# Attachment - 1 C-VALUE COMPUTATION

From Fundamentals of Hydraulic Engineering Systems by Ned H.C. HWANG and Carlos E. HITA

Hazen Williams Formula
British Measurement System

$V = 1.318\ CR^{0.63}\ S^{0.54}$ Page 73, 74

S is the slope of the energy grade line (EGL)
or head loss per unit length of pipe
($S = h_f/L$)

$R_h$ is the hydraulic radius. $R_h$ for pipe $\frac{D}{4}$

when used in S.I. units, the formula is

$V = 0.85\ CR_h^{0.63}\ S^{0.54}$.

From Water Supply Engineering by H.E. Babbitt
J.J. Doland
J.L. Cleasby

Hazen Williams formula for pipes page 326

$V = 0.0131\ CH^{0.54}\ D^{0.632}$.
$Q = 0.0103\ CH^{0.54}\ D^{2.63}$.

V = Velocity, fps
C = Friction Coefficient
H = Head Loss due to friction, ft. per 1000 ft. of pipe
D = Diameter of Pipe, ft.
Q = Rate of flow, cfs.

## Azrak - Khaw Line

25 and 26 April 1995

Attached Flow measurments as obtained in the field
The pressure at Azrak was 34 Bars. Pressure at Khaw 2.4 Bars
Hazen and Willams Formula is

$V = 0.0131CH^{0.54} D^{0.632}$
$Q = 0.0103CH^{0.54} D^{2.63}$

where V = velocity, fps
C = friction Coefficient.
H = head loss due to friction, ft per 1000 ft.
D = diameter of pipe, ft.
Q = rate of flow, cfs.

from field data

V = 2.18 m/sec = 7.15 ft/sec.
Q = 2300 m $^3$/hr = 0.64m$^3$/sec x 35.3147 = 22.56 cfs.
Dif. in pressure 316m . Dist. 66km. Dif. in Elv. 56m Khaw is higher
Total Head 260m÷66=3.94m/km = 3.94ft/1000 ft. D=.627m=2.06 ft.

$7.15 = 0.0131\ CH^{0.54}\ D^{0.632}$
$7.15 = 0.0131\ C\ (3.94)^{0.54}\ (2.06)^{0.632}$
$7.15 = 0.0131\ C\ (2.09)\ (1.58)$
$C = 165.2$

There is no losses in the pipe as the flow is equal at both stations.
The condition of the pipe is good as seen from the C-value.

PIPE: AZRAQ-KHAW

| KHAW | AZRAQ |
|---|---|
| OUTER DIAMETER= 639.4 MM<br>PIPE MATERIAL= STEEL<br>WALL THICKNESS= 4.5 MM<br>LINO. THICK.= 6MM MORTER<br>TYPE OF SENSOR : LARGE<br>SENSOR MOUNTING: V<br>SPACING 560.73 MM<br>DATE: 26,27 APRIL 1995 | OUTER DIAMETER= 638.4 MM<br>PIPE MATERIAL: STEEL<br>WALL THICKNESS= 4.8 MM<br>LINO. THICK.= 6MM MORTER<br>TYPE OF SENSOR: LARGE<br>SENSOR MOUNTING: V<br>SPACING 581.21<br>DATE 25,26 APRIL 1995 |

| | KHAW | | | | AZRAQ | | | |
|---|---|---|---|---|---|---|---|---|
| TIME | FLOW | FLOW | CU.M | VEL. | FLOW | FLOW | CU.M | VEL. |
| | int.M3 | M3/H | M3 | M/S | int.M3 | M3/H | M3 | M/S |
| 14 | | | | | 0 | 2308 | | 2.16 |
| 15 | | | | | 2300 | 2270 | 2270 | 2.13 |
| 16 | | | | | 4600 | 2293 | 4563 | 2.15 |
| 17 | | | | | 6900 | 2306 | 6869 | 2.16 |
| 18 | | | | | 9200 | 2297 | 9166 | 2.15 |
| 19 | | | | | 11500 | 2247 | 11413 | 2.10 |
| 20 | | | | | 13800 | 2275 | 13688 | 2.13 |
| 21 | | | | | 16100 | 2280 | 15968 | 2.13 |
| 22 | | | | | 18400 | 2309 | 18277 | 2.16 |
| 23 | | | | | 20700 | 2273 | 20550 | 2.13 |
| 0 | | | | | 22900 | 2254 | 22804 | 2.11 |
| 1 | | | | | 25200 | 2296 | 25100 | 2.15 |
| 2 | | | | | 27500 | 2282 | 27382 | 2.14 |
| 3 | | | | | 29800 | 2287 | 29669 | 2.14 |
| 4 | | | | | 32100 | 2335 | 32004 | 2.19 |
| 5 | | | | | 34400 | 2293 | 34297 | 2.15 |
| 6 | | | | | 36700 | 2295 | 36592 | 2.15 |
| 7 | | | | | 39000 | 2295 | 38887 | 2.15 |
| 8 | | | | | 41300 | 2294 | 41181 | 2.15 |
| 9 | | | | | 43500 | 2262 | 43443 | 2.12 |
| 10 | | | | | 45800 | 2309 | 45752 | 2.16 |
| 11 | | | | | 48100 | 2341 | 48093 | 2.19 |
| 12 | | | | | 50400 | 2314 | 50407 | 2.17 |
| 13 | 0 | 2366 | | 2.21 | 52700 | 2277 | 52684 | 2.13 |
| 14 | 2300 | 2378 | 2378 | 2.22 | 55000 | 2285 | 54969 | 2.14 |
| 15 | 4700 | 2366 | 4744 | 2.21 | 57400 | 2310 | 57279 | 2.16 |
| 16 | 7000 | 2360 | 7104 | 2.21 | 59700 | 2304 | 59583 | 2.16 |
| 17 | 9300 | 2321 | 9425 | 2.68 | 62000 | 2320 | 61903 | 2.17 |
| 18 | 11700 | 2351 | 11776 | 2.20 | 64300 | 2341 | 64244 | 2.19 |
| 19 | 14000 | 2314 | 14090 | 2.16 | 66600 | 2285 | 66529 | 2.14 |
| 20 | 16400 | 2348 | 16438 | 2.19 | | | | |
| 21 | 18700 | 2327 | 18765 | 2.17 | | | | |
| 22 | 21100 | 2339 | 21104 | 2.19 | | | | |
| 23 | 23400 | 2322 | 23426 | 2.17 | | | | |
| 0 | 25800 | 2324 | 25750 | 2.17 | | | | |
| 1 | 28100 | 2299 | 28049 | 2.15 | | | | |
| 2 | 30400 | 2358 | 30407 | 2.20 | | | | |
| 3 | 32800 | 2356 | 32763 | 2.20 | | | | |
| 4 | 35100 | 2289 | 35052 | 2.14 | | | | |
| 5 | 37500 | 2285 | 37337 | 2.14 | | | | |
| 6 | 39800 | 2369 | 39706 | 2.21 | | | | |
| 7 | 42200 | 2380 | 42086 | 2.22 | | | | |
| 8 | 44500 | 2365 | 44451 | 2.21 | | | | |
| 9 | 46900 | 2372 | 46823 | 2.22 | | | | |
| 10 | 49200 | 2326 | 49149 | 2.17 | | | | |
| 11 | 51500 | 2329 | 51478 | 2.18 | | | | |
| 12 | 53900 | 2329 | 53807 | 2.18 | | | | |

Ave. Vel at Khaw= 2.21
Ave. Vel at Azraq= 2.15
Flow from Azraq to Khaw (Azraq Records)= 1935 m3/hr
Flow from Azraq to Khaw (Khaw Records)= 2100m3/hr

Although flow rate at Zarqa is slightly larger than that at Azraq, it is explained that the difference is still within the meter accuracy.

Test for the C-value for the water supply line from Khaw to Zarqa pumping stations on 22/6/1995

| | |
|---|---|
| Length of line = 8 kms. | Elevation at Khaw 600m |
| Pressure at Khaw = 10.0 Bars | " " Zarqa 572m |
| Pressure at Zarqa = 1.5 Bars | Diff = 8.5 bars |
| Average Velocity 2.997 m/sec. | $H = 8.5 + 28 = 113$ |
| Average flow $Q = 1268\ m^3/hr$ | $S = \frac{113}{8000} = 0.014$ |

Diameter of pipe = 0.406m thickness 5mm

$V = 2.997 m/sec.$ $R = \frac{D}{4} = \frac{.396}{4} = 0.099$

Hazen Willams Formula is $R^{0.63} = 0.23$

$V = 0.85\ C R^{0.63}\ S^{0.54}$

$$C = \frac{2.997}{0.85 \times 0.23 \times 0.1} = 153$$

As the flow at both stations are the same it is considecred that there are no losses in the line and its condition is good as seen from the results of the C-value.

Test for the C-value (coefficient of roughnerss) for the water supply line from Khaw to Zarqa Pumping Station on 22/6/1995

Test for the C-value (coefficient of roughnerss) for the water supply line from Khaldieh Pumping Station to Khaw Pumping Station on 24/6/1995

KHALDYAH-KHAW LINE 24"
EXACT OUTER DIAMETE609.6 MM
INNER LINNING MM MORTER
PRESSURE AT KHALDYA 6.2 bar
PRESSURE AT KHAW = 1.4 bar
LENGTH= 17 KM
FLOW (WAJ ME 1340 CU.M./HR
DATE OF WORK 24/06/95
THICKNESS = 5 MM
ULTRASONIC METER MEASUREMENTS

| TIME OF WORK FROM | TO | FLOW CU.M./H | ELOCITY M/S |
|---|---|---|---|
| 11:00 | 12:00 | 1374 | 1.391 |
| 12:00 | 13:00 | 1378 | 1.406 |
| 13:00 | 14:00 | 1374 | 1.401 |
| 14:00 | 15:00 | 1366 | 1.403 |
| 15:00 | 16:00 | 1370 | 1.409 |
| 16:00 | 17:00 | 1374 | 1.403 |
| 17:00 | 18:00 | 1393 | 1.388 |
| 18:00 | 19:00 | 1373 | 1.389 |
| | AVERAG | 1375.25 | 1.399 |

ZARQA-KHAW LINE 16"
EXACT OUTER DIAMETE406.4 MM
INNER LINNING MM MORTER
PRESSURE AT ZARQA = 1.5 bar
PRESSURE AT KHAW = 10 bar
LENGTH= 8.5 KM
FLOW (WAJ ME 1282.4 CU.M./HR
DATE OF WORK 22/06/95
THICKNESS = 5 MM
ULTRASONIC METER MEASUREMENTS :

| TIME OF WORK FROM | TO | FLOW CU.M./H | ELOCITY M/S |
|---|---|---|---|
| 11:00 | 12:00 | 1263 | 2.987 |
| 12:00 | 13:00 | 1267 | 2.991 |
| 13:00 | 14:00 | 1273 | 2.979 |
| 14:00 | 15:00 | 1260 | 2.984 |
| 15:00 | 16:00 | 1267 | 2.973 |
| 16:00 | 17:00 | 1272 | 3.009 |
| 17:00 | 18:00 | 1265 | 3.018 |
| 18:00 | 19:00 | 1274 | 3.033 |
| | AVERAG | 1267.63 | 2.997 |

Test for the C-value (coefficient of roughness) for the water supply line) from Khaldieh pumping station to Khaw pumping station on 24/6/1995

Length of line = 17 kms.
Pressure at Khaldieh = 6.2 Bars
Pressure at Khaw = 1.4 Bars
Average flow Q= 1375 $m^3$ /hr

Elevation at Khaldieh 600m
" " Khaw 600m
Diff = 4.8 bars

$S = \frac{48}{17000} = 0.0028m$

$S^{0.54} = 0.04$

Pipe Diameter = 24" (609mm outside diameter)
Pipe Thickness = 5.8 mm D internal (609 - 12 ) 597mm
Velocity = 1.399m/sec.

$R = \frac{.597}{4} = .149m$

$R^{0.63} = 0.3$

Hazen Willams Formula is
$V = 0.85\ CR^{0.63}\ S^{0.54}$
Where V= Velocity in m/sec.
C = Coefficient
R = Hydraulic Radius $= \frac{D}{4}$ in meters
S = Slope in meters

$$C = \frac{1.399}{0.85 \times 0.3 \times 0.04} = 137$$

As the flow is almost the same at both stations this shows that there are no losses in the main line, and the condition of the pipe is good from the C-value obtained.

# Tables

# CALIBRATION OF LARGE 10 CONSUMERS IN ZARQA DISTRICT

| NAME | Trial no. | SUBSC. # | STEEL # | CONS\YR | TIME OF WORK | | DIAMETER | PIPE | DATE | WAJ METER | | WAJ | ULTRASONIC | VARIANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IN 1994 | FROM | TO | IN mm | TYPE | | R # 1 | R # 2 | CU.M. | CONS. CU.M. | % |
| AMMARI CAR WASHING STATION | 1 | 46\22825 | 208417 | 2805 | 10:45 | 11:45 | 32.0 | PVC | 17\6 | 3180.225 | 3181.313 | 1.088 | 1.007 | -7.44 |
| SHEEP & POULTRY CO. AT SUKHNA | 1 | 46\11906 | 274000 | 3048 | 13:54 | 14:54 | 33.9 | ST | 17\6 | 3729.626 | 3730.336 | 0.710 | 0.750 | 5.63 |
| JABER ZAIDAN AT RUSSAIFA ROAD | 1 | 46\27935 | 77135790 | 7940 | 13:29 | 14:29 | 34.0 | ST | 15\6 | 12716.345 | 12717.714 | 1.369 | 1.733 | 26.59 |
| NIQULA ZAIDAN AT RUSSAIFA ROAD | 1 | 46\28035 | 77135790 | 7397 | 12:28 | 13:28 | 34.0 | ST | 15\6 | 9392.315 | 9393.947 | 1.632 | 1.893 | 15.99 |
| TALHONY MILL AT RUSSAIFA ROAD | 2 | 46\27235 | 82366906 | 3570 | 12:03 | 13:03 | 34.0 | ST | 21\6 | 5455.679 | 5456.016 | 0.337 | 0.374 | 10.98 |
| JAWAD BAKERY AT DOWN TOWN | 1 | 46\22425 | 221511 | 3243 | 10:15 | 11:15 | 34.0 | PVC | 15\6 | 8271.582 | 8271.642 | 0.060 | 0.000 | - |
| JAWAD BAKERY AT DOWN TOWN | 2 | 46\22425 | 221511 | 3243 | 11:30 | 12:30 | 26.0 | ST | 15\6 | 8271.800 | 8271.977 | 0.177 | 0.000 | - |
| JAWAD BAKERY AT DOWN TOWN | 3 | 46\22425 | 221511 | 3243 | 12:52 | 13:52 | 25.0 | ST | 17\6 | 8288.324 | 8288.392 | 0.068 | 0.000 | - |
| AL-HIKMA HOSPITAL * | 1 | 46\33738 | 82366986 | 11208 | 11:54 | 12:54 | 33.0 | ST | 17\6 | 19071.575 | 19071.575 | 0.000 | 1.664 | - |
| AL-HIKMA HOSPITAL * | 2 | 46\33738 | 82366986 | 11208 | 11:45 | 12:45 | 33.0 | ST | 21\6 | 19071.575 | 19071.575 | 0.000 | 1.254 | - |
| QASR SHBEEB HOSPITAL | 1 | 46\24730 | 28324 | 12063 | 10:30 | 11:30 | 33.5 | ST | 15\6 | THIS TRIAL WAS NOT SUCCESSFUL | | | | |
| QASR SHBEEB HOSPITAL | 2 | 46\24730 | 28324 | 12063 | 11:00 | 12:00 | 33.5 | ST | 21\6 | 4900.733 | 4901.078 | 0.345 | 0.273 | -20.87 |
| ST. JOSEPH VOCATIONAL CENTER | 1 | 46\17718 | 116871 | 2055 | 9:50 | 10:50 | 34.0 | ST | 21\6 | 6191.423 | 6191.650 | 0.227 | 0.239 | 5.29 |
| LEBANON RESTAURANT AT RUSSAIFA | | NO CONSUMPTION BECAUSE THEY GET THEIR WATER FREE FROM A FACTORY BESIDE THEM | | | | | | | | | | | | |
| POULTRY SLAUGHTER HOUSE AT DLEEL | | CANCELLED BY WAJ , OUTSIDE OUR STUDY AREA | | | | | | | | | | | | |

* WATER METER WAS OUT OF ORDER

ZARQA HYDRAULIC STUDY:
FLOW METERS CALIBRATION

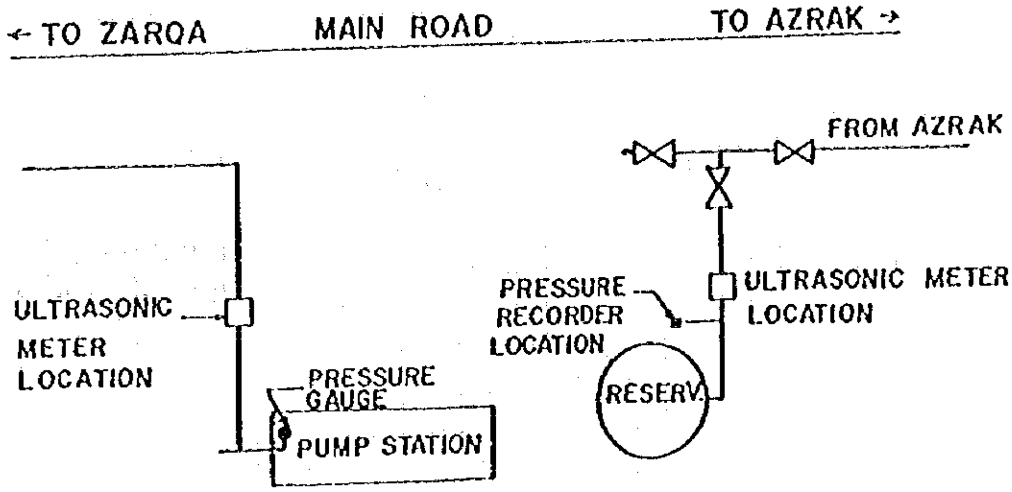
| NO. | LOCATION | DATE OF WORK | TIME OF WORK | PIPE DIAMETER MM | WAJ METER READING 1 CU.M. | WAJ METER READING 2 CU.M. | WAJ FLOW/HR CU.M. | ULTRASONIC FLOW/HR CU.M. | DIFF. WAJ-ULTR. CU.M. | DIFF/WAJ PERCSNTAGE % | MEASURED PRESUURE BAR | WAJ PRESUURE BAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AZRAQ PUMPING STATION-KHAW LINE | 25-Apr | 14:00 | 636.4 | METER WAS OUT OF ORDER | | - | 2270.0 | - | - | 34.0 | * |
| 2 | KHAW-ZARQA LINE AT ZARQA P/S | 22-Jun | 11:00 | 406.4 | 4563215.0 | 4570497.0 | 1282.0 | 1263.0 | 19.0 | 1.48 | 1.5 | * |
| 3 | KHALDYA-KHAW LINE AT KHAW P/S | 24-Jun | 11:00 | 609.6 | 4181830.0 | 4183170.0 | 1340.0 | 1374.0 | -34.0 | -2.54 | 1.4 | * |
| 4 | HASHMYA-ZARQA LINE AT ZARQA P/S | 27-Jun | 10:45 | 406.4 | 497555.0 | 498231.0 | 676.0 | 672.0 | 4.0 | 0.59 | - | * |
| 5 | AWAJAN WELL # 21 | 27-Jun | 12:50 | 154.2 | 1077076.0 | 1077179.2 | 103.2 | 89.0 | 14.2 | 13.76 | 14.3 | * |
| 6 | WELL # 18 AT RUSSAIFFA | 28-Jun | 11:53 | 152.4 | 67159.3 | 67200.0 | 40.7 | 34.0 | 6.7 | 16.46 | 3.1 | * |
| 7 | BOOSTER # 18 AT RUSSAIFA | 28-Jun | 12:09 | 152.4 | 199944.0 | 200069.0 | 125.0 | 106.0 | 19.0 | 15.20 | - | * |
| 8 | AL-BASATEEN WELL # 1 A | 28-Jun | 13:30 | 164.0 | 461650.6 | 461730.0 | 79.4 | 72.0 | 7.4 | 9.32 | 3.2 | * |
| 9 | AL-BASATEEN BOOSTER | 28-Jun | 13:44 | 162.0 | 473251.4 | 473363.2 | 111.8 | 94.0 | 17.8 | 15.92 | 21.0 | 21.0 |
| 10 | MURHEB P/S, WELL #2 | 29-Jun | 11:23 | 168.6 | 706600.0 | 706638.0 | 38.0 | 43.0 | -5.0 | -13.16 | 2.0 | * |
| 11 | MURHEB P/S, WELL #2A | 29-Jun | 11:53 | 169.0 | 96885.7 | 96969.8 | 84.1 | 82.0 | 2.1 | 2.50 | - | * |
| 12 | MURHEB-BEREEN LINE AT MURHEB P/S | 29-Jun | 12:33 | 222.7 | 941739.0 | 941804.0 | 65.0 | 72.0 | -7.0 | -10.77 | 27.0 | 27.0 |
| 13 | MURHEB-AWAJAN LINE AT MURHEB P/S | 29-Jun | 12:58 | 222.7 | 767850.0 | 767954.0 | 104.0 | 122.0 | -18.0 | -17.31 | 7.3 | 7.5 |
| 14 | AWAJAN WELL # 22 | 1-Jul | 12:36 | 165.0 | 191793.0 | 191902.0 | 109.0 | 98.0 | 11.0 | 10.09 | - | * |
| 15 | AWAJAN WELL # 23 | 1-Jul | 13:01 | 168.4 | 1402270.9 | 1402590.8 | 319.9 | 277.0 | 42.9 | 13.41 | 10.6 | 10.6 |
| 16 | KHAW-HASHMYA LINE AT KHAW P/S | 2-Jul | 11:04 | 406.4 | 9272450.0 | 9273190.0 | 740.0 | 771.0 | -31.0 | -4.19 | - | * |
| 17 | KHALDYA-KHAW LINE AT KHALDYA P/S | 2-Jul | 12:38 | 423.4 | 6181830.0 | 6182133.0 | 303.0 | 349.0 | -46.0 | -15.18 | 14.3 | * |
| 18 | HETEEN WELL # 1 AT SHNELLAR | 3-Jul | 10:58 | 170.3 | 133426.1 | 133453.7 | 27.6 | 27.0 | 0.6 | 2.17 | 1.5 | 1.5 |
| 19 | PHOSPHATE WELL AT RUSSAIFA | 5-Jul | 10:54 | 170.3 | 334076.0 | 334145.0 | 69.0 | 72.0 | -3.0 | -4.35 | 2.5 | 5.2 |
| 20 | BOOSTER # 4 AT RUSSAIFA | 5-Jul | 11:31 | 171.9 | 591565.0 | 591777.0 | 212.0 | 207.0 | 5.0 | 2.36 | 25.6 | 25.6 |
| 21 | HETEEN WELL # 2 AT SHNELLAR | 5-Jul | 13:58 | 171.9 | 39518.2 | 39543.2 | 25.0 | 26.8 | -1.8 | -7.20 | - | * |
| 22 | KHAW-ZARQA LINE AT KHAW P/S | 13-Jul | 10:31 | 327.9 | 72905504.0 | 72906512.0 | 1008.0 | 1043.0 | -35.0 | -3.47 | 9.0 | * |

*NO EXISTING PRESSURE GAGE

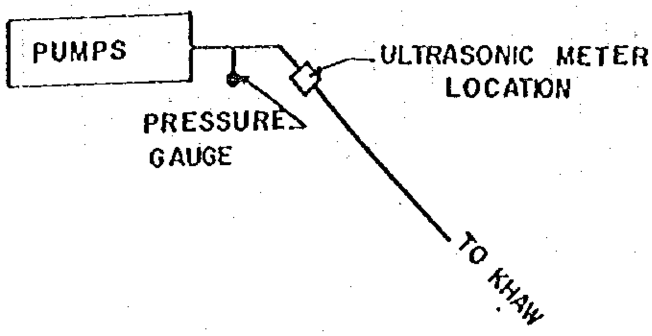
# Figures

# FLOW AND PRESSURE MEASUREMENTS

## KHAW STATION




## AZRAK STATION

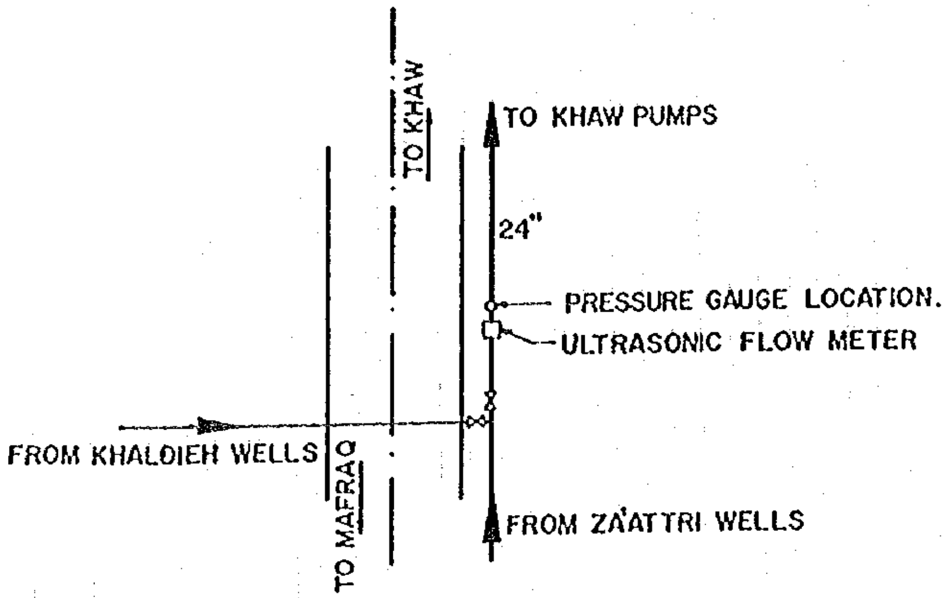



LOCATION OF ULTRASONIC METERS
AT KHAW AND AZRAK P.S

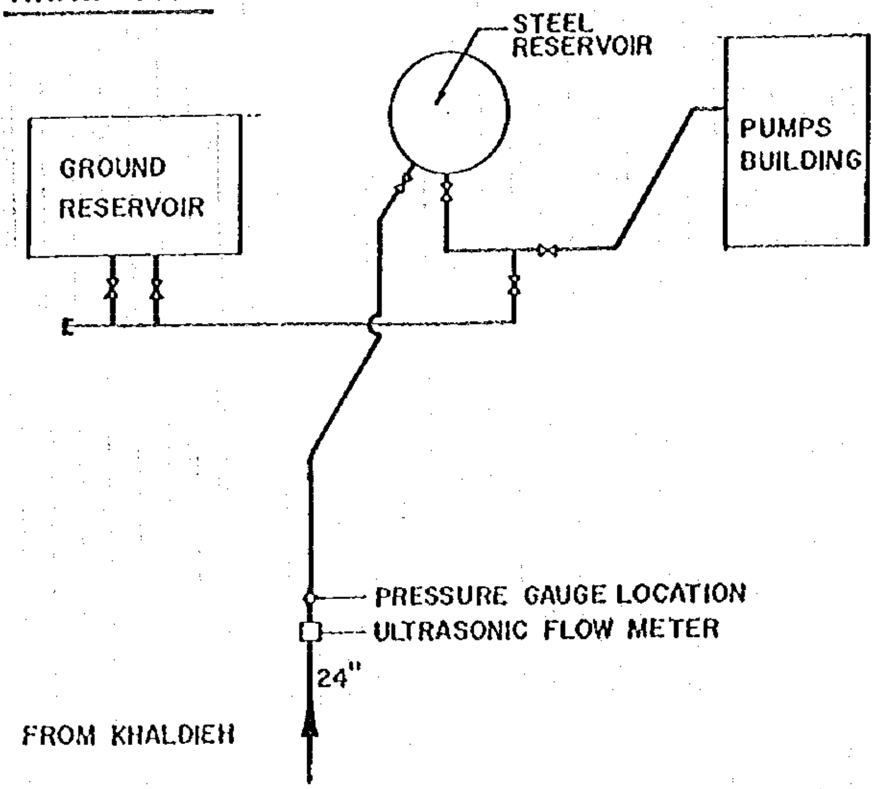
# FLOW AND PRESSURE MEASUREMENTS

## KHALDIEH-KHAW LINE

### 1 - KHALDIEH SITE.



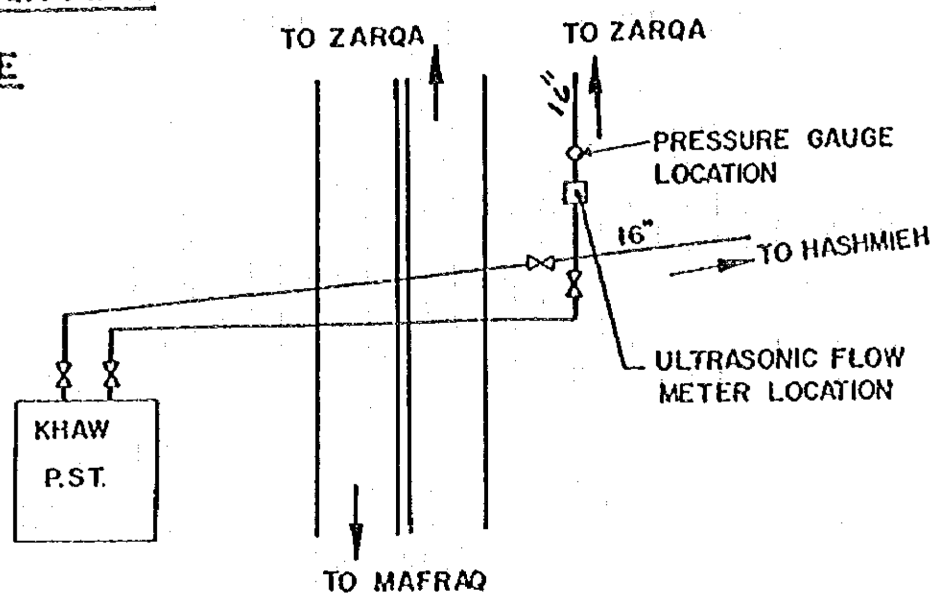

### 2- KHAW SITE.



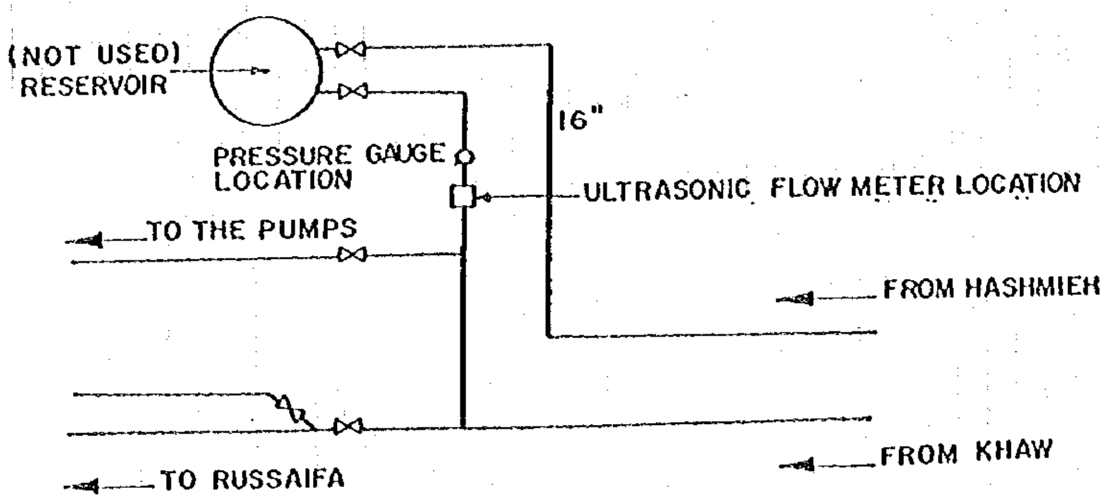
# FLOW AND PRESSURE MEASUREMENTS

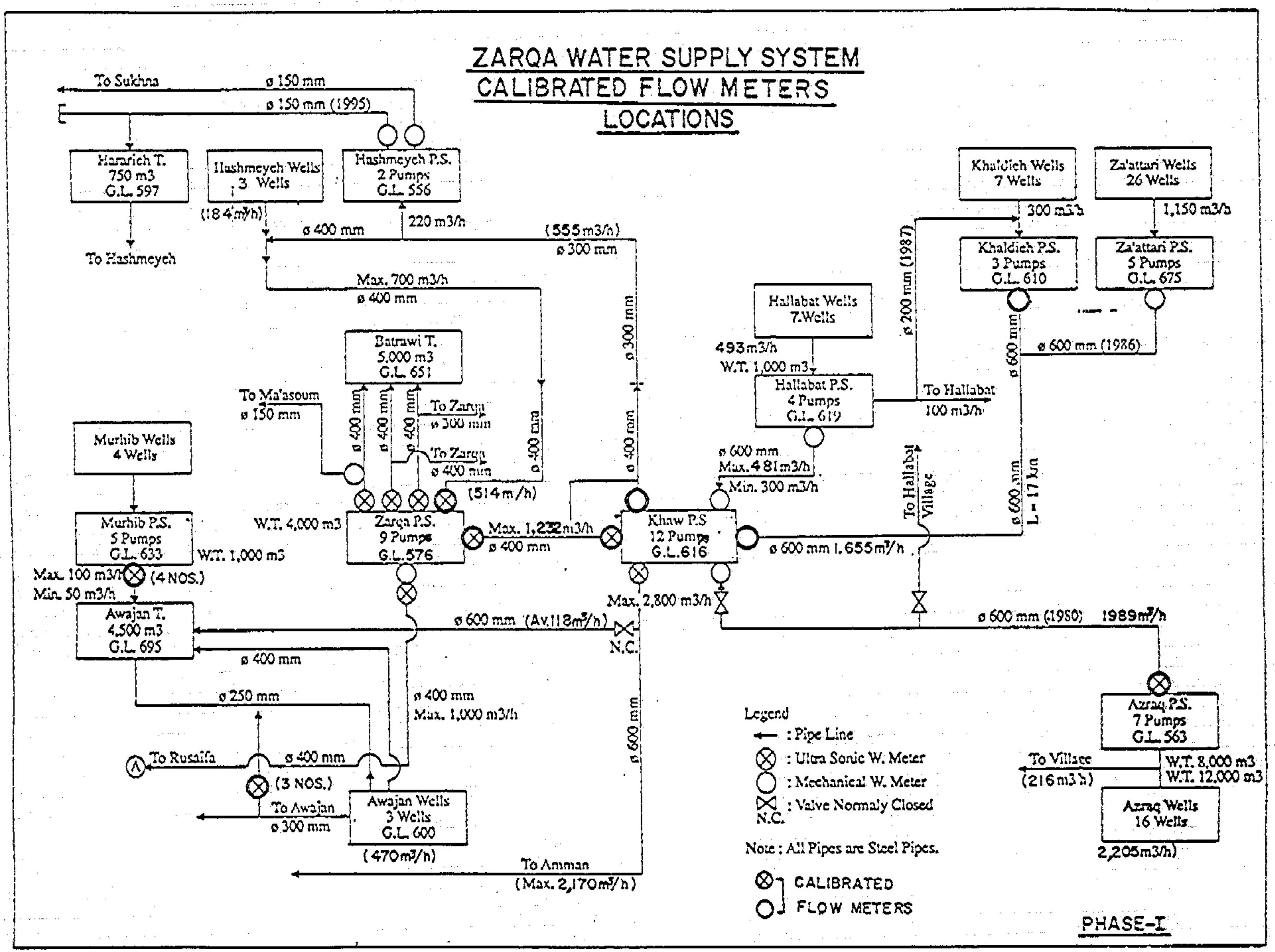
## KHAW ZARQA LINE

### 1. KHAW SITE



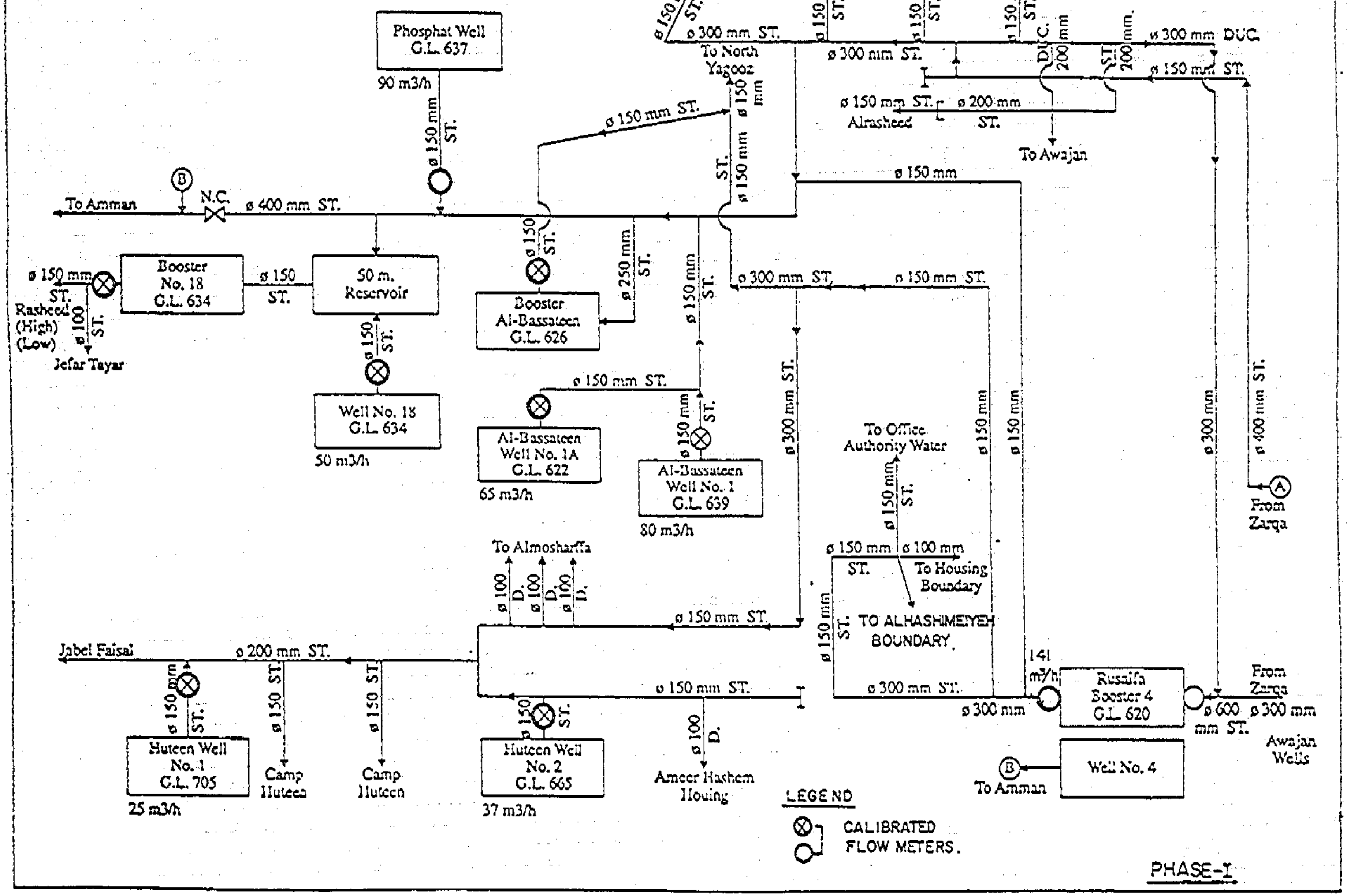

### 2. ZARQA SITE

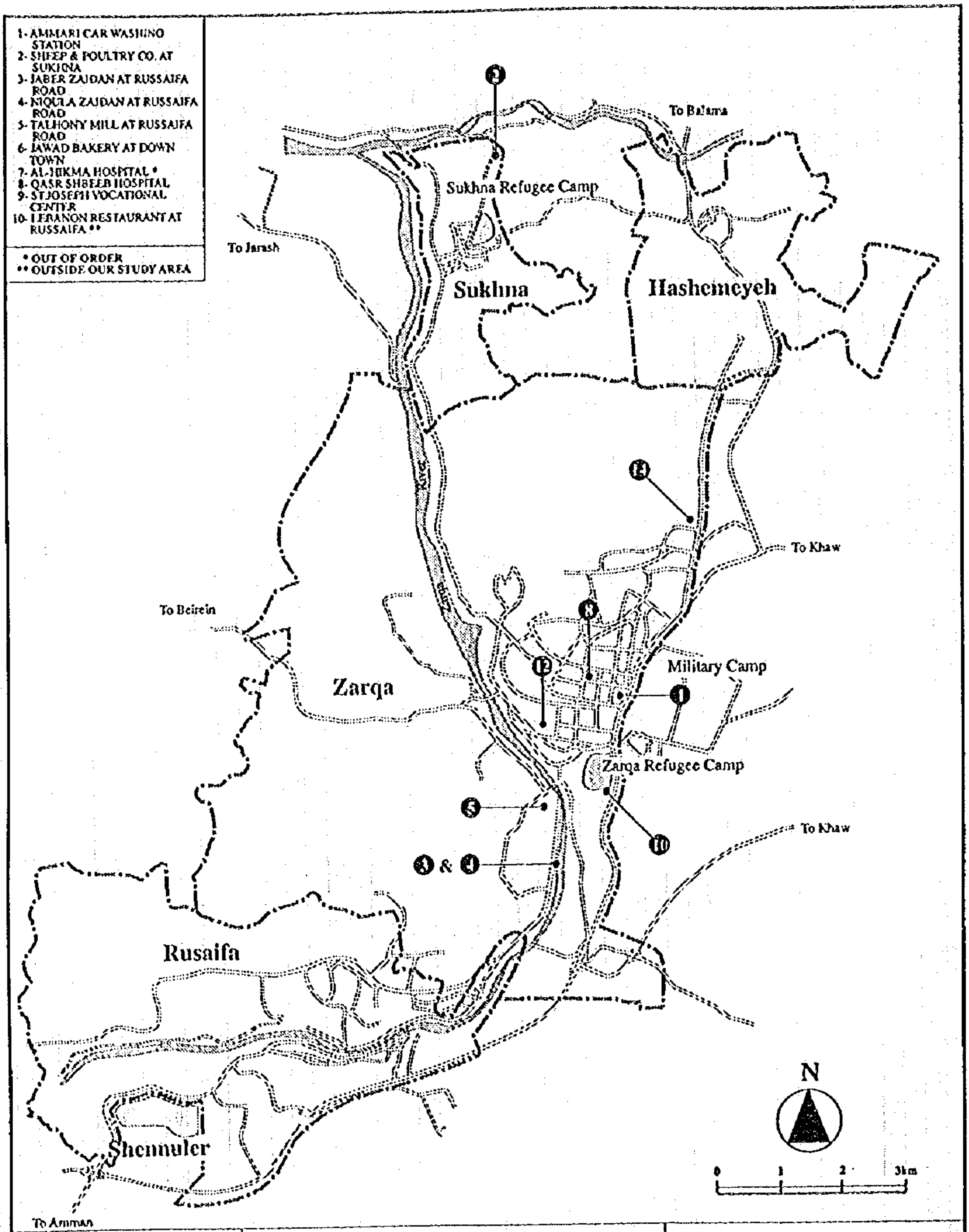




ZARQA WATER SUPPLY SYSTEM
CALIBRATED FLOW METERS
LOCATIONS
To Sukhna
ø 150 mm
ø 150 mm (1995)
Hararich T.
750 m3
G.L. 597
Hashmeyeh Wells
3 Wells
Hashmeyeh P.S.
2 Pumps
G.L. 556
To Hashmeyeh
ø 400 mm
220 m3/h
(555m3/h)
ø 300 mm
Max. 700 m3/h
ø 400 mm
Khaldieh Wells
7 Wells
Za'attari Wells
26 Wells
300 m3/h
1,150 m3/h
Khaldieh P.S.
3 Pumps
G.L. 610
Za'attari P.S.
5 Pumps
G.L. 675
ø 200 mm (1987)
ø 600 mm (1986)
Hallabat Wells
7 Wells
493m3/h
W.T. 1,000 m3
Hallabat P.S.
4 Pumps
G.L. 619
To Hallabat
100 m3/h
ø 600 mm
Max. 481m3/h
Min. 300 m3/h
To Hallabat
Village
ø 600 mm
L = 17 km
Batrawi T.
5,000 m3
G.L. 651
To Ma'asoum
ø 150 mm
ø 400 mm
To Zarqa
ø 300 mm
To Zarqa
ø 400 mm
(514m/h)
Murhib Wells
4 Wells
Murhib P.S.
5 Pumps
G.L. 633
W.T. 1,000 m3
Max. 100 m3/h
Min. 50 m3/h
(4 NOS.)
W.T. 4,000 m3
Zarqa P.S.
9 Pumps
G.L. 576
Max. 1,232 m3/h
ø 400 mm
Khaw P.S
12 Pumps
G.L. 616
ø 600 mm 1,655m3/h
Max. 2,800 m3/h
ø 600 mm (1980)
1989m3/h
Awajan T.
4,500 m3
G.L. 695
ø 600 mm (Av.118m3/h)
N.C.
ø 400 mm
ø 250 mm
ø 400 mm
Max. 1,000 m3/h
To Rusaifa
(3 NOS.)
To Awajan
ø 300 mm
Awajan Wells
3 Wells
G.L. 600
(470m3/h)
To Amman
(Max. 2,170m3/h)
Azraq P.S.
7 Pumps
G.L. 563
To Village
(216m3/h)
W.T. 8,000 m3
W.T. 12,000 m3
Azraq Wells
16 Wells
2,205m3/h)
Legend
: Pipe Line
: Ultra Sonic W. Meter
: Mechanical W. Meter
: Valve Normaly Closed
N.C.
Note : All Pipes are Steel Pipes.
CALIBRATED
FLOW METERS
PHASE-I

# ZARQA WATER SUPPLY SYSTEM
## CALIBRATED FLOW METERS LOCATIONS



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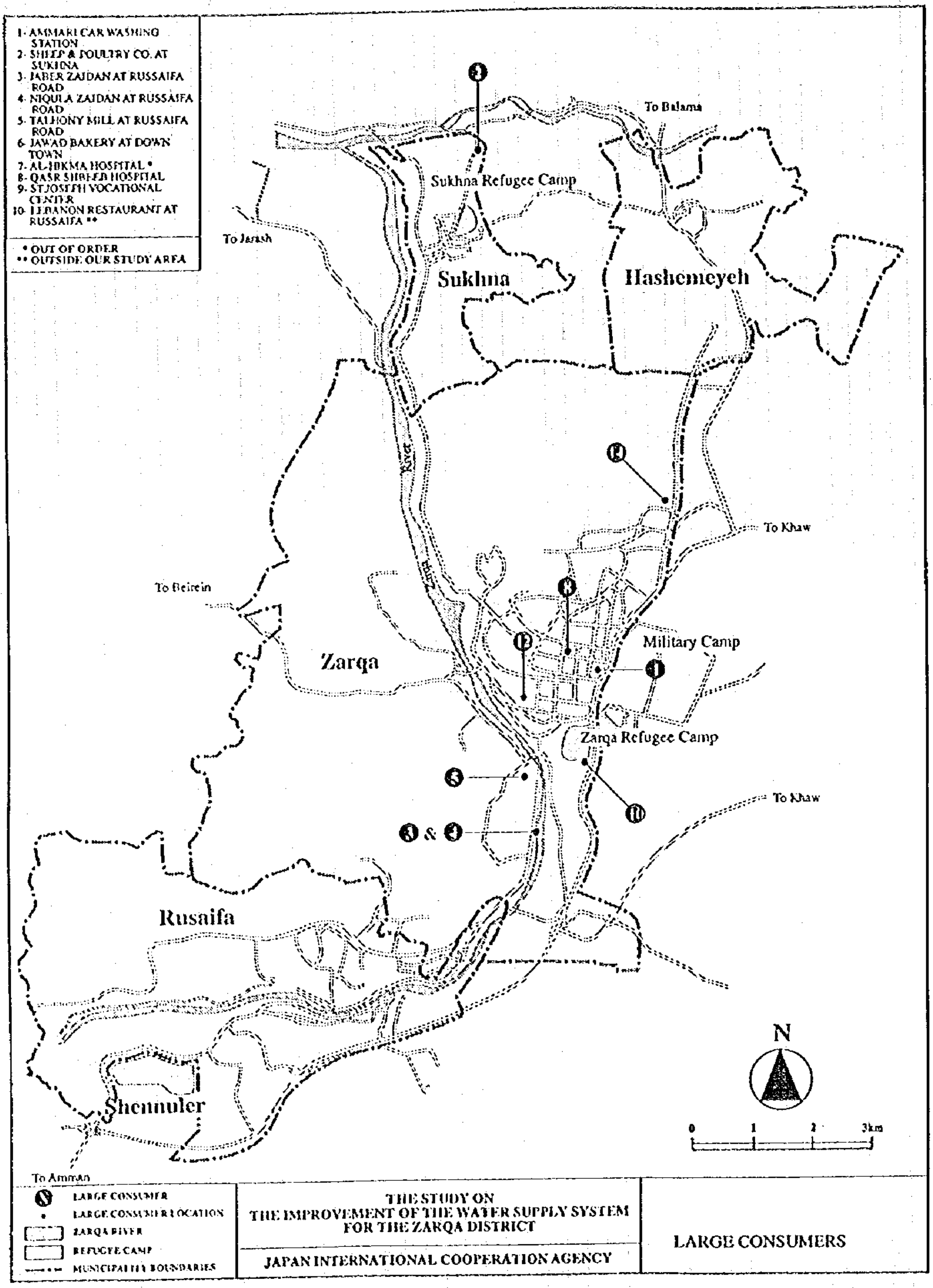
| THE STUDY ON<br>THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM<br>FOR THE ZARQA DISTRICT | LARGE CONSUMERS |
| JAPAN INTERNATIONAL COOPERATION AGENCY | |



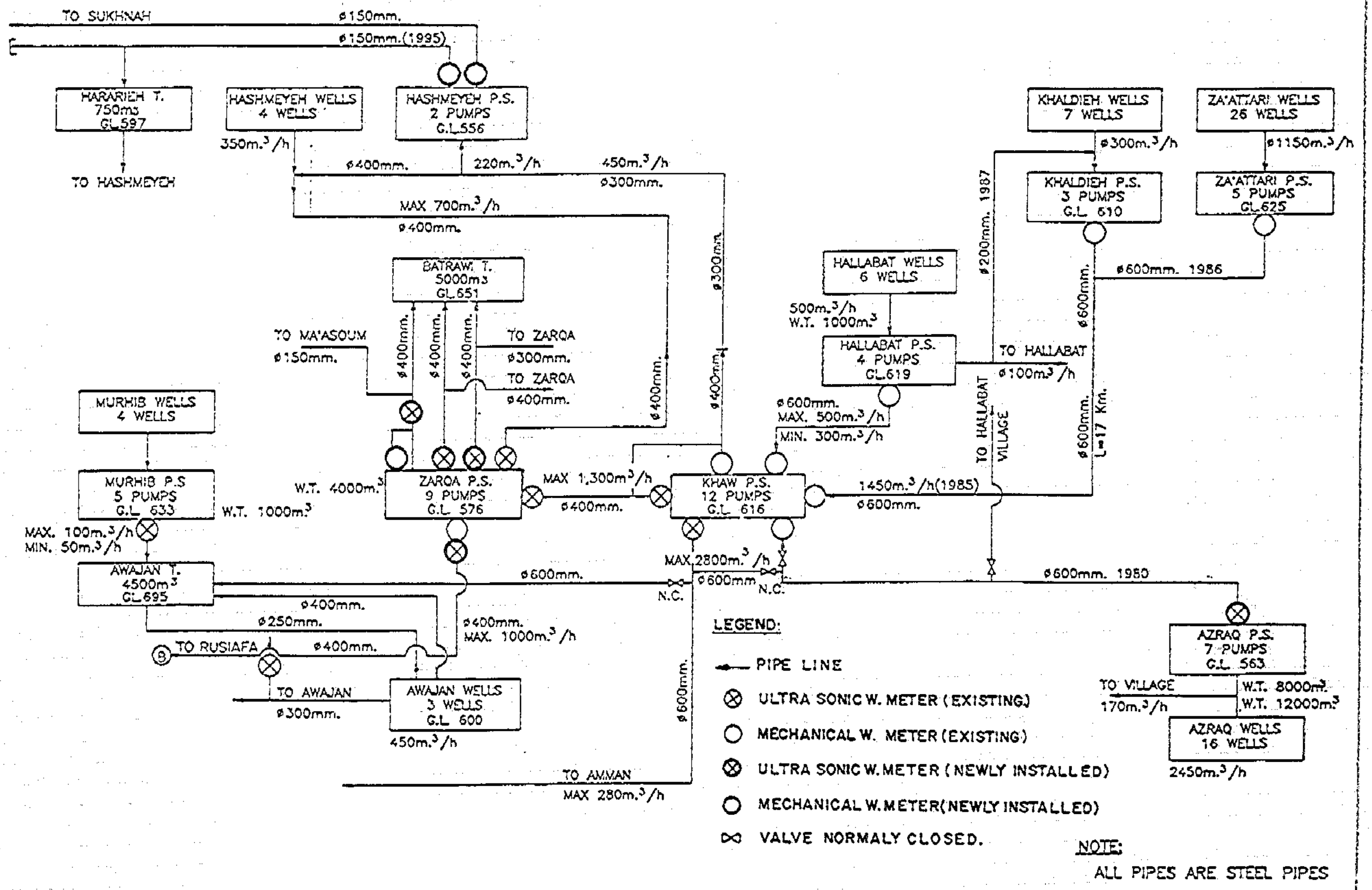

THE STUDY ON
THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM
FOR THE ZARQA DISTRICT

JAPAN INTERNATIONAL COOPERATION AGENCY

LARGE CONSUMERS

# G. INSTALLATION OF FLOW METERS

# ZARQA WATER SUPPLY SYSTEM
## ( FLOW LINES )



## H. UFW SURVEY

# Appendix II
## - Unaccounted-for Water Survey -

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# 1. INTRODUCTION

This supporting report intends to describe the unaccounted for water (UFW) survey carried out in Zarqa District, focussing on its survey areas, procedures, methods, data processing and major results. The survey that involves 8 pilot areas and subzones in the study area was phased into two: First Phase Survey from December 1994 to April 1995, and the Seconc Phase Survey from May 1995 to September 1995.

Main objectives of the survey are to evaluate the existing pipe network in 1) quantifying water lost from distribution mains, service mains, service pipelines, customer meters, 2) identyfying main components of water losses and 3) proposing scope of urgent rehabilitation and /or leakage control needed for rationalization of the whole system.

The survey applies the following two methods,

a- Combined District and Waste Metering Method (CDWM method):

CDWM method is generally effective for leakage control and pipeline maintenance. To this end, the survey area is usually separated into several subzones by boundary valves. Inflow to the subzones drops simultaneously by closure of the boundary valves at each subzone. A decrease of the inflow rate suggests which subzones leakage or water losses dominate.

Three survey areas for CDWM method were selected from Rusaifa, Zarqa and Janna & Zarqa Refugee Camp (instead of Shennuler Refugee Camp which was substituted due to extremely low water pressure) with approximately 2,000 subscribers in each area.

b- Meter Replacing Method (MR Method):

Meter Replacement method aims to identify major causes of water losses from relatively small diameter pipelines including service mains and house connections. This method may be applicable for smaller service blocks than those of the CDWM method. Before and after customer meter replacement, all meters are read twice. Difference in these meter readings provides information on meter inaccuracy and other water losses related to the customer meters, while difference between total amount of customer meter readings and inflow rate to the zone gives UFW ratio. Further, measured minimum night flow can be assumed as a rate of the leakage from the pipe works.

The survey by MR method covers five areas, each located in Rusaifa, Awajan, Zarqa, Hashemeyeh and Sukhna. Each contains approximately 200 service connections.

## 2. DESCRIPTION OF THE AREA

The survey areas were finally determined in due consideration of hydraulic profile, water pressure distribution, pipe network characteristics, and socioeconomic conditions. They are (1) Hai Hussein & Hai Al Aratfeh in Rusaifa, (2) Al Ghourieyeh in Zarqa, (3) Janna and Zarqa Refugee Camp for CDWM method, and (1) Hai Aratfeh in Rusaifa, (2) Hashemeyeh Housing Complex, (3) Sukhna Refugee Camp, (4) Al Ghourieyeh in Zarqa city center, and (5) Awajan in Zarqa for MR method. Their geographical locations within the study area are shown in Fig.-H1.

Following paragraphs brief salient features of each area in terms of water supply conditions, the pipe age and materials, geography and socioeconomic conditions.

1) Rusaifa area: The area contains Jabal Al Hussein and Jabal Al Aratfeh, old residential area in Rusaifa. As the names suggest, rocks and hills crop out in a small area of only 64ha with the ground levels varying between 610 m Average National Datum (AND) and 680 m AND. The area is fed from two 6" offtakes to the north east and north west of the area, from a 12" main running along the northern boundary near the Zarqa River. The majority of distribution mains was replaced in 1986 and 1987, but some old steel distribution mains installed in the 1960's are left unrepaired. There are no booster pumping station within the pilot area. Hence, water pressure varies to a large extent from 6.0 kg/cm2 to almost zero according to the altitude.

2) Al Ghourieyeh area: The area is characterized as a center of the commercial and residential zone in Zarqa, having a good number of shops and schools. It receives water from the Zarqa pumping station through a series of 4" - 8" pipes perpendicular to the 16" main supplies. Water pressure in the area is relatively high. The majority of pipe works is in ductile iron installed in the 1960's. Most of service mains and house connections are rehabilitated in 1980's. The area gradually adds its elevation westwards from a low level of 585m to a high level of 610mAND.

3) Zarqa Camp and Janna area: The area is situated on the south side of down town Zarqa city center with ground levels around 555-625mAND. The area is mainly a low income residential area with some shops and schools. It receives water from the Zarqa pumping station through one 6" offtake from 16" main running through the center of the city. All pipe works are recently rehabilitated except house connections which was laid in 1960's.

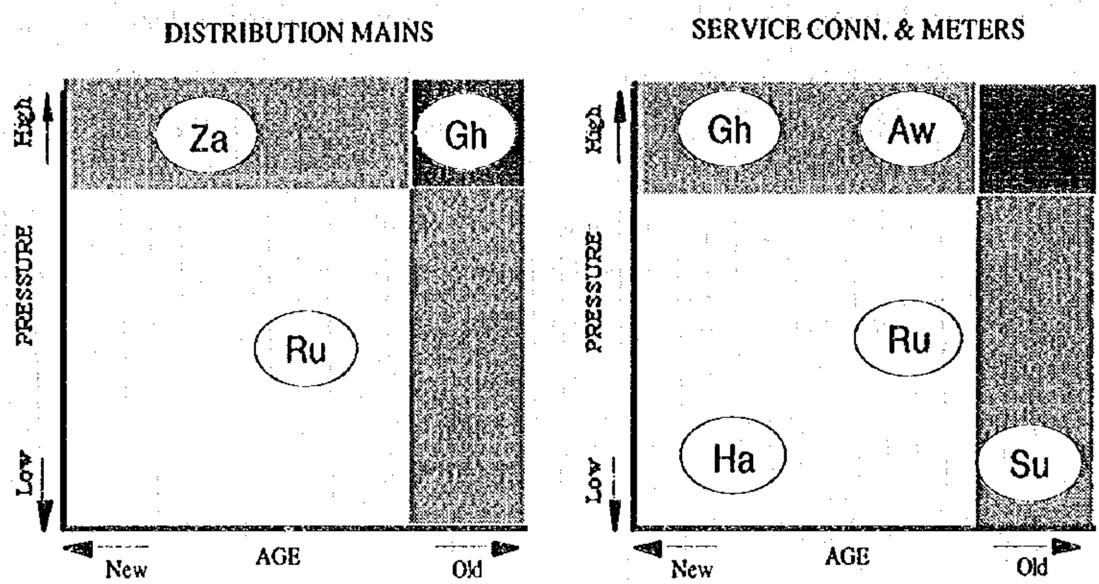
4) Awajan area: The area is on the south west side of Zarqa City adjacent to Rusaifa municipality. Characterized as residential and commercial area, there exists a number of shops, restaurants and schools. However, there is no large water users within the area. Awajan tank and Zarqa pumping station are main sources for the area, where fed from two or three 3" and 4" offtakes to the east and south of the area from 8" and 10" lines on the east and south boundaries of the area. The majority of pipe work is laid in ductile iron installed in 1980's.

5) Hashemeyeh Refinery Housing Complex: The area is situated on the north east area of Hashemeyeh town. It is a part of the housing development for the employees of the Jordan Oil Refinery. The area is also very flat with ground level around 565mAND. This area receives water from Hararieh Tank by gravity. Hence, water pressure in the area is relatively low. The area is fed from two 4" offtakes to the south of the area from a 6" main running along the south side of the area. The majority of pipe work is laid in steel installed in 1980's with the expansion of the housing project.

6) Sukhna Refugee Camp area: The area is situated in the heart of the Sukhna township. The area is flat with a ground level around 520mAND. This area is all low income housing with a couple of stores and shops. The area is fed by several 2" offtakes to the east of the area from a 4" black steel service main running along the east boundary of the area with very low water pressure. The all service pipelines and connections are galvernized steel installed in the 1960's except the 4" service main which was rehabilitated in 1980's.

From the above description, distribution mains and service connections laid in each area were scattered on X-Y coordinates in terms of pipe age and water pressure as illustrated below.

## CHARACTERISTICS OF EXISTING PIPE WORKS




Note: (Za), (Gh), (Ru), (Aw), (Ha) and (Su) denotes pilot and/or subzone areas, Zarqa Camp and Janna, Al Ghourieyeh, Rusaifa, Awajan, Hashemeyeh, and Sukhna respectively.

The figure in left above shows that Ghourieyeh pilot area is fed by old distribution mains under high water pressure, while Zarqa Camp and Janna has new pipe network. The right above suggests water pressure in Hashemeyeh and Sukhna is the lowest and house connections in Sukhna is obsolete and not rehabilitated.

## 3. CURRENT WATER AUTHORITY PRACTICE

In the billing system, each connection is defined as a "subscriber". Each subscriber is metered; the meter being located and accessed from within the subscriber's property.

Meters fitted vary in make and model. Most appear to be Class B with a nominal flow rate (Qn) of 1.5 m3/hr. International standards require a Class B meter of this Qn rating to record flowrates down to 0.03 m3/hr to 75% accuracy, which is equivalent to 78 lpcd (= 0.03 m3/hr x 24 hours/day / 9.2 average family size) in the meter replacement subzone. Whilst the standards do not require Class B meters with this Qn rating to record flows below this rate, in practice they will be frequently operating at much lower flows.

Meters installed in the pilot area usually have manufacturers seals to prevent them being dismantled. However, it is often observed during survey that there is no seal between the meter and the pipework itself, making it easy to remove the meter temporarily, either in order to turn it back to front or to replace it with a connecting pipe.

All meters are read quarterly for billing purposes. Bills are prepared at the office of WAJ Billing Department and hand delivered to subscribers by collectors. Subscribers subsequently pay their bills at the WAJ Zarqa or Ruseifa office. Subscribers not paying bills have their supplies cut off.

The cost of water is heavily subsidised by the Government with the unit rates for an area being based upon ability to pay. High water consumption attracts a stepped increase in the unit charge.

A passive leakage control policy is exercised with only identified visible leaks being repaired.

WAJ staff believe that the major causes of leaks which have been repaired result from: 1) poor quality of pipe laying including inadequate bedding preparation and use of proper underfill and backfill material; 2) corrosion of steel pipework by the aggressive soil surrounding the pipe; 3) high pressures in the pipe as a consequence of the area's topography.

WAJ staff have developed and follow certain operational procedures to protect the network from excessively high pressures. These include monitoring pump outlet pressures and switching pumps off or altering valves when set pressure levels are exceeded.

WAJ staff also believe that the major causes of UFW are illegal connections and tampered meters rather than losses from the network. They also stated that there was a reluctance by subscribers to pay more than JD 2 per quarter for their water bill, regardless of the number of occupants or amount of water used.

## 4. PHASE I SURVEY

Phase I survey conducted at Rusaifa (Hai Al Hussein & Hai Aratfeh) applies both CDWM and MR methods. The survey is of a preliminary one prior to initiation of the succeeding Phase II survey.

### 4.1 DESCRIPTION OF FIELDWORK

#### 4.1.1 Preliminary Fieldwork

Following a topographical survey, site visits and spot excavations, a 1:1000 scale schematic was prepared for the pilot area (Refer to Maps and Data Book). The schematic was based on information taken from WAJ record drawings and other as built mains record drawings, combined with local knowledge and much site survey work using electronic pipe and box locators. The layout diagram shows all pipework of 3" and above with the connecting points to 2" and smaller diameter pipework. Additional investigations were carried out within the subzone to identify all smaller pipework and meter locations.

Using the pilot area schematic, a step test was designed consisting of five step areas with the subzone forming one whole step area. For easy reference, further, none-scale schematic that shows main pipe alighnment, location of boundary valves, step test valves and flow meter location was prepared as presented in Fig. - H2.

Open pits were excavated in suitable locations to allow the fitting of the ultrasonic flow meters, one on the north east 6" inlet to the pilot area near to the bridge over the Zarqa Seil, formerly the Zarqa River, and one on the 4" feed into the subzone, outside the Aratfeh mosque. Pressure tappings were fitted at each meter site and at one additional site within the subzone.

All step test valves were physically checked by WAJ/project staff to ensure that they were operable.

On Monday 20th March 1995 a continuous supply of water to the area was commenced and the 6" flow meter and pressure chart recorder were fitted. A guard was stationed at the site to protect the equipment.

An attempt to fit the 4" ultrasonic meter was made but aborted due to insufficient signal strength. It is suspected that this was due to air in the water.

#### 4.1.2 Step Test for CDWM (21st March)

On 21st March customers roof tanks at the pilot area high spot were found to be full. The 4" flow meter and pressure chart recorder were successfully fitted and a guard stationed at the site.

Both flow meters which comprise an integral data logger and results printer were set to print records at 1 minute intervals for the step test.

Step test valve closures were carried out in two phases. The initial phase closed all but one valve for each step area to create the step test areas. Flows were monitored during this phase to ensure that no area was isolated. The second phase involved closing the final valve for each step area and monitoring flows to calculate the flow into each step area.

Starting with the valve on the unmetered 6" inlet to the north west of the pilot area, preliminary step test area valves were closed by WAJ/project staff. The times of all valve closures were noted. All closed valves were checked for water tightness using acoustic listening sticks.

The flow through the 4" subzone meter was seen to increase as expected with the closure of valves relating to the subzone step test area.

The flow through the 6" meter was seen to remain unchanged by the valve closures as expected.

At 03:45 am on 22nd March the final step test valves were closed in sequence to establish the flows to each step test area. These valves were then reopened in reverse order.

The flow meters were then reset to print at 5 minute intervals.

#### 4.1.3 METER READING EXERCISE (22nd and 23rd March)

24 hour "base line" demands were derived from the results of a meter reading exercise on 22nd and 23rd March 1995. In order to be able to replicate conditions over the two days and for a repeat exercise after the meters had been replaced, it was decided to undertake each meter

reading cycle when the inlet valve to the pilot area was closed and hence the flow through individual meters, although not zero for reasons stated above, was significantly reduced. Although the supply to subscribers was theoretically cut off, their demands continued to be met from their individual roof tanks.

At 10:40am on Wednesday 22nd March the pilot area inlet valve was closed and meter reading commenced. An additional pressure chart recorder was fitted within the subzone to help assess headloss within the area. The meter reading was completed by 12:45pm immediately after which the inlet valve was reopened.

The meter reading exercise was repeated commencing at 10:40am on 23rd March when the inlet valve was again closed. Meters were read by the same people in the same order as the day before. The exercise was completed by 12:10pm. Principle valves were promptly reopened with others being returned to there original status at a later date. All equipment was subsequently retrieved.

Between the 27th and 29th March the customer meters were replaced with new class B water meters with a Qn value of 1.5 m3/hr.

Every effort was then taken to replicate the conditions existing during the previous meter reading exercise and on Monday 3rd April a continuous supply of water to the area was commenced.

On Tuesday 4th April an ultrasonic flow meter and pressure chart recorder were fitted to the 4" subzone inlet main in precisely the same locations as before. The flow meter was set to print at 5 minute intervals. All subzone boundary valves were closed again so that water only entered the subzone via the meter.

The meter reading exercise started at 10:40am on Wednesday 5th April with the second reading starting at 10:40am the next day.

On completion, all valves were promptly returned to there original status and all equipment was retrieved.

## 4.2 DATA PROCESSING AND ANALYSIS

### 4.2.1 PILOT AREA STEP TEST (CDWM)

The results of CDWM at Rusaifa Pilot Area are summarized in Fig. - H3, and major procedures for estimating leakage ratio are described below.

1) Number of Connections and Population

Number of connections and population estimates for the step test areas are given in table below.

STEP TEST AREA POPULATION STATISTICS

| STEP TEST AREA | METERED CONNECTIONS | POPULATION |
|---|---|---|
| 1 | 262 | 2,837 |
| 2 | 876 | 9,485 |
| 3 | 323 | 3,497 |
| 4 | 678 | 7,341 |
| 5 - Subzone | 197 | 2,133 |
| PILOT AREA TOTAL | 2,336 | 25,293 |

2) Legitimate Night Usage

To obtain data on minimum night usage, a survey was conducted in a later stage at several subzones of Hashemeyeh. An average, 1.21 l/hour/subscribers obtained in this survey was considered appropriate to apply to the whole areas in Zarqa and Rusaifa.

In the meantime, the report "Managing Leakage", dated 1994 and published by WRc recommends an estimate of normal household night use of 1.7 litres/property/hour at minimum night flow. In case of Jordan, where water consumption pattern differs from those in industrialized countries, however, it is considered slightly large.

The appliance of 1.21 litres/hour/subscriber suggests the legitimate night usage (2,826 litres/hour) at whole pilot area as given below.

NIGHT USE ESTIMATES

| STEP TEST AREA | APPLYING 1.21 TO Connection (litres/hour) |
|---|---|
| 1 | 317 |
| 2 | 1,060 |
| 3 | 390 |
| 4 | 820 |
| 5 - Subzone | 238 |
| PILOT AREA TOTAL | 2,826 |

3) Ground Level

Ground levels within the area are:-

STEP TEST AREA GROUND LEVELS

| STEP TEST AREA | HIGHEST GROUND LEVEL (mAND) | LOWEST GROUND LEVEL (mAND) | UNWEIGHTED AVERAGE |
|---|---|---|---|
| 1 | 680 | 642 | 661 |
| 2 | 678 | 632 | 655 |
| 3 | 675 | 629 | 652 |
| 4 | 659 | 623 | 640 |
| 5 - Subzone | 645 | 615 | 630 |
| PILOT AREA | 680 | 615 | 647.5 |

4) Accounted-for Water Recorded by WAJ

From data supplied by the WAJ, the following statistics have been compiled relating to accounted for water for the first quarter of 1994:-

ACCOUNTED FOR WATER FOR BILLING AREAS 1 & 2

| BILLING AREA | NO. OF SUBSCRIBERS | METERED CONSUMPTION (cubic metres) | LITRES PER SUBSCRIBER PER DAY |
|---|---|---|---|
| 1 | 1,677 | 61,364 | 401 |
| 2 | 1,268 | 45,517 | 393 |

5) Total Inflow and UFW Ratio

Within the 24 hour period, **1,569,400 litres** entered the pilot area. Using the 400 litres per subscriber suggested by WAJ records would give **40% UFW**.

6) Estimated Leakage

Leakage relates to pressure and ground level. They were examined and average zone pressures calculated within the subzone and pilot area for each hour of the exercise. These pressures were analysed in conjunction with the night flow data.

The minimum hourly night flow for the pilot area was **29,500 litres** between 0240 and 0340 on 22nd March when the average zone pressure for the pilot area was calculated to be 45.7 metres available head. Raw data of the minimum hourly night flow are given on Drawing and Data Book.

Flow and pressure data for the step test were analysed. Pressures and flows were seen to drop sharply at 1:00am and 2:10am prior to the step test. Enquiries revealed this was due to the WAJ practice of turning off a booster at Rusaifa pumping station and opening a valve to supply the Awajan area. This was to prevent excessive night pressures and is a normal operational practice. However, as the final step test valves were closed no sound of rushing water and no drop in flow at the inlet meter was detected. This is attributed to a combination of low flows in the high areas because of the low pressures, and the web of small 2" pipework. Although all small pipework was located within the subzone area, this was not a feasible exercise to undertake for the whole pilot area and consequently some boundaries were not hydraulically secure. However, a daytime exercise of closing step valves at a time of higher flow did result in a drop in inlet flow, thereby confirming the choice of step test valves.

It was estimated that for the 24 hours of the meter reading exercise, the amount of leakage was **451,030 litres** corresponding to **28.7%** of total inflow respectively. This is given in Fig. - H3.

As stated above, step tests did not show a clear drop of flow rate because many unknown pipelines installed in 1960's may interconnect boundaries, providing water to the areas.

### 4.2.2 METER REPLACEMENT AT SUBZONE

Measured flow rates and leakage levels before and after meter replacement are presented in Table - H1 and Fig. - H4.

1) Before Meter Replacement

<u>House Meter Reading</u>

Out of the 197 meters within the subzone, 183 were read successfully on both occasions and results could be used to calculate a consumption. 9 were read on one occasion only owing to owners being out and the remaining 5 had either broken meters or had been disconnected.

For the 183 house meters successfully read twice in this exercise, the 24 hour consumption was 106,730 litres or 583 litres per subscriber per day.

Under normal circumstances, 192 meters would have been read and so the accounted for water over 24 hours can be obtained from the following equation.

Accounted for water = 106,730 litres + 583 litres x 9 subscribers
= **111,979 litres**

From data provided by WAJ, accounted-for water in the subzone is around **380 litres per subscribers.**

ACCOUNTED FOR WATER WITHIN THE SUBZONE

| NUMBER OF SUBSCRIBERS | METERED CONSUMPTION (cubic metres) | LITRES PER SUBSCRIBER PER DAY |
|---|---|---|
| 197 | 6,846 | 381 |

Comparison with the aboves (583 and 381 litres) suggests that there might be some losses during metering.

Ultrasonic-flow Meter Reading

The total inflow to the subzone recorded by the ultrasonic meter from 11:00am on the 22nd March to 11:00am on the 23rd march was **198,780 litres**, which implies **43.7%** UFW.

Minimum Night Flow and Leakage

According to the recomenmdation of WRC's Managing Leakage Report-26, the leakage levels throughout the time of the exercise were calculated by comparing pressures. The results are shown in Table - H1. Leakage before meter replacement is estiamted at **14.3%**.

2) After Meter Replacement

House Meter Reading

For the 181 meters successfully read twice in this exercise, the 24 hour consumption was 116,682 litres or 645 litres per subscribers per day.

Under normal conditions, 192 meters would have been read and so the accounted for water over 24 hours would have been **123,777 litres**, an increment of 10.5% on the figure prior to meter replacement.

Ultrasonic-flow Meter Reading

The total inflow to the subzone recorded by the ultrasonic meter from 11:00am on 5th April to 11:00am on 6th April was **134,210 litres**, a decrease of 32% on the previous figure.

Hourly flow recorded by the meter dropped to 220 litres between 2am and 3am on 6th April when the average zone pressure for the subzone was calculated to be 60.0 metres available head. This is lower than any estimate of legitimate household night use. This leads one to suspect a boundary valve was left open. However, the peak flow of 13,100 l/hr between 1pm and 2pm on 5th April indicates otherwise. Appendix A compares flows and pressures during the meter reading exercises before and after meter replacement. There is a clear offset of about 2,000 l/hr between subzone inlet flows recorded before and after meter replacement. This suggests a metering error involving the zero offset of the meter. If this were the case, then the true 24hr consumption of the subzone might have been nearer to 183,000 litres, a decrease of 8% on the previous figure. However, the ultrasonic flow meter software allows zero offset corrections to be calculated and taken into account and this was done on each occasion that an ultrasonic flow meter was used.

Alternatively, if the ultrasonic meter flows are correct, then there is no leakage in the subzone and only **7.8% UFW** compared with 43% previously.

Minimum Night Flow and Leakage

The minimum hourly night flow for the subzone was 440 litres between 01:00 and 02:00 on 6th April when the average zone pressure for the subzone was calculated to be 60.0 metres available head.

Supposing that minimum night usage is 1.21 litres/hour/subscriber, the amount of leakage is then estimated at 4,440 litres, corresponding to **3.3%** of total inflow.

## 5. PHASE II SURVEY

Survey procedures for CDWM and MR methods undertaken and results of the surveys are summarized in the following paragraphs.

### 5.1 CDWM METHOD

a) Zarqa Camp and Janna Pilot Area

Following procedures for field works and data processing are undertaken for Zarqa Camp and Janna Pilot area.

1. Maps of the area were prepared to a scale of 1:500 (2 sheets) on which the water system showing all pipework of 3" and above with the connecting points to 2" and smaller diameter pipework. Schematic pipe net work in Zarqa Camp and Janna was also prepared in Fig.- H5.

2. Additional investigations were carried out within the pilot area to identify all smaller pipework.

3. Using the pilot area maps, a step test was designed consisting of eight step areas which later considered areas 5 and 6 as one area due to faulty valves.

4. Open pits were excavated at suitable two locations to allow the fitting of ultrasonic flowmeters on 2" diameter pipes which are supplying a number of connections where the number of subscribers were known.

5. The pilot area contains about 1920 subscribers (consumers meters). Boundary valves were closed and the area was supplied by one 6" main line.

6. Despite efforts to obtain minimum night usage of subscribers in the area, they were not successful due to a number of roof tank unsaturated in the area. To overcome this situation, the average minimum night consumption between 2:00am and 4:00am of 22 subscribers was measured resulting in 31 litres/subscriber/hour as shown in Fig.- H6. This high value could be accounted for by storage being recovered during the high pressure available at night.

7. The average night flow measurement of the pilot area was taken using an ultrasonic flow meter. A rate of 90m3/hr was recorded as shown in Fig.- H7.

8. Due to the reason stated above, following procedures and formula was applied to obtain a rate of leakage:

$$q^* = s^* - (m^* + a^* \times n^*)$$

| | | |
|---|---|---|
| Where : | $q^*$ = | Leakage (net night flow) |
| | $s^*$ = | Average night flow input to the area |
| | $m^*$ = | Total measured night flow rate of industrial and trade consumers. |
| | $a^*$ = | Average minimum night consumption per subscribers |
| | $n^*$ = | Number of domestic connections. |

Hence, the apparent leakage level in Zarqa Camp and Janna can be estimated as follows:

$$q^* = 90{,}000 - (0 + 31 \times 1920)$$
$$= 90{,}000 - 59{,}520$$
$$= 30{,}480 \text{ lit/hr. which represents } 33.87\%.$$

9. On Thursday 3 August 1995 the step test was started on the area and valve position was set up as per enclosed drawings. Results of step test are seen in Fig.- H8 and leakage rate estimated for each sbzone is given in table below.

LEAKAGE AT EACH SUBZONE (Janna and Zarqa Camp)

| Subzone | No. of Consumers | AllowableUsage (Lit./hr.) | Step Down Result(Lit./hr.) | Leakage |
|---|---|---|---|---|
| 1 | 125 | 3,875 | 4,000 | 125 |
| 2 | 190 | 5,890 | 23,000 | 17,110 |
| 3 | 110 | 3,410 | 2,000 | No Leakage |
| 4 | 160 | 4,960 | 3,000 | No Leakage |
| * 5 | 135 | 4,185 | - | No Leakage |
| * 6 | 115 + (fm2) | 53,565 | 14,500 | * |
| 7 | 85 | 2,635 | 2,000 | No Leakage |
| (5+6+8) | - | 57,750 | 68,000 | 10,250 |
| | | 57,750 | | 10,250 |

10. Due to the faulty valves No. ST.5 (Step valve No. 5) and St.6, an isolation of Subzone No. 5 and No. 6 was hardly attained during the step test. The water continued to flow out from the valves that interconnect Subzone No. 5 & 6. These two subzones were only possible to isolate from others when the meter valve (step valve No. 8) (St.8) was closed. Therefore Subzones 5 and 6 were considered as one subzone.

At Subzone No.2 the drop in the flow rate is very high. This drop may results from a large amount of the leakage from the pipe network. It seems a little possibility that Subzone No.2 is not completely isolated and the water is continuously flowing out from the area via unknown connections or faulty circulating valves.

11. The step test results showed that major leakage are probably taking place in Subzone No. 1, 2, 5 and 6 where high flows per service connection were meausred.

c) Ghourieyeh Pilot Area

Following procedures are undertaken for Ghourieyeh Pilot Area.

1. Map of the area was prepared to a scale of 1:1000 on which the water system of all

the pipes and valves are shown. Schematic pipe network prepared is presented in Fig.- H9.

2. Additional investigations were carried out in the pilot area to identify all smaller pipes.

3. Using the pilot area map, a step test was designed consisting of eight step areas.

4. Open pits were excavated at two suitable locations to allow the installation of two ultrasonic flow meters on 150mm diameter pipes which supply the area with water. Additional one flow meter was also mounted on 50mm pipe.

5. Boundary valves were closed to ensure that water enters into the area through the flow-meter mounted pipes stated above.

6. To measure minimum night flow of the pilot area, ultrasonic flow meters were installed on 30 August 1995 and 4 September.1995. As seen in Zarqa Camp and Janna pilot area, however, an obvious trend of the minimum nigh flow was not observed in the series of the measurement. This is mainly because of the roof tanks in the area not fully saturated during the measurement. Hence, an average night flow in the hour from 2:00am to 4:00am, instead of the minimum night flow, was estimated from the flow rate curve. The similar value of the average night flow, 107m3/hour,was recorded on both nights. Figs. - H10 and H11 show results of night flow measurements on 30 August 1995 and 4 September 1995.

7. A pressure recorder was installed to monitor the pressure in the pilot area for 24 hour.

8 One ultrasonic flow meter on the 50mm pipe which supplies 205 subscribers meters was installed to obtain the average night flow consumption. It was around 34.15 lit/subscriber/hr. This high consumption rate, as described above, is due to the filling of the roof tanks during the night.

9. The apparent leakage in the pilot area is

$$V = 107{,}000 - (0+34.15 \times 921)$$

= 75,547.85 lit/hr.

or 70.6 %

10. The step test exercise was carried out on 6 September 1995. Areas and step test valves are shown on drawings and the schematic pipe network. Flow rate fluctuation during the step test is presented on Fig.- H12.

From the step test it was shown that leakage in the subzones 1-7 was very small. But the leakage in Subzone 8 is extremely large in view of a sharp drop when the mains or the flow meters valves were closed. Pipe network in Subzone 8 contains distribution mains of 6" and 8" installed in 1960's which may be a major cause of the high rate of leakage.

To confirm this matter, leak detection was conducted at the site. Pits excavation (3 out of 4) along those distribution mains encountered water burst. From the appreciable quantities of leakage, these deteriorated distribution mains are considered as major cause of the leakage .

## 5.2 METER REPLACEMENT METHOD

Schematic diagram of pipe network for each subzone was prepared in Figs.- H13 to H16. Flow rate curve before and after meter replacement at each subzone are drawn on Figs. - H17 to H19 (except those in Sukhna and Ghouerieyeh). Leakage ratio estimated from the data on pressure, ground level and flow rate for each subzone is summarized in Table - H2 to H5. Due to voluminous data of meter reading records by the survey team, they are separately compiled in "Data Book".

a) Hashemeyah Subzone

Maps of the area to a scale of 1:500 (2 sheets) was prepared based on WAJ infoamation and a series of field surveys.

After confirmation that the area was isolated, main valve was closed and the subscribers meters were read by the survey team.

On 15 July, 1995 at about 14:00, the valve supplying the water was opened for 22 hours with the ultrasonic flow meter installed as well as the pressure recorder. At noon on 16 July, 1995 the valve was closed. In the duration of 24 hours, the ultrasonic meter registered 30.35m3 or 33.11m3/day.

Out of the 201 subscribers meters, twenty one could not be read as the owners were out of home. And twenty seven did not register any flow as the owners were away. (The exercise was repeated on 22 to 23 July 1995).

UFW before meter replacement was computed at 12.02m3 or 36.31% and after replacement of meters was at 4.48m3 or 12.27%. As summarized in Table - H2, adjusted leakage ratio at the subzone due to the pressure and ground level is estimated at 8.2% and 11.9% before and after replacement respectively.

The UFW ratio dropped sharply by meter replacement, while the leakage ratio stayed almost constant. Flow rates also during measument change drastically. This may suggest a possiblity of many storage roof tanks unsaturated before initiation of the flow measurement. Although some unknow factors were recognized, the survey suggests small amount of the leakage in the area. This is also explained from the fact that WAJ Zarqa staff had carried out a repair of the deteriorated pipelines and replacement of meter before initaiation of the UFW survey in the area.

b) Sukhna Subzone

The map of the area that shows pipe network alignment was prepared to a scale of 1:500 (one sheet) before initiation of the field work.

On the basis of the map prepared, the areas was isolated and the main valves closed and the subscribers meters were read twice.

On 16 August 1995 at noon the valve supplying the water was opened for 24hour. The portables ultrasonic flow meter and the pressure recorder was installed at the inlet pipe. At noon on 17 August 1995 after 24 hour measurement the valve was closed to read customer meters. The ultrasonic meter registered 155.34m3. Out of the 192 subscribers meters, 14 were read on once and 10 meters could not be read as the owners were out of home or away.

The UFW was 73.1m3 or 47.1% before meter replacement and 63.3m3 or 45.8% after replacement. As can be seen on Table - H3, the leakage ratio was not obtained because of the unexpectedly high flow rate in the night time. This may be attributable to the fact that many storage tanks has not been saturated before the survey. (The exercise was repeated on 21 August 1995 and 22 August 1995). The high UFW ratio obtained before and after meter replacement suggests high leakage ratio in the house connections and service pipelines installed in 1960's.

c) Ghourieyeh Subzone

The area map was prepared to a scale of 1:500. The area was isolated and three ultrasonic meters were installed on 50mm steel pipes.

On 7 August 1995 at noon the water was turned on into the area. The survey team tried to measure a total flow of the three ultrasonic meters. One of the three flow meters, however, did not function as expected because of air bubble contained in the water. This exercise was repeated on 14-15 August 1995 but not successful. Table - H4 shows the leakage ratio obtained from the first measurement, supposing that flow rate of the malfunctioning flow meter is negligible. This may suggest high leakage ratio at the subzone.

d) Awajan Subzone

The map of the area with a scale of 1: 500 was prepared and compiled in "Map and Data Book". The area was isolated and the existing customer meters were read by the team.

At noon on 26 August 1995 an inlet valve to the area was opened for 24hours. The total water measured by the ultrasonic meter was 185.5m3, while customer meters registered 136.2m3. The UFW resulted from these readings was computed at 49.3m3 or 26.7%.

After meter replacement, same procedures as those in other areas are taken. The flow through the ultrasonic meter was recorded at 173.10m3. The UFW after the replacement of the meters was 34.17m3 or 19.7% of the total. As presented in Table - H5, leakge ratios obtained are 19.5% and 16.0% before and after meter replacement respectively.

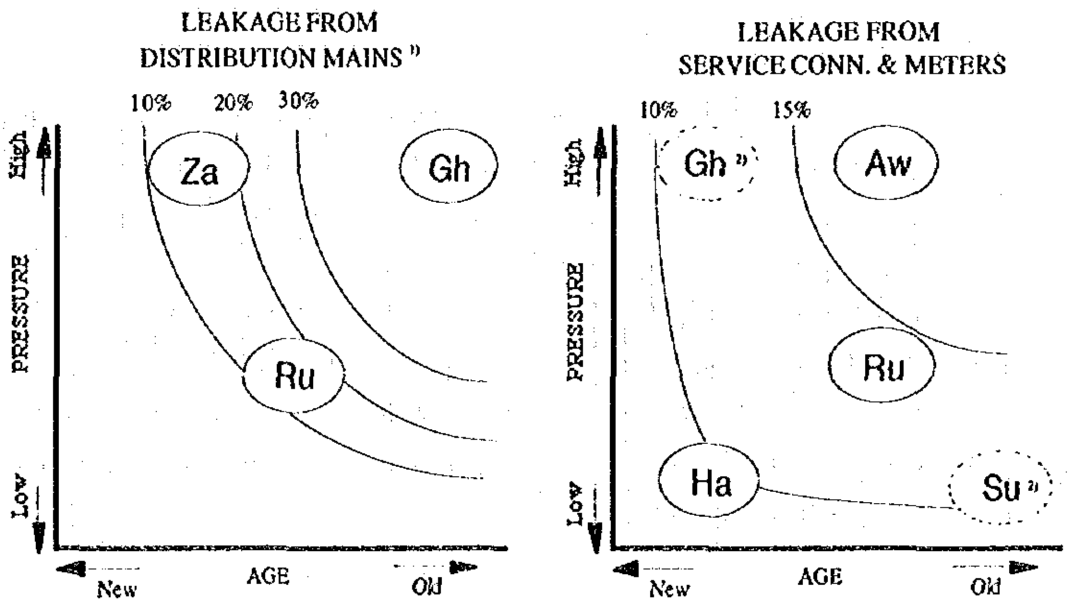
Awajan area enjoys high water pressure. Although the pipe works formed in the area are relatively new in their pipe ages, the leakage ratio is slightly higher than those in Rusaifa and Hashemeyeh.

## 6. CONCLUSIONS

Results of UFW survey at each area are summarized in Table - H6. The results are also portrayed in the figure presented in the preceding paragraph.

A large amount of the leakage from distribution mains is detected in old distribution mains under high water pressure like in Ghourieyeh. But the pipe works in Zarqa Camp and Janna and Rusaifa installed in 1980's and 1990's has relatively small percentage of leakage.

Leakage from house connections and service mains is generally in a range between 10% and 15% in every area. But Awajan area where high water pressure dominates recorded slightly high leakage ratio of 20%.




Note:
1) Leakage from distribution mains excludes that from service mains and house connections.
2) Flow meter measurement made at Ghourieyeh subzone area was not successful because of much air contained in the piped water. At Sukhna area, customers roof tanks could not be saturated before initiating survey due to extremely low water pressure.

Results of survey are also described hereunder referring to CDWM Method and Meter Replacement method.

(1) CDWM Method

The survey in Rusaifa pilot area suggests around 28.7% of leakage are responsible from its old pipe works and house connections. It is assumed leakage from major pipe works rehabilitated in 1986 and 1987 is relatively small.

The step test at Ghourieyeh pilot area shows particularly high percentage, 70%, of leakage from distribution mains of 150 mm - 100 mm, which were laid in 1960's and have been left without proper maintenance. It also suggests minor amount of leakage from the service pipelines and house connections, all rehabilitated in 1980's.

The survey at Janna and Zarqa Refugee Camp found about 30% of leakage in average although most of the old deteriorated pipe works have been replaced in 1980's and 1990's. More than half of the leakage are probably taking place at the old house connections and service pipelines installed in 1960's.

(2) Meter Replacement Method

The survey at Rusaifa area found 14.3% of leakage, which dropped significantly to 3.3% after meter replacement. This may imply most of water losses at service pipelines are resulting from meter inaccuracy and/or illegal water use by meters tampering, etc.

Hashemeyeh area showed a low level of leakage, 10%. The value was stable before and after meter replacement. This can be explained from the fact that the low water pressure dominates the area and relatively new house connections. Furthermore, nearly a quarter of the meters and pipes laid in the area had been rehabilitated by WAJ, just before initiation of the field survey.

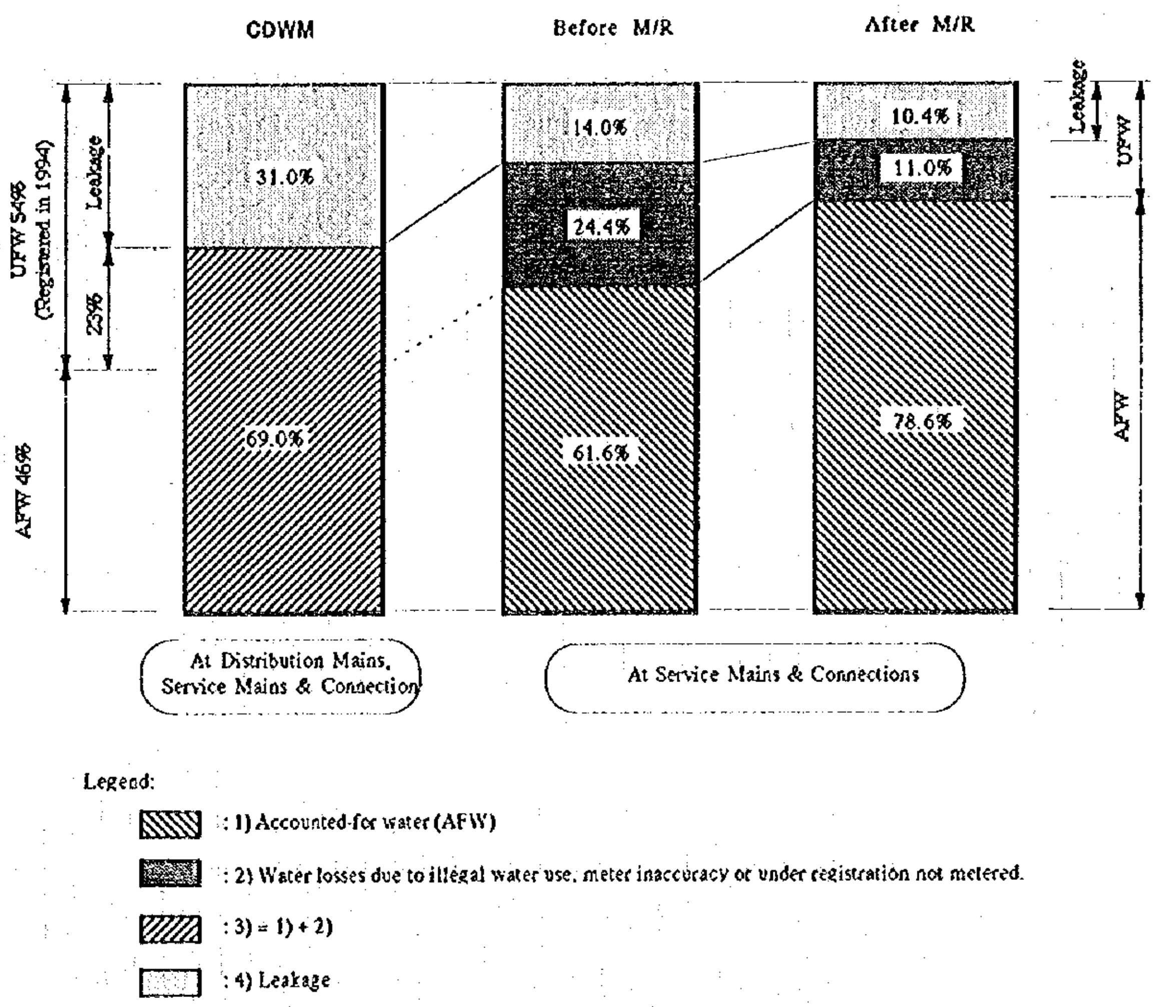
As for Ghourieyeh area, UFW survey was not successful due to air bubble in the water. One out of three ultrasonic flow meters installed recorded extremely large flow rate. Measurement was made several times but all were in vain.

Residents in Sukhna area, due to insufficient diameter of 100mm main, cannot receive water on continuous basis. Efforts made by WAJ Zarqa to supply water incessantly before initiation of the UFW survey could not overcome this situation. Most storage roof tanks in the survey area could not be saturated. This may be understood from the survey results that the flow rate in the night time exceeded that of the daytime flow and any minimum night flow was not observed. The UFW ratio obtained, however, suggests a large percentage of leakage and water losses are occurring from its old deteriorated pipe works.

Unaccounted-for water ratio in Awajan area decreased from 27% to 20% by meter replacement. On the other hand, leakage ratio stands almost constant rate of 20%. This implies major component (20%) of UFW is leakage and the remaining 7% is water losses due to meter inaccuracy and tampering by customers.

In addition to the above, UFW and leakage ratios in all areas are averaged to overview major components of water losses at distribution mains, service mains and house connections. Figure below illustrates the averaged UFW and leakage ratios obtained. In computing these averaged figures, pressure difference between the areas is not taken into consideration.

## AVERAGED UFW RATIO



The above figure may suggest an accuracy of the survey. Leakage ratio (31%) at pipe network plus other water losses (24.4%) related to customer meters are well consistent with the average UFW ratio 54% of WAJ records in 1994.

It also demonstrates that around 30% of supplied water is a leakage from pipe works including distribution, service mains and house connections. Form the leakage ratio (14.0%) obtained through meter replacement method, a half of them may be taking place at large diameter distribution mains and the remaining half at small service mains and house connections. Physical leakage from the house meters stands merely 5% from the figures obtained after meter replacement. Water losses due to illegal water use, meter inaccuracy etc., however, are significantly large, around 25% - 30%.

## 7. RECOMMENDATIONS

The UFW survey suggests that the characteristicsof each pipes and hydraulic conditions may be decisive factors of the leakage amount. It also suggests that water losses related to customer meters are not negligible. Major causes of these water losses and leakage are attributable to 1) the old deteriorated pipe lines in service under high water pressure, 2) illegal water use, 3) under-registration or meter inaccuracy From these results, it is recommended to take immediate actions for pipe rehabilitationor leakage control as follows:

1) to replace the pipe network laid in 1960's

As seen in Ghourieyeh pilot area, a large amount of water is wasted as leakage from the distribution mains. They are all installed in 1960's and still in service under high water pressure. The old deteriorated pipe network established in 1960's particularly at Zarqa municipal center and Rusaifa old township will require a full scale rehabilitation, preferably by replacement.

2) to repair/replace service mains and service pipelines

Although leak from smaller diameter pipelines is not major, some of them which have not been maintained in an appropriate condition since its installation in 1960's showed relatively large amount of the leakage. Such old and small diameter pipes as in Awajan and Sukhna are recommended to be replaced.

3) to install and replace customer meters

It is observed during the survey that many customer meters are installed on inner floors /walls of their houses. To avoid customers' access to the meters, it is recommended to remove and install them on their premises/yards with meter boxes. Old house connections installed in 1960's which are left unrepaired will also require immediate replacement.

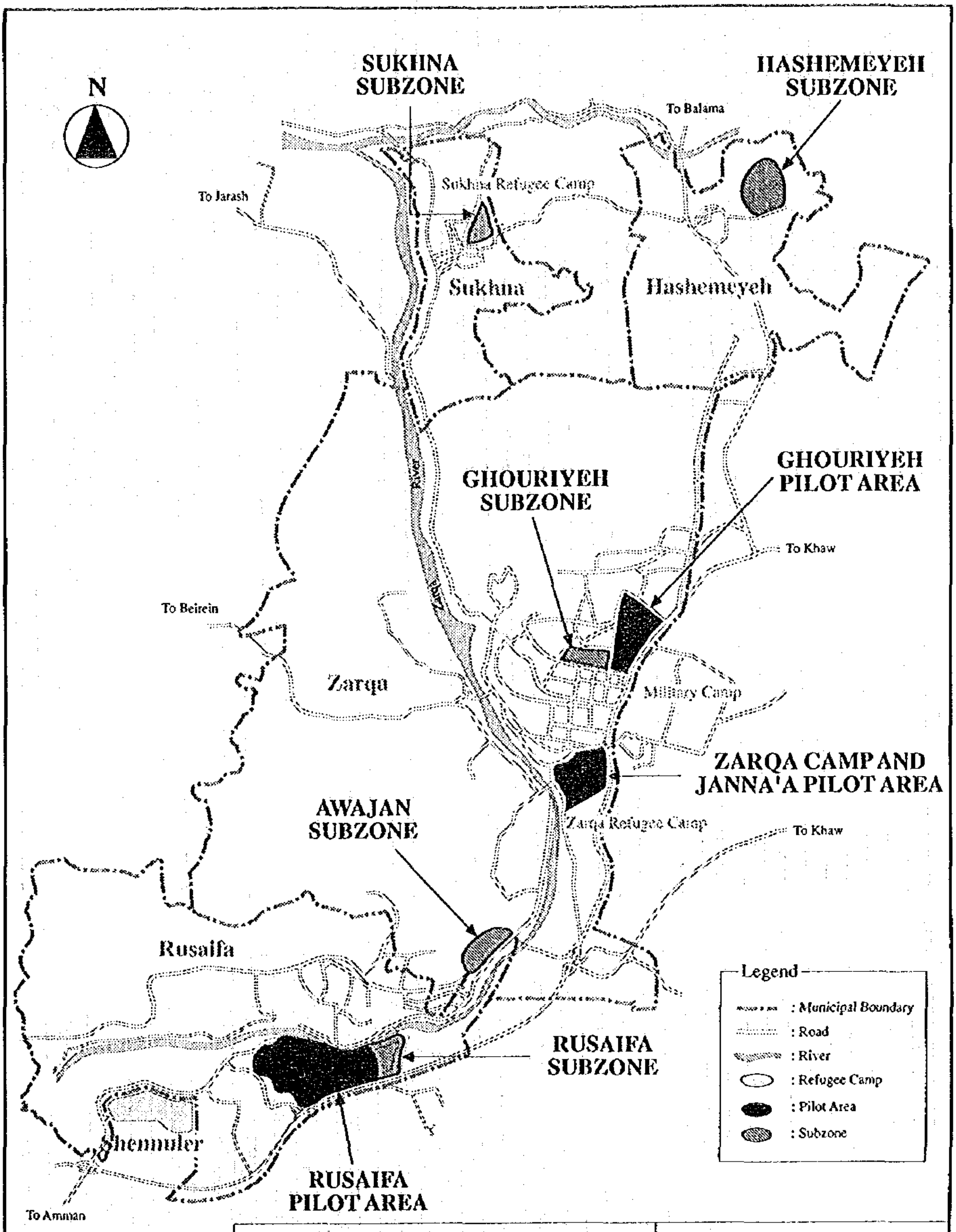
4) to conduct positive leak detection on routine basis by establishing district metering areas

Since the leakage from the relatively new pipelines is not major component, it is considered more effective to maintain such pipe works in appropriate conditions than to replace/install new pipelines. To attain this purpose, positive leak control at all pipe works shall be exercised on an routine basis. Further, early establishment of district metering areas in the service area is effective to obtain information on which areas shall have priority.

5) to improve meter reading practice of WAJ Zarqa and strengthen staffing and organization for meter reading, accounting and billing procedures.

An absence of meter reading records in WAJ (quaterly consumption data merely available) may suggest some possibility of inaccurate meter reading. It is urgent to reorganize meter reading procedures into normal ones applied worldwide. Staffing for metering and billing, as described in Supporting Report - L Organization and Operation & Maintenance Plan, will require a drastic change in number and organization. Further, the current slightly obscure billing zones shall be readjusted in accordance with the distribution zones and/or district metering zones to be established under Stage I Project.

# Figures

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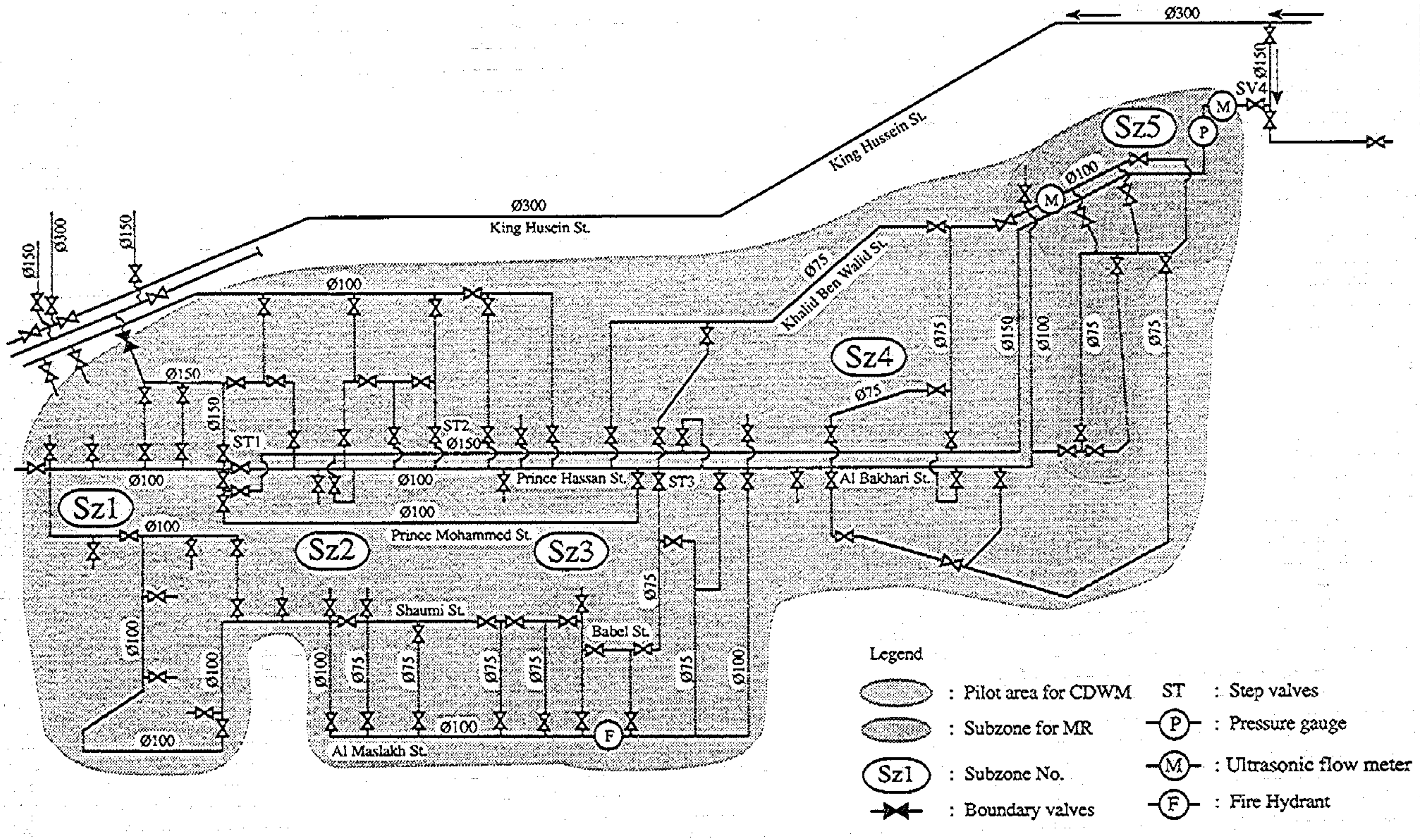
| THE STUDY ON<br>THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM<br>FOR THE ZARQA DISTRICT | Fig.- H1<br><br>UFW SURVEY AREA |
| JAPAN INTERNATIONAL COOPERATION AGENCY | |

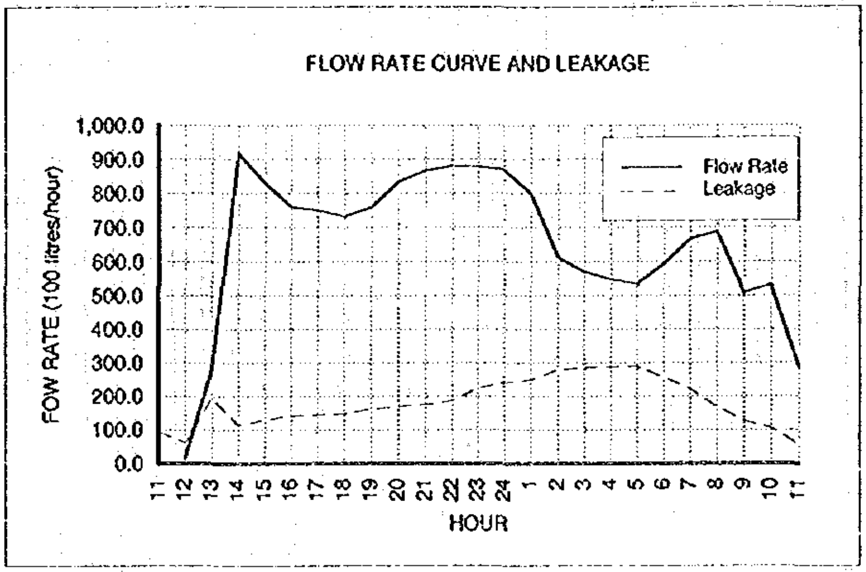



THE STUDY ON
THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM
FOR THE ZARQA DISTRICT

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.- H2
SCHEMATIC PIPE
NETWORK IN RUSAIFA

Fig. - H3 FLOW CURVE AT RUSAIFA PILOT AREA (22 - 23 March, 1995)




| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (kg/cm2) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Mar. 22 | 11 : 00 | 3,333.0 | | 6.0 | 20.5 | 93.9 |
| | 12 : 00 | 3,347.0 | 14.0 | 5.4 | 14.5 | 62.0 |
| | 13 : 00 | 3,624.0 | 277.0 | 7.7 | 36.2 | 193.9 |
| | 14 : 00 | 4,540.0 | 916.0 | 7.8 | 24.1 | 114.5 |
| | 15 : 00 | 5,369.0 | 829.0 | 7.8 | 26.7 | 130.4 |
| | 16 : 00 | 6,128.0 | 759.0 | 7.8 | 28.6 | 142.4 |
| | 17 : 00 | 6,877.0 | 749.0 | 7.8 | 28.9 | 144.1 |
| | 18 : 00 | 7,609.0 | 732.0 | 7.8 | 29.3 | 146.9 |
| | 19 : 00 | 8,367.0 | 758.0 | 8.1 | 31.6 | 162.3 |
| | 20 : 00 | 9,200.0 | 833.0 | 8.4 | 32.6 | 168.7 |
| | 21 : 00 | 10,067.0 | 867.0 | 8.6 | 33.6 | 175.6 |
| | 22 : 00 | 10,947.0 | 880.0 | 8.8 | 35.2 | 186.8 |
| | 23 : 00 | 11,825.0 | 878.0 | 9.3 | 40.2 | 223.8 |
| | 24 : 00 | 12,695.0 | 870.0 | 9.5 | 42.5 | 241.0 |
| Mar. 23 | 1 : 00 | 13,494.0 | 799.0 | 9.4 | 43.5 | 249.2 |
| | 2 : 00 | 14,106.0 | 612.0 | 9.3 | 47.1 | 277.7 |
| | 3 : 00 | 14,676.0 | 570.0 | 9.3 | 47.9 | 284.8 |
| | 4 : 00 | 15,224.0 | 548.0 | 9.3 | 48.3 | 288.4 |
| | 5 : 00 | 15,760.0 | 536.0 | 9.3 | 48.6 | 290.2 |
| | 6 : 00 | 16,352.0 | 592.0 | 9.0 | 44.5 | 256.7 |
| | 7 : 00 | 17,017.0 | 665.0 | 8.7 | 39.9 | 221.2 |
| | 8 : 00 | 17,702.0 | 685.0 | 8.0 | 32.4 | 167.8 |
| | 9 : 00 | 18,210.0 | 508.0 | 7.0 | 26.1 | 126.6 |
| | 10 : 00 | 18,741.0 | 531.0 | 6.7 | 22.7 | 106.1 |
| | 11 : 00 | 19,028.0 | 287.0 | 5.4 | 13.1 | 55.1 |
| | | Total= | 15,695.0 | 202.2 | | 4,510.3 |
| | | | | | Leakage(%)= | 28.7 |

Adjustd Ave. Zone Pressure = P'= Gr. Level at Gauge+P*10-Ave. Gr. Level of the Zone-0.0000172*Flow*Flow
Leakage Estimate = (0.5*P'+0.007*P'*P')/(0.5*AP+0.007*AP*AP)*(F0-F1)

Where: Gr.Level at Gauge (m) = 608m
Ave.Gr.Level of Zone (m) = 647.5 m
AP = Ave. Zone Pressure = 45.7 m
F0 = Min. Night Flow(100lit/hr) = 295 x 100 litres/hour
F1 = Min. Night Usage(100lit/hr/Subzone)=1.21(lit/hr/Subscriber)*(# of Subscribers)/100
F0 - F1 = Leakage

Reference: WRD Leakage Report "G", P27

Fig. - H4 (1) FLOW RATE CURVE AND LEAKAGE (RUSAIFA SUBZONE)

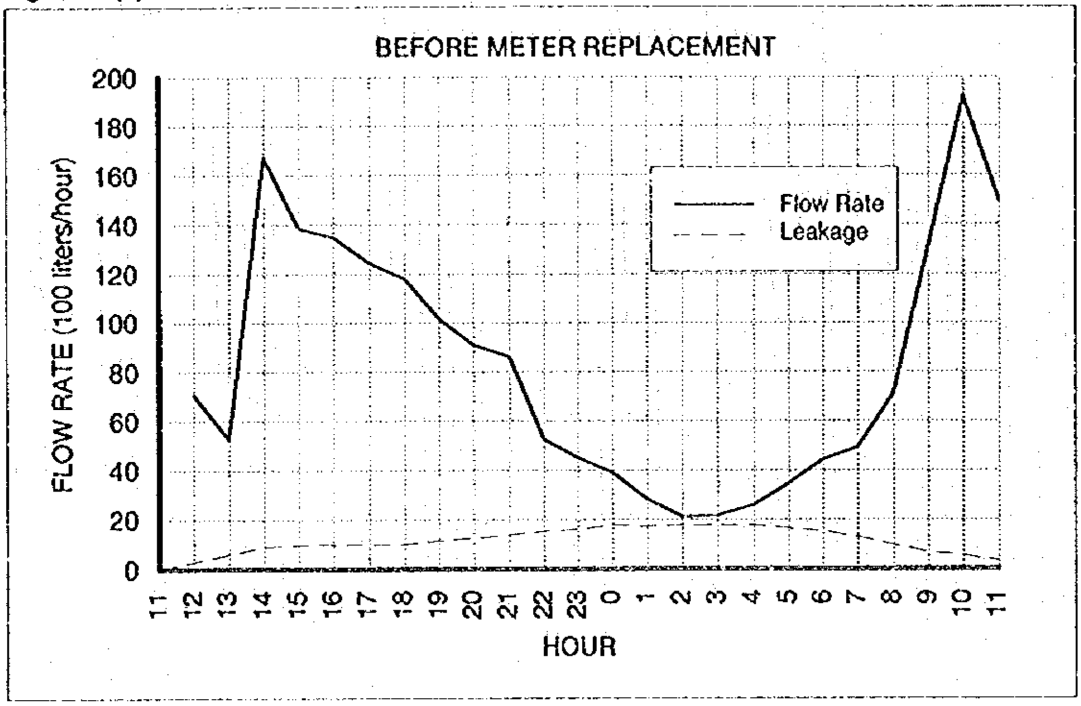
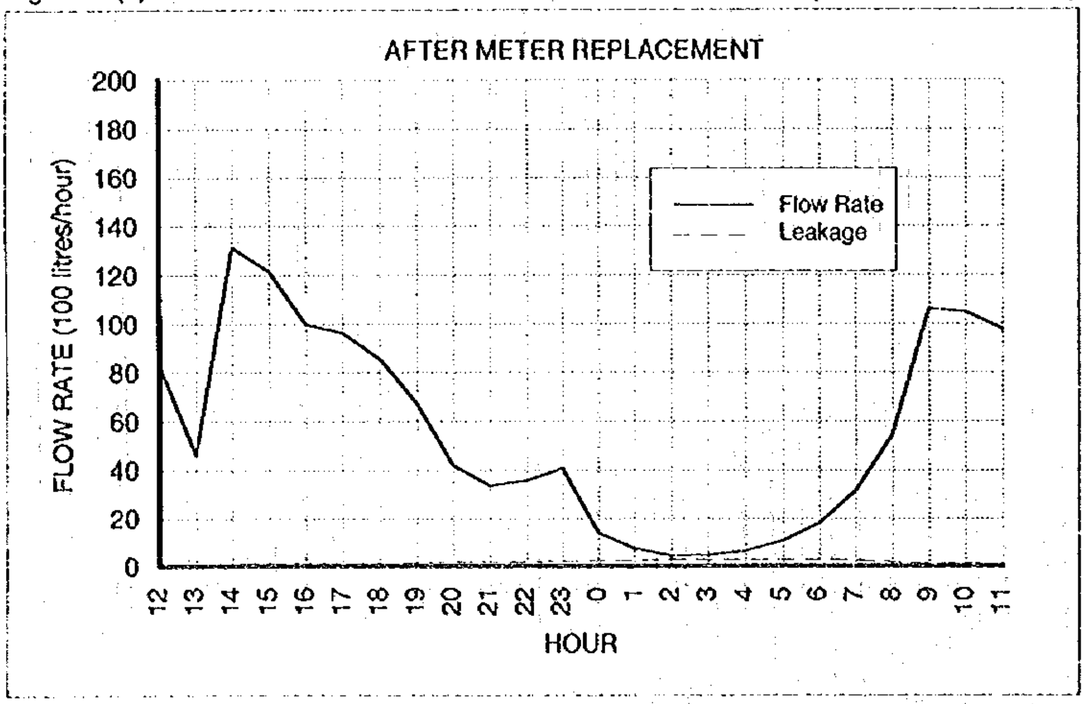
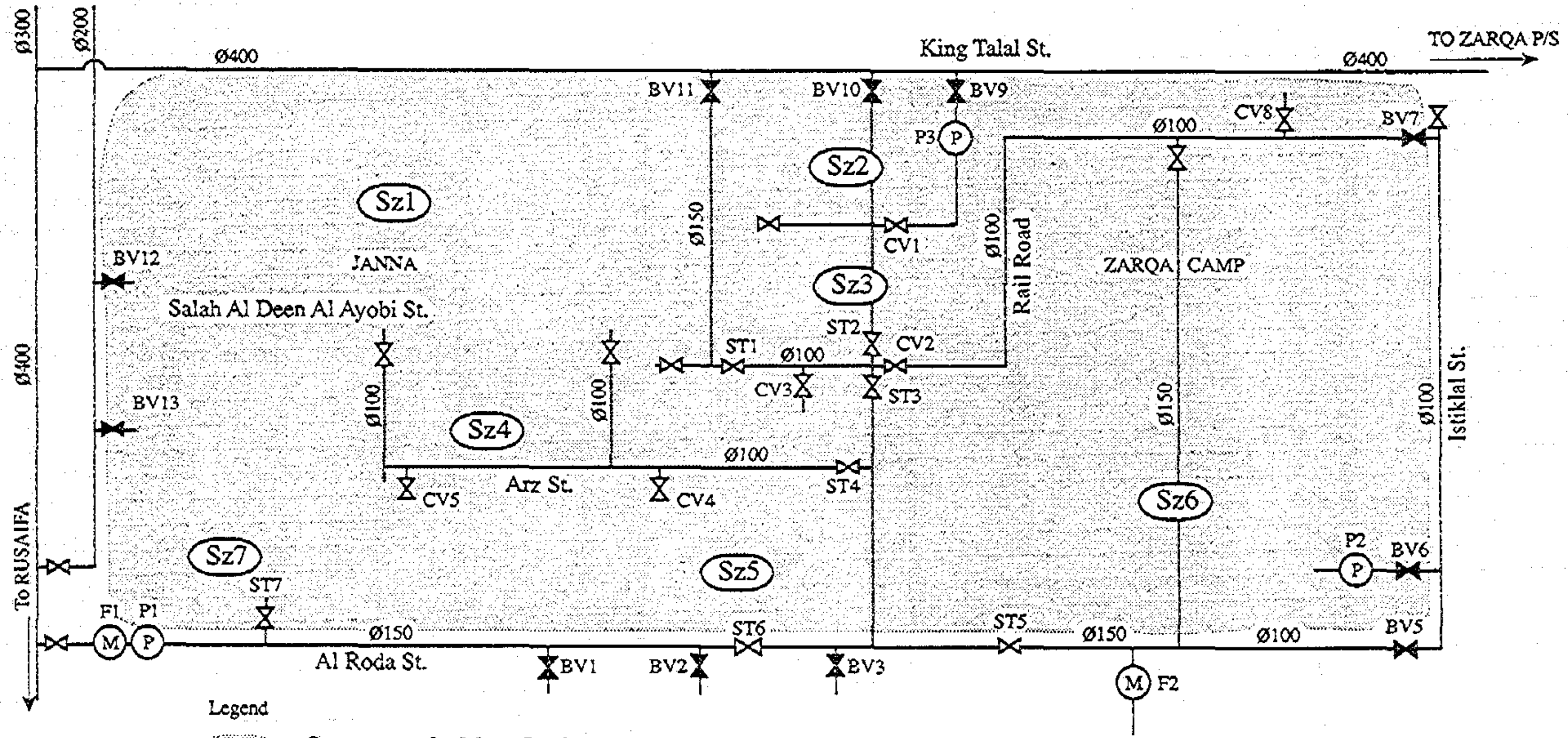



Fig. - H4 (2) FLOW RATE CURVE AND LEAKAGE (RUSAIFA SUBZONE)






Legend

- : Survey area for Meter Replacment
- Sz1 : Subzone No.
- : Boundary valves (1~7)
- ST : Step valves (1~8B)
- CV : Control valves (1~4)
- P : Pressure gauge (1)
- M : Ultrasonic flow meter (1~3)

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| THE STUDY ON<br>THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM<br>FOR THE ZARQA DISTRICT | Fig.- H5<br>SCHEMATIC PIPE NETWORK<br>IN ZARQA CAMP & JANNA<br>PILOT AREA |
| JAPAN INTERNATIONAL COOPERATION AGENCY | |

Fig.- H6 NIGHT USAGE IN ZARQA CAMP & JANNA
(at 22 subscribers) (Date: 1 August, 1995)

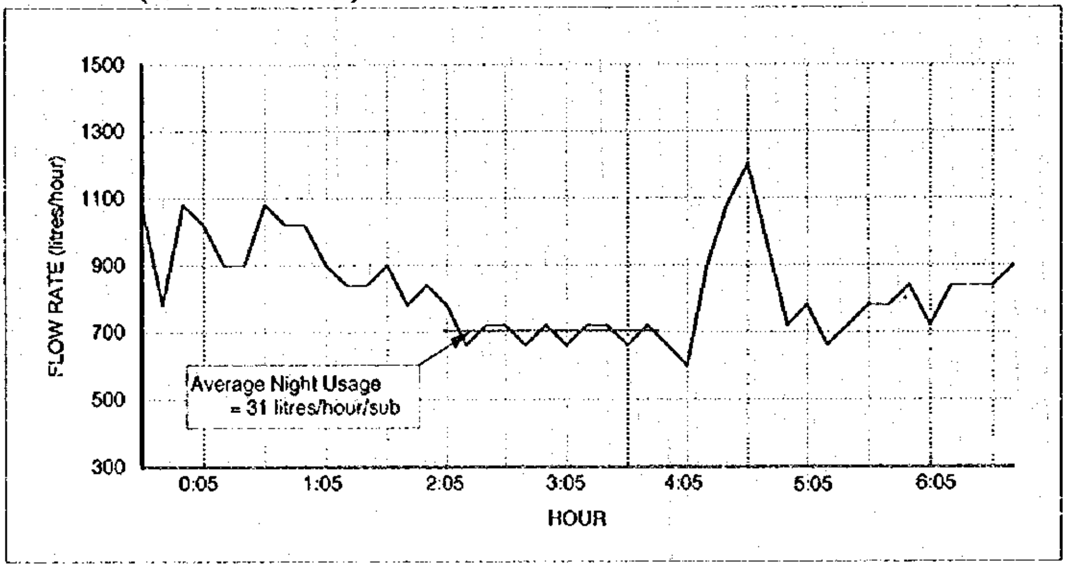



Fig.- H7 AVERAGE NIGHT FLOW IN ZARQA CAMP & JANNA
(Date: 29-30 July, 1995)

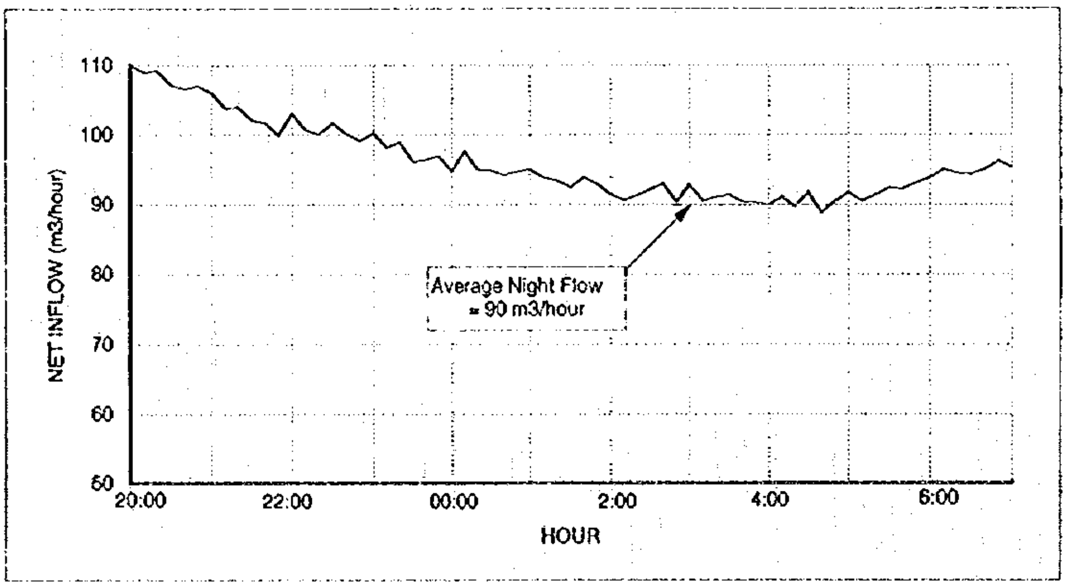
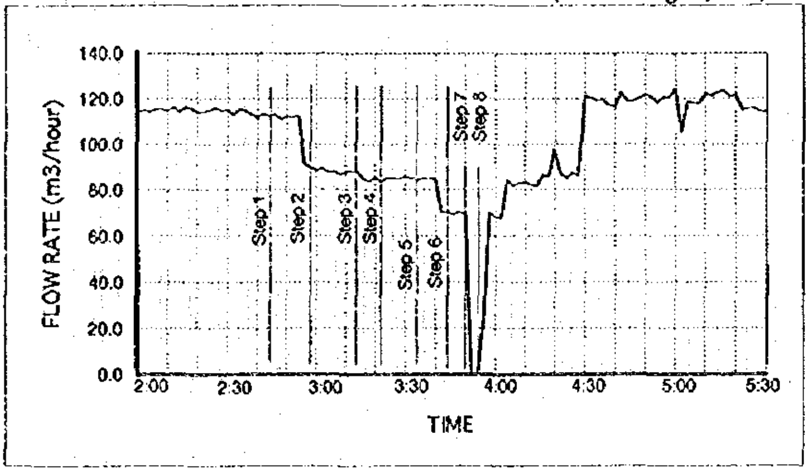


Fig.- H8 STEP TEST AT ZARQA CAMP & JANNA

(Date: 2 August,1995)




| HOUR | FLOW RATE (m3/hour) |
|---|---|
| 2 : 00 | 114.4 |
| 2 : 02 | 114.9 |
| 2 : 04 | 114.4 |
| 2 : 06 | 115.3 |
| 2 : 08 | 115.3 |
| 2 : 10 | 114.7 |
| 2 : 12 | 115.8 |
| 2 : 14 | 114.4 |
| 2 : 16 | 116.1 |
| 2 : 18 | 115.7 |
| 2 : 20 | 114.1 |
| 2 : 22 | 114.2 |
| 2 : 24 | 115.0 |
| 2 : 26 | 115.7 |
| 2 : 28 | 114.7 |
| 2 : 30 | 115.2 |
| 2 : 32 | 113.1 |
| 2 : 34 | 115.3 |
| 2 : 36 | 114.7 |
| 2 : 38 | 113.1 |
| 2 : 40 | 112.0 |
| 2 : 42 | 113.1 |
| 2 : 44 | 112.5 |
| 2 : 46 | 112.8 |
| 2 : 48 | 111.1 |
| 2 : 50 | 112.0 |
| 2 : 52 | 111.9 |
| 2 : 54 | 112.2 |
| 2 : 56 | 91.3 |
| 2 : 58 | 89.8 |
| 3 : 00 | 88.6 |
| 3 : 02 | 89.1 |
| 3 : 04 | 87.8 |
| 3 : 06 | 87.8 |
| 3 : 08 | 86.9 |
| 3 : 10 | 87.6 |
| 3 : 12 | 88.0 |
| 3 : 14 | 88.1 |
| 3 : 16 | 84.6 |
| 3 : 18 | 83.8 |
| 3 : 20 | 85.3 |
| 3 : 22 | 83.8 |
| 3 : 24 | 85.0 |
| 3 : 26 | 85.0 |
| 3 : 28 | 85.0 |

| HOUR | FLOW RATE (m3/hour) |
|---|---|
| 3 : 30 | 85.3 |
| 3 : 32 | 85.0 |
| 3 : 34 | 84.4 |
| 3 : 36 | 85.0 |
| 3 : 38 | 84.7 |
| 3 : 40 | 84.7 |
| 3 : 42 | 70.1 |
| 3 : 44 | 70.1 |
| 3 : 46 | 69.3 |
| 3 : 48 | 69.9 |
| 3 : 50 | 69.3 |
| 3 : 52 | 0.0 |
| 3 : 54 | 0.0 |
| 3 : 56 | 21.9 |
| 3 : 58 | 69.4 |
| 4 : 00 | 68.2 |
| 4 : 02 | 67.9 |
| 4 : 04 | 83.9 |
| 4 : 06 | 82.0 |
| 4 : 08 | 82.8 |
| 4 : 10 | 83.1 |
| 4 : 12 | 82.3 |
| 4 : 14 | 81.7 |
| 4 : 16 | 86.3 |
| 4 : 18 | 85.8 |
| 4 : 20 | 97.2 |
| 4 : 22 | 86.9 |
| 4 : 24 | 85.1 |
| 4 : 26 | 87.1 |
| 4 : 28 | 86.4 |
| 4 : 30 | 120.8 |
| 4 : 32 | 120.1 |
| 4 : 34 | 119.3 |
| 4 : 36 | 119.4 |
| 4 : 38 | 117.1 |
| 4 : 40 | 116.5 |
| 4 : 42 | 122.6 |
| 4 : 44 | 118.9 |
| 4 : 46 | 118.9 |
| 4 : 48 | 120.1 |
| 4 : 50 | 121.2 |
| 4 : 52 | 120.8 |
| 4 : 54 | 118.3 |
| 4 : 56 | 120.5 |
| 4 : 58 | 120.6 |

| HOUR | FLOW RATE (m3/hour) |
|---|---|
| 5 : 00 | 123.9 |
| 5 : 02 | 105.5 |
| 5 : 04 | 118.6 |
| 5 : 06 | 118.0 |
| 5 : 08 | 118.0 |
| 5 : 10 | 121.7 |
| 5 : 12 | 121.3 |
| 5 : 14 | 122.6 |
| 5 : 16 | 123.3 |
| 5 : 18 | 120.8 |
| 5 : 20 | 121.4 |
| 5 : 22 | 115.2 |
| 5 : 24 | 115.7 |
| 5 : 26 | 115.6 |
| 5 : 28 | 114.4 |
| 5 : 30 | 114.2 |

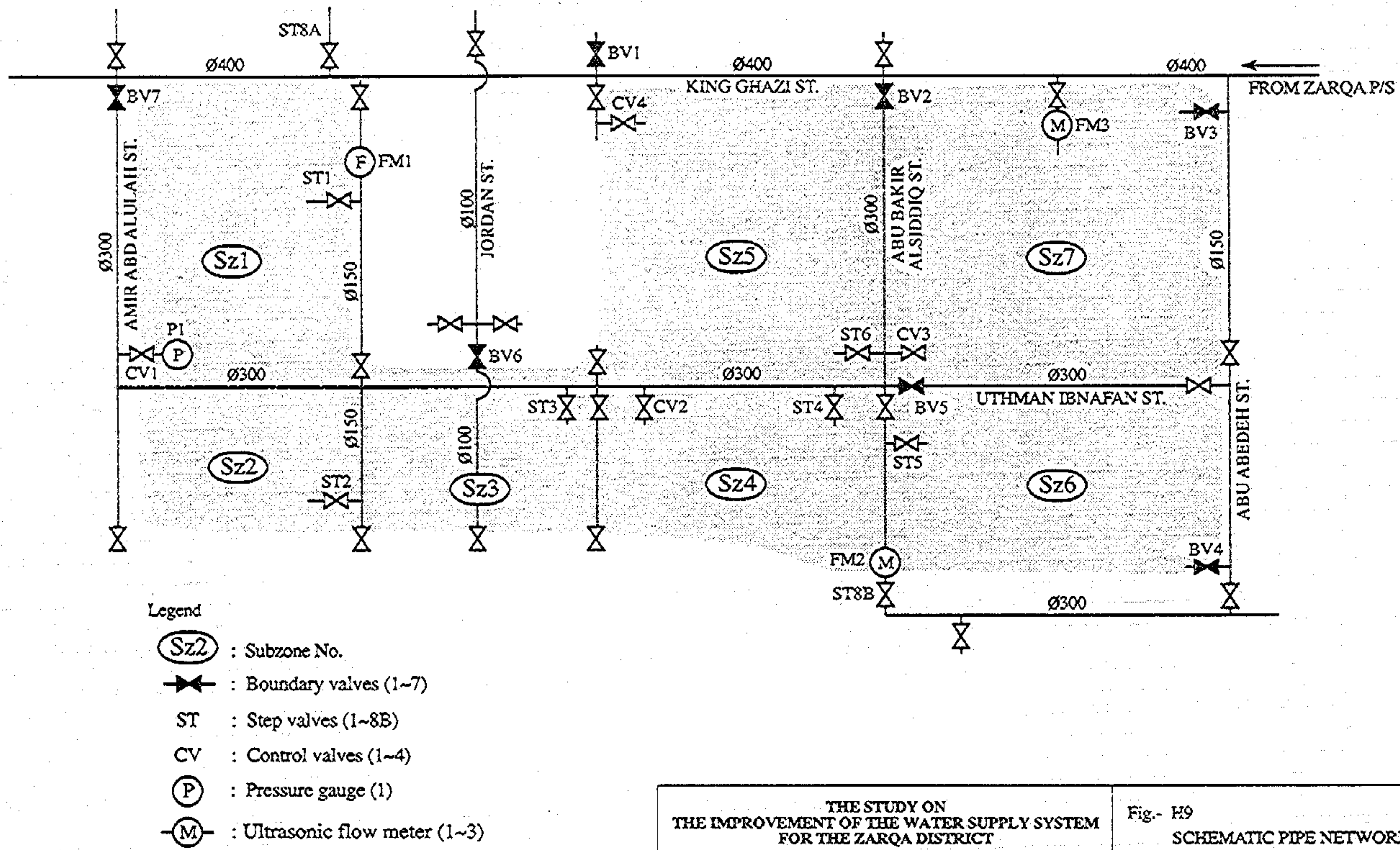



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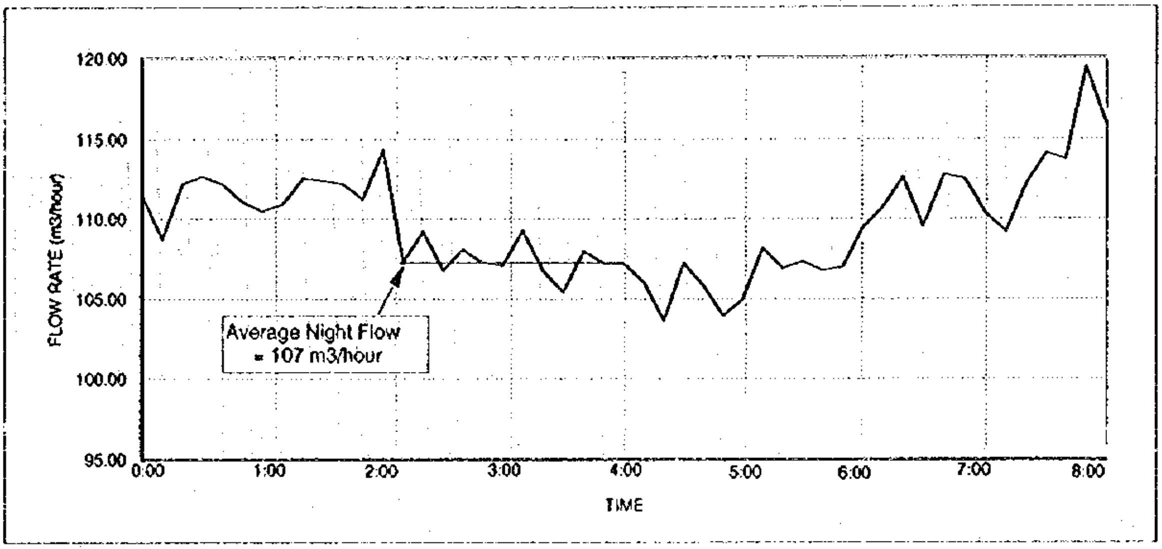
Fig.- H9
SCHEMATIC PIPE NETWORK
IN GHOURIEYEH PILOTAREA

## Fig.- H10 NIGHT TIME FLOW AT GHOURIEYEH PILOT AREA (1)

(Date: 30 August 1995)




## Fig.- H11 NIGHT TIME FLOW FOR GHOURIEYEH PILOT AREA (2)

(Date: 4 September,1995)

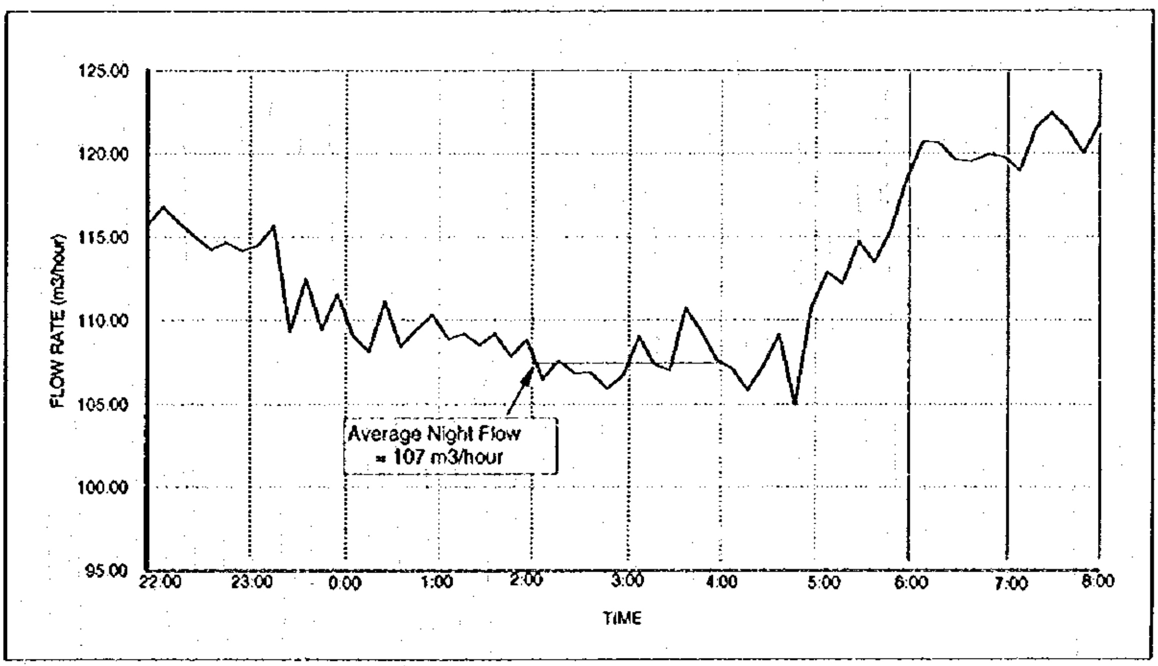
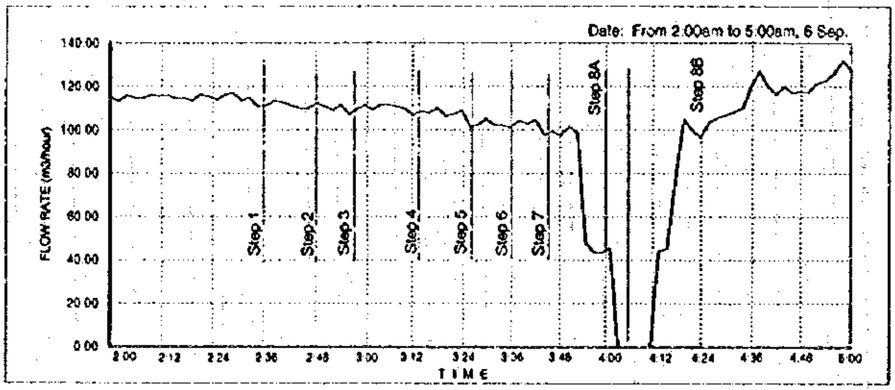
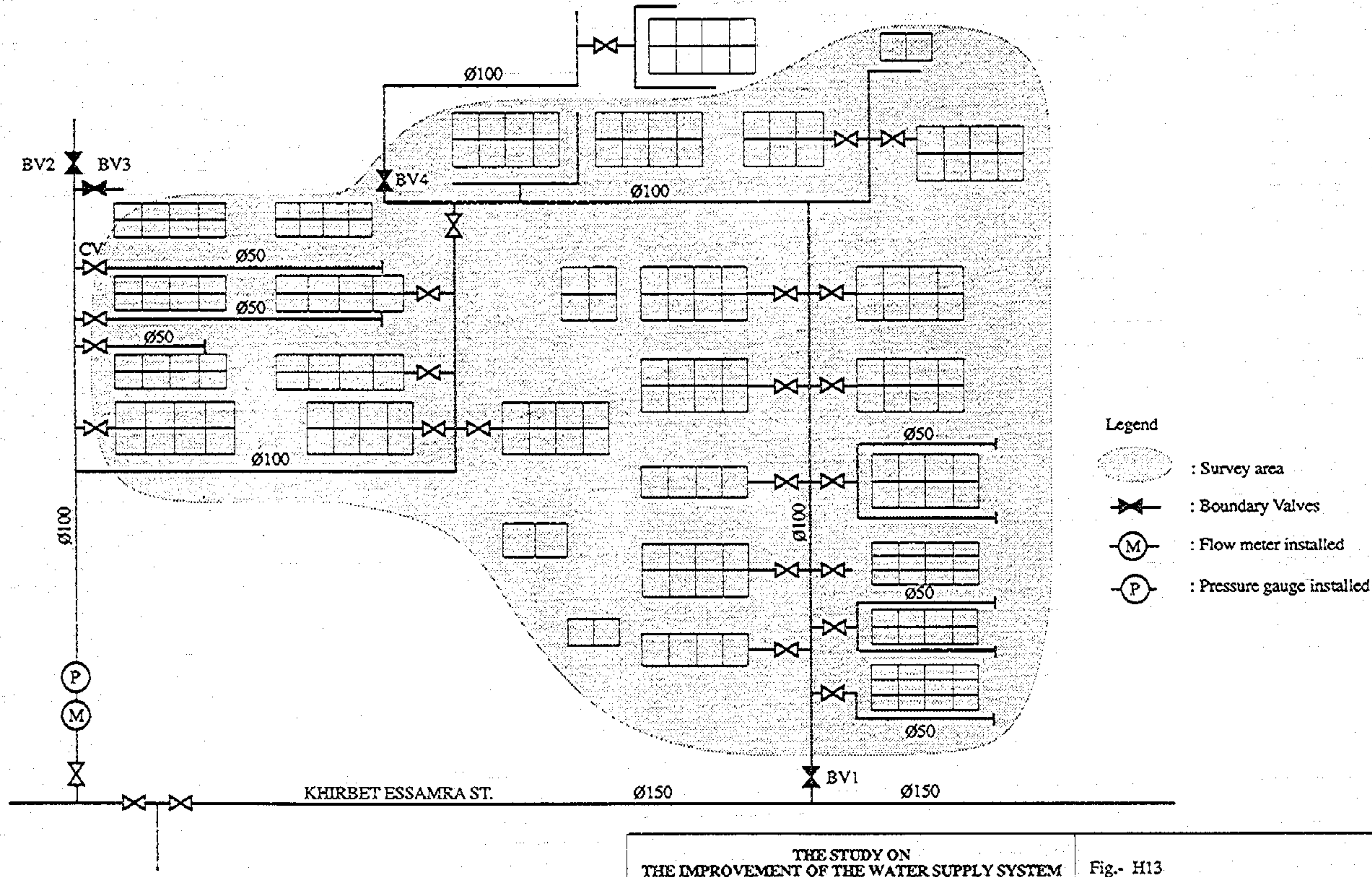


Fig.- H12 STEP TEST AT GHOURIBEYEH PILOT AREA
on 6 September 1995

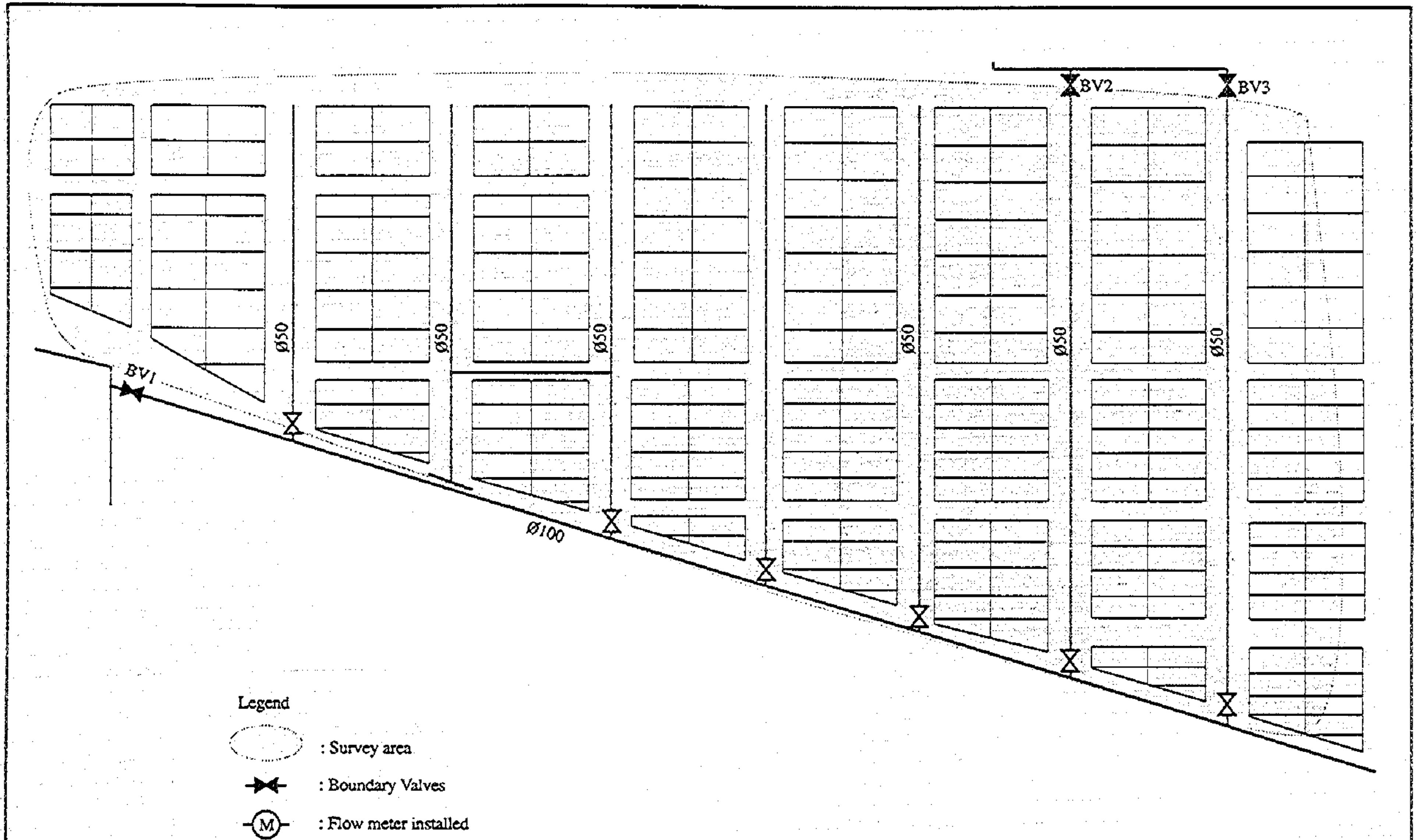



## DATA FOR STEP TEST

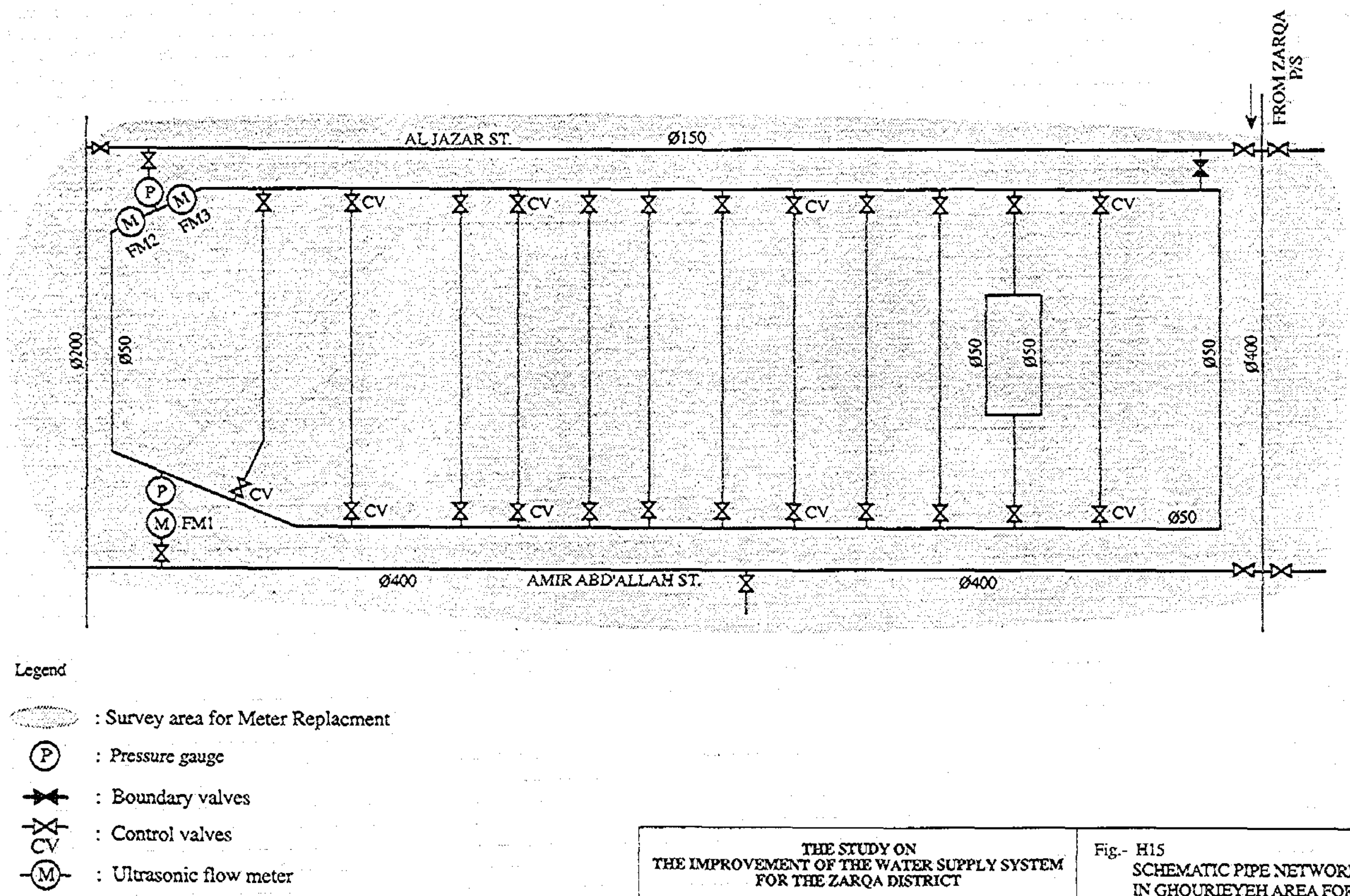
| Time | Flow Rate m3/hr FM I | FM II | FM III | Total Flow Rate m3/hr |
|---|---|---|---|---|
| 2:00 | 56.60 | 51.40 | 6.73 | 114.73 |
| :02 | 55.00 | 51.70 | 6.64 | 113.34 |
| :04 | 55.90 | 53.00 | 6.70 | 115.60 |
| :06 | 56.10 | 51.70 | 6.88 | 114.68 |
| :08 | 55.90 | 52.00 | 6.65 | 114.55 |
| :10 | 56.90 | 52.10 | 6.83 | 115.83 |
| :12 | 55.50 | 53.50 | 6.55 | 115.55 |
| :14 | 55.20 | 53.90 | 6.57 | 115.67 |
| :16 | 56.10 | 51.80 | 6.59 | 114.49 |
| :18 | 55.10 | 52.50 | 6.83 | 114.43 |
| :20 | 56.00 | 50.80 | 6.67 | 113.47 |
| :22 | 55.70 | 53.90 | 6.49 | 116.09 |
| :24 | 56.60 | 52.20 | 6.48 | 115.28 |
| :26 | 52.10 | 52.10 | 6.48 | 113.93 |
| :28 | 56.10 | 53.80 | 6.12 | 116.02 |
| :30 | 57.10 | 53.70 | 5.90 | 116.70 |
| :32 | 55.40 | 52.20 | 6.00 | 113.60 |
| :34 | 56.40 | 51.70 | 6.28 | 114.38 |
| :36 | 52.50 | 52.20 | 6.00 | 110.70 |
| :38 | 52.30 | 52.40 | 6.36 | 111.06 |
| :40 | 53.60 | 53.40 | 6.19 | 113.19 |
| :42 | 52.70 | 53.70 | 6.15 | 112.55 |
| :44 | 51.50 | 53.50 | 6.05 | 111.05 |
| :46 | 51.70 | 52.10 | 6.03 | 109.83 |
| :48 | 51.40 | 52.00 | 6.31 | 109.71 |
| :50 | 52.30 | 53.90 | 5.82 | 112.02 |
| :52 | 52.50 | 52.20 | 5.88 | 110.58 |
| :54 | 51.90 | 51.40 | 5.76 | 109.06 |
| :56 | 51.10 | 54.70 | 5.47 | 111.27 |
| :58 | 51.50 | 50.10 | 5.38 | 106.98 |
| 3:00 | 51.90 | 51.70 | 5.85 | 109.46 |
| :02 | 51.20 | 54.30 | 5.27 | 111.07 |
| :04 | 51.80 | 51.80 | 5.63 | 109.23 |
| :06 | 51.30 | 54.20 | 5.85 | 111.35 |
| :08 | 51.10 | 54.40 | 5.78 | 111.28 |
| :10 | 51.00 | 53.90 | 5.77 | 110.67 |
| :12 | 52.50 | 51.40 | 5.70 | 109.60 |
| :14 | 51.70 | 49.70 | 5.45 | 106.85 |
| :16 | 52.10 | 50.40 | 5.81 | 108.31 |
| :18 | 52.30 | 50.00 | 5.54 | 107.84 |
| :20 | 51.40 | 52.90 | 5.40 | 109.70 |
| :22 | 49.60 | 51.30 | 5.40 | 106.30 |
| :24 | 50.90 | 50.90 | 5.28 | 107.08 |
| :26 | 51.40 | 51.60 | 5.70 | 108.70 |
| :28 | 51.40 | 44.40 | 5.72 | 101.52 |
| :32 | 52.70 | 47.00 | 5.16 | 104.86 |
| :34 | 51.10 | 45.80 | 5.23 | 102.13 |
| :36 | 52.70 | 43.90 | 5.34 | 101.94 |
| :38 | 52.00 | 44.10 | 5.13 | 101.23 |
| :40 | 54.00 | 44.00 | 5.79 | 103.79 |
| :42 | 53.90 | 43.50 | 5.51 | 102.91 |
| :44 | 55.20 | 43.90 | 5.28 | 104.38 |
| :46 | 54.50 | 43.30 | 0.00 | 97.80 |
| :48 | 54.90 | 44.10 | 0.00 | 99.00 |
| :50 | 53.40 | 44.30 | 0.00 | 97.70 |
| :52 | 56.70 | 44.40 | 0.00 | 101.10 |
| :54 | 54.90 | 43.90 | 0.00 | 98.80 |
| :56 | 3.70 | 44.50 | 0.00 | 48.20 |
| :58 | 0.00 | 43.50 | 0.00 | 43.50 |
| 4.00 | 0.00 | 43.30 | 0.00 | 43.30 |
| :02 | 0.00 | 45.20 | 0.00 | 45.20 |
| :04 | 0.00 | 0.00 | 0.00 | 0.00 |
| :06 | 0.00 | 0.00 | 0.00 | 0.00 |
| :08 | 0.00 | 0.00 | 0.00 | 0.00 |
| :10 | 0.00 | 0.00 | 0.00 | 0.00 |
| :12 | 0.00 | 0.00 | 0.00 | 0.00 |
| :14 | 0.00 | 44.18 | 0.00 | 44.10 |
| :16 | 0.00 | 44.90 | 0.00 | 44.90 |
| :18 | 35.80 | 41.60 | 0.00 | 77.40 |
| :20 | 60.10 | 44.40 | 0.00 | 104.50 |
| :22 | 56.60 | 43.10 | 0.00 | 99.70 |
| :24 | 54.40 | 42.20 | 0.00 | 96.60 |
| :26 | 54.40 | 42.90 | 6.17 | 103.47 |
| :28 | 54.50 | 45.00 | 6.00 | 105.50 |
| :30 | 53.70 | 47.10 | 5.85 | 106.65 |
| :32 | 54.40 | 47.90 | 5.91 | 108.21 |
| :34 | 55.40 | 48.60 | 6.05 | 110.05 |
| :36 | 53.90 | 60.30 | 5.99 | 120.19 |
| :38 | 55.10 | 65.00 | 6.76 | 126.86 |
| :40 | 54.40 | 59.10 | 6.35 | 119.85 |
| :42 | 54.10 | 55.90 | 6.37 | 116.37 |
| :44 | 54.50 | 58.50 | 6.61 | 119.61 |
| :46 | 54.40 | 56.40 | 6.26 | 117.06 |
| :48 | 54.00 | 57.20 | 6.22 | 117.42 |
| :50 | 54.50 | 55.90 | 6.80 | 117.20 |
| :52 | 57.80 | 57.40 | 6.13 | 121.33 |
| :54 | 56.90 | 59.30 | 6.27 | 122.47 |
| :56 | 60.70 | 58.40 | 6.86 | 125.96 |
| :58 | 68.30 | 57.20 | 6.24 | 131.74 |
| 5:00 | 65.30 | 55.90 | 6.54 | 127.74 |




| THE STUDY ON<br>THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM<br>FOR THE ZARQA DISTRICT | Fig.- H13<br>SCHEMATIC PIPE NETWORK<br>IN HASHEMEYEH |
|---|---|
| JAPAN INTERNATIONAL COOPERATION AGENCY | |




| | |
|---|---|
| THE STUDY ON<br>THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM<br>FOR THE ZARQA DISTRICT | Fig.- H14<br>SCHEMATIC PIPE NETWORK<br>IN SUKHNA AREA FOR<br>METER REPLACEMENT |
| JAPAN INTERNATIONAL COOPERATION AGENCY | |




THE STUDY ON
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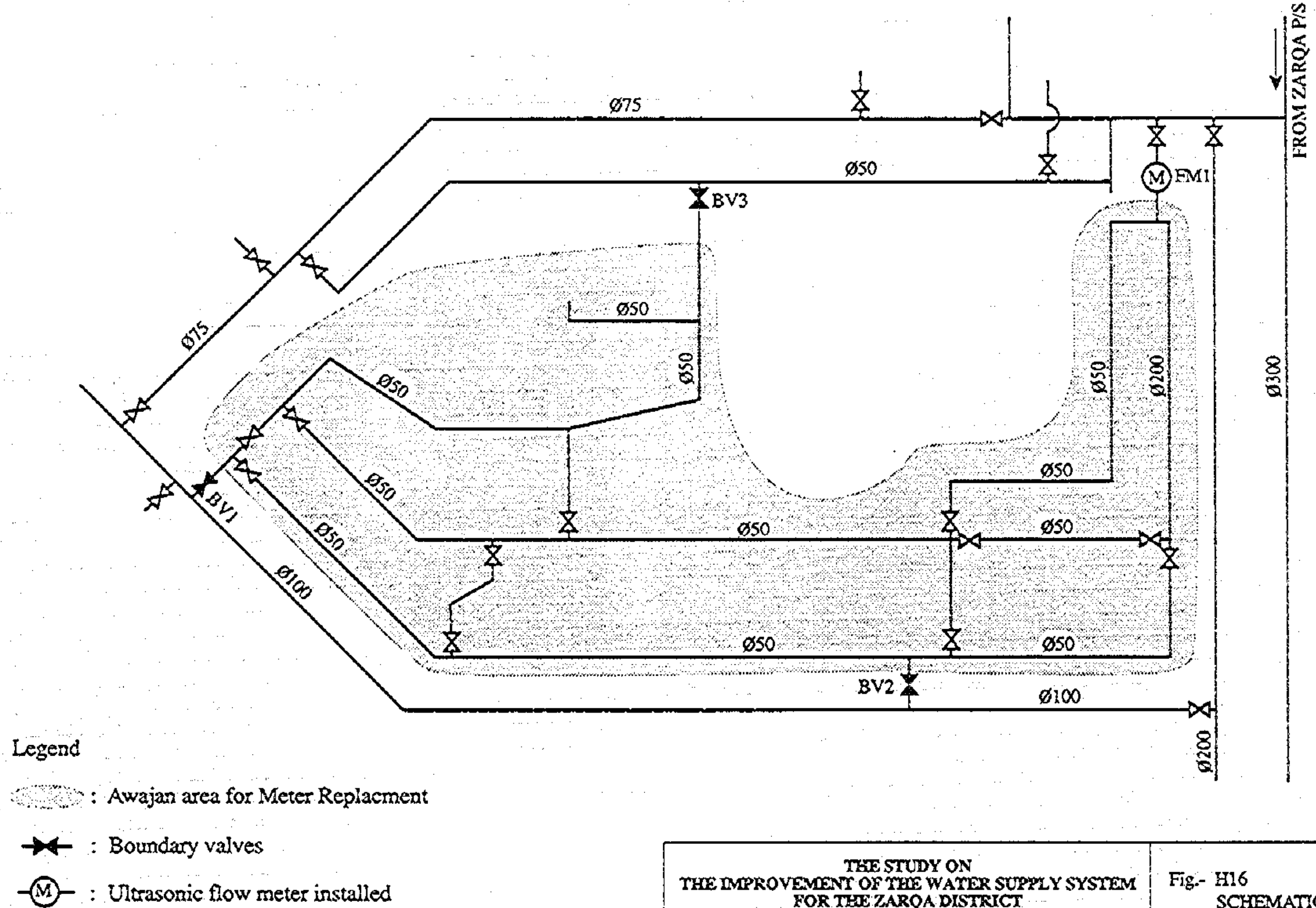
FOR THE ZARQA DISTRICT

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.- H15
SCHEMATIC PIPE NETWORK IN GHOURIEYEH AREA FOR METER REPLACMENT

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FOR THE ZARQA DISTRICT

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.- H16
SCHEMATIC PIPE NETWORK
IN AWAJAN AREA

Fig.- H17 (1) FLOW RATE CURVE AND LEAKAGE (HASHEMEYEH SUBZONE)

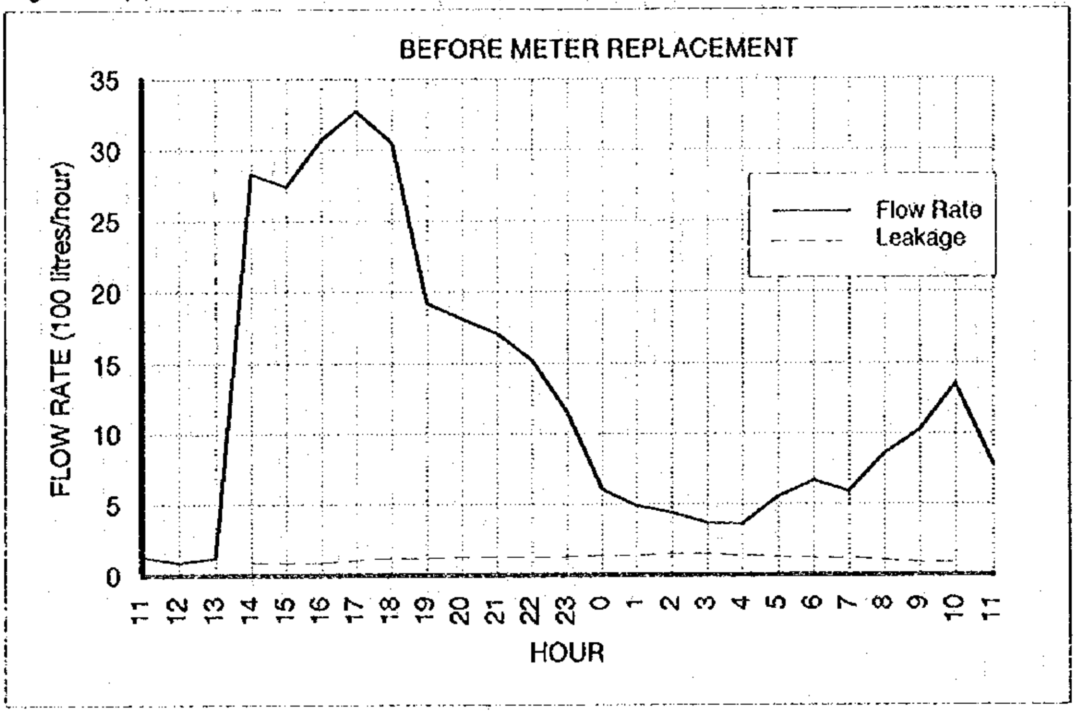



Fig.- H17 (2) FLOW RATE CURVE AND LEAKAGE (HASHEMEYEH SUBZONE)

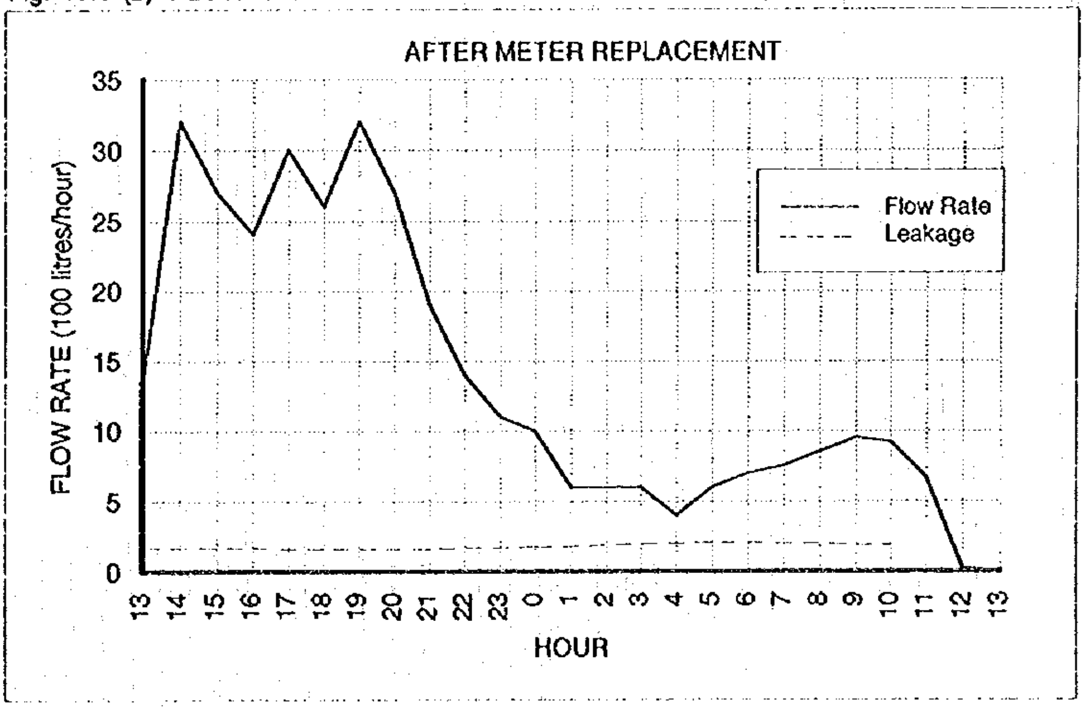


Fig.- H18 (1) FLOW RATE CURVE AND LEAKAGE (AWAJAN SUBZONE)

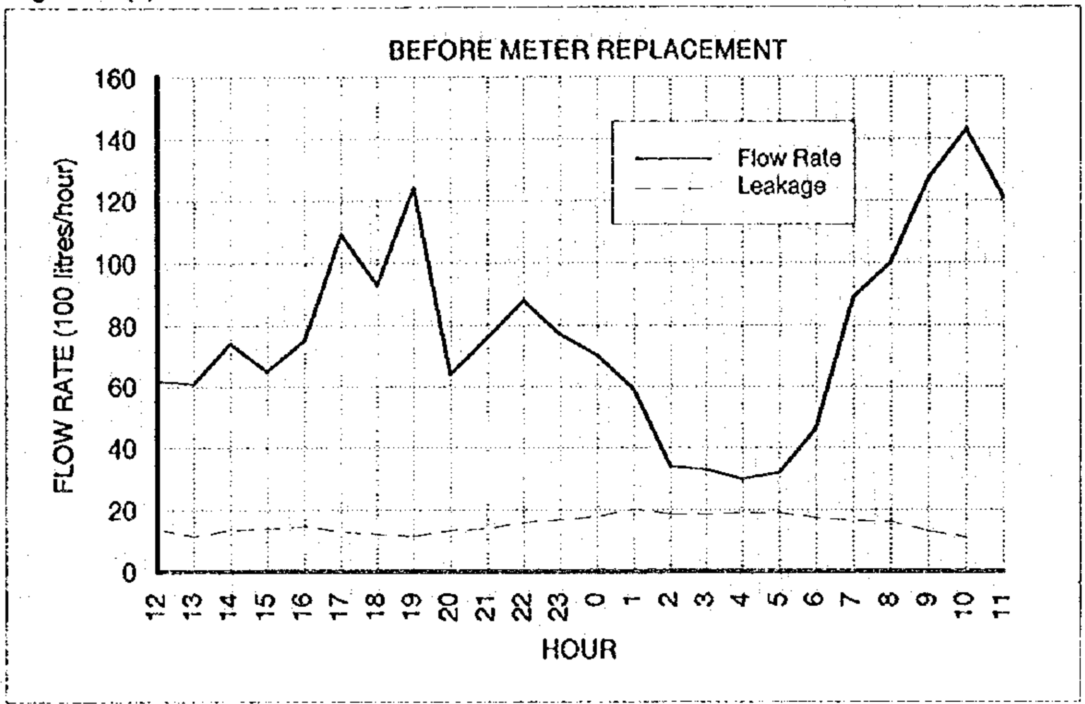
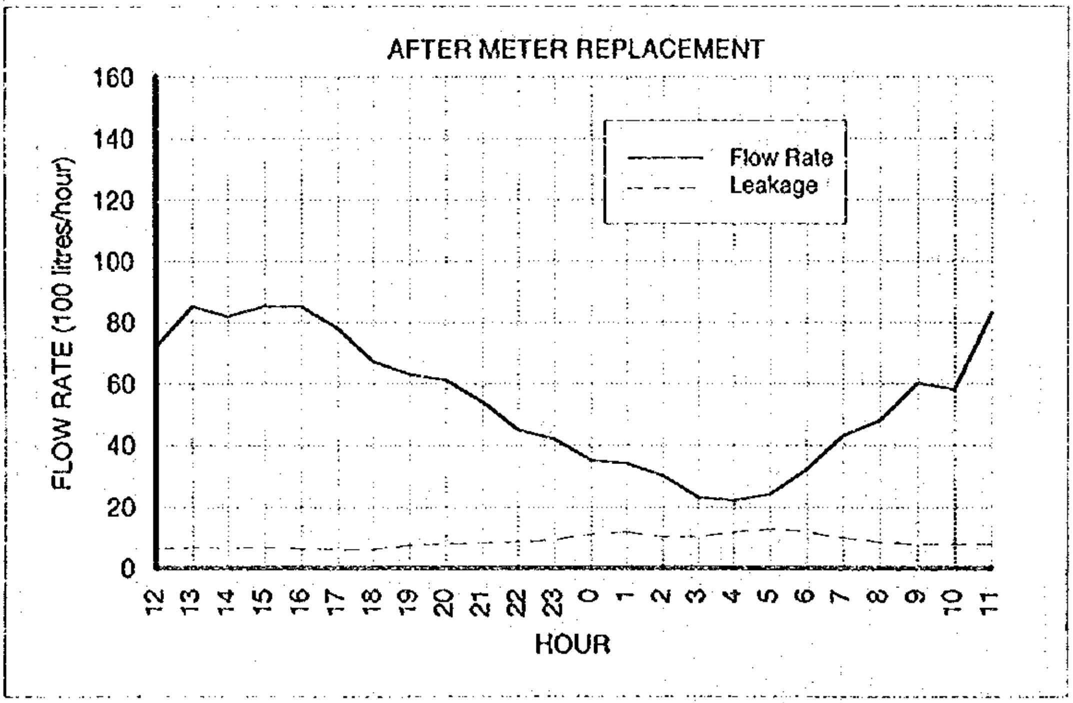



Fig.- H18 (2) FLOW RATE CURVE AND LEAKAGE (AWAJAN SUBZONE)



# Tables

Table - H1 RESULTS OF METER REPLACEMENT (SUBZONE AT RUSAIFA)

Before Meter Replacement

| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (m) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Mar. 22 | 11 : 00 | 1,521.4 | | 1.6 | | 0.0 |
| | 12 : 00 | 1,591.9 | 70.5 | 0.4 | 15.9 | 3.0 |
| | 13 : 00 | 1,644.6 | 52.7 | 1.6 | 28.0 | 6.1 |
| | 14 : 00 | 1,811.6 | 167.0 | 2.6 | 37.5 | 9.0 |
| | 15 : 00 | 1,949.9 | 138.3 | 2.8 | 39.7 | 9.7 |
| | 16 : 00 | 2,084.7 | 134.8 | 2.9 | 40.7 | 10.0 |
| | 17 : 00 | 2,209.2 | 124.5 | 2.9 | 40.7 | 10.0 |
| | 18 : 00 | 2,327.2 | 118.0 | 2.9 | 40.8 | 10.0 |
| | 19 : 00 | 2,428.6 | 101.4 | 3.3 | 44.8 | 11.4 |
| | 20 : 00 | 2,519.3 | 90.7 | 3.6 | 47.9 | 12.5 |
| | 21 : 00 | 2,605.2 | 85.9 | 3.9 | 50.9 | 13.7 |
| | 22 : 00 | 2,657.5 | 52.3 | 4.3 | 55.0 | 15.2 |
| | 23 : 00 | 2,702.3 | 44.8 | 4.5 | 57.0 | 16.0 |
| | 0 : 00 | 2,741.3 | 39.0 | 4.9 | 61.0 | 17.7 |
| Mar. 23 | 1 : 00 | 2,769.6 | 28.3 | 4.8 | 60.0 | 17.3 |
| | 2 : 00 | 2,790.5 | 20.9 | 4.9 | 61.0 | 17.7 |
| | 3 : 00 | 2,812.0 | 21.5 | 4.9 | 61.0 | 17.7 |
| | 4 : 00 | 2,837.7 | 25.7 | 4.9 | 61.0 | 17.7 |
| | 5 : 00 | 2,872.2 | 34.5 | 4.6 | 58.0 | 16.5 |
| | 6 : 00 | 2,916.2 | 44.0 | 4.3 | 55.0 | 15.2 |
| | 7 : 00 | 2,965.4 | 49.2 | 3.7 | 49.0 | 12.9 |
| | 8 : 00 | 3,036.6 | 71.2 | 2.8 | 39.9 | 9.8 |
| | 9 : 00 | 3,168.0 | 131.4 | 1.8 | 29.7 | 6.6 |
| | 10 : 00 | 3,359.7 | 191.7 | 1.4 | 25.4 | 5.4 |
| | 11 : 00 | 3,509.2 | 149.5 | 0.6 | 17.6 | 3.4 |
| | | Total | 1987.8 | 80.9 | | 284.7 |
| | | | | | Leakage(%)= | 14.3 |

After Meter Replacement

| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (m) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Apr. 5 | 11 : 00 | 60.8 | | 1.0 | | 0.0 |
| | 12 : 00 | 143.5 | 82.7 | 0.6 | 17.9 | 0.6 |
| | 13 : 00 | 189.6 | 46.1 | 1.0 | 22.0 | 0.7 |
| | 14 : 00 | 320.6 | 131.0 | 1.8 | 29.7 | 1.1 |
| | 15 : 00 | 442.1 | 121.5 | 2.2 | 33.7 | 1.3 |
| | 16 : 00 | 542.0 | 99.9 | 2.4 | 35.8 | 1.4 |
| | 17 : 00 | 638.4 | 96.4 | 2.4 | 35.8 | 1.4 |
| | 18 : 00 | 724.0 | 85.6 | 2.6 | 37.9 | 1.5 |
| | 19 : 00 | 791.3 | 67.3 | 2.9 | 40.9 | 1.6 |
| | 20 : 00 | 833.3 | 42.0 | 3.4 | 46.0 | 1.9 |
| | 21 : 00 | 867.1 | 33.8 | 3.4 | 46.0 | 1.9 |
| | 22 : 00 | 902.7 | 35.6 | 3.4 | 46.0 | 1.9 |
| | 23 : 00 | 943.4 | 40.7 | 3.5 | 47.0 | 2.0 |
| Apr. 6 | 0 : 00 | 957.2 | 13.8 | 4.0 | 52.0 | 2.3 |
| | 1 : 00 | 964.6 | 7.4 | 4.2 | 54.0 | 2.4 |
| | 2 : 00 | 969.0 | 4.4 | 4.8 | 60.0 | 2.8 |
| | 3 : 00 | 973.5 | 4.5 | 4.8 | 60.0 | 2.8 |
| | 4 : 00 | 979.8 | 6.3 | 4.8 | 60.0 | 2.8 |
| | 5 : 00 | 990.5 | 10.7 | 4.8 | 60.0 | 2.8 |
| | 6 : 00 | 1,008.4 | 17.9 | 4.8 | 60.0 | 2.8 |
| | 7 : 00 | 1,039.9 | 31.5 | 4.4 | 56.0 | 2.6 |
| | 8 : 00 | 1,094.1 | 54.2 | 3.2 | 43.9 | 1.8 |
| | 9 : 00 | 1,200.2 | 106.1 | 2.5 | 36.8 | 1.4 |
| | 10 : 00 | 1,305.1 | 104.9 | 2.3 | 34.8 | 1.3 |
| | 11 : 00 | 1,402.9 | 97.8 | 1.6 | 27.8 | 1.0 |
| | | Total | 1,342.1 | 76.8 | | 44.4 |
| | | | | | Leakage(%)= | 3.3 |

Adjustd Ave. Zone Pressure = P'= Gr. Level at Gauge+P*10-Ave. Gr. Level of the Zone-0.0000172*Flow*Flow

Leakage Estimate = (0.5*P'+0.007*P'*P')/(0.5*AP+0.007*AP*AP)*(F0-F1)

Where: AP = Ave. Zone Pressure

F0 = Min. Night Flow(100lit/hr/subzone)

F1 = Min. Night Usage(100lit/hr/Subzone)=1.21(lit/hr/Subscriber)*(# of Subscribers)/100

F0 - F1 = Leakage

Reference: WR'D Leakage Report "G", P27

Russaifah Input Data

| | Before | After |
|---|---|---|
| Gr.Level at Gauge= | 642 | |
| Ave.Gr.Level of Zone | 630 | |
| AP = Ave. Zone Pressure | 55 | 48 |
| F0 = Min. Night Flow | 17.6 | 4.4 |
| Read Once = | 10 | 12 |
| Read Twice = | 183 | 181 |

Table - H2 RESULTS OF METER REPLACEMENT (SUBZONE AT HASHEMEYEH)

Before Meter Replacement

| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (m) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Jul. 15 | 11 : 18 | 8.6 | | 0.9 | | 0.0 |
| | 11 : 58 | 9.9 | 1.3 | 0.9 | 11.0 | |
| | 12 : 58 | 10.8 | 0.9 | 0.9 | 11.0 | |
| | 13 : 58 | 12.0 | 1.2 | 0.9 | 11.0 | |
| | 14 : 50 | 40.3 | 28.3 | 0.9 | 11.0 | 0.9 |
| | 15 : 50 | 67.7 | 27.4 | 0.9 | 11.1 | 0.9 |
| | 16 : 50 | 98.4 | 30.7 | 0.9 | 11.2 | 0.9 |
| | 17 : 50 | 131.1 | 32.7 | 1.1 | 13.0 | 1.1 |
| | 18 : 50 | 161.6 | 30.5 | 1.2 | 14.0 | 1.2 |
| | 19 : 50 | 180.8 | 19.2 | 1.3 | 14.5 | 1.2 |
| | 20 : 50 | 198.9 | 18.1 | 1.3 | 15.0 | 1.3 |
| | 21 : 50 | 216.0 | 17.1 | 1.3 | 15.0 | 1.3 |
| | 22 : 50 | 231.2 | 15.2 | 1.4 | 15.5 | 1.3 |
| | 23 : 50 | 242.7 | 11.5 | 1.4 | 15.5 | 1.3 |
| Jul. 16 | 0 : 50 | 248.7 | 6.0 | 1.4 | 16.0 | 1.4 |
| | 1 : 50 | 253.6 | 4.9 | 1.5 | 16.5 | 1.4 |
| | 2 : 50 | 258.0 | 4.4 | 1.5 | 17.0 | 1.5 |
| | 3 : 50 | 261.7 | 3.7 | 1.5 | 17.0 | 1.5 |
| | 4 : 50 | 265.3 | 3.6 | 1.5 | 16.5 | 1.4 |
| | 5 : 50 | 270.8 | 5.5 | 1.4 | 15.5 | 1.3 |
| | 6 : 50 | 277.4 | 6.6 | 1.3 | 14.5 | 1.2 |
| | 7 : 50 | 283.3 | 5.9 | 1.2 | 14.0 | 1.2 |
| | 8 : 50 | 291.8 | 8.5 | 1.1 | 13.0 | 1.1 |
| | 9 : 50 | 302.0 | 10.2 | 0.9 | 11.0 | 0.9 |
| | 10 : 50 | 315.5 | 13.5 | 0.9 | 11.0 | 0.9 |
| | 11 : 20 | 323.3 | 7.8 | 0.0 | 2.0 | |
| | | | 303.5 | 25.6 | | 24.8 |
| | | | | | Leakage(%)= | 8.2 |

After Meter Replacement

| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (m) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Jul. 22 | 13 : 15 | 4.0 | | 1.9 | | 0.0 |
| | 13 : 30 | 17.0 | 13.0 | 1.9 | 20.5 | 1.7 |
| | 14 : 30 | 49.0 | 32.0 | 1.9 | 20.8 | 1.7 |
| | 15 : 30 | 76.0 | 27.0 | 1.9 | 20.8 | 1.7 |
| | 16 : 30 | 100.0 | 24.0 | 1.8 | 20.3 | 1.7 |
| | 17 : 30 | 130.0 | 30.0 | 1.8 | 20.1 | 1.6 |
| | 18 : 30 | 156.0 | 26.0 | 1.8 | 19.8 | 1.6 |
| | 19 : 30 | 188.0 | 32.0 | 1.8 | 19.5 | 1.6 |
| | 20 : 30 | 215.0 | 27.0 | 1.8 | 19.9 | 1.6 |
| | 21 : 30 | 234.0 | 19.0 | 1.8 | 20.0 | 1.6 |
| | 22 : 30 | 248.0 | 14.0 | 1.8 | 20.4 | 1.7 |
| | 23 : 30 | 259.0 | 11.0 | 1.9 | 20.8 | 1.7 |
| Jul. 23 | 0 : 30 | 269.0 | 10.0 | 1.9 | 21.3 | 1.8 |
| | 1 : 30 | 275.0 | 6.0 | 2.0 | 21.9 | 1.8 |
| | 2 : 30 | 281.0 | 6.0 | 2.1 | 22.5 | 1.9 |
| | 3 : 30 | 287.0 | 6.0 | 2.1 | 23.2 | 2.0 |
| | 4 : 30 | 291.0 | 4.0 | 2.2 | 23.8 | 2.0 |
| | 5 : 30 | 297.0 | 6.0 | 2.2 | 24.2 | 2.1 |
| | 6 : 30 | 304.0 | 7.0 | 2.2 | 24.1 | 2.1 |
| | 7 : 30 | 311.5 | 7.5 | 2.2 | 23.8 | 2.0 |
| | 8 : 30 | 320.0 | 8.5 | 2.1 | 23.2 | 2.0 |
| | 9 : 30 | 329.5 | 9.5 | 2.1 | 22.8 | 1.9 |
| | 10 : 16 | 338.7 | 9.2 | 2.1 | 22.7 | 1.9 |
| | 11 : 31 | 345.4 | 6.7 | 0.2 | 3.6 | |
| | 12 : 31 | 345.6 | 0.2 | 0.0 | 2.4 | |
| | 13 : 30 | 345.6 | 0.0 | 0.0 | 2.0 | |
| | | Total | 334.7 | 43.2 | | 39.8 |
| | | | | | Leakage(%)= | 11.9 |

Adjustd Ave. Zone Pressure = P'= Gr. Level at Gauge+P*10-Ave. Gr. Level of the Zone-0.0000172*Flow*Flow

Leakage Estimate = (0.5*P'+0.007*P'*P')/(0.5*AP+0.007*AP*AP)*(F0-F1)

Where: AP = Ave. Zone Pressure

F0 = Min. Night Flow(100lit/hr/subzone)

F1 = Min. Night Usage(100lit/hr/Subzone)=1.21(lit/hr/Subscriber)*(# of Subscribers)/100

F0 - F1 = Leakage

(shaded) : Measurement during start-up or valve closure, canceled.

Reference: WR'D Leakage Report "G", P27

Hashemeyeh Input Data

| | Before | After |
|---|---|---|
| Gr.Level at Gauge= | 564 | |
| Ave.Gr.Level of Zone | 562 | |
| AP = Ave. Zone Pressure | 12.18 | 19.65 |
| F0 = Min. Night Flow | 3.1 | 3.9 |
| Read Once = | 21 | 28 |
| Read Twice = | 153 | 161 |

## Table - H3 RESULTS OF METER REPLACEMENT (SUBZONE AT SUKHNA)

**Before Meter Replacement**

| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (m) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Aug. 16 | 11 : 45 | 7.7 | | | | 0.0 |
| | 12 : 45 | 73.2 | 65.5 | 0.4 | -0.1 | -0.3 |
| | 13 : 45 | 133.4 | 60.2 | 0.5 | 0.9 | 4.4 |
| | 14 : 45 | 188.7 | 55.3 | 0.5 | 0.9 | 4.4 |
| | 15 : 45 | 243.1 | 54.4 | 0.8 | 3.9 | 19.2 |
| | 16 : 45 | 290.9 | 47.8 | 0.9 | 5.0 | 24.5 |
| | 17 : 45 | 335.6 | 44.7 | 0.8 | 4.0 | 19.3 |
| | 18 : 45 | 382.0 | 46.4 | 0.7 | 3.0 | 14.2 |
| | 19 : 45 | 429.3 | 47.3 | 0.6 | 2.0 | 9.3 |
| | 20 : 45 | 487.2 | 57.9 | 0.6 | 1.9 | 9.2 |
| | 21 : 45 | 544.7 | 57.5 | 0.7 | 2.9 | 14.1 |
| | 22 : 45 | 591.8 | 47.1 | 0.8 | 4.0 | 19.3 |
| | 23 : 45 | 651.0 | 59.2 | 1.1 | 6.9 | 35.1 |
| Aug. 17 | 0 : 45 | 716.4 | 65.4 | 1.4 | 9.9 | 52.1 |
| | 1 : 45 | 783.6 | 67.2 | 1.8 | 13.9 | 76.7 |
| | 2 : 45 | 850.0 | 66.4 | 2.0 | 15.9 | 89.8 |
| | 3 : 45 | 915.0 | 65.0 | 1.9 | 14.9 | 83.2 |
| | 4 : 45 | 991.4 | 76.4 | 1.8 | 13.9 | 76.6 |
| | 5 : 45 | 1,071.1 | 79.7 | 1.2 | 7.9 | 40.4 |
| | 6 : 45 | 1,155.9 | 84.8 | 0.7 | 2.9 | 13.8 |
| | 7 : 45 | 1,230.1 | 74.2 | 0.8 | 3.9 | 19.0 |
| | 8 : 45 | 1,322.9 | 92.8 | 0.5 | 0.9 | 4.0 |
| | 9 : 45 | 1,405.4 | 82.5 | 0.7 | 2.9 | 13.8 |
| | 10 : 45 | 1,480.8 | 75.4 | 0.8 | 3.9 | 19.0 |
| | 11 : 45 | 1,553.4 | 72.6 | 0.9 | 4.9 | 24.2 |
| | | Total | 1,545.7 | 22.9 | | 685.5 |
| | | | | | Leakage(%)= | 44.3 |

**After Meter Replacement**

| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (m) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Aug. 21 | 12 : 00 | 0.0 | | | | |
| | 13 : 00 | 33.0 | 33.0 | 0.3 | -1.0 | -5.5 |
| | 14 : 00 | 77.0 | 44.0 | 0.3 | -1.0 | -5.6 |
| | 15 : 00 | 133.0 | 56.0 | 0.5 | 0.9 | 5.3 |
| | 16 : 00 | 194.0 | 61.0 | 0.6 | 1.9 | 10.9 |
| | 17 : 00 | 252.0 | 58.0 | 0.3 | -1.1 | -5.7 |
| | 18 : 00 | 303.0 | 51.0 | 0.2 | -2.0 | -10.9 |
| | 19 : 00 | 355.0 | 52.0 | 0.3 | -1.0 | -5.7 |
| | 20 : 00 | 410.0 | 55.0 | 0.3 | -1.1 | -5.7 |
| | 21 : 00 | 470.0 | 60.0 | 0.3 | -1.1 | -5.8 |
| | 22 : 00 | 537.0 | 67.0 | 0.7 | 2.9 | 16.7 |
| | 23 : 00 | 603.0 | 66.0 | 0.9 | 4.9 | 29.0 |
| Aug. 22 | 0 : 00 | 656.0 | 53.0 | 1.3 | 9.0 | 55.5 |
| | 1 : 00 | 712.0 | 56.0 | 1.5 | 10.9 | 69.5 |
| | 2 : 00 | 769.0 | 57.0 | 1.6 | 11.9 | 76.7 |
| | 3 : 00 | 826.0 | 57.0 | 1.6 | 11.9 | 76.7 |
| | 4 : 00 | 885.0 | 59.0 | 1.7 | 12.9 | 84.1 |
| | 5 : 00 | 945.0 | 60.0 | 1.6 | 11.9 | 76.7 |
| | 6 : 00 | 1,016.0 | 71.0 | 2.2 | 17.9 | 123.3 |
| | 7 : 00 | 1,089.0 | 73.0 | 0.9 | 4.9 | 28.9 |
| | 8 : 00 | 1,157.0 | 68.0 | 0.7 | 2.4 | 13.8 |
| | 9 : 00 | 1,214.0 | 57.0 | 0.7 | 2.9 | 16.9 |
| | 10 : 00 | 1,277.0 | 63.0 | 0.2 | -2.1 | -11.1 |
| | 11 : 00 | 1,340.0 | 63.0 | 0.3 | -1.1 | -5.8 |
| | 12 : 00 | 1,383.0 | 43.0 | 0.3 | -1.0 | -5.6 |
| | | Total | 1,383.0 | 19.3 | | 616.7 |
| | | | | | Leakage(%)= | 44.6 |

Adjustd Ave. Zone Pressure = P'= Gr. Level at Gauge+P*10-Ave. Gr. Level of the Zone-0.0000172*Flow*Flow

Leakage Estimate = (0.5*P'+0.007*P'*P')/(0.5*AP+0.007*AP*AP)*(F0-F1)

Where: AP = Ave. Zone Pressure

F0 = Min. Night Flow(100lit/hr/subzone)

F1 = Min. Night Usage(100lit/hr/Subzone)=1.21(lit/hr/Subscriber)*(# of Subscribers)/100

F0 - F1 = Leakage

(shaded): Due to low water pressure, measurement was not successful and data were canceled.

Reference: WRD Leakage Report "G", P27

Sukhna Input Data

| | Before | After |
|---|---|---|
| Gr.Level at Gauge= | 517 | |
| Ave.Gr.Level of Zone | 521 | |
| AP = Ave. Zone Pressure | 9.54 | 8.02 |
| F0 = Min. Night Flow | 52.1 | 51.3 |
| Read Once = | 14 | 11 |
| Read Twice = | 168 | 169 |

Table - H4 RESULTS OF METER REPLACEMENT (SUBZONE AT GHOURIEYEH)*

Before Meter Replacement

| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (m) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Aug. 7 | 12 : 00 | 0.0 | | 0.6 | | - |
| | 13 : 00 | 0.0 | 0.0 | 0.6 | 7.3 | - |
| | 14 : 00 | 70.5 | 70.5 | 0.6 | 7.1 | - |
| | 15 : 00 | 147.9 | 77.4 | 0.6 | 6.6 | - |
| | 16 : 00 | 206.2 | 58.3 | 0.6 | 6.6 | - |
| | 17 : 00 | 314.2 | 108.0 | 0.6 | 6.5 | - |
| | 18 : 00 | 444.7 | 130.5 | 0.6 | 6.4 | - |
| | 19 : 00 | 525.9 | 81.2 | 0.6 | 6.7 | - |
| | 20 : 00 | 601.0 | 75.1 | 0.6 | 6.8 | - |
| | 21 : 00 | 678.6 | 77.6 | 0.6 | 7.1 | - |
| | 22 : 00 | 772.0 | 93.4 | 0.6 | 7.1 | - |
| | 23 : 00 | 875.5 | 103.5 | 0.7 | 7.6 | - |
| Aug. 8 | 0 : 00 | 981.8 | 106.3 | 0.7 | 8.2 | - |
| | 1 : 00 | 1,093.5 | 111.7 | 0.7 | 7.6 | - |
| | 2 : 00 | 1,182.0 | 88.5 | 0.7 | 8.2 | - |
| | 3 : 00 | 1,310.9 | 128.9 | 0.9 | 9.4 | - |
| | 4 : 00 | 1,428.0 | 117.1 | 0.9 | 9.7 | - |
| | 5 : 00 | 1,547.3 | 119.3 | 0.9 | 9.9 | - |
| | 6 : 00 | 1,671.0 | 123.7 | 0.8 | 9.1 | - |
| | 7 : 00 | 1,792.4 | 121.4 | 0.8 | 8.7 | - |
| | 8 : 00 | 1,912.1 | 119.7 | 0.7 | 7.9 | - |
| | 9 : 00 | 2,030.9 | 118.8 | 0.6 | 6.7 | - |
| | 10 : 00 | 2,145.5 | 114.6 | 0.6 | 6.7 | - |
| | 11 : 00 | 2,258.0 | 112.5 | 0.6 | 6.7 | - |
| | 12 : 00 | 2,307.5 | 49.5 | 0.6 | 6.9 | - |
| | | Total | 2,307.5 | 16.4 | | |
| | | | | | Leakage(%)= | - |

After Meter Replacement

| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (m) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Aug. 14 | 12 : 00 | 0.0 | | 0.5 | | - |
| | 13 : 00 | 0.0 | 0.0 | 0.5 | 6.2 | - |
| | 14 : 00 | 3.9 | 3.9 | 0.5 | 6.2 | - |
| | 15 : 00 | 23.3 | 19.4 | 0.5 | 6.2 | - |
| | 16 : 00 | 33.5 | 10.2 | 0.5 | 5.7 | - |
| | 17 : 00 | 47.4 | 13.9 | 0.5 | 6.2 | - |
| | 18 : 00 | 55.2 | 7.8 | 0.5 | 6.2 | - |
| | 19 : 00 | 57.1 | 1.9 | 0.5 | 6.2 | - |
| | 20 : 00 | 61.0 | 3.9 | 0.5 | 6.2 | - |
| | 21 : 00 | 66.7 | 5.7 | 0.5 | 6.2 | - |
| | 22 : 00 | 72.9 | 6.2 | 0.5 | 6.2 | - |
| | 23 : 00 | 82.9 | 10.0 | 0.6 | 7.2 | - |
| Aug. 15 | 0 : 00 | 90.0 | 7.1 | 0.7 | 7.8 | - |
| | 1 : 00 | 116.6 | 26.6 | 0.7 | 7.7 | - |
| | 2 : 00 | 171.4 | 54.8 | 0.9 | 9.6 | - |
| | 3 : 00 | 242.2 | 70.8 | 0.9 | 9.6 | - |
| | 4 : 00 | 322.1 | 79.9 | 0.8 | 9.1 | - |
| | 5 : 00 | 393.7 | 71.6 | 0.9 | 9.6 | - |
| | 6 : 00 | 470.8 | 77.1 | 0.7 | 8.3 | - |
| | 7 : 00 | 542.5 | 71.7 | 0.7 | 8.1 | - |
| | 8 : 00 | 620.1 | 77.6 | 0.7 | 7.6 | - |
| | 9 : 00 | 672.5 | 52.4 | 0.5 | 6.1 | - |
| | 10 : 00 | 708.5 | 36.0 | 0.5 | 6.2 | - |
| | 11 : 00 | 751.9 | 43.4 | 0.5 | 6.1 | - |
| | 12 : 00 | 786.6 | 34.7 | 0.5 | 6.2 | |
| | | Total | 786.6 | 14.8 | | |
| | | | | | Leakage(%)= | - |

Adjustd Ave. Zone Pressure = P'= Gr. Level at Gauge+P*10-Ave. Gr. Level of the Zone-0.0000172*Flow*Flow

Leakage Estimate = (0.5*P'+0.007*P'*P')/(0.5*AP+0.007*AP*AP)*(F0-F1)

Where: AP = Ave. Zone Pressure

F0 = Min. Night Flow(100lit/hr/subzone)

F1 = Min. Night Usage(100lit/hr/Subzone)=1.21(lit/hr/Subscriber)*(# of Subscribers)/100

F0 - F1 = Leakage

*.......Due to malfunctioned ultra-sonic flow meter by air, inflow rate to the subzone is no more reliable. This can be explained from the fact that the flow rates before and after meter replacement are changing considerably.

Reference: WRD Leakage Report "G", P27

Ghoarieyeh Input Data

| | Before | After |
|---|---|---|
| Gr.Level at Gauge= | 611 | |
| Ave.Gr.Level of Zone | 610.22 | |
| AP = Ave. Zone Pressure | 6.54 | 5.91 |
| F0 = Min. Night Flow | 49.5 | 7.1 |
| Read Once = | 25 | 15 |
| Read Twice = | 178 | 179 |

### Table - H5 RESULTS OF METER REPLACEMENT (SUBZONE AT AWAJAN)

**Before Meter Replacement**

| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (m) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Aug. 26 | 11 : 30 | 3.3 | | 7.3 | | 0.0 |
| | 12 : 30 | 65.0 | 61.7 | 8.2 | 54.4 | 13.6 |
| | 13 : 30 | 126.0 | 61.0 | 7.6 | 48.4 | 11.5 |
| | 14 : 30 | 200.0 | 74.0 | 8.2 | 54.4 | 13.6 |
| | 15 : 30 | 265.0 | 65.0 | 8.3 | 55.4 | 14.0 |
| | 16 : 30 | 340.0 | 75.0 | 8.5 | 57.4 | 14.7 |
| | 17 : 30 | 449.0 | 109.0 | 8.0 | 52.3 | 12.9 |
| | 18 : 30 | 542.0 | 93.0 | 7.8 | 50.4 | 12.2 |
| | 19 : 30 | 666.0 | 124.0 | 7.6 | 48.2 | 11.5 |
| | 20 : 30 | 730.0 | 64.0 | 8.1 | 53.4 | 13.3 |
| | 21 : 30 | 806.0 | 76.0 | 8.3 | 55.4 | 14.0 |
| | 22 : 30 | 894.0 | 88.0 | 8.8 | 60.4 | 15.8 |
| | 23 : 30 | 971.0 | 77.0 | 9.0 | 62.4 | 16.6 |
| Aug. 27 | 0 : 30 | 1,041.0 | 70.0 | 9.3 | 65.4 | 17.8 |
| | 1 : 30 | 1,100.0 | 59.0 | 9.9 | 71.4 | 20.3 |
| | 2 : 30 | 1,134.0 | 34.0 | 9.5 | 67.5 | 18.6 |
| | 3 : 30 | 1,167.0 | 33.0 | 9.5 | 67.5 | 18.6 |
| | 4 : 30 | 1,197.0 | 30.0 | 9.6 | 68.5 | 19.0 |
| | 5 : 30 | 1,229.0 | 32.0 | 9.6 | 68.5 | 19.0 |
| | 6 : 30 | 1,275.0 | 46.0 | 9.2 | 64.5 | 17.4 |
| | 7 : 30 | 1,364.0 | 89.0 | 9.0 | 62.4 | 16.6 |
| | 8 : 30 | 1,464.0 | 100.0 | 8.9 | 61.3 | 16.2 |
| | 9 : 30 | 1,591.0 | 127.0 | 8.1 | 53.2 | 13.2 |
| | 10 : 30 | 1,734.0 | 143.0 | 7.5 | 47.1 | 11.1 |
| | 11 : 30 | 1,855.0 | 121.0 | 7.3 | 45.2 | 10.5 |
| | | Total | 1852 | 213.1 | | 361.9 |
| | | | | | Leakage(%)= | 19.5 |

**After Meter Replacement**

| Date/Time Month Day | Hour | Integ. Flow (*100 l) | Hourly Flow (100 l) | Gauge Pres. (kg/cm2) P | Adj. Ave Zone Pres. (m) P' | Leakage Estimate (100 l) |
|---|---|---|---|---|---|---|
| Sep. 20 | 11 : 30 | 3.0 | | 8.0 | | 0.0 |
| | 12 : 30 | 75.0 | 72.0 | 7.2 | 44.4 | 6.4 |
| | 13 : 30 | 160.0 | 85.0 | 7.4 | 46.4 | 6.8 |
| | 14 : 30 | 242.0 | 82.0 | 7.3 | 45.4 | 6.6 |
| | 15 : 30 | 327.0 | 85.0 | 7.4 | 46.4 | 6.8 |
| | 16 : 30 | 412.0 | 85.0 | 7.2 | 44.4 | 6.4 |
| | 17 : 30 | 490.0 | 78.0 | 7.1 | 43.4 | 6.2 |
| | 18 : 30 | 557.0 | 67.0 | 7.1 | 43.4 | 6.2 |
| | 19 : 30 | 620.0 | 63.0 | 7.8 | 50.4 | 7.6 |
| | 20 : 30 | 681.0 | 61.0 | 8.0 | 52.4 | 8.0 |
| | 21 : 30 | 735.0 | 54.0 | 8.1 | 53.4 | 8.3 |
| | 22 : 30 | 780.0 | 45.0 | 8.2 | 54.5 | 8.5 |
| | 23 : 30 | 822.0 | 42.0 | 8.6 | 58.5 | 9.4 |
| Sep. 21 | 0 : 30 | 857.0 | 35.0 | 9.3 | 65.5 | 11.1 |
| | 1 : 30 | 891.0 | 34.0 | 9.6 | 68.5 | 11.9 |
| | 2 : 30 | 921.0 | 30.0 | 9.0 | 62.5 | 10.4 |
| | 3 : 30 | 944.0 | 23.0 | 9.0 | 62.5 | 10.4 |
| | 4 : 30 | 966.0 | 22.0 | 9.6 | 68.5 | 11.9 |
| | 5 : 30 | 990.0 | 24.0 | 10.0 | 72.5 | 12.9 |
| | 6 : 30 | 1,022.0 | 32.0 | 9.6 | 68.5 | 11.9 |
| | 7 : 30 | 1,065.0 | 43.0 | 8.8 | 60.5 | 9.9 |
| | 8 : 30 | 1,113.0 | 48.0 | 8.2 | 54.5 | 8.5 |
| | 9 : 30 | 1,173.0 | 60.0 | 8.0 | 52.4 | 8.0 |
| | 10 : 30 | 1,231.0 | 58.0 | 8.0 | 52.4 | 8.0 |
| | 11 : 30 | 1,314.0 | 83.0 | 8.0 | 52.4 | 8.0 |
| | | Total | 1,311.0 | 206.5 | | 209.9 |
| | | | | | Leakage(%)= | 16.0 |

Adjustd Ave. Zone Pressure = P'= Gr. Level at Gauge+P*10-Ave. Gr. Level of the Zone-0.0000172*Flow*Flow

Leakage Estimate = (0.5*P'+0.007*P'*P')/(0.5*AP+0.007*AP*AP)*(F0-F1)

Where: AP = Ave. Zone Pressure
F0 = Min. Night Flow(100lit/hr/subzone)
F1 = Min. Night Usage(100lit/hr/Subzone)=1.21(lit/hr/Subscriber)*(# of Subscribers)/100
F0 - F1 = Leakage

Reference: WRD Leakage Report "G", P27

Awajan Input Data

| | Before | After |
|---|---|---|
| Gr.Level at Gauge= | 587 | |
| Ave.Gr.Level of Zone | 614 | |
| AP = Ave. Zone Pressure | 85.24 | 82.6 |
| F0 = Min. Night Flow | 28.7 | 17.9 |
| Read Once = | 9 | 7 |
| Read Twice = | 169 | 169 |

Table - H6 SUMMARY OF THE UFW SURVEY

| Area Name | Date of Work B/A 1) | Total No. of Meters | Meter Replaced by WAJ 2) | Meters Read Twice B/A | No. of Illegal Connect. | UFW % B/A | Leakage % B/A | Remarks |
|---|---|---|---|---|---|---|---|---|
| (CDWM Method) | | | | | | | | |
| 1. Rusaifa | 20-21/3/95 | 2,336 | - | - | - | - | 28.7 | |
| 2. Al Ghourieyeh | 4-6/9/95 | 921 | - | - | - | - | 70.6 | |
| 3. Janna and Zarqa Camp | 3/8/95 | 1,920 | - | - | - | - | 33.9 | |
| (Total or Average) | | 5,177 | | | | | 31.0 3) | Average excludes Ghoarieyeh area. |
| (Meter Replace. Method) | | | | | | | | |
| 1. Rusaifa | 22-23/3/95 | 197 | - | 183/183 | 5 | 43.6/7.8* | 14.3/3.3 | * Visible leaks were |
| | 27-29/3/95 | | | | | | | repaired before M/R. |
| 2. Hashemeyeh | 15-16/7/95 | 201 | 75 | 153/161 | 0 | 36.3/12.3 | 8.2/11.9 | |
| | 22-23/7/95 | | | | | | | |
| 3. Al Ghourieyeh | 7-8/8/95 | 215 | 8 | 178/169 | 0 | ** | ** | ** Not obtained |
| | 14-15/8/95 | | | | | | | |
| 4. Sukhna | 16-17/8/95 | 195 | 52 | 168/169 | 0 | 47.1/45.8 | ** | ** Not obtained |
| | 21-22/8/95 | | | | | | | |
| 5. Awajan | 26-27/8/95 | 182 | 20 | 169/168 | 0 | 26.6/19.7 | 19.5/16.0 | |
| | 2-3/9/95 | | | | | | | |
| (Total or Average) | | 990 | | | 5 | 38.4/21.4 4) | 14.0/10.4 4) | |

1) B/A implies Before/After replacement of meters by the survey team

2) Meters replaced by WAJ just within one month before the test of replacement by the survey team.

3) The average excludes that of Ghourieyeh area.

4) Water pressure was not consiered in obtaining averages. These values show a general trend of UFW.

# I. WATER QUALITY ANALYSIS

## Appendix I
## - Water Quality -

### Table of Contents

## APPENDIX I WATER QUALITY

### 1. General

To find the quality problems of drinking water in the governorate, an evaluation program of two stages was applied. The first stage includes a water quality study for each well field supplying the governorate, based on the available water quality records.

The second stage includes a water sampling program. This program includes water sampling from major reservoirs and boosters. Also, water samples were collected from selected private houses within the governorate. Chemical and biological analyses were carried out for the collected water samples. The results were evaluated according to the Jordanian standards of drinking water. The second stage program is discussed and presented in section 4.

The last part of this Appendix presents the quality of wastewater from the industrial factories located in the Study Area.

### 2. Data Availability and Accuracy

In Jordan, water resources are under the responsibility of the government represented by the Ministry of Water and Irrigation (MOWI) and its two authorities; the Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA). The legal framework for the MOWI is provided by law No. 18 of 1988 (WAJ-Law), and law No. 19 of 1989 (JVA-Law).

Table I-1 shows Jordanian standards No. 286 for drinking water that were put in 1988 and amended in 1990. The standards are similar to the World Health Organization (WHO) guidelines and the US Environmental Protection Agency (EPA) standards in many aspects and provide the basis for drinking water quality control.

For industrial wastewater, there is the Jordanian standards No. 202 of 1991, presented in Table I-2, which provide maximum allowable limits of industrial wastewater quality for discharge to stream, wadi and sea for groundwater recharge and water reuse.

Water quality records for each wellfield supplying the governorate were collected from MOWI and WAJ department in Zarqa for evaluation purposes. The records were screened and revised. The range and average yearly values as well as the last measured reading were considered in this study.

## 3. Water quality Of Supplying Wellfields

A total number of nine water wellfields are supplying the governorate with its drinking water demand. Water quality conditions in each wellfield are studied and evaluated, based on Jordanian standards No. 286 for drinking water (JSDW, 1990).

### (1) Awajan Wellfield

This field consists of three productive wells (AJ21, AJ22 and AJ23). Water quality for the period between 1990 and 1994 indicates a close similarity in the chemical characteristics as shown in Table I-3, representing the range, average yearly value and last measured reading for Total Dissolved Solid (TDS), $NO_3$, Sodium (Na), Chloride (Cl) and Sulfate ($SO_4$) concentrations.

All the three wells show high $NO_3$ concentrations, where the overall average yearly values range from 55 to 70 mg/l, around the maximum limit for drinking water. Na and Cl concentrations range from 170 to 350 mg/l which are higher than the permissible limits, but lower than the maximum limits. $SO_4$ concentration ranges from 50 to 100 mg/l, less than permissible limit.

Salinity in AJ23 is the lowest, where the overall average yearly value ranges between 750 to <1,000 mg/l, while the rest of wells shows an overall average yearly value of between 1,000 and 1,200 mg/l. Salinity in AJ23 shows a clear increasing, as shown in Fig. I-1 to that in AJ21 and AJ22. The same increase is also for $NO_3$ concentration as shown in Fig. I-2.

### (2) Al-Azraq Wellfield

This field consists of 15 wells. The quality records for the period 1988 -1994, presented in Table I-4 show the average yearly value for TDS and $NO_3$ concentrations.

Water is excellent for drinking demand. The overall yearly average values of TDS and $NO_3$ concentrations range from 270 to 670 mg/l and from 3.1 to 13.8 mg/l, respectively. The excellent water quality is resulted from the location of this field in the upstream of a recharge area, far away from the highly populated areas, where pollution sources occurs.

The lowest water salinity is recorded in well No. 6, where the overall average values range from 255 to 258 mg/l. The highest water salinity was recorded in well No. 9, as the overall average salinity values are between 435 to 670 mg/l.

The highest $NO_3$ concentration was recorded in well No. 8, as the overall average yearly concentration range from 11.5 to 13.8 mg/l. Gradual and genteel increase in TDS and $NO_3$ concentrations is clear as indicated in Table I-4.

### (3) Hallabat Wellfield

Water salinity records are available for the years 1993 and 1994 for the following wells; HA3a, HA3b, HA5, HA6, HA7, HA8 and HA10.

Quality is very good for drinking demands, as shown in Table I-5. The overall average yearly values for TDS range from 386 to 651 mg/l and for $NO_3$ concentration range from 8.0 to 10.4 mg/l in 1994. Na, Cl and $SO_4$ concentrations range from 50 to 143 mg/l within permissible limits.

### (4) Ganyah Spring

This spring supplies Ganyah area with its drinking water. Available water quality data of this spring is only for the year 1994, where three measurements were carried out. Water is contaminated by $NO_3$, with concentration ranging from 43 to 48 mg/l. TDS values range from 445 to 452 mg/l and the Na, Cl and $SO_4$ concentrations range from 50 to 120 mg/l. These values are less than the permissible limits.

### (5) Hattin Camp Wells

Two wells (HC1 and HC2) are supplying the camp in Ruseifa with its drinking water. Water quality records for the year 1994 are presented in Tables I-6 and I-7, respectively. TDS values range from 436 to 653 mg/l in HC1 and 591 - 970 mg/l in HC2. $NO_3$ concentration ranges from 13.7 to 55 mg/l in HC1 and 12.7 to 43.1 mg/l in HC2. An indication of water pollution is clear from the high variation of $NO_3$ concentration within the year. However, water quality of these wells are still within the permissible limits.

### (6) Hashemeyeh Well-Field

This field includes four wells (Hm1, Hm2, Hm3 and Hm5). Water quality records for the period between 1988 and 1994 were used in this study.

A clear similarity appears as indicated in Table I-8 that shows TDS and $NO_3$. The overall average yearly values for both TDS and $NO_3$ concentrations range from 1,300 to 1,600 mg/l and from 35 to 54 mg/l, respectively. TDS concentrations are over the permissible limit but within the maximum limit while $NO_3$ concentrations are below the permissible limit.
A general increasing trend is clear of the TDS value, as shown in Fig. I-3. As for $NO_3$ concentration, it shows a general decreasing trend since the year 1992 for wells Hm3 and Hm5, as shown in Fig. I-4 while $NO_3$ concentration for well Hm2 shows a general decreasing trend since 1990, however, in 1994 it starts to increase as presented in Fig. I-4.

Na and Cl range from 260 to 535 mg/l, which are within the maximum limits while sulfate concentration ranges between 160 to 240 mg/l, around the permissible limit.

### (7) Murhib Well-Field

This field is composed of four wells M1, M2, M3 and M4. Water quality records for the period 1993 and 1994 are presented in Table I-9.

Groundwater is fresh and of the best among the water fields supplying the governorate. The salinity ranges from 472 to 552 mg/l, which is excellent for drinking. $NO_3$ concentration ranges from 8.8 to 27 mg/l. This concentration is relatively high comparing to the water salinity where water of well M1 is the lowest in $NO_3$ concentration. The sharp variation in $NO_3$ concentration in this field may be attributed to a start of pollution process. Serious actions must be taken to stop these process before polluting this wellfield.

The concentrations of Cl, Na and $SO_4$ range from 25 to 125 mg/l, less than the permissible limits.

### (8) Ruseifa Wells

The Ruseifa area is supplied with water from the following wells, (deep phosphate well, Ruseifa well No. 18, New Um Al-Basatin well and Old Um Al-Basatin well). Water quality is described below based on the records for the year 1994.

- Deep Phosphate well :

Water quality record is presented in Table I-10. Groundwater is characterized by a low salinity rate fluctuating narrowly between 385 to 394 mg/l. $NO_3$ concentration in this well is the lowest, ranging from 0 to 0.31 mg/l. Water is excellent for drinking.

- Ruseifa well No. 18

Water quality record is presented in Table I-11. TDS and $NO_3$ concentrations range from 394 to 780 mg/l and from 1.99 to 52.70 mg/l, respectively. These concentrations are close to the permissible limits but below the maximum limits.

Table I-11 indicates the presence of direct relation between TDS and $NO_3$ concentrations, where by increasing or decreasing TDS value, $NO_3$ concentration follow the same trend. Concentrations of Cl, Na and $SO_4$ are within the permissible limits.

- New Um AL-Basatin well:

Water quality record is presented in Table I-12. Water salinity ranges from 630 to 683 mg/l, within the drinking water. $NO_3$ concentration ranges from 41 to 50 mg/l above the permissible limit for drinking.

- Old Um AL - Basatin well :

Water quality record is presented in Table I-13. Salinity ranges from 728 to 804 mg/l within drinking water standards. $NO_3$ concentration is above the permissible standard limit ranging between 47.1 to 59.1 mg/l.

**(9) Zarqa well No. 14**

Water quality records for the period between 1990 to 1994 were used. Water samples were collected and analyzed in a heterogeneous way representing two months of the year, for the period between 1990 and 1993 as shown in Table I-14. Water quality record for the year 1994 were screened and presented in Table I-15 on average monthly bases.

The overall average monthly value of TDS value ranges from 1,430 to 1,770 mg/l exceeding mostly the maximum limit. $NO_3$ concentration ranges from 45 to 61 mg/l exceeding the permissible limit but within the permissible limit. Fig. I-5 presents the yearly variation in TDS value ,where a clear increase in salinity appears in summer period. The same statement can be applied for the $NO_3$ concentration as shown in Fig. I-6. Cl and Na concentrations are within the maximum limits, while $SO_4$ concentration is within the permissible limits.

## 4. Water Sampling Program

As part of our study, a comprehensive water sampling program was conducted in the Study Area. This program includes collecting of four sets (two sets for wet season and also two sets for dry season) of water samples from the reservoirs, pumping stations and house taps within the periods of January 1995 to August 1995. Location and number of sampling in the Study

Area are presented in attachment. Besides, aeration and soda ash tests are conducted for the deteriorated water in Zarqa well No. 14.

## 4.1 Method of Analysis

In order to study the characteristics of the water from the sources to the users and to study any changes in the reservoirs and/or the pumping stations, general and special tests were conducted.

The purpose of carrying these tests is to study the physical, chemical and biological characteristics of water. Water quality analysis items for the samples from pumping stations, reservoirs and house taps are as follows:

a) **Physical**
   - Temperature (at sampling point)
   - pH (at sampling point)
   - Odor
   - Taste
   - Color
   - Turbidity

b) **Chemical**
   - Dissolved Oxygen (at sampling point)
   - Chloride
   - Sulfate ($SO_4$)
   - Total dissolved solid (TDS)
   - Alkalinity
   - Chlorine residual (at sampling point)
   - Nitrogen $NH_4^+$
   - Hardness
   - $Fe^{++}$
   - $Mn^{++}$
   - Nitrate ($NO_3$)
   - Nitrite ($NO_2$)

c) **Biological**
   - Fecal coliforms
   - Bacteria

Besides, the special test is done to study a specific changes in the chemical composition of water. These tests include:

1. Langlier Index: The purpose is to estimate the corrosiveness and the tendency towards

scaling and fouling behavior of water. This test is important for long steel pipe. This test was conducted on the following three sites that feed the longest steel pipe in the network:

- Al-Azraq station (outlet)
- Al-Kahaldia station (outlet after injecting into the outlet of Za'atari station).
- Al-Zarqa station (outlet to Rusaifa).

2. Aeration: This method is used normally to remove dissolved gases from water. The process in most of the cases results in oxidation of iron and other metals which will precipitate and thus the TDS of water will decrease although slightly. Zarqa well No. 14 was selected for this test because of its high productivity and high TDS.

3. Stability of Chlorine: This test was done to determine the decrease in the concentration of chlorine in water after storage in roof tanks and how long the chlorine concentration will remain within the desired range. Three sites were selected for this test. These are in Zarqa, Rusiefa and Hashemeyeh.

4. Chemical Dosage: The purpose of this test is to study the water hardness where it can be reduced by adding soda ash. This test was applied on Zarqa well No. 14.

5. Fluoride: Water that contains fluoride higher than the some limit may require deflouridation in order to prevent fluorosis. This test was applied in Al-Zarqa station (outlet to Zarqa).

6. Chlorine: This test was done to determine the rate of consumption of chlorine along the distance from the chlorinating point. This test was applied on three points along the outlet of Al-Zarqa station and Ruseifa booster.

## 4.2 Result of Analysis

The analysis results of the four samplings are presented in attachment.

### (1) General Chemical Test

1. Salinity: In general, salinity in the Study Area is above the permissible limit. Clear variation occurs in the salinity values for the same point through the four samplings, which can be attributed to the mixing process of water in the reservoirs and pumping stations, as the pumped groundwater wells changed periodically.

2. Total Hardness: One of the major problems of water quality in the Study Area is the high total hardness value. In all the samplings, total hardness values are above the permissible limit, and further exceed 500 mg/l of the maximum limit, especially in summer time.

3. Chloride: About 90 % of the chloride concentration is above the permissible limit. The reason is the over-extraction of water from the highly depleted upper aquifer system in the Study Area especially in summer time.

4. Nitrate and sulfate concentration in Zarqa is below the permissible limits. In general, it doesn't exceed 25 mg/l .

5. Chlorine :The chlorine concentration is less than 2 mg/l for all the collected water samples.

6. Dissolved Oxygen: Concentration of the DO >2 mg/l , with a corrosive effect to metals.

7. Concentrations of the measured water ions show a gentle increase trend during summer season, as indicated from the analysis results of the third and fourth water samplings.

### (2) Special Test result

1. Langlier Index: Calculation of the L.I. shows negative values, indicating a corrosive effect.

2. Aeration : Aeration tests show a very slight decrease in the water electrical conductivity by less than 2%.

3. Chlorine stability in time (roof tank) : These tests results indicate that the chlorine concentration should be increased in water, especially in summer time when water is kept in the consumers tanks for more than four days .

4. Fluoride: Concentration of $F^{-}$ in Zarqa water is below the permissible limit.

5. Chemical dosage: The result shows a sufficient decrease in total hardness of 15 to 58%. The amount of lime added is the stoechiometric limiting reactant, and the yield was very encouraging.
6. Chlorine stability in distance: The result shows that chlorine concentration decreases from 1.6mg/l at Zarqa station to 0.6mg/l after 6km and to 0.3mg/l at a distance of 10km from the station to the direction of Rusaifa in winter.