JAPAN INTERNATIONAL COOPERATION AGENCY

DAMASCUS CITY WATER SUPPLY AND SEWERAGE AUTHORITY
SYRIAN ARAB REPUBLIC

# THE STUDY
# ON
# THE DEVELOPMENT OF WATER SUPPLY SYSTEM
# FOR
# THE DAMASCUS CITY

## PHASE II

## VOLUME III

FINAL REPORT
SUPPORTING REPORT

DECEMBER 1997



NIPPON KOEI CO., LTD

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| ESTIMATE OF PROJECT COST | |
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| Currency Exchange Rate: | US$1 = SL45 = Yen 115 |

## LIST OF REPORTS

# ABBREVIATIONS

**Organizations**

| | | |
|---|---|---|
| ACSAD | - | The Arab Center for the Studies of Arid Zone and Dry Lands |
| BRGM | - | Bureau de Reche rche Geologique et Miniere, France |
| CBS | - | Central Bureau of Statistics |
| CGE | - | Compaginie Generale des Eaux, France |
| DAWSSA | - | Damascus City Water Supply and Sewerage Authority |
| EDWSSR | - | Establishment of Drinking Water Supply and Sewerage in the Rural Province of Damascus |
| EPEF | - | Establishment Public Des Eau De Damas (Figeh) |
| HIAST | - | Higher Institute of Applied Sciences and Technology |
| IED | - | Industrial Establishment for Defense |
| JICA | - | Japan International Cooperation Agency |
| MHU | - | Ministry of Housing and Utilities |
| MOI | - | Ministry of Irrigation |
| MOF | - | Ministry of Finance |
| SAR | - | Syrian Arab Republic |
| SPC | - | The State Planning Commission |
| STE | - | Syrian Telephone Exchange |
| WHO | - | World Health Organization |

**Others**

| | | |
|---|---|---|
| CIP | - | Cast Iron Pipe |
| CIS | - | Customer Information System |
| DBMS | - | Data Base Management System |
| DIP | - | Ductile Iron Pipe |
| DMA | - | District Meter Areas |
| EIA | - | Environmental Impact Assessment |
| EIRR | - | Economic Internal Rate of Return |
| FLS | - | Financial Ledger System |
| FMIS | - | Financial Management Information System |
| GDP | - | Gross Domestic Product |
| GIS | - | Geographical Information System |
| HDET | - | Hand-held Data Entry Terminals |
| H/W | - | Hardware |
| IEE | - | Initial Environmental Evaluation |
| LAN | - | Local Area Network |
| LIMS | - | Laboratory Information Management System |
| MIS | - | Management Information System |
| MMS | - | Maintenance Management System |
| ND | - | Nominal Diameter |
| NPV | - | Net Present Value |
| O&M | - | Operation and Maintenance |
| OS | - | Operating System |
| PE | - | Polyethylene |
| PVC | - | Polyvinyl Chloride |
| SGP | - | Steel Galvanized Pipe |
| S/W | - | Software |
| SCADA | - | Supervisory Control and Data Acquisition (System) |
| UAS | - | Unified Accounting System |
| UFW | - | Unaccounted for Water |
| UPS | - | Uninterrupatble Power Supply System |
| VAT | - | Value Added Tax |

# ABBREVIATIONS OF MEASUREMENT

**Length**

| | | |
|---|---|---|
| mm | = | millimeter |
| cm | = | centimeter |
| m | = | meter |
| km | = | kilometer |

**Area**

| | | |
|---|---|---|
| $cm^2$ | = | square centimeter |
| $m^2$ | = | square meter |
| ha | = | hectare |
| $km^2$ | = | square kilometer |

**Volume**

| | | |
|---|---|---|
| $cm^3$ | = | cubic centimeter |
| l | = | liter |
| $m^3$ | = | cubic meter |
| MCM | = | million cubic meter |

**Weight**

| | | |
|---|---|---|
| mg | = | milligram |
| g | = | gram |
| kg | = | kilogram |

**Time**

| | | |
|---|---|---|
| s | = | second |
| min | = | minute |
| h | = | hour |
| d | = | day |
| y | = | year |

**Electrical Measurement**

| | | |
|---|---|---|
| V | = | Volt |
| A | = | Ampere |
| Hz | = | Herz |
| W | = | Watt |
| kW | = | kilowatt |
| MW | = | Megawatt |

**Other Measures**

| | | |
|---|---|---|
| % | = | percent |
| HP | = | horsepower |
| °C | = | Celcius degree |

**Derived Measures**

| | | |
|---|---|---|
| l/s | = | liter per second |
| $m^3/s$ | = | cubic meter per second |
| $m^3/h$ | = | cubic meter per hour |
| $m^3/d$ | = | cubic meter per day |
| lpcd | = | liter per capita per day |
| $kgf/cm^2$ | = | kilogram forceper square centimeter |
| kWh | = | kilowatthour |
| MWh | = | megawatthour |
| kVA | = | kilovolt ampere |
| mg/l | = | milligram per liter |
| $\mu$g/l | = | microgram per liter |
| meq/l | = | milliequivalents per liter |
| $\mu$S/cm | = | microsiemens per centimeter |

**Currency**

| | | |
|---|---|---|
| US$ | = | US Dollar |
| SL | = | Syrian Pound |

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# CURRENCY EQUIVALENT

(as of July 1997)

US$ 1 = SL 45.0

## TRANSLITERATIONS OF ARABIC PLACE NAMES (1/2)

| | | | |
|---|---|---|---|
| عباسيين | Abasiyin | بيت جن | Beit Jenn |
| أبو زاد | AbuZad | بيت تيما | Beit Tima |
| أشرفية | Achrafye | برزة | Berze |
| عين عوينات | Ain Awenad | بلودان | Bloudan |
| عين بدا | Ain Beda | بقين | Boukein |
| عين حبيب | Ain Habib | دحاديل | Dahadil |
| عين حداد | Ain Hadad | دار المعلمات | Dar al Moalimat |
| عين حاروش | Ain Haroush | داريا | Daraya |
| عين حور | Ain Hour | دير مقرن | Deir Moukaren |
| عين عيسى | Ain Issa | دير العشاير | Deir al Ashayer Shahour |
| عين نورية | Ain Nourieh | حوض التشتيت | Dissipation Basin |
| عين رضوان | Ain Roudwan | دربل | Dourbol |
| عين صبا | Ain Saba | دمر | Dummar |
| عين صالح | Ain Saleh | عسالي | El Esaly |
| عين الباردة | Ain el Baradeh | الفوار | El Fawar |
| عين الخضرة | Ain el Khadra | الفيض | El Feid |
| عين المالحة | Ain el Malha | حفيرة | El Hafirieh |
| عين الصاحب | Ain el Saheb | الهامة | El Hame |
| عين التينة | Ain el Tineh | العرق | El Irk |
| أكراد | Akrad | الشوابط | El Shuwhat |
| جامع القصاب | Al Aksab Mosque | عش الوروار | Esh al Warwar |
| الضاحية | Al Dahia | فاسريا | Fasraya |
| الخضرة | Al Khadra | نبع الفيجة | Figeh Spring |
| الشارع | Al Masharc | فراسكين | Fraskin |
| القزاز | Al Qazzaz | الغوطة | Ghouta |
| السهل | Al Sahl | حفير الفوقا | Hafir el Foka |
| عرطوز | Artooz | حاليا | Halaya |
| قدم عسالي | Asalie Kadam | حسيبة | Hassibeh |
| الاعوج | Awaj | حسينية | Huseiniyeh |
| باب مصلى | Bab Mosallah | ابن النفيس | Ibn Alnafeas |
| باب شرقي | Bab Sharki | ابن عساكر | Ibn Assaker |
| باب السلام | Bab el Salam | جناني | Janani |
| شارع بغداد | Baghdad Street | جرمانا | Jaramana |
| بردى | Barada | جمرايا | Jemarya |
| بساتين | Basateen | جوبر | Jobar |
| بسيمة | Bassime | جوبر عكاش | Jobar Akache |

## TRANSLITERATIONS OF ARABIC PLACE NAMES (2/2)

| | | | |
|---|---|---|---|
| جوبر عمادية | Jobar Imadye | قطيفة | Qutayfeh |
| جوبر قباني | Jobar Kabani | رنكوس | Rankous |
| جرجانية | Jourjaniyeh | رأس الحاجب | Ras Hasib |
| قابون | Kaboon | رأس الوادي | Ras el Wadi |
| قدم | Kadam | الرازي | Razy |
| كفرسوسة | Kafar Souseh | ريمة | Rimeh |
| كفر العواميد | Kafar el Awamid | ركن الدين | Rukn Aldyn |
| قنوات | Kanawat | سعسع | Saasaa |
| قاسيون | Kassioun | صفصافة | Safsafi |
| قطنا | Katana | سردا | Sarada |
| الكرش | Kersh | ساروجة | Sarouja |
| خان الفندق | Khan el Founduk | صيافة | Sayafeh |
| خورشيد | Khorshead | سبيراني | Sebrani |
| قدسيا | Kudsaya | صيدنايا | Sednaya |
| كيوان | Kywan | شاغور | Shaghour |
| لوان | Lawan | شخاب | Shakhab |
| معلولا | Maaloula | ينابيع جانبية | Side Spring |
| معرونة | Maaroune | سومرية | Somareyeh |
| مضايا | Madaya | سيرونكس | Syronics |
| مهدي بن بركة | Mahadi Bin Baraka | طبالة | Tabbaleh |
| شارع المالكي | Malki street | طبية | Tabibiyeh |
| مزرعة | Mazraa | تضامن | Tadamoun |
| ميسلون | Meisaloun | تقدم | Takadom |
| منبج | Membej | تلمذية | Talmasieh |
| مزة | Mezze | تكية | Tekieh |
| ميدان | Midan | المدينة القديمة | The Old City |
| منين | Mnin | تشرين | Tishreen |
| مخيم | Mokhayam | المدينة الجامعية | University City |
| مهاجرين | Mouhajreen | وادي مروان | Wadi Marwan |
| النبوع | Naboua | الوالي | Wali |
| نهر عيشة | Naher Esheh | يعفور | Yaafoor |
| ناظم باشا | Nazem Basha | يرموك | Yarmouk |
| النبك | Nebk | زبداني | Zabadani |
| أمية | Omayad | | |
| أمويين | Oumawiyin | | |
| منطقة الرئاسة | Presidential Area | | |

# APPENDIX A

# DMA SYSTEM

APPENDIX A
DMA SYSTEM

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# 1. INTRODUCTION

This Supporting Report, Leakage Control and DMA (District Meter Areas) System, describes results of the study on management of the distribution network including leakage control to secure the efficient and simple control of transmission and distribution systems in the City.

The objectives of the study are to:

i) Identify the present conditions of the transmission and distribution systems,
ii) Analyze the distribution network systems,
iii) Formulate the plan for the DMA system to enhance leakage detection efforts in the distribution systems,
iv) Select a Pilot DMA and establish the trial operation of a flow rate monitoring system for the Pilot DMA.

The report consists of five major items: 1) basic concept and approach of the study, 2) field surveys, 3) network analysis and DMA planning including the pilot area study, 4) Improvement plan for the distribution systems, and 5) cost estimates and implementation schedule.

## 2. LEAKAGE CONTROL POLICY AND DMA SYSTEM

### 2.1 Leakage Control Policy

#### (1) Necessity of leakage control

In Damascus, the demand for water increases while the availability of new water resources decreases. According to the Master Plan Study (Phase I) a water deficit will likely occur after 2005, since the capacity of water resources (296 MCM/year) is limited by DAWSSA's existing water rights. Water resources will not meet the estimated water requirements of 297 MCM/year. The Master Plan Study recommends that DAWSSA should make efforts to save water and reduce unaccounted for water (UFW) in cooperation with Damascus Municipality.

The loss of water through transmission and distribution system leakage has always been of concern to DAWSSA. The present UFW in the system is estimated at 63 % of water production and consists of 14.4 % for meter malfunction, 13.6 % for informal use and 35.0 % for system leakage. The rather large system leakage is a wasteful use of valuable resources. Leakage increases the likelihood of inadequate water pressure and may, in some cases, increase the risk of water contamination.

A leakage control policy is essential and important for any water utility. However, in most water systems it is impossible and not cost effective to try to achieve zero leakage. Actual costs of measurement, detection and repair for accomplishing zero leakage would vastly outweigh the costs of lost water. The adequate leakage control policy should be based on an economic balance between the benefits of leakage reduction and the costs of planning, implementing and running the leakage control program.

The active and well-planned leakage control program is a positive indicator of DAWSSA's overall management ability and effectiveness and also a direct measure for enhancement of its efficiency. It is imperative that DWSSA adopt an active policy for reduction of UFW, and that the determined policy optimize the operation of the whole supply system, availability of resources and satisfaction of demand.

(2) Policy and methodology of leakage control

There are two main types of leakage control policies namely, passive control and active control. The passive control policy is purely reactive, attending to and repairing known leaks. With an active policy, intense effort is put into real-time monitoring, inspection and immediate rectification. In both cases, information systems for leakage control will play a vital role. For passive leakage control, it is necessary that leak detection be carried out regularly and logging of leak detection efforts and repairs be processed in a database. For active control, leak detection survey should be linked in real time to the Supervisory Control and Data Acquisition (SCADA) system for water utility to be established by DAWSSA, and leak detection and repair records should be processed in a sophisticated database in order to utilize for long-run system operation and maintenance planning.

The leakage control plan shall be formulated based on appropriate leakage control method in consideration with relation between leakage and pressure, hydraulic analysis and review of the whole water supply system in the City. The following leakage control methods can be used in the service area:

i) Pressure control

Reduction in pressure may reduce the rate of loss through each leak and also affect the rate of leakage outbreak. As this control does not provide leakage detection, it is adopted to supplement other methods.

ii) Passive leakage control

In this method only those leaks which become self-evident are identified and repaired. A leak may be self-evident because water shows on the surface or may become apparent upon ad hoc investigation following consumer complaints. This method allows leakage to rise to unacceptably high levels and is seldom an economical alternative for urban water supply systems.

iii) Regular acoustic sounding

This method involves teams of inspectors seeking leaks by systematic direct sounding on all service connections, hydrants and valves throughout the distribution system and listening for the characteristic noise of leakage. This method can be divided into two phases: 1) survey to define and localize suspected areas of leakage and 2) survey to detect and pinpoint the leaks. This method is useful and adopted for leakage detection, but is not usually sufficient for systematic monitoring and leakage control.

iv) District metering

District metering is one of the most effective leakage monitoring methods. Meters are installed throughout the distribution system in order to measure continuously the integrated flow into a defined area marked by boundary valves (districts). The meters are read regularly and increases of the total water supply at a district can indicate the presence of leaks.

v) Waste (sub-zone) metering

In the waste metering method, meters are positioned in a number of discrete areas. The areas are isolated and fed by a single supply through the meter. The valve operation is performed at night, and the minimum flow rate is measured through the meter. If a significant increase in water use is noted since previous measurement, leakage is probably occurring. This method has some disadvantages including; costly operation and no leakage detection in the case where there is no change in the minimum flow to the sub-zone.

vi) Combined district and waste metering

This method consists of both district metering and waste metering. When increase in supply is indicated on the district meter, the waste meters are set downstream of the district in order to subdivide the metered area into more manageable units, and detect the area containing the most leaks. The district metering method must be established prior to setting up the waste metering.

In this study, the leakage control plan is formulated based on the DMA system supplemented by pressure control and regular acoustic sounding as described in the Chapter 4.

(3) Leakage control plan

A leakage control plan was proposed by the Master Plan Study as follows, based on a comparison of alternatives for leakage control policies and methodologies.

i) A program of mains renewal to reduce the level of leaking lead joints on cast iron mains and reinforce the existing distribution system thus safeguarding supplies.
ii) A program for setting up the DMA system that will enable DAWSSA to monitor the distribution system and identify areas of high leakage.
iii) A program for setting up regulated pressure zones which will reduce the levels of leakage in high pressure zones. This program will support the DMA system.
iv) A program for reinforcement of regular acoustic sounding surveys for leak detection in the distribution system.

The water leakage reduction program based on the DMA system for the distribution system in the City was selected from master plan as one of the priory projects for the Feasibility Study. In this study stage, the DMA system will be introduced on a pilot basis and a plan and formulated to implement a system appropriate to an urbanized city with the existing water supply system like Damascus. The other leak reduction programs identified in the Master Plan, especially the water main replacement program proposed as an urgent project, will also be reviewed and reexamined in this stage because of their close relationship to the objectives of the DMA system.

## 2.2 Basic Concepts of DMA System

The DMA system is primarily intended to provide systematic monitoring of water flows into hydraulically discreet sections of the distribution network to identify the presence of leakage, therefore the integrity of the piping system.

Dividing the whole water service area into separate districts defined by boundary valves or pressure zones, and effectively monitoring water supply by district metering make it possible to maintain proper water pressure, reduce leaks, and quickly discover and deal with failure at an early stage. This is done by monitoring the state of flow in the network and breakout demand district by district. It thus contributes to the collection and analysis of basic data for water service improvement, leakage detection and prevention, distribution planning and so on. It is also useful to simplify water supply restricting operation in droughts and other unusual situations.

DMA districts are further subdivided into smaller blocks based on the type of water demand in the district, conditions of the existing distribution system (reservoirs, pumping stations, pipeline), topographical features and urban development. In principal, permanent meters are installed at defined blocks in order to monitor flow and obtain valuable information on water leakage and flows throughout the system. This information is valuable when optimizing day-to-day operations and planning future improvements and extensions, including input into network analysis modeling. The main advantage of this method is that leakage detection and repair are always done wherever monitoring indicates an increase in consumption.

It is extremely beneficial to design the district using mathematical network analysis models since district metering involves closing in a district and supplying water through one or more meters. In this method, flow and pressure systems within the proposed district can be verified. Once district metering is installed DAWSSA will have the ability to reduce leakage to a target level (25 % of water production). The future leakage monitoring and detection effort required by DAWSSA is based on this target level.

The advantages and disadvantages of the DMA system are summarized below;

i) Advantages

- It is possible to evaluate the uniformity of water supplying capacity in the entire distribution system.

- It prepares the flow database for basic factors to be utilized in future leakage detection programs.
- It determines realistic leakage potential in the distribution system, and permits to evaluate more detailed leakage detection efforts and plans from an economic aspect.
- It will facilitate finding deficiencies in the whole water supply system, including the transmission and distribution systems.
- Supplemental information such as peak and average demands can be easily developed from the DMA system. This will be useful in computer model calibration and demand forecasts.
- Labor and equipment investment plans can be prioritized.
- It prepares maps of the system to reflect DMA boundaries, and mapping system will be introduced easily.

ii) Disadvantages

- Implementation cost may be high compared with other methods such as pressure control and regular acoustic sounding.
- It is difficult and costly to execute the DMA plan because new sectional valves must be installed on the existing distribution network.
- It may lead to erroneous results at the district where there are unknown cross connections or unsuitable valving operations.
- Water supply shortages during emergency, such as fire protection and breakdown of main facilities, may occur temporarily because the sectional valves required for monitoring reduces some of the operating flexibility for alternate supply.

## 3. APPROACH OF THE STUDY

Taking into account the above mentioned basic policy and concepts in the Chapter 2, the following approach to the study was taken:

### 3.1 Formulation of The Plan for DMA System

The formulation of the DMA system plan was carried out according to the technical approach as shown in Figure A-3.1. The technical approach is described as follows:

#### (1) Strategies for water district planning

The plan for the DMA system was developed based on the following strategies.

i) The DMA system should be established as a countermeasure to alleviate water shortage problems by improving leakage detection through the regional control of water supply amounts.

ii) In the analysis of the distribution network, consideration should be given not only to the existing network but also to the analysis of networks extended into informal areas.

iii) The DMA system should be established as appropriate on distribution systems that are well maintained and simple to operate.

iv) Flow meters should be installed on those loop mains where flow is sufficiently high in order to avoid the difficulty of installing sectional valves.

v) The monitoring of flow rates in the proposed DMA plan should be coordinated with the SCADA system.

In order to enforce the aforesaid strategies, supplementary data collection and field surveys, such as leakage survey and topographic survey, should be carried out and all the data should be analyzed for evaluating the existing water supply services.

(2) Network analysis

In all but the simplest system, a network analysis is considered an essential first step for implementing the DMA system. The network analysis should be carried out based on the existing water supply conditions classified by administrative zones (population & demand), water supply facilities (pipe & valves) and water pressure zones. The analysis should be also conducted with three cases; wet season, dry season and urgent case such as a fire.

Accurate data on minimum night flows and water pressure distribution in the network will be necessary in order to analyze the distribution network properly. In order to be useful, data can only be taken during full flow conditions in the distribution network which occur during the wet season. The water pressure measurements will be carried out at the hydrants on the water mains. Flow rate measurements will be carried out at the outlet of the main reservoirs connected to the distribution network.

A preliminary analysis of the existing distribution network should be based on the results obtained by the surveys and the network analysis should be reexamined after planning the DMA system.

(3) District planning

The DMA plan is an essential requirement for the water leakage reduction strategy. In addition, DMA should help operators to manage the flow rates and water pressures and simplify operations in emergency situations such as drought and fire.

Planning the delineation of DMA districts was based on a number of different procedures such as:

i) The water supply district was divided by distribution source, such as main service reservoirs (Wali, Eastern and Western reservoirs),
ii) The water supply district was divided by geographical conditions, such as topography, roads, land use pattern and geographical features,

iii) The existing five pressure ranges (Low, Medium, High I & II, Superior High) were reviewed and the water supply districts were ranked at allowable water pressure,

iv) The water supply district boundaries were determined by obstructions such as rivers/drainage channels and rails,

v) Distribution conditions were classified based on water demand, population served and pipe length,

vi) O&M functional conditions like as water billing collection centers (26 centers) were considered.

(4) Examination and formulation of DMA system

The planning for DMA should consider the size of the metered districts for determining areas adequate for leakage control. The DMA system is practically divided into three block classifications based on the size of the service area as follows:

| Classification | | Scale |
|---|---|---|
| Major | Minor | |
| Service area | Large block | A service zone of an individual reservoir, Total length of distribution main: 50-300 km |
| Large block | Medium block | Total length of distribution main: 30-50 km |
| Medium block | Small block | Total length of distribution main: 10-15 km, Population served: 15,000-20,000 |

The above indicates the scale for each block system adopted as criteria to plan the DMA system. Planning of the small block system is conducted only to determine feasibility and is not proposed and is not proposed for implementation at the initial stage, since smaller blocks are usually introduced after the basic DMA system has been operational.

The DMA plan is established to minimize the number of inflow and outflow points for each block. Each block is selected based on criteria such as geographic conditions, topography, pipeline length, and population served. In general, the boundary for a DMA is usually formed by using sectional valves, but it is very difficult and costly to execute the DMA plan by mounting new sectional valves on the existing distribution network inside Damascus city. Flow meters will, therefore, be utilized instead of sectional valves.

(5) Evaluation of DMA plan

Ideally, the DMA system should be evaluated after at least 5 years of operation using data obtained from DMA flow monitoring. In this study, preliminary the evaluation is carried out in consideration of local property factors, such as DAWSSA's classification of water pressure and allocation of water demand. The main evaluation factors consist of stability (water pressure, water quantity, water quality), maintainability (simplicity, accessibility), efficiency (frequency in use of system), economic viability (construction cost, operation & management cost) and level of service (dissatisfaction of consumers). In the study, stability will be the most important factor for evaluating the DMA plan in the present conditions of distribution network of DAWSSA.

The evaluation criteria for stability consist of following indexes.

| Evaluation Factor | Evaluation Index |
|---|---|
| Water pressure | Static water pressure<br>Dynamic water pressure |
| Water quantity | Rate of turnover of service reservoir<br>Conveyance capacity in emergency case |
| Water quality | Concentration of residual chlorine |

In this study, water pressure was adopted as the primary evaluation factor since it is the most critical service factor for water supply. Additionally, length of water mains at each medium block was also used as an important factor for the evaluation in consideration of monitoring ability of DAWSSA.

3.2 Implementation of DMA System

(1) Determination of priority areas for implementation of DMA system

To supplement the leakage detection and control plan proposed by the Master Plan, metered districts should be established throughout the service area. The following factors are used for determining priority areas for implementation of the DMA system:

i) Stability (water pressure, water quantity) adopted for evaluation of DMA plan

ii) Population and water demand

iii) Informal population

iv) Cast iron pipe used ratio

(2) Selection of pilot DMA

A pilot area was selected among the proposed medium blocks for the purpose of demonstrating flow rate monitoring with ultrasonic flow meters and obtaining the necessary data for leakage control as mention later in the Section 6.4. In the selected pilot area, a leveling survey was carried out to confirm the elevation of the water mains and location of valves.

(3) Implementation program for DMA system

The implementation program for the DMA system was prepared during this study in consideration of the present conditions of the water supply services, cost, on-going projects, contractors, procurement of construction materials and labor force, manner of procurement of water supply equipment and materials, and the manner of construction.

The implementation program consists of 1) manner of procurement for construction works, equipment and materials, 2) construction methods, 3) cost estimate, 4) implementation schedule and 5) disbursement schedule for project cost.

(4) Recommendation of the flow rate monitoring system

Flow rate monitoring is proposed as part of the DMA system to establish a water leakage control method and a water consumption monitoring system in the distribution network. The main objectives of flow rate monitoring are:

i) To identify leakage at medium block (leakage level is more than $1m^3/hr$, monitoring factors are a minimum night time flow and unit flow),

ii) To monitor the actual conditions of water consumption and forecast a water consumption pattern daily, monthly and seasonally,

iii) To reduce the amount of water lost due to leakage,

iv) To prepare a database for planning emergency water supply and restoration works in the network after completion of DMA system,

# 4. FIELD SURVEY

## 4.1 General

The following field surveys were carried out in order to understand the existing conditions in the distribution system and obtain data required for the water supply district planning and distribution network analysis;

i) Flow measurement on water mains
ii) Pressure measurement on water mains
iii) Meter reading and interview survey on individual reservoirs at Midan and Yarmouk
iv) Leakage detection survey on selected water mains

## 4.2 Survey Areas

Field surveys were conducted within the existing DAWSSA water supply service areas except Dummar and Kassioun Mountain in the City as shown in the Figure A-4.1. The total target area for field surveys is approximately 72 $km^2$ and the total length of water main is estimated at 1,057 km. The existing main facilities in the survey areas are located as shown in Figure A-4.2.

## 4.3 Survey Methods

### 4.3.1 Flow Measurement

Selected service reservoirs for flow and velocity measurements are identified below:

i) Wali Old Reservoir (I.A) ND1000 mm Line : IA-D04.ND1000
ii) Wali Old Reservoir (I.A) ND500 mm Line : IA-D04.ND500
iii) Wali Old Reservoir (I.A) ND250 mm Line : IA-D04.ND250
iv) Akrad Low Reservoir (I.E) ND500 mm Line : IE-B03.ND500
v) Eastern Reservoir (II.E) ND600 mm Line : IIE-D09.ND600
vi) Eastern Reservoir (II.E) ND800 mm Line : IIE-D08.ND800

vii) Western Reservoir (H.O) ND1200 mm Line : HO-D06.ND1200

viii) Western Reservoir (H.O) ND1200 mm Line : HO-D10.ND1200

ix) Western Reservoir (H.O) ND700 mm Line : HO-D05.ND700

x) Mezze Reservoir (M.1) ND800 mm Line : M1-M01.ND800

xi) Mezze Reservoir (M.1)-(M.2) D800 mm Line: M2-M02.ND800

To assess the conditions of the existing distribution lines, flow rates were measured at the eleven outlets of the five key reservoirs that are used as the main supply to the City as shown in Figure A-4.3. Portable ultra sonic meters with monitoring system were used to measure flow through water main. These are solid state electronic meters that measure velocity and converts this into volumetric and mass units. The ultra sonic meter has the following features and specifications:

i) Waterproof and submersible type with waterproof cylindrical multi-pin for all connection,

ii) Provision of the its internally chargeable battery for a normal operation (4 hrs) and the externally portable waterproof battery for a full day operation,

iii) Provision of data logging function to process data by computer,

iv) Provision of diagnostic menu for on-site or remote support to assure full confidence in flow data,

v) Specifications;

| | |
|---|---|
| Measured fluid | : Any sonically conductive liquid |
| Fluid temperature | : -40°C to +120°C (standard) |
| Velocity range | : ±12 m/sec |
| Accuracy intrinsic calibration | : 1% to 2% (±3 mm/sec to ±6 mm/sec) |

Continuous measurement was conducted twice: for seventy two (72) hours during May 19 to 22 and for forty eight (48) hours during May 27 to 29, 1997.

#### 4.3.2 Pressure Measurement

Pressure measurement was carried out for the same purpose as the above mentioned flow measurement. Portable water pressure recorders with the following distinctive features and specifications were used.

i) Three variable time settings are available: 24 hrs, 72 hrs and 168 hrs.
ii) The pressure range for allowable measurement is 5 kg/cm$^2$ and 10 kg/cm$^2$.
iii) Automatic prevention of overlapped time charts is built-in.
iv) It is compact waterproof robust plastic housing type.
v) Operation is done by a quartz clock.
vi) It is recorded by a felt pen with cartridge ink supply.

Continuous measurement was conducted three times for forty-eight (48) hours from May 19 to 21, from June 10 to 13 and from August 10 to 11. Pressure was measured at ten (10) hydrants in the first period, at nine (9) hydrants in the second period and ten (10) hydrants in the last period located in the main network as shown in Figure A-4.3.

#### 4.3.3 Meter Reading and Interview Survey on Individual Reservoirs

In the Master Plan Study (Phase I), meters in Dar Al Moalimat and Ruku Aldyn areas were read for 6 months so as to obtain data related to per capita consumption and meter accuracy. Meter reading in this Study (Phase II) was aimed mainly at finding out and clarifying the typical daily water consumption pattern. Meter reading was conducted at several building types as described below in Midan and Yarmouk which were selected for the flow monitoring in the pilot area.

i) Condominium : 1 sample
ii) Small House : 7 samples
iii) Mosque : 1 sample
iv) Police office : 1 sample

Master meter reading and the investigation of the water use of each house were carried out at ten samples in total (7 in the formal area and 3 in the informal area) from July 7 to August 11, 1997.

House master meter readings were recorded at the beginning and the end of the measurement (with 24 hour interval), and the amount of water used per day was calculated from the difference of the two values. At the same time ultra sonic flow meters were installed to record the water use conditions over 24 hours. The ultra sonic meters were used in order to confirm the reliability of house meters, and to analyze the data fully. Meter reading and flow measurement in formal areas were conducted continuously for twenty-four (24) hours at each building type during July 7 to August 11, 1997. Additionally, flow measurement at Three (3) informal houses in Mezze-Razy was carried out to capture actual water consumption during August 4 to 7, 1997.

Interview surveys on the use of individual storage reservoirs were also carried out by assistant surveyors employed by the JICA Study Team during June 15 to 31. This interview survey was intended to enhance accuracy of results on water consumption patterns obtained by the above mentioned meter reading, since almost all the buildings have individual storage reservoirs of various capacity which may influence water consumption patterns. The survey method consisted of interviews with questionnaire written in both English and Arabic, and one hundred (100) interviewees were selected at Midan and Yarmouk according the following categories:

| Type of Building | Number of Samples |
|---|---|
| 1) House (≦ 2 stories) | 33 |
| 2) House (≧ 3 stories) | 10 |
| 3) Apartment/Condominium | 47 |
| 4) Government Office Building | 2 |
| 5) Hospital | 4 |
| 6) School | 4 |
| Total | 100 |

### 4.3.4 Leakage Detection

At present, leakage detection surveys are carried out by three leakage teams in DAWSSA as recommended in the Master Plan Study (Phase I). In this Study, leakage detection efforts were concentrated on old cast iron mains with lead joints, which, as shown in Figure A-4.4, have a history of leaking. The intention of this concentrated effort was to measure loss of water from leakage in the distribution mains and reexamine the necessity for the urgent pipe replacement program proposed in the Master Plan.

Leakage detection surveys were carried out by the acoustic leakage sound detection method on four separate occasions. On June 22, a leakage detection survey was carried out on a cast iron main of ND200 mm near the Jemarya pumping station. Other surveys were conducted on old cast iron mains in the City from July 1 to 15, 1997. The following equipment was used:

i) Pipe/cable locators
ii) Leak noise correlators
iii) Acoustic listening ear set
iv) Excel sounding sticks/bars
v) Leak noise detector

## 4.4 Findings

### 4.4.1 Flow Rate

Flow measurement records for 11 pipelines are illustrated in Figures A-4.5. Flow velocity also is shown in Figures A-4.6 and A-4.7. The results of flow rate and velocity measurement at water mains are summarized in Tables A-4.1 to A-4.3. The measured average daily flow rate was 479,537 $m^3/d$ in this study which is lower than the water consumption of 612,308 $m^3/d$ estimated in the Master Plan study. This big difference is coursed by reasons that the measured flow does not reflect the present water shortage problem and the M/P water consumption is estimated taking the potential water demand in account.

A comparison of the flow in each line shown in Table A-4.2, reveals that the flow rate in the pipeline (HO-D10.ND1100 mm) from the western reservoir to block D10 is high and hourly fluctuations of consumption are also very high. The normal flow velocity of this line varies from 2.0 m/s to 2.3 m/s. During 11:00 a.m. and 1:00 p.m. on May 20, 6 peaks of flow velocity with an instantaneous maximum velocity of 4.0 to 6.0 m/s were recorded (Figure A-4.8). These peaks in velocity are considered abnormal. The existing flow capacity of this line is less than the potential water demand in the service area, other than this one occurrence, very few instances of abnormally high velocity were recorded. Based on the results of measurement, the instantaneous maximum flow velocity in other pipelines is approximately less than 2.0 m/s as shown in Table A-4.3.

Recommended maximum velocity is commonly not more than 3.0 m/s for water main and less than 2.0 m/s to prevent damage to the lining inside pipe. There is a serious concern that the pipeline may suffer from serious damage since the high velocities (more than 2.5 m/s) increase the risk of cavitation and water hammer effects.

Minimum night flow is estimated at an average 4.34 $m^3$/sec from results of flow measurements as shown in Table A-4.1 and A-4.2.

### 4.4.2 Pressure

Pressure records for the first and the second measurement periods are compared in Figures A-4.9 to A-4.11 respectively. In this study, the existing distribution conditions were evaluated from the pressure records based on the following DAWSSA criteria:

i) High pressure zone : 50 m to 60 m
ii) Medium pressure zone : 40 m to 50 m
iii) Low pressure zone : 30 m to 40 m

The results of pressure measurement are summarized in Table A-4.4. Almost all the pipelines in this survey are within normal conditions except the HO-D10 pipeline. It is suspected that the HO-D10 pipeline may have a significant leak, therefore, it shall be investigated in more detail by DAWSSA.

### 4.4.3 Residential Meters and Interview Survey on Individual Storage Reservoirs

The records for the flow meters are shown in Figures A-4.12 to A-4.15 for each type of house. The reading investigation of the house meters was carried out for six samples (Sample No. 1 to 6). It is estimated that the rate meter malfunction is more than 10 percent and the observed accuracy is quite low (See Table A-4.5). The reasons may be that house meters are too old, are broken, or that the malfunctions occur especially when taps are opened and closed frequently. The house meters No. 3 and No. 6 were not operating. The results of measurements taken with flow meters and house meters are summarized as follows:

| Sample No. | House Type | Area | Formal/ Informal | Flow Meter | House Meter | Meter Malfunction of House Meter |
|---|---|---|---|---|---|---|
| | | | | $m^3$/day | $m^3$/day | % |
| 1 | Condominium | D10.5 | Formal | 3.369 | 3.040 | 10 |
| 2 | Small House | D10.4 | Formal | 0.142 | 0.110 | 23 |
| 3 | Small House | D10.4 | Formal | 0.287 | 0.000 | - |
| 4 | Police Office | D10.5 | Formal | 30.970 | 0.804 | 97 |
| 5 | Small House | D10.5 | Formal | 6.670 | 1.040 | 84 |
| 6 | Small House | D10.5 | Formal | 22.550 | 0.000 | - |
| 7 | Mosque | D10.4 | Formal | 4.750 | Not equip | |
| 8 | Small House | D11 | Informal | 40.140 | Not equip | |
| 9 | Small House | D11 | Informal | 5.070 | Not equip | |
| 10 | Small House | D11 | Informal | 35.010 | Not equip | |

The samples that show the period in which water is supplied to house water storage tanks are No. 1, No. 5 and No. 8. The water supply period is from 8 p.m. to 7 a.m. for No. 1 and from 10 a.m. to 2 p.m. for No. 8 (See Figure A-4.12 to A-4.15).

The examples No. 1 and No. 6 indicate that there is leakage because water use is indicated at all times during the 24 hour monitoring period. The pattern of water consumption on different days is not the same, but it is quite stable from 0 a.m. to 5 a.m.

Daily water consumption patterns were identified from this survey. The peak daily water consumption occurs during 9:30 a.m. to 1:00 p.m. and during 9:00 p.m. to 0:00 a.m. where houses have an individual storage reservoir. For houses without individual storage reservoir, water is used continuously with peak consumption occurring during 11:00 a.m. to 9:00 p.m.

The results of the interview survey on individual reservoirs in the pilot area and the Mezze-Razy & Kafar Souseh-Lawan informal area are shown in Tables A-4.6 and A-4.7 respectively. An analysis of data from the interview survey is summarized below:

| | Occupancy (%) | Capacity ($m^3$) | Manual Operation (%) | Night Time Water Filling (%) |
|---|---|---|---|---|
| 1. Pilot Area | 96 | 1.4 | 22 | 17 |
| . House | 96 | 0.8 | 22 | 19 |
| . Others | 100 | 6.6 | 20 | 0 |
| 2. Informal Area* | 97 | 0.8 | 22 | 21 |
| . Formal | 98 | 0.9 | 21 | 21 |
| . Informal | 96 | 0.8 | 22 | 20 |
| 3. Average | 97 | 1.1 | 22 | 19 |

Note: * is the Mezze-Razy & Kafar Souseh-Lawan informal area.

The survey results indicate that 100 % of those interviewed with individual storage reservoirs use them regardless of the season and at least 21 % of individual reservoir users operate their reservoir daily.

### 4.4.4 Leakage

The Master Plan Study estimated the average loss due to leakage in the system at approximately 7.0 $m^3/h/km$ in 1995. In this study, the leakage detection survey was carried out not only on old cast iron mains installed more than 25 years ago but also on ductile cast iron mains in order to compare leakage rates between the two.

The loss due to leakage in the system was estimated from the results of the leakage detection survey using the acoustic leakage sound detection method as shown in Table A-4.8. Total system loss from leakage is estimated as 209 $m^3/hr$ consisting of 168 $m^3/hr$ on distribution mains and 41 $m^3/hr$ on service mains. There was no leakage from the ductile iron mains in this survey. Frequency of leakage per unit pipe length is 3.8 leaks/km and the unit loss per pipe length is 30.3 $m^3/hr/km$.

The old cast iron mains shall be replaced as soon as possible since the loss of 30.3 $m^3$/hr/km is extraordinary high in comparison to the average loss in the system of 7.0 $m^3$/hr/km estimated in the Master Plan Study. Most of the leakage is occurring at decrepit lead joints and pipe failures caused by corrosion of cast iron.

# 5. NETWORK ANALYSIS

## 5.1 General

### (1) Area and boundaries for analysis

Damascus city consists of fifteen administrative districts and the Kassioun Mountain area. The water network analysis in the City was carried out for 14 administrative districts excluding Dummar district and Kassioun Mountain area as illustrated in Figure A-5.1. The total area for analysis is estimated approximately at 7,200 ha. For the network analysis, the study area was subdivided into smaller units as follows:

i) Six (6) boundaries at main service reservoirs: Wali (I.A & I.S), Eastern (I.E), Eastern (II.E), Western (II.O), Mezze (M1).
ii) Five (5) pressure zones: Low, Medium, High I, High II and Superior High
iii) Damascus center low is divided into five zones according to the existing network conditions and land use pattern.

### (2) Objectives of analysis

The network analysis is mainly aimed at:

i) understanding the present operating conditions of the water supply system in the City,
ii) planning the DMA system,
iii) developing an improvement plan for water leakage detection.

Other objectives of the network analysis are directly related to the UFW and leakage control, such as determination of priority areas for leakage control, determination of necessary arrangements and recommendations for pressure control.

## 5.2 Network Model and Facilities Used

### 5.2.1 Network Model

In order to analyze the network properly, it is necessary to systematically elaborate an extremely simplified model, compatible with the requirements for accuracte network analysis. The network model should reflect the results obtained from the field survey as described in the Chapter 4.

A system layout reflecting upgraded data on the existing water distribution system in the City was prepared for the network analysis as shown in Figure A-5.2. District planning was examined preliminarily based on the system layout. The existing network was analyzed based on blocks classified by the primary DMA plan as shown in Figure A-5.3. The network model was elaborated with water mains grouped into 9 blocks. The characteristic of each block is summarized as follows:

| No. of Block | Pressure Zone | Water Source (Service Reservoir) | Area (ha) |
|---|---|---|---|
| B03 | Berze Medium | Akrad Low (I.E) | 199.0 |
| D04 | Damas Center Medium | Wali Old (I.A) | 213.0 |
| D05 | Damas Center Medium | Western (II.O) | 205.0 |
| D06 | Damas Center Low | Western (II.O) | 368.0 |
| D08 | Damas Center Low | Eastern (II.E) | 202.0 |
| D09 | Damas Center Low | Eastern (II.E) | 720.0 |
| D10 | Damas Center Low | Western (II.O) | 2,205.5 |
| M02 | Mezze High I & II | Mezze High (M.2) | 137.5 |
| M01 | Mezze Medium | Mezze (M.1) | 825.2 |

### 5.2.2 Facilities Used

The distribution system was analyzed with a computer program named Visual Pipeline Network Simulator (VIPNES Version 1.1), developed by Japan Pipeline System Engineering INC. This section gives a brief summary of the main features of the program and describes its various features since the detailed manual of the program was prepared separately during this study.

VIPNES is a multipurpose simulator, used to solve pressure and flow problems in meshed pipe networks and detect pipelines with stagnant water or reverse flow, moreover to assist planning of DMA and pipe replacement. Using the network data such as pipeline data and demand data, the program calculates basically velocity, flow rates and pressure. Main features of the program are summarized as follows:

i) Calculation method

The calculation is based on the algorithm of the Mesh Flow method. Like the Hardy Cross method, the Mesh Flow method is one of the flow methods, also known as the node method, which involves satisfying the flow continuity equation at each of the nodes in the model by adjusting the hydraulic heads.

The Mesh Flow method is able not only to calculate faster than the Hardy Cross method but also to allocate demand to both pipelines and nodes. In this method, network analysis is executed by the Newton Raphson Method that repeatedly solves linearized network equation consisting of determinants at each mesh. The head loss of pipeline is obtained by the Hazen-Williams' equation.

ii) Calculation process

The calculation starts from selecting any node or pipeline where it is possible to determine the algebraic sum of the flow rate originating either from pipes leading to this node/pipeline, or from external flow exchanges. This sum will have a non-zero value until the hydraulic heads and flow rates in the network have been balanced. The head is then modified in this node/pipeline so as to satisfy the continuity equation. In the same manner, all the other nodes/pipeline in the network are reexamined, except nodes for reservoirs where the head is usually fixed.

Even in case that the network is divided into blocks, the above process is automatically repeated at each block at the same time for a sufficient number of times in order that the flow continuity at each node keeps practically unaltered by the calculation of a neighboring node. Calculation conveyance is accelerated between the conventional series of iterations by an overall resolution of complete system of previously line arisen continuity equations.

iii) Allowable network size for analysis

Maximum number of nodes : 2,500
Maximum number of pipelines : 5,000

Less than 1,000 nodes are recommended for proper operation when it is necessary to calculate and draw the network by the computer in a few minutes.

iv) Program organization

The program is constructed on the spread sheet software EXCEL that is widely used. Users can therefore analyze data of their own or execute the customizing by using the EXCEL's standard functions.

The simulation consists of a series of steady state network analysis throughout the simulated time period. The simulation also models the variation in the reservoir level. The simulation results can give a snapshot view of variables for the network of any required time during the simulated period. The simulation can also provide a profile of the performance of individual network features, such as reservoir level, nodal or block pressure/flow, for the whole or part of the simulation period.

The program has an excellent mutual function between the calculation table and the network chart so as to search automatically on the calculation table for particular data that are selected from a specific pipe on the network chart, and vice versa. This function is available not only for the network chart but also for water pressure and flow distribution charts.

### 5.3 Model Construction

This section describes the construction of a network model covering the existing water supply area in the City. The network model was developed during May to August, 1997. In VIPNES, the following input data are required for model construction:

i) Pipe data (length, diameter and roughness coefficient)
ii) Variable head reservoir and pumping data
iii) Node data (identification number, elevation and coordinates)
iv) Estimated population served and allocation of demand

#### 5.3.1 Topographic Data

Topographic data was prepared by DAWSSA based on a 1971 topographical map. Topographic conditions in the area are illustrated in Figure A-5.4. The value in this figure indicates the elevation above mean see level of ground above existing water mains in the network.

The elevation in the area varies from 855.00 m to 688.80 m above mean see level. Wali Old reservoir is the key service reservoir for water supply system in the City and is located at elevation of 801.30 m above mean sea level. Berze High I (B01) is the highest elevation with 855.00 m and the lowest elevation is in Yarmouk in Damas Center Low (D10).

#### 5.3.2 Population Served

Population projections were conducted in the Master Plan Study (Phase I) based on 1994 Census results obtained from the Central Bureau of Statistics. According to the results of population projection, the existing population served in the Study area is estimated approximately at 1,225,000. This number of population served includes the number of informal residents (about 26 %) since informal residents actually take water from DAWSSA's system without any payment. Population served at each district is summarized as shown in Table A-5.1.

DAWSSA classifies the service area by water charge collection centers, and by meter reading areas. Populations served for each method of classification are estimated in Tables A-5.2 and A-5.3 respectively. These population served estimates are used for DMA planning of medium and small blocks.

### 5.3.3 Reservoir and Pipe Data

Reservoirs and pipelines for the network analysis were selected based on the system layout drawing with the primary DMA plan prepared for this study. Details of the selected reservoirs are shown in Table A-5.4. Reservoir statistics used in the model are summarized below:

| Name of Reservoir (Code No.) | Capacity ($m^3$) | Elevation above mean sea level (m) | |
|---|---|---|---|
| | | H.W.L | L.W.L |
| Akrad Low (I.E) | 4,100 | 790.00 | 785.00 |
| Wali Old (I.A) | 7,500 | 804.53 | 800.53 |
| Western (II.O) | 42,704 | 764.00 | 755.50 |
| Eastern (II.E) | 28,240 | 753.38 | 749.38 |
| Mezze High (M.2) | 2,901 | 821.24 | 817.24 |
| Mezze (M.1) | 8,732 | 776.25 | 772.25 |

Pipe data for the analysis are determined with the following features:

i) Initial and final nodes
ii) Diameter and length
iii) Roughness coefficient

In the model, water mains with diameter over 250 mm were mainly analyzed. The length of each pipe was digitized and calculated by the program. Roughness coefficient of all pipes was uniformly assumed to be 110 based on the DAWSSA's standard. Total number of pipelines is 937 for the analysis.

### 5.3.4 Nodes and Allocation of Demand

A node is defined with the following features:

i) Planimetric X-Y coordinates
ii) Altimetric Z coordinate (ground level)
iii) Classified water demand based on the land use pattern

X-Y-Z coordinates of nodes in the model were derived from the information on the system layout. All nodes corresponding to the water main connections and to the changes in pipe diameter were included in this model. Nodes related to the major valves and to the pumping stations were also considered. The total number of nodes for analysis is 921.

The existing water demand in the City is estimated for each administrative district as shown in Table A-5.5 according to the water demand forecast done by the Master Plan Study. Water demand for each large block was allocated in proportion to the area of the districts within each block. Water demand per node within a block was calculated by dividing total water demand in the block with the total number of nodes in the block. Allocation of water demand for large blocks is based on the existing water demand projections as shown in Table A-5.6.

Since there was no demand data for D07 block, the demand was calculated as follows. First, the population of D07 was divided in proportion to the length of contact with adjacent blocks. Then, this fraction of population of D07 proportional to the contact length was assigned to the corresponding block adjacent to D07, and the average per capita demand of each adjacent block was calculated from the water consumption of the block and the corrected population of the block. Based on the average per capita demand and the fraction of population of D07 assigned to the adjacent block, the demand for D07 block was estimated as 19.962 $m^3$/day. The demand for each adjacent block was calculated similarly from the populations of the blocks and the average per capita demand of the block.

### 5.3.5 Summary of Model Constructions

The model statistics are summarized below:

| Statistic Item | Description |
|---|---|
| Population | 1,225,000 |
| Unit water requirement per capita (lpcd) | 446 |
| Number of nodes | 921 |
| Number of pipelines | 937 |
| Number of service reservoirs | 6 |
| Number of production well pumping stations | 9 |
| Number of fringe well pumping stations | 19 |

Total length of pipeline to be analyzed is estimated at 368 km corresponding to 35 % of the total length (1,050 km) of pipeline in the study area with a diameter more than ND80 mm.

Input data of production well and fringe well pumping stations are shown in Tables A-5.7 and A-5.8 respectively. The network model is presented in Figure A-5.5.

### 5.3.6 Preliminary Simulation Results

Preliminary simulation was carried out based on the above mentioned network model. The results of the preliminary simulation showing water pressure and flow in the whole network are presented in Figures A-5.6 and A-5.7 respectively. The simulation identified the following deficiencies (for location of blocks, see Figure A-5.3):

i) Water head in the Kafar Souseh, Kadam, Shaghour, Jobar and Kaboon districts is less than 10 m and in some areas had a negative value, which means no service pressure.
ii) Water head at Block D05 in the Mezze district is less than 10 m.
iii) Water head at southern area of Block D10 is less than 10 m.
iv) Water head at high and medium pressure zones classified by DAWSSA is one or the other but not both than 60 m.
v) The simulation detected pipelines with stagnant water or reverse flow in Blocks D04.1, eastern area of D06, D05, southern area of D09, Midan area in D10.

vi) Velocity of the pipeline:HO-D10.D1200 as described in the Chapter 4 is more than 2 m/s.

5.4 Calibration

Calibration is necessary to confirm and improve the assumptions set up during the creation of the model. Calibration was basically made through comparisons between field survey measurements as described in the Chapter 4 and preliminary simulation results.

An important factor that would affect this comparison is the influence of storage reservoirs. As it was evident from the interview surveys, private storage reservoirs (average capacity 0.8 $m^3$) with private booster pumps connected to the distribution system are very common in Damascus, and they may affect the pressure in the system. On the basis of reservoir usage data obtained in the interview survey, it was assumed that there is no fluctuation of the pressure at given points in the network during the daytime.

The field survey of flow and pressure measurements was conducted for calibration of the simulation as described in the Chapter 4. It was observed that the computed flow and pressure agreed well with the measured data except in the Midan, and Yarmouk districts. Accordingly, computations reflect the actual condition of the existing network.

In the Midan, and Yarmouk districts, the comparison of pressure between the measurements of the field survey and the simulated computations with the model are summarized below:

| | Midan | Yarmouk |
|---|---|---|
| Measurements | 25 m to 53 m | 10 m to 40 m |
| Computations | less than 15 m | less than 15 m |

It is likely that the differences between the measurements and the computations are due to informal water demand. The allocation of informal water demand in the Midan, and Yarmouk districts was therefore revised based on the measurements.

## 5.5 Simulation Results and Recommended Improvements

The results of the preliminary simulation as described in the section 5.3.6 are summarized below:

i) Water pressures in the pipeline of D800 mm laid under in Nazemu Basya St., 1200 mm (diameter) line from Western Reservoir to D10 block that surrounds the city, and Mezze area, were not particularly low, and there was no pipe with abnormal flow rate. Many pipes with low pressures were found in D05, D09, and M05 blocks.

ii) The water pressure was significantly low in the Yarmouk area (including the Pilot Area) in the south of Assad Motor Way (D10 block). In this region, the pressure was mostly equal or lower than 2.0 kgf/cm$^2$.

iii) The water pressures in the entire D05 block (including Mezze - Razy and Kafar Sousch - Lawan areas) were equal or lower than 1.0 kgf/cm$^2$.

iv) The water pressures of the terminal pipes around the city were equal to or lower than 1.0 kgf/cm$^2$ in all pipes except for M01 and M02 blocks.

Simulation of the 3 cases (wet season, dry season and fire accident) was conducted again after the preliminary simulation was calibrated based on the measurements during wet season. The simulation results of flow and pressure after the calibration are presented in Figures A-5.8 to A-5.15. The simulations showed that the supply capacity differs significantly from one large block to another large block. The average service population per 100 cm$^2$ of pipe cross-sectional area for DAWSSA'S system is 2,275. This is not so different from the average value in Japanese systems, which is about 2,000 service population per 100 cm$^2$ (for 100 mm diameter pipe, the average supply volume is 600 m$^3$/day).

However, when this parameter was used to compare the large blocks, significant differences were found: for D09 and D10, the values were 4,150 and 7,088 respectively, while for D04, it was 824. This trend is in good agreement with the results of water pressure simulations. These differences among the large blocks have to be rectified to equalize the distribution of water resources.

A suggested improvement would be the partial incorporation and re-grouping of D10 block to neighboring D06 and D08 blocks, and D09 block to neighboring D08 block. These changes require installation of connecting pipes and isolation valves. Some regions in B03 and D10 blocks are showing low pressure problems due to insufficient pipe diameters. These pipes have to be replaced with pipes of larger diameters. The recommendations given here will significantly improve the water supply conditions, although it will be difficult to achieve ideal equalized distribution. B03, D04, and M02 blocks still have enough supply capacities, but pressure control and distribution control will be required. The proposed DMA plan was designed by considering such factors.

Water consumption based on the measurements during wet season for each large block is estimated as follows (see Figure A-5.3 for the location of blocks):

| Large Block No. | Consumption $m^3$/day | Population | Per Capita Consumption $m^3$/day/capita | % |
|---|---|---|---|---|
| B03 | 24,926 | 23,500 | 1.06 | 200.61 |
| D04 | 60,461 | 84,900 | 0.71 | 134.69 |
| D05 | 29,606 | 82,480 | 0.36 | 67.89 |
| D06 | 72,535 | 102,400 | 0.71 | 133.97 |
| D08 | 38,055 | 58,500 | 0.65 | 123.03 |
| D09 | 28,692 | 117,300 | 0.24 | 46.26 |
| D10 | 171,700 | 673,300 | 0.26 | 48.23 |
| M01 | 23,572 | 55,900 | 0.42 | 79.75 |
| M02 | 29,990 | 86,500 | 0.35 | 65.57 |
| Average | | | 0.53 | 100.00 |

The maximum per capita consumption value is 4 times the minimum value. Consumption in blocks D04, D06, D08 and B03, which are in the center of the city, are above the average, but consumption in blocks D05, D09, D10, M01 and M02, which are around the perimeter of the city is less than the average. To reduce the difference, the boundary line of the large block must be changed.

Though the service population in block D05 is almost 83,000 (Table above), the supply to this block is fed by two lines of merely ND250 mm in diameter. This lack of supply capacity, i.e., too small diameter in comparison to the demand, is the reason for the low pressure in D05 block. The interview survey conducted in the informal areas of Mezze-Razy and Kafar Sousch-Lawan, which are parts of D05 block, also showed a large number of complaints about low pressure. These informal areas of Mezze-Razy and Kafar Sousch-Lawan should be separated from D05, and fed from the Mezze distribution network as an independent block, D11.

According to the simulation results based on the measured demand (Figure A-5.8, A-5.10 and A-5.12), there is a tendency that the pressures of D02, D05, D09 and D10 are low. The simulation predicte that the flow condition in the main network improves significantly with the proposed improvements. Even in the 4 blocks where the pressures are rather low, the water head will be above 30 m with the implementation of suggested changes, and the regional difference in water supply capacity will be reduced.

Results and recommendations of the wet season simulation, water quality simulation and fire accident simulation are summarized below (as for location of blocks, see Figure A-5.3):

(1) Simulation result based on measurement flow during wet season

i) Water pressures in the Nazembasha line, center of the city surrounded by 1200 mm (diameter) line from Western Reservoir to D10 block, and Mezze area, were not particularly low, and there was no pipe with abnormal flow rate. Low pressure pipes were found in D05, D09, and D11 blocks.
ii) The pipes with low pressure in the Yarmouk region (including the Pilot Area) in the south of Assad Motor Way (D10 block) were concentrated in the western part of the area. This result differs from the simulation based on the demand from the Master Plan.
iii) The water pressures in the entire D05 block (including Mezze - Razy and Kafar Sousch-Lawan areas) were equal or lower than 1.0 kg/cm$^2$.
iv) The number of low pressure terminal pipes around the city was fewer than the case with the demand from the Master Plan.
v) The results of the simulations showed that the water pressures are low in the D05 block regardless the demand scenarios.

(2) Simulation result in case of fire accident at D06.5

The simulation for fire accident was carried out at the old city since there are many old houses built of wood in the old city suffered from a fire in the past. The simulation for a fire accident in D06.5 is based on the following:

i) A fire occurs in every 10 $km^2$
ii) Water can be drained from 4 hydrants for a fire
iii) 1 $m^3$/min. of water can be used from a hydrant
(Based on the assumption of Japan's fire regulations)

The simulation results are presented in Figures A-5.16 and A-5.17. The result showed no extreme decrease in water pressure in the block D06.5 and adjacent blocks.

(3) Simulation result of the water quality

Based on the results of the water quality study carried out in the Master Plan Study, the diffusion of nitrate from the Production Wells and Fringe Wells was also simulated. The results show that there are no areas where nitrate infractions exceed the drinking water standard (see Appendix C). It model also predicted that the concentration of residual chlorine will not decrease significantly, from the fact that the longest travel time in the system is 11 hours.

(4) Recommendations based on the simulation results

To achieve even water distribution, it is essential to clearly assign a role to each water pipe based on its purpose. Usually water pipes are classified as transmission pipelines, distribution mains, distribution secondary pipes, and distribution tertiary pipes. However, the present systems lack such clear definition of functions, and some distribution pipes are used as transmission pipes, and some distribution mains serve as distribution secondary pipes. There are even cases where distribution tertiary pipes are used as distribution secondary pipes.

The following functions should be respected:

- Transmission pipeline: used to transmit water between reservoirs.
- Distribution main: used to transmit water from reservoir to the distribution network
- Distribution secondary pipe: used for the main distribution network
- Distribution tertiary pipe: used to supply water to customers.

This assignment of functions is advantageous to control head loss, and to attain even distribution of water. It is also useful for rationalization and optimization of network operation and maintenance.

# 6. DMA PLANNING

## 6.1 General

The technical approach (Figure A-3.1) described in Chapter 3 was adopted to plan the DMA system. The DMA planning was conducted taking into consideration of not only the leakage control but also to facilitate the management of flow rates and pressures in the network on a daily basis and even during emergency conditions.

## 6.2 Design Criteria

The existing conditions of the water supply system were considered for planning the DMA. The existing conditions were examined based on the field surveys and the network analysis as described in the Chapters 4 and 5. According to the results obtained from the field surveys and the analysis, design criteria for planning the DMA were determined in this study as follows:

### (1) System layers

The existing water supply area consisting of 14 administrative districts is the basis of the water service districts for the DMA planning. This basic area should be divided principally into two water service layers in order to coordinate with the SCADA system. The upper layer consists of trunk lines (distribution trunks) between service reservoirs and service areas. This layer is monitored by the SCADA system.

The lower layer consists of distribution pipelines in service areas and is considered the more important and complicated of the two layers in terms of leakage control. In this study, the lower layer is referred to as the DMA system layer.

(2) Division of the DMA system layer

The DMA system layer is divided into 20 metered districts based on geographic conditions, topography, population served, diameter and length of water main adopted in the network analysis.

(3) Size of the metered districts

The main water service layer should be divided into blocks of an appropriate size based on the following criteria:

- Boundaries of large blocks are determined by covering areas of main service reservoirs and water network units. The standard size of total length of water mains varies from 50 km to 300 km per block in principle.
- The large block is divided into medium blocks with pipe lengths between 30 km and 50 km per medium block.

(4) Major districts

The major districts are designated by large blocks, where, flow monitoring will be conducted mainly by the SCADA system.

(5) Diameter of distribution main

For planning the DMA in the City, the diameter of water main is basically classified by the size of the metered districts below:

i) Large block system : more than 250 mm
ii) Medium block system: more than 150 mm

(6) Method of district partition

The boundary of the metered districts is usually formed by using the sectional valves or installation of new pipeline on to the existing pipelines. However, in this study, installation of new sectional valves and pipes were minimized, and strategically use of flow meters were considered.

(7) Factors for evaluation of the DMA plan

Finally, the DMA plan should be evaluated by the factor of the stability that is considered to stand for the present water use condition. The main indexes are a dynamic water pressure and a conveyance capacity of pipeline in emergency case. The other indexes, such as a static water pressure and a concentration of residual chlorine, also is adopted but only to support the evaluation of the DMA plan.

## 6.3 DMA Planning

### 6.3.1 DMA Plan

The DMA plan is examined with the size of the metered districts for determining adequate areas for leakage control. The DMA system was practically formulated by the following two systems:

(1) Large block system

The large block system is established taking into consideration not only coordination with the SCADA system for water supply control but also convenience of simulation for the network analysis and distribution planning. Large block system is proposed as shown in Figures A-6.1. Figure A-6.2 shows the outline of the upper layer (Block SCADA01).

The existing water supply area in the City is divided into 20 large blocks as illustrated in Figure A-6.1. Since the upper layer is considered as the first large block, the total number of large blocks is 21 in the study area. Characteristics of each large block are shown in Table

A-6.1. Each large block is made up of the trunk lines (distribution mains) with a minimum diameter of 250 mm.

(2) Medium block system

The medium block system is necessary to monitor the distribution conditions such as flow, pressure and quality, and to facilitate prompt detection and correction of failures in the network at an early stage. Large blocks are further divided into medium blocks of appropriate size according to the location of valves, boundaries of water charge collection districts, meter reading districts and so on.

The medium block system as illustrated in Figure A-6.3 is determined based on the existing activity of leakage detection efforts by DAWSSA. Medium blocks are formed mainly from distribution sub-mains with diameter more than 150 mm within the large block system. However, some of the distribution tertiary pipes with a diameter larger than 80 mm were included in the analysis.Total pipe length for each block is approximately 30 km to 50 km. Characteristics of each medium block are shown in Table A-6.2. The pipe length analyzed at each block is summarized in Table A-6.3.

6.3.2 Proposed DMA Plan

A DMA system is proposed, as shown in Figure A-6.3, to optimize water distribution and to facilitate leakage control. To operate the water supply system, DAWSSA has to deal with enormous amount of pressure and flow rate data, which can be time consuming and costly. The DMA system provides water supply administrators with a set of units that can be used to handle such data in an organized and cost-effective way.

The DMA system was proposed based on the following criteria:

| Classification | Scale |
|---|---|
| Large block system | Water resources, Network unit,<br>Total length of distribution main : 50-300 km |
| Medium block system | Total length of distribution main : 30-50 km |
| Small block system | Total length of distribution main : 10-15 km,<br>Population served : 15,000-20,000 |

In order to evaluate the DMA system, characteristics of the proposed blocks are defined based on the results of this study as presented in Table A-6.4. Results of evaluation indicate that the proposed blocks generally satisfy DAWSSA's pressure standard, and the pipe length scale criteria (Table above) are also met, except for some large blocks with small size, such as Blocks E01 and D01.

The proposed blocks in the large block system were examined to determine the priority for implementation as shown in Table A-6.5 (1/2). The following number of large blocks by priority is recommended:

| | |
|---|---|
| • High priority blocks | : 6 blocks |
| • Medium priority blocks | : 8 blocks |
| • Low priority blocks | : 7 blocks |

The priority for implementing DMA system in the proposed blocks also is evaluated from the view point of necessity of leakage control as shown in Table A-6.5 (2/2). Areas with high priority are identified as medium blocks located to the south of D10 and M11 in the Kafar Souseh district. The number of blocks by priority is summarized below:

| | |
|---|---|
| • High priority blocks | : 10 blocks |
| • Medium priority blocks | : 21 blocks |
| • Low priority blocks | : 18 blocks |

In order to implement the DMA system, required arrangements in the existing distribution system are proposed as illustrated in Figure A-6.4.

### 6.4 Selection of DMA Pilot Area

The purpose for selecting a pilot area is to demonstrate flow rate monitoring using the ultrasonic flow meters and to obtain the minimum night flow data for leakage detection control. As shown in Figure A-6.5, an area consisting of the medium block D10.5 located in Midan district and the medium block D10.4 located in Yarmouk district in the large block D10 was selected for the following reasons:

i) Midan and Yarmouk districts have a much high population density and water consumption compared with other districts.

ii) According to the land use pattern, these districts are mostly residential and there are very few offices, factories and hotels.

iii) The results of flow measurement indicate that total daily flows and the flow rate in the pipeline from the western reservoir to Block D10 are very high.

iv) The results of pressure measurement indicate that the daily water pressure in Block D10 fluctuates widely.

v) The largest part of the City is located in the low pressure zone. Midan and Yarmouk districts are also located in the lowest pressure zone, therefore they are considered represcntive.

Midan and Yarmouk districts are therefore considered as typical of water consumption pattern, minimum night flow and loss of system leakage in the City.

# 7. PILOT DMA AREA STUDY

## 7.1 Description of Pilot Area

### (1) Area and population

The proposed pilot area (medium block D10.5 and D10.4) is located in Midan and Yarmouk districts in the southern part of the City as illustrated in Figure A-6.5. The area and population in the pilot area are estimated as follows;

| | Medium Block D10.5 | Medium Block D10.4 |
|---|---|---|
| Name of District | Midan | Yarmouk |
| Area (ha) | 181 | 227 |
| Population | 88,300 | 214,700 |

### (2) Land use

The pilot area is characterized by residential and commercial land use areas. The area includes the informal connection areas at Tadamon & Zaherea with population of 86,068 and at Takadom 36,750 (ref. Figure A-6.5).

### (3) Water demand

Water demand in the pilot are is forecasted as follows;

| | Medium Block D10.5 | Medium Block D10.4 |
|---|---|---|
| Water Demand ($m^3$/day) | 37,270 | 65,900 |
| Water Demand ($m^3$/day) for Informal Residents | 0 | 24,560 |
| Sub total ($m^3$/day) | 37,270 | 90,460 |
| Percentage (%) | 29 | 71 |
| Total ($m^3$/day) | 127,730 | |

## 7.2 Field Survey

### (1) Flow measurement

Flow measurements in the Pilot Area were conducted from June 10 to June 15 at 8 measurement points as illustrated in Figure A-7.1, in order to grasp a actual water consumption and a minimum night flow conditions . Results of the flow rate measurement are summarized in Table A-7.1. The water consumption data are utilized for the network analysis and minimum night flow for estimating system leakage.

The method of flow measurement is the same for the field survey at the distribution mains as described in the Chapter 4.

Flow measurements at each measurement point are shown in Figure A-7.1. Measured water consumption in Midan and Yamouk are indicated in Figures A-7.2. The results of the measurements are summarized as follows;

| | Medium Block D10.5 | Medium Block D10.4 |
|---|---|---|
| Water Consumption ($m^3$/day) | 56,865 | 60,382 |
| Percentage (%) | 49 | 51 |
| Total ($m^3$/day) | 117,247 | |

### (2) Pressure measurement

A pressure measurement survey was carried out at 6 hydrants in the Pilot Area with the portable water pressure recorders over the same period as the flow measurement. The measurement points are shown in Figure A-4.3 at the Chapter 4.

The area is supplied with water from the Western service reservoir (HO) located at the elevation of 755.50 m. The results of the pressure survey are summarized as follows;

| Measurement Points | | Static Elevation (m) | Water Pressure (kgf/cm²) | | | Head Loss (m) |
|---|---|---|---|---|---|---|
| No. | EL (m) | | Max. | Min. | Variable | |
| P5 | 678.00 | 77.50 | 4.0 | 1.8 | 2.2 | 37.5 |
| P6 | 683.50 | 72.00 | 5.3 | 3.6 | 1.7 | 19.0 |
| P7 | 686.00 | 69.50 | 5.0 | 2.5 | 2.5 | 19.5 |
| P8 | 675.00 | 80.50 | 3.8 | 1.5 | 2.3 | 42.5 |
| P9 | 673.50 | 82.00 | 3.5 | 1.0 | 2.5 | 47.0 |

The area belongs to the low pressure zone with water pressure less than 30 m as classified by DAWSSA.

(3) Leveling survey

The route survey was carried out in order to confirm the locations and elevations of the existing distribution mains in the pilot area. The elevation in Midan varies from 688.67 m to 678.87 m and in Yarmouk from 682.00 m to 670.40 m. Results are summarized as follows:

| Flow Rate Monitoring Points | Elevation above mean sea level (m) | |
|---|---|---|
| | Top of Pipe | Surface of Road |
| 1. Diameter : ND 700 mm | 687.81 | 688.67 |
| 2. Diameter : ND 250 mm | 687.67 | 688.67 |
| 3. Diameter : ND 600 mm | 681.69 | 683.16 |
| 4. Diameter : ND 300 mm | 681.77 | 682.34 |
| 5. Diameter : ND 300 mm | 680.40 | 680.89 |
| 6. Diameter : ND 300 mm | 677.65 | 678.87 |
| 7. Diameter : ND 400 mm | 678.69 | 680.93 |
| 8. Diameter : ND 200 mm | 679.99 | 681.28 |

Distribution mains in this area consists of the following pipes:

| Diameter of Distribution Mains | Length (m) |
|---|---|
| ND 700 mm (DIP) | 438 |
| ND 600 mm (DIP) | 2,989 |
| ND 500 mm (DIP) | 596 |
| ND 400 mm (DIP) | 575 |
| ND 300 mm (CIP) | 276 |
| ND 250 mm (DIP) | 223 |
| ND 200 mm (DIP) | 2,745 |
| ND 150 mm (DIP) | 1,904 |
| ND 100 mm (DIP) | 190 |
| Total | 9,936 |

## 7.3 Existing Network Analysis

### (1) Existing network system

The current system supplies water to the Pilot Area (D10.5/D10.6) through the following pipes (see Figure A-7.1).

- ND250 mm × 1 line
- ND300 mm × 2 lines
- ND600 mm × 1 line
- ND700 mm × 1 line

### (2) Analysis of problem

i) Problem: Water pressure in the west of Salah Al Din Al Ayoby Street (D10.5) is significantly low (see Figure A-5.8, A-5.10 and A-5.12).

Analysis: The current system is designed to provide water to this area through a ND200 mm pipe which is a branch of ND700 mm pipe, and also by a ND250 mm pipe that comes from D10.1 block. However, due to the demand in other areas, the ND200 mm pipe does not have sufficient capacity to supply water to this area. Likewise the supply of ND250 mm pipe is used up in D10.2. Consequently, the supply to this area is insufficient.

ii) There is no other major problem in the area.

### (3) Recommendation

To reduce the difference in water supply capacity within D10.5, a ND400 mm pipe shall be newly installed to connect the ND800 mm from the Western Reservoir to the existing ND200 mm and ND250 mm (refer to the Figure A-7.3).

## 7.4 Minimum Night Flow and UFW

### (1) Minimum night flow and UFW in the pilot area

Minimum night flow and UFW in the pilot area is estimated based on the results of the field surveys:

i) The minimum night flow measured in the Pilot Area is 1.19 $m^3$/sec (4,280 $m^3$/hr) (Based on the measurement on June 14, 1997 (0:30 a.m. - 4:30 a.m.) as shown in Table A-7.1.)

ii) The population serviced in the Pilot Area is 303,000 persons.

iii) The total number of households in the Pilot Area is 37,900 households.
The total number of households is estimated by dividing the population serviced by the estimated average household size in low income, informal areas (8 persons/household) obtained in the interview surveys (Master Plan study and this study).

iv) The minimum night flow consists of water used to replenish water storage tanks, other actual water use at night, leakage, and informal use.

v) The amount of water used to replenish water storage tanks is estimated from the following data obtained in the interview surveys,

- 19% of the households replenish their water storage tanks at night.
- The replenishment is usually carried out between 8 p.m. to 7 a.m. (11 hours).
- The average capacity of a water storage tank is 0.8 $m^3$.

The amount of water used to replenish water storage tanks in the Pilot Area was estimated as follows.

37,900 household × 19 % = 7,200 households

$0.8\ m^3 \div 11\ hr = 0.073\ m^3/hr$

7,200 households × 0.073 $m^3/hr$ = 525.67 $m^3/hr$

The nighttime water use of the rest of the 81 % of the households (30,700 households) was estimated from the result of a meter reading study.

It is judged from the meter reading that No. 1, No. 5 and No. 9 are the average night flow if storage tanks are installed, and the sample No. 2 is also the average night flow if storage tanks are not installed.

According to a meter reading study, the actual water use at a house between 0:30 a.m. to 4:30 a.m. was 0.0179 $m^3/hr$ as shown in Figures A-4.12 to A-4.14.

On the basis of this information, the total night time water use of these 30,700 households was estimated as follows.

30,700 households × 0.0179 $m^3/hr$ = 550 $m^3/hr$

Based on the available information given above, a preliminary estimate of the breakdown of minimum night flow was attempted.

| | ($m^3/hr$) | (l/property/hr) | (%) |
|---|---|---|---|
| Minimum Night Flow | 4,280 | 113 | 100 |
| Storage Tanks | 526 | 14 | 12 |
| Other Water Use | 550 | 15 | 13 |
| UFW* | 3,010 | 84 | 75 |

*: UFW (unaccounted-for-water) includes leakage and informal use.

(2) Minimum Night Flow in DMA Area

It was estimated from the result of the meter reading and the interview survey that 12 percent of water is used to fill up water storage tanks. The meter reading indicates that a considerable amount of water is used late at night.

Minimum night flow

| Area | Measurement minimum flow data | | Persons | Household | Ltr/ Property/ hr | Used to replenish tank | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Number of house | Consumption | |
| | $m^3$/sec | $m^3$/hr | | | | | $m^3$/hr | % |
| Measurement Area (DMA) | 4.34 | 15,624 | 1,261,600 | 210,267 | 74 | 39,950 | 2,905 | 19 |
| Pilot Area | 1.19 | 4,284 | 303,000 | 37,900 | 113 | 7,201 | 526 | 12 |

There is no large difference in the daily water use between the pilot area and the rest of the city. There is also no big difference between the pilot area and the whole city in the ratio of the amount of water used to replenish water tank to the minimum night flow. It is also possible that a large volume of water that is assumed to be used to fill water tanks is actually used for other purposes.

# 8. LEAKAGE DETECTION AND CONTROL

## 8.1 Monitoring and Inspection of Blocks

To run the DMA system efficiently, it is important to take into account both operation itself and operation costs. A monitoring program based on the DMA system is proposed in Figure A-8.1. The suggested monitoring plan is given below.

All DMA blocks shall be monitored once per season (wet and dry), and large blocks are to be monitored and inspected monthly. Considering the safe and accurate installation of monitors, an installation team shall consist of two workers per team. A team will be able to install maximum of 7 portable monitors a day, and all monitors that surround DMA have to be installed at the same time. Therefore, it will take two teams to install all monitors in a medium block as the maximum number of monitors is 13.

The monitoring shall be conducted for 24 hours, which will take 2 days to complete. To monitor all 49 DMA (exclusive SCADA01) blocks in wet season (4 months), a total of 98 days will be needed, and two teams will be needed for monitoring and maintenance of medium blocks. Large blocks shall be monitored and inspected monthly because flow meters equipped with data logger will be used. The team required for these tasks shall consists of two workers. Every month, all 23 blocks are to be monitored with the standing monitors, and the pressure/flow rate data to be collected. Considering the data handling, an appropriate data acquisition interval would be 5 minutes. An engineer is also needed for simulations and analysis of leakage. Therefore, the entire operation requires 3 teams and one engineer, or seven workers. The DMA monitoring and inspection program is proposed in Figure A-8.1.

## 8.2 Leakage Detection Survey

According to the Master Plan, 75,646,000 $m^3$/year, or about 35 % of the total distributed water, is lost by leakage. It is well known that a leakage is large economic loss, and it also induces secondary disasters such as collapse of roads and secondary pollution of water supply system. It also burdens the water supply management.

The results of leakage surveys conducted this time demonstrated frequent leakage from old cast iron pipes, as pointed out in the Master Plan report. The average leak rate from a single leakage site was also large. The estimated leakage per km of pipe was about 7 $m^3$/hr/km. Furthermore, many leaks are concentrated on cast iron pipes.

The current leakage control teams in DAWSSA consist of 4 teams with 5 surveyors/team, giving a total of 20 surveyors. However, regular survey is not practiced, and their activities are generally limited to case-based ones.

The suggested leakage survey activities are summarized below.

(1) Selection of priority survey areas

- Cast iron pipes
- High pressure zones
- D10 block (especially Yarmouk area): based on DMA study
- Areas with high minimum flow: based on uni-flow measurement

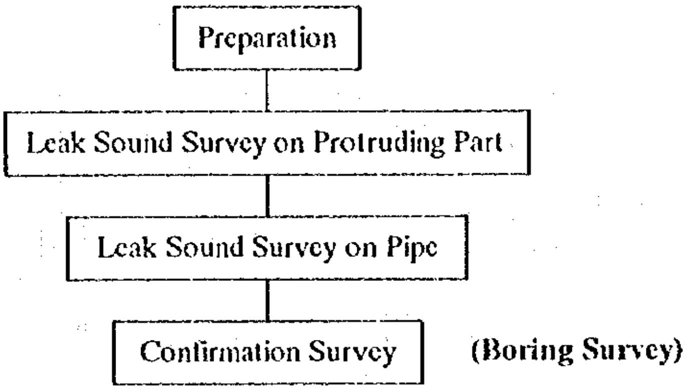
(2) Survey methods

| | |
|---|---|
| Day time activities 1 | Leak sound surveys of protruding part of system, such as hydrant and valves |
| Night time activities | Leak sound survey of pipes at the sites where leakage is suspected in the Day time activities above. |
| Day time activities 2 | Confirmation of leakage at the site selected by leak sound survey of pipes above. |

The confirmation survey is performed to minimize the error about the location of the leakage. The leakage site is pinpointed by comparing the leak sounds at different holes (about 19 mm) in the ground (road) drilled by a hammer drill as illustrated below.

(3) Survey flow

Survey flow is conducted as follows:




The ground in Damascus is hard, and sound of leakage is easily transmitted to the ground surface. Therefore, leakage survey based on leak sound method appears to be the most suitable choice.

(4) Organization of survey teams

The total length of distribution pipes in 49 medium DMA blocks is about 1,220 km. Assuming these pipes are investigated once a year, and 200 working days per year, the survey distance is about 6.1 km/day, or 30.5 km/week (5 days). This work load requires at least two teams of two surveyors per team, or 4 surveyors.

Instrumentation (for 2 teams)

| | |
|---|---|
| Leak detector | 4 |
| Leak sound detection bar | 4 |
| Pipe locator | 2 |
| Hammer drill | 2 |
| Boring bar | 2 |
| Automobile | 2 |

Other (paint, hydrant opener, etc.)

The teams need to be coordinated and their works have to be scheduled. A full-time system is recommended. The feasible work volume by the teams is estimated as shown in Table A-8.1. Suggested schedules are given in Figure A-8.2.

### 8.3 Leakage Detection and Control

A leakage detection and control program based on the DMA system is proposed and the proposed program has the following components:

i) A mains renewal plan to reduce the level of leaking lead joints on cast iron mains and reinforce the existing distribution system thus safeguarding supplies.
ii) A plan setting up the DMA system that will enable DWSSA to monitor the distribution system and identify areas of high leakage.
iii) A plan for setting up regulated pressure zones which will reduce the levels of leakage in high pressure zones. This program supports the DMA system.
iv) A program for reinforcement of regular acoustic sounding surveys for leak detection at the distribution system in cooperation with the DMA system.
v) A program for water supply improvement with establishment of DMA system in informal areas like the Mezze-Razy and Kafar Souseh-Lawan System planned in this stage.

As presented in Figure A-6.3, DMA system is formulated to provide DAWSSA with an active leakage control program. A monitoring program based on the DMA system for the distribution system in the City was proposed as shown in Figure A-8.1. The schedule for the program of reinforcing regular acoustic sounding surveys is presented in Figure A-8.2.

The implementation schedule for setting up the DMA system is shown in Figure A-11.1 and discussed later in Chapter 11. The program for setting up regulated pressure zones was included in the DMA program. The water main replacement program proposed as an urgent priority by the M/P is recommended, and is described in detail in the Appendix G, because it is closely linked to the implementation of the DMA system.

# 9. IMPLEMENTATION PLAN

## 9.1 DMA Plan

The DMA plan was proposed as shown in Figure A-6.3. The DMA system requires a set of sluice valves, flow rate monitors, and/or pressure monitors to be installed at the intersections of pipes with the DMA borders. To set the borders, therefore, it is important to take into account the cost of installation and O&M, in addition to the general operational requirements. Considering these requirements, the borders were set so that the number of intersections per medium block is 8 or smaller. In the end, it was possible to design DMA blocks with the maximum number of portable monitors to be 13 per medium block.

The total numbers of the DMA blocks are as follows.

| | | |
|---|---|---|
| Large block | : | 14 blocks (including the first layer and except large blocks that are divided into medium blocks.) |
| Medium block | : | 36 blocks (except large blocks that also serve as medium blocks) |
| Total | | 50 blocks |

## 9.2 Preparing Equipment and Site Preparation

### 9.2.1 Requirement of pipeline arrangement (see Figure A-6.4)

(1) To merge northern sections of D06.4 and D10.1 into D06, the following arrangement will be needed.

1. Install a pipe (ND400 mm, 0.75 km) that connects D06 to D10.1 and D06.4
2. Renew the existing connecting pipe (ND150 mm, 0.6 km) to ND300 mm.
3. Install two sluice valves (ND150 mm) to isolate the northern part of D06.4.
4. Connect the separated part of D06.4 to newly installed ND400 mm pipe.
5. To connect D06.4 to ND400 mm pipe, connect the existing ND100 mm to the ND400 mm pipe.

(2) To merge D08.4 to D08, the following arrangement will be needed.

1. Renew the existing ND200mm, 0.5 km to ND400 mm.
2. Connect the newly installed ND400 mm pipe to existing ND500 mm pipe.
3. Connect the newly installed ND400 mm pipe to existing ND200 mm pipe.
4. Separate the ND600 mm pipe and ND500 mm pipe in D10.1, and install two sluice valves (ND500 mm) to merge ND500 mm pipe to D08.

(3) Correction of water pressure condition in blocks D10.4 and D10.5

The uneven pressure distribution in Blocks D10.4 and D10.5 can be reduced by installing a feeder pipe (ND400 mm) that connects the existing water main (ND800 mm) at D10.1 to the existing water main (ND250 mm) at D10.5.

(4) Measures for reduction in water pressure in some area of D01 and D02

There are some pipelines whose water pressure is over 10 kg/cm$^2$ in parts of D01, and D02. Valves need to be set up on D01, 150 mm, and D02, 400 mm, to reduce the water pressure.

(5) To solve the low pressure problem in D05, connect existing ND800 mm pipe to ND300 mm pipe. Also, the remaining water head around the divergent point is more than 81 m, so a valve has to be set up to reduce the water pressure.

(6) Capability of the pipeline to supply water from the western reservoir to the Mezze Reservoir

The maximum velocity in the existing ND600 mm (3.5 km) is over 5 m/sec in the high water season. To supply water without exceeding the maximum recommended velocity of 2.5 m/sec, this pipeline must be changed to D800 mm.

### 9.2.2 Installation of Flow Meters, Valves, and Pipes

The locations of standing (permanently installed) and seasonal monitors are given in Figure A-9.1. The standing monitors are installed at the entrance to large blocks. The seasonal monitors are arranged to surround each block so that the flow rate in the block can be monitored on a seasonal basis. The chambers are installed to house both standing and seasonal monitors. The total numbers of newly installed monitoring chambers, valves and pipes are given below.

| Items | Amount |
|---|---|
| 1) Standing monitoring chamber | 32 |
| 2) Seasonal monitoring chamber | 133 |
| 3) Sluice valves | ND150 mm x 3, ND500 mm x 2 |
| 4) Pressure reduction valves | ND800 mm x 1, ND400 mm x 1, ND150mm x 1 |
| 5) Pipes | ND200 – 400 mm x 2,000 m |

Flow meters, pipes and valves required for the establishment of DMA system are summarized in Table A-9.1 and detailed informations are presented in Table A-9.2.

# 10. COST ESTIMATES

## 10.1 Construction Cost

The estimated cost of the proposed project is summarized as follows ;

(Unit : US$ 1,000)

| Items | | L.C. | F.C. | Total |
|---|---|---|---|---|
| 1. | Direct Construction Cost | 628 | 2,647 | 3,275 |
| | 1) Ductile cast iron pipes | 89 | 385 | 474 |
| | 2) Valves | 4 | 278 | 282 |
| | 3) Water & Flow meters | 282 | 1,918 | 2,200 |
| | 4) Valve & Meter chambers | 253 | 66 | 319 |
| 2. | Tax and Duty | 411 | 0 | 411 |
| 3. | Administration Cost 10% of Direct cost | 63 | 0 | 63 |
| 4. | Engineering Cost 10% of Direct cost | 63 | 265 | 328 |
| | Sub-Total ( Items 1 to 4 ) | 1,165 | 2,912 | 4,077 |
| 5. | Physical Contingency | 75 | 291 | 366 |
| | Sub-Total ( Items 1 to 5 ) | 1,240 | 3,203 | 4,443 |
| 6. | Price Contingency | 64 | 125 | 189 |
| | Total | 1,304 | 3,328 | 4,632 |

Note:
1. L.C. means local currency portion and F.C. means foreign currency portion.
2. Physical contingency is 10% of sum of items 1, 3 and 4.
3. Price contingency is 5% of local currency portion and 3% of foreign currency portion of items 1, 3, 4 and 5.

## 10.2 Operation and Maintenance Costs

(1) Operation and maintenance costs for the DMA System project is estimated at about US$36,000 / year

(2) The leakage repair costs are estimated to increase gradually as a result of DMA starting with a US$35,000/year increase after the first year and a total increase of US$250,000/year after the program is fully implemented.

(3) Flow meter replacement costs for the DMA System project is estimated at about US$3,014,000, after 15 years of operation.

## 11. IMPLEMENTATION SCHEDULE

The implementation of the District Meter Area (DMA) System project is planned to be completed by the year 2006.

The implementation of the projects is planned for the purpose of properly executing the work by taking into consideration: the conditions for the projects, including contractors, procurement of construction materials and labor force; the manner of procurement of water supply equipment and materials; and the manner of construction.

### 11.1 Capability of Local Contractor

Contractors and suppliers who intend to undertake the construction works and the supply of construction equipment and materials for public works shall be registered with the government agencies concerned. The Syrian Construction Contractors Association is responsible for contractor classification and registration.

DAWSSA pre-qualifies contractors by classifying them into (eight) fields of engineering activities and ranking them into one of three groups depending on their financial strength, equipment capability, and the number of qualified engineers and experience in the field.

These eight fields are 1) Supply and Execution of Pipes and Metals works 2) Pump Installations 3) Mechanical & Electrical Installations 4) Pipe Laying for transmission Lines 5) Laying of House Connections 6) Road Constructions 7) Fitting Castings and 8) Electric Board works.

First, second and third ranked contractors are nominated for tendering on DAWSSA's projects, in the each field. Fifteen (15) contractors are registered in the first rank, seven (7) contractors are in the second rank and nine (9) contractors are third rank.

DAWSSA has experienced contractor capabilities through many projects already executed. The local registered contractors have the capabilities and experience required to construct the proposed projects without the used of foreign experienced contractors. Local contractors have sufficient construction machinery and equipment including heavy construction machines.

11.2 Construction and Procurement Methods

The methods of construction and procurement of equipment and materials used on the DMA project are all executed in Syria except for high technology components which are procured through international competitive tendering. Civil works are generally procured by local competitive tendering procedure in accordance with DAWSSA guideline.

(1) Alternatives:

a) Turn-key contract: for the entire construction works through international tendering

b) Several contract packages: for construction works including pipe materials and pipe laying works, mechanical and electrical equipment and installation, and civil and secondary works through international tendering.

c) Separated contracts: contracts separated into international tendering for procurement of flow meters and pipe materials and local tendering for construction works.

For the above mentioned alternatives, a) and b) are usually applied to large scale works and/or for advanced high technology components or methods. The ability of local contractors is deemed suitable for the implementation at the proposed projects, except procurement of flow meters, because the proposed projects consist of ordinary civil works without any advanced high technology. Therefore alternative c) is selected as the recommended tendering procedure.

(2) The manner of procuring the materials and civil works will be as follows;

(a) International tendering

- Pipe materials and accessory for pipelines
- Supply of mechanical and electrical equipment include supervision
- Flow meters

(b) Local tendering

Civil engineering works are grouped into multiple-packages by area or contract period for local tendering by the registered contractors.

- Pipe laying works of distribution pipe lines
- Construction civil works include flow meter chambers
- Execution of mechanical and electrical works with DAWSSA supervisor, assisted by foreign supervisor

## 11.3 Implementation Schedule

In preparing a realistic schedule for the implementation of the project, it is assumed that DAWSSA will organize the construction activities. Most construction works will be conducted by local contractors and supervised by DAWSSA or it's designated consultant. DAWSSA has well trained staff, experienced in this type of project and are well qualified to carry out project management functions.

The project is expected to start in 1998 and be complete in 2006 with financing signed in June of 1998, detailed design starting in January of 1999 and pipes procured in January of 2000, as shown Figure A-11.1.