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REPORT

TO

UNITED STATES DEPARTMENT O

AGENCY FOR INTERNATIONAL DEV

ON

FEASIBILITY STUDY

OF

WATER SUPPLY AND SEWERAGE FACILITIES

FOR

TAIZ, YEMEN ARAB REPUBLIC

VOLUME I

MASTER PLAN AND FEASIBILITY STUDY

CONTRACT NO. AID/ASIA-C-1081

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April 30, 1975

United States Agency for International
Development
Department of State
Office of Contract Management
Regional Operations Division-Asia
Washington, D. C. 20523

Attention: Mr. Franklin H. Moulton

Subject: Report on Feasibility Study for Taiz Water Supply and Sewerage Project
USAID Contract No. AID/Asia-C-1081

Gentlemen:

Transmitted herewith are twenty copies of the subject Report in three volumes. The Report has been prepared and is submitted in accordance with the terms of our contract with USAID dated April 17, 1974.

We wish to express our thanks to the staff of the Agency for International Development for their assistance and cooperation during the investigation and preparation of this Report. We thoroughly enjoyed our relationship with the people of Yemen and officials of the Yemen Arab Republic Government and we look forward to the recommendations of this Report being implemented for the benefit of the people of Taiz.

Very truly yours,

James P. McGoldrick
Vice President

/ts

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CHAPTER 1

CHAPTER 1

INTRODUCTION

AUTHORIZATION

This report was performed under the authority of Contract No. AID/ ASIA - C-1081 between the Agency for International Development, an agency of the United States of America, and James M. Montgomery, Consulting Engineers, Inc., a California corporation. The contract, which is a cost plus fixed-fee type, became effective on April 17, 1974, and had an estimated completion date of March 17, 1975.

PURPOSE AND SCOPE OF REPORT

The purpose of this report is to assist the Yemen Arab Republic Government (YARG) to provide the present and future population of Taiz with an adequate potable and safe water supply and also to investigate the practicability of constructing a wastewater collection, treatment and disposal facility.

The report included herein consists of three volumes. Volume No. I describes the engineering and feasibility studies and master plans for both water supply and wastewater systems. Volume No. II describes the geology of the area, and discusses the water resources investigations and results thereof. Volume No. III discusses management, legislation, ordinances, training needs and proposed implementation of the training program. More specifically, the work performed under this contract included:

<u>The Survey and Evaluation of:</u>

1. Existing maps and aerial photographs, geological, climatological, and hydrological reports, census statistics, water requirements availability of power, etc.;

2. Available water resources;

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3. Existing water systems;

4. Existing sewer system.

Selection of a Mapping Firm to:

Utilize existing aerial photographic negatives to prepare topographic mapping of the Taiz Metropolitan Area and the watershed and basins in the vicinity of Taiz.

The Development of:

1. A test well drilling program for additional ground water information;

2. Projections of future populations, service connections, required water production and consumption, and power requirements;

3. Projections of wastewater flows;

4. A master plan of phased water system improvements;

5. A master plan of phased wastewater collection system and treatment facilities;

6. Estimated capital costs related to future water system development;

7. Estimated capital costs related to future wastewater collection and treatment.

The Preparation of:

1. A financial analysis of future revenues and expenses;

2. A socio-economic analysis including the development of a schedule of proposed water and wastewater rates and charges and investigation of cost-benefit relationships;

3. Preliminary plans, outline specifications, design criteria and analysis, equipment and construction standards, all in sufficient detail to define the project to permit A.I.D. or international lending agencies to consider financing the project.

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The Development of:

1. A training program covering well construction, development and maintenance, pump operation, water treatment practices, distribution system operation, meter maintenance, basic construction practices and basic water system engineering;

2. A training program for water system managers, warehousing and accounting personnel;

3. An implementation plan and estimated costs of such training programs;

4. Future organizational structure and operational procedures;

5. Recommended legislation and ordinances.

DESCRIPTION OF PROJECT

The proposed water system expansion includes renovations and additions to the present system which consist of wells, pumping units, chlorination facilities and a distribution system consisting of reservoirs, pressure control structures, mains, services and customer meters. The additions are planned for two separate phases of construction. Separate recommendations relating to future organizational structure and operating procedures, and a comprehensive training program also are proposed for implementation. The proposed sewerage improvements include an expansion of the present sewage collection system and the construction of wastewater treatment facilities including percolation beds. Recharged effluent permits eventual reuse of the water when blended with the natural basin ground water. The improvements are planned for two phases of construction. Phase I includes the development of wells, reservoirs and transmission facilities for a ground water basin north of the city, renovation and expansion of the distribution system, collector and trunk sewers, and a waste water treatment and reclamation facility. Phase II includes development of wells and transmission facilities for a separate ground water basin west of Taiz, expansion of the sewage collection system and treatment plant plus the addition of sewage lift stations.

The selection of Phase I and Phase II design years of 1985 and 1995, respectively, was based primarily on considerations of available water resources. The overall master plan design date of 1995 was initially determined. This date represents the estimated year at which time

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projected water demands equal the available water resources as determined by the water resources investigation. The Phase I design year was selected, since 1985 is the year that the projected water demands equal the water supply available from the largest single water source area. This source is to be developed as the Phase I source.

KENNEDY MEMORIAL WATER SYSTEM

The Contract refers to the Taiz Cooperative Organization (TCO) in terms of assisting in providing certain items of logistic support such as well drilling equipment, materials and crews. Since such support is the direct responsibility of the General Director of the Kennedy Memorial Water System for Taiz, reference to the existing Taiz water system organization, and related items will be identified throughout the report as KMWS.

TAIZ WATER AND SEWERAGE AGENCY

Since this report presents proposed improvements relating to both water supply and sewerage facilities plus recommendations for a new organization to be responsible for operating the completed improvements, the term Taiz Water and Sewerage Agency (TWSA) is used throughout the text in reference to the proposed improvements, organization and related items.

SOURCES OF INFORMATION

Data used in the report and as background for the study were obtained from the following agencies:

Yemen Arab Republic Government Offices

1. Ministry of Public Works
2. Ministry of Health
3. Ministry of Services
4. Highway Authority
5. Central Planning Office
6. National Water and Sewage Authority
7. Institute of Public Services

Taiz Provincial and Municipal Offices

1. Governor, Taiz Province
2. Commander, Taiz Province
3. Head, Taiz Municipality
4. Taiz Cooperative Organization
5. Taiz Electric Company
6. Kennedy Memorial Water System

Other Agencies

1. United Nations Development Programme

   World Health Organization

   International Labor Organization

   Food and Agriculture Organization
2. United States Embassy - Yemen
3. United States Agency for International Development - Yemen
4. Saudi Arabian Embassy - Yemen
5. Kuwait Fund

Banks

1. Central Bank of Yemen
2. Yemen Bank for Reconstruction and Development
3. The British Bank of the Middle East

Some members of the civic, business, and medical sectors also have contributed vital information relevant to the project. Data was also gathered directly from the field to supplement, verify, or update the prepared information received from the above-listed sources.

A list of specific reports and papers to which reference was made during the preparation of the report appears as Appendix A - Bibliography.

ABBREVIATIONS

The abbreviations listed below have been used in this report:

AID	-	Agency for International Development
amp	-	ampere(s)
BOD	-	biochemical oxygen demand
bldg	-	building
cap	-	capita
cfs	-	cubic feet per second
cm	-	centimeter
COD	-	chemical oxygen demand
cu cm	-	cubic centimeter(s)
cu ft	-	cubic foot (feet)
C	-	degree centigrade
F	-	degree Fahrenheit
dia	-	diameter
DO	-	dissolved oxygen
ea	-	each
FAO	-	Food and Agriculture Organization
fps	-	feet per second
gal	-	gallon
GDP	-	gross domestic product
gpd/acre	-	gallons per day per acre
gpd/cap	-	gallons per day per capita
gpm	-	gallons per minute
ha	-	hectare(s)
Hz	-	Hertz
hp	-	horsepower
hr	-	hour
IBRD	-	International Bank for Reconstruction and Development
ID	-	inside diameter
IDA	-	International Development Association
ILO	-	International Labor Organization
kg	-	kilogram(s)
KMWS	-	Kennedy Memorial Water System

kv	-	kilovolt(s)
kw	-	kilowatt(s)
kwh	-	Kilowatthour(s)
l	-	liter(s)
lb	-	pound
lpcd	-	liters per capita per day
LS	-	lump sum
m	-	meter
max	-	maximum
mg	-	milligram(s)
mgd	-	million gallons per day
mho	-	micromho(s)
mg/l	-	milligram(s) per liter
mil gal	-	million gallons
min	-	minimum
min	-	minute(s)
ml	-	milliliter(s)
mm	-	millimeter(s)
MPN	-	most probable number
MSL	-	mean sea level
No.	-	number(s)
NWSA	-	National Water and Sewerage Authority
OD	-	outside diameter
OT	-	ortho-tolidine
OTA	-	ortho-tolidine-arsenite
ppm	-	part(s) per million
PRC	-	People's Republic of China
psi	-	pound(s) per square inch
P.W.	-	present worth
rpm	-	revolutions per minute
sec	-	second
sq	-	square
sq cm	-	square centimeter(s)
sq ft	-	square foot (feet)
sq m	-	square meter
sq mi	-	square mile
TCO	-	Taiz Cooperative Organization
TDS	-	total dissolved solids
TEC	-	Taiz Electric Company
TS	-	total solids
TSS	-	total suspended solids
TWSA	-	Taiz Water and Sewerage Agency
UNDP	-	United Nations Development Programme
USAID	-	United States Agency for International Development

USAID/Y	-	United States Agency for International Development/Yemen
v	-	volt(s)
w	-	watt(s)
WHO	-	World Health Organization
YAR	-	Yemen Arab Republic
YARG	-	Yemen Arab Republic Government

PROJECT STAFF

Following is a listing of the consultant's personnel who participated in the preparation of this report:

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3. Kennedy Memorial Water System Personnel

   Following is a listing of KMWS employees who contributed significant assistance to the project effort:

Name	Position
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Ali M. Abdul Iziz	Technical Supervisor

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Name	Position
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Hussein Salah-El-Din	Head, Laboratory
Richard Fahey (Peace Corps)[a]	Laboratory Technician

4. United States Agency for International Development/Yemen

Following is a listing of USAID/Y personnel who contributed significant assistance to the project effort:

Name	Position
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CHAPTER 2

CHAPTER 2

SUMMARY

DESCRIPTION OF STUDY AREA

The Yemen Arab Republic, situated in the southwestern region of the Arabian Peninsula, is bounded on the north and east by Saudi Arabia, on the south by the People's Democratic Republic of Yemen, and on the west by the Red Sea. (See Figure 2-1).

Taiz is the capital of the Province of Taiz which occupies the extreme southern portion of the YAR. It is the second largest city in Yemen with a present population of about 95,000. Elevations within the city vary about 300 meters but average approximately 1300 meters. The city is drained by two major wadis.

Taiz lies along the foot of Jabel Sabir, the jagged peaks of which rise to 2,900 meters immediately southof the city. A broad vista of moderate to rugged hills and narrow valleys extends northward for several tens of kilometers from the city.

The region has a warm and slightly humid climate with annual rainfall of about 540 mm. Except for periods of dust storms, which last for a week or more, the climate can be classified as almost ideal. These winds occur mostly in the early summer.

SOCIO-ECONOMIC AND ENVIRONMENTAL ASPECTS

Yemen is one of the 25 poorest countries in the world. Per capita income is only about $100 per year. About 90 percent of the population is engaged in low productivity agriculture. Urbanization is taking place with the rapid growth of three cities: Sana'a, the capital; Hodeida, a sea port; and Taiz, a commercial city in the south of the country.

The YAR receives economic assistance from twenty nations. The major aid givers are the USSR and the People's Republic of China. Currently, next most important are Saudi Arabia and Kuwait. The Western World's chief aid giver at present is West Germany. The United States at the moment ranks sixth or seventh among aid givers in the YAR.

Summary

The imports of Yemen are nearly ten times its exports which continue to grow rapidly. The trade imbalance is made possible chiefly by remittances from abroad of $100 million a year by Yemeni workers who are employed chiefly in Saudi Arabia. The result of this is that the Rial (1975 conversion rate, $1.00 = 4.575 YAR Rials) is presently not a weak, overvalued currency.

The city of Taiz is growing and its people are experiencing a rise in income. (Population estimated 1965, 25,000; 1975, 95,000). Like Yemen as a whole, its growth is based on:

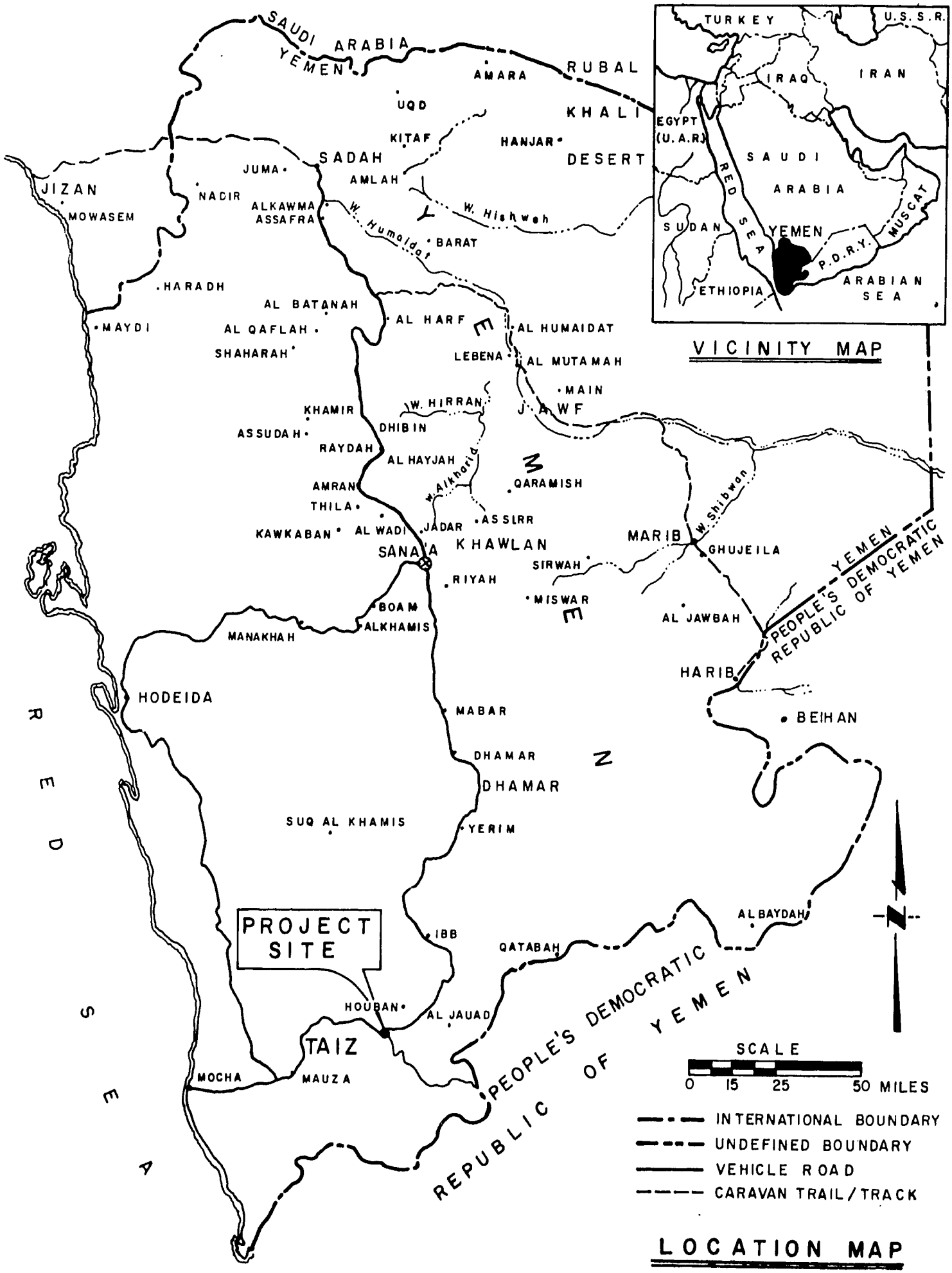
- the impact of highway building which has increased the movement of people and goods
- emigrant remittances which have increased the purchases of consumption goods in its stores
- its rising population which combined with local rising income has generated a local building boom.

Taiz lies on several hills. The buildings are of stone, brick, concrete, and mud brick -- never wood. The city is remarkably compact. Major streets often define the boundaries of large groups of houses that are reached by passageways that are often too narrow for vehicles. The total number of private residences and apartment buildings was judged from an aerial survey to be 7,460 and the number of commercial and government structures to be 628.

The city has a power system with 8,400 subscribers and a telephone system with 1,000 subscribers. There are two water systems; the Kennedy Memorial Water System has 8,525 connections and a hillside water system from springs has 800 subscribers. The city has no sewer system other than nine kilometers of sewer line and has no wastewater treatment plant.

The city functions chiefly as a marketing and financial center for the agriculture of the south of the YAR. It is also becoming a rising distribution center for manufactured goods, chiefly imports. Its manufacturing concerns are limited to a large biscuit plant, soft drink bottlers, and a number of small firms quarrying stone, making concrete blocks, doing carpentry, tailoring, baking and printing.

Wage rates of unskilled labor appear to be increasing at least 10 percent per year in Taiz in the past two years. The wage rates of skilled labor,



LOCATION MAP

FIGURE 2-1

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.

particularly construction labor, appear to be increasing much more rapidly. There does not appear to be any significant amount of unemployment. Labor migrates readily abroad and also between the agricultural villages and Taiz.

Health conditions in Taiz are poor. International aid programs have provided a remarkable expansion of medical facilities, particularly hospitals. Preventive health programs have not been equally developed. Most of the population suffers from gastro-intestinal diseases. Cholera and malaria epidemics have occurred in recent years. Doctors estimate that seventy percent of all disease in Taiz is water related and that almost everyone -- doctors included -- suffer an average of one incapacitating illness a year.

CONCLUSIONS

The YAR will very likely continue in the next decade to grow economically based on the same combination of factors as in the immediate past. External resources will be provided by international programs and by emigrant remittances. Internally agricultural productivity will rise, rural labor will shift from the country to the growing cities where base industries will develop, and service activities will grow.

Taiz will participate fully in the YAR's development. It is strategically located in the best agricultural area of Yemen. It will be the beneficiary of international aid programs that will raise agricultural productivity in the immediate area for which it is a marketing and commercial center. Its relation with these areas will be further reinforced by the development of secondary roads into the area.

Taiz has an able entrepreneurial class that will develop industrial and service enterprises in direct response to the economic opportunities presented. It appears likely that the present plans for a plastic pipe factory, a carton materials and packaging plant and a soap plant will be carried through, since the sponsors have the resources and ability to execute such plans.

A disproportionate amount of resources appear to have been directed toward hospital construction in Taiz when an expansion of the number of physicians and auxiliary health workers and preventive medical programs would have been more appropriate.

The construction of the proposed water and wastewater system besides fitting into the expected growth of the community and providing necessary amenities of life will make a great contribution to the prevention of water-

related disease and should thereby raise considerably the economic productivity of the community. Furthermore, it should make possible the release of hospital beds, physicians'time, etc., to the health needs of the rural areas for which it is already serving as a center.

RECOMMENDATION

The building of a water system in Taiz is recommended on the grounds that:

- the prospective economic growth of the community justifies the construction of such a system,
- there are substantial health and productivity benefits that would accrue to such a project.

EXISTING WATER SYSTEM

Taiz has the largest piped water system in the country. Over 70 percent of the residents receives water from the Kennedy Memorial Water System (KMWS). The remainder use water from mountain springs south of the city and hand dug wells.

The system, which was designed and built by USAID, was completed in 1965. By 1967, USAID assistance and supervision ended after which production difficulties were encountered.

In recent years, water service from the system has deteriorated due to insufficient supply for the large population increase, poor water quality from sewage infiltration into the well field aquifers and service interruptions from equipment break-downs and pipeline corrosion.

The system has since been brought back to its original design capacity (53 lps) with USAID assistance. This however, is inadequate for present population needs.

Because of the insufficient water supply, the distribution system is only pressurized a portion of the time. When the water pressure is turned off in various neighborhoods to ration the supply, negative pressures are created in the pipes that pull in liquid wastes from septic tank drainage and cesspools through leaks in the pipeline. This creates a serious health hazard. There are at least 48 known locations where cesspools have been constructed around existing water mains.

Summary

Three well fields, Houban, Hougala, and Hougfa, with a total of 10 wells constitute the present supply. All wells discharge into the Houban booster reservoir. From here the water is pumped to the Main Yard storage tanks. There is no metering of source water.

The Main Yard storage tanks supply water to approximately 70 percent of the consumers; the balance of the water is pumped to a higher elevation to supply the rest of the consumers.

The shortage of spare parts and absence of normal preventive maintenance places the pumping plant in a critical condition.

Only chlorination is provided to the water supply. At times no chlorine is supplied due to lack of inventory.

Four steel covered storage reservoirs are sited on ground locations. Tank walls have been weakened by corrosion; interiors need cleaning and repainting.

The existing piping system consists entirely of unlined steel pipe in diameters of 1/2-inch to 12-inch. Brass gate valves with no insulation from the steel, were used on mains 3-inch and smaller and iron body valves were used on larger mains. As a result, extensive electrolytic and/or galvanic corrosion has resulted.

Four pressure reducing valves are incorporated into the system; two have failed resulting in a maximum field pressure, at one location, of 10.2 kg/sq cm.

Due to the lack of corrosion control in the system all piping is deteriorating rapidly. Leak repair crews are repairing 30 to 45 leaks per week. Mineral deposits are building up internally from the highly mineralized water.

All services are metered; now over 8500 meters mostly, 1/2-inch and 5/8-inch sizes. There is a well-equipped meter shop but a low supply of spare parts.

The system has no fire hydrants; one old fire truck carries its own water tank.

Chemical water quality of supply is deteriorating rapidly. Total solids in 1964 were 1049 mg/l; now 2150 mg/l. Current nitrate concentration is 170 mg/l.

Present quality is due to its well supply being located downstream of the city in the same watershed; all wastewater is percolating into the shallow aquifer that supplies the wells.

Bacteriological tests of tap water over a 10-month period show a high percentage of unsafe samples; spot sampling of well discharges resulted in safe samples. This reveals that the cause of unsafe samples lies within the system and not in the source of supply.

CONCLUSION

The existing distribution system is in a critical condition from an operational and public health concern.

POPULATION PROJECTIONS

An official census has never been taken in the YAR.

In 1962 the population of Taiz was estimated to be 20,000, however, due to the war in Yemen (1962-1967) and later the influx of immigrants from the neighboring People's Democratic Republic of Yemen (starting in 1969) the city expanded rapidly.

The Project Team conducted a random sample survey to determine the present population. Demographic data was then collected from selected areas. The total number of buildings were then counted from aerial photographs taken of Taiz in 1973 by the British Royal Air Force. Based on the random survey, the population of Taiz was estimated to be 84,800 in 1973.

Based on other studies for Sana'a and Hodeida, and a comparison with the Taiz building construction rate, the growth rate was estimated to be 6 percent annually.

Future population projections for the years 1975, 1985, and 1995 were 95,300, 170,600 and 305,400 respectively.

Currently, water service is provided to an area of about 500 hectares. Phase I and II improvements are planned to provide service to some 1,080 and 1,330 hectares, respectively.

It is assumed that the present character of land use will remain unchanged with the exception that areas on the roads leading to the old and new airports will become industrial.

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Summary

FUTURE WATER DEMANDS

For 1973 total water production averaged 4,542 cu m/d and metered sales averaged 3,627 cu m/d.

Because of intermittent service and entrapped air in the system an accurate estimate of unaccounted-for water is not available; an estimate is 30 percent. A goal of 20 percent unaccounted-for water is used for 1985 and beyond.

Domestic (residental) water usage at present is estimated to be 45 lpcd, which is expected to reach 80 and 90 lpcd in the years 1985 and 1995, respectively.

Present population served is approximately 60,000 which is expected to increase to 136,500 and 275,000 by the years 1985 and 1995, respectively. This would correspond to 80 percent and 90 percent of the total population.

Twenty public faucets, gradually increasing to 25, will be installed throughout the city to serve the needs of the poor. It is proposed that these faucets be located at or near mosques and the water be metered and paid for either by the mosque or the municipality.

Fifteen public toilets are planned.

Provision is made for increases in institutional, hotel and commercial uses amounting to 3125 and 6835 cu m/d for the years 1985 and 1995, respectively.

Industrial usage is estimated to be 500 and 1600 cu m/d for the years 1985 and 1995, respectively.

Future annual water production for the years 1985 and 1995 is estimated to be 6.4 and 14.4 million cubic meters, respectively. Present annual production is 1.7 million cubic meters.

Maximum daily demands are equal to 150 percent of average daily demand.

Peak hour demands are equal to 150 percent of the maximum daily demand.

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RECOMMENDED WATER SUPPLY FACILITIES

The water system improvements will be implemented in three steps:

- Immediate improvements to partially restore a portion of the original serviceability of the system.
- Phase I construction to fill the projected needs to 1985.
- Phase II construction to fill the projected needs to 1995.

The most economical source for water is the development of local wells.

The well fields, when developed, will be capable of producing 14.4 million cubic meters a year of acceptable quality water, which will provide for the needs of Taiz until the year 1995. Additional and more-distant sources of water will have to be located and developed if adequate quantities of water are to be made available to the inhabitants of Taiz beyond the year 1995.

All new facilities will be designed and constructed so as to facilitate maintenance of all components.

The study area can most economically be served water by utilizing 7 service (pressure) zones each serving properties between a 50 m elevation differential.

Special water service providing 3/8-inch diameter meters and low rates will be made available to low-income families that constitute about 30 percent of the total population. This will enable many families who currently cannot afford service to have a continuous supply of potable water.

IMMEDIATE IMPROVEMENTS

The following improvements will be incorporated immediately to restore a portion of the water system's serviceability.

- Restore continuous water service.
- Reduce unaccounted-for water.
- Institute an active corrosion control program.
- The existing chlorination facilities will be relocated to the Houban booster site.

- Establish and maintain a pipe log and as-built water main system.
- Provide closed-loop heat exchangers with chemical treatment for existing engines.
- Replace hand-wheels with square operating nuts on all buried valves.
- Install telephone communications between Hougala well and Houban booster site.

PHASE I

Ten water wells will be developed in the El Hiama basin as a part of Phase I. (See Figure 2-2).

Upon development of the El Hiama well field, the water from the Hougala-Houban wells will be used only for agricultural purposes. This will accelerate the improvement of ground water quality. Phase I also includes the following:

- El Hiama transmission main (27 km in length with 650 mm and 750 mm diameters).
- Reservoirs at Upper Thaabat. Upper Medina and Lower Medina.
- Booster pump station at Lower Thaabat.
- Approximately 23.9 kilometers of distribution mains (minimum size of 100 mm) with pressure-break structures in lieu of pressure-reducing valves.
- Chlorination facilities

PHASE II

Phase II improvements include the following:

- Development of the well fields (total of 10 wells) at Mikbaba. Wadi Salah, Upper Wadi Houban, Wadi Amed, and Dh'bab.
- Restoration of the Houban-Hougala well field facilities, including two additional wells in Hougala.

Summary

- Enlargement of the Lower Thaabat booster pump station.
- Reservoirs of Lower Thaabat, Main Yard, Lower Medina, and Upper Thaabat.
- Approximately 11.4 kilometers of distribution mains and 19.4 kilometers of transmission mains.
- New booster pump station at Dh'bab.
- Chlorination and other appurtenant facilities.

Two alternative sources of water, in addition to the method selected, were considered:

- Impoundment of surface run-off
- Desalting of brackish water and sea water

Both of these were concluded to be impractical.

WASTEWATER SYSTEM

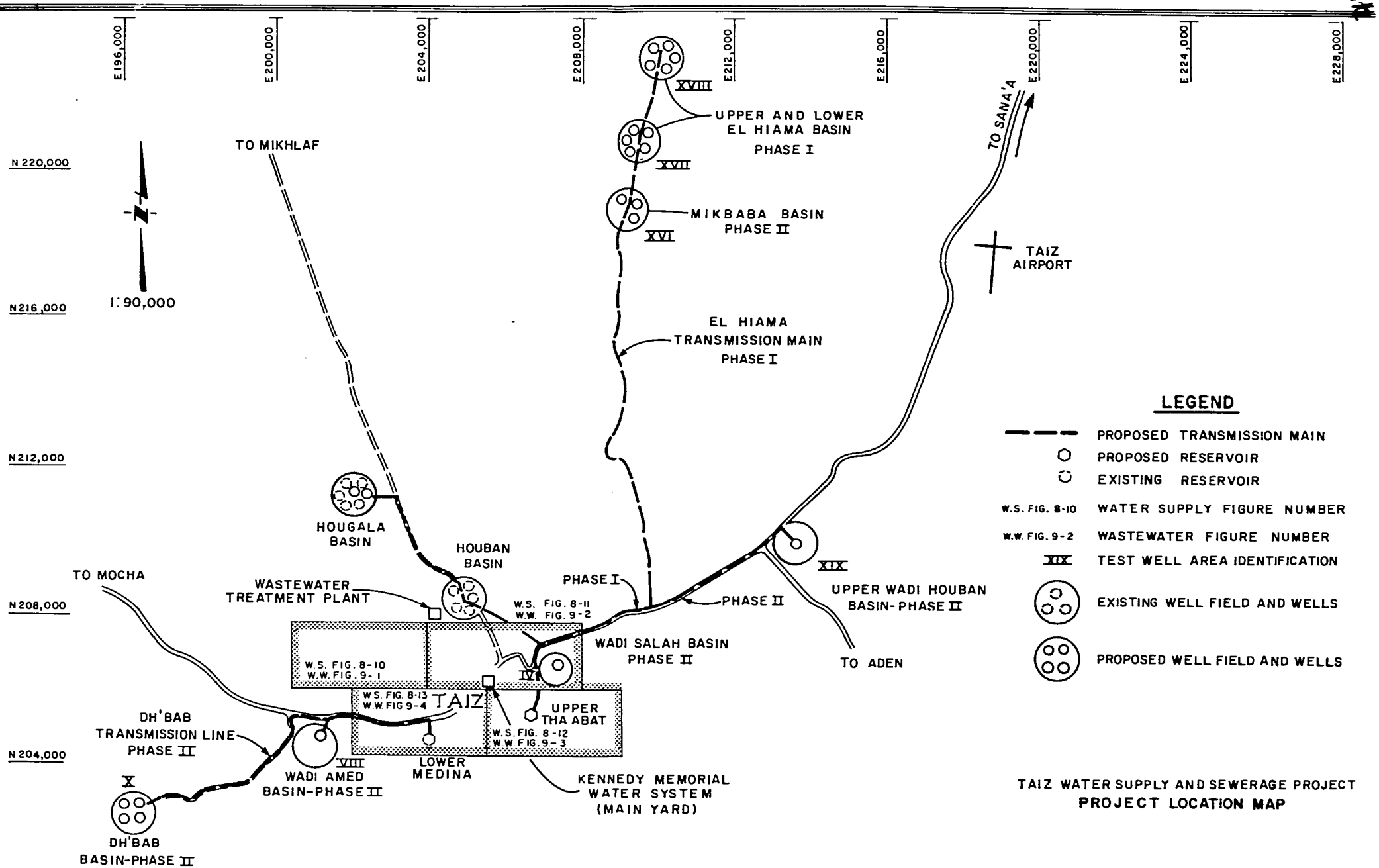
COLLECTION SYSTEM

Taiz has the only wastewater collection system in the YAR. However, it serves only a small portion of the city. The need for expansion and provision for treatment facilities for public health improvement is of the utmost importance.

Extensive contamination of the existing water system is common, which is primarily caused by intermittent water service, numerous back-flow siphonage possibilities, and limited sanitary facilities.

The existing sewer system, 9 km in length, has 263 connections. This system serves approximately 2,000 people in an area with an approximate population of 12,500. A WHO survey showed less than 40 percent of the houses in this area had flush systems. Of these, only 25 percent are connected to the existing collection system. Most residences discharge wastes directly onto streets, however some discharge into cesspools under the streets. The remainder of the residents either use pit latrines or open holes.

The effects of these conditions are reflected in the high infant mortality rate and the high incidence of diseases associated with gross pollution.



TAIZ WATER SUPPLY AND SEWERAGE PROJECT
PROJECT LOCATION MAP

FIGURE 2-2

Summary

The existing system only carries sanitary wastes; there are no storm sewers, as they are not considered necessary due to the steep terrain.

Sewer pipe is locally-made non-reinforced concrete pipe, which is poor quality. Sewer installation practices are also poor.

The wastewater collection system is owned and administered by the municipality of Taiz. The Engineering Department is divided into 3 sections, Planning, Utilities, and Public Health. There are currently no personnel who are technically qualified in sewer design.

Immediate Improvements

Recommended immediate improvements are as follows:

- Construction of public toilets.
- Quality control program for locally-made concrete pipe.
- Improved sewer installation practices.
- Utilization of plastic pipe for house connections and small laterals as soon as it becomes available.
- Separation of existing waterlines and cesspools.

Phase I Collection System

The proposed collection system for Phase I is designed to serve the area that is expected to be developed by the year 1985. A total of 62,000 m (15 mm to 680 mm) constitutes Phase I footage.

Phase II Collection System

Phase II footage amounts to 46,000 m (150 mm to 380 mm). In addition pumping stations are provided in both the East and West Industrial Zones.

WASTEWATER TREATMENT

Selection of a wastewater disposal scheme was approached through examination of two alternative plans which were exportation and treatment and reclamation of the sewage discharges.

EXPORT PLAN

A wadi located downstream of the Hougala well field was considered for possible discharge of raw sewage.

Although this plan would represent the lowest cost solution to disposal of Taiz' liquid wastes, this plan was abandoned for the following reasons:

- Health risk is too great, however remote;
- Considering the limited supply of water available to support the city's anticipated growth, export of relatively good quality of reclaimable wastewater out of the basin cannot be justified.

TREATMENT AND RECLAMATION

To minimize future shortages of water, the plan to treat the wastewater and allow it to be percolated into the ground water basin below Taiz for reuse is recommended. Under this plan the basins currently providing water to Taiz, which have deteriorated greatly in water quality, will be taken out of service as water supply sources, and allowed to rejuvenate through natural percolation of the cleaner treated water and the natural basin ground water.

PROJECTED WATER QUALITY FOR HOUGALA BASIN

Treatment Alternatives

Alternative treatment methods considered are:

- Neighborhood septic tanks
- Raw sewage lagoons
- Mechanically aerated lagoons
- Imhoff tanks
- Trickling filters
- Various combinations

RECOMMENDED FACILITY

Two-stage trickling filter plant followed by percolation beds.

Phase I. Phase I construction involves a 90 lps capacity plant consisting of 2 primary clarifiers, 2 parallel trains of two-stage trickling filters with fixed nozzles and 2 secondary clarifiers. Final effluent is applied to one of 4 percolation beds.

Phase II. For Phase II, parallel trains will be added. Total plant capacity for 1995 will be 270 lps.

ELECTRICAL

Electrical facilities were placed in operation in 1965 to support the power requirements of the Kennedy Memorial Water System. These installations consisted primarily of a diesel-generator power station in Taiz and a pole line to the booster pump station at Houban. Subsequently, the pole line was extended to new well fields at Hougfa and Houban and 75 kw and 150 kw generator units were installed at Hougala. The main generator station in Taiz consists of three generators with an aggregate rated capacity of 685 kw. While this capacity may be adequate for the loads served to date, practical installation realities have demonstrated that actual developed capacity is inadequate. The major operating limitations are: inadequate generator cooling (restricts generator output to 55% of rated), severe voltage drop in the transmission line between Houban and Hougala, and almost total breakdown of engines on dual drive pump units. As a result of these physical plant limitations, supplementary generators had to be installed at Hougala, excessive power loss occurs in the Hougala transmission line and general operation of the Kennedy Memorial Water System is marginal.

PROPOSED SYSTEM EXPANSION

Although corrective design is beyond the scope of this project, design that is performed for the project will recognize the "field facts of life" and will incorporate the use of circuit breakers instead of fuses, adequate conductor size, simple controls, lightning protection and interchangeability of major components. Design will recognize the lack of reserve capacity of the local Taiz electric utility by using this service primarily as an emergency source only.

Electric work proposed in support of Phase I water supply and sewerage expansion is described below:

Summary

1. The El Hiama well field is isolated from existing power sources and will require a prime power generating station consisting of three 200 kw generators and pole line distribution to ten wells. Simple automatic control of the wells will be accomplished via a level switch at the control tank.

2. Electrical work for the booster pumps at Lower Thaabat consists of station wiring for power and light and the construction of a primary pole line from the generators at the Main Yard. These generators will have adequate capacity for this load provided the recommended cooling system improvements are installed. For back-up power it is recommended that a short pole line be constructed to circuits of the Taiz Electric Power Company. Boosters will be controlled by level at the Upper Thaabat reservoir.

3. Electrical work for the wastewater treatment plant will consist of wiring for station power and light, and the installation of a local 62.5 kw generator with provisions for connection of a portable standby generator.

4. Intercommunication facilities are proposed between the El Hiama control tank and the Main Yard, and between the Upper Thaabat reservoir and the Main Yard to facilitate manual control. Indication of the Upper and Lower Thaabat reservoirs at the Main Yard is recommended.

Electric work proposed in support of Phase II water and sewerage systems will be extensive but the exact scope will be predicated on the installations existing at the time of Phase II. The proposed electrical work is described below:

1. At Hougala, electrical support work will be required to connect the two proposed 75 hp wells and a second 150 kw generator will be required to power these units. Control will be from existing devices.

2. Electrical work at the wastewater treatment plant will be needed for connection of the additional treatment units. When this work is done a second 62.5 kw will be required.

3. The Wadi Salah well will require a 480-volt pole line from the electrical system at American Camp.

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4. The Wadi Amed well will require a local 80 kw generator and provisions for connection of a portable standby generator.

5. Major electrical installations are required at Dh'bab consisting of wiring for the three 400 hp booster pumps, a pole line for four wells and three 450 kw generators. Control will be from the Lower Medina reservoir.

6. The well at Upper Wadi Houban will require a local 150 kw generator and an overhead pole line to the Biscuit Factory for standby power.

7. The Phase II water supply expansion at Houban replaces the existing boosters with larger units plus one additional pump. New wiring and starters will be required; also, two 200 kw standby generators are recommended as alternate supply to the existing electrical supply facilities. (See Item 9 below)

8. Electrical work in support of the East Industrial Zone lift station consists of station wiring for power and light, an 80 kw standby generator and connections to the existing Kennedy Memorial Water System primary circuit. (See Item 9 below)

9. The increased load described in Items 7 and 8 above will necessitate the installation of a fourth generator, 275 kw capacity, at the Main Yard.

10. Electrical work in support of the West Industrial Zone lift station consists of station wiring for power and light and construction of a short primary pole line to the Taiz Electrical Power System, and provision for a portable standby generator.

11. Intercommunication facilities are proposed between the Dh'bab boosters and the Lower Medina reservoir to facilitate manual control. In addition to the controls described above, time switches are recommended for isolated wells; such recommendations may be replaced by more sophisticated methods as the situation requires.

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ENVIRONMENTAL IMPACTS OF THE PROPOSED PROJECT

PRIMARY IMPACTS

CONSTRUCTION ACTIVITIES

Short-term disturbances to local environment.

INITIAL ECONOMIC CONSIDERATIONS

Construction will stimulate local economy.

SOCIAL AND VISUAL IMPACTS

Project implementation will improve public health and well-being of Taiz residents. These benefits far outweigh any negative impacts associated with the proposed trickling filter plant.

WATER QUALITY AND SUPPLY

Proposed water system expansion will greatly improve water quality and public health in Taiz as a result of reduced nitrate and coliform levels. Water quality will meet WHO International Standards for Drinking Water (1971).

Water production will be significantly increased and the improved system will reliably provide continuous safe water service to all future customers.

The majority of the service will be provided by house connections; however, public toilets and faucets will also be installed to improve the public health standards for all city visitors and inhabitants.

System personnel will be trained in all facets of operation and maintenance.

SECONDARY IMPACTS

GROWTH-INDUCING IMPACTS

As more people influx to Taiz, provisions will have to be made for additional government services.

SOCIO-CULTURAL-ECONOMIC IMPACTS

The standard of living will improve once water becomes widely available.

The proposed project will allow water from the Houban-Hougala wells to be used for agriculture (until 1991) and will generate a source of fertilizer (digested sludge). These beneficial impacts should improve agricultural productivity within the study area, and heighten Taiz' importance as an agricultural center for Southern Yemen.

NO PROJECT ACTION

A continuation of existing public health and water quantity and quality problems. Failure to improve the existing conditions will result in further deterioration of the community and act as a deterrent to further economic growth.

SPECIFICATIONS AND STANDARDS

OUTLINE SPECIFICATIONS

Included are outline specifications for the construction of the Taiz water and sewerage facilities. The completed specifications together with other elements of the contract documents will be an important part in assuring a high quality finished product.

EQUIPMENT AND MATERIAL STANDARDS

Each of these standards, when incorporated into the contract documents, will define the quality of the equipment and materials required for a completed facility.

COST ESTIMATES

Cost estimations were made for all aspects of the recommended project and in sufficient detail to evaluate the best alternative project. All estimates are based on January, 1975, prices and no allowances have been made for escalation. These estimates are intended to accurately show the project development and annual operation and maintenance costs.

The recommended rate schedule is designed to provide adequate quantities of water to low-income families at an inexpensive rate, and to put the principal burden of supporting the system on industry and affluent

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users and minimize the total annual water demand to delay the time when new and additional water sources must be exploited.

FINANCIAL AND ECONOMIC ANALYSIS

The recommended master plan has been evaluated and determined to be financially feasible with an internal rate of return of 11.69 percent, based upon full projected water sales and loan terms indicated by the YAR wherein 75 percent of the total capital expenditures will be a loan from a foreign source. Fifty-six percent of this loan will be re-lent by the government of YAR to the National Water and Sewage Authority at 7.25 percent per annum over a 25 year period with a five year grace period with interest only payments and the remaining 44 percent being given as a grant. The remaining 25 percent of the total capital expenditures comprise the local contribution to be eligible for a foreign loan, and are not considered to require any payback. The effect of reduced water sales reduces the internal rate of return to only 8.2 percent if water sales are only 70 percent of that projected.

The economic justifications of this project, as a National Economic Project are considerable. A variety of economic factors were considered which included the benefits received for a reduction in medical costs, saving of lost working time, extension of life of workers, and increased productivity. A varied combination of these benefits and the magnitude of these contributions were evaluated, all of which indicated a substantial economic justification for the recommended project.

CHAPTER 3

CHAPTER 3

DESCRIPTION OF STUDY AREA

GEOGRAPHY AND CLIMATE

The Yemen Arab Republic, situated in the southwestern region of the Arabian Peninsula, is bounded on the north by Saudi Arabia, on the south by the People's Democratic Republic of Yemen, on the east by the Rub-al-Khali Desert (the Empty Ouarter) of Saudi Arabia, and on the west by the Red Sea. Although the eastern boarder has never been delineated, Yemen is estimated to contain approximately 195,000 sq sm within its present boundaries. Except for a 70 km wide coastal plain along the Red Sea, the topography of Yemen is mountainous, with elevations of over 3,600 meters. The majority of the population live on interior plateaux which vary in altitude from 1,200 to 2,750 meters.

There are three main geographical divisions in Yemen:

1. The Tihama, a sandy and semi-desert coastal plain 70 kilometers wide, along the shore of the Red Sea. The climate in this region is hot with very high humidity, and there is little rainfall. The port of Hodeida is the most important town in this region.

2. The highlands, lying inland, consist of high plateaux broken by mountains rising to over 3,600 meters. The climate is temperate with summer temperatures rarely exceeding 35 C. Rainfall averages 450 mm per year. More than three-quarters of the population live in this region, the chief cities being Sana'a and Taiz each with a population of about 95,000.

3. The eastern plateau slopes gradually down to the desert of the Rub-al-Khali, with water and vegetation becoming progressively rarer. There are great extremes of temperatures, with summers being extremely hot while winter nights can drop below freezing.

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Description of the Study Area

The prevailing winds in Yemen are from the east. There are two rainy seasons -- the small rains in the spring and the heavier rains in the summer. Few crops are irrigated but Yemen has many small canals leading the runoff into terraces and fields, into storage tanks and ancient cisterns, in an effort to obtain maximum use of rainfall. While most of the trees seem to have been cut down decades ago, a growth of brush and scrub gives the rocky mountains, hills and wadis a green appearance a good part of the year.

Taiz is the capital of the Province of the same name which occupies the extreme southern portion of the Yemen Arab Republic and is located at approximately 13° 36'N - 44° 02'E. The city occupies a topographic position on the northern slopes of a granite massif called Jabel Sabir. Elevations within the city vary over a range of more than 300 meters, but average approximately 1,300 meters. Jabel Sabir rises to an elevation of 2,900 meters within a distance of five miles. The major portion of the city is constructed on alluvial fans present at the mouth of wadis issuing from the mountain. The city is drained by two major wadis. The westerly of these drains about 85 persent of the city and the easterly wadi drains the remaining 15 percent. The city extends onto the slopes above the fans and scattered houses are visible high on the mountain. The major portion of the city is contained within two areas, the Medina (walled city) and the Jahmabia. The Jahmabia is in the highest topographic position of the two.

The region has a warm and slightly humid climate with annual rainfall of around 540 mm. See Table 3-1 for meteorological data for Taiz for the period 1963 to 1968. Table 3-2 lists temperature and rainfall data taken immediately prior to and during the period of project study. Except for periods of dust storms, which last for a week or more, the climate can be classified as almost ideal. These winds, which come from the Northeast, occur mostly in the early summer.

GEOLOGY

GEOLOGIC SETTING

The city of Taiz lies along the foot of the east-west trending escarpment of the Jabel Sabir massif, the jagged peaks of which rise to an elevation of more than 2,900 meters directly south of the city. A broad vista of moderate to rugged hills and narrow valleys extends northward for several tens of kilometers from the city.

The abrupt slopes of Jabel Sabir are formed along a major linear fault zone which continues some 8.5 kilometers west and 8 kilometers east of Taiz.

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TABLE 3-1

METEOROLOGICAL DATA FOR TAIZ[a]

Item	Period (1963-1968)
Temperature (deg C)	
Mean Annual	24.8
Mean Maximum	30.8
Mean Minimum	18.8
Absolute Highest	37.6
Absolute Lowest	10.8
Relative Humidity (Percent)	
Annual Average at 8.00 hr	51.5
Annual Average at 14.00 hr	42.0
Annual Average	46.3
Minimum Monthly Average	27.0 (Mar 1964)
Maximum Monthly Average	79.0 (Dec 1966)
Wind Velocity (knots)	
Annual Average at 8.00 hr	5.7
Annual Average at 14.00 hr	10.6
Annual Average	8.2
Rainfall (mm)	
Annual Average	540 (1963-1966)
Avg. No. of Days of Precipitation/Yr	96 (1963-1966)
Max. Rainfall on any one day	65 (1963-1968)

[a] Taken from IBRD Report, 1973

TABLE 3-2

TEMPERATURE AND RAINFALL DATA FOR TAIZ[a]
WATER YEAR 1973-1974

Period	Temperatures (F) High	Low	Rainfall (in)
Nov 1973	79.3	57.8	1.04
Dec	75.4	54.0	0.41
Jan 1974	76.6	55.0	0
Feb	76.4	59.9	1.31
Mar	78.1	63.7	0.46
Apr	85.4	67.6	0.27
May	85.8	68.6	3.40
June	85.8	69.5	5.42
July	84.7	69.5	2.28
Aug	84.5	67.3	5.31
Sept	85.0	65.0	2.65
Oct	84.4	63.5	1.80
	WATER YEAR TOTAL		24.35 (Nov 1973 to Oct 1974)
			or, 618.5 mm

[a] Taken by Richard Fahey, Peace Corps, Taiz

Dissected alluvial fans and terraces, associated with erosion and uplift of the Jabel Sabir, butt against the escarpment and locally form the surface upon which the city lies. Throughout the region to the north the physiography is also formed largely by structural disruptions. Stream valleys and mountain flanks lie primarily along fault trends, reflecting the effects of past regional upheavals.

LITHOLOGIC FEATURES

Rock types occurring in the area of investigation are primarily of igneous origin. Metamorphic and older sedimentary areas are relegated to localized outcrops. Younger sedimentary deposits are found predominantly in the Taiz Alluvial Fan and along stream courses incising the older igneous rocks. Rocks comprising the Jabel Sabir block are generally of deep-seated igneous origin and have been assigned by earlier investigators as Cretaceous in age. Granite, quartz monzanite, and other rocks of acidic igneous character predominate.

In the region east, north and west of Jabel Sabir a broad suite of fine grained igneous rock types, usually associated with shallow or surface emplacement, are prevalent. Rhyolite, andesite, porphyrytics and basalt are most common. The time of emplacement of these rocks has previously been determined as Tertiary, however, surface evidence indicates that regional volcanism may have persisted through Quaternary time.

Metamorphic rocks located in the vicinity appear to be related to the Jabel Sabir fault zone. These rocks occur generally as small hills west of Taiz in the immediate vicinity of the faulted escarpment. Contact metamorphism in this location appears to have produced only low grade quartzites, schists and gneises. Sedimentary rocks exposed are associated primarily with the alluvial fan derived from the north flank of Jabel Sabir and the narrow stream valleys crossing the region. Boulder fanglomerates, conglomerates, and silt and clay strata, and beds of volcanic ash (igneous effusive) are found to be present in the alluvial fan. Unconsolidated gravel, sand, silt and clay comprise the bulk of the stream valley alluvium. Alluvial fan and valley alluvial sediments are considered to have been deposited essentially continuously from Late Tertiary through Quaternary time.

In a small group of hills west of Taiz along the Jabel Sabir fault zone, a fossiliferous limestone occurs. No age has been determined for these sediments, but stratigraphic position suggests Pre-Cretaceous deposition.

Of the rock types briefly described above, the most significant in the context of water resources is the Quaternary Alluvium occurring within stream valley.

STRUCTURAL AND GEOMORPHIC FEATURES

The area of investigation has, in past geologic history, been a region of intense tectonic activity. Most formations in the vicinity have been severely faulted and otherwise disrupted, as evidenced by existing landforms. Directional orientations of mountainous ridges and stream valleys north of Taiz reflect structural breaks or weaknesses with general regional trends.

Stream courses in the region relate to the youthful nature of the surfaces they incise. Streams on the north flank of Jabel Sabir flow in narrow, steep, V-shaped valleys, which are practically devoid of alluvial fill. These streams usually continue along deeply incised courses across the alluvial fan, at the top of the Jabel Sabir escarpment, then enter the alluvial filled valleys to the north of Taiz. Portions of the alluviated valleys are in erosional as well as depositional phases of development, attesting unstabilized surface gradients.

Streams rising to the north of Taiz follow erratic and dendritic drainage patterns which, for the most part, follow alignments of structural weakness. It is within the alluvial fill of these valleys that ground water is accumulated and stored, and from which the new water sources for the city of Taiz can be derived.

CHAPTER 4

CHAPTER 4

SOCIOECONOMIC AND ENVIRONMENTAL ASPECTS

POLITICAL AND SOCIAL BACKGROUND

Yemen, located on the southwest corner of the Arabian Peninsula, bordering the Red Sea, is one of the 25 least developed countries in the world. Per capita income is reported for 1972 as U.S. $108. The population estimate for 1973 is 6,217,000, and the estimated growth rate of the population is 2.5 percent per annum. The area of the country is approximately 190,000 sq km, lying between Saudi Arabia on the north and northwest (boundaries undefined) and the People's Democratic Republic of Yemen on the southwest and south.

The health and living conditions of Yemen are extremely poor. Yemen life expentancy is now estimated at 30 to 40 years. Infant mortality is still at nearly 240 per thousand for the first year of life and 435 per thousand for the first 12 years. In the past it is believed that infant mortality was probably 50 percent. Literacy is probably not much more than 10 percent, being, of course, much higher in the cities. All the available statistics point to a very low level of development with marked development nevertheless now taking place with urbanization and improvements in agricultural productivity. However, Yemen remains overwhelmingly an agricultural country with probably 90 percent of the population engaged in a low productivity agriculture that is generally of a self-sustaining type.

In addition to health, the second major social concern for Yemen is the level of education. There is a shortage of schools of every type that is needed for Yemen's development. The school population is rapidly growing but still probably does not comprise more than 15 percent of the students eligible for primary education. Secondary education is a recent development and virtually all the teachers in the secondary educational system come from abroad. Very little is provided in the way of technical education. There is no agricultural training institute and the only real technical training available in the country is provided by the Sana'a Technical School which is an aid project of the People's Republic of China. A growing number of Yemeni students are pursuing

secondary and higher education abroad. There are probably more scholarships available to Yemeni for higher education abroad than there are Yemeni prepared to fill such scholarships. This situation is the product of the concern of nearly 20 nations with the provision of some modest measure of international aid to Yemen. Scholarships, apparently, are a favored vehicle for such aid. To date, however, results have been rather discouraging. In the period 1964-72, of the 2,000 Yemenis who were sent abroad to study, only 400 returned.

Politically, Yemen has undergone great changes in recent years. In 1962 the Imam was deposed. Until 1962 Yemen had lived in relative political and economic isolation. Since that time, a highly complex international political situation has evolved around Yemen in which other nations, particularly Saudi Arabia and Egypt, have been involved. Following the overthrow of the Imam, Egypt sent troops to the country to aid the new republican government against the dissident royalists who were supported financially by Saudi Arabia. In 1967 Egyptian troops withdrew and by 1971 the major differences of the Yemeni were resolved with the acceptance of a new constitution.

The civil war period in Yemen was also marked by serious drought and famine. Since then, economic conditions have improved markedly. Political conditions, however, still remain unstable with a recent change of government occurring in June of 1974. While with the Egyptian military withdrawal Egyptian influence in Yemen has disappeared, the new political issue is the relationship of the Yemen Arab Republic (YAR) to the People's Democratic Republic of Yemen in the south. An agreement was signed in November, 1972, between the two governments providing for a merger of the two states. It appears now that such a merger is extremely unlikely. The Yemen Arab Republic currently devotes approximately 60 percent of its budget for the military and internal security. The military are much in evidence in Yemen, particularly in the southern part of the country around Taiz which lies near the border with South Yemen. Military conflict between the People's Democratic Republic of Yemen (South Yemen) and the Arab Republic of Yemen could occur in the future.

The YAR currently attracts the attention of the USSR and other western European soviet bloc nations which are very substantial aid givers. It also is the subject of political interest to Saudi Arabia and other Arab states of the Persian Gulf, particularly Kuwait, who are providing an

increasing amount of economic aid. Least politically motivated, according to the Yemeni, is the economic aid of the People's Republic of China which has become increasingly important. The PRC is now the second largest aid giver after the USSR. Lastly, the Western World continues to provide aid to Yemen, the largest aid giver currently being West Germany followed by the United States and the United Kingdom.

More important than the aid programs, however, in the development of Yemen in the past decade, has been the rising number of Yemeni employed in other countries, especially Saudi Arabia. The remittances of these workers probably amount to over one hundred million dollars and affect somewhere between one-half million and one million people.

MONETARY SYSTEM AND INTERNATIONAL ECONOMIC RELATIONS OF YEMEN

The currency unit of Yemen is the rial which is divided into 40 buqshas. Yemen has a central bank and is a member of the International Monetary Fund. The Central Bank intends in the near future to make the rial divisible into 100 fils. All figures in this report express fractional amounts as 100ths of a rial.

The par value of the rial is $.225 (March, 1975). Although Yemen is experiencing inflation of probably more than 15 percent a year in recent years the rial has been surprisingly stable (appreciating relative to the dollar in 1973). This is accounted for by the fact that although Yemen's imports exceed exports by 10 to 1, Yemen receives substantial amounts of foreign exchange through emigrant remittances and the aid programs of foreign nations.

THE ECONOMY OF YEMEN

Yemen consists of two economic sectors. The first containing probably 90 percent of the population generates about 70 percent of the domestic national product. This is the low productivity agricultural sector. The second sector consists of three expanding cities and their environs: Sana'a, Taiz and Hodeida. These cities contain most of the trade (12.1 percent of GDP), government (5.3 percent of GDP), and construction (3.2 percent of GDP) of the economy. There are only five other cities of reputedly 20,000 - 40,000 population. These cities have no basic utilities and serve chiefly as distribution centers and enlarged agricultural communities. Yemen has no sizeable industrial plants

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employing more than 100 workers other than a large textile plant in Sana'a (2,000 or more employees), a cement plant in the Hodeida area (200), and a biscuit manufacturing plant (300) in Taiz. There are also, of course, a variety of small undertakings such as bakeries, tailors, building material makers, etc. The total contribution of the industrial sector is estimated to be only 2.7 percent of GDP.

Relative to the figures quoted above, it should be noted that there are few reliable demographic, economic, or social statistics for no actual censuses have ever been undertaken in Yemen despite the publication in 1973 of a Statistical Yearbook. It is readily apparent to an observer, however, that while the rural sector continues in great poverty, much is happening in the three cities. These cities are becoming substantial distribution centers with increasing numbers of stores stocked with a wide variety of goods. Also in each of the three cities a construction boom is going on. Sana'a, Taiz and Hodeida are tied together by a network of three modern highways which are the basis for the increasing economic integration of the country in recent years. First, there is a road from Hodeida, the port city, to Sana'a, the capital up on the high plains. This paved, winding road up the mountainside from the Red Sea is the work of the People's Republic of China. The Chinese are now engaged also in building a new road north from Hodeida to the Saudi Arabian frontier. This road will open up the north of Yemen which is the poorest area of Yemen economically. A second modern highway runs directly south from Sana'a to Taiz. This road was originally built by the Americans in 1964. It opened up a large and relatively productive agricultural area to the impact of the cities. The road, formerly known as "the road of dust," is now almost completely paved as a result of a West German aid project. A third paved highway built by the Russians goes from Hodeida southeast parallel to the Red Sea coast but inland, and connects with a road from the coast to Taiz. These roads have accomplished the transformation of Yemen by promoting the movement of goods and people between the major areas of the country.

AGRICULTURAL AREAS

There are five major agricultural areas. They have distinctively different physical features and also differ in types of cultivation and likely development potential.

Eastern Slopes

The Eastern Slopes extending into the Arabian desert have little population and are of little agricultural value.

Central Uplands

The Central Uplands to the west lie 2600 to 2750 meters above sea level. Between mountain areas there are flat plains upon which crops, chiefly cereals, are grown erratically as a result of low and variable rainfalls. In the center of this area is the capital city of Sana'a.

Western Slope

Further west toward the Red Sea is the area of the Western Slope that is intensively terraced, has well distributed rainfall and grows cereals and coffee.

Tihama

The semi-arid coastal plain along the Red Sea is known as the Tihama. Agriculture is carried on in the foothills by a system of spate irrigation which consists of diverting natural rainfall so that it is most effectively utilized only on crop land. The use of ground water is increasing in the area. It grows all of the cotton exported by the country. It includes the port city of Hodeida.

Southern Uplands

This area includes the lower part of the southern and southeastern escarpment of the central highlands. The climate is warm and relatively humid. Rainfall is relatively high (600-800 mm per annum) and the area is intensively farmed, often by terrace agriculture, with emphasis on cereals, fruits, vegetables and coffee. The area is considered to have a high potential for agricultural improvement through the use of fertilizer and insecticides and improved utilization of surface water. The number two city of the country, Taiz, and the subject of this report, is located in this area.

NATURAL RESOURCES

Yemen is poor in natural resources. To date, no oil has been discovered within its boundaries. Rock salt has been the only mineral found worth developing (production 100,000 tons).

Commercial fishing is currently being promoted with the assistance of the U. N. Forestry may have some potential.

SUMMARY

Agriculture is and will continue to remain the principal economic activity of the country. Unfortunately, good agricultural land and water are both very scarce. Arable land is estimated at five million hectares of which only two million are considered cultivable.

Yemeni agriculture is literally built on several thousand years of terracing of mountainsides. Yemeni farmers are well regarded. Land and water are carefully utilized. The majority of farmers own their own farms, but these farms are very small and probably do not involve much more than ten percent of the total cultivated land. Another 20 percent of the land is owned by the state and religious trusts. The remainder is in the form of large holdings, much of which is leased. The present leasing system is viewed by agricultural experts as archaic. The use of fertilizer, better seeds, agricultural methods, etc., presents great possibilities and a variety of large imaginative projects for raising agricultural productivity under international auspices are now in process (USSR, East Germany, West Germany, World Bank and UN/FAO).

In conclusion, Yemen is a medieval agricultural society that is emerging by virtue of improved transportation into a unified economy with a rising market-oriented agricultural sector. High birth rates and increased agricultural productivity will result in a continuing increase in surplus agricultural population that will be released to the cities or will go abroad. Presently probably 90 percent of the population lives off the land, but this percentage is certain to fall. While agricultural productivity will rise, the importance of agriculture as a proportion of the Gross National Product will continue to decline as the second economic sector, the three urban centers, continues its growth.

The growth and rising per capita income in the urban centers stems not from the increased demands of the countryside, since the countryside still remains technologically stagnant and a mere exporter of people. Nor does the rising activity of the centers stem from their own development of base industries. Rather, the activity of the cities centers both on a construction boom derived from their population growth and

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from the rise of retailing activities that offers a surprising variety of imported goods keyed to the growth of income in their market area.

The propelling force behind Yemen's economic growth in its cities at the moment lies in two matters: 1) emigrant remittances that make possible increased consumption outlays by Yemeni, and 2) foreign aid that generates, through highway building and other projects, both employment and further increased incomes that can be spent on consumption goods. Thus, a multiplier process is at work.

The inflow of foreign exchange from these two sources makes possible the consumption by Yemen of over $100 million of imports, although export earnings are only about $10 million. Foreign aid consists not only of project loans, but also loans for budget support which come chiefly from Saudi Arabia (over $10 million a year) and also from Iraq and Kuwait ($1 million a year). Despite the unusual imbalance of imports over exports of about nine or ten to one, it has been possible for Yemen to accumulate foreign exchange reserves and to maintain the stability of the exchange value of its currency.

Development through emigrant remittances and international aid over the next decade may provide a firmer base for Yemen's economic development than might be supposed. Emigrant remittances are the far larger component by probably a factor of five to one when contrasted with present aid levels. Actually emigrant remittances should continue to grow. The prosperity of Saudi Arabia and the other Persian Gulf states, all of which are underpopulated, means for probably at least a decade, a continuing demand for Yemeni workers who will continue to support families in Yemen since they are not permitted to migrate. Meanwhile, Yemen's strategic position on the Red Sea with the reopening of the Suez Canal should continue to attract the interest of all the major powers to maintaining some sort of presence in the area which will probably continue to take the form of aid programs just as it has in the past decade.

THE ECONOMY OF TAIZ

DATA SOURCES

Accurate statistics are rare in the Yemen Arab Republic. A census has never been taken. In Taiz there is no recording of deaths. Births

are registered at the option of the parents. The chief administrative officer (Mayor) reports that in 1974 only two births were registered.

In the face of the deficiencies of actual data, the Statistics Department of the Central Planning Organization of the Prime Minister's Office has issued a Statistical Yearbook 1973 which contains estimates of many magnitudes relative to population, agriculture, industry, etc., including a set of national economic accounts. Unfortunately, only a small part of this data relates directly to Taiz and some of it appears questionable. Nevertheless, this work is to be appreciated. It has been used in conjunction with a sampling survey relative to population, building structures, employment and water use made by the project survey team for this study. These two studies have been supplemented by interviews as a third source of information. All three sources doubtless involve some errors.

POPULATION

The 1973 population of Taiz was estimated by the Project Team, on the basis of a sample survey to be 84,000 and at present (1975) is estimated to be 95,000. As might be expected in a growing city which is economically progressing, the mayor believes that this is an understatement. He points out that large numbers of people sleep on the streets; that many workers come to Taiz and live in dormitories; that there are also squatters, but insists their number is less than 500; and that there is also a student population of 30,000, many of who come from outside the city and board in Taiz. The Project Team, however, believes that its sample does take care of these matters and that the figure of 95,000 is a reasonably good estimate.

THE CITY AND ITS HOUSING

Taiz lies on several hills which are connected by a few principal streets that follow the topography of the area. These major streets are paved and define the boundaries of large groups of houses to which access is had by passageways that generally cannot admit vehicles. Thus, the city is remarkably compact with hardly any sprawl along the highways leading to it. Density is declining somewhat as passable new streets are being constructed in the outlying hillside.

The buildings are of stone, brick, concrete, and mud bricks. Because of the shortage of timber in the country, frame houses are not seen.

Yemeni stone work is exceptionally attractive and new public buildings and the homes of the upper classes are increasingly built with fine stone work. Upper class neighborhoods are developing up the hillsides, although good homes are often seen in nondescript sections of town.

Taiz does not employ the typical Yemeni architecture that is found in Sana'a and which is apparently many centuries old. This involves a high rise building of five or six stories in some cases, but always of at least two to three stories. When Yemeni families are obliged to increase their living space for new generations, the extended Yemeni family has generally simply extended its house up another floor. Such old buildings, built over many years of different progressively lighter materials as the building grows upward, are the delight of foreign architectural students. Taiz does not follow this pattern, being generally content with two story buildings. The explanations given are that Taiz is a relatively new city and people have preferred modern western houses. Also, it is claimed that since Taiz has many thunderstorms, people fear that lightning may strike tall buildings. What is important is that even in Taiz one story buildings are extended up a floor. Thus, city density may increase in the future in already built-up sections by the addition of a second floor to buildings.

Currently Taiz is experiencing a building boom, both residentially and in public buildings. A huge hospital is being constructed by a grant from the People's Republic of China and also Kuwait and Saudi Arabia are contributing impressive stone school buildings. Construction costs for better residential housing run $40 to $60 a square meter. At the other end of the income scale the city is planning to build low cost housing for its lowest paid workers. Such housing will cost $16 to $20 a square meter.

It is said that the lower classes can no longer afford to buy or build a home. The fortunate poor are those who have inherited a home. An unskilled worker doing manual labor can expect to earn little more than $50 a month. Monthly rental of a hovel would be no more than $2 or $3, but such a family must expect to pay 70 - 80 percent of its income for food. Generally, families are large and there are several income earners in the family unit. Food needs and even space needs are likely to increase proportionately with the number of wage earners in the unit.

The Taiz governmental workers will pay about $5 per month rent for their low cost model housing. Part of this will be credited toward

their eventual owership of a unit within a six-unit building. The construction cost of a unit is estimated to be slightly over $2,000.

It appears that probably 70 percent of the population live in buildings worth less than $3,000. This means that the cost of a water and sewerage system when expressed as the total cost of an individual connection will be large relative to the value of the piece of property served.

The present city administrator is considering setting aside specific areas for squatters. Provision of water standpipes to such areas would aid in confining squatter areas to regions consistent with a city plan.

The total number of private residences and apartment buildings was judged from a 1973 aerial survey to be 7,400 and the number of commercial and government structures to be 630.

CITY GOVERNMENT AND CITY PLANNING

In the Yemen Arab Republic there are no city governments. Local officials are appointed by the governor of the state. Taxes are collected by the national government and allotted to the city. Some functions closely associated with city governments, such as street construction and maintenance are performed directly by the central government through the highway department.

No city plan for Taiz as yet exists, although the city has had the short-term services of an American city planner, who worked out a low cost housing project for the city. A distressing matter is the absence of any central records relative to the ownership of land. Also, the city as yet does not have a system of street numbering and the mayor complains that he does not even have a satisfactory map of the city and hopes this project will provide him with one.

UTILITIES

Electric System

The city has a power system with 8,400 subscribers. Installed electrical capacity is KW 4.300. The rate for electric current is 19 buqshas per KWH. Employees number 150.

Water System

The city has two water sources. The Jabel Sabir system involves the delivery of water from springs on the hillside to subscribers, generally at the higher elevations. Users pay a flat fee of R 50 per month. The other system is the Kennedy Memorial System. It has approximately 8,600 connections and charges 36 buqshas per cubic meter. Water delivery is poor.

Telephone System

The city has 1,000 telephone subscribers. This figure probably measures the number of upper and upper middle class income people. Service is not dependable. The British Cable and Wireless Company Ltd. has an office in Taiz for cables, telex, and international telephone service, but this also often does not function.

Sewage System

The city has no sewage system proper and no sewage treatment plant. About 9 kilometers of sewer line have been constructed. Payments for a connection have ranged from R100 to as high as R1,000, depending upon the number of toilets and the income level of the property owner.

Radio Station

There is a radio station in Taiz, but it operates only a limited number of hours per day. The Sana'a radio station broadcasts 24 hours a day and is widely listened to in Taiz. Presently there are plans for a television station in Sana'a, but none for Taiz.

TRANSPORTATION

Intercity

There are no railroads in the country. All goods move by truck. There is passenger bus service between Sana'a and Hodeida and also jitney taxi service. Taiz has an international airport handling planes as large as the DC-6. In 1973, 268 flights landed there from within the country and 401 flights came from abroad. Service, however, is not dependable. Delays are common and during August, 1974, the runway was closed for repairs.

Intracity

There is no bus service within the city as yet, although there are hopes one may be organized. Fortunately, distances are not great and there are many taxis. Large employers of labor provide bus or truck transportation to common gathering points for their workers. In 1973 there were 865 trucks, 827 taxis and 465 private cars in Taiz. There were also 865 motorcycles and scooters.

BASE INDUSTRIES

Services to Agriculture

Taiz functions chiefly as a marketing and financial center for the agriculture of Southern Yemen. The agriculture of the area is of very low productivity but has great potential for improvement. At present the bulk of the people engaged in agriculture live at a subsistence level. However, some villages are exporters of agricultural products and with higher productivity and increased access to market through the construction of roads, the role of subsistence agriculture will decline.

Manufacturing Concerns

Biscuit Plant. This is the largest industry in Taiz. It is located five miles outside the city and supplies its own power and water. Operating on a three-shift basis it sometimes employes as many as 350 people, a third of whom are women. It has several different assembly lines for the production of different types of biscuits and sweets.

The plant uses the most modern equipment which it has imported from Germany chiefly. It does not employ any foreign technicians, its own employees being able to make any necessary repairs to keep the production lines functioning.

Flour, sugar and most other raw materials as well as wrappers and cartons are imported from abroad. The management complains of the import duties that it must pay on its raw materials. Most onerous is the fact that when it exports it receives no refund (drawback) of the import taxes paid on the raw materials. Despite this competitive handicap it is able to export 15 percent of its production to Saudi Arabia and the People's Republic of South Yemen.

Soft Drink Plants. Three firms, Stem, Alcozare, and Super produce soft drinks for Taiz and the southern area of the country. These three firms employ over 100 workers.

Paint Factory. There is a local paint manufacturer that makes paints and shapes its own cans. Employment is less than 50. Expansion of this activity is being considered.

Aluminum Fabricator. A small firm fabricates pots and pans and other products from aluminum. Employment is less than 50.

Other Small Industries. There is a nail factory and also a number of small firms quarrying stone, making concrete blocks, doing carpentry, tailoring, baking, and printing.

RETAIL AND SERVICE ACTIVITIES

There are many small shops selling clothes, shoes, furniture, cloth, jewelry, etc. In almost all cases the inventories of such stores are very small and can be seen at a glance by the customer. New shop buildings are being built so that the scale of a retailing operation may increase but it will still remain quite small. There is a public market building for the sale of produce in addition to small stalls at the sides of some streets.

EMPLOYMENT AND WAGE RATES

When allowance is made for the high proportion of children in the population and also for the Moslem convention that women generally do not work, the percentage of the population in the labor force may not be much higher than 25 percent. (28 percent was the figure established by a sampling survey for Sana'a.)

Unemployment is probably low in Taiz. The Sana'a study just cited placed it at only 1 percent for that city and a statistical office report places it at only 3 percent for the country. This is amazing in the light of the 10 to 20 percent rates found in most of the cities of under-developed countries. The explanation may be that Taiz and Yemen are still considerably behind other less developed countries relative to changes in the labor force. Large migrations of labor to Taiz is a matter of merely the past ten years. During that time Taiz has expanded economically and has been able to absorb the influx from the countryside in

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gainful employment. Furthermore,the labor market situation is strengthened by the possibility of migration to Saudi Arabia and other countries. Also, at this time many workers who work in the city have probably not established roots there as shown by the large number that live in dormitories. If employment is slack they probably return to their rural areas, rather than continue in the city as confirmed city dwellers looking for work.

Wage rates are low, but apparently rising - chiefly as a result of the inflation that is taking place and the boom in construction work and road building which use both skilled and unskilled labor.

Some idea of the rise which has been occurring in wage rates in Taiz is given by the following data in Table 4-1 obtained from the highway department for various types of labor.

TABLE 4-1

HIGHWAY DEPARTMENT WAGE RATES

Classification	1972 Jan. (Rials/mo.)	1974 July (Rials/mo.)
Machinist	260	510
Plumber	220	510
Welder	260	490
Carpenter	260	330
Blacksmith	220	330
Electrician	220	330
Battery Man	330	330
Radiator Repair	220	330
Truck Driver	220	330
Generator Operator	220	330
Clerk	180	290
Painter	200	---
Tire Repairman	200	250
Typist	200	250
Timekeeper	220	250
Heavy Equipment Operator	180	630
Mechanic	260	510

These increases may be explained on the basis of the large highway construction project now (1974) taking place north of Taiz on the paving and reconstruction of the Taiz-Sana'a highway. This project is being done by foreign contractors and not the highway department. Upon the basis of past experience with other employers stating inflated wage figures, there may be some overstatement of the July 1974, figures.

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The Swedish Save the Children Project operates a hospital for children in Taiz that employes about 100 local Yemeni workers. Table 4-2 shows the same substantial increase in wages over the period January 1972 to July 1974.

TABLE 4-2

SWEDISH CLINIC WAGE RATES

Classification	1972 Jan. (Rials/mo.)	1974 July (Rials/mo.)
Nurses	680	860
Dressers	300	405
Assistants	300	405
Clerks	370	490
Drivers	330	490
Watchmen	280	400
Cooks	330	450
Cleaners	180	300

PROSPECTS FOR THE GROWTH AND ECONOMIC DEVELOPMENT OF TAIZ

BASIS FOR EXPECTED ECONOMIC IMPROVEMENT AND GROWTH

Improvement in the Agricultural Productivity of the Area Served by Taiz

Yemen will apparently for a long time remain a predominantly agricultural country. One of the major objectives of the government policy is to raise agricultural productivity physically and financially. The building of roads opens agricultural areas that can then exchange their products in the agricultural centers more profitably as subsistence

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agriculture is replaced by a more productive agriculture based on production for the markets in cities from which increased varieties and quantities of goods can be obtained in exchange. With an assured market greater specialization and greater productivity can be attained in crop production.

As mentioned, Taiz is already linked to the countryside by relatively good roads that are usable throughout the year. The World Bank has just financed some roads south and southeast of the city that will open up the agricultural area around the small town of Turba. There are also under consideration, plans for other roads that would connect Taiz with the area northeast of it.

More important in the immediate future is the Southern Uplands Rural Development Project. This project would include the area on both sides of the highway toward Sana'a and past the town of Ibb. As conceived by the FAO and the IBRD the project would involve 487 agricultural villages with a total population of 172,000. It is designed to raise the agricultural productivity of the area by improving agricultural methods chiefly by the introduction of fertilizer and pest control. In addition, it envisions improving rural infrastructure by building feeder roads, improving village water supplies and making minor irrigation improvements and land protective works. The project will involve 50,000 hectares of agricultural land and agricultural credits totaling $14 million.

Immediate Prospects for New Industries in Taiz

The family of Hayel Saeed Anam and their associates (owners of the biscuit factory) have now under construction the following projects:

1. A carton and packaging material plant to provide the biscuit plant needs for these items. (Probably 70 workers)

2. A mattress sponge making plant in conjunction with No. 3 below.

3. A plastic pipe factory. The building and equipping of this plant will be through Wavin Overseas Corporation, England. The plant will have a capacity of 1,160 tons per year operating on a one-shift basis. It will be able to produce plastic pipe in sizes one-half inch to 6 inches. (Probably 300 workers)

Beyond these operations the same group is considering:

A soap plant. This plant would import palm oil from Malaysia and manufacture soap and related products. Unilever would assist in its construction and operation and it would employ from 400 to 500 workers per shift.

There is also another project now closed which may reopen:

A shoe factory. Presently the factory building is closed. It is said that mistakes were made in the equipment purchased and the company will be reorganized. It formerly employed about 40 people.

ECONOMICS OF PUBLIC HEALTH IN TAIZ

There are no reliable statistics on matters of public heath in Taiz, births and deaths are not required to be recorded. The crude birth rate for the country has been estimated (WHO) to be 490 and the crude death rate to be 240. Hospitals in Taiz, with the exception of the Swedish Children's Hospital and the U. N. Health Center, do not keep meaningful medical records. The reports of the latter two institutions do not lend themselves to ready extrapolation since their work is specialized and also the statistics reported run in terms of functions performed: inoculations, dressings, injections, number of patients seen, etc., rather than in terms of diseases treated. Thus, there are no meaningful statistics on the incidence of different diseases. Reliance has had to be placed upon general impressions gained from interviews with doctors and public health administrators. All agree that statistical reports are needed and presumably the government will eventually remedy this situation.

INCIDENCE OF DISEASE

Taiz is a city of sickness - and particularly gastrointestinal sicknesses. Ninety percent of the population is reputed to suffer from worms. At the Swedish Hospital 80 percent of nearly 18,000 children examined in the last two years had some type of parasite in their stools according to the laboratory examination. Gastrointestinal diseases are widespread among all groups. Diarrhea is virtually a continuous complaint of all of the population. There is general agreement among doctors that lack of bodily cleanliness and poor sanitation are the chief spreaders of disease in Taiz.

Bilharazia and infectious hepatitis abound. Cholera epidemics have averaged one a year over the past five years. In 1972, according to the U.N. Health Center, there were 265 recorded cases and 21 deaths; and in 1973, 196 recorded cases and 12 deaths. A malaria epidemic occurred in 1973 with 104 cases and 18 deaths.

Among contagious water borne diseases only typhoid has not presented a major problem. Substantial inoculation programs against polio (the Swedish Children's Hospital) and cholera (U.N. Public Health Center) have been pursued. Also, there is a malaria control program (U.N. Public Health Center). However, there is agreement among doctors in Taiz that not enough attention is given to preventive medicine. The most important conclusion derived from interviews was that 70 percent of all the disease in Taiz is water related.

EXISTING HEALTH FACILITIES

Health facilities in Taiz have greatly expanded since 1965 when it was reported (AID) that Taiz had one hospital (150 beds) and 15 doctors. Thanks chiefly to aid programs, the quantity of medical facilities is now quite impressive.

There are five hospitals, a leprosarium, and a U.N. Outpatient Health Center. Figures on the number of beds range from 800 to 1,580. The People's Republic of China is in the process of building as an aid project .. magnificent 500 bed hospital to replace the present 200 bed Military Hospital that is located in an unbelievably dilapidated former military building in which Chinese and Yemeni physicians now practice.

There are reportedly somewhere between 40 and 73 physicians in Taiz, the variability of the number probably is related to the fact that many of the physicians are from abroad and come and go. Also, there is the matter of how doctors are to be identified relative to the definitions of the USSR, China, Italy, France, Sweden and Egypt, from which the present group of physicians come. There are probably also another 100 assistants and technicians. In addition, there are about 30 pharmacists. Including unskilled labor, "the health industry of Taiz" may well employ over 1,000 people.

Relative to its population, Taiz probably now has better than the 9 hospital beds per 1,000 of population found in the United States. However, to some extent Taiz must serve as a health center for the province which has a population of probably over a half-million. Much of the

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population in the province, however, lives in remote agricultural villages and has no concept of modern medicine and depend upon local folk doctors (sofis). Physicians in Taiz estimate that possibly two-thirds of all those who are seriously ill never see a physician. Rural medical services are furnished to a limited extent by outpatient clinics that are held on different weekdays in various villages for which doctors make a circuit. Thus, probably at least 65 percent of the medical services provided in Taiz are consumed by the residents of that city.

The surprising quantity of medical facilities within the city of Taiz does not reflect a satisfactory handling of medical problems there, but rather the concerned reaction of the U. N. and the major governments of the world to the magnitude of the health problems of the Yemen Arab Republic. This has led to generous tangible programs of hospital building and provision of staff physicians, without much concern for the more intangible matters involved in disease prevention. The result,as mentioned,has been the development of a "health industry" which may conceivably account for as much as 5 percent of the gainful employment in Taiz and more than 10 percent of its local GDP if the full costs of foreign physicians are considered.

FAMILY INCOME STRATIFICATION

It is estimated that approximately 30 percent of the families in the urban area of Taiz earn 450 Rials per month or less.

Little relevant information or statistics are available to develop accurate income stratifications of the population. However, the information that does exist consists of a stratification prepared by Italconsults in a report to the United Nations on the cities of Sana'a and Hodeida, salary tables for the KMWS, Highway Authority, the Swedish Clinic and miscellaneous salary structures of private businesses in Taiz.

The income stratification structure developed by Italconsults through an extensive survey program for the UNDP is the most accurate and most useful for the urban areas in Yemen. The report findings are as listed on Table 4-3.

TABLE 4-3

FAMILY INCOME STRATIFICATION LEVELS

Monthly Income Ranges	Average Monthly Income* (Rials)	Number of Families in Range	Percent of Families	Percentile Groupings
0-185	98	200	1.7	
185-350	262	1,080	9.1	29.60
350-500	456	2,230	18.8	
500-580	543	2,940	24.8	
580-650	608	2,100	17.7	
650-720	701	670	5.6	64.58
720-800	731	1,670	14.1	
800-900	880	280	2.4	
900 & up	922	690	5.8	5.82
Totals		11,860	100.0	100.00

*Note: Calculated average family income based on family size

An examination of the salary structure of the KMWS, the Highway Authority (Table 4-2) and the Swedish Clinic (Table 4-3) revealed a broad range of salaries, with the KMWS at the low end of the scale. Approximately 90 percent of the KMWS employees earn less than 400 Rials per month. When converted to represent family income and allow for those families with more than one wage earner, approximately 80 percent of the families with a member working for the KMWS have an income of 400 Rials or less. The KMWS does have a reputation of paying substantial salaries and as a result many of the employees leave for other firms or government agencies when a position is available. Another factor that gives the KMWS a high percentage of low-salaried employees is the fact that more than half of its staff consists of low-paid security guards, laborers, well operators and drivers. This is primarily due to the number and location of water wells that are staffed with separate operators and guards.

The Highway Authority has minimum salary rates; 250 Rials per month for typists and tire repairmen and 330 Rials per month for other skilled and semi-skilled workers. These salaries are from about 100 to 300 Rials per month higher than those paid for comparable positions at the KMWS. The salaries at the Swedish Clinic are even higher than those

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paid by the Highway Authority, which may be partly due to the fact that it is operated by a foreign agency. However, other firms pay comparable salaries, such as the Biscuit Factory that pays a monthly salary of over 300 Rials per month for laborers, plus provides rather substantial medical benefits and transportation to and from work. Another indicator is a local electrical contractor who pays approximately 600 Rials per month for apprentice electricians, which is considerably above the KMWS scale.

The lowest known salary in Taiz is that of the municipal street sweepers who earn about 4 Rials per day or 100 Rials per month. This represents the minimum base of the poor-income group, which agrees with the data contained in Table 4-3.

Based upon the data that has been collected and presented in the previous paragraphs, the family income stratification information developed by Italconsults for Sana'a and observation by the project team, the family income stratification levels presented in Table 4-4 were developed. These income stratifications are utilized in Chapter 14 of this report in the development and justification of the proposed water rate schedule.

TABLE 4-4

FAMILY INCOME STRATIFICATION LEVELS IN TAIZ

Description	Monthly Income Range (Rials)	Percent of Families within Income Range
Poor-Income Group	100 to 215	10%
Low-Income Group	216 to 450	20%
Middle-Income Group	451 to 900	65%
Upper-Income Group	901 and up	5%
		100%

CHAPTER 5

CHAPTER 5

EXISTING WATER SYSTEM

GENERAL

Taiz, the second largest city in Yemen with a present estimated population of 95,000 (1975) has the largest piped water system in the country. Over 70 percent of the residents receive water from the Kennedy Memorial Water System (KMWS). The remainder use water from mountain springs south of the city and hand dug wells.

In recent years, water service from the system has deteriorated due to insufficient supply for the large population increase, poor water quality from sewage infiltration into the well field aquifers and service interruptions from equipment break-downs and pipeline corrosion.

Because of the insufficient water supply, the distribution system is only pressurized a portion of the time. When the water pressure is turned off in various neighborhoods to ration the supply, negative pressures are created in the pipes that pull in liquid wastes from septic tank drainage and cesspools through leaks in the pipeline. This creates a serious health hazard.

Schematic elevations of components of the existing system are shown in Figure 5-1 and the existing water distribution system is shown on figures in conjunction with proposed improvements in Chapter 8 - Recommended Water Facilities.

HISTORY

Historically, a major portion of the population of Taiz was served water from several mountain springs from Jabel Sabir, south of the city. These springs delivered water by gravity through open channels to the mosques and small tanks in various parts of the city. Completely unprotected, the water was not potable by the time it reached Taiz. The total combined spring supply was estimated to be 4.73 lps (75 gpm).

Existing Water System

The first change in centuries occurred in 1961 when the USAID (then ICA) financed the installation of pipelines and public street faucets throughout the city. Though this represented a distinct improvement, there was still considerable inconvenience and sanitary hazard in transporting the water from the public faucets to the dwellings.

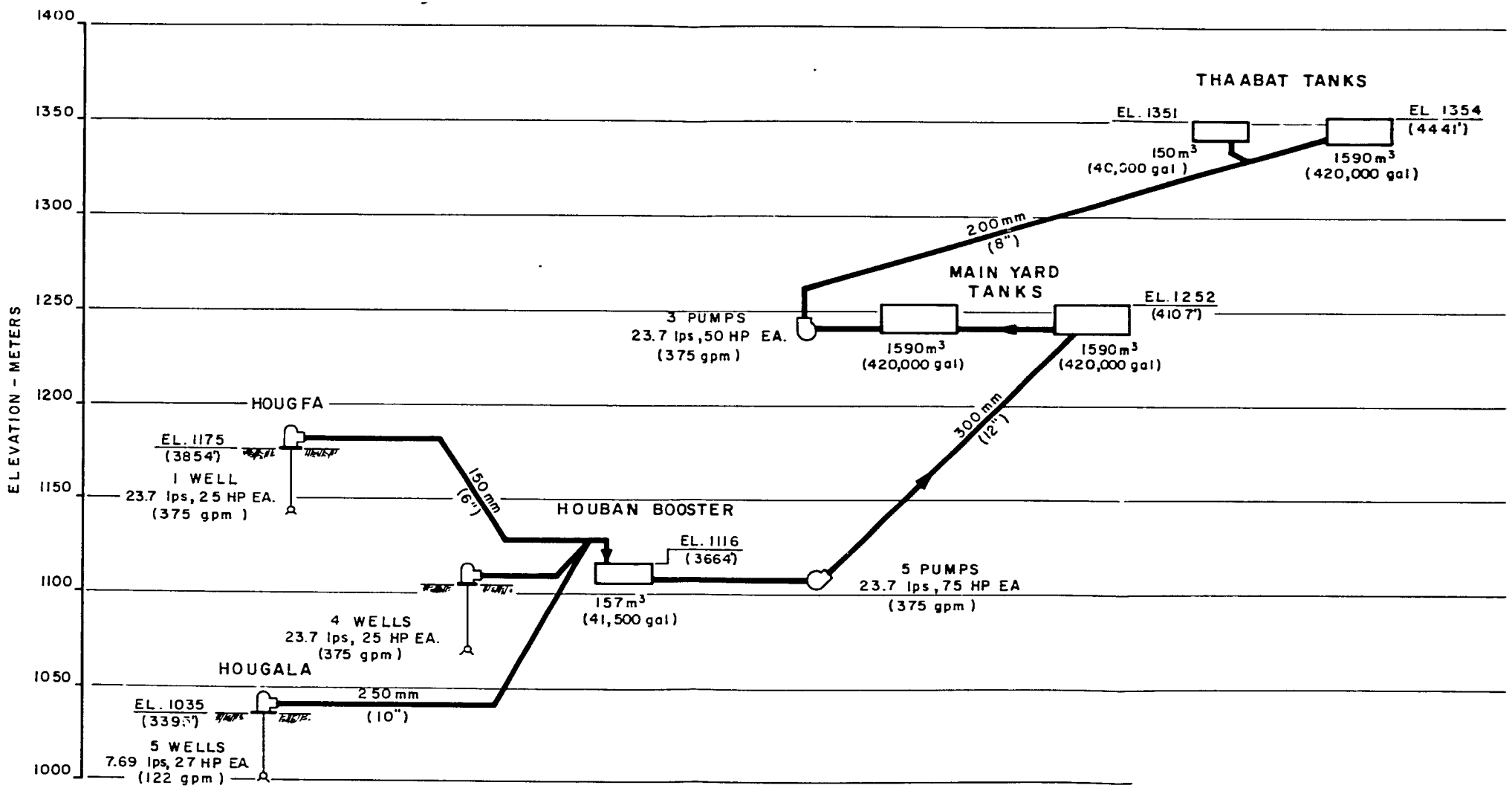
USAID continued its support to Yemen in August 1962 with the start of design of a piped water system for Taiz. The following month, the Government of Yemen was overthrown by a Republican force. The continuing fighting caused some delays in the physical work on the site, but not in the preparation of reports and plans. In March 1963, an agreement was signed with the new government reiterating the basic agreement of the previous year. The system was completed in September 1965 when the population was estimated to be 20,000 to 25,000. Its source of supply was four wells with a design capacity to meet the estimated requirement of 3788 cu m/day (1 mgd) with only three wells being operated 16 hours per day. Three additional wells were also installed to be available for connection to the system in the future if required. Within a year there were 3600 connections to the system.

USAID assistance ended in April 1967 and production difficulties began later that year with lowering ground water levels. Additional wells were installed in the same well field, known as Houban, and by August 1968 some 13 wells were in operation with a total production of 2380 to 2500 cu m/day (0.63 to 0.66 mgd).

In 1968 and 1969 separate studies by the People's Republic of China and World Health Organization (WHO) both recommended that a new well field be developed 4 kilometers downstream of the Houban Field to be known as the Hougala Field. Six wells were constructed and connected to the system.

During 1969, another well field about 2 kilometers upstream of Houban was placed in operation with two wells. This field is now known as the Hougfa Field and formerly was considered to be part of the Houban Field.

At the present time there are only 10 wells functioning out of 21 wells installed since 1967, and their total output is 4542 cu m/day (1.20 mgd) for the system that currently has over 8,500 connections.



TAIZ WATER SUPPLY AND SEWERAGE PROJECT

SCHEMATIC PROFILE
EXISTING WATER SYSTEM

FIGURE 5-1

SOURCES OF SUPPLY

As mentioned previously, the sources of supply for the KMWS are exclusively wells. The mountain springs from Jabel Sabir are fully developed and are privately owned. Even though piped spring water exists within the upper service areas of the KMWS, its use is closely controlled and the maximum yield from all of the springs amounts to only 7 to 8 percent of the total water consumption.

Water consumption from hand dug wells within Taiz is minimal due to the availability of the piped systems.

At present, all of the water supply for the KMWS is provided by wells located in the Houban, Hougala and Hougfa Well Fields. The individual well logs and flow test data for all of the wells are shown in Volume II, Water Resources Evaluation. All ten existing wells discharge into the Houban Booster suction reservoir at elevation 1116 m (3684 ft). Their general locations are shown on Figure 2-2.

Hougala Well Field consists of five supply wells and an irrigation well at approximate ground elevation of 1035 m (3395 ft). Each well is equipped with an electric submersible pump with a rating of 27 hp and 7.69 lps capacity (122 gpm) at 135 m TDH (444 ft). Power is supplied by a newly installed (Oct 1974) 150 kw diesel-driven generator supplying all of the wells. In the event of a generator failure limited power can be supplied by the Main Yard generator. The wells discharge into a buried, non-coated, 10-inch diameter, 1/4-inch wall thickness, steel pipeline 4050 m (13,300 ft) in length that empties into the Houban Booster Reservoir. Originally, a buried telephone cable for voice communication was installed between Hougala and Houban immediately adjacent to the pipeline. The cable has since failed, and there have been at least three corrosion leaks in the pipeline.

Houban Well Field presently consists of four wells located in the vicinity of Houban Booster that discharge directly into the pump suction reservoir. Each well is equipped with an electric vertical turbine pump with a rating of 7.5 hp and 23.7 lps capacity (375 gpm) at 45.7 m TDH (150 ft). The Hougfa Field has a single well at ground elevation of 1175 m (3854 ft), equipped similar to the Houban wells, and it discharges directly into the booster reservoir. The Houban and Hougfa wells are supplied power from the Main Yard generators through overhead wires.

Each well field is manned with security guards 24 hours a day and telephone communications exists between Houban and the Main Yard.

Presently there is no metering of source water into the system. This omission prevents KMWS from determining its unaccounted-for water in the distribution system.

During late July, 1974, the project team conducted combined flow tests of each well field using volumetric level/time measurements at the Houban Reservoir. The results were:

	Flow	
	lps	gpm
Hougala Wells (Nos. 2, 3, 4, and 6 operating)	34.4	546
Houban Wells (Nos. 2, 6, and 11 operating)	4.7	74
Hougfa Well	13.9	220
Total Supply to System	53.0	840

Also, during this same test a Hazen-Williams C-value, or internal roughness of the 10-inch Hougala transmission pipeline was calculated to be 90.

PUMPING PLANT

All wells discharge into a reinforced concrete/masonry pump suction reservoir at Houban that has a capacity of 157 cu m (41,500 gal) and an overflow elevation of 1116 m (3664 ft). From here, the water is pumped to the Main Yard storage tanks at elevation 1252 m (4107 ft) by five vertical turbine can-pumps through 2431 m (7678 ft) of buried, non-coated, 12-inch diameter, 3/8-inch wall thickness, steel pipeline. Each pump has a rated capacity of 23.7 lps at 159 m TDH (375 gpm at 520 ft). Two of the pumps are driven by 75 hp, 2950 rpm electric motors and the other three by 75 hp diesel engines through right-angle gear drives.

A "C-value" for the 12-inch discharge pipeline was calculated to be 86.

Existing Water System

The Main Yard storage tanks supply water to approximately 70 percent of the consumers; the balance of the water is pumped to the Thaabat tanks at elevation of 1354 m (4441 ft) to supply the rest of the consumers (30 percent). Pumping at the Main Yard is provided by three vertical turbine can-pumps having a rated capacity of 23.7 lps at 114 m TDH (375 gpm at 375 ft). One pump is driven by a 50 hp, 2950 rpm, electric motor and the other two by 75 hp diesel engines through right-angle gear drives. The pumping arrangement is shown on Figure 5-2.

As originally designed and constructed, the Houban pumps were equipped with combination electric motor/engine drives and the Main Yard pumps with electric drives only. Due to critical power generation and transmission problems from the Main Yard generators, the pump drivers have been gradually shifted from electric to diesel engines. Cooling for the engines is provided by once-through passage of water from the discharge to the suction through the engine jackets, and as a result, a large amount of oil is visible on the water surface in the storage tanks.

The shortage of spare parts and absence of normal preventive maintenance places the pumping plant in a very critical condition and could render the entire water system inoperative at any time.

WATER TREATMENT

Only chlorination is provided to the water supply.

The chlorination arrangement is shown on Figure 5-2 and consists of two "V-Notch" chlorinators, each having a maximum feed rate of 13.6 kg/day (30 lbs/day). One chlorinator is used as a standby. Chlorine gas is supplied into the chlorinators from 68 kg (150 lb) cylinders. While feeding, the cylinder is positioned on a platform scale used to measure weight loss.

Presently, the chlorine solution is fed into the 12-inch pipeline from Houban Booster prior to the water entering tank No. 1 at the Main Yard at a dosage of 1.0 mg/l. The valving of the two tanks is arranged so that the water must pass from Tank No. 1 into Tank No. 2 before entering the system, providing ample detention time. Daily tests for chlorine residual are performed to insure at least 0.5 mg/l prior to entering the system. When the water is turned on in the system, a slight residual can usually be detected after a period of time.

As noted in a subsequent Section - Water Quality, the bacteriological tests records for recent months show periods of continuous positive samples. This indicates the water was unsafe to drink during these periods, and was caused by failure to feed any chlorine due to lack of inventory.

DISTRIBUTION SYSTEM

RESERVOIRS

The KMWS distribution system includes four covered, cylindrical steel water tanks having a combined storage capacity of 4920 cu m (1.30 mg). The tanks are all located at ground elevation as shown on Figure 5-1.

The original system design envisioned the use of reinforced concrete. However, due to the lack of qualified contractors and suitable aggregate, excess-property steel tanks were installed. These are the U.S. Corps of Engineers bolted design having a uniform wall thickness of 1/4 inch.

The tank interiors only received three coats of red lead primer and the tank walls have been weakened by corrosion. A number of pinhole leaks have already been repaired by spot welding.

TRANSMISSION AND DISTRIBUTION MAINS

The existing piping system consists entirely of unlined steel pipe in diameters from 1 inch to 12 inch with total footage estimated to be in excess of 50,000 meters. See Figures 8-10 to 8-13 for sizes 1-1/2 inch and up.

Basically, standard weight steel pipe was used throughout the system. Eight-inch and smaller pipe had exterior galvanized coating with screw connections, and ten and twelve inch were coated with paint and used mechanical connections. Brass gate valves with no insulation from the steel, were used on mains three inch and smaller, and iron body valves were used on larger mains.

Pressure control between Thaabat Tanks and the Main Yard Tanks (an elevation difference of 102 m) was originally provided by four pressure reducing valves installed in the main pipelines. Two of the valves on the 10-inch line out of the Thaabat Tanks have failed

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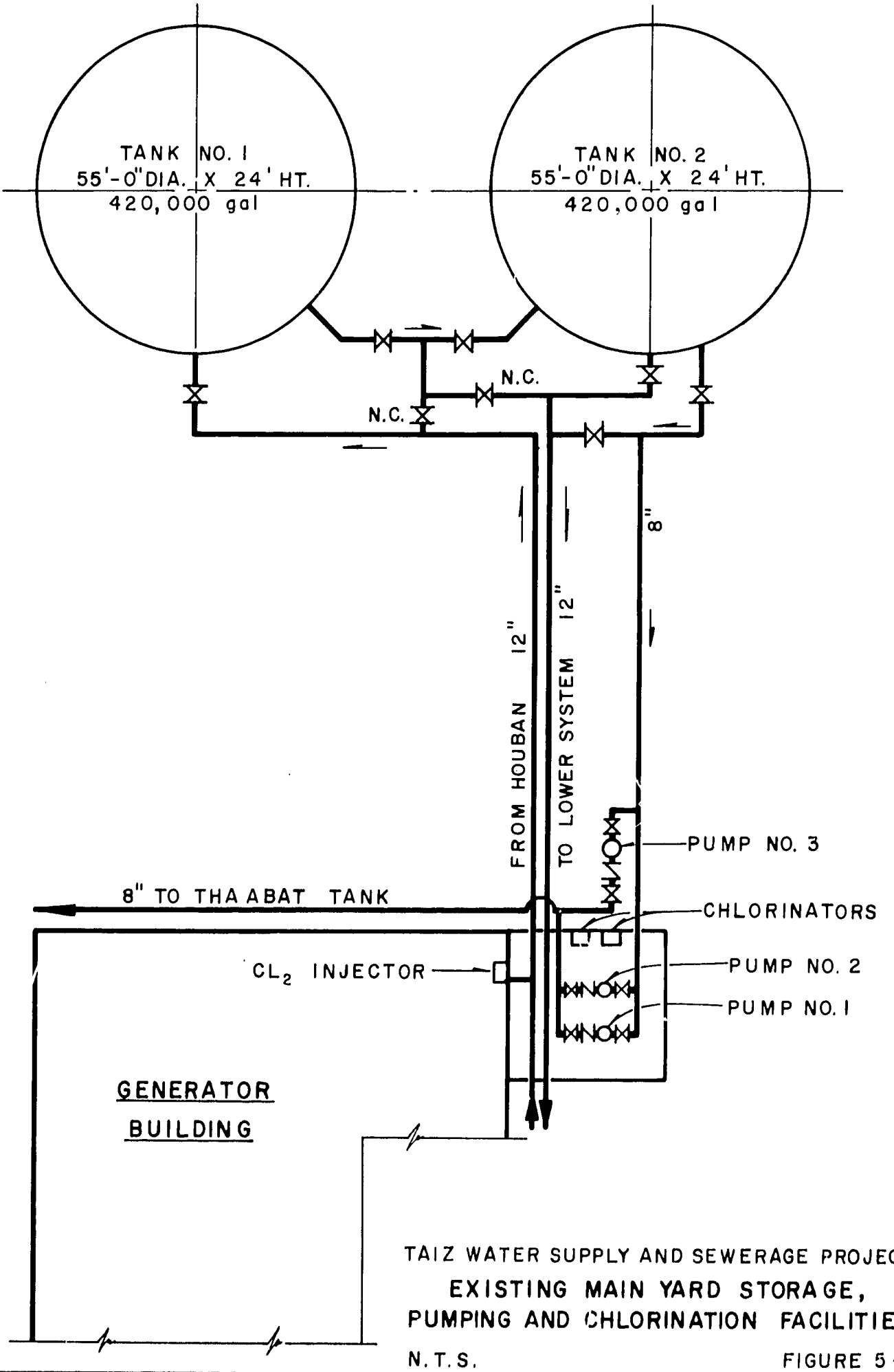

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

EXISTING MAIN YARD STORAGE, PUMPING AND CHLORINATION FACILITIES

N.T.S.

FIGURE 5-2

in the open position. As a result, an 8-inch valve at one location is left permanently closed, and all water service to the Medina area is supplied from another service zone. Besides cutting the water supply to the lower service area in half, this present condition results in a higher static pressure than originally designed, upstream of the closed valve. This was confirmed by field pressure readings of 10.2 kilograms per square centimeter (145 psi).

Due to the lack of any corrosion control in the system, all buried piping is deteriorating rapidly through external corrosion and internal deposits from the highly mineralized water. At present, leak repair crews are repairing between 30 to 45 leaks per week with the same type of material that failed. Since new steel pipe is anodic or sacrificial to old steel, the new pipe sections "cut in" will undoubtedly fail at an accelerated rate in a few years. Brass valves directly connected to the steel pipe are causing pin-hole leaks due to dissimilar metals and internal deposits are breaking off and plugging meter screens continually.

More seriously, it has been reported that sewage cesspools have been constructed around existing water mains in at least 48 locations in the city. Cases have occurred where fecal matter has been found on meter screens that was siphoned through water pipe leaks within the cesspools when the water was routinely turned off.

The existing distribution system is presently in a critical condition from an operational and public health concern.

SERVICES AND CUSTOMER METERS

There are presently over 8500 services and meters in the system, and approximately 30 new connections were being added each month until a recent moratorium on new services. No accurate account of services by meter size exists, but except for a very small number of larger meters for military, hospitals and some commercial establishments, the services are basically all 5/8 inch and 1/2 inch diameters. The first 6000 meters installed were Badger 5/8" x 3/4" Model SMD and the remaining are Kent 1/2" Model PSM. The Badger meters are installed in Ford cast iron meter boxes with locking lids and the Kent Meters are wall-mounted in exposed locations.

A well-equipped meter shop exists at the Main Yard. No routine meter maintenance is done, but meters reported "stuck" are returned to the shop for repairs. The prevalent failure of the meters has been in the registers and breakage of the Badger nutating disc or the Kent piston guide. The failures are probably due to excessive meter speed when air and water pass through the meter each day when the water is turned back on. The shop has a very low supply of spare parts and is currently manufacturing its own replacement discs for the Badger meters.

The same corrosion problems of the distribution system affect the buried portions of the service lines.

FIRE HYDRANTS

There are no fire hydrants in the system, and the present fire department for the city consists of a single old fire engine located in the Medina. Due to the non-combustible construction of rock or masonry structures in the city, the condition is considered adequate by local officials. The fire engine carries its own water tank which is refilled at a tank truck fill-station at the Main Yard.

WATER QUALITY

CHEMICAL QUALITY

A relative comparison of selected chemical quality characteristics or substances found in KMWS water for the years 1964, 1967 and 1974 is shown in Table 5-1.

It is obvious from comparing the data that the chemical water quality of the KMWS is deteriorating rapidly. The current nitrate concentration of 170 mg/l is almost four times the recommended limit of 45 mg/l set by the WHO International Drinking Water Standards, 1971.

The present poor water quality of the KMWS is due to its well supplies being located downstream of the City of Taiz in the same watershed. All wastewater from the city is percolating into the shallow aquifer that supplies the wells and has increased the chemical concentrations to unacceptable levels.

TABLE 5-1

COMPARISON OF
CHEMICAL QUALITY - HISTORICAL AND PRESENT

Characteristic or Substance[a]	Year of Test 1964	1967	1974
pH	7.2	7.3	7.2
Alkalinity (as bicarbonate only)	252	440	350
Hardness	378	353	750
Total Solids	1049	1400	2150
Nitrate	-	-	170
Ammonia	0.09	0.15	-
Sulfate	284	290	441
Magnesium	42	56	67
Chloride	235	246	445

Note: [a] All analytic data are in mg/l

BACTERIOLOGICAL QUALITY

Results of coliform tests for bacteriological quality of the water supplied by KMWS are shown in Table 5-2. Test records prior to October, 1973 are not available.

The monthly average value for 10 months is 34 percent positive, which indicates an extremely poor quality water. Spot sampling of the well discharges resulted in negative coliform bacteria. This reveals that the cause of the poor bacteriological water quality record is due to the unsanitary condition of the system and not of the source of supply.

TABLE 5-2

BACTERIOLOGICAL TEST RESULTS

Month	Total Number of Tests	Tests Positive	Percent Positive
August, 1974	10	4	40
July	27	5	10
June	16	7	44
May	27	8	30
April	16	5	31
March	26	11	42
February	10	1	10
January	22	7	32
December, 1973	13	9	69
November	0	-	-
October	6	2	33
TOTAL	173	59	Avg. 34%

CHAPTER 6

CHAPTER 6

POPULATION PROJECTIONS

GENERAL

A census has never been taken in the YAR. However, estimates based on tax collection records put the population of the YAR in 1971 at 5.9 million with an annual growth rate established at 2.2 percent.[a]

In 1962 the population of Taiz was estimated at 20,000[b], however, due to the war in Yemen (1962-1967) and later the influx of immigrants from the neighboring People's Democratic Republic of Yemen (starting in 1969) the city expanded rapidly. Popular estimates of the present population of Taiz vary from 80,000 to 150,000.

RANDOM SAMPLE SURVEY

For the purposes of this report a more accurate population estimate had to be developed. To accomplish this, a random sample survey was conducted in the city. The city was divided into representative areas based on apparent population densities and land usage as shown on Figure 6-1. Demographic data was then collected from selected areas on the random sample basis. Results of this survey are shown on Table 6-1. The total number of buildings within the city were then counted from aerial photographs taken of Taiz in 1973 by the British Royal Air Force. Private residences and apartment buildings numbered 7,460 and commercial shops numbered 630. From this random sample survey, the population of Taiz was estimated to be 84,800 in 1973. This total includes a factor for students from outside Taiz who live within the city during the school year and other temporary or transient people. A detailed breakdown of the derivation of the population is contained in Table 6-2, in addition to a detailed distribution of the types of water service supplied, KMWS, mountain spring, or none by number of families, total population.

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[a]IBRD Economic Report on Yemen Arab Republic (1971).

[b]USAID Estimate for Taiz Water Supply Design (1963-64).

TABLE 6-1

RANDOM SAMPLE SURVEY OF TAIZ, JUNE 1974

Items	Areas III	V	VI	IX	XI	Totals
No. Bldgs	50	38	36	24	36	182
No. Dwelling Units	62	62	47	34	42	247
No. Families	65	66	55	37	44	267
No. People	487	409	400	270	341	1,907
Avg Persons/Bldg	9.74	10.76	11.11	11.25	9.47	10.48
Avg Persons/ Dwelling Unit	7.85	6.60	8.51	7.94	8.12	7.72
Avg. Persons/ Family	7.49	6.20	7.27	7.30	7.58	7.20

An analysis of the age structure of the surveyed population shows that 56 percent of the population is in the age group between 0-16 years, and 44 percent are 17 years and older. Table 6-3, which shows the breakdown of the population by age group and sex, also indicates that the female population and male population are divided approximately 50-50.

TABLE 6-3

POPULATION BY AGE GROUP AND SEX
(Random Sample Survey)

Age Group	Population Male	Female	Total	Percent of Age Group To Total Male	Female	Total
0 - 8 years	397	367	764	42	38	40
9 - 16 years	167	150	317	17	16	17
17 years and over	387	439	826	41	46	43
Totals	951	956	1,907	100	100	100

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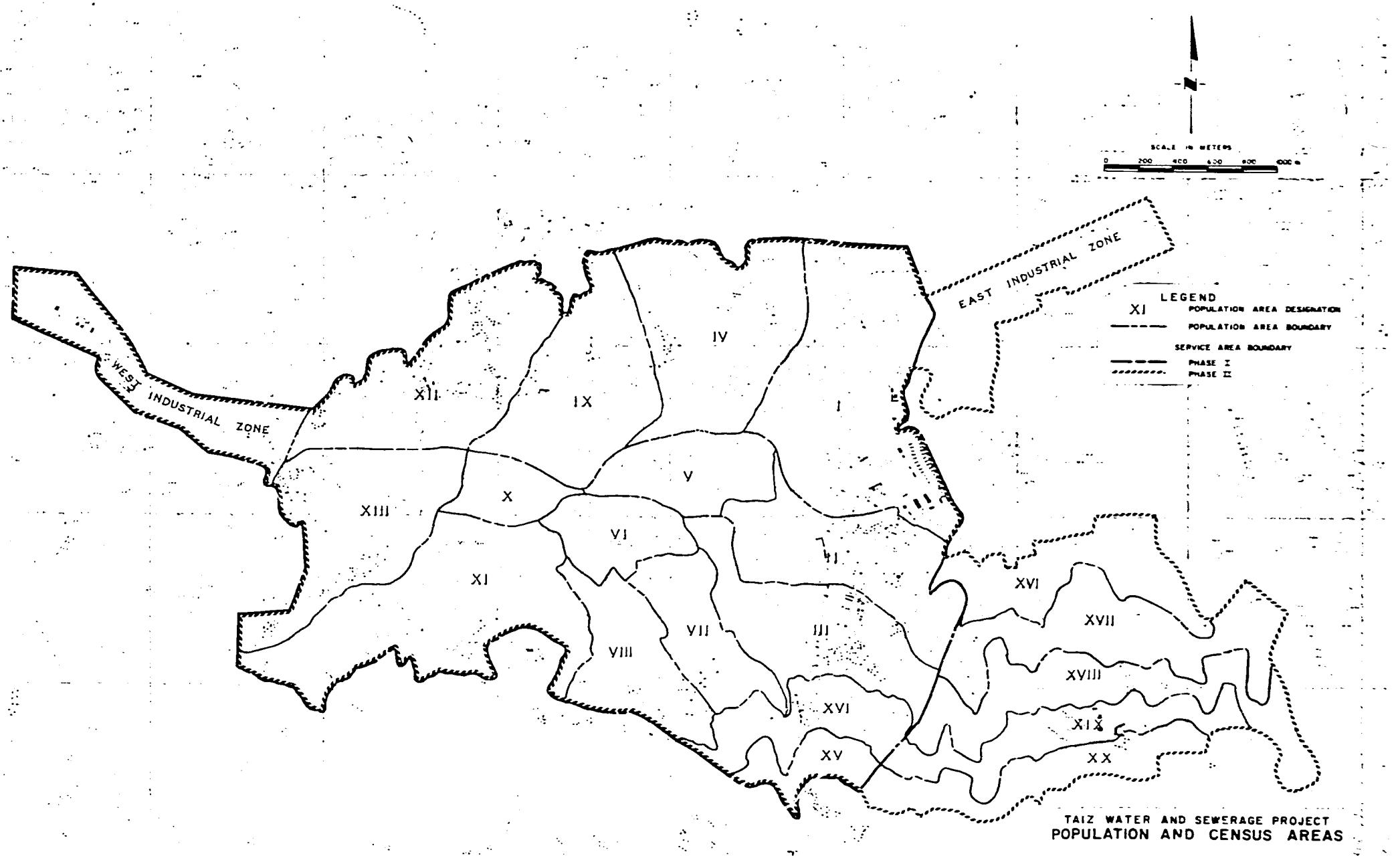


TAIZ WATER AND SEWERAGE PROJECT
POPULATION AND CENSUS AREAS

TABLE 6-2

1973 POPULATION AND WATER SERVICE ESTIMATE

Description	Census Area Statistics													Totals	Notes
Population and Census Area	1	2	3	4	5	6	7	8	9	10	11	12	13		
Most Equivalent Area	9	5	3	9	5	6	5	3	9	6	11	9	6 & 11		
No. of Houses and Apartment Buildings	370	580	675	285	640	710	300	425	410	410	1425	380	850	7460	Aerial Count
No. of Shops	20	20	15	30	45	90	0	0	40	130	220	8	20	628	Aerial Count
No. of Buildings	390	600	690	315	685	800	300	425	440	540	1645	388	870	8088	Aerial Count
No. of Persons per House and Apt. Building	11.25	10.76	9.55	11.25	10.76	11.11	9.55	9.55	11.25	11.11	9.22	11.25	10.16	-	From Census Survey
Estimated Population, 1973	4160	6240	6450	3210	6890	7890	2870	4060	4610	4560	13140	4280	8640	77000	
Number of Persons per Family	7.30	6.20	7.39	7.30	6.20	7.27	7.49	7.49	7.30	7.27	7.58	7.30	7.42	-	From Census Survey
Number of Families	570	1007	861	439	1111	1085	382	542	632	626	1734	586	1165	10740	
Estimated Population Living in Commercial Shops	80	80	60	120	180	360	0	0	120	520	870	30	80	2500	
Estimated Student and Transient Population	290	140	150	220	470	530	200	280	320	320	900	300	580	5300	
Total Estimated Population														84800	
Percent of Dwelling Units per Building (Houses & Apts.)	1.42	1.63	1.21	1.42	1.63	1.30	1.21	1.21	1.42	1.30	1.14	1.42	1.22	-	From Census Survey
Estimated No. of Dwelling Units	525	918	817	405	1043	923	373	514	592	533	1624	540	1037	9851	
Percent of Dwelling Units w/ EMWS Service	100.0	98.1	58.1	100.0	98.1	78.7	58.1	58.1	100.0	78.7	52.4	100.0	65.5	-	From Census Survey
Estimated Number of Dwelling Units w/EMWS Service	525	900	475	405	1026	726	210	299	582	419	851	540	680	7668	
Percent of Families w/Spring Water Only	0	1.5	40.0	0	1.5	5.4	40.0	40.0	0	5.4	43.2	0	24.3	-	From Census Survey
Estimated No. of Families w/Spring Water Only	0	15	344	0	17	59	153	217	0	34	749	0	283	1871	
Estimated Population w/ Spring Water Only	0	93	2576	0	105	429	1146	1625	0	247	5677	0	2100	13998	
Percent of Families w/no Water Service	1.1	9.0	9.2	5.4	9.0	18.2	9.2	9.2	5.4	18.2	9.1	5.4	13.6	-	From Census Survey
Estimated No. of Families w/no Water Service	31	91	79	237	100	197	35	50	31	114	158	32	158	1316	
Estimated Population w/no Water Service	226	562	593	1710	620	1446	263	373	256	832	1195	231	1175	9492	
Percent of Families w/EMWS Water Service	94.6	89.1	50.7	94.6	89.1	76.4	50.7	50.7	94.6	76.4	47.7	94.6	62.0	-	From Census Survey
Estimated No. of Families w/EMWS Service	539	900	436	415	993	829	191	275	598	478	827	554	722	7760	
Estimated Population w/ EMWS Service	3934	5562	3270	3032	6158	6026	1451	2088	4361	3477	6266	4047	5355	55022	

Average Family Size = 77000 ÷ 10740 = 7.2
Average Number of Persons per Building = 84000 ÷ 8088 = 10.4
Average No. of people per dwelling unit = 7.8

Note: The population demographics and water source data for survey area 13 are considered to be more closely related to an average of areas 6 and 11, rather than any single test area.

BUILDING CONSTRUCTION

The growth rate of the construction of new buildings within a community is frequently of value in estimating population growth trends. Recent records of building construction, taken from permits issued by the municipality of Taiz, are listed in Table 6-4.

TABLE 6-4

BUILDING CONSTRUCTION IN TAIZ

Year	No. Licenses	Area (sq m)	Estimated No. Buildings	Percent Growth
1974	-	-	-	6.0[a]
1973	398	62,756	8,088[b]	5.42
1972	347	61,478	7,690	4.94
1971	319	53,961	7,343	4.68
1970	209	29,235	7,024	3.17
1969	233	28,900	6,815	3.67
1968	239	33,873	6,582	4.05
1967	437	3,018	6,343	8.00
1966	-	-	5,469	-
1965	-	-	-	-
1964	-	-	-	-
1963	-	-	-	-
1962	-	-	2,200[a]	-

[a] Approximate

[b] Based on Building Count from Aerial Photos - 1973. This includes all dwellings and commercial shops.

POPULATION PROJECTIONS

Demographic studies[a] estimate the population of Sana'a at 78,000 with an average growth rate of 6.6 percent (3.35 percent due to natural increase and 3.25 percent to influx of migrants), and Hodeida's population at 46,000, with an average growth rate of 5.9 percent (3.55 percent due to natural increase and 2.35 percent to migrants).

Based on the studies conducted for Sana'a and Hodeida, the only other large cities in the YAR, and a comparison with the building construction growth rate in Taiz, the growth rate of Taiz was estimated to be 6 percent annually. Future population projections based on this growth rate are shown in Table 6-5.

TABLE 6-5

POPULATION PROJECTIONS FOR TAIZ
(Years 1973-1995)
6% Growth Rate

Year	Population	Year	Population
1973	84,800	1986	180,800
1974	89,900	1987	191,600
1975	95,300	1988	203,100
1976	101,000	1989	215,300
1977	107,100	1990	228,200
1978	113,500	1991	241,900
1979	120,300	1992	256,400
1980	127,500	1993	271,800
1981	135,100	1994	288,100
1982	143,200	1995	305,400
1983	151,800	-	-
1984	160,900	-	-
1985	170,600	-	-

[a] Part of the UNDP/WHO assisted studies for the proposed Sana'a water supply project, January 1973.

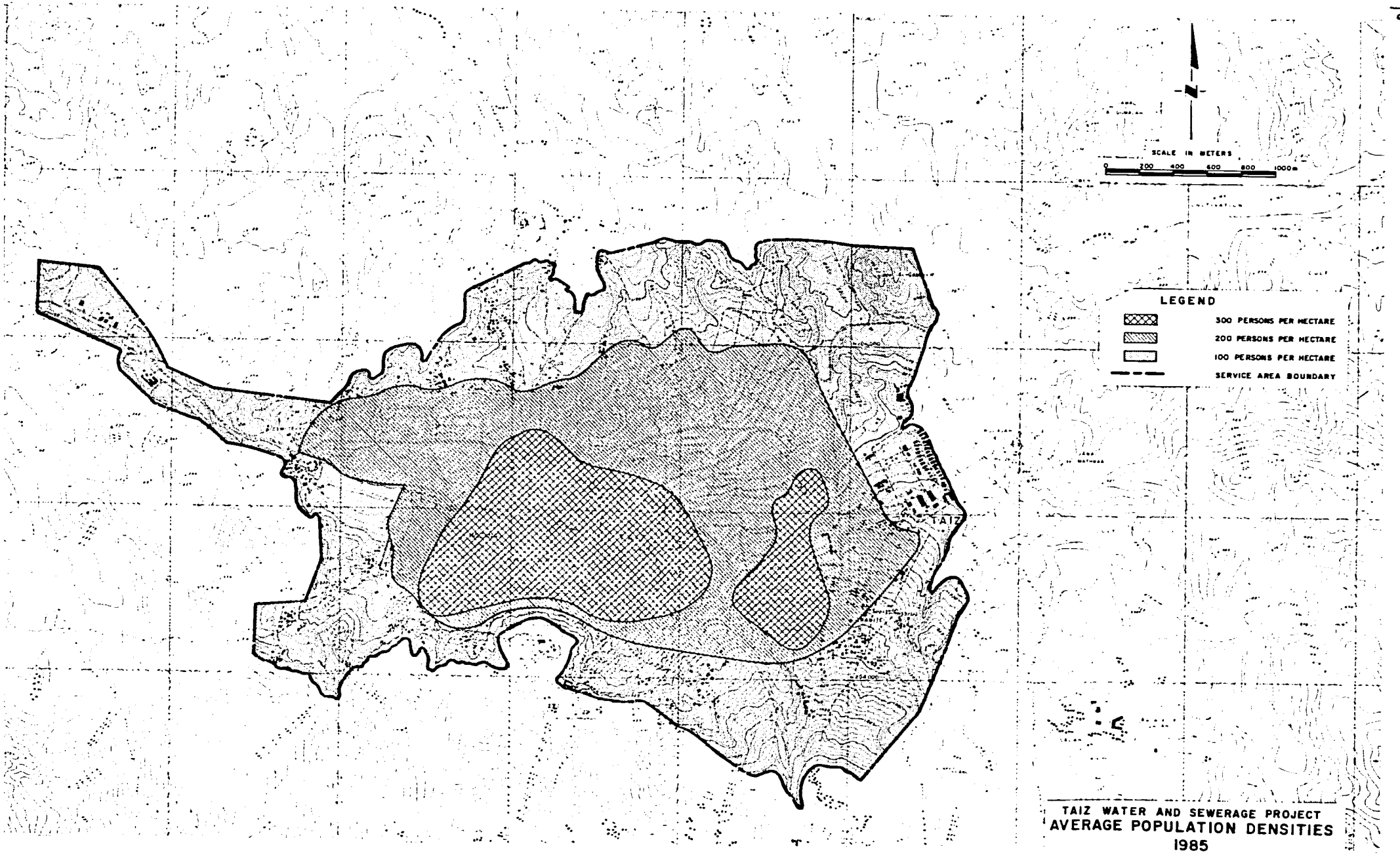
EXTENT OF WATER SERVICE AREA

The KMWS currently provides water service to an area of approximately 500 hectares (1,235 acres). Phase I and II improvements considered in this report for the years 1985and 1995 are planned so as to provide service to some 1,080 and 1,330 hectares, respectively. See Figures 8-10 through 13, Chapter 8. The planned service area is 166 percent larger than the present service area. The limits of the proposed service area were determined based on the projected population, land usage, and the areas that could be economically served. An area west of the city, along the highway to the old airport, together with an area east of the city, along the highway to the new airport, is planned for use as the industrial sectors of the city.

FUTURE POPULATION DENSITIES

Taiz does not have a city development plan or zoning regulations. It was therefore assumed that the maximum future density of any area would not be greater than the maximum density which has developed to date, which is approximately 300 persons per hectare (120 persons per acre) as determined by the random survey. It was also assumed that the present character of land use in Taiz would remain unchanged and continue to be primarily a residential and commercial community with the exception of the two industrial sectors mentioned above.

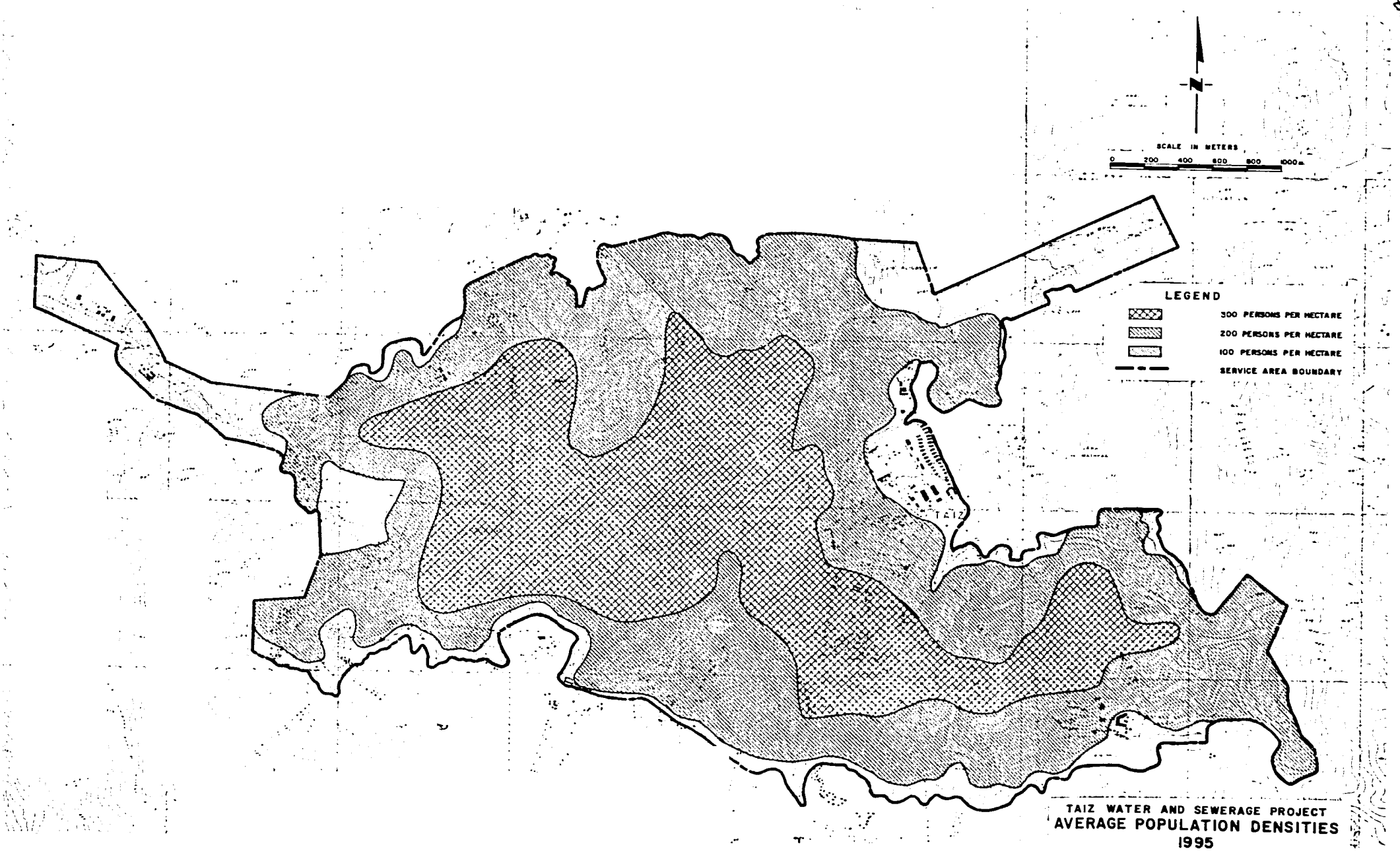
Using the projected population as a total, and considering maximum densities and making allowances in the case of wadis, population densities were made for all of the census areas and industrial zones. These are listed for the years 1985 and 1995 in Table 6-6 and graphically illustrated in Figures 6-2 and 6-3.



TAIZ WATER AND SEWERAGE PROJECT
AVERAGE POPULATION DENSITIES
1985

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.

FIGURE 6-2



TAIZ WATER AND SEWERAGE PROJECT
AVERAGE POPULATION DENSITIES
1995

JAMES M MONTGOMERY, CONSULTING ENGINEERS, INC

FIGURE 6-3

TABLE 6-6

STUDY AREA POPULATION DENSITIES
(Years 1985 and 1995)

Population Area No.	Area (ha)	Density (Pop/ha) 1985	Density (Pop/ha) 1995	Population 1985	Population 1995
I	67.7	175	250	11,800	16,900
II	58.1	200	250	11,600	14,500
III	81.0	150	225	12,100	18,200
IV	91.7	150	250	13,700	22,900
V	41.5	250	300	10,400	12,500
VI	30.7	300	300	9,200	9,200
VII	70.2	150	225	10,500	15,800
VIII	38.7	175	225	6,800	8,700
IX	74.9	150	275	11,200	20,600
X	20.4	300	300	6,100	6,100
XI	81.0	250	275	20,100	22,300
XII	99.6	150	275	14,900	27,400
XIII	117.4	150	250	17,600	29,400
XIV	37.0	80	200	6,800	7,400
XV	28.0	80	200	5,400	5,600
XVI	54.8	-	200	-	11,000
XVII	71.1	-	225	-	16,000
XVIII	65.7	-	225	-	14,800
XIX	48.2	-	200	-	9,700
XX	39.7	-	200	-	7,900
West Ind	50.0	50	80	2,500	4,000
East Ind	65.0	-	70	-	4,500
				170,700	305,400

CHAPTER 7

CHAPTER 7

FUTURE WATER DEMANDS

GENERAL

Numerous factors affect the future water demands of a municipality. Principal of these are the aerial extent of the water system's future service area, the nature of land use within that area, and population growth. Each of these factors was discussed in Chapter 6, Population Projections. Discussed in this chapter are present and projected per capita water use figures for various users, industrial estimates, leakage and unaccounted-for values and a summary of future water demands.

PRESENT WATER USAGE

CONSUMPTION

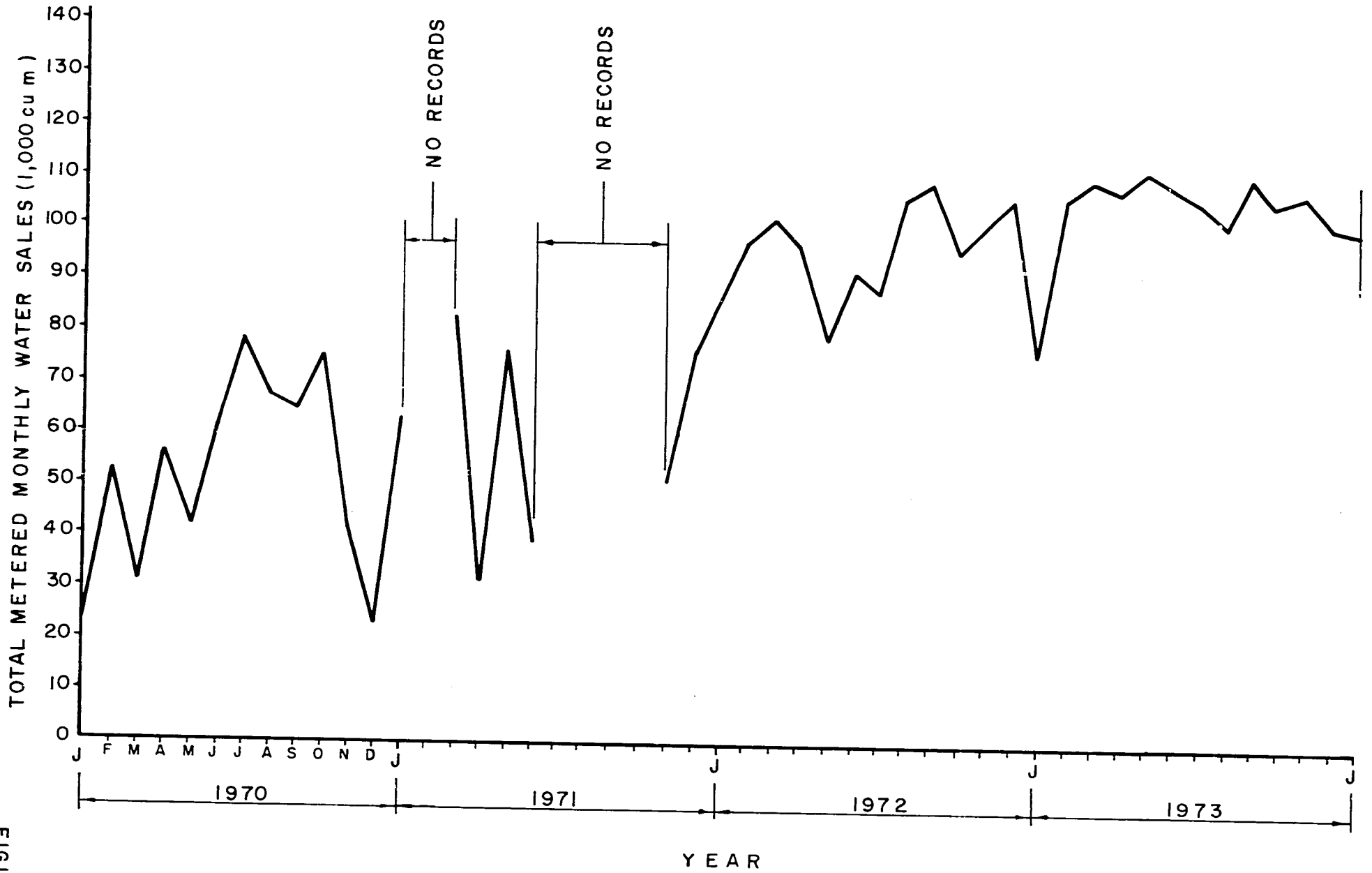
Although water production is not metered at the well sites, all service connections are metered. Total metered water sales for the city are presented in Figure 7-1 for the years 1970-73. Major non-domestic water users for 1973 are listed in Table 7-1. Domestic and non-domestic water demands for 1973 are presented in Figure 7-2.

LEAKAGE AND UNACCOUNTED-FOR WATER

As discussed in Chapter 5, Existing Water System, there is no metering of water produced from the existing wells or delivered to the main facilities located in the city. The only information that is available is the total metered sales. With this limited information no accurate estimate to determine the amount of water lost through leakage in the transmission and distribution system is possible. The intermittent supply of water throughout the distribution system also adds to the difficulty of determining the amount of leakage and unaccounted-for water. This is due to the higher than actual totals recorded by the meter caused by entrapped air when the water is first being supplied to an area of town previously turned off.

An attempt was made to estimate the amount of the unaccounted-for water. Tests, using orifice plates, were conducted on all of the production wells within the system, as well as a flow test at the Houban pump station with all wells being operated. This test agreed very closely with the summation of the tests on the individual production wells. Records had been maintained for 1973 and 1974 that showed the operation of the wells and pump station and a comparison was made using the test results and the annual recorded water sales. The test indicated a 21 percent difference between the quantity of water produced and water metered. Because of the intermittent service discussed above which causes all meters to register high, this test result is not considered to be accurate. Based on observations of the overall condition of the existing system and experience with unaccounted-for factors in systems of similar size and condition, a value of 30 percent was assumed to be a realistic estimate of current unaccounted-for water. In our projection of future demands, this value was gradually decreased to 20 percent to reflect the new proposed additions to the system and the repair of the existing distribution system through improved maintenance programs.

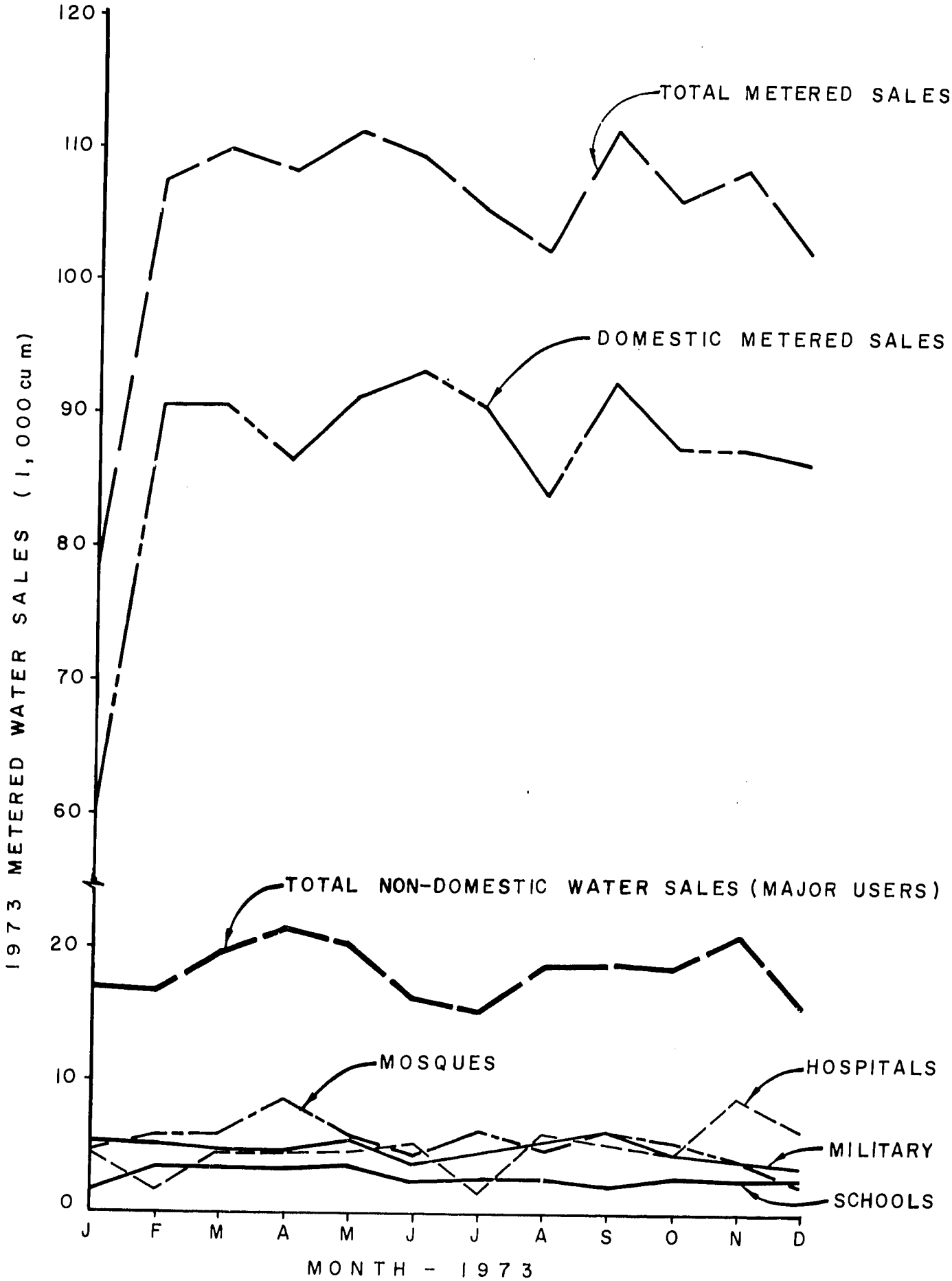
A 20 percent loss of water through leakage is considered a reasonable estimate for Taiz, after the system is expanded and rehabilitated, and personnel are trained in maintenance procedures. In systems of highly developed countries with highly trained personnel, ten percent leakage is considered reasonable. At the other end of the scale, the estimated 30 percent losses now being experienced are high for any system regardless of its location. Therefore, the projected 20 percent losses are reasonable.



HISTORICAL METERED WATER SALES – CITY OF TAIZ

FIGURE 7-1

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.



1973-METERED WATER SALES TO MAJOR CONSUMERS

FIGURE 7-2

TABLE 7-1

MAJOR NON-DOMESTIC WATER USERS

(Metered Sales for the Year 1973)

Type	cu m/year		Notes
Institutional			
Mosques			
Private	20,443		5 Mosques
Government	44,490	64,933	12 Mosques
Hospitals & Clinics			
Republican	45,922		2 Meters, 304 Beds
Nasser	3,952		85 Beds
WHO	3,880		
Military	5,080	58,834	3 Meters, 200 Beds
Highway Authority		25,541	2 Meters
Schools		34,760	20 Schools
Military			
Tanks Camp	6,705		
Military Police	2,352		
Military Workshop	764		
Receiving Camp	2,581		
Military Center	7,550		
Sahmalia Police Sta	521		
Security Sta	567		
Internal Security, No. 1	857		
Internal Security, No. 2	84		
National Security	201		
Hod El-Ashraf Sta	80		
(Name Unknown)	937		
Central Security	6,341		
Asshamassi Police Sta	93		
Republican Palace	23,400		2 Meters
Prison	3,075		
Bab-Mose Police Sta	151		Incl. Passport Office
General Security	3,261	59,520	
YARG Offices		3,547	12 Offices

(continued on next page)

TABLE 7-1 (Continued)

Type	cu m/year		Notes
Embassies			
Russian	4,374		
Italian	1,099		
Chinese	534		
Iraq	1,065	7,072	
Commercial & Industrial			
Commercial			
Casino Complex			
Restaurant	2,247		
Swimming Pool	1,451	3,698	
Hotels			
Delux	4,807		
Akwah	4,770	9,577	
Shops, Cafes, etc.			600±
Industrial			
Soft Drink Producers			
Super	11,926		
Steem	2,371	14,297	
Total		281,779	

SERVICE CONNECTIONS

Records of the KMWS showed a total of 8,525 metered service connections in September, 1974. A listing of the annual number of service connections from May 1967, through September, 1974, recorded by KMWS, is contained in Table 7-2.

These records appear to agree very closely with the information developed in the random survey as summarized on Table 6-2. This table shows that in March of 1973 approximately 7,670 dwelling units were connected to the KMWS system. At that time the KMWS records showed approximately 7,640 meters in service of which a small percentage were non-domestic. As can be observed, the totals do not exactly equal each other but are sufficiently close to demonstrate the validity of the survey and that the estimates developed therefrom are adequate for the purposes of this report.

TABLE 7-2

SERVICE CONNECTIONS

Year	Total Cumulative Connections	Increase	Average Number Connections For Year
1967 (May)	3,900	-	-
1967 (Dec.)	5,023	1,123	4,460
1968 (Dec.)	5,375	352	5,200
1969 (Dec.)	5,571	196	5,475
1970 (Dec.)	5,989	418	5,780
1971 (Dec.)	6,835	256	6,410
1972 (Dec.)	7,479	644	7,160
1973 (Dec.)	8,135	656	7,810
1974 (Sept.)	8,525	390	-

MOUNTAIN SPRING SOURCE

The mountain springs currently supply about 400 cu m/d to residents within the city, most of who are located at the higher elevations and are too high in elevation to receive KMWS water. It is estimated that this is the sole source of water to approximately 1,870 families or 14,000 people, as well as an alternate source for approximately 340 dwellings that have both a KMWS and a mountain spring water supply. Assuming 90 percent of the spring supply is consumed by those services having it as a sole source, a per capita consumption of approximately 26 lpcd can be estimated.

Prior to 1965, when the KMWS system was constructed, the mountain springs were the sole source of water for the entire population of Taiz, which was estimated to be about 20,000 people. Not all families were connected to this source, which required a considerable outlay of money to purchase the pipe to go from the dwelling to the spring, a few large diameter distribution pipes were placed to serve more than one

customer. The service connection rate for spring water services is a flat rate of 50 Rials per month. It is therefore assumed that families having such service would not be of the low- or poor-income group.

This source, although not a major source in terms of quantity, will have a definite impact on the estimated number of new customers of the TWSA system. It is doubtful that many of the existing users of spring water will relinquish their existing service for TWSA. However, it is estimated that one-half of the spring water services will also obtain a TWSA service connection.

WATER REQUIREMENTS

GENERAL

The present demands for Taiz have been developed from metered water sales. These figures were adjusted to compensate for the existing inadequate supply of water needed to meet present demands. The unit demand figures were then applied to the total number of persons or connections for each classification to arrive at a realistic total water demand.

It is recommended that the demand figures be continually reviewed and adjusted based on future records of sales.

RESIDENTIAL CONSUMPTION

An examination of total metered water sales shown in Table 7-3 indicates an average consumption of 60 lpcd in 1973. The average daily domestic sales were 2775 cu m in 1973, which includes that amount distributed by the mosques. When distributed uniformly among the population, this equals an average daily consumption of 46 lpcd.

This average daily conumption as stated, only represents historic consumption by the users from an inefficient and overtaxed system. Numerous problems exist as stated in Chapter 5, Existing Water System, which include such things as intermittent service, entrapped air, limited supply, and numerous other problems. These problems, particularly the limited supply of water, create inconveniences to the user, who in an attempt to obtain enough water to serve his needs, will collect and use as much water as possible when the water is available. This applies to all users; consequently, there is essentially no difference in water use across the entire spectrum of water users, because the total quantity of water available does not meet the total demand of each individual user. Only when the demands of a class of user are met, is there a water use trend established as far as metered sales is concerned.

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TABLE 7-3

METERED WATER SALES FOR TAIZ
1970 - 1973

	1970	1971 (7 months)	1972	1973
Total Metered Sales (cu m)	616,975	421,971	1,175,000	1,323,968
Average cu m/day	1,690	2,010	3,219	3,627
Number Connections (avg/yr)	5,780	6,410	7,160	7,810
Pop served @ 7.8 persons/conn.	45,000	50,000	55,800	60,900
Approx. Population @ 6% growth	71,200	75,500	80,000	84,800
% Population Served	63.2	66.2	69.7	71.8
Average Consumption (lpcd)	38	40	58	60
Average Consumption/ Conn. (l)	292	314	445	442
Ratio $\frac{\text{Max. day}}{\text{Avg. day}}$	1.44	1.33	1.14	1.11

It has been projected that the percentage of population served by service connections will increase and also the per capita domestic usage will increase.

These projections are reflected in Table 7-4.

TABLE 7-4

PROJECTED DOMESTIC WATER DEMANDS

Year	Population	Pop Served %	Total Pop Served	Per Cap Req. lpcd	Net Demand cu m/d
1973	84,800				
1980	127,500	75	95,600	75	7,170
1985	170,600	80	136,500	80	10,920
1990	228,200	85	194,000	85	16,490
1995	305,400	90	274,900	90	24,740

RELIGIOUS INSTITUTIONS

It is customary for persons to attend a mosque up to five times daily at which time the hands, face and feet are washed. It is also customary that people living close to the mosques can obtain water free of charge for personal use.

It is proposed that metered public water faucets be installed at each mosque to serve those people who are unable to afford a water connection and have been receiving their water from the mosques. It is proposed that this service be paid for either directly by the respective mosque or by the municipality.

The estimated consumption by the mosques is based solely on use for religious purposes. In 1973, the average daily consumption was 180 cu m. Of this, only 30 cu m was estimated to have been used within the mosque for religious purposes. This estimate and the future demands for mosques are based on a direct relation to the population. In this case, it was estimated that half of the male population over nine years of age will attend a mosque five times a day and will use one-half a liter of water on each visit. A summary of these estimates is listed in Table 7-5.

TABLE 7-5

PROJECTED WATER DEMANDS
FOR RELIGIOUS INSTITUTIONS

Year	Total Demand cu m/d
1973	180[a]
1980	45
1985	60
1990	80
1995	110

[a]Actual volume delivered to mosques. This volume includes approximately 150 cu m/d made available to the public.

PUBLIC FAUCETS

As discussed above, approximately 150 cu m/d was carried off from mosques by families unable to pay for house connections in 1973. It is proposed to install 20 public faucets initially, including one at each mosque and later increase the total to 25. It is estimated that such public usage will amount to 190 cu m/d and remain fairly constant.

This estimate is based on the population that does not have service connections. As the population increases in future years, the number of families without service connections will decrease, resulting in a somewhat constant population that will receive their entire supply of water from these public taps. The demand is based on a very low per capita consumption of six liters per day. This takes into account the fact that all of this water is hand carried to the homes and that public sanitation facilities will be provided in the low-income areas, whereas private facilities would consume a considerably greater amount of water.

PUBLIC TOILETS

To provide proper sanitation facilities in residential areas of exceedingly low income, it is proposed to construct 15 public toilet facilities The cost of the water consumed will have to be absorbed by the municipality as a public service. This service to low- and poor-income families will make water, which in most cases would have been carried from public faucets, available to the population for domestic uses.

It is proposed that these public toilets be located to adequately serve approximately 400 people. Initially the overall usage will be below the design levels, but as the population reaches the estimated maximum densities, the usage by the surrounding population will reach or exceed the design levels of 400 per public toilet. The total estimated daily demands are listed in Table 7-6.

TABLE 7-6

PROJECTED WATER DEMANDS FOR PUBLIC TOILETS

Year	Number of Service Conn.	Unit Demand cu m/conn/d	Total Demand cu m/d
1980	15	5.5	75
1985	15	9	125
1990	15	9	125
1995	15	9	125

HOSPITALS

There are presently five hospitals and a leprosarium in Taiz with a total of 900 beds (1 bed per 95 residents). A new hospital is under construction by the Chinese. It will have approximately 500 beds and replace the old military hospital (200 beds).

Present consumption data for Nasser Hospital indicates a demand of 115 l/day/bed. This is very low by international standards, which range from 400 to 800 l/bed, and the future demand has been increased accordingly.

Projected demands are presented in Table 7-7.

TABLE 7-7

PROJECTED WATER DEMANDS FOR HOSPITALS

Year	Residents/Bed	Number of Beds	Unit Demand lpd/bed	Total Demand cu m/d
1980	85	1,500	300	450
1985	85	1,920	350	670
1990	80	2,500	400	1,000
1995	80	2,850	450	1,300

SCHOOLS

There were 20 schools with metered service connections in 1973. Information contained in Table 7-8 was supplied by the Taiz Department of Education which lists the distribution of the total school population.

Metered water sales for schools in 1973 averaged 130 cu m/d or approximately 5.5 liters/student/d.

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TABLE 7-8

STUDENT DISTRIBUTION BY AGE GROUPS

School	Age Group	No. Students 1973-1974	%	No. Students 1974-1975	%	% Total Pop 1973	1974
Elementary	7-12	19,000	79	20,000	74	22	22
Intermediate	13-15	3,000	13	4,500	17	4	5
Secondary	16-18	2,000	8	2,500	9	2	3
Total		24,000	100	27,000	100	28	30

The projection of demands, as presented in Table 7-9 were based on the above information reflecting a gradual increasing percentage of school-age children attending schools in later years of the study period.

TABLE 7-9

PROJECTED WATER DEMAND FOR SCHOOLS

Year	% Total Pop in School	Number of Students	Unit Demand lpcd	Total Demand cu m/d
1980	33	42,100	8	335
1985	35	59,700	10	595
1990	36	82,200	12	985
1995	37	113,000	14	1,580

MILITARY INSTALLATIONS

In 1973 there were 19 metered service connections to military installations. The future water demands were projected on the basis of metered water sales records and are presented in Table 7-10. The projected demands reflect the estimated increases in the number of military personnel and water consumption. Total consumption has been increased from 160 cu m per day in 1973 or about 8.5 cu m per connection per day to those listed in Table 7-9.

TABLE 7-10

PROJECTED WATER DEMANDS
FOR MILITARY INSTALLATIONS

Year	Number of Serv. Conn.	Unit Demand cu m/conn /d	Total Demand cu m/d
1980	19	13.7	260
1985	20	18.0	360
1990	21	22.4	470
1995	21	25.5	535

GOVERNMENT OFFICES AND EMBASSIES

There were 5 metered service connections to governmental offices and foreign embassies in 1973. An examination of water sales records indicated an average demand of 5.8 cu m/conn. /d.

Based on this data, the future demands have been projected as presented in Table 7-11.

TABLE 7-11

PROJECTED WATER DEMANDS FOR
GOVERNMENT OFFICES AND EMBASSIES

Year	Number of Serv. Conn.	Unit Demand cu m/conn /d	Total Demand cu m/d
1980	8	6.2	50
1985	10	6.5	65
1990	12	6.6	80
1995	14	6.8	95

HOTELS

Data for hotels in 1973 are summarized as follows:

TABLE 7-12

HOTEL DISTRIBUTION BY CLASS

Items	1st Class	2nd Class	Total
No. of Beds	150	151	301
No. of Rooms	80	76	156
No. of Hotels	1	3	4

Average demand per connection based on available records is 13 cu m/d. Future requirements were projected as presented in Table 7-13.

TABLE 7-13

PROJECTED WATER DEMANDS FOR HOTELS

Year	Number of Serv. Conn.	Unit Demand cu m/conn./d	Total Demand cu m/d
1980	7	18.6	130
1985	9	18.9	170
1990	12	21.7	260
1995	14	27.1	380

SMALL COMMERCIAL AND MANUFACTURING ESTABLISHMENTS

Based on the data collected during the random sample survey of Taiz, the number of cafes, shops and small businesses is estimated as follows:

Number of Small Establishments = Approximately 600

Percent Connected = 70%

It is estimated that the number of service connections of small commercial and manufacturing establishments will increase at approximately 7 percent per annum. This rate of increase is reasonable when considering the population growth rate and the anticipated influx of small industry. Water demand for commercial consumption is estimated to increase at the rate of 4.5 percent per annum per connection. This is estimated to be adequate to meet the needs of increased water usage required for improved sanitary standards and the greater water demands for modernized light industry. A summary of these demands is contained in Table 7-14.

TABLE 7-14

PROJECTED WATER DEMANDS FOR
SMALL COMMERCIAL AND INDUSTRIAL ESTABLISHMENTS

Year	Number of Connections	Unit Demand cu m/conn./d	Total Demand cu m/d
1980	700	.31	220
1985	1,000	.37	375
1990	1,400	.49	680
1995	1,600	.58	925

LARGE COMMERCIAL AND MANUFACTURING ESTABLISHMENTS

There are only two industrial users of water at present; these produce soft drinks. One uses 33 cu m/d and the other 7 cu m/d.

Prospects for future large commercial and manufacturing industries for the Taiz vicinity appear to be encouraging. Chapter 4, Socio-Economic and Environmental Aspects, discusses several plants now under construc- and one large plant now under consideration. In view of the adequate labor market, good transportation to Sana'a, Hodeida, and smaller cities, an allowance was made to provide an adequate water supply to meet the demands for the expected influx of industry.

Total water demands for such users were estimated to be 500 and 1600 cu m/d for the years 1985 and 1995, respectively.

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SUMMARY OF WATER DEMANDS

A summary of the water requirements by general classification of consumers is presented in Table 7-15 and Figure 7-3.

PRESSURE ZONES

The proposed water system of Taiz will be divided into seven pressure zones as described in Chapter 8-Recommended Water Supply Facilities. The total domestic and non-domestic average day water demand for each zone was determined using the projected population to be served, and the expected non-domestic demands. The determination of these demands for the years 1985 and 1995 and the respective production requirements are contained in Table 7-16.

DESIGN FLOW

Many of the projections relating to water consumption are based upon the average daily demand. That is, the demand for water for the average day of the year. This amount is proper for planning purposes.

The design of booster pumping stations, distribution pipelines and the operation of the water system, however, are based upon the maximum requirements for water. These maximum demand requirements are referred to as the maximum daily and peak hour demands. That is, the requirements during the day and hour of maximum demand for any year.

Numerous investigations have concluded that for other cities with populations and potential industries similar to that projected for the study area, it is economical and reasonable to base the design of the water facilities on the following:

- Maximum daily demand is equal to one hundred-fifty percent of the average daily demand.
- The peak hour demand is equal to one hundred-fifty percent of the maximum daily demand.

Design flows considered appropriate for the TWSA are listed in Table 7-17.

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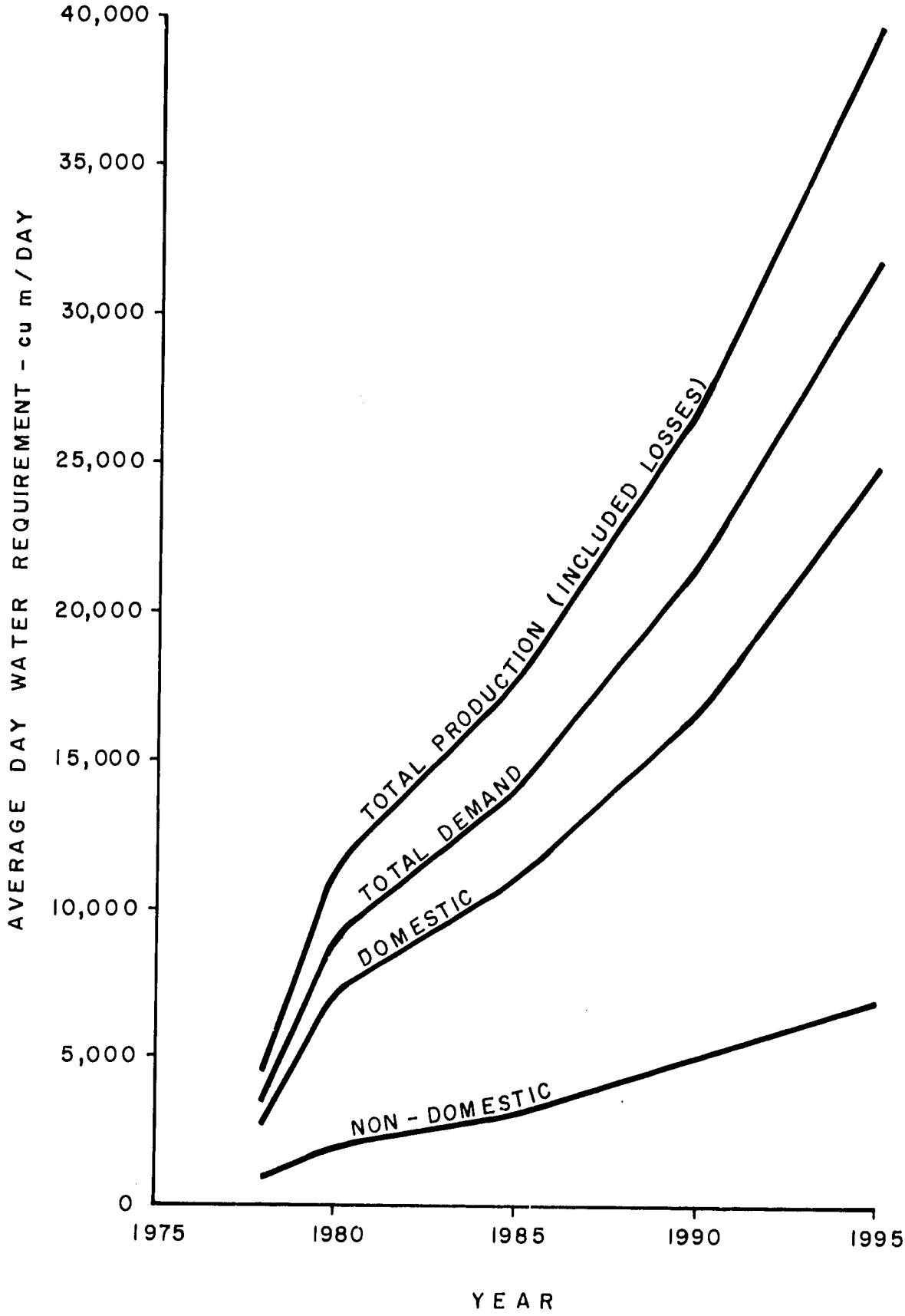

ESTIMATED FUTURE AVERAGE DAY WATER REQUIREMENTS

TABLE 7-15

SUMMARY OF WATER DEMANDS AVERAGE DAY IN CU M/DAY

Item	1973	1980	1985	1990	1995
Domestic	2,625	7,170	10,920	16,490	24,740
Religious Institutions	30	45	60	80	110
Public Faucets	150	190	205	190	185
Hospitals	160	450	670	1,000	1,300
Public Toilets	--	75	125	125	125
Schools	95	335	595	985	1,580
Military Installations	160	260	360	470	535
Gov't. Offices & Embassies	29	50	65	80	95
Hotels	52	130	170	260	380
Small Commercial & Mfg.	107	220	375	680	925
Large Commercial & Mfg.	45	225	500	1,000	1,600
Total Non-Domestic	828	1,980	3,125	4,870	6,835
Total Average Demand	3,453	9,150	14,045	21,360	31,575
Unaccounted-For Water	N.A.	2,290	3,510	5,340	7,890
Unaccounted-For Water (%)	N.A.	20	20	20	20
Production Required/Day	4,542	11,440	17,550	26,700	39,465
Population Served	60,140	95,600	136,500	194,000	274,900
Per Capita Demand (lpcd)	--	120	129	138	144
Per Capita Domestic Demand (lpcd)	--	75	80	85	90
Annual Production ($10^6 m^3$)	1.80	4.18	6.41	9.75	14.4

TABLE 7-16

FUTURE AVERAGE DAY DEMANDS BY PRESSURE ZONES (Years 1985 and 1995)

	Zone	Population	Percent Pop Served	Total Pop Served	Per Cap Req lpd	Net Dom Demand cu m/day	Net Non-Domestic Demand cu m/day	Total Net Demand cu m/day	Unaccounted-For Water Percent	Total Zone Production cu m/day
1985	I	28,400	80	22,700	80	1,820	275	2,095	20	2,620
	II	65,600	80	52,500	80	4,200	2,500	6,700	20	8,375
	III	35,800	80	28,600	80	2,290	200	2,490	20	3,110
	IV	25,500	80	20,400	80	1,630	100	1,730	20	2,160
	V	9,500	80	7,600	80	610	50	660	20	825
	VI	3,800	80	3,000	80	240	--	240	20	300
	VII	2,000	80	1,600	80	130	--	130	20	160
		170,600		136,400		10,920	3,125	14,045		17,550
1995	I	44,300	90	39,900	90	3,590	2,000	5,590	20	6,990
	II	93,000	90	83,700	90	7,530	3,600	11,130	20	13,910
	III	56,600	90	51,000	90	4,590	500	5,090	20	6,360
	IV	51,800	90	46,600	90	4,190	400	4,590	20	5,740
	V	29,000	90	26,100	90	2,350	235	2,585	20	3,230
	VI	17,100	90	15,400	90	1,390	50	1,440	20	1,800
	VII	13,600	90	12,200	90	1,100	50	1,150	20	1,440
		305,400		274,900		24,740	6,835	31,575		39,470

TABLE 7-17

FUTURE PEAK DEMANDS BY PRESSURE ZONES

Zone	Demands	Years 1985 (lps)	Years 1995 (lps)
I	Avg. Day	30.2	80.6
	Max Day[a]	45.3	120.9
	Peak Hr[b]	68.0	181.4
II	Avg. Day	96.8	160.7
	Max Day	145.2	241.0
	Peak Hr	217.8	361.6
III	Avg. Day	35.9	73.6
	Max Day	53.9	110.4
	Peak Hr	80.8	165.6
IV	Avg. Day	25.0	66.6
	Max Day	37.5	99.9
	Peak Hr	56.2	149.9
V	Avg. Day	9.7	37.2
	Max Day	14.5	55.8
	Peak Hr	21.8	83.7
VI	Avg. Day	3.5	21.0
	Max Day	5.2	31.5
	Peak Hr	7.9	47.3
VII	Avg. Day	1.8	16.7
	Max Day	2.7	25.0
	Peak Hr	4.1	37.6

[a]150% of Avg. Day Demand
[b]225% of Avg. Day Demand

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CHAPTER 8

CHAPTER 8

RECOMMENDED WATER SUPPLY FACILITIES

One of the primary objectives of this report is to recommend an effective and efficient water supply system that will provide suitable water to all potential users. Such a system is herein presented which incorporates the existing system wherever possible in addition to new expanded facilities.

The recommended facilities will restore the existing system's effectiveness and furnish increased capacity in three stages:

- Immediate improvements necessary to restore the system's serviceability and also to prolong the useful life of the existing facilities.

- Phase I system improvements necessary to provide adequate water service to the community for the short-term (1985) growth projections.

- Phase II system improvements required to furnish adequate water service to the service area for the long-term (1995) growth projections.

The immediate improvements include modifications and renovations to the entire system as it exists. The expansions and extensions included in Phase I and Phase II include only those improvements necessary to provide an adequate supply of water transmission and water storage.

BASIS OF DESIGN

The recommended water system is designed so as to continually provide satisfactory water service to all of the projected design populations. Delivered water will meet the recommended World Health Organization International Standards for Drinking Water, 1971.

Phase I improvements are designed for the system demands projected for the near-term growth pattern within the service area; and the Phase II improvements are designed for the projected long-term growth projections. The projected populations and demands for each phase are included in Chapters 6 and 7, respectively; while a summary of the basic design criteria used is included in Table 8-1.

TABLE 8-1

DESIGN CRITERIA FOR WATER SYSTEM COMPONENTS

Component	Design Criteria
Source of Supply	Maximum day flow[a]
Chlorination	Maximum day flow
Pumping Facilities	
Wells	Maximum day flow
Boosters	Maximum day flow[b]
Mains	
Transmission	Maximum day flow, C = 120[c]
Distribution	Peak hour flow[d], C = 120
Storage	33% Maximum day flow
System Pressure	
Static	Maximum, 65 m (93 psi)
Residual	Minimum, 14 m (20 psi)
Pressure-break Structures	Peak hour flow

[a]Equivalent to flow during day of maximum demand.
[b]Provide maximum day flow with largest unit out of service.
[c]Hazen-Williams "C" value.
[d]Equivalent to flow during peak hour demand.

Uppermost in importance in the completed water facility is service reliability, economic balance, together with providing a safe drinking water which is free of contamination. It is to this end that the design criteria for the several components of the completed facilities have been established.

SUPPLY WELLS

The water supply wells, with motors and appurtenances are designed to furnish maximum day demand for continuous service.

In order to guard against the overloading of pump motors, the motor sizes are determined by calculating the system characteristics based upon both new and old pipes.

The recommended water system includes a minimum of one well to function as a standby, which is to be utilized during periods when one of the duty units is out of service.

CHLORINATION

The chlorination equipment provided is capable of disinfecting the water supply. Included are chlorinators, cylinder scales, gauges, filters, valves and piping sufficient to deliver ten milligrams per liter of chlorine to the water supply during periods of peak demand, although most operating conditions necessitate chlorine demands of two milligrams per liter. The chlorinating facilities are located so that all water supplies are disinfected prior to delivery to any part of the distribution system.

BOOSTER PUMPING STATIONS

The capacities of the booster pumping stations are sufficient to provide the maximum day demands on a continuous basis. This will include sufficient capacity to completely fill the reservoirs served during the eight-hour late evening and early morning period while also supplying the system demands.

The stations include a minimum of two duty pumping units and one standby pumping unit. The standby unit is equal in capacity to the largest duty pump. The facility also includes water meters, surge protection devices, pressure gauges, check valves and isolating butterfly valves.

STORAGE RESERVOIRS

The reservoir storage capacity provided is sufficient to furnish the difference between the system demand and the maximum day supplied by the well field pumping system or booster pump station. The minimum reservoir capacity that is provided for each phase of the projected demands is one-third of the maximum daily system demand.

To provide maximum protection and reliability, the storage required for the second phase is provided in no less than two structures at each site. This enables the system to function even during those infrequent times when one reservoir must be removed from service.

Each reservoir installation is designed to be equipped with valves, inlet-outlet, and by-pass piping to enable one reservoir to be removed from service for normal maintenance. Automatic overflow piping is also included. The operation of each reservoir is by means of automatic altitude valves or by manual control.

FLOAT TANKS

The reduction of pressure between high and low service zones is accomplished by means of float tanks. Each float tank is designed to accommodate the projected peak hour flow and is located at elevations which ensure proper service pressures. Each tank includes a float operated butterfly valve, isolation valves, inlet and discharge piping, overflow piping and is covered. Provisions are included to accommodate emergency chlorination at each float tank using portable chlorinating facilities.

Each float tank installation includes security fencing, double protective screens at all openings, above ground construction and other provisions necessary to protect the water system from contamination.

WATER MAINS

The numerous factors that are considered in the selection of the water main sizes and proposed locations include:

- Construction cost
- Long-term power costs
- Short- and long-term flow requirements

- Corrosion-inducing properties of water supply
- Total dynamic pumping heads
- Existing main sizes
- Condition of existing water mains
- Cost of financing
- Projected maintenance costs
- Available local materials
- Service zone pressure

Each of these items has influenced the tentative pipe sizes selected for the recommended system. In order that all factors are properly considered, a computer program has been employed that ensures that the recommended system includes a proper balance between reliability, economy and flexibility. Included as Table 8-2 is a sample showing one of a score of the prints produced as a part of the study. The sample is the last computer run for service pressure Zones I & II.

TABLE 8-2

COMPUTER PRINT-OUT FOR ZONES I & II

Flow Rates are Expressed in Cubic Meters Per Second and Pressures in Kilonewtons Per Square Meter

TAIZ WATER SUPPLY SYSTEM
ZONES 1 AND 2
PEAK FLOW

FLOWRATES ARE EXPRESSED IN CUBIC METERS PER SECOND AND PRESSURES IN KILONEWTONS PER SQUARE METER

PIPE NUMBER	LENGTH (METERS)	DIAMETER (METERS)	ROUGHNESS	MINOR LOSS	PUMP CHARACTERISTICS				CONNECTING NODES	
1	250.00	0.4000	120.00	0.00	0.00	0.00	0.00		0	1
2	500.00	0.3000	120.00	0.00	0.00	0.00	0.00		1	2
3	650.00	0.3000	120.00	0.00	0.00	0.00	0.00		2	3
4	850.00	0.4000	120.00	0.00	0.00	0.00	0.00		1	4
5	600.00	0.2500	120.00	0.00	0.00	0.00	0.00		4	5
6	400.00	0.2500	120.00	0.00	0.00	0.00	0.00		5	6
7	600.00	0.4000	120.00	0.00	0.00	0.00	0.00		6	7
8	400.00	0.2000	120.00	0.00	0.00	0.00	0.00		7	8
9	800.00	0.1500	120.00	0.00	0.00	0.00	0.00		8	9
10	750.00	0.3000	120.00	0.00	0.00	0.00	0.00		9	10
11	900.00	0.4000	120.00	0.00	0.00	0.00	0.00		7	12
12	650.00	0.4000	120.00	0.00	0.00	0.00	0.00		8	12
13	280.00	0.3500	120.00	0.00	0.00	0.00	0.00		10	12
14	2100.00	0.3500	120.00	0.00	0.00	0.00	0.00		10	11
15	100.00	0.0100	120.00	0.00	0.00	0.00	0.00		6	8

JUNCTION NUMBER	FLOWRATE	PIPE NUMBERS			ELEVATION	PATH FROM PREVIOUS JUNCTION		
1	0.000	-1	2	4	1185.000	1		
2	0.070	-2	3		1185.000	2		
3	-0.111	-3			1235.000	3		
4	0.070	-4	5	7	1185.000	-3	-2	4
5	0.000	-5	6		1235.000	5		
6	0.050	-6	15		1235.000	6		
7	0.129	-7	8	11	1185.000	-6	-5	7
8	0.065	-8	9	-15	1235.000	8		
9	0.065	-9	10		1235.000	9		
10	0.068	-10	13	14	1185.000	10		
11	-0.107	-14			1185.000	14		
12	0.000	-11	-12	-13	1185.000	-14	13	

LOOP NUMBER	PIPE NUMBERS				
1	-8	11	-13	-10	-9
2	-6	-5	7	8	-15

PATH NUMBER	ENERGY DIFFERENCE	PIPE NUMBERS				
1	0.000	1	4	7	11	-12

TRIAL NUMBER	FLOW CORRECTION
10	0.000
20	0.000
30	0.000
40	0.000
50	0.000
60	0.000
70	0.000
80	0.000
90	0.000

TABLE 8-2 (Continued)

100	0.000

THESE ARE THE RESULTS FOR TRIAL NUMBER 100

PIPE NUMBER	FLOWRATE	HEAD LOSS	PUMP HEAD	MINOR LOSS	VELOCITY	HL/1000	PCT. CHNG.
1	0.134	0.800	0.000	0.000	1.073	3.200	0.0000
2	-0.040	-0.704	-0.000	0.000	-0.575	-1.408	0.0000
3	-0.111	-5.896	-0.000	0.000	-1.572	-9.072	0.0000
4	0.175	4.430	0.000	0.000	1.397	5.212	0.0000
5	0.050	3.077	0.000	0.000	1.030	5.129	0.0000
6	0.050	2.051	0.000	0.000	1.030	5.129	0.0000
7	0.054	0.358	0.000	0.000	0.433	0.597	0.0000
8	0.050	6.134	0.000	0.000	1.617	15.336	0.0000
9	-0.014	-4.816	-0.000	0.000	-0.814	-6.020	-0.0000
10	-0.079	-3.668	-0.000	0.000	-1.126	-4.890	-0.0000
11	-0.125	-2.532	-0.000	0.000	-1.001	-2.813	-0.0000
12	0.166	3.056	0.000	0.000	1.321	4.702	0.0000
13	-0.040	-0.182	-0.000	0.000	-0.417	-0.651	-0.0000
14	-0.107	-8.482	-0.000	0.000	-1.119	-4.039	0.0000
15	0.000	1.363	0.000	0.000	0.230	13.630	0.0000

JUNCTION NUMBER	ELEVATION	PRESSURE	GRADE LINE
1	1185.000	649.200	1251.199
2	1185.000	656.105	1251.904
3	1235.000	223.598	1257.800
4	1185.000	605.745	1246.768
5	1235.000	85.224	1243.690
6	1235.000	65.101	1241.638
7	1185.000	602.226	1246.409
8	1235.000	51.731	1240.275
9	1235.000	98.964	1245.091
10	1185.000	625.270	1248.759
11	1185.000	708.455	1257.242
12	1185.000	627.056	1248.941

THE AVERAGE (ABSOLUTE) CHANGE IN FLOWRATE FROM THE PREVIOUS TRIAL = 0.00000

PROPOSED WATER SYSTEM

The hydrogeology of the various water basins is discussed in detail within Volume II of this report. A summary of that data, however, as related to the yield from each well field, is included here for convenience.

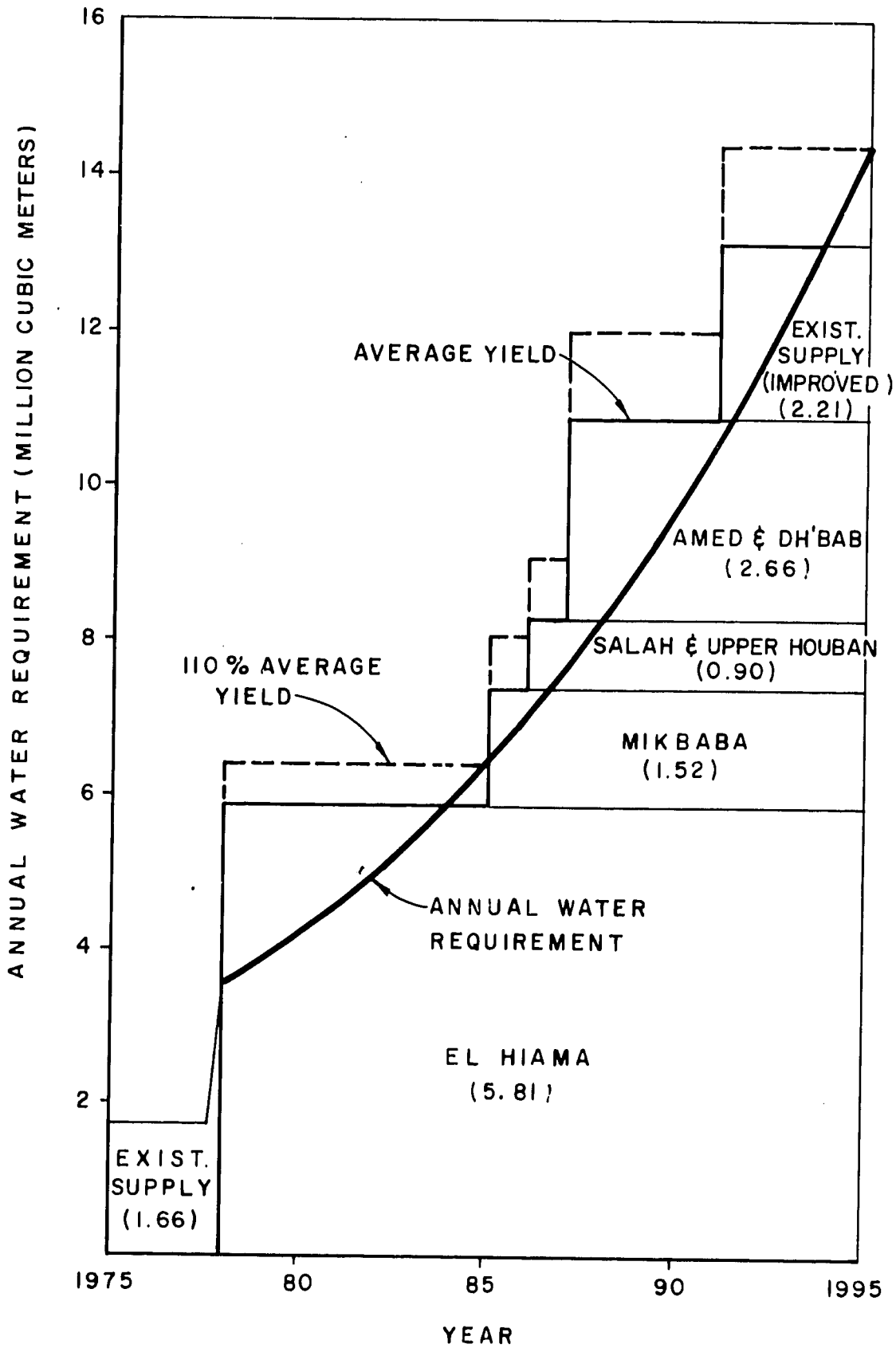
WATER SUPPLY

The water supply for the study area is to be furnished from the various fields in the estimated quantities included in Table 8-3, titled Well Field Design Flows. A graphic presentation of the annual water requirements and source of supply, together with the projected time when the water from each field would be required is shown in Figure 8-1. As shown on Figure 8-1, producing wells in the El Hiama Basin are required as a part of Phase I construction. Subsequently, the balance of the fields will be developed as required, starting with the Mikbaba basin, which is projected to be required in 1985. The existing well fields in Hougala and Houban basins will be refurbished and placed back in domestic service in approximately 1991.

TABLE 8-3

WELL FIELD DESIGN FLOW

Phase	Water Basin	Annual Yield (million cubic meters)	Peak Design Flow (lps)	Peak Design Flow (mgd)
I				
	El Hiama	5.81	276.35	6.30
II				
	Mikbaba	1.52	72.30	1.65
	Wadi Salah - Upper Wadi Houban	0.90	42.81	0.98
	Wadi Amed - Dh'bab	2.66	126.52	2.89
	Houban-Hougala	2.21	105.12	2.40
	Totals	13.10	623.10	14.22



ANNUAL WATER REQUIREMENT AND SOURCE OF SUPPLY

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.

FIGURE 8-1

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The quantities designated in Table 8-3 as the peak design flows are equal to one hundred fifty percent of the safe annual yield for each well field. These quantities are estimated to be required intermittently during days of maximum demand.

Preliminary design data relating to each of the new recommended water wells is included in Table 8-4, titled Water Well Design Capacity. The approximate location of each well field is denoted on the several other figures included in this section.

TABLE 8-4

WATER WELL DESIGN CAPACITY

Phase	Water Basin	Number of New Wells	Well Capacity (lps)
I			
	El Hiama	10[a]	27.6
II			
	Mikbaba	3[b]	24.1
	Wadi Salah	1	21.0
	Upper Wadi Houban	1	21.8
	Wadi Amed	1	7.9
	Dh'bab	4	27.6
	Houban-Hougala	2	27.6

[a]Includes two standbys.
[b]Includes one standby.

The existing Houban-Hougala field will not supply water for domestic purposes prior to approximately 1991. Instead, this field will be used only for agricultural uses until the quality of this water improves.

All wells are designed so as to operate unattended through time clock control. Each well will be equipped with a recorder to totalize the operating time of each motor. Each well field will also include a recording flow meter. Power and standby generation is furnished and is discussed in detail in the chapter entitled, ELECTRICAL.

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SERVICE ZONES

The study area varies between elevations 1135 and 1485, a total vertical distance of 350 meters. Most domestic water appliances operate satisfactorily with pressures between 14 and 65 meters. The study area, therefore, consists of seven service zones, each serving properties situated between a 50 meter elevation differential. The maximum water surface together with the minimum and maximum elevations for each of the seven service zones are shown in Table 8-5, titled Service Zones.

TABLE 8-5

SERVICE ZONES

Zone	Maximum Water Surface	Service Elevation Maximum	Service Elevation Minimum
I	1200	1185	1135
II	1252 (existing)	1235	1185
III	1300	1285	1235
IV	1354 (existing)	1335	1285
V	1400	1385	1335
VI	1450	1435	1385
VII	1500	1485	1435

The designated service elevations are approximate; and the zone serving any specific property is dependent somewhat upon available distribution mains and the distance between the property and storage reservoir, or float tank.

BOOSTER PUMPING STATIONS

The water supply pumping stations are designed to provide maximum day demand on a continuous basis.

The pumping stations will be constructed so as to accommodate Phase I projected demand flows with accommodations for expansion at some time in the future in order to provide Phase II projected demand flows. Each

station will include a minimum of two duty pumping units and one stand-by pumping unit.

Table 8-6, titled Pumping Stations, includes data relevant to the basic design of these facilities for the projected Phase I and Phase II demand flows. Figure 8-2 denotes a preliminary design for the Lower Thaabat Booster Pumping Station.

TABLE 8-6

PUMPING STATIONS

Location	Pumping To	Design Capacity (lps)	Pumping Units	Note
Phase I Construction				
Lower Thaabat	Upper Thaabat Zones V, IV & VII	22.4	2 - Duty pumps 1 - Standby 3 - Total	--
Phase II Construction				
Lower Thaabat	Upper Thaabat Zones V, IV & VII	112.3	3 - Duty pumps 1 - Standby 4 - Total	-- Enlarge Phase I Pump Station
Dh'bab	Lower Medina Zones I & II	118.3	2 - Duty pumps 1 - Standby 3 - Total	--
Houban	Main Yard Zones I & II	115.70	2 - Duty pumps 1 - Standby 3 - Total	--

The equipment currently in use at the Hougala and Houban pumping stations will have been in service for more than twenty years, by the time the water from these well fields will again be needed. It is, therefore, reasonable to anticipate complete reconstruction of these existing facilities when again required in about the year 1990.

The pumping stations will be attended, and will be operated manually or by time clocks. Design includes voice communications with a main operations center, thereby eliminating the requirement for control systems, which are often difficult to maintain.

All pumping facilities will include recording flow meters and protection against excessive hydraulic surges. Pumps will be sized so as to operate in the lower speed ranges. Except in special cases, the full load motor speeds will be a maximum of approximately 3000 revolutions per minute. The booster station designs will incorporate horizontal pump and motor shafts in order to minimize maintenance.

RESERVOIRS AND FLOAT TANKS

The storage reservoirs are sized so as to be able to deliver to the service zone all demand flows in excess of the projected maximum day demand. This storage capacity is one-third of the projected maximum day demand. The preliminary design data relating to all storage facilities is included in Table 8-7, titled Storage Reservoirs.

TABLE 8-7

STORAGE RESERVOIRS

Phase	Location	High Water Elevation	Zones Served	Capacity (cubic meters)
Existing	Main Yard	1252	I, II	1560
Existing	Main Yard	1252	I, II	1560
Existing	Lower Thaabat	1354	III, IV	1590
Phase I	Upper Thaabat	1500	V, VI, VII	1620
Phase I	Upper Medina	1354	III, IV	1640
Phase I	Lower Medina	1252	I, II	3500
Phase II	Lower Thaabat	1354	III, IV	2850
Phase II	Main Yard	1252	I, II	500
Phase II	Lower Medina	1252	I, II	3500
Phase II	Upper Thaabat	1500	V, VI, VII	1620

The recommended construction plan takes full advantage of all existing storage reservoirs which are constructed of steel plate. The proposed reservoirs are, however, proposed to be constructed of concrete where cost estimates indicate a cost advantage in utilizing concrete. Figures

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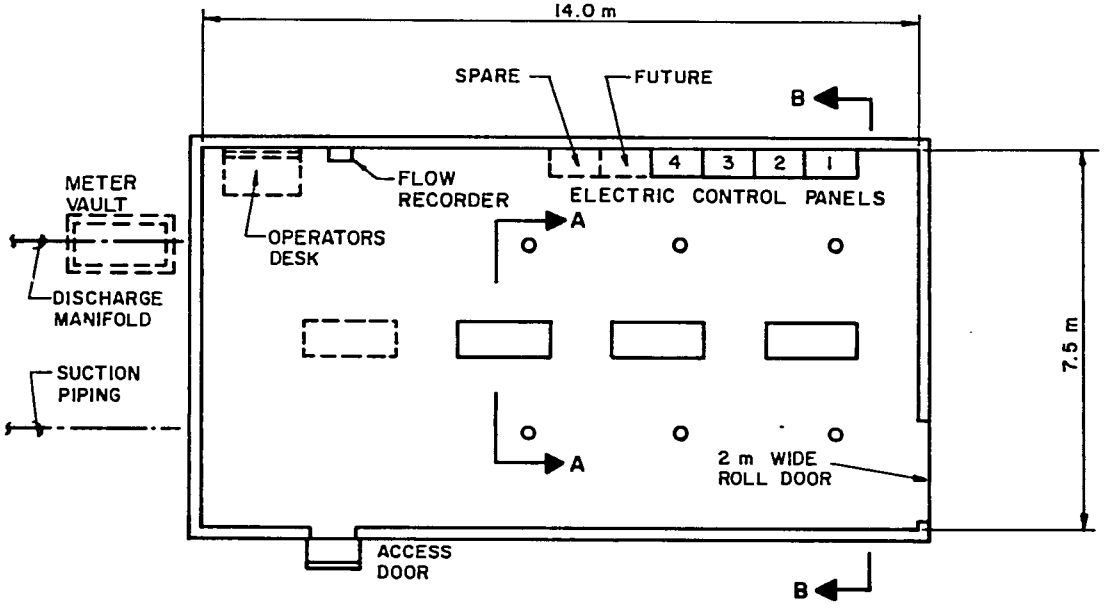
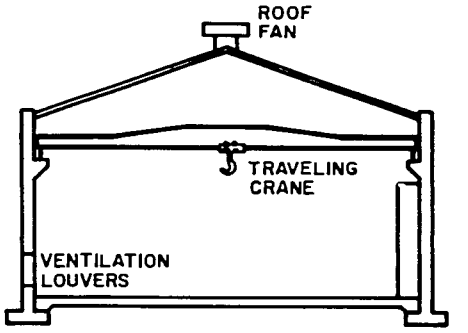
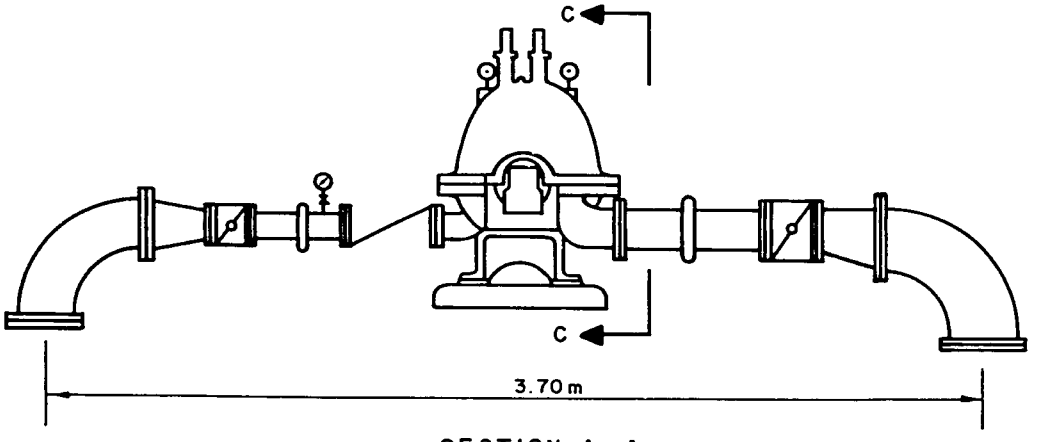


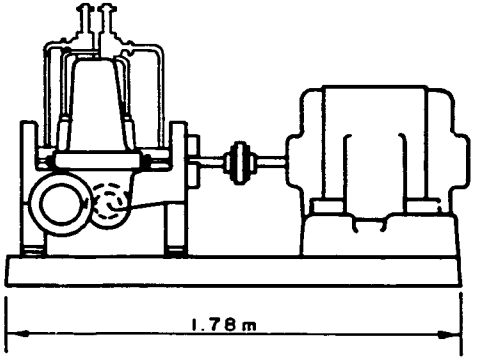
PLAN
SCALE 1:100



SECTION B-B
SCALE 1:100



SECTION A-A
SCALE 1:20



SECTION C-C
SCALE 1:20

TAIZ WATER SUPPLY AND SEWERAGE PROJECT
BOOSTER PUMPING STATION

8-3 and 8-4 depict the yard piping to the Main Yard Reservoirs and Typical New Reservoir, respectively.

Float tanks will be constructed and utilized in lieu of pressure reducing valves. They will protect the lower portions of service zones I, III, V and VI from excessively high water pressures. A typical float/tank pressure break structure is shown in Figure No. 8-5. The high water elevations for the pressure break structures serving the respective service zones are denoted in Table 8-8, titled Pressure Break Structures.

TABLE 8-8

PRESSURE BREAK STRUCTURES

Phase	Zone Served	High Water Elevation	Invert Elevation
I & II	I	1200	1197
I & II	III	1300	1297
I & II	V	1400	1397
I & II	VI	1450	1447

DISINFECTION

The disinfection of the water is required to produce a safe water that is free of pathogenic bacteria. The disinfection will be accomplished by the proper application of chlorine solution. The points of application will be near the supply well fields, well upstream of where the first customer is to be served. The transmission main is to provide the necessary contact time to insure adequate bacterial kill.

Four chlorination stations are required, each with sufficient capacity to add ten milligrams per liter of chlorine, based upon the maximum projected flow. Shown in Table 8-9, titled Chlorination Facilities, are the relevant data pertaining to the four chlorination stations.

One chlorination station is required for Phase I, which will be located easterly of the service area. The station will be located near the highway, immediately downstream of where the flows originating from water basin El Hiama join the flow originating from water basin Upper Wadi Houban.

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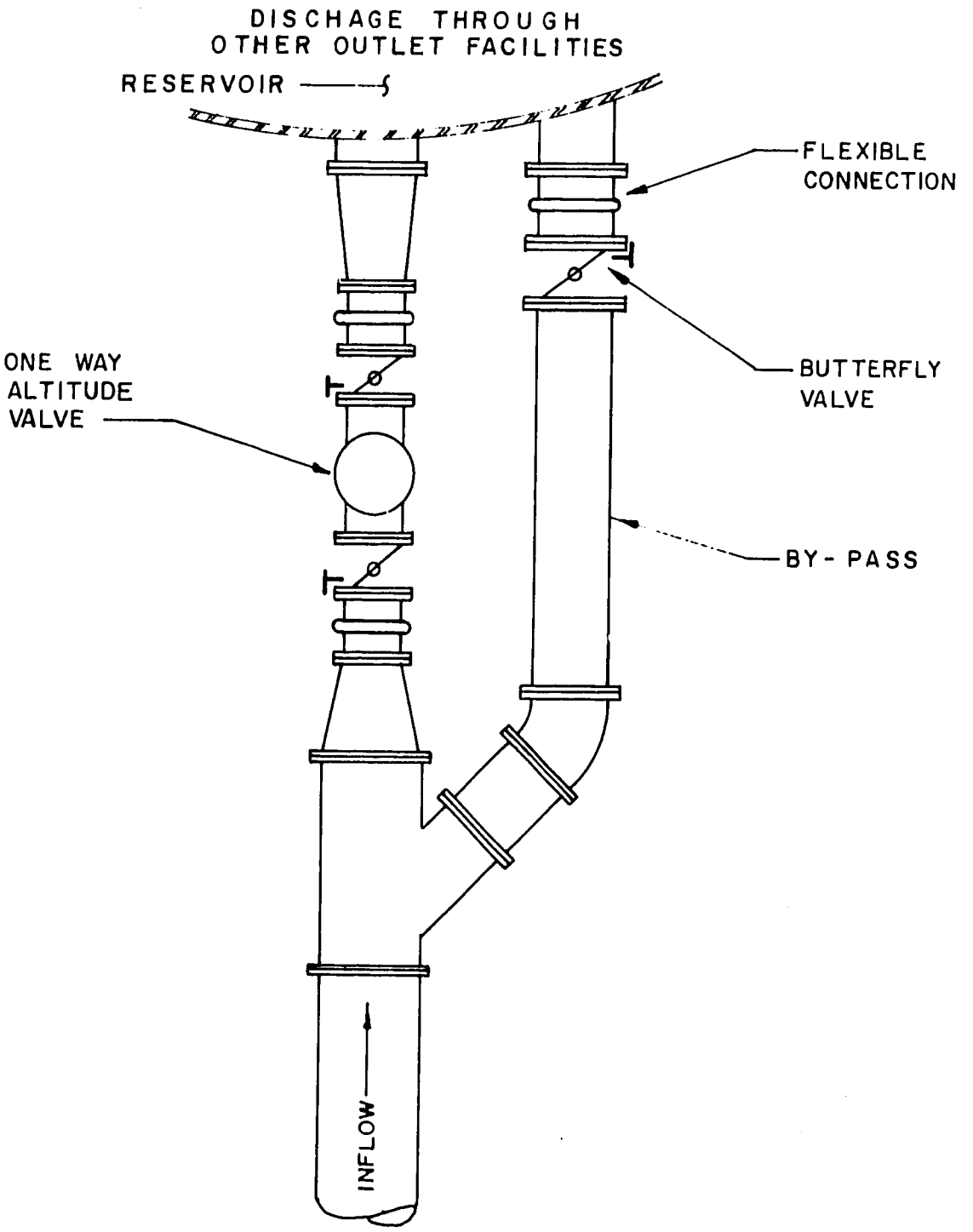
TABLE 8-9

CHLORINATION FACILITIES

Phase	Well Field Water Source	Maximum Flow (lps)	Chlorine Demand (kg per day)	Chlorine Gas Cylinders[a]			
				In Use	In Reserve	In Storage	Total Supply
I	XVI, XVII XVIII, XIX	370.2	320	2-Ton	2-Ton	7-Ton	31 days
II	IV	21.0	18	2-150 lb	2-150 lb	4-150 lb	20 days
II	X, VIII	126.2	110	1-Ton	1-Ton	2-Ton	33 days
II	Houban	105.1	91	1-Ton	1-Ton	1-Ton	30 days

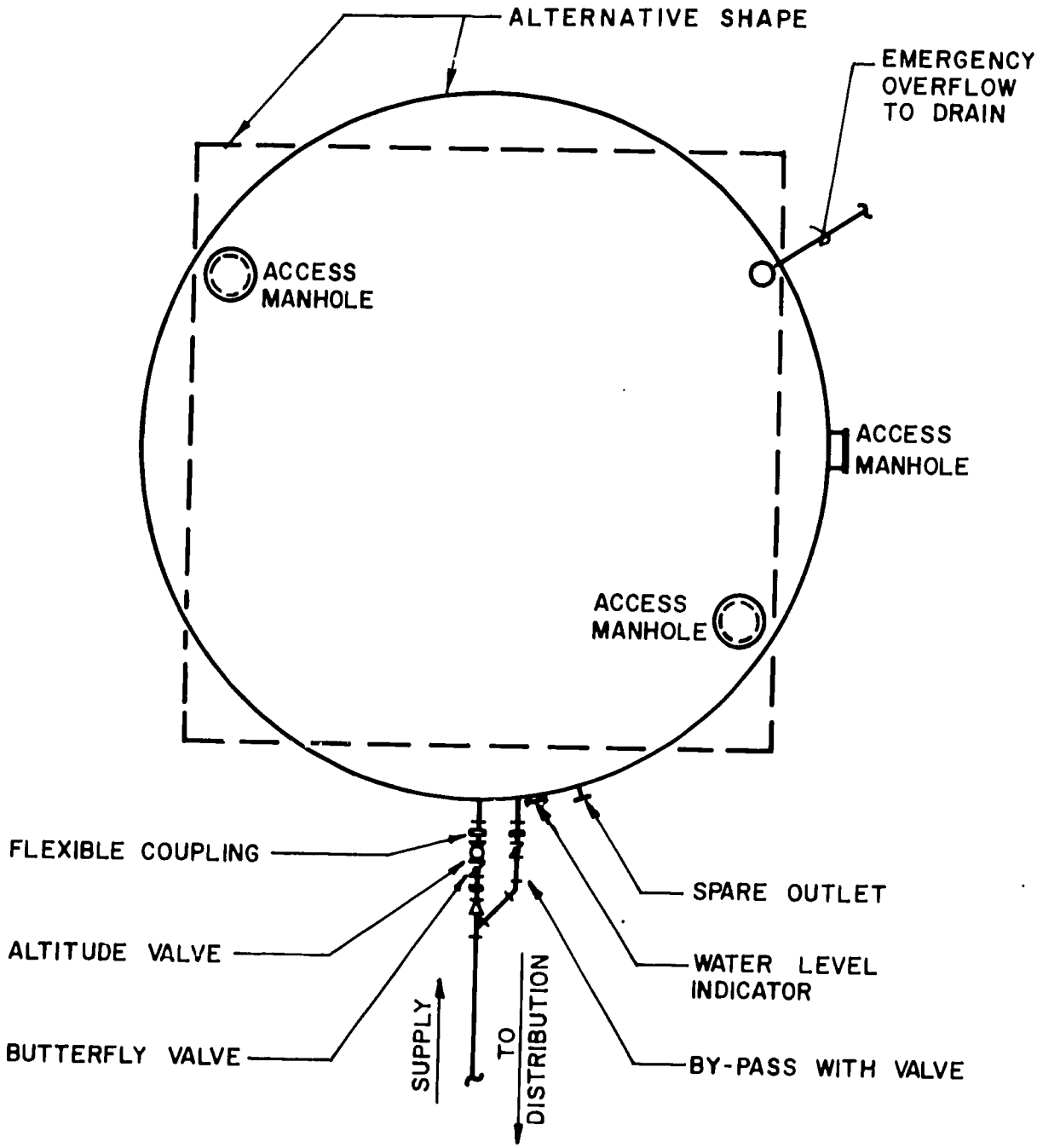
[a]Chlorine gas is available locally only in English units, therefore, cylinder weights are listed in English pounds and long tons. The equivalent metric weights are one English long ton equals 909 kg and 150 pounds equals 68 kg.



TAIZ WATER SUPPLY AND SEWERAGE PROJECT

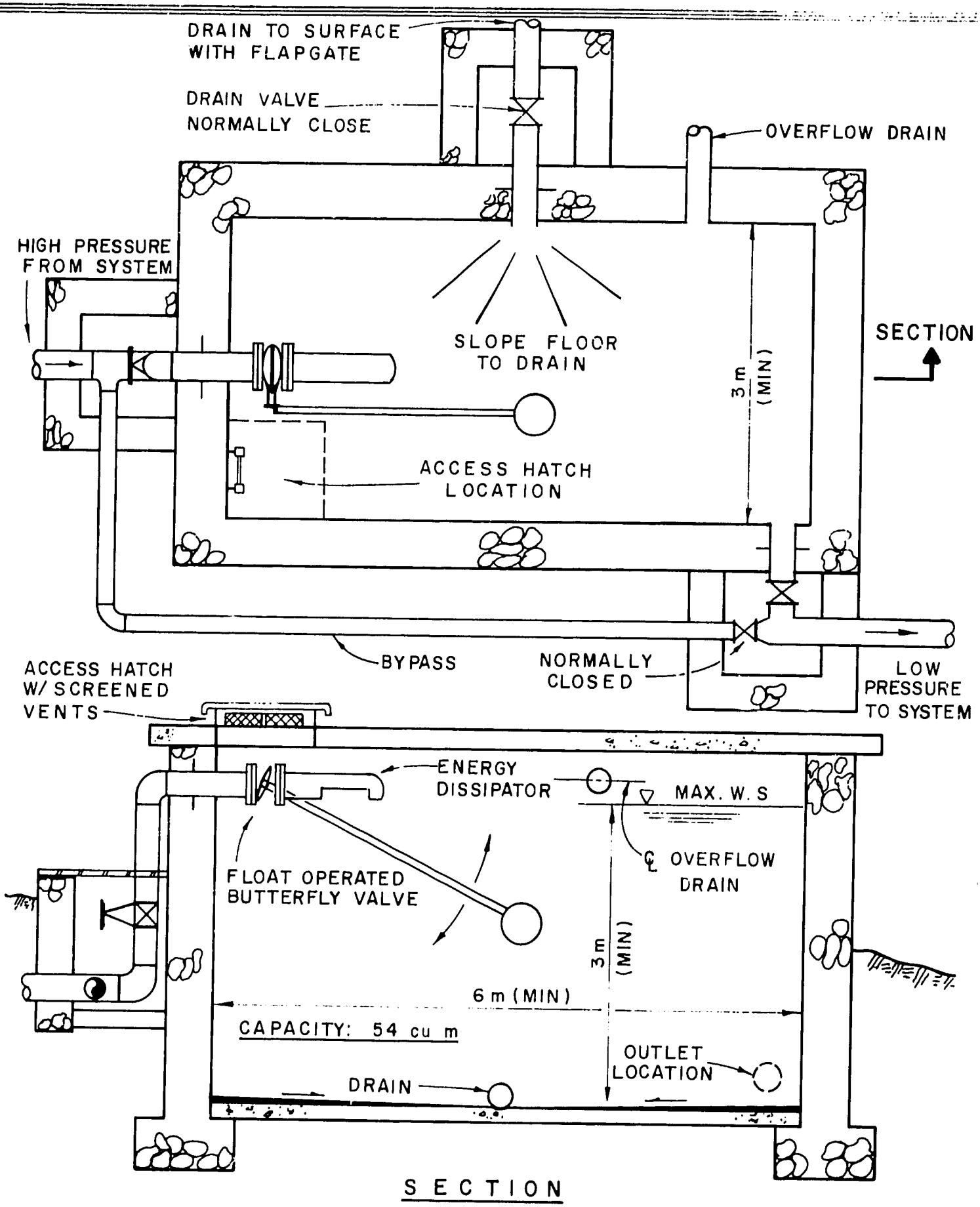
INFLOW TO MAIN YARD
RESERVOIR COMPLEX

FIGURE 8 - 3



TAIZ WATER SUPPLY AND SEWERAGE PROJECT

TYPICAL NEW RESERVOIR



SECTION

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

PROPOSED PRESSURE-BREAK STRUCTURE

SCALE 1:50

FIGURE 8-5

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At times of maximum flow, the approximate chlorine contact time will be in excess of one hour, which is satisfactory.

TRANSMISSION AND DISTRIBUTION MAINS

All proposed transmission and distribution mains are shown in Figures 8-6 through and including 8-13. Shown on Figures 8-6 through 8-9 are the plans and profiles of the transmission mains between the outlying well fields and the service area. For the most part, the operating pressure of the transmission lines will be compatible with pressure zones each main traverses; and consequently, will also serve as distribution mains.

The El Hiama transmission main, however, between the supply well fields and the reservoirs of the Main Yard and at Lower Thaabat will not be operating at a pressure compatible with the service requirements of Pressure Zones I, II, III, or IV. This transmission main will be compatible only with the service requirements of Service Zone V.

Likewise, each of the other transmission mains will be functioning at pressures which will be compatible only with Pressure Zone Number II, even though portions of the lines will be constructed within Service Zone I.

The proposed system includes pipelines of the sizes shown for each phase as shown in Table 8-10, titled Proposed Transmission and Distribution Mains.

The profile of the entire system is shown schematically in Figure 8-14.

SERVICE CONNECTIONS

The existing water system in Taiz is somewhat unique in the world in that all service connections are metered and the meters are owned by the user. Consistent with this, all recommendations are based on established procedures wherever it is to the advantage of the water supply system.

Two types of service connections are recommended. One type, referred to as standard service is the same as has existed in the past, that is the user purchases his own meter and pays the standard water rate. The other, referred to as special service, is available only to approximately 30 percent of the population which constitutes the low-income group. These service connections will consist of a 3/8-inch meter owned by the TWSA and the water rates will be set at a nominal rate to encourage use by this low-income group. This is discussed in greater detail in Chapter 14.

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TABLE 8-10

PROPOSED TRANSMISSION AND DISTRIBUTION MAINS

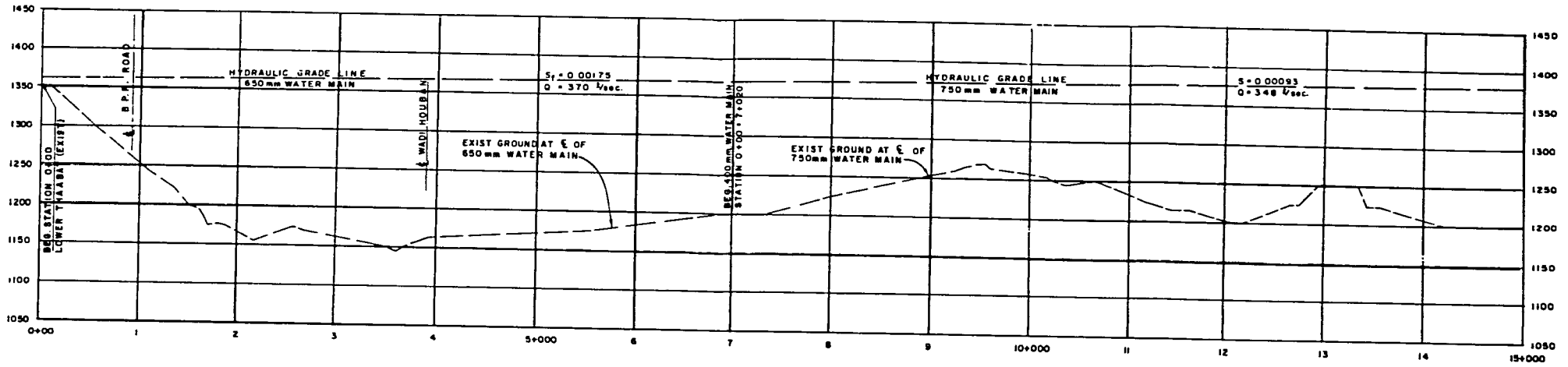
Description	Size (mm)	Total Length in Meters Phase I	Phase II
Transmission			
	750	15,000	
	650	7,000	
	500	850	
	400		6,000
	350	1,000	8,600
	300		3,300
	150		500
	100		1,000
Distribution			
	400	4,500	
	350	3,470	
	300	4,000	350
	250	1,700	3,860
	200	5,670	7,145
	150	3,050	
Total Length		46,240	30,755

PUBLIC FAUCETS

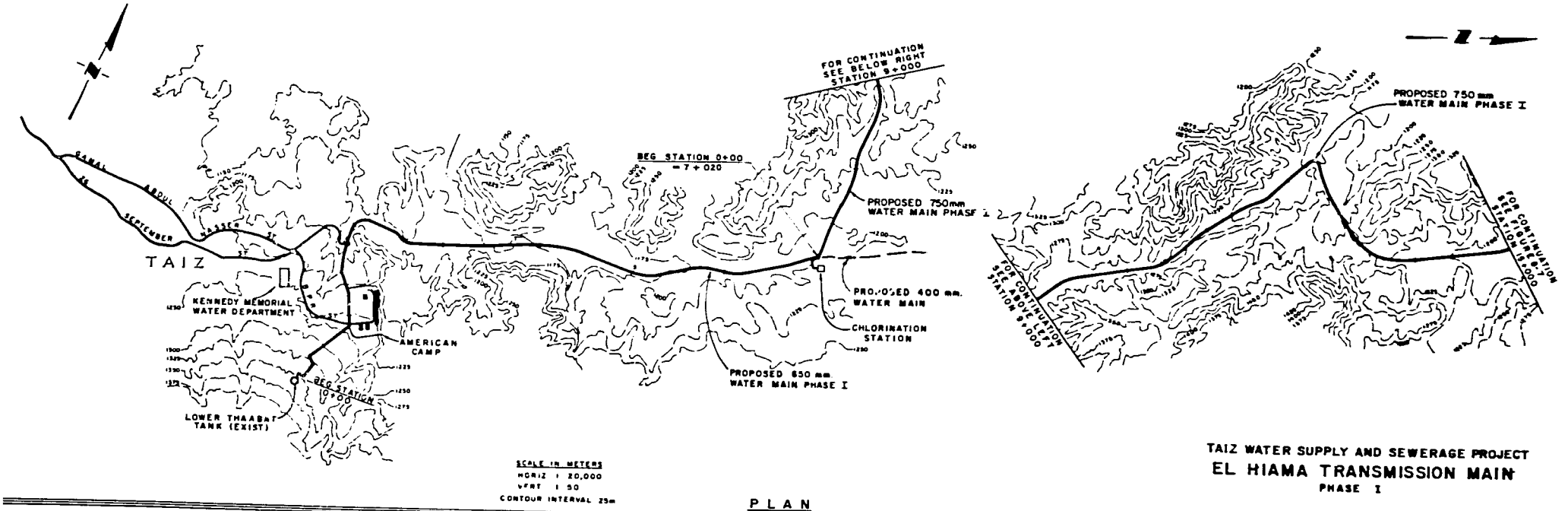
The service area will be served by public faucets equipped with spring-loaded operators. A typical installation is shown on Figure 8-15. This type of installation will be installed at each mosque and a limited number of additional locations.

FIRE HYDRANTS

Approximately 25 above-ground fire hydrants as shown on Figure 8-16 will be installed throughout congested or high-density areas. These are to accommodate the local fire suppression agencies.



PROFILE



SCALE IN METERS
HORIZ 1 20,000
VERT 1 50
CONTOUR INTERVAL 25m

PLAN

TAIZ WATER SUPPLY AND SEWERAGE PROJECT
EL HIAMA TRANSMISSION MAIN
PHASE I

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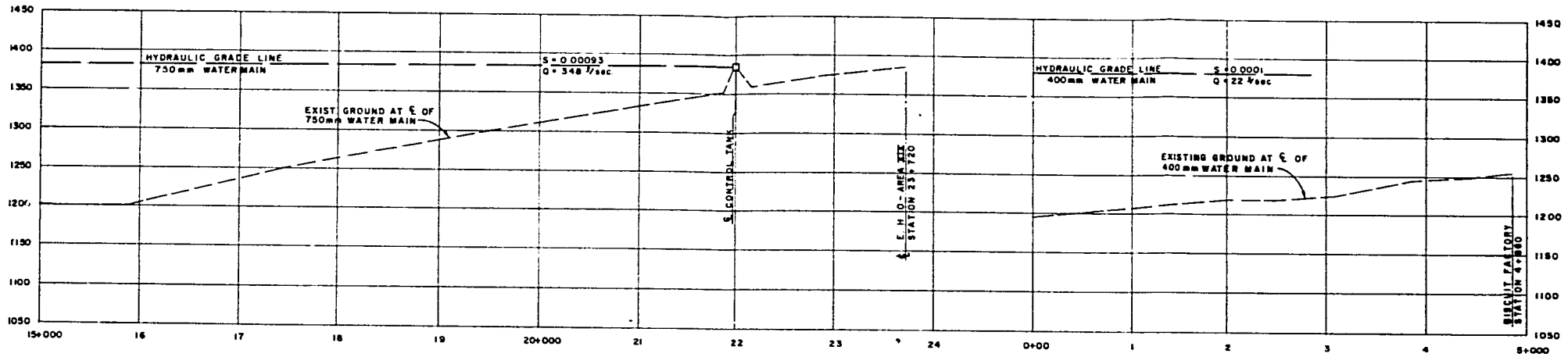
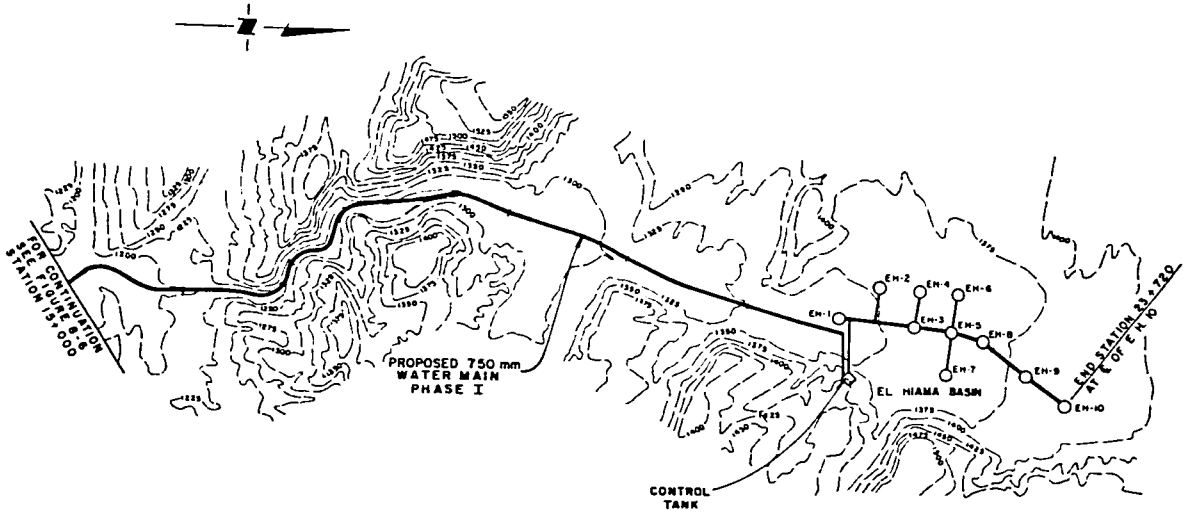
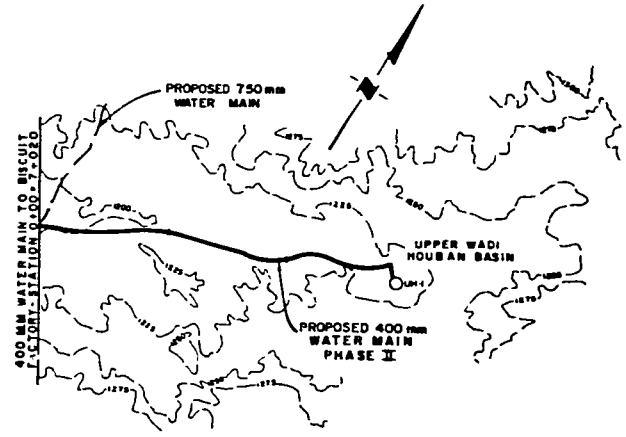
FIGURE 8-6



PROFILE





SCALE IN METERS
HORIZ 1: 20,000
VERT 1: 50
CONTOUR INTERVAL 25m

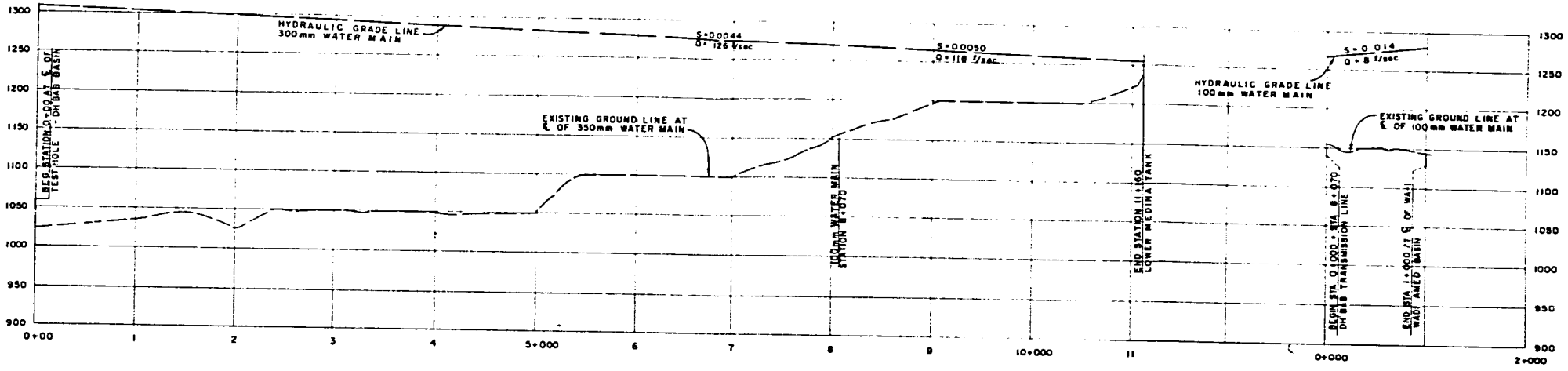
PLAN

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

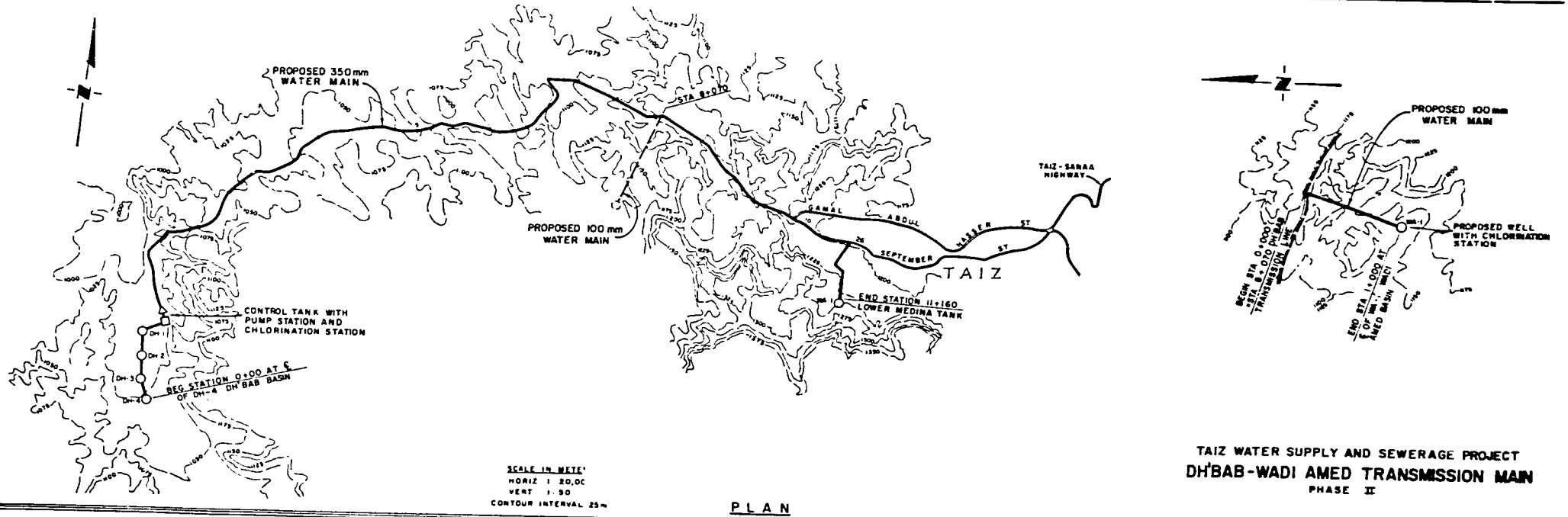
EL HIAMA TRANSMISSION MAIN

JAMES M MONTGOMERY, CONSULTING ENGINEERS, INC.

FIGURE 8-7



PROFILE



SCALE IN METE'
HORIZ 1 20,0C
VERT 1 50
CONTOUR INTERVAL 25m

PLAN

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

DH'BAB-WADI AMED TRANSMISSION MAIN

PHASE II

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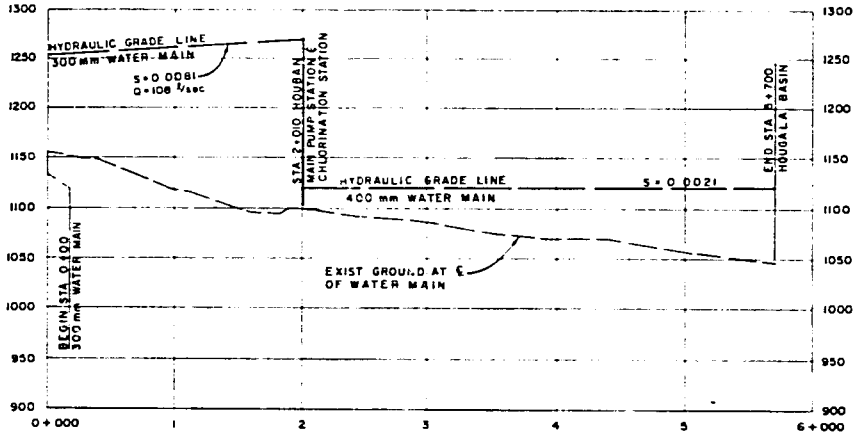
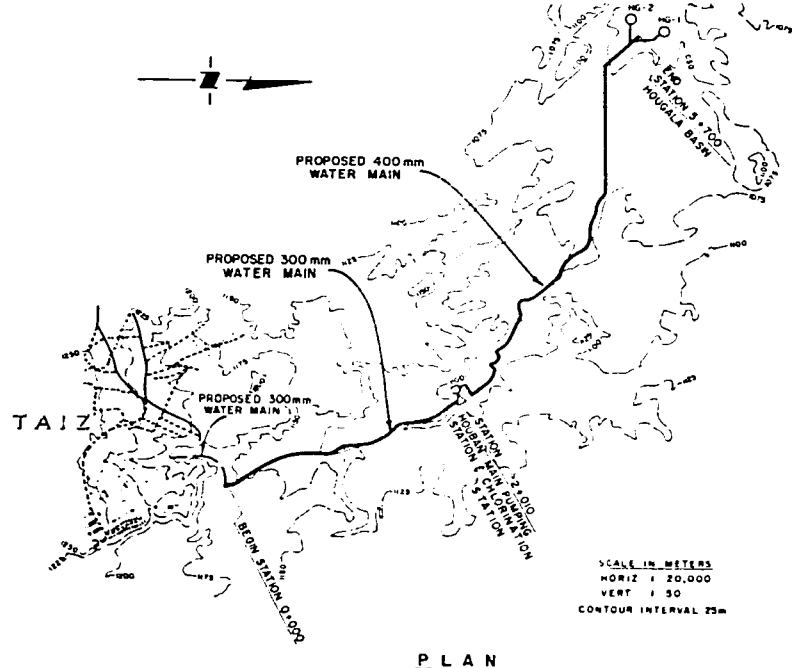
FIGURE 8-6



PROFILE



PLAN

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

HOUBAN-HOUGALA TRANSMISSION MAIN

PHASE II

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

EXISTING AND PROPOSED DISTRIBUTION SYSTEM IMPROVEMENTS

NORTHWEST SECTION-PHASE I AND II

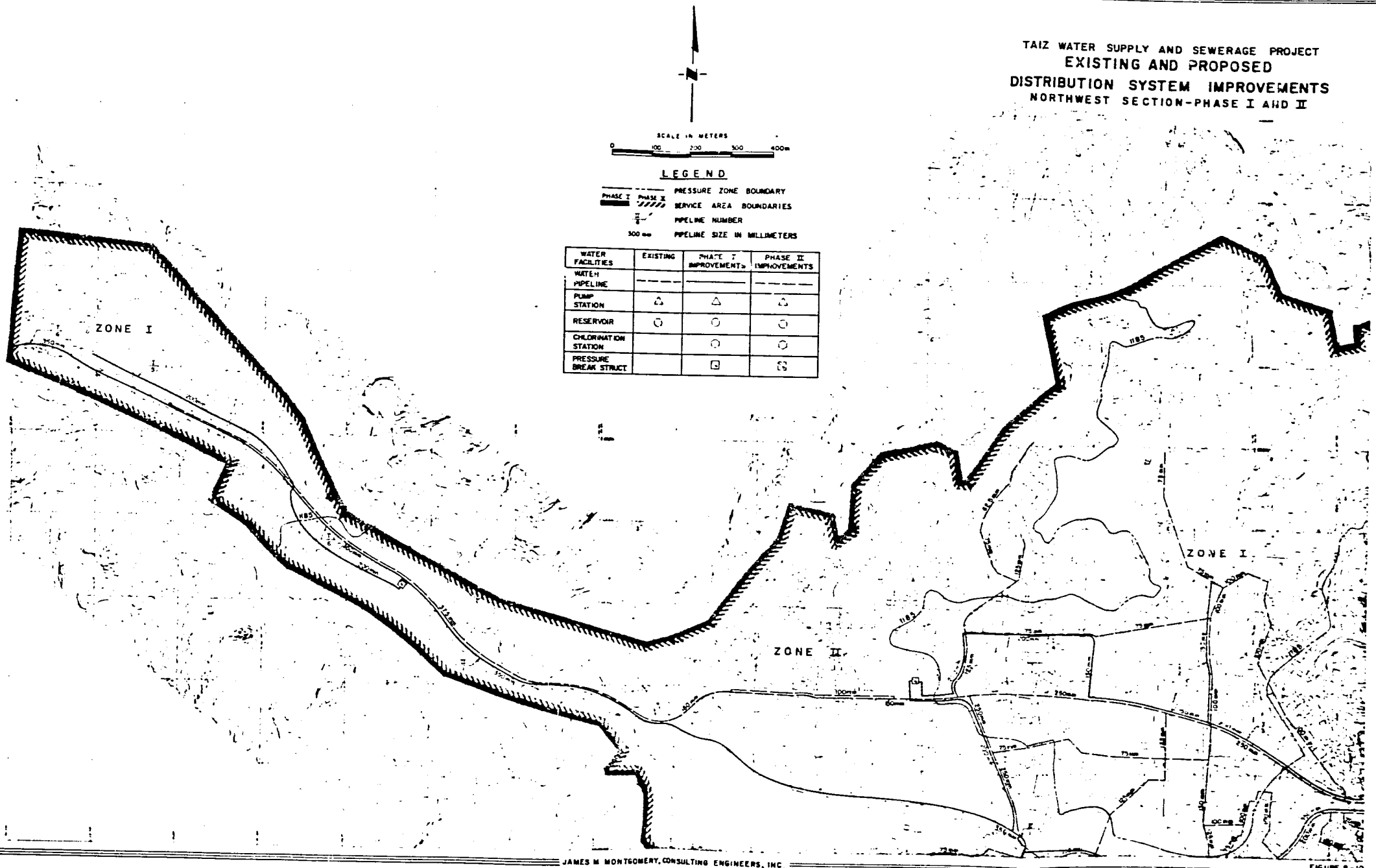


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FIGURE 8-10

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

EXISTING AND PROPOSED DISTRIBUTION SYSTEM IMPROVEMENTS

NORTHEAST SECTION-PHASE I AND II

LEGEND

- PHASE I / PHASE II — PRESSURE ZONE BOUNDARY
- PHASE I / PHASE II — SERVICE AREA BOUNDARIES
- PIPELINE NUMBER
- 300 mm — PIPELINE SIZE IN MILLIMETERS

WATER FACILITIES	EXISTING	PHASE I IMPROVEMENTS	PHASE II IMPROVEMENTS
WATER PIPELINE			
PUMP STATION	△	△	△
RESERVOIR	○	○	○
CHLORINATION STATION		○	○
PRESSURE BREAK STRUCT.		⊡	⊡

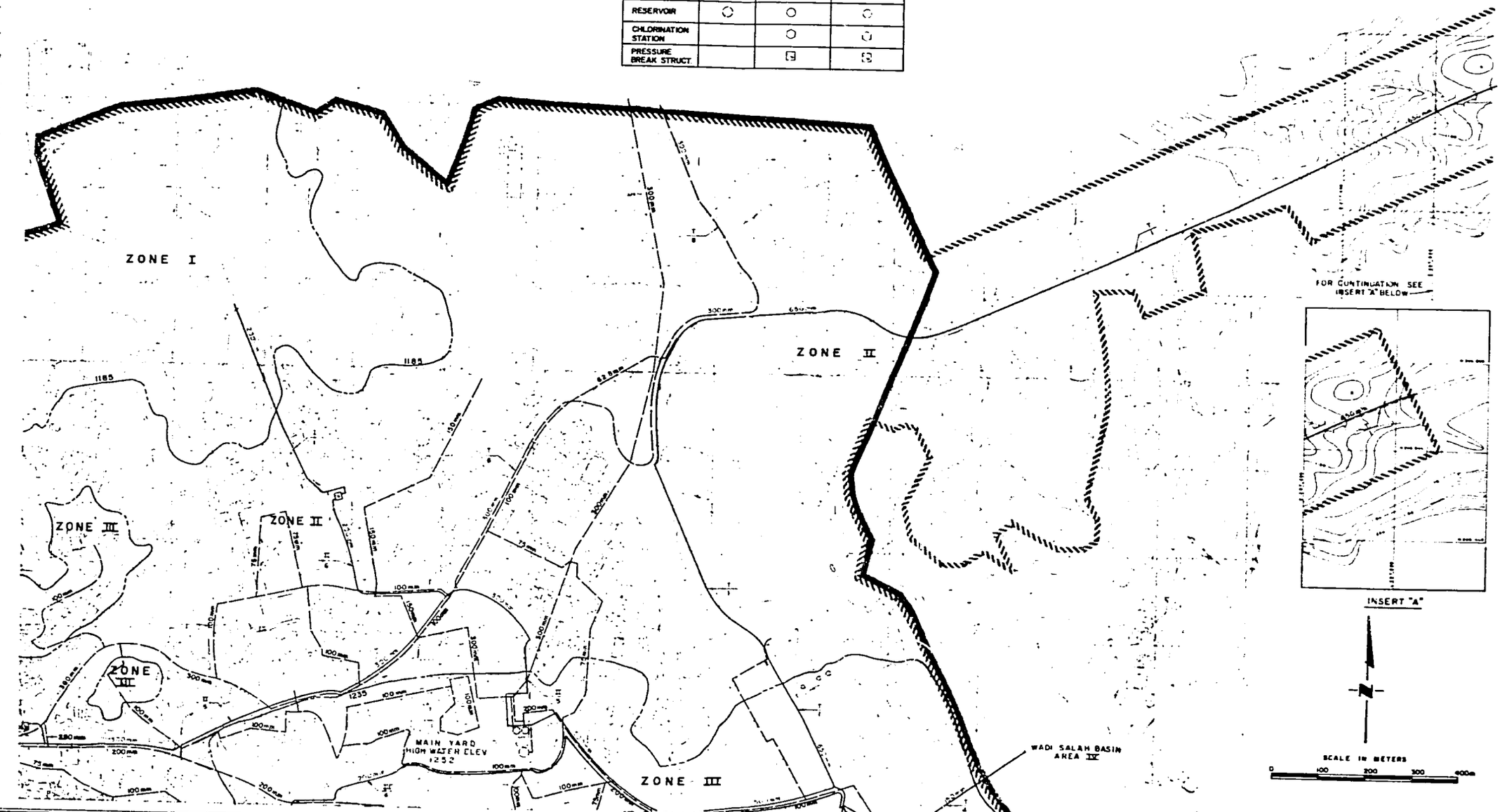

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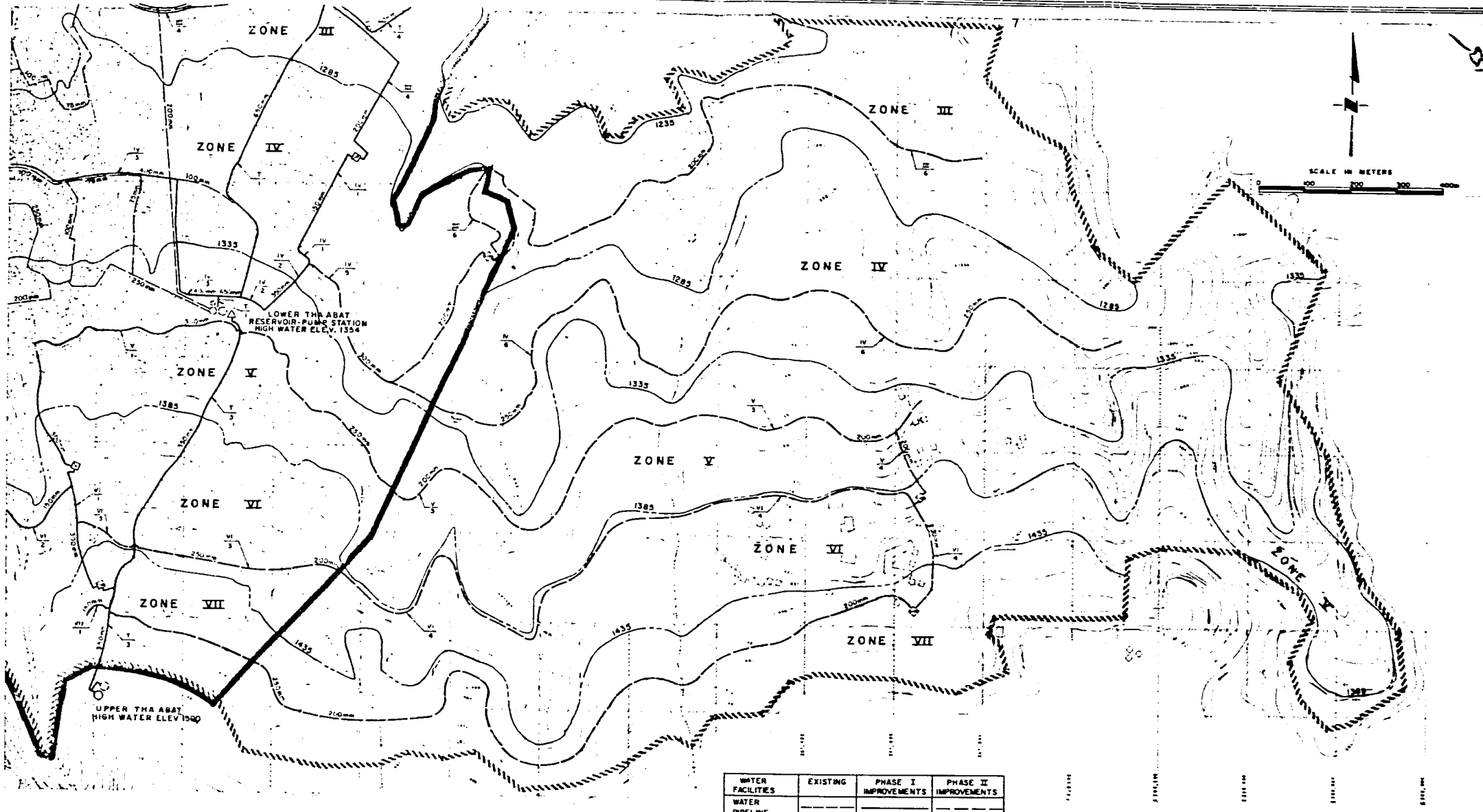
FIGURE 8-11



WATER FACILITIES	EXISTING	PHASE I IMPROVEMENTS	PHASE II IMPROVEMENTS
WATER PIPELINE			
PUMP STATION	△	△	△
RESERVOIR	○	○	○
CHLORINATION STATION		○	○
PRESSURE BREAK STRUCT		⊠	⊠

LEGEND

PRESSURE ZONE BOUNDARY

PHASE I PHASE II SERVICE AREA BOUNDARIES

PIPELINE NUMBER

300mm PIPELINE SIZE IN MILLIMETERS

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

EXISTING AND PROPOSED

DISTRIBUTION SYSTEM IMPROVEMENTS

SOUTHEAST SECTION-PHASE I AND II

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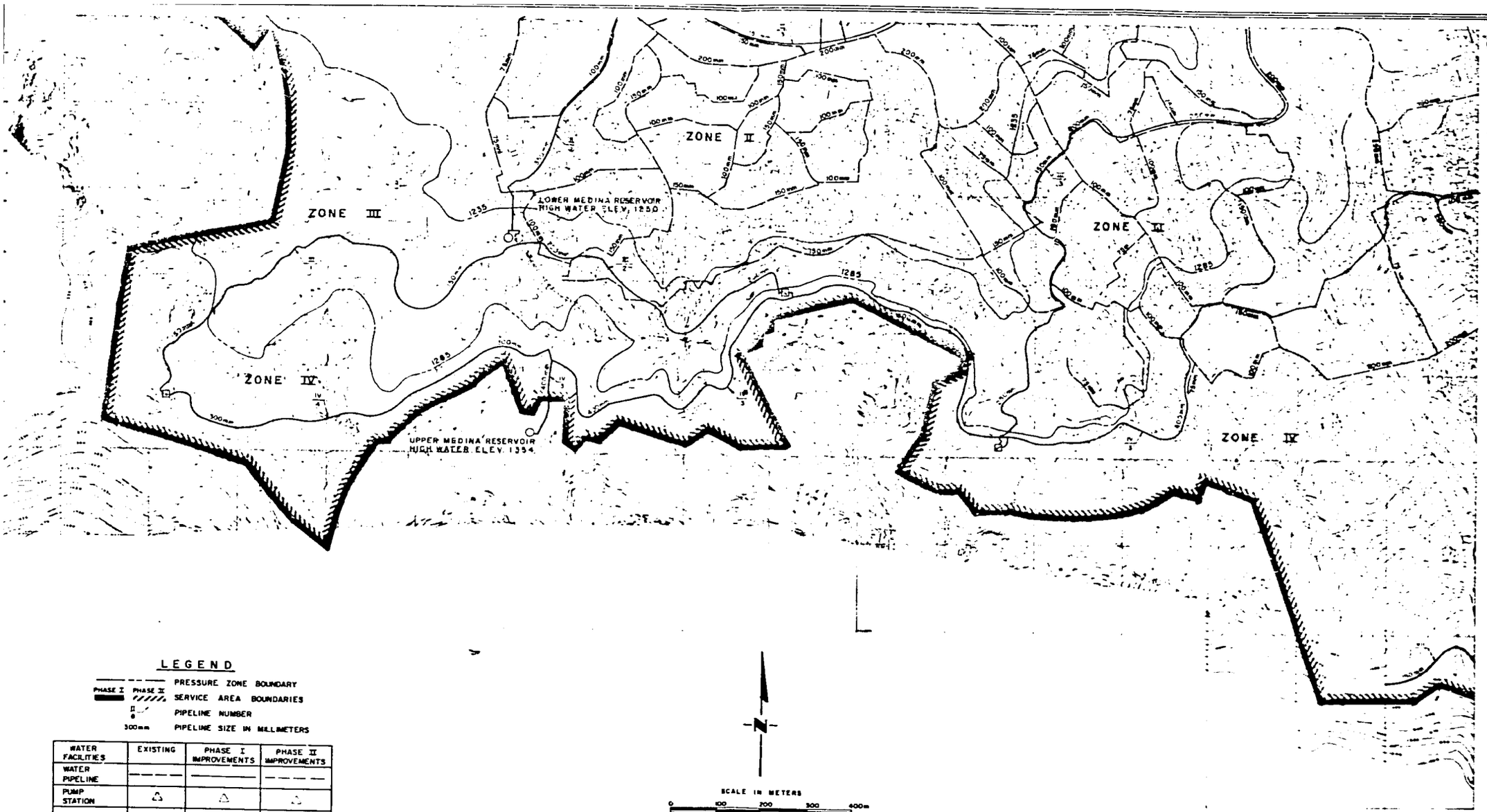
FIGURE 8-12



LEGEND

PHASE I — PHASE II — PRESSURE ZONE BOUNDARY

SERVICE AREA BOUNDARIES

PIPELINE NUMBER

300mm PIPELINE SIZE IN MILLIMETERS

WATER FACILITIES	EXISTING	PHASE I IMPROVEMENTS	PHASE II IMPROVEMENTS
WATER PIPELINE			
PUMP STATION			
RESERVOIR			
CHLORINATION STATION			
PRESSURE BREAK STRUCT			

N

SCALE IN METERS

0 100 200 300 400m

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

EXISTING AND PROPOSED DISTRIBUTION SYSTEM IMPROVEMENTS

SOUTHWEST SECTION-PHASE I AND II

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FIGURE 8-13

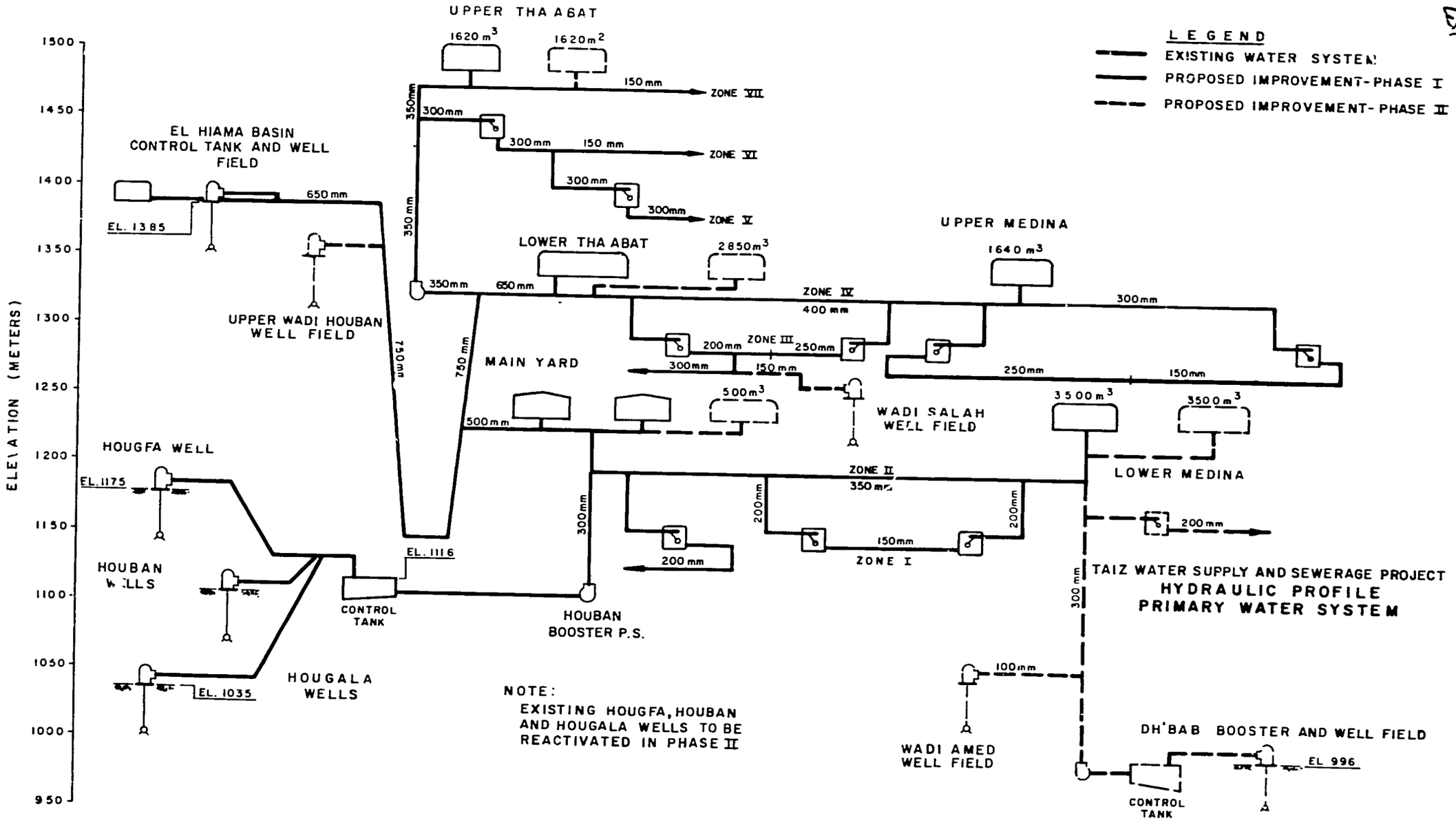
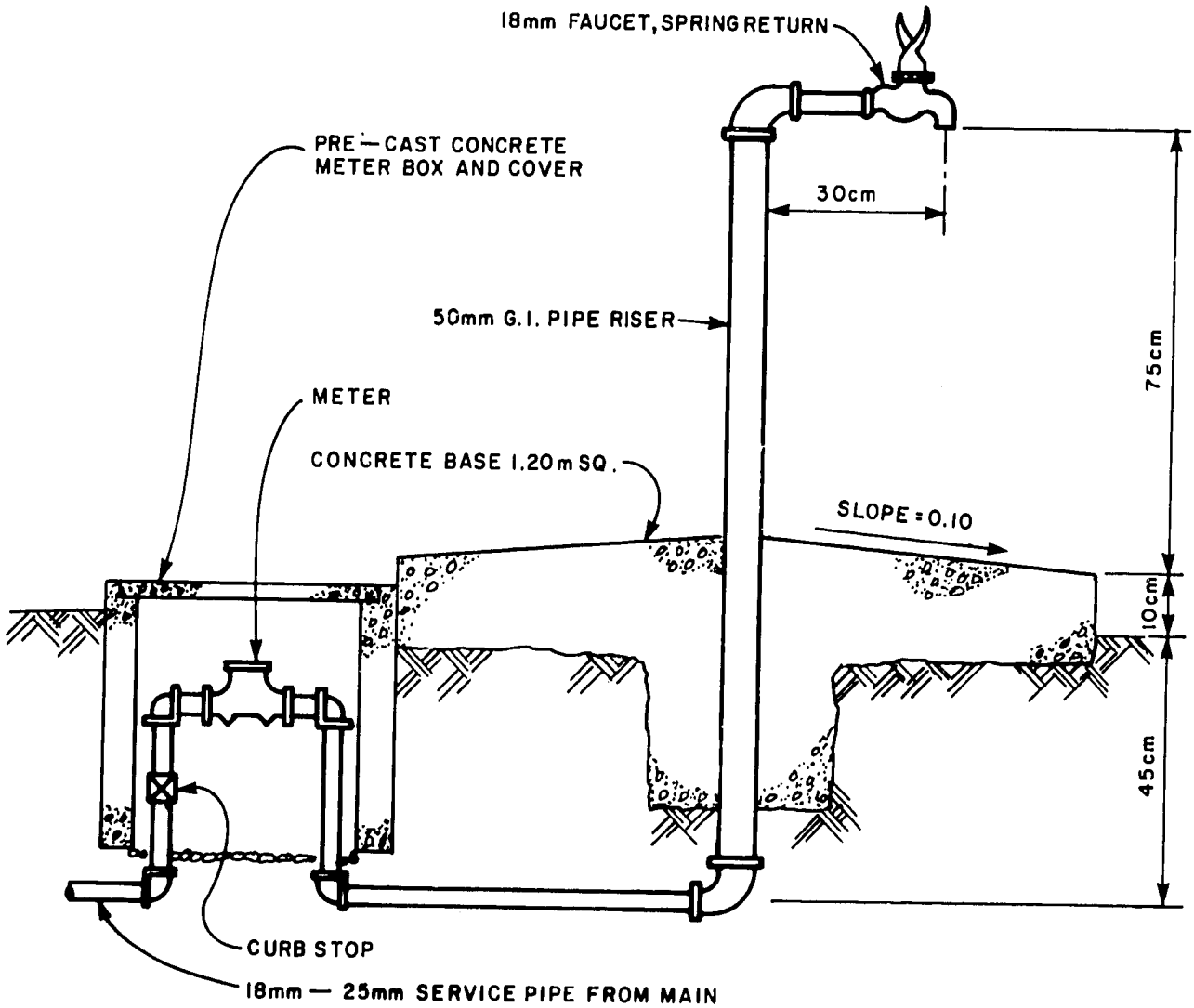

LEGEND
EXISTING WATER SYSTEM
PROPOSED IMPROVEMENT-PHASE I
PROPOSED IMPROVEMENT-PHASE II
ELEVATION (METERS)
1500
1450
1400
1350
1300
1250
1200
1150
1100
1050
1000
950
UPPER THA ABAT
1620 m3
1620 m2
150 mm
ZONE VII
350mm
300mm
300 mm
150 mm
ZONE VI
300 mm
300mm
ZONE V
EL HIAMA BASIN
CONTROL TANK AND WELL
FIELD
650 mm
EL. 1385
350 mm
UPPER WADI HOUBAN
WELL FIELD
LOWER THA ABAT
2850m3
350mm
650 mm
ZONE IV
400 mm
UPPER MEDINA
1640 m3
300mm
750mm
750 mm
MAIN YARD
200mm
ZONE III
250mm
300mm
150 mm
250mm
150mm
500m3
500 mm
WADI SALAH
WELL FIELD
3500 m3
3500 m3
HOUGFA WELL
EL. 1175
ZONE II
350 mm
LOWER MEDINA
200mm
300mm
200mm
200 mm
150mm
ZONE I
HOUBAN
WELLS
EL. 1116
CONTROL
TANK
HOUBAN
BOOSTER P.S.
300 mm
TAIZ WATER SUPPLY AND SEWERAGE PROJECT
HYDRAULIC PROFILE
PRIMARY WATER SYSTEM
HOUGALA
WELLS
EL. 1035
NOTE:
EXISTING HOUGFA, HOUBAN
AND HOUGALA WELLS TO BE
REACTIVATED IN PHASE II
100mm
WADI AMED
WELL FIELD
DH'BAB BOOSTER AND WELL FIELD
EL 996
CONTROL
TANK

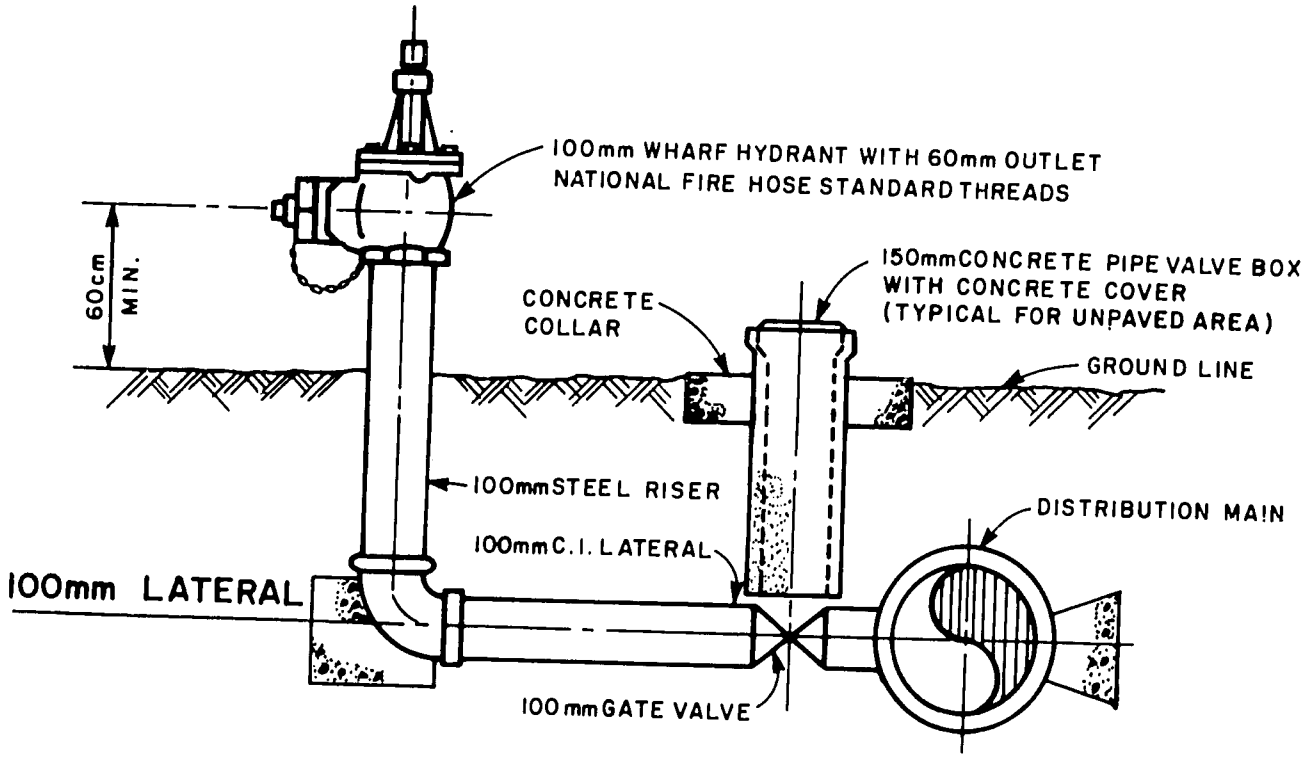
FIGURE 8-14

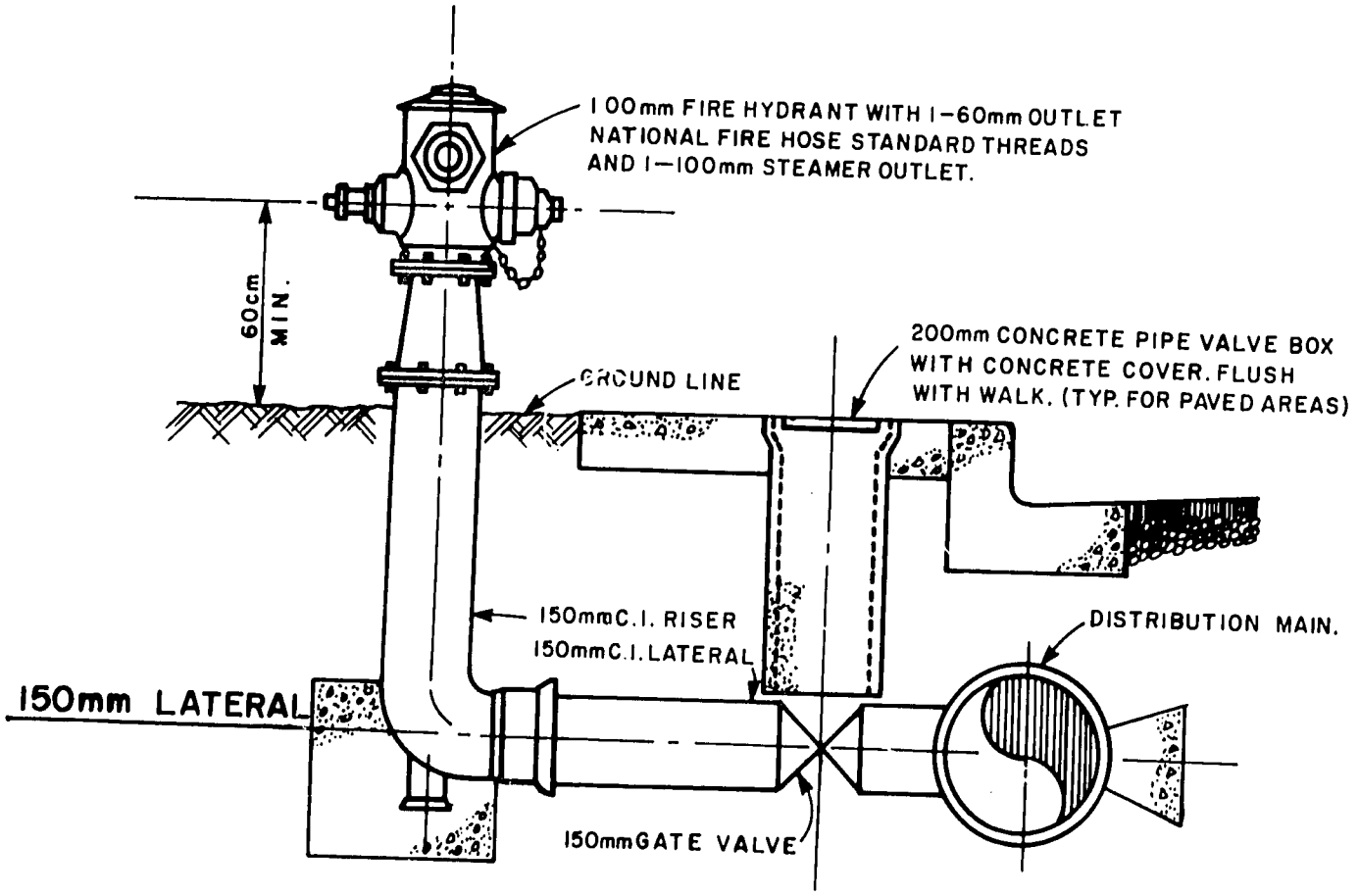


TAIZ WATER SUPPLY AND SEWERAGE PROJECT

TYPICAL PUBLIC FAUCET

FIGURE 8—15





TAIZ WATER SUPPLY AND SEWERAGE PROJECT

TYPICAL FIRE HYDRANT DETAILS

FIGURE 8-16

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IMMEDIATE IMPROVEMENTS

The USAID representative in Taiz, who has served as an advisor to the water system since June 1972, has cooperated in a program for the replacement of faulty equipment. The program has also been directed to improve maintenance procedures. These programs should continue. All of the existing facilities are to be fully utilized in the recommended water system. It is, therefore, imperative that spare and replacement parts are obtained in support of the existing system.

RESTORATION OF CONTINUOUS WATER PRESSURE

The present practice of enforcing water rationing by routinely shutting down portions of the distribution system must be discontinued. Until additional water supplies are developed, other means of rationing are necessary in order to maintain system pressure.

Acceptable forms of water rationing include voluntary customer cooperation and flow restrictions at the service meter. All distribution main valves should be maintained in an open position, except during emergency repairs, in order to prevent negative pressures from occurring in the pipelines. The defective pressure reducing valves must be repaired in order to prevent excessively high water pressures from occurring in the lower portions of the system.

The current moratorium on new service connections should also continue.

REDUCTION IN UNACCOUNTED-FOR WATER

At the present time, water production exceeds metered consumption by approximately 30 percent. This is excessive and immediate steps should be taken to reduce this amount to a goal of 20 percent. Prompt leak repairs, improved corrosion control to minimize leaks and constant surveillance to prevent unauthorized use of water are necessary.

Metering of source water production is required as soon as possible. Metering will aid in establishing records for unaccounted-for water. It is necessary that a propeller-type master meter be installed at Houban Booster on the 12-inch supply pipeline to the Main Yard. This will continuously indicate, record, and totalize the water supply to the system. This information will provide management with the necessary data to monitor pump operation and efficiency as well as permit progress reports on the effectiveness of reducing system losses.

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CORROSION CONTROL

An active corrosion control program should be established. The program should include obtaining a supply of plastic pipe and tubing for use in the repair or replacement of service lines and small water mains. In addition to reducing leaks, the inclusion of plastic or other non-metallic material into the system will prolong the life of the adjacent steel pipe by insulating adjacent sections of the pipelines from stray electrical currents.

The corrosion control program should also include the installation of electrical insulating bushings between existing brass valves and fittings and the adjacent steel pipe.

The continued inspection, cleaning, repairing and restoration of protective coatings on the surfaces of the steel water storage tanks is mandatory if these facilities are to be of continual usefulness. An approved AWWA Standard Coal-Tar Enamel System is recommended, together with subsequent cleaning and inspection performed every two years.

RELOCATION OF CHLORINATION FACILITIES

Until Phase I construction is completed, the existing chlorination equipment at the Main Yard should be relocated to Houban Booster site and housed in a suitable isolated enclosure. This will allow both tanks at the Main Yard to fluctuate in parallel and effectively double the existing storage capacity, provided all the valves remain open.

The chlorine solution can be fed into the Houban reservoir in proportion to the pumping, and chlorine residuals can be monitored in the Main Yard. At the present flow, the 12-inch pipeline will provide a detention time of 53 minutes prior to any consumptive use.

MISCELLANEOUS IMPROVEMENTS

Other recommended immediate improvements include:

- Establish and maintain a pipe log together with as-built pipe maps of the system.
- Provide closed-loop heat exchangers with chemical control to prevent deposits, for all of the pump-drive engines. This is necessary in order to eliminate lubricating oil from entering the water system.

- Remove handwheels from the buried valves and replace with square operating nuts for more convenient operation with a tee-handle valve key carried by operating crews.

- Install an overhead telephone line on the existing power poles between Houban and Hougala and re-establish telephone communication with the operator at the Hougala site.

ALTERNATIVE WATER SOURCES

There are two alternative sources of water for the study area in addition to that selected for this project:

- Impoundment of surface run-off

- Desalting of brackish ground water or sea water

IMPOUNDMENT OF SURFACE RUN-OFF

The feasibility of impounding surface run-off for subsequent treatment and use as a source of water has been evaluated as a part of this study. The requirements necessary to ensure success for this alternative include a reliable annual precipitation with little likelihood of years of drought together with a suitable dam and reservoir site. The dam site must possess suitable foundation material with durable embankment support. The reservoir site should be relatively deep, which will produce a reservoir with a minimum surface area exposed to evaporation losses. The gradient of the stream bed must be flat so as to minimize the height of the dam. Also, the invert of the reservoir must be impervious in order to minimize water losses through seepage.

The largest available drainage area contains less than one hundred forty-five square kilometers, on which falls less than 600 millimeters of precipitation a year. This drainage area will produce sufficient water during years with average precipitation. However, the area occasionally experiences water years with very little precipitation and there is no drainage area available that is capable of producing the required firm water demand during such years.

Field investigations failed to identify a dam and reservoir site suitable for the construction of an impounding reservoir. Therefore, the possibility of combining the flow from several watersheds in order to produce a firm water supply is not feasible.

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It is concluded that the impounding of surface run-off is, therefore, not a viable alternative.

DESALTING OF BRACKISH GROUND WATER OR SEA WATER

The desalting of brackish ground water or sea water was investigated as an alternative source of water. The alternative, however, is found wanting in several important considerations.

There are no nearby sources of suitable brackish waters that are in sufficient quantities to consider desalting. The nearby waters are suitable for use without desalting. The source of sea water is approximately 100 kilometers distant from the study area.

The quantity of water required in order to serve the study area is near the upper limit of the "state of the art" of water desalting. It is not likely that the local labor available could operate or maintain such a complex facility in a manner that would make this alternative an economical source of supply.

A preliminary cost estimate indicates that the cost to produce well water in close proximity to the study area is less costly than producing desalted water near the sea. Cost estimates also show that the cost to transport the finished water to the study area from the well fields to be less costly than the transportation costs from the closest point on the sea.

CHAPTER 9

CHAPTER 9

WASTEWATER SYSTEM

GENERAL

Taiz has the only existing wastewater system in the YAR. The system is owned and administered by the Municipality of Taiz. The existing system serves only the central part of the city. The need for expansion and improvement of the system for prevention of health hazards is of utmost importance in Taiz. This fact is apparent from the most casual inspection of the community. Extensive contamination of the water system is not uncommon throughout the city, which is principally due to intermittent water service, numerous cross-connections, and limited sanitary facilities.

The area surrounding Taiz is relatively arid. There are few natural surface streams and no natural lakes in the immediate area. For centuries this has meant that the people have had to adopt stringent water conservation measures and to be frugal with their limited water resources. As a result, the water from natural springs located above the city is used entirely within the city, and the remaining water needs of the people and of agriculture are met by water supplies pumped from the Houban-Hougala well field and water taken from hand dug wells. Natural recharge of the underground aquifers is limited and, in the case of aquifers below Taiz, a portion of the recharge comes from sewage returns from Taiz. The lack of any wastewater system or treatment facilities has caused gross pollution of the existing water supply from the Houban-Hougala area, which has reached a level that greatly reduces the usefulness of the water as a potable water supply. Total dissolved solids (TDS) currently exceed 2,000 mg/l, hardness exceeds 400 mg/l, and the nitrate concentration exceeds 170 mg/l. The concentrations of these and other inorganic salts in the existing water supply are increasing at an accelerated rate as the population of Taiz grows, and the water taken from the Houban-Hougala area as a water source is recycled, returning to the basin with a higher concentration of dissolved solids than when it was used as a potable water. When the first water supply system was completed in 1965, the TDS level of the water supply was about 800 mg/l. Since that time, the population has greatly increased with the large influx of people from Aden, which has been

accompanied by an increase in the TDS levels to values in excess of 2,000 mg/l. Although historical information is not available for nitrate levels, it is certain that these have increased as a result of increasing population and sewage discharges.

Another major problem caused by the lack of an adequate sewage system is related to public health. Only a very few of the houses are equipped with sanitary flush toilets. A WHO survey showed that less than 40 percent had flush systems within the homes. Most toilets and sinks discharge directly to the streets and alleys and the few sewers that do exist discharge directly into the wadis within the city.

The remainder of the sewage is discharged to cesspools, most of which are located under the city streets and alleys, creating not only odors and insect nuisances, but also a continuing threat of direct contact of sewage with feet, food and water. The results of these conditions are reflected in the high infant mortality rate and the high incidence of diseases associated with gross pollution.

Many cases of intestinal parasites are known to go untreated and unreported, and only receive treatment as a result of some other condition or accident that causes the patient to seek medical help. Interviews with several foreign doctors practicing in Yemen indicate that a very high percentage, more than one-fourth of their patients, suffer from intestinal and other types of parasites. Round worms, tape worms and bilharzia are commonplace.

The extremely high level of nitrate in the water supply is thought to be responsible for many cases of infant mortality and abortions, but no statistics on this are available. A great deal of literature exists that deals with the relationship of high nitrate levels in water supplies with the incidence of methemoglobanemia; however, due to the fact that most births are not attended by medical personnel and few pregnant women receive medical attention during either their pregnancy or after childbirth, and the lack of any records, it can only be assumed that this is a significant factor in Taiz.

Cholera is known to occur frequently, particularly in the areas near the wadis. Other water related diseases are present in the Taiz area, but no statistical information is available to establish the extent of these diseases. Dysentery is known to be endemic among the population.

Wastewater System

The planning of any wastewater system must give consideration to (1) the quantity and characteristics of the wastewater, (2) promotion of public health through elimination of health hazards, and (3) the economic ability of the community to pay for the system.

During the preparation of this report, the entire service area was studied, utilizing the existing and projected land use, the future population densities, and ground elevations based on area contour maps.

EXISTING SYSTEM

Prior to 1970, the Taiz wastewater system consisted of only 0.5 kilometers (1,500 ft) of sewers extending from the Medina area to Wadi Seena. From 1970 to date, the Municipality of Taiz has extended the system and installed, or has under construction, approximately 9.0 kilometers (27,000 ft) of trunk sewers as shown on Figures 9-1 through 9-4. The existing system serves an area of 75 hectares (185 acres) which has a total population of approximately 12,500. The records of the Municipality of Taiz show a total of 263 connections to the existing system in 1974. Utilizing the average number of people per housing unit as determined by the random sample survey described in Chapter 6, approximately 2,000 persons, or 16 percent of the population within the area served, are connected to the existing system.

Taiz has no wastewater treatment facilities. The existing system discharges raw sewage directly into wadis and other natural drainage areas at several locations throughout the city. This creates multiple health hazards and also pollution of the present source of water supply as described in Chapter 5, Existing Water System.

Approximately 40 percent of the population has water flush systems in their homes. Due to an inadequate wastewater collection system, most of these homes dispose of wastes either to cesspools, or directly into streets and wadis. The remainder of the residents use pit latrines or open holes in the ground.

Spot samples of raw sewage collected from the existing system were analyzed. The results are shown on Table 9-1.

TABLE 9-1

TAIZ SEWAGE CHARACTERISTICS

Description	Sample Characteristics	
Sample Number	1	2
Chemical Oxygen Demand (COD) mg/l	1,270	1,540
Total Dissolved Solids (TDS) mg/l	2,490	2,480
Total Solids (TS) mg/l	3,140	3,370
Water Supply TDS (mg/l) (weighted average)	1,680[a]	

[a]Area served by sewers receives 80 percent groundwater; 20 percent mountain water.

These values indicate an average increase of 800 mg/l in TDS and an average BOD of 940 mg/l. Using an average per capita contribution of 0.12 pounds (54 grams) per day of BOD, this results in an average sewage flow of about 15 gallons (85 liters) per day per capita. This flow is greater than the average per capita water supply to Taiz; however, this is explained by the fact that the area served has 12,500 residents (or approximately 1,620 families), with 263 sewer connections. All of these families with sewer connections have water service, which increases the per capita water consumption to approximately 78 lpcd for those with water service.

Storm Drainage

The existing system carries sanitary wastes only. Due to the steep terrain and excellent drainage of the city and limited rainfall, storm drainage is not considered to be a major problem in Taiz.

Sewer Pipe

The existing system is constructed of locally manufactured non-reinforced bell and spigot concrete pipe. The pipe is manufactured by numerous small establishments in a "backyard" operation. Concrete

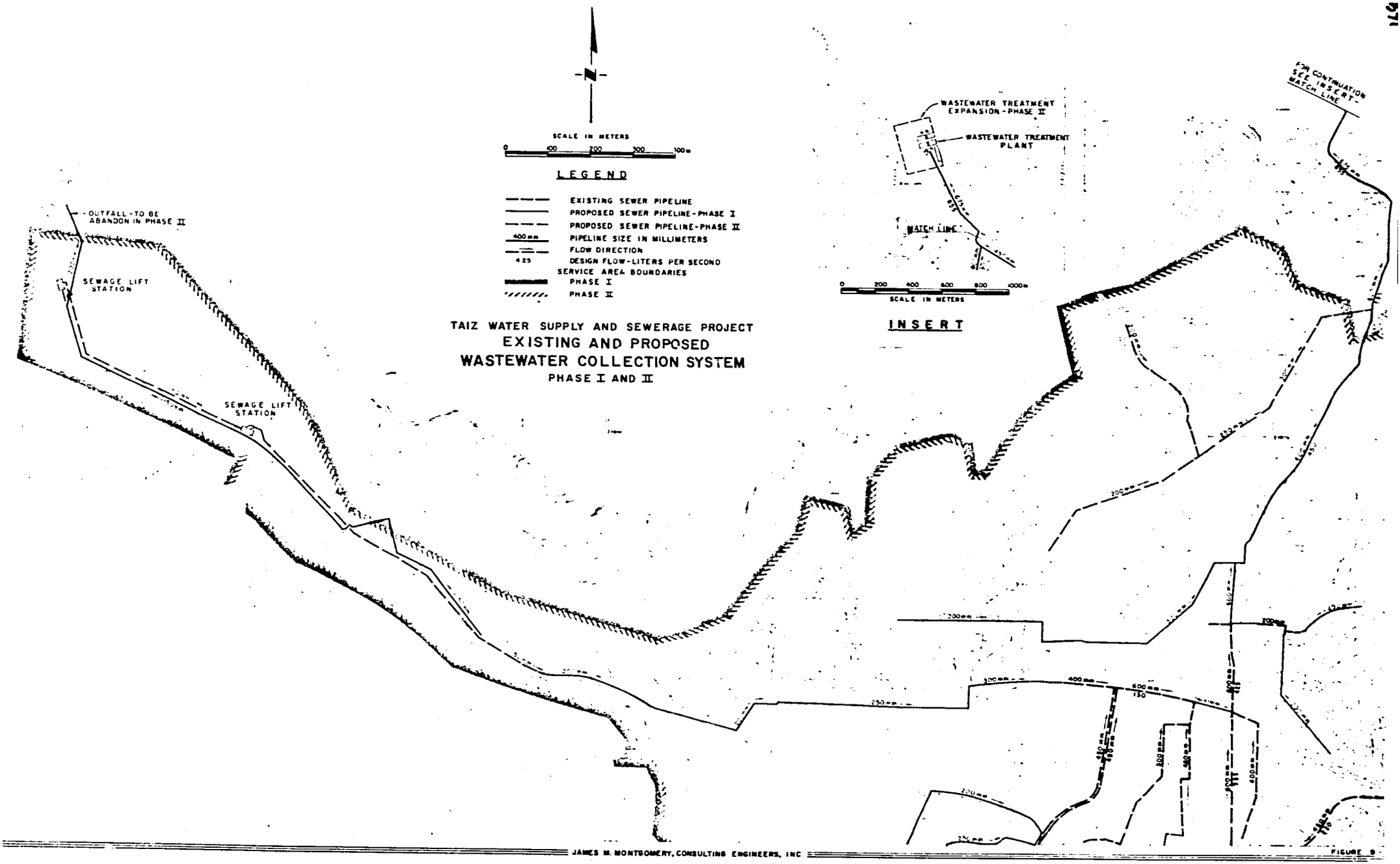

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FIGURE 9

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

EXISTING AND PROPOSED WASTEWATER COLLECTION SYSTEM

PHASE I AND II

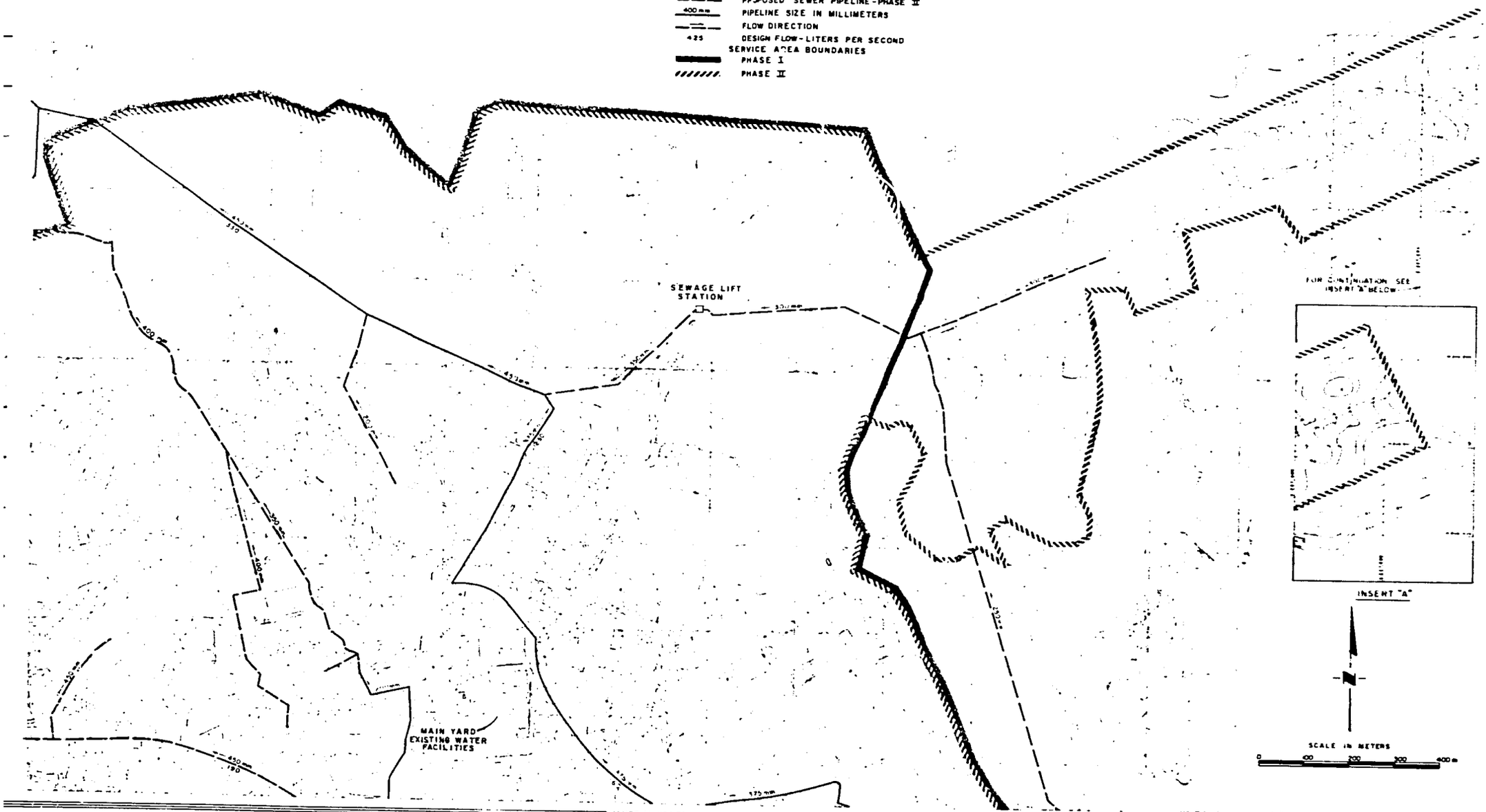

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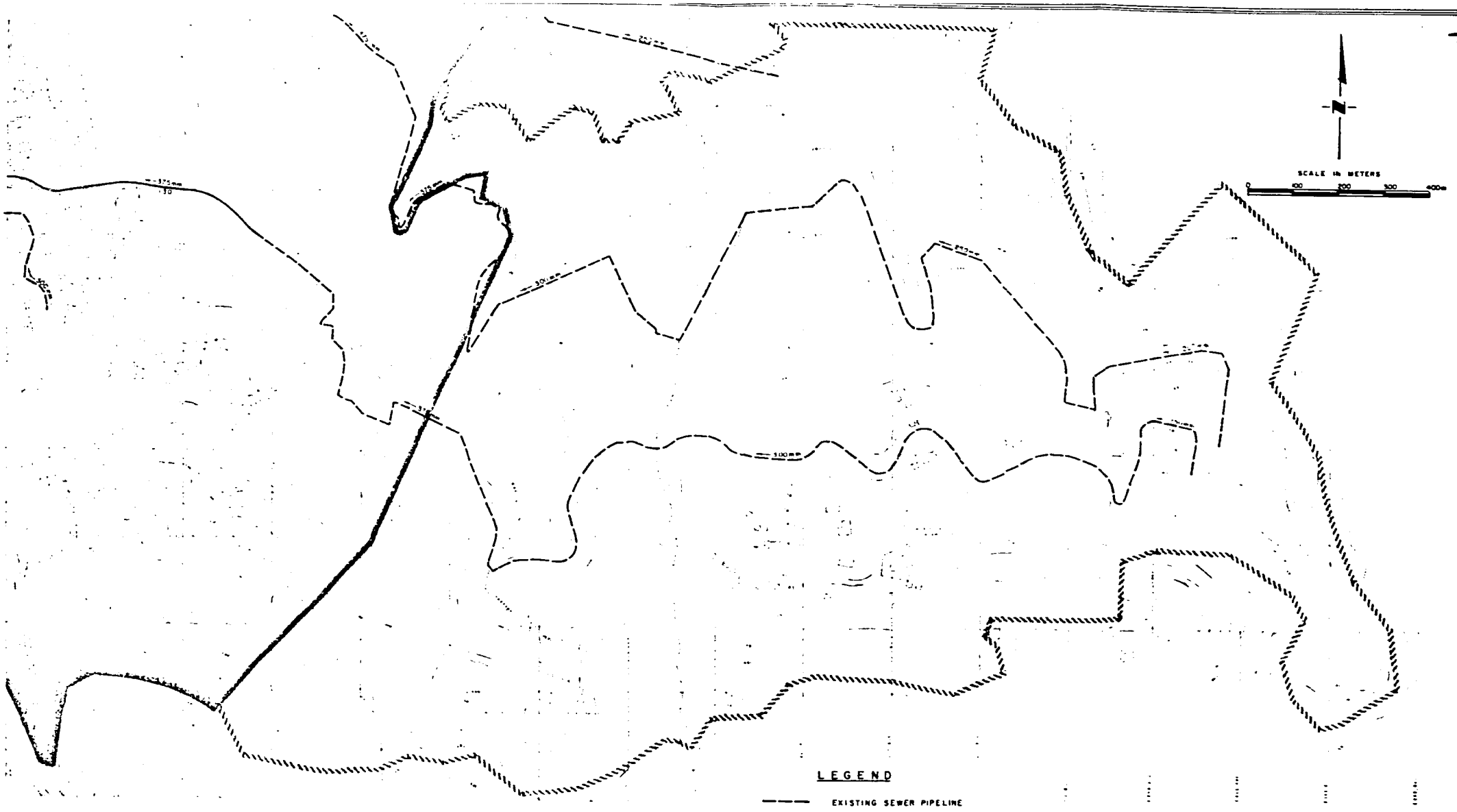
FIGURE 9-2



LEGEND

- EXISTING SEWER PIPELINE
- PROPOSED SEWER PIPELINE-PHASE I
- PROPOSED SEWER PIPELINE-PHASE II
- 400mm PIPELINE SIZE IN MILLIMETERS
- FLOW DIRECTION
- 425 DESIGN FLOW-LITERS PER SECOND

SERVICE AREA BOUNDARIES

- PHASE I
- PHASE II

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

EXISTING AND PROPOSED WASTEWATER COLLECTION SYSTEM

PHASE I AND II

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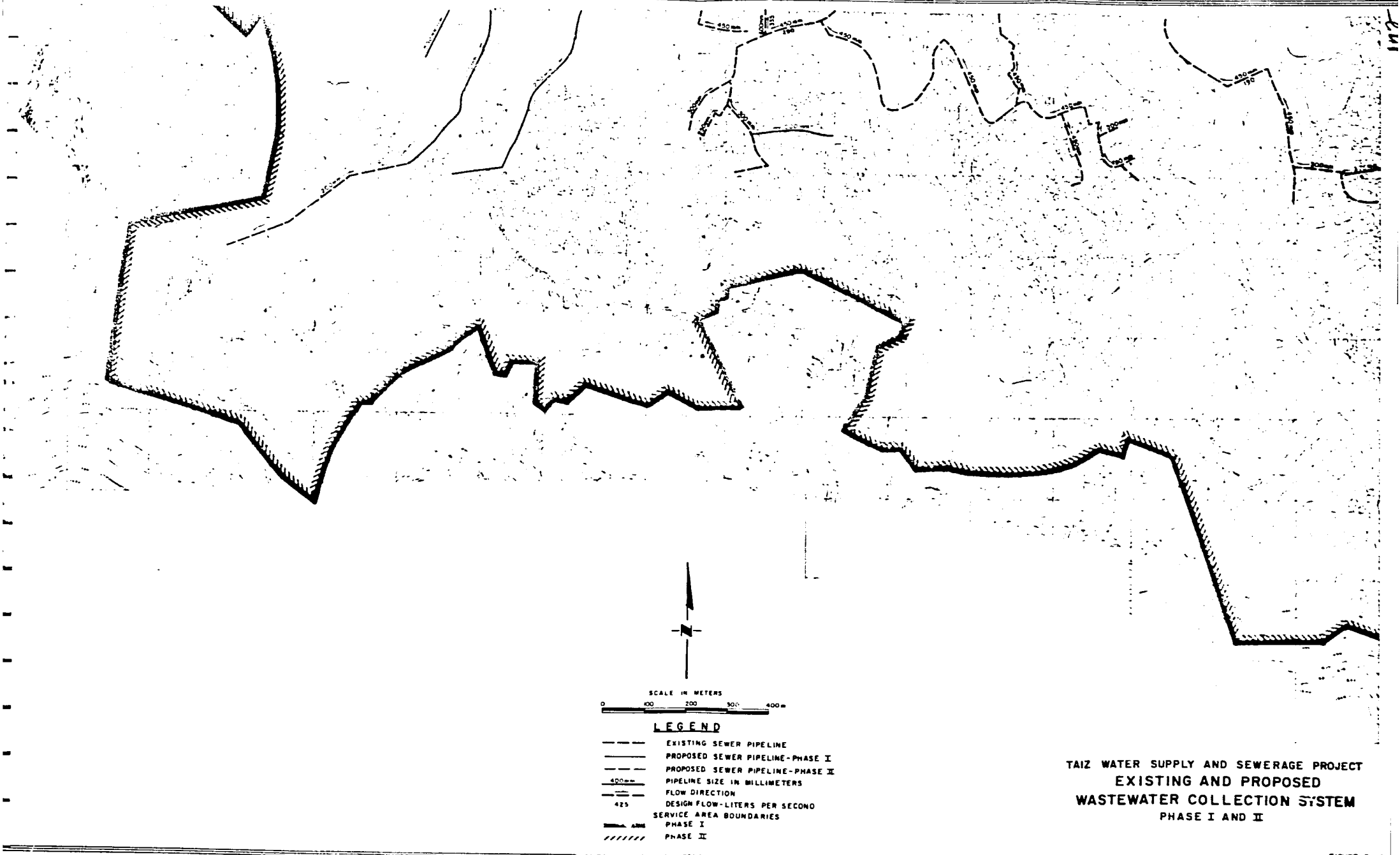
FIGURE 9-3



TAIZ WATER SUPPLY AND SEWERAGE PROJECT
EXISTING AND PROPOSED
WASTEWATER COLLECTION SYSTEM
PHASE I AND II

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FIGURE 9-4

pipe is available in diameters of 100 mm (4 in) to 900 mm (36 in) in one meter (3 ft) lengths. Tees and elbows are currently available in 100 mm (4 in) and 150 mm (6 in) diameters. The structural quality of the pipe is generally poor due to improper techniques and poor quality control. The concrete for pipe is hand mixed, placed in steel forms and hand rodded. No vibration is used. The pipe is either air cured or water cured by submerging in water at the discretion of the pipe manufacturer.

Installation and Construction

Current practices for installation of sewers is not acceptable by most construction standards. Depth of cover over pipe is generally one meter (3 ft) which is adequate; however, all pipe is utilized regardless of its condition, either before or after the pipe has been laid. Jointing the pipe consists of merely applying mortar over the bell and the next section of pipe with no attempt to insert mortar into the joint. The trench is hand-excavated and no control is made for alignment or grade. Little or no care is exercised to shape the foundation or to provide a suitable bed for the pipe. Also, little care is taken in backfilling of the trench to make sure that the material used is of suitable granular quality or compacted under and around the pipe. Backfill consists of shoveling the excavated material, consisting of rocks of all sizes and gravel, back into the trench. This results in having rocks lying next to the installed pipe, no compaction, and an improper bedding condition.

Manholes

Present methods for construction of manholes is acceptable. Manholes are constructed of masonry with a cement plaster applied on the inside. The manholes are one meter by one meter (3 ft x 3 ft) and are adequate in size for maintenance. Due to a lack of standard maintenance equipment, manholes are generally spaced at intervals of less than 50 meters (150 ft), which is acceptable.

Existing Revenues and Expenses

There are currently no sewer rate charges collected by the municipality. The only revenue accruing to the municipality is a variable charge collected at the time a connection is made to the system. This charge is dependent upon the applicant's ability to pay and ranges from 100 to as much as 1000 Rials (20 to 200 U.S. dollars). The charge includes the permit fee, plus a portion of the main trunk sewer construction

cost. In addition to this, the applicant pays for the house connection installation from the laterals to the dwelling. All expenses for the wastewater system are paid from the City General Fund for which no budget has ever been prepared.

EXISTING ORGANIZATIONAL STRUCTURE

The Taiz wastewater system is owned and administered by the Municipality of Taiz. The Engineering Department is divided into three sections, Planning, Utilities and Public Health as delineated in Figure 9-5.

MANAGEMENT

The Municipalities Organizational Chart showed 140 persons, not including the General Director or Assistant Director, were employed in the Engineering Department at the time this study was completed. Three of these staff positions are occupied by the heads of the three engineering sections. Each section chief reports directly to the Assistant Director who in turn reports to the General Director.

There are currently no personnel in the Engineering Department who are technically qualified in sewer design. Sewers are presently designed by the "eye-ball" method and consequently are oversized to meet the needs of the year 1995. Maintenance is performed by using personnel from the 120 street sweepers employed by the municipality. The street sweepers are primarily responsible for cleaning the streets and solid waste collection.

RECOMMENDED IMMEDIATE IMPROVEMENTS

It is apparent from inspection of the Taiz area that improvements in the sanitary standards of the area are urgently needed. The health and well-being of a community is a vital prerequisite to progress and development, and unsanitary disposal of human wastes causes more harm to the public health of a community than any other single factor. Much can be done at the present time to improve sanitary conditions within the municipal area with a minimum of expense. It is vital that these improvements include modifications in the construction practices used by the municipality in their ongoing program for expansion of the existing sewer system so that it is constructed properly and can be incorporated in the proposed future system. These improvements can be accomplished with resources available to the municipality or with aid from the National Government. Some obvious remedial measures are as follows:

ORGANIZATION CHART - MUNICIPALITY OF TAIZ

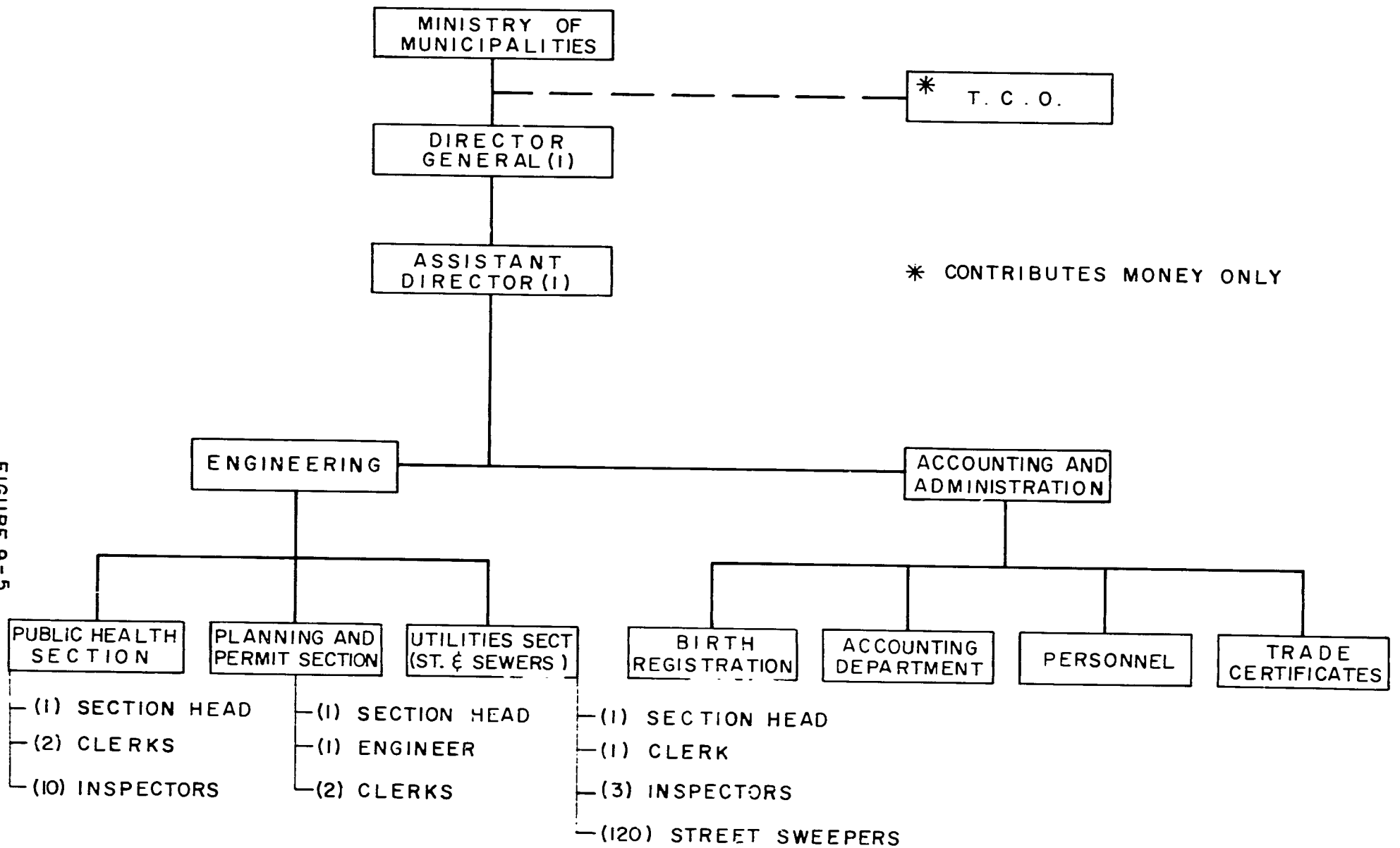

FIGURE 9-5

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1. Implementation of a program to construct public toilets, adequate to serve a neighborhood population of approximately 400 persons each. These public toilets as described later in this chapter should be constructed at convenient locations in the Medina and other low-income areas, and be maintainted in a clean and sanitary manner to promote public use. An educational program on the utilization and sanitary maintenance of these facilities should be emphasized and should parallel the construction of these public toilets.

2. Initiate a quality control program for locally manufactured concrete pipe. This program should include a standard concrete mix design, exclusive use of limestone fine and coarse aggregate, improved vibration techniques, better control of the end joints and water curing. A minimum of 7 days curing, utilizing a water "bath" or sprinkling system with burlap bags, should be enforced to improve structural strength of the pipe. A suitable limestone aggregate should be used for all sewer pipe to provide additional protection against hydrogen sulfide attack. A qualified construction inspector should also be appointed by the municipality to supervise and enforce these improvements.

3. Utilize proper sewer installation and bedding procedures. Installation procedures can be improved by the use of batter boards to control alignment and slope which are currently uncontrolled. Use of pea gravel bedding and compaction to a depth of 15 cm (6 in) over the top of the pipe will increase the loading factor to acceptable standards.

4. Use plastic pipe for house connections and small laterals as soon as it is locally available. Estimated start of manufacture of this pipe at a plastics plant located northeast of Taiz near the biscuit factory is expected by mid-1975. A minimum size of 4 inches should be used by residences and 6 inches for the upper reaches of the street laterals.

5. An inspection program of all existing cesspools to eliminate those that are constructed near existing water pipelines. At the time this report was prepared, almost 50 existing cesspools were known to have water pipes passing directly through them. The cesspools were constructed around the water pipes,

rather than relocating the water pipes or the cesspool. As a result, numerous cases of water contamination have been recorded in those areas where this condition exists.

QUANTITY OF SEWAGE

Water consumption for various land-use classifications was investigated. At present, water consumption is limited by the availability of water and by a limitation on ability to distribute water. Present per capita water consumption in the residential areas is estimated to be approximately 45 liters (12 gallons) per day. It is predicted that this rate will increase rapidly after an adequate water supply system is built to serve the area. Total domestic water consumption is expected to be approximately 80 lpcd by 1985 and 90 lpcd by the year 1995. It is estimated that approximately 80 percent of the water consumed will be returned as sewage. Due to the steep terrain of the city and low ground water table, infiltration of water into sewers is minor and has been neglected for the purposes of this report. An estimated ultimate sewage flow of 72 lpcd plus appropriate peaking factors were used to determine the sewer sizes in residential areas. A projected water demand for various non-domestic uses was made in Chapter 7, Future Water Demands. It is estimated that 95 percent of this water will be returned as wastewater.

For this study, the projected sewered population was estimated on the basis of the anticipated population for the city. By the year 1995, approximately 90 percent of the total estimated population will be served by sanitary sewers and 60 percent of the population will be served by the year 1985. The unsewered population will be in areas that cannot feasibly be sewered. In these areas, all houses should be connected to septic tanks.

DESIGN CRITERIA

The design of a wastewater collection system depends upon such factors as the quantity of flow, a coefficient of pipe roughness, the desired depth of flow during peak periods, the range of allowable velocities, the slopes for various pipe sizes, and economical limits of trench excavation.

COEFFICIENT OF FRICTION OF SEWER PIPES

In this report, the Manning's formula for flow calculations has been used, with a roughness coefficient of 0.013. This roughness factor accounts for variation in smoothness of the pipe interior when fabricated and

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installed. It is also sufficiently conservative to allow for grease accumulation, slime growth, settlement of the pipe with attendant cracking, or other similar effects on the smoothness of the pipe interior in the future.

PEAKING FACTORS

The wastewater collection systems were sized not only for average flow conditions, but also to transport flows substantially above or below the average flow. The rates at which water is used, and consequently, at which wastewater is produced, vary greatly, not only throughout each day, but also during each weekly, monthly and yearly period. In general, the smaller the contributing population, the wider the range of the fluctuation in flow. Figure 9-6 is a graphical representation of the expected ratio of the maximum instantaneous flow rate to that of the average daily flow rate which an area produces in the Taiz community. By the use of this curve, the average daily flows are adjusted to reflect the instantaneous flow or peak flows needed for the design of the collectors. All collection sewers were sized to flow full at peak flow, to minimize the cost. The minimum diameter of primary collectors, however, is 200 mm (8 in). This is the minimum size that will ensure ease of maintenance and be relatively free of stoppage problems.

VELOCITY

A minimum velocity of 0.6 meters per second (2 fps) when flowing one-half full was adopted in the sizing of collector lines in order to prevent deposition of grit and other solids. A maximum velocity of 3.3 meters per second (10 fps) is used to preclude scour at those times when the wastewaters may contain sand or other abrasive materials, except in those lines 200 mm or smaller where higher velocities can be tolerated in short stretches to eliminate drop manholes.

MANHOLE STRUCTURES

Manhole structures are constructed for the purpose of maintaining the collection system and must not be utilized as convenient locations for the connection of house sewers. The presence of such connections in manhole structures interferes with normal maintenance of the facilities. The spacing of manholes was generally limited to a maximum of 100 meters to facilitate ease of cleaning.

Manhole structures are included at each major change in alignment and grade. They are also included as junction chambers where two or more collection lines join.

Because drop manhole structures are difficult and more costly to maintain, they are used only where a vertical curve or an extra standard manhole cannot be used in lieu of the drop structure.

CURVED ALIGNMENT SEWERS

Considerable economy can be realized by constructing selected sewers along a curved alignment. In addition to reducing the number of manholes required, the number of water pipe crossings are normally greatly reduced. Curved alignments within curved streets also permit the sewer to be constructed along one side of a roadway in lieu of crossing from one side of the road to the opposite side. This greatly reduces interference with the movement of people and traffic during construction.

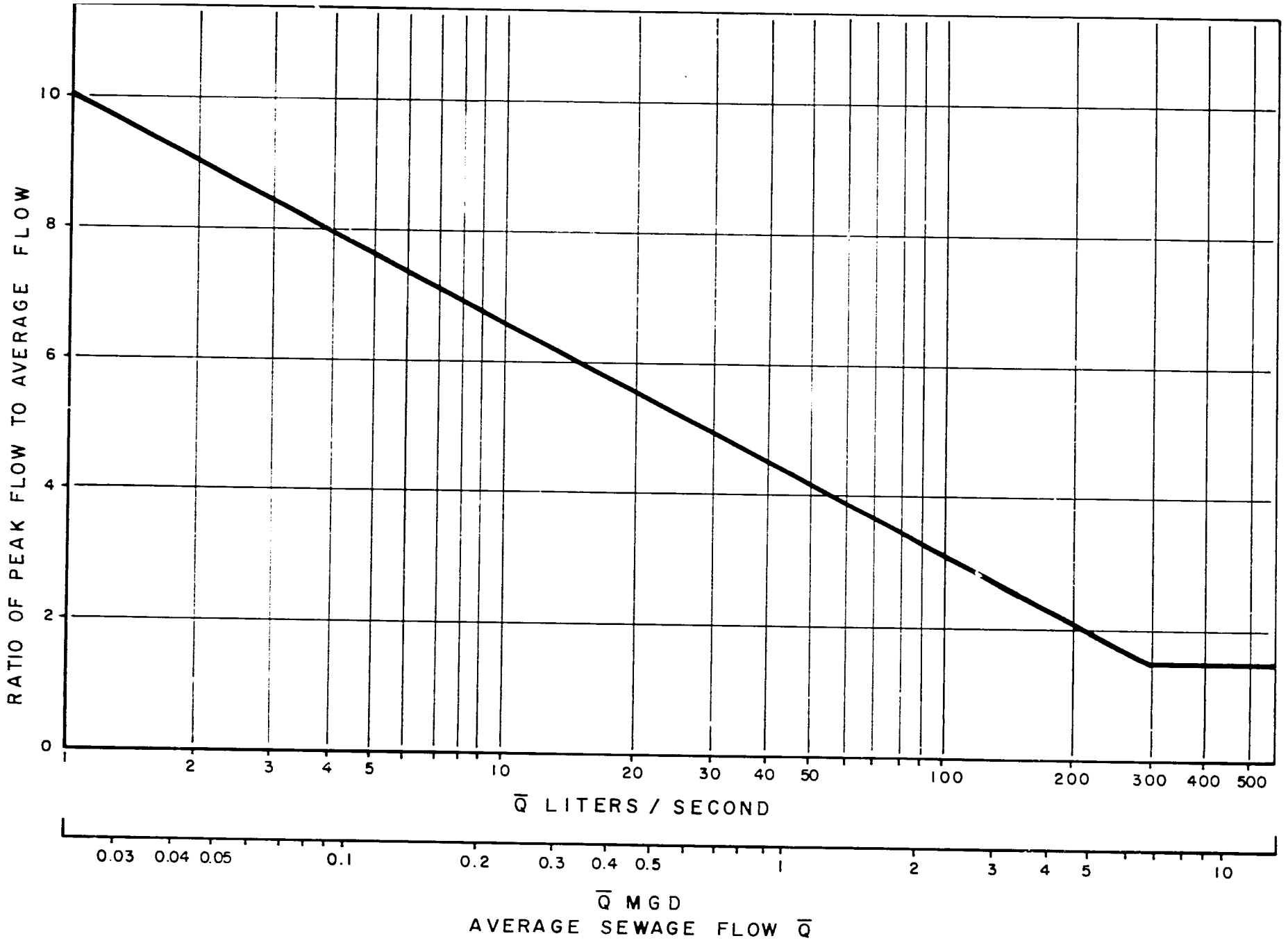
A significant portion of any agency's budget will be expended on the maintenance of manhole structures. With fewer sewer manhole structures by virtue of the curved alignment, operation and maintenance expenses are reduced.

Experience has shown that sewers can satisfactorily be constructed with almost any radius. The minimum radius is dictated by the maximum deflection permissible at each joint. By utilizing pipe of approximately 1.5 meters in length, the minimum radius of alignment is 30 meters.

Vertical as well as horizontal curves are incorporated satisfactorily. However, only one curve is permitted between any two sewer manhole structures. Vertical curves are especially useful in lieu of drop manhole structures in areas of irregular terrain.

STORM DRAINAGE

No provisions were made to transport any storm flows. The general steep terrain of the project area and the high intensity of the storms would require a greatly oversized system to handle the storm runoff and eliminate contamination caused by flooding of the system. This oversizing of the system and treatment facilities would greatly increase the cost, which is not warranted.



RATIO OF PEAK HOUR FLOW TO AVERAGE SEWAGE FLOW

FIGURE 9-6

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DESIGN FLOW RATES

Due to the steep terrain of the city, the drainage areas for each trunk sewer are relatively small; therefore, all trunk sewers are sized to safely transport the expected ultimate flows.

INDUSTRIAL AND COMMERCIAL SEWAGE FLOWS

Flows of 24 cu m/hectare/day (2,000 gal/acre/day) for Phase I development and 53 cu m/hectare/day (4,660 gal/acre/day) for Phase II development are anticipated as the peak flows for all of the industrial and commercial areas.

DOMESTIC SEWAGE FLOW

The estimated domestic sewage flows are based upon the anticipated population densities for all the various areas of the project area and the amount of wastewater developed on a per capita basis as discussed in the section of this report titled "Quantity of Sewage."

SEWER PIPE MATERIALS

Sewer pipe can be locally made PVC (up to 160 mm), plain or reinforced concrete, or imported PVC, and asbestos-cement pipe, depending upon cost and availability.

PROPOSED COLLECTION SYSTEM

In order to provide a systematic and economical expansion of the existing wastewater collection system, a master plan of wastewater improvements was developed for the Taiz area on the basis of two phases of construction, designated as Phases I and II. The proposed wastewater collection system coincides with the area served by the proposed water system and is indicated on Figures 9-1 through 9-4 for each of the construction phases. The existing wastewater system was analyzed and determined to be adequate in capacity and was incorporated in the proposed master plan for wastewater improvements.

The proposed wastewater collection system for Phase I is designed to serve that area of Taiz that is expected to be developed by the year 1985. It is anticipated that 60 percent of the projected population will be connected to the wastewater system at that time (1985). Phase II will provide for the extension of the system to serve the entire study area in which approximately 90 percent of the population will be connected to

the wastewater system, as discussed in the sub-chapter titled "Quantity of Sewage." These estimates are based on the assumption that all new buildings, i.e. residences and commercial constructed after the adoption of this report will be connected to the sewerage system. The number of existing residences and commercial buildings currently not connected should be encouraged to become connected to the system. An estimate of the future connections is listed in Table 9-2.

TABLE 9-2

ESTIMATED NUMBER OF SEWER CONNECTIONS

Description	Year			
	1973	1975	1985	1995
Estimated Population	84,800	95,300	170,600	305,400
Number of Buildings	7,460	9,100	16,500	29,600
Number of Buildings not Connected to Sewers	7,225	8,600	6,500	3,000
Number of Buildings Connected to Sewers	235	500	10,000	26,600
Percent (%) Buildings Sewered	3.15%	5.5%	60.6%	89.9%

PHASE I

Sewage Collection System

The Phase I sewage collection system is designed with adequate capacity to transmit the peak flows for the anticipated future population and industrial development of Taiz in the year 1995, but is restricted to serve only the Phase I service area. This procedure results in an overall cost saving of the total master plan development, by eliminating the need to install parallel or replace Phase I sewers with higher capacity sewers to carry the ultimate Phase II flows.

This causes the Phase I construction to be slightly higher by having some sewer lines oversized, but makes the overall cost considerably less expensive than if replacement or parallel lines were required in

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Phase II. The Phase I sewage collection system for all pipe sizes 200 mm and greater is shown on Figures 9-1 through 9-4. In addition to the proposed location of the collection lines and diameters, the peak design flows are shown for all the principal mains, 380 mm and larger, regardless if they are new sewer pipes or part of the existing system.

As previously stated, the existing system was utilized to the greatest extent possible to minimize the capital cost investment. In general, the existing system was greatly oversized, which permitted its use to convey those large flows from the expanded service area.

A summary of the sewer pipe that makes up the existing and proposed Phase I sewage collection system is listed in Table 9-3.

TABLE 9-3

SUMMARY OF PHASE I SEWER PIPE

Description	Quantities (Meters)
Existing Sewage Collection System	
200 mm Diameter	400
250 mm	1,700
300 mm	1,300
400 mm	1,200
450 mm	3,800
600 mm	800
Total	9,200
Proposed Sewage Collection System	
150 mm Plastic	46,800
200 mm	2,740
250 mm	690
300 mm	250
380 mm	8,370
450 mm	1,350
600 mm	1,020
680 mm	650
Total	61,870
House Connections	
100 mm Plastic	70,200

House Connections

It is important that as many residences and commercial establishments as possible be connected to the wastewater collection system to reduce health hazards and ground water contamination; however, the low-income of a large portion of the population of Taiz will inhibit the number of voluntary connections. A recommendation has been made in Volume III, which prohibits the delivery of water to a dwelling unless adequate sewage facilities exist, either connected to the sewage collection system or to an approved septic tank, except in very low income areas where public toilets are provided. To encourage all families to become connected to the sewage collection system, the installation of a house connection from the structure to the sewer lateral has been included as part of the recommended project. The cost of the pipe, locally fabricated plastic pipe, and the cost of installation have been included as a capital cost. The residences are not required to pay a connection fee.

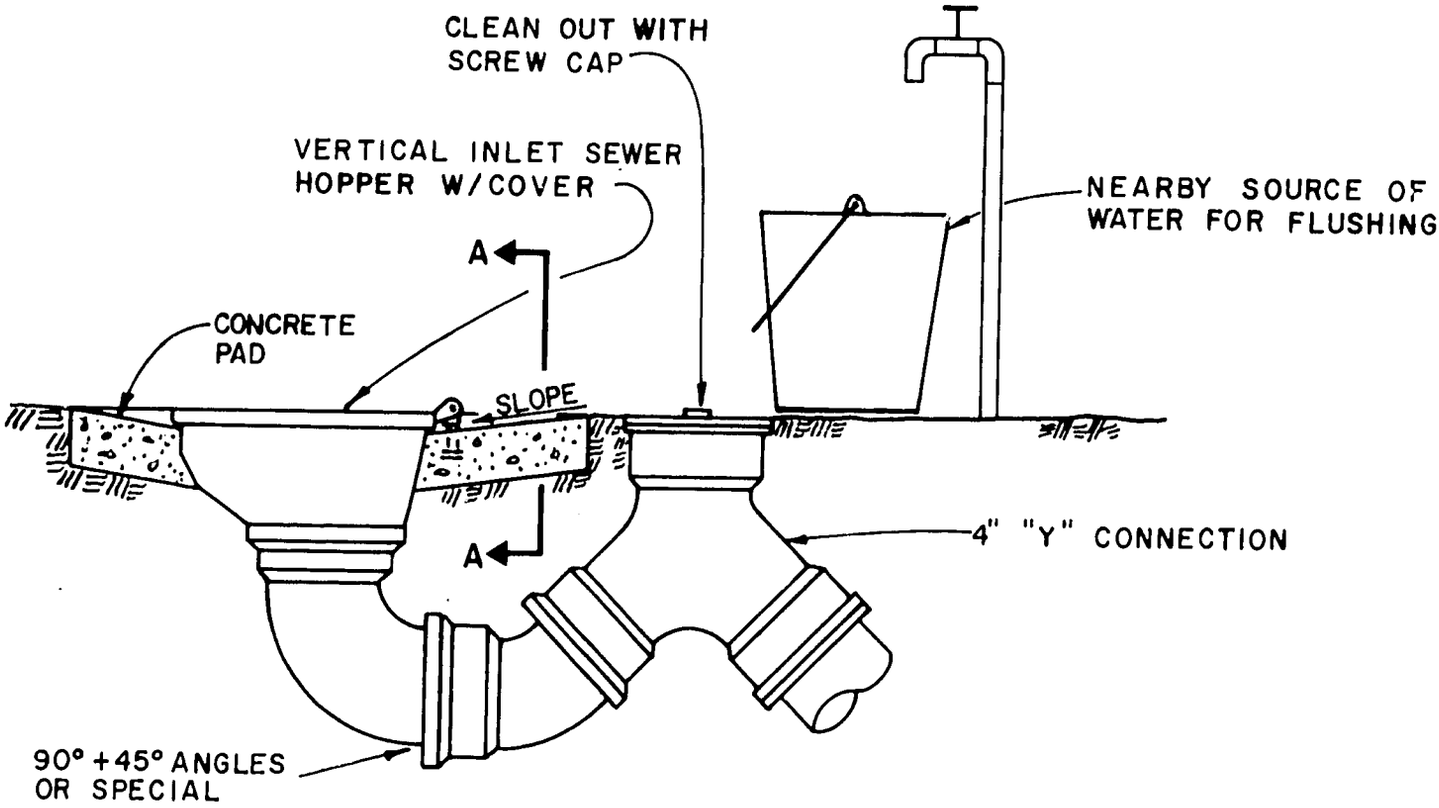
All costs associated with making house connections after the completion of the project, as well as the operation and maintenance costs of the entire wastewater system, will be covered by the revenues received from water sales and service charges.

Low Cost Water Seal Privy

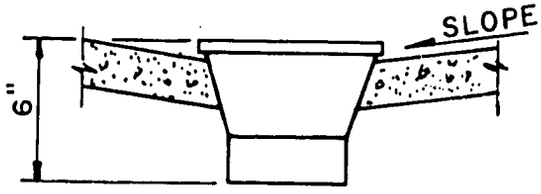
To further encourage all residences to install sanitary facilities and become connected to the wastewater system, it is recommended that a low cost privy be fabricated, locally if possible, and sold to the residences of Taiz at a low price. The installation must also be included as a part of the package to ensure that proper installation of these facilities is maintained. The cost of installation of the water seal privy has not been included in this report because of the possible complexities associated with the installation in the various commercial establishments and the multi-storied residences. A sketch of a proposed water seal privy is shown on Figure 9-7.

Public Toilets

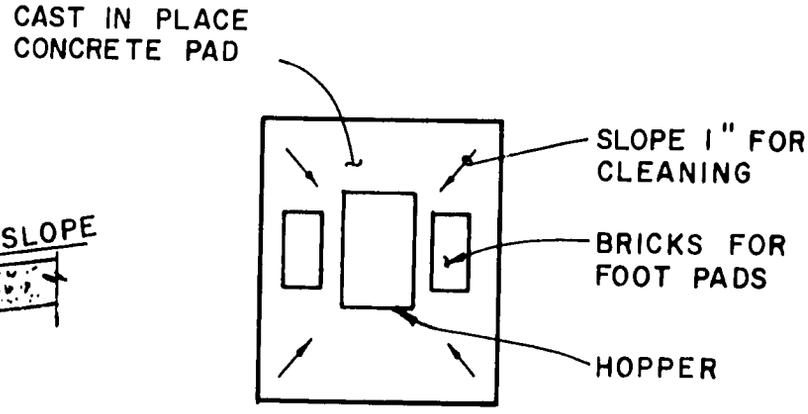
It is recommended that public toilets (water flush) be constructed in existing low-income high-density areas which lack indoor sanitary facilities. Each toilet should be constructed at a convenient location adequate to serve approximately 400 persons and limiting the maximum walking distance for most of the residents to be served to less than 150 meters (500 ft). A proposed sketch of a public toilet is shown on Figure 9-8.



TYPICAL VERTICAL SECTION

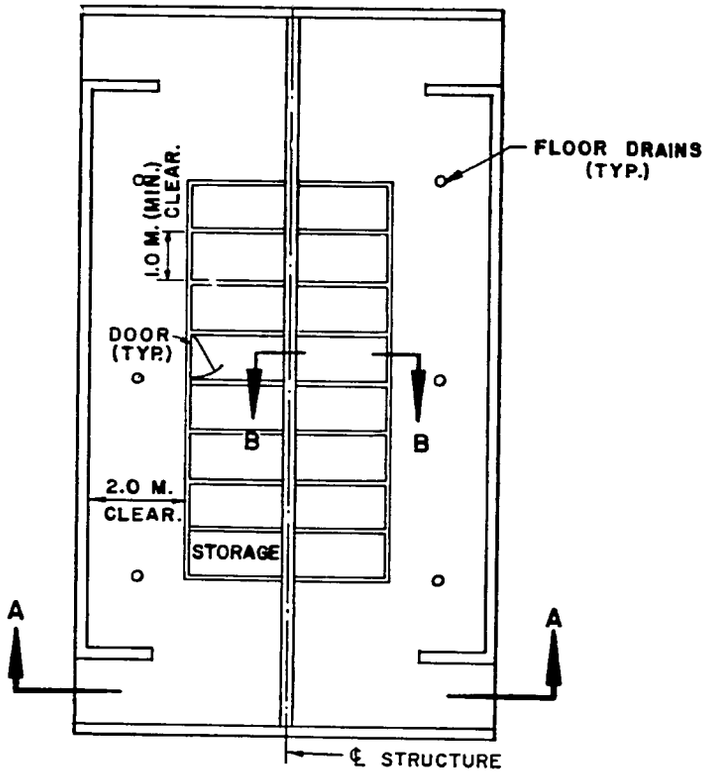


SECTION A-A



PLAN VIEW
NOT TO SCALE

WATER SEAL PRIVY



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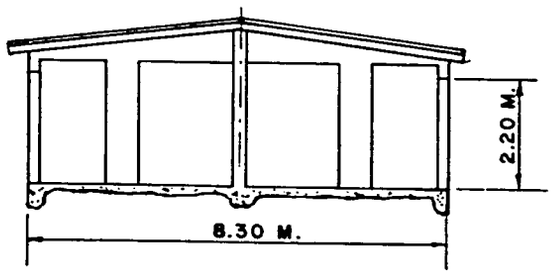

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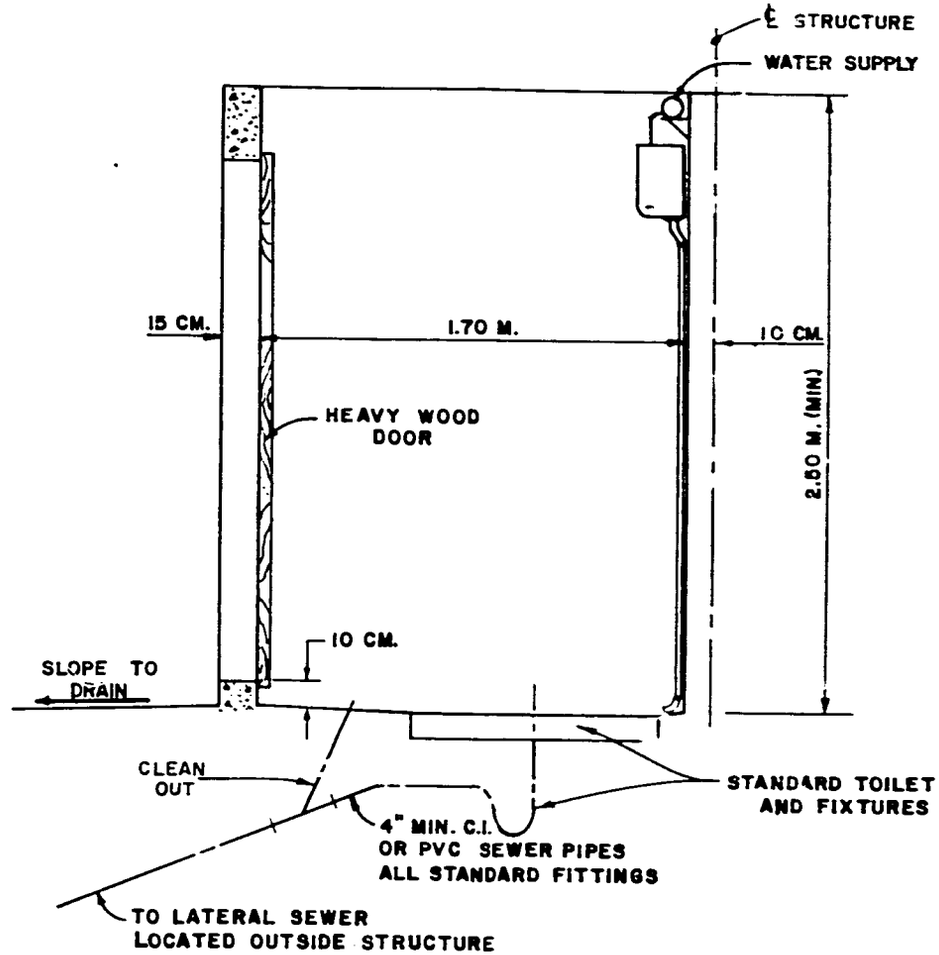

SECTION B-B
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TAIZ WATER SUPPLY AND SEWERAGE PROJECT
PUBLIC TOILET

FIGURE 9-8

A total of 15 public toilets is estimated to be adequate to serve the needs of the low-income population Phase I. Due to the increased per capita income and proposed mandatory connections for all new construction, no public toilets will be required in Phase II.

PHASE II

The Phase II portion of developing the wastewater collection system consists of expanding the installed Phase I system to meet the sewage discharges anticipated by the year 1995. The populated and industrialized areas expected to develop are, in general, to the east of Taiz, both along the base of Jabel Sabir, and along the Taiz-Sana'a Highway. The wastewater discharges from the residential areas at the base of Jabel Sabir will flow by gravity into the proposed Phase I wastewater collection system to the wastewater treatment plant. The wastewater discharges from the East Industrial Zone will require pumping to get the wastewater discharges into the Phase I system to flow by gravity to the wastewater treatment plant. A similar situation exists in the West Industrial Zone which is expected to expand to a point where it will become necessary to install two package-style sewage lift stations to pump the sewage up into the Phase I system for gravity flow to the wastewater treatment plant. For the proposed layout for the Phase II wastewater collection system, see Figures 9-1 through 9-4.

A summary of the sewer pipe and major facilities proposed for this phase of the development is listed in Table 9-4.

TABLE 9-4

SUMMARY OF PHASE II SEWERAGE FACILITIES

Description	Quantities
Sewer Pipe	
150 mm - Plastic	37,200 m
200 mm	1,460 m
250 mm	3,220 m
300 mm	2,400 m
380 mm	2,200 m
Total	46,480 m
Force Mains	
350 mm	350 m
150 mm	1,950 m
Total	2,300
House Connections	
100 mm - Plastic	56,700 m
Sewage Lift Station	
Q = 135 liter per second	1
Q = 25 liter per second	2

WASTEWATER TREATMENT

At the present time, the disposal practices for sewage within the city of Taiz result in the disperson of the sewage generated by the community over a wide area. With the advent of the increased water supply to the community, such practices would result in an intolerable situation being created within the city, and downstream, both from a public health and aesthetic standpoint. Therefore, it will be necessary to collect the increased quantity of sewage and to convey it to a location where treatment and disposal can be accomplished.

The selection of a sewage disposal scheme was approached through examination of two alternate plans. Initially considered was a scheme which would export from any presently active ground water basins all sewage produced in Taiz. The second concept explored was based on maximum reclamation of sewage water through treatment and recharge of the effluent to a ground water basin proximate to Taiz.

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EXPORT PLAN

The accomplishment of the primary health objectives of the sewerage scheme, i.e., removal of untreated wastes from the vicinity of the urban population of Taiz, could be done by transporting these wastes through an outfall sewer to a remote, uninhabited area. This plan would eliminate the need for treatment facilities and attendant operating costs.

An area exists in a wadi located some 7 kilometers downstream of the city, below the Hougala well field, where raw sewage could be discharged with a minimum risk of creating health hazards and aesthethic insult. This potential discharge location is minimally populated and appears to have been abandoned as an agriculture area due to the high salt content in the soil and soggy condition that exists through most of the year. Gravity flow is possible to this site and would require 7,000 meters of 685 mm diameter pipeline.

Although the raw sewage export plan would represent the lowest cost solution to disposal of Taiz' liquid wastes, this plan was abandoned for the following reasons:

- The risk of creating a serious health hazard by discharging raw sewage in an "apparently" uninhabited area is too great. The vast majority of the population of Yemen is rural and located in small villages virtually everywhere in the mountainous regions of the country. Human and animal contact with raw sewage deposited in any location, no matter how remote from the city, is certain to occur.

- The chemical quality of the sewage to be produced by Taiz, with implementation of the proposed water system expansion, in terms of TDS and nitrates, is far superior, than the present quality of water in the Hougala ground water basin. Considering the extremely limited supply of water available to support the city's anticipated growth, export of relatively good quality, reclaimable sewage out of the basin cannot be justified.

TREATMENT AND RECLAMATION PLAN

The principal purpose of the sewerage scheme is to eliminate the present and potential highly hazardous health and nuisance sewage situation in Taiz. Also of considerable importance to the city is its long-term water source budgets. An evaluation of all water sources within the areal scope of the water resources investigation reveals that water

in sufficient quantity and acceptable quality is available to satisfy the anticipated needs of the city for only twenty years. Therefore, the plan to treat all collectable sewage from Taiz for purposes of reclamation and recharge has been adopted.

Projected Water Quality for Houban-Hougala Basin

The increasing concentrations of total dissolved solids, nitrate concentrations and other inorganic salts in the present water supply from the Houban-Hougala wells makes it mandatory to discontinue this supply as soon as the supply from the El Hiama basin becomes available.

When the first phase project water supply from El Hiama basin reaches Taiz, it is proposed that water production for municipal purposes be discontinued at Houban and Hougala well fields. The water supply derived from El Hiama will have quality characteristics superior to those supplies presently derived from the Houban-Hougala sources. Project quality analyses indicate total dissolved solids concentrations in waters from El Hiama to range between 500 and 600 milligrams per liter while waters currently produced from Houban-Hougala average near 2,300 milligrams per liter.

It is expected that the high quality El Hiama waters will circulate through the water supply system, enter the proposed sewerage system and be discharged from a wastewater treatment plant into Wadi Taiz. At the point of discharge it has been determined that treated effluent will contain an average of 1,000 milligrams per liter of total dissolved solids. Through time, the quantity and quality of effluent discharged will improve the quality of waters in Wadi Taiz and Hougala Basin.

Figure 9-9 depicts the hypothetical change of water quality which will occur in Hougala basin as a result of the treated effluent discharge. At the time the Houban-Hougala supply is removed from the municipal system it is anticipated that water production will continue at Hougala for irrigation purposes. Water quality in Hougala basin will improve slowly as low quality water recycling is reduced and better quality natural waters blend with low quality ground water presently migrating down Wadi Taiz. Within a short time after the sewage treatment plant becomes operational, wastewater will migrate down Wadi Taiz and begin to blend with low quality water in storage. Within five years, the treated effluent will be actively flushing lower quality waters out of Hougala and a relatively rapid decrease in total dissolved solids will commence in the well field area. The improvement of well field water quality will

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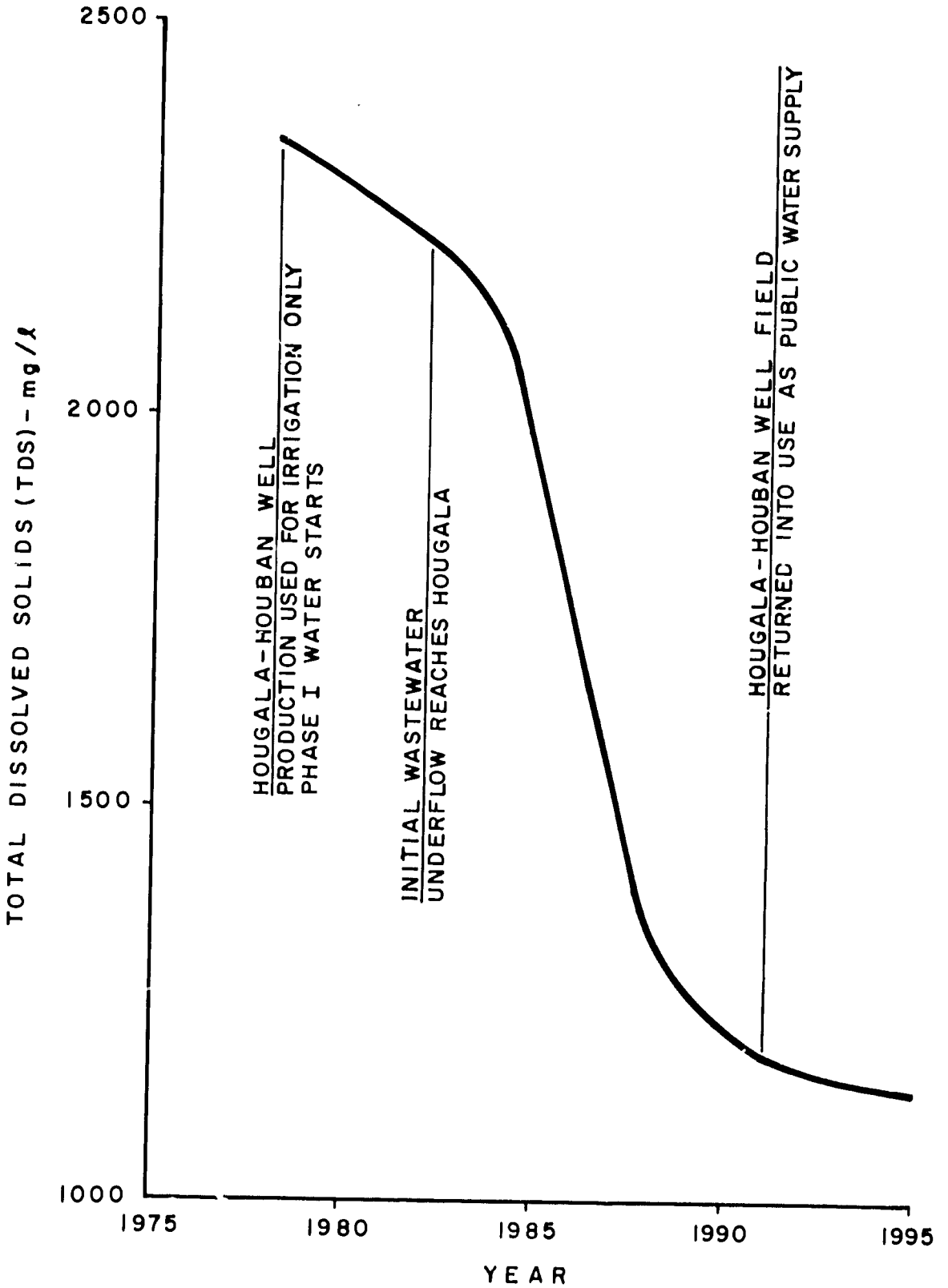

HYPOTHETICAL T.D.S. CHANGE
VS.
TIME IN HOUGALA BASIN

continue until the quality of the treated wastewater is approached. In 1991 the Hougala well field would be placed back in municipal system service. At that time Hougala basin TDS water quality will average approximately 1,200 milligrams per liter.

This wastewater discharge concept appears favorable in that it provides for maximum use of an existing water source and facilities while improving the source water quality to a level suitable for future reuse in the municipal system.

TREATMENT ALTERNATIVES

The proposal to reclaim the sewage of Taiz for reclamation through recharge requires a high degree of treatment. The site selected for the treatment and recharge facilities is located within a sparsely inhabited agricultural area downstream of the city in Wadi Taiz. Therefore, a degree of treatment producing an effluent approaching a secondary effluent in quality is essential.

Several treatment methods are examined that would be capable of meeting the above effluent quality criteria.

Alternative treatment methods considered are:

1. Neighborhood septic tanks
2. Raw sewage lagoons
3. Mechanically aerated lagoons
4. Imhoff tanks
5. Trickling filters
6. Various combinations

Neighborhood Septic Tanks

The sizing of septic tanks is dependent upon two factors, namely organic loading and hydraulic loading. Typical design values of 0.02 pounds of volatiles per cubic foot per day, a retention time of 90 days for the solids and a per capita contribution of 0.16 pounds of volatiles per day

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results in a tank size of 15,000 gallons to serve 100 people. For the present population, this would require about 1,000 tanks and for the estimated design population, 2,300 tanks. Pumping these tanks every 90 days would require pumping 35 tanks per working day. The sludges pumped out would have to be disposed of some 7 kilometers from the city and the round trip would require two hours. Including spares, this would require 20 septic tank pumping rigs with crews, and would consume about 40,000 gallons of fuel per year.

The cost of each septic tank is estimated to be $3,200 plus leaching field or absorption pit. This would require a total cost of $7,560,000 for septic tanks only for the estimated future population and a cost of $3,200,000 for the present population. To these construction costs must be added the cost of house connections and absorption pits.

Raw Sewage Lagoons

The sizing of raw sewage lagoons is based on the expected natural reaeration capacity of the particular location. Experience in similar climates, (Southern California) indicates that a value of 84 kg of BOD per day per hectare of surface area (75 pounds of BOD per day per acre of surface area) is acceptable. This would require a land area of 235 hectares (580 acres), which is not available within a reasonable distance of the city.

Mechanically Aerated Lagoons

Using floating mechanical aerators to provide the oxygen for treatment requires a total of 1,100 hp. The annual power required would cost in excess of $240,000 per year. No further consideration is given to this alternative.

Imhoff Tanks

The criteria for sizing these tanks are similar to those for septic tanks. Because of the high strength of the sewage, it is not possible to meet the minimum solids storage requirement and maximum liquid retention time simultaneously, with reasonable geometry. This alternative is not considered further herein.

Trickling Filters

The next logical treatment method to consider is trickling filters. To avoid high power consumption and to reduce the necessity of importing expensive equipment, fixed nozzle filters are considered.

Preliminary cost estimates of this alternative are presented in Chapter 13. Unit processes include metering, screening, primary sedimentation, 2-stage filters with final clarification, final effluent percolation beds with recycle of effluent to the inlet end of the plant and sludge lagoons for sludge digestion. All effluent from the first phase plant would be recharged to the ground water basin.

Other Treatment Alternatives

Several combinations of primary clarification plus lagoons, with and without mechanical aeration, were also considered. These proved to either require too much land area or too much power, or both. Again, these are not given further consideration.

SUMMARY OF ALTERNATIVES

A summary of the various alternatives is listed below:

Treatment Method	Remarks
Neighborhood septic tanks	High maintenance and capital costs - impractical
Raw sewage lagoons	Requires more land than available
Mechanically aerated lagoons	Excessive power required
Imhoff tanks	Technically infeasible
Trickling filters	Permits recharge
Primary plus lagoons	Excessive land or power required - impractical

RECOMMENDED WASTEWATER RECLAMATION FACILITY

In order to meet the future water supply requirements of Taiz, it is necessary to recharge as much as possible of the sewage generated within the city to the Hougala ground water basin. The degree of treatment needed to ensure the continued feasibility of the recharge program without excessive maintenance and nuisances can be provided by a two-stage trickling filter plant designed for minimum capital, operation and maintenance costs. Recharge can be improved and controlled by providing percolation beds within the fenced plant grounds.

DESIGN CRITERIA

A summary of design criteria and assumptions is contained in Table 9-5.

TABLE 9-5

WASTEWATER TREATMENT DESIGN CRITERIA

Parameter	Design Criteria and Assumptions
Design Year	1985
Hydraulic Loading	adwf (90 lps) pdwf (200 lps)
Reliability	Standby units as necessary to permit unit failure without effluent quality impairment
Plant Layout	Gravity flow to minimize pumping, provide for future expansion
Primary Clarifier Loading	25 cu m/sq m/d at adwf
Trickling Filter Loading	0.40 kg/cu m/d
Secondary Clarifier Loading	25 cu m/sq m/d at adwf
Recirculation Rate	100% at adwf
Sludge Lagoons (det time)	90 days with 1 unit being drained
Percolation Bed Loading	0.3m/day

PHASE I FACILITIES

Phase I facilities are designed for an average dry weather flow of 90 lps. Figure 9-10 illustrates a plan view and Figure 9-11 represents a schematic profile of the plant.

The headworks include manually-raked fixed screens, trash racks and flow-splitting flumes. The screened sewage proceeds to two circular primary clarifiers with mechanical sludge scrapers and skimmers.

The effluent from each clarifier proceeds to a splitter structure to divide the flow into two parallel trains of two-stage trickling filters. Fixed nozzles are installed on two meter centers along laterals spaced one meter apart to ensure uniform loadings.

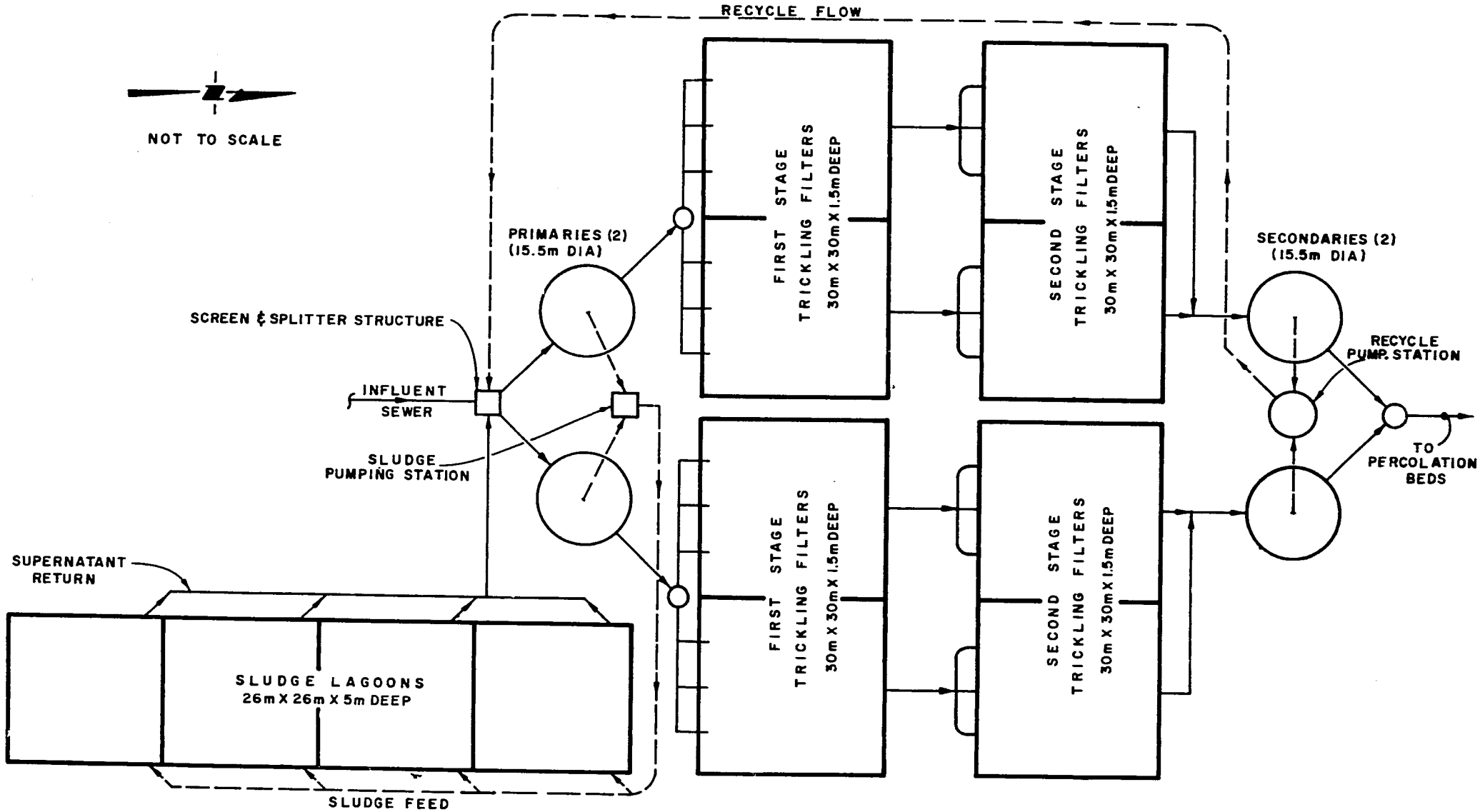
The effluent from each pair of trickling filter trains goes to a secondary clarifier with mechanical sludge removal. The final effluent is applied to one of four percolation beds.

A recirculation pump takes suction from the sludge hoppers of the secondary clarifiers and pumps back to the headworks for diluting and freshening incoming sewage. The humus collected in the secondary clarifiers will settle in the primary clarifiers and be removed by the primary sludge pumps to the sludge lagoons.

PHASE II facilities

As the sewage flows approach the design capacity of the plant, parallel trains of 90 lps can be added. Additional sludge lagoons and percolation capacity must also be included for the additional units.

Total plant capacity for the year 1995 is estimated to be 270 lps, or three times the 1985 capacity.



TAIZ WATER SUPPLY AND SEWERAGE PROJECT
WASTEWATER TREATMENT PLANT
PLAN - PHASE I

FIGURE 9-10

TAIZ WATER SUPPLY AND SEWERAGE PROJECT
WASTEWATER TREATMENT PLANT
SCHEMATIC PROFILE - PHASE I

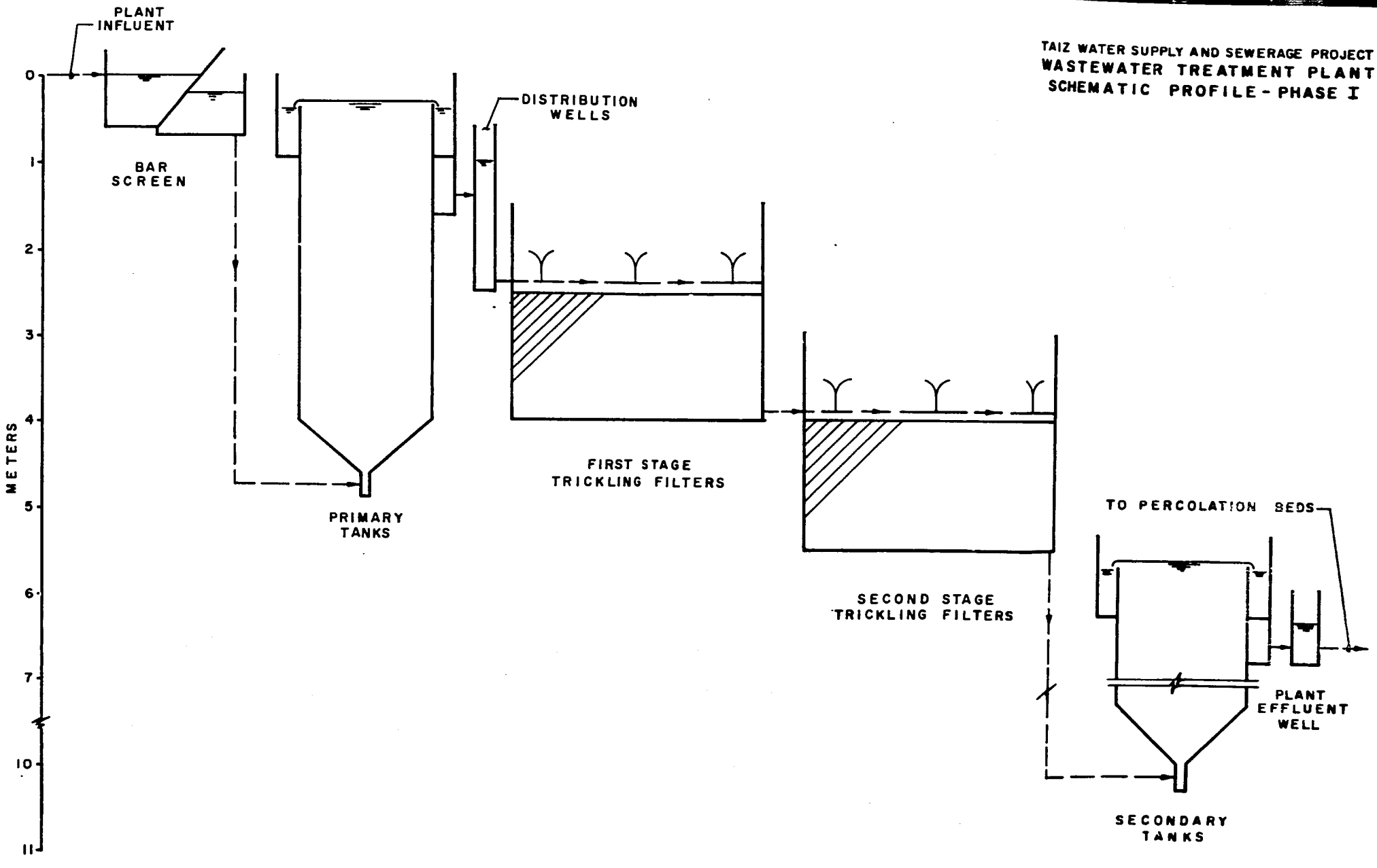


FIGURE 9-11

CHAPTER 10

CHAPTER 10

ELECTRICAL

HISTORY

The original electrical system was designed in 1962 as part of the water system for the city of Taiz. Location of Taiz and surrounding basins is shown on the Project Location Map, Figure 10-1. It was designed as a self-sufficient generation, distribution and utilization system with no ties provided to outside electrical systems. The design capacity included provision for two 25 hp future wells, plus 125 kw reserve generating capacity over and beyond maximum and motor starting demand, as shown in Table 10-1 and Figure 10-2

The original system was placed in operation in 1965. It included the following:

- Three engine generators - two 275 kw and one 135 kw; all 2400-volt, 3-phase, 3-wire, 50 Hz, 2400-volt switchgear, 2400/480-volt transformer, 2400/120-208-volt transformer, and 480-volt and 120-208-volt lighting and utilization system, all at the Main Yard.

- A 2400-volt, 4-wire (3 phases and one ground), 2.4 km long overhead copper transmission line of wood pole construction from the Main Yard to the Houban main booster pumping station.

- A 500 kva, 2400/480-volt, 3-phase, dry type transformer, 480-volt distribution and motor control equipment, 480/120-volt transformer with associated lighting and utilization equipment, all at the Houban main booster pumping station.

- 480-volt and 120-volt (5-wire) overhead copper feeder lines of wood pole construction to the Houban wells and 480-volt motor starting equipment and lighting at each

TABLE 10-1

ORIGINAL ELECTRICAL LOADS - 1965
(From Ruiz-Hummel Report)

Item	Motor Size	Hp Total	KW Max.	KW Normal
Wells				
Pumps, 4 wells	25 hp ea	100	75	60
Pumps, 2 wells (future)	25 hp ea	50	38	-
Lighting, 4 wells (1 kw ea)	-	-	4	4
Lighting, 2 wells (1 kw ea) (future)	-	-	2	-
Main Booster Pump Station				
4 Pumps	75 hp ea	300	180	135
Lighting	-	-	2	2
Generator & Chlorinator Bldg				
2 Pumps (Pump Station No. 2)	60 hp ea.	120	100	75
Light and Power	(Various)	20	15	10
Storage Tank No. 2				
Perimeter Lighting	2 kw	-	2	2
Perimeter Lighting (Night only)	7 kw	-	7	7
Shops Bldg				
2 Bays @ 3 kw	6 kw	-	6	17
9 Shops @ 3 kw	27 kw	-	27	-
Heavy Mach. Shop (Whse No. 4)	(Various)	80	60	30
Lighting	-	-	2	2
Operations Bldg				
10 Air Conditioners	1 hp ea	10	10	10
Lighting	5 kw	-	5	5
Executive Bldg.				
Lighting	5 kw	-	5	5
Warehouses (3)				
Lighting 3 @ 1.6 kw	-	-	4.8	4.8
			544.8	368.8
			(or 550)	(or 370)
Normal Demand	370			
Plus Diff of Max	180			
Maximum Demand	550			
Starting Load over Max Demand	75 kw			
Generating Capacity	750; Reserve 125 kw			

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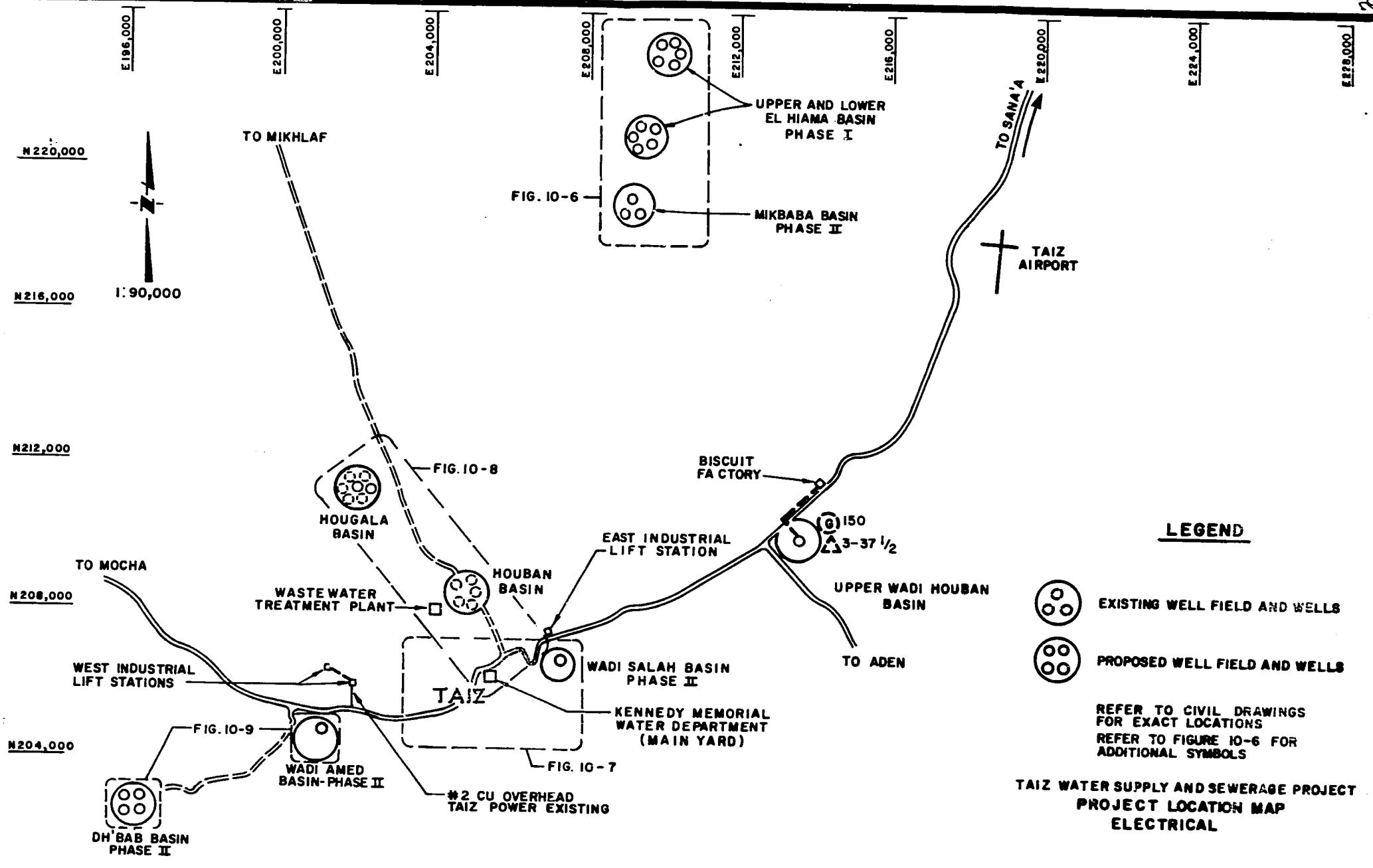
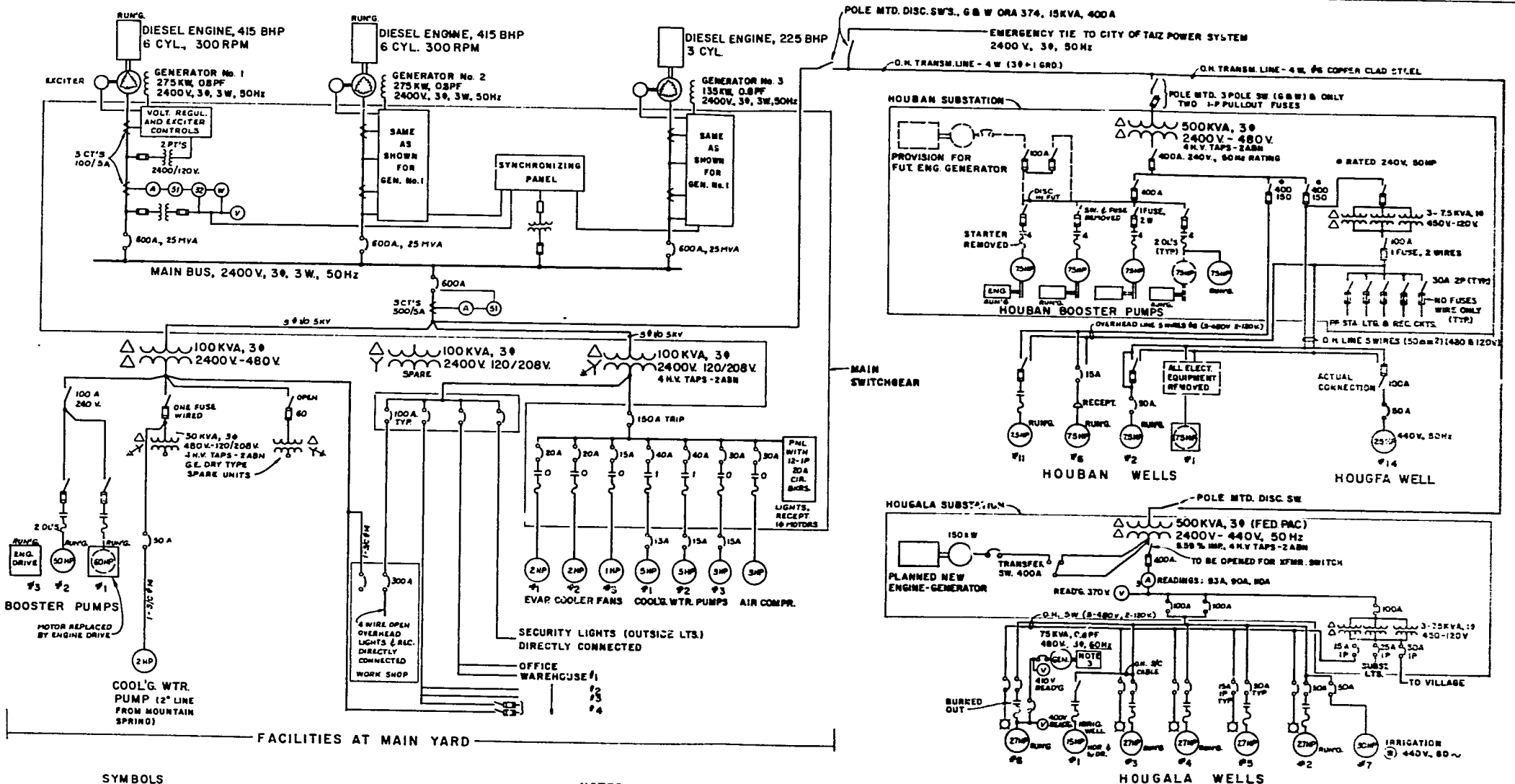


TAIZ WATER SUPPLY AND SEWERAGE PROJECT
PROJECT LOCATION MAP
ELECTRICAL

FIGURE 10-5



SYMBOLS

- CIRCUIT BREAKER
- SWITCH
- SWITCH & FUSE COMBINATION
- MOTOR WITH HP RATING
- TRANSFORMER
- MAGNETIC MOTOR STARTER W. OVERLOADS

NOTES

1. ALL CIRCUIT BREAKERS & SWITCHES ARE 3 POLE, EXCEPT AS NOTED.
2. LOAD READINGS, PUMP RUNNING AND OTHER CONDITIONS SHOWN ARE AS OF SEPT. 11, 1974.
3. 75 KVA ENG. GENERATOR IS LOCATED AT WELL No. 1.
4. STARTERS AT HOUGALA WELL ARE "SCHIELE INDUSTRIE WERKE KG (GERMANY) SCHUTZ VDE 0660, 380V, 50Hz, 60A (ADJUSTABL 4^ TO 63 AMPS)

TAIZ WATER SUPPLY AND SEWERAGE PROJECT

ELECTRICAL POWER SYSTEM
SINGLE LINE DIAGRAM
EXISTING CONDITIONS - SEPT. 1974

FIGURE 10-2

well. There was also provided a telephone line between the Main Yard and the Houban booster pumping station. For this line, an underground cable along the pipeline was installed. This telephone line is still in operation.

In 1969 two new well fields were developed, namely Hougala and Hougfa. To serve these two well fields, the overhead lines were extended. For the Hougfa wells, the existing 480-volt and 120-volt line was extended from the Houban wells. For the Hougala well field, the 2400-volt overhead transmission line was extended from the Houban main booster station to the new Hougala substation with a new 4.0 km long overhead transmission line of steel pole construction. Copper clad steel wires were used instead of copper wire. The Hougala substation was installed. It included a 15kv, 400 amp, pole-mounted disconnect switch, a 500 kva, 2400/480-volt, 3-phase, dry type transformer; 480/120-volt transformers, a 480-volt distribution board with circuit breakers, three ammeters and a voltmeter; and a 120-volt system with circuit breakers, lights and receptacles. The 480-volt feeder to the wells was a cable installed underground without conduits, together with telephone cables for a private telephone system. Shortly after installation, the underground power cables failed and were replaced by overhead 5-wire pole lines carrying a 480-volt power and a 120-volt lighting circuit. Motor control equipment at each well included a circuit breaker and a motor starter. A telephone cable was also installed along the 10-inch pipeline between the Houban substation and the Hougala substation. This telephone line is at present out of service and has apparently been out for some time.

Also in 1969, an engine generator, rated 85 kw, 0.8PF, 240/416-volt, 3-phase, 4-wire, 50 Hz, was installed at well site No. 1. Reportedly, this unit was supplying power to three wells before the 2.4 kv overhead transmission line from Houban station and the Hougala substation was installed. At present, the generator is missing and reportedly the generator, or a replacement unit, will be reinstalled. Another unit rated 60 kw, 75 kva, 120-208/480-volt, three-phase, 4-wire, 60 Hz is running at this well site providing power for Well No. 6. September 1974 meter readings at the unit were 416-volt, 50 Hz.

Since 1972 effort was directed towards restoring the system to its original capacity. Some changes were made to offset the loss of generating capacity of the main generator engines due to engine cooling problems. The following changes and additions to the system were implemented during that period:

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- Replacement of the electric motor drive on Main Yard booster pump No. 1 with a right angle gear drive and an engine, and installation of a third booster pump with an engine drive.

- Installation of a 2 hp cooling water circulation pump to provide spring water for the main engine cooling system. This pump has not been operated due to spring water supply problems.

- A fifth booster pump with a 75 hp motor has been installed at the Houban booster pumping station.

A 150 kw engine generator was installed in October 1974 for the Hougala well field to provide standby and backup service.

PRESENT STATUS

The electrical system has essentially remained unchanged since the original installation in 1965 and expansion in 1969. Figure 10-2 shows the single line diagram of the total system as of September 1974 when a physical survey was conducted by the project staff together with members of the Taiz Water Department. This survey indicated that new designs must consider maintenance and reliability of paramount importance. This survey included field measurement of Main Yard generator loading. During the course of several days of measurement, average demand load was 245 kw and maximum demand load was 320 kw. Table 10-2 is a tabulation of existing power production capacity.

Despite the fact that the basic system has remained unchanged, present conditions render the installation hazardous to operate, unreliable, and inadequate. The hazardous and unreliable conditions appear to be a product of original incorrectly installed equipment, lack of proper materials available during expansion and maintenance work, lack of professional planning and supervision, removal of existing equipment, and general deterioration due to the lack of preventive maintenance. The inefficient cooling systems for the main generators prevent these units from developing their rated capacities.

MAIN YARD AREA

The Main Yard area includes the generator buildings with engine-generators, switchgear, transformers and booster pumps, the operations building, the executive building, a shop building, and warehouses. The

2400-volt system seems to be in good condition. However, there are several items which can cause equipment failure, such items are:

- The 2.4 kv system is delta connected and ungrounded.
- There is no lightning protection
- There is no overcurrent protection for the overhead line. The design criteria, when implemented, will prevent these deficiencies.

2400-VOLT DISTRIBUTION LINES

The 2400-volt distribution line from the Main Yard to the Houban booster pumping station is 2/0 copper line with overhead ground wire and wood pole construction. There are no fuses or other circuit protection devices on the supply side of the line except the 600 amp main circuit breaker in the switchboard at the Main Yard; no lightning arresters are provided.

The line from the Houban booster station to the Hougala well field substation is copper-clad steel wire on steel poles. There are no circuit protection devices and no lightning arresters on the line.

HOUBAN AREA

Sizes and capacities of the original electrical installation in the Houban area are given in Figure 10-2 and Table 10-2. However, the existing conditions show a great deal of deterioration. Of the original four 75 hp diesel-electric motor dual drives, none are at present operable as dual drive. On the first unit, the starter for the motor is missing, on the second unit the switch and fuse for the motor are missing, on the third unit the engine is disconnected, and on the fourth unit the electric motor has been removed. The starter for the fourth unit is connected to the new fifth 75 hp electric motor driven pump installed outside of the pump room. Wells No. 2, 6, and 14 (Hougfa) have no motor starters and therefore no overload protection. The switch and fuse at Hougfa well are connected in reverse, leaving the fuses energized when the switch is open.

HOUGALA AREA

Several changes were made on the electrical distribution system for the Hougala wells since the original installation in 1969. The original starter for Well 6 is burned out and disconnected. Well 6 is now directly connected to the 75 kva (60kw) generator which is located at Well 1 site. The

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TABLE 10-2

TOTAL POWER PRODUCTION CAPACITY
(Existing Water System)

Prime Mover	Capacity
Engine Generators	
Main Yard	
Generator No. 1	275 kw (150)[a]
Generator No. 2	275 kw (150)[a]
Generator No. 3	135 kw (70)[a]
Subtotal	685 kw (370)[a]
Hougala Well Field	
Generator at Well 1 supplying Well 6	60 kw
Standby Generator	150 kw
Total	895 kw = 1200 hp (580 kw) = (777 hp)
Engine Drives	
Main Yard	
2 - 75 hp Booster Pumps	150 hp
Houban Area	
4 - 75 hp Booster Pumps	300 hp
4 - Engines for wells en route	
1 - 10.8 hp	11 hp
3 - 16.1 hp	48 hp
Total	509 hp
Total Power Production	
Generators	1200 hp (777)[a]
Engine Drives	509 hp (509)[a]
Grand Total	1709 hp (1286)[a]

[a]Reduced capacity due to inefficient cooling system.

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recently installed Well 7 (irrigation well) has no starter and no overload protection. Most of the wiring in the Hougala area is by multiconductor cable rather than wire and conduit. Voltage and current readings taken during a field survey on September 11, 1974 were 370-volt, and phase currents of 93, 90, and 110 amps. This voltage is unacceptably low for a 440-volt system.

PROPOSED SYSTEM EXPANSION

DESIGN CRITERIA

General

The proposed water system expansion is described in Chapter 8 and has been planned for construction in two phases, i.e., Phase I accommodates anticipated demand to 1985 and Phase II accommodates anticipated demand to 1995. The proposed electrical expansion is also planned for two stages, to follow the water system program.

Existing transmission lines of the local utility (Taiz Electric Company) are not located close enough to the proposed Phase I facilities to consider their use as a prime power source. Not only would line construction costs be excessive, but additional generation capacity would still have to be provided to supplement the existing generators which are presently operating at full capacity. As a matter of fact, the existing generators are loaded to the extent that no new loads are presently being accepted by the utility and, therefore, it cannot be considered as a source of prime power. However, the proposed electrical supply and distribution systems for Phase II installations make use of a variety of existing power sources and local generators as indicated in the single line diagrams; these recommendations represent a blend of existing equipment status with a forecast of conditions when Phase II is implemented. Examples are in order: 1) It is assumed that there will not be any available electric power in Wadi Amed and Dh'bab basin so local generation in these areas has been proposed. 2) The Phase II Houban booster pumps could be adequately supplied from existing KMWS facilities, but it is also more than likely that equipment conditions at that time will dictate the installation of full capacity standby generation. 3) In the event that utility power is available at the time of installation, designers should consider the utility as prime power with local generation as back-up. The object of these examples is to alert project planners to temper the Phase II criteria given here with field conditions at time of design.

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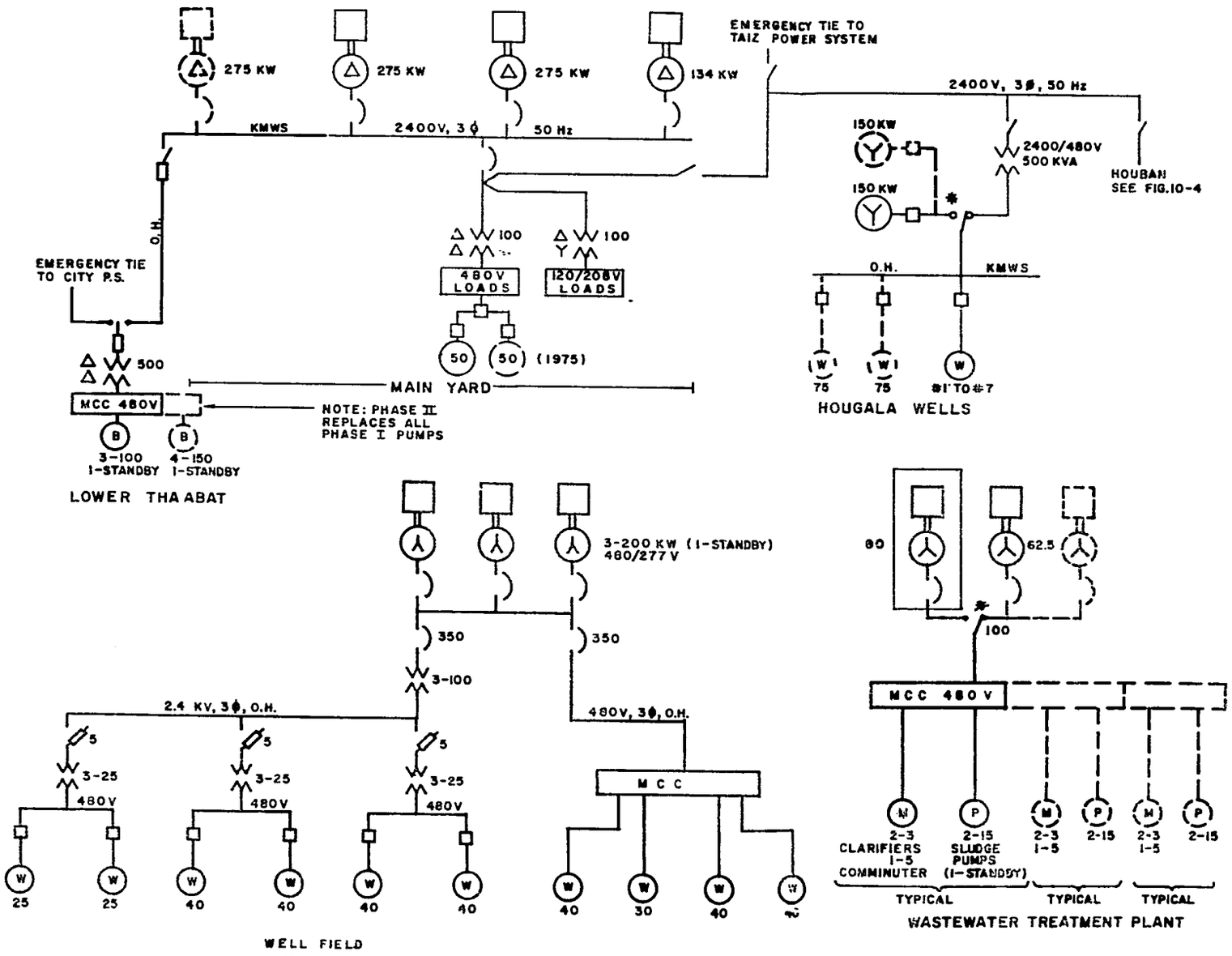
Electrical design must be formulated in a manner that will readily accept moderate additions in load or connection to external power supply lines. For example, basic design should permit the connection of an outside distribution line to a particular installation without extensive shutdown, replacement of transformers, or alteration to the basic structure.

Additional flexibility is also necessary, without any regard to other electrical facilities, to allow some equipment to be removed from service for maintenance without deactivating an entire pumping or treatment installation. Such major provisions are included in the Single Line Diagrams, Figures 10-3 and 10-4 and take the form of fixed and portable standby generator units, three single-phase transformers in three-phase substations, and provisions for switching to alternate sources. Isolated multiple pump locations are provided with three generators, one of which is a standby unit, while pumping stations which are served by an overhead distribution system are backed-up by local generators without standby capacity. These arrangements accommodate inevitable equipment breakdown while minimizing spares investment and operational complications. Pumping installations of only one or two units are served by a single generator; however, back-up capability would be provided by a portable generator that could be transported wherever the need arose. Generator units have been sized to simplify repair parts stocking and to allow easy temporary or permanent relocation of generators as conditions warrant. Detail designs should further this intent to attain flexibility by providing equipment which can be easily expanded, service pullboxes that can accommodate underground or overhead services; spare raceway, adequate switching for alternate feed and for isolation; and sufficient engine and generator instrumentation to alarm dangerous conditions and to prevent equipment damage. One of the basic concepts of the detail design should be manual operation only wherever practicable; manual back-up positions in those cases where automatic operation is necessary, manually operated transfer and selector switches, and design employing one or two standard sized units for parts interchangeability and flexibility.

Distribution and Transmission

High voltage transmission at 2.4 kv has been selected to conform with existing KMWS high voltage distribution circuits; further 2.4 kv is ideal for the moderate amount of power involved. However, it is likely that future growth will indicate that a 12.4 kv transmission is more suitable;



SYMBOLS:

- DIESEL ENGINE GENERATOR △=DELTA Y= WYE CONNECTED WITH KW RATING
- 100 — TRANSFORMER WITH KVA RATING
- 400 — SWITCH AND FUSE WITH AMPERE RATING
- 800 — CIRCUIT BREAKER WITH AMPERE RATING
- (COMB.) MOTOR STARTER (S)
- EXISTING EQUIPMENT
- PROPOSED EQUIPMENT PHASE I (1985)
- PROPOSED EQUIPMENT PHASE II (1995)
- 100 — 2-POSITION SWITCH WITH AMPERE RATING
- W — WELL MOTOR TYPICAL FOR UNITS SHOWN
- 3-100(150) — I.E. (3 WELLS, 100HP EACH) B=BOOSTER PUMP (150) INDICATES MOTOR SIZE, PHASE II
- O.H. — OVERHEAD LINE
- MCC — MOTOR CONTROL CENTER
- MC — MOTOR CONTROL AND OTHER EQUIPMENT
- 1-STANDBY — ONE UNIT IS STANDBY
- KMWS — KENNEDY MEMORIAL WATER SYSTEM

NOTES:

(1) ALL EQUIPMENT SHOWN IS 3-PHASE, 3-WIRE 50 HZ

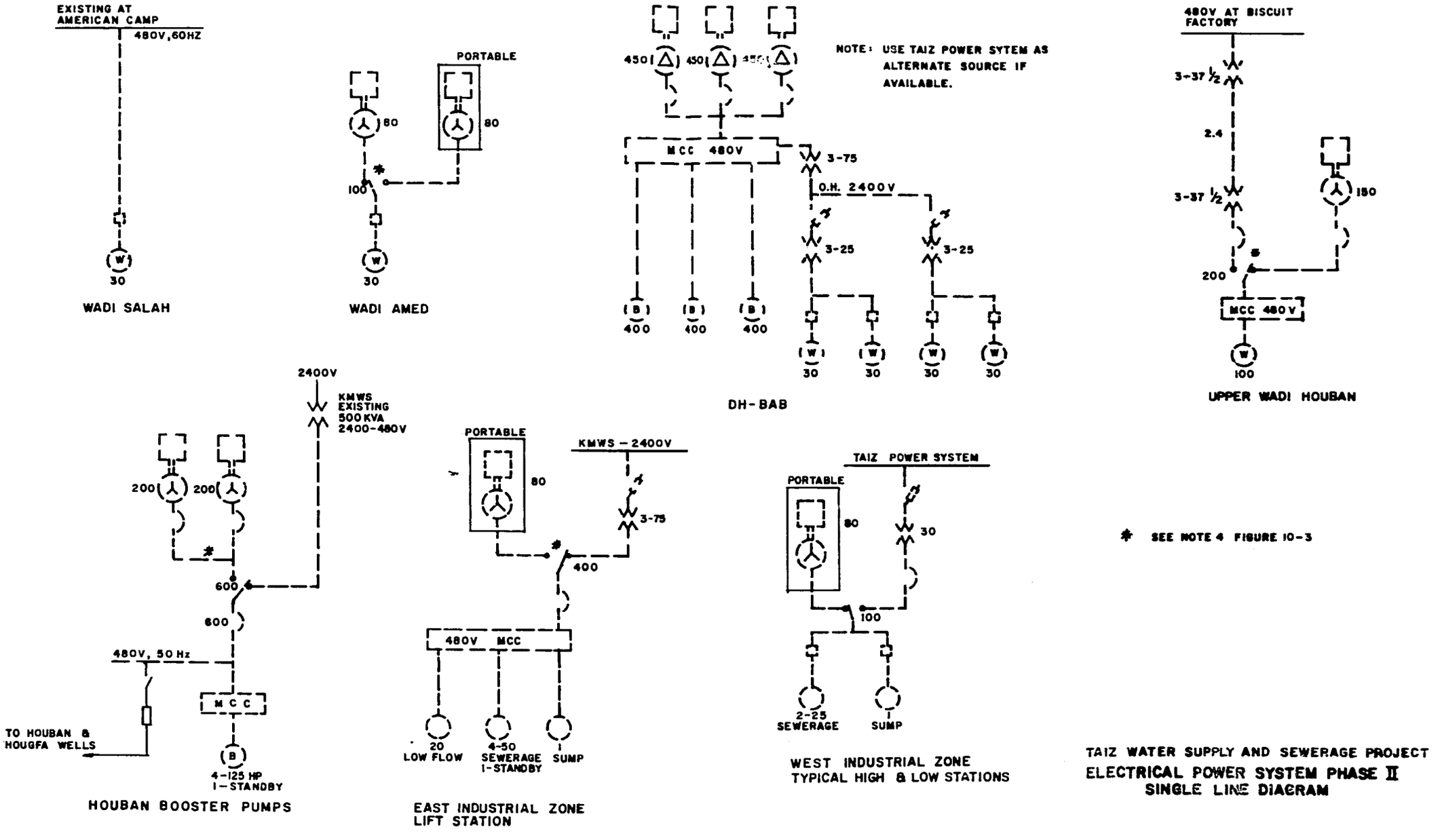
(2) 480-120/240 V TRANSFORMERS AND PANELS FOR LIGHTING AND OTHER EQUIPMENT NOT SHOWN, BUT WILL BE AT EACH STATION.

(3) ALL GENERATORS HAVE 0.8 POWER FACTOR, AND ARE SIZED FOR SEQUENCED MOTOR STARTING.

* (4) USE UTILITY AS ALTERNATE OR PRIME SOURCE AS AVAILABLE AT INSTALLATION

TAIZ WATER SUPPLY AND SEWERAGE PROJECT
ELECTRICAL POWER SYSTEM PHASE I & II
SINGLE LINE DIAGRAM

FIGURE 10-3



TAIZ WATER SUPPLY AND SEWERAGE PROJECT

ELECTRICAL POWER SYSTEM PHASE II
SINGLE LINE DIAGRAM

FIGURE 10-4

in fact, a report prepared for the Taiz Electric Company[a] recommends such a conversion. For this reason, considerations at the 12.4 kv level are discussed below.

480-volt generators have been selected for most locations because they are more readily available, in the sizes shown, than higher voltage units, and they are less expensive. Use of 480-volt units decreases overall system costs, since these generators can be quickly placed in service at other locations as conditions warrant. For example, at some future date, the generators for El Hiama may no longer be needed because power is available from utility supply lines; at that time the generators can be used at a different location, perhaps Dh'bab, and the transformer left in place to supply power to 480-volt loads from the 2.4 kv utility lines. Use of 480-volt generators has the obvious advantage of reducing transformer capacity requirements, since much of the load can be supplied direct.

The 2,400-volt transmission line proposed here, as well as other 2,400-volt overhead circuits, should be insulated at 15,000-volts to facilitate fixture changeover to this voltage. The cost of this increase is usually the cost of longer insulators and longer cross arms which is insignificant compared to other line costs. Related transformers would be dual-voltage, i.e., having 2.4 and 12.4 windings. These units would have two cover bushings with a multiple rating of 2400/4160 x 7200/12,470-volts; such units are commercially available. When the upgrading is implemented, a multiple grounded 12,470-volt wye system is recommended with the ground neutral installed above the three-phase conductors. Phase I and II high voltage transmission at 2,400-volts is obviously required wherever a direct tie to the existing 2,400-volt systems is recommended. At El Hiama (Phase I), transmission could be either 2,400 or 12,470-volts; however, 2,400-volts is recommended because of the moderate load and because the existing lines, experience and spare parts are all at the 2,400-volt level. For similar reasons, 2,400-volt instead of 12,470-volt transmission is recommended for the Phase II installations at Dh'bab and Upper Wadi Houban. However, as mentioned elsewhere, it may be prudent at the time of installation to design a 12,470-volt system which can be accomplished quite easily.

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[a]Power Development Plan. 1972-1982, Engineering and Power Development Consultants Limited, England, September 1972.

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The following tabulation, Table 10-3, is included here to integrate the data related to the increase in load imposed on existing installations and to demonstrate the requirement for additional Main Yard generation capacity.

Repairs

There are no recommendations (containted in this study) for general improvement of the existing electrical installations. However, it is imperative that the cooling systems of the existing main generators be improved in order to allow these units to develop their rated capacity which is needed to supply power for the new booster pumps at Lower Thaabat.

It is suggested that consideration be given to the correction of some of the existing faults described in Present Status before new Phase I and II installations are tied to existing electrical facilities.

Automatic Control

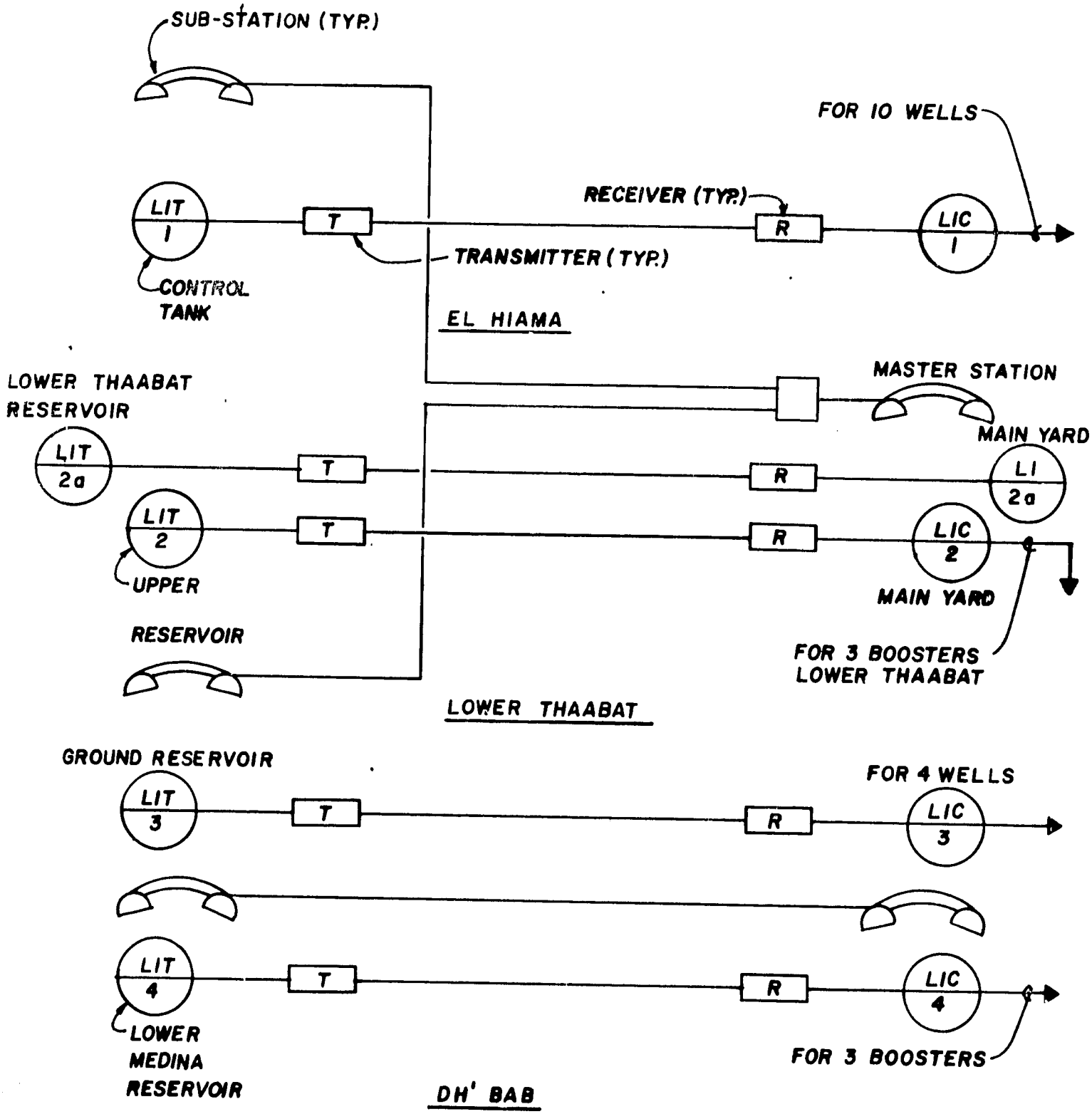
Pumping installations at Dh'bab, Lower Thaabat and in El Hiama include remote control and communication facilities and are shown schematically in Figure 10-5. Isolated wells in Wadi Salah basin, Wadi Amed basin, and Upper Wadi Houban basin would be locally controlled by a time switch. Industrial lift stations would be locally controlled via time switch and wet well level.

Remote control will be accomplished with multi-conductor cable using direct current circuitry and sensitive relays for communication reliability over the moderately long distances involved. Multi-conductor cable will be installed overhead on poles or in common trenches with water lines depending on field circumstances. Where a serviceable pair of existing cable is available, possibly along the Main Yard, Houban-Hougala route, the use of tone telemetry will be considered as a less expensive alternate to installation of new multi-conductor cable.

PHASE I FACILITIES

El Hiama

The electrical installation consists basically of a generating station, distribution transformers and pole line transmission. The Single Line



TAIZ WATER SUPPLY AND SEWERAGE PROJECT
TELEMETERING AND COMMUNICATION
BLOCK DIAGRAM

FIGURE 10-5

TABLE 10-3

GENERATOR LOADING
(Main Yard and El Hiama)

Generators (kw)	Gen Loc	Demand Load (kw)	Remarks
Existing			
60	Hougala Well No. 6	20	Well No. 6 direct connected to generator
150	Hougala Substation	115 Hougala Well Field	Generator for standby duty, 115 kw load is part of 320 kw load above
685	Main Yard	320	(320 kw maximum demand per field measurement). Standby generator not running. Well No. 6 and its generator not included.
Phase I			
685	Main Yard	320	Existing - Recap.
		200	Lower Thaabat duty pumps
		20	Wastewater Treatment Plant
685	Main Yard	540	Recap. - Existing and Phase I. 896 = starting load
600	El Hiama	320	Standby generator included. Standby well excluded
Phase II			
685	Main Yard	540	Recap. - Phase I
275	Main Yard	195	Additional generator. Net increase (375-180) in load; new Houban boosters replace existing.
		40	Wastewater Treatment Plant Phase II increment
		150	Hougala - Two additional wells
960	Main Yard	925	Total - Standby generators at Hougala not shown.

Diagram is on Figure 10-3 and the Electrical Plot Plan is shown on Figure 10-6. Since there are no external power sources available for standby service, three 200 kw, 480-volt generators are proposed; one is a standby unit. 480-volt power obtained directly from the generators will be fed overhead to nearby wells. Distant wells will be fed 480-volt power via three 2.4 kv to 480-volt pole-mounted step down transformers; these will be connected to a 2.4 kv distribution line which will receive power from a bank of 480-volt to 2.4 kv station transformer with its 480 winding connected to the generators.

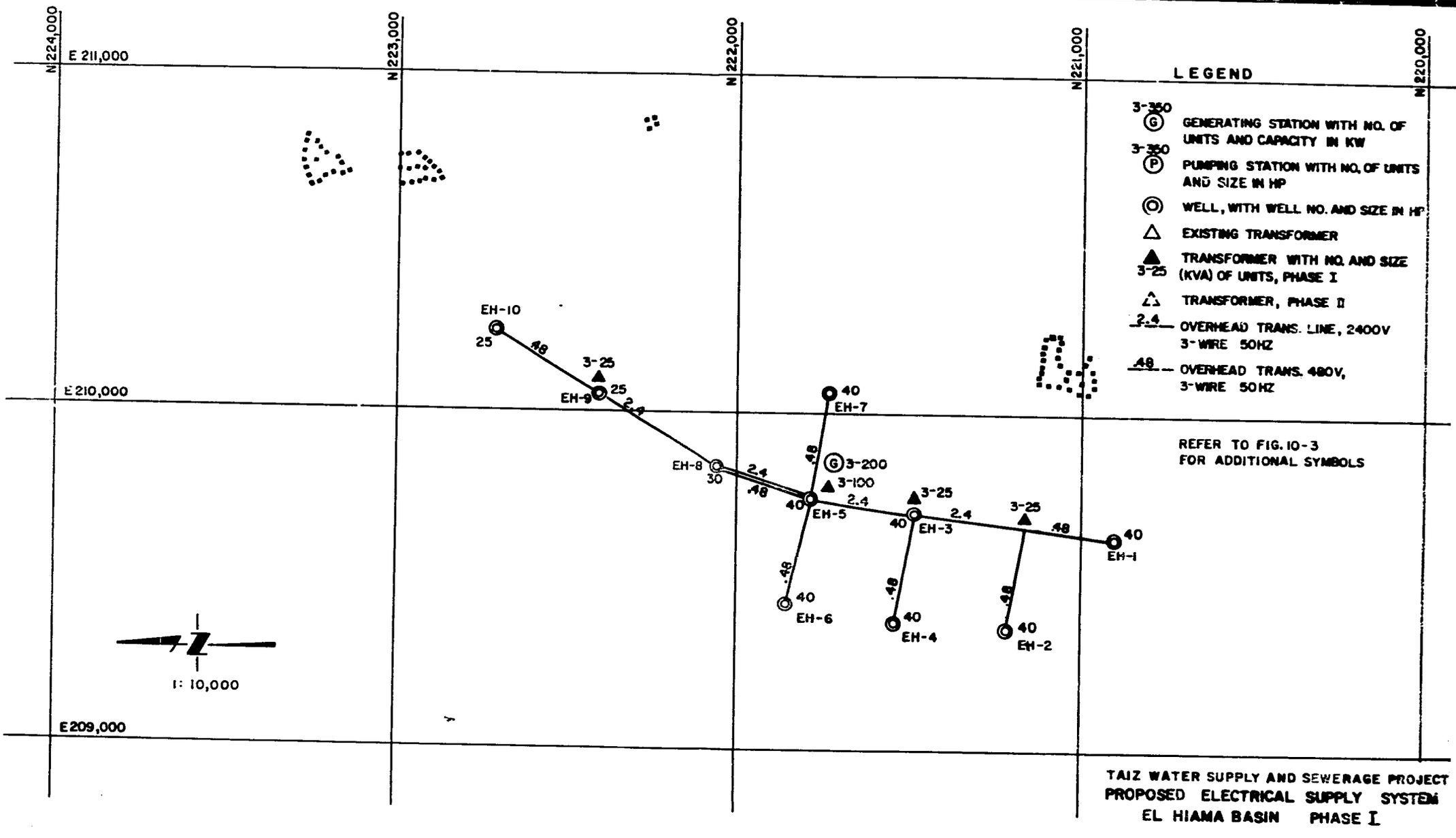
Automatic pump control will be obtained by direct wire using a multi-point level switch at the control bank and individual pump starters. A communication circuit is proposed between the control bank and the Main Yard.

Lower Thaabat

Electrical installation consists of a motor control center and a station transformer connected to existing sources via a new 2.4 kv pole line. Single Line Diagram is given on Figure 10-3; the Electrical Plot Plan is on Figure 10-7. Reference to Table 10-3 demonstrates that the existing generators have sufficient capacity to supply the Lower Thaabat booster pumps in addition to existing loads providing that cooling system improvements are performed. A 2.4 kv pole line will be designed to the Main Yard which will terminate in a high voltage transfer switch which will be tied to the Taiz Electric Power System for standby service. The station transformer has been sized to accept Phase II installations. Automatic pump control will be accomplished with a level controller instead at the new Upper Thaabat reservoirs connected to each booster pump starter.

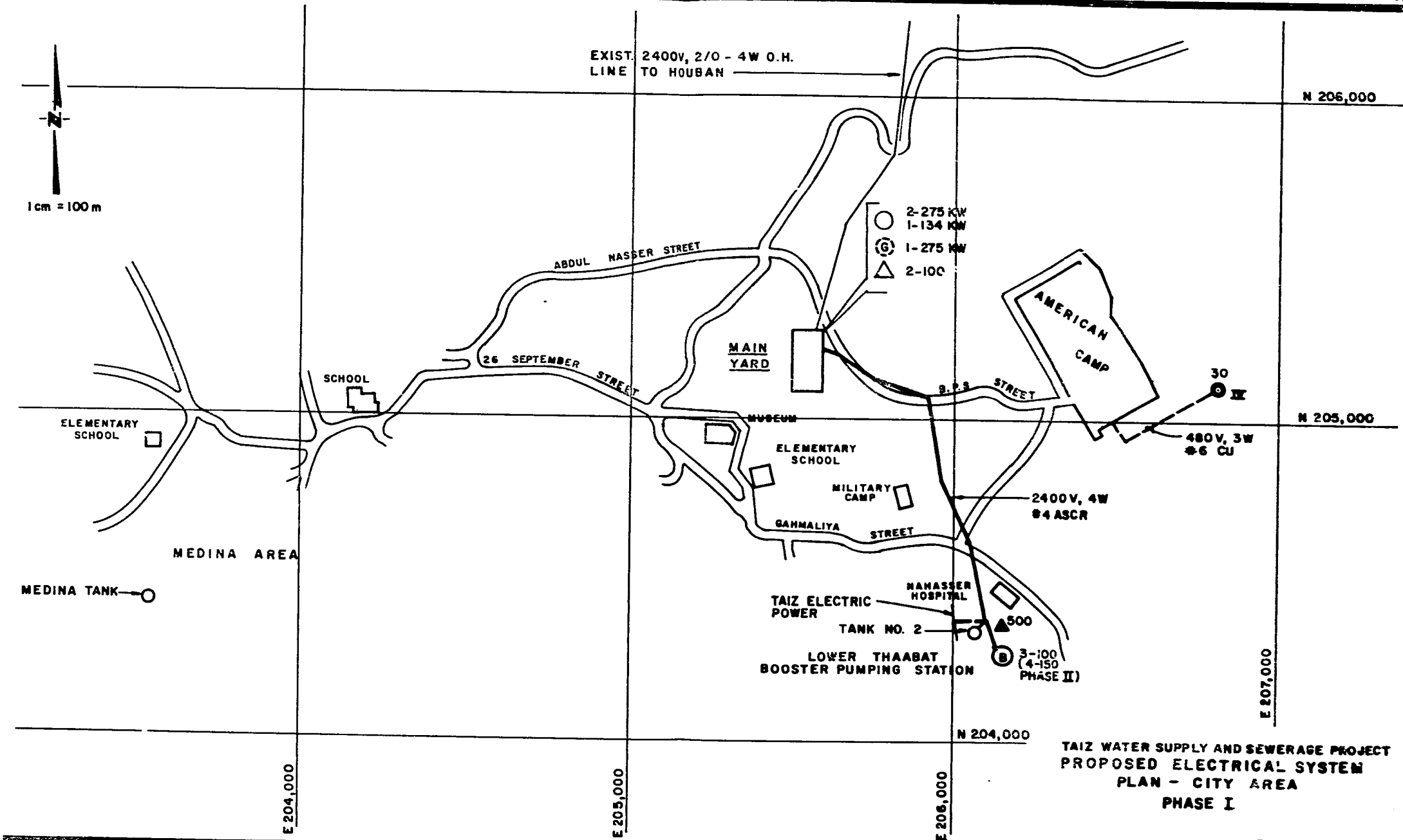
Wastewater Treatment Plant

The electrical installation will consist basically of an on-site generator and a motor control center along with provisions for a portable standby generator. Single Line Diagram is shown on Figure 10-3; Electrical Plot Plan on Figure 10-8. Reference to the plot plan indicates that the treatment plant is close to the 2.4 kv KMWS transmission line between Hougala and Houban; however, it was not considered for plant supply because conductor size is grossly inadequate and receiving voltage would be unacceptably low. If this source were to be used, the line



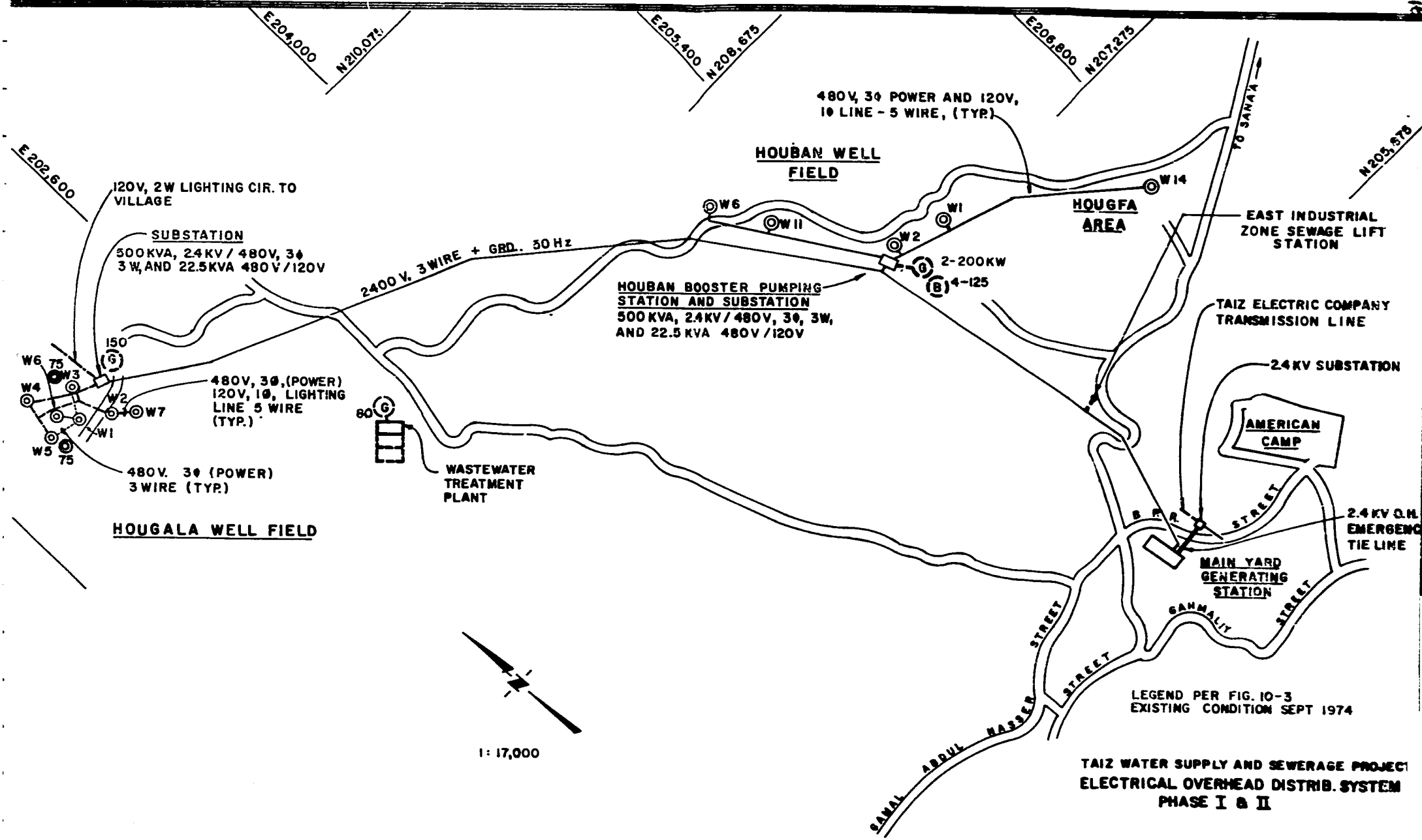
TAIZ WATER SUPPLY AND SEWERAGE PROJECT
PROPOSED ELECTRICAL SUPPLY SYSTEM
EL HIAMA BASIN PHASE I

FIGURE 10-6



TAIZ WATER SUPPLY AND SEWERAGE PROJECT
PROPOSED ELECTRICAL SYSTEM
PLAN - CITY AREA
PHASE I

FIGURE 10-7



TAIZ WATER SUPPLY AND SEWERAGE PROJECT
ELECTRICAL OVERHEAD DISTRIB. SYSTEM
PHASE I & II

FIGURE 10-9

would have to be reconductored and a new pole line must be constructed from the existing line south to the wastewater treatment plant. These costs are thousands of dollars higher than the local generator proposed.

PHASE II FACILITIES

General

Phase II proposals represent the least costly method of attaining this project's objectives. However, plans and field conditions existent at the time of Phase II installations may indicate deviations from the proposals given here. For example, the additional standby generator for the Hougala wells may not be required because the 2.4 kv overhead transmission line had been rebuilt and would have capacity to supply prime power to the Hougala well field. Likewise in the future, it may be desirable to provide automatic control of the Hougala wells from a level controller at the existing Houban reservoir.

Wastewater Treatment Plant

Phase II electrical installation will provide the wiring required by the expansion of the plant. At the time of expansion, a fixed standby generator is proposed. Single Line Diagram is shown on Figure 10-3; and Plot Plan on Figure 10-8.

Hougala

Phase II will provide wiring for two additional well pumps and additional 150 kw standby generation capacity. Control will be by time switch. Single Line Diagram is shown on Figure 10-3; Plot Plan, Figure 10-8.

Lower Thaabat

Will provide wiring for replacement pumps and for one additional pump; re-use existing controls. Single Line Diagram, Figure 10-3; Plot Plan, Figure 10-7.

Main Yard

Provide generator to match the existing 275 kw diesel driven units. Refer to Table 10-3 for generator loading data. Single Line Diagram Figure 10-3 Plot Plan, Figure 10-7.

Wadi Salah Basin

Will provide 480-volt pole line from existing circuits at American Camp to pump. Note that the American Camp wiring is 60 hertz so that this pump motor will be unique for this project. Also, a 60 hertz generator will probably not be available for standby service. Inasmuch as this will provide only a small portion of total water requirements, well shutdown is not considered critical. Control will be by time switch. Single Line Diagram, Figure 10-4; Plot Plan, Figure 10-7.

Wadi Amed

Will provide local generator, provisions for portable standby generator and well pump wiring. Control will be by time switch. Single Line Diagram, Figure 10-4; Plot Plan, Figure 10-9.

Dh'bab Basin

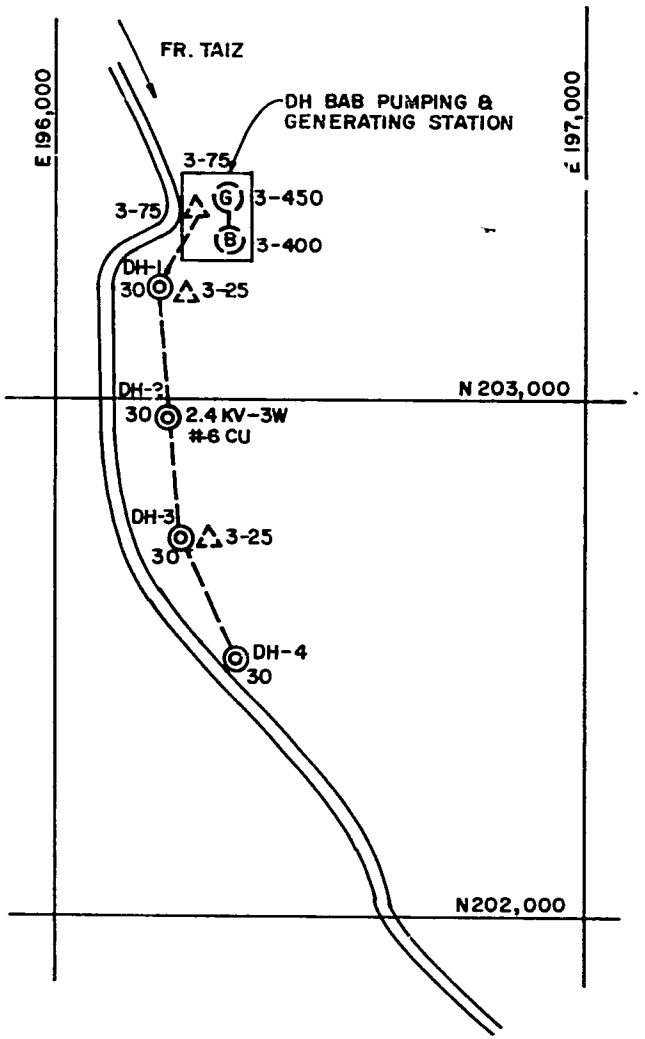
Will provide generating station, distribution transformers, motor starters, and pole line transmission. Single Line Diagram is shown on Figure 10-4; Plot Plan is on Figure 10-9. Since there are no external sources of standby power, three 400 kw, 480-volt generators are proposed; one is a standby unit. The three 400 hp booster pumps (one is a spare unit) will be 480-volt units close to the generators, the wells are separated from the generators by a distance that requires 2.4 kv transmission via a step-up substation near the generators and pole-mounted transformers near each pair of wells. The booster pumps will be controlled by water level in the reservoir at Lower Medina, while the wells will be controlled by the level in their ground storage tanks.

Upper Wadi Houban Basin

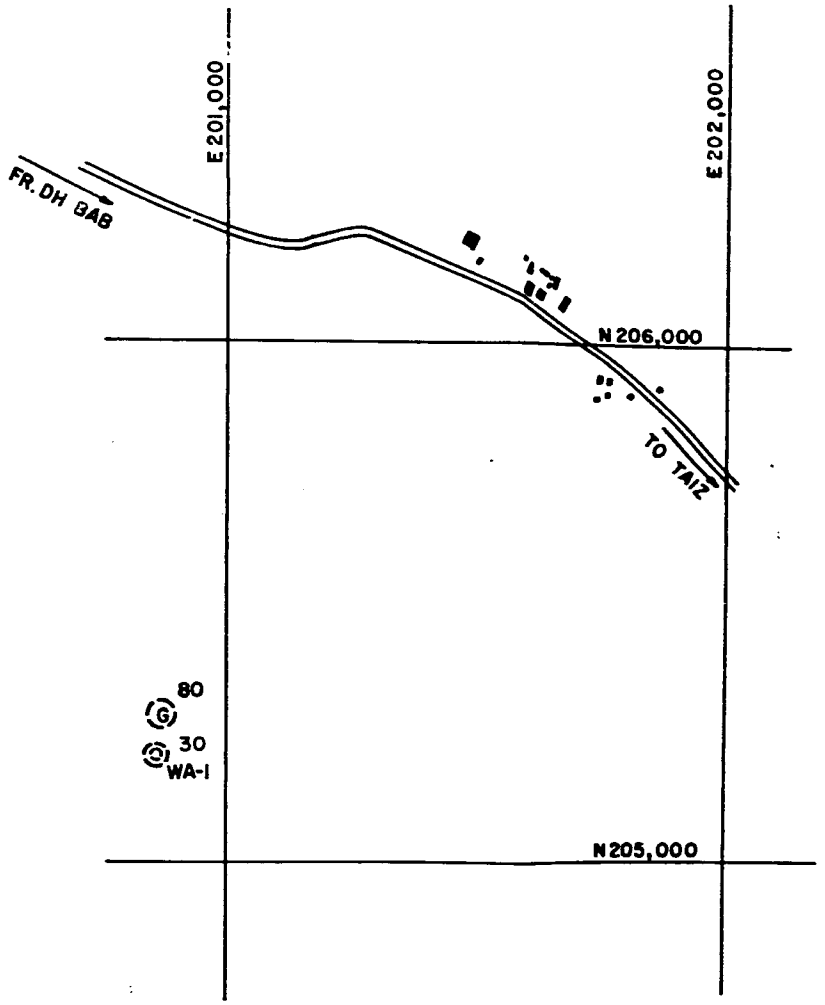
Will provide prime electric service from Biscuit Factory, standby generator and wiring for well pump motor. Service from Biscuit Factory will be by a 2.4 kv transmission line using step-up and step-down transformers. Single Line Diagram is shown on Figure 10-4; Plot Plan is on Figure 10-1. A manual control station will be provided at the factory.

Houban Basin

Will provide standby generation and wiring for four new pumps which will replace the five existing units. Single Line Diagram is shown on Figure



DH' BAB BASIN



WADI AMED BASIN

TAIZ WATER SUPPLY AND SEWERAGE PROJECT
ELECTRICAL POWER SYSTEM PHASE II

FIGURE 10-9

10-4; Electrical Plot Plan is on Figure 10-8. Prime power for three 125 hp duty pumps will be obtained from the existing 500 kva transformer; standby power will be provided by two 200 kva generators. Existing controls will be retained.

East Zone Industrial Lift Station

Will provide power service and 480-volt wiring for lift station pumps. Single Line Diagram is shown on Figure 10-4; Electrical Plot Plan is on Figure 10-8. Prime power will be obtained from the high voltage transmission line installed for the Lower Thaabat booster described in Phase I. A step-down transformer along with provisions for a portable standby generator and motor control center will be included.

West Zone Industrial Lift Stations

Will provide prime power electric service for lines of the Taiz Power System, provisions for portable standby power and wiring for lift stations. Single Line Diagram is shown on Figure 10-4; Plot Plan, Figure 10-1.

CHAPTER 11

CHAPTER 11

ENVIRONMENTAL IMPACTS OF THE PROPOSED PROJECT

ENVIRONMENTAL SETTING

The Taiz Study Area is located in the interior highlands where the average elevation is 1,300 meters. Taiz is situated on the northern slopes of a granite massif called Jabel Sabir. The major portion of the city is constructed on alluvial fans present at the mouths of wadis that drain the region. A more detailed description of the geography of the Study Area appears in Chapter 3. The region has a warm and slightly humid climate with an annual rainfall of approximately 540 mm. The mean summer temperature is 27C; the mean winter temperature is 19C. The prevailing winds, which are from the east, are dry and at times violent; whereas, the winds from the west are comparatively moist and blow chiefly during the summer months.

Some of the richest soils in the Yemen Arab Republic can be found in this inland plateau region. Despite moderate rainfall, the natural vegetation is xerophytic, or typical of areas with limited water supplies (Acacia, Grewia, Maerus). Thus, it is important to note that most rainfall occurs during the summer months and the winters are very dry. The slopes are filled with acacia and many thorny or xerophytic shrubs. The "ilb" (Zizyphus spina-Christi) grow on the cultivated terraces surrounding Taiz or on the flooded sections of the wadi banks Some carobs can be found on the terraces of the Jabel Sabir, near Taiz. Upon the high plateau most trees disappear, except for some tamarisk (T. Orientalis), a few Acacias, and Zizyphus which can be found along irrigation channels or in the wadi beds. Cereals, fruits, such as apricots and grapes, vegetables, and coffee are grown in the Study Area. Taiz is the center for the production of the narcotic leaf qat (Ceatha Eludis), which is widely used in Northern Yemen.

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Asiatic and Mediterranean animals are commonly found in the interior highlands of Yemen. A variety of rodents inhabit the Study Area, while gazelles and a variety of primates can be found in the outer, more lush regions of Taiz. The hyarx, which is approximately the size of the European hare, is a tailless, furry animal typically found on hillsides.

With an estimated population of 95,000 (1975), Taiz has only a few paved streets. The city is currently experiencing a building boom, with foreign money aiding in the development of schools and hospitals. Most of the population lives in stone buildings; however, few homes have adequate sanitary facilities, as discussed in Chapter 9. Local officials are appointed by the governor of the state, and the municipal government is run under the auspices of the national government.

Although Taiz is considered the principal agricultural market and financial center for Southern Yemen, industry is beginning to develop in the Study Area. The construction of roads to link outer sections of the region to Taiz and to other cities will encourage not only wider agricultural markets, but also new commercial markets. Industries located in the Taiz Study Area include an aluminum products factory, a paint factory, a biscuit factory, soft drink plants, and other small industries. Large migrations of labor to Taiz have been occurring for the past ten years, as discussed in Chapter 4.

SUMMARY OF PRESENT WATER AND WASTEWATER SYSTEMS

Wells located in the Houban and Hougala basins are currently serving a population three times greater than the design flow of the system. An acute shortage of water consequently exists in the Study Area and the estimated average domestic water consumption rate is 45 liters per capita per day. Service interruptions are common, and the water quality has continued to deteriorate to dangerous levels. Surface and subsurface waters containing sewage wastes from Taiz proper and Wadi Taiz migrate toward the present well systems and eventually percolate into the shallow basins that supply the wells. As a result, the chemical concentrations have increased to unacceptable levels; the nitrate concentration exceeds 200 mg/l, which is over four times the recommended WHO limit of 45 mg/l, and the 1974 total solids average is 2,150 mg/l. Fecal contamination, frequently found in the water supply, is largely due to sewage infiltration (See Chapter 9). In addition, the prohibitive cost and limited availability of chlorine have restricted the use of local chlorination facilities.

The wastewater system is considerably more primitive than the water system. According to a WHO survey, less than 40 percent of the homes in Taiz have water flush toilets, and only 25 percent of the homes are connected to sewer lines which transport raw sewage into wadis. As described in Chapter 9, most toilets and sinks discharge directly into the streets of Taiz, or to cesspools located below the city streets. The remainder of the residents use pit latrines or open holes in the ground. The structural quality of the pipe used in the existing sewage system is generally poor, and the current practices for installation of the sewers have been determined to be unacceptable by most construction practices.

The high incidence of parasitic infection and waterborne diseases, such as infectious hepatitis and cholera, have been attributed to the poor sanitation facilities. Increasing population, and thus sewage discharges, has greatly reduced the usefulness of the current water supply and aggravated an already serious public health situation.

IMPACTS OF THE PROPOSED PROJECT

The environmental impacts of the proposed project can be divided into two major classifications: primary and secondary impacts. Areas of immediate interest focus on the vast benefits to the public health and welfare anticipated as a result of project implementation. The adverse short-term impacts that construction activities will have on the local environment will be discussed and evaluated. Major potential areas of long-range concern include effects on local ground water tables, growth-inducing impacts, as well as adequately identifying possible cross-impacts upon the socio-cultural-economic aspects of the Taiz community.

PRIMARY IMPACTS

The primary environmental impacts of the proposed project are associated initially with the construction phases, and subsequently, with the anticipated improvement in the availability and quality of potable water within the Taiz Study Area. The proposed project involves expansion and modification of the presently inadequate water system; the Phase I construction period will consist of the development of new well areas, (as shown in Figure 8-7), the installation of pumping units, chlorination facilities, and a distribution system, including reservoirs. For Phase I, the proposed sewerage improvements include a major expansion of the present sewage collection system and transport by gravity interceptor to a 90 lps two-stage trickling filter treatment plant.

Detailed descriptions of the proposed water and wastewater projects, including layout and location maps for the proposed wells, and accompanying water system facilities and treatment plant and associated transport facilities, can be found in Chapter 8 and Chapter 9, respectively. Phase I is recommended for immediate implementation, whereas Phase II design and construction will be delayed until 1985. Therefore, the environmental analysis and discussion will focus on Phase I implementation.

Construction Activities

Construction of the water transmission and distribution system routes will cause short-term disturbances to the local environment. Local residents will experience temporary disturbances associated with construction activities, such as increased noise levels, dust, particulate matter, and exhaust fumes, and traffic congestion. Construction of the water system will require clearing and excavation along the proposed routes, possibly disturbing local vegetation and wildlife. Efforts will be made to avoid routing the transmission line through hard rock, but some blasting may be required. In other areas, portions of the pipeline will be exposed to avoid such hard rock outcroppings. However, since most of the transmission lines will be installed below ground level, the effect of the construction on the local ecology is expected to be only short-term. Any damage done to the intricate terracing system in the highlands will be repaired; however, a certain amount of wind erosion can be anticipated. During the first growing season after construction work is completed, local plant species will return to the site. Although some cultivated fields will be disturbed, productivity losses are expected to be only seasonal. Overall, agricultural productivity in the Hougala area is expected to be improved by the proposed project as water for irrigation purposes becomes more readily available.

Development of the Upper and Lower El Hiama wells as a source of supply includes installation of required electric pumps, collection pipelines, construction of a reservoir, and chlorination facilities. Booster stations, storage reservoirs, and a pumping station will be provided as necessary. The construction will permanently alter the terrestial ecology and visual appearance of the well sites. A small number of farmers in the immediate area will no longer be able to utilize a portion of their agricultural land. However, the increased availability of water for irrigation will increase agricultural productivity per acre, which is intended to compensate for any acreage losses. Water from the Houban-Hougala wells will be available for irrigation during Phase I.

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The short-term impacts associated with construction of the wastewater collection system and treatment facilities are similar to those disruptive activities associated with implementation of the water project. Construction of treatment facilities one kilometer north of Taiz will permanently alter the ecology of the plant site. From preliminary design calculations, it is projected four parcels of land, each three acres in size, will be required for effluent disposal. Some agricultural lands may be lost in the proximity of the disposal area. During Phase I, industrial flows from the western sector of Taiz will be carried by gravity sewer for discharge into a wadi approximately 1/2 kilometer outside of the industrial zone. In Phase II, when industrial flows are expected to increase significantly, a 6-inch force main will be constructed to serve this western sector, requiring installation of two buried (prefabricated) pump stations operating in series. Flows from future development in the eastern zone will also be pumped to the treatment facility. It is anticipated the pump station in the eastern zone will be a built-in-place structure; some blasting will be required at the time of installation.

No ambient air or noise data are currently available. Construction work will temporarily increase local dust and air contaminant levels. However, the effects are likely to be minor as compared with present levels in the area, where most roads are presently unpaved and quite dusty. Local noise levels may increase during the construction phase as a result of increased traffic from hauling equipment.

Trenching operations will be conducted in sections thus minimizing disruptive activities, but construction work will require some roads to be temporarily closed or partially obstructed, in populated sectors of the Study Area. Some road improvements will be carried out, however, to expedite implementation of the proposed project. Clearing, excavation and construction wastes such as shrubs, rocks, and debris will be properly disposed of locally.

Power Requirements

Energy consumption will be limited principally to the use of gasoline and diesel fuel for the operation of generators at the well fields and reservoir site. Electricity will be required for operation of pumps and mechanical equipment at both the well site, the wastewater treatment plant (50-60 hp), and along transmission routes. Standby capacity will be provided.

Project Safety

Irreversible environmental damage resulting from implementation of the proposed project is unlikely. The possibility of seismic activity is not a major concern in the project area. Although there is no accurate data on seismic activity, there are several tall masonry towers in the area (that are several hundred years old) that show little evidence of ground movement. As discussed in Chapter 9, normal sismic loadings in Zone I construction should be incorporated in the structural design. Rigid construction specifications for additions and renovations, in addition to field inspections, will prevent leakage from the system. However, the possibility of slides damaging an exposed pipeline does exist. Construction problems resulting from high ground water are not anticipated, nor is flash-flooding considered a major concern.

Initial Economic Considerations

Although supervisory and technical personnel would be brought to the project during each phase of construction by the contractor most of the construction work will be carried out by local laborers. For example, hand labor will be used for trenching operations wherever possible. Construction of the proposed project will stimulate the local economy by mobilizing skilled workers. Materials manufactured in the proximity of Taiz, such as piping, cement, and concrete blocks will be utilized during construction, wherever feasible. The construction activities should help to stimulate the local economy by creating more jobs. The immediate impact of the construction on agricultural economy should be minor, but the increased water supply for irrigation should eventually improve productivity, as discussed earlier. Once construction is completed, small operating and maintenance staffs will be required for the water and wastewater systems.

Social and Visual Impacts

Although the proposed project will cause the displacement and relocation of some individuals living in the area of the proposed well sites and support facilities, and possibly in the treatment plant and disposal areas as well, project implementation will improve the quality of life for all the people living in the Study Area. First, the anticipated improvement in the water supply and water quality will benefit the public health and well-being of Taiz residents. Second, sewage will no longer

be flowing in the streets of Taiz, which has created not only a public health hazard, but has presented an acsthctically unpleasant appearance and odor. These benefits far outweigh any negative impacts associated with the proposed trickling filter plant. In addition, recirculation will aid in reducing nuisances due to odors and flies. Digested sludge will be disposed of properly; it is anticipated digested sludge will be used as a soil conditioner and fertilizer. The percolation beds and sludge lagoons will be continuously patrolled to keep out unauthorized persons.

The raw sewage to be disposed of in the Western Industrial Zone is not a desirable situation. However, it is not cost effective at this time to pump the small industrial flow to the treatment facility. If a public health problem develops at the disposal site, temporary installation of septic facilties may be required. During Phase II, a force main will transport this waste to the treatment facility.

Construction activities will be scheduled so as to permit local labor to observe religious holidays including "Ramadan".

Local Water Quality and Supply

The proposed water system expansion and modifications will greatly improve water quality and public health in the Taiz Study Area as a result of reduced nitrate and coliform levels. Water analyses performed on samples from test holes at the sites of the proposed Phase I wells show NO_3 levels below 20 mg/l (present water supply: 170 mg/l) and total solids falling between 500 and 1,000 mg/l (present water supply TDS: 2,100-2,600 mg/l). Water quality will meet the recommended WHO International Standards for Drinking Water (1971).

Water production will be significantly increased and the improved system will reliably provide water service to all future customers. The majority of the service will be provided by house connections; however, public toilets and faucets will also be installed to improve the public health situation for all city inhabitants. The toilet facilities will be designed to serve a neighborhood population of approximately 400 persons each; construction and maintenance are discussed in Chapter 9. A program to educate local residents on the utilization and sanitary maintenance of these facilities is recommended. Wastewater from toilets will enter the collection system and no public health or nuisance problems are anticipated at faucet sites. Residents of the Study Area will be assured an ample water supply will be available for their use.

The improvements to the present water system will minimize the water lost through leakage and, will for the first time, meter production. Although all service connections are metered, an estimated 30 percent of the water is unaccounted-for presently. The proposed project will help conserve water by improving the transmission and distribution system. In addition, all existing cesspools that have been constructed near water pipelines will be eliminated or relocated, as necessary.

Approximately 40 percent of the homes in Taiz presently have water flush toilets, and only 25 percent of the total population is connected to sewer lines which transport raw sewage into Wadi Taiz for disposal in the midst of the city. The proposed wastewater facilities will serve 60 percent of the population by the year 1985, and 90 percent of the total estimated population by the year 1995. The populace that cannot be feasibly sewered should be connected to septic tanks. Residents in low-income homes will be encouraged to install low-cost water seal privys which could be connected to the sewer. Presently, the waste flowing from the Study Area can be considered as domestic equivalent. There are no toxic wastes being discharged into the sewers at this time. Storm drainage is not considered significant in Taiz due to steep terrain and limited rainfall.

A trickling filter plant has been proposed as the best apparent treatment alternative to economically achieve the desired level of treatment, as well as conserve scarce resources. The treated effluent will be applied to four sets of intermittent percolation beds, in an effort to recharge the Hougala groundwater basin. Care will be taken to assure that the effluent is not used by anyone for direct irrigation of food crops. However, the digested sludge will be used as soil conditioner and fertilizer.

Fire Protection Capabilities

Fire protection will be provided to only certain portions of the city. Since most buildings were constructed from stone and brick, water hydrants will be installed only in new industrial and commercial areas, as well as in sections of the city where combustible materials and furnishings are being used.

Water/Wastewater Systems Operation and Maintenance

Area personnel will be trained in well construction, pump operation and maintenance, water treatment practices, distribution system

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operation, meter maintenance, basic construction practices and basic water system engineering. The program will also include laboratory training on the proper testing and analysis of water samples. The water supply will be monitored for chemical and bacteriological quality control.

Treatment plant personnel will be trained in the operation and maintenance of the facility. A small operating staff, consisting of a superintendent/chemist, a maintenance man and laborers to maintain the plant spreading basins and the sludge lagoons will be needed. Sludge removal equipment may be required at a later date, and manpower requirements will rise after the Phase II expansion.

The water and wastewater systems will be under the jurisdiction of the Taiz Water and Sewerage Agency.

SECONDARY IMPACTS

The Growth-Inducing Impacts of the Proposed Action

Taiz does not have a city land-use plan or any zoning regulations. Although light industry is emerging in the area west of the city, along the highway to the old airport, it is assumed residential and commercial growth will continue to be responsible for most future development.

Phase I and II will provide water to an area 160 percent larger than the present service area. Consequently, it is expected that the expansion of the water distribution system will stimulate growth within the Taiz locality. Residents of outlying regions that suffer from water shortages will be attracted to Taiz once the proposed project is constructed. As discussed in Chapter 6, the proposed project will have an accelerating effect on regional population growth, and thus, a 6 percent annual growth rate has been assumed constant throughout the project study period. In 1985, at the end of Phase I, the projected Taiz Study Area population will be 171,000; at the end of Phase II, in 1995, it is estimated the area will encompass 305,000 people. Projections of the average population density within the Study Area have been made for the years 1985 and 1995 and are graphically displayed in Figure 6-2 and Figure 6-3.

As more people influx to Taiz, provisions will have to be made for additional government services, such as schools, hospitals, and roads, as well as housing. New buildings within the service area must be

properly connected to not only the water system, but also the wastewater collection system. The capacity of the treatment facilities (approximately 90 lps) and disposal site are considered adequate to meet flows during the 10-year planning period, and could be easily expanded. As actual sewage flows approach the design capacity of the plant, parallel trains of 90 lps could be added. Ultimate plant capacity is anticpated to be 270 lps.

Socio - Cultural - Economic Impacts

The standard of living within the Taiz Study Area will improve once water becomes widely available. People will begin to demand indoor water and sanitary facilities, and average per capita domestic consumption is expected to increase from 45 liters per capita per day in 1975, to 80 lpcd in 1985, and 90 lpcd by the year 1995. Commercial business and light industry is being encouraged to develop in Taiz in order to expand the local economy. It is projected that hotel and commercial/light industrial water requirements will jump from 75 cu m/day and 120 cu m/day, respectively, to 380 cu m/day and 825 cu m/day by 1995.

The proposed project will allow water from the Houban-Hougala wells to be used for irrigation and will generate a source of fertilizer, digested sludge. These beneficial impacts should improve agricultural productivity within the Study Area, and heighten Taiz' importance as an agricultural center for Southern Yemen. However, improved agricultural yields may lead to a surplus in agricultural laborers.

Although the Phase I water system will be designed to meet demands anticipated in 1985, as discussed in Chapter 7, the ground water supply in the proximity of Taiz is inadequate to allow unlimited water consumption through the year 1995. Thus, a program to encourage restrictive water usage is recommended for implementation at the beginning of Phase I service to avoid acute water shortages at the end of Phase II. All connections would be metered and a service charge applied for a meter size over 3/8 -in. In addition, water charges would be levied proportional to water usage and group classification. These restrictive measures are necessary to assure water will be available for all sectors of the Taiz society in years to come - for, a water crisis in the year 1995, when a larger population has become accustomed to a higher standard of living, would have unforeseen environmental ramifications.

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Impacts on the Ground Water and Local Environment

The proposed two-stage trickling filter treatment plant will provide 50 percent SS removal and 85 percent BOD removal. The final effluent, will be applied to one of four sets of intermittent percolation beds located in an area with high recharge capacity. The beds will be dosed for eight hours and allowed to drain and dry for at least one day between spreadings to prevent clogging. Scarifying will be carried out as necessary.

The Houban-Hougala well fields will be pumped to provide water for irrigational purposes, after their use as a potable water supply is discontinued during Phase I. This pumping should accelerate the improvement in the water quality anticipated as a result of ground water recharge as described in Chapter 9, Projected Water Quality for Houban-Hougala Basin. Future salt-balance estimates were made and are shown graphically in Figure 9-9. Future TDS concentrations are expected to be approximately 1,100 mg/l, while the present TDS concentration is in excess of 2,300 mg/l.

As a result of the ground water recharge program, the subsurface flow will be increased. It is possible that the lateral movement of the ground water will result in resurfacing water downstream. The high nutrient content of accumulating water may result in algae blooms upstream from the dam located approximately 5 kilometers north of Taiz. See Figure 5-2, Volume II - Water Resources Evaluation.

The water supply in the Taiz area is sufficient to meet needs through Phase II provided conservation measures discussed previously, are employed. No overdrafting of the ground water basins will occur.

No Project Action

The immediate effect of no project action would be a continuation of the existing public health and water quality problems, as well as the severe water shortage. However, failure to improve the existing conditions within the Taiz Study Area will result in further deterioration of the community. No project action would limit future agricultural productivity, and act as a deterrent to future economic growth. Consequently, no project action would perpetuate long-term

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risks to the health and safety of the residents, deplete the beneficial uses of the local environment, and damage the economic and social welfare of Taiz.

Alternative Projects

The proposed wastewater project, including a two-stage trickling filter plant was determined to provide the desired level of waste treatment, allow ground water recharge for minimum capital, operation and maintenance costs. The only other viable alternative under consideration was the transport of the raw waste approximately 7 kilometers downstream of the city for discharge into a wadi. Although this is the least cost solution, the public health and aesthetic impacts are quite undesireable. More importantly, the Hougala basin could not be utilized for maximum yields. In view of the Study Area's water problems, the ability to reclaim water by groundwater recharge became an overriding factor in project selection.

The only alternative to the proposed water project and development of additional wells is the upgrading of the current water supply. However, the poor quality of the water from the Houban-Hougala basins and the limited supply available precludes this as a viable alternative. The proposed wastewater system and groundwater recharge program will allow the return of the Houban-Hougala wells for potable water in Phase II, as discussed above.

CHAPTER 12

CHAPTER 12

SPECIFICATIONS AND STANDARDS

The useful life, together with the cost to operate and to maintain the water and wastewater systems, are largely dependent upon the quality of construction. The quality of construction will be greatly influenced by the standards of construction incorporated into the completed project as well as the standards of manufacturing incorporated into the various products utilized. The ultimate aim of all specifications and standards is to assure that the finished product is compatible with the intended use and in keeping with the purchase price.

OUTLINE SPECIFICATIONS

Included in this chapter is an outline specification for the construction of the Taiz Water and Sewerage Facilities. The completed construction specifications together with the other elements of the construction contract documents will be an important part in assuring a high quality finished product.

EQUIPMENT AND MATERIAL STANDARDS

Compiled in the Equipment and Material Standards are the manufacturing tolerances that are acceptable for inclusion into the project. Each of these standards, when incorporated into the contract documents, define in detail the quality of the equipment and materials required for a completed facility.

OUTLINE SPECIFICATIONS

for

CONSTRUCTION OF

TAIZ WATER AND SEWERAGE FACILITIES

CONTRACT DOCUMENTS

GENERAL CONDITIONS

SPECIAL CONDITIONS

100 GENERAL

101 EARTHWORK

101.01 Excavation

(a) General

(b) Excavation Beneath Structures

(c) Excavation Beneath Paved Areas

(d) Pipeline Trench Excavations

101.02 Backfill

(a) General

(b) Backfill Around and Beneath Structures, and Beneath Paved Areas

(c) Backfill Beneath Reservoir

(d) Backfill Around Reservoir

(e) Pipeline Trench Backfill

(f) Embankment Fill

(g) Compaction Tests

(h) Cutting and Restoring Existing Pavement

102 PAVING

102.01 General

102.02 Cutting and Restoring Pavement

102.03 Subgrade Preparation

102.04 Aggregate Base

102.05 Prime Coat

102.06 Asphaltic Concrete

103 FENCING

103.01 General

103.02 Materials

103.03 Installation

104 PAINTING AND COATINGS

104.01 General

104.02 Factory - Applied Coatings and Touch-Up

104.03 System A - Ungalvanized Ferrous Metal, General

104.04 System B - Galvanized Ferrous Metal, General

104.05 System C - Ungalvanized Ferrous Metal, Submerged

104.06 System D - Galvanized Ferrous Metal, Submerged

104.07 System E - Ungalvanized Ferrous Metal, Corrosive Atmosphere

104.08 System F - Galvanized Ferrous Metal, Corrosive Atmosphere

104.09 System G - Buried Galvanized and Black Steel Pipe

104.10 System H - Buried Miscellaneous Ferrous Surfaces

104.11 System I - Plastics

104.12 System J - Concrete Block, Interior

104.13 System K - Wood, Interior, Stain

104.14 System L - Wood, Interior, Flat

105 CONCRETE

105.01 General

105.02 Proportioning

(a) General

(b) Water - Cement Ratio and Compressive Strength

(c) Tests

105.03 Cement and Admixtures

(a) Cement

(b) Air Entraining Agent

(c) Admixture

(d) Calcium Chloride

105.04 Concrete Aggregates

105.05 Water

105.06 Consistency

105.07 Trial Batch

105.08 Shrinkage Tests

105.09 Shrinkage Limitations

105.10 Measurement of Cement and Aggregate

105.11 Measurement of Water

105.12 Forms

105.13 Construction Joints

(a) General

(b) Construction Joint Sealant

(c) Waterstops

(d) Expansion Joint Filler

105.14 Corrosion Protection Requirement

105.15 Preparation of Surfaces for Concreting

105.16 Exclusion of Water

105.17 Mixing

105.18 Transporting and Placing

105.19 Order of Placing Concrete

105.20 Tramping and Vibrating

105.21 Curing and Waterproofing

105.22 Care and Repair of Concrete

105.23 Finish of Concrete Surfaces

105.24 Treatment of Surface Defects

105.25 Architectural Finish

106 MASONRY

106.01 Materials General

106.02 Sand

106.03 Cement

106.04 Water

106.05 Masonry Units

106.06 Mortar

106.07 Workmanship

106.08 Inspection and Testing

107 REINFORCEMENT STEEL

107.01 General

107.02 Materials

107.03 Installation

(a) Cleaning

(b) Fabrication

(c) Straightening

(d) Placing

(e) Splicing

108 STRUCTURAL STEEL

108.01 Materials

108.02 Shop Drawings

108.03 Fabrication and Erection

109 MISCELLANEOUS METAL WORK

109.01 General

109.02 Galvanizing

109.03 Welding

109.04 Bolts

109.05 Ladders

109.06 Steel Pipe Handrails

109.07 Pipe Columns

109.08 Metal Decking

109.09 Steel Stairs

109.10 Safety Stair Thread

109.11 Metal Grating and Floor Hatches

109.12 Iron Castings

109.13 Seat Angles, Supports, and Guides

110 STEEL TANKS AND APPURTENANCES

110.01 General

110.02 Roof and Columns

110.03 Bottom

110.04 Accessories

110.05 Inspection and Weld Tests

110.06 Painting and Protective Coatings

110.07 Testing and Disinfecting

110.08 Fuel Oil Storage Tanks

110.09 Lubrication Oil Storage Tanks

111 PIPING - WATER

111.01 General

111.02 Mortar Lined and Coated Steel Pipe

(a) General

(b) Pipe Design

(c) Lining

(d) Coating

(e) Internal Bracing

(f) Transportation and Handling

(g) Installation

111.03 Welded Steel Pipe

(a) General

(b) Joints

(c) Welding

(d) Lining

(e) Installation

111.04 Small Steel Pipe

111.05 Asbestos - Cement Water Pipe

(a) Materials

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(b) Installation

111.06 Polyvinyl Chloride Pipe (PVC)

111.07 Polyethylene Plastic Pipe

111.08 Victalic Couplings

111.09 Sleeve-Type Couplings

112 VALVES AND METERS

112.01 General

112.02 Check Valves

112.03 Gate Valves

112.04 Air Vacuum and Air Release Valves

112.05 Butterfly Valves

112.06 Miscellaneous Small Valves

112.07 Insulating Bushings

112.08 Propeller-Type Flow Meters

113 TESTING AND DISINFECTING

113.01 General

113.02 Preliminary Cleaning and Flushing of Reservoir

113.03 Testing and Disinfection of Reservoir and Appurtenant Piping

(a) General

(b) Chlorination

(c) Retention Period

(d) Filling of Reservoir

(e) Leakage Allowance

113.04 Testing Piping

113.05 Disinfection of Piping

(a) General

(b) Preliminary Flushing

(c) Chlorination

(d) Retention Period

(e) Chlorinating Valves

(f) Connections to Existing System

113.06 Disinfecting Wells

113.07 Bacteriological Tests

114 CONSTRUCTING OF WATER WELLS

114.01 General

114.02 Pilot Bore

114.03 Installation of Conductor Casing

114.04 Reaming Pilot Bore for Well Casing

114.05 Installation of Well Casing

114.06 Perforated Casing

114.07 Installation of Gravel Envelope

114.08 Alignment of Well

114.09 Gravel Make-Up Pipe and Sounding Tube

115 DEVELOPING AND TESTING OF WATER WELLS

115.01 General

115.02 Production Testing

115.03 Disposal of Drilling Waste and Test Pumpage

115.04 Capping of Wells

116 EQUIPPING OF WATER WELLS

116.01 General

116.02 Operating Conditions

116.03 Experience Requirement

116.04 Pump Efficiency Tests

116.05 Pump Construction

116.06 Pump Motors

116.07 Water Level Indicator

117 SEWER PIPING

117.01 Materials General

117.02 Concrete

117.03 Mortar

117.04 Polyvinyl Chloride Pipe

117.05 Asbestos Cement Pipe

117.06 Non-Reinforced Concrete Pipe

117.07 Reinforced Concrete Pipe

117.08 Excavation, Shoring and Backfilling

117.09 Installation

117.10 Installation in Tunnel and Jacked Casing

117.11 Inspection

118 SEWER MANHOLES AND APPURTENANCES

118.01 General

118.02 Manholes

(a) Materials

(b) Brick

(c) Concrete

(d) Construction

118.03 Cast Iron Frames and Covers

(a) Materials

(b) Testing

(c) Installation

118.04 Junction Structures

118.05 Terminal Clean Out Structures

118.06 House Laterals

118.07 Wye Connections

118.08 Inspection

119 LEAKAGE TESTS FOR SEWERS

119.01 General

119.02 Infiltration Test

119.03 Hydrostatic Exfiltration Test

119.04 Air Testing

119.05 Allowable Leakage

119.06 Repair of Leaks

119.07 Inspection During Tests and Retests

120 PLASTIC AND FIBERGLASS ITEMS

120.01 General

120.02 Plastic Materials

120.03 Fiberglass Materials

120.04 Construction

120.05 Manufactured Items

(a) Gates

(b) Flumes

(c) Guides

(d) Piping

(e) Valves and Fittings

120.06 Installation

120.07 Inspection

121 ELECTRIC MOTORS

121.01 General

121.02 Manufacturer and Supplier

121.03 Motor Characteristics and Power

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121.04 Construction and Standards

(a) General

(b) Outdoor Motors

(c) Indoor Motors

(d) Space Heaters

(e) Bearings

(f) Insulation Class and Temperature Rise

(g) Motor Voltage

(h) Miscellaneous

121.05 Shop Drawings

121.06 Certificates

122 PUMPING EQUIPMENT

122.01 General

122.02 Chlorine Solution Pumps

122.03 Horizontally Split Case Centrifugal

122.04 Vertical Turbine Submersible

122.05 Sump Pump

122.06 Piston Sludge Pump

122.07 Fuel Pump

122.08 Filter Recirculation Pumps

122.09 Water Seal Pump

122.10 Manufacturing Experience

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122.11 Testing and Certificates

122.12 Installation

122.13 Inspection

123 CHLORINATION EQUIPMENT

123.01 General

123.02 Chlorinators

(a) Operation

(b) Gauges

(c) Controls

(d) Flow Recorder

123.03 Injectors

123.04 Valves, Meters, Adaptors and Diffusers

123.05 Extra Parts

123.06 Scales

(a) Service

(b) Weighing Racks

(c) Load Cells

(d) Platform Scales

123.07 Chlorine Detectors

123.08 Filters, Cross-Over and Accessories

123.09 Installation

123.10 Testing, Certificates, and Inspection

124 FLOW METERS AND RECORDERS

124.01 General

124.02 Palmer-Bowlus Flume

124.03 Turbine Water Meter

124.04 Installation

124.05 Recorders

124.06 Testing, Certificates and Inspection

125 MISCELLANEOUS MECHANICAL EQUIPMENT

125.01 General

125.02 Sewage Clarifier

(a) Manufacturing Experience

(b) Construction, Welding, and Fabrication

(c) Drive Mechanism

(d) Collector Mechanism

(e) Shafts, Bearings, and Seals

(f) Miscellaneous Metal

(g) Finishing

(h) Shop Drawings

(i) Assembly, Testing, and Inspection

125.03 Comminutor

(a) Type

(b) Materials

(c) Lubrication

(d) Spare Parts

(e) Controls

(f) Assembly Check

(g) Manufacturer

125.04 Grit Separation and Washing

125.05 Trickling Filter

(a) Dosing Siphon

(b) Nozzles

(c) Drain

(d) Media

(e) Recirculating Pump Facilities

126 EQUIPMENT AND SUPPLIES

126.01 General

126.02 Laboratory Equipment

126.03 Laboratory Supplies

126.04 Water System Equipment

126.05 Water System Supplies

126.06 Wastewater System Equipment

126.07 Wastewater System Supplies

126.08 Administrative Equipment

126.09 Administrative Supplies

127 ELECTRICAL

127.01 General

127.02 Scope

(a) Overhead Distribution

(b) Distribution and Motor Control Equipment

(c) Equipment Installation and Wiring

(d) Lighting

(e) Communications

(f) Remote Control

127.03 Codes and Standards

(a) American National Standards Institute

(b) Institute of Electrical and Electronics Engineers

(c) National Electric Manufacturers Association

(d) Underwriters Laboratory

127.04 Testing and Test Equipment

(a) Equipment

(b) Procedures

127.05 Grounding

127.06 Raceway

127.07 Conductors

127.08 Terminations

255

127.09 Switches

(a) Disconnect Switch

(b) Time Switch

127.10 Overhead Distribution

(a) Poles

(b) Guys

(c) Sagging

(d) Lightning Arresters

(e) Insulators

(f) Grounding

127.11 Transformers

(a) Liquid Filled Transformers

(b) Dry Type Transformers

127.12 Distribution and Motor Control Equipment

(a) Switchboards

(b) Motor Control Centers

(c) Starters

(d) Circuit Breakers

(e) Control Devices

127.13 Power Generating Equipment

(a) Engine

(b) Generator

(c) Accessories

(d) Switchgear

127.14 Panelboards

127.15 Lighting

127.16 Spare Parts

127.17 Remote Control

(a) Level Transmitter/Switch

(b) Control Cable

(c) Receiver/Recorder

127.18 Intercommunication System

128 ARCHITECTURAL WORK

128.01 General

128.02 Rough Carpentry

128.03 Finish Carpentry and Millwork

128.04 Caulking, Sealants and Moisture Protection

128.05 Insulation and Fireproofing

128.06 Sheet Metal Work

128.07 Roofing

128.08 Doors, Windows and Frames

128.09 Glass and Glazing

128.10 Finish Hardware

128.11 Plaster

128.12 Gypsum Drywall

128.13 Ceiling Systems

128.14 Flooring

128.15 Tile Work

128.16 Wall Covering

128.17 Accessories and Specialties

128.18 Plumbing Fixtures

128.19 Ornamental Work

129 LANDSCAPING

129.01 General

129.02 Materials

129.03 Staking

129.04 Finish Grading

129.05 Soil Preparation

129.06 Trees, Shrubs and Ground Covers

129.07 Maintenance

EQUIPMENT AND MATERIAL STANDARDS

PIPE	
Asbestos Cement Pipe	AWWA C-400
Welded Steel Pipe	AWWA C-201
Mill Steel Pipe	AWWA C-202
Non-Reinforced Concrete Pipe	ASTM C-14
Reinforced Concrete Pipe	ASTM C-76
Polyvinyl Chloride Pipe	ASTM D-2241
PIPELINE ACCESSORIES	
Steel Pipe Coating & Wrapping	AWWA C-203
Cement Lining of Steel Pipe	AWWA C-205
Steel Pipe Fittings	AWWA C-208
Steel Pipe Flanges	AWWA C-207
Steel Pipe Welded Joints	AWWA C-206
Gate Valves	AWWA C-500
Butterfly Valves	AWWA C-504
Altitude Valve	Cla-Val Co.
BUILDING AND CONSTRUCTION MATERIALS	
Portland Cement, Type II	ASTM C-150
Concrete Reinforcing	ASTM A-15
Steel Plate	ASTM A-283

Specifications and Standards

Cast Iron	ASTM A-48
Painting of Steel Water Tanks	AWWA D-102
Cement Block	ASTM C-90
Concrete Aggregates	ASTM C-33
Masonry Construction	Uniform Building Code
Concrete Construction	A. C. I. Code
Vitrified Brick Masonry	ASTM C-32

UNIT CONSTRUCTION AND INSTALLATIONS

Steel Water Reservoirs	AWWA D-100
Inspection and Repair of Steel Tanks	AWWA D-101
Painting Steel Water Tanks	AWWA D-102

EQUIPMENT

Non-Clog Sewage Pump	Vertical Open Shaft
Sewage Pump Seals	Water Seals with Centrifugal Pump and Air Break Tank
Station Sump Pump	Automatic Float Control
Sewage Check Valve	Spring-Loaded, Flanged, Iron Body
Sewage Gate Valve	Hand Operator, Flanged, Iron Body
Equipment Removal	Cast in Place Lifting Hooks
Sewage P.S. Manifold	Welded Steel
Vertical Turbine Pumps	AWWA E-101

Water Booster Pumps	Horizontally Split Centrifugal, Worthington Co.
Sewage Barminutor	Model C, Chicago Pump Co.
Sewage Flow Meter	Palmer-Bowles Flume
Sewage Clarifier	Circular, Center Feed with Continuous Sludge Removal, Dorr-Oliver Co.
Sewage Sludge Pumping	Positive Displacement Plunger Pump, Variable Capacity, Dorr-Oliver Co.
Sewage Grit Removal	Aerated Grit Chamber, Chicago Pump Co.
Chlorinator	10 to 100 pounds per day, V-Notch, Wall Mounted, Wallace & Tiernan Series A-741
Chlorinator	100 to 300 pounds per day, V-Notch, Wallace & Tiernan, Series 25-060
Chlorinator	350 pounds per day and above, V-Notch, Wallace & Tiernan Series V-800
Beam Scale	2000 pound Fairbanks Portable
Pit Scale	3000 pound Load Cells
Chlorine Analyzer	Wallace & Tiernan
Hand Hoist	4000 pound Capacity
Ventilator	Electric
Cylinder Change Over	Automatic, Wallace & Tiernan

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CHAPTER 13

CHAPTER 13

COST ESTIMATES

ESTIMATED CAPITAL COSTS

A summary of all estimated construction costs for the two-phase development of the project recommended is contained in Table 13-1. This table also contains the distribution of the local and foreign costs for each of the two phases. A more detailed listing of the individual project items for both phases of the development is contained in Appendix B of this report

ANNUAL CAPITAL DEVELOPMENT COSTS

A detailed listing of all project costs and the annual cash requirements to complete both Phases I and II of the project are contained in Table 13-2. The annual disbursement of funds is based on an estimated starting date of the Phase I construction of July 1, 1976, and allowing 24 months to complete the project. Both of these time elements are considered reasonable, which allows ample time for all associated parties to complete all the necessary arrangements and have construction personnel at the job site. This schedule can be modified to reflect an accelerated or developed starting date, but is intended to reflect the estimated flow of funds.

TOTAL PROJECT VALUATION

The total value of the existing systems and facilities is relatively substantial; however, all those facilities that were financed by the United States Department of State, Agency for International Development, do not qualify as eligible assets or contribution for a loan with the same agency. Only those facilities which were independently financed or were a local contribution to the existing facilities are considered. Only three items fall into this category that are of any significant value which are: (1) the existing sewage collection and transmission facilities which were locally financed and essentially constructed after 1970; (2) the

TABLE 13-1

SUMMARY OF CONSTRUCTION COSTS
PHASES I AND II

Description	Phase I				Phase II			
	Local Costs		Foreign Costs	Total Costs	Local Costs		Foreign Costs	Total Costs
	Rials[a]	U.S. $	U.S. $	U.S. $	Rials[a]	U.S. $	U.S. $	U.S. $
Water Supply System								
Wells and well pumps	503,200	110,000	140,000	250,000	411,800	90,000	135,000	225,000
Ground level reservoirs	1,235,300	270,000	90,000	360,000	1,546,300	338,000	112,000	450,000
Chlorination facilities	77,800	17,000	40,000	57,000	187,600	41,000	93,000	134,000
Transmission pipeline	3,957,400	865,000	2,536,000	3,401,000	2,388,100	522,000	783,000	1,305,000
Distribution system	2,335,500	510,500	607,500	1,118,000	1,047,700	229,000	299,500	528,500
Booster pump stations	141,800	31,000	171,000	202,000	1,249,900	273,200	408,800	682,000
Restrictive water meters	-	-	185,000	185,000	-	-	168,000	168,000
Wastewater System								
Wastewater treatment facilities	4,748,800	1,038,000	415,000	1,453,000	9,429,100	2,061,000	845,000	2,906,000
Wastewater collection & transmission	7,657,600	1,673,800	170,000	1,843,800	5,856,900	1,280,200	149,800	1,430,000
Public toilets	171,600	37,500	30,000	67,500	-	-	-	-
Sewage lift stations	-	-	-	-	567,300	124,000	186,000	310,000
Other								
Electric generation facilities	173,900	38,000	220,000	258,000	343,100	75,000	425,000	500,000
Vehicles, equipment, etc.	-	-	275,000	275,000	-	-	100,000	100,000
Total Direct Costs	21,002,900	4,590,800	4,879,500	9,470,300	23,027,800	5,033,400	3,705,100	8,738,500
Engineering costs = 12%	1,559,600	340,900	795,500	1,136,400	1,439,300	314,600	734,000	1,048,600
Contingencies = 13%	2,730,400	596,800	634,400	1,231,200	2,993,400	654,300	481,700	1,136,000
Training Program	549,000	120,000	683,800	803,800	-	-	-	-
Total Costs	25,841,900	5,648,500	6,993,200	12,641,700	27,460,500	6,002,300	4,920,800	10,923,100

[a] Conversion rate, U.S. $1.00 = 4,575 YAR Rials

TABLE 13-2

PROJECTED ANNUAL PROJECT COSTS

U.S. DOLLARS

Description	Phase I Total	Phase I 1976	Phase I 1977	Phase I 1978	Phase II Total	Phase II 1984	Phase II 1985
Water Supply System							
Wells and Well Pumps	250,000	50,000	150,000	50,000	225,000	100,000	125,000
Ground Level Reservoirs	360,000	40,000	200,000	120,000	450,000	200,000	250,000
Chlorination Facilities	57,000	10,000	30,000	17,000	134,000	60,000	74,000
Transmission Pipelines	3,401,000	201,000	2,000,000	1,200,000	1,305,000	550,000	755,000
Distribution System	1,118,000	143,000	675,000	300,000	528,500	250,000	278,500
Booster Pump Stations	202,000	20,000	120,000	62,000	682,000	250,000	432,000
Restrictive Water Meters	185,000	-	185,000	-	168,000	168,000	-
Wastewater System							
Wastewater Treatment Facilities	1,453,000	150,000	900,000	403,000	2,906,000	1,350,000	1,556,000
Wastewater Collection System	1,843,800	400,000	943,800	500,000	1,430,000	616,200	813,800
Sewage Lift Station	-	-	-	-	310,000	158,800	151,200
Public Toilets	67,500	20,000	35,000	12,500	-	-	-
Other							
Electric Generation Facilities	258,000	50,000	150,000	58,000	500,000	200,000	300,000
Vehicles, Equipment, etc.	275,000	275,000	-	-	100,000	100,000	-
Total Direct Costs	9,470,300	1,359,000	5,388,800	2,722,500	8,738,500	4,003,000	4,735,500
Contingencies 13%	1,231,200	176,600	700,600	354,000	1,136,000	520,400	615,600
Engineering 12%	1,136,400	163,100	646,600	326,700	1,048,600	480,400	568,200
Training Program	803,800	203,800	400,000	200,000	-	-	-
Land and R/W Acquisition							
Water Well Field	20,000	10,000	10,000	-	24,000	18,000	6,000
Transmission Line, Reservoirs & Pumping Stations	100,000	50,000	50,000	-	42,000	36,000	6,000
Wastewater Treatment Plant	100,000	50,000	50,000	-	204,000	150,000	54,000
Totals	12,861,700	2,012,500	7,246,000	3,603,200	11,193,100	5,207,800	5,985,300

Note: The above cost figures are based on January 1975 prices.
No allowance has been provided in this estimate for escalation.

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land which was donated by the local government to the USAID-financed water supply system constructed in the mid-1960's which was valued at U.S. $100,000[a] in 1962; and (3) the locally financed wells constructed subsequent to the USAID-financed water supply project of the 1960's.

Of these three items, only the existing sewage collection system and the land will contribute any value to Phase I of the proposed project. The existing wells drilled in the Houban-Hougala area after the completion of the USAID-financed project, can only be of value in the Phase II portion of the proposed project when this well field is put back into domestic service. However, the maximum expected life span of the wells is 15 years, which will not give them any value when the need for productive wells for this area exists. These existing wells will have to be either redeveloped or new wells drilled. An evaluation of the estimated construction values is contained in Table 13-3, as to their value as local contribution to the proposed project.

A summary of the total value for both Phase I and II of the proposed project is contained in Table 13-4.

OPERATIONS AND MAINTENANCE COSTS

An estimate was made for all the operations and maintenance ("O&M") costs to operate the completed system, and is listed in Table 13-5. This table also lists the projected "O&M" costs for continued operations of the existing system. A study of this table will reveal that the overall "O&M" costs will be reduced substantially when the new system is put into operation. The primary reason is the fact that the water supply from the El Hiama basin will flow by gravity to the Lower Thaabat reservoir, whereas the current source of water from the Houban-Hougala basin must all be pumped up to the city. Another important fact is the more efficient electrical generation equipment and pumps of the new system.

The basic operations and maintenance costs are based on the recommended staffing and salary structure, plus normal maintenance costs. Chlorine is estimated at US$1,020 per 2,000 lb cylinder and electric power to be US$0.10 per kwh.

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[a] Bonnie Sether, J.F.K. Memorial Water Supply System - Taiz, Yemen, July 1965, pp5.

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TABLE 13-3

APPRAISED VALUE OF EXISTING FACILITIES
ELIGIBLE AS CONTRIBUTION
(U.S. DOLLARS)

Description	Year Constructed	Original Value	Estimated Life Span	Depreciated Value (1976)	Adjusted Value
Sewage Collection System Replacement cost = 341,200	1971-1974	282,000	±15 years	244,400	295,700
Land	1961	100,000	-	-	250,000

Note: "Adjusted Value" is the value in 1976 based on January 1975 prices.

TABLE 13-4

TOTAL VALUE OF PROPOSED PROJECTS

Phase I	1975 U.S. $
Land currently owned by the Kennedy Water Supply System	$ 250,000
Present value of existing sewer system	296,000
Land and Right-of-way to be acquired	220,000
New construction capital requirements for project	12,642,000
Total	$13,408,000
Phase II	
Land and Right-of-way to be acquired	$ 270,000
Present value of existing Houban-Hougala well field	-
Total capital requirements to construct project	10,923,000
Total	$11,193,000

Note: The above cost figures are based on January 1975 prices. No allowance has been provided for escalation.

TABLE 13-5

SUMMARY OF OPERATIONS AND MAINTENANCE COSTS (U.S. DOLLARS)

	O & M Cost Existing System	Operation & Maintenance	Cl_2	Power Costs: Water Supply System	Power Costs: Wastewater System	Total Costs
1975	432,000	-	-	-	-	432,000
76	482,000	-	-	-	-	482,000
77	532,000	-	-	-	-	532,000
78	291,000	141,000	3,000	47,500	2,500	485,000
79	-	227,000	7,000	120,500	5,000	359,500
1980	-	257,000	8,500	153,000	6,000	424,500
81	-	282,500	9,500	171,500	6,000	469,500
82	-	312,500	10,500	190,500	7,000	520,500
83	-	341,000	12,000	216,000	7,000	576,000
84	-	365,500	13,000	234,000	8,000	620,500
1985	-	391,000	13,500	258,000	8,000	670,500
86	-	428,500	15,500	407,000	16,400	867,400
87	-	471,000	17,000	456,000	27,200	971,200
88	-	511,500	18,500	738,000	38,700	1,306,700
89	-	554,000	20,500	767,500	49,000	1,391,000
1990	-	598,000	21,500	803,500	61,200	1,484,200
91	-	647,500	23,000	843,500	73,800	1,587,800
92	-	700,000	25,500	1,016,000	86,500	1,828,000
93	-	756,500	27,000	1,061,500	99,400	1,944,400
94	-	813,500	30,000	1,108,500	113,900	2,065,900
1995	-	872,500	32,500	1,162,000	128,500	2,195,500

Note: The above cost figures are based on January 1975 prices. No allowances have been made for escalation.

An additional summary was made that separates the local labor, local materials, and foreign goods and services components of the annual operation and maintenance costs. These costs are listed in Tables 13-6 and 13-7 and cover only those costs related to the proposed Phases I and II development. Costs to operate the existing water supply system are not included.

Those costs listed on Table 13-6 are based on January 1975 prices and have not been escalated to reflect any future rates of inflation. Inflation is considered on Table 13-7, on which the local labor is inflated at the rate of 8 percent per year, local materials inflated at the rate of 15 percent per year and the foreign goods and services inflated at the rate of 10 percent per year through the year 1985, after which costs are held constant through the year 1995.

TABLE 13-6

OPERATION AND MAINTENANCE COSTS

ANNUAL COSTS - 1975 PRICES
(U. S. Dollars)

Year	Local Labor	Local Materials	Foreign Goods and Services	Total Annual Costs
1975	-	-	-	-
1976	-	-	-	-
1977	-	-	-	-
1978	122,000	14,000	58,000	194,000
1979	194,000	25,000	140,000	359,000
1980	217,000	31,000	176,000	424,000
1981	239,000	33,000	198,000	470,000
1982	258,000	36,000	226,000	520,000
1983	287,000	42,000	247,000	576,000
1984	308,000	44,000	269,000	621,000
1985	330,000	48,000	293,000	671,000
1986	365,000	48,000	454,000	867,000
1987	402,000	53,000	516,000	971,000
1988	434,000	59,000	814,000	1,307,000
1989	471,000	64,000	856,000	1,391,000
1990	509,000	68,000	907,000	1,484,000
1991	549,000	75,000	964,000	1,588,000
1992	595,000	81,000	1,152,000	1,828,000
1993	642,000	88,000	1,214,000	1,944,000
1994	690,000	95,000	1,281,000	2,066,000
1995	740,000	102,000	1,354,000	2,196,000

TABLE 13-7

OPERATION AND MAINTENANCE COSTS
ANNUAL COSTS INFLATED (U. S. Dollars)

Year	Local Labor		Local Materials		Foreign Goods and Services		Total Costs
	Inflation Rate 8%	Inflated Cost	Inflation Rate 15%	Inflated Cost	Inflation Rate 10%	Inflated Cost	
1975	1.000	-	1.000	-	1.000	-	-
1976	1.080	-	1.150	-	1.100	-	-
1977	1.166	-	1.322	-	1.210	-	-
1978	1.260	154,000	1.521	21,000	1.331	77,000	252,000
1979	1.360	264,000	1.749	44,000	1.464	205,000	513,000
1980	1.469	319,000	2.011	62,000	1.611	284,000	665,000
1981	1.587	379,000	2.313	76,000	1.772	351,000	806,000
1982	1.714	442,000	2.660	96,000	1.949	440,000	978,000
1983	1.851	531,000	3.059	128,000	2.144	530,000	1,189,000
1984	1.999	616,000	3.518	155,000	2.358	634,000	1,405,000
1985	2.159	712,000	4.046	194,000	2.594	760,000	1,666,000
1986	2.159	788,000	4.046	194,000	2.594	1,178,000	2,160,000
1987	2.159	868,000	4.046	214,000	2.594	1,338,000	2,420,000
1988	2.159	937,000	4.046	239,000	2.594	2,112,000	3,288,000
1989	2.159	1,017,000	4.046	259,000	2.594	2,220,000	3,496,000
1990	2.159	1,099,000	4.046	275,000	2.594	2,353,000	3,727,000
1991	2.159	1,185,000	4.046	303,000	2.594	2,501,000	3,989,000
1992	2.159	1,285,000	4.046	328,000	2.594	2,988,000	4,601,000
1993	2.159	1,386,000	4.046	356,000	2.594	3,149,000	4,891,000
1994	2.159	1,490,000	4.046	384,000	2.594	3,323,000	5,197,000
1995	2.159	1,598,000	4.046	413,000	2.594	3,512,000	5,523,000

CHAPTER 14

CHAPTER 14

FINANCIAL AND ECONOMIC ANALYSIS

GENERAL

This section considers a proposed plan for financing the recommended project, future revenues and expenses for the Taiz Water and Sewerage Agency throughout the time span of the master plan, the ability of this agency to remain solvent, and the economic impacts imposed by the proposed project.

The lack of complete and adequate records on past operations made certain projections hypothetical, however emphasis was placed on developing realistic projections for future operations. The operations of the existing water supply system and sewage collection system were not included in these evaluations in order to reflect a more accurate picture of the proposed project and its benefits. One exception was in the determination of the cost per cubic meter of water, where a comparison of current costs was made with estimated future costs. The only source of revenues considered, is from the sale of water and the related service charges. All other current sources of income such as the existing practice of drilling water wells for the private sector, were not considered.

FINANCING AND REVENUES

SOURCES AND LOAN TERMS

The source of funds needed to complete these proposed developments is all-important in determining the viability of the project. For this project, the Central Planning Organization of the Yemen Arab Republic has been presumed to be the recipient of the loan funds from an international lending agency and will be responsible for amortizing the loan to the respective international lending agency. It is also presumed that the Central Planning Organization will re-lend 56 percent of the monies received to the National Water and Sewerage

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Authority at 7-1/4 percent per annum with payback terms of interest only for five years followed by 20 years of interest plus principal payments, and the remaining 44 percent of the monies received by the CPO will be given to the NWSA in the form of a grant.

The total amount of the funds to be received by the CPO, and consequently the amount of funds made available to the NWSA in the form of loan and grant funds is dependent upon the requirements of the international lending agency. For this report, the requirements of U. S. Department of State, Agency for International Development (AID) were used which require the recipient country, in this case the Yemen Arab Republic, to provide a minimum of 25 percent of the total value of the completed project in the form of monies, or a contribution-in-kind. A total of 75 percent of the total value of the project was therefore the amount of funds estimated to be made available from the CPO to the NWSA. The Taiz Water Supply and Sewerage Agency is responsible to the NWSA for making amortization payments to the CPO and will carry the loan to the CPO on their books. A summary of the capital requirements from both the international and national sources is contained in Table 14-1.

ANNUAL CAPITAL REQUIREMENTS FOR PROJECT DEVELOPMENT

The annual capital expenditures for the construction of Phases I and II are listed in Table 14-2. The total local contribution and the total foreign contribution of the capital requirements are listed by two computation methods: 1) based on January 1975 prices to develop the proposed systems, and 2) escalated at the rates of 15 percent per year for the local contribution and 10 percent per year for the foreign contribution to estimate the actual total monies needed to develop this project. The foreign contribution is further divided into those portions of the foreign loan that will be made available to the TWSA in the form of a loan and a grant.

ANNUAL DEBT SERVICE

Table 14-3 presents the annual loan repayment schedules for that portion of the foreign contribution loaned to TWSA by the CPO (56 percent of the foreign contribution). These schedules are based on both the 1975 project development costs and those costs escalated at the rate of 10 percent per annum until used to develop the project. These annual debt service costs to TWSA will be fixed once the loan monies are received. These costs will not be affected by inflation as are the annual operation and maintenance costs which reflect the annual increases in labor and material costs.

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TABLE 14-1

TOTAL CAPITAL REQUIREMENTS
FOREIGN AND LOCAL FUNDS

	Phase I		Phase II	
Total value of completed project		13,407,400		11,193,200
Total amount of local contribution (25% of total project value)		3,351,800		2,798,300
Total value of local contribution of existing system, including land	545,700		—	
Total remaining local contribution	2,806,100		2,798,300	
Total amount of International loan to Central Planning Organization (75% of total project value)		10,055,600		8,394,900
56 percent as a loan from CPO, @ 7.25% per annum	5,631,100		4,701,100	
44 percent as a grant from the Central Planning Organization	4,424,500		3,693,800	

TABLE 14-2

DISTRIBUTION AND SOURCES OF ANNUAL CAPITAL REQUIREMENTS
(U.S. Dollars)

Year	Total Capital Requirement	Local Contribution		Foreign Contribution			
		Total Costs (1975)	Escalated Costs (15% per annum)	CPO Loan to TWSA (56%)	CPO Grant to TWSA (44%)	Total Costs (1975)	Escalated Costs (10% per annum)
Phase I							
1976	2,013,000	439,000	505,000	881,000	692,000	1,573,000	1,731,000
1977	7,246,000	1,581,000	2,090,000	3,172,000	2,493,000	5,665,000	6,855,000
1978	3,603,000	786,000	1,196,000	1,578,000	1,239,000	2,817,000	3,750,000
Total	12,862,000	2,806,000	3,791,000	5,631,000	4,424,000	10,055,000	12,336,000
Phase II							
1984	5,208,000	1,302,000	4,580,000	2,187,000	1,719,000	3,906,000	12,280,000
1985	5,985,000	1,496,000	6,053,000	2,514,000	1,975,000	4,489,000	15,526,000
Total	11,193,000	5,604,000	10,633,000	4,701,000	3,694,000	8,395,000	27,806,000

Note: All monetary values listed except the Escalated Costs are based on January 1975 prices. The Escalated Costs for the Local and Foreign Contribution have been escalated at the respective rates of 15 and 10 percent per annum.

TABLE 14-3

TWSA LOAN REPAYMENT SCHEDULE
WATER AND WASTEWATER SYSTEM
(U.S. DOLLARS)

Year	Base Costs			Escalated Costs		
	Phase I	Phase II	Total	Phase I	Phase II	Total
1975	-	-	-	-	-	-
76	-	-	-	-	-	-
77	63,900	-	63,900	70,300	-	70,300
78	293,900	-	293,900	348,600	-	348,600
79	408,300	-	408,300	500,800	-	500,800
1980	408,300	-	408,300	500,800	-	500,800
1981	408,300	-	408,300	500,300	-	500,800
82	452,300	-	452,300	549,300	-	549,300
83	607,700	-	607,700	737,700	-	737,700
84	671,900	-	671,900	825,200	-	825,200
1985	651,500	158,600	810,100	800,200	373,900	1,174,100
1986	631,100	340,800	971,900	775,200	846,700	1,621,900
87	610,700	340,800	951,500	750,100	846,700	1,596,800
88	590,300	340,800	931,100	725,100	846,700	1,571,800
89	569,900	340,800	910,700	700,000	846,700	1,546,700
1990	549,400	450,200	999,600	675,000	1,104,600	1,779,600
1991	529,000	568,000	1,097,000	650,000	1,411,900	2,061,900
92	508,600	550,900	1,059,500	624,900	1,369,600	1,994,500
93	488,200	533,900	1,022,100	599,900	1,327,200	1,927,100
94	467,800	516,800	984,600	574,800	1,284,900	1,859,700
1995	447,400	499,800	947,200	549,800	1,242,600	1,792,400

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WATER RATES

There are three economic and social objectives that the water rate scheduled is intended to achieve. To some extent these objectives reinforce each other, but there are also trade-offs between them.

Public Health Improvements Through Extensive Use of the System by Lower-Income Groups

Having incurred all the costs of constructing a system, it is important that the system be used almost universally in order that the health benefits of such a system be assured. This involves inducing lower-income groups to use the system by extending the service to them at a price within their ability to pay. This can be accomplished by offering lower income groups a special type of water service at a low rate and by providing them with a sewage connection at no cost.

It is recommended that approximately the thirty percent of the population that comprises the low and poor income groups, as discussed in Chapter 4, be eligible for a special water service through the use of a meter with a 3/8-inch outlet. Such a meter will provide a low flow water service. The availability of such water service can be limited by specifying that it will only be provided to dwelling units below a certain value. This figure can be set so as to assure that no more than 30 percent of the population receives the special low delivery water service.

The low and poor income families electing the special service would pay a minimum charge of 5 Rials per month for which they would be entitled to receive 5 cu m of water. For water usages greater than 5 cu m per month, as would be the case for large families, an additional 5 cu m of water could be obtained at the rate of 1.5 Rials per cu m. For additional amounts of water above 10 cu m, users of the special service will pay the regular steeply progressive rates to be levied on the other 70 percent of domestic users who will pay rates that will make the system financially viable. This special water service is designed to be within the low and poor income groups' ability to pay.

It must be noted that 70 percent of the dwelling units already have a water connection to the KMWS system and that the present water rate is nearly 1 Rial per cu m. This price is currently being paid for intermittent water service. Low and poor income groups will thus continue paying approximately the same unit price they are currently paying for a low but continuous water supply and will not be burdened

with paying for entrapped air and water, which is the existing situation. The unit cost of water to the low and poor income groups will actually be lower than the existing situation when entrapped air is taken into account.

A large number of families eligible for this special low rate service already have a water service connection to the KMWS system. Of the approximately 30 percent of households currently without a service connection, it is estimated that 1/3 or 10 percent of the total families in Taiz are in the poor income group earning less than 215 Rials per month and cannot afford a service connection of any type, and another 2/9 of the unconnected families will qualify as low income families eligible for this service. This is discussed in greater detail in the section entitled "Distribution of Water Service" in this chapter.

It is recommended that this special service be made available at no cost to qualifying families. The only cost to the individual home owner would be the internal plumbing costs, which in most cases is estimated to involve a short length of pipe passing through the wall from the meter into the house and a spigot. All costs to provide and install the service connection from the water main through the special meter would be absorbed by the TWSA. The meter and connection would remain the property of the TWSA. At such time as the home owner should elect to install a regular service meter and thus disqualify himself from the special low cost water rates, he would be obligated to assume the cost of the house connection and purchase his own meter.

The thirty percent of families eligible for this service, as delineated in Table 4-4, is assumed to be in an an income range from a minimum of 100 Rials to possibly as high as 450 Rials per month. They will pay water bills from a minimum of 5 Rials per month (5 cu m) to 12.5 Rials for 10 cu m, for larger size families. The amount of water they will consume will be a matter of their own decision as to how much they believe they can afford. In any case, the poorest family with an income of only 100 Rials per month will have available a minimal amount of water (5 cu m for 5 Rials) at no more than 5 percent of their income. Large families may need more than 5 cu m and will also likely have more than one wage earner and thus may not be income-wise in this group. If the combined family income is 400 Rials, consumption of 10 cu m under the rates for this special service will involve 3 percent of income. Excess water consumption (10 cu m) by the very poorest of families with an income of 100 Rials per month would involve 10 percent of their income, which is approximately equal to what they are now estimated to pay on the average for a small fraction of this quantity of water purchased from private vendors. It is presumed

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that in the cases of those families in the very low income range, most will not obtain a service connection but will receive the majority of their water from a public faucet.

Economization of the Use of Water

The proposed schedule of water rates is steeply progressive for all users other than government and charitable organizations. The objective of this rate schedule is to encourage the economization of water. The available water supply of satisfactory quality in the vicinity of Taiz is limited, and will eventually impose limits on the growth of the community. Taiz water users have already developed a pattern of low water use consumption because of the intermittent delivery and low flow of water in many areas of the city. While the new system will make water readily available, it is important that the citizens realize that water is an expensive item for Taiz, not merely because of the high cost of a water and sewerage system, but because of the scarcity of good continuing water sources. Hence the price for even minimal amounts must be relatively high, and excessive consumption must be discouraged by progressive rates that will exert a penalty from those who use water carelessly.

The exemption of governmental and charitable units from the progressivity features of the rate schedule is based upon the fact that the application of progressive rates would cause a gross inequity between these units based upon size. For example, a large hospital would pay an average price for water higher than that paid by a small hospital. What is proposed is that there be one uniform rate for all such organizations of 1.5 Rials per cu m regardless of the amount of water consumed. This rate is almost equal to the estimated average cost of water for the system as a whole over Phase I. The rate charged should in no case be higher than average cost considering that the functions performed by these organizations - such as the provision of free water by public faucets - are cultural requirements or community benefits. Public faucets will be metered; such water must be paid for by either the municipality or by the mosques. Most of the public faucets will be adjacent to mosques. In cases where public faucets already exist in mosques, wall meters must be installed and the faucet located in a position agreeable to the party paying for the water, i.e. the mosque or the municipality.

A single progressive rate schedule is proposed for household and commercial establishments. This is justified on the grounds of simplicity and also equity in that most of the commercial connections are small family shops that would appear to justify the same treatment as residences. The 70 percent of the households that would utilize

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the standard water service would, along with the commercial enterprises, pay a base charge of 10 Rials for 5 cu m with progressive rates of 2.0 Rials/cu m for the next 5 cu m and 2.5 Rials and 3.0 Rials for each additional cu m. All water used in excess of 30 cu m would involve a rate of 4.0 Rials. The objective of the final 4.0 Rials rate on all water over 30 cu m is designed to deter the use of water for garden purposes. This expensive 4.0 Rials rate would also be uniformly applied to all industrial use of water on the grounds that high water using industries should be discouraged from locating in Taiz. The existing and likely future industrial firms that would pay this rate are obviously great beneficiaries of the existence of the system and have the ability to pay this rate which will still be for them a relatively insignificant operating cost. Because of water quality and availability problems, the industrial enterprises of Taiz are not likely to develop their own private systems. The application of progressive rates to industrial enterprises would be discriminatory among them according to size. It is expected that even without a progressive rate feature beyond 30 cu m industries will economize on water rate at the 4.0 Rials price.

Financial Viability

The third objective of the rate schedule is to generate sufficient revenues which will, at a minimum, cover the actual scheduled amortization, interest and operating costs of the project. This will require that the average rate schedule must generate revenues at least sufficient to cover the cost of operation of the water and wastewater system in the next decade, about one million dollars a year. Since community gross domestic product appears to be in excess of $25 million, the project should be within the financial capability of the community as a whole.

The more important matter is the apportionment of the costs of the system among the different elements of the community through the rate schedule. Here an attempt has been made to draw from the community on the basis of ability to pay. As mentioned earlier, 30 percent of the family units will be entitled to a special service (Category 1-A in Water Rate Schedule, this Chapter) at a low price of 5 Rials per 5 cu m. By virtue of the low rate, as well as its presumed low consumption of water, this group would contribute only about 5 percent of the system's revenues.

Seventy to seventy-five percent of the total annual revenues will come from the 70 percent of households who will purchase water at the standard service rate (Category 1-B). This group, it is estimated, will in fact

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pay an average 40 Rials per month if they consume all the water that the proposed system will produce. Consumption at the proposed progressive rates for this group may fall short of this amount. Such loss of revenue by lower than estimated consumption will, however, mean that the development of Phase II new water sources can be delayed and that the period of adequacy of water supplies for the growing population of Taiz will be extended.

Categories 2 (governmental and charitable) and 3 (industrial and hotels) will, under the proposed rate schedule, account for nearly 20 percent of the water consumption and only a bit more than 20 percent of the revenues. Unfortunately, the industrial and hotel units that have the greatest ability to pay are relatively small in number and water consumption. With time their importance will grow somewhat. The maximum progressive rate for these categories will be 4 Rials per cu m water - about four times what they are currently paying. In the case of the anticipated new larger hotels, water costs may run as high as one or two Rials per day per occupied room. Such a charge can readily be passed on by the hotel to the customer - possibly by an addition to the customer's bills. Bottling companies will also have substantial increases in water bills. Because of poor quality and the problems of availability of local water it is not likely that they would resort to maintaining their own wells. The cost of water to them at the proposed 4.0 Rial rate would amount to only about a third of a cent per 12 ounce bottle and would represent only about 2 percent of the present selling price.

A further source of revenue will come from monthly charges for meter use by all units other than households. These charges are graduated upon the basis of the size of the meter. They are designed progressively in order to obtain additional money based upon the crude rule that larger units of government and business can probably afford to pay more and also that larger users of water probably involve more than proportionate service costs.

It is also proposed that water rates be advanced 2 percent per year compounded. This will tap the increased real income of the community which it is hoped will rise between 2-1/2 percent and 5 percent per capita per annum. Despite such substantial improvement in projected ability to pay, it is proposed that rates not be advanced by as much. The proposed rate schedule itself is progressive. This means that with higher income and accompanying higher water consumption per household (more toilets per dwelling, more water using appliances, etc.), water bills will increase more than proportionate to the increase in consumption. The purpose of the 2 percent increase per year compounded is

not only to make the project financially viable but also to serve the se-second objective of restraining the rate of increase in water consumption so as to prolong the period in which the resources in the immediate Taiz area will be able to meet the needs of the growing city.

WATER RATE SCHEDULE

Category 1. Households and Commercial

A. Special Service (3/8-inch connection)
Households only

Meter: Provided free

Water: 5 Rials minimum charge for 5 cu m per month

1.5 Rials for each additional cu m from 6-10

For all water in excess of 10 cu m regular service rate (B) will apply

B. Regular Service (5/8-inch connection)

Meter: Will be purchased by customer

Water: 10 Rials minimum charge for 1-5 cu m per month

2.0 Rials for each additional cu m from 6-10

2.5 Rials for each additional cu m from 11-20

3.0 Rials for each additional cu m from 21-30

4.0 Rials for each additional cu m over 30

Category 2. Governmental and Charitable

Meter: Purchased by customer

Water: 1.5 Rials per cu m for all water used

Monthly Meter Charge

5/8-inch meter; 50 Rials

3/4-inch meter; 100 Rials

1-inch meter; 150 Rials

1 1/2-inch meter; 200 Rials

2-inch meter; 300 Rials

Category 3. Industrial and Hotels

Meter: Purchased by customer

Water: Apply schedule of Regular Service (1-B)

Monthly Meter Charge: Apply same charges as in Category 2.

ABILITY OF RESIDENTIAL CUSTOMERS TO PAY WATER RATES

The following is a justification of the various income groups' ability to pay for their water service. Each is expressed as a percent of the extreme income ranges within each group.

Poor-Income Group:

Family Income Range = 100 to 215 Rials per month
Minimum Charge = 5 cu m for 5.0 Rials
Percent of Income:

5.0 Rials ÷ 100 Rials = 5.0 percent
5.0 Rials ÷ 215 Rials = 2.3 percent

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Low-Income Group:

Family Income Range = 215 to 450 Rials per month
Estimated Monthly
Charge = 10.0 cu m = 12.5 Rials
Percent of Income:

12.5 Rials ÷ 215 Rials = 5.8 percent
12.5 Rials ÷ 450 Rials = 2.8 percent

Middle-Income Group:

Family Income Range = 450 to 900 Rials per month
Estimated Monthly
Charge = 10.0 cu m for 20.0 Rials
Percent of Income:

20.0 Rials ÷ 450 Rials = 4.4 percent
20.0 Rials ÷ 900 Rials 2.2 percent

The highest apparent cost for water as related to family income is for a family at the lower limit of the low-income group. This particular family would have to pay as much as 5.8 percent of its income for 10.0 cu m of water. Note that this family is not obligated to purchase this amount of water. It is only obligated to pay a minimum charge of 5 Rials for 5.0 cu m of water in order to maintain a service connection. This cost would be only 2.3 percent of the family income.

DISTRIBUTION OF WATER SERVICE

An evaluation of the data collected during the random survey conducted within the city of Taiz, indicates that approximately 7760 of 10,950 families in 1973, or 71 percent, were connected to the KMWS system, 17 percent received all their water through a piped connection to a mountain spring, and 12 percent had no water service connection of any sort. A summary of this data, showing the distribution of the families and population that do and do not have water service is shown on Table 14-4. At the time this report was prepared, an increase in the percentage of the unconnected population existed due to the moratorium which prohibits new service connections to the KMWS system; however, if an increased supply of water was made available, those families who have applied to the KMWS for a service connection, and have been unable due to the moratorium, would install a connection as soon as possible. This would reduce the percentage of families not connected to any source to essentially the same value as in 1973.

TABLE 14-4

DISTRIBUTION OF WATER SERVICE

Description	Families		Population	
	Totals	Percentage	Totals	Percentage
With KMWS Water Service	7,760	71	55,000	70
With Mountain Spring Service Only	1,870	17	14,000	18
With no Water Service	1,320	12	9,500	12
Totals	10,950	100	78,500	100

Note: Data presented is taken from Table 6-2. These totals are for residents of Taiz and do not include commercial establishments or the transient or seasonal student population.

Of the 12 percent of the families that have no water service of any type, 10 percent are assumed to be poor people whose family income is less than 215 Rials per month and cannot afford water service of any type. The remaining two percent are assumed to be that portion of the families living at high elevations in the city or in areas where water service does not exist, that would elect to have a water service connection if this service was made available to them and those families that live together with another family.

It is assumed that the poor people comprising 10 percent of the population with no water service of any type will, in all probability, be reduced in the future as the economic situation improves in Taiz and Yemen as a whole. For purposes of this report, we have conservatively estimated that the percent of poor people unable to afford any water service at the proposed rates will remain constant at 10 percent throughout the duration of the master plan. It is further assumed reasonable that the number of families receiving their water from mountain spring sources will not relinquish that service, but by 1985 half of these will also connect to the proposed TWSA system. None of the families currently connected to the mountain spring sources are considered to be in the poor class of people (i.e. that 10 percent of the families with an income of less than 230 Rials per month) because of the high flat

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rate fee that they are paying for water, although some of these families may qualify to be in the low-income group. The low- and poor-income groups are considered to be approximately 30 percent of the families that earn less than 450 Rials per month.

Utilizing this criteria as a basis, 10 percent of the families that make up the lowest income group will not elect to receive water service through an installed water connection, but will get their water from a public source, and only half of the existing families currently connected to a mountain spring source will elect to purchase TWSA water. Approximately 4,750 new meters will be installed in 1978, when the system goes into operation. Of this total, 1,050 will be 3/8-inch meters provided by TWSA to low- and poor-income families and the remaining 3,700 will be purchased by the individual families or dwelling unit owners for installation and connection to the TWSA system. This estimate is determined as follows:

Total population in 1978		113,500
Number of Families		15,800
Families that will not connect to the TWSA system		
Poor families with no service = 10%	1,600	
Families with spring water electing not to purchase TWSA water	950	
Families already connected to KMWS system	8,500	
Total number of families that will not get new water service		11,050
Potential number of new service connections		4,750
Total number of low- and poor-income families that do not already have water service and are eligible for Category IA water service: 2/9 x 4750 =		1,050
Total number of middle and upper income families who will purchase metered water through a service connection: 7/9 x 4750 =		3,700
Total		4,750

The distribution of families that do and do not have KMWS water service connections is assumed to be uniform throughout all income groups.

By 1985 it is estimated that 21,050 families will receive water from the TWSA through service connections, of which 2,790 will receive the special Category IA service and 18,260 families will purchase water from the TWSA at the regular Category IB rate. These estimates are based on the same criteria where the percentage of poor people will stay constant at 10 percent of the total population and only half of the families that received mountain spring water in 1973 will elect to connect to the TWSA system. A derivation of these totals is as follows:

Total population (1985)		170,600
Estimated number of families at 7.20 persons per family		24,400
Families that will not connect to TWSA system		
Poor families with no service = 10%	2,400	
Families with spring water that elect not to purchase TWSA water	950	
Families already connected to KMWS	8,500	
Total number of families that will not get new water service		11,850
Potential number of additional service connections		12,550
Total number of low- and poor-income families who do not have water service in 1975 and are eligible for Category IA water service: 2/9 x 12,550		2,790
Total number of middle and upper income families that will purchase metered water through a service connection: 7/9 x 12,550		9,760
Total		12,550

A total of 3,000 special 3/8-inch diameter water meters were used for estimating the project development costs.

WATER SALES AND REVENUES

The expected water sales throughout the duration of the master plan are discussed in detail in Chapter 7, Future Water Demands. A summary of the projected water sales and revenues received based upon the proposed water rate schedule is listed in Table 14-5. A detailed summary of the actual distribution of water sales between the various types and classes of users and revenues received in Rials, based on the proposed water rate schedule, is shown in Appendix C.

TABLE 14-5

WATER SALES AND REVENUES

(U. S. Dollars)

Year	Volume Produced	Volume Sold	Revenues
1975	-	-	-
76	-	-	-
77	-	-	-
78	1,587,500	1,270,000	606,100
79	3,688,000	2,950,000	1,466,000
1980	4,180,000	3,340,000	1,711,700
81	4,575,000	3,660,000	1,925,600
82	5,025,000	4,020,000	2,168,900
83	5,475,000	4,380,000	2,418,600
84	5,950,000	4,760,000	2,831,500
1985	6,410,000	5,120,000	2,960,700
86	7,025,000	5,620,000	3,327,200
87	7,675,000	6,140,000	3,723,900
88	8,338,000	6,670,000	4,160,200
89	9,012,000	7,210,000	4,597,600
1990	9,750,000	7,790,000	5,087,700
91	10,650,000	8,520,000	5,682,400
92	11,588,000	9,270,000	6,363,700
93	12,512,000	10,010,000	7,037,200
94	13,450,000	10,760,000	7,720,700
1995	14,400,000	11,530,000	8,462,700

COSTS

A summary of all operations and maintenance costs for both the water supply and wastewater system are contained in Table 13-5, Summary of Operations and Maintenance Costs. The annual interest and amortization payments for the loan as discussed in the section entitled, "Sources and Loan Terms," of this chapter, plus depreciation costs, are listed in Table 14-7.

Depreciation

The manner in which depreciation is treated has a very strong and direct impact upon the financial viability of an institution. This is particularly the case of relatively small agencies in underdeveloped countries that receive large loans and are obligated to repay these loans, provide good service to a low-income population, and properly maintain the system. In most cases, large sums of money are needed to repay the loans and cover the normal operation and maintenance expenses of the system, in relation to the revenues received from the sale of water. Because depreciation is handled as an expense, yet is an intangible item, the rate at which the depreciation of the facilities is annually written off has a definite impact on the annual net income or loss of an operation.

A modified depreciation schedule has been utilized in this report that differs from the traditional Straight Line Method for all major facilities to defer the major depreciation expenses to a later date, at a time when the annual revenues have substantially increased due to the increased sale of water and the annual debt service for the project development costs has been reduced or eliminated. In this case, all facilities with an expected life span of 25 years and 50 years are being depreciated by this proposed modified method. The rates at which these facilities were depreciated in this analysis are listed in Table 14-6. All facilities with an expected life span of 20 years or less were depreciated uniformly using the Straight Line Method. A comparison of the total annual depreciation expenses is contained in Table 14-7, which demonstrates the reduction of the values written off as depreciation by the proposed modified method in comparison to the Straight Line Method during the first half of the expected life span of the major facilities.

Unit Cost of Water

As a convenient comparison to other municipal water and sewerage agencies, and to check the uniformity of costs to verify the compensating effect of loan repayment, operation expenses and depreciation,

TABLE 14-6

ANNUAL RATES FOR DEPRECIATION
MODIFIED SCHEDULE

Age of Facility	Expected Life Span of Facility	
	25 Years	50 Years
1-5	1/75	1/275
6-10	2/75	2/275
11-15	3/75	3/275
16-20	4/75	4/275
21-25	5/75	5/275
26-30		6/275
31-35		7/275
36-40		8/275
41-45		9/275
46-50		10/275

TABLE 14-7

COMPARISON OF ANNUAL DEPRECIATION EXPENSES

Year	Modified Depreciation Schedule			Straight Line Method		
	Phase I	Phase II	Total	Phase I	Phase II	Total
1975	-	-	-	-	-	-
76	-	-	-	-	-	-
77	-	-	-	-	-	-
78	-	-	-	-	-	-
79	107,100	-	107,100	259,500	-	259,500
1980	107,100	-	107,100	259,600	-	259,600
81	107,100	-	107,100	259,500	-	259,500
82	107,100	-	107,100	259,600	-	259,600
83	107,100	-	107,100	259,500	-	259,500
84	145,200	-	145,200	259,600	-	259,600
1985	145,100	-	145,100	259,500	-	259,500
86	145,200	92,500	237,700	259,600	235,000	494,600
87	145,200	92,500	237,700	259,500	235,000	494,500
88	145,100	92,500	237,600	259,600	235,000	494,600
89	183,300	92,500	275,800	243,600	235,000	478,600
1990	165,900	92,500	258,400	243,700	235,000	478,700
91	166,000	133,800	299,800	243,600	235,000	478,600
92	165,900	133,800	299,700	243,700	235,000	478,700
93	166,000	133,800	299,800	243,600	235,000	478,600
94	204,000	133,800	337,800	243,700	235,000	478,700
1995	205,300	133,800	339,100	243,600	235,000	478,600

the cost of water produced and sold is determined and evaluated. Then costs are based upon all costs for which the agency is obligated to meet, which include all operations and maintenance costs, debt service, and depreciation. For this project, a low unit cost is reached shortly after the new system is put into effect, when the existing less efficient system is taken out of service. From this low point around 1980 and 81, which will help the TWSA accumulate reserves and gain financial strength, the unit costs rise gradually to a peak around 1986-1988, which is the result of the Phase II portion of the project being completed, the accompanying interest payments and the Phase I principal payments that reached their peak in 1983. Following this period in time, the unit cost of water gradually decreases as the reduction in debt service exceeds the annual increase in operations expenses and depreciation expenses as proposed in this report. If the traditional method of determining depreciation by having a uniform annual amount were used, the unit costs of water would greatly exceed those proposed on Table 14-8 through 1995, which would put an unjust burden on the TWSA at a time when finances are urgently needed to gain financial strength rather than spread the annual expenses at a more uniform rate throughout the life of the project. In this manner, the major depreciation expenses will be in the latter half of the life span of the major facilities after the capital improvements loans have been repaid.

INTERNAL RATE OF RETURN

The internal rate of return reflects the actual return on investment. It is the return on only those inputs used to create and operate the TWSA, as related to the monies received for its outputs as a business. Items such as depreciation, interest and amortization payments on loans are not considered as expenses, because they are not monies spent or needed to operate the system as an entity. Depreciation is a write-off to reflect wear and age.

The internal rates of return were determined for the proposed master plan to demonstrate the financial soundness of the entire master plan and the rates of return if only Phase I were constructed. These evaluations were made based on anticipated sales of 100 percent of those projected and the sensitivity of the financial viability of the proposed master paln, Phases I & II, and Phase I alone, if water sales are only 85 and 70 percent of that which was projected. A summary of these internal rates of return is contained in Table 14-9. The detailed analyses for each of these situations are in Appendix D, Tables D-1 through 6, along with a detailed breakdown of the anticipated water demands and revenues shown on Tables D-7 and 8.

TABLE 14-8

COST PER UNIT OF WATER

(1) Year	(2) Total "O & M" Costs	(3) Annual Service Connection Cost for Restricted Meters	(4) Depreciation	(5) Total Interest and Amortization of CPO Loan	(6) Total of Columns 2, 3, 4 & 5	Annual Water Production (cu m)	Cost per Cubic Meter Produced		Annual Water Sales (cu m)	Cost per Cubic Meter Sold	
							US $	Rials		US $	Rials[a]
1975	432,000	-	18,500	-	450,500	1,871,400	0.241	1.10	1,310,000	0.344	1.57
1976	482,000	-	18,500	-	500,500	1,871,400	0.267	1.22	1,310,000	0.332	1.75
1977	532,000	-	18,600	68,880	619,500	1,871,400	0.331	1.51	1,310,000	0.473	2.16
1978	485,000	5,000	18,600	289,530	798,100	2,523,200	0.316	1.45	1,925,000	0.415	1.90
1979	359,500	7,500	107,100	408,250	882,400	3,688,000	0.239	1.09	2,950,000	0.299	1.37
1980	424,500	5,000	107,000	408,250	944,800	4,180,000	0.226	1.03	3,340,000	0.283	1.29
1981	469,500	7,500	107,100	408,250	992,400	4,575,000	0.217	0.99	3,660,000	0.271	1.24
1982	520,500	7,500	107,000	455,760	1,090,800	5,025,000	0.217	0.99	4,020,000	0.271	1.24
1983	576,000	7,500	107,100	604,490	1,295,100	5,475,000	0.236	1.08	4,380,000	0.296	1.35
1984	620,500	7,500	145,200	671,890	1,445,100	5,950,000	0.243	1.11	4,760,000	0.303	1.39
1985	670,500	10,000	145,100	810,060	1,635,700	6,410,000	0.255	1.17	5,120,000	0.319	1.46
1986	867,400	12,500	237,700	971,900	2,089,500	7,025,000	0.297	1.36	5,620,000	0.371	1.70
1987	971,200	10,000	237,700	951,490	2,170,400	7,675,000	0.283	1.29	6,140,000	0.353	1.62
1988	1,306,700	12,500	237,600	931,080	2,487,900	8,338,000	0.298	1.36	6,670,000	0.373	1.71
1989	1,391,000	10,000	275,800	910,660	2,587,500	9,012,000	0.287	1.31	7,210,000	0.359	1.64
1990	1,484,200	12,500	258,400	999,620	2,754,700	9,750,000	0.282	1.28	7,790,000	0.354	1.62
1991	1,587,800	15,000	299,800	1,096,990	2,999,600	10,650,000	0.282	1.29	8,520,000	0.352	1.61
1992	1,828,000	15,000	299,700	1,059,510	3,202,200	11,588,000	0.276	1.26	9,270,000	0.345	1.58
1993	1,944,400	17,500	299,800	1,022,060	3,283,800	12,512,000	0.262	1.20	10,010,000	0.328	1.50
1994	2,065,900	15,000	337,800	984,600	3,403,300	13,450,000	0.253	1.16	10,760,000	0.316	1.45
1995	2,195,500	15,000	339,100	947,150	3,496,800	14,400,000	0.243	1.11	11,530,000	0.303	1.39

[a] Conversion rate: 1.00 U.S. Dollar = 4.575 Rials

Note: The above cost figures are based on January 1975 prices. No allowance has been provided for escalation

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TABLE 14-9

INTERNAL RATES OF RETURN

Percent of Projected Water Sales	Phases I and II	Phase I
100	11.69	8.40
85	10.08	6.19
70	8.19	4.34

ECONOMIC JUSTIFICATION OF PROJECT

ALTERNATIVE PROJECT

The recommended project is considered to be the best technically, the most economical, and financially viable water supply, and sewerage system for the city of Taiz. It was designed to best meet the conditions as they exist in the YAR and successfully provide a continuous supply of potable water and to remove all sewerage from the city of Taiz. All efforts were made to provide systems which minimize maintenance, ensure continuous service and minimize power and operating costs. Certain items are included in the recommended design which are more costly than would be required in a high maintenance and cost oriented society, but are more than justified by the fact their presence will reduce maintenance problems, reduce lost revenues due to service interruption, and reduce water-related diseases created by non-continuous water service.

As an alternative to utilizing water from the ground water basins surrounding Taiz, the second most economical method of providing potable water to Taiz would be desalination of saline water from the Red Sea. Brackish ground water is not readily available in adequate quantities in the vicinity of Taiz. Collection of surface run-off is not

considered workable because of the high rate of evaporation, highly seasonal rains, relatively small drainage areas upstream of possible dam sites and poor geologic conditions for adequate dam foundations.

Cost estimates were made for a multistage desalination plant, adequate to treat water with salinity of 30,000 milligrams per liter, transmission pipeline and pump station, all sized to provide water in equal quantities and qualities as the recommended system. The distribution, storage and treatment system within the city is the same as is proposed in the recommended project. A detailed summary of those cost estimates is in Appendix B, Tables B-3 and B-4. A summary of the costs for the alternative project is contained in Table 14-10.

Annual Costs: Following is a summary of all annual costs for the alternative project for 1985.

Operation and maintenance of all project facilities	U.S. $5,811,300
Interest and amortization on CPO Loan	3,693,700
Depreciation account for replacement of facilities	461,000
Total, annual costs	$9,966,000
Annual water production requirement for 1985	6,410,000 cu m
Cost of water per cu m	U.S. $1.55

Benefit-Cost Ratio of Alternate Project and Recommended Project:

1. Benefit-Cost Ratio Based Upon Initial Investment

Initial investment-Alternative Project (Phase I)	$79,975,000
Initial investment-Recommended Project (Phase II)	12,641,000
Ratio	6.33

2. Benefit-Cost Ratio Based Upon Annual Cost (1985)

Annual cost-Alternative Project	$ 9,966,000
Annual cost-Recommended Project	1,635,700
Ratio	6.09

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TABLE 14-10

SUMMARY OF COSTS FOR ALTERNATIVE PROJECT
(U.S. Dollars)

Description	Local Labor	Other Local Costs	U.S. Costs
Phase I			
Land and R/W Acquisition	750,000	-	-
Local labor and material including 13% contingencies	14,100,000	-	-
Materials and construction, including 25% contingencies and engineering on all labor and materials (U.S. cost)	-	2,525,000	62,600,000
Total, Phase I Investment	14,850,000	2,525,000	62,600,000
Total, All Required Funds	-	-	79,975,000
Phase II			
Local labor and material including 13% contingencies	8,367,000	-	-
Materials and construction including 25% contingencies and engineering on all labor and materials	-	1,200,000	6,368,000
Total, Phase I Investment	8,367,000	1,200,000	6,368,000
Total, All Required Funds	-	-	15,935,000

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INCIDENTAL BENEFITS OF THE PROPOSED PROJECT

Impact of Construction

The first phase of the project will involve expenditures for local labor and materials over three years (1976-78) of $5,650,000, and the second phase $6,000,000 over the years 1984 and 1985. These expenditures, of course, will have an impact on local incomes by the amount of the expenditure, but the subsequent expansion of income will not be large, since probably 70 percent of increased incomes will be spent for food coming from outside Taiz and also for imports from abroad. While there is no substantial number of unemployed workers in Taiz at present to draw upon, the knowledge of employment opportunities on the project for unskilled labor will doubtless draw labor from low productivity employment in the countryside without much pressure on wage rates. Wages of skilled construction laborers have risen appreciably during the present period of construction on the Taiz-Sana'a highway, and the completion period of that project may merge with commencement of this project so that some of the skilled and unskilled labor released from it may be utilized. In any case the demand for Yemeni construction workers in Saudi Arabia and the Persian Gulf area appears so strong for the future, that the problem of Yemen will be the retention of its skilled labor. However, the emigration of such labor is not a loss for Yemen, but a source of expanded income through the remissions of the workers to their families at home. Thus, this project may be a useful training ground for unskilled construction workers who will become more skilled and thus may be better able to migrate and to send substantial remissions home.

Linkages

The principal forward linkage of the project is, of course, the consumers who will utilize the water and obtain health benefits for which calculations have been attempted. Hotels and bottling companies will benefit by better quality and more dependable water although the price they pay will be higher. These benefits are measured at least in part - as also in the case of the consumers - by the price they will pay for the water.

Backward linkages as a continuing matter are minor, since regular purchases of supplies by a water and sewerage system are limited chiefly to chlorine which cannot be obtained locally. The important matter is the temporary linkage to the local construction materials

industry during the construction period of the project. The expenditures of the project will provide a market for the plastic pipe factory that is now under construction and for the already existing concrete pipe, block, and aggregate industries.

LOCAL COSTS

PHASE I (1976-78)

Local Labor	$3,660,000
Other Costs	1,990,000
Total Local Costs	$5,650,000

PHASE II (1984-85)

Local Labor	$4,040,000
Other Costs	1,960,000
Total Local Costs	$6,000,000

ESTIMATION OF THE BENFITS OF THE PROJECT

Convenience to the Consumer

A water and sewerage system for a city furnishes one of the amenities of life for which individuals are willing to pay. The value placed on its services is measured for the purposes of this report by the amount that it is estimated consumers will pay in a situation where a progressive rate schedule relative to the quantity of water is applied with the intention of restricting water consumption. More voluntary restriction of water consumption than that estimated may occur and so benefits have also been calculated on the basis that actual revenues may only be 70 percent of the expected amount. Such estimates of the value of water to the consumer do not include the premium that could be obtained from the consumer if the consumer were faced by an exploitative situation in which maximum receipts were exacted from him under a threat that he must choose between the given quantity of water offered or receive no water from the system. Some economists have argued that the estimate of the benefits of a water system to consumers should be calculated on this basis. Since this view is controversial and since meaningful estimation of such an amount appears doubtful, the matter of the "surplus" that consumers would pay for water from a system, rather than go without, has not been used as a measure of the significance of having piped water.

Health Benefits

In Yemen there are virtually no statistics on health. Yet it is apparent that Yemen and Taiz are particularly unhealthy places as is shown by what is known about infant mortality. In the absence of solid statistics, the opinions of physicians have been used. They estimate that everyone in Taiz each year has at least one incapacitating illness of two weeks on the average and that seventy percent of diseases in Taiz is water-related. Since such figures are astoundingly high, the value of health benefits has been figured at 50 percent as well as 100 percent in determining the possible range of net national rates of return for the project.

The health benefits of a water and sewerage project appear to accrue in three ways. Estimates have been made for each of these benefits over the ten year span of the Phase I of the project.

1. Benefits from the Saving of Medical Services:

   Forty-two percent of the population is estimated to become ill each year from water-related disease. This is based on the estimate of one illness a year per person and that seventy percent of such disease is water-related and that sixty percent of such water-related disease could be avoided through the widespread use of a water and sewerage system. In health studies estimates for rural communities have placed reduction of water-related diseases at 52 percent through the introduction of only a water system. The full medical costs using the average of the 42 percent of the population falling ill of water-related disease, are estimated at $25 for each illness.

2. Benefit from the Saving of Lost Working Time:

   The number of gainfully employed losing time from work as a result of water-related disease is figured at 25 percent of the number of those ill each year from water-related disease. Lost output by these workers is estimated at $50 for the two weeks or more they may be ill.

3. Benefit from the Extension of Life of Workers:

   The number of deaths of workers in the labor force from water-related disease is estimated at one per thousand of population each year. It is further assumed that had these workers not

died of water-related disease their working life on the average would have been extended for five years and that the present value of the work they would have performed would be approximately $5,000.

Productivity Benefits

As a result of the existence and widespread use of a water and sewerage system, there should be substantial gains in worker productivity. Workers freed of intestinal parasites and dysentery will be more productive per man hour. The improved cleanliness of the people and environment should have further effects on efficiency. It is extremely difficult to evaluate such indirect benefits, but it seems conceivable that they might make labor productivity 4 percent greater. Another 1 percent gain in efficiency might come from industry itself. For example, while the water system is not designed for fire fighting, the incidence of fire loss should be less. Also the present excessive hardness of the water causes considerable damage to water-using appliances and probably doubles the soap consumption of the community. Since all these factors are matters of conjecture upon which detailed research has not been performed, alternative calculations of the internal net national rate of return both including and excluding the 5 percent productivity benefit have been made.

INTERNAL RATE OF RETURN AS A NATIONAL ECONOMIC PROJECT

A decade ago hardly any economic calculations of the benefits of a water and sewage system were made. Benefits, because of their relation to health and life were said to be "incalculable." It should not then be surprising that crude attempts to calculate the benefits in a situation of low productivity and bad health should yield such an astounding rate of return as 38.8 percent as was determined under one set of anticipated benefits and revenues for this project. There are probably few projects in a less developed country that offer a better use of resources. By the creation of a water and sewage system, a less developed country acquires a local industry, provides workers some training in the responsibilities of industrial life, stimulates the construction industry, provides the community with a basic amenity associated with being economically developed, and furthermore greatly improves the health of its people and thereby their productivity. Water and sewage projects are unfortunately for capital-scarce-less-developed nations highly capital intensive. However, unlike other capital intensive projects, recognition of the true length of life of such systems and the relatively small depreciation they involve means that the capital services they require are somewhat less costly per unit of output than at first appears.

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Economic Benefits and Costs

The total economic benefits of the project consist of the payments made by the consumers for the services and also include the benefits from the extension of life, reduction of medical costs, loss of labor time from illness and gains in productivity of the community. The total economic costs of the project, that is the construction and maintenance outlays, are the engineering estimates of the actual expected money outlays.

The current Taiz labor market involves no employment problem, although there is doubtless under-employment in the neighboring agricultural areas. Labor utilized on the project will have meaningful other alternatives - such as employment in the local construction boom or employment abroad. Thus, no correction in the form of shadow pricing of the estimated labor costs has been made. Also, no correction has been made in the price of imported materials, since the exchange rate appears to be a realistic one, rather than an overvalued rate as appears in so many other underdeveloped countries.

Internal Rates of Return as Related to Population

While the estimated economic costs of the project appear reasonably certain, this cannot be said for the benefits realized. Water receipts may be generated as estimated. Population may not grow as projected. More important the rate schedule in relation to incomes and people's preferences may not generate the estimated revenues. Hence, internal rates of return have been figured for situations where receipts might fall to 85% or even 70% of the projected amount.

Internal Rates of Return as Related to Economic Benefits

The value of the benefits derived from better health and efficiency are even more uncertain. Adequate data on health for Yemen simply does not exist. Even if the exact amount of illness were known, there is no reliable post data from elsewhere in the world on the impact of the introduction of a water and sewage system in a situation where bad health from waterborne disease was widespread. Furthermore, the subtle effects of better quality water, greater availability of water and hence greater cleanliness upon labor efficiency are difficult to evaluate and apparently no detailed studies on this matter to date have appeared. Yet, there is no denial of the existence of all the benefits mentioned. The problem is that of accurate calculation.

To establish some minimal expectation in regard to benefits, internal rates of return have been calculated for a situation of minimal benefits which involves eliminating the productivity benefit and reducing the health benefits associated with the project by one half. Even if projected receipts also were only seventy percent of those expected, the minimal expected internal rate of return of the project would be 15.0%.

Results of Evaluation

A summary of the Internal Net National Rates of Return is contained in Table 14-9, which relates water sales of 100, 85 and 70 percent of that projected, to 100 percent and minimal economic benefits received. The minimal economic benefits are the extension to life and the reduction of medical costs and loss of labor reduced by 50 percent of those anticipated and the productivity benefits not considered as a benefit. The detailed analysis to determine the internal rates of return in Table 14-11 is in Appendix E, Tables E-1 through E-5.

TABLE 14-11

INTERNAL NET NATIONAL RATES OF RETURN

Percent of Projected Water Sales	100 Percent Economic Benefits	Minimal Economic Benefits[a]
100	38.8	18.9
85	37.5	-
70	35.9	15.0

[a] Extension to life and reduction of medical costs and loss of labor reduced by 50 percent and the productivity benefit eliminated from determination of economic benefits received.

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HISTORICAL FINANCIAL REPORTING

A summary of the income statements for the years 1972 and 1973 as prepared by the KMWS is contained in Table 14-12, plus additional information that affects the net profit and loss figures.

In 1973 an excess of revenues over expenses of 53,397.00 Rials was reported. This figure did not include 53,093.80 Rials in taxes due to the government which would have reduced the net earnings to approximately 300 Rials for the year. It should also be noted that these costs incurred were for maintaining the water system in a state of status-quo. The entire system was maintained in minimal operating condition with no attempts to expand or renovate the system. Such activities would have required a considerable increase in expenses for the year and would not have had any effect on increasing revenues due to the fact that no more water was available for such purposes. Another factor that must be taken into account when reviewing these statements is that a water rate increase was made effective in April 1973, which raised the rates from 24 to 36 Buqshas (0.6 Rials to 0.9 Rials). This greatly improved the revenue picture on the statements, however, is somewhat fixed by the fact that KMWS is selling all the water they have available, and further improvement cannot be realized until they are able to increase their sales or water rates.

The outstanding debts or accounts receivable were not available for 1972. Such information could have been used to make a comparison to show improved financial management and collections if the debts and accounts receivable were reduced from the previous year. It must be remembered that 1971 was the first year any attempt was made to reestablish a uniform accounting system and reporting financial statements to the public after the practice was discontinued in the middle 1960's.

WATER SYSTEM TAXATION

It is recommended that no taxes be levied on the consumers or the TWSA by local or national agencies. As a municipal agency, the TWSA is intended to serve in the best interest of the municipality and is a non-profit agency designed to provide water and sewerage facilities. For this reason no allowances have been made for any taxes in the financial and economic analysis. If taxes are imposed on the agency or users, they would be passed directly on from the consumers to the collecting agency and would not have any effect on the financial evaluation of the recommended system.

The existing KMWS system is obliged to collect water taxes, but due to their undesirable financial situation are using the majority of these funds to help operate their system and are passing only a portion of these funds on to the federal government. As a result of this, the KMWS shows a net profit for the year. If all accrued taxes for the year of 1973 had been paid, the true net profit would be about 300 Rials, considerably less than that reported on their annual statements as shown in Table 14-12.

TABLE 14-12

INCOME STATEMENT
KENNEDY MEMORIAL WATER SYSTEM

(From Annual Reports)

Description	1973	1972
Revenue Sources:		
Water Sales	R1,119,193.62	R 893,909.65
Meter Repair and Maintenance	82,737.40	48,100.85
Well Development	370,869.65	97,865.88
Other	133,445.00	108,227.92
Total Revenues	R1,706,245.67	R1,148,104.30
Operating Expenses:		
Salaries and Related Costs	688,718.60	566,017.25
Materials and Fuel	662,882.98	567,013.23
Rent	50,529.00	-
Depreciation	143,942.00	105,001.00
Other Expenses	71,415.91	86,500.41
Bad Debts	- -	31,500.00
Total Expenses	R1,617,468.49	R1,356,031.89
Profit (Loss) Before Taxes	88,777.18	(207,927.59)
Taxes Paid	35,380.18	30,255.08
Net Recorded Profit (Loss) on TWSA Books	R 53,397.00	R (238,182.67)
Additional Information:		
Taxes, Total Annual	88,474.25	71,205.95
Taxes Paid	35,380.45	30,255.08
Total Annual Taxes not Paid	R 53,093.80	R 40,950.87
Outstanding Debts	96,499.78	N/A
Prepayments	3,845.38	N/A
Accounts Receivable	983,105.31	N/A

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CHAPTER 15

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CHAPTER 15

PLAN FOR PROJECT IMPLEMENTATION

GENERAL

The Taiz Water Supply and Sewerage Project is a major undertaking for the government of the Yemen Arab Republic. About $12,860,000 will be expended over the next three years during implementation of the project. A program of such magnitude will require substantial manpower, money and materials to be employed in a well planned and well coordinated effort to bring about its successful completion. An outline of a plan to carry out the program is presented herein. Although many of the final design details of the facilities are unknown at this time, it is nevertheless possible to describe the critical activities which must be carried out and to describe related events and their interdependent time sequence.

The extremely hazardous health environment now existing in Taiz has been described in previous chapters of this report. It is known that the inadequacies of the existing water and sewerage facilities within the city are major contributors to its environmental health problems. Therefore it is imperative that the proposed system improvements be placed into operation at the earliest possible date. To accomplish this, the activities upon which the entire project schedule is dependent must be initiated soon after evaluation of this report has been completed. These activities are discussed later in this chapter under Administrative Activities and Engineering and Construction Activities.

The Implemation Plan described below is designed to proceed in parallel with the plans presented in Volumes II and III of this report for implementation of water resources development and institutional development. The Project Implementation Schedule, Figure 15-1, is based on several assumptions regarding availability and sources of capital, contracting procedures and procurement policies to be employed. These assumptions are as follows:

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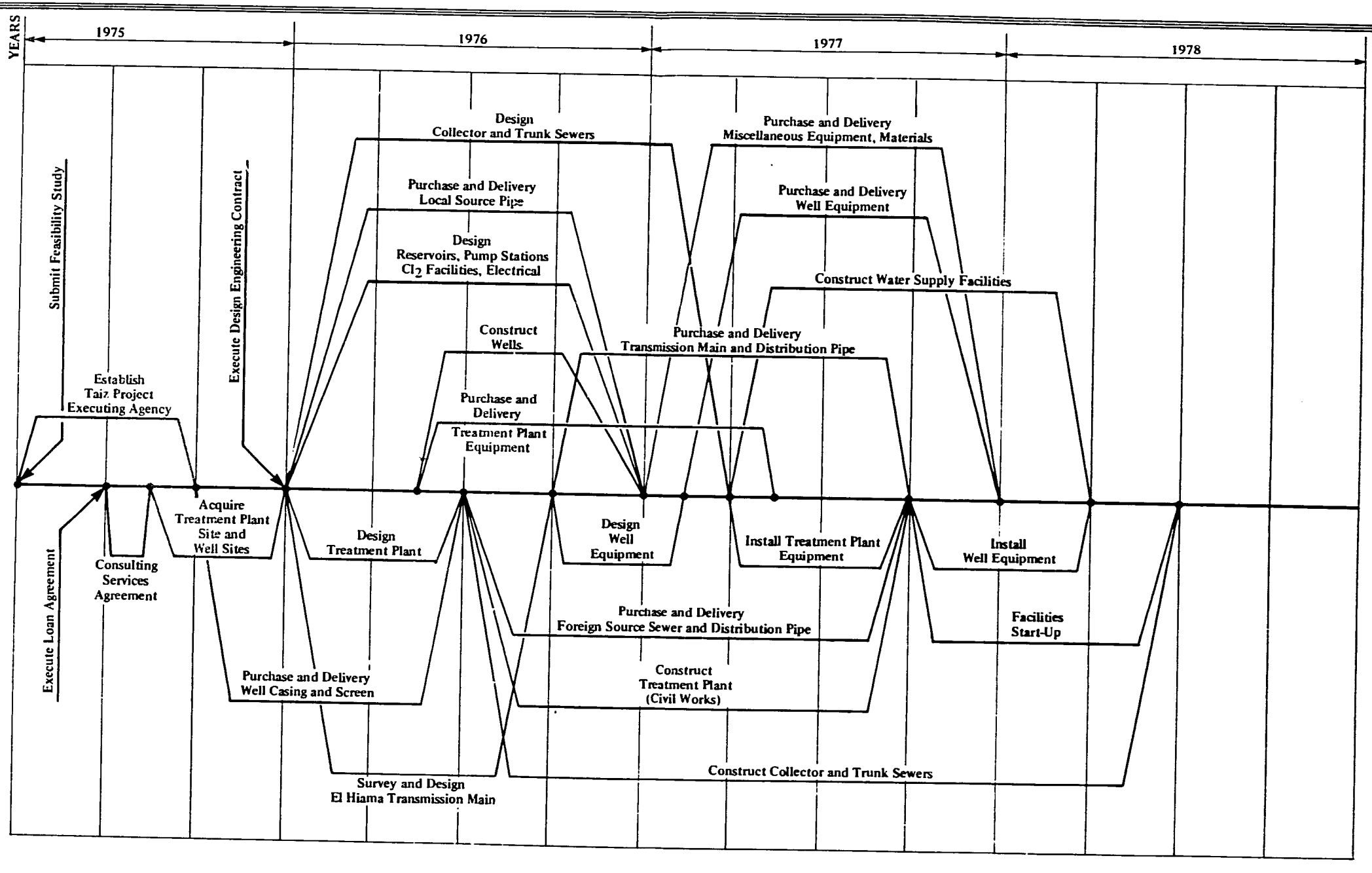
Plan for Project Implementation

1. Availability and Sources of Capital

The financing plan envisions 25 percent of required capital being provided by YARG from sources other than the anticipated USAID loan. Part of this contribution by YARG is in the form of land and facilities which are a part of the existing Taiz water supply and sewerage systems. The remainder of the local contribution of 25 percent will be in the form of cash, goods and services required to complete the project. It is assumed that this portion of the local source funding will become available very shortly after the USAID loan agreement is executed. This funding is projected to be used in the early stages of project implementation to acquire the land and rights-of-way required, construct the production wells and finance technical assistance costs associated with these activities.

2. Contracting Procedures and Procurement Policies

It is anticipated that major foreign source equipment and materials required by the project will be purchased directly by the TWSA through procurement specifications and documents prepared by its consultant. The installation of major equipment items and the construction of large hydraulic structures and the El Hiama transmission main is planned to be carried out by a foreign contractor. The installation of water distribution piping and appurtenances as well as collector sewers and minor structures is planned for execution by local contractors.



TAIZ WATER SUPPLY AND SEWERAGE PROJECT
PROJECT IMPLEMENTATION SCHEDULE
FIGURE 15-1

Plan For Project Implementation

ADMINISTRATIVE ACTIVITIES

Following appraisal of this report by YARG and USAID a loan agreement between these agencies should be executed as soon as possible. A Taiz project executing agency should be established by YARG as a parallel activity to loan negotiations. This agency could be set up under the NWSA or could be the existing organization now operating the Taiz system. It is essential that the executing agency appoint a Project Director and staff to carry out the many responsibilities of the YARG in implementing the project.

The agreement covering grant funds and re-lending terms between the Central Planning Organization and the National Water and Sewerage Authority should be completed at approximately the same time as the USAID loan agreement. The provisions for principal and interest payments by the Taiz Project executing agency should also be worked out at this time. With these agreements in existence, it should be possible to commence work on the project, utilizing local source funds, at an early date.

ENGINEERING AND CONSTRUCTION ACTIVITIES

The most critical activity associated with the physical implementation of the proposed improvements is that pertaining to development of the water source facilities. The long lead time required for the delivery of well pumps, electric motors and power generation equipment renders completion of drilling, development and testing of the proposed wells, at the earliest possible time, essential to timely progress of the project. Equipment for the wells and generating station cannot be selected and procurement documents prepared therefor until well production rates and drawdown characteristics have been determined. To accomplish early completion of the production wells, it is recommended that the consultant be engaged, immediately following completion of the loan negotiations, to proceed with assisting the executing agency with well site selection and acquisition and the preparation of procurement documents for well casing and screen, appurtenant well drilling supplies and equipment. It is assumed that YARG will make at least two of the Ingersoll-Rand, Model T-4 drilling rigs available to the project as well as required crews and support equipment.

Plan For Project Implementation

Selection and acquisition of the proposed wastewater treatment plant site should also be accomplished during the initial implementation period. This is recommended as the final location and topography of the acquired plant site as well as soil conditions thereon will influence design of the facility.

Negotiations of a new contract for design engineering services should be completed in time for actual design work of the facilities to commence early next year. Plan and profile surveying for the proposed El Hiama transmission main and for the proposed water distribution mains and sewers can be started at that time. The design of the El Hiama transmission main and preparation of procurement documents for the large diameter pipe, valves and appurtenances should be actively pursued to permit pipe deliveries in Taiz by early 1977. It is anticipated that the smaller gauge (lower pressure) pipe will arrive in Taiz approximately 6 months after orders are placed. This will permit construction of the facility to begin in mid-1977.

Design and construction of the proposed wastewater treatment plant is a critical item in completion of the sewerage system. The mechanical sludge removal equipment, sludge and recirculation pumps, skimmers, pump motors and generating equipment all require long delivery times. Construction of civil works at the site can begin in mid-1976 with installation of equipment starting in early 1977.

Approximately 130,000 meters of sewer line and house connections will be installed under this project. Of this amount, it is expected that 114,000 meters will be supplied by the soon-to-be -open Taiz PVC pipe factory in the 100 mm and 150 mm sizes. It is recommended that negotiations be initiated with the local PVC manufacturer to insure supply and delivery of the required quantities of sewer pipe by the beginning of next year. In order to install the quantity of sewer proposed, several local contractors should be employed on a number of different headings that will result in an overall installation rate of approximately 300 meters per day.

The total time requirement for design and construction of the project will be determined by the completion time required for the above principal activities. Approximately 30 months are estimated to be required for completion of these design and construction activities. The design, procurement and construction of all other facilities such as; interim improvements, reservoirs, water distribution system, pump station, chlorination facilities, meters and service connections and miscellane-

ous electrical power supply and control facilities, should be accomplished within the 30-month time frame.

APPENDIX A

APPENDIX A

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APPENDIX B

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Table B-1

PHASE I - COST ESTIMATES
FOREIGN AND LOCAL COMPONENTS

(U.S. DOLLARS)

Description	Quantity	Units	Unit Price	Total Cost	Local Costs	Foreign Costs
Water Supply System						
Wells and Well Pumps						
El Hiama Basin	10	ea	25,000	250,000	110,000	140,000
Ground Level Storage Reservoirs						
Upper Thaabat	1	L S	-	87,000	65,000	22,000
Upper Medina	1	L S	-	87,000	65,000	22,000
Lower Medina	1	L S	-	186,000	140,000	46,000
Chlorination Facilities	1	L S	-	57,000	17,000	40,000
Transmission Pipeline						
650 mm Diameter	22,000	m	147.50	3,245,000	815,000	2,430,000
500 mm Diameter	850	m	101.00	86,000	26,000	60,000
350 mm Diameter	1,000	m	69.50	70,000	24,000	46,000
Distribution System						
Zone I	-	L S	-	114,300	45,300	69,000
Zone II	-	L S	-	106,400	42,400	64,000
Zone III	-	L S	-	219,500	87,500	132,000
Zone IV	-	L S	-	439,000	175,000	264,000
Zone V	-	L S	-	44,300	17,300	27,000
Zone VI	-	L S	-	24,000	9,600	15,000
Zone VII	-	L S	-	14,000	6,000	8,000
Pressure Break Structures	9	ea	5,000	45,000	40,500	4,500
Flow Regulating Structure	1	L S	-	35,000	27,500	7,500
Thaabat Booster Pump Station	1	L S	-	202,000	31,000	171,000
Service Connections	-	-	-	75,000	58,500	16,500
Restricted Meters	3,000	L S	-	185,000	-	185,000
Wastewater						
Wastewater Treatment Facilities	-	L S	-	1,453,000	1,038,000	415,000
Wastewater Collection & Transmission System						
100 mm (4")	70,200	m	10.00	702,000	702,000	-
150 mm (6")	46,800	m	13.20	617,800	617,800	-
200 mm (8")	2,740	m	19.50	53,400	35,400	18,000
250 mm (10")	690	m	20.75	14,300	9,300	5,000
300 mm (12")	250	m	24.80	6,200	3,700	2,500
380 mm (15")	8,370	m	32.20	269,500	149,500	120,000
460 mm (18")	1,350	m	39.90	53,900	29,400	24,500
600 mm (24")	1,020	m	57.00	58,100	58,100	-
685 mm (27")	650	m	59.00	38,400	38,400	-
Manholes	-	L S	-	30,200	30,200	-
Public Toilets	15	ea	4,500	67,500	37,500	30,000
Other						
Electrical Power Generation Facilities	-	L S	-	258,000	38,000	220,000
Vehicles, Maintenance Equipment, Concrete Forms, etc.	-	L S	-	275,000	-	275,000
Totals				9,470,300	4,590,800	4,879,500

Note: The above cost figures are based on January 1975 prices.
No allowances have been provided in this estimate for escalation.

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Table B-2

PHASE II - COST ESTIMATES FOREIGN AND LOCAL COMPONENTS

(U.S. DOLLARS)

Description	Quantity	Units	Unit Price	Total Cost	Local Costs	Foreign Costs
Water Supply System						
Wells and Well Pumps						
Upper Wadi Houban	1	ea	25,000	25,000	10,000	15,000
Wadi Salah Basin	1	ea	25,000	25,000	10,000	15,000
Dh'bab Basin	4	ea	25,000	100,000	40,000	60,000
Wadi Amed Basin	1	ea	25,000	[illegible],000	10,000	15,000
Houban-Hougala Basin	2	ea	25,000	50,000	20,000	30,000
Ground Level Storage						
Reservoirs						
Lower Thaabat	1	L S	-	151,000	113,000	38,000
Main Yard	1	L S	-	27,000	20,000	7,000
Lower Medina	1	L S	-	186,000	140,000	46,000
Upper Thaabat	1	L S	-	86,000	65,000	21,000
Pressure Break Structures	3	L S	-	15,000	13,000	2,000
Regulating Structure -						
Dh'bab	1	L S	-	32,000	24,000	8,000
Chlorination Facilities						
Dh bab Trans. Pipeline	1	L S	-	52,000	16,000	36,000
Houban Reservoir	1	L S	-	51,000	16,000	35,000
Wadi Salah	1	L S	-	31,000	9,000	22,000
Transmission Pipeline						
100 mm (4")	1,000	m	18.20	18,000	7,000	11,000
150 mm (6")	500	m	28.00	14,000	6,000	8,000
300 mm (12")	3,300	m	59.00	195,000	78,000	117,000
350 mm (14")	8,600	m	69.50	598,000	239,000	3[illegible],000
400 mm (16")	6,000	m	80.00	480,000	192,000	288,000
Distribution System						
Zone III	-	L S	-	68,400	27,000	41,400
Zone IV	-	L S	-	131,000	52,000	79,000
Zone V	-	L S	-	88,200	35,000	53,200
Zone VI	-	L S	-	102,400	41,000	61,400
Zone VII	-	L S	-	91,500	37,000	54,500
Restrictive Water Meters	-	L S	-	168,000	-	168,000
Booster Pump Station						
Thaabat Expansion	-	L S	-	88,000	35,200	52,800
Houban Rehabilitation	-	L S	-	224,000	90,000	134,000
Dh'bab Pump Station	-	L S	-	370,000	148,000	222,000
Wastewater						
Wastewater Treatment Plant	-	L S	-	2,906,000	2,061,000	845,000
Sewage Lift Stations	-	L S	-	310,000	124,000	186,000
Wastewater Collection & Transmission System						
100 mm (4")	56,700	m	10.00	567,000	567,000	-
150 mm (6")	37,200	m	13.20	491,000	491,000	-
200 mm (8")	1,400	m	19.50	28,500	18,900	9,600
250 mm (10")	3,220	m	20.75	66,800	43,300	23,500
300 mm (12")	2,400	m	24.50	59,500	35,500	24,000
380 mm (15")	2,200	m	32.20	70,800	39,300	31,500
Manholes	-	L S	-	30,200	30,200	-
Force Mains	-	L S	-	116,200	55,000	61,200
Other						
Electrical Power Generation Facilities	-	L S	-	500,000	75,000	425,000
Vehicles, Maintenance Equipment, etc.	-	L S	-	100,000	-	100,000
Totals				8,738,500	5,033,400	3,705,100

Note: The above cost figures are based on January 1975 prices.
No allowances have been provided in this estimate for escalation.

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TABLE B-3
PHASE I - COST ESTIMATE
ALTERNATIVE WATER SUPPLY

Description	Quantity	Units	Unit Price	Cost $
Pumping Station and Intake Structure	-	LS	-	2,800,000
Transmission Pipeline	-	LS	-	52,800,000
Desalination Plant	-	LS	-	2,200,000
Chlorination Facilities	-	LS	-	57,000
Distribution System	-	LS	-	1,038,000
Reservoirs	-	LS	-	156,000
Pressure Break Structures	9	ea	5,000	45,000
Thaabat Booster Pump Station	-	LS	-	202,000
Restricted Meters	-	LS	-	185,000
Wastewater System	-	LS	-	3,364,000
Other	-	LS	-	533,000
Total Direct Costs				63,380,000

TABLE B-4
PHASE II - COST ESTIMATE
ALTERNATIVE WATER SUPPLY

Description	Quantity	Units	Unit Price	Cost $
Pumping Station and Intake Structure	-	LS	-	800,000
Desalination Plant	-	LS	-	2,700,000
Chlorination Facilities	-	LS	-	134,000
Distribution System	-	LS	-	481,500
Pressure Break Structures	-	LS	-	15,000
Reservoirs	-	LS	-	450,000
Booster Pump Stations	-	LS	-	682,000
Wastewater System	-	LS	-	4,336,000
Other	-	LS	-	600,000
Total Direct Costs				10,198,500

APPENDIX C

TABLE C-1

WATER USE AND REVENUES

PHASE I

Years

Users	1973 Connections	1973 Million m^3/Yr.	1973 Rials/Yr.	1977 Connections	1977 Million m^3/Yr.	1977 Rials/Yr.	1978 Connections	1978 Million m^3/Yr.	1978 Rials/Yr.	1979 Connections	1979 Million m^3/Yr.	1979 Rials/Yr.	1980 Connections	1980 Million m^3/Yr.	1980 Rials/Yr.
Residential	7,800	0.99		(10,000)	(1.395)		(10,800)	(2.07)		(11,600)	(2.35)		(12,400)	(2.62)	
Restrictive Meter	-			3,000	0.11		3,200	0.23	250,000	3,500	0.25	273,000	3,700	0.27	289,000
Regular Meter	7,800	0.99		7,000	1.285		7,800	1.84	4,134,000	8,100	2.10	4,835,000	8,700	2.35	5,481,000
Institutional				(102)	(0.25)		(104)	(0.34)	635,000	(108)	(0.43)	774,000	(110)	(0.51)	847,000
Public Faucets	-			20	0.03		20	0.07		21	0.07		21	0.07	
Public Toilets	-			15	0.01		15	0.02		15	0.02		15	0.03	
Mosques	17	0.07		17	0.04		17	0.01		18	0.02		18	0.02	
Hospitals	5	0.06		6	0.065		6	0.10		6	0.13		6	0.16	
Schools	20	0.03		20	0.035		21	0.06		22	0.09		23	0.12	
Military	19	0.06		19	0.06		19	0.07		19	0.08		19	0.09	
Gov't. Offices	5	0.01		5	0.01		6	0.01		7	0.02		8	0.02	
Hotels	4	0.02		4	0.02		5	0.03	129,000	6	0.04	157,000	7	0.05	213,000
Commercial	400	0.04		450	0.045		500	0.06	120,000	600	0.07	144,000	700	0.08	168,000
Industrial	3	0.03		4	0.03		5	0.04	169,000	6	0.06	266,000	7	0.08	333,000
TOTALS		1.31	1,119,000*		1.74**	2,861,000***		2.54	5,437,000		2.95	6,449,000		3.34	7,381,000
TOTAL REVENUES INCLUDING 2% INCREASE/YR.								1.02 x 5,437,000 = R5,546,000			1.04 x 6,449,000 = R6,707,000			1.06 x 7,381,000 = R7,831,000	

Years

Users	1981 Connections	1981 Million m^3/Yr.	1981 Rials/Yr.	1982 Connections	1982 Million m^3/Yr.	1982 Rials/Yr.	1983 Connections	1983 Million m^3/Yr.	1983 Rials/Yr.	1984 Connections	1984 Million m^3/Yr.	1984 Rials/Yr.	1985 Connections	1985 Million m^3/Yr.	1985 Rials/Yr.
Residential	(13,500)	(2.89)		(14,500)	(3.17)		(15,500)	(3.44)		(16,600)	(3.74)		(17,700)	(3.99)	
Restrictive Meter	4,000	0.29	312,000	4,400	0.32	343,000	4,600	0.33	359,000	5,000	0.36	390,000	5,300	0.38	413,000
Regular Meter	9,500	2.60	6,098,000	10,100	2.85	6,727,000	10,900	3.11	7,357,000	11,600	3.36	7,992,000	12,400	3.61	8,593,000
Institutional	(110)	(0.53)	926,000	(113)	(0.58)	1,006,000	(115)	(0.64)	1,098,000	(115)	(0.69)	1,773,000	(119)	(0.75)	1,267,000
Public Faucets	21	0.07		21	0.07		22	0.07		22	0.07		23	0.07	
Public Toilets	15	0.03		15	0.03		15	0.04		15	0.04		15	0.05	
Mosques	18	0.02		18	0.02		19	0.02		19	0.02		20	0.02	
Hospitals	6	0.16		6	0.18		6	0.20		6	0.22		6	0.24	
Schools	23	0.14		24	0.16		24	0.18		24	0.20		25	0.22	
Military	19	0.09		20	0.10		20	0.11		20	0.12		20	0.13	
Gov't. Offices	8	0.02		9	0.02		9	0.02		9	0.02		10	0.02	
Hotels	7	0.05	213,000	8	0.05	215,000	8	0.05	215,000	9	0.05	217,000	9	0.06	257,000
Commercial	750	0.09	180,000	800	0.10	202,000	850	0.11	223,000	900	0.12	245,000	1,000	0.14	290,000
Industrial	7	0.10	413,000	8	0.12	495,000	8	0.14	575,000	9	0.16	657,000	9	0.18	737,000
TOTALS		3.66	8,142,000		4.02	8,988,000		4.38	9,827,000		4.76	11,274,000		5.12	11,557,000
TOTAL REVENUES INCLUDING 2% INCREASE/YR.			1.082 x 8,142,000 = R8,810,000			1.104 x 8,988,000 = R9,923,000			1.126 x 9,827,000 = R11,065,000			1.149 x 11,274,000 = R12,954,000			1.172 x 11,557,000 = R13,545,000

* Breakdown not Available.
** Based on July, 1977, completion date.
*** Based on new rates effective July, 1977.

Note: Conversation rate: YAR Rials 4.575 = U.S. $1.00

TABLE C-2

WATER USE AND REVENUES

PHASE II

Years

Users	1986 Connections	1986 Million m^3/Yr.	1986 Rials/Yr.	1987 Connections	1987 Million m^3/Yr.	1987 Rials/Yr.	1988 Connections	1988 Million m^3/Yr.	1988 Rials/Yr.	1989 Connections	1989 Million m^3/Yr.	1989 Rials/Yr.	1990 Connections	1990 Million m^3/Yr.	1990 Rials/Yr.
Residential	(19,200)	(4.29)		(20,700)	(4.79)		(22,200)	(5.20)		(23,700)	(5.61)		(25,200)	(6.02)	
Restrictive Meter	5,800	0.42	452,000	6,200	0.45	484,000	6,700	0.48	523,000	7,100	0.51	554,000	7,600	0.55	593,000
Regular Meter	13,400	3.97	9,489,000	14,500	4.34	10,398,000	15,500	4.72	11,394,000	16,600	5.10	12,299,000	17,600	5.47	13,255,000
Institutional	(119)	(0.80)	1,343,000	(121)	(0.86)	1,435,000	(122)	(0.92)	1,526,000	(122)	(0.98)	1,616,000	(127)	1.07	1,757,000
Public Faucets	23	0.07		23	0.07		23	0.07		23	0.07		24	0.07	
Public Toilets	25	0.05		15	0.05		15	0.05		15	0.05		15	0.05	
Mosques	20	0.02		20	0.02		20	0.02		20	0.02		21	0.03	
Hospitals	6	0.26		6	0.26		7	0.31		7	0.33		7	0.36	
Schools	25	0.24		26	0.27		26	0.30		26	0.33		27	0.36	
Military	20	0.14		20	0.15		20	0.15		20	0.16		21	0.17	
Gov't. Offices	10	0.02		11	0.02		11	0.02		11	0.02		12	0.03	
Hotels	10	0.06	2[illegible],000	10	0.06	259,000	11	0.07	300,000	11	0.08	340,000	12	0.09	382,000
Commercial	1,050	0.16	336,000	1,100	0.18	382,000	1,200	0.20	429,000	1,300	0.22	471,000	1,400	0.25	539,000
Industrial	10	0.21	859,000	10	0.25	1,018,000	11	0.28	1,140,000	11	0.32	1,300,000	12	0.36	1,462,000
TOTALS			12,788,000			13,976,000			15,312,000			16,580,000			17,988,000
TOTAL REVENUES INCLUDING 2% INCREASE/YR.		1.195x12,788,000 =R15,222,000			1.219x13,976,000 =R17,037,000			1.243x15,312,000 =R19,033,000			1.268x16,580,000 =R21,034,000			1.294x17,988,000 =R23,276,000	

Years

Users	1991 Connections	1991 Million m^3/Yr.	1991 Rials/Yr.	1992 Connections	1992 Million m^3/Yr.	1992 Rials/Yr.	1993 Connections	1993 Million m^3/Yr.	1993 Rials/Yr.	1994 Connections	1994 Million m^3/Yr.	1994 Rials/Yr	1995 Connections	1995 Million m^3/Yr.	1995 Rials/Yr.
Residential	(27,300)	(6.62)		(29,400)	(7.22)		(31,500)	(7.82)		(33,600)	(8.42)		(35,700)	(9.03)	
Restrictive Meter	8,200	0.59	640,000	8,800	0.63	686,000	9,500	0.68	741,000	10,100	0.73	795,000	10,700	0.77	835,000
Regular Meter	19,100	6.03	14,667,000	20,600	6.59	16,070,000	22,000	7.14	17,488,000	23,500	7.69	18,823,000	25,000	8.26	20,277,000
Institutional	(127)	(1.13)	1,8[illegible],000	(127)	(1.20)	1,952,000	(131)	(1.28)	2,077,000	(131)	(1.35)	2,182,000	(132)	(1.44)	2,317,000
Public Faucets	24	0.07		24	0.07		25	0.07		25	0.07		25	0.07	
Public Toilets	15	0.05		15	0.05		15	0.05		15	0.05		15	0.05	
Mosques	21	0.03		21	0.03		22	0.04		22	0.04		22	0.04	
Hospitals	7	0.38		7	0.40		7	0.42		7	0.44		7	0.47	
Schools	27	0.40		27	0.44		28	0.49		28	0.53		28	0.58	
Military	21	0.17		21	0.18		21	0.18		21	0.19		21	0.20	
Gov't. Offices	12	0.03		12	0.03		13	0.03		13	0.03		14	0.03	
Hotels	12	0.10	42[illegible],000	13	0.11	464,000	13	0.12	504,000	14	0.13	546,000	14	0.14	586,000
Commercial	1,450	0.27	587,000	1,500	0.29	634,000	1,550	0.30	655,000	1,575	0.32	705,000	1,600	0.34	752,000
Industrial	12	0.40	1,622,000	13	0.45	1,824,000	13	0.49	1,984,000	14	0.54	2,166,000	14	0.58	2,346,000
TOTALS			19,785,000			21,630,000			23,449,000			25,230,000			27,113,000
TOTAL REVENUES INCLUDING 2% INCREASE/YR.		1.319x19,785,000 =R25,967,000			1.346x21,630,000 = R29,114,000			1.373x23,449,000 = R32,195,000			1.4 x 25,230,000 = R35,322,000			1.428x27,113,000 = R38,717,000	

Note: Conversion rate: YAR Rials 4.575 = U.S. $1.00

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APPENDIX D

APPENDIX D

INTERNAL RATE OF RETURN AS A BUSINESS ENTERPRISE

In these internal rate of return tables, the annual revenues are those revenues received from the direct sale of water and the related service charges which are tied to the size of meter. No other sources of revenues are considered. The "O & M" costs are only those direct expenses to operate and maintain the water and wastewater systems such as power costs, wages and chlorine. The services connection costs listed in these tables are those annual costs to the TWSA to install the restricted (3/8-inch) meters intended for use by the low-income families. The equipment replacement costs are monies needed to replace old and worn equipment, such as vehicles, motors which have an expected life span of from 10 years for vehicles and maintenance equipment, 15 years for wells and well pumps to 20 years for low speed diesel generators.

TABLE D-1

INTERNAL RATE OF RETURN AS A BUSINESS ENTERPRISE FOR PHASES I AND II 100 PERCENT OF PROJECTED WATER SALES (U.S. DOLLARS)

Year	Population	Percent Connected To Water System	Population Served	Annual Sales (1000) (cu m)	Annual Revenues	"O & M" Costs	Service Connection Costs	Equipment Replacement Costs	Capital Investments	Net Benefits	Alternative Rates of Return: 10% Interest, P.W. Factor	10% Interest, Present Worth	12% Interest, P.W. Factor	12% Interest, Present Worth
1975	95,300	-	-	-	-	-	-	-	-	-	1.0000	-	1.0000	-
1976	101,000	-	-	-	-	-	-	-	2,012,500	(2,012,500)	0.9091	(1,829,600)	0.8929	(1,797,000)
1977	107,100	-	-	-	-	-	-	-	7,246,000	(7,246,000)	0.8264	(5,988,100)	0.7972	(5,776,500)
1978	113,500	73	82,900	1,270	606,100	194,000	5,000	-	3,603,200	(3,196,100)	0.7513	(2,401,200)	0.7118	(2,275,600)
1979	120,300	74	89,000	2,950	1,466,000	359,500	7,500	-	-	1,099,000	0.6830	750,600	0.6355	698,400
1980	127,500	75	95,600	3,340	1,711,700	424,500	5,000	-	-	1,282,200	0.6209	796,100	0.5674	727,500
1981	135,100	76	102,700	3,660	1,925,600	469,500	7,500	-	-	1,448,600	0.5645	817,700	0.5066	733,900
1982	143,200	77	110,300	4,020	2,168,900	520,500	7,500	-	-	1,640,900	0.5132	842,100	0.4523	742,200
1983	151,800	78	118,400	4,380	2,418,600	576,000	7,500	-	-	1,835,100	0.4665	856,100	0.4039	741,200
1984	160,900	79	127,100	4,760	2,831,500	620,500	7,500	-	5,207,800	(3,004,300)	0.4241	(1,274,100)	0.3606	(1,083,400)
1985	170,600	80	136,500	5,120	2,960,700	670,500	10,000	-	5,985,300	(3,705,100)	0.3855	(1,428,300)	0.3220	(1,193,000)
1986	180,800	81	146,400	5,620	3,327,200	867,400	12,500	-	-	2,447,300	0.3505	857,800	0.2875	703,600
1987	191,600	82	156,700	6,140	3,723,900	971,200	10,000	-	-	2,742,700	0.3186	873,800	0.2567	704,100
1988	203,100	83	168,600	6,670	4,160,200	1,306,700	12,500	275,000	-	2,566,000	0.2897	743,400	0.2292	588,100
1989	215,300	84	180,900	7,210	4,597,600	1,391,000	10,000	341,200	-	2,855,400	0.2633	751,800	0.2046	584,200
1990	228,200	85	194,000	7,790	5,087,700	1,484,200	12,500	-	-	3,591,000	0.2394	859,700	0.1827	656,100
1991	241,900	86	208,000	8,520	5,682,400	1,587,800	15,000	-	-	4,079,600	0.2176	887,700	0.1631	665,400
1992	256,400	87	223,100	9,270	6,363,700	1,828,000	15,000	-	-	4,520,700	0.1978	894,200	0.1456	658,200
1993	271,800	88	239,200	10,010	7,037,200	1,944,400	17,500	250,000	-	4,825,300	0.1799	868,100	0.1300	627,300
1994	288,100	89	256,400	10,760	7,720,700	2,065,900	15,000	-	-	5,639,800	0.1635	922,100	0.1161	654,800
1995	305,400	90	274,900	11,510	8,462,700	2,195,500	15,000	100,000	-	6,152,200	0.1486	914,200	0.1037	638,000
										Salvage Value = 15,729,500	0.1486	2,337,400	0.1037	1,631,200
										Totals		2,051,300		(370,700)

Note: The above cost figures are based on January 1975 prices. No allowance has been provided for escalation.

Internal Rate of Return = 11.7 percent

TABLE D-2

INTERNAL RATE OF RETURN AS A BUSINESS ENTERPRISE FOR PHASE I 100 PERCENT OF PROJECTED WATER SALES (U. S. DOLLARS)

Year	Population	Percent Connected To Water System	Population Served	Annual Sales (1000) (cu m)	Annual Revenues	"O&M" Costs	Service Connection Costs	Capital Investments	Net Benefit	Alternative Rates of Return: 8% Interest, P.W. Factor	8% Interest, Present Worth	12% Interest, P. W. Factor	12% Interest, Present Worth
1975	95,300	-	-	-	-	-	-	-	-	1.0000	-	1.0000	-
1976	101,000	-	-	-	-	-	-	2,012,500	(2,012,500)	0.9259	(1,863,400)	0.8929	(1,797,000)
1977	107,000	-	-	-	-	-	-	7,246,000	(7,246,000)	0.8573	(6,212,000)	0.7972	(5,776,500)
1978	113,500	73	82,900	1,270	606,100	194,000	5,000	3,603,200	(3,196,100)	0.7938	(2,537,100)	0.7118	(2,275,000)
1979	120,300	74	89,000	2,950	1,466,000	359,500	7,500	-	1,099,000	0.7350	807,800	0.6355	698,400
1980	127,500	75	95,600	3,340	1,711,700	424,500	5,000	-	1,282,200	0.6806	872,700	0.5674	727,500
1981	135,100	76	102,700	3,660	1,925,600	469,500	7,500	-	1,448,600	0.6302	912,900	0.5066	733,900
1982	143,200	77	110,300	4,020	2,168,900	520,500	7,500	-	1,640,900	0.5835	957,500	0.4523	742,200
1983	151,800	78	118,400	4,380	2,418,600	576,000	7,500	-	1,835,100	0.5403	991,500	0.4039	741,200
1984	160,900	79	127,100	4,760	2,831,500	620,500	7,500	-	2,203,500	0.5002	1,102,200	0.3606	794,600
1985	170,600	80	136,500	5,120	2,960,700	670,500	10,000	-	2,280,200	0.4632	1,056,200	0.3220	734,200
							Salvage Value =		8,884,700	0.4632	4,115,400	0.3220	2,860,900
							Totals				203,700		(1,815,600)

Note: The above cost figures are based on January 1975 prices. No allowance has been provided for escalation.

Internal Rate of Return = 8.4 percent

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TABLE D-3

INTERNAL RATE OF RETURN AS A BUSINESS ENTERPRISE FOR PHASES I AND II 85 PERCENT OF PROJECTED WATER SALES (U.S. DOLLARS)

Year	Volume (1000) (cu m)	Revenues (US$)	Operations & Maintenance Costs: Water Supply System	Operations & Maintenance Costs: Service Connections	Operations & Maintenance Costs: Wastewater System	Operations & Maintenance Costs: Equipment Replacement Costs	Capital Investments	Net Benefits	Alternative Rates of Return: 8% Interest: P.W. Factor	Alternative Rates of Return: 8% Interest: Present Worth	Alternative Rates of Return: 12% Interest: P.W. Factor	Alternative Rates of Return: 12% Interest: Present Worth
1975	-	-	-	-	-	-	-	-	1.0000	-	1.0000	-
1976	-	-	-	-	-	-	2,012,500	(2,012,500)	0.9259	(1,863,400)	0.8929	(1,797,000)
1977	-	-	-	-	-	-	7,246,000	(7,246,000)	0.8573	(6,212,000)	0.7972	(5,776,500)
1978	1,080	515,200	117,400	4,200	35,600	-	3,603,200	(3,245,200)	0.7938	(2,576,000)	0.7118	(2,309,900)
1979	2,508	1,246,100	271,000	6,400	77,600	-	-	891,100	0.7350	655,000	0.6355	566,300
1980	2,839	1,454,900	318,700	4,200	93,500	-	-	1,038,500	0.6806	706,800	0.5674	589,200
1981	3,111	1,636,800	356,200	6,400	99,600	-	-	1,174,600	0.6302	740,200	0.5066	595,100
1982	3,417	1,843,600	392,500	6,400	116,600	-	-	1,328,100	0.5835	774,900	0.4523	600,700
1983	3,723	2,055,800	438,100	6,400	121,700	-	-	1,489,600	0.5403	804,800	0.4039	601,600
1984	4,046	2,406,800	474,000	[illegible],400	128,500	-	-	1,797,900	0.5002	899,300	0.3606	648,300
1985	4,352	2,516,600	516,200	8,500	135,600	-	5,207,800	(3,351,500)	0.4632	(1,552,400)	0.3220	(1,079,200)
1986	4,777	2,828,100	684,300	10,600	154,000	-	5,985,300	(4,006,100)	0.4289	(1,718,200)	0.2875	(1,151,800)
1987	5,219	3,165,300	759,200	8,500	177,200	-	-	2,220,400	0.3971	881,700	0.2567	570,000
1988	5,670	3,536,200	1,048,800	10,600	201,400	275,000	-	2,000,400	0.3677	735,500	0.2292	458,500
1989	6,128	3,908,000	1,105,700	8,500	224,600	341,000	-	2,228,200	0.3405	758,700	0.2046	455,900
1990	6,622	4,324,500	1,168,400	10,600	248,000	-	-	2,807,500	0.3152	913,300	0.1827	529,400
1991	7,242	4,830,000	1,241,100	12,700	285,600	-	-	3,290,600	0.2919	960,500	0.1631	536,700
1992	7,880	5,409,100	1,309,800	12,700	315,800	-	-	3,770,800	0.2703	1,019,200	0.1456	549,000
1993	8,508	5,981,600	1,522,700	14,800	337,900	250,000	-	3,856,200	0.2502	964,800	0.1300	501,300
1994	9,146	6,562,600	1,607,900	12,700	379,600	-	-	4,562,400	0.2317	1,057,100	0.1161	529,700
1995	9,800	7,193,300	1,702,000	12,700	408,300	-	-	5,070,300	0.2145	1,087,600	0.1037	525,800
						Salvage Value - Phase I = 8,023,100						
						Salvage Value - Phase II = 7,740,200		15,763,300	0.2145	3,381,200	0.1037	1,634,700
						Totals				2,418,600		(2,222,200)

Internal Rate of Return = 10.1 percent

Note: The above cost figures are based on January, 1975, prices. No allowance has been provided for escalation.

TABLE D-4

INTERNAL RATE OF RETURN AS A BUSINESS ENTERPRISE FOR PHASE I 85 PERCENT OF PROJECTED WATER SALES (U.S. DOLLARS)

Year	Annual Sales		Operations and Maintenance Costs				Net Benefits	Alternative Rates of Return			
								6% Interest		8% Interest	
	Volume (1,000 Cu m)	Revenues (US $)	Water Supply System	Service Connections	Wastewater System	Capital Investments		P.W. Factor	Present Worth	P.W. Factor	Present Worth
1975	-	-	-	-	-	-	-	1.0000	-	1.0000	
1976	-	-	-	-	-	2,012,500	(2,012,500)	0.9434	(1,898,600)	0.9259	(1,863,400)
1977	-	-	-	-	-	7,246,000	(7,246,000)	0.8900	(6,448,900)	0.8573	(6,212,000)
1978	1,080	515,200	117,400	4,200	35,600	3,603,200	(3,245,200)	0.8396	(2,724,700)	0.7938	(2,576,000)
1979	2,508	1,246,100	271,000	6,400	77,600	-	891,100	0.7921	705,800	0.7350	655,000
1980	2,839	1,454,900	318,[illegible]	4,200	93,500	-	1,038,500	0.7473	776,100	0.6806	706,800
1981	3,111	1,636,800	356,[illegible]	6,400	99,600	-	1,174,600	0.7050	828,100	0.6302	740,200
1982	3,417	1,843,600	392,500	6,400	116,600	-	1,328,100	0.6651	883,300	0.5835	774,900
1983	3,723	2,055,800	438,100	6,400	121,700	-	1,489,600	0.6274	934,600	0.5403	804,800
1984	4,046	2,406,800	474,000	6,400	128,500	-	1,797,900	0.5919	1,064,200	0.5002	899,300
1985	4,352	2,516,600	516,200	8,500	135,600	-	1,856,300	0.5584	1,036,600	0.4632	859,800
						Salvage Value	8,884,700	0.5584	4,961,200	0.4632	4,115,400
						Totals			117,700		(1,095,200)

Internal Rate of Return = 6.2 percent

TABLE D-5

INTERNAL RATE OF RETURN AS A BUSINESS ENTERPRISE FOR PHASES I AND II 70 PERCENT OF PROJECTED WATER SALES (U. S. DOLLARS)

Year	Annual Sales		Operations & Maintenance Costs				Capital Investments	Net Benefits	Alternative Rates of Return			
									8% Interest		10% Interest	
	Volume (1000) (cu m)	Revenues (US$)	Water Supply System	Service Connections	Wastewater Systems	Equipment Replacement Costs			P.W. Factor	Present Worth	P.W. Factor	Present Worth
1975	-	-	-	-	-	-	-	-	1.0000	-	1.0000	-
1976	-	-	-	-	-	-	2,012,500	(2,012,500)	0.9259	(1,863,400)	0.9091	(1,829,600)
1977	-	-	-	-	-	-	7,246,000	(7,246,000)	0.8573	(6,212,000)	0.8264	(5,988,100)
1978	889	424,300	201,500	3,500	32,100	-	3,603,200	(3,416,000)	0.7938	(2,711,600)	0.7513	(2,566,400)
1979	2,065	1,026,200	237,800	5,200	69,600	-	-	713,600	0.7350	524,500	0.6830	487,400
1980	2,338	1,198,200	278,800	3,500	84,500	-	-	831,400	0.6806	565,800	0.6209	516,200
1981	2,562	1,347,900	311,400	5,200	89,900	-	-	941,400	0.6302	593,300	0.5645	531,400
1982	2,814	1,518,200	343,000	5,200	95,200	-	-	1,074,800	0.5835	627,100	0.5132	551,600
1983	3,066	1,693,000	382,500	5,200	110,100	-	-	1,195,200	0.5403	645,800	0.4665	557,600
1984	3,332	1,982,000	413,800	5,200	116,300	-	-	1,446,700	0.5002	723,600	0.4241	613,500
1985	3,584	2,072,500	450,400	7,000	122,800	-	-	1,492,300	0.4632	691,200	0.3855	575,300
1986	4,496	2,329,000	591,400	8,800	134,000	-	-	1,594,800	0.4289	684,000	0.3505	559,000
1987	4,298	2,626,700	656,700	7,000	148,000	-	5,207,800	(3,392,800)	0.3971	(1,347,300)	0.3186	(1,080,900)
1988	4,669	2,912,100	897,800	8,800	162,700	275,000	5,985,400	(4,417,600)	0.3677	(1,624,400)	0.2897	(1,279,800)
1989	5,047	3,218,300	947,100	7,000	176,800	341,200	-	1,746,200	0.3405	594,600	0.2633	459,800
1990	5,453	3,561,400	1,001,300	8,800	192,400	-	-	2,358,900	0.3152	743,500	0.2394	564,700
1991	5,964	3,977,700	1,064,800	10,500	207,900	-	-	2,694,500	0.2919	786,500	0.2176	586,300
1992	6,489	4,454,600	1,233,200	10,500	225,600	-	-	2,985,300	0.2703	806,900	0.1978	590,500
1993	7,007	4,926,000	1,304,300	12,200	244,300	250,000	-	3,115,200	0.2502	779,400	0.1799	560,400
1994	7,532	5,404,500	1,378,200	10,500	263,800	-	-	3,752,000	0.2317	869,300	0.1635	613,500
1995	8,071	5,923,900	1,459,800	10,500	282,200	-	-	4,171,400	0.2145	894,800	0.1486	619,900
					Salvage Value - Phase I =		8,023,100					
					Salvage Value - Phase II =		8,007,800	16,030,900	0.2145	3,438,600	0.1486	2,382,200
					Totals					210,300		(1,975,500)

Internal Rate of Return = 8.2 percent

Note: The above cost figures are based on January, 1975, prices.
No allowance has been provided for escalation.

TABLE D-6

INTERNAL RATE OF RETURN AS A BUSINESS ENTERPRISE FOR PHASE I 70 PERCENT OF PROJECTED WATER SALES (U.S. DOLLARS)

Year	Annual Sales		Operations and Maintenance Costs				Net Benefits	Alternative Rates of Return			
								2% Interest		6% Interest	
	Volume (1,000 u m)	Revenues (US $)	Water Supply System	Service Connections	Wastewater System	Capital Investments		P. W. Factor	Present Work	P. W. Factor	Present Work
1975	-	-	-	-	-	-	-	1.0000	-	1.0000	-
1976	-	-	-	-	-	2,012,500	(2,012,500)	0.9804	(1,973,100)	0.9434	(1,898,600)
1977	-	-	-	-	-	7,246,000	(7,246,000)	0.9612	(6,964,900)	0.8900	(6,448,900)
1978	889	424,300	201,500	3,500	32,100	3,603,200	(3,416,000)	0.9423	(3,218,900)	0.8396	(2,868,100)
1979	2,065	1,026,200	237,800	5,200	69,600	-	713,600	0.9238	659,200	0.7921	565,200
1980	2,338	1,198,200	278,800	3,500	84,500	-	831,400	0.9057	753,000	0.7473	621,300
1981	2,562	1,347,900	311,000	5,200	89,900	-	941,400	0.8880	861,100	0.7050	683,600
1982	2,814	1,518,200	343,000	5,200	95,200	-	1,074,800	0.8706	935,700	0.6651	714,800
1983	3,066	1,693,000	382,500	5,200	110,100	-	1,195,200	0.8535	1,020,100	0.6274	749,900
1984	3,332	1,982,000	413,800	5,200	116,300	-	1,446,700	0.8368	1,210,600	0.5919	856,300
1985	3,584	2,072,500	450,400	7,000	122,800	-	1,492,300	0.8203	1,224,100	0.5584	833,300
						Salvage Value	8,884,700	0.8203	7,288,100	0.5584	4,961,200
						Totals			1,769,900		(1,249,900)

Internal Rate of Return = 4.3 percent

NOTE: The above cost figures are based on January 1975 prices. No allowance has been provided for escalation.

APPENDIX E

TABLE E-1

INTERNAL RATE OF RETURN AS A NATIONAL ECONOMIC PROJECT

100 PERCENT PROJECTED WATER SALES
100 PERCENT OF ESTIMATED ECONOMIC BENEFITS
(U.S. Dollars)

Year	Population	"O & M" Plus Annual Costs	Capital Investments	Revenues From Water Sales	Benefits: Extension of Life	Benefits: Reduction of Medical Costs	Benefits: Reduction of Loss of Labor	Benefits: Productivity Benefit	Net Benefits	Alternative Rates of Return: 35% Interest P.W. Factor	35% Interest Present Worth	40% Interest P.W. Factor	40% Interest Present Worth
1975	95,300	-	-	-	-	-	-	-	-	1.0000	-	1.0000	-
1976	101,000	-	2,012,500	-	-	-	-	-	(2,012,500)	0.7407	(1,490,700)	0.7143	(1,437,500)
1977	107,100	-	7,246,000	-	-	-	-	-	(7,246,000)	0.5487	(3,975,900)	0.5102	(3,696,900)
1978	113,500	199,000	3,603,200	606,100	286,800	595,900	297,900	720,700	(1,294,800)	0.4064	(526,200)	0.3644	(471,800)
1979	120,300	367,000	-	1,466,000	627,200	1,263,200	631,600	1,569,900	5,190,900	0.3011	1,563,000	0.2603	1,351,200
1980	127,500	429,500	-	1,711,700	683,800	1,338,800	669,400	1,714,900	5,689,100	0.2230	1,268,700	0.1859	1,057,600
1981	135,100	477,000	-	1,935,600	748,600	1,418,600	702,300	1,871,100	6,189,200	0.1652	1,022,500	0.1328	821,900
1982	143,200	528,000	-	2,168,900	816,800	1,503,600	751,800	2,047,800	6,760,900	0.1224	827,500	0.0949	641,600
1983	151,800	483,500	-	2,418,600	894,200	1,593,900	797,000	2,231,500	7,351,700	0.0904	666,600	0.0678	498,400
1984	160,900	628,000	-	2,831,500	975,700	1,689,400	844,800	2,429,600	8,143,000	0.0671	546,700	0.0484	394,100
1985	170,600	680,500	-	2,960,700	1,067,200	1,791,300	895,700	2,661,400	8,695,800	0.0497	432,200	0.0346	300,900
								Salvage Value =	8,884,700	0.0497	441,600	0.0346	307,400
								Totals			776,000		(233,100)

Internal Rate of Return = $0.35 + 0.05 \left[\frac{776,000}{776,000 + 233,100}\right]$ = 38.8 percent

Note: The above cost figures are based on January 1975, prices. No allowances have been provided for escalation.

TABLE E-2

INTERNAL RATE OF RETURN AS A NATIONAL ECONOMIC PROJECT

100 PERCENT OF PROJECTED WATER SALES
MINIMAL ECONOMIC BENEFITS
(U.S. Dollars)

Year	Population	"O & M" and Annual Costs	Capital Investments	Revenues From Water Sales	Benefits: Extension of Life	Benefits: Reduction of Medical Costs	Benefits: Reduction of Loss of Labor	Net Benefits	Alternative Rates of Return: 15% Interest P.W. Factor	15% Interest Present Worth	20% Interest P.W. Factor	20% Interest Present Worth
1975	95,300	-	-	-	-	-	-	-	1.0000	-	1.0000	-
1976	101,000	-	2,012,500	-	-	-	-	(2,012,500)	0.8696	(1,750,100)	0.8333	(1,677,000)
1977	107,100	-	7,246,000	-	-	-	-	(7,246,000)	0.7561	(5,478,700)	0.6944	(5,031,600)
1978	113,500	199,000	3,603,200	606,100	143,400	297,900	149,000	(2,605,800)	0.6575	(1,713,300)	0.5787	(1,508,000)
1979	120,300	367,000	-	1,466,000	313,600	631,600	315,800	2,360,000)	0.5718	1,349,400	0.4823	1,138,200
1980	127,500	429,500	-	1,711,700	341,900	669,400	334,700	2,628,200	0.4972	1,306,700	0.4019	1,056,300
1981	135,100	477,000	-	1,925,600	374,300	709,300	351,200	2,883,400	0.4323	1,246,500	0.3349	965,700
1982	143,200	528,000	-	2,168,900	408,400	751,800	375,900	3,177,000	0.3759	1,194,200	0.2791	886,700
1983	151,800	583,500	-	2,418,600	447,100	796,900	398,500	3,477,600	0.3269	1,136,800	0.2326	808,900
1984	160,900	628,000	-	2,831,500	487,800	844,800	422,400	3,958,500	0.2843	1,125,400	0.1938	767,200
1985	170,600	680,500	-	2,960,700	533,600	895,700	447,800	4,157,300	0.2472	1,027,700	0.1615	671,400
								Salvage Value = 8,884,700	0.2472	2,196,300	0.1615	1,434,900
								Totals		1,640,900		(487,300)

Note: The above cost figures are based on January 1975, prices. No allowances have been provided for escalation.

Internal Rate of Return = 18.9 percent

TABLE E-3

INTERNAL RATE OF RETURN AS A NATIONAL ECONOMIC PROJECT

85 PERCENT OF PROJECTED WATER SALES
100 PERCENT OF ESTIMATED ECONOMIC BENEFITS
(U.S. Dollars)

Year	Population	"O & M" Costs	Capital Investments	Annual Revenues Water Sales	Total Economic Benefits	Net Benefits	Alternative Rates of Return			
							35% Interest		40% Interest	
							P. W. Factor	Present Worth	P. W. Factor	Present Worth
1975	95,300	-	-	-	-	-	1.0000	-	1.000	-
1976	101,000	-	2,012,500	-	-	(2,012,500)	0.7407	(1,490,700)	0.7143	(1,437,500)
1977	107,100	-	7,246,000	-	-	(7,246,000)	0.5487	(3,975,900)	0.5102	(3,696,900)
1978	113,500	157,200	3,603,200	515,200	1,901,300	(1,343,900)	0.4064	(546,200)	0.3644	(489,700)
1979	120,300	355,000	-	1,246,100	4,091,900	4,983,000	0.3011	1,500,400	0.2603	1,297,100
1980	127,500	416,400	-	1,454,900	4,406,900	5,445,400	0.2230	1,214,300	0.1859	1,012,300
1981	135,100	462,200	-	1,636,800	4,740,600	5,915,200	0.1652	977,200	0.1328	785,500
1982	143,200	515,500	-	1,843,600	5,120,000	6,448,100	0.1224	789,200	0.0949	611,900
1983	151,800	566,200	-	2,055,800	5,516,600	7,006,200	0.0904	633,400	0.0678	475,000
1984	160,900	608,900	-	2,406,800	5,939,500	7,737,400	0.0671	519,200	0.0484	374,500
1985	170,600	660,300	-	2,516,600	6,415,600	8,271,900	0.0497	411,100	0.0346	286,200
				Salvage Value =		8,884,700	0.0497	441,600	0.0346	307,400
				Totals				473,600		(474,200)
				Internal Rate of Return					37.5	percent

TABLE E-4

INTERNAL RATE OF RETURN AS A NATIONAL ECONOMIC PROJECT

70 PERCENT OF PROJECTED WATER SALES
100 PERCENT ESTIMATED ECONOMIC BENEFITS
(U.S. Dollars)

Year	Population	"O & M" Costs	Capital Investments	Annual Revenues Water Sales	Total Economic Benefits	Net Benefits	Alternative Rates of Return			
							35% Interest		40% Interest	
							P.W. Factor	Present Worth	P.W. Factor	Present Worth
1975	95,300	-	-	-	-	-	1.0000	-	1.0000	-
1976	101,000	-	2,012,500	-	-	(2,012,500)	0.7407	(1,490,700)	0.7143	(1,437,500)
1977	107,100	-	7,246,000	-	-	(7,246,000)	0.5487	(3,975,900)	0.5102	(3,696,900)
1978	113,500	237,100	3,603,200	424,300	1,901,300	(1,514,700)	0.4064	(615,600)	0.3644	(552,000)
1979	120,300	312,600	-	1,026,200	4,091,900	4,805,500	0.3011	1,446,900	0.2603	1,250,900
1980	127,500	366,800	-	1,198,200	4,406,900	5,238,300	0.2230	1,168,100	0.1859	973,800
1981	135,100	401,300	-	1,347,900	4,740,600	5,687,200	0.1652	939,500	0.1328	755,300
1982	143,200	443,400	-	1,518,200	5,120,000	6,194,800	0.1224	758,200	0.0949	587,900
1983	151,800	497,800	-	1,693,000	5,516,600	6,711,800	0.0904	606,700	0.0678	455,100
1984	160,900	535,300	-	1,982,000	5,939,500	7,386,200	0.0671	495,900	0.0484	357,500
1985	170,600	580,200	-	2,072,500	6,415,600	7,907,900	0.0497	393,000	0.0346	273,600
					Salvage Value =	8,884,700	0.0497	441,600	0.0346	307,400
					Totals			167,700		(724,900)
					Internal Rate of Return				35.9	percent

Note: The above cost figures are based on January 1975, prices.
No allowance has been provided for escalation.

TABLE E-5

INTERNAL RATE OF RETURN AS A NATIONAL ECONOMIC PROJECT

70 PERCENT OF PROJECTED WATER SALES
MINIMAL ECONOMIC BENEFITS
(U. S. Dollars)

Year	Population	O & M and Annual Costs	Capital Investments	Revenues from Water Sales	Benefits: Extension of Life	Benefits: Reduction of Medical Costs	Benefits: Reduction of Loss of Labor	Net Benefits	Alternative Rates of Return: 15% Interest P.W. Factor	15% Interest Present Worth	20% Interest P.W. Factor	20% Interest Present Worth
1975	95,300	-	-	-	-	-	-	-	1.0000	-	1.0000	-
1976	101,000	-	2,012,500	-	-	-	-	(2,012,500)	0.8696	(1,750,100)	0.8333	(1,677,000)
1977	107,100	-	7,246,000	-	-	-	-	(7,246,000)	0.7561	(5,478,700)	0.6944	(5,031,600)
1978	113,500	237,100	3,603,200	424,300	143,400	297,900	149,000	(2,825,700)	0.6575	(1,857,900)	0.5787	(1,635,200)
1979	120,300	312,600	-	1,026,200	313,600	631,600	315,500	1,974,300	0.5718	1,128,900	0.4823	952,200
1980	127,500	366,500	-	1,198,200	341,900	669,400	324,700	2,167,400	0.4972	1,077,600	0.4019	871,100
1981	135,100	406,100	-	1,347,900	374,300	709,300	351,200	2,376,600	0.4323	1,027,400	0.3349	795,900
1982	143,200	443,400	-	1,518,200	408,400	751,800	375,000	2,610,000	0.3759	981,100	0.2791	728,500
1983	151,800	497,800	-	1,693,000	447,100	796,900	398,500	2,837,700	0.3269	927,600	0.2326	660,000
1984	160,700	535,300	-	1,982,000	487,800	844,800	422,400	3,201,700	0.2843	910,200	0.1938	620,500
1985	170,600	580,200	-	2,072,500	583,600	845,700	447,800	3,419,400	0.2472	845,300	0.1615	552,200
							Salvage Value =	8,884,700	0.2472	2,196,300	0.1615	1,434,900
							Totals			7,700		(1,728,500)

Note: The above cost figures are based on January 1975 prices.
No allowances have been provided for escalation.

Internal Rate of Return 15.0 percent