No. 4

BASIC DESIGN STUDY REPORT
ON
THE IMPROVEMENT OF WATER SUPPLY SYSTEM
OF
MAJURO ATOLL
IN
THE REPUBLIC OF THE MARSHALL ISLANDS

DECEMBER, 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

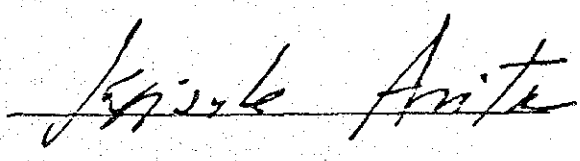
In response to the request of the Government of the Republic of the Marshall Islands, the Government of Japan has decided to conduct a basic design Study on the Improvement of the Water Supply System Project in Majuro Atoll and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to the Republic of the Marshall Islands a study team headed by Mr. Ryuji Matsunaga, First Basic Design Division, Grant Aid Planning & Survey Department, from August 4th to August 31st, 1986.

The team had discussions on the Project with the officials concerned of the Government of the Republic of the Marshall Islands and conducted a field survey in the Majuro Atoll area. After the team returned to Japan, further studies were made, a draft report was prepared and a mission to explain and discuss it was dispatched to the Republic of the Marshall Islands. As a result, the present report has been prepared.

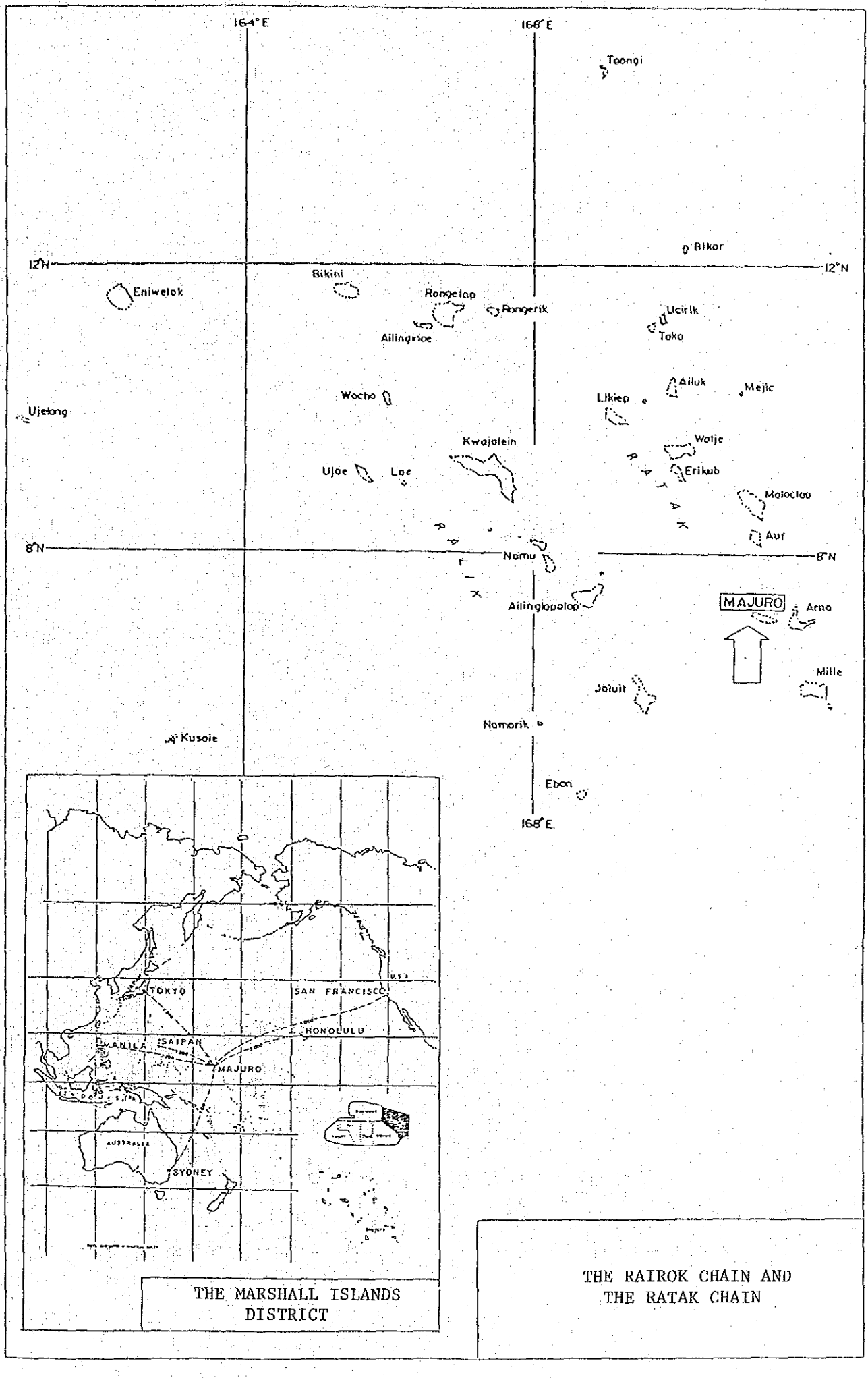
I hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

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

December, 1986



Keisuke Arita
President
Japan International Cooperation Agency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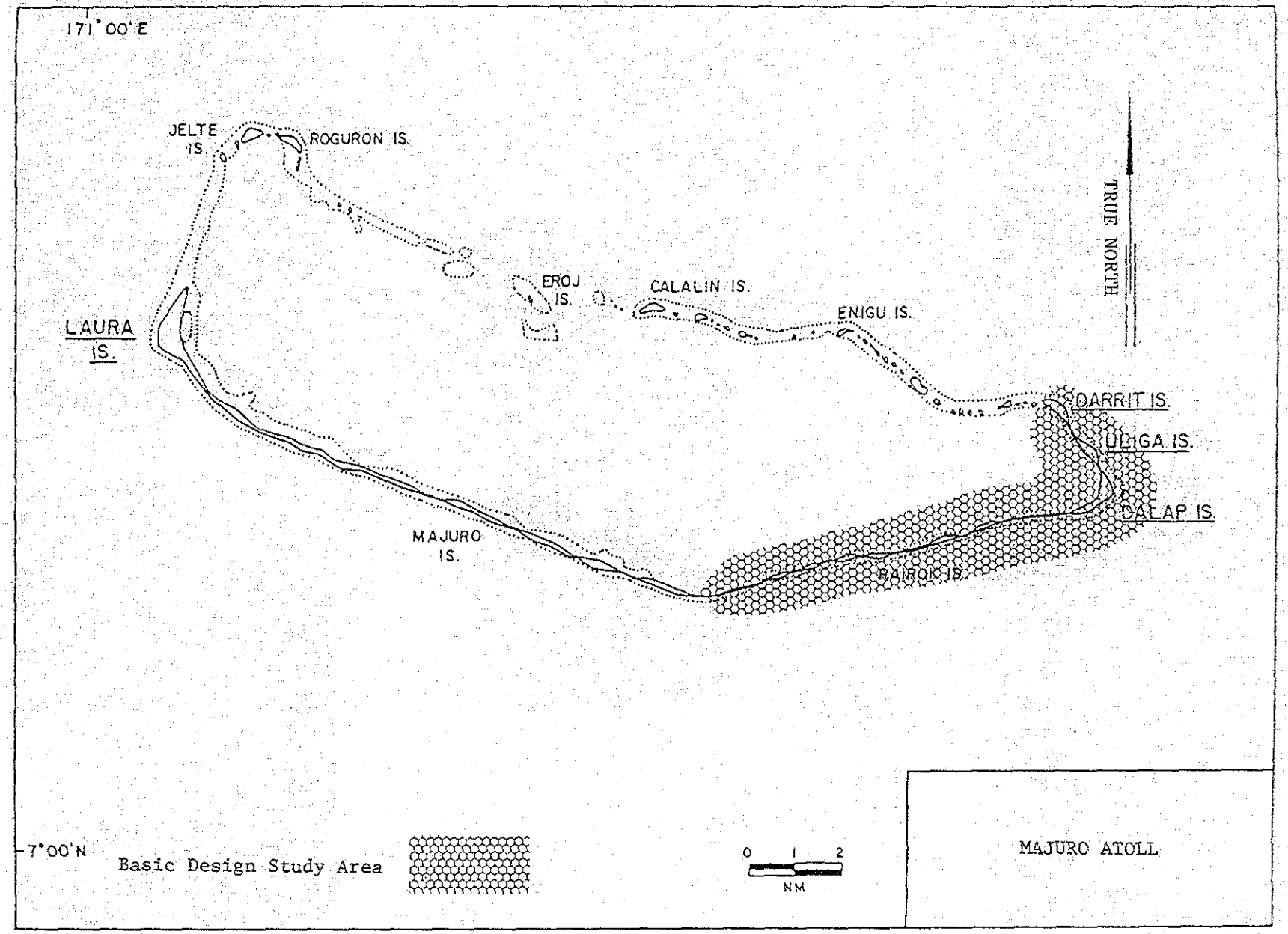
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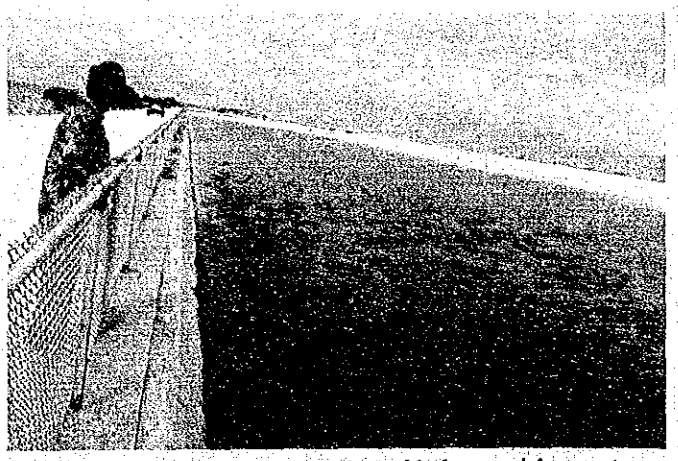
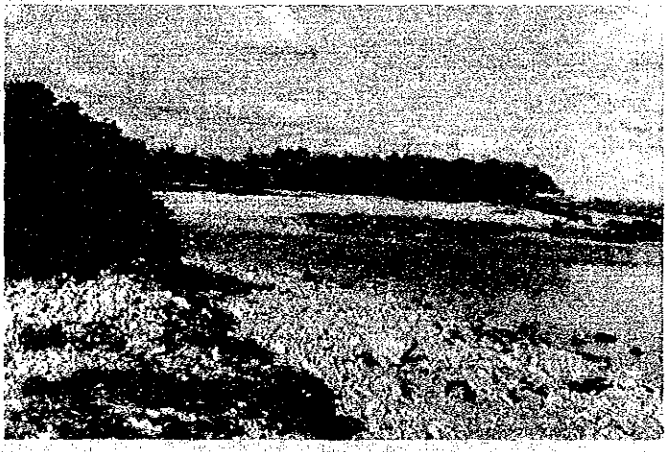


Raw Water Catchment at Majuro Airport

(Taken on August 6th, 1986, immediately after torrential rain)

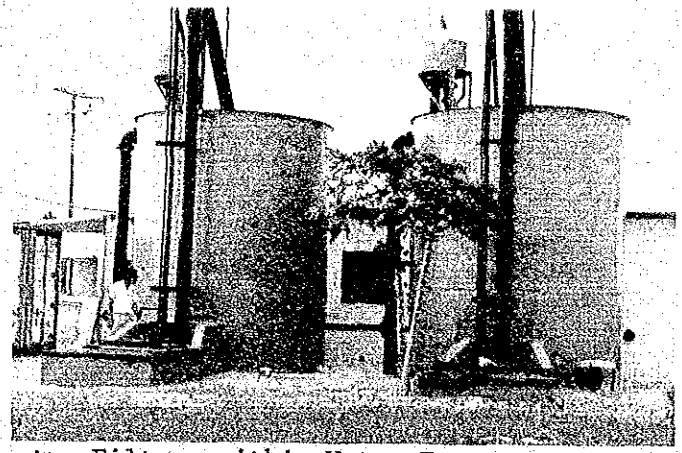
Pump House No. 4

Raw Water Reservoir for Water Treatment Plant "C"

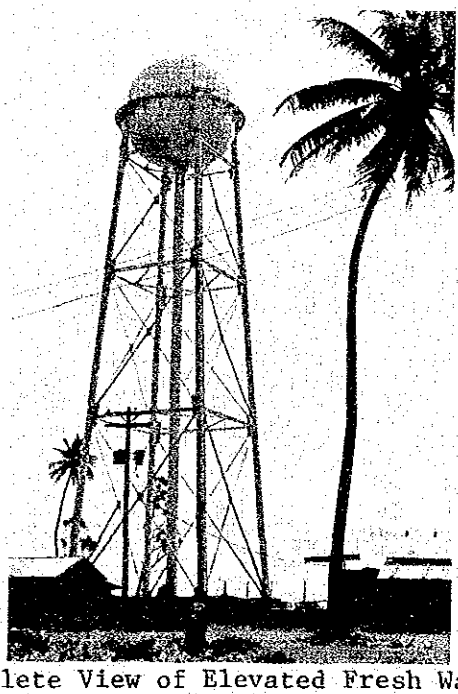


Proposed Site for Construction of New Raw Water Reservoir, Right View

Left View



Gravity Filters within Water Treatment Plant "C"



Complete View of Elevated Fresh Water Storage Tank No. 2

Column Base of Elevated Tank
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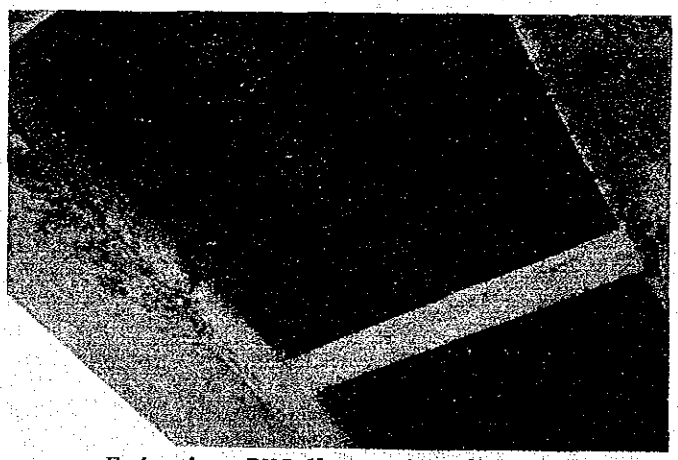

Existing PVC Water Supply Pipe
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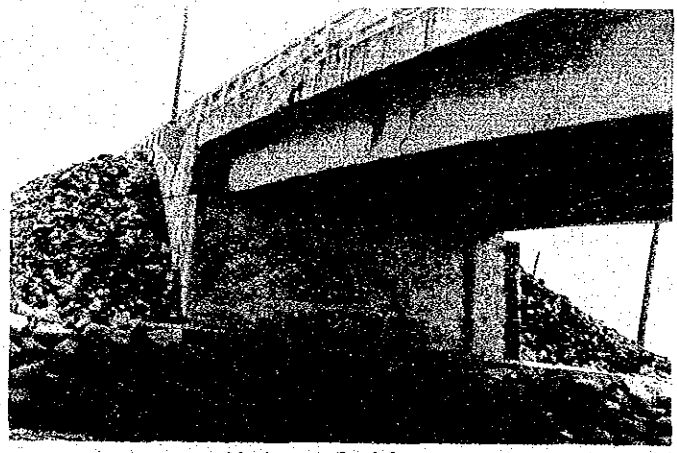
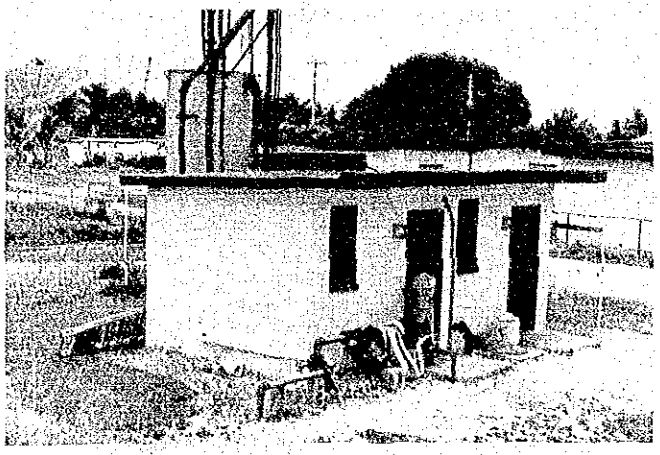


Majuro Bridge



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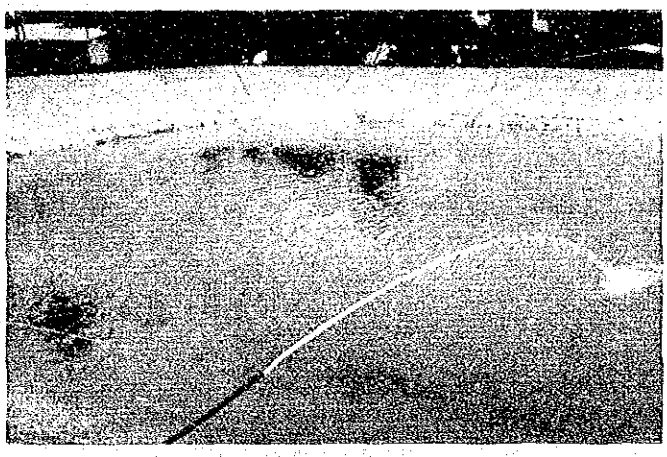

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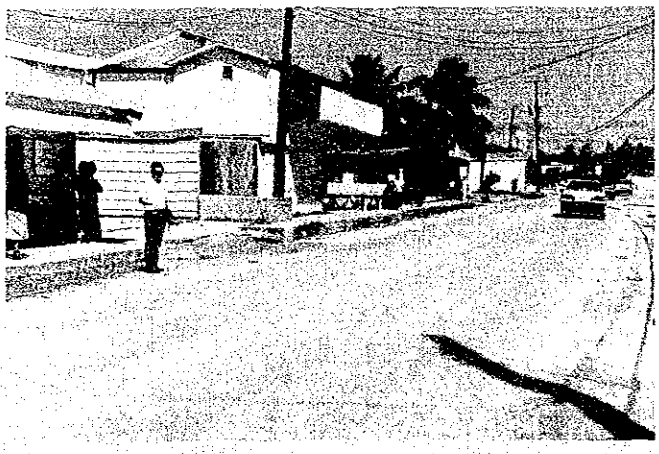

Street of DUD Area
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Sewer Construction Site

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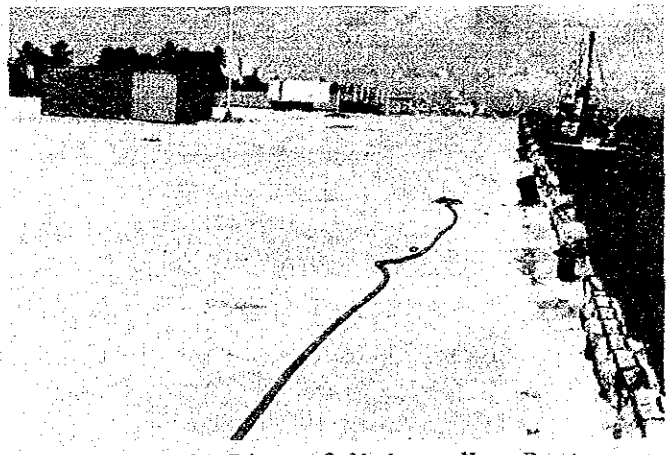

Alongside Pier of Majuro New Port

Shallow Well in Laura District

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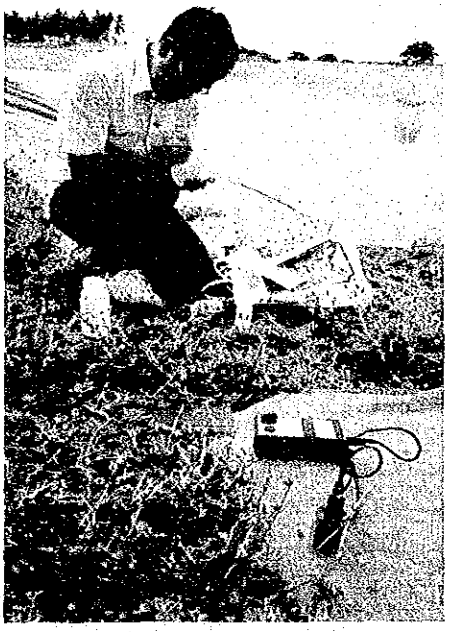

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ABBREVIATIONS

AC Pipe	Asbestos Cement Pipe
CIP	Capital Improvement Projects
DPW	Department of Public Works
DUD	Darrit, Uliga & Dalap
DWG.	Drawing
E/N	Exchange of Notes
EXIST.	Existing
Fig.	Figure
F/W	Fresh Water
GPM	Gallon Per Minute (= 3.785 liter/minute)
HP	Horse Power
kGal	Kilo-gallon
MPW	Ministry of Public Works
NINE GROUP	Nine Well Enterprise Co., Ltd. & Nine Golden Engineering Co., Ltd.
P/H	Pump House
PII	Pacific Internationl, Inc.
PPM	Parts Per Million
psi	Pound Per Square Inch (= 0.0703 kgf/cm^2)
Q'ty	Quantity
RMI	The Republic of the Marshall Islands
RPM	Revolutions Per Minute
R/W	Raw Water
TDH	Total Dynamic Head
T/P	Treatment Plant
TTPI	Trust Territory of the Pacific Islands
UN	United Nations
W/T	Water Treatment

SUMMARY

SUMMARY

The water demand on Majuro Atoll in the Republic of the Marshall Islands (RMI) has been annually increasing due to rapid population growth, improvement in the living standard, the provision of hospitals and hotels and the development of water-consuming industries including fish processing. Therefore, the urgent preparation of a stable water supply system for the capital, Majuro, has become a matter of utmost importance.

The existing water supply system was provided in 1973 using U.S.A. grant aid and it employs the method whereby rainwater is collected from Majuro Airfield, stored at 5 existing reservoirs (total capacity: 15 million gallons), purified and then directly supplied to households and offices.

This system, however, has already become inadequate to supply an appropriate water quantity to the current population. As a result, the water supply is normally restricted to 13 hours a day (from 6:30 to 19:30). Moreover, depending on the rainfall situation during the rainy season, severe restrictions are imposed during the dry season, for example the water supply is limited to 2 hours three times a day (morning, midday and evening), 2 hours twice a day (morning and evening), 2 hours once a day, or on occasions only 2 hours every 2-3 days. Also, a uniform fresh water supply in the area has not been achieved due to the lack of an adequate water supply network.

Under such circumstances, RMI requested the Government of Japan to provide a grant aid for the Project for Improvement of the Water Supply System. In response to this request, the Government of Japan decided to carry out a basic design study and accordingly, the Japan International Cooperation Agency sent a study team to RMI to prepare the basic design of the project.

In consultation with officials of RMI, the Study Team conducted a field survey consisting of the evaluation of the fresh water supply

situation on Majuro Atoll, the collection of materials and information on the 5 Year Development Plan of RMI and existing fresh water supply facilities, a topographical survey and soil investigation along fresh water supply pipeline route, water quality and water pressure tests, a study on the served area and the served population, a study on the operation and maintenance of the existing facilities and a study on the available construction equipment, etc. On arrival back in Japan, the Study Team compiled the optimum basic design based on the results of this field survey.

The basic schemes for the Project for Improvement of Water Supply System have been decided as follows;

(1) The design target year will be 2000 which is also the target year for the completion of RMI's National Development Plan formulated in 1981.

(2) The design served area for the fresh water supply will be between Majuro Airport and Rita, including the Darrit, Uliga and Dalap (DUD) area.

(3) The planned population, served population and diffusion rate in the target year of 2000 will be 16,000, 15,520 and 97%, respectively.

(4) The design average daily water supply volume in the target year of 2000 will be 3,600m^3/day which is equivalent to an average supply volume of 200 ℓ/capita with 140 ℓ/capita being used for daily life.

The water collection and supply system will consist of the following.

a) Rainfall in the catchment at Majuro Airport (airport field and surrounding area) will be collected for storage at raw water reservoirs located near the Airport. After treatment, the water will then be stored in the fresh water reservoir.

b) Sea water inflow prevention facilities will be constructed near the existing pump house No. 4 to prevent the supply of fresh water being contaminated with a high salt content due to the inflow of sea water into the catchment during stormy weather.

c) Using the fresh water supply pumps in the existing facilities of water treatment plant "C", fresh water will be pumped up to the existing elevated fresh water storage tanks (No. 1 and No. 2) in DUD area via a new fresh water supply pipeline.

d) An additional gravity filter and supplementary pumping facilities will be installed within water treatment plant "C" in order that an adequate operational capacity and a stable supply of clean fresh water can be provided.

e) The water distribution will be based on gravity flow from the elevated fresh water storage tanks using the existing fresh water supply-distribution pipelines. This method intends a stable and uniform water distribution to houses and offices in the served area extending from Rita to Majuro Airport.

f) The present water supply system will be modified to secure an almost uniform fresh water distribution to the entire served area. A standard system will be introduced whereby new supply pipelines are installed and the existing fresh water storage tanks are utilized while the existing fresh water supply-distribution pipelines are used only as distribution pipelines. However, the function of a direct water distribution to houses and offices from the fresh water supply pump house of water treatment plant "C" will be maintained as in the case of the present system.

g) The new system operates the fresh water supply pumps automatically in accordance with the water level in the elevated fresh water storage tanks.

h) New water meters will be provided to those houses and offices which currently do not have meters. The provision of these water meters is intended to prevent water leakage from faucets and pipes in houses and offices, increase the effective usage rate, enable a fair water billing based on the amount used, improve operation and maintenance, establish a viable waterworks and enlighten residents.

i) The existing elevated fresh water storage tanks will be used, being improved, repaired and maintained.

j) The newly installed fresh water supply pipelines will mainly consist of 350, 300 and 250mm dia. ductile cast iron pipes. Steel pipes (250 and 200mm dia.), however, will be used for the fresh water supply and distribution pipelines for the elevated fresh water storage tanks in consideration of workability and safety. The optimum pipe size will be selected based on the water demand in the design target year.

An outline of the Project for Improvement of Water Supply System is as follows.

Outline of the Project for Improvement of Water Supply System

Served Area	Between Rita and Majuro Airport
Design Served Population	15,520 persons
Design Daily Supply Volume	3,600 m^3/day
Water Source	Existing Source
Reservoir	Construction of new raw water reservoir (capacity: 9 million gallons)
Pump house No.4	Conversion of existing pump house: construction of sea water inflow prevention facilities and partial improvement of existing raw water pump house.
Water Treatment Facilities	Conversion of existing facilities: installation of one automatic siphon gravity filter (226 gallons/minute) and supplementary pumping facilities.
Elevated Fresh Water Storage Tanks	Improvement and repair of existing tanks (100,000 gallons x 2) and erection of supplementary facilities.
Fresh Water Supply Pipelines	o Construction of fresh water supply pipelines with supplementary facilities Ductile Cast Iron Pipe: ϕ350 mm x 12.2 km Ductile Cast Iron Pipe: ϕ300 mm x 2.6 km Ductile Cast Iron Pipe: ϕ250 mm x 0.2 km Steel Pipe: ϕ250 mm x 132 m (for two elevated fresh water storage tanks) Steel Pipe: ϕ200 mm x 80 m (for two overflows) Supplementary facilities: one unit (gate valve, air valve and mud discharge pipe) RC Surge Tank: three units
Water Distribution Pipelines	Existing asbestos cement fresh water supply-distribution pipelines (ϕ8", 10" and 12") will be used.
Water Meter for Leakage Prevention	Provision of water meters: about 750 pieces

The main responsibility to be borne by RMI, roughly estimated at 628,400 US dollars (104 million Japanese yen), is as follows.

- o Land reclamation for a new raw water reservoir and installation of riprap for protection from sea water before handover of site for construction commencement.
- o Riprap removal before excavation and replacement after installation of new fresh water pipelines.
- o Customs duties and other costs imposed on equipment and material imported from Japan and third countries.
- o Installation cost of water meters.

The organization responsible for the implementation of the Project on RMI side will be the Ministry of Public Works (MPW). It will be important for RMI to smoothly implement the entire construction work of the Project by being in close communication and consultation with the Japanese Consultant and Construction Contractor.

The Project will consist of two phases, the contents of which are as follows.

(1) Phase I

1) Construction of sea water inflow prevention facilities and partial improvement of existing raw water pump house.
2) Additional installation of a gravity filter and supplementary pumping facilities.
3) Construction of a raw water reservoir (capacity: 9 million gallons).
4) Improvement and repair of existing elevated fresh water storage tanks and erection of supplementary facilities.

(2) Phase II

1) Construction of fresh water supply pipelines.

2) Provision of water meters.

The required construction period, including the detailed design and tendering periods, will be 14.5 months for Phase I and 17.5 months for Phase II after signing of the Exchange of Notes (E/N).

The annual operation and maintenance cost for the fresh water supply system will be some 210,000 US dollars (approximately 34,650,000 Japanese yen) and the system will be maintained by MPW.

MPW will be responsible for the proper implementation of the work to be carried out by RMI, i.e. land reclamation for the new raw water reservoir (capacity: 9 million gallons), installation of riprap, removal and replacement of riprap along routes where fresh water lines are to be laid down, securing of land required for all construction work related to the Project and the free supply of required water and electricity on construction sites.

It is hoped that the implementation of the Project will achieve a stable supply of clean potable water to residents of DUD area and the surrounding areas in Majuro, the capital of RMI, therefore, contributing to the stabilization and improvement of the living standard, the improvement of the health environment and also the vitalization of industrial activities. As the Project clearly promises positive effects in the subject area, it is significant for both Japan and RMI that it will be conducted with Japan's grant aid.

CHAPTER 1

GENERAL

CHAPTER 1 GENERAL

It is a primary feature of the Oceanian countries that they form their nations by integrating many of the isolated islands. Because of the scattered nature of the islands the political and economic functions are inevitably concentrated in a main island and one or two secondary islands. This means that overpopulation of the main islands and the depopulation of the other isolated islands.

Majuro atoll, the main island of RMI, is where the main functions of political and economic life are concentrated and is subjected to a rapid increase of population due to a reduction of the infant mortality rate and an increase in the birth rate as well as immigration from other islands. The population is especially concentrated in DUD area, the political and economic center, as people seek more attractive employment opportunities. DUD area is located in the southeastern part of the Majuro atoll and occupies two thirds of the total area of the atoll. Major public facilities such as government buildings, schools and the hospital as well as new and old ports, power station and residences and churches are concentrated in DUD area.

About 1,200 houses, two thirds of the estimated total of 1,700 houses in Majuro atoll and most of the present population of about 11,000 people is concentrated in DUD area. Moreover, the infrastructure of the area is still considered far from being in a satisfactory condition due to the deferred development plan.

The existing water supply facilities of Majuro atoll was constructed in DUD area in 1973 with the assistance of U.S.A. grant aid. However those facilities, indispensable for stable domestic water supply and regional industrial development, are presently insufficient in quantity and quality. Further, it is difficult to secure a stable water supply source in the narrow land space of the atoll under the specific geographic conditions of having no rivers, lakes and ponds.

In the present water supply system water having fallen on the runway of Majuro airport is collected and supplied to five raw water reservoirs with a total storage capacity of 15 million gallons (about 56,800 m^3) to be stored and purified later. The purified water is stored in the fresh water reservoir and supplied to each house and public facility directly by pumping. The present capacity of the raw water reservoirs can meet consumption for about 47 days only and is insufficient to provide an adequate amount of water even for the present population. Accordingly the normal water supply is restricted to 13 hours (from 6:30 to 19:30) a day. In the dry season the water supply is limited to three times a day (morning, midday and evening), two times a day (morning and evening) and once a day at night only, or at times of severe rationing once in two or three days (2 hours each). In August 1986, at the time of the study team's visit, water was supplied only for three hours in the morning, two hours at midday and three hours at night.

Further, due to the deficiency of the water supply network, a uniform water supply is not furnished. In stormy weather the water quality is downgraded by a high salinity concentration caused by sea water influx to the catchment. The extreme water shortage in the terminal water distribution areas is caused by the specific system which supplies water from the water supply pipelines to each house and other commercial and industrial areas by direct pumping. In addition degradation and loss of function are caused by insufficient operation and maintenance of the treatment facilities in DUD area due to the shortage of construction funds and standby equipment, further the anchoring and the main columns of the elevated tanks have deteriorated by corrosion. Therefore, an improvement plan is urgently required.

The water supply system improvement project of Majuro atoll was proposed as a first priority project under the category of public works in the 5 year Development Plan of RMI.

Under such circumstances RMI has requested the Government of Japan for grant aid for the proposed water supply improvement project. The Government of Japan reviewed the request and decided to carry out a basic design study of the proposed project. Based on the above deci-

sion, the Japan International Cooperation Agency dispatched a study team (Appendix-2) headed by Ryuji Matsunaga, First Basic Design Study Division, Grant Aid Planning & Survey Department, to the project site from August 4th to August 31st, 1986.

The objective of this survey is the identification of the existing water supply systems, adequacy of the proposed project and effects of Japan's grant aid for the water supply improvement project of Majuro atoll requested by RMI.

In this survey examinations of the raw and fresh water quality, water supply pressure, longitudinal survey along the planned route as well as testing soil excavations were performed.

The study team performed the site survey and had discussions regarding the background of the request of RMI and objectives of the Project with the officials concerned of RMI and persons of U.S.A. concerned for CIP (Capital Improvement Projects), who are executing the plan, design and construction supervision of the water supply facilities for RMI.

The results of the discussions are mentioned in the minutes as shown in the Appendix-1. After returning to Japan, the study team prepared a report on the basic design study for the water supply improvement project in Majuro atoll taking into account the existing situation of water supply, water supply facilities, operation and maintenance, and other projects related to this proposed project.

CHAPTER 2

BACKGROUND OF PROJECT

CHAPTER 2 BACKGROUND OF PROJECT

2-1 Outline of the National Development Plan

The Marshall Islands were placed under U.S.A. trusteeship by a UN Trusteeship Council and the constitution of the Marshall Islands was established on May 1st, 1979 and the self-governing government started representing the people of the Marshall Islands regarding international issues. The official name of the Republic of the Marshall Islands was adopted and its intention for independence was declared in 1982.

In the meantime, the Compact of Free Association was drafted, this Compact defines the future friendly relationship between the two sovereign Nations in the fields of policy, economics, and naval and military affairs after the termination of UN trusteeship by U.S.A. in 1978.

The Compact of Free Association was approved by RMI in September, 1983 by means of national voting and later approved by U.S.A. in January, 1986. Presently, a bill to terminate the UN trusteeship is presented to UN Security Council to be approved.

However, the Compact of Free Association between the Government of the United States and the Republic of the Marshall Islands came into effect on Oct. 21, 1986.

Two partial plans were prepared in the past. They were the project (1976 - 1981) to deal with eventual economic problems and the investment project (1981 - 1995) including the feasible plan for industrialization in the development plan of the Marshall Islands. These plans have not been realized however, because there were no implementation programs or a comprehensive development strategy. RMI established the full-scale development plan of the first 5 year development plan (1985 - 1989) in 1984. The first five year comprehensive development plan constitutes the initial phase of a

15 year long term development program. This plan was established based on the basic concept of the Compact of Free Association and the implementation schedule. The first 5 year plan consisting of 4 parts and 22 chapters was drafted by the direction of the National Planning Committee and the duties of the government and representative private agencies are defined.

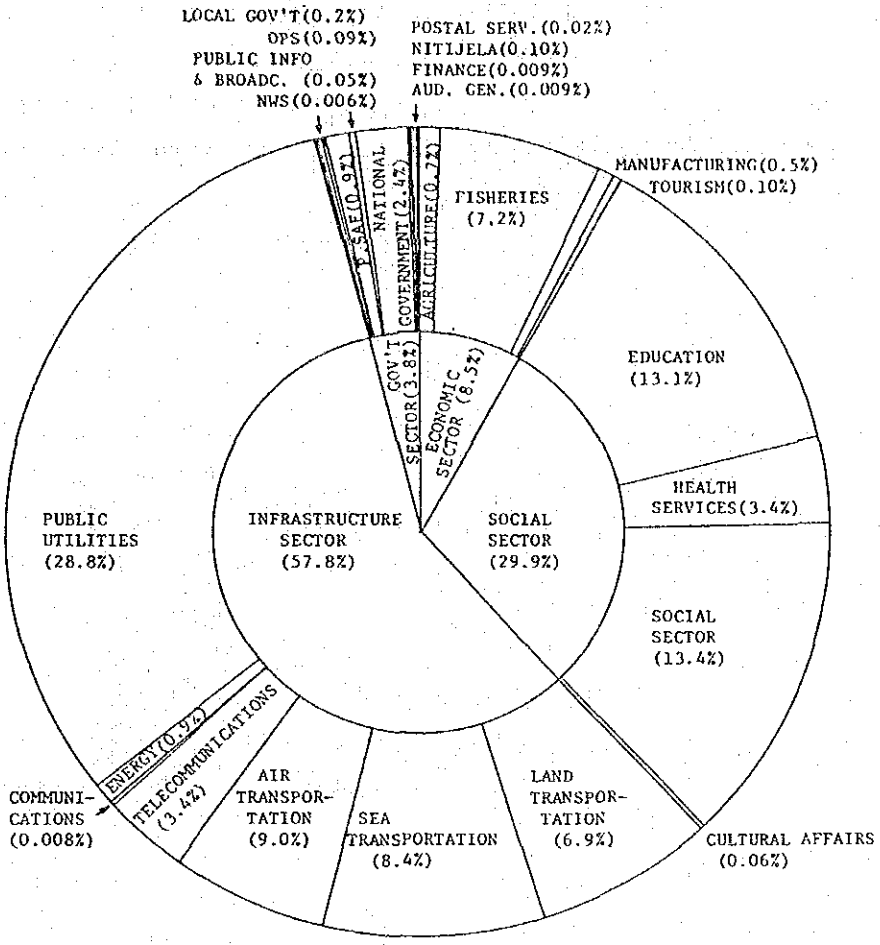
The objectives of the first 5 year plan are:

1. to ensure that sustained efforts are made towards the realization of the long term goal of self-reliance;
2. to lay a firm foundation for the building of a sound economy which will ensure a continuous increase in the living standards of the people;
3. to ensure continuous efforts are undertaken to create productive employment opportunities for the rapidly growing labor force;
4. to bring about increasingly equitable development both among different atoll groups of the Republic and among different income groups of the population;
5. to preserve the Nation's cultural and environmental heritage for the benefit of present and future generations.

In part 3, the Sectorial Plan, related to the proposed project, the plans for the 13 sectors ranging from agriculture and fishery, to judicial and legal services are mentioned and their components are 1. Organization, 2. Problem and Issue, 3. Objective, 4. Strategy and 5. Program and Project.

The above are manifested by each sector in the circular graph as shown by Fig. 2-1. It is indicated by this Fig. that the greater emphasis is placed on the development of the infrastructure sector.

Fig. 2-1 Sectoral breakdown of funding requirements, 1985-89



The issue of the water supply facilities is mentioned in Chapter 19 of the 5 year development plan and deals with the water supply and its distribution. The need for the improvement of the water suply facilities is emphasized and is to be dealt with urgently to meet the demand of the naturally increasing population and the converging of the people to find jobs in the Majuro atoll, the political and economic centre, especially in DUD area from the isolated islands. Presently, the residents are suffering from strict water supply rationing in the dry season due to the scarcity of water, erratic water supply to the terminal portion of the distribution area, shortened water distribution times and the partial deterioration of the facilities. In the target year of the first 5 year

plan the existing water supply facilities are recommended to be improved to achieve water supply to satisfy 75% of total daily demand, in other words, 18 hours water supply per day.

Further, in order to achieve development of industries and tourism expected in the 5 year plan, the water supply facilities should be improved with first priority.

2-2 Water Supply Development Program

The emphasis of the water supply development program is placed on the Majuro Atoll and Ebeye of the Kwajalein atoll because about 60% of the total population of RMI is in these two districts as shown in Table 2-1. Table 2-2 indicates all projects included in the 5 year water supply development program from 1985 to 1989 in Majuro atoll and Ebeye. According to this plan, the water supply improvement program of the Majuro atoll requires the investment of 163,640,000 US dollars.

The sewerage construction costs (US $12,500,000) for DUD area is included in Table 2-2 because groundwater has to be utilized as the present and future water source for living in the atoll and the development of the sewerage system is considered indispensable to protect the groundwater from contamination.

Table 2-1 Population and its density in Majuro atoll and Ebeye in 1980

	Population	Rate (%)	Area (km^2)	Population Density (head/km^2)
Majuro Atoll	11,791	38	9.6	1,228
Breakdown (DUD area)	(8,595)	(28)	(1.3)	(6,602)
Ebeye	6,169	20	0.3	20,563
Subtotal	17,960	58		
Total in Marshall	30,873	100	169.0	183

2-3 The Relation of the Water Supply Development Program to the Present Project

As shown in Table 2-3, the 5 year water supply development program's object is, to develop water sources, increase the water supply quantity, water quality preservation, increase the treatment capacity and stable operation of the water supply facilities, adequate distribution of water and saving of water consumption. Accordingly, the construction program of the raw water reservoir of 12 million gallons and the water meters installation program, scheduled in the 5 year plan, are to be studied in this project. However, the financial problem is not yet presently solved as mentioned in Subsection 2-5-3, and the above programs are not in progress as expected.

Further, the uneven distribution of the water, reduced capacity and deterioration of some facilities are not planned to be improved in the 5 year plan.

Actually, unless the improvement program of the existing facilities as included in the proposed project is implemented, some fundamental problems can not be solved and the other projects already implemented will not be able to function effectively.

Accordingly, the proposed project will enable the improvement of the existing facilities to achieve considerable parts of the objectives of the long term plan for water supply development of RMI which is still not as yet assured to materialize.

Table 2-3 indicates the correlation of the first 5 year plan and the present project.

Table 2-2 Project to Improve and Expand the Water Supply Facilities in Majuro Atoll and Ebeye (1985 - 1989)

	Project	Objective	Amount	Period	Financial source
Majuro Atoll	LAURA LENS WELL	Abundant groundwater in Laura distric was identified by the investigation. About 500,000 gal/d will be exploited to utilize 250,000 gal/d for Laura district and 250,000 gal/d for DUD area.	$3 Million	1985 ∿ 1987 (3 years)	2.5-CIP 0.5-COMPACT CAPITAL
	MAJURO 12-MILLION GALLON PROJECT	There are presently water reservoirs of 18 million gallons but the stored water is redueced in dry season. A new resorvoir of 12 million gallons will be added.	$500,000	1986 ∿ 1988	COMPACT CAPITAL
	BACKFLOW PREVENTER PROJECT	The backflow preventer will be provided to prevent back-flow of groundwater contaminated by seawater to enter water supply mains.	$66,500	1985 ∿ 1987	COMPACT CAPITAL
	WATER METER PROJECT	The water meters will be installed in every house to rein-force the control system of the waterworks.	$48,000	1985 ∿ 1986	COMPACT CAPITAL
	POWER DESALINATION PLANT PROJECT	The desalination plant (250,000 gal/d) will be constructed utilizing the remaining heat of the thermal pwoer plant.	$250,000		CIP
	MAJURO SEWER	The sewerage system will be constructed in DUD area.	$12.5 Million	1985 ∿ 1988	CIP
Ebeye	POWER/DESALINATION PLANT PROJECT	The thermal power plant (diesel/heavy oil) and desalination plant (250,000 gal/d) will be constructed in the southern strip of Ebeye.	$17 Million	1985 ∿ 1988	THE KWAJALEIN ATOLL DEVELOPMENT AUTHO-RITY (KADA)
	WATER DISTRIBUTION PRO-JECT	The construction of new water distribution system and the improvement of the existing water distribution system will be executed in connection with the development of residential and commercial areas resulted from the opening of the highway	$3 Million	1986 ∿ 1989	KADA
	RESERVOIR, CATCHMENT PROJECT	A catchment facility of 750,000 sq.ft. and 4 reservoirs of 3 million gallons each will be constructed.	$4.5 Million	1986 ∿ 1987	KADA

Table 2-3 Relation of the first 5 year plan to proposed project

Project	Objective	First 5 year Plan	Proposed Project
LAURA LENS WELL	To secure water source	o	
MAJURO 12-MILLION GALLON PROJECT	To increase stored water, and increase water supply volume in dry season	o	o
BACKFLOW PREVENTER PROJECT	Conservation of water quality	o	
WATER METER PROJECT	Administration of waterworks and saving of water consumption	o	o
POWER DESALINATION PLANT PROJECT	Increase of water supply quantity	o	
MAJURO SEWER	Improvement of living environment and prevention of groundwater contamination	o	
SEA WATER PREVENTER PROJECT	Conservation of water quality		o
NEW TREATMENT AND PERTINENT FACILITY	Increase of capacity of existing facilities		o
DISTRIBUTION NETWORK AND PERTINENT FACILITY	Adequate water distribution		o
REPAIR, IMPROVEMENT OF ELEVATED TANK	Adequate water distribution		o

2-4 Water Supply Situation

The present drinking water supply depends on rainwater as its source and there are serious problems of national concern such as undeveloped water supply facilities, unsatisfactory maintenance of the water supply systems, the deterioration of the facilities, serious water shortage caused by a yearly increasing population, and an extremely uneven water distribution depending on the areas.

As mentioned previously, the water source for DUD area is the rainwater that has fallen on the runway and its surroundings at the Majuro airport located about 10 km west of the capital. Such rainwater is collected and stored in the reservoirs as the main water source for public water supply. The residents are also making their individual efforts to obtain drinking water by collecting the water that has fallen on the roofs of their houses and collected in individual storage tanks as a supplementary facility for public water supply.

As for Laura district, the island is wide and an impermeability layer is formed at several meters to more than ten meters underground and foraminifaral sand is accumulated in the upper part of this layer. The soil condition of Laura district as above mentioned is ideal to bear groundwater, and further the population is less and the groundwater is not contaminated by sewerage water. The residents also have to utilize individual rainwater storage tanks in addition to the above abundant groundwater because the public water supply system is not completed.

In DUD area, there are 3 wells for existing groundwater sources. However, because the soils consist mainly of coral sands, the coefficient of permeability is large, and the salinity of the groundwater is high because the island is narrow and sea water is likely to intrude.

In spite of the fact that many people are living in the island, a sewerage system is not provided and the water from the individual

houses is contaminating the groundwater through the underground infiltration pits. Therefore, the wells for the underground water sources are not utilized presently.

The water supply system and its situation in Majuro atoll differs greatly between DUD area and Laura district as mentioned above.

The present situation of the water source is mentioned below.

(1) The rainwater of Majuro airport (DUD area)

The rainwater collected from the runway of about 2,400 m long and the catchment area at both sides of the runway is stored in the existing raw water reservoirs of 15 million gallons (about 56,800 m^3) located near the airport and purified later and then supplied to DUD area. through water supply pipes (ϕ 12", asbestos pipe) laid along the main road.

This water supply facility was constructed in 1973 by U.S.A. grant aid.

This water supply quantity fluctuates greatly between the dry season and rainy season. A great amount of water is consumed by the hotels, factories and high class residences in the area adjacent to the water supply pumps because of a method to supply the water to every residential and industrial areas, directly by water supply pumps located close to the reservoir. Therefore, the water supply quantity fluctuates greatly by areas as well as examplified by the terminal water distribution area where the quantity of the supplied water is extremely small.

Accordingly, the lift of the water to the elevated tanks can not be achieved due to the lack of water pressure, and the elevated tanks are not in a functional condition.

(2) The water from roof collection (DUD area and Laura district)

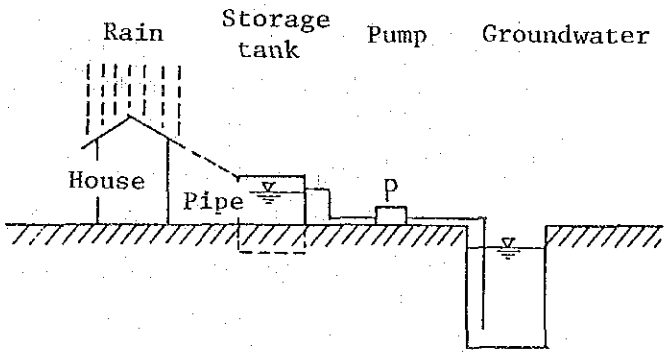
The rainwater collected from the roofs of major buildings (hospital, schools) in DUD area is a precious drinking water

and utilized in the buildings. The buildings and the public water supply system are connected by pipe and the excess water is planned to be utilized as public drinking water. However, rainwater is utilized in the buildings only, and the water to supplement the public water supply is not yet secured.

On the other hand, a storage tank is provided at each individual house to obtain drinking water. In the abnormal drought of 1983, the emergent situation of water supply for only one hour per 3 days resulted and the drinking water was seriously affected. The situation was more or less improved in 1984 after the U.S.A. offered 420 stainless steel storage tanks (about 2 m^3) to DUD area to alleviate this emergency.

(3) Groundwater (Laura district)

As mentioned previously there are some problems in the use of the groundwater in DUD area but in Laura district the groundwater is pumped up and stored in the storage tanks or directly collected from the wells for drinking purposes because the public water supply system is not complete.



Contamination of the groundwater is thought to be partially existing in the specific area similar to DUD area, but there is no particular problem in general in Laura district and the groundwater is abundant. Therefore, the development is considered to continue being prospective. However, the dependent rate on the groundwater is only 10 - 15 % averaged in the whole of Majuro atoll. There are houses utilizing the combined method of above (2) and (3) as shown in the sketch.

2-5 Existing Water Supply System and Waterworks

2-5-1 Existing water supply system and related problems

(1) Outline of existing water supply system

Construction of the water supply facilities for DUD area was completed in September, 1973 by U.S.A. (American International Constructor Inc.), and in 1981 new construction and improvement works were performed.

These are presently the only water supply facilities for DUD area. The whole system is simplified and totally automated. The outline of these facilities and the system is as follows.

The raw water is collected by gravity flow through collection pipes of 8" to 18" dia. installed at the catchment of Majuro airfield. The raw water is later supplied to the raw water reservoirs by four raw water pumps (each 500 GPM-35' TDH).

The raw water is filtered by filters and stored in the fresh water reservoir and supplied to two elevated tanks by three fresh water supply pumps (each 500 GPM-230'TDH) and then to every house by the fresh water distribution pipe of 12" - 8" dia. The system itself is simple but there are various problems such as fluctuation of the water suply quantity and the shortage of water pressure and thus the system is not fulfilling its functions sufficiently as mentioned in a later section.

The outline of the existing water supply system is shown in Table 2-4 and Fig. 2-2.

Table 2-4 Water supply facilities

		Q'ty	Specification
(1) Existing Water Catchment of Airfield	WATER Catchment Area	314,000 m^3	
	Collecting Pipe		8" to 18" (AC Pipe)
	Raw Water Pump	4	500^{GPM} x $35'^{TDH}$ x 15^{HP}
	Raw Water Pipeline	1,500 m	10" (AC Pipe)
W/T Plant "C" (Water Treatment)	Raw Water Reservoirs	5	3,000 kGal/each
	Sand Filters	2	12' diameter, Automatic Gravity Filter 226GPM/each
	Filter Transfer Pumps	3	226^{GPM} x $48'^{TDH}$ x 10^{HP}
	Deepwell Pumps	2	500^{GPM} x $25'^{TDH}$ x 5^{HP}
	Fresh Water Reservoir	1	2,000 kGal
	Fresh Water Supply Pumps	3	500^{GPM} x $230'^{TDH}$ x 40^{HP}
Fresh Water Distribution System	Fresh Water Distribution Main Pipeline	16,000m	6" to 12" (AC pipe)
	Elevated Tanks	2	100 kGal x 145' height

		Q'ty	Specification
(2) Existing Water Catchment of Hospital Area	Raw Water Pumps (R/W P/H No.1)	2	200^{GPM} x 75'^{TDH}
Skimming Wells	Skimming Wells	3	
W/T Plant "A"	Raw Water Reservoir	1	500 kGal
	Sand Filter	1	57^{GPM}
	Fresh Water Pump	2	900^{GPM} x 148'^{TDH}
(3) Existing Water Catchment of High School Area	Raw Water Pumps (R/W P/H No.2)	2	500^{GPM} x 175'^{TDH} x 50^{HP}
	Raw Water Pump (R/W P/H No. 3)	2	150^{GPM} x 172'^{TDH} x 7.5^{HP}
W/T Plant "B"	Raw Water Reservoir	1	500 kGal
	Sand Filter	1	57^{GPM}
	Fresh Water Pumps	2	90^{GPM} x 148'^{TDH}

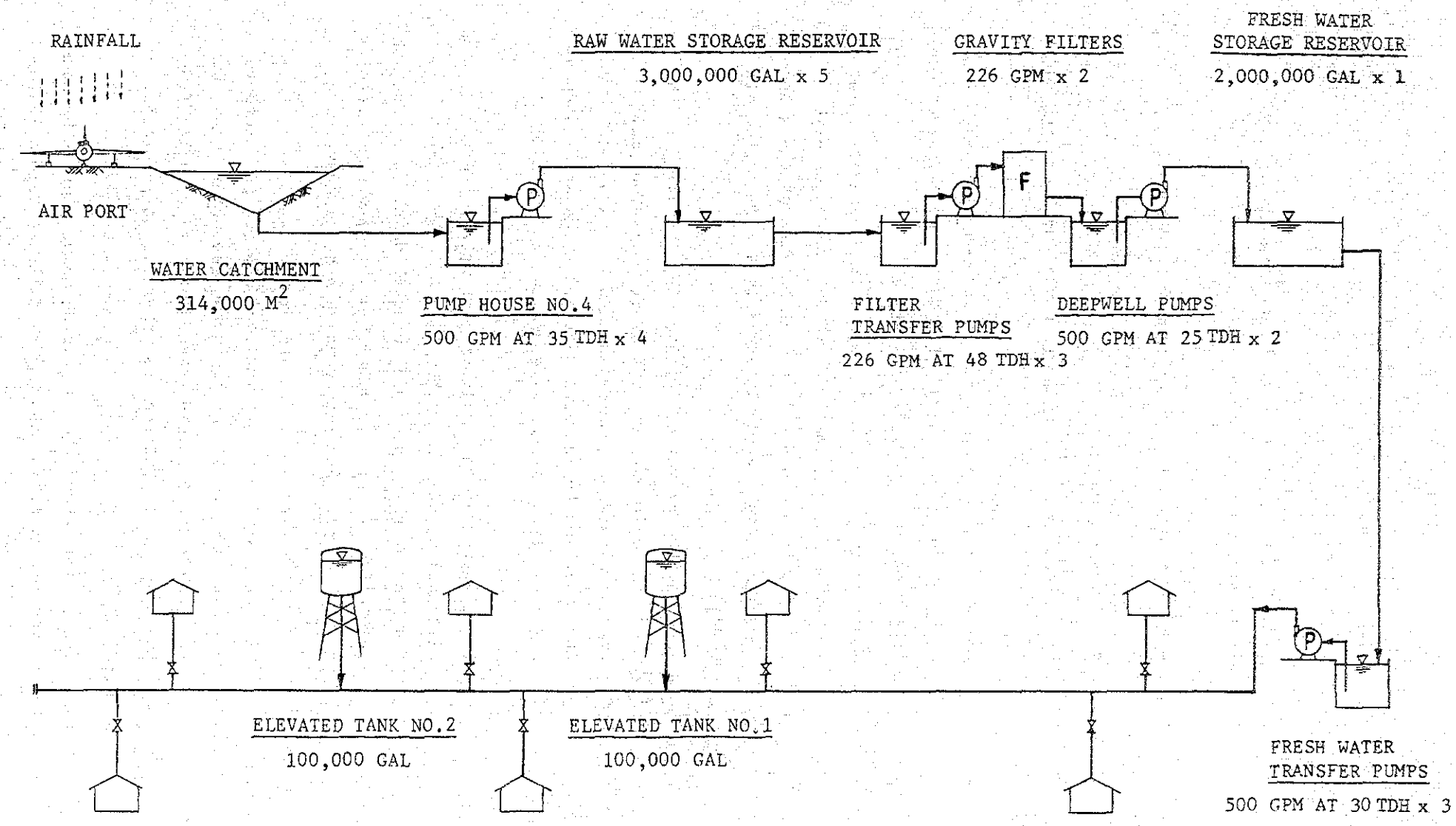


Fig. 2-2 Conceptual representation of existing water supply system

(2) Existing situation of the water supply facilities and related problems

a. Catchment at airport runway and its surroundings

The riprap (blocks to reduce wave action) are situated both at the Pacific Ocean side and the lagoon side of the catchment at the airport runway and its surroundings.

However in stormy weather, sea water is likely to flow directly into the catchment because the height of the riprap blocks is not sufficient.

The frequency of such phenomenon is dependent on the year. And within this year (1986), water of high salinity has been supplied 4 to 5 times by the above phenomenon causing complaints from residents, hotels and others.

The diameter of the collection pipe installed in the catchment adjacent to Laura district is too small, therefore, stagnant water 40 - 50 m wide and 100 m long is often seen for several days along the main roads at the side of the lagoon after torrential rainfall.

b. The diameter of the collection transfer pipe (about 6 m distance) at pump house No. 4 is 6", the same as the diameter of the outlet pipe of each pump, therefore, the collection capacity is less than the discharge capacity of each pumping facility causing a bottleneck in the whole system.

Although visual examination could not be performed for the impeller and the shaft of the raw water pumps, because they are built in the casing, it is judged from the operation situation that there is no particular problem.

It is recommended that a comprehensive measure be made based on inspection and study of the system including

the above item at the time of the airport expansion works to be executed in near future.

c. Except for the partial area for the improvement of the collective transfer pipe mentioned in item b. above it is considered that there is no problem with transfer capacity and supply water leakage because the diameter of the transfer pipe to the raw water reservoirs is ϕ 10" (asbestos cement pipe)

d. The storage capacity of the raw water reservoirs is 15 million gallons (3 million gallon/reservoir x 5 reservoirs). This capacity is able to meet demand for about 47 days only and can not supply the required amount of water needed in the dry season.

RMI and CIP are planning to construct a reservoir of 12 million gallons in order to avoid abnormal water rationing and to maintain normal water supply even if an abnormal drought situation occurs as that of 1983 when scarce rainfall (average 38 mm/month) continued for about 6 months. The prospect of implementation of the construction has not been assured as yet.

The structure of the present reservoirs are the reduced level and banking type with water-proofing sheet placed inside and therefore there is no problem with regard to safety and leakage. However, in the situation where the new reservoir is planned to be constructed at the side of the existing raw water reservoir adjacent to the airport runway, it is necessary to pay full attention to the type of the structure built, its scale, and construction method in order to avoid any obstruction to the present and future flight operations of the airport.

The water-proofing sheet of the existing raw water reservoirs was once replaced in the past. The waterproofing sheet initially placed was CPE sheet and the surface

of the sheet was damaged by strong sun light and lost its function after one year in operation.

The HYPALON sheet is presently used and there is no problem with regard to the strength of the sheet and to the quality of water stored for drinking purpose.

The cleaning of the raw water reservoirs is performed for about one week a year. Recently a submerged pump is used to drain the reservoir but its operation takes a long time causing expensive costs and functional troubles because there is no drainage system at these times.

e. The planned capacity of the water treatment plant "C" and the operation capacity are as follows.

Design Capacity of Water Treatment Plant:

226 GPM x 2 (total 3 filter transfer pumps with 1 standby pump, 2 deep well pumps with 1 standby pump)

Existing Operation Capacity of Treatment Plant:

337 GPM x 2 (treatment facilities are overloaded, all pumps are in full operation)

The two existing gravity filters are operating at an overloaded capacity of 150% and there is little time available for maintenance.

The back wash operation of the filter is performed automatically for seven minutes mostly once a week. The filter sands have not been replaced. However, the sands are sometimes supplemented. Sands from Taiwan (REPMTEK LTD) is presently used as domestic sands for filtration can not be obtained because the island is formed mainly of coral atoll.

Three filter transfer pumps (design transfer capacity: 226 GPM/pump) are presently installed.

There is little time for maintenance because all of the pumps are in simultaneous operation without a standby pump. Further, the diameter of the collection pipe is

small, therefore, the conduction capacity will be reduced and a bottleneck will be caused in the event that new pumps are provided.

f. There is presently one fresh water reservoir (2 million gallons) and this reservoir is completely covered and arranged so as to protect the reservoir from any intrusion of impurities from outside, thus there is no problem for the time being.

However, cleaning of the fresh water reservoir, and maintenance and repair of the cover will be required in future.

Accordingly some measures will be necessary, for instance, modification of the existing raw water reservoir to a fresh water reservoir.

g. The water supply pumps at the water treatment plant "C" are manually operated and controlled by an operator because no automatic facilities are provided for.

The water flow volume is not accurately established because as yet no water meters are provided.

The volume can be estimated only by the design capacity of the system and the operation hours the pumps are working as recorded in the daily operation report prepared by the operator.

The pumping pressure is set between 50 - 90 psi compared with a design pressure of about 100 psi.

(1) Normal (when sufficient water is stored in the reservoirs)

Water supply hour:	(6:30)		(19:30)
Pumps in operation:	2	1	2

2 pumps are operated in case pumping pressure is increasing from 50 psi to 90 psi

1 pump is operated in case pumping pressure is decreasing from 90 psi to 50 psi

(2) Water rationing (water rationing is intensified when the water in the reservoir is less than the designated quantity)

When the water in the reservoirs is less than 5 million gallons:

2 pumps in operation for 2 hours a day, operation of one pump is suspended when the pressure is over 90 psi.

When the water in the reservoirs is under 3 million gallons:

2 pumps in operation for 2 hours every two days.
Same as above.

h. The water supply of the existing facilities to every house and other buildings is made by directly connecting the distribution pipes to the water supply pipeline. Accordingly in the initial upper portion of the supply network, close to the water treatment plant "C", most of the water is consumed and in the terminal lower portion of the supply network of Rita district, the water remaining for use is an extremely small amount resulting in uneven distribution of water.

Such an uneven water distribution will be intensified in future because the construction of residences and public facilities is increasingly anticipated for areas served by the initial upper portion of the supply network.

Leakage from the existing water supply pipeline to the surface of the ground or the road has not been verified. Although detailed investigation was very difficult to perform regarding this matter because the pipes are burried, the external aspect of the existing water supply pipeline (asbestos cement pipe) were found to be without defect and no leakage was traced as a result of the trial excavations undertaken.

Leakage was not found even by the test pits (19 locations) performed for the soil investigation in the area adjacent (within 1 - 2 m) to the existing water supply pipeline.

i. In 1986 RMI and the study team performed measurements of the water pressure distribution along the water supply pipeline from Rita district, the terminal water distribution district, to the water treatment plant "C", and measurements of the water pressure fluctuations at two locations in Rita district and the area near the Rita primary school about every five minutes within two hours from 17:00 to 19:00 on August 18th, 1986.

The water pressure in Rita District was about 5-45 psi and it fluctuated at about 50 - 90 psi at treatment plant "C" as shown in Appendix-8.

The water pressure in Rita district is considered to fluctuate depending on the water pressure of the transfer pumps and the situation of the water intake of every house and commercial building.

The water pressure distribution along the water supply pipe decreased drastically in accordance with the distance from treatment plant "C" as shown in Fig. A8-2 in Appendix-8.

This explains the reason why the water can not be raised to the existing elevated water tank and why the water

distribution in Rita district is poor as mentioned in item h above.

j. The existing two elevated water tanks are not used because of the water pressure mentioned in item i. Water pressure over 45 m is required to lift the water in Rita district owing to the height of the elevated water tank and the distance of the distribution pipe to Rita district, but it is extremely rare that water pressure is raised over 45 m in Rita district.

Because the existing elevated water tanks were built in an area with an oceanic climate with high temperature and humidity, and also near the sea coast, they are subjected to strong sea breeze and sea spray, and thus the anchor bolts and base plates are severely corroded, requiring extensive repairs.

As for the structure, corrosion of the main column and lower part of the bracing is apparent. The existing stairs are seriously corroded, further inspection and maintenance is dangerous without a safety cage. Further, the bolts of the steel frame were replaced with that made of stainless steel by MPW in 1983 and coating applied, therefore, no corrosion is found.

k. As for the treatment plant "A", raw water is planned to be collected from the water collecting facilities utilizing the roof of the hospital and the wells (skimming well), but presently only rainwater from the water collection facilities of the hospital is collected.

Because the water from the well is of a high salinity concentration, it is used for flushing toilets only and not for drinking purposes. The rainwater collected from the collection facility is stored in the raw water reservoir (500,000 gallons) and supplied to the hospital after treatment.

l. As for the treatment plant "B", the raw water is collected from the water collection facility of the high school. The collected rainwater is stored in the raw water reservoir (500,000 gallons) and supplied to the public water supply system after treatment at the treatment plant "B" and utilized as public water. The gutters and down pipes of the high school is deteriorated and presently repair is scheduled.

m. The water collection facility of the Rita primary school is deteriorated and even the pumping facility of pump house NO.3 is not utilized.

n. A small storage tank is provided for all houses, in order to store rainwater run off from the roof for drinking purposes.

The drinking water was seriously in short supply in the abnormal drought of 1983 and the U.S.A. offered 420 stainless steel storage tanks (about $2m^3$ each) to the residents in DUD area.

The storage system of every house was improved by this offer, but the fundamental problem has not yet been solved.

Further, each individual house has a small storage tank to store the supplied water for drinking purposes. In some cases, the pipe is connected to the washing machine and it is feared that the washing water would flow backward by siphon action and this action would contaminate the clean water in the pipeline.

Further, during the present investigation it was found that the faucets of some houses were kept open and water was overflowing into storage tank. RMI and CIP are studying countermeasures to be taken for such a waste of water.

o. The houses equipped with water meters from DUD area to Airport are as follows.

	Darrit	Uliga	Dalap	Long Islands (To airport)	Total	%
Houses with water meters	361	47	182	89	679	47
Horses without water meters	271	182	155	141	749	53
Total	632	229	337	230	1,428	100

The water meters of the existing water supply pipe and even the water meters of every house are not completely installed so that the thorough operation and control of the water supply can not be achieved.

It is therefore difficult to collect the water charge in accordance with the water consumption and in addition the water consumption is increasing due to the poor understanding of the residents regarding saving water and also the demand and supply is not balanced, especially in Rita district, where the water is often under supplied.

p. The water is supplied to DUD area normally for 13 hours (from 6:30 to 19:30), but in a dry season water is supplied 3 times during the morning, midday and night. Depending on the rainfall situation, the water supply is strictly limited to two times during morning and night or only one time at night. In a 5 to 6 months period in 1983, the water was supplied for only one hour every three days because of the scarce rainfall in that year.

The water supply rotation during the stay of the study team (August, 1986) was three times within each day, morning (3 hours), midday (2 hours) and night (3 hours) and there was a serious shortage of available supply.

2-5-2 Waterworks

(1) Organization

The responsible agency of the waterworks of RMI is the Ministry of Public Works. This Ministry has the duty and authority for the operation and maintenance of the water supply facilities. The organization chart is shown in Fig. 2-3.

As for the waterworks, mainly the water system & planning supervisor is dealing with the operation and maintenance of the system.

(2) Financial Policy

The water supply planning and the construction works have been financially assisted by the U.S.A. so that the financial burden for the construction has not been placed on the shoulders of RMI.

Since trusteeship by the U.S.A., the waterworks have been operated under the same administrative system and a water charge has been imposed.

Actually, however, there are many houses without water meters and the procedure to collect the water charge from the residents is not well arranged.

The Government's intention is to overcome this situation. In the 5 year development plan, adequate operation and autonomy of the waterworks is planned by imposing effective water charges.

The present water charges are as follows;

a. General residents

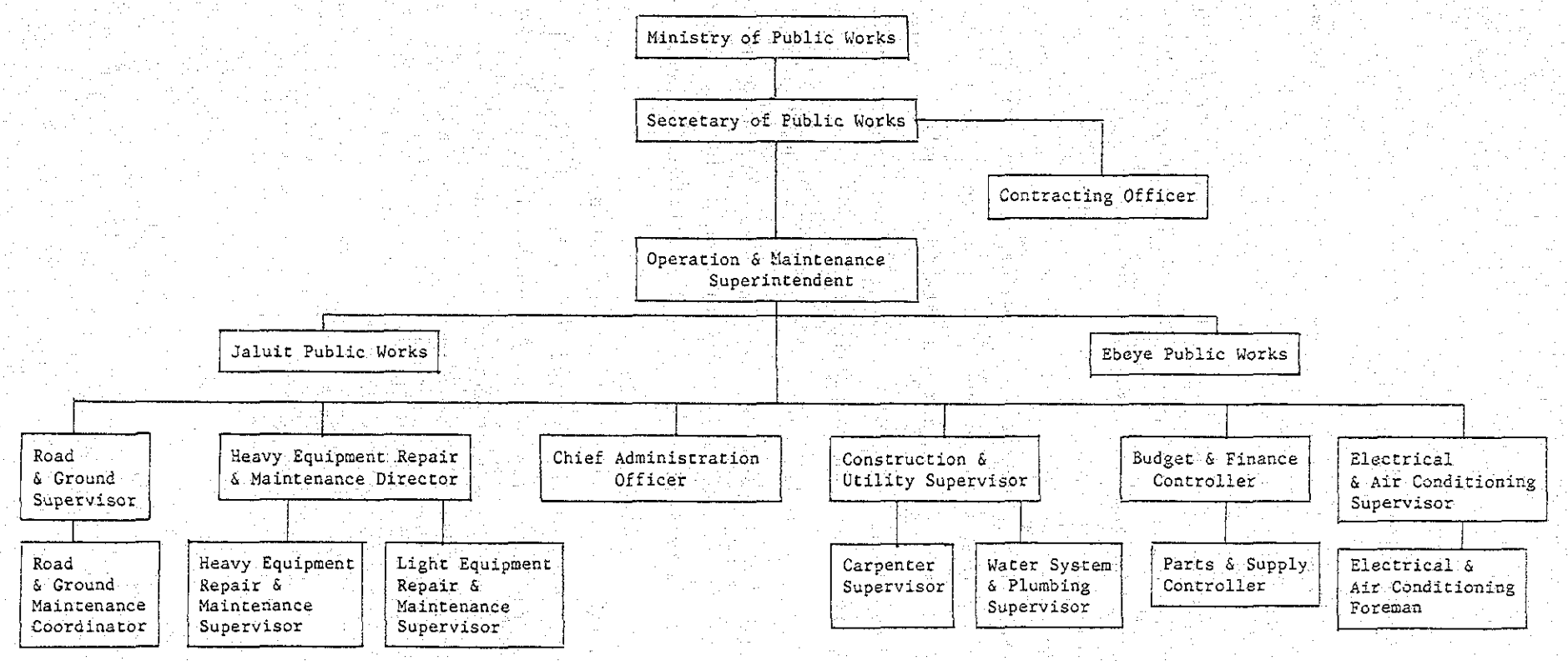
Under 10,000 gallons: $8/10,000 gallons
Over 10,000 gallons: $0.008/gallon

b. Commercial Sector (hotel, office, restaurant, etc.) and the Public Sector

$0.008/gallon

The reading of the water meter and the collection of the water charge are executed by the Ministry of Finance, but the collection rate is not high and the income from billings is presently not exactly known.

Fig. 2-3 Organization of the Ministry of Public Works
(Republic of the Marshall Islands)



2-5-3 Finance and foreign aid

Table 2-5 and 2-6 indicate the annual income and expenditure from 1981 to 1984.

The magnitude of the financial requirement is expanding gradually. Income tax and import tax are increasing significantly the amount of government domestic income while financial aid from the U.S.A. still occupies over 60% of the total income in the year indicating that the national finance is overwhelmingly dependent on the U.S.A. The ordinary revenue and expenditure is yearly being refined and improved, but the revenue is so small that the capital to invest in new projects is minimal.

The investment for public works is separately accounted from the ordinary revenue and expenditure.

The budget necessary for the 5 year development plan is 336.9 million dollars as shown in Table 2-7. While the prospective capital to be funded is 215.4 million dollars as shown in Table 2-8, the shortfall amount is 121.5 million dollars.

Although the Compact of Free Association, which occupies the greater part of the prospective fund, was effected in October, 1986, the execution of the 5 year development plan based on this Compact Fund is almost 2 years behind schedule. Consequently, financial assistance from countries other than the U.S.A. is still urgently required.

Table 2-5 Recurrent Revenues, 1981 - 1984

($000's)

	FY 1981	FY 1982	FY 1983	1984
LOCAL REVENUE				
INCOME TAX	2,011	2,448	2,747	3,050
BUSINESS GROSS REVENUE TAX	1,928	1,808	2,190	1,670
IMPORT TAX	1,009	1,270	1,912	2,612
SALES TAX	281	261	231	197
FUEL TAX	39	91	-	694
BUSINESS LICENSE FEES	-	-	144	146
TOTAL INDIRECT TAX	5,268	5,878	7,224	8,369
FISHING RIGHTS INCOME	1,000	1,275	763	842
INTEREST INCOME	-	-	22	7
LOAN PAYMENTS	-	-	54	-
NON-TAX REVENUES(FEES AND SALES)	881	1,084	993	1,223
SEAPORT, SHIPPING & TELECOM RECEIPTS	-	-	-	930
	7,149 (31.0%)	8,237 (32.2%)	9,056 (34.6%)	11,371 (37.5%)
U.S. GRANTS				
BASIC GRANT	7,831	9,769	10,484	11,277
FUEL SUPPLEMENT	828	343	-	-
TRANSITION FUNDS AND OTHER	600	537	510	241
SPECIAL MAINTENANCE	430	730	712	1,821
FEDERAL GRANTS	6,166	6,252	5,444	5,582
TOTAL U.S. REVENUES	15,855 (69.0%)	17,631 (68.8%)	17,150 (65.4%)	18,921 (62.5%)
TOTAL REVENUE	23,004 (100%)	25,631 (100%)	26,206 (100%)	30,292 (100%)

Table 2-6 Recurrent Expenditures by program area, 1981 - 1984

($000's)

	FY 1981	FY 1982	FY 1983	1984
GENERAL FUND				
HEALTH SERVICES	3,220	3,275	3,880	4,342
EDUCATION	2,874	2,974	2,589	2,774
TRANSPORTATION AND COMMUNICATIONS	2,228	1,795	1,348	1,678
INTERIOR AND OUTER ISLAND AFFAIRS	164	236	213	138
RESOURCES AND DEVELOPMENT	1,453	1,119	702	633
INTERNAL SECURITY	653	766	743	724
ADMINISTRATION/CHIEF SECRETARY OFFICE	190	208	265	266
FINANCE	399	709	1,920	773
PUBLIC WORKS	4,135	4,390	3,589	2,578
SOCIAL SEIVICES	234	253	170	156
FOREIGN AFFAIRS	536	411	362	418
CABINET	355	439	429	564
NITIJELA	614	648	557	741
COUNCIL OF IROIJ	102	104	105	139
AUDITOR GENERAL	38	75	42	73
PUBLIC SEIVICE COMMISSION	181	135	288	233
PUBLIC DEFENDER	51	57	49	57
JUDICIARY	54	107	196	274
ELECTORAL COMMISSION	-	-	-	90
TOTAL	17,463	17,701	17,447	16,651
U.S.				
FEDERAL GRANTS	6,166	6,252	5,444	5,582
OTHER	1,030	1,267	730	-
TOTAL	24,659	25,220	23,621	22,233

Table 2-7 Total funding requirements, 1985 - 1989

(x 1,000$)

SOURCE	1985	1986	1987	1988	1989	TOTAL
FEDERAL PROGRAMS	10,438	8,446	8,336	107	100	27,828
CAPITAL IMPROVEMENT PROGRAM	7,200	10,300	8,700	1,000	-	27,200
KWAJALEIN ATOLL DEVELOPMENT AUTHORITY	15,345	17,346	26,556	30,209	26,754	116,228
DEBT SERVICE	15,150	14,623	10,958	6,331	5,128	52,190
TIED COMPACT PROJECTS (OF WHICH:)	6,980	5,628	2,600	14,266	11,511	40,984
(SECTION 215(a,2) & 215(b,2))	(3,075)	(1,375)	(1,070)	(1,070)	(1,580)	(8,170)
(SECTION 216(a,1) & 216(b))	(2,525)	(2,825)	(-)	(3,440)	(-)	(8,790)
(SECTION 216(a,2))	(38)	(98)	(98)	(520)	(520)	(1,273)
(SECTION 216(a,3))	(897)	(897)	(897)	(897)	(897)	(4,487)
(SECTION 221(b))	(445)	(443)	(535)	(8,338)	(8,513)	(18,264)
COMPACT CAPITAL PROJECTS	15,395	16,817	13,446	12,977	13,489	72,123
OTHER PROJECTS	117	130	29	29	39	344
TOTAL PLAN PROJECTS	70,625	73,508	70,825	64,918	57,021	336,897

Table 2-8 Source of available funding, 1985 - 1989

(x 1000$)

SOURCE OF FUNDS	1985	1986	1987	1988	1989	TOTAL
FEDERAL PROGRAMS	9,400	7,800	7,800	100	100	25,200
CAPITAL IMPROVEMENT PROJECTS (CIP)	7,200	10,300	8,700	1,000	-	27,200
KWAJALEIN ATOLL DEVELOPMENT AUTHORITY (KADA)	15,900	3,300	3,400	3,500	3,600	29,700
DEBT SERVICES (COMPACT)	15,150	14,623	10,958	6,331	5,128	52,190
COMPACT TIED	9,100	5,100	5,100	5,100	5,100	29,500
COMPACT CAPITAL ACCOUNT	-	-	642	5,569	7,172	13,383
OTHER SOURCES	117	130	29	29	39	344
SUB-TOTAL	56,867	41,253	36,629	21,629	21,139	177,517
SURPLUS FROM RECURRENT BUDGET	2,800	4,500	9,100	10,600	10,900	37,900
TOTAL FUNDS AVAILABLE	59,667	45,753	45,729	32,229	32,039	215,417

2-6 Components of Request

The Majuro atoll of RMI consists of islands of low altitude 2 - 3 m above sea level, which surround an oval lagoon of 40 km from east to west and 10 km from north to south, and with shallow reefs. There is no river and spring and they have to depend on rainwater for their water source and are suffering water shortages every year as mentioned previously.

The population of the Majuro atoll was about 14,000 in 1985 and mostly concentrated in DUD area located in the eastern part of the island, where a water supply system was constructed in 1973 and later limited expansion works was performed in 1983.

In this water supply system, rainwater is collected by the catchment facility utilizing the runway of the Majuro airport and supplied to DUD area by a water supply pipeline of about 16 km from the airport after being filtered at the water treatment plant "C" near the airport.

The water demand of RMI is increasing yearly due to the recent rapid population increase, the development of large water consumers such as hospitals, hotels, and fishery processing factories and other industries. In addition, extreme water shortage is caused in the terminal water distribution areas because in the existing water supply system, there is a shortcoming that the water is supplied by pumping directly to all houses and other buildings from the water supply-distribution pipeline. Therefore, it is urgently required to establish a plan for a stable and uniform water supply in the capital of Majuro.

It is necessary to expand and improve the existing facilities to exploit effectively the annual amount of rainwater of 3,400 mm, the only water source of Majuro atoll, in order to alleviate the extreme water shortages in the dry season of each year.

Under such a situation, the present request of grant aid was made to the Government of Japan. The request was made fundamentally to improve the existing water supply facilities in order to solve the existing problems of water supply to DUD area. The components of the request are as follows.

1. Construction of a new reservoir with a capacity of about 9 million gallons.
2. Construction of a new main of about 10 miles (16 km)
3. Construction of two additional elevated water tanks
4. Installation of water measuring devices
5. Other miscellaneous works, such as the replacement of pumps at the airport, an additional sand filter plant and chlorination equipment.

CHAPTER 3

OUTLINE OF PROJECT SITE

CHAPTER 3 OUTLINE OF PROJECT SITE

3-1 General

3-1-1 Location and topography

(1) Location

The Marshall Islands are located in the north latitude between 4°-14° and east longitude between 160°-173° in the Central Pacific Ocean and consists of 31 atolls islands. Within a sea area of 1,300,000 km^2 1,152 islands are scattered, but the total land area of these islands is only 181 km^2. The Majuro atoll is oval in shape and is 40 km from east to west and 10 km north to south. It is located south-east (north latitude 7°, east longitude 172°) of the Marshall Islands group and consists of 64 islands of low altitude including the lagoon 410 km^2, and its land area is only 11 km^2. It is located extremely far from the major capitals of advanced countries, about 3,220 km from Honolulu, Hawaii and about 4,020 km from Tokyo, Japan.

The project area is located at the southeast sector of the Majuro atoll, extending from Majuro airport to DUD area, about 16 km, through Rairok district (from airport to Majuro bridge). In DUD area, there are major public facilities such as government buildings, schools, hospital, churches, new and old ports, power plant, and residential areas which occupy about two thirds of the area of the islands.

(2) Topography

The Marshall Islands archipelago consists of 31 atoll islands and 5 isolated islands. Among these, the Majuro atoll is the biggest and is located at south-eastern end of the Marshall Islands. The atoll islands are formed by the plural loops of

the small islands which resulted from coral inhabiting a shallow sea formed by geological activities.

The Majuro atoll is a flat, long and narrow strip of land with a width varying between 7 - 500 m and with no river, lake or spring water. The lagoon (inland sea) is surrounded by the reef to the extent of 90 km and has an area of 410 km^2.

The topography of this project site is from 15 m to several hundred meters wide and about 1.3 - 3.4 m of altitude and flat with a gentle rise and fall.

As for the overland traffic, DUD area and Laura district is connected by a paved double track road (width of 6.5 m) of about 56 km.

The trunk roads are generally well paved, but most of the drainage is for the natural rainfall and in some area in DUD area the drainage ditches (30 - 40 mm depth), cross the road in the form of a U-shape in some areas in DUD to draw the rainwater towards the lagoon. On the other hand, the rainwater collected in these drainage ditches during torrential rain is causing damage to the cars and the pavement. Except for a section (about 500 m) of the main street of DUD area, the shoulder of the road is not paved but covered by sand and grass and part of the area close to the sea coast is banked by riprap. Road signal and signs are rarely found.

The means of the transport in the island is mainly by private cars and taxies. A bus runs twice a day between DUD area and Laura district.

The taxi charge in DUD area is a flat rate of 30 cents (US$) for adults and 10 cents for children. The development of an efficient transport system between the separate island will

also be necessary for the development of those dispersed islands.
The outline of the project site is mentioned below.

The land area of the existing facilities is to be utilized for the site of the sea water preventive facility at pump house No. 4, filter facility and elevated tanks (No. 1 and No. 2). The area for the raw water reservior is at present partly enclosed within an isolated lagoon on the ocean side, therefore, this public land adjacent to the existing reservior facing the airport will be developed. The public land facing the open sea is to be utilized for the site of the new water supply pipeline same side as for existing supply-distribution pipeline, because the land area at the side of the major trunk road facing the lagoon is to be utilized for the sewage pipeline construction. The project site is outlined in the table below.

Outline of project site

	Outline of project site
Sea water preventive facility at pump house No. 4	There is a distance of about 20 m, between pump house No.4 at the airport and the lagoon. The major trunk road is located outside of the border fence. The soil condition is comparatively good and no rock base is found.
Raw water reservoir (additional capacity of 9 million gallons)	Adjacent to the existing raw water reservoir facing the airport the area for the two raw water reservoir is partly enclosed within a shallow isolated lagoon formed by man-made sand bar and riprap which supports vegitation. The backfilling to this area to the level of the road surface is to be completed by RMI before the start of the present project construction.

(cont'd)

Outline of project site

(cont'd)

	Outline of project site
Water treatment plant "C" (filter, supplementary pumps and additional distribution pipe)	The concrete block warehouse and container store at the site for the new water treatment facility will be removed. The site for the installation of the pump and distribution pipeline will be finally determined at the stage of detailed design because the existing facilities complicate installation at this site.
Water supply facility (addition of new supply pipeline)	The ground surface is flat and soil condition is generally good although ledge is partly exposed. These exists electric-light poles and palm trees along the distribution pipeline route which will hinder the construction works. This problem will be solved by protection of the poles and relocation of the palm trees. There are burried services under the road in DUD area. And there is a probability of seepage of groundwater during excavation. The part of the pipeline to the approach of the Majuro bridge is to be burried under the existing sidewalk.
Distribution facility (The repair and reinforcement of the existing elevated tanks No.1 & No.2)	A part of the site surrounding the main columns of the elevated tank is about one meter higher than the surrounding area but the area is generally flat. There is land available for the construction of the access road. A heavy coating of corrosion protection will be necessary because the site is close the sea and brine damage is foreseen. There is a nursery school (old Majuro hospital), school, and church surrounding elevated tank No.1 and also the high school around elevated tank No.2, therefore, it is necessary to pay attention not to cause public nuisance during the construction.

3-1-2 Population

(1) Population Increase

The population of the Marshall islands has increased substantially after the end of the second world war. It was found that the population of about 14,900 in 1960 was doubled to 30,873 at the time of the national population census in September, 1980. In the meantime, during 1966-1973, the population of Kwajalein atoll increased at an average annual rate of 7.5%, and in Majuro atoll at an average annual rate of 11.9% while the population of the islands was halved. The population inflow into Majuro atoll is the main reason for the above phenomenon. During 1973-1980, the average annual rate of population increase for Majuro atoll was reduced and stabilized to 2.0% in contrast to other islands. The natural population increase rate of the whole islands have kept a high annual 3.1% due to the high birth rate and low death rate, especially females under the age of 29 is 75.9% of the total, which indicates that the population increase rate will be kept at the higher level in future.

In the 5 year development plan initiated from 1985, the population is estimated to increase at annual average rate of 3.9% to reach about 45,600 in 1990. The present population in DUD area is about 13,000 and increased from 1973 to 1980 at an annual average rate of 1.5%. It is estimated to reach about 16,000 in the year 2000.

(2) The age component

As shown in Fig. 3-1, the components of the younger generation occupy an extremely large portion. The average age of the population in 1980 was 14.8 years old, in other words, the age of half of the population total is under 15 years old.

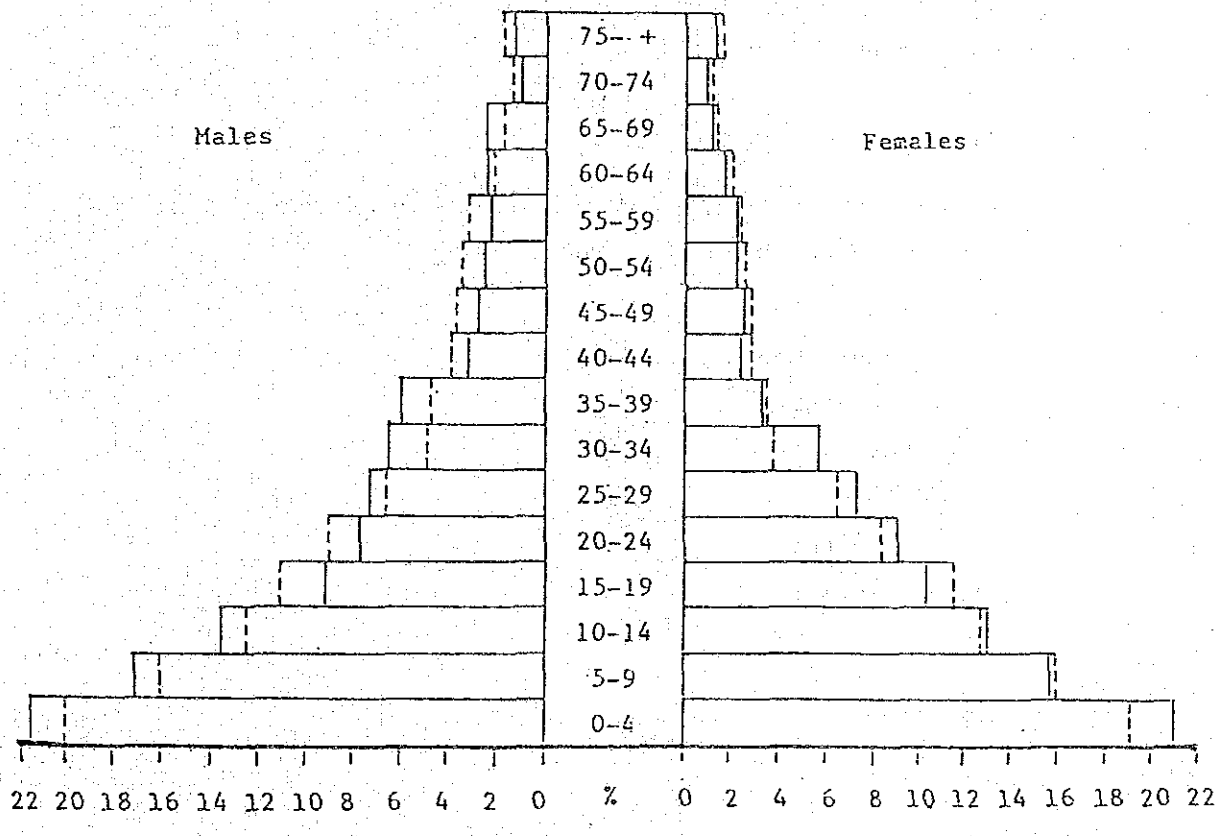
(3) Population distribution (1980)

		Population	%	Population density/mile^2
City	Majuro	11,791	38.2	3,142
	(DUD area)	(8,583)	(27.8)	(16,731)
	Kwajalein atoll	6,624	21.4	1,046
	(Ebeye)	(6,169)	(20.0)	(51,408)
Local		12,453	40.4	202

Fig. 3-1 Population distribution by age and sex, 1973 and 1980

1973 Median Age: 14.7
1980 Median Age: 14.8

1973: --------
1980: ————————



Source : Quarterly Bulletin of Statistics, TTPI, Vol. III, No.2, 1980;
1980 Census of Population, U.S. Bureau of the Census