Unaccounted -for Water: Guidelines for the Formulation of a Policy and Implementation of Practical Methods for the Control thereof

W de Vallier

WRC Report No.489/2/97

UNACCOUNTED-FOR WATER: GUIDELINES FOR THE FORMULATION OF A POLICY AND IMPLEMENTATION OF PRACTICAL METHODS FOR THE CONTROL THEREOF

W de Vallier

WRC REPORT NO 489/2/97
ISBN 1 86845 348 0
ISBN SET NO 1 86845 349 9

This manual is the product of a research project funded by the Water Research Commission entitled "THE DEVELOPMENT OF PROCEDURES FOR THE CONTROL OF UNACCOUNTED-FOR WATER IN WATER DISTRIBUTION SYSTEMS AND FOR THE REDUCTION OF WATER LOSS", WRC Report No 489/1/97. The Manual was handed to the Committee of the SABS Code of Practice for the Management of Potable Water Distribution Systems for incorporation into the Code of Practice.

This Manual is considered to be evolutionary in nature and will be revised and updated on a regular basis until the SABS Code of Practice is published. Any comments, suggestions and criticism will be welcomed by the author.

De Leuw Cather (North) (Pty) Ltd
P O Box 31384
BRAAMFONTEIN
2017
Tel No: (011) 403-3731 Attention: Mr W de Vallier

CONTENTS

PAGE

1. INTRODUCTION

1.1 Intent and Purpose of the Manual

This Manual is intended to be compatible with and form part of a series of documents covering all aspects of the management and control of unaccounted-for water (UAW) in water distribution systems. These are:

a) The Water Law Review and the accompanying White Paper.
b) The draft National Water Supply Regulations.
c) SABS XXXX-1:1996 Code of Practice for the Management of Potable Water Distribution Systems (Currently PRJ 801/54826).

The Manual is aimed primarily at Local Authorities with no or inadequate policies for the control of UAW. It offers guidelines for the formulation and implementation of an appropriate policy for the control of UAW, taking into account the human, material and financial resources required. It is not envisaged to introduce fundamental new concepts in the field of UAW control, but rather to collate current state-of-the-art knowledge into one single reference document, for use by senior management, middle managers and field operators alike.

1.2 The Need to Conserve Water

Worldwide the general trend in addressing increasing water demands caused by growing population and spreading urbanisation has been to develop new resources involving the construction of large dams and the associated transfer systems to convey the water to the various demand centres, but without ever looking critically at the efficiencies of water use from existing schemes.

The semi-arid nature of South Africa with a mean annual precipitation of 483 mm as compared with a world average of 860 mm, has led to a situation where demand will soon exceed the average annual rainfall. Furthermore, virtually all of the most suitable dam sites have already been fully developed and any new resource development will be considerably more expensive, per unit of stored water, than were previous schemes (marginal costing). Non-conventional sources, such as desalination, are available but at a high price.

The cheapest and most easily available water, therefore, is that which has already been stored, treated and put into supply systems, but which has previously been wasted, lost from the system or inefficiently used. The achievement of effective water conservation therefore requires better efficiency of both water delivery systems and water usage, i.e. it requires the implementation of an effective water conservation management policy. Water conservation can be implemented in two main areas, viz:

1.2.1 Supply management

Supply management relates to the improvement of the water system efficiency, which is accomplished through:

a) Active leak detection and repair.
b) Reactive leak repair.
c) Pressure management.
d) Distribution system maintenance.
e) Meter maintenance.
f) Data base management.

1.2.2 Demand management

Demand management relates to the reduction of non-essential water use by all categories of consumers and involves:

a) Education and public awareness.
b) Water regulations.
c) Water pricing and tariff structure policy.
d) Universal metering.
e) Consumer plumbing system maintenance.
f) Retrofitting water-saving devices.
g) Garden watering regulations.

h) Recreational water usage.

i) Water restrictions.

j) Creative and innovative presentation of utility bills.

If the price of water does not reflect the true value of that commodity and if the supply area is not fully metered, it becomes extremely difficult to encourage consumers to participate in conservation programmes.

A significant component of the overall water conservation management is the control of UAW in a distribution system.

1.3 Literature Review

Much of the basic methodology upon which accepted procedures for the control of UAW and the reduction of water loss have been developed, was first published in the early 1980s in the United Kingdom as "Leakage Control Policy and Practice[1]", and revised in 1995 and published in a series of reports entitled: "Managing Leakage[2]". Extensive adaptation of these publications to suit local conditions and the results of the research project entitled "The Development of Procedures for the Control of Unaccounted-for Water in Water Distribution Systems and for the Reduction of Water Loss," WRC Project No 489, forms the basis of this Manual. Considerable local innovation and experience have also been included.

A complete list of all publications reviewed is given in the reference list at the back of this Manual.

2. DESCRIBING UNACCOUNTED-FOR WATER

2.1 General

UAW is defined in various ways in different countries of the world. The following are a few examples:

a) Germany : "UAW is the difference between the quantity of water entering a system and the sum of water billed, including the water which is measured but for some reason not paid for".

b) Hong Kong : "UAW is the unrecorded consumption represented by the total raw water input into a system, less the recorded consumption in domestic, commercial and industrial supplies to consumers as measured by consumer meters, and other known quantities of free supplies and system losses such as wash water in treatment works".

c) Malaysia and Philippines prefer the term "non-revenue water" (NRW) to UAW.

d) Japan and Brazil prefer the term "effectively used water".

2.2 Definition of UAW

For the purpose of this Manual, UAW is defined as:

"The difference between the measured volume of potable water having entered a distribution system and the measured amount of water having left the distribution system at a specific time", i.e.

$$UAW_{total} = V_{in} - V_{out}$$

where UAW_{total} = total unaccounted-for water for the system at any time

V_{in} = measured volume of water having entered the system up to that time

V_{out} = measured volume of water having left the system to that time

The measured amount of water leaving the system specifically excludes all estimates of water abstracted from the system for items such as pipe burst and flushing, fire fighting, theft, reservoir leaks and overflows, meter stoppages, unmetered connections etc. Diagrammatically the definition can be represented as shown in Figure 1.

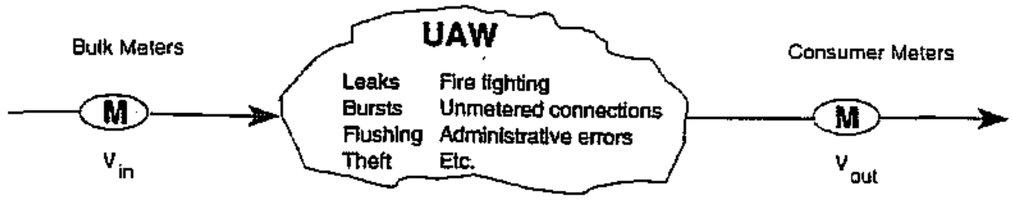

Figure 1 : Definition of UAW

The measured volume of water leaving the system is limited to the aggregate of consumptions registered by metered consumer connections whether the consumer is charged for the consumption or not. Typical consumptions which are not charged for include irrigation of Municipal parks and sports fields, flushing of reservoirs, fire fighting, etc.

The reason for excluding estimated water abstraction from the equation is to eliminate the possibility of these figures being manipulated to give a lower UAW quantity.

For UAW to be calculated using the above expression, all metered inflows and outflows would have to be determined at exactly the same instant. This is impractical, if not impossible, to achieve. Hence a more manageable expression of UAW is:

$$UAW_{ave}\,(M\ell/d) = V_{in}\,(M\ell/d) - V_{out}\,(M\ell/d)$$

where UAW_{ave} = the average value of UAW in $M\ell/d$

V_{in} = average daily volume of water entering the system in $M\ell/d$

V_{out} = average daily volume of water leaving the system in $M\ell/d$

This expression is dependent on accurate historic records.

In terms of the above expressions, leaks downstream of meters measuring the abstraction of water from a distribution system do not affect the overall UAW.

Loss of water through these leaks, however, forms an important part of water conservation management.

2.3 Units of UAW

Internationally, the most popular expression of UAW is as a percentage of the total measured volume entering the distribution system or as a percentage of the total water production. Although this unit is considered simplistic and even meaningless by some, it is nevertheless a popular expression that is readily understood and easily used for comparative purposes. For the expression to be more meaningful it should not be quoted in isolation but rather in conjunction with the actual volume of the UAW. Factors pertaining to meter inaccuracies have a significant influence on the accuracy of this expression.

Leakage, often considered the most important single component of UAW, is commonly expressed as a specific rate based on the total length of water mains in the distribution system (ℓ/m.h) or the number of consumer connections in the distribution system (ℓ/connection.h). The former expression, i.e. ℓ/m.h, is considered the more appropriate measure of leakage as it is directly related to the relevant component in the system i.e. the water mains.

The specific leakage rate measured in ℓ/connection.h is considered somewhat artificial as it is largely influenced by the density of development of the distribution system. Furthermore, the use of communal stand pipes in informal townships makes this expression meaningless.

2.4 Components of UAW

2.4.1 General

The numerous components of UAW can, for the sake of convenience, be grouped into the following categories:

a) Leakage from the reticulation system.

b) Flushing of mains.

c) Reservoir leaks, overflows and flushing.
d) Fire fighting usage if unmetered.
e) Meter inaccuracies.
f) Unmetered connections.
g) Theft and unauthorised usage.
h) Errors in meter reading, data capture and processing.

These components can be divided into two groupings, viz.:

i. those components attributable to administration errors; and
ii. those components attributable to the physical loss of water from a distribution system and discrepancies in measurements resulting from meter inaccuracies.

2.4.2 UAW components attributable to administration errors

These components include the following:

a) Errors in meter reading whether accidental or deliberate.
b) Errors in transferring meter reading data to the accounting system.
c) Errors in the consumer data base.
d) Delays and errors in invoicing consumers.
e) Delays and errors in registering new consumers.
f) Bad debts.

The above components result in loss of revenue recorded by the Treasury Department of the Local Authority and not necessarily the unmeasured abstraction of water from the distribution system. Accidental errors in the reading of meters and transferring meter reading data are generally corrected with subsequent meter readings. Deliberate errors in the reading of meters, especially if done in collusion with the consumer, constitutes theft.

2.4.3 UAW components attributable to physical losses

These components make up almost the entire volume of UAW and include the following in rough order of magnitude:

a) Leakage from reticulation components

Leakage from reticulation components can be subdivided into three groups, viz:

i. Visible leaks such as pipe burst and breakages, leaks at valve flanges, hydrants and pipe fittings.

ii. Invisible leaks where water leaking from the system has found its way into underground fissures or entered other services such as sewers, stormwater pipes and cable ducts.

iii. Leaks downstream of the consumer meter. These leaks can be either visible or invisible. As previously explained these leaks do not influence the UAW figure as they have been recorded on the consumer meter. However, the volume of water wasted through these leaks, especially in former black townships, can be extremely high.

b) Meter inaccuracies

Meter inaccuracies can be subdivided into the following categories:

i. Inherent meter errors which result in meters either over-reading or under-reading the actual volume of water passing through them.

ii. Meter malfunction such as breakages or blockages which results in under-reading or zero reading.

iii. Incorrect meter sizing which results in the actual flow being outside the accurate measuring range of the meter. This situation occurs mainly with large consumers and generally the meters are over-sized for the actual demand.

iv. Incorrect meter installation which affects meter accuracy. This applies specifically to meters that are susceptible to turbulent flow such as multi-jet, turbine and magnetic induction meters.

c) Unmetered connections

Unmetered connections can be divided into two categories, viz:

i. Authorised connections which are consumer connections installed by the Local Authority. These connections include irrigation points for Municipal parks and sports fields, standpipes in informal settlements, etc.

ii. Unauthorised connections which are connections installed by consumers without the permission and/or knowledge of the Local Authority. These connections occur mainly in informal settlements and areas of land invasion.

d) Flushing of mains

Flushing of mains occur on initial filling of a reticulation system and when repair work or pipe scouring operations are carried out in a system. Flushing is also carried out to maintain water quality by removing stagnant water where there is insufficient circulation or by removing "red water" where there is high internal corrosion of steel pipes.

e) Fire fighting

Fire hydrants and hose reels are often unmetered so that any abstraction of water through these points, for any purpose, is not measured.

f) Reservoir leaks, overflows and flushing

Leaks in reservoirs are a common occurrence and are generally expensive to repair. Often, reservoir leaks are not visible and are only detected through drop tests investigations. Generally, reservoir leaks are only repaired when the amount of water leaking from a reservoir makes it economically justifiable to implement extensive reservoir repairs.

Reservoir overflows result from the failure of inlet control mechanisms. The most common type of overflow system is a bellmouth arrangement constructed inside the reservoir. The overflow pipe is usually connected to the scour pipe which in turn is lead to some natural water course or stormwater pipe. This often results in overflows remaining undetected for long periods of time especially in the case of intermittent overflows occurring during hours of low demand.

Flushing of reservoirs occurs when the reservoirs undergo routine maintenance or unscheduled emptying for repairs. The water used for flushing is scoured to waste.

g) Theft

The most common forms of the theft are the by-passing of or tampering with consumer meters and the use of fire hose reels for purposes other than fire fighting. Very often the culprit is unaware of the illegality of using fire hose reels for purposes other than fire fighting, believing that the hose reels are metered through his domestic water connection.

A less common form of theft is the collusion between a consumer and meter reader whereby the meter reader falsifies consumption figures.

Unauthorised connections described in 2.4.3.c.ii is currently a sensitive social issue and is therefore not classified as theft.

3. DEVELOPING A UAW STRATEGY

3.1 General

The development of a UAW Strategy must be done systematically as discussed below. The UAW Committee must be established with proper terms of reference determining its powers, duties and responsibilities. The formulation of policies must be carefully investigated and discussed by all interested parties to ensure that no conflict of interest or violation of existing statutes or Local Authority by-laws occurs.

3.2 Establishing a UAW Committee

The first step in developing a UAW Strategy is the establishment of a UAW Committee. The Committee will need to be made up of personalities with both status and authority. Technical, financial and administrative disciplines must all be represented and all have the common goal of reducing UAW in the most efficient manner possible. A typical UAW Committee structure is shown in Figure 2.

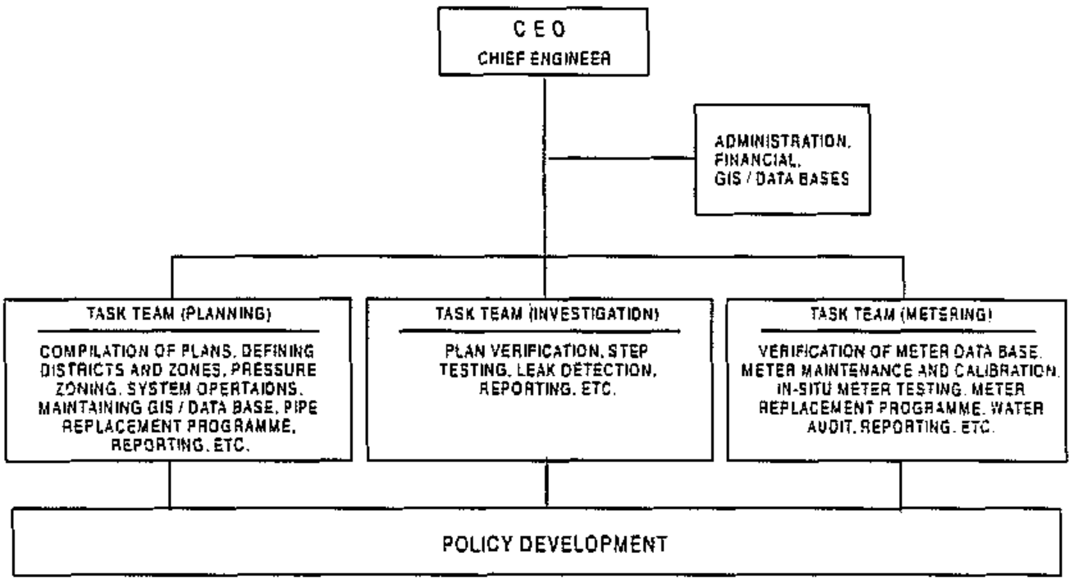

Figure 2 : Structure of a UAW Committee

The UAW Committee will need to be knowledgeable on matters of UAW control but will not necessarily have to be expert enough to devise, plan and implement the entire UAW control operation itself. This function, or certain aspects of the programme can be either contracted out to specialists or even given over to private sector participation, where the functions would be taken over by the private sector but not the assets nor the authority and responsibility of the Local Authority. Thus, the powers, duties and responsibilities of the UAW committee are largely fixed, but the method of operation is fairly flexible as regards procedures and methodologies. The important factor is that the best interests of the consumer remain a priority at all times.

The number and functions of the Task Teams can be varied to suit the size and complexity of a distribution system.

3.3 Formulating UAW Policies

Once the UAW Committee has been established it can formulate the UAW policies it intends implementing. The areas to be covered by the policies include the following:

3.3.1 Financing and budgeting

The initial capital expenditure of setting up a UAW strategy and the continual implementation of UAW control systems will, of necessity, be financed by the Local Authority. Although initial capital costs may be high the benefits of reducing UAW will soon be evident resulting in the whole UAW strategy becoming self-financing.

Initial financial feasibility needs to be determined after which the UAW strategy can be funded incrementally as savings accrue.

3.3.2 Storage of information

It is absolutely essential for UAW control that comprehensive and up to date information pertaining to the distribution system is available to the UAW Committee. This information can be either in the form of drawings, registers and catalogues or stored electronically in the form of databases or computer based geographical information systems (GIS). Although costly to set up initially the benefits of a GIS will soon justify its expense.

3.3.3 District and zone metering

The Committee must compare the benefits of permanent district and zone meters as opposed to portable meters. Clearly the installation of permanent meters in all districts and zones may be prohibitively expensive as an initial exercise. The systematic installation of permanent meters over a three to five year period may be more cost-effective. Furthermore, financial provision must be made for the regular maintenance and/or replacement of the meters.

3.3.4 Meter reading responsibilities

Traditionally, the Treasury Department of a Local Authority is responsible for the reading of consumer meters, invoicing consumers and collection of revenue while the Water Department is responsible for the reading of bulk meters and the maintenance of the distribution system. This split in responsibility, specifically the reading of meters, leads to many administrative problems and inefficiencies. Furthermore, the Treasury Department structure their meter reading rounds along township boundaries rather than reservoir or supply zones. This makes it difficult to carry out a water audit of bulk meters versus consumer meters.

3.3.5 Goals, targets and time frame

Although the ultimate goal of the UAW strategy is to achieve UAW figures within the acceptable national norms, realistic targets and time frames must be set by the UAW Committee. Unrealistic targets lead to despondency and loss of interest in the exercise.

3.3.6 Pricing policy and tariffs

The question of payment of services is a highly politicised debate. Pricing policy and tariffs should be determined by the Local Authority in consultation with the UAW Committee.

3.3.7 Universal metering

The preferred policy is one of universal metering, i.e. individual metering of all consumers within the Local Authority's area. Although highly desirable, this policy is not always possible, especially in informal settlements. A policy of metering the consumption in these settlements must be formulated by the UAW Committee.

3.4 Staffing of UAW Task Teams

3.4.1 General

The entire Water Department of a Local Authority has an active role to play in controlling UAW. They will assist and be guided by a core of specialists who will focus all of their working time and energy only on UAW management.

For medium to large sized Local Authorities, an average of five to ten percent of water branch staff at all levels should be assigned full time to water loss management. A small Local Authority will have to appoint a proportionally greater number of persons to the Task Teams.

3.4.2 Task Team staff qualities

Each Task Team must be headed by an engineer or senior technician who has a sound technical background and is knowledgeable in all aspects of the distribution system. He will also be responsible for managing the Task Team and liaising with the rest of the UAW Committee on all matters relating to the facets of UAW control entrusted to his Task Team.

The members of the Task Teams need to be dedicated, meticulous and enthusiastic in their approach to their tasks. Much of their work, such as *in-situ* meter testing, step testing, sounding, etc., is tedious and labourious. Errors due to boredom or lack of interest will have a negative effect on results.

3.4.3 Training

The members of the Task Teams must be appropriately trained for the functions that they are to perform. They must be fully conversant with the operation of the GIS, leak noise correlators, sounding sticks and all other tools and software at their disposal for UAW control.

4. PREPARATORY WORK AND FIELD INVESTIGATIONS

4.1 General

Before any corrective measures for the control of UAW can be implemented a tremendous amount of preparatory work and field investigations needs to be undertaken to determine the general status of the distribution system and to assess the relative values of the components of UAW. This initial work forms the foundation of the system data base which, in time and with regular up-dating, will become an invaluable tool for the UAW Committee to use in reviewing UAW policies, preparation of system audits, assessment of cost benefits of UAW control and forward planning requirements.

4.2 Preparation of an Information Data Base

The preparation of a data base or GIS containing all pertinent details of the distribution system is essential. No meaningful work can commence on the control of UAW without this information.

The data can be kept as hard copies, i.e. layout plans, registers and logbooks, etc., or captured on a computer based GIS. The latter system is more desirable from the point of view of ease of storing and retrieval of information. The GIS should contain the following data:

a) A full set of layout plans covering the entire distribution system. The following information should be shown on the plans:

   i. Key plan indicating the relative position of each plan in the system.
   ii. Title block with name of water distribution system, description of the area of the system shown on that plan, scale, date of last up-date, date and initials of plan approval.
   iii. Latitudinal and longitudinal grid and north point.
   iv. Cadastral boundaries, servitudes and right of ways.
   v. Stand numbers and street numbers.
   vi. Township names and street names.
   vii. All bulk and distribution mains with their individual position relative to the road reserve or servitude boundary indicated.

b) A pipe data base containing the following:

   i. Position of mains with an off-set distance from cadastral boundaries.
   ii. Depth of pipe.
   iii. Size, material and pressure class of pipe.
   iv. Age or year of installation of pipe.

c) A consumer data base containing the following:

   i. Stand number and township names.
   ii. Street address.
   iii. Position of connection.
   iv. Type and size of connection.
   v. Make, type and size of meter.
   vi. Meter number.
   vii. Date installed.
   viii. Date of last service.

d) A data base of bulk supply meters, whether the meters belong to the Local Authority or the Supply Authority, containing the following:

   i. Location of meter.
   ii. Make, type and size of water.

iii. Meter number.
iv. Date installed.
v. Date of last service.

e) An isolation, air and scour valve data base containing the following:
   i. Position of valve.
   ii. Make, size and type of valve.
   iii. Status of valve under normal operating conditions.
   iv. Opening and closing directions.
   v. Date installed.
   vi. Date of last service.

f) A control valve data base containing the following:
   i. Position of valve.
   ii. Make, size and type of valve.
   iii. Direction of flow.
   iv. Pressure setting for pressure reducing and pressure sustaining valves.
   v. Date installed.
   vi. Date of last service.

g) A fire hydrant data base containing the following:
   i. Position of hydrant.
   ii. Make and type of hydrant.
   iii. Connection type.
   iv. If metered, make, type and size of meter.
   v. Size of supply main.
   vi. Date installed.
   vii. Date of last service.

h) A data base of fire connections to properties containing the following:
   i. Position of fire connection.
   ii. Size and type of connection.
   iii. If metered, make, type and size of meter.

iv. Date installed.
v. Date of last service.

i) A management meter data base containing the following:
   i. Position of meter.
   ii. Make, type and size of meter.
   iii. Direction of flow.
   iv. Date installed.
   v. Date of last service or calibration.

j) A data base of the centre line, identity and size of other services with depths and offset distances from cadastral boundaries for:
   i. Electricity cables.
   ii. Telephone and other signals cables.
   iii. Gas pipes.
   iv. Sewer pipes.
   v. Storm water pipes.
   vi. Other authority water pipes.
   vii. Lines of poles for street lights etc.
   viii. Rows of planted trees on pavement.
   ix. Any other services.
   x. Any dead/disconnected/abandoned services still in the ground.

4.3 Verification of Existing Data

Once all available drawings and data have been collected and scrutinised in the office, the information must be verified by field investigation. Preferably, the field investigations must be carried out before the data are captured on a GIS.

The UAW Committee must appoint a Task Team with the task of investigating and verifying the existence and position of all components of the distribution system. The assistance of other service departments must be enlisted to verify the existence and position of all other services in the area covered by the distribution system.

The Task Team must also study the drawings of one township or one township extension at a time and try to establish the pattern of valves and hydrants installation in that particular area. Any deviation from that pattern, e.g. 2 valves at an intersection when the pattern is typically 3 valves for similar intersections for that area, indicates the possibility of a fitting having been installed but not marked on the drawings. The team must search for and establish if such fittings are present or not and amend the records accordingly.

The Task team must also verify consumer records. In general, both the Treasury Department and the Water Department of a Local Authority have a set of consumer records. This often results in discrepancies and inaccuracies in the information due largely to the two sets of records not being updated simultaneously or by the same personnel. The team must verify the information of every consumer and connection, whether metered or not, and create a consumer data base as described in item 4.2.c.

Once the field investigations have been completed the base plans must be updated and the date recorded on the plan. Alternatively, the information must be captured on a GIS.

The UAW Committee must decide on the most cost-effective and time-effective manner for carrying out this work. The work can be done in-house by the Local Authority or by an outside specialist or a combination of the two.

4.4 Assessment of UAW Components

Where historic data exist, the UAW Committee must analyse the information in an attempt to assess the relative magnitude of each component of UAW.

Based on this assessment the Committee can then prioritise the area and sequence of implementing UAW control measures. Where no such data exist, the implementation of UAW control measures should follow the sequence described later.

In either instance it is imperative to keep accurate records of all measurements and findings of investigations done in the field for subsequent analysis and comparative purposes.

5. IMPLEMENTATION OF UAW CONTROL MEASURES

5.1 General

The implementation of measures to control UAW must be done in a pragmatic and systematic way. In general the implementation should follow the sequence described below, although more than one task can be undertaken simultaneously dependent on the size of the UAW Committee.

5.2 Division of a Distribution System

The distribution system under the jurisdiction of a Local Authority must be divided into districts and zones as follows:

5.2.1 District

A district is any portion of a water distribution system which is identifiable by discreet boundaries, effectively without any limit in size. The district may comprise of any number of sub-districts and zones containing various categories of consumers. All points of entry and exit of water from the district must be measured, preferably by permanent dedicated meters.

5.2.2 Sub-district

A sub-district is a separately isolatable section of a district comprising one or more zones with approximately 30 000 residential properties or their equivalent.

5.2.3 Water loss management zone

A water loss management zone is a separately isolatable section of a sub-district of approximately 3 000 residential properties or their equivalent.

5.2.4 Sector

A sector is a further sub-division of a sub-district or zone and is created by closing a number of isolating valves. A sector is created specifically for monitoring minimum night flows and for conducting step tests. It is not a permanent sub-division and is only created during hours of low demand with all valves being re-opened immediately after the field tests have been concluded.

5.2.5 Pressure control zone

A pressure control zone is a zone where the upper pressure limit is controlled either by a supply reservoir or a pressure reducing valve. The boundaries of a pressure control zone must not cross the boundaries of water loss management zones.

Pressure control zoning is a very effective way of controlling leaks and is described in detail later.

Depending on the size and/or layout of a distribution system, some of the above divisions can be synonymous. A typical layout of a distribution system is shown in Figure 3.

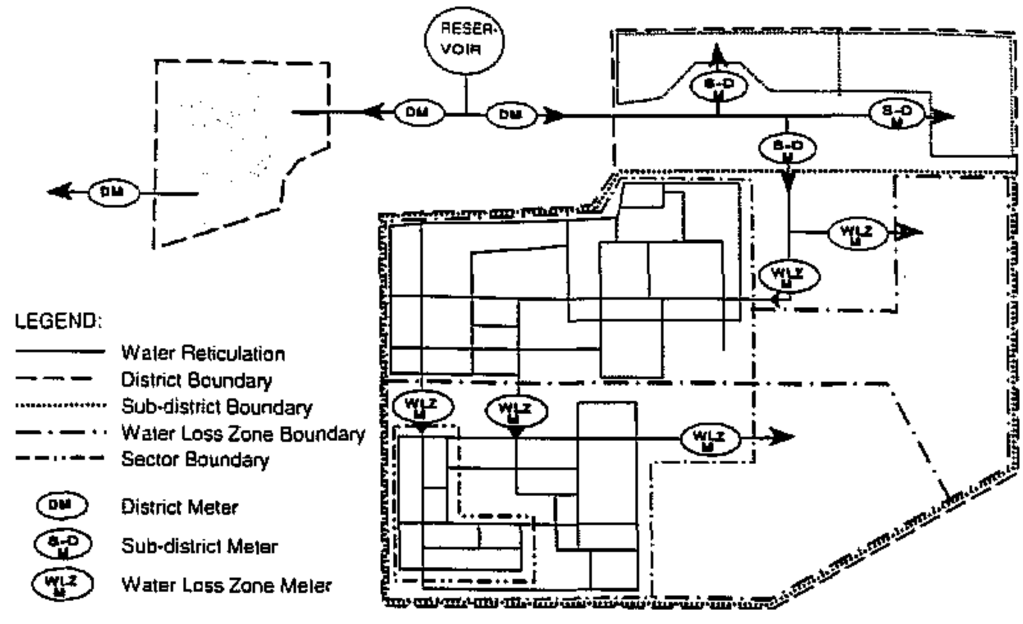

Figure 3: Distribution System Divisions

The sub-division of a distribution system into districts and zones as described above makes the system more manageable especially for functions such as step testing, monitoring minimum night flows, etc.

5.3 Planning the Districts and Zones

The division of new reticulation systems or extension of existing systems into districts and zones must be done as part of the design of the system. The installation of metering points, whether for permanent or temporary meters, must form part of the construction of the new reticulation. The planning of districts and zones within an existing reticulation systems must take cognisance of the existing pipework as well as physical constraints such as roads, bridges, buildings, etc. Generally, district and zone boundaries should be placed along natural breaks in the reticulation, thereby requiring minimum changes to the existing pipework.

Natural breaks in the district pipe work are generally found along green belts, natural topographical features, large parks and sport complexes. They are also found along railway lines, major roads and between different townships and township extensions.

Typical examples of natural breaks in the water distribution network are illustrated in Figure 4.

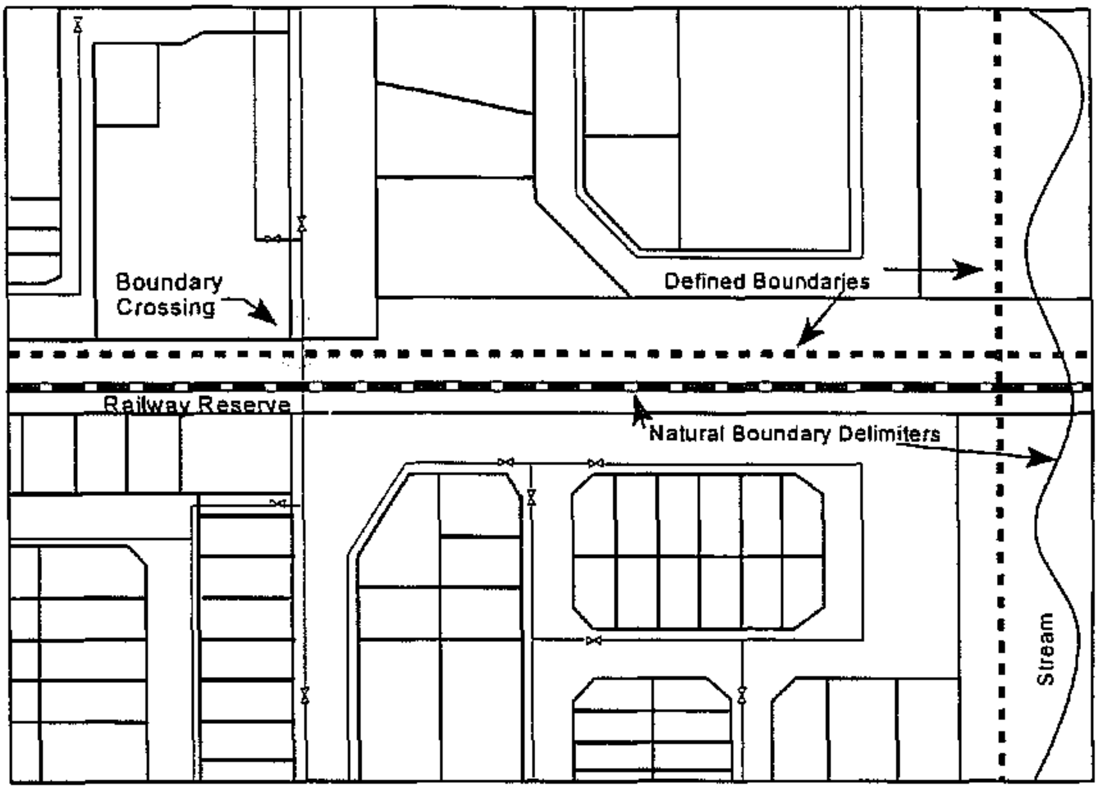

Figure 4: Typical Natural Breaks

The size of area can also be influenced by the choice of type and size of management meter to be used in supplying an area. A 150 mm Woltmann type meter for example can deliver enough water to supply 2 500 to 3 000 properties and still be sensitive enough to measure minimum night flows. A magnetic induction meter of the same size could handle a bigger area and also be sensitive at lower flow rates.

The proposed boundary closures and metered entry points to each district, sub-district and zone of the distribution system must be tested mathematically with a water network analysis program to ensure that the distribution system does not suffer any negative effects.

5.4 Field Testing of the Planned District and Zone Divisions

It is prudent to test the distribution system's reaction to the proposed sub-division before the boundaries of the planned sub-divisions are permanently created. The testing is done by recording the residual pressures at selected points within each planned district, sub-district or zone for at least a week under existing conditions. The sub-divisions are then created to coincide as closely as possible to the proposed sub-division by closing selected valves. Residual pressures are again recorded for at least a week and compared with the original recordings.

The affected consumers must be informed in advance of the UAW management project and the possibility of short periods of disruption in the water supply during modifications and testing. The consumers should be encouraged to report any adverse changes that they may experience with their water supply to the Task Team.

Once the UAW Committee is satisfied that the proposed sub-divisions will have no ill effects on the distribution system, the permanent boundaries can be created. The boundaries must be created by introducing discontinuities in the reticulation system in the form of "cut-and-plug" operation or sealing a valve in the closed position, leaving the metered mains as the only entry and exit points to the sub-division.

The discreteness of each sub-division must then be confirmed by closing the remaining open supply points to the sub-division under investigation and observing the pressure fluctuation in the sub-division. A total loss of pressure in the sub-division being investigated indicates complete discreteness of the sub-division. A partial loss of pressure is indicative of an ineffective discontinuity or the presence of an unknown open connection into the sub-division.

5.5 Selection of District and Zone Meters

Once the sub-divisions of a distribution system have been finalised, suitable meters must be selected to monitor the volume of water entering and, in some meters must be selected to monitor the volume of water entering and, in some instances, exiting each sub-division. The selection of the meter type and size is dependent on the anticipated peak and minimum flow of each sub-division. If no flow data are available the peak and minimum flow can be approximated to 4 x the annual average daily demand (aadd) and ¼ x aadd respectively. Site conditions, such as the availability of electricity and telecommunication cables, security, vandalism, etc. must also be considered in choosing the location and type of meter installation.

Generally district and sub-district meters should be permanent installations while water loss management zone and sector meters can be either permanent or temporary installations. Typical details of permanent and temporary meter installations are given in Figure 5 and Figure 6 respectively.

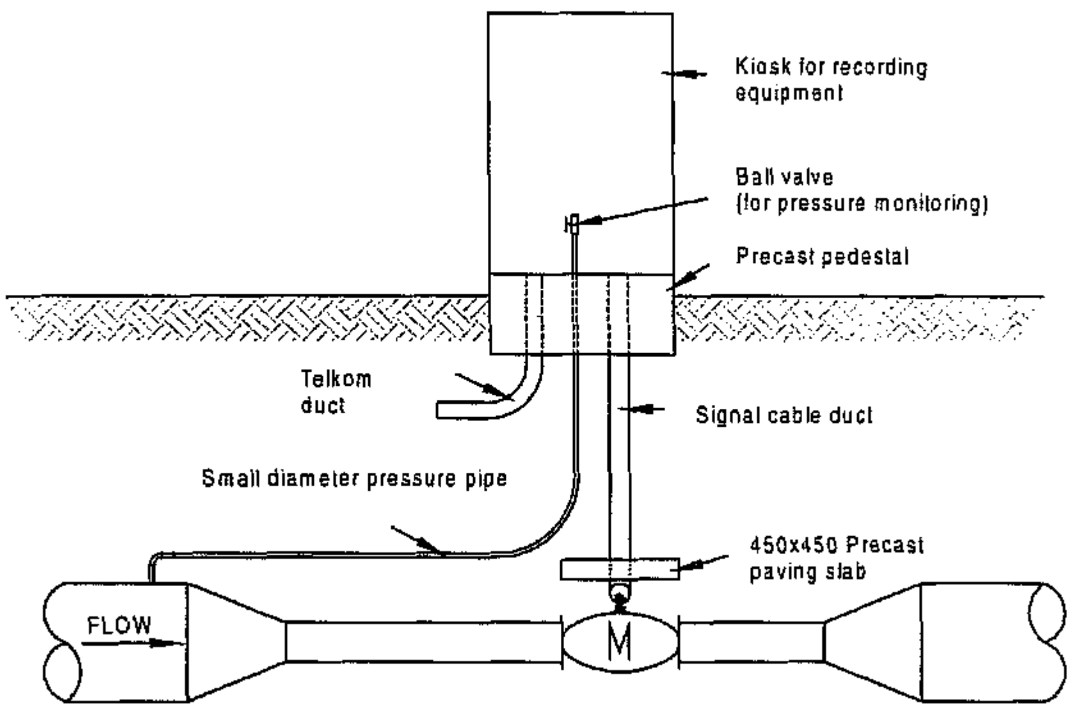

Figure 5A : Typical Permanent Meter Installation (Buried)

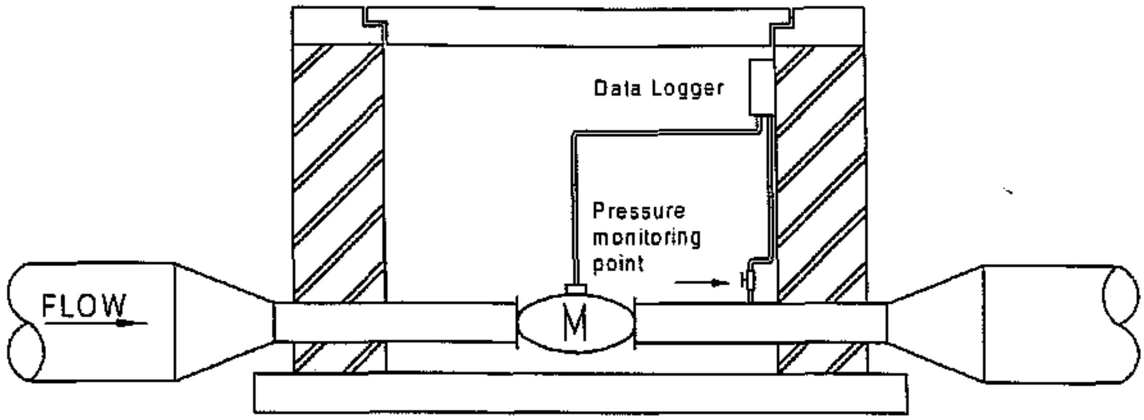

Figure 5B : Typical Permanent Installation (In Camber)

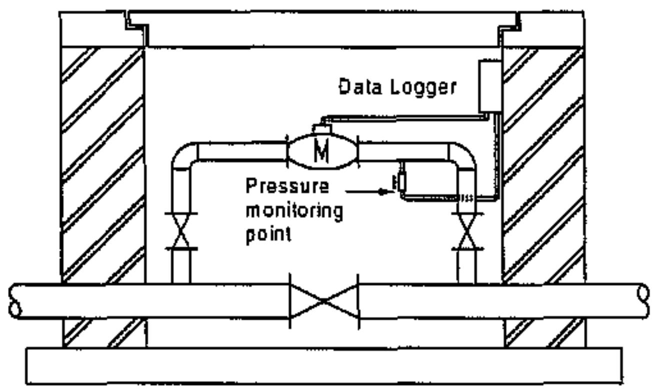

Figure 6: Typical Temporary Meter Installation

The choice of meter supplier must be carefully made. The supplier must be able to make prompt deliveries of meters and spares, be able to repair meters and calibrate them to international standards. Cost of meters is important but should be considered secondary to successful performance.

The hierarchy of metering of a distribution system is shown in Figure 7.

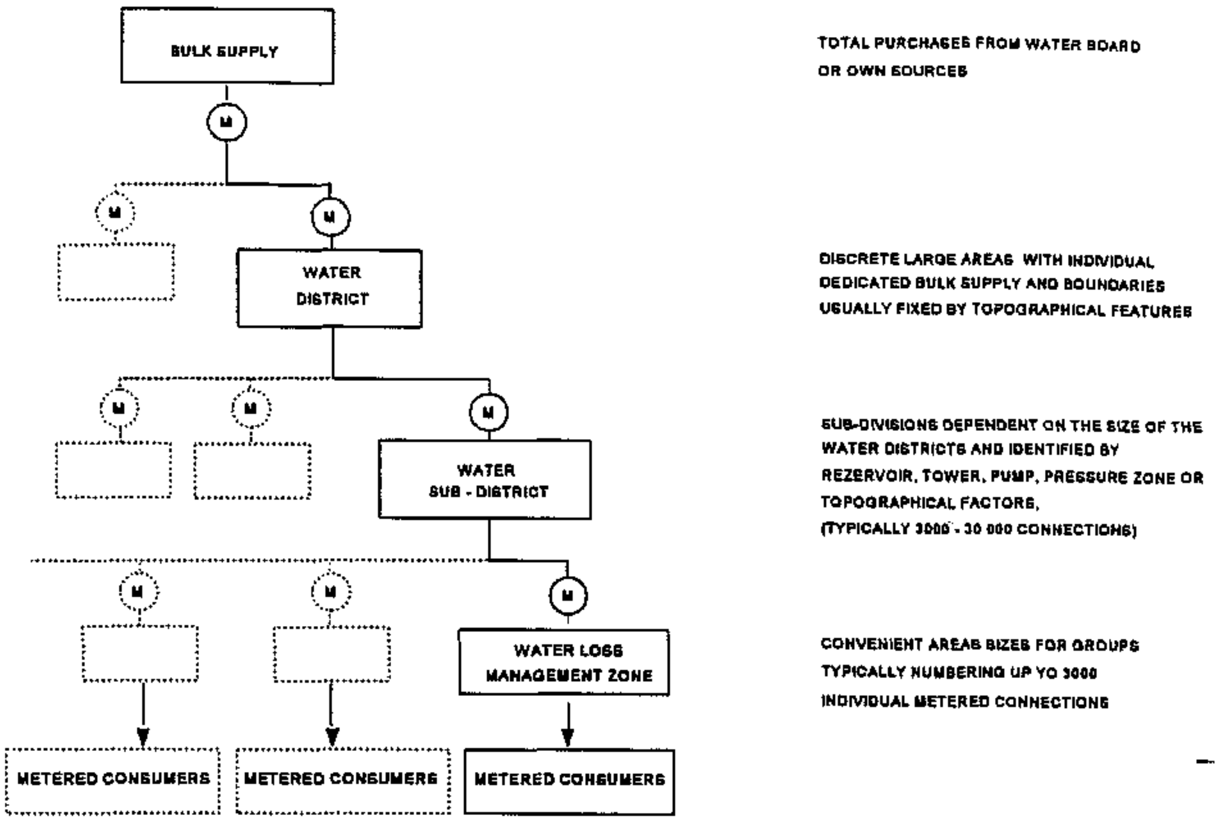

Figure 7: Typical Metering Hierarchy

5.6 Design of District and Zone Meter Installations

The design of meter installations must be done strictly in accordance with the manufacturer's requirements. Most meter manufacturers state a minimum length, expressed as a multiple of pipe diameters, of straight pipe of the same internal diameter as the meter to be installed upstream and downstream of the meter. These lengths of straight pipe are required to enable the water flow profile to become normalised before passing through the meter. Non-compliance with the manufacturer's installation requirements may have a significant effect on the accuracy of the meter.

Metering points that are subjected to reversal of flow must be equipped with meters capable of measuring bi-directional flow. Alternatively, a non-return valve must be fitted, preferably downstream of the meter. Reversal of flow at a metering point should only be allowed if specifically designed to do so, however.

Consideration should also be given to the installation of dirt traps upstream of mechanical meters which are susceptible to solid particles which may have entered the water system.

A typical metering point is shown in Figure 8.

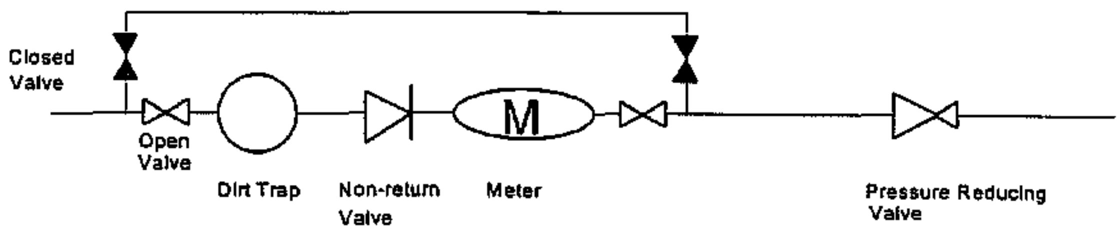

Figure 8 : Typical Metering Point Installation

Figure 8 shows a meter installation with a by-pass. The by-pass allows maintenance work to be carried out on all elements of the metering point without interrupting the water supply through that particular point. In this instance the pressure reducing valve, if required, is installed downstream of the by-pass.

By-passes to metering points are not required if a zone is supplied through more than one metering point. In this instance the pressure reducing valve, if required, should be installed upstream of the meter but downstream of the dirt trap if a dirt trap is installed.

Isolating and bypass valves at manifolds which have to be kept either open or closed to operate the system properly should be fitted with locking caps to ensure that the settings are not tampered with. The locking caps should be colour coded to indicate whether the locked valve is kept normally open or normally closed.

An isolating valve immediately upstream of a Woltmann type meter can, if opened too quickly, result in the destruction of the meter mechanism by a high velocity jet of water impacting on the impeller vanes. These valves should be locked in the fully open position and only be operated by suitably qualified personnel.

5.7 Location of District and Zone Meters

The location of a meter must be carefully chosen to ensure that it is accessible at all times. Areas which are regularly used by pedestrian or vehicular traffic should be avoided. Figure 9A shows a good location for a metering point while Figure 9B shows a poor location for a metering point.

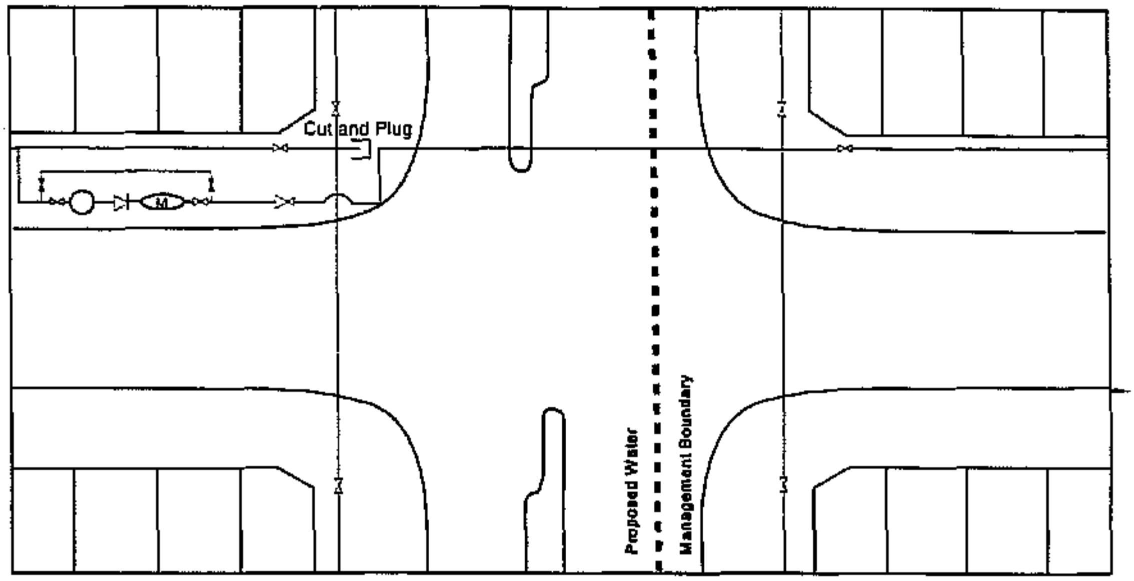

Figure 9A : Good Metering Point Location

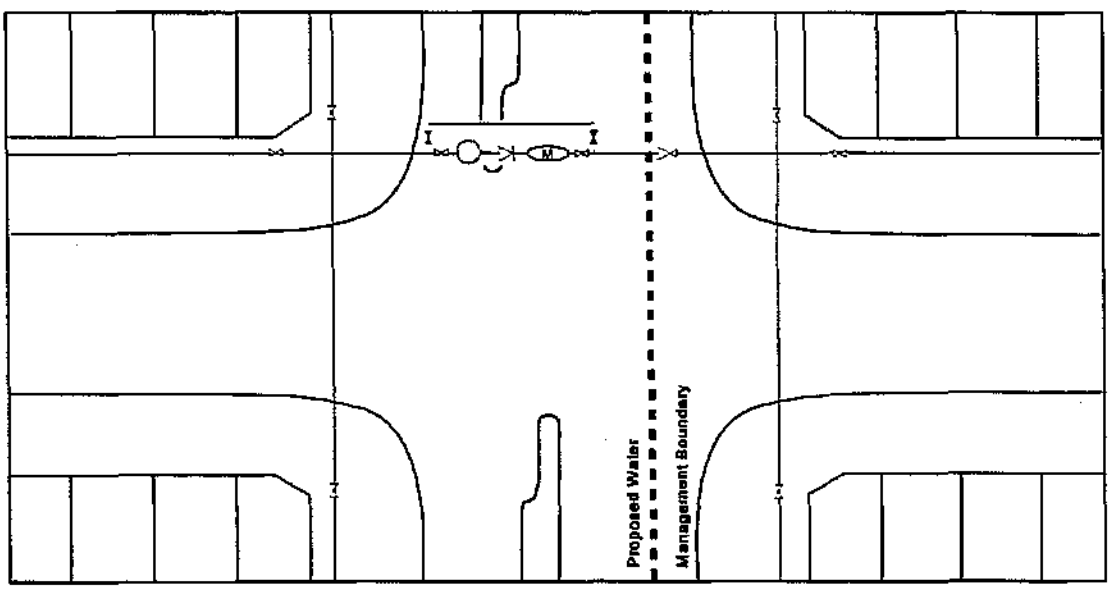

Figure 9B : Poor Metering Point Location

5.8 Physical Installation of Meters and Meter Manifolds

The physical installation of meters and meter manifolds must be carefully planned to minimise the interruption of water supply to consumers. The installation of district and sub-district meters almost invariably results in interruption of water supply to the areas in question. The affected consumers must be notified in advance of the planned interruption of water supply.

The main to be metered must be exposed to verify its type, class and diameter so that the correct couplings can be obtained. Valves required to isolate the affected section of main must be tested to verify that the main can be fully isolated. The meter manifold should be pre-assembled in the workshop or on site and installed as a unit immediately after the section of main has been cut out to accommodate the manifold. All the valves that were closed to isolate the main must then be opened to re-instate the water supply.

The above process is repeated until the entire distribution system has been sub-divided into the planned districts and zones.

5.9 Monitoring of Districts and Zones

As each district, sub-district and water loss management zone is defined and the metering points of each sub-division are installed, the total volume and flow pattern of water entering and leaving a sub-division at the point of measurement can be accurately monitored and logged. All points of inflow to and outflow from an area must be logged simultaneously.

A typical daily demand pattern of a district or zone is shown in Figure 10.

The demand pattern of a sub-division is related to its land use, demographic composition and seasonal variations. The long-term monitoring of daily demand patterns will provide invaluable information on demand growth trends needed for effective planning of storage and distribution capacities of a system.

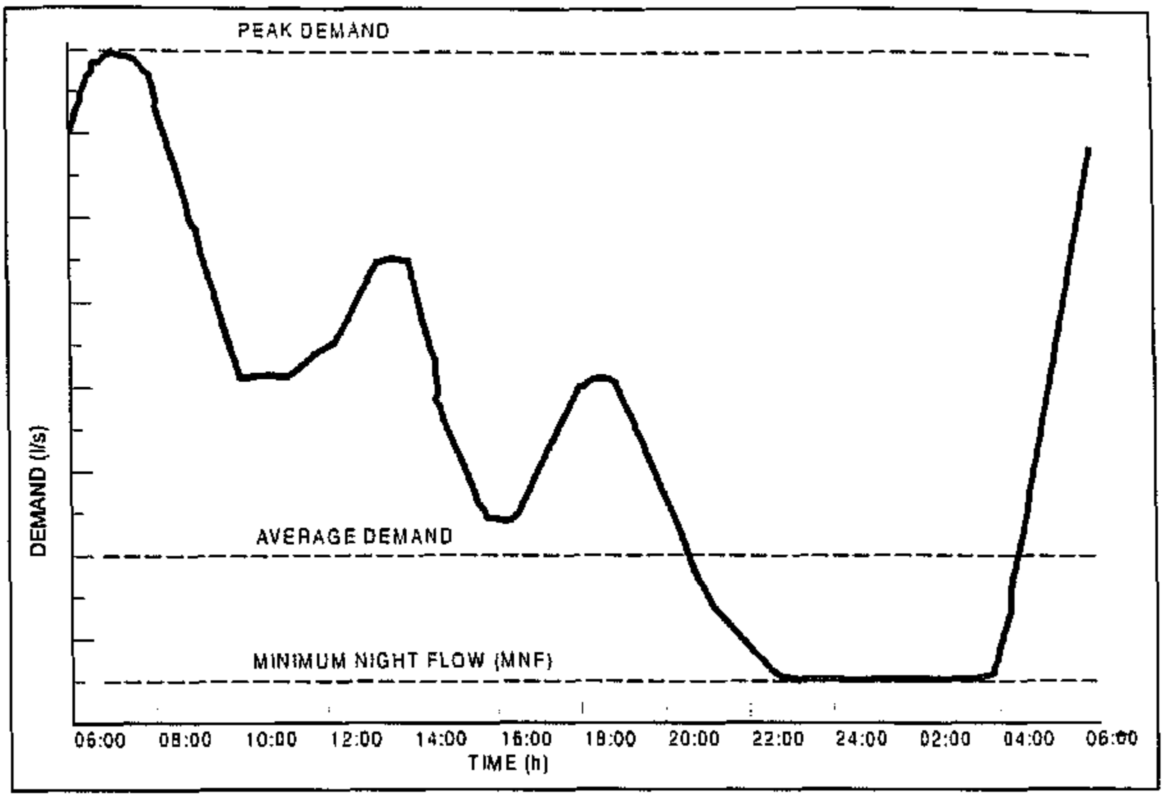

Figure 10 : Typical Daily Demand Pattern

5.10 Determining Specific Loss

Specific loss, **Ls,** is defined as the net minimum night flow of a sub-division. It is expressed either in cubic metres per connection per hour (m^3/c.h) or in cubic metres per kilometre of pipeline per hour (m^3/km.h). The latter expression is generally considered the more appropriate as it relates directly to the distribution system rather than cadastral entities of a sub-division.

The specific loss is computed by dividing the minimum night flows (MNF), which generally occur between midnight and 04:00, by either the number of connections or the length of reticulation mains in a sub-division, i.e.

$$Ls_{(m^3/c/h)} = \frac{MNF_{(m^3/h)}}{\text{No of connections}} \quad \text{or} \quad Ls_{(m^3/km/h)} = \frac{MNF_{(m^3/h)}}{\text{Total length of mains (km)}}$$

The **Ls** for each sub-division must be monitored and recorded on a regular basis. The **Ls** of various sub-divisions of like composition can then be compared and an acceptable maximum **Ls** defined.

5.11 Prioritising Areas for UAW Corrective Measures

Once the **Ls** and MNF values of all or several sub-divisions are known, the UAW Committee is in a position to evaluate these parameters and prioritise the sub-divisions requiring UAW corrective measures. Prioritising should take both the **Ls** and the total volume of MNF of a sub-division into consideration.

When all sub-divisions have been prioritised the Task Team (Investigation) will be in a position to commence the leak detection exercise.

6. LEAK DETECTION

6.1 General

Leakage of water from a reticulation system is generally the most significant component of UAW. It results in not only a loss of revenue for the Local Authority but also the wastage of a resource which is becoming increasingly scarcer. For these reasons it is important that leak detection and reduction be given significant attention by the UAW Committee. Leak detection methods include:

a) Reporting of visible leaks
b) Step testing
c) Leak noise correlation
d) Subsurface radar inspection.

6.2 Reporting of Visible Leaks

The reporting of visible leaks and bursts, whether by the public, meter readers or Local Authority officials, should be encouraged. The collection and processing of leak reports need not be a UAW Task Team function but the analysis of the occurrance of leaks and bursts can be indicative of problem areas within a distribution system which may require the attention of the UAW Committee.

6.3 Step Testing

Step testing works on the principle of monitoring the flow into a sub-division while systematically isolating portions of the reticulation in the sub-division. The term step testing arises from the steps in a flow vs. time graph resulting from the isolation of portion of the reticulation. A typical step test graph, shown in Figure 10A, is for the typical reticulation layout shown in Figure 10B.

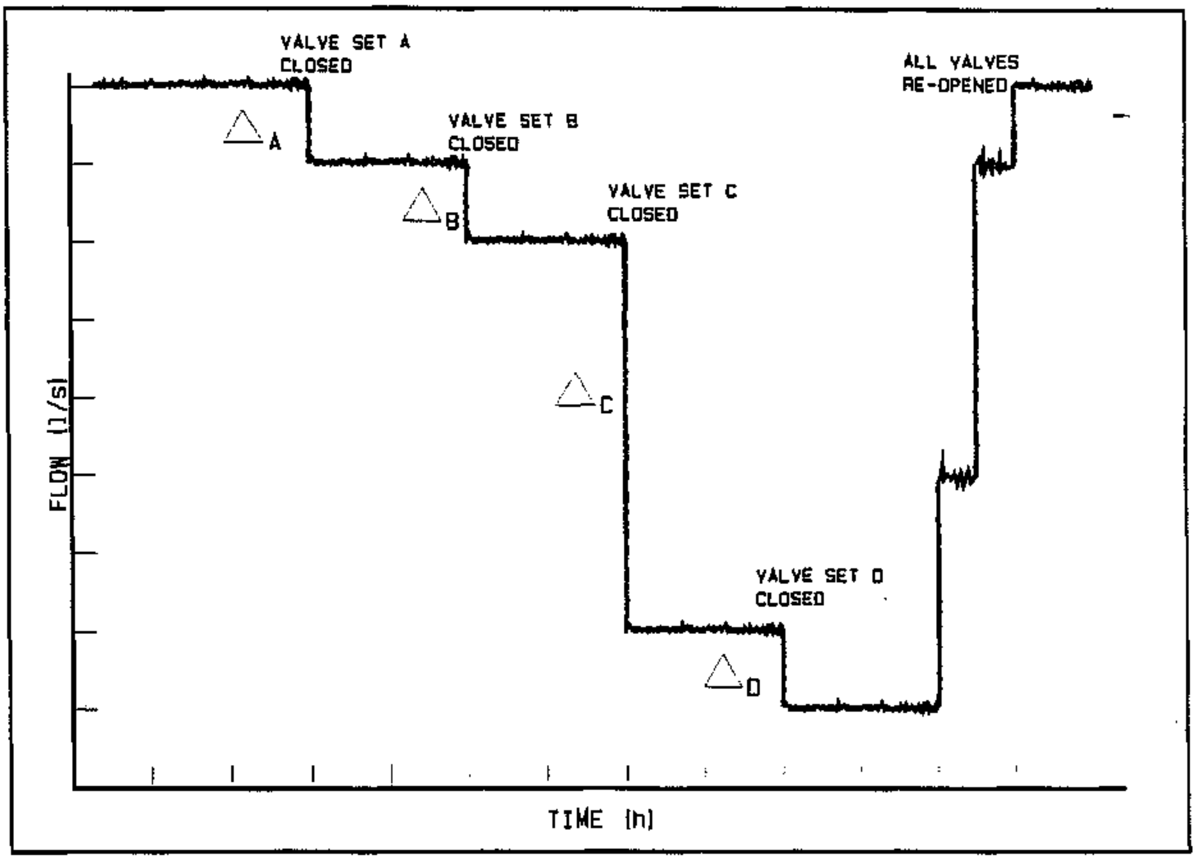

Figure 10A : Typical Step-Test Graph

Step testing results in the interruption of water supply to consumers, albeit for only a few hours. It is advisable, therefore, to conduct step tests at night, preferably during periods of MNF.

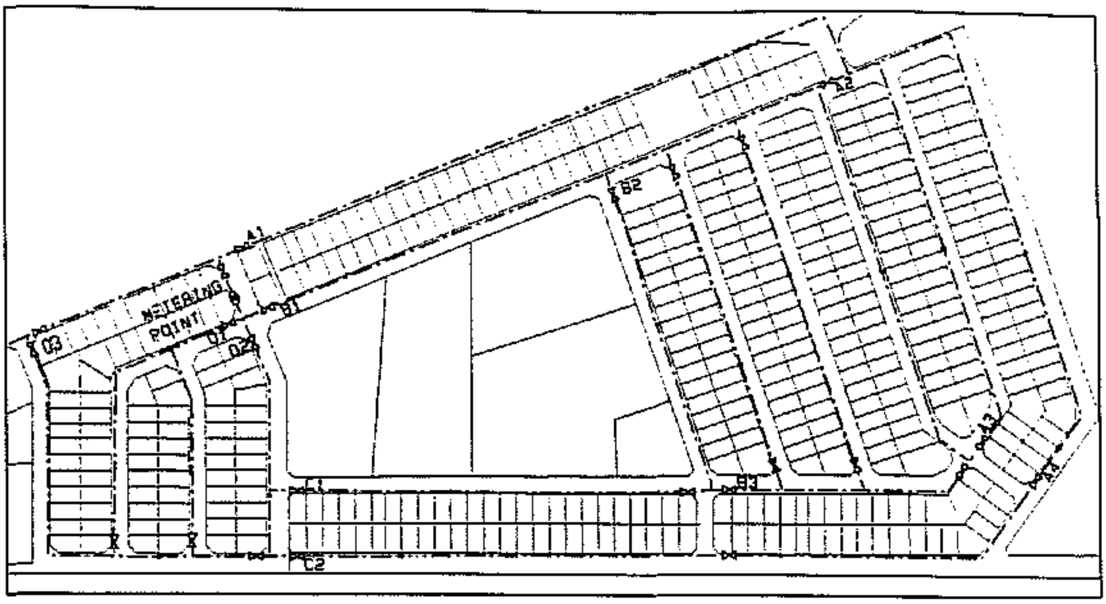

Figure 10B : Typical Reticulation Layout

Before step-testing can commence the UAW Task Team must undertake a certain amount of preparatory work. Using the most up to date plans the Task Team must determine sections of a sub-division to be investigated. These sections, called sectors, are created by closing specific valves. The sectors should be approximately equal in size. The valves to be closed must be tested in the field to ensure that they are operational prior to the test being conducted.

Many of the valves that have to be closed to create sectors can be closed during the day in preparation for the actual step test that night. Only enough inter sector boundary valves are left open to ensure that the system can meet the water demand in the area for the rest of the day. The fewer the valves that have to be closed at night to achieve the step test, the quicker the test can be completed and the shorter the period that the sectors remain without water. Experience has shown that 30 to 40 valves is the practical maximum number of valves which can be closed and reopened in a 4 to 5 hour shift.

Step-testing is so planned that the furthest sector is closed off first with the rest of the sectors being closed sequentially and progressively closer to the chosen metering point until the final sector, at the metering point, is isolated.

The flow rate will drop with each sector closure as the area being supplied becomes smaller. The process will be continued, one sector at a time, until the flow rate drops to zero with all the sectors closed. The specific loss, **Ls**, can then be determined for each sector and the Task Team can then decide on the next leak detection action to be taken.

Once the step test is completed for the whole area, all of the valves temporarily closed for the test are reopened to restore the water supply network to its previous configuration.

6.4 Invisible Leak Detection Procedures

Water escaping from a defect in a pressurised pipe produces a characteristic and recognisable sound. This leak noise travels along the pipeline in both directions simultaneously. The velocity of propagation of the noise is influenced by the pipe material, lining material, the condition of the pipe and the diameter of the pipe. Various techniques can be used to trace this noise, viz:

6.4.1 The sounding stick

This is an electronic acoustic microphone which amplifies the leak noise. Accessories permit either direct physical contact with the pipe (the best option where available), or indirectly using a ground-microphone or geophone. This instrument is still recognised as the main tool available to the leak detection industry.

6.4.2 The leak noise correlator

The leak noise correlator is a devise which determines the position of a leak by measuring the noise from the defect from two points on the pipe. Microphones, known as transducers are placed in contact with the pipeline and detect the leak noise over a considerable distance. The distance that a leak noise will travel is determined by the pipe material, pipe diameter, the condition of the pipe, and the 'loudness' of the leak, which in turn is determined by the pressure in the pipeline and the shape and sharpness of the defect in the pipe. A schematic of a typical noise correlator operation is shown in Figure 11.

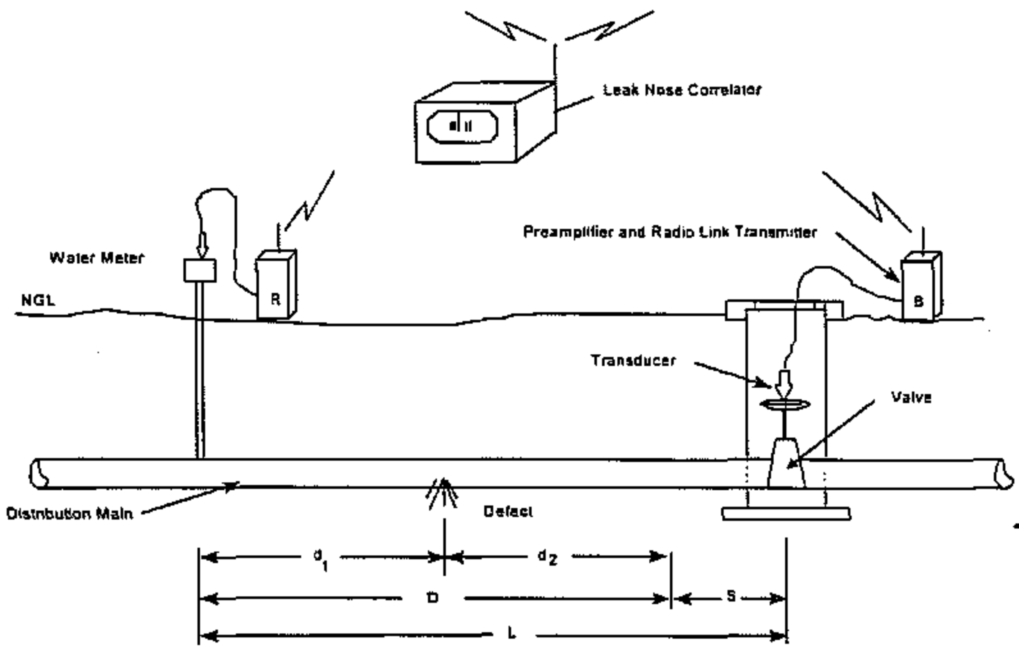

Figure 11: Layout of a Typical Leak Noise Correlator Operation

In Figure 11, the leak sound travels the distance $\mathbf{d_1}$ to reach the nearer transducer to the defect. Simultaneously, the noise has travelled in the other direction an equal distance $\mathbf{d_2}$. The time taken for the leak noise to travel the remaining distance **s**, at velocity **v**, to reach the further transducer, is then measured by the correlator in milli-seconds and is referred to as the time delay, $\mathbf{t_d}$. Thus $s = vt_d$ (m). The distance between the transducers, **L**, is determined accurately with a measuring wheel. Then **D** = **L** - **s**, and the position of the leak is at D/ 2.

Hence $$\mathbf{d_1} = \frac{L - vt_d}{2}$$

The velocity **v** of sound through water is dependent on the pipe material and the pipe diameter. The following approximate values of **v** can be used for analysis purposes:

steel	1 340 m/s
concrete and fibre cement	1 000 m/s
uPVC	700 m/s
polypropylene and polyethylene	400 m/s

Other piping materials will fit between the above generic pipe materials.

6.4.3 Sub-surface interface radar

Sub-surface interface radar is an instrument which detects various degrees of saturation of the soil. The sensor is either mounted on a sled or hand held and moved across the ground surface over the area of investigation. An image relating to degrees of saturation of the soil is projected on to a screen for interpretation by the operator. The data can also be saved for later computer analysis in the office.

Sub-surface interface radar has limitations. The success in using this type of equipment is largely dependent on the experience of the operator using the equipment.

7. METERING

7.1 General

The component of UAW relating to meter inaccuracies can be significant. Meter inaccuracies generally result in loss of revenue for the Local Authorities rather than the physical loss of water as in the case of leakage. The most common cause of meter inaccuracy is the incorrect selection of meter type and/or size for a particular installation. This is particularly so in the case of large consumers.

There is abundant literature available from meter manufactures and other sources regarding the accuracy of meters under test-bench conditions for both new and used meters. *In-situ* testing of water meters is necessary to determine their accuracy under installed rather than test-bench condition. The accuracy of meters is influenced by their age, conditions of installation and correct sizing.

Generally meter accuracy deteriorates with time. The *in-situ* testing of meters over a period of time will indicate a trend in deterioration of accuracy. This trend is used to determine the optimum time of replacement of meters in an area.

7.2 Procedure for Domestic Water Meter Testing

The test procedures for the testing of domestic water meters are as follows:

a) An area within the Local Authority's boundary is chosen and demarcated on a plan. A sample of stands are chosen at random in the area.

b) Field record sheets are prepared for the chosen area. An example of the sheet is given in Figure 12.

c) Notice of the proposed meter tests, written on the Local Authority's letterhead, are distributed to the affected consumers in advance, explaining the purpose of the test and giving other pertinent details of the exercise an examples of the notice is given in Figure 13.

d) The day before the test the test rig is checked to ensure that it is in proper working order.

e) On the day of the test one of the team members goes ahead of the test crew and checks that the meters to be tested are working and have no leaks. He also advises residents that the meter test is to be carried out shortly.

f) The test crew request the resident not to use any water for the duration of the test. Before setting up the test rig the crew ascertains that there are no leaks on the property by checking that the meter is completely stopped. If leaks are found, no test is carried out at that site.

g) Three tests each for slow, medium and fast flows are carried out and recorded on the data sheets.

h) Once the test is completed the resident is thanked for his co-operation and the test crew moves on to the next site.

i) The test sheets are transferred to a spreadsheet and analysed.

Insitu meter testing - Domestic meters DATE:		Field data sheet	Type of Test: Volumetric Tested by	
METER		LOCATION		
Number:		Acc. No:		
Make:		Suburb:		
Model:		Address:		
Size (mm):		Stand No:		
Unit (kl or gal):		Remarks:		
Age (Years):				
Test	Initial reading V_i	Final reading V_f	Time (sec.)	Volume Tank V_T
I				
Slow				
Medium				
Fast				
II				
Slow				
Medium				
Fast				
III				
Slow				
Medium				
Fast				
Remarks:				

Figure 12 : Typical Field Data Sheet

TO THE RESIDENT — Local Authority

WATER METER TESTING IN *(name of suburb)* — logo and address

During the month of *(state month)*, this department will be carrying out flow tests on your water meter. The results form an important part of the research conducted by this Department into water meter performance. We will be requiring access to your garden tap. Every effort will be made to minimise the disruption of your water supply. This will be limited to approximately one hour during the hours of *(state hours)* on the day in question. The water used will amount to less than R1,00 (One Rand).

Your co-operation will be greatly appreciated.

DIRECTOR

Figure 13 : Notice of Meter Test

7.3 Test Rigs for Domestic Water Meters

Two basic types of test rigs can be used as shown schematically in Figure 14 and Figure 15. The test rig shown in Figure 14 uses a scale to determine the volume of water which passed through the consumer meter while that shown in Figure 15 uses a check meter for this purpose. The latter test rig is generally more efficient to use. This rig does not limit the volume of water used for each test. Furthermore, the scale of the former test rig is sensitive to wind disturbances. A drawback of the latter test rig is that the check meter must be of a very high quality capable of accurately measuring flows as low as 1ℓ/min.

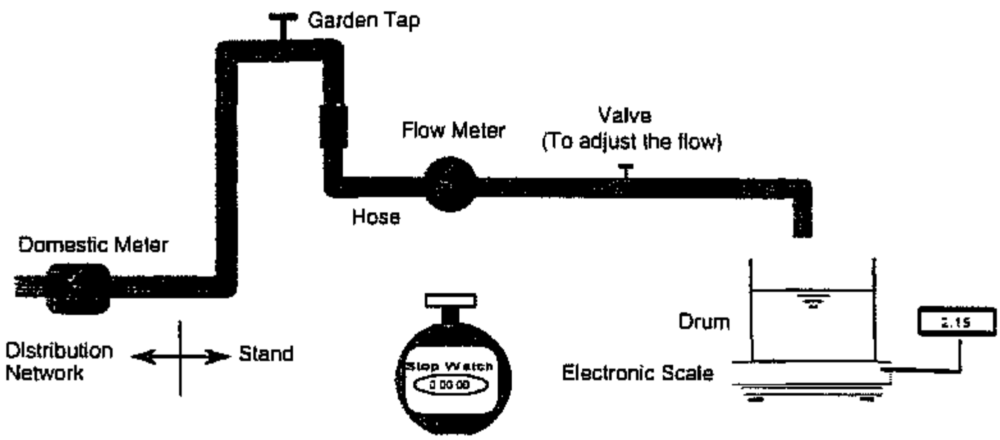

Figure 14: Schematic of Test Rig with Scale Measurements

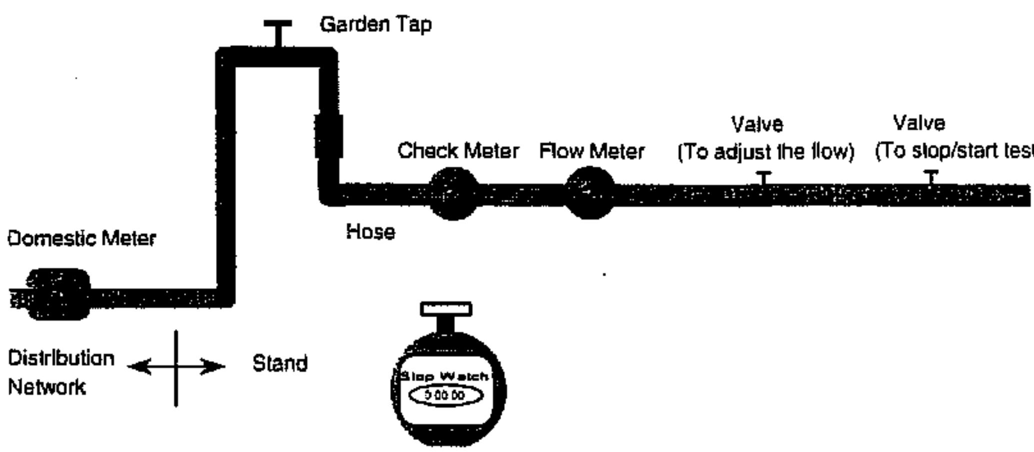

Figure 15: Schematic of Test Rig with Check Meter Measurements

7.4 Reading of *In-situ* Meters

It is imperative that the person reading the meters is acquainted with reading the graduations or fractions on the meter. Generally meter readers from the Local Authority are accustomed to reading whole numbers only and have difficulty in reading the decimal graduations accurately. This will result in test results, especially for the low flow tests, having to be discarded because of spurious readings. If meter readers from the Local Authority are used to assist in this exercise, it is essential that they be instructed in the correct reading of decimal graduations of the meters.

7.5 Analysis of Test Results

Meter errors are calculated using the following formula:

$$\text{Error (\%)} = \frac{V_{read} - V_{measured}}{V_{measured}} \times 100$$

where V_{read} = volume of water read on the test meter

$V_{measured}$ = volume of water measured by the test rig

In the above equation a positive error indicates that the meter is over-reading, i.e. less water has passed through the meter than is indicated on the meter. A negative error indicates that the meter is under-reading, i.e. more water has passed through the meter than indicated.

7.6 Procedures for Meter Testing of Large Consumers

The procedures for the *in-situ* meter testing of large consumers are similar to those used for domestic water meters with the exception that test points must be installed in the consumer connection prior to the test. This will allow the monitoring of the check meter for extended periods of time without causing any inconvenience to the consumer.

The schematic of the test rig used for this exercise is shown in Figure 16.

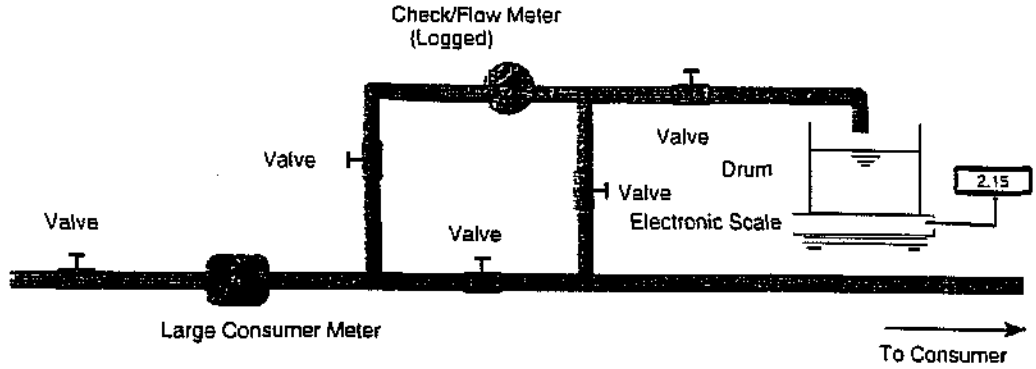

Figure 16 : Schematic of Test Rig for Large Consumer Meter Tests

Two types of tests must be carried out at each meter, viz:

a) Meter accuracy test to determine the accuracy of the meter at low, medium and high flows. The principles used for this test are identical to those used for the domestic water meter tests.

b) Meter size and type test to determine the correct size and type of meter for the individual consumer. Water to the consumers is diverted through a check meter and logged for a 24-hour period. The demand pattern thus recorded is analysed to ascertain the correct size and type of meter for the particular consumer.

7.7 Meter Replacement Policy

In-situ meter testing as described above should be carried out regularly, say once a year, to determine a performance pattern of various meter types installed in different areas and under different working conditions. Once a performance pattern has been established the UAW Committee will be in a position to formulate a meter replacement policy for the various meter types and conditions prevailing in various areas of their Local Authority.

Meters found to be faulty or inaccurate during *in-situ* testing must be replaced as soon as possible, especially in the case of large consumers.

LITERATURE

1. Arscott (1991) "Leakage Control Night Usage" IWO Journal.
2. AWWA (1991) "Evaluating Residential Water Meter Performance" AWWA Research Foundation.
3. AWWA (1989) "Flowmeters in Water Supply". AWWA Manual M33.
4. Bessey, SG. and Lambert AO (1993) "Leakage Control : The Cost to the Consumer and the Environment". BICS Conference.
5. Castle Meters (1985) "Modern Techniques of Leak Detection and Waste Management Through Water Loss Analysis". Water Management Services.
6. Chapman, HC. (1990) "The Need and Implementation of a Water Loss Control Programme for Local Authorities". Richard Bay.
7. De Leuw Cather (1992) "Pilot Project to evaluate Electronic Meter Reading Systems". Johannesburg City Council
8. Exploratory Committee (1996 draft) "Code of Practice for the Management of Potable Water Distribution Systems".
9. Furness, R. Dr "Flow Measurement Seminar". ABB Kent Taylor (England).
10. Heide, GF. (1990) "Asset Renewal - Repair or Replace" Association of Water Offices Journal 26, No1.
11. Hopkins, D., Savage, P. and Fox, E. (1990) "Flow-Rate and Patterns of Water Consumption and Unaccounted-for Water Losses in Urban Areas, WRC Report No 206/1/91.
12. Lambert, AO. (1994) "Accounting for losses : The Burst and Background (BABE) Concept". I.W.E.M. Journal April 1994.
13. Leonie, T. (1990) "A Review of Domestic Water Metering". Water Management Services.
14. Malan, GJ. (1994) "Municipal Water Loss Management : Guidelines for Local Authorities". Municipal Engineer, July 1994.
15. National Water Supply Regulations (1996). Department of Water Affairs and Forestry.
16. Noss, RR., Newman, GJ. and Male, JW. (1987) "Optimal Testing Frequency for Domestic Water Meters". Journal WR Planning and Management, Vol.113, No.1.
17. Papendorf, GWH. and Rohner, K. (1992) "Report on Aspects for Water System Management as Practised by Various Local Authorities in South Africa". Water

and Gas Department, Johannesburg City Council.

18. SABS (1994) "Specification : Water Meters for Cold Potable Water". SABS 1529-1 : 1994 and 1529-2 : 1994.

19. Shore, DG. (1988) "Economic Optimization of Distribution Leakage Control". Journal of IWEM, No.2.

20. Simpson, GC. "Development and Testing of Datalogging Equipment for the Monitoring of Water Consumption Patterns" WRC Report No. 225/1/90.

21. Smith, JA. (1992) "An Examination of Recent Developments in Leakage Control Monitoring Techniques". Water Supply.

22. Technical Working Group on Waste of Water (1980) "Leakage Control Policy and Practice". Department of the Environment and the National Water Council (UK).

23. Tort, X., Valls, M., Coll, J. and Asencio, E. (1988) "Techniques for collecting Data for a Study of Errors in Measurement in Water Meters". Aqua No. 1.

24. U.K. Water Industry (1994) "Managing Leakage". WRC.

25. Various (1989) "International Report ; Unaccounted-for Water and the Economics of Leak Detection". IWSA.

26. Wallace, PL. (1987) "Water and Revenue Losses : Unaccounted-for Water". AWWA.

27. Weimer, D. (1992) "Unaccounted-for Water and the Economics of Leak Detection". IWSA, Copenhagen, 1992.