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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

WATER AUTHORITY OF JORDAN
MINISTRY OF WATER AND IRRIGATION
THE HASHEMITE KINGDOM OF JORDAN

THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT IN THE HASHEMITE KINGDOM OF JORDAN

FINAL REPORT

MAIN REPORT

JULY 1996

TOKYO ENGINEERING CONSULTANTS
IN ASSOCIATION WITH
NIPPON KOEI

JAPAN INTERNATIONAL COOPERATION AGENCY

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(as of October 1995)

PREFACE

In response to the request from the Government of the Hashemite Kingdom of Jordan, the Government of Japan decided to conduct the Study on the Improvement of the Water Supply System for the Zarqa District and entrusted the study to the Japan International Cooperation Agency (JICA).

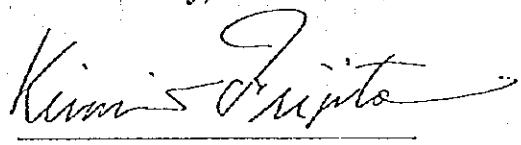
JICA sent to Jordan a study team headed by Mr. Kazufumi Momose of Tokyo Engineering Consultants Co., Ltd. associated with Nippon Koei Co., Ltd., several times between November 1995 to May 1996.

The team held discussions with the officials concerned of the Government of Jordan , and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

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

I wish to express my sincere appreciation to the officials concerned of the Government of the Hashemite Kingdom of Jordan for their close cooperation extended to the team.

July, 1996



Kimio Fujita
President
Japan International Cooperation Agency

JULY, 1996

Mr. Kimio FUJITA
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit herewith the Final Report entitled "The Study On The Improvement Of The Water Supply System For The Zarqa District In The Hashemite Kingdom Of Jordan".

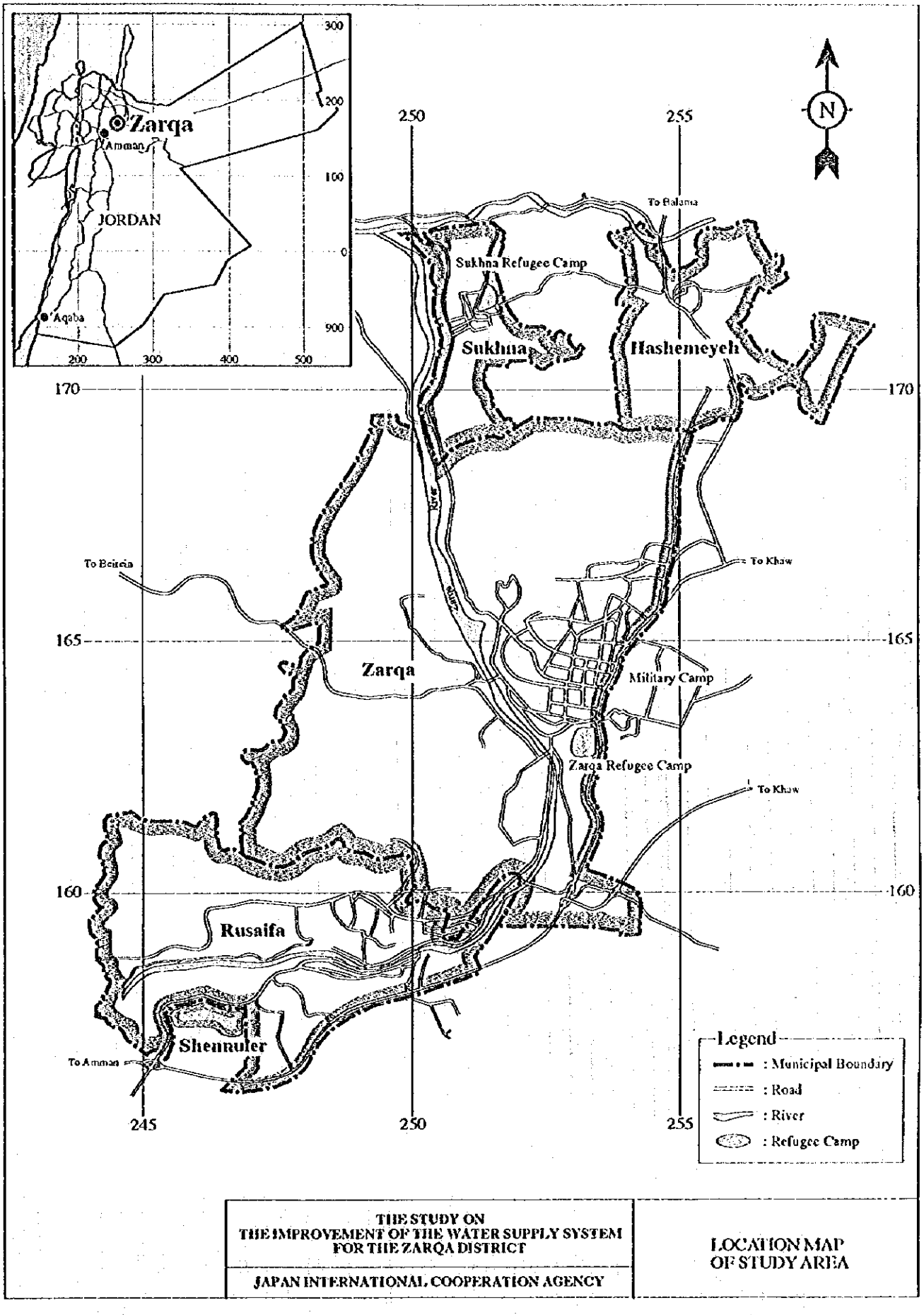
This report has been prepared by the Study Team in accordance with the contracts signed on October 1994, May 1995, October 1996 and May 1996 between the Japan International Cooperation Agency and the Joint Venture of Tokyo Engineering Consultants and Nippon Koei.

The report consists of the Summary in English and Japanese, the Main Report in English, the Supporting Report in English. The Summary summarizes the results of all studies and includes conclusions and recommendations. The Main Report contains the results of survey, analysis and explains about long-term development plan and short-term development plan.

All members of the Study Team wish to express grateful acknowledgment to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Health and Welfare, Embassy of Japan in Jordan and JICA Jordan office, and also to the officials of the Water Authority of Jordan for all assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the improvement of the water supply system for the Zarqa District.

Yours faithfully,

Kazufumi MOMOSE
Team Leader



THE STUDY ON
THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM
FOR THE ZARQA DISTRICT

JAPAN INTERNATIONAL COOPERATION AGENCY

LOCATION MAP
OF STUDY AREA

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

1. INTRODUCTION

Zarqa district, the Study Area, is situated 35km northeast of capital Amman and has been developed as an industrial city. In the Study Area water rationing has been practiced due to the limited availability of the water resources. It has been aggravated by high ratio of unaccounted-for water. The water resources shortages are prevailing not only in the Study Area but also in Jordan. The various majors are, therefore, being planned from the view point of the whole nation. Accordingly, the water resources issue is not dealt in this report. This report, instead, deals with the issues which are solved within the Study Area. They are;

- Reducing unaccounted-for water
- Rationalizing distribution system

2. PROJECTION OF POPULATION AND WATER DEMAND

The population of the Study Area is projected to increase to 739 thousands in 2005 and 938 thousands in 2015 with an annual growth rate of 2.4 to 3.2 %.

The average per capita consumption (on accounted-for water basis) in the Study Area is, at present, 52 lpcd, where water rationing is practiced. This would be, however, 70 lpcd if water is supplied continuously. For the future water consumption, another 20 lpcd is added in consideration of the future change in living standard, a way of life and likely decrease of household size. As a result, 90 lpcd is adopted as the target value for 2015.

To estimate demand, UFW within the system is added to consumption in the subscribers. The UFW ratio will decrease from 54% in 1994 to 30% in 2015, as meter reading and billing procedures (major reasons for UFW high ratio) as well as leakage control measures are strengthened and improved in the course of the project development. In estimating daily maximum water demand, a peak factor (Daily maximum/Daily average = 1.20), due to the seasonal and daily fluctuation is employed. As a result, the present demand of 97,000 m^3/day will increase to 145,000 m^3/day in 2015.

Water Demand

Year	1994	2000	2005	2010	2015
Population Served	534,700	644,800	739,200	832,300	938,500
Average per capita consumption (liter)	70	75	80	85	90
UFW ratio (%)	54	48	42	36	30
Maximum Daily Demand (m^3/day)	97,000	112,000	122,000	133,000	145,000

3. WATER BALANCE

Water sources available within the study area are allocated, taking into consideration of the water balance in whole country and will be allocated as well. Considering a) the water resources development projects such as the "dividend" of the Peace Treaty and the Disi Aquifer and b) water demand in the country, the following water resources will be allocated to the Study Area;

- Existing resources such as Azraq wells
- Converted resources which are now used for Amman

Considering the progress of the water resources development projects, the above resources will be used until 2005. However, after 2005, additional water resources need to be added to meet the water demand in the Study Area. The additional water resources will be located to the west of the Study Area while both the existing and the converted sources are located to the east of the Study Area. Accordingly, the transmission pipelines will change in direction in the year 2005.

4. WATER SUPPLY IMPROVEMENT PLAN

For formulating the long term development plan, the following development concept is applied in due consideration of the present problems;

1) More Efficient Use of Available Water
2) Improvement of Water Supply System
3) Re-use of Wells with Low Water Quality
4) System Expansion for Future

The facilities with the above concept is planned for the target year of 2015 with two staged implementation plan. For the first stage plan with a target year of 2005, feasibility study was conducted. The facilities are shown in Table and Figure. The project cost is 63 million US dollars for the first stage plan and is 22 million US dollars for second one.

5. ORGANIZATION AND OPERATION & MAINTENANCE

For the successful implementation of the Stage I Project, a Project Implementing Office (PIO), headed by a Project Manager (PM), is to be organized in WAJ Zarqa. The Project contains civil works for rehabilitation and expansion, which are considered slightly different in nature. It is therefore recommended that two teams, Rehabilitation team and Expansion team are organized under PM.

Rehabilitation of the deteriorated distribution and service mains are proposed to reduce UFW. More important measures to reduce UFW are strengthening of the leakage control organization to have active leakage control measures instead of the passive ones. Also, measures to reduce metering errors which is one of the major portion of the UFW, should be taken.

6. PROJECT EVALUATION

The estimated EIRR is 8.8%, which indicates that the project is economically justifiable. However, FIRR is negative due to low revenue associate with low tariff. To gain 5 % FIRR, the tariff needs to be doubled. In this case, ratio of the tariff against the household revenue will reach to approximately 1 % from the current 0.4 %. The 1 % is within the so-called tolerable ratio of 4 % and the tariff increase is within the allowable range.

Annual required fund for the project varies from US$ 2.0 million to US$ 15.8 million during the implementation period of 1998 - 2004.

WAJ has spent about JD 48.4 million or US$ 69.1 million annually on an average during the past 5 years. Compared with this figure, the estimated annual fund requirement for the project corresponds to 2.9 - 22.9% of the annual WAJ investment. The annual fund requirements is less than 20 % of WAJ investment except that of 2001 and is considered within the reasonable investment level of WAJ.

Further, substantial socio-economic impacts are expected from the implementation of the project. The improvement of the basic human needs through the alleviation of water shortage and rationing is considered a great benefit to the Study Area as well as the resulting regional development. Taking into account all the above the project is justified economically and socially and its early implementation is to be recommended.

7. ENVIRONMENTAL IMPACT ASSESSMENT

The following issues are concerned with the project implementation; 1. Resettlement, 2. Economic Activity (Impacts on existing tenant or lower income people), 3. Traffic and Public Facilities, 4. Archaeological Treasures and 5. Water Pollution

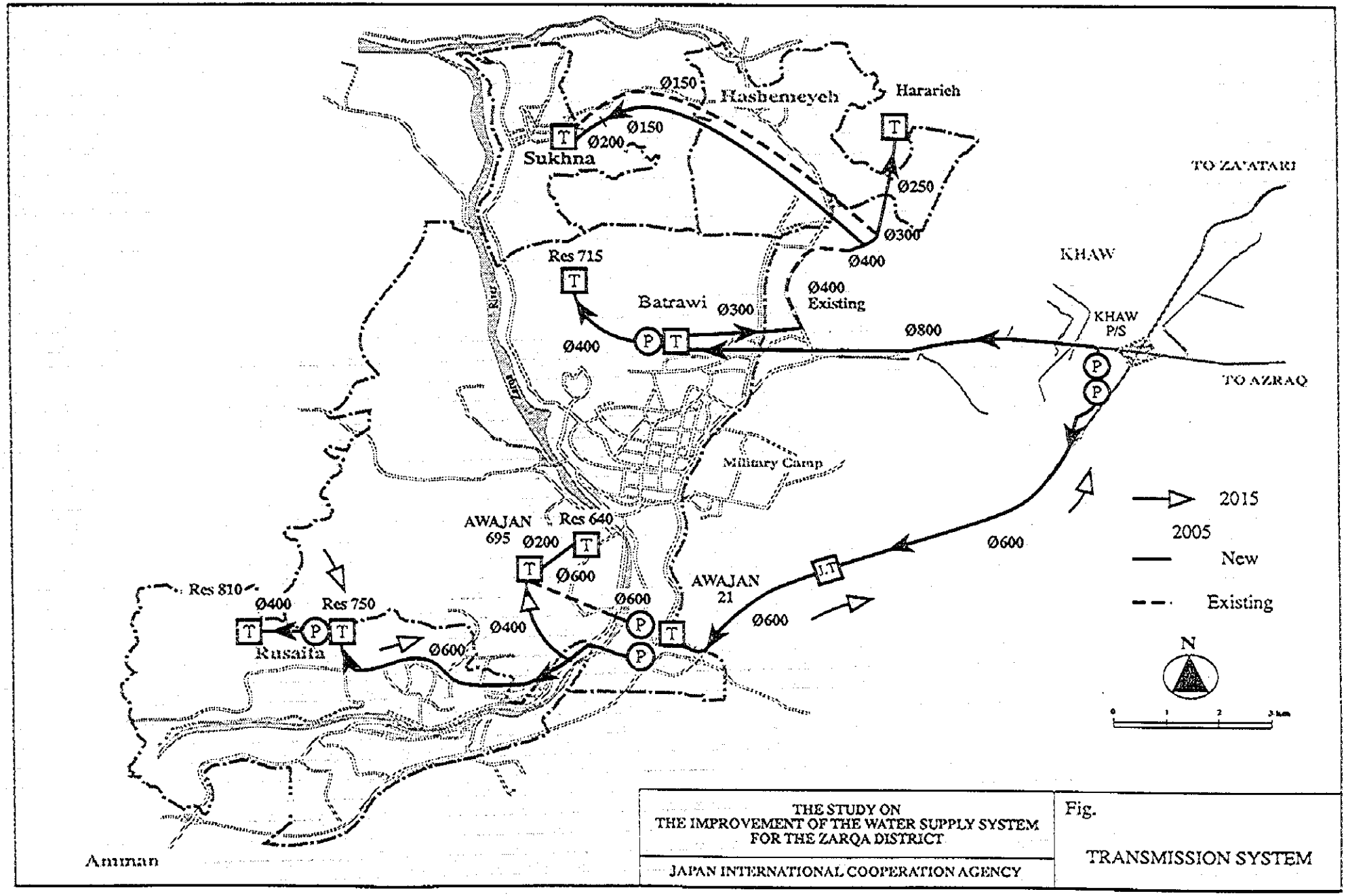
However, the impacts are minimized with the following measures;

1. The facilities are planned to avoid resettlement.
2. Lower income people does not reside the hilly areas which will be the major beneficially areas with the project implementation.
3. Sewerage facilities will be served by 2000.

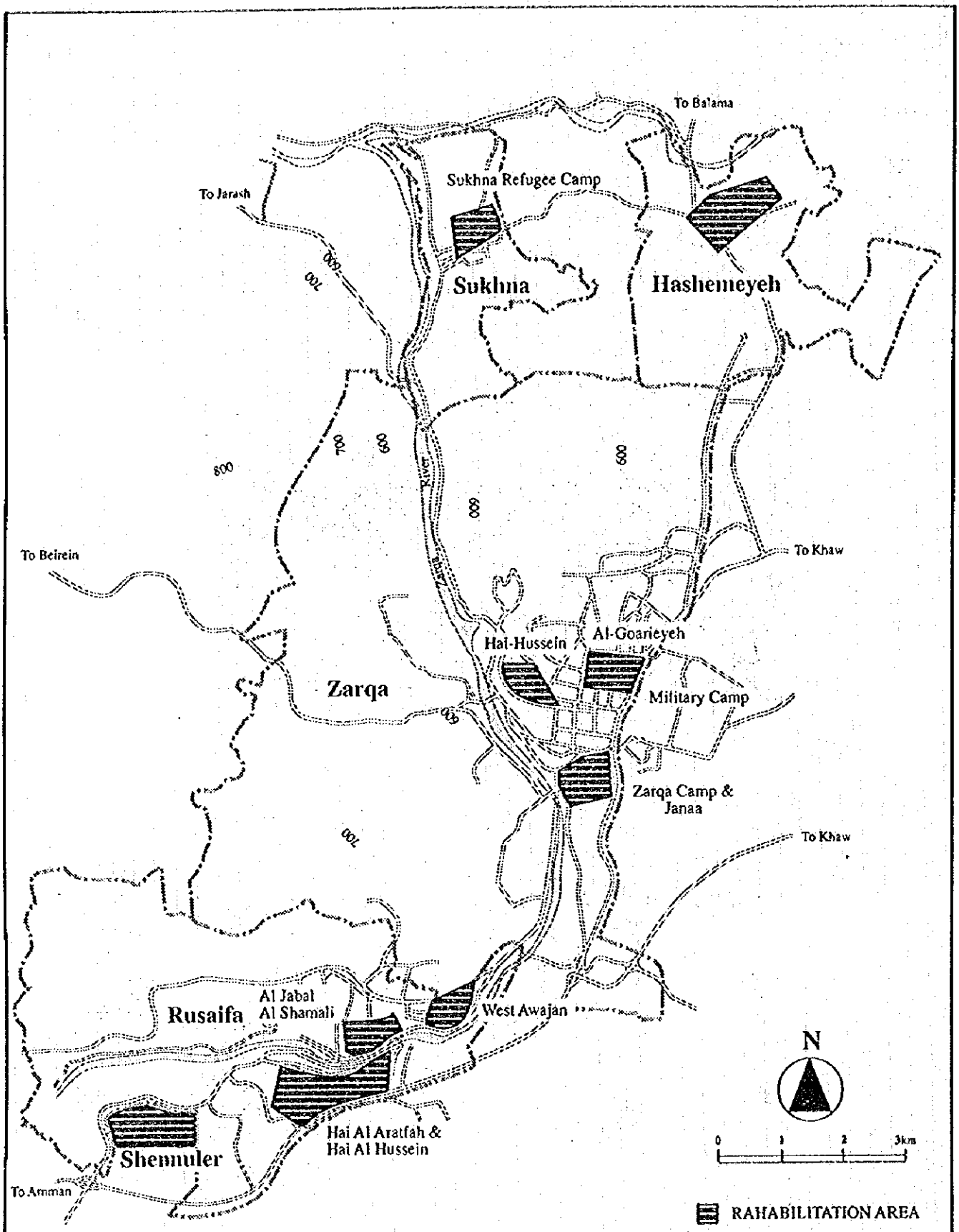
Table FACILITIES FOR THE STUDY

Target	Facility	Size
1) Reduction of UFW		
	Replacement of Distribution Pipe	150 mm X 17.4 km
		100 mm X 75.0 km
		50 mm X 13.1 km
	Replacement of Service Pipe and Meter	12,700 meters
		20 mm X 140 km
	Creation of District Metering Area	25
2) Zoning System		
- Transmission Pipe	Khaw PS - Batrawi Res	800 mm X 7.9 km
	Batrawi Res - Res 715	400 mm X 2.2 km
	Batrawi Res - Hashemeyeh offtake	400 mm X 0.1 km
		300 mm X 2.3 km
	Hashemeyeh offtake - Hararieh Res	250 mm X 1.9 km
	Hashemeyeh offtake - Sukhna Res	200 mm X 1.0 km
		150 mm X 6.8 km
	Khaw PS - Awajan PS	600 mm X 12.2 km
	Awajan PS - Awajan 695 Res	600 mm X 0.3 km & Existing 600 mm
	Awajan PS - Awajan 635 Res	200 mm X 0.8 km
	Awajan PS - Rusaifa 750 Res	600 mm X 6.6 km
	Rusaifa 750 Res - Rusaifa 815 Res	400 mm X 1.8 km
- Pumping Station	Khaw Pump for Batrawi, Hararieh and Sukhna	9.7 m^3/min. X 77 m X 310 kW X 6
	Khaw Pump for Awajan PS	4.1 m^3/min. X 79 m X 110 kW X 5
	Batrawi Pump for Res 715	2.7 m^3/min. X 87 m X 75 kW X 4
	Awajan Pump for Awajan 695 Res	5.4 m^3/min. X 121 m X 220 kW X 5
	Awajan Pump for Rusaifa 750 Res	4.4 m^3/min. X 193 m X 290 kW X 6
	Rusaifa Pump for Rusaifa 815 Res	3.2 m^3/min. X 75 m X 75 kW X 4
- Reservoir	Batrawi 650 - Expansion	12,500 cubic meters
	Res 715 - New	4,000
	Hararieh Res - New	2,000
	Sukhna Res - New	1,000
	Awajan 695 Res - Expansion	5,500
	Awajan 635 Res - New	2,000
	Rusaifa 750 Res - New	10,000
	Rusaifa 815 Res - New	5,000
- Distribution Pipe	Rusaifa 815 - Schneler	4,600
	Rusaifa 750 - Rusaifa	1,700
	Being revised	
3) Utilization of Existing Wells		
- Collector Pipe	Zarqa well - Khaw PS	Existing (400 mm)
	Hashemeyeh - Khaw PS	250 mm X 5.7 km
	Awajan 23 well - Awajan PS	Existing
	Rusaifa valley wells - Awajan PS	500 mm X 2.9 km
- Pump	Zarqa well - Khaw PS	3.0 m^3/min. X 150 m X 150 kW X 1
	Hashemeyeh - Khaw PS	3.0 m^3/min. X 150 m X 150 kW X 1
	Rusaifa valley wells - Awajan PS	Existing
- Collector Tank	Awajan PS - New	5,000 m3
	Khaw PS	Existing (12,000m3)

PS: Pumping Station Res: Reservoir



THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig.
JAPAN INTERNATIONAL COOPERATION AGENCY	TRANSMISSION SYSTEM



THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.- REHABILITATION AREA

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ABBREVIATIONS

AC	advisory committee
AFW	Accounted-for water
"	inch = 25.4 mm
BHN	basic human needs
BS	British Standard
CDWM	combined district and waste metering method
CIP	cast iron pipe
cu . m	cubic meters
d	day
dB	desibell
DIP	ductile iron pipe
DG	director general
donum	1,000 m2
EEM	environmental examination matrix
EIA	enviromental impact assessment
EIRR	economic internal rate of return
EL	elevation
FIRR	financial internal rate of return
ft	foot = 30.5 cm
GDP	gross domestic product
GL	ground level above mean sea level
GNP	gross national product
GSP	galvanized steel pipe
ha	hectare = 10,000 m2
HP or hp	horse power = 0.746 kw
hr	hour
IEE	initial environmental examination
IRR	internal rate of return
ISO	International Standards Organization
JD	Jordan Dinar
JICA	Japan International Cooperation Agency
JICAEG	JICA:s environmental guidelines
JIS	Japan Industrial Standard
JTU	Jackson Turbidity Unit
km2	square kilometer
KW or kw	kilowatt
lpcd	liter per capita per day
LS	lump sum
m	meter
MCM	million cubic meters
mln	minute

m2	square meters
m3	cubic meters
mg/l	milligrams per liter
mm	milimeter
MNF	minimum night flow
MWI	Ministry of Water and Irrigation
n.a.	not available
No .	number
NPV	net present vaiue
OECD	Organization for Economic Cooperation and Development
OM	operation and maintenance
p.a.	per annum
PS	pumping station
PVC	poly-vinyl chloride pipe
s	second
SP	steel pipe
sq. km	square kilometers
sq.m	square meters
TDS	total dissolved substances
UFW	Unaccounted-for water
WAJ	Water Authority of Jordan
WHO	World Health Organization

PART I LONG TERM DEVELOPMENT PLAN

I. INTRODUCTION

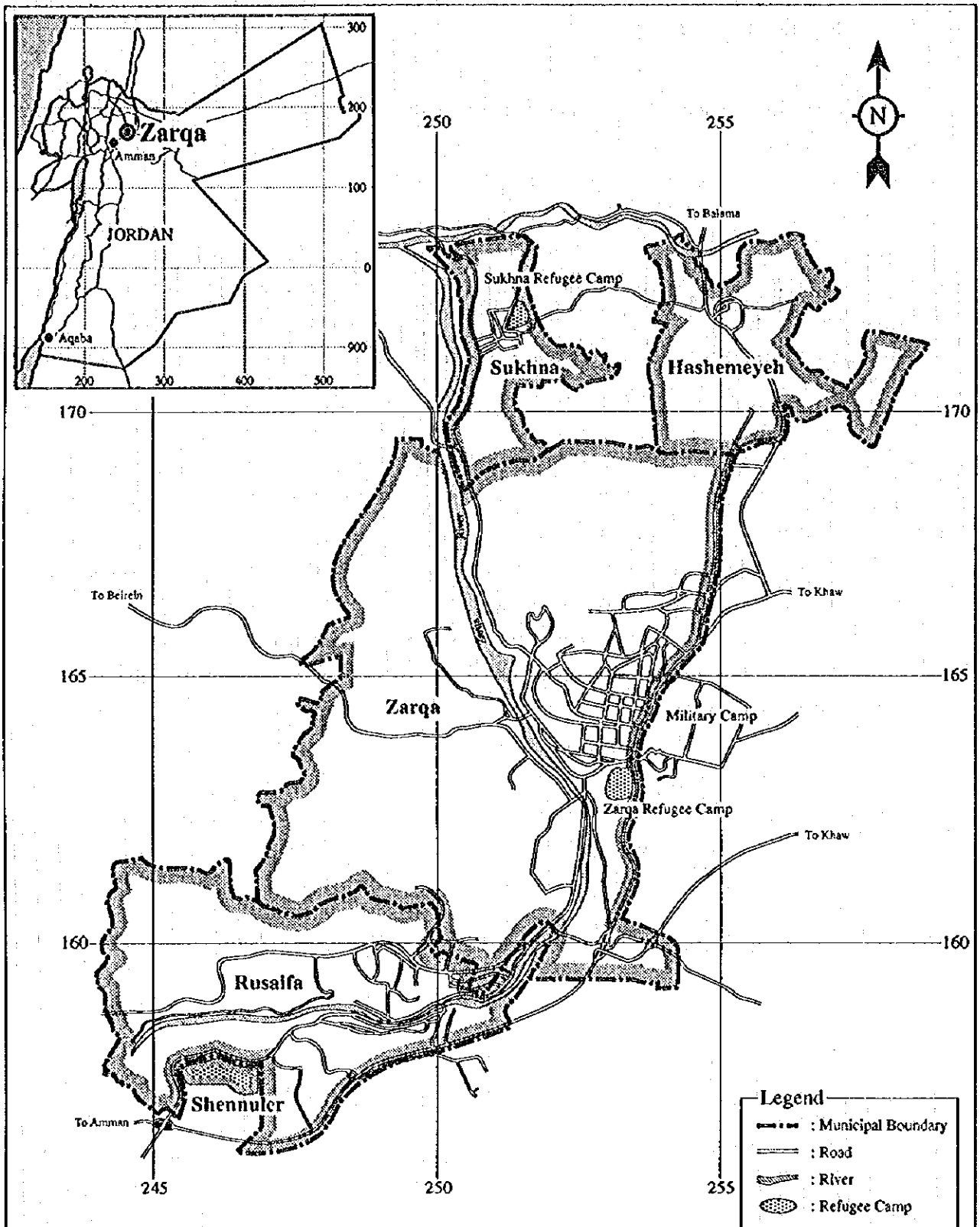
I. INTRODUCTION

The goals of the study are to 1) formulate a long-term development plan of the water supply system in Zarqa District with a time horizon of 2015 and 2) carry out a feasibility study of the Stage I project identified in the long-term development plan.

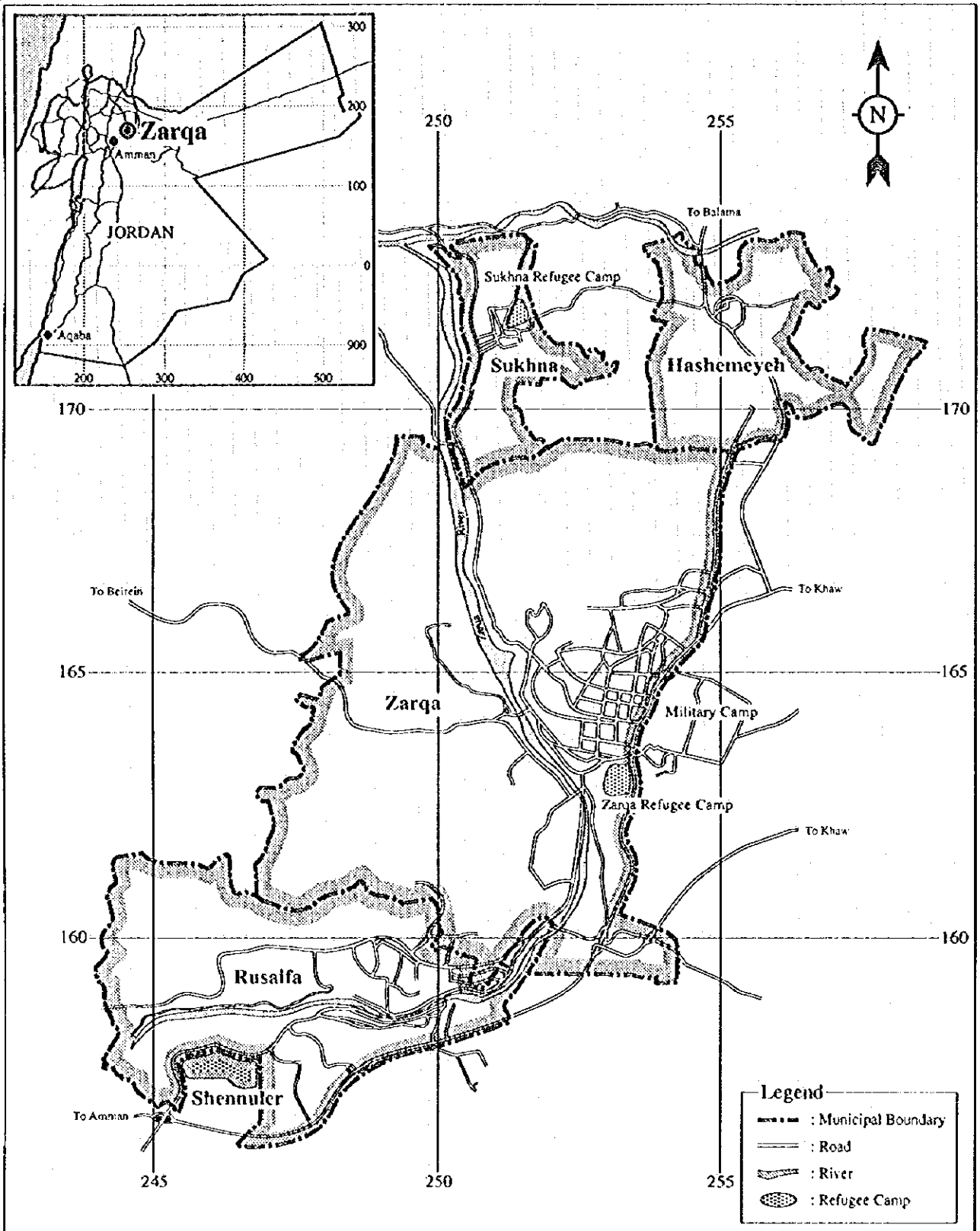
As defined in the Scope of Work, the Study Area (See Fig.- 1.1) is Zarqa District which covers: 1) Zarqa municipality including New Zarqa and Awajan, 2) Rusaifa municipality, 3) Shennuler Refugee Camp, 4) Hashemeyeh municipality and 5) Sukhna municipality. The existing water sources, transmission lines and pumping stations which feed the area are also considered as parts of the Study Area.

This Report prepared by the JICA Study Team compiles results of surveys and analyses carried out from November, 1994 to March, 1996. We describe the long-term development plan based on the latest data and information collected during the study. The surveys and analyses included "household survey" and "factory survey" on present water use, "pipe detection and spot check survey" for preparation of system layout, "water sampling and testing", "unaccounted-for water survey", "flow meter calibration", "hydraulic network analysis", etc. Following the long-term development plan, the feasibility study was carried out for the projects that were identified in the first stage plan.

The Report consists of three separately compiled volumes: Main Report, Supporting Report and Data. The Main Report, does not necessarily present in detail the methodology and results of the various surveys and analyses carried out. For more detail, reference can be made to the relevant chapters and sections of the Supporting Report.



THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig.- 1.1 LOCATION MAP OF STUDY AREA
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig.- 1.1 LOCATION MAP OF STUDY AREA
JAPAN INTERNATIONAL COOPERATION AGENCY	

II. STUDY AREA

II THE STUDY AREA

This chapter describes general features of the Study Area including natural, socio-economic and public health conditions. Various data and statistics for the Study Area were not readily at hand though efforts were made to collect them during the study period. In cases where the data was not available, we have used similar data from Zarqa Governorate. This assumption is reasonable since in 1994 the population in the Study Area represented 86 % of the total population in the Governorate.

2.1 NATURAL CONDITIONS

2.1.1 Topography

Zarqa District, one of the fastest growing regions in Jordan, is situated 35km northeast of capital Amman. Zarqa district is concentrated around the Zarqa river which runs east through Rusaifa then turns north with Zarqa on its eastern side. Through Rusaifa the elevation of the river is around 650 m AND (above national datum) with properties on the north and south sides having ground elevations rising to 815 m AND and 776 m AND respectively. As the river runs north it drops to 525 m AND while central Zarqa rises to over 625 m AND to the east (See Fig.- 2.1).

The area is transitional with several ridges extending from the southwest to northeast. Shennuler stands on the southern hills. Rusaifa municipality spreads over the lower flats and higher hills that surround Shennuler and the Zarqa River. Hashemeyeh and Sukhna municipalities are on the northern lower flat. Between these municipalities, Zarqa municipality extends on the right bank of the Zarqa River.

2.1.2 Climate

Located at the western fringes of the inland desert, the Study Area is characterized by an arid climate throughout the year. The annual rainfall ranges from 160 mm to 310 mm and virtually all of the rainfall is between the months of October and April. The coldest and hottest months in the Study Area are January and August respectively with the recorded temperature extending from 2.5℃to 39℃. The mean annual temperature is 17℃. The average annual relative humidity is a very low 51 %.

2.1.3 Geology and Soil

The entire Study Area is underlain by a series of calcareous marine sediments. Of these sediments, only three formations are important to this study: B1-2 (Amman), A7 (Wadi Sir), and A4 (Hummar).

The B1-2 and A7 units form an unconfined upper aquifer within the Study Area. The B1-2 unit overlies the A7 and consists of chalk, marl, limestone, chert, and phosphate beds that range from 80 to 115 m in thickness. The cherty portions of the formation are typically folded and are commonly found in the Study Area, especially in the vicinity of Zarqa.

The A7 unit forms the base of the upper aquifer and consists of 100 m of white to light grey limestone that is occasionally chalky and marly. This unit is cavernous and forms an excellent aquifer. Outcrops of the A7 formation are common northwest of the Study Area.

The A4 unit forms the lower confined aquifer and is separated from the upper aquifer (A7) by 75 to 100 m of massive limestone. The A4 unit mainly consists of 40 - 60 m of crystalline, dolomitic limestone that is occasionally highly fractured. It gradually thins out and becomes increasingly marly towards Zarqa which decreases its water bearing properties. Outcrops of the A4 formation occur northwest of Zarqa at Sukhna and Nimra.

In addition to these older sediments, recent alluvial deposits cover much of the Study Area near the Zarqa River and related side wadis. The composition and depth of the deposits vary considerably, but 30 to 50 m of material can occur in the area from Zarqa to Sukhna. Alluvial deposits are known to provide for surface flow of the Zarqa River during summer months when the river becomes dry.

The dominant geological structure in the area is the Amman-Zarqa syncline, which begins southwest of Amman and plunges northeastward to Zarqa. The syncline is responsible for the marked topographic relief to the northwest and southeast of the Zarqa River where slopes of 20 to 30 percent are common. In addition, the syncline has an important effect on groundwater flow as it controls the direction of flow from west to east. With the exception of the B1-2 unit, all formations are parallel to the syncline. The slope of the northwest limb has an average grade of 3 to 5 percent, while the southeast limb has slopes of 20 to 40 percent.

Associated with the syncline is the Amman-Zarqa flexure, which is a transition zone between the syncline and anticline. The flexure occurs southeast of the Zarqa River in association with a system of faults, and serves as the southeast boundary of both aquifers. Folding and faulting activities within this area have created a zone that is more permeable than other bedrock areas.

Soils in the Study Area are mainly Yellow Mediterranean (YM) and Red Mediterranean (RM). The YM soils are extensive throughout the area from Amman to Zarqa. The RM soils are occur at the extreme western boundary of the Study Area and continue westward to the Jordan River. To the east of Zarqa, soils are classified as grey desert soils which are infertile and contain high concentrations of salts. The YM and RM soils have a high corrosion potential for uncoated steel because of salt accumulations throughout the profile.

The densely developed hillsides have very shallow soils, and as a result, many wastewater disposal systems are constructed with little or no sub-drainage beneath the disposal area. Consequently, wastewater leaches into the groundwater without adequate treatment and contaminates the upper aquifer.

Geological Succession

PERIOD	EPOCH	GROUP	FORMATION	SYMBOL	LITHOLOGY
Quaternary	Holocene (Recent)		fan, talus, terrace, river		sand, clay, gravel
	Pleistocene	Jordan Valley	lisan	J	marl, clay, gypsum, sand, gravel
Tertiary	Pliocene		undifferentiated		conglomerate, marl
	Miocene				
	Oligocene				
	Eocene Paleocene	Belqa			
Upper Cretaceous	Maestrichtion				
	Campanion		Amman	B2	silicified limestone, chert
	Santonian		Wadi Ghudran	B1	chalk, chalky marl
	Turonian	Ajlun	Wadi Sir	A7	limestone
	Cenomanian		Shueib	A5-6	marly limestone
			Hummar	A4	limestone
			Fuheis	A3	marl
			Naur	A1-2	marl, limestone
Lower Cretaceous	Albian	Kurnub		K	white sandstone with dolomite and shale; variclored sandstone with limestone, shale, dolomite and marl
	Aptian				
	Neocomian				
Jurassic		Zarqa	Azab	Z2	limestone, marl, dolomite, sandstone, shale
Triassic			Main	Z1	sandstone, calcareous sandstone, limestone, shale, gypsum

2.1.4 Water Resources

Water resources and their limited availability are a major concern not only in the Study Area but also throughout Jordan. This concern can be largely attributed to several factors affecting the area's water resources. As mentioned before, the area is characterized by a dry arid climate. Rainfall is concentrated in the winter months, with the summer months generally receiving no rainfall. In addition, wide fluctuations in annual rainfall make water planning efforts very difficult. Intermittent streams, known as wadis, are common in the Study Area and constitute the major portion of the surface water system. These streams dry up during the summer months and during this period surface water is unavailable to the area. The primary water source for the Study Area is, therefore, groundwater.

(1) Zarqa River

The Zarqa River and its tributaries comprise the only significant running water environment in the area. This river is the second largest river in Jordan. Total catchment area of this river is 4,025 km2 with 650 km2 at the north of old Zarqa city. The Zarqa River originates at Jabal Durz, just west of Amman and flows northeast to Zarqa. From Zarqa, the river changes course and flows north to Sukhna, where it is met by Wadi Dhuleil, a major tributary. Turning westward the river continues until it flows into the King Talal Dam. It has an average annual total flow of 62.4 MCM (Million Cubic Meters) per year, including about 50 MCM of treated wastewater discharged to Wadi Dhuleil from As-Samra wastewater treatment plant. Except for this waste water discharge, it has virtually zero natural flow for eight to nine months annually.

Enhancement of monitoring and control of the wastewater launched in 1992 by the Government has significantly decreased untreated wastewater effluents from the industrial factories. However, evidences show that some industries are still discharging nitrogen compounds, oxygen demanding substances and a variety of inorganic compounds, including heavy metals. Agricultural runoff from irrigation also contributes phosphorus and nitrogen compounds and pesticides.

(2) Groundwater

Zarqa Governorate depends totally on groundwater to meet its water demands. This water is abstracted from "Amman-Zarqa" and "Azraq" basins which are considered as the major productive groundwater basins in Jordan.

(2) - 1 Amman-Zarqa basin

The Amman-Zarqa basin has an area of 3,900 km2. Groundwater in the Zarqa-Ruseifa area belongs to the Amman-Zarqa basin. The shallow, upper aquifer is unconfined and as such, the water level is free to rise and fall in response to seasonal fluctuations. The lower aquifer is separated from the upper aquifer by a layer of massive limestone. This is a confined condition in which the water level fluctuates in response to piezometric pressures.

Recharge sources to this basin are natural and artificial. Natural recharge sources include the lateral flow of groundwater from the western highlands, percolation of surface and rain water. Return flow of domestic water through leakage from the water supply system forms a non-negligible part of recharge to this basin as an artificial source where it was estimated by WAJ Team-1989 to be about 10 MCM. Direct infiltration throughout the Zarqa-Ruseifa region takes place where outcrops of the B1-2 and A7 formations commonly occur.

Large volumes of water reach the upper aquifer by indirect infiltration through alluvial deposits of the Zarqa River and associated side wadis. Unlike the upper aquifer, recharge of the A4 formation occurs mainly by direct infiltration in the outcrop areas. Outcrops of the A4 formation northwest of Amman are the major recharge zones for the lower aquifer.

Major abstraction in this basin occurs from the upper and middle aquifer systems. There are a total of 670 active groundwater wells within this basin.

Total recharge to this basin is 88 MCM according to the recent study by Salameh, et al. in 1993. While the total consumption from this basin is 190 MCM, according to WAJ annual report-1993, which is divided into:

- 65 MCM for domestic use
- 118 MCM for agricultural use
- 7 MCM for industrial use

This consumption is equal to about 216% of the total recharge to the basin, resulting in a high depletion rate for the basin.

The depth of wells varies considerably from the shallow, hand-dug wells along the Zarqa River to wells deeper than 200 meters which withdraw water from the lower aquifer.

Chemical analysis of well water during 1976 noted significant increases in total dissolved solids (TDS), chlorides and nitrates compared to earlier tests. These parameters usually indicate the intrusion of domestic sewage contamination. The upper aquifer wells in the Zarqa-Sukhna area

sampled during 1976 had average nitrate concentrations of 36.6 mg/l, chlorides of 187 mg/l, and TDS of 790 mg/l.

(2) -2 Azraq basin

The area of this basin is 12,710 km2. Recharge sources for this basin include the lateral flow of ground and surface water from the Syrian mountains. The total number of active groundwater wells within this basin is 583.

Water consumption in this basin is concentrated on the upper aquifer system. Recharge to this basin is about 25 MCM while the total abstraction is about 51 MCM (WAJ annual report-1993) divided as follows:

- 25 MCM for domestic use pumped to Amman and Zarqa areas.
- 25 MCM for agricultural use
- 0.2 MCM for industrial use

Total consumption equals about 202% of the total recharge. A significant amount of this water is pumped into Amman and Mafraq Governorates.

2.2 SOCIO-ECONOMIC CONDITIONS

2.2.1 National Economy

The gross domestic product (GDP) of Jordan was JD 3,882 million in 1993 at current price and the per-capita income is estimated at about JD 970 (US$1,385). From 1973 to 1984 Jordan enjoyed unprecedented economic growth. The GDP grew at 11.1 % p.a. during 1973 - 1979 and 9.9 % during 1980 - 1985. However, a recession occurred from 1985 to 1989. The GDP decreased at an average rate of -1.2 % p.a. during that period. Economic recovery began in 1990 and economic growth to date has been relatively steady. The average GDP growth rate was 6.0 % during the period of 1989 - 1993). Past GDP trends are presented in Appendix B.

The economic structure of Jordan is explained by the sector share of GDP as presented below.

Sector Share of GDP (1993)

Sector	GDP (%)
Agriculture and Forestry	10.3 %
Mining and Quarrying	4.1 %
Manufacturing	17.0 %
Construction *1	12.2 %
Wholesale, Retail, Hotel and Restaurant	11.8 %
Transport, Storage and Communication *2	22.2 %
Finance and Real Estate	22.4 %
Total	100.0 %

Source: Department of Statistics
*1 includes electricity and water
*2 includes social service

As indicated above, the manufacturing sector has a relatively small share of 17 %. The sector share of secondary industries including manufacturing and construction accounts for less than 30 %, while that of the services sectors accounts for 56 %.

In 1993 total exports including re-exports were JD 865 million, while total imports were JD 2,414 million. The resulting trade balance was JD -1,589 million. During the past decade (1983 - 1993) exports increased at the high growth rate of 15.6 % p.a., while imports grew at the moderate rate of 8.3 % p.a. However, the basic nature of this trade balance has not changed and the imbalance has increased year by year. This trade imbalance is being offset by a non-trade balance and foreign assistance. (Historical trends for exports and imports are presented in Appendix B).

In 1993, the Jordan government had a revenue of JD 1,368 million. Expenditures were JD 1,341 million and the resulting budget surplus was JD 27 million. In 1993, about JD 574 million was allocated for capital expenditure which is equivalent to 14.8 % of GDP.

During the period of 1988 - 1991 consumer prices increased at the high rate of 16.4 % p.a. on average. After 1991, consumer price increases leveled off to (4.4 % p.a. during 1991 - 1993) This trend continues to date. The currency exchange rate has been relatively stable at around US$ = JD 0.6 during the past 5 years.

A National Economic Development Plan was prepared for the period of 1993 - 1997 by the Ministry of Planning.

The targets set out in the 5-year plan are as follows:

(1) GDP (1991 constant price) will increase from JD 3,452 million in 1992 to JD 4,147 million in 1997 at an average growth rate of 6 % p.a.

(2) Population will increase at 3.2 % during the plan period and the per-capita GDP (1991 constant price) will increase at an average growth rate of 2.7 %.

(3) Inflation rate will be controlled at 4 - 5 % p.a. during the plan period to correct structural imbalances and to achieve fiscal and monetary stability.

(4) Unemployment rate will be to reduce to 9.6 % in 1997 (from the current 18 %)

2.2.2 Administrative Boundary and Population

Zarqa Governorate, located in the northern region of the country, is one of the eight governorates in Jordan. Zarqa Governorate consists of one district called the Zarqa district and two nahias, namely the Azraq nahia and the Birain nahia. Zarqa district is further divided into eight municipalities and other localities, while the Azraq nahia and the Birain nahia are divided into several municipalities.

The total area of the Zarqa Governorate is about 5,201 km^2, which is equivalent to 6 % of the country's total (89,000 km^2).

The Study Area is located in Zarqa district and includes many urban areas such as the municipalities of Zarqa, Rusaifa, Hashemeyeh, Sukhna and the Shennuler refugee camp. The Study Area covers 90.5 km^2 or about 1.7 % of Zarqa Governorate.

The administrative boundary for each municipality in the Study Area was obtained from each municipality and is presented in Fig. 2. 2.

According to the National Population and Housing Census conducted in 1994 by the Department of Statistics, the total population of the Zarqa Governorate was 623,943, which is equivalent to 14.8 % of the national population. From 1979 to 1994, the population of Zarqa Governorate increased at an annual growth rate of 4.3 %. The population of the Study Area was 534,674 in 1994 and grew at an average 3.9 % per year during 1979 - 1994, which indicates relatively lower growth for the same period in the Governorate.

Population density of the Study Are in 1994 is presented in Fig. 2.3. The area and population for the municipalities of the Zarqa Governorate and the Study Area for 1979 and 1994 are presented in the following table.

Area and Population

Study Area	Area (km2)	1979	1994	Average Growth Rate (%)
Zarqa Municipality *1	58.9	219,344	344,524	3.06
Sukhna Municipality	5.6	4,390	9,764	5.47
Hashemeyeh Municipality	6.2	4,148	13,038	7.93
Rusaifa Municipality	18.9	49,885	131,130	6.65
Schnneler Camp	0.9	23,261	36,218	3.00
Study Area Total	90.5	301,028	534,674	3.90
Other Areas	5,110.5	32,032	89,269	7.07
Total Zarqa Governor	5,201	333,060	623,943	4.27

Source: Department of Statistics
*1 Includes new Zarqa and Awajan
*2 High increase rate during 1979 - 1994 is due to the returnees from the Gulf countries.

2.2.3 Regional Socio-economy

Located at about 20 km (by road) north east of Amman, Zarqa is the third largest Governorate in Jordan. Rapid population growth has occurred due to the influx of refugees from Palestine (particularly after 1948 and 1967) and migration from rural areas (since the military base was established). The most recent increase of the population occurred when Jordanians returned from neighboring Arabic Countries after the Gulf War. (1990 - 1991). The south part of Zarqa has been developed as an industrial city and attracted factory laborers from rural areas.

As indicated by historical development, the study Area has been growing as the main industrial and urban area in Jordan. About 45 major factories in Rusaifa and Zarqa municipalities, are operating, which include mining, dairy products, paper, iron and steel product, ceramic, breweries and distilleries. In Hashmeyeh two of the nation's key industrial plants are operating, namely, a petroleum refinery plant and a thermal power plant. Names of the major factories and their water consumption are presented in Appendix B.

Though agriculture is not a predominant sector in the Study Area, the area along the Zarqa river is being used mainly for vegetable production. Animal husbandry including chicken farming is also practiced in the suburban area.

There are no available statistics regarding regional production in Zarqa Governorate. But the Regional Gross Domestic Product (RGDP) is roughly estimated at around JD 590 million in 1993 based on the population statistics.

The average number of persons per family household is 7.1 in Zarqa. Based on the population of 534,674, about 75,300 households live in the Study Area.

Though detailed information on the economic activity of households in Zarqa or the Study area are not available, about 25 % of the residents are considered to be involved in industrial and construction sectors, while about 70 % in the service sectors. The agriculture sector employs a very limited percentage of the residents.

The average household income in 1992 was JD 4,003 per year in Zarqa Governorate, which is relatively lower then the Jordanian average of (JD 4,607). Based on the average family size of 7.1 persons per household, the per-capita income is estimated at JD 559 in Zarqa.

Distribution of household income is presented below

Income Distribution in Zarqa/Jordan

Income Range (JD)	Zarqa	Jordan
I < 1,200	5.6 %	7.6 %
1,200 < I < 2,400	28.4 %	27.1 %
2,400 < I < 3,600	25.8 %	22.6 %
3,600 < I < 4,800	16.1 %	14.6 %
4,800< I < 6,000	10.2 %	9.8 %
6,000 < I < 7,200	5.0 %	5.8 %
I > 7,200	8.9 %	12.5 %
Total	100.0 %	100.0 %

Source: Household Expenditure and Income Survey, 1992

As indicated in the above, about 50 % of the households get annual income ranging JD 1,200 - 3,600 both in Zarqa and Jordan (this figures roughly coincide with the results of our household survey). Only 6 - 7 % of the household have an income less than JD 1,200 and 9 - 12 %. have incomes higher than JD 7,200. According to the household survey conducted by the JICA Team, household incomes in Zarqa municipality are larger than those of Rusaifa municipality.

Total household expenditures are estimated at JD 4,197 per year on an average in Zarqa Governorate. (household expenditures in Jordan total JD 4,562 on average). Out of the total expenditure, about 38 % is allocated for food and beverages, 23 % for housing and 11 % for transportation. The amount allocated for fuel, electricity and water is only JD 200 (JD 16.7/month/h) or 5 % of the total expenditure.

2.3 PUBLIC HEALTH AND HYGIENE

The study area is generally well serviced by infrastructure for public hygiene. About 99 % of the households are serviced by WAJ domestic water supply system. (According to the household survey conducted by us in December 1994, 96 % of the households use WAJ pipe system, 3 % use WAJ water tanks and 1 % use wells). However, water rationing is required in some areas, particularly, during the summer season. The installation of roof tank/ground reservoir and purchasing domestic water from private water tankers is common practice. Public health is being affected by deteriorating water quality caused by waste water intrusion into the wells.

In Zarqa Governorate, about 58 % of the residents are connected to the public sewerage system and the remaining 42% use cess pools. This is a relatively high installation ratio compared to other developing countries. However, waste water volumes exceed the capacity of the treatment plant installed at As Samura by more than twice, which results in discharging partially-treated water into rivers which deteriorates the living environment in Zarqa. Sewerage effluent is also used for agricultural irrigation which and has contributed the deterioration of public health and hygiene.

Other unfavorable public hygiene & health aspects in the Study Area are rapid urbanization and industrialization. Increased traffic and discharges from major factories installed along Ruseifa - Zarqa municipalities cause air pollution and water contamination. According to our factory survey, some factories are dumping industrial wastes and sludge into the public sewer lines or directly into Zarqa river without proper treatment.

All the wastes from factories and households in the Study Area are collected by trucks and dumped at the designated disposal site for land reclamation located in Rusaifa, a few hundred meters east from the Zarqa - Amman Highway.

The land near the boundary of Rusaifa and Amman is allocated for liquid waste disposal. The liquid waste is collected by tankers with a capacity of 10m3 and dumped into a waste water pond for evaporation. However, contaminated water from the pond is occasionally flushed out into the tributary of the Zarqa river during the winter season.

In Zarqa Governorate there are one governmental hospital (and one more under construction), six private hospitals and one army hospital. In addition, there are two comprehensive health centers being operated under which about 15 secondary health centers are established. There exist 22 mother and child centers and 14 dental clinics.

The doctor to population ratio in Zarqa is 1/1500 and the bed to population ratio is 1/976. The

above figures indicate that the health care services in Zarqa Governorate are equal or slightly better than the national average.

Though the living environment has not been improved so much in total, statistics shown in the following table indicate that the number of patients suffering from typical water-borne diseases in Zarqa Governorate has decreased:

No. of Registered Patients of Waterborne Diseases

Name of Diseases	Average No. of Patients (1978 - 1979)	Average No. of Patients (1991 - 1993)
Typhoid	44	4
Para/Typhoid	14	2
Infectious Hepatitis	31	94
Dysentery	1	7

Source: Zarqa Governorate

Enteritis and diarrhea are the most commonly reported water borne diseases in Zarqa. In 1993, 11,030 persons were reportedly infected by diarrhea and 402 persons were hospitalized.

2.4 URBAN DEVELOPMENT AND LAND USE

2.4.1 Present Urban Development

The present urban development in the Study Area can be grouped into the following three *different development categories*:

Residential development

Considering the rapid urbanization observed in the Study Area, the most important factor is residential development. Residential development started from the core of the municipalities such as Zarqa city and Rusaifa as well as Hashemeyeh and Sukhna. The development area has been expanding in the west to south direction from the core. New housing development is underway in Awajan, north of Zarqa and north Hashemeyeh. At present, there are ten on-going public housing projects in the Study Area, providing 5,307 plots / buildings for the estimated served population of 82,080.

Industrial development

The Study Area has been recognized as the most industrialized area in Jordan, and major industrial establishments such as a petroleum refinery plant and a thermal electricity power plant are concentrated around this area. In addition, most major industrial establishments are located in the Study Area, particularly along the Zarqa-Rusaifa corridor from the south of Zarqa to the

east of Rusaifa. Recently, government agencies have been directing new industrial establishments to locate on upland areas to the south of Zarqa to facilitate access from the Amman-Zarqa highway.

Refugee camp development

Three Palestinian refugee camps are located in the Study Area, namely, the Shennuler camp, the Zarqa camp, and the Sukhna camp, each of which was established in 1968, 1948, and 1968, respectively. Population in the camps, except Shennuler camp, seem to have already reached saturation levels.

2.4.2 Present Land Use

On the basis of available aerial photographs, results of field surveys and the preliminary results of the Greater Zarqa Comprehensive Development Plan, present land use in the Study Area was prepared by the JICA Study Team as presented in Fig.2.4. A brief description of the present land use is as follows:

The composition of land use in the Study Area is presented below.

Present Land Use

Major Land Use	Land Area (km2)	(%)
Residential	29.0	32.0
Mixed	11.2	12.4
Industrial	7.2	8.0
Agricultural	3.7	4.1
Public	1.9	2.1
Open Space	1.4	1.5
Refugee Camp	0.8	0.9
Vacant Land	35.3	39.0
Total	90.5	100.0

The characteristics of land use in the Study Area are as follows:

(1) The steepest land located to the west of the Study Area is vacant. It dominates land use and represents 39% (35.3 ha) of the total land area.

(2) The residential area extends towards the north and southwest directions from Zarqa city. It is the second largest land use and.

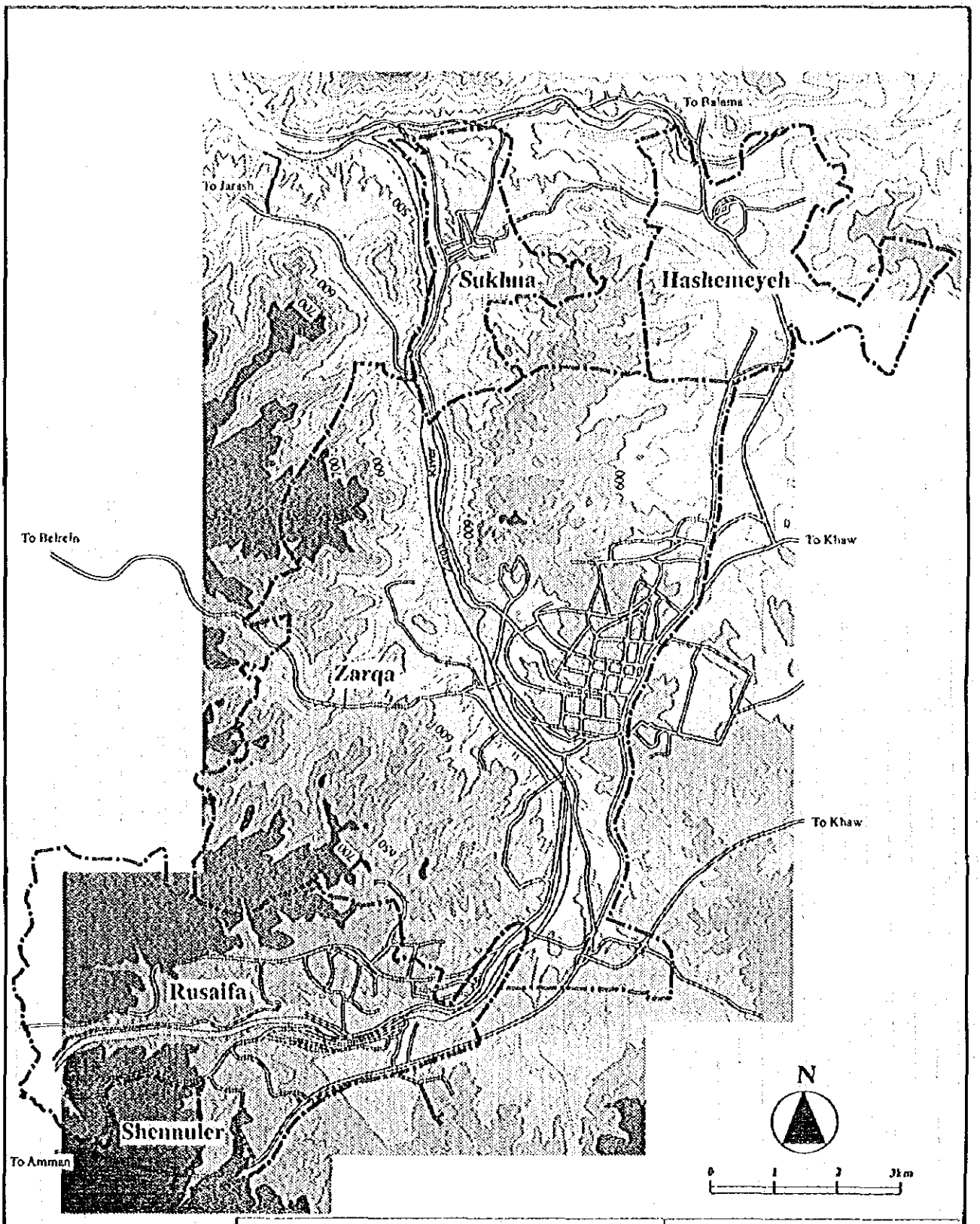
(3) The mixed area, which is defined as high density residential mixed with commercial represents 12% of the total land area. This area is located mainly in Zarqa and Rusaifa along the highway.

(4) The industrial area is relatively large and represents 8% of the total land area. This area

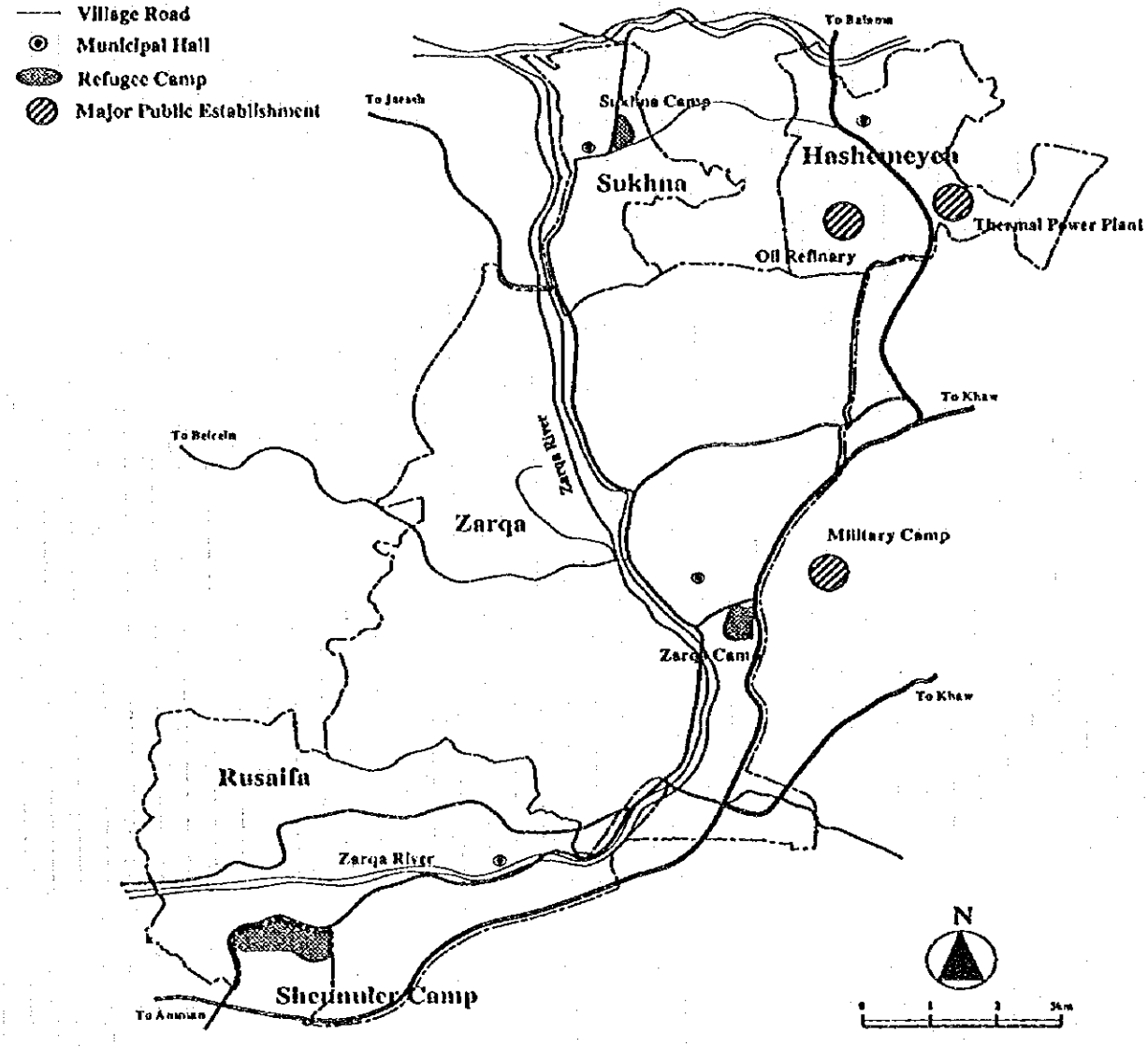
is located to the southeast of Zarqa, west of Rusaifa and south of Hashemeyeh.

(5) The agricultural area is relatively small and represents 4% of the total land area. It extends along the Zarqa river.

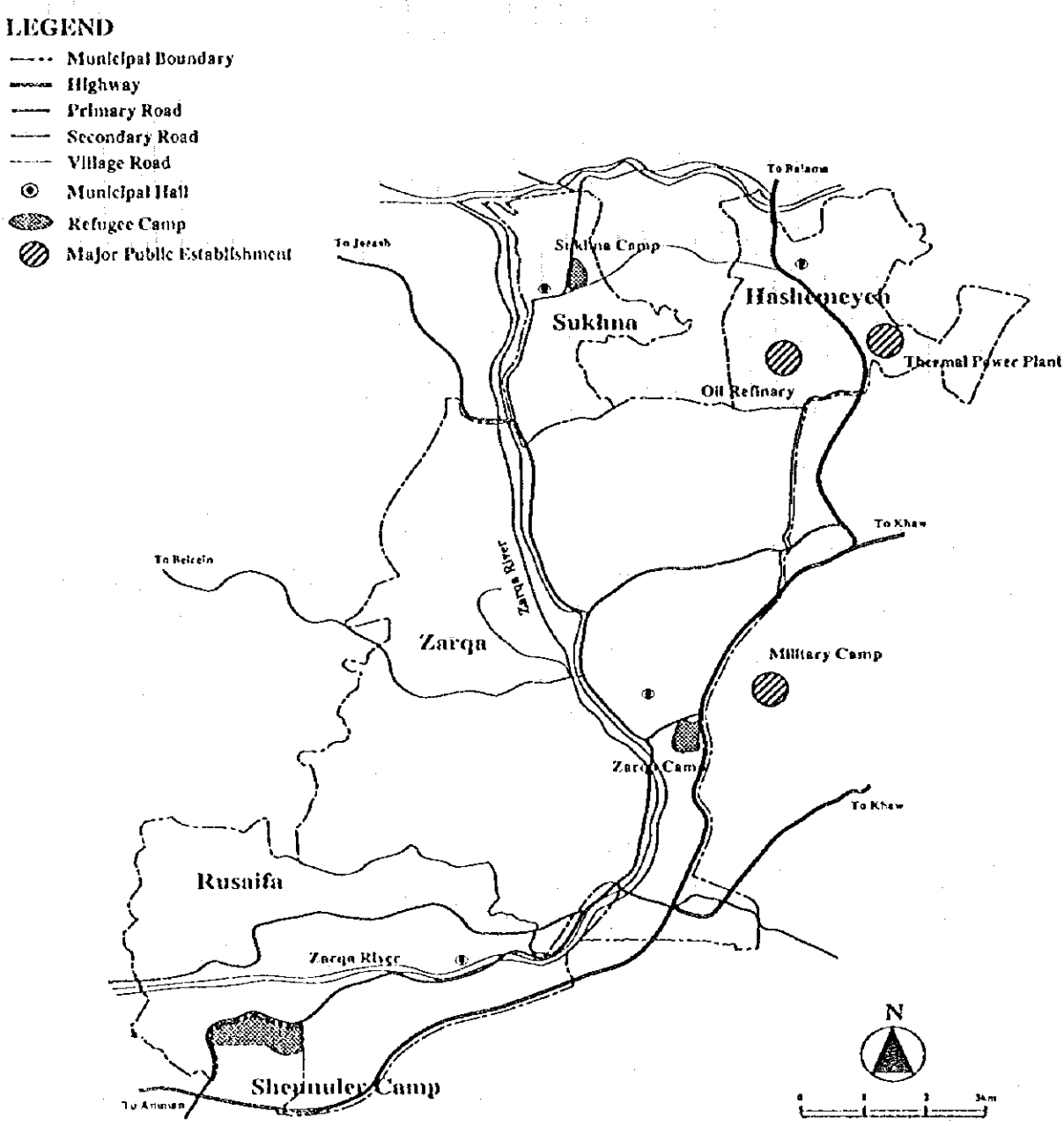
(6) The remaining area is divided by public and open space (bus stop, park, etc.) land uses and refugee camps which account for about 5% in total.



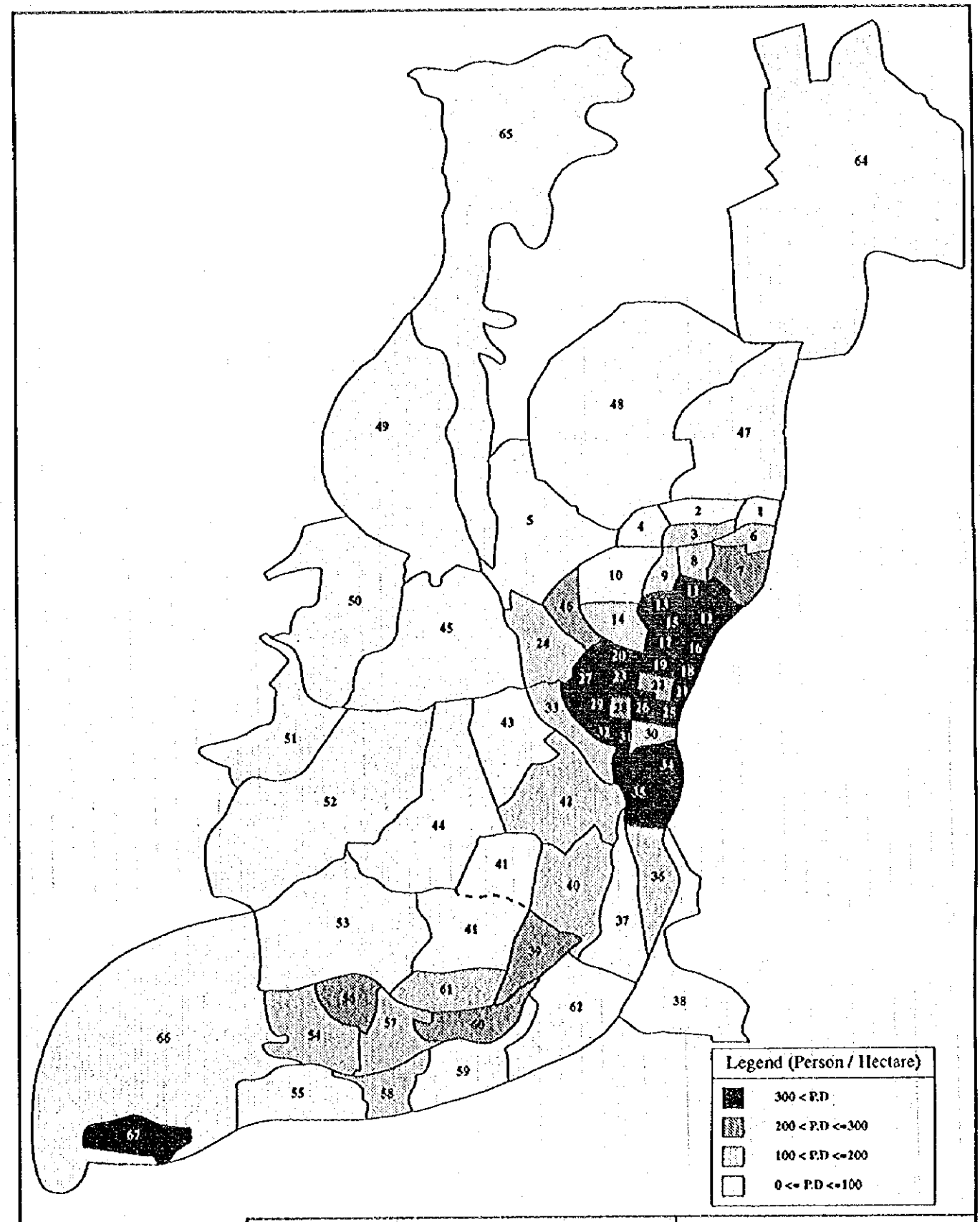
THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig.- 2.1 TOPOGRAPHY
JAPAN INTERNATIONAL COOPERATION AGENCY	



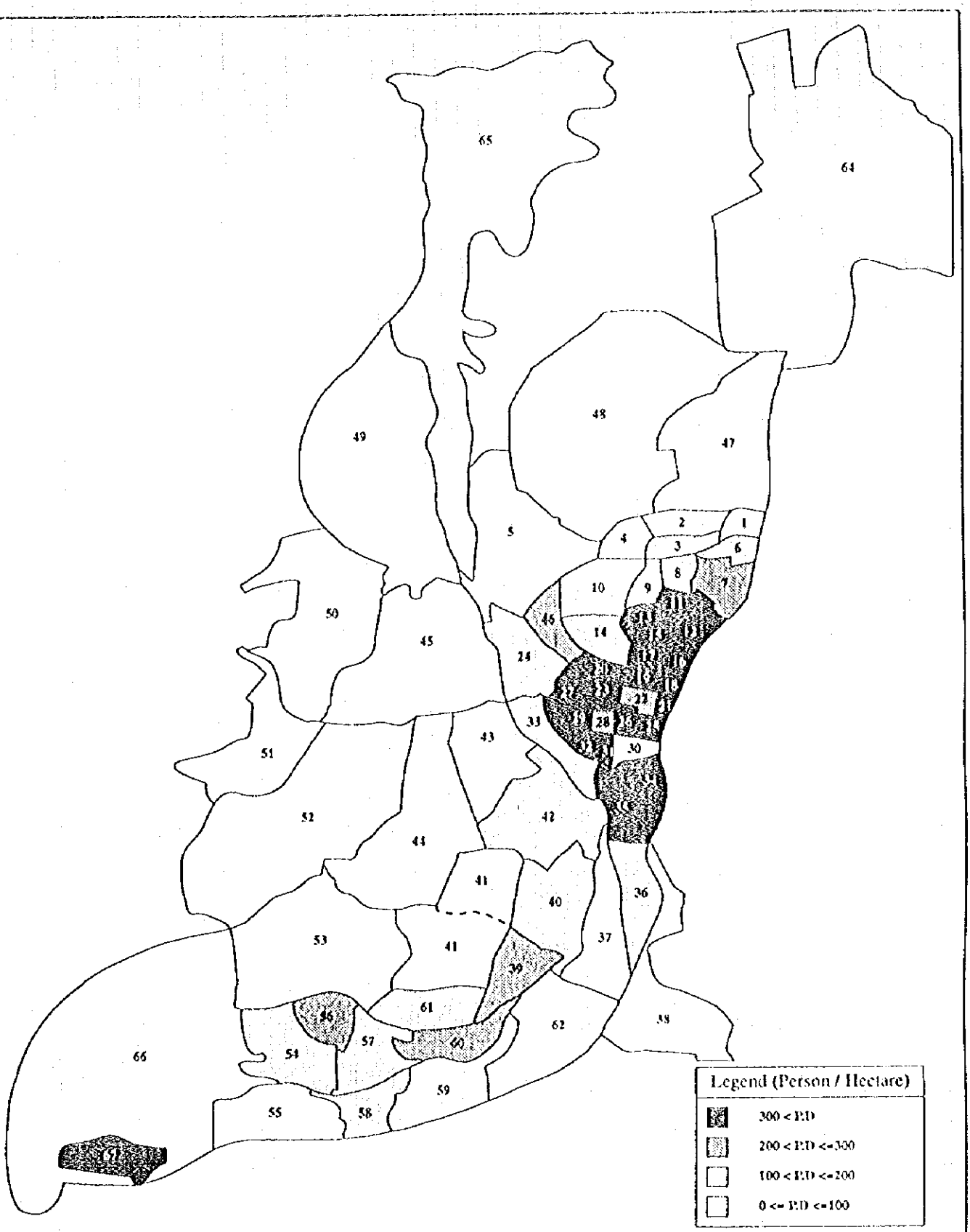
THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig.-2.2 ADMINISTRATIVE BOUNDARY IN THE STUDY AREA
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig.-2.2 ADMINISTRATIVE BOUNDARY IN THE STUDY AREA
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig.- 2.3
JAPAN INTERNATIONAL COOPERATION AGENCY	POPULATION DENSITY IN 1994

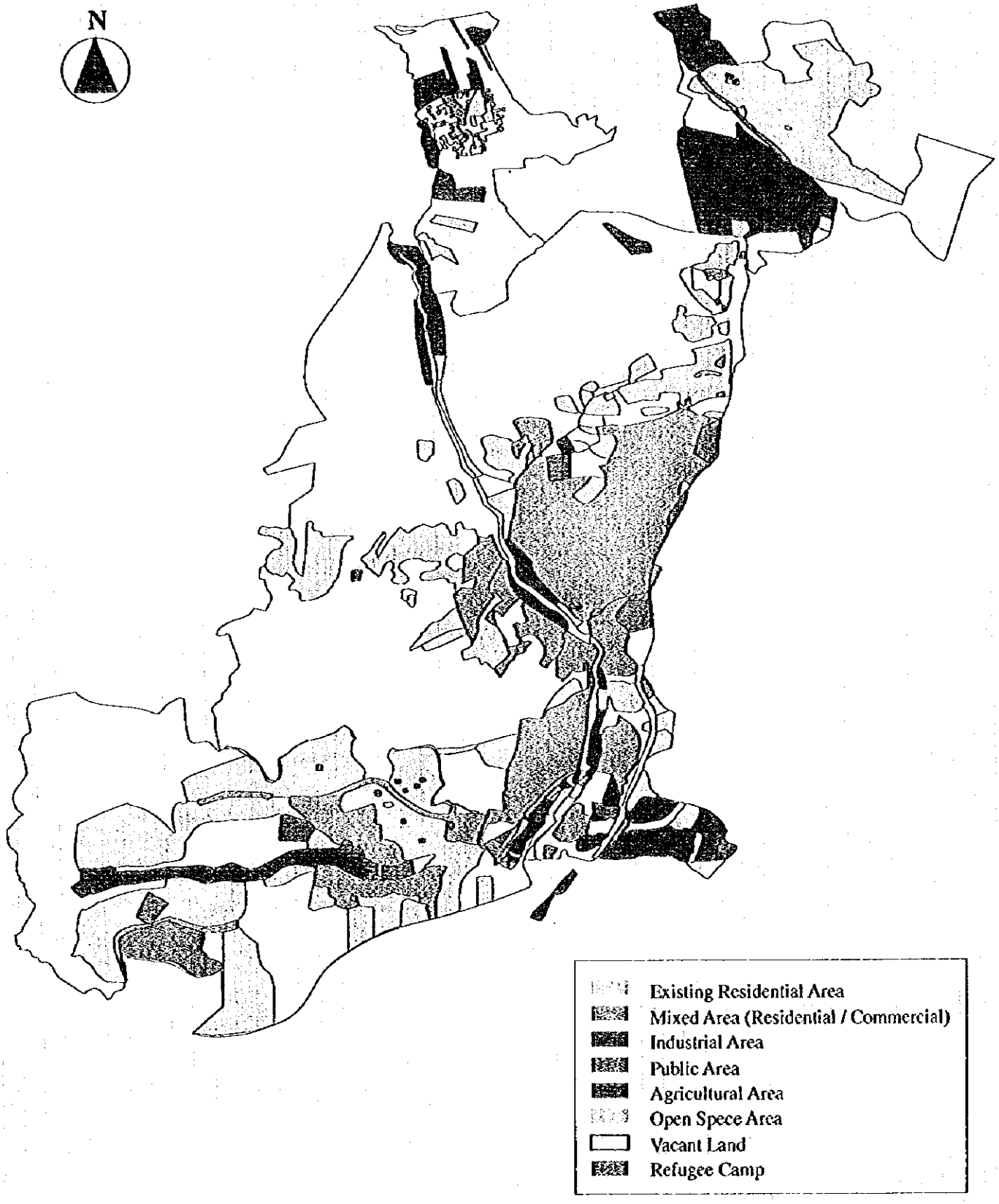


THE STUDY ON
THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM
FOR THE ZARQA DISTRICT

JAPAN INTERNATIONAL COOPERATION AGENCY

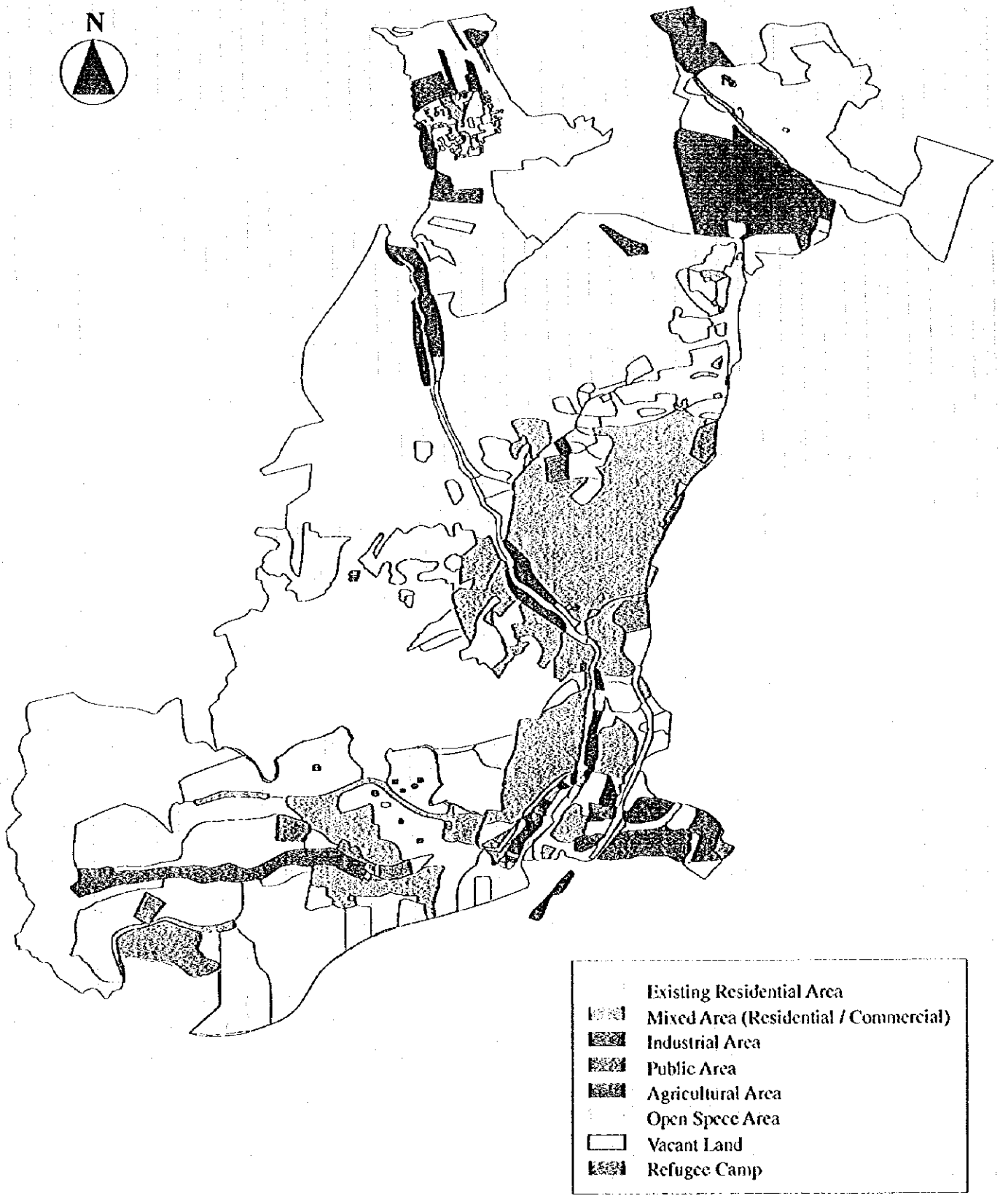
Fig.- 2.3

POPULATION DENSITY IN 1994



Source: Greater Zarqa Comprehensive Development Plan Study Team

THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.- 2.4 Present Land Use, Study Area



Source: Greater Zarqa Comprehensive Development Plan Study Team

THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig.- 2.4
JAPAN INTERNATIONAL COOPERATION AGENCY	Present Land Use, Study Area

III. PRESENT WATER USE

III. PRESENT WATER USE

3.1 SERVICE AREA AND POPULATION SERVED

The service area is the same as the Study Area previously defined. The service area has expanded at a rapid pace trying to keep up to municipal development. The following table shows the increasing number of subscribers in WAJ Zarqa over the past 6 years.

Numbers of Subscribers (WAJ Zarqa)

Year	Nos. of Subscribers
1989	60,262
1990	64,102
1991	65,061
1992	69,203
1993	73,392
1994	74,564

Source: WAJ Zarqa

The number of subscribers in Zarqa Governorate reached 14% of the total number of subscribers in the country at present.

In Zarqa Governorate the number of subscribers registered in November 1994 was 74,564. Excluding Azraq and other suburban areas, it is assumed that around 63,900 subscribers or 532,000 people are served in the study area. The service ratio in the study area is estimated at 99% in 1994. This high percentage can be explained by the hydrogeological features and historical urban development of the area. There are no major water sources other than deep well groundwater. Neither perennial river flow nor shallow well potable groundwater are available due to the semi-arid climate and the decreasing groundwater levels in Zarqa and Amman area.

People who are not served by the public water supply system or people who do not receive sufficient water are obliged to buy water from tanker trucks. There are 18 private wells in Zarqa Governorate, 9 in Awajan, 2 in Hashemeyeh, 4 in Hallabat and 3 in Azraq as seen in table which follows.

Number of Private Wells and Water Supplied
(Zarqa Governorate)

Area	Nos. of Wells	Water Supplied (m^3/day)
Awajan	9	5,350 - 5,600
Hashemeyeh	2	950
Hallabat	4	1,624
Azraq	3	1,660
Total	18	9,734 - 9,880

Source: WAJ Zarqa, 1994

These wells produced approximately 10,000 m3/day in total in 1994 or 13 % of the total supplied by WAJ Zarqa.

Most of the groundwater extracted from the private wells is sold to tank lorry owners in Zarqa, Rusaifa, Azraq, Amman, Irbid and Mafraq. The tank lorries convey and sell water to the public and small- and medium-sized factories who face critical water shortage. Information obtained from WAJ officials indicates not less than 200 such privately owned tankers, in Zarqa Governorate.

In addition, there are several irrigation wells along the banks of the Zarqa River which runs northward along the Zarqa - Sukhna road. Groundwater from these wells is supplied to the farm land stretching along the Zarqa River. Although exact numbers were not confirmed, the population served by these wells is small.

From the above information and the results of the household survey, the population not served by WAJ is assumed to be around 2,000 in the Study Area in 1994.

3.2 WATER SERVICE LEVEL

Water supply is not continuous and a rationing program is often implemented due to shortages. More than half the households suffer from water shortages. Most of Rusaifa and the northern fringe of Zarqa are the areas where the frequent rationing is practiced particularly in summer seasons (See Fig. - 3.1). Hydraulic analysis clearly shows that most of the Rusaifa area could not obtain water if water rationing were not practiced. Some customers buy their water from tankers because their properties have been built at an elevation higher than the existing system was designed to serve.

This situation has been worsened by the rapid rise in the area's population as many new properties are built higher than existing reservoirs in the area. Consequently, many booster pumps are installed.

Most households have water storage facilities (roof tanks and/or underground storage) to cope with the water rationing or intermittent supply. Such roof tanks are usually made of galvanized steel with a storage capacity of 1 m^3 or 2 m^3.

The household survey indicates that almost one third of the households are not satisfied with WAJ water supply services. To confirm the customers' ability to pay, the ratio water payment to the household income was computed from the results of the household survey. On average, customers pay 1.3 % of their income for water services which is less than the normal threshold of 3%. To look further into this issue, the Team focused on customer complaints filed at WAJ in 1994. As seen in Fig.- 3.2, a total of 2,727 and 849 complaints were raised against Zarqa and Rusaifa offices respectively. These are equivalent to one out of 20 subscribers in Zarqa and 27 subscribers in Rusaifa. According to the data, these complaints stem from ineffective and/or inaccurate meter reading and billing by WAJ in addition to frequent water shortages.

3.3 WATER CONSUMPTION

Water consumption data (on daily average and accounted-for water basis) is available since 1985 when WAJ was established under the Ministry of Water and Irrigation. From the number of subscribers in Zarqa Governorate, the per capita water consumption can be estimated as shown below.

Daily Average Per Capita Water Consumption (Zarqa Governorate)

Year	Demand (lpcd)	Consumption (accounted for) (lpcd)	UFW* (lpcd)	UFW Ratio (%)
1989	97	50	47	49
1990	108	53	55	51
1991	117	56	61	52
1992	112	50	62	55
1993	119	55	64	54
1994	126	-	-	-

Source: WAJ Zarqa
*UFW implies Un-Accounted For Water.

Per capita water demand (water supplied) gradually increased from 97 lpcd to 126 lpcd (liters per capita per day), although per capita consumption on an accounted-for water basis stood at an almost constant value of 50 - 55 lpcd.

This implies that the UFW ratio increased over the same period. In order to identify causes of this high ratio of UFW, a survey was conducted applying the Combined District and Waste Metering (CDWM) method and the Meter Replacement Method (MRM). The results suggest that UFW is 15 - 30 % leakage mostly from smaller distribution and service mains and 20 - 30 % administrative losses related metering inaccuracies, meter tampering by subscriber and WAJ billing errors.

The above per capita consumption is suppressed because the supply could not meet the true demand. A household survey was conducted to determine the unsupressed consumption. According to the survey for Zarqa where sufficient supply is available, the per capita consumption averaged 72 lpcd in the summer. During the winter season, per capita consumption drops to 57 lpcd. These two figures are considered to be the actual unsuppressed per capita consumption.

The 1994 water consumption data provided by WAJ is presented in the table below. WAJ registers all subscribers grouping them into one of three water-use categories, i.e., domestic (inclusive of commercial), large consumers, and government. Out of them, domestic water use is predominantly large, at 98.3 % of the total while the large volume consumers account for 0.5% and the government 1.2%. Industrial water use is not separated since WAJ places a top priority on supplying potable water to the public. According to the factory survey, WAJ supplies water to the factories only for drinking purposes. Factories usually have their own wells for in-plant process water.

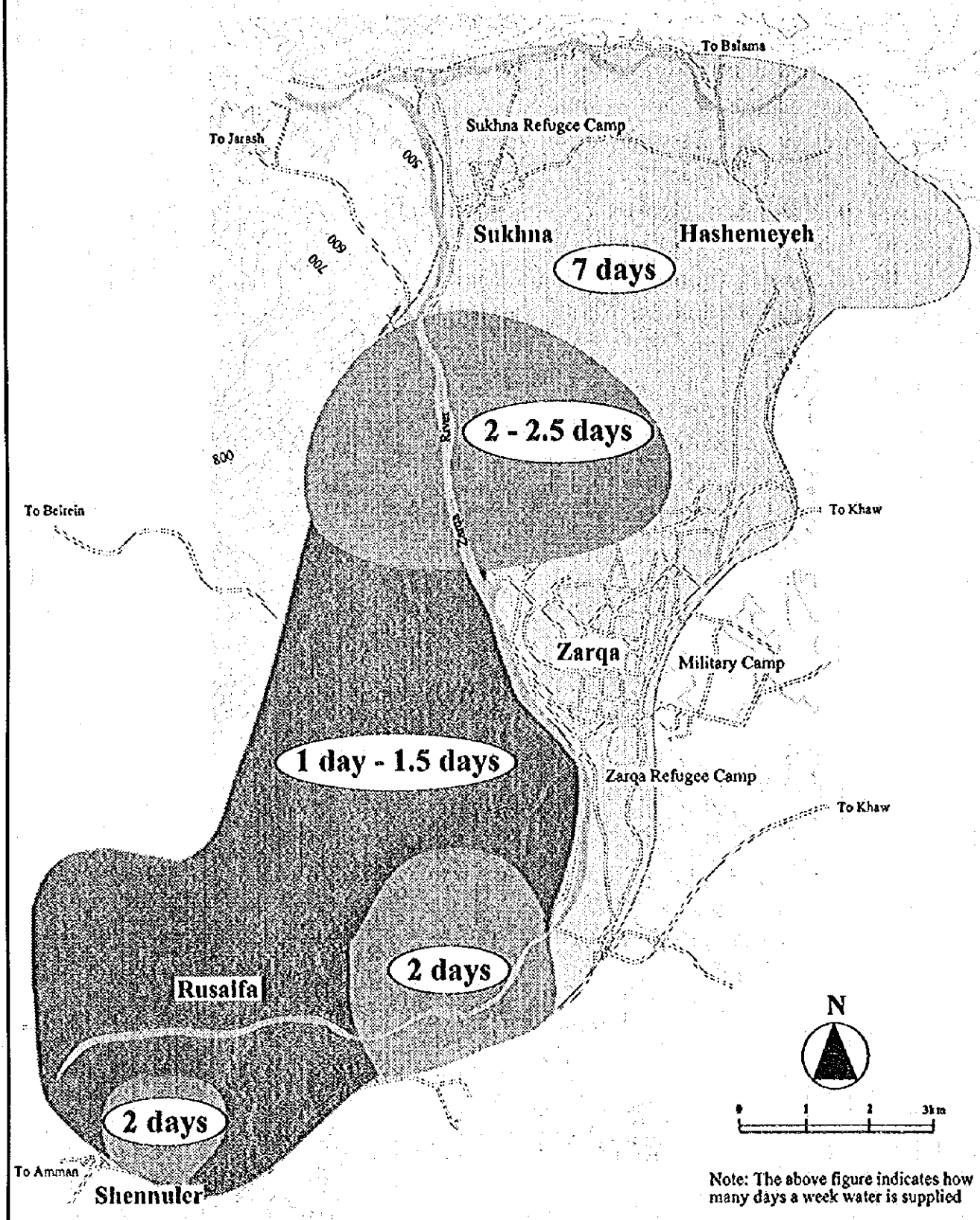
Water Consumption by Category in 1994
(Zarqa Governorate)

Category	Water Consumption (m3)	Percentage (%)
Domestic	13,047,820	98.3
Others	224,458	1.7
-Large Consumers	69,525	0.5
-Municipalities	154,933	1.2
Total	13,272,278	100

Source: WAJ Zarqa

3.4 QUALITY OF WATER SUPPLIED

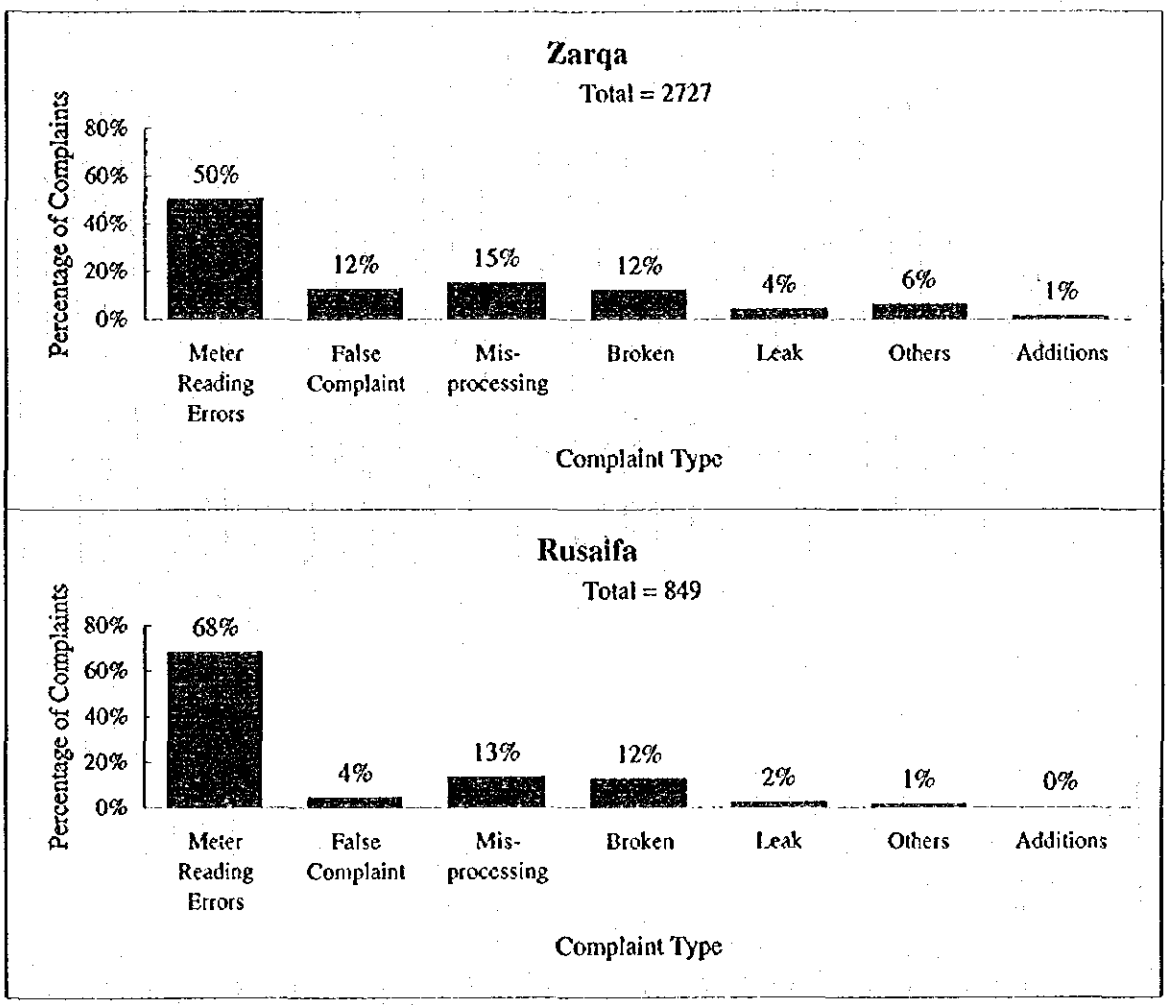
Except for salinity and total hardness results from laboratory testing conducted under the current study indicate that all sampled house tap water was within the 'maximum allowable level' set by the Jordanian Standard No. 285 for Drinking Water. High concentrations of salinity above the 'permissible level' of 1,500mg/l were observed in 80% of the samples (See Fig.- 3.3). High values of total hardness were also recorded with ranging from 200mg/l in the Zarqa/ Hashemeych areas to 400mg/l in Rusaifa/Schenuller. The permissible level for hardness is 100mg/l. Residual chlorine levels were adequate in all house tap and roof tank samples. Quality of groundwater is discussed in the following chapter.



Note: The above figure indicates how many days a week water is supplied

THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.- 3.1 WATER RATIONING AREA

Fig.- 3.2 MAJOR COMPLAINTS BY SUBSCRIBERS

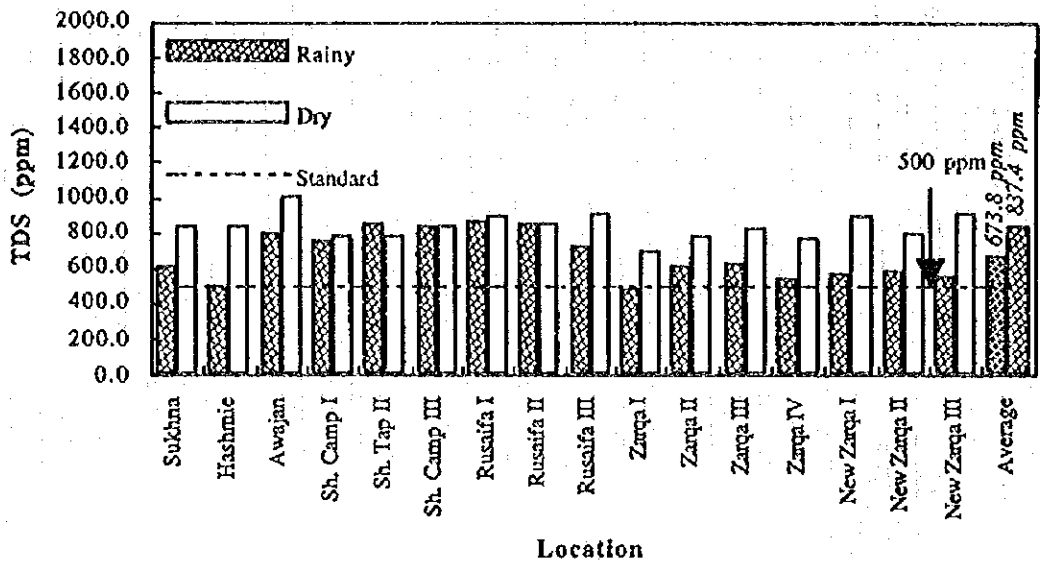


Source : WAJ, 1994

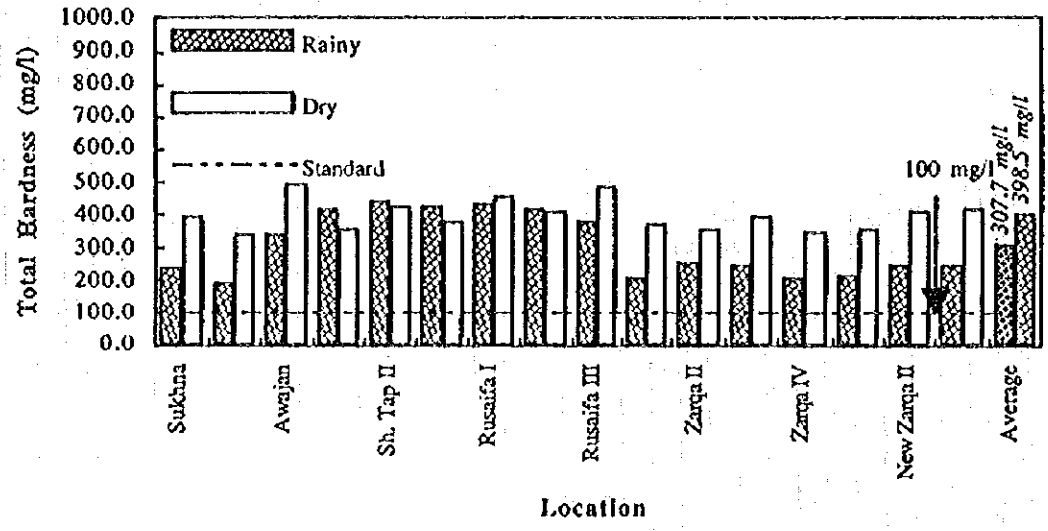
Note:
Meter Reading Errors: Errors caused by meter readers such as absence of periodical reading and reading errors probably resulting in subscribers' payment deduction.
False complaint: Complaints solved, against which subscribers has not the right to complain.
Mis-processing: Either in moving numbers or incorrect data entry.
Broken: Meter broken out.
Leak: Non-visible leak with the inner net.
Others: Any other complaints except the mentioned above.
Additions: Underestimated previous reading resulting in subscribers' additional payment.

Fig.- 3.3 TDS & HARDNESS OF THE TEPPED WATER

TDS values of the collected water samples from the house taps



Total Hardness values of the collected water samples from the house taps



IV. EXISTING WATER SUPPLY SYSTEM

IV. EXISTING WATER SUPPLY SYSTEM

The water supply systems in the country are interconnected to each other mainly because of the scarcity of available water. Water resources depend mostly on deepwell groundwater. In the following sections, the historical development and outline features of the existing water supply system is first introduced. Then, the major functions of the system and facilities are described with technical data and information.

4.1 OVERVIEW

The water supply system in Zarqa District dates back to 1934 when the municipal council of Zarqa, then the responsible agency for water affairs, laid water pipelines to supply groundwater to the residents. In 1964, a first full-fledged expansion project was launched to meet increasing water demand due to the rapid growth of the industry and population in the area. Under this project, main existing facilities such as Zarqa wells No. 14, 14a, and 16, Zarqa booster pumping station, Batrawi tank and 16" distribution mains were constructed and started operation in 1967.

However design capacities were not enough to keep pace with the remarkably high growth rate of the population. Expansion of the water supply system was inevitably carried out shortly thereafter, aiming at obtaining additional water sources from the Azraq wellfield and wellfields in Mafraq Governorate. Water transmission mains connecting Za'atari, Khaldieh and Hallabat wellfields to Khaw pumping station were completed in 1975 and those connecting Azraq well field to Khaw pumping station were completed in 1984. These facilities were constructed to mainly to meet the demands of Zarqa municipality and Amman. Rusaifa municipality, at the time when WAJ was established, was responsible for its own water supply system. The resources were not necessarily sufficient to provide water to the whole population. As a result, the system was developed on an ad-hoc basis and was constructed in a piecemeal fashion.

Zarqa district is divided into two separate water supply areas: Hashemeyeh and Sukhna to the north, and Zarqa and Rusaifa to the south. These are interconnected by the Khaw-Zarqa trunk main:

Water for the Hashemeyeh and Sukhna areas is taken from the Khaw-Zarqa trunk main and then boosted into the distribution system at Hashemeyeh booster station. Thereafter, there are separate feeds to the areas of Hashemeyeh and Sukhna. Both these areas have reservoirs which float on the system, namely Hararieh and Sukhna reservoirs.

Water from Khaw is boosted to a tank at the Zarqa pumping station. In addition, water from wells in Hashemeyeh is sent to the Zarqa pumping station where it is boosted into the Zarqa and

Rusaifa distribution areas. The remaining water for these areas comes from the following wells: Awajan 21, 22 and 23, Rusaifa 18, Rusaifa phosphate well, Al Basatin 1 and 1A, Hutteen 1 and 2 and the Murhib wells. Murhib water is boosted to the Awajan reservoir which floats on the system. Rusaifa well 18 boosts into an adjacent tank from where it is boosted into distribution. The remaining wells pump directly into distribution. There are additional booster pumps at Al Basatin and Rusaifa site 4. Water from Rusaifa well 4 is pumped to Amman and does not feed the area. In addition to the Awajan reservoir, there is a reservoir at Batrawi which in theory floats on the system but in practice is often dry.

During the period from 1990 and 1993, WAJ Zarqa executed a large scale rehabilitation and improvement works on the deteriorated pipe networks including installation of distribution mains, service mains and house connections. This intensive work covered most of Zarqa District, excluding Goariah and Hai Hussein, in the northern built-up area of Zarqa municipality. Investment costs, borne by the central government, exceeded 13 million JD. Despite these efforts, the distribution network, particularly in Ruseifa, is still weak.

Fig.- 4.1 shows location of the wellfields together with transmission lines and main distribution facilities scattered in Zarqa and Mafraq governorates. Fig.- 4.2 portrays locations of such main facilities as pumping stations, tanks and reservoirs in Zarqa district. Further efforts are made with an emphasis on providing information on the system alignment and water transmission as seen in Fig.- 4.3 which portrays a system flow chart of the existing water supply system, including ground level at wellfields, pumping station, reservoirs and tanks, year of construction, diameter, materials and flow rate of transmission mains with sufficient details of technical information.

4.2 WELLFIELDS

Water resources in and outside of the Zarqa district have been widely explored. Hashemeyeh, Awajan and Murhib wells in the Zarqa district were explored in 1986, 1987 - 88 and 1994,. Also, Hallabat wells were developed between 1989 and 1993 for Zarqa district and Amman. The water supply system in Zarqa District depends entirely on deep-well groundwater from the wellfields scattered in Zarqa and Mafraq governorates. In 1994, almost 76% of the raw water came from Zarqa District.

Most of the abstracted groundwater is conveyed to Khaw pumping station, then pumped up to Zarqa, Hashemeyeh pumping stations and Amman municipality. Villages and communities located nearby wellfields also enjoy a minor percentage of groundwater from pipelines connected directly to the wellfields/pumping stations. The Rusaifa and Shenuller areas are supplied from Zarqa pumping station, supplemented by Awajan and several small wells. Sukhna is supplied from Hashemeyeh pumping station.

In general, each pumping station has a storage reservoir/tank. To supply water effectively, there are several service reservoirs/tanks at strategic points of the service area. From these tanks or directly from the pumping stations, water is distributed to the service areas.

(1) Number of Wells, Groundwater Abstraction Rate, etc.

The wellfields which feeding the study area take water from one of two hydro-geologically groundwater basins; the Azraq basin and the Amman-Zarqa basin. Main wellfields are located in Azraq, Hallabat, Hashemeyeh, Murhib in Zarqa Governorate and Za'atari, Khaldieh in Mafraq Governorate. Zarqa District depends on 72 wells out of which 39 are located in Zarqa Governorate and 33 wells in Mafraq Governorate. Tables - 4.1 to 4.2 provide technical dimensions of these wells and the working conditions of mechanical equipment. In addition, there are nine major wells abandoned in the study area as given below:

Abandoned Wells

Name (m3/hr)	Dug Year	Abandoned Year	Flow Rate	Reason for Abandonment
Sukhna Well No.1	1960s	1980	100	High TDS (1,600)
Hashemeyeh Well No. 1	late 1960s	1993	15	High TDS (1,900) & small production
Hashemeyeh Well No. 4	late 1960s	late 1970s	16	High TDS (1,600) & small production
Zarqa Well No. 13	1966	1966	130	No use, high TDS (2,500)
Zarqa Well No. 14 *	1966	1985	250	High TDS (1,600) &NH4
Zarqa Well No. 14a	1966	1985	250	High TDS (1,600) &NH4
Zarqa Well No. 16	1966	1966	130	No use, high TDS (2,500)
Bereen No.2	1988	1989	50	Contaminated by sewage
Bereen No.3	1988	1989	50	Contaminated by sewage
Total			991	

Source: WAJ Zarqa * It resumed operation in 1995.

Tables - 4.3 to 4.5 also provide information on water abstraction rates at each wellfield and net water fed to Zarqa Governorate in 1994. Although the level of the groundwater table decreases year by year, total abstraction rates at these wellfields jumped from 25.6MCM in 1993 to 31.9MCM in 1994.

Azraq wellfield is one of the main sources for Zarqa and Amman. Located at 563 m above the mean sea level, Azraq is the lowest the farthest wellfield feeding Zarqa. It produced 19.3 MCM in 1994. All 16 wells constructed in the 1980s are in operation although, during the winter season some wells stop operation due to a decrease in demand. Groundwater is collected through two 16" mains into storage reservoirs, then pumped to 24" transmission mains.

Za'atari and Khalidieh wellfields are located southeast of Mafraq municipality, wherefrom, 17.0 MCM groundwater was abstracted in 1994. About 51% of the groundwater from Za'atari

wellfield is transmitted to Khaw PS and the remaining is used by Mafraq and Irbid governorates. Khaldieh wellfield is located 15 km south of Za'atari. A black steel transmission main from Za'atari with diameter of 16", increases its flow rate, since most groundwater yields from Khaldieh wellfield are injected to Za'atari - Khaw main. The balance is utilized for irrigation and domestic purposes in Khaldieh municipality.

In Hallabat wellfield located 12 km east of Khaw pumping station, there are 8 wells. They produced 4.3MCM groundwater in 1994. Its yields are all used in Zarqa Governorate.

Awajan wellfield constructed in 1987 is located in the center of the industrial area of Rusaifa and Zarqa. It has three wells in operation. Despite their slightly deteriorated water quality, they are supplying substantial amount of groundwater with an abstraction rate of 4.1MCM in 1994.

Murhib wellfield and its pumping station were recently constructed in 1992. They are located at in the western hilly area of Zarqa municipality where ground elevations are rather high at 633 m. There are 5 wells in total, including one constructed in 1994. They produced 0.6MCM high purity groundwater in 1994. All water, except small amount supplied to the nearby residential area, is conveyed to Awajan tank at elevation 693 m.

The Hashemeyeh wellfield was first developed in the 1960s. There are four wells in operation. They produced 1.6MCM in 1994. The groundwater abstracted usually contains high concentration of TDS. To minimize effects of TDS, the water is blended with water transmitted from Khaw pumping station before being distributed.

There are also small wells in Ruseifa; Ruseifa 4, Ruseifa 18, Phosphate, Bassateen and Hutteen.

WAJ annual reports indicate the need for comprehensive water management between domestic, irrigation and industrial water users. According to a recent study by WAJ, the present groundwater abstraction rate for irrigation, industry and water supply totaled 50.6 MCM in Amman and Zarqa area in 1993. This is almost double the natural recharge rate of 25 MCM. This excessive abstraction has caused significant decline of groundwater yields, water table levels ,water quality, and has accelerated the water shortage crisis in Jordan.

(2) Groundwater Quality

There are two groundwater basins, Azraq basin and Amman-Zarqa basin. The quality of the Azraq basin is within the drinking water standard. Azraq basin groundwater contains less dissolved matter and hardness compared with Amman-Zarqa basins. The TDS ranges from 270 to 670 mg/l and NO_3 ranges from 3.1 to 13.8 mg/l in Azraq well fields. Also, the quality of

Hallabat and Za'atari wells, belonging to the Amman-Zarqa basin is within the drinking standard with the exception of Khaldia wells. In the Hallabat well fields, TDS and NO3 concentrations are in the favorable range of 385 mg/l - 651 mg/l and 8 mg/l - 10.4 mg/l.

On the other hand, quality of the upper aquifer in the Amman Zarqa basin has been degraded as a result of urban and industrial growth. According to the "Groundwater Quality Data in Jordan" published in Feb. 1987, groundwater is alkaline with pH value of 7.1 to 8.1 and saline with concentrations of chloride ion higher than 200 mg/l.

Groundwater from Awajan wellfield shows a high concentration of NO3, ranging from 55 mg/l to 70 mg/l, around the maximum limits of 70 mg/l specified in the drinking water standard,. TDS values averaged between 750 mg/l - 1,000 mg/l exceeding the maximum limits of 500 mg/l but staying within maximum acceptable limit of 1,500 mg/l. The water from Zarqa wells showed the same tendency. TDS values fell between 1,430 and 1,770 mg/l, hovering close to the maximum limit. NO3 is between 45 to 61 mg/l, nearing the maximum limit. In the Hashemeyeh wellfield, TDS and NO3 concentrations are also high, ranging from 1,300 mg/l to 1,600 mg/l and 35 mg/l - 54 mg/l.

4.3 PUMPING STATIONS

The pumping stations are constructed adjacent to the wellfields to pump the collected groundwater into the reservoirs. Stations are located at the Azraq, Hallabat, Za'atari, Khaldieh, and Murhib wellfields. Groundwater abstracted from Awajan, Hashemeyeh and other small wellfields is fed directly into the distribution system.

In addition, there are several booster pumping stations within and/or on the way to the service area. They are Khaw pumping station, Zarqa pumping station.

Distribution piping is added to newly developed areas when the need arises. But the simple addition distribution piping does not guarantee water supply to the areas. Hence, there exists some small booster pumping stations, particularly in Rusaifa area. Further more, the newly developed areas are located mainly on the hill sides which requires high pump head.

Pumps installed are all volute type. Technical information on the pumps installed at all pumping stations are summarized in Table 4.7. Major booster pumping stations are outlined as follows:

(1) Khaw PS

Khaw pumping station, located 60 km west of Azraq and at 614 m above the mean sea level, receives water transmitted from the Azraq, Hallabat, Za'atari and Khaldieh wellfields. Khaw

PS is one of the largest pumping stations in the country. Of the 16 pumps installed, 9 pumps are used to boost water to Amman and 7 pumps are used to boost to Zarqa and Hashemeyeh. The amount of water pumped to Amman and Zarqa is 2,200m 3/hour and 1,700 m3/hour respectively according to the 'Water Agreement'. Flow rates are controlled primarily by on/off operation of the pumps.

(2) Zarqa PS

This pumping station is located north of the densely populated area in Zarqa municipality, at an elevation of 574 m It receives water from Khaw PS, Hashemeyeh wells, Zarqa No. 14 and 14A wells. At present, however, WAJ Zarqa is obliged to stop operations at Zarqa well No. 14 and 14A due to deteriorated groundwater quality. There are two storage tanks in the pumping station with a capacity of 4,000 m3 and 500 m3. After construction of the large tank in 1986, the small circular tank was abandoned due to the lack of chemical dosing equipment. There are 9 pumps and motors installed to distribute water through three 16" mains and one 6" main to the following areas:

Zarqa municipality including the Zarqa central area, new Zarqa, and Awajan: boosting up to Batrawi tank and diverting on its way to the service area through two 16" mains.

Rusaifa and Shenuller: pumping through a single 16" main at the outlet of the Zarqa PS and then reducing its diameter to 6" at the administrative boundary between Zarqa and Rusaifa, and again boosting at Rusaifa Booster PS.

Ma'asoun in Zarqa municipality: boosting to distribute directly to the customers through a single 6" main.

(3) Hashemeyeh P.S.

Hashemeyeh pumping station constructed in 1982 is equipped with 2 pumps. Water pumped from Khaw PS is boosted at this station to supply Hashemeyeh and Sukhna. There is no storage tank at this station. Groundwater is pumped directly from the wells into the Hashemeyeh - Sukhna mains.

(4) Rusaifa Booster P.S.

Water pressure from Zarqa PS and from the three wells in Awajan is not sufficient to supply commercial and residential areas in Rusaifa and Shneller directly. The station was expanded in 1986 to boost and supply water to the higher zones.

With respect to instrumentation at all pumping stations, Table - 4.8 shows type, year of installation, working condition, etc. of flow meters and pressure gauges installed. Flow meters are usually installed at every pump stations to measure inflow and outflow rates. The most typical type of the flow meter are the ultrasonic and vane wheel types. They are generally working well. In contrast, pressure gages are not necessarily functioning because of a lack of proper maintenance and repair.

4.4 TRANSMISSION AND DISTRIBUTION MAINS

Transmission mains from Khaw to Azraq, Za'attari/Khaldieh, Hallabat, and Amman are all 600 mm in diameter. The Khaw - Zarqa main is 400 mm in diameter. Mains are all black steel pipes with inner mortar lining. All the pipelines were installed in 1970's and 80's.

Flow and pressure measurement surveys conducted on the Azraq - Khaw line, Khaldieh - Khaw line and Khaw - Zarqa line suggest leakage from transmission mains is very small in quantity. Furthermore, testing confirmed that mains have retained a large C-value compared to typical mains of the same age and material.

The larger mains in the distribution pipe network, are predominantly black steel . It is in 1966 that ductile iron pipes were first installed in Zarqa municipality under a World Bank project. The majority of pipelines in southern Zarqa City were replaced or installed in steel in the mid 1980s. Since the 1990s, smaller mains including house connections have been rehabilitated and replaced mainly in Zarqa city. For smaller mains, galvanized pipes and polyethylene pipes are used. Polyethylene pipes, according to WAJ officers, may not be a proper material in cases of high water pressure because of their flexible nature.

The UFW survey suggests major leakage is occurring in small diameter distribution pipes and service mains which were laid in the 1960s and early 1970s. These deteriorated pipes are predominantly black steel, cast iron and/or galvanized steel.

The total length of piping installed in Zarqa District is given in table below:

Total Pipe Length & Volume

Diameter (mm)	75	100	150	200	250	300	400	600	Total
Length (m)	78,960	94,675	57,705	32,195	2,265	22,765	31,615	6,800	326,980
Volume (m3)	349	743	1,019	1,011	111	1,608	3,971	1,922	10,734

Note: The above excludes Sukhna and Hashemeyeh.

Total pipe length reached 327 km as of 1994, excluding small diameter pipes 50mm or less in the District and all pipes in Sukhna and Hashemeyeh. This is equivalent to 0.6m/population served (per capita length of pipeline installed) and 21 l/population served (per capita storage volume of the pipe network)[1]. Both parameters clearly suggest insufficiency of the pipe network in terms of size and length.

Most of the valves in the system are gate valves. Very few butterfly valves are used. There are no clear application standards. According to WAJ officials, in the case where water pressure is low, butterfly valves are preferred. However, since pipes are usually small, less than 600mm in diameter and high water pressure dominates throughout the district it seems more practical and cost effective to use gate valves. From an engineering points of view, a few adjustments will be necessary since gate valves are designed to work under specific and limited conditions.

There are several fire hydrants installed in the pipe network. Most of them can hardly be identified and have never functioned since they were installed.

Distribution pipelines installed to date have the following general characteristic:

- Construction could not keep pace with the rapid municipal development since the 1960s mainly because of financial constraints. As a result, the water authority has installed more small diameter distribution mains as a provisional measure.

- To overcome topographical constraints a rather high pump head was applied at the pumping station. Coupled with a slightly misaligned and undersized distribution network as mentioned above, the direct supply with a high pump head results in 1) inefficient energy consumption, 2) high pressure in the lower elevation zones and 3) a larger amount of water loss from the distribution pipe network.

4.5 SERVICE RESERVOIRS

In general, reservoirs/tanks at the pumping stations are constructed with sufficient storage capacity. These storage tanks are used to regulate inflow and outflow rates of the water and to allow chlorine dosage for disinfection.

Service reservoirs at Batrawi and Awajan work as balancing reservoirs, floating in the distribution network. Most function as intended by the design except for smaller, older tanks constructed in the 1960's which have deteriorated. Hallarieh tank constructed in the 1960's is

[1] Similar size cities in Japan recorded 3.0 meters per capita and 103 litres per capita in 1991, which are approximately five times larger than those in Zarqa District.