ϕ 150 mm. However, most of them are broken, necessitating replacement of these air valves.

5) Installation of Chlorination Equipment at the Distribution Reservoirs

A distance of more than 50 km exists between the treatment plants and distribution reservoirs, which has resulted in very little trace of the existence of free residual chlorine in the reservoirs, even though chlorination is done at the plant. Since the concentration of free residual chlorine at house faucets should normally be 0.1 ppm to be safe for drinking, the water supply needs re-chlorination at the distribution reservoirs. For this purpose, dosing equipment should be installed at both the University and Kimara distribution reservoirs, for feeding calcium hypochlorite solution into the reservoirs.

The time schedule for the above stated programme, totalling 15 months, consists of approximately four (4) calender months for detailed design and selection of contractor, and eleven (11) calender months for construction work, following the signing of Exchange of Notes between the two Governments. Implementation of the recommended five-point programme is considered necessary for immediate improvement of the water supply of the City. Completion of this project is expected to greatly contribute to the welfare of its citizens and increase of industrial productivity.

ABBREVIATIONS

A. Abbreviation of Measures

(1) Length

ft = foot = 30.5cm

" = inch = 25.4mm

(2) Area

ha = hectare = 10^4 m^2

(3) Volume

gal = British gallon = 4.546 litres

MG = Million gallons

(4) Currency

Shs = Shillings (unit of Tanzanian currency, US$1 = 17.8 Shs = ¥240)

US$ = US dollar

¥ = Japanese Yen

(5) Other Measures

ppm = parts per million

ppb = parts per billion

% = per cent

HP = 0.746 kw

(6) Derived Measures Based on the Same Symbols

lcd = litre per capita per day

m^3/s = cubic metre per second

m^3/min = cubic metre per minute

m^3/d = cubic metre per day

B. Other Abbreviations

El. = elevation

HWL = high water level

LWL = low water level

ϕ = diametre of pipe in mm

DCIP = ductile cast iron pipe

CIP = cast iron pipe

SP = steel pipe

FOB = free on board

CIF = cost, insurance and freight

C. Abbreviation of Organizations

JICA	= Japan International Cooperation Agency
DSM	= Dar es Salaam
NUWA	= National Urban Water Authority
NUWA DSMB	= NUWA Dar es Salaam Branch Office
MWE	= Ministry of Water and Energy
TANESCO	= Tanzania Electric Supply Company, Ltd.
MCT	= Ministry of Commerce and Transportation
TPT	= Tanzania Posts and Telecommunications
MLHUD	= Ministry of Lands, Housing and Urban Development
MOF	= Ministry of Finance
DSM WSCS	= Dar es Salaam Water Supply Corporation Sole

LIST OF TABLES

LIST OF FIGURES

LIST OF DRAWINGS

CONTENTS

Chapter 1

INTRODUCTION

CHAPTER 1. INTRODUCTION

The city of Dar es Salaam (referred to as DSM hereinafter) is the capital of the United Republic of Tanzania (referred to as Tanzania hereinafter), and also the largest city in Tanzania as the center of its political, economic and cultural activities.

The water supply system of the City is managed by NUWA DSMB (formerly called DSM Water Supply Corporation Sole), with the Ruvu River as its major water source, approximately 60 km west of the City, for the supply of some 220,000 m^3 per day. However, supply condition in the higher area covering the western hillside of the City is not satisfactory due to frequent disruption of supply, causing not only inconvenience to the general consumers but also public facilities including the university and international airport, and additionally affecting production of the factories located in the area. The need for improvement is therefore evident and urgent.

Under the circumstances, the Government of Tanzania formulated an improvement plan aiming at solution of this unsatisfactory water supply service, and submitted a request for grant aid for implementation of the improvement programme to the Government of Japan. In response, the Government of Japan sent a preliminary study mission through JICA on May 1983 to Tanzania, for the purpose of confirming the substance of the request, including background study of the proposed programme, feasibility of its implementation and the desirable approach for cooperating in its implementation.

Based on the proposal of the mission, the Government of Japan sent a technical team from June 15 to July 11, 1984, for the purpose of formulating the basic design work of the programme, including the following:

1) Confirmation of the substance of the work.
2) Observation and survey of the current condition of DSM water supply service and the status of the existing facilities.
3) Collection of data and information necessary for the work.
4) Field survey of the areas proposed for construction works.

In addition to the above, the team held valuable discussions with the Government authorities concerned regarding items of basic importance in the programme. Members of the team, its itinerary and list of the officials interviewed, together with minutes of the meetings, are included as appendices in the present report.

The report thus submitted herewith is to present a practical design plan for facilities considered to provide the most adequate requirements for immediate improvement of DSM water supply services with the results contributing toward an improved economy of the nation as a whole.

Chapter 2

BACKGROUND OF THE PROJECT

Chapter 2. BACKGROUND OF THE PROJECT

2-1 General Background

Statistics for 1983 show 39 percent of the Tanzanian population served at the various levels of service by the present distribution system, with 88 percent of the urban population and 36 percent within the rural areas served by the system. Among the urban population, only about one-fourth enjoy the benefit of full house connection, while the remaining majority receives water from standpipes.

The administration of Tanzania's water supply system, including both urban and rural system, is under the control of the Ministry of Water and Energy (MEW). The National Urban Water Authority (NUWA) was inaugurated in July 1, 1983, based on the law proclaimed May 22, 1981 to increase coverage of water supply in urban areas and provide guidance, supervision and financial assistance for the waterworks, following the declaration of the International Drinking Water Supply and Sanitation Decade by the General Assembly of the United Nations in 1980.

Water supply development projects in various regions have been implemented by aid programmes of the developed countries and through international financing banks. For example, the Government of Sweden provided financial assistance for projects in seven regions, including Kilimanjaro Region, in the amount of 35 million Swedish kronor each for fiscal years 1983/1984 and 1984/1985. Also, the Government of Canada provided financial aid of 2.6 million dollars for the Dar es Salaam water supply system for the 5-year period from 1977 to 1981. Approximately 80% of the 144 million Shs for the rural water supply system and 75% of the 106 million Shs for the urban water supply system were provided through aid programmes for water supply development projects in the fiscal year 1981/1982. Assistance has also been provided from Norway, Finland, Denmark, West Germany, England, USA, Australia, as well as the World Bank and EC.

2-2 Existing Water Supply System of Dar es Salaam

2-2-1 Development of Existing System

Dar es Salaam city, the commercial, industrial and financial center of Tanzania, has been developing since the end of World War II. Its population which was only 48,000 in 1948, had increased to 1,300,000 as of 1984.

The Mtoni water treatment plant, fed from the Mzinga River basin, was constructed in 1952 to meet the increasing water demand. However, as the capacity of the Mtoni water treatment plant became inadequate to meet the increasing water demand, development of the Ruvu River located about 60 kilometers west of the city, began in 1959 with the first phase of the Upper Ruvu plant development project. The plant underwent expansion through several phases up to 1974. Subsequently, the Lower Ruvu plant started operation in 1976. The overall daily capacity is now about 270,800 cubic meters. The development of the Dar es Salaam water supply system is tabulated in Table 2-1. Most of the existing facilities were constructed with government financial aid from England, West Germany and Canada.

Although expansion of the DSM water supply system will become inevitable, improvement of the existing system to enable its use to its full existing capacity is expected to produce more immediate and effective results, and therefore considered more important. The DSM water supply system has been operating as a financially autonomous body through its revenue from water charges. However, its weak financial status (e.g., it cannot afford to improve or repair its existing facilities), requires its relinace on the Central Government which, in turn, must rely on foreign governments or international agencies.

Table 2-1. History of Dar es Salaam Water Supply System

Year	Events	Facilities		
		Mtoni WTP	Upper Ruvu WTP	Lower Ruvu WTP
1900	Establishment of initial water supply system (Piped water supply using shallow wells)	Water Source : Mziga River	Water Source : Ruvu River	Water Source : Ruvu River
?	Abolishment of shallow wells	Plant capacity: 1.5MGD (6,800 m3/d)	Plant Capacity: 18MGD (82,000 m3/d)	Plant capacity: 40MGD (182,000 m3/d)
?	Drilling of boreholes (Establishment of distribution network)	Financing:England	Financing:England & West Germany	Financing:Canada & West Germany
1930				
?	Development of Gerezani Creek			
1949	Start of Mtoni Project	Start of construction		
1952		Completion of construction		
1953		Start of operation at full capacity (Q=1.5MGD)		
1955	Start of Upper Ruvu Project		Start of Design	
1959			Completion of 1st phase construction work (Q=4MGD)	
1964			Completion of 2nd phase (Q=6MGD)	
1966			Completion of 3rd phase (Q=8MGD)	
1968	Preparation of Dar es Salaam Master Plan			
1971			Completion of 4th phase (Q=12MGD)	
1972	Start of Lower Ruvu Project			Start of survey & design
1975			Completion of 5th phase (Q=18MGD) Note: Because of delay of the Lower Ruvu project due to financing, 5th phase work was requested to the Government of West Germany)	
1976				Completion of 1st phase construction work (Q=40MGD)
1979	Review of Dar es Salaam Master Plan			

Note: WTP = Water treatment plant
MGD = Million gallons per day (4,546 m3/d)
Q = Water quantity

2-2-2 Administrative Structure

The NUWA DSMB, established in July 1, 1984 under the jurisdiction of NUWA, took over the functions of the former organization of the Dar es Salaam Water Supply Corporation Sole and now holds responsibility for the Management, treatment and distribution of water in Dar es Salaam.

the organization charts of NUWA and NUWA DSMB are shown in the following Fig. 2-1.

2-2-3 Distribution System

1) Service Area

The wide service area encompasses approximately 18,250 hectares (ha), extending 25 km from north to south and 15 km from east to west, and is divided into two pressure zones, referred to as Upper Service Area and Lower Service Area, shown in Fig. 2-2. The Upper Service Area, covering 8,250 ha (45 percent of the service area), extends inland, rising in elevation from 40 to 110 meters (m). This area, which includes such important facilities as the University, international airport and various factories which are vital to the City functions, is served by the Kimara Reservoir, which receives water from the Upper Ruvu Plant and is located at an elevation of 130 m, about five km west of the Ubungo intersection.

The coastal Lower Service Area faces the Indian Ocean on the east, covering 10,000 ha (55 percent of the service area), with ground elevation up to 50 m. This area is served by the University Reservoir. The reservoir, which receives water from the Lower Ruvu Plant, is located at an elevation of 75 m, about 10 km northwest from the center of the city.

2) Served Population

Out of the total population of 1,284,000 estimated for the 1984 census in Dar es Salaam, of which 1,162,400 are estimated to be residing in the lower area, with only 121,600 residing in the upper area.

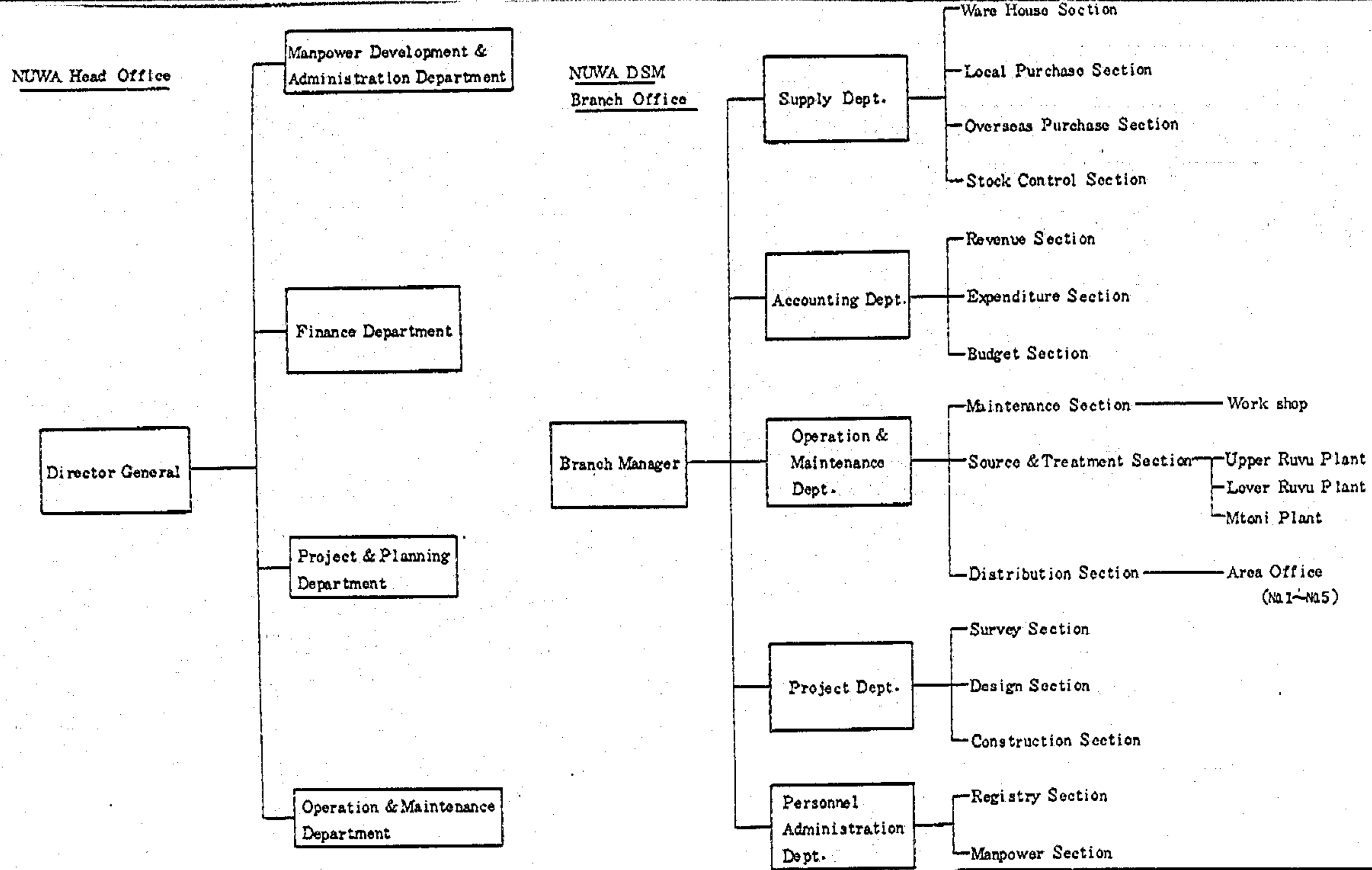

FIG. 2-1 ORGANIZATION CHART OF NUWA AND NUWA DSMB

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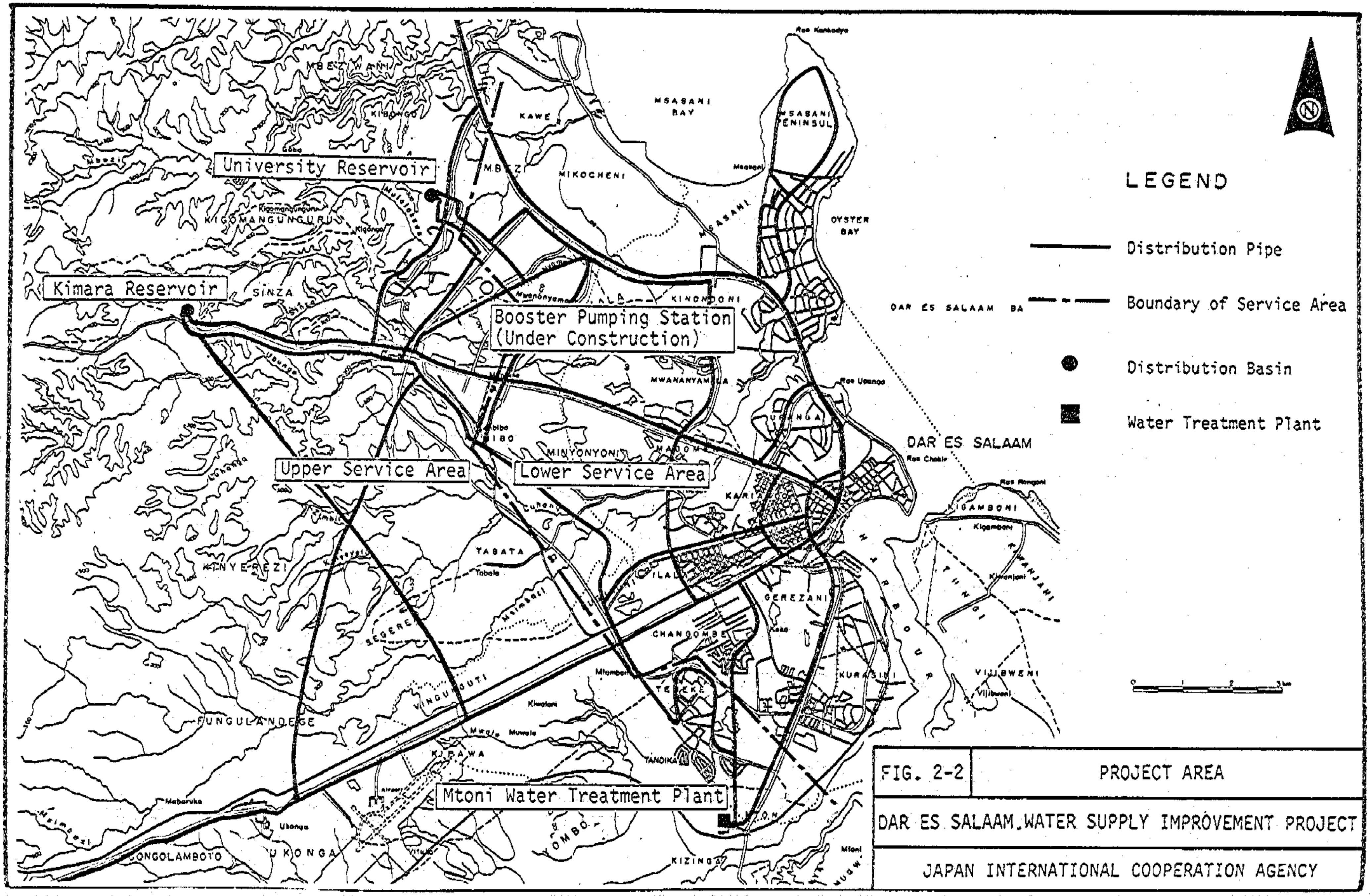

FIG. 2-2 PROJECT AREA

DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT

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3) Water Demand

The water demand in 1984, of approximately 230,000 m3/d, as estimated by NUWA DSMB, is as shown in Fig. 2-4 (section 2-2-5), in the following classifications:

Area	Demand (m3/d)
Residential	150,000
Served Population: 1,113,000	
Per Capita Demand l/d: 135	
Industrial & Institutional	80,000
Total	230,000

4) Water Distribution

Existing water treatment plants have a total rated capacity of 270,800 m3/d as shown below:

Water Treatment Plant	Rated Capacity	
Mtoni	6,800 m3/d	(1.5 MGD)
Upper Ruvu	82,000 "	(18 ")
Lower Ruvu	182,000 "	(40 ")
Total	270,800 "	(59.5 ")

A distinctive feature of the Dar es Salaam water supply system is its long transmission mains for the two major plants, the Upper Ruvu and the Lower Ruvu plants. Purified water is pumped a distance of more than 50 km from the respective plants to the distribution basins at Kimara and at University reservoirs, respectively. (See Fig. 2-3 for the location of each plant).

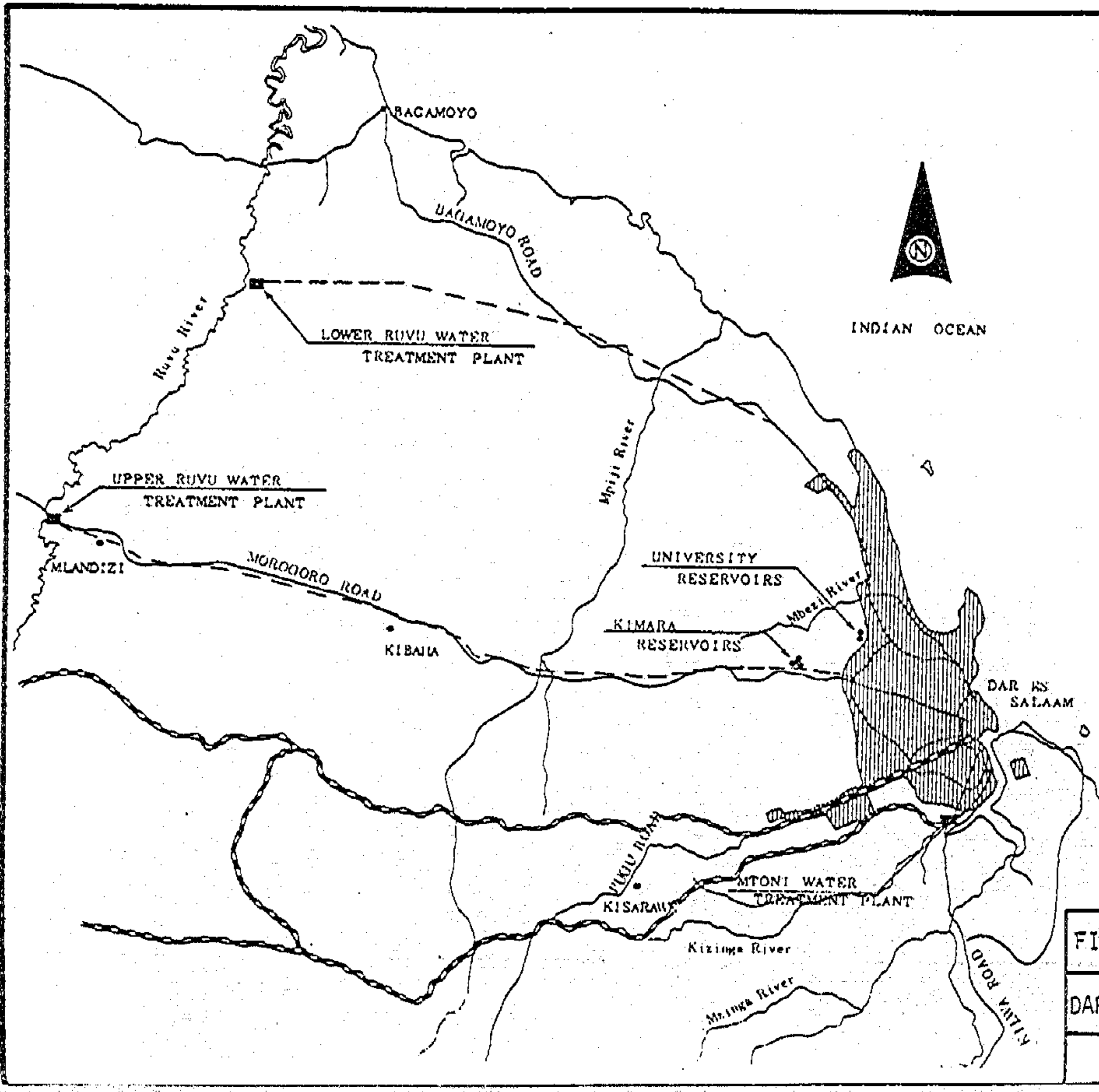

FIG. 2-3	LOCATION OF DAR ES SALAAM WATER SUPPLY FACILITIES
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Deterioration of facilities of the Mtoni and the Upper Ruvu plants have resulted in frequent suspension of water service in several locations of the service areas. In addition, it was found that tap water contained turbidity and no residual chlorine.

The water is distributed by gravitational flow in each zone, which are basically divided into the Upper and Lower service areas by valves. However, there are some places without valves which should have been installed to provide proper division of the service areas.

Although the present total capacity of 270,800 m^3/d satisfies the overall water demand of the city, suspension of water service occurs frequently in the Upper Service Area, which includes the international airport, Dar es Salaam University and industrial areas.

It was found during the reconnaissance study of the Team that the Lower Ruvu low lift pumps could pump raw water at only half capacity; i,e., 91,000 m^3/d due partly to breakdown, and that the Upper Ruvu low lift pump capacity was only 24,000 m^3/d, totalling only 115,000 m^3/d. Hence, as a countermeasure, distribution is being conducted as follows:

- Discontinuation of distribution service from the Kimara Reservoir for 15 hours from 2:00 p.m. to 5:00 a.m. of the following morning by closing the outlet valves.

- Distribution control through adjustment of major valves in the distribution system.

As a result, water pressure was found through field water pressure test conducted at 15 points to be lower than required.

2-2-4 Operation and Maintenance

The DSM water supply system is presently being operated and maintained under the following conditions:

1) Inspection

As the inspection control system is not established, the facilities and/or equipment are not periodically inspected. Therefore, they are inspected and repaired only after breakdown or damage occurs. In case deteriorated or damaged parts are beyond repair, they are left as they are.

However, effort is being made to repair all equipment necessary for securing water quantity, such as the intake and transmission pumps. If repair is not possible, they are replaced. However, since all equipment and spare parts are imported, long restriction of water service results whenever replacement of parts or equipment becomes necessary.

Facilities in the Mtoni and Upper Ruvu Plants are considerably deteriorated. Therefore, there are fears of breakdown of existing pumps which would souse immediate suspension of water service.

2) Spare Parts

Spare parts, all of which must be imported from abroad, are quite insufficient. Therefore, it would be difficult to establish a maintenance schedule in advance. However, the technical staff in the plants are capable of minor repairs as long as spare parts are available.

3) Chemical Dosing

It is important to secure chemicals for water purification because of the highly turbid condition of the raw water of the Ruvu River. However, both coagulant and alkaline agents are not sufficiently available all the time. In addition, the chlorination system installed at the treatment plants are not working efficiently, resulting in very little evidence of residual chlorine in the distribution reservoirs.

2-2-5 Future Water Demand and Development Plan of Facilities based on DSM Master Plan

The DSM Master Plan was established in 1968 and reviewed in 1979 with the cooperation of and financial aid from the Canadian Government. The urban population forecast for DSM, based on the DSM Master Plan and the Bureau of Statistics, under the city government's policy of decentralization of population, is shown in Table 2-2.

Table 2-2. Dar es Salaam Population Forecast

Year	Master Plan (second projection)	Bureau of Statistics Estimate (unit: x10^3)
1984	1,183	1,284
1988	-	1,383
1989	1,546	-
1998	-	2,268
1999	2,368	-
2008	-	3,719

Regarding water supply the following plan was established: The estimated amount of water demand was calculated from the forecasted unit water consumption per day (specified as to domestic, industrial, institutional and school use) as shown in Table 2-3. In estimating water demand, residential area is deemed to be supplied with house connections and standpipes as a basis for per capita water consumption. The future water demand predictions prepared by NUWA DSMB and DSM Master Plan are shown in Table 2-4 and Fig. 2-4.

The water supply development plan established for the DSM Master Plan is shown in Table 2-5 for reference.

Table 2-3. Unit Water Consumption Forecast by DSM Master Plan

Year	Residential Area		Industrial Area (l/ha)	Institutional Area (l/ha)
	House Connection (lcd)	Stand Pipe (lcd)		
1979	185	94	50,000	9,000
1984	205	100	50,000	13,000
1989	225	107	50,000	17,000
1999	270	120	50,000	25,000

Data Source: Dar es Salaam master Plan, October 1979

Table 2-4. Water Demand Prediction by NUWA DSMB

Year	Per Capital Consumption (lcd)	Population	Water Consumption (m^3/d)		
			Domestic	Institutional & Industrial	Total
1978	130	843,090	109,600	54,800	164,400
1988	140	1,382,668	193,580	96,790	290,370
1998	150	2,267,576	340,140	170,070	510,210
2008	160	3,718,824	595,030	297,520	892,550

Data Source: NUWA DSMB

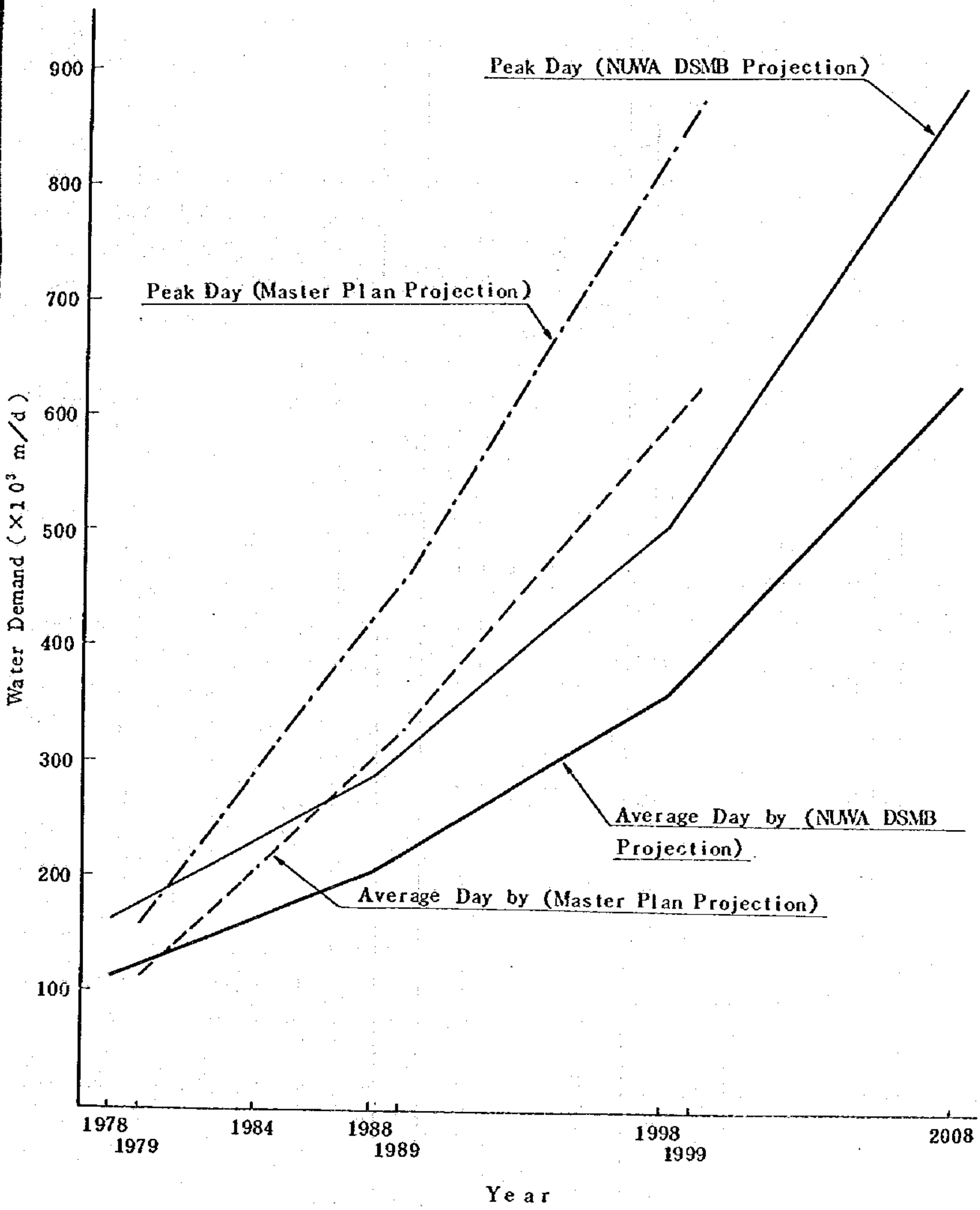

FIG. 2-4	PROJECTED WATER DEMAND BY MASTER PLAN AND NUWA DSMB
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Table 2-5. Development of Water Supply System (Dar es Salaam Master Plan 1979) (Unit:x10^3)

	1984			1989			1999		
	Existing	Extension	Total	Existing	Extension	Total	Existing	Extension	Total
(I) Water Demand (m3/d)			295			460			880
(II) Water Source	Ruvu River Mzinga River	-	-	Ruvu River Mzinga River	Ruvu Dam		Ruvu River Ruvu Dam	-	-
(III) Water Treatment Plant (m3/d)									
Upper Ruvu	82	-		82	-	82	82	-	82
Lower Ruvu	182	91		273	273	546	546	273	819
Mtoni	7	-		7	-	7	Abolish	-	-
Total	271	91		362	273	635	628	273	901
(IV) Distribution Reservoir (m3)									
Kimara	33	-	33	33	-	33	33	-	33
Kigamboni	-	5.5	5.5	5.5	-	5.5	5.5	-	5.5
University	46	23	69	69	20	89	89	27	116
Mbagalla	-	-	-	-	15.5	15.5	15.5	-	15.5
Pugu	-	-	-	-	-	-	-	54	54
Kigamboni	-	-	-	-	-	-	-	25	25
Total	79	28.5	107.5	107.5	35.5	143	143	106	249

Note: Transmission Pipelines and distribution pipelines are also planned to be installed in accordance with the capacity to be developed.

2-3 Problems of the Existing Water Supply Facilities

The Dar es Salaam water supply system is composed of three water treatment plants. The Upper Ruvu and Lower Ruvu plants have capacities of 82,000 m^3/d and 182,000 m^3/d respectively and withdraw raw water from the Ruvu River, located 60 km from the city, flowing from the southwest to northeast. The oldest Mtoni plant has a rated capacity of 6,800 m^3/d and withdraws raw water from the Mzinga river basin located south of the city area. Each plant is designed for water purification process consisting of flocculation, sedimentation, rapid sand filtration and chlorination. Both the Upper Ruvu plant and Mtoni plant are old and faced with problems of deterioration.

Most of the city area water supply is distributed from the Kimara and University reservoirs. The Kimara Reservoir was constructed at HWL. EL.135.9 m for supplying water by gravity flow to the high area where the international airport, Dar es Salaam University, factories, etc. are located. The University Reservoir was constructed at HWL. EL. 70.4 m for supplying water also by gravity flow to the low area where the city centre, port, etc. are located. Mtoni plant supplies a narrow area covering the low and high areas in the south of the city.

Due to the development progress of the Dar es Salaam water supply system, initial division into Upper and Lower service areas was made on the occasion of completion of the Lower Ruvu plant system. Prior to this, the Upper Ruvu plant system had been supplying the entire service area. The development of the system apparently had not been based on an integrated plan. Consequently, as mentioned later, occurrence of water shortage in some areas is the result of the existing improper division of the service area.

Next, present situation of the facilities and problems realized through field investigation are presented hereunder.

2-3-1 Upper Ruvu Plant System

Operation of the Upper Ruvu plant system was started in 1959 by using raw water from the Ruvu River as water source. Its capacity had reached 82,000 m^3/d when the 5th phase construction was completed in 1975, with financial aid from England and West Germany. At present, equipment from both countries are being operated together. The water treatment process and present condition of these facilities are shown in Fig. 2-5. Problems identified as a result of the investigation are as follows:

1) Intake

- Silt deposits near the intake
- Improper installation of screens
- Lack of grit chamber to prevent high-turbidity raw water inflow during the treatment process

2) Intake Pump Station

- Deterioration of the intake pumps
- Breakdown of air pressure tank for water hammer countermeasure

3) Raw Water Mains

- Water leakage caused by deterioration of pipes
- Breakdown of flow meters

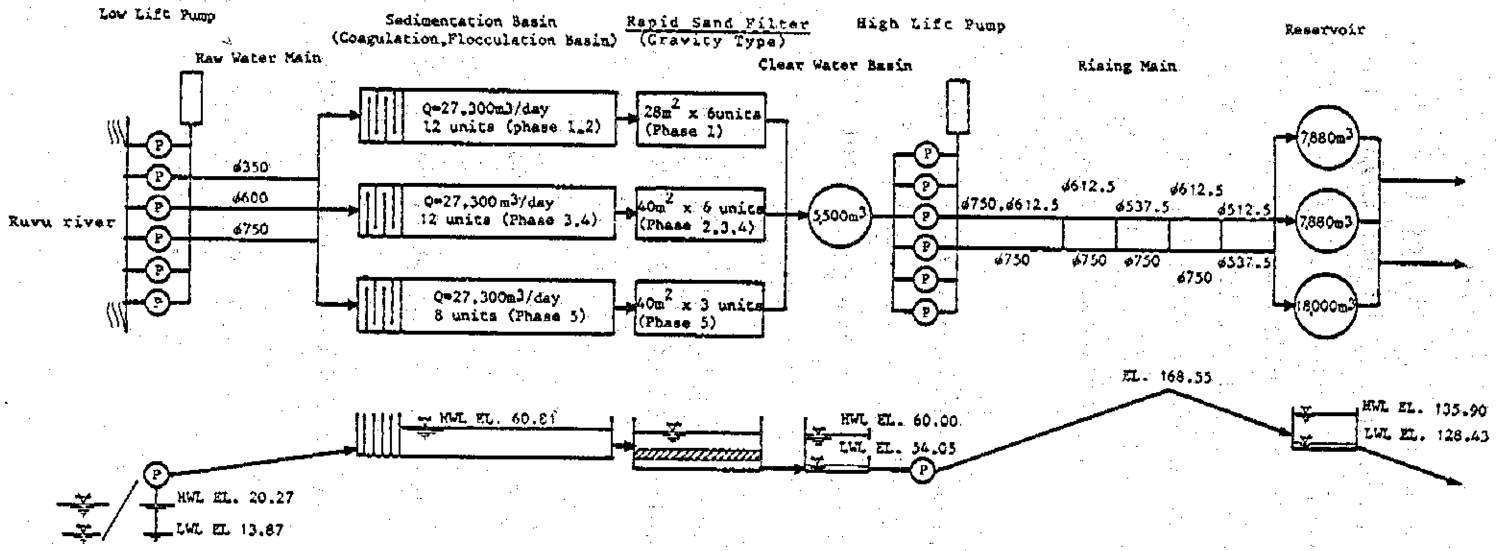
4) Water Treatment Plant

- Deterioration of the chemical dosing facilities, with chlorination equipment out of use
- Leakage from the inlet, outlet and drain valves of the rapid sand filters
- Lack of a laboratory and instruments
- Deterioration of the water transmission pumps
- Breakdown of air pressure tank for water hammer countermeasure

5) Water Transmission Mains

- Insufficiency of the water transmission capacity of the pipeline (assumed)

- Breakdown and leakage of the air valves
- Breakdown of flow meters



Low Lift Pump Station	
No	Pump Specification, Condition
1	22.8m³/min x 70.2m x 380kw In infrequent operation
2	22.8m³/min x 70.2m x 380kw Under repair
3	22.8m³/min x 70.2m x 380kw Out of operation
4	11.4m³/min x 70.2m x 190kw Out of operation, lack of spare parts
5	22.8m³/min x 70.2m x 380kw In operation but unstable
6	22.8m³/min x 70.2m x 380kw In operation but unstable

No.1-3 (England) Operation start from 1970

No.4-6 (W. Germany) Operation start from 1974

Water Treatment Plant (Q=82,000m³/day)			
Sedimentation Basin (Coagulation, Flocculation Basin)	Rapid Sand Filter (Gravity Type)	High Lift Pump	
		No	Pump Specification, Condition
• Broken chemical dosing equipments • Broken desludging system and control valves • Broken decancing troughs	• Many breakdowns at inlet valves and outlet valves. • Operation is not normal condition	1	34.1m³/min x 152.5m x 1120kw Operation, accident frequent
		2	22.8m³/min x 152.5m x 800kw Under Repair
		3	22.8m³/min x 152.5m x 800kw Operation but frequent breakdown
		4	11.4m³/min x 152.5 x 400kw (13.6m³/min x 243.8m Future)
		5	13.6m³/min x 152.5m x 480kw (13.6m³/min x 243.8m Future)
		6	For back washing (13.6m³/min. 243.8m Future)

Pumps are made in England

Kimara Reservoir
• 1 Uunit Out of use (7,880m³)

FIG. 2-5 SCHEMATIC FLOW AND PRESENT CONDITION OF UPPER RUVU PLANT SYSTEM

DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

2-3-2 Lower Ruvu Plant System

Operation of this plant was started in 1976 at the capacity of 182,000 m^3/d with the Ruvu River as its water source. The intake facility is constructed about 20 km downstream of the intake point of the Upper Ruvu plant. The plant is divided into two units, each with a capacity of 91,000 m^3/d. The water treatment process consists of flocculation, sedimentation, rapid sand filtration and chlorination. After being purified, the water is transmitted by pumping to the University Reservoir which is located about 50 km away from the water treatment plant. An adjacent lot in the water treatment plant site is reserved for future expansion of another unit of 91,000 m^3/d capacity. The water treatment process and present condition of the facilities are shown in Fig. 2-6.

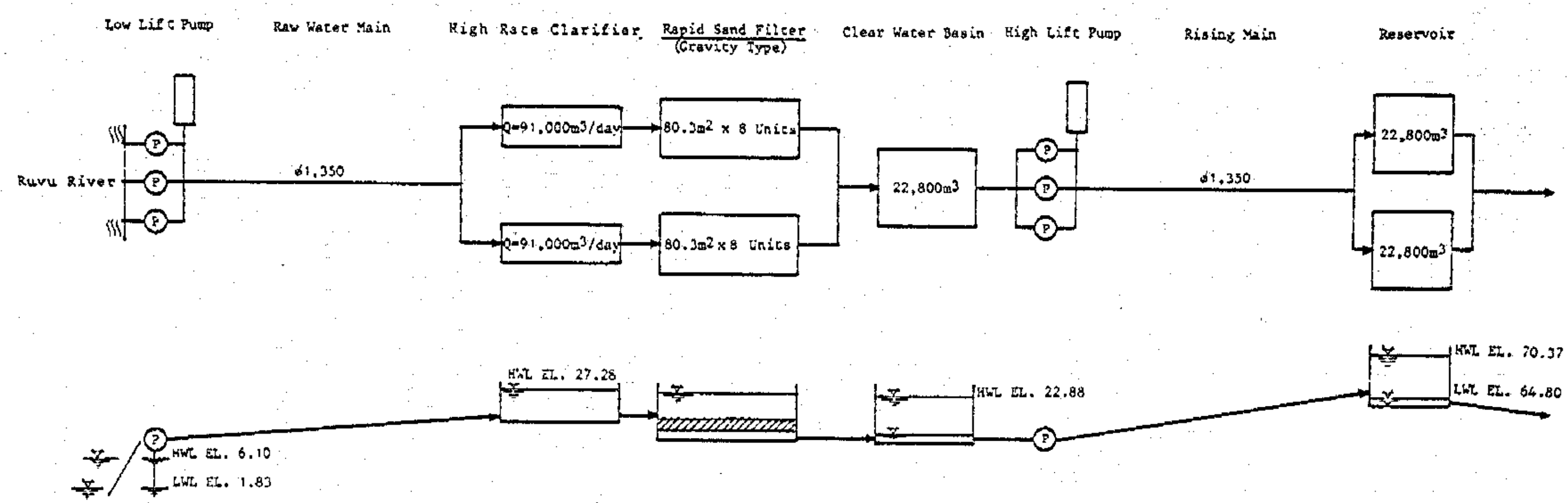
The facilities of the Lower Ruvu plant system were constructed in 1976 by financial assistance from the Government of Canada. It took four years to complete the facilities, beginning with land survey and designing. About 50 Canadian engineers participated in the construction work.

Problems of the Lower Ruvu plant are not numerous since the facilities are comparatively new. Following are those problems identified through field investigation:

- Breakdown of intake pumping system (completion of repair scheduled within July)
- Highly turbid water is conveyed to the water treatment plant due to lack of grit chamber
- Water purification capacity decrease to half capacity during washing one-half of the sedimentation basin.
- Excessively rapid filtration rate (designed rate: 280 m/d)
- Breakdown of flow meters

2-3-3 Mtoni Plant System

Mtoni water treatment plant draws surface and river bed water from the Mzinga River basin where it is located, south of the city. The facilities



Low Lift Pump Station
Pump Specification, Condition . 16 m³/min x 24 m x 375 kw x 3 sets (1 sets Including spare) . 2 sets Broken

Water Treatment Plant (Q=182,000m³/day)		
High Race Clarifier	Rapid Sand Filter (Gravity Type)	High Lift Pump
Bad access road --- Troubles for transportation of chemicals	Broken Winfila nozzles --- Stop operation 1 unit	Pump Specification, Condition . 63 m³/min x 108 m x 1425kw x 3 sets (1 set Including Spare)

University Reservoir

FIG. 2-6 SCHEMATIC FLOW AND PRESENT CONDITION OF LOWER RUVU PLANT SYSTEM

DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

have been in operation since 1952. The plant capacity is 6,800 m^3/d, using the same purification process as the other two plants. After being purified, water is distributed by pumps directly to the city, covering a small supply area. The water treatment process and present condition are indicated in Fig. 2-7.

The Mtoni plant capacity represents only 3% of the total capacity of the Dar es Salaam water supply system. In addition, the scarcity of raw water and the old, worn-out condition of the facilities make expansion and maintenance of this plant less significant for future operation of the plant. Following are the problems concerning the Mtoni plant system.

- Deterioration of facilities
- Only one pump each is available for intake and for water distribution

2-3-4 Water Distribution Facilities

There are two major distribution reservoirs in the city. One is the Kimara Reservoir (storage capacity: 34,000 m^3) for the Upper Ruvu system and the other is the University Reservoir (storage capacity:45,600 m^3) for the Lower Ruvu system. One of the three basins of the Kimara Reservoir is out of use due to water leakage from the bottom slab. As a result, present total storage capacity has been reduced from 79,400 m^3 to 71,500 m^3 with 6.3 hour retention time for maximum daily demand. Water is distributed by gravity flow but a small section south of the city is supplied from the Mtoni plant by direct pumping system.

Distribution pipes are installed to a length extending 529 km, including a 96 km-long section using pipes of more than ϕ400 mm. The type of pipes used are steel pipe, cast iron pipe, prestressed concrete pipe and polyvinyl chloride pipe. Steel pipes were used mainly for those of large diameter (ϕ700 mm - ϕ1,350 mm) at the time of construction eight years ago of the Lower Ruvu system.

Problems facing the distribution facilities are planned to be resolved as follows:

- Division of the service area into the Upper and Lower service areas due to the wide difference in elevation, extending from El. 0 to El. 110m,

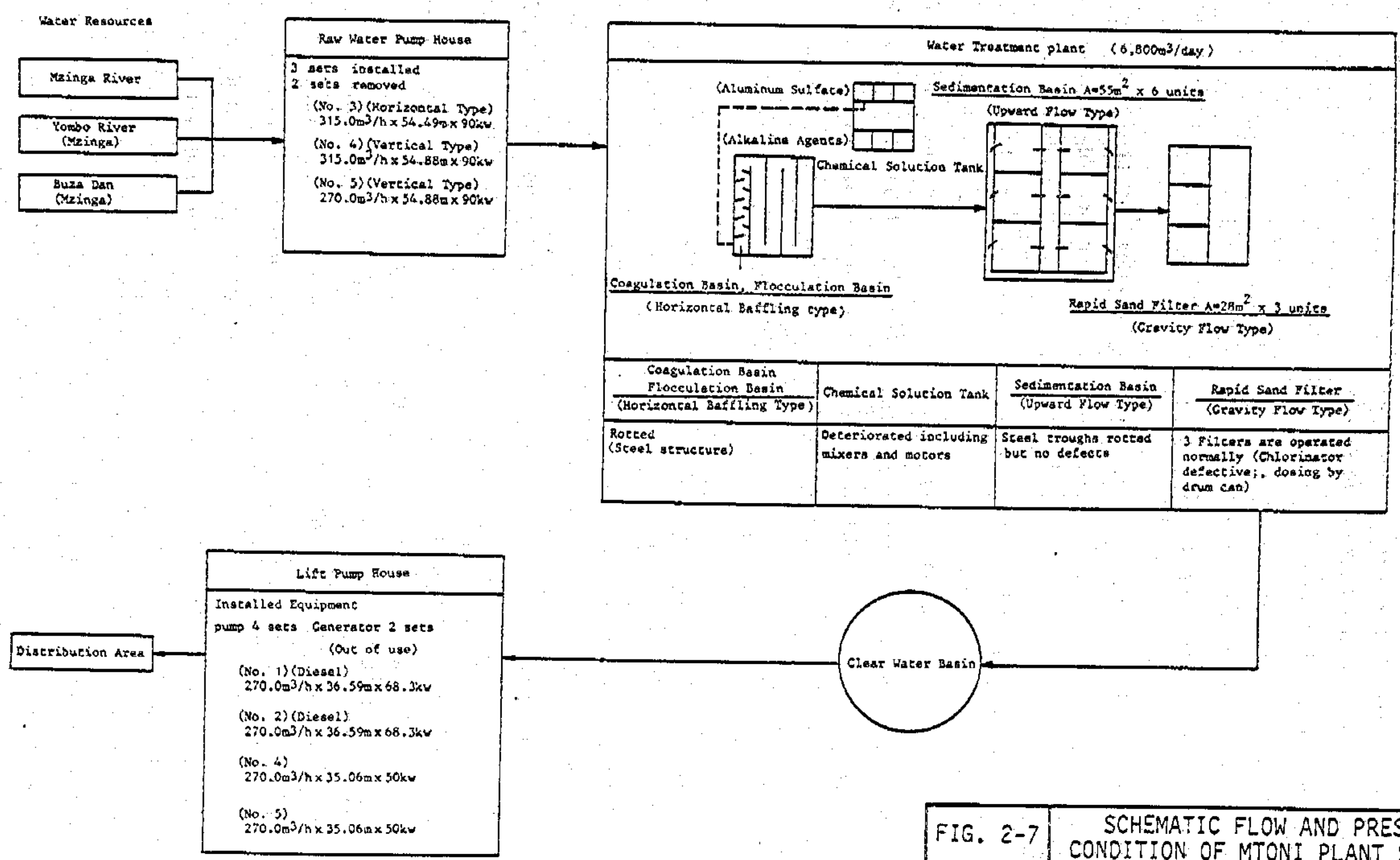


FIG. 2-7	SCHEMATIC FLOW AND PRESENT CONDITION OF MTONI PLANT SYSTEM
DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT	
JAPAN INTERNATIONAL COOPERATION AGENCY	

which causes uneven or inadequate flow

- Installation, supplementing and replacement of distribution pipelines to solve the water shortage problem
- Countermeasure for water leakage; for example, replacement of the ϕ1,350 mm and ϕ700 mm steel pipes between the University Reservoir and the city area
- Installation of water meters for improving revenue
- Countermeasure for water leakage of one basin at the Kimara Reservoir

Also, the following measures, which were recommended by the preliminary study mission for the improvement plan, were taken into consideration in order to secure adequate water quantity by eliminating water shortage areas in the Upper Service Area and by rehabilitating the function of existing facilities.

1) To install control valves on the ϕ525 mm and ϕ300 mm mains from the Kimara reservoir to secure a constant water supply from the reservoir to the Upper Service Area while at the same time taking into consideration any possible detrimental effect on the water supply to the Lower Service Area.

2) To install a connecting pipeline (ϕ700 mm, L=4.5 km) between the University reservoir and Ubungo and constructing a boosting pump station (420 kw x 3 pumps) to provide water from the Lower Service Area to the Upper Service Area.

3) To replace intake pumps (one (1) 490 HP pump and one (1) 1,070 HP pump) for the Upper Ruvu plant system to secure existing flow rate.

Of the above three recommended steps, Step 2) which is intended to supplement the supply from the Lower Service Area to the Upper Service Area, was modified to utilize the existing pipeline and the booster pumps instead of the connecting pipeline and the booster pumps. This construction work has already been started by the Government of Tanzania for completion as soon as possible. The booster pump station, as a basic rule, is operated to supply water of the Lower Ruvu system to the Kimara Reservoir in the Upper Ruvu system when the Upper Ruvu system suffers water shortage. Accordingly, the booster pump is operated intermittently, as required. The boosting pump station is designed to supply 13.2 m^3/min by three pumps (including one stand-by unit). As of July, construction work on the basements of the pump well and the pump station had been started. Fig. 2-2 indicates the location of the booster pumping station.

The basic project plan is based on consideration of the existing problems and the study mission recommendations, one of which is already being undertaken as described above.

Chapter 3

CONTENTS OF THE PROJECT

Chapter 3 CONTENTS OF THE PROJECT

3-1 Objectives of the Plan

Various problems facing the Dar es Salaam water supply system have been clarified in Chapter 2. These are divided into five categories, which are examined to determine the best methods for improving the present water supply situation.

1) To establish an effective water distribution system based on rehabilitating the functions of existing facilities in order to eliminate the water shortage areas in the city. For example, division of the service area, replacement of the low lift and high lift pumps in the Upper Ruvu plant, replacement of defective air valves installed on the rising mains, etc.

2) Repair or replacement of time-worn equipment to operate and maintain the system appropriately and installation of new equipment required for upgrading the operation and maintenance of the system. For example,, pressure gauges of pumps, flow meters, etc.

3) Rehabilitation and installation of equipment such as the chemical feeding equipment at Upper Ruvu Plant, chlorination equipment at the Kimara and the University reservoirs, etc., for improving water quality.

4) Relocation, expansion, and countermeasures for leakage of the water distribution network system. For example, installation of pipes for Msasani area and Kigamboni area and replacement of and/or supplementing the old pipes in the City Centre.

5) Establishing a future plan which formulates the future use of Upper Ruvu Plant, expansion of the Lower Ruvu Plant and a long-term development plan, taking the present situation into consideration.

However the most pressing problem for improving the Dar es Salaam water supply system is the frequent suspension of water service, especially, the water shortage areas in the Upper Service Area, which presents a great social problem.

Therefore, the basic design study aims to formulate an urgent plan for establishing an effective water distribution system, as described under the aforesaid countermeasure 1), and to carry out the basic design of the facilities required for implementation of the plan. This plan is based on provision of a grant from the Government of Japan.

3-2 Plan Formulation and Urgent Improvement Programme

The purpose is neither to increase the capacity of the existing facilities nor expansion of facilities but establishment of an effective water distribution system based on the existing flow capacity by rehabilitating the functions of certain facilities and supplementing required parts of other facilities.

Considering the points prescribed; viz., the urgent plan recommended by the Preliminary Study Team and the boosting pump station under construction, the following three items are selected as the major objectives of the urgent improvement programme for reasons as described.

1) Division of the Upper and Lower Service Areas

a. The service area in Dar es Salaam extends in elevation from 0 m to 110 m. With such a difference in elevation for the service area, internal pressure of pipes in the low area, such as the City Centre where many old pipes are laid, rises more than 10 kg/cm^2 caused by static head from the high water level of the reservoir, causing additional water leakage.

b. The City Centre of Dar es Salaam is located in the lower part of the service area, where the most water is consumed. As long as the distribution network is designed properly, insufficient water pressure over the entire pipe network, even at the farthest end of the pipeline during peak flow, will not occur. However, the large water consumption in the Lower Service Area would cause insufficient water pressure in the Upper Service Area, unless the distribution network is installed based on a careful design by hydraulic analysis. This unusual condition has been proven by water pressure test during the field investigation. (See Appendix:3)

c. When the boosting pump station (the Link Project, now under construction) supplying water to the Kimara Reservoir and the Upper Service Area is operated, water pressure in the outlet pipes of the booster pump will exceed more than 10 kg/cm^2, which will cause more water leakage from the existing old pipes.

d. Accordingly, the service area of Dar es Salaam must be divided at least into two areas, such as the Upper Service Area (El.30m to El.110 m) and the Lower Service Area (El.0m to 30 m) in order to balance the water amount consumed in the respective service areas as well as the capacity of the Upper and the Lower treatment plants.

2) Installation of Connecting Pipeline from the University Reservoir to the Lower Service Area

a. If the service area is divided into the Upper and the Lower service areas, there is fear of raising problems of water shortage and insufficient residual pressure in some places in the Lower Service Area which are presently being supplied from the Kimara Reservoir.

b. Water from the University Reservoir is distributed by ∅1,350 mm diameter main pipes. It is assumed that there would be difficulty in distributing the maximum hourly flow by using only this pipeline.

c. According to the two points mentioned above, installation of a new pipeline connecting the University Reservoir and suitable distribution pipes in the Lower Service Area would be necessary to obtain maximum hourly flow in order to avoid probable water shortage and water pressure problems due to the division of the service area.

3) Replacement of Low Lift and High Lift Pumps in the Upper Ruvu Plant

a. The Upper Service Area and Lower Service Area will be created in proportion to the capacity of the respective water treatment plants. However, it is doubtful whether the low lift and high lift pumps in the Upper Ruvu Plant can provide constant water transmission to the Kimara Reservoir because of deterioration of the equipment.

b. The capacity of the pump unit is designed taking into consideration the water transmission capacity of the rising mains connecting the Upper Ruvu Plant and the Kimara Reservoir which is assumed at approximately 42,000 m3/d. The number of pumps to be replaced are determined by the condition of the existing pumps. Countermeasure for water hammer is to be examined carefully.

The foregoing three points are considered to be effective methods for the urgent improvement programme. Similar results are expected from the following two measures:

4) To replace leaking air valves on the rising mains in order to reduce water leakage in order to secure continuously adequate water transmission quantity.

5) To install chlorination equipment at the Kimara and University reservoirs
At present, residual chlorine does not remain in the reservoirs which evidences incomplete water disinfection and threatens to seriously affect the health of the residents. An effective countermeasure would be to feed chlorine at the reservoirs in order to keep residual chlorine at the far end of the distribution pipes.

The above five countermeasures, including those concerning the above-mention air valves and chlorination equipment, are considered to be the most appropriate points for the urgent improvement plan.

3-3 Basic Design

3-3-1 Policy of Basic Design

The basic design is carried out according to the following three points as basic policy.

- Basic design is conducted for rehabilitating the function of the existing facilities and not intended to expand the system capacity

- The design shall be coordinated with the existing facilities

- Ease of operation and maintenance shall be important points to be considered in selection of facilities and equipment to be installed.

Up to the present, no water supply design manual has ever been instituted by the Government or any water supply organization concerned. When the United Nations Congress in November 1980 designated the decade from 1981 to 1990 as the UN International Drinking Water Supply and Sanitation Decade, the Government of Tanzania took this opportunity to step up its plan for constructing facilities to increase the coverage of water service for the country. This is being accomplished by reorganizing the water supply administration bodies concerned, as well as through technical and economical assistance from overseas countries. Preparation of a water supply design manual was necessitated in connection with implementation of the plan, and at present, a draft is under examination and modification for the purpose of using it as a design manual for the country. The draft water supply design manual is basically to be used for planning facilities. Therefore, items not stipulated in this manual will follow the Design Criteria for Water Works Facilities, 1978, issued by the Japan Water Works Association.

3-3-2 Basic Plan

1) Establishment of Planned Supply Amount

Regarding water supply planning in general, the scale of facilities is decided on the basis of planned supply amount as determined by water demand prediction. Two future water demand predictions, are used, one made by the NUWA DSMB in early 1984 and the other in the Dar es Salaam Master Plan, 1979, although the rate of increase is too high to be considered a real water demand. Moreover, sufficient data is not available to predict future water demand on the occasion of this study.

Accordingly, the scale of the facilities are determined considering the water distribution flow for the planned supply amount, when the water demand reaches the flow corresponding to the capacity of existing facilities, since the project aims to rehabilitate the function of the existing facilities.

Also, the water transmission capacity of the rising mains is doubtful, compared with the capacity of 82,000 m3/d for the Upper Ruvu Plant. Therefore, planning is carried out, firstly, by examining the water transmission capacity of the rising mains and establishing the capacity of the existing facilities.

2) Water Transmission Capacity of the Rising Mains

Planning of the intake and water transmission for the Upper Ruvu Plant system are determined with the scale of facilities in close relation to the capacity of rising mains.

The plant has a capacity of 82,000 m^3/d. Two means are considered to obtain the capacity of 82,000 m^3/d: (1) by deciding the number and capacity of the pumps to be replaced according to the possible water transmission flow and without changing the total head of the existing high lift pumps and (2) by increasing the internal water pressure of the pipeline.

It is not favourable to increase water pressure because the higher the water pressure the higher the increase in water leakage from pipes, as exists in problems even now. Consequently, the plan is carried out on the basis of method (1) mentioned above; i,e., by replacing inoperable and irreparable pumps.

For the purpose of examining the water transmission flow rate of the rising mains, the system head curve which is derived from the friction loss calculation of the pipeline and the performance curve of the existing pumps were obtained. The flow rate tentatively obtained from the above examination will then be confirmed by plotting the hydraulic gradient line which shows the interrelationship between the pipeline profile and the residual water pressure at various points of high places. The examination of the rising mains is described in detail as follows.

Profile of the water transmission facilities is schematically drawn in Fig. 3-1 for calculation of friction loss of the pipeline and for plotting system head curve.

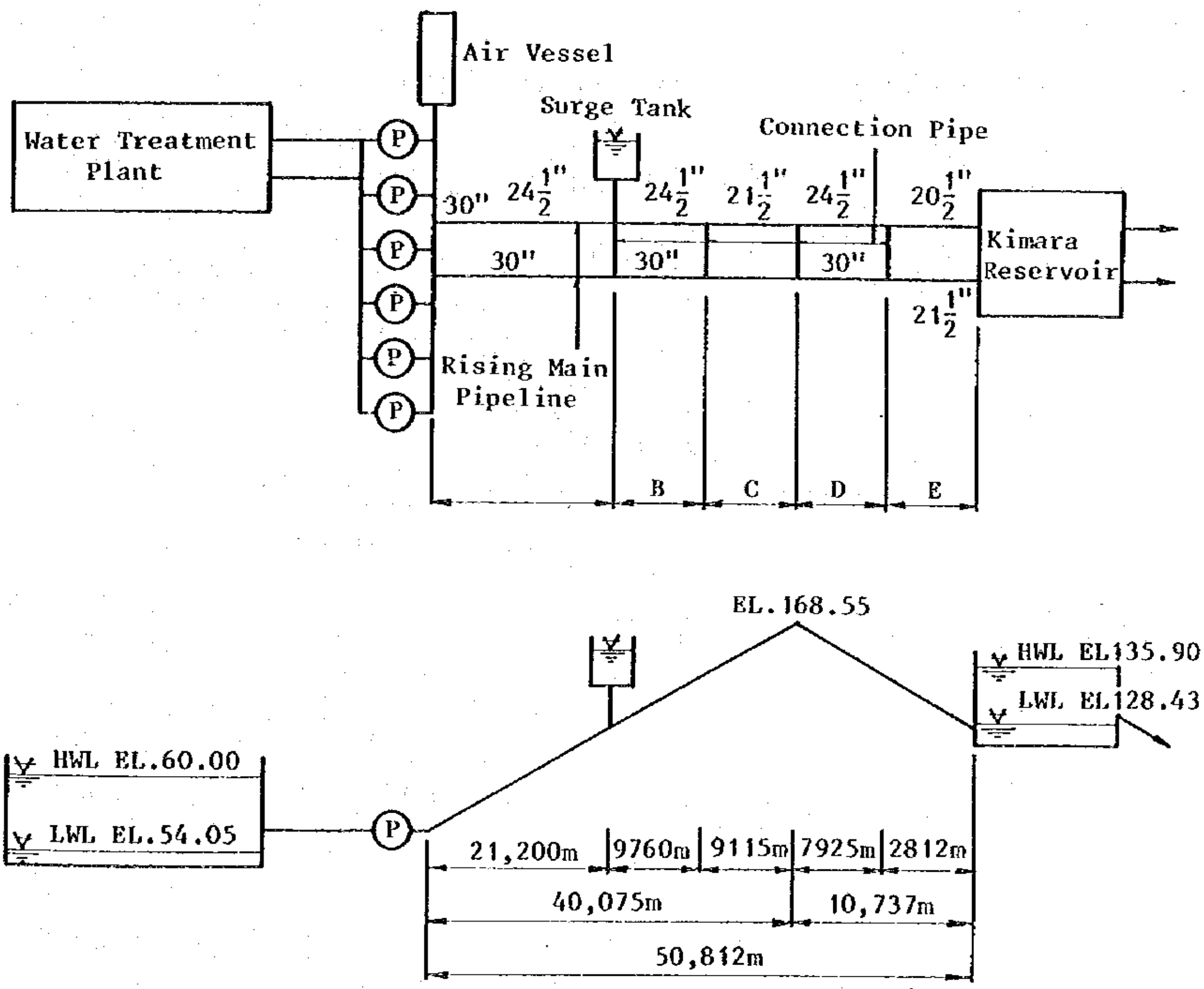
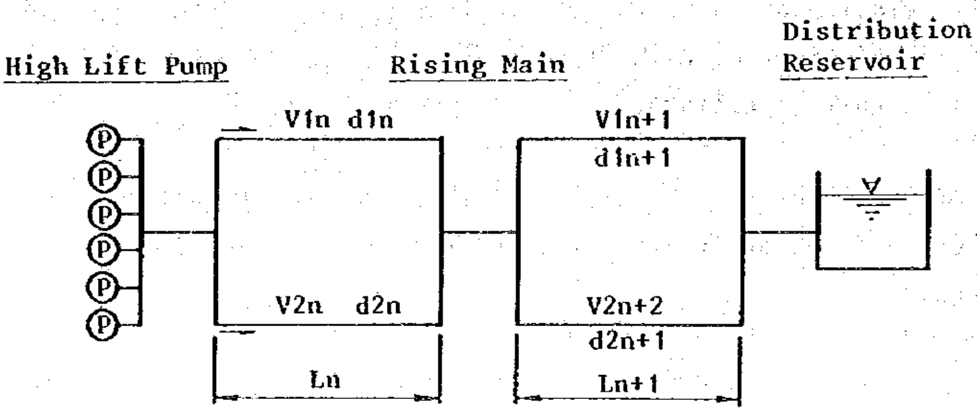


Fig. 3-1. Schematic Profile of the Rising Main

The friction loss is calculated by dividing the pipeline into five sections since the pipe size is different in each section. Results of the calculation are shown in Table 3-1, assuming the velocity coefficient (C value) at 110 and the water transmission flow at 20,000 to 100,000 m3/d.



As the head loss of each pipeline is the same,

$$\text{Head Loss} = fr \cdot (L/dn) \cdot (Vn^2/2g)$$

$$\text{Where, } fr = (134/C^{1.85}) \cdot (1/dn^{0.167}/Vn^{0.15}) \text{ ...... (Hazen-Williams formula)}$$

$$\text{Therefore, } (Vn^{1.85}/dn^{1.167}) = \text{constant}$$

$$(V2/V1) = (d2/d1)^{0.63}$$

$$(Q2/Q1) = (d_2^2 \cdot V2/d_1^2 \cdot V1) = (d2/d1)^{2.63}$$

Table 3-1. Friction Head Lose

Pipe Diameter Type*		Pipeline Diameter	Pipeline Length(m)	Factor	Flow Rate (m³/d) 20,000 (0.232m³/s)	40,000 (0.463m³/s)	50,000 (0.578m³/s)	60,000 (0.695m³/s)	82,000 (0.950m³/s)	100,000 (1.157m³/s)
A	1	612.5ϕ ($24\frac{1}{2}$")	30,960	Flow Rate (m³/s)	0.086	0.171	0.214	0.257	0.351	0.428
				Velocity (m/s)	0.292	0.580	0.726	0.872	1.191	1.453
				Fr. Loss Coef.	0.0293	0.0264	0.0255	0.0248	0.0237	0.0230
&				Fr. Head Loss(m)	6.5	22.8	33.8	48.6	86.6	125.6
B	2	750ϕ (30")	30,960	Flow Rate (m³/s)	0.146	0.292	0.364	0.438	0.599	0.729
				Velocity (m/s)	0.330	0.661	0.824	0.991	1.356	1.650
				Lr. Loss Coef.	0.0278	0.0250	0.0242	0.0235	0.0225	0.0218
				Fr. Head Loss(m)	6.4	23.0	34.6	49.0	87.0	125.1
C	1	537.5ϕ ($21\frac{1}{2}$")	9,115	Flow Rate (m³/s)	0.068	0.136	0.170	0.204	0.279	0.340
				Velocity (m/s)	0.300	0.599	0.749	0.899	1.230	0.498
				Fr. Loss Coef.	0.0298	0.0268	0.0260	0.0253	0.0241	0.0234
				Fr. Head Loss(m)	2.3	8.3	12.6	17.7	31.5	45.2
	2	750ϕ (30")	9,115	Flow Rate (m³/s)	0.164	0.327	0.408	0.491	0.671	0.817
				Velocity (m/s)	0.371	0.740	0.924	1.111	1.519	1.849
				Fr. Loss Coef.	0.0273	0.0246	0.0238	0.0231	0.0221	0.0214
				Fr. Head Loss(m)	2.3	8.3	12.6	17.7	31.7	45.3
E	1	512.5ϕ ($20\frac{1}{2}$")	2,812	Flow Rate (m³/s)	0.109	0.217	0.271	0.326	0.445	0.542
				Velocity (m/s)	0.528	1.052	1.314	1.580	2.157	2.627
				Fr. Loss Coef.	0.0276	0.0249	0.0241	0.0234	0.0223	0.0217
				Fr. Head Loss(m)	2.2	7.7	11.6	16.3	29.0	41.9
	2	537.5ϕ ($21\frac{1}{2}$")	2,812	Flow Rate (m³/s)	0.123	0.246	0.307	0.369	0.505	0.615
				Velocity (m/s)	0.542	1.084	1.353	1.626	2.2226	2.710
				Fr. Loss Coef.	0.0272	0.0246	0.0238	0.0231	0.0220	0.0214
				Fr. Head Loss(m)	2.1	7.7	11.6	16.3	29.1	41.9
D	1	612.5ϕ ($24\frac{1}{2}$")	7,925	Flow Rate (m³/s)	0.086	0.171	0.214	0.257	0.351	0.428
				Velocity (m/s)	0.292	0.580	0.726	0.872	1.191	1.453
				Fr. Loss Coef.	0.0293	0.0264	0.0255	0.0248	0.0237	0.0230
				Fr. Head Loss(m)	1.7	5.8	8.6	12.5	22.2	32.1
	2	750ϕ (30")	7,925	Flow Rate (m³/s)	0.146	0.292	0.364	0.438	0.599	0.729
				Velocity (m/s)	0.330	0.661	0.824	0.991	1.356	1.650
				Fr. Loss Coef.	0.0278	0.0250	0.0242	0.0235	0.0225	0.0218
				Fr. Head Loss (m)	1.6	5,9	8.8	12.5	22.3	32.0
Total Friction Head Loss(m)		Assuming c=110			12.7	44.9	67.6	95.5	170.1	244.9

* Refer to Fig. 3-3

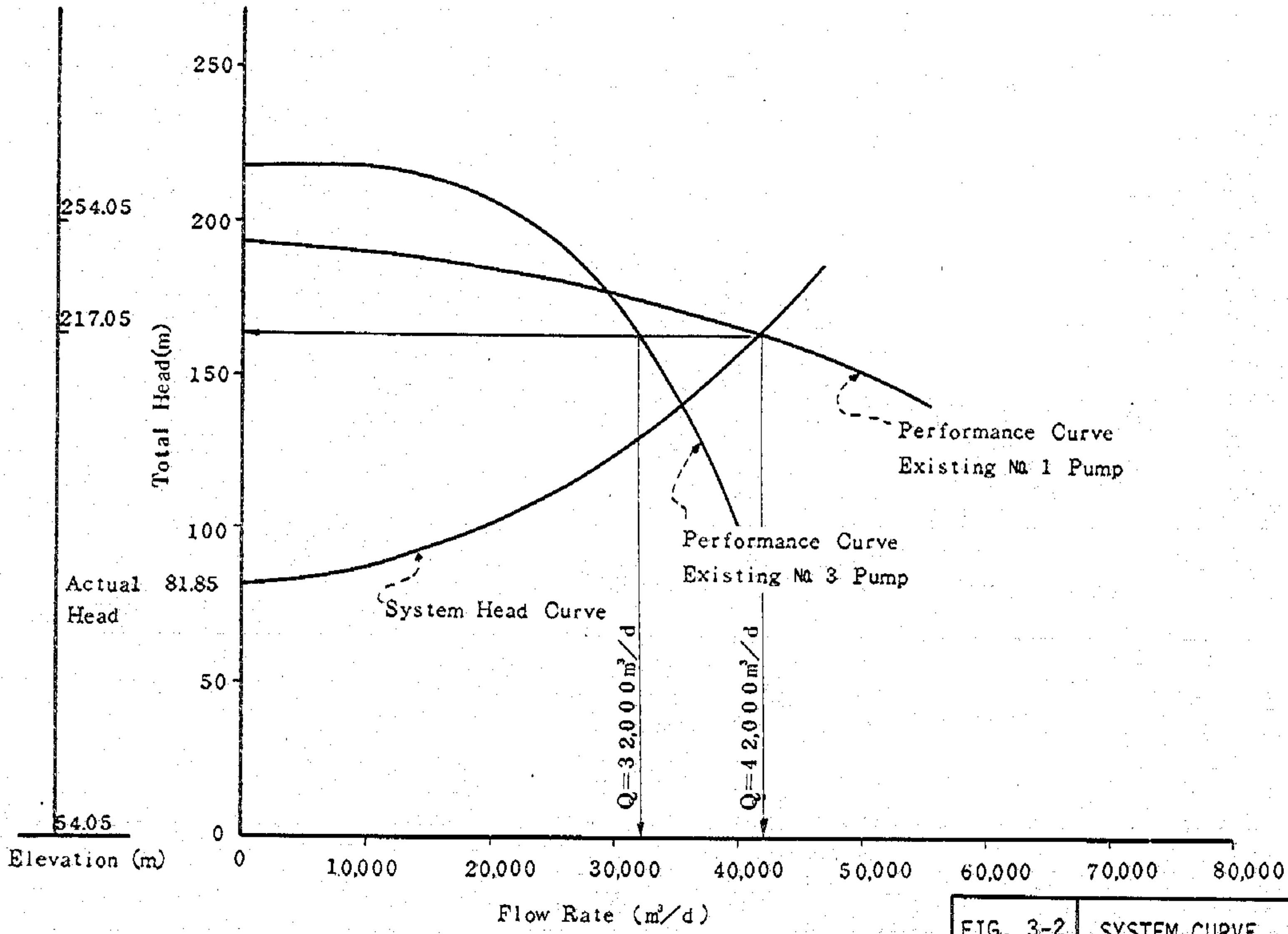


FIG. 3-2	SYSTEM CURVE
DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT	
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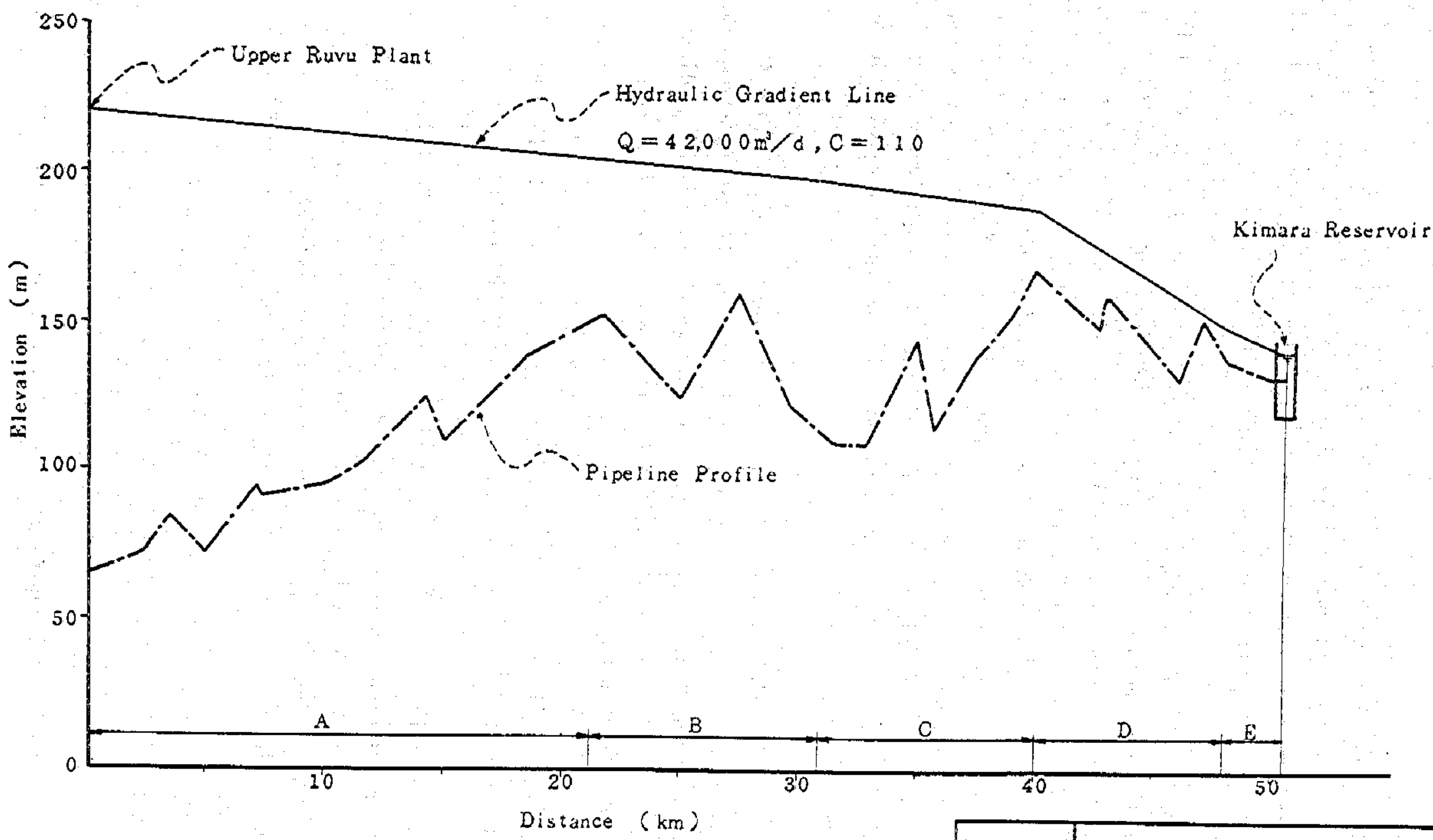


FIG. 3-3	HYDRAULIC GRADLENT LINE (C=110)
DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT	
JAPAN INTERNATIONAL COOPERATION AGENCY	

The system head loss curve is plotted in Fig. 3-2, based on the total friction head loss and flow rate indicated in Table 3-1. Also, the performance curves of existing pumps No.1 and No.3 drawn with the system head curve in Fig. 3-2. illustrate the system curve of the pumping facilities.

Regarding No.1 existing pump, in Fig. 3-2, the operating point where it intersects the system head curve and performance curve indicate the flow rate of 42,000 m3/d at the total head of 163m. In the case of No.3 existing pump, the flow rate is given at 33,000 m3/d at the same total head. When the existing pumps No.1 and No.3 are operated at the same time, the flow rate increases a little, in relation to the increase of output pressure in pipes. It is preferable not to increase water pressure since it causes an increase in the amount of water leakage from the pipes. Therefore, the maximum capacity of water transmission is determined at 42,000 m3/d which is the operating point of No.1 existing pump.

Next, the hydraulic gradient line at the flow rate of 42,000 m3/d is drawn and indicated in Fig. 3-3. It was confirmed that the rising mains have the capacity to transmit flow at 42,000 m3/d through the hydraulic gradient line, as shown in Fig. 3-3, which does not fall under the ground level at various points of the high places.

A trial calculation is shown below to determine whether the flow of 42,000 m3/d meets the water demand of the Upper Service Area.

Population of Upper Service Area in 1979 : 85,500

Rate of population growth during 1978 to 1984 : 7.3%/yr

Predicted population of Upper Service Area in 1984 : 121,600

Water demand by use in Upper Service Area (Appendix - 5)

Domestic use	:	12,170 m3/d
Hotel use	:	470 "
Industrial use	:	22,520 "
Institutional and school use	:	6,840 "
Total		42,000 "

Water consumption per capita per day : $(12,170/121,600) \times 10^3 = 100$ lcd

The rate of water consumption as suggested in the draft water supply design manual of Tanzania is as follows:

People using kiosks or public taps:	25 lcd
People with house connection	
low income group housing:	70 lcd
high income group housing:	200 lcd

Based on the above rates, the per capita water consumption rate of 100 lcd, assuming 100% rate of water service, would be sufficient for domestic use water demand.

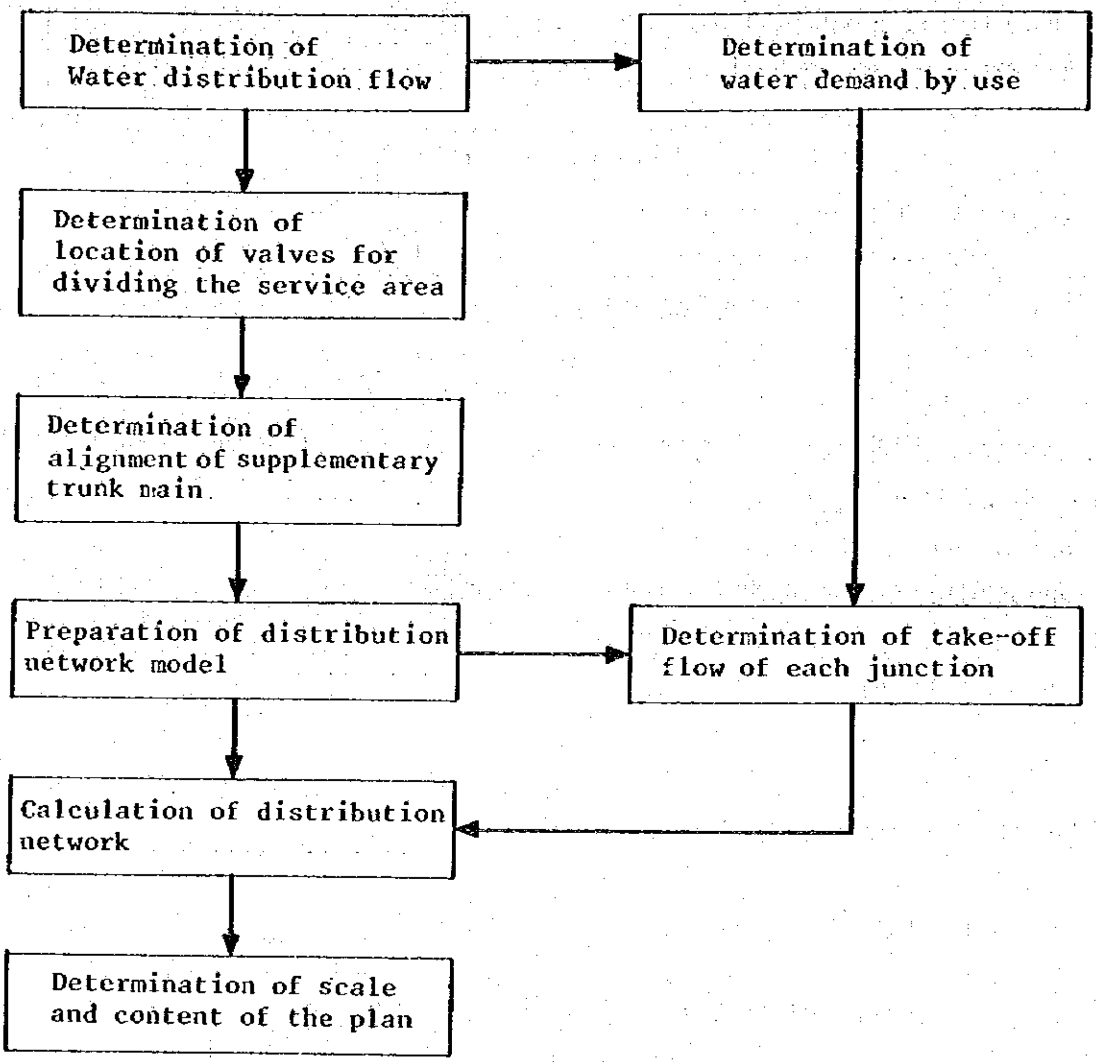
Accordingly, it is assumed that if the water transmission flow of 42,000 m3/d is secured, the water demand in the Upper Service Area will be satisfied for the time being.

3) Water Distribution Plan

a. Introduction

Water distribution plan is formulated to determine the location of valves for division of the water service area into the Upper and Lower service areas and to determine the alignment and size of distribution trunk main to supplement water service in the Lower Service Area in order to avoid possible water shortage as a result of division of the service area.

The scale and content of the plan will be determined in accordance with the following flow diagram:



b. Determination of Water Distribution Flow

The water distribution flow under normal operating condition could not be obtained during the field investigation period. Accordingly, the water distribution plan is based on the rated capacity of the existing plants, and the flow (maximum daily water demand) in the Upper and Lower service areas are determined as follows:

Upper Ruvu system, Kimara Reservoir	:	42,000 m^3/d
Lower Ruvu system, University Reservoir	:	182,000 m^3/d
Total		224,000 m^3/d

c. Determination of Water Demand by Use

In order to categorize water demand, four classes of water use are established as follows:

- Domestic and commercial use
- Institutional and school use
- Industrial use
- Hotel use

Each rate of water demand by use is determined by referring to the water consumption records obtained from the NUWA DSMB and the Dar es Salaam Master Plan, which are indicated in Table 3-2 and Table 3-3 respectively. The rate of each water use is determined as shown in Table 3-4, considering past recorded rates.

Table 3-2 Past Water Consumption Record by Use (1)

(Unit: m^3/d)

Year	Domestic & commercial use	Institutional, school & industrial use	Total
1948	3,840	1,420	5,260
1958	14,140	7,080	21,220
1968	35,260	17,630	53,890
1978	109,600	54,800	164,400

Data Source : NUWA DSMB

Table 3-3 Past Water Consumption Record by Use (2)

(Unit: m^3/d)

Year	Domestic & Commercial Use	Institutional & School Use	Industrial use	Total
1979	61,520	12,860	27,650	102,030

Data Source : Dar es Salaam Master Plan

Table 3-4 Rate of Water Demand by Use

	NUWA DSMB		Master Plan			Adopted Value		Remarks
	Water Consumption (m^3/day)	Ratio(1) (%)	Water Consumption (m^3/day)	Ratio(1) (%)	Ratio(2) (%)	Ratio(1) (%)	Ratio(2) (%)	
Domestic and commercial use	109,600	67	61,520	60	60	65	65	Including hotel use
Institutional and school use	54,800	33	12,860	40	13	35	13	
Industrial use			27,650		27		22*	
Total	164,400	100	102,030	100	100	100	100	

Note: * Comparing the adopted rate of water use to that of Kawasaki city in Japan which is similar to Dar es Salaam in scale and characteristics of the city, the latest rate of industrial use is 16%. Considering the recycling of water for industrial use in Kawasaki city, the rate of total water demand would be almost the same as in Dar es Salaam.

Water distribution flow for hotels was determined based on the number of hotel rooms, guest occupancy per room and the per capita consumption by guests, as shown in Table 3-5.

Table 3-5. Water Consumption of Hotels

Hotel	Number of rooms	Guest occupancy per room*	Number of guests	Per capita consumption**	Water consumption
	(1)	(2)	(3)=(1)x(2)	(4)	(5)=(3)x(4)
	Room	Person	Person	lcd	m^3/day
Kunduchi Beach Hotel	100	4	400	250	100
Silver Sand Hotel	80	4	320	250	80
Banari Beach Hotel	64	4	256	250	60
Rungwe Beach Hotel	50	4	200	250	50
Africana Hotel	180	4	720	250	180
Kilimanjaro Hotel	198	2	396	250	100
New Africa Hotel	104	2	208	250	50
Mocel Agip Hotel	57	2	114	250	30
Twinga Hotel	28	2	56	250	10
Oyster Bay Hotel	20	2	40	250	10
Total	881	-	2,710	-	670

Note: * The guest occupancy per room for the resort hotels were estimated at 4 persons, considering family use. Other hotels were estimated at 2 persons/room.

** Per capita consumption was determined at 250 lcd, based on the figures of 250-300 lcd quoted in the Air Conditioning and Sanitary Engineering Handbook of Japan.

Water distribution flow by use was determined as shown in Table 3-6.

Table 3-6. Water Distribution Flow by Use

Water Use	Ratio of Water Use (%)	Water Distribution Flow (m^3/day)
Domestic and commercial	65	144,930*
Institution and school	13	29,120
Industry	22	49,280
Hotel	-	670
Total	100	224,000

* 224,000 m^3/d x 65% - 670 m^3/d
(Hotel water use ratio is included in the Domestic and Commercial Use 65% ratio)

d. Determination of Location of Valves for Dividing the Service Area

Following are trial calculations to determine the elevation for efficient water distribution from the University Reservoir.

Elevation for efficient water distribution = LWL of Univ. Res. - Residual Head - Head Loss of Pipeline
= 64.8 - 15.0 - 22.5 = 27.3m, say 30m

Where,

Low water level of University Reservoir = El. 64.8m
Residual Head : 15.0m
Head Loss of Pipeline : L x I = 15 x 1.5 = 22.5m
Length of Pipeline : L = 15km (ϕ1,350mm and ϕ1,050mm)
Hydraulic Gradient : I = 1.5/1,000 (average)

Consequently, if the division of the area to be supplied from the University Reservoir is made around elevation of 30m, the residual water pressure can be kept above 15m, which is considered to be sufficient water pressure for city supply. The water service area of Dar es Salaam is divided as drawn in Fig. 3-4 by setting the highest boundary line of the Lower Service Area at 30m elevation.

For the purpose of dividing the service area, field investigation was conducted to check the existence of valves for the entire distribution network at around 30m elevation. As a result, the location for new valves to be installed were set for Manzese and Mtambani. Installation of valves at these two places will divide the service area into the Upper and the Lower areas. The size of valves are determined to be the same as the existing pipelines of ϕ375mm for Manzese and ϕ300mm for Mtambani respectively.

e. Determination of Alignment of the Distribution Trunk Main

The distribution trunk main aims to supplement water service to the Lower Service Area, especially during operation of the booster pumping station. Therefore, the pipe connection must be done at the most suitable place for efficient distribution of water in the Lower Service Area.

At present, there are two trunk main systems: Route① and Route② (see Fig. 3-5). For Route①, large diameter pipes are used and installed in the lower part of the Lower Service Area. Meanwhile, water pressure test conducted during the field investigation showed 1.6kg/cm^2 at the end of Route① and that of Route② showed almost 0 kg/cm^2. Considering these conditions, reinforcing the Route② system

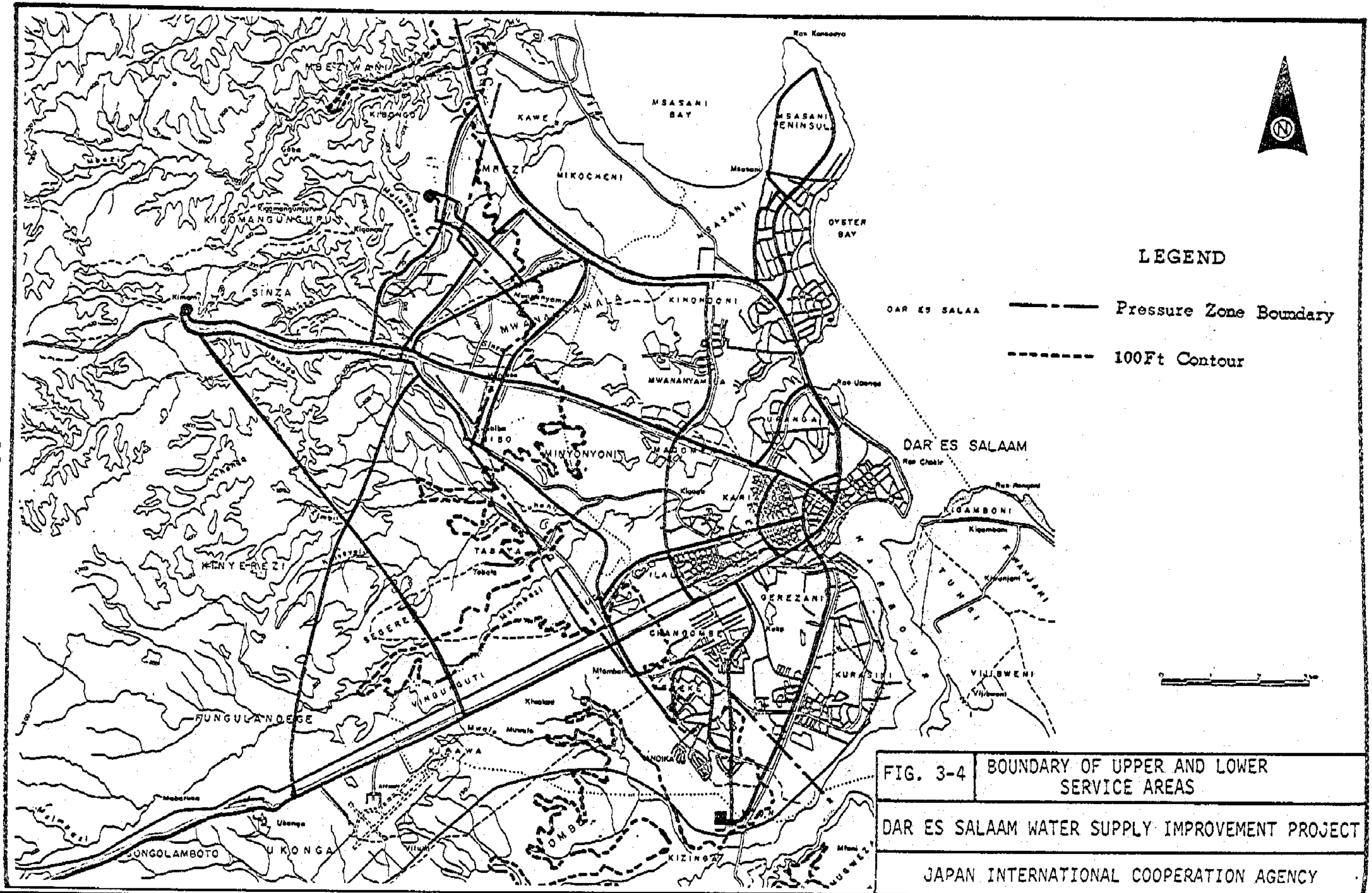


FIG. 3-4	BOUNDARY OF UPPER AND LOWER SERVICE AREAS
DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT	
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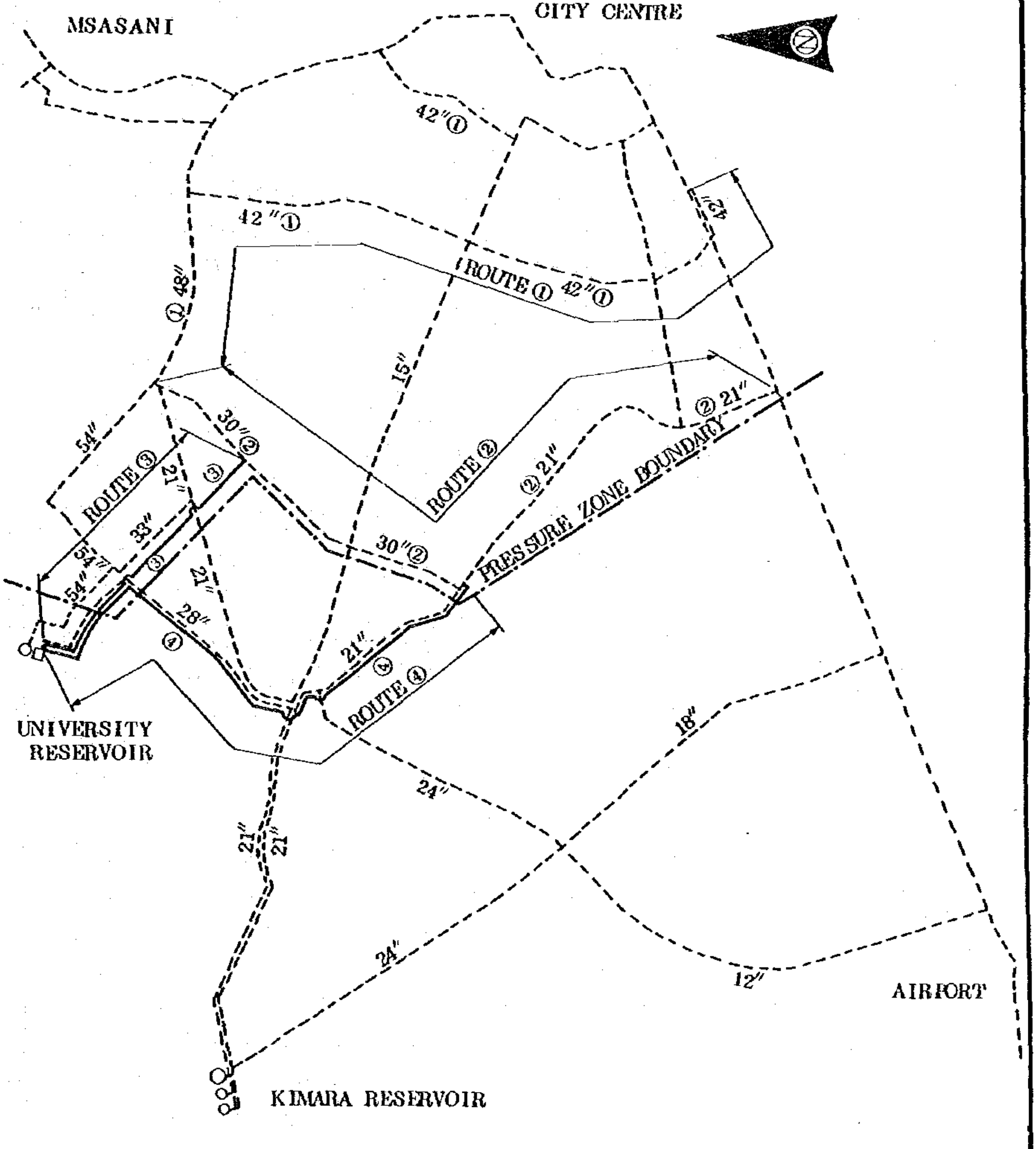

LEGEND

- - - - Existing Pipeline
——— Propose Pipeline
—·— Pressure Zone Boundary

FIG. 3-5	TRUNK MAINS IN LOWER DISTRIBUTION AREA
DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT	
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would improve the efficiency of water distribution in the Lower Service Area.

Two routes for the new pipeline are considered. Those are Route ③ and Route ④. The length of pipeline for Route ④ would be longer than that for Route ③, resulting in higher installation cost. Also, Route ④ will be inconvenient for supplementing water distribution to the Lower Service Area since alignment of the pipeline route would pass through the Upper Service Area.

Consequently, Route ③ is selected for the alignment of the distribution trunk main and will be called Kijito Nyama Trunk Main hereinafter.

f. Preparation of Distribution Network Model

The major pipelines to frame a skeleton for the Upper and Lower distribution network are chosen and drawn in Fig 3-6. This network is used for the network model for hydraulic calculation.

g. Determination of Take-off Flow at Each Junction

To determine the take-off flow at each junction of the model network, water demand is allocated by use for each block. Regarding the method for allocation, that for domestic and commercial use was allocated by population rate in each block. Institutional, school and industrial use was allotted by the rate of the site area and allocated to each block. The flow for each hotel was directly allocated to the block where the hotel is sited. The allocated flow to each block was further allotted to each junction of the network within the block. Details of the calculation of take-off flow is shown in Appendix - 5.

h. Hydraulic Calculation of Distribution Network

i) Hydraulic Equation

The Hazen - Williams formula was employed, assuming the

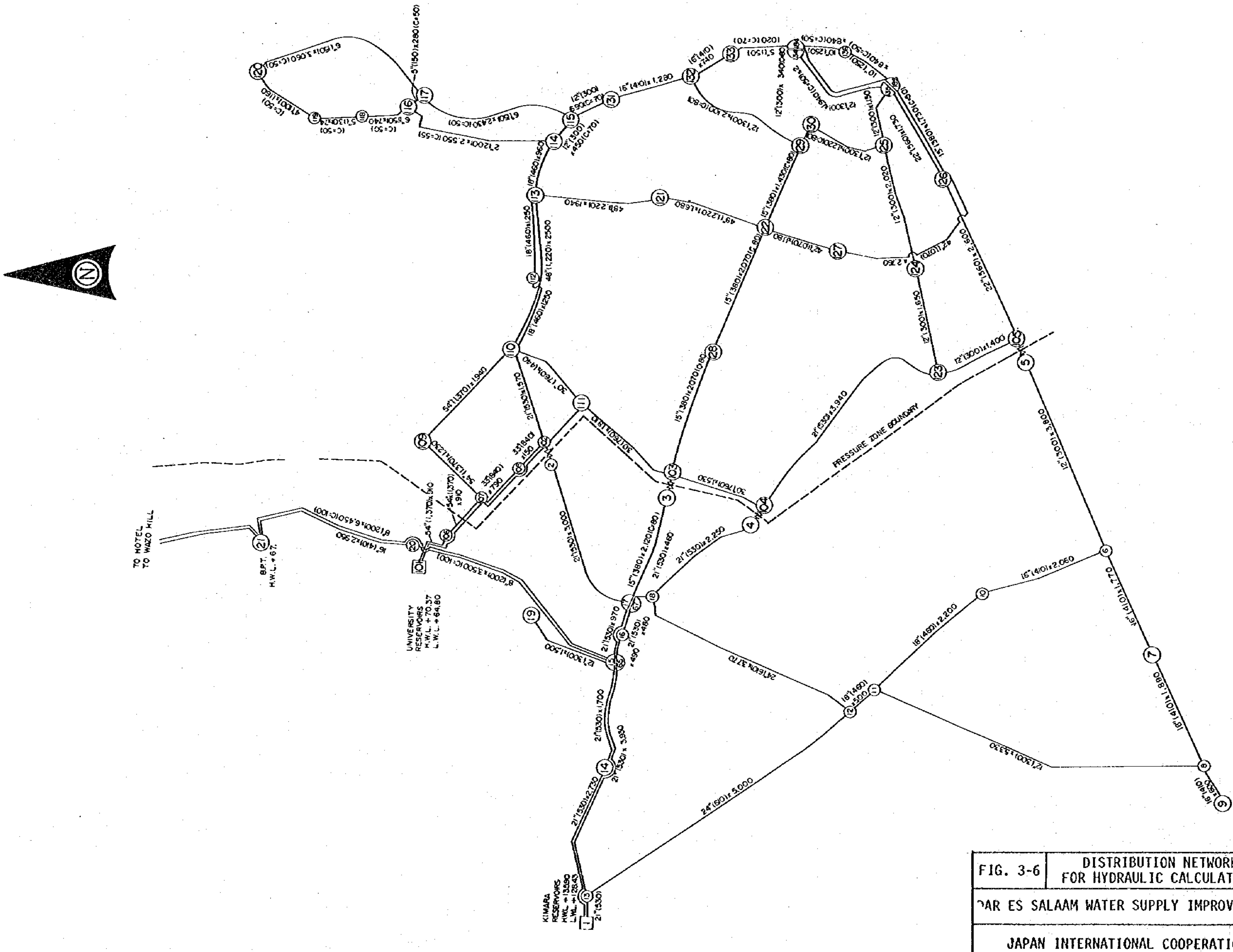


FIG. 3-6	DISTRIBUTION NETWORK FOR HYDRAULIC CALCULATION
DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT	
JAPAN INTERNATIONAL COOPERATION AGENCY	

C value at 110. Calculation was conducted by computer after preparing the energy method network programme.

ii) Design Flow

The design flow to be used for hydraulic calculation is based on the maximum hourly flow obtained from the maximum hourly flow coefficient calculated as follows:

Maximum daily flow = Average daily flow x 1.4*
Maximum hourly flow = Average daily flow x 2.0*
Therefore,
Maximum hourly flow coefficient = 2.0/1.4 = 1.43
(* indicates figures in the Dar es Salaam Master Plan)

The design flow of each distribution system was calculated using the maximum hourly flow coefficient as shown in Table 3-7.

Table 3-7. Design Flow (Maximum Hourly Flow)

Distribution system	Maximum daily flow (m^3/d) (1)	Maximum hourly flow coeff. (2)	Maximum hourly flow (m^3/d) (3) = (1) x (2)
Upper Ruvu	42,000	1.43	60,060
Lower Ruvu	182,000	1.43	260,260
Total	224,000	-	320,320

iii) Determination of Cases for Network Calculation

Four cases for hydraulic calculation of the network were determined in consideration of present and future operation of the distribution system.

Case-1: To calculate the flow to be distributed by the Kimara and University reservoirs and from the upper area to lower area under existing condition before the service area is divided.

Case-2: To calculate a situation of insufficient water pressure after division of the service area.

Case-3: To calculate an improved situation of Case-2 with regard to the low water pressure area. Also, for selecting the size of the new trunk main. Pipe size is tentatively determined at ϕ800mm and ϕ900mm considering the connection with the ϕ750mm existing pipe in the downstream.

Case-4: To calculate in case of changes in water pressure situation, the head of booster pump and the inflow rate to the Kimara Reservoir when the booster pumping station (under construction) is being operated under Case-3 condition.

Each case for hydraulic calculation is summarized in Table 3-8.

Table 3-8. Cases of Hydraulic Calculation

Case	Number of Service Area	Distribution Trunk Main	Booster Pumping Station *	Distribution Flow (m^3/d)	
1	1	-	-	Kimara University	42,000 182,000
2	2	-	-	Kimara University	42,000 182,000
3	2	ϕ800 & ϕ900	Not operating	Kimara University	42,000 182,000
4	2	ϕ800	In Operation	Kimara University Booster P.S.	23,000 201,000 19,000

Note:* Indicates the booster pumping station for transmitting and distributing water from the lower area to the upper area which is being constructed by NUWA DSMB under the Link Project.

i. Results of Calculation

Outputs of the computation are attached in Appendix-6. All junctions showing a fall in water pressure below 15m were picked out and shown in Fig. 3-7. The results of the calculations are summarized as follows:

Case-1: Without dividing the service area into the upper and lower service areas, the distribution flow from the Kimara and University reservoirs are obtained at $124{,}000m^3/d$ and $196{,}000m^3/d$ respectively. The flow from the Kimara Reservoir shows two times the plant capacity. On the contrary, the flow from the University Reservoir shows only 75% of the plant capacity. The distribution flow in each service area is not balanced.

The phenomenon occurred caused by the large elevation difference of 64m between the Kimara Reservoir (HWL:El. 135.9m) and the University Reservoir (HWL:El. 64.8m). The operation of more than two reservoirs in a service area with such a large elevation difference as in Dar es Salaam, without regulating water pressure, would be almost impossible. Thus, it was proved that the service area of Dar es Salaam must be divided at least into an upper and lower service area.

Case-2: When the service area is divided, the water pressure drops below 15m in the Kimara Area in the Upper Service Area and at three places in the Msasani area; one place south of Morogoro Road and two other places at the end of the pipeline in the Lower Service Area.

The drop in pressure at the Kimara area is unavoidable since it occurred at a place of particularly high elevation. New pipeline must be installed to solve the lack of water pressure in the Lower Service Area and supplement the existing distribution network.

Case-3: Computation was conducted based on the new pipe being of ∅800mm and ∅900mm diameter. In case of ∅800mm pipe, water pressure becomes insufficient at two places. These are the Msasani and Mtambani areas. The same places showed lack of water pressure for computation of the ∅900mm pipe.

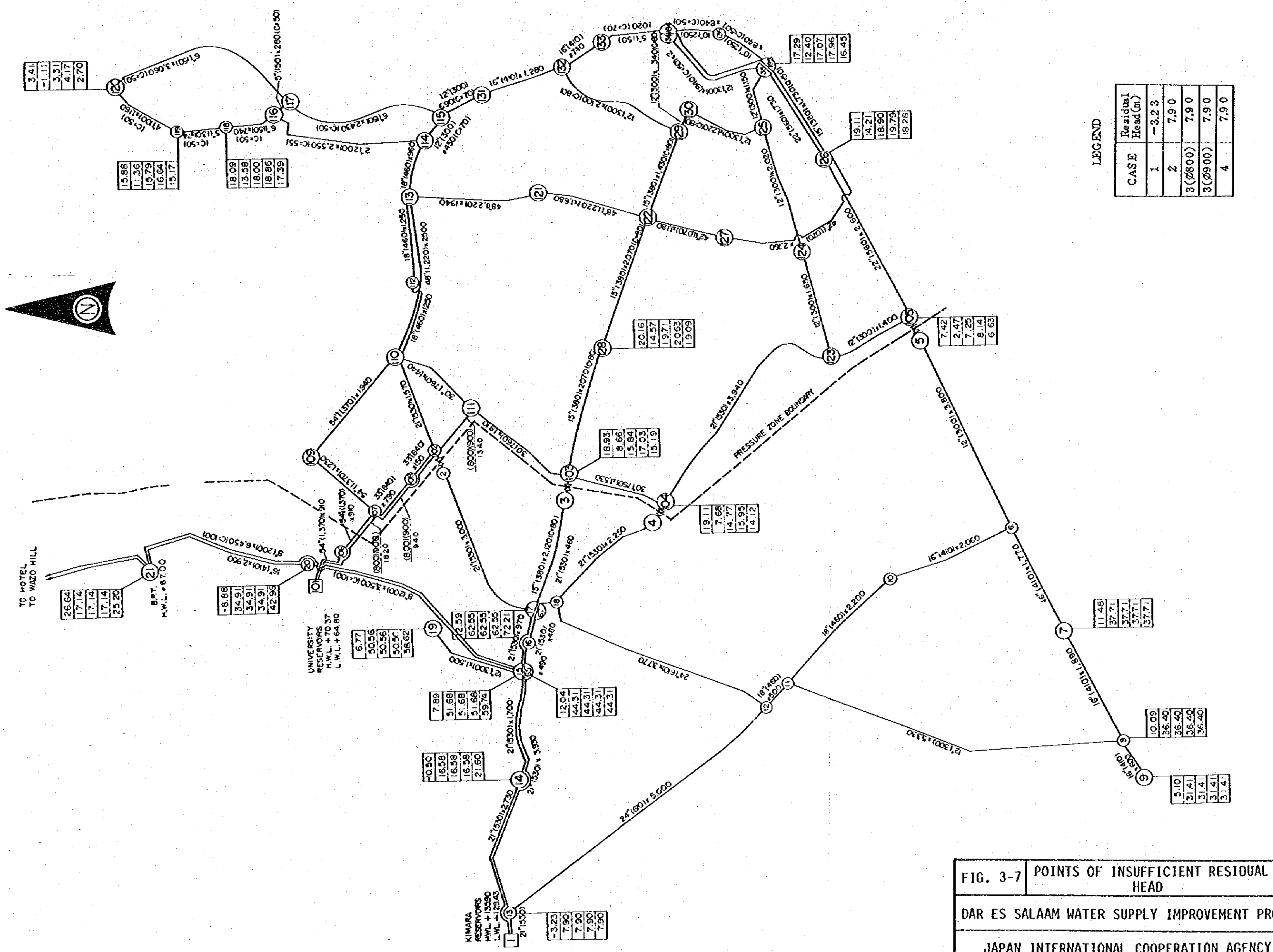
It was found from hydraulic analysis that there was little difference in the effective water pressure of the distribution network use of either in regard to the pipe diameter being ∅800mm or ∅900mm.

Case-4: When the booster pumping station is in operation water pressure of most of the typical junctions fall about 60cm, compared to that of Case-3, and the water distribution condition is not particularly different.

j. Determination of Scale of the Valves for Division of the Service Area and the Kijito Nyama Trunk Main

The diameter of the new distribution trunk main was examined by computation of Case-3 and Case-4. The computation results proved that the difference of ∅800mm and ∅900mm in pipe diameter did not change the water distribution situation.

Accordingly, the diameter of the new distribution trunk main is determined at ∅800mm because of its lower cost. This long pipeline is laid for the length of 4,100m between the University Reservoir and Mwana Nyamala. (The distribution trunk main is called the Kijito Nyama Trunk Main hereinafter). Ductile cast iron pipe is adopted for the type of pipe due to reasons of economy and



LEGEND

CASE	Residual Head (m)
1	−3.23
2	7.90
3 (∅800)	7.90
3 (∅900)	7.90
4	7.90

FIG. 3-7	POINTS OF INSUFFICIENT RESIDUAL HEAD
DAR ES SALAAM WATER SUPPLY IMPROVEMENT PROJECT	
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superiority of material.

Specifications for the Kijito Nyama Trunk Main are as follows:

Pipe Diameter : ϕ800mm
Length of Pipeline : 4,100m
Type of Pipe : Ductile Cast Iron Pipe, Class 4, T-Type Joint

Connection to Existing Pipes

ϕ700mm: 1 place
ϕ1,350mm: 1 place, ϕ800mm x 30m
ϕ525mm: 1 place, ϕ500mm x 20m
ϕ750mm: 1 place

Washout : 1 place, ϕ300mm x 6m with sluice valve
Air Valve : 7 places, ϕ100mm dual head
River Crossing: 1 place, ϕ800mm x 45m
Valve : 10 units
ϕ500mm x 1 unit, Butterfly Valve
ϕ800mm x 8 units, " "
ϕ1,350mm x 1 unit " "

Regarding the valves to divide the service area, it was proved in the process of hydraulic analysis of the distribution network that the installation of valves at Manzese and Mtambani complete the division of the water service area. The diameter of the valves are determined to coincide with those of the existing pipelines; these are ϕ375mm and ϕ300mm for Manzese and Mtambani respectively. Sluice valve is adopted for the type of valve in consideration of the superiority of its closing mechanism.
Thus, the valves are determined as follows;

Manzese : ϕ375mm sluice valve and chamber x 1 unit
Mtambani : ϕ300mm sluice valve and chamber x 1 unit

4) Water Intake Plan

At present, six low lift pumps are installed. Pump Nos. 1, 2 and 3 (England) and Nos. 4, 5 (West Germany) and 6 started operation from 1970 and 1974 respectively. It is considered that the wear and tear on the runner and on the impeller, where contact with water has resulted in lowered efficiency in pumping, were caused by silt deposits in the pump well from the turbid waters of the Ruvu River. Also, two pumps are out of order due to the lack of spare parts. Possibility of continuous operation of the intake facilities is uncertain. Present use situation is shown in Table 3-9.

Table 3-9. Present Condition of Low Lift Pumps

Pump No.	Specifications	Manufacturer	Condition of Operation
1	22.8 m^3/min x 70.2m x 380kw	England	In operation; low efficiency
2	" " "	"	Under repair, operation to resume from mid-July
3	" " "	"	Out of use
4	11.4 m^3/min x 70.2m x 190kw	W. Germany	Out of use since July; no spare parts
5	22.8 m^3/min x 70.2m x 380kw	"	In operation but unreliable due to frequent disrepair
6	" " "	"	(same as above)

The pump Nos. 1, 5 and 6 are under use at present and securing a flow of 66.8m^3/min, however continuous operation is not expected. Especially, No. 3 and No. 4 pumps are inoperable now. As shown in Table 3-11, No. 4 pump had been operated as needed but the uneven monthly operation hours through the years showed unstable condition of the pumping unit. Therefore, No. 3 and No. 4 are designated as suitable pumps for replacement.

a. Intake Flow

The flow transmitted to the Kimara Reservoir was determined at $42,000m^3/d$ due to restrictions of the water transmission system although the rated capacity of the Upper Ruvu system is $82,000m^3/d$. Accordingly, the intake flow is determined based on the maximum daily flow of 42,000 m^3/d. Considering water leakage from the 7 km-long raw water main and water use within the water treatment plant, the intake flow must be determined by adding 10% to the maximum daily flow. Therefore,

$$\text{Intake Flow} = 42,000m^3/d \times 110\%$$
$$= 46,200m^3/d$$

b. Pump Capacity

Intake pumps are designed with the same capacity of the existing No. 3 and No. 4 pumps in consideration of balancing with other pumps for joint operation. (Intake pump is called low lift pump hereinafter). Therefore, the total capacity of the new units are calculated as,

$$(22.8m^3/min + 11.4m^3/min) \times 60min \times 24hrs = 49,200\ m^3/d$$

The capacity obtained is 1.07 times of the intake flow of $42,000m^3/d$; however, the low lift pumps are designed in the same capacity as the existing pumps considering the deteriorated raw water main and for balanced operation with other existing pumps. Total pump head is determined at 70.2m which is the same head with the existing pump.

c. Replacement Items

New No. 3 low lift pump : $22.8m^3/min \times 70.2m \times 380kw \times 1$ unit
New No. 4 low lift pump : $11.4m^3/min \times 70.2m \times 190kw \times 1$ unit

Auxiliary equipment such as sluice valves, check valves, pressure meters, pressure tank, piping, etc. and electrical works are included as necessary for the scope of work.

5) Water Transmission Plan

Six units of water transmission pumps had been installed originally. However, only two pumps are now in operation, while one pump is under repair and the other three units have been removed. Present condition of the pump units is tabulated in Table 3-10 below:

Table 3-10. Present Condition of High Lift Pumps

Pump No.	Specifications	Condition of Operation
1	34 m^3/min x 152.5m x 1,120 kw	In operation, frequent breakdown
2	22.8 m^3/min x 152.5m x 800 kw	Under repair
3	22.8 m^3/min x 152.5m x 800 kw	In operation; frequent breakdown
4	11.4 m^3/min x 152.5m x 400 kw	Removed
5	13.6 m^3/min x 152.5m x 480 kw	Removed
6	(unknown)	Removed

Note: Pumps are manufactured in England

a. Water Transmission Flow

Design capacity of the water transmission flow was determined at 42,000 m^3/d as described previously (3.3.2, Section 2, Water Transmission Capacity of the Rising Mains), obtained from the interrelations of the capacity and performance curve of the existing pump No.1 and the pipeline profile of the rising mains.

b. Pump Capacity

Pump capacity to be replaced is determined based on the water transmission flow of 42,000 m^3/d and the capacity of existing pumps. There are three pump usage possibilities for securing the flow: (1) No.1 pump, (2) No.2 and No.4 pumps, and (3) No.3 and No.4 pumps. Considering the operational condition of the No.1 and No.3 pumps running presently, replacement of No.2 and No.4 pumps is considered the best means for securing the flow. Accordingly, the design flow of the water transmission pump is given as follows:

$$(22.8\ m^3/m + 11.4\ m^3/m) \times 60\ min \times 24\ hours = 49,200\ m^3/d$$

Total head is determined at 152.5m which has the same head as that of the existing pump. (Water transmission pump is called the high lift pump hereinafter.)

c. Replacement Items

New No.2 high lift pump: 22.8 m^3/min x 152.5m x 800 kw
New No.4 high lift pump: 11.4 m^3/min x 152.5m x 400 kw

Auxiliary equipment, such as sluice valves, check valves, pressure meters, pressure tank, piping, etc. and electrical works, are included as necessary for the scope of work.

System curve of the high lift pumps are indicated in Fig. 3-8.

6) Replacement of Air Valves

It is assumed that water leakage of the rising mains is mostly caused by damage of air valves. In this plan, water leakage must be minimized by replacing leaking air valves which, in addition to replacement of the high lift pumps, would achieve the purpose of securing water transmission flow.

Location of the leaking air valves and the numbers to be replaced were determined referring to the "Dar es Salaam Water Supply Upper Ruvu Low Lift, High Lift and Gravity Mains Survey Drawings, 1973". Table 3-12 indicates the required minimum number of air valves to be replaced.

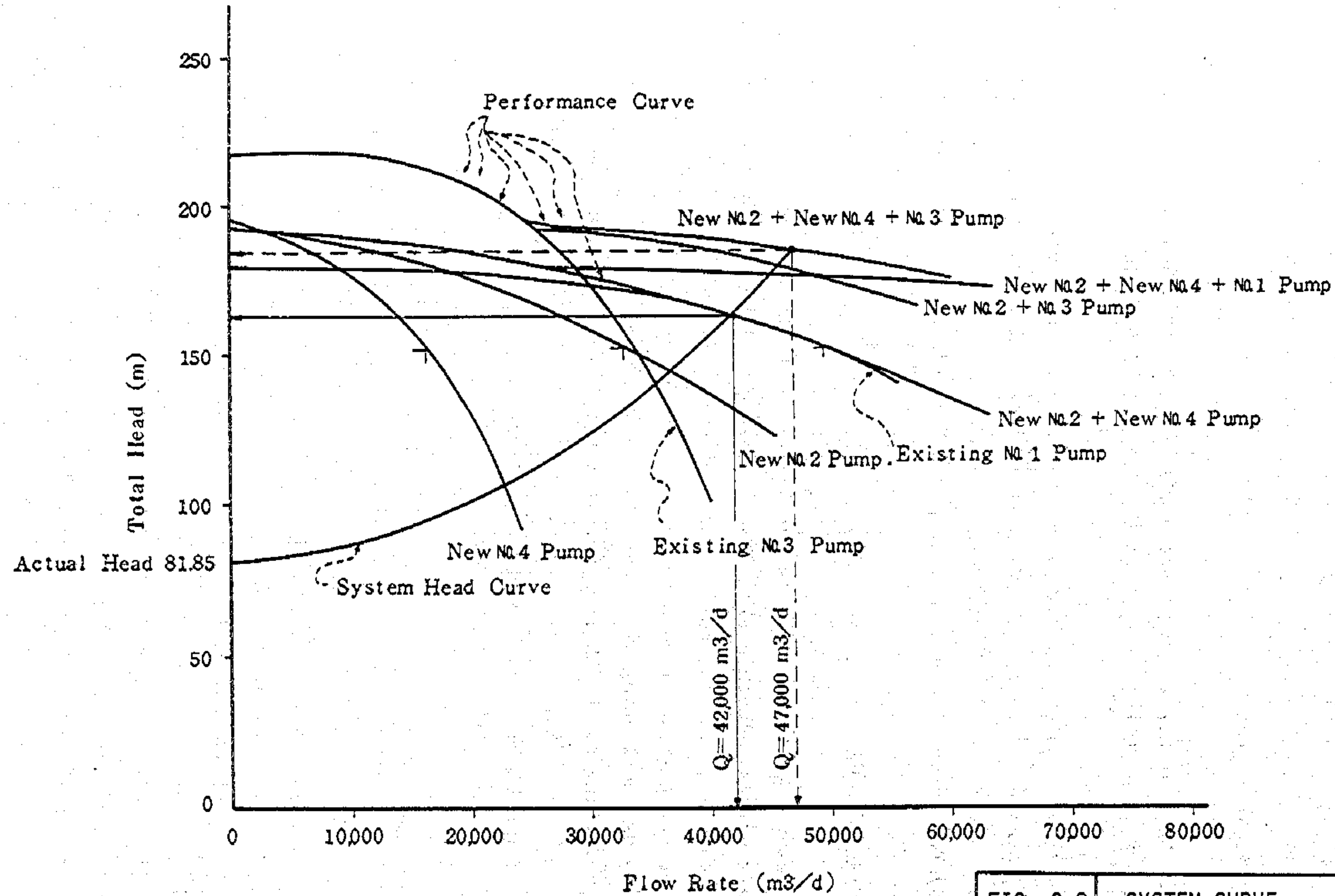

FIG. 3-8	SYSTEM CURVE
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Table 3-11. Monthly Hours and Rate of Pump Operation

(Unit: hours)

Month	Low Lift Pump					High Lift Pump					
	No.1	No.2	No.4	No.5	No.6	No.1	No.2	No.3(old)	No.3(new)	No.4	No.7
1983 June			428	429			86	198	397		
July	548		527	447	64		371	150	534	21	
Aug.	642		545	632	203		506	161	675		
Sept.	621		414	251	249		287	432	588		
Oct.	532		286	394	454		424	222	525		
Nov.	342	524		499	686		683	90	690		
Dec.	3	619	150	646	635		595	132	637	9	19
1984 Jan.		423	245	636	645		550		514		234
Feb.		504	302	171	458	2	620		641		434
Mar.		701	58	174	673	210	479		647		475
Apr.	178	705	115	378	700	684			465		108
May	727	256	454		654	685	8		309		39
June	473		230	98	338	398			197		
Total	4,066 (43.9%)	3,732 (40.3%)	3,754 (40.5%)	4,755 (51.3%)	5,759 (62.2%)	1,979 (21.4%)	4,609 (49.8%)	1,385 (15.0%)	6,819 (73.6%)	30 (0.3%)	1,309 (14.1%)

Note: ( ) indicate the rate of operation

Table 3-12 Air Valves to be Replaced

Distance from the Plant (m)	Diameter		Type	Number	Drawing Number	Situation
	Pipe (inch)	Air Valve (inch)				
4,800	24 1/2	4	Dual Head	1	HMS/14	Leaking
9,820	24 1/2	4	" "	1	" 26	Broken
14,394	30	4	" "	1	" 37	Broken
17,867	30	6	" "	1	" 46	Leaking
20,946	30	6	" "	1	" 54	Leaking
"	24 1/2	4	" "	1	" 54	Under Soil
30,739	24 1/2	4	" "	1	" 78	Under Soil
33,700	21 1/2	4	" "	1	" 86	Under Soil
39,077	21 1/2	4	" "	1	" 99	Under Water
"	30	6	" "	1	" 99	Leaking
48,455	21 1/2	4	" "	1	" 123	Removed
48,738	21 1/2	4	Single Head	1	" 123	Removed
50,218	20 1/2	6	Dual Head	1	" 127	Removed

7) Installation of Chlorination Equipment at the Reservoirs

At present, chlorination equipment is installed in each water treatment plant. However, the feeding system at the Upper Ruvu plant is broken and chlorine is being fed manually. Also, in the Lower Ruvu plant, difficulty of obtaining chlorine gas requires the use of sodium hypochlorite or calcium hypochlorite solution.

Problems of chlorination are raised by the long rising mains of more than 50 km length for the respective plant systems, causing the residual chlorine to be consumed on the way to the distribution reservoirs. The chlorination systems have not been working effectively, resulting in insufficient disinfection and hygienically unsafe or dangerous for water distribution.

Accordingly, it is necessary to install chlorination equipment at the site of the Kimara and University reservoirs to enable sufficient residual chlorine to remain in the water to be distributed. Planning for the chlorination equipment is indicated as follows.

a. Kimara Reservoir

Distribution Flow:	42,000 m^3/d
Rate of Dosing:	Max. 3 ppm, Ave. 1.5 ppm
Chemical to be Used:	Calcium Hypochlorite (60 % chlorine)
Method of Dosing:	Injection by Diaphragm pumps
	60 l/hr x 0.2 kw x 2 units
	53 l/hr x 0.2 kw x 1 unit
Solution & Storage Tank:	$2.5m^3$ x 2 tanks, steel structure
Dosing Point:	Inlet pipes, 2 points
Housing:	8.0(L) x 9.0(W) x 4.5(H) m

b. University Reservoir

Distribution Flow:	182,000 m^3/d
Rate of Dosing:	Max. 3 ppm, Ave. 1.5 ppm
Chemical to be Used:	Calcium Hypochlorite (60% chlorine)
Method of Dosing:	Injection by Diaphragm pumps
	484 l/hr x 0.4 kw x 2 units
Solution & Storage Tank:	10 m^3 x 2 tanks, steel structure

Dosing Point: Junction Well, 1 point

Housing: 8.0(L) x 9.0(W) x 4.5 (H) m

Facilities and/or equipment required for this plan are summarized below:

Construction Site	Content of Facilities		Appurtenances
Valves for Division of Service Area			
Manzese	ϕ 375 mm	1 set	Valve Chamber
Mtambani	ϕ 300 mm	1 set	Valve Chamber
Kijito Nyama Trunk Main			
University Reservoir - Mwana Nyamala	ϕ 800, Ductile Cast Iron Pipe, Class 4, Length = 4,100m		Valves, Washout, Air Valves, etc.
Low Lift and High Lift Pumps			
Upper Ruvu Intake Plant	22.8 m^3/min x 70.2m x 380 kw x 1 unit 11.4 m^3/min x 70.2m x 190 kw x 1 unit		Sluice Valve, Check Valve, Pressure Tank, etc.
Upper Ruvu Water Treatment Plant	22.8 m^3/min x 152.5m x 800 kw x 1 unit 11.4 m^3/min x 152.5m x 400 kw x 1 unit		(Same as above)
Air Valves			
Upper Ruvu Water Treatment Plant - Kimara Reservoir	ϕ100mm - 9 places ϕ150mm - 4 places		—
Chlorination Equipment			
University Reservoir	Solution & Storage Tank 10m^3 x 2 units Dosing Pump 484 l/h x 0.4 kw x 2 units		Chlorination House 72 m^2