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Unaccounted-for Water in Rural Water Systems

A Case Study

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Executive Summary

Waste and loss of potable water is a major problem in Egypt. Valuable capital and energy resources are wasted every day due to an estimated 50 percent loss of the total potable water production.

The study covered by this report was designed to measure the unaccounted-for-water (UFW) losses in two rural Egyptian communities. It examined all water operations aspects of each village and introduced local water supply systems staff to efficient methods of system operation and monitoring. During the study, the Potable Water Supply (PWS) section of the LD II-P project and water staff of the villages found that meaningful results can be obtained without sophisticated equipment and measuring devices.

This report investigates in detail, the water consumption and losses in the Nahtai and El-Ghorieb Villages, Zefta Markaz, Gharbiya Governorate. Both are served by independent water supply systems, one of which was included in an earlier study.

Findings of the study are based on nearly 25,000 supply and consumer meter readings taken over the 33-day study period, and comprehensive data collected on water consumers of the respective study areas. Water samples were analyzed for bacterial pollution, and pressure recordings were taken to ensure that the networks were continuously under pressure during the studies. Using input/output meter readings of the two study areas, the UFW loss was found to be 19 and 30 percent, or 3.0 and 2.9 liters/service/hour for Nahtai and El-Ghorieb villages, respectively.

An earlier loss reduction activity in Nahtai Village estimated losses at over 50 percent or 130 liters/service/hour. This high figure was caused by an increase in pressure from a new water tower (15m higher than the original tower) and the poor condition of pipelines and service connections. Since then much of the 6" piping and many service connections on the same main have been replaced. This is not the case in El-Ghorieb Village, where most of the network piping is old.

Another possible explanation for the lower loss figure in Nahtai is that the village community made every effort to minimize losses during the study period. If this is so, then the study proves that village communities have the capacity to minimize losses with little external assistance.

The results of the UFW study indicate that significant economic benefits can result from the measurement of unaccounted-for-water, followed by the appropriate replacement or repair of those

parts of the system responsible for the losses. The Recommendations section of this report includes a table with a range of hypothetical UFW losses, corresponding actions to reduce losses, and the resulting potential savings. The purpose of the table is to demonstrate that rural villages with independent water sources can invest in reducing water losses and, within one year, recoup that investment. For example, if a village with 500 services and 15 L/service/hour UFW invests LE 1,000 on water loss reduction, that village will save LE 1,000 during the first year in electricity savings alone, without considering potential future capital investment savings.

Introduction

An unaccounted-for-water (UFW) study can be conducted on any water supply system to obtain information regarding water losses. It is similar to performing a financial audit where the income and expenditures of a business are examined and balanced.

The National Water Research Council estimates the present annual domestic water consumption to be 3.1 billion m^3.[1] It is thought that 50 percent of this is lost through leakage and waste from defective plumbing fittings. By reducing this loss to 25 percent, the present capacity of existing major water and wastewater treatment plants is expected to be sufficient until the turn of the century.

The UFW indicator is one of the most popular ways for water authority managers to measure the efficiency and performance of water systems. It serves as a water audit to compare the quantity of water supplied with that consumed, the difference being the UFW. In Egypt various studies have been conducted including:

- Provincial Water Supply Project, Binnie-Taylor (1980) (found water loss to be 30 percent).

- Feasibility Study on Water Supply and Sanitary Drainage in Qena and Asswan Governorates, Upper Egypt Consultants, (1986) (found water loss to be 30 percent and above).

- El-Salam Company for Contracting and Commerce (while rehabilitating water networks in Beheira between 1983-86, found open ended pipes, above-ground bursts, and collapsed pipelines that caused more than 75 percent of all water to be wasted).

- Summary Report on Water Loss Reduction Program in Five Egyptian Villages, Chemonics LD II Project, (1990) (found loss varying from 43 to 59 percent and from 40 to 138 liters/service/hour).

- Concise feasibility study for water supply and sewerage in Menoufiya Governorate, K-Konsult, Sweden (1992) (found losses from 17 to 44 percent).

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[1] ***Water Resources Assessment for Egypt***, Mahmoud Abu Zeid, Chairman Water Research Center, Ministry of Public Works and Water Resources, Cairo. (Presented to a Round Table Conference, Cairo, October 1991.)

This unaccounted-for-water study is a continuation of two past studies. The first is a nine-month water loss reduction program which produced *Water System Loss Reduction Manual* and *Water System Loss Reduction Guidelines* (February 1990); the second is *Evaluating the Loss Reduction Program in Four Villages* (August 1991), which recommends further work to improve and accelerate loss reduction efforts.

USAID identified the need for actual measured water loss data in order to support further funding for loss reduction programs, and subsequently approved a scope of work on 22 May 1991. This report is a deliverable of the Annual Work Plan of LD II-P program under Potable Water Supply Activity PW 7.1.

Please note that all appendices referred to in this report are included in a separate volume entitled *Technical Appendices: Unaccounted-for-Water in Rural Water Systems* (PWS 4-02.A (E), April 1992).

DEFINITIONS

Accounted-for-water

Accounted-for-water includes all metered water, including estimated metered consumption, which generates revenue.

Wasted Water

Wasted water includes all water lost from overflowing tanks, standpipes left open, and water for open circuit cooling systems for diesel engines at pump stations. Water wasted through faulty plumbing connections and fixtures downstream of consumer meters is also included.

Unaccounted-for-water (UFW)

The cause of UFW losses generally falls into one of the following categories:

- Leaks from broken or cracked pipes, or fittings
- Unauthorized users
- Inoperable consumer meters that under-register the amount of water consumed
- Un-metered or flat-rate consumers

- Public use (fire fighting, road watering, etc.)

- Inaccessible meters (such as those inside locked premises)

UFW equals the total metered water supplied to the network less the metered water consumed. Expressed as a percentage, it becomes:

$$\text{UFW (\%)} = \frac{(\text{total metered supply - metered consumption}) \times 100}{\text{total input water}}$$

or, in liters per service per hour,

$$\text{UFW (liters/service/hour)} = \frac{(\text{daily supply - metered consumption}) \times 1{,}000}{\text{number of services} \times 24 \text{ hours}}$$

SCOPE OF WORK

The principal purpose of this study was to measure as accurately as possible the UFW losses from two independent village water supply systems.

On 22 March 1991 USAID approved the start of activity by long-term Potable Water Supply (PWS) section personnel, assisted by a short-term local engineer in the collection and appraisal of field data. The scope of work included the following tasks:

- Select two rural water supply systems typical of the independent systems found throughout the country.

- Install pressure and flow measuring instruments on pump station outlets.

- Map the distribution system and install consumer meters on all large consumer connections and ensure that at least 60 percent of all residential consumer meters are in working order.

- Record supply and consumption for at least 15 days in the two villages.

- Install pressure recorders to ensure the networks are pressurized for the duration of the study.
- Collect and analyze water samples from wells, water towers, and networks for fecal contamination.

- Expose and inspect at least 20 of the oldest water connections for leakage and corrosion.

- Summarize all collected data and calculate measured water losses.

STUDY ACTIVITIES

To complete the study, advisors:

- Purchased imported instruments and equipment, and local supplies for the study.

- Selected two villages with independent water supply systems.

- Conducted workshops for village and markaz staff to acquaint them with the program and their roles.

- Reviewed and updated existing network maps.

- Designed UFW study in each village.

- Installed bulk water meters, valves and consumer meters as needed.

- Used ultrasonic meters and pressure recorders to verify the accuracy of bulk meters and the continuity of water supply.

- Inventoried served and un-served properties and number of consumers served.

- Recorded supply and consumer meter readings daily for a period of at least 15 days.

- Analyzed water samples for bacterial contamination.

- Evaluated collected data and analyzed the results.

- Prepared a report of the study.

Section 1
Study Implementation

PRELIMINARY TASKS

Following is a list of preliminary tasks required to complete the study:

- Appoint a water loss advisor. A description of the qualifications and scope of work for this position (see Appendix D) was prepared prior to the interviews. A person with excellent qualifications was chosen and approved, and field work began 1 October 1991.

- Select and order flow and pressure instruments and equipment for conducting bacterial analysis. This was a priority because most of the equipment (see Appendix B) was imported.

- Select the pilot villages. This selection was based on experience gained through the PWS section's 1988 water loss reduction program and the results of the evaluation study by A. A. Warith Consulting Engineers (1991). A brief discussion on the rationale of village selection follows.

Selection of Pilot Villages

The first site selected was Nahtai Village in Zefta Markaz, Gharbiya Governorate. A participant in the original water loss study, Nahtai's staff and village council had demonstrated that they could work well with the PWS section staff. Also, Nahtai's water system seemed to be well-managed.

The size of the community, about 10,000 persons with 600 total services, was typical of the 13 village water systems surveyed in the governorates of Gharbiya, Menufiya, Sharqiya, and Giza in 1988.[2] More importantly, the village was willing to provide help in conducting the proposed UFW study, and had used LD II-P funds to replace water mains largely responsible for the high losses found in the earlier study.

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[2] See ***Water System Loss Reduction Guidelines*** (LD II-P publication O&M-M-2 (E), February 1990)

Another village was needed to act as a control measure and to assure impartiality in the study. The village needed to be close to Nahtai for accessibility, and in the same governorate so that it would be subject to the same governmental regulations regarding water systems. As with Nahtai, the village council and staff would need to appreciate the purpose of the study and be willing to cooperate with the team.

The village of El-Ghorieb, about six kilometers from Nahtai, was selected on the basis of its proximity to Nahtai and its village staff, who were interested in conducting the study. The population was estimated at 6,500 persons with 648 house connections.

A two-day training course was held to introduce the officials and participants from both villages to the study and its objectives. Appendix E is a schedule of the training session.

DETAILS OF FIELD WORK

After completion of the preliminary tasks, the team followed standard guidelines for conducting a leak detection program. Advisors:

- Mapped the pipe networks.
- Checked the accuracy of the bulk meter either volumetrically or by using an ultrasonic flow instrument to assure accuracy of the quantity of water flow readings into the network.
- Conducted measurements to determine night-time flow by recording the hourly quantity of water flowing into the network.
- Took readings of newly installed zone meters to determine the quantity of water flowing into each zone.
- Obtained daily water consumption figures for each zone at the time of the survey.
- Took pressure readings at selected areas throughout the network during high and low consumption periods to help analyze or confirm high water use or losses, and their locations.

- Collected and tested water samples for fecal contamination.[3]

WORK PROGRAM

Nahtai Village

Figure 1 is a map of Nahtai Village showing the layout of the pipe network and water facilities. The first task was to measure the daily quantity of water delivered to the network from the pump station. This was done by reading the existing bulk meter on the outlet from the water tower. The accuracy of the meter was checked volumetrically by measuring changes in the tank water level over a period of time; these readings were verified using a portable sonic meter.

As shown in Figure 1, one area of the village serving 233 consumers was selected as the study zone. Meters were installed in the mains to measure the quantity of water entering and leaving this zone, thus measuring the total supply to the 233 consumers.

Over a period of 34 days, daily metered water consumption of dwellings, public buildings, schools, mosques and commercial buildings in the study zone was recorded. Figures representing this daily consumption rate and the total supply of water into the study zone were used to calculate the unaccounted-for-water loss.

El-Ghorieb Village

Figure 2 is a map of El-Ghorieb Village showing the layout of the pipe network and water supply facilities. In this village, the water loss study zone encompassed the entire network and included all consumers.

A new bulk meter was installed on the pump station outlet. This and the 648 consumer meters were read daily for 23 days. These figures were used to calculate the unaccounted-for-water losses.

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[3] As an additional check on water quality, collection and testing of water samples for fecal contamination is done routinely during most UFW studies.

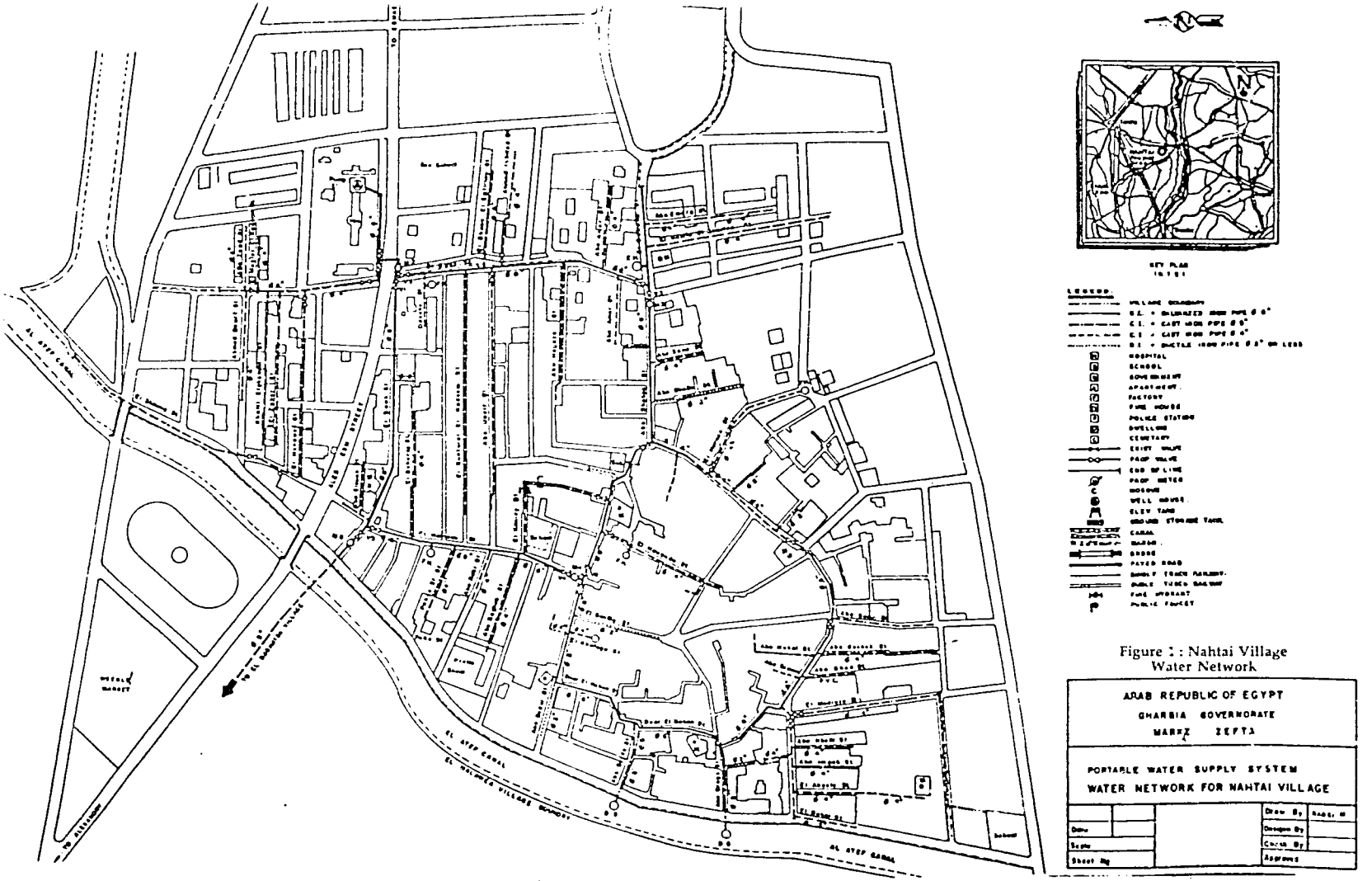


Figure 1 : Nahtai Village Water Network

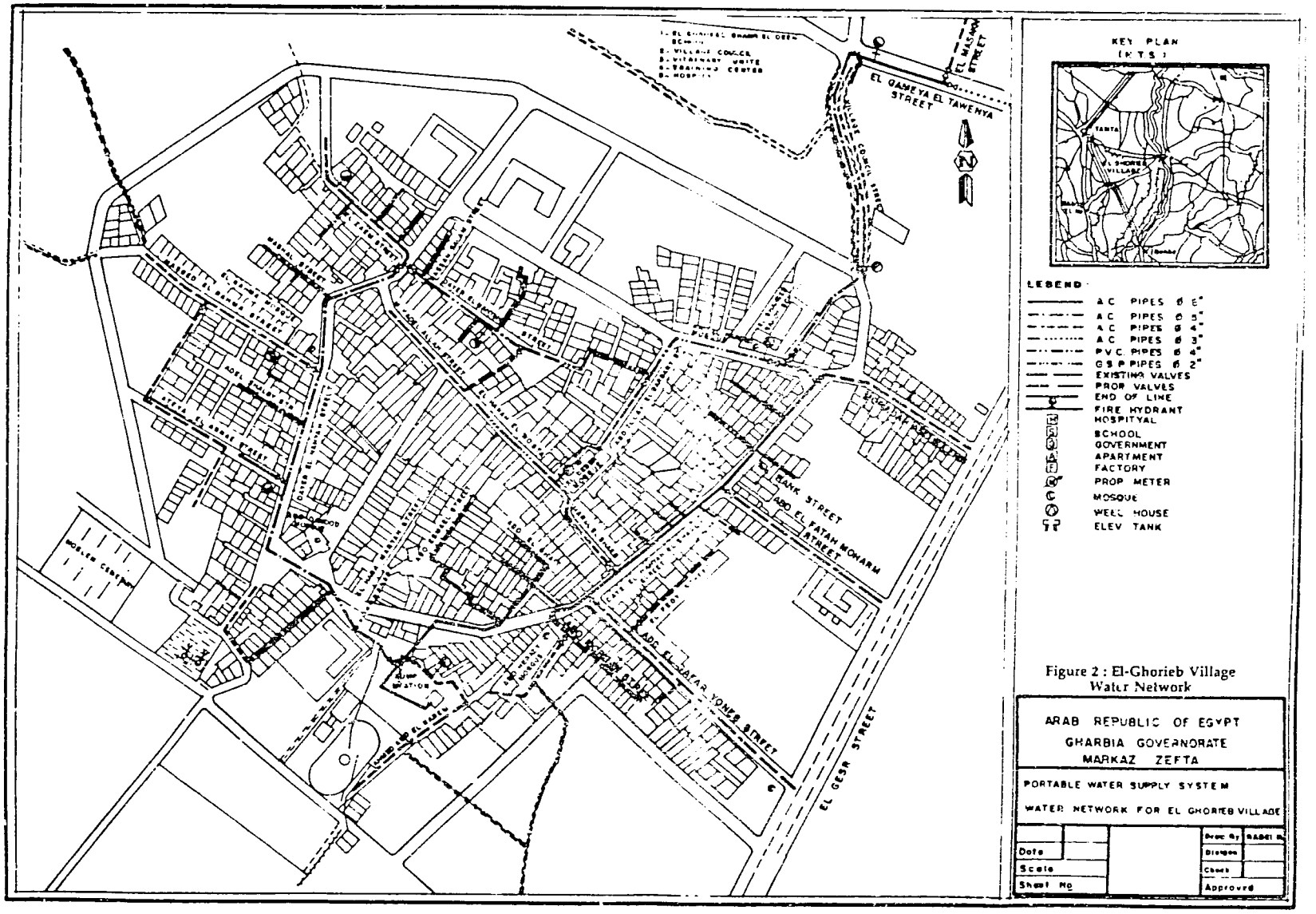


Figure 2 : El-Ghorieb Village Water Network

SURVEYS

In addition to preparing maps and records of water use and consumption in both study zones, data were collected on the village populations, buildings and structures, and water facilities (pump capacity, water tower dimensions, length of pipelines by size, and number of buildings with water connections).

Locations of the valves, water meters and pressure recorders are shown on the water network maps for the two villages in Figures 1 and 2. These maps also show the route and size of each water main.

Pressure recordings were taken in both villages to verify the reliability of the supply during the water loss surveys. Copies of these recordings are in Appendices H and I; the results are discussed in Section 2.

Water samples were collected from the source, storage tank, and the network for bacteriological (fecal) testing. These samples and two control samples were processed according to the Millipore Filter Process. Results are shown in Appendix J and discussed in Section 2.

Section 2
Findings

The main difference between the water supply systems of the two study villages was the previous loss reduction work in Nahtai. In 1990-91, most of Nahtai's six-inch water mains were replaced as a result of LD II-P water loss reduction technical assistance. It was assumed that the leakage losses in Nahtai would be low compared with losses from the old pipe network serving El-Ghorieb.

All collected data were analyzed to obtain daily unaccounted-for-water losses. These are shown graphically in Figures 3 and 5 for Nahtai and El-Ghorieb villages respectively.

In measuring the amount of UFW attributable to leakage, hourly readings were taken of the output from the two village pump stations at Nahtai and El-Ghorieb. The purpose of taking hourly readings over a 24-hour period was to determine the minimum hourly flow rate. As reported by K-Konsult, the minimum night flow is a good indicator of the level of leakage in a system. This is because night-time use is generally low, suggesting that a high percent of night-time flow (as compared to daily flow) indicates water loss rather than water use.

GENERAL STATISTICS

Nahtai Village

Nahtai is a typical rural Delta village administered by Zefta Markaz, Gharbiya Governorate. It is on the main road from the governorate capital, Tanta, to Zefta and is located about 15 km east of Tanta. Agriculture is the main economy of the community.

The estimated population (1990) of Nahtai is 9992. Of its 1442 buildings, 599 (41.5 percent) have water service connections. The selected study area covered 233 served buildings (39 percent of the total number of services).

Residents of Nahtai receive water from a local well source. Water is pumped from the well to the distribution system and to a new water tower. The water tower is 30 meters high with a capacity of 100 m^3. Under normal conditions the pumps are operated for 16 hours a day (two eight-hour shifts); during the UFW study water was supplied 24 hours a day.

Table 1 provides a summary of the basic data for Nahtai Village.

Table 1

UNACCOUNTED FOR WATER STUDY

BASIC DATA - NAHTAI VILLAGE

STATISTICS FOR WHOLE VILLAGE:

POPULATION	9992	
NO. OF BUILDING	1442	
TOTAL WATER -		
SERVICE CONNECTIONS	599	
% OF BUILDING CONNECTED	41.5	%

STATISTICS FOR STUDY AREA:

POPULATION IN STUDY AREA	1320	
PER CAPITA CONSUMPTION IN STUDY AREA	50.2	L/C/d.

PIPE INVENTORY FOR STUDY AREA:

PIPE INVENTORY	150mm	100mm	50mm
Pipe Length (m)	955m	2028m	60m
Fire Hydrants	3	-	-
Standpost Taps	-	-	-
Valves	4	3	2

SERVICE CONNECTIONS IN STUDY AREA:

SERVICE CONNECTIONS	%	NO.
Meters inaccessible	7.7	18
Residential Meters	88.4	206
Non Residential Meters	2.6	6
Block of apartments	1.3	3
	100.0	233

NOTES :

(1) THE STUDY AREA HAS 39% OF SERVICES FOR THE WHOLE VILLAGE

(2) THE UFW STUDY INCLUDED ONLY PART OF THE WHOLE NETWORK

El-Ghorieb Village

El-Ghorieb is also a rural village administered by Zefta Markaz. It is located off the main road from Banha to Zefta, about 3 km south of Zefta and 5 km from Nahtai. While agriculture is the main economy, there is a small cement block industry, the water for which is provided from a private source.

The 1990 estimated population was 7,500, and 648 of the 1,040 buildings (62 percent) have water service connections. The selected study area covers the entire network and includes all 648 served buildings.

Residents of El-Ghorieb receive water from a local well and pump station. Water is pumped into the pipe network or to a water tower 12 meters high with 20 m^3 capacity. Under normal operating conditions, supply to the water tower is shut off each night and there is no water in the network between about 11 pm and 6 am. During the UFW study, water was supplied to the network 24 hours a day.

Table 2 provides a summary of the basic data for El-Ghorieb Village.

TABLE 2

UNACCOUNTED FOR WATER STUDY

BASIC DATA - EL GHORIEB VILLAGE

STATISTICS FOR WHOLE VILLAGE:

POPULATION	7500
NO. OF BUILDING	1040
TOTAL WATER - SERVICE CONNECTIONS	648
% OF BUILDING CONNECTED	62%

STATISTICS FOR STUDY AREA:

POPULATION IN STUDY AREA	3420
PER CAPITA CONSUMPTION IN STUDY AREA	30 L/C/day

PIPE INVENTORY FOR STUDY AREA:

PIPE INVENTORY	150mm	125mm	100mm	75mm	50mm
Pipe Length (m)	600	980	2730	180	380
Fire Hydrants	-	-	9	-	-
Standpost Taps	-	-	-	-	-
Valves	3	1	17	-	8

SERVICE CONNECTIONS IN STUDY AREA:

SERVICE CONNECTIONS	%	NO.
Meters inaccessible	23.9	155
Residential Meters	58.8	381
Non Residential Meters	9.6	62
Block of apartments	7.7	50
	100.0	648

NOTES :

(1) THE STUDY AREA HAS 39% OF SERVICES FOR THE WHOLE VILLAGE

(2) THE UFW STUDY INCLUDED ONLY PART OF THE WHOLE NETWORK

DETAILS OF STUDY AREAS

Nahtal Village

The unaccounted-for-water study was confined to that central part of the network shown in Figure 1. The 233 buildings served are supplied via a total of 3 km of pipe lines. One-third of this is new asbestos cement 6" piping and two-thirds is older 4" piping. There is also a short length of 2" service pipe line. Table 1 provides a pipeline inventory for the study area.

Seventy-five percent of the meters for the 233 water connections in the study zone were in working order. Defective meters were replaced with new meters supplied for purposes of the study. No accuracy tests were conducted on any of the original working meters.

Water entering and leaving the area was measured by four specially installed bulk meters. Consumption was registered by the 233 consumer meters. Eight percent of these were inaccessible (inside locked buildings), 90 percent served residential buildings and the remaining two percent served non-residential buildings such as a school, mosques, a bakery and public buildings. There were no public standpost taps in the zone and fire hydrants were not opened during the study.

The bulk and consumer meters were read daily for a period of 34 days, and the collected data were analyzed by computer.

Daily pressure recordings were taken over 19 of the 34 days of the UFW study. These showed that, except for a period of a few hours on three separate days, the pipes were continuously under pressure during the 19 days of pressure recording (see Appendix H).

El-Ghorieb Village

The study of this village included the whole water network as shown in Figure 2. The 648 service connections are supplied by 5.5 km of pipelines. About 90 percent of this piping is either old asbestos cement or galvanized iron pipe; 30 percent of the piping is 6" or 5" asbestos cement, 55 percent is 4" or 3" AC or uPVC piping, and the remaining 15 percent is 2" galvanized iron service pipe. Table 2 provides a pipeline inventory for the study area.

Water supplied to the network from the pump station was measured by a specially installed 4" Kent Helix 3000 meter. Consumption was registered by 648 consumer meters.

Ten percent of served buildings were empty and closed, and 24 percent of the domestic consumer meters did not work. Non-domestic consumers including a school, a village community center (hospital, school, maintenance center, and offices), six mosques, a telephone exchange, and two agricultural units accounted for 1.5 percent of the total. The remaining 64.5 percent of the meters serve residential consumers. There are no public standpost taps and none of the nine fire hydrants were opened during the study period.

The bulk meter and 648 consumer meters were read daily for a period of 23 days; the collected data were analyzed by computer.

Daily pressure recordings were taken over 12 of the 23 days of the water loss study. Pressure recordings were taken at two sites alternately with one recorder (see Appendix I). One recording site was the pump station; the other was located at the end of one branch of the network. The recordings show that the network was continuously under pressure on the days of the recordings. Further analysis of the pressure recordings is given later.

UNACCOUNTED-FOR-WATER LOSS

During the study period, total of 25,000 meter readings were collected and analyzed using a computer data base to determine UFW and water consumption based on the actual numbers of consumers. Data was collected from bulk and consumer water meters on a daily basis (see Appendices F and G).

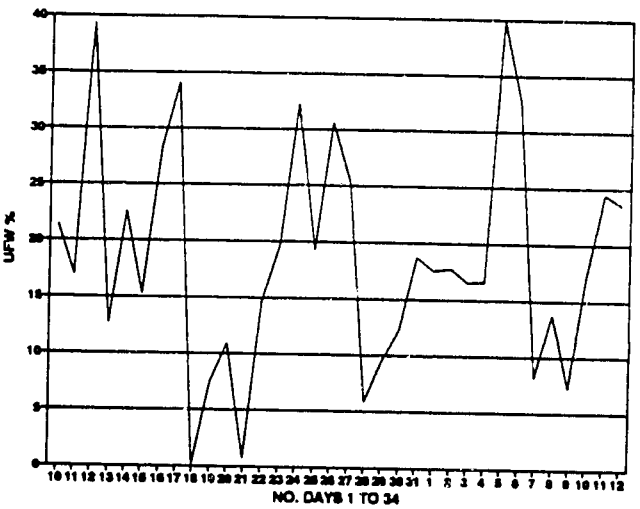
Nahtal Village

The daily losses in the study area over the 34-day period of investigation are shown in Figure 3 by percentage and liters/service/hour. Figure 4 shows the daily variation between supply and consumption, the white area below the top graph representing losses. The data shown on Figure 4 is discussed in more detail in the water consumption section.

Figure 3

NAHTAI VILLAGE

DAILY UNACCOUNTED FOR WATER LOSS
IN STUDY AREA



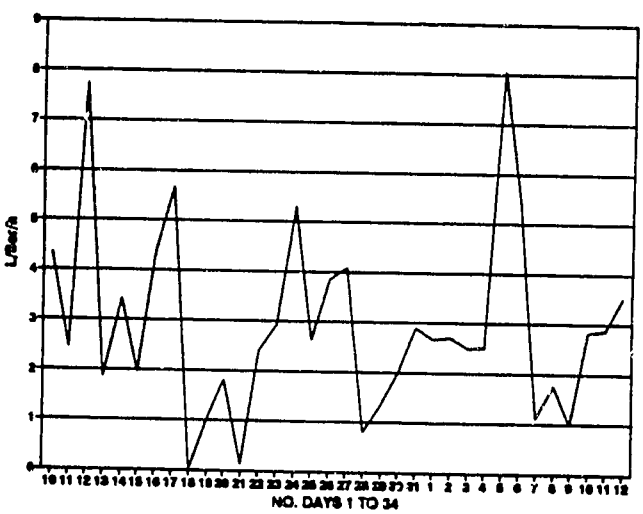
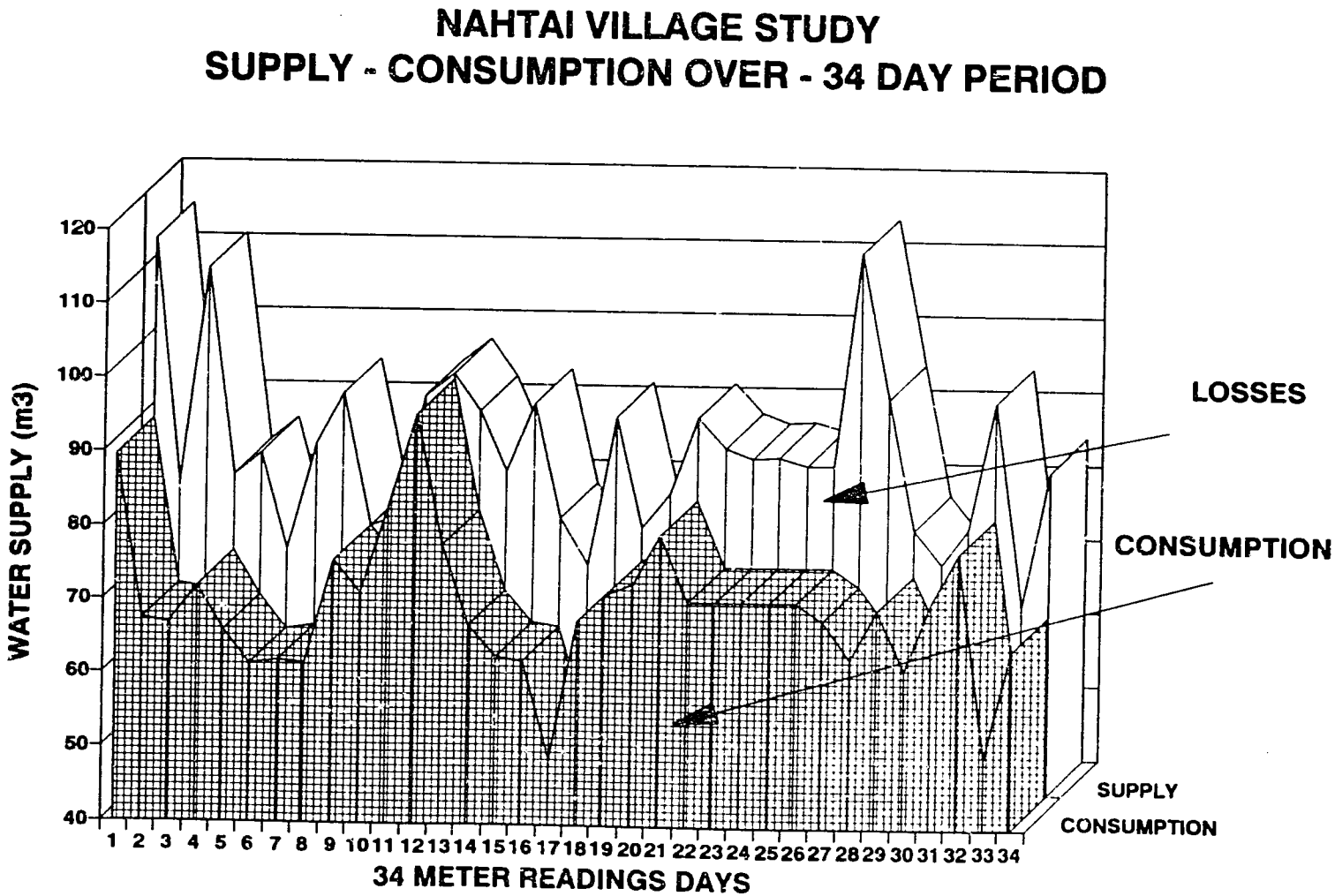


Figure 4


NAHTAI VILLAGE STUDY
SUPPLY - CONSUMPTION OVER - 34 DAY PERIOD
WATER SUPPLY (m3)
120
110
100
90
80
70
60
50
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
34 METER READINGS DAYS
LOSSES
CONSUMPTION
SUPPLY
CONSUMPTION

The total net amount of water supplied to the Nahtai study area over the 34-day period was 2911.5 m^3 compared to a consumption over the same period of 2351.3 m^3. These figures indicate that the total unaccounted-for-water loss over the 34 days was 19.2 % or 3 liters/service/hour. The data are summarized in Table 3.

Table 3: Summary of UFW Results for Nahtai Village

Total Supply (m^3)	Total Consumption (m^3)	UFW Losses (Percentage)	UFW Losses (Liters/ service hour)
2911.5	2351.3	19.2	3.0

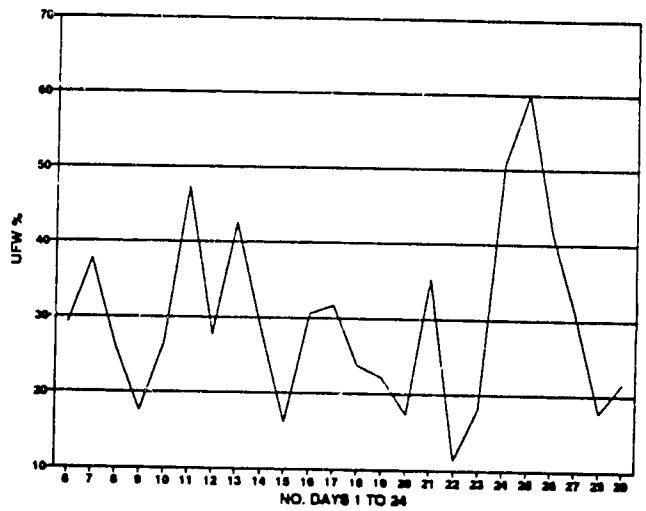
El-Ghorieb Village

The daily losses from El-Ghorieb network over the 23-day study period are shown in Figure 5 by percentage and liters/service/hour. Figure 6 shows the volume of loss on a daily basis, which is discussed in more detail in the water consumption section.

Figure 5

EL GHORIEB VILLAGE

DAILY UNACCOUNTED FOR WATER LOSS
IN STUDY AREA



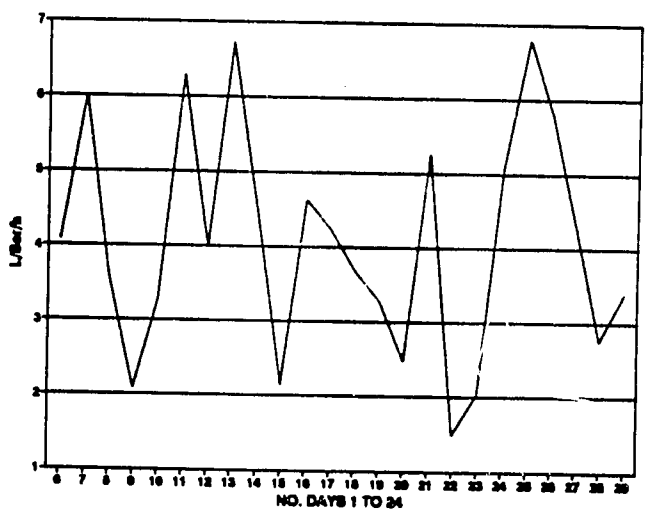
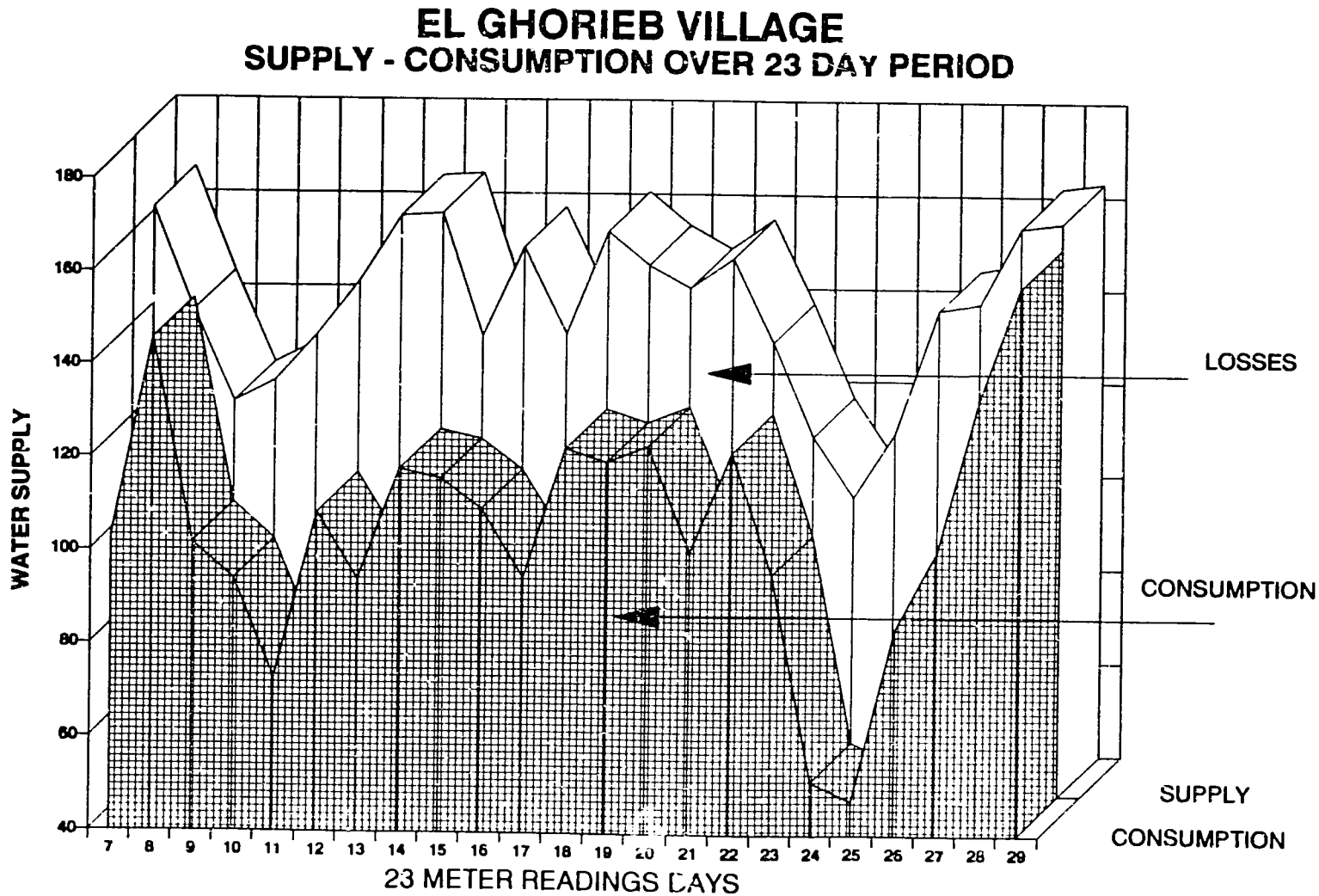


Figure 6


EL GHORIEB VILLAGE
SUPPLY - CONSUMPTION OVER 23 DAY PERIOD
WATER SUPPLY
180
160
140
120
100
80
60
40
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
23 METER READINGS DAYS
LOSSES
CONSUMPTION
SUPPLY
CONSUMPTION

The total quantity of metered water delivered to the network from the pump station over the 23-day study period was 3,462.4 m^3 compared to a metered consumption over the same period of 2,411.6 m^3. Hence the UFW loss over the study period was 30 percent or 2.9 liters/service/hour. The data are summarized in Table 4.

Table 4: Summary of UFW Results for El-Ghorieb Village

Total Supply (m^3)	Total Consumption (m^3)	UFW Losses (Percentage)	UFW Losses (Liters/ service hour)
3462.4	2411.6	30	2.9

WATER CONSUMPTION

Nahtai Village

The water consumption for the UFW district in Nahtai was determined by measuring all the consumer meters on a daily basis for 34 days (see Appendix F). A consumer survey in the study area showed 1,320 people benefitted from a piped water service, representing an average of 5.6 persons/building. The average per capita consumption is 50.2 Lcd as shown in Table 1.

Figure 7 shows that the average daily water demand of the 233 service connections in Nahtai was 69.2 m^3/day. No weekly pattern was apparent from the analysis; peak demands occurred on a Monday, Tuesday, Friday and Saturday, and minimum demands on Sunday, Monday, Tuesday, Thursday and Saturday. Inconsistencies in the time of day meter readings were taken could account for some of the swings from peak to minimum demands, but this would normally show larger variations on adjoining days which is not evident in the Nahtai data.

Figure 8 shows the number of services for different ranges of average daily consumption per service. The average is 297 liters/service/day. Fifty percent of the services use less than 200 liters/service/day and 90 percent less than 600 liters/service /day.

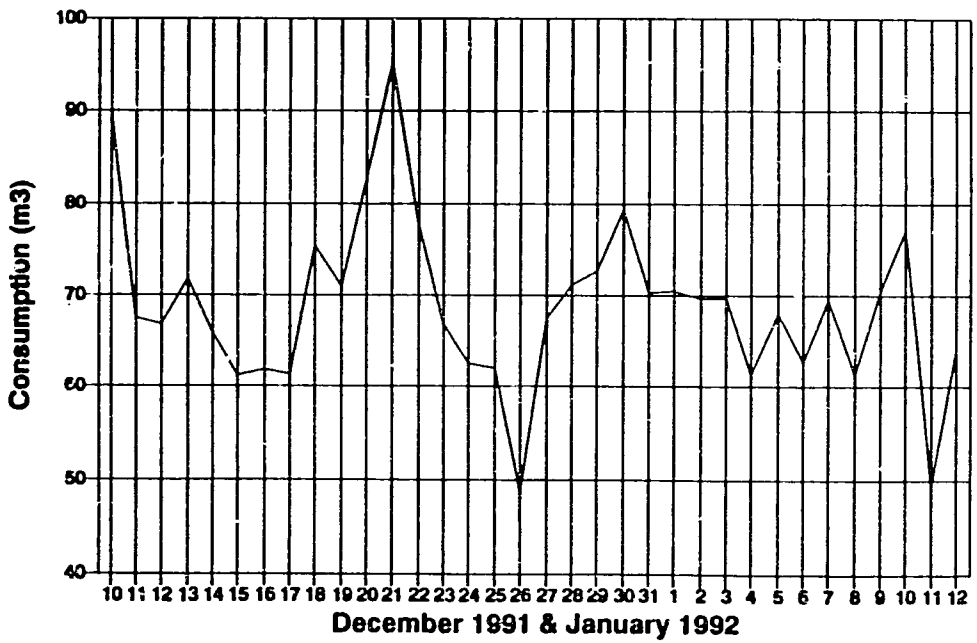
Non-residential consumers represent 2.5 percent of all services in the study area; they account for eight percent of consumption.

A 500-pupil school consumes on average only 0.4 liters/pupil/day (200 liters/day total consumption), suggesting that water is used for drinking purposes only; mosques use between 0.9 and 1.8 m^3/day

and the bakery uses 100 liters/day. The largest consumer was a block of eight flats using an average of 5.7 m^3/day or nearly 1000 liters/day/residential unit. These premises should be investigated for wastage of water.

Figure 7

NAHTAI VILLAGE
TOTAL DAILY WATER CONSUMPTION
FOR U.F.W DISTRICT

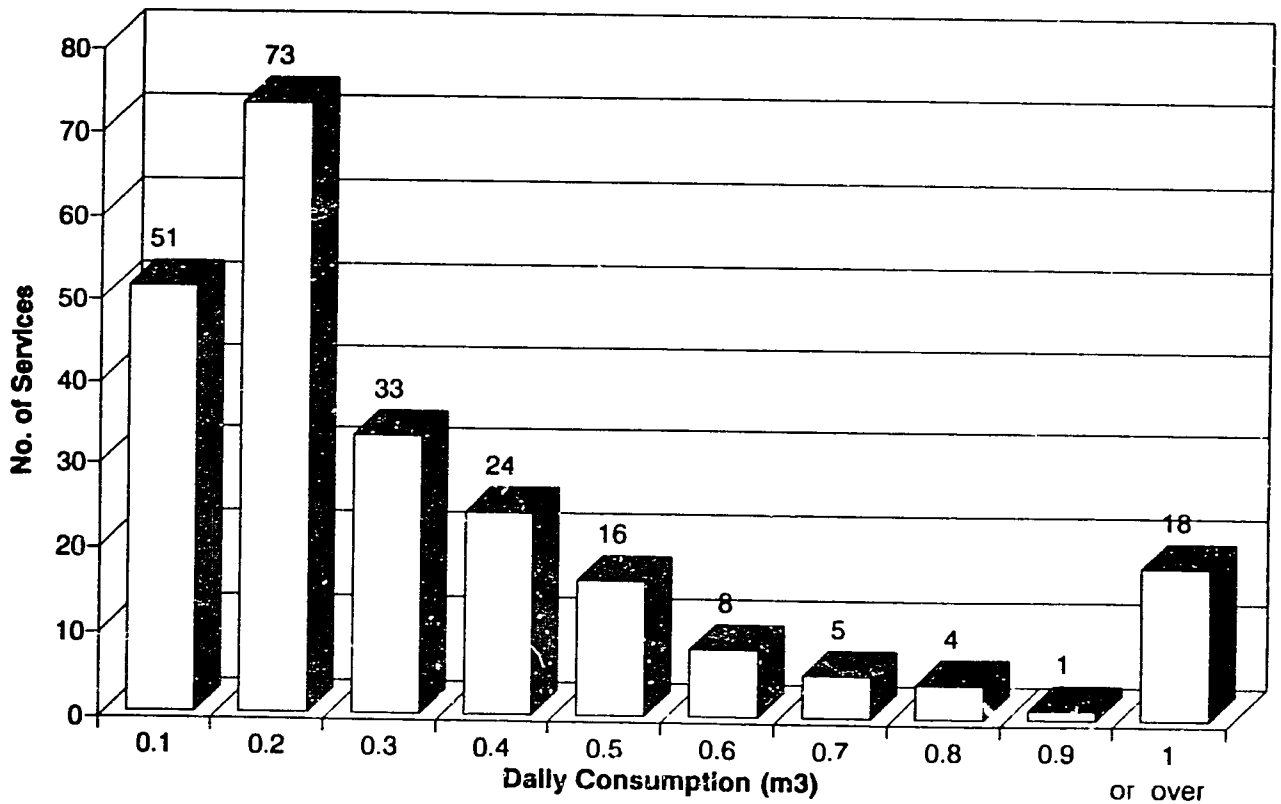


DECEMBER 1991 CALENDAR					
Sat		7	14	21	28
Sun	1	8	15	22	29
Mon	2	9	16	23	30
Tue	3	10	17	24	31
Wed	4	11	18	25	
Thu	5	12	19	26	
Fri	6	13	20	27	

JANUARY 1992 CALENDAR					
Sat		4	11	18	25
Sun		5	12	19	26
Mon		6	13	20	27
Tue		7	14	21	28
Wed	1	8	15	22	29
Thu	2	9	16	23	30
Fri	3	10	17	24	31

Figure 8

NAHTAI VILLAGE STUDY
NUMBER OF SERVICES FOR RANGE OF AVERAGE CONSUMPTION/DAY



El-Ghorieb Village

Over the 24-day study period in El-Ghorieb, individual consumer meters were read daily and details were collected on the total number of consumers in each served building (see Appendix G). The number of consumers in El-Ghorieb who are served by working meters is 3,664, representing 8.5 persons/building. The average per capita consumption is 29 Lcd.

The average daily demand of the 648 service connections was 100 m^3/day. As in Nahtai, no weekly pattern was apparent. One significantly low demand occurred on Tuesday, 25 February when demand dropped to almost 47 m^3/day. A peak of 158 m^3/day occurred on Saturday, 29 February.

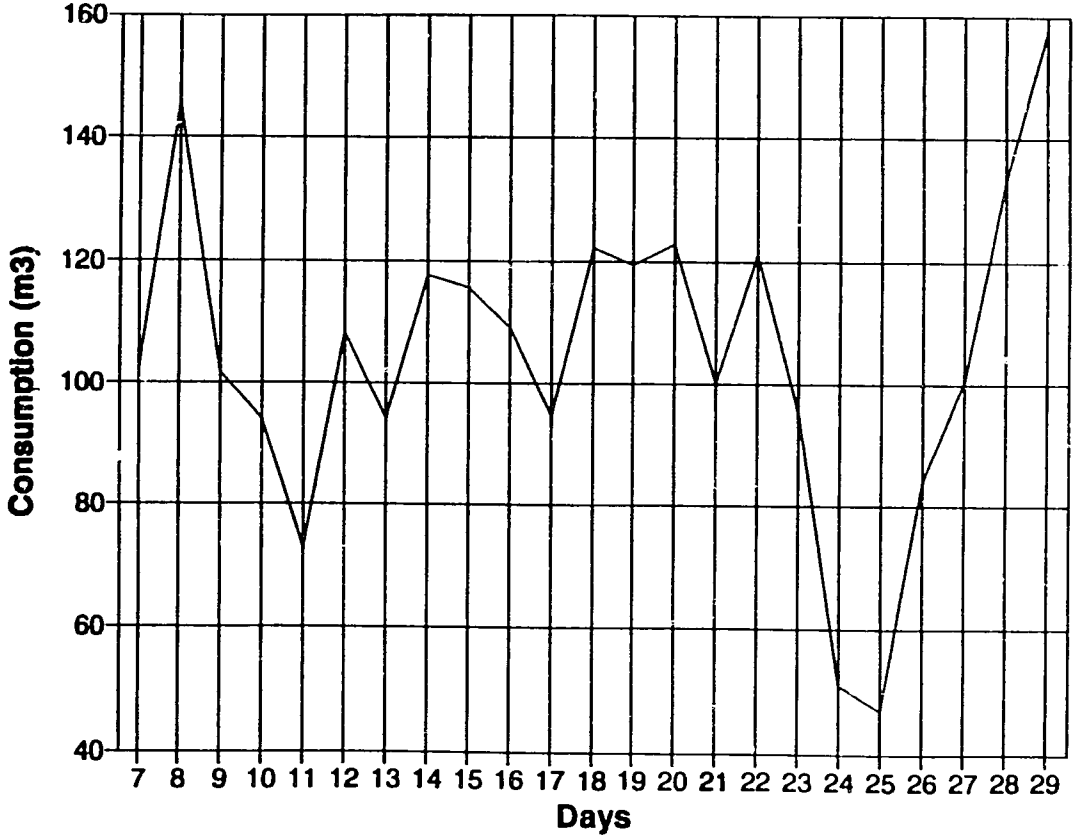
The village community center was the largest consumer, using 317.6 m^3 (13 percent of the total metered consumption). Non-residential consumers (1.5 percent of the total number of consumers) accounted for 21 percent of the total consumption.

Figure 9 shows the total daily water consumption for El-Ghoreib Village.

Figure 10 shows the number of services for different ranges of average daily consumption per service. The average is 162 liters/service/day, with nearly 75 percent of services using less than 200 liters/service/day. A 514-pupil primary school consumes on average 0.6 liters/pupil/day (330 liters/day total consumption), about 50 percent more than a similar school in Nahtai. Mosques use between 0.5 and 2.7 m^3/day; the largest consumer, the community center, used an average of 13.2 m^3/day.

Figure 9

EL GHORIEB VILLAGE
TOTAL DAILY WATER CONSUMPTION
FOR UFW DISTRICT



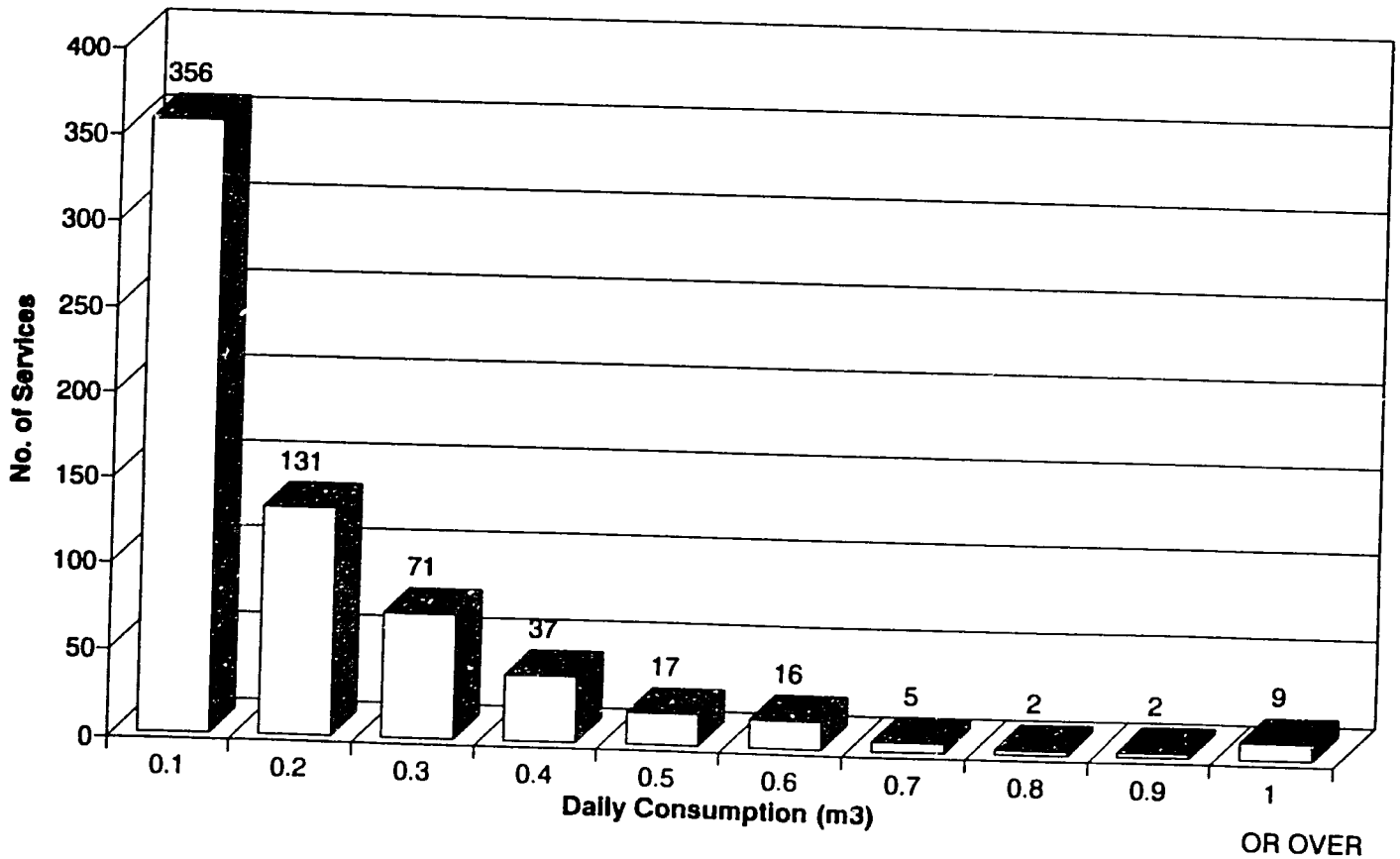
FEBRURAY 1992

Sat	1	8	15	22	29
Sun	2	9	16	23	
Mon	3	10	17	24	
Tue	4	11	18	25	
Wed	5	12	19	26	
Thu	6	13	20	28	
Fri	7	14	21	28	

Figure 10

EL GHORIEB VILLAGE STUDY

NUMBER OF SERVICES FOR RANGE OF AVERAGE CONSUMPTION / DAY



MINIMUM NIGHT FLOW (MNF)

As mentioned previously, water losses can be attributed to sources other than leakage, such as under-registration of consumer meters, illegal connections, and un-metered supplies. One means of isolating and estimating losses due to leakage is to measure the flow rate into a system during the night when there is normally no consumer demand.

The method employed in this study to calculate night-time use was to record hourly readings (midnight to four am) from the meters of the pump stations supplying each village. Calculations of the night-time use were made by determining the total consumption during the four-hour period and comparing it with the total daily average.

$$\text{MNF (liters/service/hour)} = \frac{\text{average night hourly consumption}}{\text{number of services}}$$

Generally, if the MNF is 3-5 liters/service/hour, one can certainly assume that there are a few leaks in the system. If the MNF exceeds this, an in-depth study of the system is recommended to look for breaks or leaks in the system.

Nahtai Village

In October 1991, prior to the start of the UFW study in Nahtai, the water production of the pump station supplying the entire village was recorded by the pump station meter for a 5-day period. The average 24-hour supply was 336 m^3 and the average flow for the four-hour period between midnight and 4 am was 33 m^3.

The MNF figure for the study area equates to a UFW loss of 3 liters/service/hour; the figure for the whole village was 13.8 liters/service/hour. The high MNF figure for the whole village suggests that there is some demand during the night to fill roof tanks which may overflow as a result of higher night-time pressures; it also suggests that there are high losses in parts of the network outside the study area.

It can be assumed that the leakage loss in the study area (3 liters/service/hour) is low for two reasons. First, much of the network pipeline was replaced shortly before conducting the study and secondly, consumers tend to reduce water usage during data collection activities.

El-Ghorieb Village

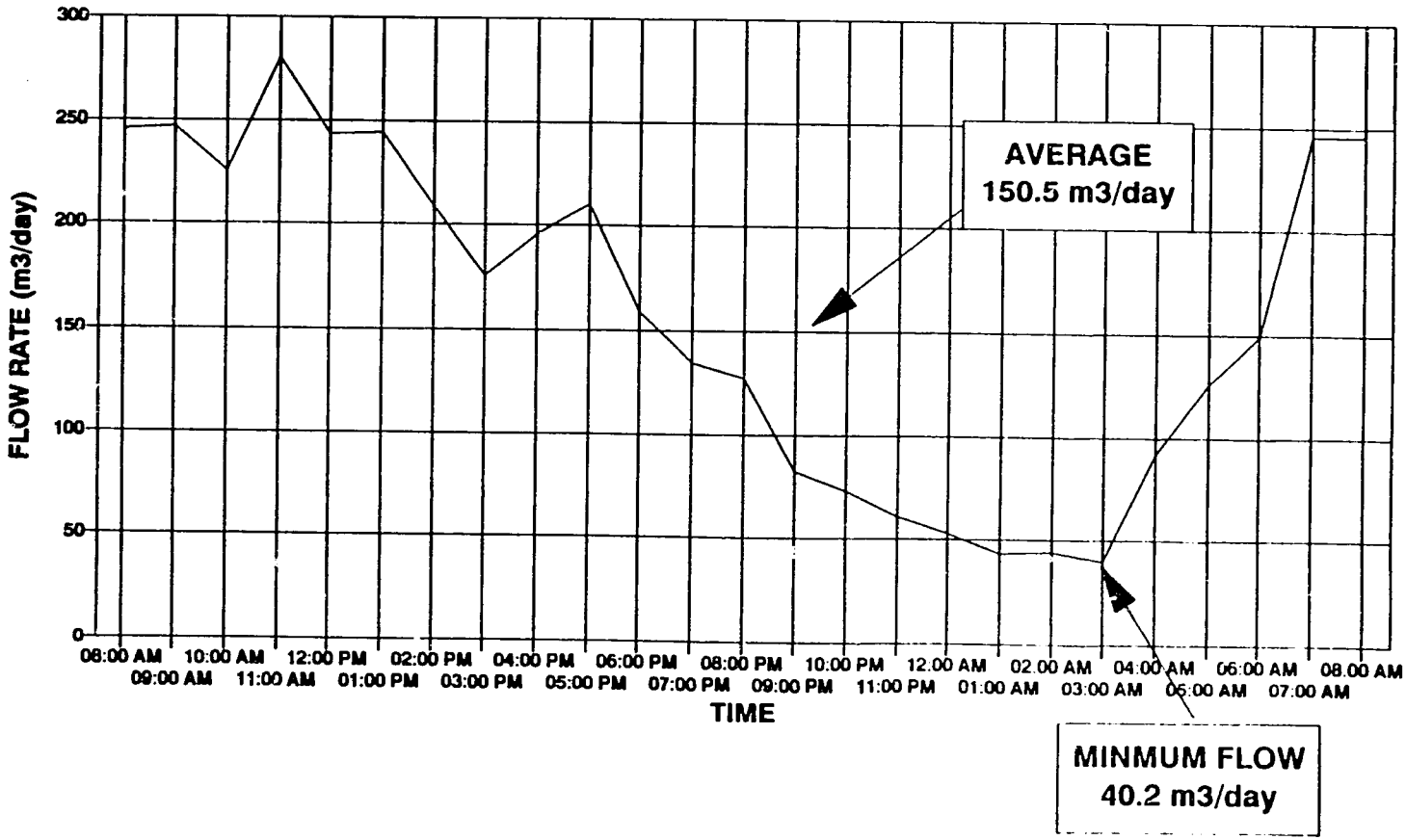
The total flow delivered from the pump station supplying El-Ghorieb was recorded by the station operators at hourly intervals over the 23-day study period. Figure 11 is a graphic representation of the aggregated water supply (by hour) for the 23-day period.

The average daily flow was 150.5 m^3/day with an aggregated minimum flow of 40.2 m^3/hour occurring at 3 am, and an 11 am aggregated peak flow of 279.9 m^3/hour. Translated into a leakage factor, the MNF is equivalent to a flow of 2.7 liters/service/hour compared to the UFW loss equivalent to 2.9 liters/service/hour.

Figure 11

EL GHORIEB VILLAGE

AGGREGATE OF 23 DAYS WATER SUPPLY BY HOUR



PRESSURE TESTS

Nahtai Village

The results of the 19-day pressure tests in Nahtai during the UFW study are shown in Appendix H. The night-time pressure is about 27m, close to the stated top water level of the water tower (30m). The average daytime pressure is estimated at 12m, or 44 percent of the maximum night pressure.

The high night-time pressure could account for the high minimum night flow recorded for the whole system.

During the 19 days of pressure recording, there were a few minor interruptions in the water supply, lasting a maximum of two hours each.

El-Ghorieb Village

Two pressure recorders were installed for 12 days during the UFW study as shown in Appendix I. One was sited at the pump station and the other at the end of a distribution pipe. Ground level at the end of the network is about 5m below the pump station. As the two instruments recorded almost the same pressure, the head loss remained constant at about 5m, even at night.

No supply interruptions were recorded and the instruments indicated that the pumps operated about 12 times daily for about 30 minutes on each occasion. Day and night-time pressures at both locations remained constant at about 13m.

BACTERIOLOGICAL SAMPLING

A total of 118 samples were analyzed for fecal coliform bacteria, 43 from Nahtai and 74 samples from El-Ghorieb. Of 22 samples taken from private handpump wells, 14 (64 percent) were polluted. The remaining samples were taken from wells, water towers, and consumer outlets. None of the samples from the wells or water towers were polluted; 24 percent of the samples from consumer outlets showed signs of pollution. Neither village disinfects piped water with chlorine or other means. Table 5 and Appendix J summarize the bacterial testing results.

Table 5: Results of Fecal Coliform Bacterial Tests for Nahtai and El-Ghorieb Villages*

SAMPLE SOURCE	NAHTAI			EL-GHORIEB		
	Total Number of Samples	Results		Total Number of Samples	Results	
		Safe %	Unsafe %		Safe %	Unsafe %
Wells and Water Tower	6	100	0	4	100	0
User Outlets	30	70	30	54	80	20
Private Hand Pumps	7	14	86	16	50	50

*Neither village disinfects piped water with chlorine or other means.

SUMMARY OF PROBLEMS ENCOUNTERED DURING THE STUDY

Initiating any new project can present unanticipated problems and delays in planned completion. Problems encountered during the administration and implementation of the unaccounted-for-water study in the villages of Nahtai and El-Ghorieb are summarized below. They are presented to help those conducting future UFW studies to anticipate and proactively address similar circumstances.

- Lack of record maps of water networks, including details of valves and connections.
- Difficulty with village staff expediting mapping of networks, compiling records, and installing new valves, and zone and consumer meters.
- Lack of historic supply and consumption data, especially for non-domestic users (offices, schools, mosques, and private commercial buildings).
- Delays in receiving imported flow-measuring instruments and special equipment.
- Intermittent power supplies affecting usage of electronic instruments for extended data logging.
- Difficulty in gaining access to some consumer meters.
- Malfunctioning of some meters during the study period.

- Difficulty in gaging the quantity of water used to supplement water consumption from private handpumps and canals.

Section 3
Conclusions and Recommendations

CONCLUSIONS

High potable water losses are a significant drain on the national economy of Egypt. This UFW study in two Egyptian villages highlights the significance of water losses from independent rural water supply systems. The conclusions arising from this study are as follows.

- The unaccounted-for-water losses in both villages are comparable (3.0 liters/service/hour in Nahtai and 2.9 liters/service/hour in El-Ghorieb). Expressed as percentages, the UFW for Nahtai is 19 percent and 30 percent for El-Ghorieb.

- An earlier loss reduction activity in Nahtai Village estimated losses at over 50 percent or 130 liters/service/hour. This high figure was caused by an increase in pressure from a new water tower (15m higher than the original tower) and the poor condition of pipelines and service connections. Since then much of the 6" piping and many service connections on the same main have been replaced. This is not the case in El-Ghorieb Village, where most of the network piping is old.

- Minimum Night Flows (MNF), as related to the average hour day flow is 10 percent for Nahtai and 27 percent for El-Ghorieb.

- The winter per capita consumptions are 50 and 29 Lcd for Nahtai and El-Ghorieb respectively. These figures exclude consumption from handpumps and canals, and are less than the national design figure of 80 Lcd for rural domestic consumers connected to a piped supply.

- The number of non-domestic consumers is small (2.5 and 1.5 percent for Nahtai and El-Ghorieb respectively). These meters register 8 percent in Nahtai and 21 percent in El-Ghorieb of the total water consumptions.

- Bacterial analyses show that water from wells and water towers is generally free from pollution. Samples taken from user outlets from the pipe networks were considered

average to good, while most water from private handpumps was contaminated.

- The use of pressure recorders is an easy method of gauging the state of a pipe network. In Nahtai, the head loss across the system is high during peak flows, suggesting the network is overloaded. In El-Ghorieb there is little head loss even during peak periods, suggesting the network is over designed.

- The studies show that village staff are capable of preparing network maps and that records which may be helpful in improving the efficiency of water supply systems are maintained.

- The water losses in the two study areas are less than the findings of the water loss reduction study (conducted in 1989 as an activity of the LD II-P program) which estimated losses at more than 50 percent.

RECOMMENDATIONS

The above results indicate that significant economic benefits can result from the measurement of unaccounted-for-water, followed by the appropriate replacement or repair of those parts of the system responsible for the losses. Along with potential savings in capital expenditures, reduced water loss can result in significant energy savings as well.

Table 6 provides a range of UFW losses, corresponding actions to reduce losses, and the resulting potential savings. The purpose of the table is to demonstrate that rural villages with independent water sources can invest in reducing water losses and, within one year, recoup that investment. For example, if a village with 500 services and 15 L/service/hour UFW invests LE 1,000 on water loss reduction, that village will save LE 1,000 during the first year in electricity savings alone, without considering potential future capital investment savings. The above is based on the following equation:

$$\frac{500\ \text{(services)} \times 15\ \text{(L/S/day)}}{3600} \times \frac{30\text{m (head)}}{75 \times 0.6\ \text{(overall efficiency)}}$$

$$\times\ 0.746\ \text{(kw/hp)} \times 24\ \text{(hours/day)} \times 365\ \text{(days/year)}$$

$$\times\ 0.1\ \text{(LE/kw)} \approx \text{LE 1000/year savings}$$

Table 6
POTENTIAL SAVINGS PER YEAR FOR RURAL VILLAGES WITH INDEPENDENT WATER SOURCES

UFW RANGE	SUGGESTED ACTION*	POTENTIAL SAVINGS PER YEAR**
Over 15 L/service /hour	**For 15 L/service/hour loss:** Aim to reduce losses to 5 L/service/hour by investing LE 1,000. **For more than 15 L/service/hour loss:** Invest additional LE 1000/100 for each increment of 10 L/service/hour over 15 L/service/hour. **Example:** If loss is 25 L/service/hour for 500 services, the annual investment should be: Investment for first 10 L/service/hour loss = LE 1,000 Investment for additional 10 L/service/hour loss= LE 1,000 Total Investment = LE 2,000	10 L/service/hour represents an electricity cost of LE 1,000 per year (for 500 services). 25 L/service/hour represents an electricity cost of LE 2,500 per year
5-10 L/service /hour	**For 5-10 L/service/hour loss:** Invest LE 500 to fund location and replacement of faulty pipes and services.	5 L/service/hour represents an electricity cost of LE 500 per year
Less than 5 L/service /hour	**For less than 5 L/service/hour loss:** Weekly inspection of all pipelines and services. Check water tower for overflowing.	

* Based on a network with 500 services
**Based on an electricity cost of 10 pt/kwh

The following recommendations are related to what could be done under the continuation of LD II-P or a similar project.

- An active program should be introduced to reduce the water losses from independent water systems. As a project of several phases, the first phase would consist of a series of workshops promoting the concept of UFW to village chiefs.

- All villages with small independent water systems should have a well-maintained, working meter to measure the water output from the pump station. Regular meter reading will enable pump operators to report abnormally high demands.

- Village water systems should try to install meters in good working order on all non-domestic consumer connections.

- Per capita consumptions for design purposes should be matched to the development level of the community. Using an average figure of 80 Lcd may overstate the consumption of many rural communities, while in other areas, such as Damietta, 80 Lcd may be underestimating demand.

- A further study should be undertaken to determine water demands during summer months.

- An active program on hygienic handling of potable water would reduce the incidence of contamination by consumers of water drawn from pipe networks.