ZS 668: 2008
ICS 13.060.20; 91.140.60

Zambian Standard

MANAGEMENT OF POTABLE WATER IN WATER SUPPLY SYSTEMS – Code of practice

ZAMBIA BUREAU OF STANDARDS

DATE OF PUBLICATION

This Zambian Standard has been published under the authority of the Bureau on 3 rd April 2008.

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TECHNICAL COMMITTEE RESPONSIBLE

The preparation of this Zambian Standard was entrusted upon the Water &Environmental Pollution, TC4/7-2 Technical Committee upon which the following organizations were represented:

AHC-MMS Ltd	Mr. Emmanuel Chipulu
	Mr. Mushany Kapusanu
	Ms. Lavina Simewo
Kafubu Water & Sewerage Company	Mr. Dennis Kapoya
Lusaka Water & Sewerage Company	Mr. Henry Mtine
MLGH/DISS	Mr. Mr. C. Mulambo
National Water Supply & Sanitation Council	Mr. Paul Banda
	Mr. O. Chanda
	Mr. Kelvin Chitumbo
Nkana Water & Sewerage Company	Mr. Athanasius K. Mwaba
Northwestern Water & Sewerage Company	Mr. Sebastian Chilekwa
Southern Water & Sewerage Company	Mr. Joseph Munalula
University of Zambia	Mr. James Madalitso Tembo
Zambia Bureau of Standards	Mrs. Prisca Mulonda Shapole
	Mr. Saili Kancheya

ZAMBIA BUREAU OF STANDARDS, P.O. BOX 50259, ZA 15101 RIDGEWAY, ZAMBIA

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FOREWORD

This Zambian Standard, Code of Practice, has been prepared by the Water & Environmental Pollution, TC4/7-2 Technical Committee. The need to have a Code of Practice in the Management of Potable Water in distribution systems in Zambia necessitated the preparation of this standard. It is intended to guide the water supply service providers through a series of processes, each adapted to the local circumstances in order to achieve the optimal level of water loss.

Drawings included in this standard are of a diagrammatic nature and should not be accepted as working drawings for any purpose whatsoever.

In the case of a dispute regarding any provision of this standard, the Water Supply and Sanitation Act, No. 28 of 1997 and its accompanying Regulations take precedence.

In the preparation of this standard assistance was drawn from the following publications:

SABS 0306: 1999: The Management of Potable Water in Distribution Systems, by the South African Bureau of Standards;

The Water Supply and Sanitation Act No. 28 of 1997 of the Laws of Zambia.

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0. INTRODUCTION

Zambia though endowed with abundant water in the region, has many of its nationals unable to access clean and adequate water supply. Additionally, the growth in the demand for water exceeds the rate of development of new supplies. Development of new water sources is becoming increasingly costly. Lately Zambia has experienced droughts which have impacted negatively on the river flows and the underground water levels.

Water is a scarce resource and as such, water demand management (WDM) and control of the loss of water from the systems will go a long way in conserving this precious and scarce resource for the future generation.

This standard has thus been introduced in order to reduce the volume of water that is lost annually through leaks, wastage and other commercial losses.

1. SCOPE

1.1 This Zambian Standard covers the management, administrative and operational functions required by water services authorities in order to account for potable water within distribution systems and to apply corrective actions to reduce and control unaccounted-for water (UFW).

1.2 The aim of this Zambian Standard is to present a uniform approach for all water services authorities:

a) to establish a strategic plan for the management of potable water delivery;

b) to offer direction for the implementation of such a plan;

c) to quantify the extent and cost of unaccounted-for water in potable water distribution systems;

d) to determine the appropriate resources required for the operation of water services authorities;

e) to establish the accurate method for accounting for potable water;

f) to establish methods of reducing UFW and

g) to reduce unaccounted-for water to agreed acceptable levels as set by the regulator.

It is fundamental in the management of a water supply system to accurately and consistently measure the quantities of water entering and leaving the system.

1.3 This standard is applicable to the management of all water that enters or leaves a water supply, and to all pipes, fittings, fixtures and components and storage and treatment facilities, up to and including the end fitting.

1.4 This standard is designed to provide assistance and guidance to the water supply industry in the implementation of Water Demand Management (WDM) in a meaningful and positive manner. The guidance given will appropriately reflect the considerable recent advancements in techniques and technology.

1.5 The standard will serve to refresh the experienced water demand manager and to provide the less experienced with essential grounding in the subject. It will also indicate that training of personnel is required to achieve certain competencies in the art of water demand management.

1.6 This standard addresses problems encountered with metering and with the management of data, presents water balance and water auditing procedures, and provides a tool in preparing the water audit that can be used by the water supply service providers (WSSP). It offers a uniform approach which will strengthen research and development opportunities on a national basis.

2. NORMATIVE REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. All standards are subject to revision and, since any reference to a standard is deemed to be a reference to the latest edition of that standard, parties to agreements based on this standard are encouraged to take steps to ensure the use of the most recent editions of the standards indicated below. Information on currently valid national and international standards can be obtained from the Zambia Bureau of Standards.

ZS ISO 9001, *Quality Management Systems – Requirements.*

SABS 1529-1, *Water meters for cold potable water – Part 1: Metrological characteristics of mechanical water meters of nominal bore not exceeding 100 mm*.

SANS 10252-1, *Water supply and drainage for buildings – Part 1: Water supply installations for buildings.*

SABS 0400, *The application of the National Building Regulations.*[(CAP. 480) Local government (Urban Building & Drainage).

Public Health Act, Cap 295 of the Laws of Zambia.

Weights and Measures Act, Cap 403 of the Laws of Zambia

3. DEFINITIONS, ABBREVIATIONS AND SYMBOLS

3.1 Definitions

NOTE – There is no consistent international terminology, and no apparent consistency in the results which are achieved, or how they are expressed. Where mutually applicable, the definitions used are the same as those used in the Water Supply and Sanitation Act, 1997 (No. 28 of 1997)

For the purposes of this standard, the following definitions shall apply:

3.1.1. **acceptable:** Acceptable in terms of recognized international reference works, or acceptable to all parties involved, and, in the event of a dispute, acceptable in terms of the arbitration result.

3.1.2. air lock: A partial or complete restriction of the flow of water through a pipe, as the direct result of an accumulation of air in the pipeline.

3.1.3. air-release valve: A device fitted to a pipeline for the purpose of allowing the escape of entrained air.

3.1.4. anticlockwise closing valve; left-hand closing valve: A valve that closes when the spindle is rotated in an anticlockwise direction.

3.1.5. approved: Approved by any water supply service providers, including approval contained in the Public Health (Building) Regulations (CAP 295 of the laws of Zambia), or in the National Water Supply Regulations, or approved by any review board in terms of the above Act.

3.1.6. area: Any arbitrary extent of land under the jurisdiction of a water service provider.

3.1.7. average daily demand [V_{add}]: The average volume of water that enters an area or district during a 24 h period, calculated from the total measured over a known number of days, weeks, months or years and so specified.

3.1.8. average demand flow rate [Q_{ad}]: The average volume rate of flow into an area or district, obtained from the formula

$$Q_{ad} = \frac{V_{add}}{24}$$

Where,

Q_{ad} is the average demand flow rate, in cubic metres per hour; and

V_{add} is the average daily demand volume, in cubic metres.

3.1.9. backflow: The flow of water in a direction opposite to the normal direction of flow.

3.1.10. billing volume [V_b]: The total volume of water actually recorded as having passed through a consumer meter during a specified time interval, for a given area, town, district, and for which payment would normally be made.

3.1.11. bulk supply meter: A bulk water meter installed in the water distribution system, either at the point of ingress or at any other point, to measure the amount of water that passes through that point and that could be used for bulk revenue purposes.

3.1.12. check valve: A water fitting installed in a water distribution system for the purpose of automatically preventing the water from flowing in a direction opposite to that from which it was supplied.

3.1.13. clockwise closing valve; right-hand closing valve: A valve that closes when the spindle is rotated in a clockwise direction.

3.1.14. service line: A pipe that is vested in the water supply service providers authority and is installed by it for conveying water from a main (see **3.1.35**) to a water installation or boundary water meter (see **3.1.57**), and subject to water pressure from that main.

3.1.15. consumer water meter: A device that measures the volume of water leaving a water distribution system and entering an installation, for the purpose of billing and accounting for water.

3.1.16. **cross connection:** A link between two pipes.

3.1.17. **dead-end:** A section of the water distribution system that extends from a main, serves one or more connections but does not return to the main, or to any other main or pipeline.

3.1.18. **district:** Any part of a water distribution system which is identifiable by discrete boundary points. It has no upper limit, comprises any number of sub districts and zones containing various categories of consumers, and is served with water which passes through a permanent dedicated district water meter or meters, for the purpose of accurately measuring the amount of water entering the district.

3.1.19. **district manifold:** See manifold.

3.1.20. **district meter:** A bulk water meter installed either permanently or temporarily in the water distribution system,

a. that measures the volume of water entering a district to assist in water balance determinations, and

b. that is also capable of registering the rate of flow into the district for minimum night flow rate (MNF) purposes.

NOTE – Such meters are normally not used for revenue collection purposes.

3.1.21. **drawing:** Any drawing, plan or representation of the water distribution system, or any physical information that relates to the water distribution system, including from an electronic geographic information system (GIS).

3.1.22. **end cap:** A fitting fixed to the end of a pipe to terminate the flow of water at that point and to seal the pipeline.

3.1.23. **end fitting:** A terminal water fitting that is fitted to a pipeline to control the flow of water

3.1.24. **fire hydrant:** A terminal water fitting that is connected to a pipeline and to which a fire hose can be fitted.

3.1.25. **flow rate [*Q*]:** The total volume of flow of water through a given section of a pipe during a specified time interval.

3.1.26. **flow volume [*V*]:** The total volume of water that flows through a given section of a pipe.

3.1.27. **geophone; ground microphone:** A device placed on the surface of the ground to amplify the sound produced by escaping water and to enable easier location, of a leak.

3.1.28. **hydrant:** An outlet from a water main, usually consisting of an upright pipe with a control valve and a nozzle to which a hose can be attached for drawing water direct from the main for the purpose of fighting fires.

3.1.29. **hydrograph:** A graph that shows the variation in water flow over a given period of time.

3.1.30. **isolating valve:** A water fitting that is used to shut off part of a water distribution system from the remainder. The term includes the control valve to certain categories of consumer, such as schools, hotels, hospitals, clinics, commercial buildings, shopping complexes and malls, industries, large blocks of flats, and any other building or establishment where there is an extensive or complex water installation or where automatic or continuous flowing water fittings are or might be installed.

3.1.31. leakage (volume): That part of the unaccounted-for water that leaks or escapes other than as the result of a deliberate or controllable action over a specified period.

3.1.32. leak noise correlator: A two-channel electronic microprocessor that measures the time delay in matching the sound frequency spectrum of a leak noise from two different locations on a pipeline, for the purpose of pinpointing the position of the leak.

3.1.33. loss: The volume of water that flows through a given section of a pipe during a specified time interval, and that is not consumed or used as a result of deliberate or controllable action.

3.1.34. loss rate: The volume rate of flow (through a given section of a pipe) of water that is not being consumed or used as the result of a deliberate or controllable action.

3.1.35. main(s): Any pipe, other than a connection pipe, that is vested in the water services provider and used by it to convey water to consumers.

3.1.36. manifold: A permanent structure built into the water distribution system at a convenient position where it enables the flow rate and the volume of the water that enters a district, sub district or zone, to be monitored on a permanent or a temporary basis.

3.1.37. marginal cost: The addition to the total cost for producing one additional unit of water.

3.1.38. metering/monitoring: The metering of water at a water metering point that is also monitored by means of a data logger.

3.1.39. minimum night flow rate [Q_{mnf}]: The lowest consistently repeatable flow rate into an area or district, measured during the period of lowest consumption (typically from midnight to 04:00 h), and which includes legitimate consumption, leakage on premises and leakage from the distribution system.

3.1.40. net minimum night flow rate; minimum night flow loss rate [Q_{mnfl}]: The flow rate obtained by subtracting any legitimate consumption rate at the time of the minimum night flow rate measurement, from the minimum night flow rate Q_{mnf}.

3.1.41. non-return valve: A type of check valve.

3.1.42. percentage loss: A term used to quantify water lost from a water distribution system.

3.1.43. pressure-reducing valve: A water fitting that reduces the pressure on the downstream side to a set upper limit.

3.1.44. pressure zone: Any area within a water distribution system that is supplied from a single pressure-control device or reservoir, the boundaries of which are normally incorporated within, coincide with or encompass, but never cross, the district, sub district or zone boundaries.

3.1.45. sectoring: A process of closing isolating valves within a given district, sub district or zone, with the purpose of subdividing the specific area into two, three or four sectors, to determine whether the minimum night flow rate is evenly distributed or mainly concentrated in one or more sectors.

3.1.46. sounding: A method of searching for leaks, in which trained inspectors use an electronically amplified microphone, stethoscope or ground microphone to listen for the sound of escaping water. The following related definitions apply here:

a) **pinpointing**: The term given to the practice of placing a geophone on the surface, to audibly locate leak noise with the use of an electronic amplifying device. (See also **3.1.27** geophone.)

NOTE – Sounding can be carried out at any time of the day or night. Most operators prefer sounding at night when both consumption and ambient noise are at a minimum, and the system pressure is high.

b) **prelocating**: The term given to the practice of placing a microphone (that is connected to an electronic acoustic device which amplifies the sound of escaping water) directly in contact with the pipe or fitting to enable a leak to be audible through earphones.

NOTE – A rod fitted with an earpiece (stethoscope) can also be used; however, a great deal of experience is needed before comparable results can be achieved.

3.1.47. specific loss rate [Q_{sl}, Q_{sp} or Q_{sc}]: The loss rate (determined in litres per hour) divided respectively by the total length of piping (in kilometres), by the number of properties or by the number of connections.

NOTE – When the specific loss rate is being calculated, the length of distribution piping used normally excludes any connection pipes and trunk mains present. Trunk mains losses are important but are determined separately from the water balance and included as a separate item in the monthly water reports.

3.1.48. step-testing: A procedure whereby water is introduced into an isolated section of a water distribution system. The section of the system contains one or more internal intermediate isolating valves, each capable of terminating the supply of water into the subsection downstream of that valve. By systematically closing the intermediate valves while the section is under pressure and the flow into the section is being recorded, flow into the various subsections will be cut off as they become isolated, thus causing a “step” in the graph generated by the flow rate recorder. The cause of the “step” can then be located in the section of pipe work between the valve (the closing of which caused the “step”) and the previously closed valve, using conventional leak location techniques.

3.1.49. sub district: A separately isolatable section of a district that comprises one or more zones in which quantities of water entering and leaving can be measured.

3.1.50. unaccounted-for water [V_{UFW}] (see also **3.1.55** water balance): The difference between the measured volume of water put into the supply and distribution system and the total volume of water measured to authorized consumers whose fixed property address appears on the official list of the water services provider.

NOTES

1. A local authority that supplies water can only account for that water if there is an identified consumer who can be billed, irrespective of whether the consumer is in fact billed or not or whether payment is received. Any accounting system is a balance sheet of debits and credits; therefore, in order to account for water there has to be a discrete consumer with an address for billing purposes.

2. Water used by the water services provider itself, such as for parks and gardens, street washing, pipe flushing, firefighting or fire drills, etc., can only be included as accounted-for if it is accurately measured, either metered or by volume, and an account is reflected on the water balance sheet. It is the accounting system that accounts for the water. There has to be an address to which a water bill can be sent. Accounting-for in this sense pertains to being responsible for, which implies an individual or a single body served through a meter or by volume measurement.

3.1.51. vacuum relief valve: A large-orifice valve installed in a water distribution system to prevent a vacuum from forming in a pipeline as a result of the outflow of water from the pipeline.

3.1.52. valve: A water fitting to control the flow of water.

3.1.53. waste: Water that, having been obtained from a source and put into a water distribution system, leaks or is allowed to escape or is taken therefrom for no useful purpose.

3.1.54. water audit: A procedure to account for the water entering an area through a meter and the cumulative consumptions within the area, taking into account the distribution layout and the nature of the area.

3.1.55. water balance: The difference between the measured volume of potable water put into a water distribution system and the total volume of potable water measured at any intermediate point in the water distribution system. Effectively, a statement setting out the amount of water flowing in and water flowing out on an area-by-area basis.

NOTE – This definition excludes losses in the treatment processes (such as backwash water). It includes any measured losses or use (either metered or by direct volume measurement), such as reservoir overflows, tankers used for street washing or pipe flushing. Estimates of any nature are expressly excluded.

3.1.56. water distribution system: Any system of structures, aqueducts, pipes, valves, pumps, meters or other associated equipment, including all mains, connection pipes and water installations that are used or that are intended to be used in connection with the supply of water.

3.1.57. customer water installation: An installation that is used or that is intended to be used for the conveyance or storage of water in any building or on any site, and that includes any pipe or fitting, but excludes any water meter vested in the water supply service providers.

3.1.58. water loss manifold: See **3.1.36** manifold.

3.1.59. water meter: A device to accurately measure and record the total volume of water that has passed through it.

3.1.60. water supply service providers: Any municipality that is responsible for ensuring access to water services.

3.1.61. zone: A separately isolatable section of a sub district, or their equivalent, and in which quantities of water entering and leaving can be measured.

NOTE – Ideally, a zone should be fed from only one source.

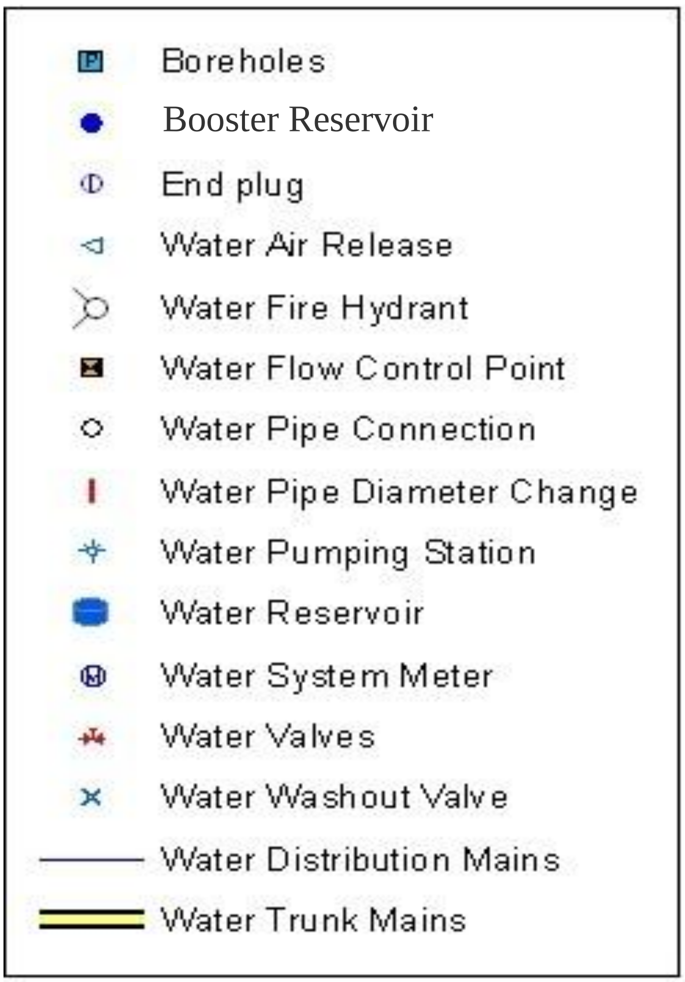
3.2 Abbreviations

ADD	Average daily demand
AMR	Automatic meter reading
BDE	Borland Data Engine
CBD	Central Business District
CEO	Chief Executive Officer
FFT	Fast Fourier transform
GIS	Geographic information system
HDPE	High density polyethylene
HHT	Hand-held electronic meter reading terminals
HOD	Head of Department
IRR	Internal rate of return
LNC	Leak noise correlator (see **3.1.32**)
LV	Left-hand (anticlockwise) closing valve (see **3.1.4**)
MAST	Mobile advanced step-testing
MNF	Minimum night flow rate
NPV	Net present value
NRV	Non-return valve
NWASCO	National Water Supply & Sanitation Council
PC	Personal computer
PRV	Pressure-reducing valve (see **3.1.43** and **9.4.1**)
Q flow rate	(see **3.1.25**)
Q_{ad}	Average demand flow rate (see **3.1.8**)
Q_{mnf}	Minimum night flow rate (see **3.1.39** and **6.2.5**)
Q_{mnfl}	Minimum night flow loss rate (see **3.1.40**)

Q_{sc}	Specific loss rate in litres per hour per connection (see **3.1.47**)
Q_{sl}	Specific loss rate in litres per hour per kilometre of pipe length (see **3.1.47**)
Q_{sp}	Specific loss rate in litres per hour per property (see **3.1.47**)
*R*am	Average-to-minimum demand flow rate ratio, equal to *Qad*/*Qmnf*
RSV	Resilient seat valve (see **4.3.1.3** and **10.8.1.12**)
RV	Right-hand (clockwise) closing valve (see **3.1.13**)
SV	Scour valve (see **4.4.5.4**)
UFW	Unaccounted-for water (see **3.1.50**)
V	Flow volume (see **3.1.26**)
V_{add}	Average daily demand volume (see **3.1.7**)
V_b	Billing volume (see **3.1.10**)
*V*UFW	Unaccounted-for water volume (see **3.1.50**)
WAR	Water audit report
WDM	Water demand management
WLM	Water loss management
ZABS	Zambia Bureau of Standards

3.3 Symbols

The following symbols are used in water distribution system documentation:



4. MANAGEMENT, POLICY AND SYSTEMS

4.1 Management plans for unaccounted-for water

4.1.1 Water supply service providers need to account for all water put into supply in a standard, consistent manner in order to make proper comparisons and establish benchmarks for the performance of the water service provider. Personnel are accountable to all sectors of the public that they serve. Simplified management reports covering the financial and volumetric aspects of water supply shall be made freely available to the community that is being served and the existence of these reports shall be actively promoted. Such reports should be available in the language of preference in the area.

All water services authorities in Zambia are required to gather adequate quantifiable data on the extent of the problem, and to take action to reduce unaccounted-for water. Effective water conservation will be achieved through total management of both the water delivery system and the use of water by the consumer. That is, an effective water conservation management policy is necessary.

Any strategic management plan for unaccounted-for water comprising a policy, a strategy and a programme, culminates in the relatively simple task of finding and repairing leaks. After the plan has been set up and training has taken place, it is anticipated that most water services authorities, whatever their size, will be able to maintain such a plan. It is recommended that specialist assistance be called in if the quantities of unaccounted-for water become unacceptably large in terms of this standard, and the cause or location cannot be found.

4.1.2 Nothing short of a firm commitment to improvement on the part of the Water supply service providers (including the Boards, the Chief Executive Officer (CEO) and all Head's of Department (HOD)) is essential to ensure the success of any water loss control programme. If unequivocal commitment does not exist amongst the staff throughout the entire organization, any attempt at reducing unaccounted-for water is doomed to failure even before it starts.

4.1.3 Every water supply service provider, however large or small, shall compile, implement and comply with a water management programme.

4.1.4 The Water supply service provider shall either establish a unit or appoint consultants

a) to investigate and evaluate the magnitude of the water losses,

b) to identify the main contributing factors, and

c) to prepare a strategic plan for implementing water loss management.

4.1.5 Each Water supply service provider shall prepare an annual water audit for submission to NWASCO. This will provide a measure of the water services provider's efficiency and if all water services authorities use a common approach, the annual audit could be used as a direct comparison between Water supply service providers.

4.1.6 Affluent areas typically use more water than less affluent areas. This is not necessarily at variance with the National Water Policy, as long as there is sufficient water and provided that the "excess" water is paid for at a realistic price

a) to cover the real cost of the water,

b) to cover the real value of the water, and

c) to provide an excess income to enable the water supply service providers to install water distribution mains in disadvantaged, low-income areas.

NOTES
1. The **cost** of the water is the sum total of the real physical costs incurred by the water services provider in delivering the water to the property boundary of the consumer, divided by the total volume of water put into supply.

2. The **value** of the water is a function of its scarcity. If there is an abundance of water but few consumers, the value will be low. However, if the converse is the case, the value rises considerably even to the point where countries will value water high enough to risk warfare.

3. The final **price** of the water charged to consumers is a balance between the cost and the value, plus an amount to generate a trading surplus to use for future works.

4.1.7 Top management of any water supply service providers (including the appropriate Boards and departmental heads) has to become involved in the unaccounted-for water problem on an ongoing basis. Money has to be spent and decisions have to be taken which will depend on the extent of the problem, the degree of activity, the aggressiveness of the actions, the speed of implementation and the extent of any reorganization.

4.1.8 Unaccounted-for water (which includes all physical and non-physical losses for the entire water supply and distribution system), forms a significant component of water conservation.

4.1.9 Water conservation, in turn, is a part of water demand management and includes all the administrative and behavioural control measures that include those measures that encourage water conservation behaviour by end users and which influence water use. In addition, economic control measures relate to all water pricing mechanisms which are an effective means of conserving water. Managerial and technological control measures include all aspects relating to the water systems and which are used to deliver and monitor water use. All of these control measures can be divided into two groups, the one relative to the water supply service providers and the other to the consumer or end user, as follows:

a) the water supply service providers, concerning

   1) manpower requirements,

   2) skills competence,

   3) infrastructure development,

   4) bulk-water metering/monitoring,

   5) asset management,

   6) active leak detection and repair (including physical network inspection and repair),

   7) reactive leak repair,

   8) pressure management,

   9) water distribution system maintenance,

   10) meter maintenance of

      i) bulk supply meters,
      ii) bulk distribution monitoring meters,
      iii) large commercial consumer meters,
      iv) large industrial consumer meters,
      v) consumer meters,

11) database management, meter reading and billing,

12) quality of service, and

13) customer relations (help-line).

b) customer aspects, which comprise the reduction of non-essential and inefficient water use by all categories of consumers, and includes

1) education and public awareness,

2) general water regulations,

3) universal metering,

4) water restrictions,

5) water pricing policy and tariff structures,

6) consumer installation maintenance,

7) retrofitting programmes,

8) water-efficient devices and appliances,

9) recreational water use,

10) creative and innovative presentation of utility bills, to encourage water conservation, and

11) building and site audits.

4.1.10 If the price of water does not reflect the true value of the commodity (see **4.1.6**), and if the supply area is not fully metered, it becomes extremely difficult to encourage conservation programmes.

4.1.11 The main components of a strategic management plan (see 4.10) for unaccounted-for water, are

a) a management function,
b) an administrative function, and
c) an operations function.

4.2 The UFW committee

4.2.1 The composition of the UFW committee will vary (see figure 1) from large to smaller water supply service providers. The most senior person, the CEO or equivalent, would chair the committee.

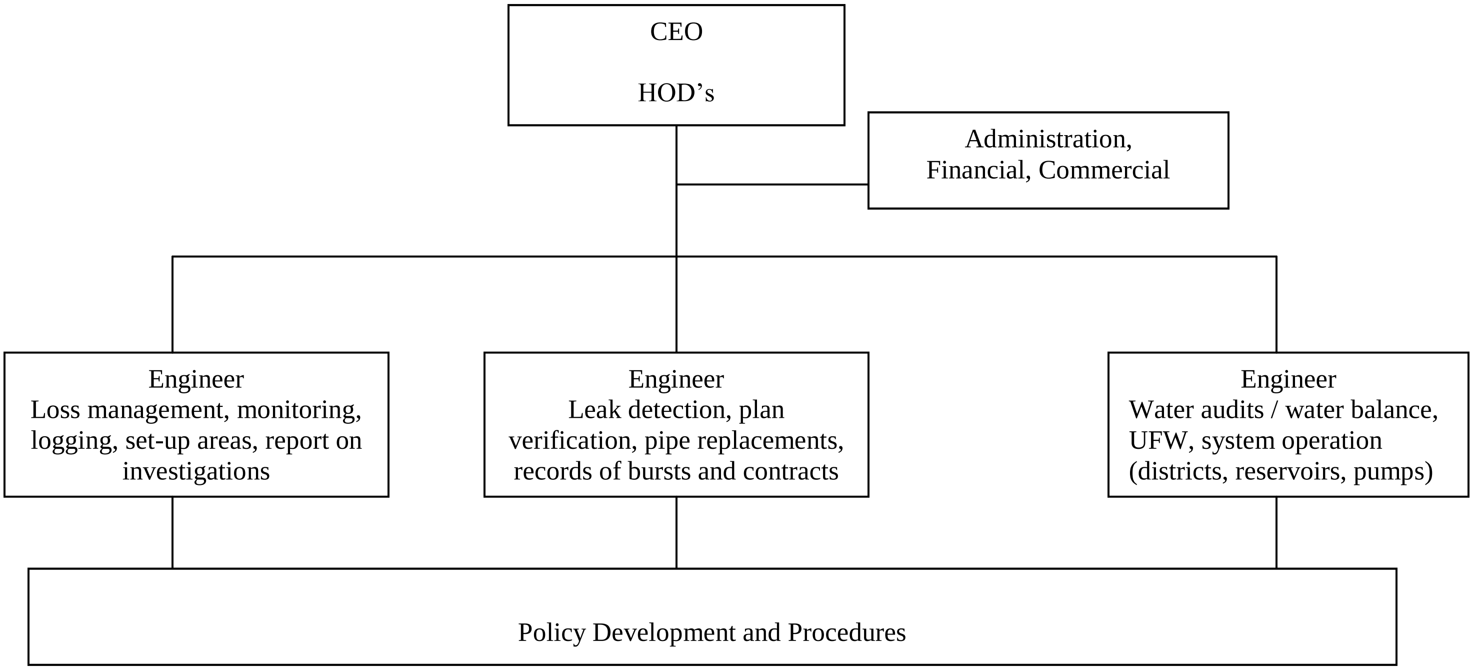


Figure 1 — Functional diagram of a UFW committee

4.2.2. The UFW committee members will need to be knowledgeable about matters involving unaccounted-for water and the principles of water loss control but they will not necessarily have to be expert enough to devise, plan and implement the entire unaccounted-for water control operation itself. This function, or certain aspects of the programme, can be carried out by the water demand management unit or contracted out to specialists. The powers, duties and responsibilities of the UFW committee are largely fixed, but the method of operation is fairly flexible as regards procedures and methodologies. The assets, the authority and the responsibility would remain those of the water services provider. The important factor is that the best interests of the consumer remain a priority at all times.

4.2.3. The development of an unaccounted-for water strategy should take place systematically, as discussed below. The UFW committee shall be established with suitable terms of reference that determine its powers, duties and responsibilities. The formulation of policies shall be carefully investigated and discussed by all interested parties, to ensure conformity with existing statutes and local authority bylaws.

4.2.4. Once established, the UFW committee shall set about the task of developing an unaccounted-for water strategy for the water supply service providers. Members of the committee will therefore need to be personalities with both status and authority. Technical, financial, commercial and administrative disciplines shall all be represented, with the common goal of reducing unaccounted-for water in as efficient a manner as possible. As a very minimum, the UFW committee should comprise the Director of engineering and the heads of the units involved with Billing and Finance. The CEO should normally be the chairperson of the committee.

4.2.4.1 Financing and budgeting

Initial capital expenditure for setting up an unaccounted-for water programme and the implementation of unaccounted-for water control systems will be required and shall be provided for. Although initial capital costs may be high, the benefits of reducing unaccounted-for water should render the unaccounted-for water programme self-financing. This occurs when the ratio cost/benefit is less than 1, or, more correctly, when the net present value (NPV) exceeds zero or when the internal rate of return (IRR) exceeds the cost of the capital.

4.2.4.2 System information

Comprehensive and up-to-date information pertaining to the water distribution system (see **4.4**) is essential for the effective functioning of the UFW committee. Although a GIS may be costly to set up initially, its benefits to a larger water supply service providers will invariably justify the expense.

4.2.4.3 Bulk metering

Key metering/monitoring positions shall be identified. The benefit of permanent meter installations for use in districts, sub districts or zones, should be considered, each case on its own merits. Clearly, the immediate installation of permanent meters in all districts, sub districts and zones could be prohibitively expensive, unless unaccounted-for water levels are exorbitant. In well-maintained systems, the systematic installation of permanent meters over a period of two to five years might be justified.

4.2.4.4 Meter reading

Traditionally, the financial department of a water supply service provider is responsible for reading consumer meters, invoicing consumers and collecting revenue. 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, can lead to administrative problems and inefficiencies. Furthermore, commercial meter reading routes tend to be structured along township boundaries or other lines, rather than reservoir or supply zones. Meter reading routes should be consistent with supply zone boundaries to reduce unacceptable delays of a few days between the reading of meters within the same supply zone. This will facilitate the carrying of water balance of bulk meters versus consumer meters.

NOTE – A system in which the reading of water meters is done by people who are not under the control of the Water Department leads to an undesirable separation of responsibilities and is strongly discouraged.

4.2.4.5 Goals, targets and time frame

The ultimate goal of the unaccounted-for water programme is to achieve the acceptable national norms, realistic targets and time frame policy adopted by the UFW committee. This would normally be the most cost-effective programme for unaccounted-for water control, given the ruling price of water. The programme would comprise short-term, medium-term and long-term goals with their respective effects on the cost of unaccounted-for water, the cost of leakage and therefore the economic viability of the programme. As water becomes more scarce, the marginal cost (value) of the lost water could be used to determine benefits. Unrealistic targets will result in the failure of the programme, owing to the lack of enthusiastic support (see also **4.1.2**).

4.2.4.6 Pricing policy and tariffs

A policy addressing the issues of non-payment for services, subsidization and rising block rate tariffs shall be determined by the water supply service providers/local authority through the UFW committee and, in sensitive areas, also involving the communities and other end-user groups in the consultations. The cost of water management, unaccounted-for water and leakage has a direct influence on the pricing policy and tariff.

Provisions of the Water Supply and Sanitation Act, 1997 (No. 28 of 1997) shall be adhered to when determining any policy or tariff.

4.2.4.7 Universal metering

The required policy is universal metering (i.e. individual metering of all consumers within the service area). Universal metering can be achieved through individual metering or so-called mini-bulk metering or prepayment metering (standpipes), etc. The purpose is to know where the water goes (total volumes, minimum night flow rate, peak demand), and to compare this with the calculated per capita consumption. This information can then be analysed to indicate areas of concern.

Provisions of the Water Supply and Sanitation Act, 1997 (No. 28 of 1997) shall be adhered to when determining any policy or tariff.

4.2.5. The UFW committee shall then formulate the policies it intends to implement. Such policies include those given in 4.2.4.1 to 4.2.4.7.

4.3 System delimitation

4.3.1. General considerations

When the structure of a water distribution system is being established (**see figure 2**), decisions need to be made regarding the following:

a) the subdivision of the water services provider's distribution area into districts, sub districts and zones (see **4.3.1.1**);
b) the positioning of water loss manifolds;
c) whether these facilities will be permanent or temporary;
d) the nature of the monitoring equipment to be used (mechanical/non-mechanical meters, data loggers, flow-rate recorders, strip chart recorders, etc.) This will largely depend on whether the water loss manifold is for a large district, a zone or a smaller area and for a permanent or temporary installation; and
e) total and annual cost estimates.

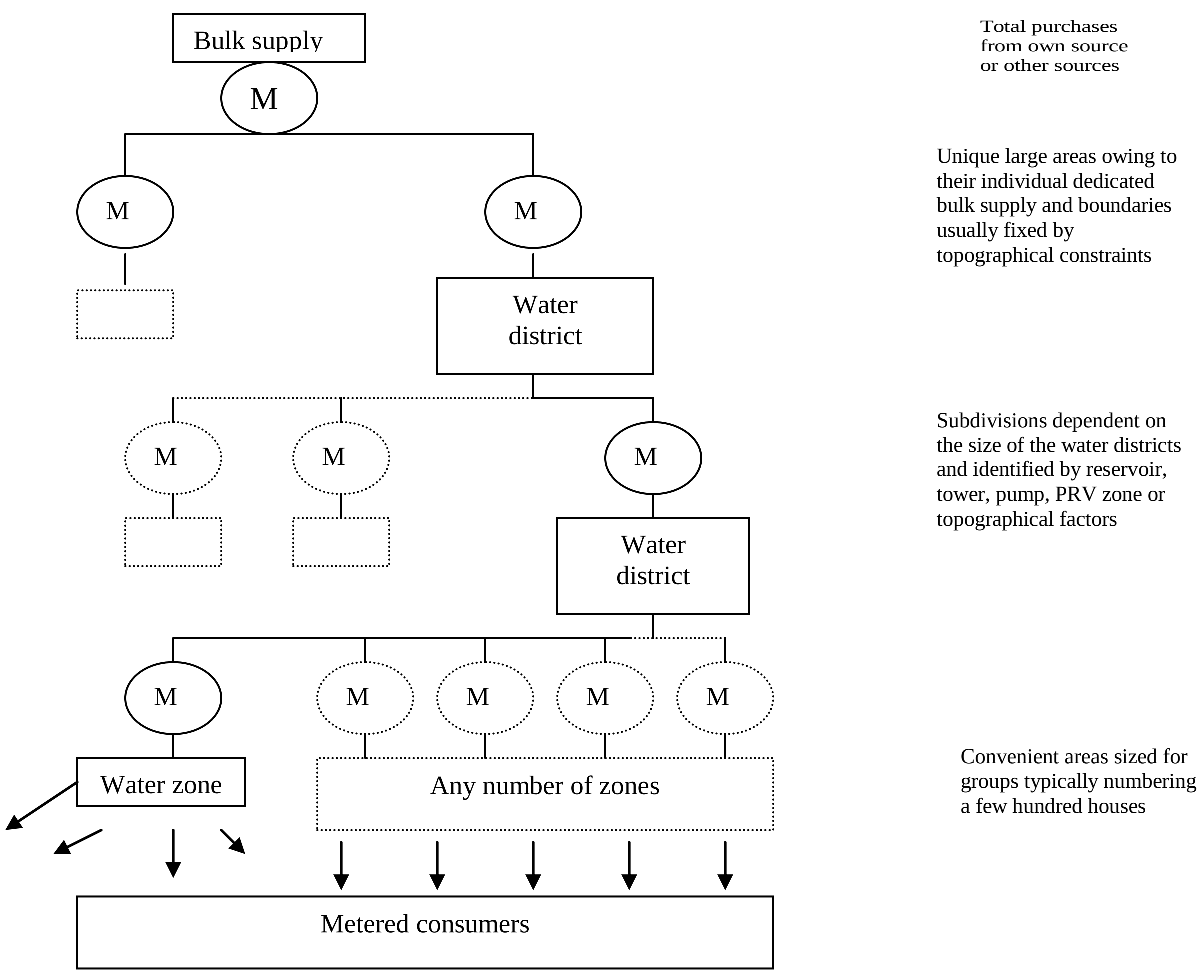


Figure 2 — Typical structure for a water distribution system

4.3.1.1 The division of a water distribution system into districts, sub districts and zones (**see figure 3**) shall be part of the design process. The installation of metering/monitoring points forms an integral part of the construction of the reticulation system. Permanent metering/monitoring points are preferred because of the advantages to be found in ongoing regular monitoring of the water supply network.

4.3.1.2 All metering/monitoring points shall be labelled for easy and accurate identification and location. It is recommended that a logical cascading numbering system be designed according to the route of the delivery system, as suggested in **figure 4.**

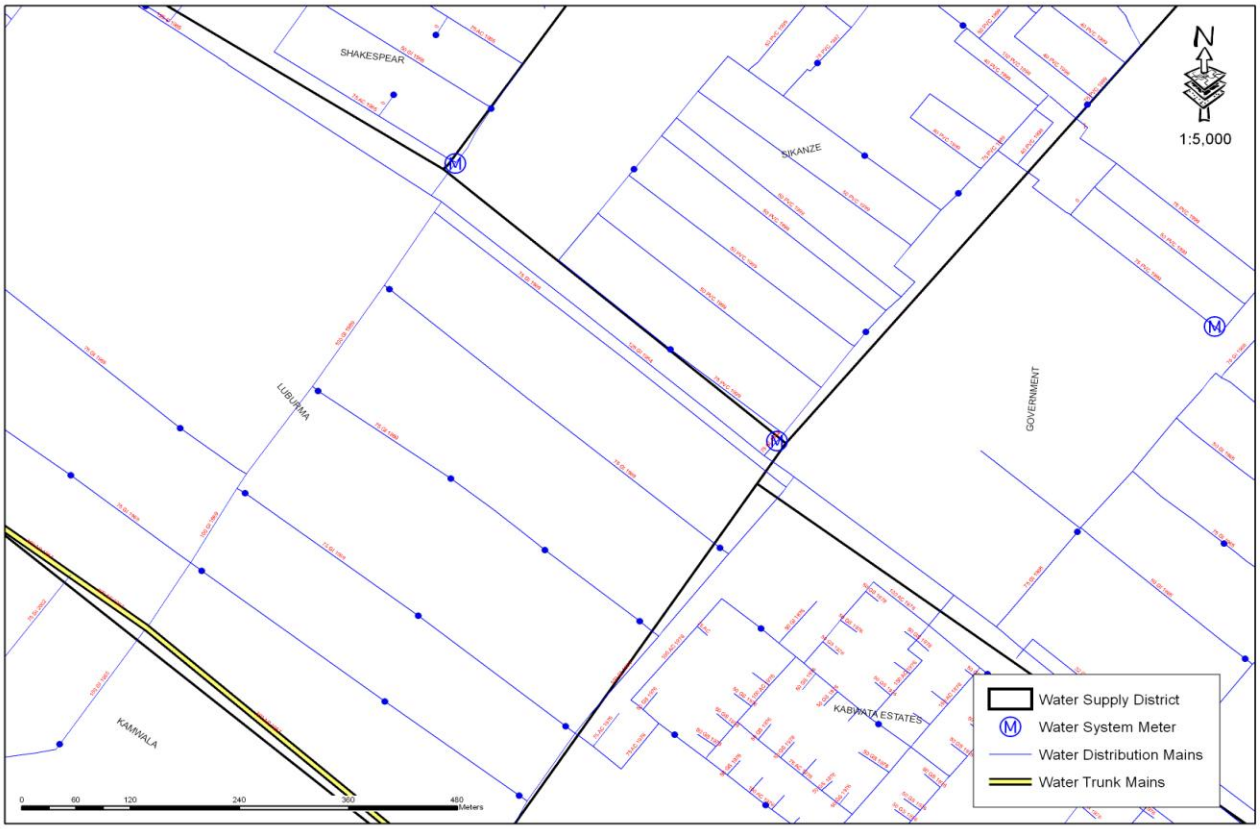


Figure 3 — Diagram of subdivisions of a water distribution system

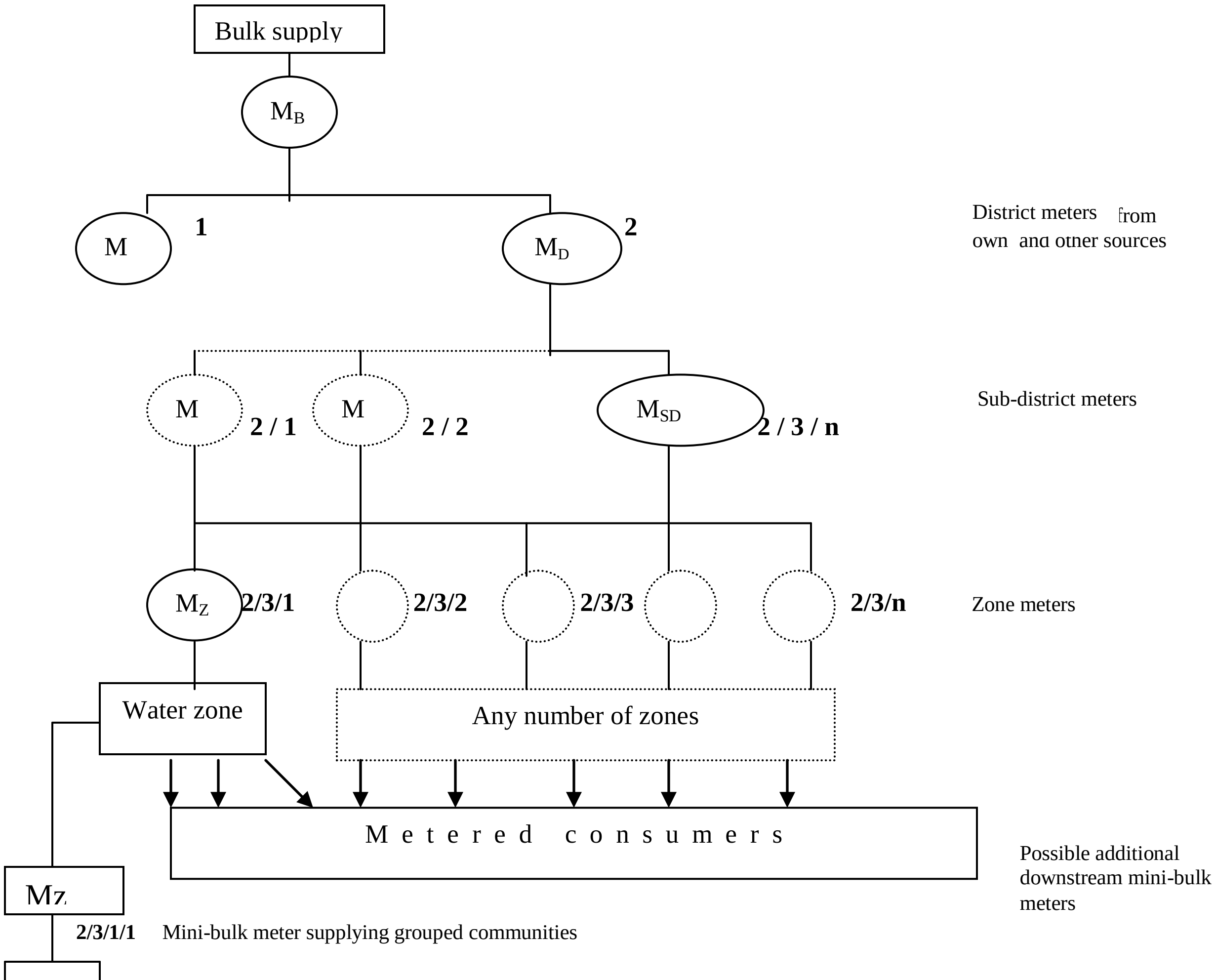


Figure 4 — Cascading numbering system for bulk water meters

4.3.1.3 The lids of waterworks valve boxes can be colour coded for easy recognition in the field and to determine the type of valve or its status.

Colour codes for valve boxes can be used to indicate normally open or closed valves (red is often used for closed valves).

A white marker can be used on kerbs and gutters in conjunction with white surrounds to the valve boxes to facilitate their location in the field.

4.3.2. Choice and establishment of boundaries

The planning shall take cognizance of existing pipe work and of physical constraints. Generally, boundaries should be placed along natural breaks in the distribution system.

4.3.2.1 Natural breaks in the distribution system are generally along green belts, natural topographical features, large parks and sport complexes. They could also be along railway lines, along major roads and between different townships or township extensions, as illustrated in figures 5, 6 and 7.

Figure 5 — Single boundary crossing

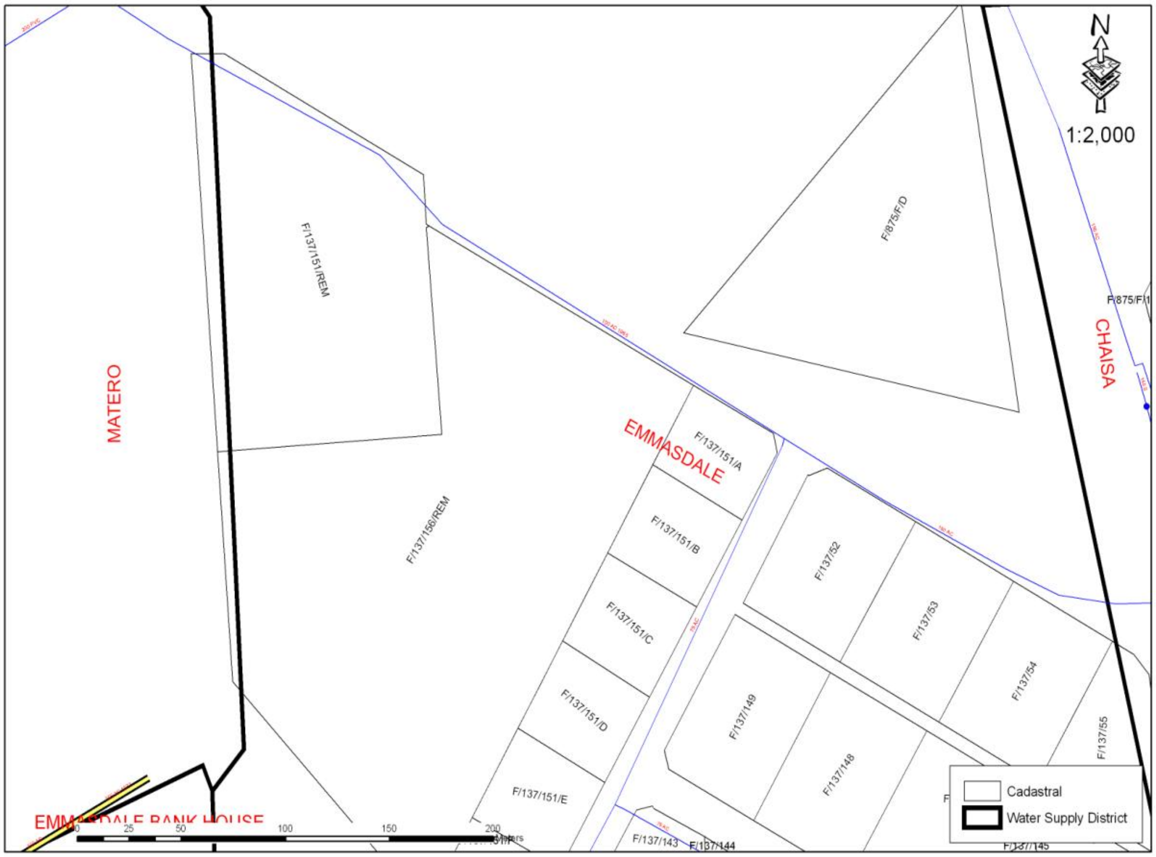


Figure 6 — Double boundary crossing

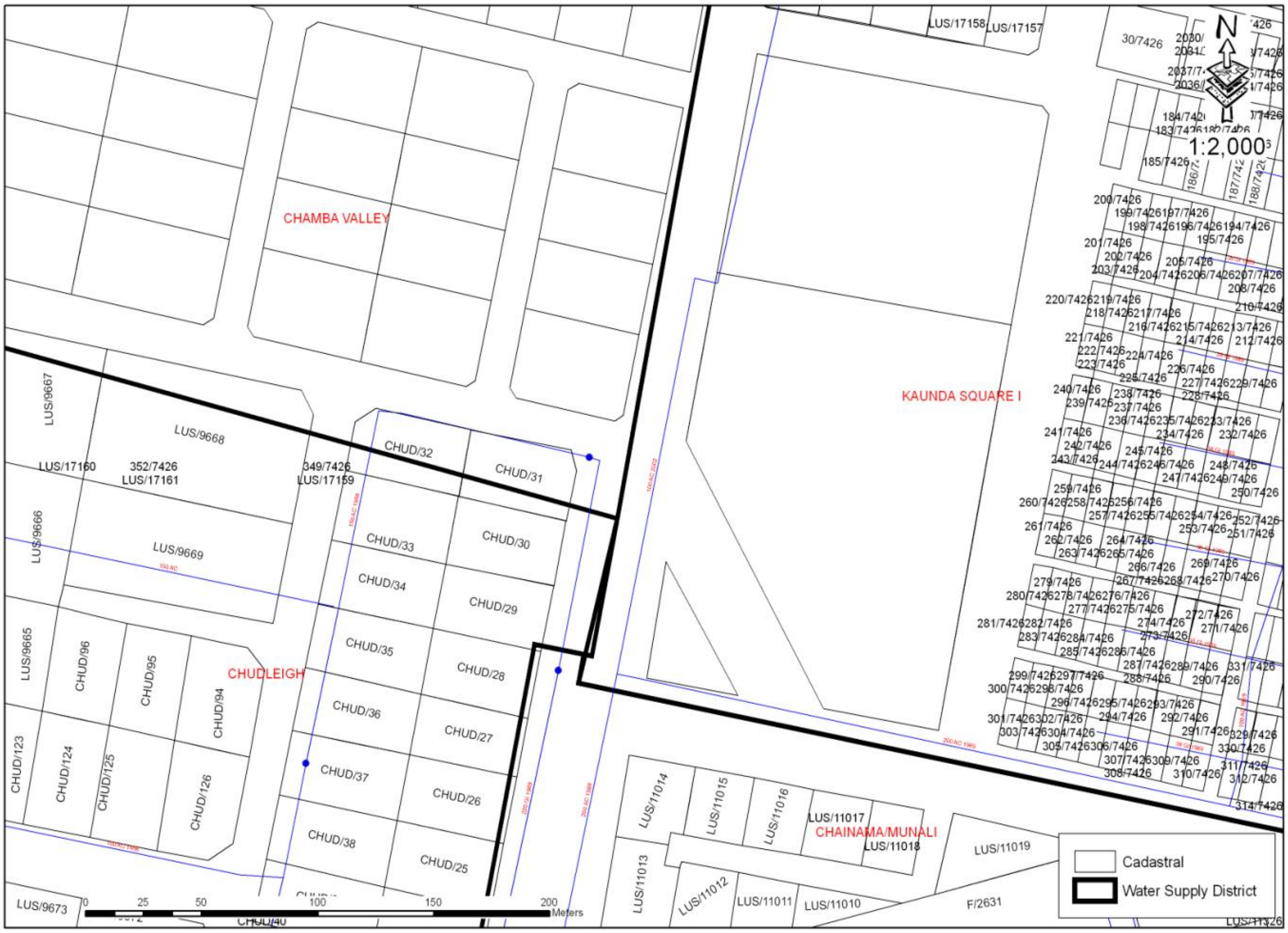


Figure 7 – Multiple boundary crossings

4.3.2.2 In existing networks, well-chosen boundaries around districts, sub districts and zones will result in a minimum number of changes to the distribution system. The impact of the planned boundary closures and of metered entry points to each district, sub district and zone on the distribution system, should preferably be tested mathematically with a water network analysis program. If negative effects (low pressure, inadequate flow rate or excessive velocities) are indicated, then the proposals will have to be adapted to minimize these negative effects. The boundaries around sub districts and zones should preferably (but need not necessarily) be used to permanently isolate the area. Instead they could be used for short-term flow monitoring exercises which would limit the negative effects of the proposed isolation.

4.3.2.3 Prior to actually making any changes, it is prudent to test the reaction of the distribution system to subdividing, before the boundaries of the planned subdivisions are permanently created and before any capital is invested in installing management meters in these areas. Testing is done by recording (logging) the working pressures in the distribution system for at least a week at selected points within each planned district, sub district or zone, before making any changes.

4.3.2.4 The public shall at all times be kept informed of the unaccounted-for water management project, and warned of the possibility of disruptions in the water supply during modifications and testing. Upon completion of the work, public co-operation should be encouraged to report any adverse changes that might be experienced with the water supply.

4.3.2.5 A comparison of the final pressure readings with those estimated during the network analysis should be made and any significant differences analysed.

4.3.2.6 Once the integrity of each area has been proven, the network is left with the boundary valves closed and water moves across management boundary lines only through those designated points which are, or will be, fitted with management meters. For easier identification of closed valves, their valve-box lids can be painted red (see **4.3.1.3**).

4.3.2.7 Alternatively, the water supply service providers might prefer to remove closed valves and cut and cap the pipe ends of all pipes that are of diameter 150 mm or smaller. To facilitate emergency planning, the cut ends could each be fitted with a fire hydrant, to enable water to be fed in either direction across the cut section.

4.3.2.8 For larger pipelines, the valves are fitted with a cap that is padlocked over the valve spindle to prevent operation of the valve. The locking caps are usually colour coded to indicate whether the locked valve is normally kept open or kept closed (see **4.3.1.3**).

4.3.3. Choice and installation of meters

4.3.3.1 Suitable meters shall be selected to monitor the volume of water entering and, in some instances, exiting each area. Generally, district and sub district meters are permanent fixtures while zone meters can be either permanent or temporary (see NOTE below) installations. Water loss management sector meters will most often be part of a potable facility.

NOTE – The installation for a temporary meter is a permanent structure built into the water distribution network but with a by-pass section that accommodates a meter body into which a meter can be installed as and when required (see figure 8). This practice economizes on meters and consequently also on meter maintenance, since one meter can serve any number of metering points, on a temporary basis. Use could also be made of a temporary/potable meter that is housed in a trailer.

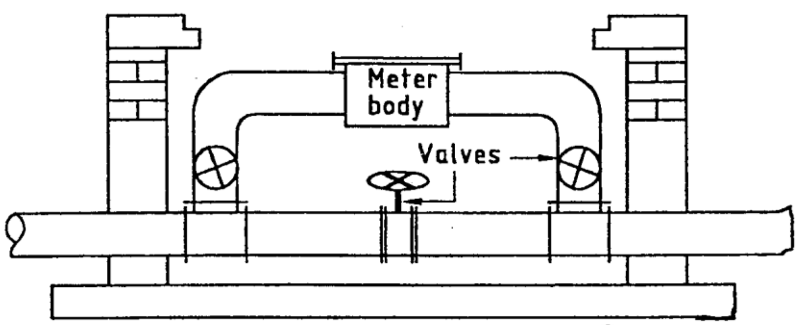


Figure 8 — Schematic layout of a temporary meter installation

4.3.3.2 The correct selection of a meter is crucial and is dependent on the hydrograph (see **3.1.29**). The anticipated peak flow and minimum flow shall be established for each area and verified through monitoring. In addition, fire flow requirements and seasonal variations shall also be included in the calculation to obtain the anticipated peak. At least a week of logging is required to ensure that the weekly peak is recorded.

4.3.3.3 Turbine water meters with a 1:100 turn-down flow range has been recommended for water loss management.

NOTE – Operating the isolating valve just upstream of a Turbine meter has been known to destroy the meter mechanism when the high velocity jet of water that results from the valve being opened too rapidly when the system is being refilled, impacts on the impeller vanes. These valves can be capped and padlocked in the fully open position so that the operator is only able to use the downstream isolating valve when the operator is working on the network. This will reduce the probability of causing damage. The upstream valve should only be unlocked when work is being carried out on the water meter itself.

4.3.3.4 Magnetic flow meters are more expensive but have both significant advantages (accuracy) and significant disadvantages (such as the need for a power supply and for sophisticated lightning protection). While cost is obviously important, it is secondary to performance. Meter accuracy, however, starts becoming dominant in the case of revenue (billing) meters for piping above 150 mm diameter, since the sale of an additional 1 % to 2 % of the volume that passes through such a meter will, in all likelihood, pay for the meter within an acceptable pay-back period. The necessary calculation will have to be done.

4.3.3.5 It is convenient to make provision for a pressure tapping near each monitoring meter so that flow and pressure can be logged simultaneously. The combined information is useful when troubleshooting is required or when a water network analysis is being undertaken.

4.3.3.6 The metering point of a water management area is a convenient place to install other fittings such as a pressure-reducing valve (PRV), a reflux valve, dirt traps/strainers, or air release valves, as required. Care should be taken to ensure that turbulence from the other fittings does not affect the accuracy of the meter. Wherever possible, other fittings and devices should be located downstream of the meter.

4.3.3.7 Isolating valves and, in most instances, a bypass facility, should be incorporated to permit servicing of the meter, the PRV and other control valves without disrupting the water supply to the area.

4.3.3.8 There is more to operating a metering/monitoring point than simply installing a meter. A water management metering point can consist of a manifold containing numerous fittings and devices, and can be quite extensive (**see figure 9**). Such manifolds should, therefore, be planned with care.

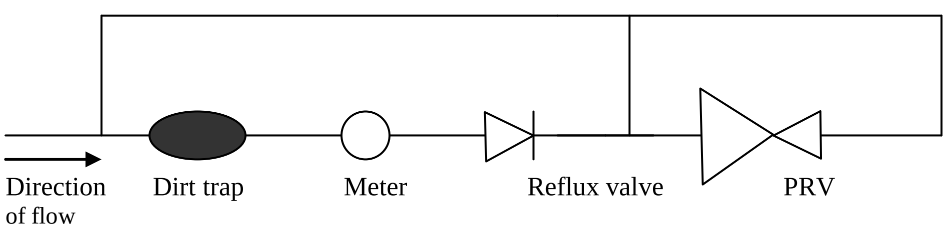


Figure 9 — Typical layout of a metering/monitoring point

4.3.3.9 Figures 10, 11 and 12 illustrate a fairly typical case of a metering/monitoring point. A water loss Management boundary and a metering point should be established as shown in **figure 10**.

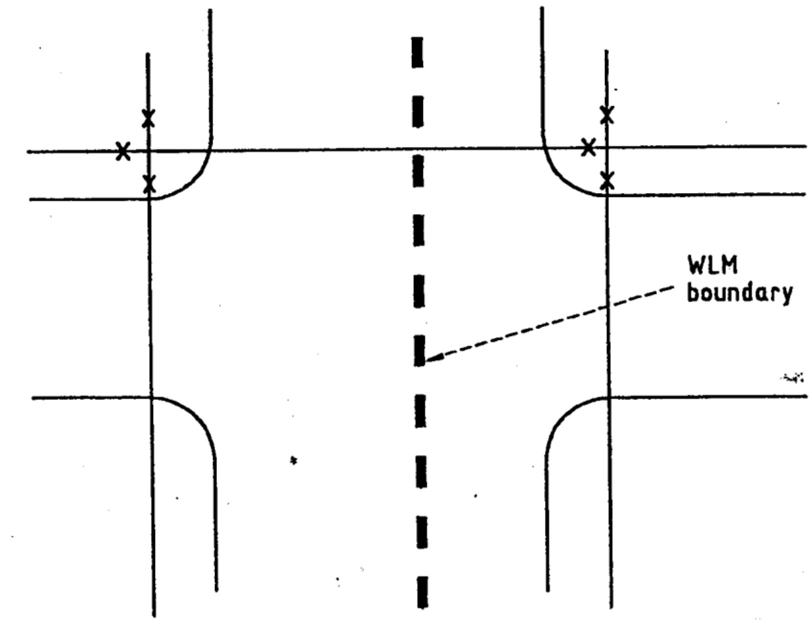


Figure 10 — Designated metering point before subdivision

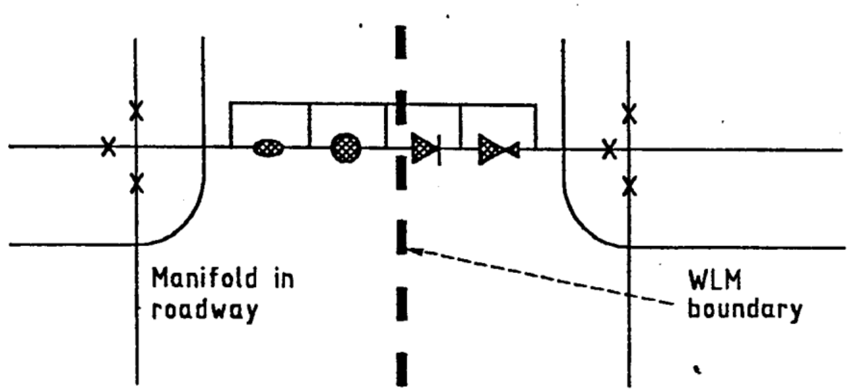


Figure 11 — An undesirable installation solution for the water management point

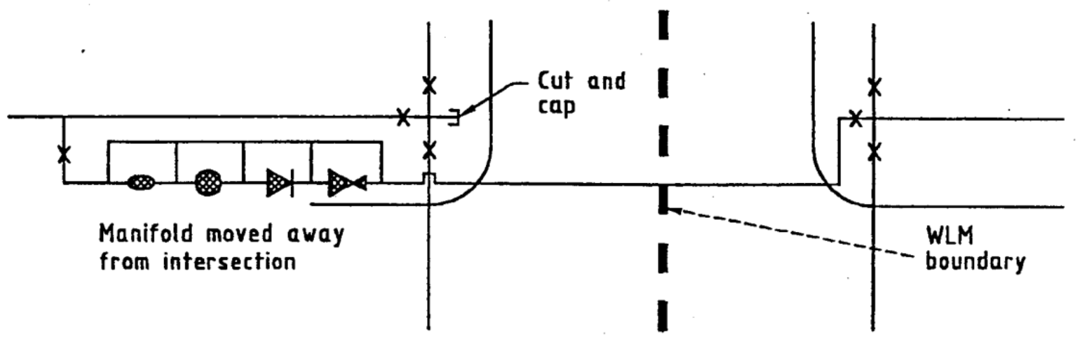


Figure 12 — Preferred position for the water management point

4.3.3.10 The integrity of any district, sub district or zone (which means that the water distribution system is operating as it was designed to, i.e. all valves meant to be closed are closed and valves meant to be open are in fact open), is fragile owing to the nature of people and the circumstances under which they are expected to perform reliably. Continuous or very frequent monitoring and analysis of the management meter data will immediately reveal a discrepancy from the anticipated pattern of readings and alert the water loss management team.

A water management point could be installed as shown in **figure 11**, but it would be undesirable because the installation would be inaccessible unless the traffic was diverted. A preferable, although more costly, solution is shown in **figure 12**.

4.4 System information

4.4.1. Types of information required

For every district, sub district and zone, an inventory of the infrastructure needs to be obtained, and the following information needs to be obtained through extensive preparatory work and field investigations and made available for use before any corrective measures for the control of unaccounted-for water can be implemented:

a) an inventory of the existing infrastructure (see **4.4.2**), preferably in the form of a database;
b) a background set of operational data against which future situations and results can be assessed (see **4.4.3**);
c) an estimate of the initial magnitudes of the various contributions to unaccounted-for water (see **4.10**); and
d) target levels for

    1) unaccounted-for water,
    2) leakage,
    3) per capita consumption, and
    4) conservation goals.

This information should preferably be compiled in the form of a database or a GIS. Storage and retrieval of data should be uncomplicated, with free and easy access to the information. Periodic updating should be a built-in feature.

4.4.2. Inventory

It is useful to overlay, either electronically or manually, a grid reference system (for example, in the form of a GIS or geographic positioning system) onto the plans of the water distribution system. Within each grid, all fittings and fixtures can be located and identified by indicating the grid number and the relevant symbol. Thus G4-RSV2 would mean the second RSV in grid reference G4. Such a system simplifies the identification of any particular fitting, not only for the water department of the water services provider, but also for other services such as the fire department, emergency vehicles, etc. In the field, each fitting should be labelled by means of a stamped stainless steel plate affixed to it and bearing that identification.

4.4.3. Operational data

This initial work forms the foundation of the system database which, in time and with regular updating, will become an invaluable tool for the UFW committee to use in reviewing unaccounted-for water policies, preparation of system audits, assessment of cost benefits of unaccounted-for water control and forward planning requirements.

4.4.4. Planning of a database or a GIS

No meaningful work can commence on the control of unaccounted-for water without information. The preparation of a database or a GIS that contains all pertinent details of the distribution system is essential. The data can be kept as hard copies, i.e. layout plans, registers and logbooks, etc., or captured on computer (GIS). A GIS system should be chosen if it offers easier storage and retrieval of information.

4.4.5. Contents of a database or a GIS

4.4.5.1 A series of current as-built plans, ideally to a scale of 1:2 500 or, failing that, 1:5 000 or 1:10 000, and indicating the following:

a) a key plan indicating the relative position of each sheet in the series of drawings, showing the latitude and longitude grid and the north point;
b) the accurate location of the water distribution system, including offset dimensions and depth;
c) all township names, street names and plot numbers;
d) the location and identification of every property;
e) the number of dwellings on each property;
f) the nature of the property if not residential;
g) the position and size of the connection pipe serving the water installation on the premises;
h) the pipe size, pipe materials and the nature of the fittings, fixtures and components installed on the mains, including pressure class and date of installation;
i) the soil type (with respect to corrosivity/ cathodic protection);
j) the water quality (with respect to internal corrosion);
k) complaints history;
l) the design software that was used to do the water network analysis, indicating the design nodes;
m) a list of fittings associated with each node;
n) the contours;
o) the pressures and pressure zones;
p) the registered titles of all surrounding and adjacent undeveloped property; and
q) the date of the last revision or update.

4.4.5.2 A plan that shows the centre line, identity and size of other services, with depths and offset distances, shall also be available in the water department, including:

a) electricity cables;
b) telephone and other signal cables;
c) gas, sewer and storm water pipes;
d) other authorities' water pipes;
e) any other services; and
f) abandoned/disconnected services still in the ground.

NOTES
1. These requirements could, in some cases, necessitate the extensive re-draughting and re-verification of existing plans.
2. Township layouts invariably have a "pattern", for example, 3 valves at each major pipe or street intersection, or constant fire-hydrant spacing. Deviations from the pattern could possibly indicate that a fitting has been installed but not marked up on the drawings. Such cases need to be verified in the field and noted in the database.

4.4.5.3 A consumer database, available as a "Help-desk" phone-in service, and containing the following information:

a) the street address and stand number;
b) the position of the connection relative to the plot boundary;
c) the type and size of the connection;
d) the position of the meter relative to the plot boundary;
e) the make, type, size and number of the meter;
f) the date installed;
g) the date last tested; and
h) the consumer's consumption record and complaints history.

4.4.5.4 Larger cities and towns shall have separate data information systems for meters, valves (control valves and isolation valves could also be separate), fire hydrants, fire connections, air release valves and scour valves (SVs), etc. The data stored in such a system should include information on:

a) the position/location (above or below ground);
b) the make, type and size (rising or floating jumpers);
c) the fitting number;
d) the date of installation;
e) the date last serviced or tested;
f) the direction of opening and closing and the normal operational status;
g) the name of the supplier/service agent;
h) the spares inventory;
i) the performance record, both of the fitting and the supplier/service agent; and
j) the consumption record.

NOTE – A database, developed and maintained by the water services provider, indicating and describing the position of the water meter on the plot boundary, has proven to be a useful facility (see **4.4.5.3**).

4.4.5.5 Plans to a scale of not smaller than 1 : 10 000 that show separately metered districts (which could also be reservoir zones) and indicate the position of the district meter and its identification.

4.4.5.6 A computer based system for the logging, recording and analysing of all data obtained from the district meter and that will essentially comprise the average daily demand (ADD), the minimum night flow, and, at the end of each meter reading period, which shall not exceed one month, the billing volume (Vb).

NOTES

1 Smaller water services authorities and district water committees can carry out this function largely manually, especially if their cost recovery system is manually based.
2 When presented in graphical format, the data mentioned above can form the backbone of any water management programme.

4.4.5.7 Commercial software packages and technical equipment and other services, which are suitable for use in unaccounted-for water programmes, and that can be categorized into:

1) Software packages:

   a) network analysis;
   b) reticulation/leakage;
   c) meter management;

d) water balance/audit;
e) pressure management; and
f) night flows.

2) Services:

a) management services;
b) network analysis;
c) leak detection services;
d) water balance/audit; and
e) water loss control.

3) Equipment:

a) leak noise correlator (LNC);
b) sounding stick;
c) pipe locators;
d) valve locators;
e) measuring wheel; and
f) gas injection and sensors.

4) Meters:

a) customer meters;
b) mini-bulk meters;
c) bulk supply meters;
d) electromagnetic meters;
e) ultrasonic meters;
f) insertion meters; and
g) externally attached meters.

5) Accessories:

a) data loggers;
b) flow rate recorders;
c) flow control devices;
d) meter calibration;
e) automatic meter reading (AMR);
f) remote meter reading; and
g) telemetry.

4.4.6. Database verification

4.4.6.1 As the different departments within a commercial utility or service provider have traditionally each compiled their own consumer details, the address list of, for example the operations department, will not agree 100 % with the address list of, say, the commercial/ billing department. It is, therefore, essential to compare each and every water account and the address details thereon, with all other services, such as cadastral maps from the planning authorities and councils, to ensure that all properties are accounted for and that the zone, sub district and district to which they are allocated are verified. A consolidated database shall then be compiled and a specific responsibility assigned for maintaining it.

4.4.6.2 Once the merging of all the individual data into a common database has been achieved, the entire contents of the database need to be confirmed in situ. This is an extremely onerous task, therefore, as a first step, verify the discrepancies between the various databases.

4.5 System extension

4.5.1. Where a water distribution system is to be extended, the existing system should be analysed to ensure that it is suitable for extension, after which the entire design will be reassessed and modified as appropriate.

4.5.2. Where urban in-fill or densification is envisaged, the distribution system will have to be reassessed in terms of **4.5.1**, to ensure that not only the peak daily demand but also the hourly peak can be met by the distribution system.

4.5.3. Where high-rise and large buildings are envisaged, adequate on-site storage shall be provided to enable filling to take place during off-peak periods.

4.5.4. Adequate provision shall be made for compliance with the Local Government Act in respect of fire regulations.

4.5.5. The probable flow demand for any water installation shall be determined in accordance with the relevant clauses in the Building regulations.

4.6 Suggested management and staffing structures

Proposals on how the water services provider might establish a division within the city, town, district or community, specifically dedicated to undertake the planning, implementation and operation of a water management programme, are given in Annex O.

4.7 System management

4.7.1. All districts, sub districts and zones shall be tested for losses at least once year. This period shall be reduced if the leakage rate (expressed for example in kilolitre per hour per kilometre), exceeds the target level by a factor of three or more, prior to the one year.

NOTES

1. System testing should be an ongoing activity that moves from area to area. There should be sufficient teams working to ensure that the entire water distribution system can be tested over a two-year period, after which testing will resume with the areas that were tested initially.

2. Water balance reporting will be on a monthly basis, involving all permanent monitoring points. Ideally, unaccounted-for water and minimum night flow rate measurements for the entire system should be determined and reported on at monthly intervals for each zone or smallest measurable area, for internal controls.

3. The frequency at which areas should be tested can be more accurately determined using optimization methods available via computer software (see **4.4.5.7**)

4.7.2. Monitoring of the water distribution system at each permanently installed system meter is an ongoing function and a water audit shall be carried out at least annually.

4.7.3. Permanent manifolds can be built into the distribution system for the purpose of measuring the volume of water entering the district over a given monitoring period. These installations are variously referred to as “district” or “water loss” manifolds.

4.7.4. Temporary installations for smaller situations can be used. These are typically road-side facilities comprising anything from a flow rate meter that lies on the sidewalk and is coupled to fire hydrants on either side of an isolating valve, to a vehicle-mounted (either a van, kombi, caravan or trailer) installation.

4.7.5. A district manifold can be used in two basic ways:

a) A permanently installed meter and a data-logging facility are used as an ongoing, data-gathering, monitoring point for water balance purposes. Continuous (monthly) plotting of the average daily demand, minimum night flow rate and revenue values will indicate when the district should receive attention. When discrepancies become apparent, the meter and instrumentation should be checked first.

b) A temporary meter is installed in a permanently built-in meter body only when the district is to be tested and is moved to other district manifolds as and when required. This procedure is appropriate in smaller districts, sub districts or zones, in newer developments where little leakage is experienced, or in established areas where experience has shown that leakage growth rates are low.

4.8 Procedures to account for water

The basic steps to implement a water loss management programme are set out in Annex **N**. The following series of stages of a water management programme follows logically from the procedures described in **4.10**:

a) Development of a long-term strategic water management plan (which will provide for the augmentation and development of new resources, additional treatment and infrastructure capacity, long-term development planning, etc.) from which will emerge a water management programme (which concerns the management of the water and the infrastructure that makes up the water distribution system).
b) District determination and subdividing the water distribution system into manageable sectors.
c) Design of manifold facilities.
d) Construction of manifold facilities.
e) Installation of metering and monitoring equipment.
f) Measurements of

   1) minimum night flow,
   2) average daily demand,
   3) billing volume, and
   4) pressure.

g) Analysis of data to determine

   1) the magnitude of leakage within the system,
   2) the effects of pressure reduction, where feasible,
   3) the unit cost of leakage and to derive the benefits of reducing leakage, and
   4) the cost of operating the chosen method of leak detection and compare with the unit cost of leakage, remembering that it is not feasible to aim for zero leakage.

4.9 Benefits of a quality management system

4.9.1. As described in ISO 9001: 2000, quality counts. If a water services provider is to be effective, it should consider the quality of its products and services and consider listing in terms of ISO 9001: 2000.

4.9.2. A quality system should be developed, implemented and maintained for the purpose of achieving the objectives set out in the quality policy of the organization. Such a system should be assessed at defined intervals to ensure its continued suitability and effectiveness.

4.9.3. To meet the continuing challenges in operating and maintaining a water supply service, the water services provider shall offer products and services that

a) meet a well-defined need, use or purpose,
b) satisfy customer expectations,
c) comply with applicable standards and specifications,
d) comply with the requirements of society,
e) reflect environmental considerations,
f) are competitively priced compared with other benchmark suppliers worldwide, and
g) are provided economically.

4.9.4. In meeting the above criteria, the water services provider shall take cognizance of its

a) legal obligations (laws, regulations, codes, rules, statutes),
b) social responsibilities (environmental protection, health, safety, security, conservation of energy and natural resources), and
c) fiscal responsibilities (obtain the most economical product, not necessarily the cheapest initially, through assessment of local requirements and of product performance and availability).

4.9.5. The water services provider shall ensure that the technical, administrative and human factors that affect the quality of its products and services are under control and are orientated towards the reduction, elimination and prevention of quality non-conformities.

4.9.6. A quality system is a proactive system in which non-conformities are eliminated before they can cause serious damage. This results in a decrease in the number of failures that need to be found and made good retroactively. As shown in figure 13, there is an increase in prevention costs with a subsequent decrease in appraisal and failure costs, resulting in an overall cost benefit for the water services provider.

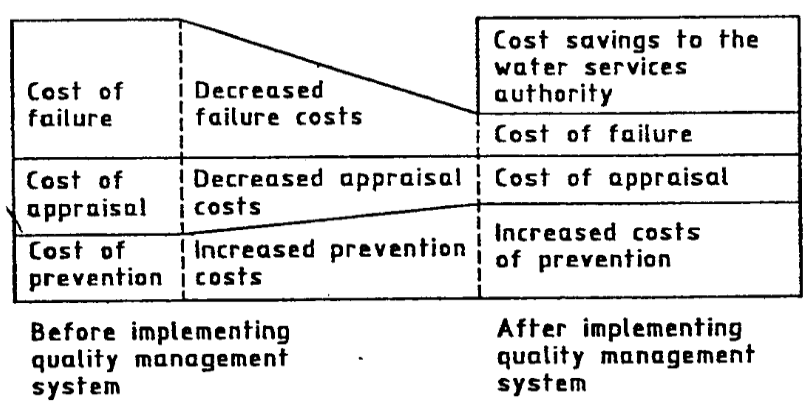


Figure 13 — Cost benefit of a quality management system

4.10 A strategic plan for managing leakage

4.10.1. Benefits of addressing unaccounted-for water

In aging water distribution systems, it would appear that leaks occur at a rate of one leak every 1 km to 2 km, annually. Indications are that, on an annual basis, cost/benefit ratios will remain favourable under such circumstances. In newer or better maintained systems, the cost/benefit ratios can be kept favourable by increasing the period between leak surveys.

Many of the components of today's water distribution systems, some of which date back to the colonial or pre-independence era, are close to exceeding, or have exceeded, their design life. An unaccounted for water programme as outlined in this standard can identify the condition of such components and can assess whether to replace or repair them.

Leaks frequently occur in consumers' installations and often without their knowledge. A water loss detection programme will identify such leakages and, through notifying the consumer, will save the consumer money and at the same time reduce total system water demand. When understood, water loss detection programmes will be welcomed by consumers.

Every water services provider will benefit financially, will enhance its public image and will fulfil its statutory obligations far more readily if water loss management were to be implemented as quickly, efficiently and economically as possible.

When a reduction in the total demand for water is crucial, such as when the supplies are fully extended and new resources are either not available or very costly to develop, the water services provider may find it prudent to also locate and repair leaks on private properties, at nominal charge, just to reduce the water demand on the system. This also applies in areas where non-payment is prevalent.

Reducing the level of water losses will reduce the operating costs of water services authorities and defer the need for the development of new water resources and the construction of additional treatment works, thus releasing capital for use elsewhere.

Water which has already been stored, treated and put into supply, but which has previously been wasted or lost from the system or inefficiently used, is the cheapest and most readily available water to the water services provider.

4.10.2. Steps in the strategic plan for managing leakage

The following steps, derived from **4.1** to **4.9**, are aimed at municipalities and larger water services authorities that have no water management plan in place, or, at best, a very superficial inadequate water balance, probably full of factors (estimates) that, despite all honourable intentions, distort the true picture and make the water services provider's results look too favourable. For smaller authorities and district water committees, simpler appropriate systems should be developed in conjunction with people who are knowledgeable in water management.

4.10.2.1 Appoint a UFW committee that consists of senior officials, to develop a policy and from that, a strategic plan for implementing water management within the water supply area. The UFW committee shall obtain information to establish the overall extent and cost of unaccounted-for water (both physical and non-physical components) in order to establish the magnitude of the problem for the water services provider as a whole.

4.10.2.2 Design a strategic network of bulk supply meters, district meters, sub district meters and zone meters.

4.10.2.3 Identify the most strategically important of the meters mentioned in **4.10.2.2** and permanently install them first.

4.10.2.4 Develop a plan to complete the installation of the rest of the meters over the next two to five years.

4.10.2.5 Undertake a meter survey of each area and locate any non-metered premises and meters that are faulty or of the incorrect size. Rectify the area.

4.10.2.6 Verify each area against billing records, to ensure that each billing address is in fact within the correct zone boundary.

4.10.2.7 Undertake an inventory of each area served (number of houses, commercial properties, cafes, schools, institutional buildings, hospitals/clinics, etc.) and calculate an approximate figure for expected consumption (see Annex **B**).

4.10.2.8 Collect data from the strategic meters installed and analyse the results by comparing the data collected with the billed volume of water delivered, to obtain a superficial water balance. Large imbalances could indicate leakages or many illegal connections in some areas. This can be verified by checking the minimum night flow rate into the area against the average daily demand. A high ratio would suggest illegal connections while a low ratio would suggest leakage, if the unaccounted-for water is high.

4.10.2.9 To enable theoretical analysis, apply conversion factors to the pressures to convert all pressures to 500 kPa for comparative purposes.

4.10.2.10 Prioritize the areas by volume differences, minimum night flow rate (see figures 14 and 15) or, if the information is available, in terms of specific loss rate, Q_{sl}, (see **3.1.47** and **5.1**). Various water services authorities would apply a weighting procedure to obtain their priority listing.

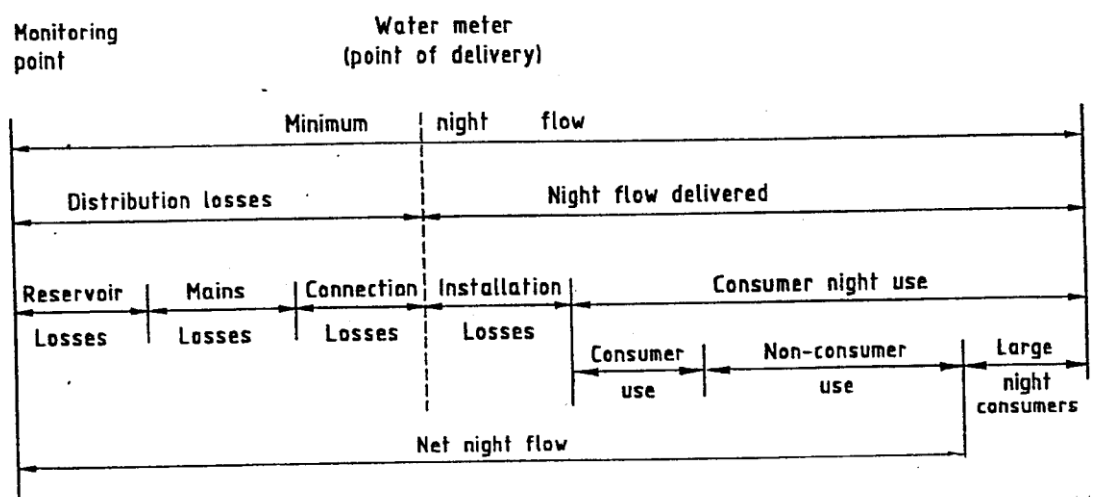


Figure 14 — Schematic representation of the components of night flows

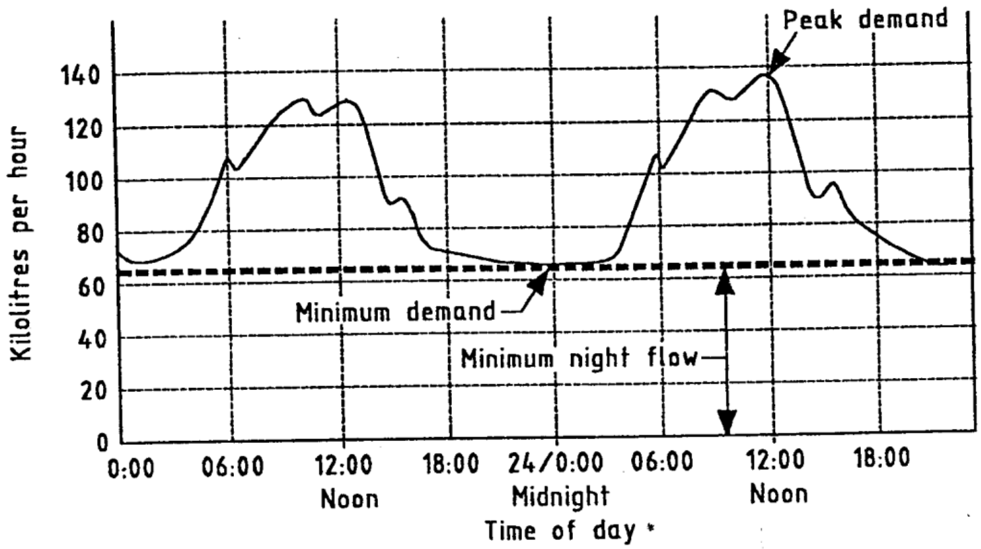


Figure 15 — Typical diurnal flow pattern to determine minimum night flow from a meter trace using a data logger

4.10.2.11 Implement normal water loss control procedures (including metering/monitoring and pressure-control measures) in each area, according to the priority listing.

4.10.2.12 Monitor net minimum night flows (see **3.1.40**) and repeat the step given in **4.10.2.10**.

4.10.2.13 Generate an annual water audit for submission to the CEO and to the UFW committee. The generation of monthly reports is to be encouraged for departmental controls.

4.10.2.14 Develop or acquire a more sophisticated computerized water management system, which should be up and running within two years. Such systems would include some or all of the following:

a) Geographic Information Systems (GISs);
b) Management Information Systems; and
c) Integrated Information Systems;

depending on the size and complexity of each individual distribution system. These are expert systems requiring experts to run them, and they are costly to install but, once they have been installed, even complex water distribution systems finally become manageable and the generating of reports is no longer the onerous task most water services authorities find it today.

4.10.2.15 At a minimum level of sophistication, an interrogatable database shall be available from which to extract water meter information concerning zero readings, major variations, excessive usage, various consumer groupings, etc.

4.10.2.16 A comprehensive strategic plan should also include economic analyses involving NPV or IRR analysis or both, in order to establish whether the plan is economically viable. (This is not always apparent when one uses simple cost/benefit comparisons.)

5. LOSS RATES AND TARGET LEVELS

5.1 Specific loss rate

5.1.1. It has been comprehensively shown (see **3.1.42**, **6.1.2** and **Annex A**) that the practice of expressing water losses, unaccounted-for water, minimum night flow loss rate, etc., in terms of percentage only, is deprecated.

5.1.2. The preferred term is specific loss, Q_{sl} (see **3.1.47**)**,** which is obtained from the following formula:

$$Q_{sl} = \frac{Q\left(m^3/h\right)}{L\left(km\right)}$$

Where:

Q_{sl} is the specific loss rate per unit pipe length, in cubic metres per hour per kilometre of pipe length;

Q is the volume rate of water loss, in cubic metres per hour; and

L is the length, in kilometres, of distribution mains only, excluding the length of connection pipes and trunk mains.

Sub districts and zones will typically not have trunk mains running through them. An appropriate correction factor is applied in the case of high density or low density areas.

5.1.3. Specific loss rate can also be expressed in litres per hour per property for the area concerned, or in litres per hour per connection, by dividing the net minimum night flow by the number of properties in the area or by the number of connections respectively.

Care should be exercised if service coverage is below about 90 % because these measures of loss rate are not always identical. The number of properties could exceed the number of connections because some groups of properties (two or more) will share the same connection pipe. Alternatively, in developing areas, the service coverage could be less than the total number of properties available for development and the number of connections will therefore, be less than the number of properties.

5.1.4. Whenever required, values for specific loss rate can be established for each management district, sub district and zone where permanent meters have been installed, by simply logging the management meter for a day or two. Usually, the key (strategic) meters are fitted with a logger on a permanent, ongoing basis.

5.1.5. The specific loss rate values for all areas should be plotted on a monthly graph, to observe the loss trends (growth of leakage) for each area.

5.1.6. All specific loss rate values are expressed in identical units (for example, cubic metres per hour per kilometre) and ranked in descending order. It is preferable if these values come from the same (latest) measurement cycle. The area with the highest specific loss rate will also have the highest water losses. This ranking will provide the basis for scheduling maintenance or repair work in the area.

NOTE – A small area with a higher specific loss rate could have a lower priority than a larger area with a smaller specific loss rate but with a much higher total volume of water lost.

5.1.7. Factors that affect specific loss rate are:

a) the soil type (see also **5.3**);
b) the system integrity (tightness);
c) the supply pressure;
d) the materials of pipes and connections;
e) the quality of pipe work installation practice;
f) the nature and efficiency of corrosion protection;
g) the number of connections to the system;
h) the number of valves, fittings and fixtures in the system; and
i) the pipe-bed material.

NOTE – Chipped stone and coarse gravels can act as subsoil drains over a distance of many kilometres.

5.2 Comparative ratios

5.2.1. A fundamental aim of any water loss control programme is to identify what leakage exists and then to take the necessary corrective action. A useful action indicator is provided by the comparative ratio: $R_{am} = Q_{ad}/Q_{mnf}$; as illustrated by the following example:

If the average demand flow rate Q_{ad} for a given area is, say, 100 units, and the minimum night flow rate Q_{mnf} is 10 units, then R_{am} is 10. However, if Q_{ad} increases to 150 units while Q_{mnf} becomes 50 units, then R_{am} is 3. The implication is that the closer R_{am} approaches the value 1, the worse is the condition of the distribution system.

Obviously, an example such as the above can be fraught with complications and other variables that make a specific ratio for an area impossible to determine. However, normally both Q_{ad} and Q_{mnf} are relatively simple to obtain and, in all likelihood, already form part and parcel of a water department's daily tasks. The water services provider could then use the ratios to prioritize those areas for which specific loss rates should first be determined and could then decide where to implement the corrective actions first.

5.2.2. Other useful action indicators are based on the ratios V_{add}/V_b and Q_{mnf}/V_b and can be employed in a month-by-month comparison of successive years for an area, or just for a single property or group of properties. If the consumption of an area or a property increases but the revenue from it decreases, then either losses are occurring or theft is taking place. In either event, an investigation is necessary. Each water services provider is encouraged to develop its own ratio indicators as the early warning part of its water loss control programme.

5.3 Impact of soil type

5.3.1. A map that shows soil types (see **4.4.5.1**) is necessary since the predominant soil type in an area has a major influence on the level of water losses, as indicated in table 1.

The following should be noted:

a) heavy clayey soils are more prone to soil movement; and
b) leaks are not easily seen in coarse, gravelly soils.

Table 1 — Effect of soil type on relative loss rates

1	2	3
Predominant soil type[1)]	**Range of typical loss rates**	**Relative values of typical specific loss rates, Q_{sl} (ℓ/h/km)**
Sandy Loamy Stony[2)]	Lowest | Highest	10 20 40
1) Typical relative values for wet and clayey/marshy areas are not available. 2) Includes building rubble and gravels.		

5.3.2. The three factors that most affect the above values for each soil type are:

a) corrosion;
b) soil movement; and
c) the possibility of leaks becoming visible.

5.3.3. Soil aggressiveness generally increases from light, non-binding soils to heavy, binding soils.

5.4 Target levels

5.4.1. Water loss management is not an exact science, although today it is less of an art than it was only a few years ago. Therefore it is understandable that there is no single magical figure of acceptable loss rates that applies in all circumstances.

5.4.2. The components of unaccounted-for water (see **6.2.1**), water losses (see **6.2.4**) and minimum night flow rates (see **6.2.5**) and the factors that influence total water losses (see 6.3) all need to be considered when target levels are being determined.

5.4.3. Older systems, more densely populated areas, unmetered areas and inadequately administered areas can be expected to have higher net loss rates than well-managed areas.

5.4.4. Typical target levels would be around 5 l/h per plot. Older areas (exceeding 25 years) could rise to 7 l/h per plot, while newer areas (less than 10 years) could drop to 2 l/h per plot or 3 l/h per plot.

5.4.5. In an area that consists primarily of residential properties, the target level for background leakage is normally 1.7 l/h per plot, while for non-residential properties, the average value could be around 8 l/h per plot, with a wide range of values anywhere between 2 l/h per plot and 30 l/h per plot. The ratio of residential to non-residential properties will therefore affect the target level leakage rate.

Should the ratio of the number of residential/non-residential properties drop to below 100:1 (i.e. significant numbers of commercial, industrial, institutional and other non-residential consumers), then the target levels should be re-evaluated to reflect the potential increase.

5.4.6. Most residential areas will not be totally homogeneous but will have commercial, educational, medical, police buildings, etc., in their midst, all of which have different values of active night flow attributed to them. Target values could be as given in Table 2.

Table 2 — Typical target values for minimum night flow rates (Q_{mnf})

1	2	3
Classification	**Target values for (Q_{mnf}) (l//h per plot)**	
	Range	**Average**
Households (25 % active):	1 to 2	1.5
Non-households[1)]:		
Retail	3 to 7	5.0
Hotel	8 to 12	10.0
Education	20 to 30	25.0
Sports stadiums	5 to 50	20.0
Financial	3 to 7	5.0
Medical	30 to 50	40.0
Offices/Commercial	3 to 7	5.0
Large consumers (> 500 l/h):	sum of all users	
1) See 5.4.9.		

5.4.7. Housing density in any given area (properties per hectare), and the ratio of urban estates (more than 3 000 m^2 per property) to smaller residential urban properties (less than 3 000 m^2 per property), will also affect the target levels by virtue of the varying mains length per property.

5.4.8. As an indication of the nature of water losses (at a reference pressure of 500 kPa) that can be encountered from the various components of a distribution system, the example in Table 3 could be used as a starting point.

Table 3 — Typical water loss rates

1	2	3
Component	**Type of loss**	**Typical loss rate, R/h**
Distribution mains	Background leaks Visible leaks Underground leaks	(30 to 50) x length of mains in km Number x flow rate Number x flow rate
Connection pipes	Background leaks Visible leaks Underground leaks	(1 to 4) x no. of connection pipes Number x 1 500 Number x 1 500
Community installations	Standpipes Background leaks Visible leaks Underground leaks	(200 to 600) x number (1 to 10) x no. of properties Number x 1 200 Number × 1 200
	Non-payment, flat rate and unmetered areas with house	

	connections	500 to 1 500 × number

5.4.9. Automatic flushing urinals in any building could consume up to 250 l/h. Properties with multiple automatic flushing urinals shall be identified in the system before the minimum night flow rate is measured. The use of non-user-activated automatic flushing devices is prohibited in the National Water Supply Regulations to be published in terms of the Water Supply and Sanitation Act, 1997 (No. 28 of 1997).

5.4.10. The above loss rates for the different parameters are, in effect, key performance indicators. There are advantages and disadvantages associated with each one depending on the conditions in the area being monitored. Thus, it is essential that as many alternative expressions as practical be given, at least two different measurements being the absolute minimum. Any one on its own is, probably, totally meaningless.

5.4.11. An example calculation for estimating background Q_{mnf} values is given in Annex **B**.

5.5 Economic level of leakage

5.5.1. To determine the economic level of acceptable leakage, evaluate the costs of increasing water loss control activity against the benefits to be derived from such activity, making reference to **figure 13** (see **4.9.6**) and Table 4.

Table 4 — Evaluation of costs/benefits

1	**2**
Costs	**Benefits**
Cost of reducing leakage	Cost benefits from reducing leakage
Select appropriate water loss control techniques	Reduction in maintenance/operating/treatment costs
Increase water loss control activity until costs equal benefits	Financial benefits of deferred capital construction

5.5.2. Economic levels of leakage can be found with the aid of optimization methods available in commercial computer software (some categories are given in **4.4.5.7**). After implementation of the appropriate water loss control programme, the remaining leakage is the economic level of leakage.

6. UNACCOUNTED-FOR WATER

6.1 Calculation of unaccounted-for water

6.1.1. Water balance

6.1.1.1 A water balance can be achieved, using district, sub district and zone meters, by performing the following tasks:

a) measure the volume of water put into supply;
b) measure the authorized metered volume used;
c) measure (by installing meters or by temporary meters) the authorized unmetered volume used;
d) measure water losses (by means of step-testing); and
e) analyse the results (and cost the unaccounted-for water).
f) Each of the five tasks of the water balance set out in (a) to (e) above involves a wide range of activities and components.

6.1.1.2 By definition (see **3.1.55**), the difference between the results of the first two tasks in **6.1.1.1** represents the water balance. Estimates of water leaving the distribution system are excluded from the definition to avoid the possibility of figures being adjusted (whether intentionally or inadvertently) to return more favourable (lower) values. The first time this water balance calculation is attempted, the resulting unaccounted-for water is invariably huge. Then follows a systematic attempt to account for the different components of the unaccounted-for water and to take the necessary corrective actions to reduce the difference to a more acceptable level.

6.1.1.3 Traditionally, the water delivered to metered consumers and the (favourably) estimated non-metered uses were deducted from the input into the water distribution system. The difference was attributed to distribution losses, but without any knowledge or understanding of how, where and why those losses occurred.

6.1.2. Units of unaccounted-for water

6.1.2.1 The use of the term **percentage or kilo loss** has been shown to be unhelpful when quantifying leakage or unaccounted-for water to a technical audience (see **3.1.42** and Annex A). It shall only be used when reporting on carefully stated, specific circumstances.

Unaccounted-for water, when compared with the total quantity of water put into supply, fluctuates widely in time and cannot, therefore, be expressed in a single fixed figure such as percentage, without extensive qualification. To be truly meaningful, percentage should always be related either to the distribution system or to service points supported by at least one of the following three more commonly used specific leakage rate units, for technical reporting:

- litre per hour per plot or litre per hour connection,
- cubic metres per hour per kilometre of mains length, or
- cubic metres per hour per kilometre of distribution system (includes connections).

NOTE – The term "percentage" is simple, widely used and perceived to be easily understood. As such, it is unlikely to disappear from usage. The specific leakage rate expressed in kilolitres per hour is more appropriate as a measure of leakage since it is directly related to the relevant component in the system, i.e. the pipe. The units litres, cubic metres and kilolitres (l, m^3 and kl) are all equally acceptable, but consistency should be observed by the reporting person. Similarly, the terms "property", "plot" or "connection" can all be used, although they do not, normally, mean the same. Care and consistency need to be observed.

6.1.2.2 The length of the distribution system can be derived from the sum of:

mains length + (average length of connection pipes x No. of connections)

6.1.2.3 As one connection pipe can, and often does, serve two or more properties, it shall not be assumed without verification that the number of connections equals the number of properties served.

6.1.2.4 Because of the large number of components of water losses and the variety of factors affecting those components, concern is expressed at setting target night flows based on only one of the unit parameters given in 6.1.2.1.

6.2 Identification of components

6.2.1. Components of unaccounted-for water within distribution systems

6.2.1.1 Components of unaccounted-for water include the following (**see figure 16 and 10.4**):

a) authorized but unmetered consumption: low income housing; communal taps, unmetered standpipes and unmetered yard connections;

b) authorized but unmetered use: fire fighting and fire drills (if unmetered), parks, street washing, mains and drains flushing, scouring and swabbing, construction water, fire hydrant testing, water drained from mains in order to carry out repairs to the pipe work or fittings, commissioning of mains, service reservoir commissioning and cleaning;

c) unauthorized unmetered consumption: unauthorized connections, illegal use from fire hydrants and hoses, reversed meters;

d) inaccurate registration of metered consumption: unrecorded reverse flow, under-registration of consumer meters or over-registration of inflow bulk meters (or both) can lead to an apparent selling of more water than is purchased, meter malfunction due to breakage or blockage, incorrect sizing, incorrect installation, which affects meter recording accuracy, particularly in the case of meters that are sensitive to turbulent flow and swirl;

e) storage reservoir overflows;

f) storage reservoir leakage;

g) water distribution system losses: leaks and bursts;

h) non-physical losses: meter reading errors, book entry errors, billing errors and delays in billing, addressing and consumer database errors, delays and errors in registering new consumers, bad debts; and

i) bad zoning through incorrect isolation across zone boundaries.

NOTE – As a matter of policy, no unmetered connections should be provided in a system irrespective of the end user. In terms of the Local Government Ordinance, a service cannot be provided free of charge if there is a tariff requiring payment for the service.

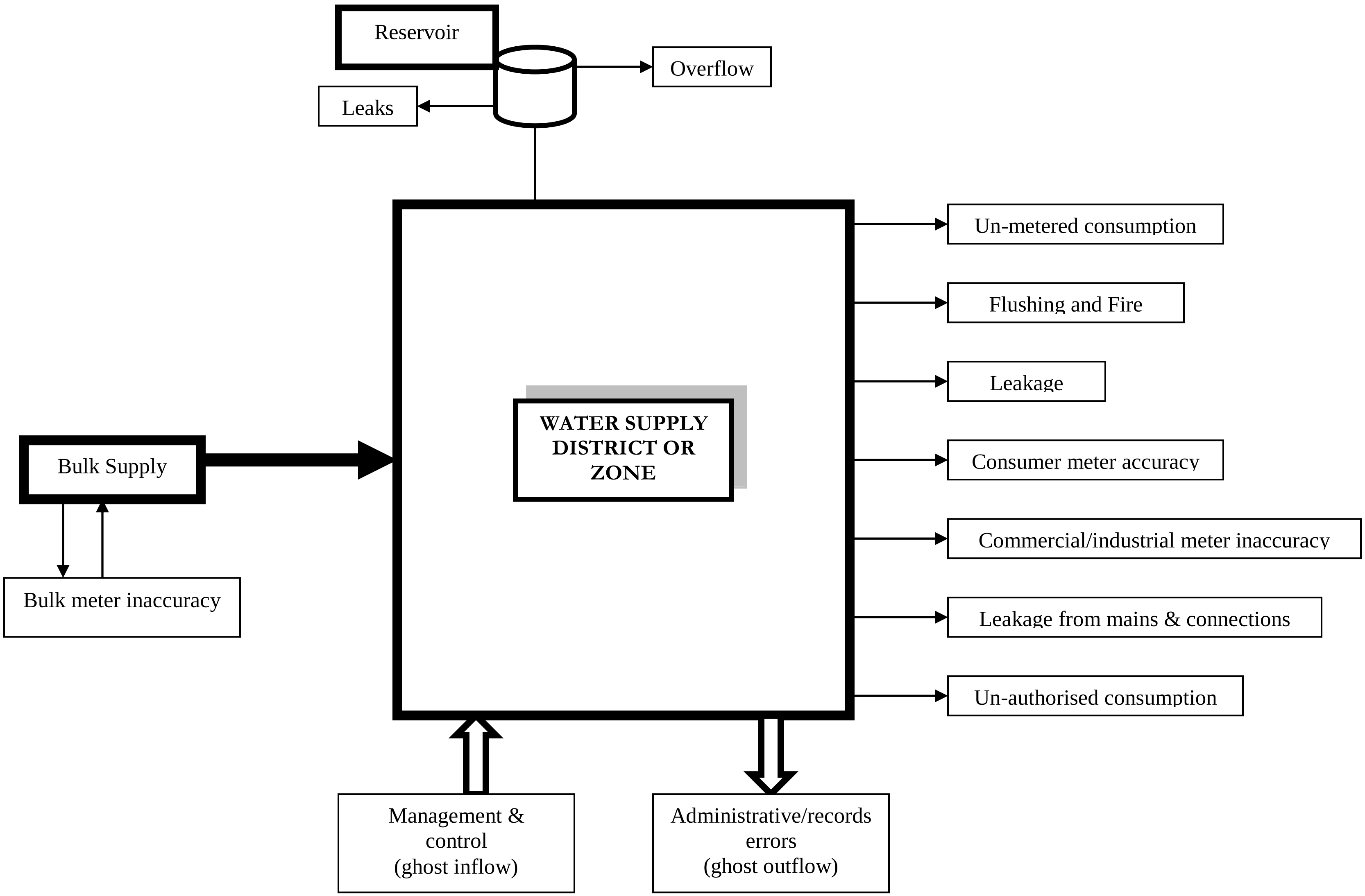


Figure 16 — Schematic representation of unaccounted-for water

6.2.1.2 Leaks downstream of consumer meters should not affect the overall unaccounted-for water, however, meters that are not read, non-payment and meter inaccuracies will all adversely impact on unaccounted-for water. Loss of water through leaks on consumer premises forms an important part of water wastage, which shall be addressed under water demand management.

6.2.1.3 Authorized unmetered consumption shall be systematically eliminated as a matter of urgency through the installation of suitable meters, even if the tariff structures for these are zero-rated or flat rated (see also **10.4**).

6.2.1.4 Reservoir overflows invariably result from the failure of inlet control mechanisms often located inside the reservoir. The overflow pipe shall be designed to discharge visibly to atmosphere before being channelled to some natural watercourse or storm water drain. This will prevent overflows from remaining undetected for long periods of time especially in the case of intermittent overflows that occur during hours of low demand. Because overflows do not always run continuously, when an overflow event occurs, it should trigger some or other device that indicates that an overflow event has taken place. This should form part of the reporting procedure.

6.2.1.5 Components for unaccounted-for water can be divided into

a) legitimate uses, and

b) potentially recoverable losses.

While it is uneconomical and almost impossible to eliminate all recoverable losses, these can be reduced by prompt action in tracing and repairing the components thereof through active leakage control, the overriding objective of which is to limit the duration of underground bursts.

6.2.2. Alternative meter reading techniques

6.2.2.1 One of the major components of the non-physical losses of unaccounted-for water is associated with incorrect meter readings, incorrect book entries and the incorrect transfer of data from the meter book to the treasury department's billing system.

A practical and very effective method of reducing meter reading and data capture errors is through the use of hand-held electronic meter reading terminals (HHT). These devices obviate the need to write the meter reading by hand into a book, since an electronic device with a key-pad is used to key in the meter reading. A number of check facilities are built into the device to ensure accuracy, correctness and honesty.

NOTE – Studies indicate that time savings of 15 % in meter reading, 40 % in supervision, and 50 % in data capture could be achieved through the use of an HHT. The incidence of meter reading errors is dramatically reduced, since errors during the transfer of readings from an HHT to the consumer database are non-existent. Errors that previously occurred during downloading from traditional meter books are eliminated.

6.2.2.2 Local suppliers are encouraged to investigate and set up trials for more advanced meter reading techniques such as automatic meter reading (AMR) devices as and when they become available. In this way, they stay abreast with technological advancements.

NOTE – Even if the task of reading meters has been contracted out to the private sector, staying abreast of developments remains a duty of the local suppliers.

6.2.3. Metering problems where prepayment systems are operated (see 11.2)

6.2.3.1 All prepayment systems have one common concern, which is the time-lag between the purchase of credits and the actual consumption of the water. This makes accurate water auditing difficult to achieve. Continuous running averages of water put into supply and water sales can help to minimize this specific disadvantage. This makes the installation of the bulk monitoring system even more crucial so that an accurate water balance can be achieved. By knowing the population inventory downstream of the zone meters and watching the growth of minimum night flow rate, shrewd operators will be able to identify those areas most in need of attention.

6.2.3.2 There is considerable debate whether the cost saving to a water services provider will exceed the capital and installation costs of unconventionally metered and billed (prepayment) situations. Some evidence suggests that holistic savings will indeed exceed costs because of a reduction in wastage.

6.2.4. Components of water losses

6.2.4.1 Components of water losses include the following:

a) background leakage: which is the aggregation of individual leaks and overflows of less than 250 l/h and therefore economically too small to seek out. Background leakage occurs throughout the year and would not normally be actively pursued;

b) visible leakage: leaks that are commonly reported by the public and are usually in excess of 500 l/h and includes "bursts" which are catastrophic leaks; and

c) underground leakage: leaks that usually run to ground (borehole recharge), or to storm water drains, or to sewer drains, or to post office conduits, or through fissures to a surface water body. Underground leakage can be limited by active leakage control.

NOTES

1. Essentially, a water management programme is aimed at underground leakage (unreported leaks). Background leakage is totally unaffected, irrespective of the amount of men or money thrown at the problem.

2. Any leakage between 250l/h and 500 l/h is classified as a leak if it is found and repaired, or as background leakage if it is not located or reported. It would not normally be actively pursued, but is often stumbled upon or becomes visible, in which case it is considered a leak and not background leakage. Visible leakage should always be repaired, irrespective of the size of the leakage.

6.2.4.2 Components of water losses can be divided into:

a) distribution system losses, comprising losses from

   1) service reservoirs,
   2) trunk and service mains,
   3) distribution mains,
   4) connection pipes, and

b) customer losses, comprising losses from

   1) installations, and
   2) plumbing in buildings.

Each of the components of water losses (background, visible and underground, see **6.2.4.1**), can occur to a greater or lesser extent on each of the above six components of the water distribution system, giving a matrix of 18 possible loss components.

6.2.5. Components of minimum night flow rates

6.2.5.1 Components of minimum night flow rates include the following (see figures 14 and 15):

a) background leakage;

b) normal household night use;

NOTE – The normal household night use will result from only a small proportion of active residential properties.

c) normal non-household night use (cafes, garages); and

d) large night users (clinics and hospitals, restaurants, hotels, automatic flushing urinals at schools, etc.), exceeding 500 l/h.

6.2.5.1 Superimposed on the minimum night flow will be periodic occurring visible and underground leaks.

6.2.5.2 The net minimum night flow rate, or weighted values of the net minimum night flow rate, are.sent into the area. However, each of the above components needs to be quantified before areas are prioritized, to ensure that the loss detection crews do not spend time looking for leaks that do not exist or that do not justify attention.

6.2.5.3 The minimum night flow rate will assist with the early detection of underground leaks and careful analysis can be used to predict the actual number of underground leaks to expect.

6.2.6. The use of background night flows for comparative purposes

6.2.6.1 The use of background night flow values can be adjusted for comparison purposes, by using the following parameters:

a) night pressure;

b) infrastructure condition (inferred from the background leakage);

c) pressure corrected background leakage per kilometre of main;

d) pressure corrected background leakage per connection;

e) pressure corrected background leakage per property (installation and plumbing);

f) active night population;

g) non-residential night use; and

h) large night users (exceeding 500 l/h).

Software models (see **4.4.5.7**) are ideal for the above assessment.

6.2.6.2 Minimum night flows can be analysed to determine the probable number of leaks that contribute to the flow. As described in 6.2.5, not all of the minimum night flow is leakage, since some, often much, water is used. A simple calculation is offered in **Annex C**.

6.3 Factors that influence total water losses — Leak size

6.3.1. A leak does not have to be very large to be significant, as table 5, calculated at the international reference pressure of 500 kPa, indicates.

Table 5 — Leak sizes and loss rates at 500 kPa

1	2	3	4	5	6
Leak sizes and losses					
Equivalent size		**Loss**		**Rate**	
mm	*dia*	*l/min*	*l/h*	*m*^{3}*per day*	*m*^{3}*per day*
0.5		0.33	20	0.48	14.4
1.0		0.97	58	1.39	41.6
1.5		1.82	110	2.64	79
2.0		3.16	190	4.56	136
2.5		5.09	305	7.30	218
3.0		8.15	490	11.75	351
3.5		11.3	680	16.3	490
4.0		14.8	890	21.4	640
4.5		18.2	1100	26.4	790
5.0		22.3	1340	32.0	960
5.5		26.0	1560	37.4	1120
6.0		30.0	1800	43.2	1300
6.5		34.0	2050	49.1	1478
7.0		39.3	2360	56.8	1700

6.3.2. Background leakage, being considered as a uniformly distributed seepage, is affected by

a) the number of connections,

b) the length of the main,

c) the average night pressure, and

d) the condition of the infrastructure.

6.3.3. Leak losses, both visible and underground, are affected by

a) the time it takes to become aware of the leak,

b) the time it takes to locate the leak,

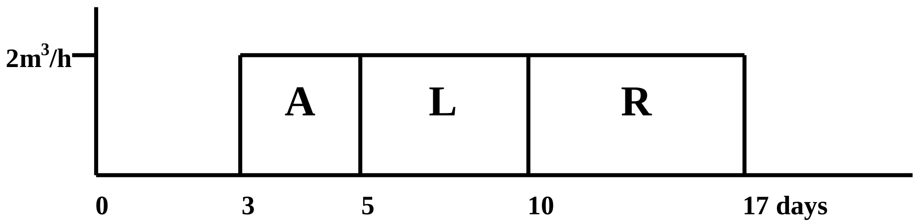
c) the time it takes to repair the leak,

d) the average running time of the leak (days) multiplied by the average flow rate (cubic metres per day), and

e) the frequency of bursts per kilometre of mains per year or per thousand properties per year.

Figure 17 shows the implications of delaying the repair of leaks.

Awareness: A = 2m^3/h x 2d = 96m^3
Location: L = 2m^3/h x 5d = 240m^3
Repair: R = 2m^3/h x 7d = <u>336m^3</u>
Total for 14 days = <u>672m^3</u>
Where, h is hour and d is the number of days



NOTE – In terms of the Regulations promulgated under the Water Supply and Sanitation Act, 1997 (No. 28 of 1997), this leak should have been reported, located and repaired within 48 h, for a total loss of only 96 m^3 instead of the 672 m^3 actually lost: 7 times that amount!

Figure 17 — Implications of time delay in the water balance

6.3.4. Local influences for the factors given in **6.3.3** are

a) water pressure,

b) soil type,

c) climate,

d) traffic,

e) pipe material, age, condition, joint type,

f) workmanship,

g) corrosion potential (based on pipe material, soil conditions and resistivity, age, soil moisture, pervious/impervious covering),

h) standard of mapping and documentation,

i) standards of service,

j) price and scarcity of water,

k) notification procedures,

l) manpower, and

m) economics.

6.4 Measurement and evaluation of components

6.4.1. General

6.4.1.1 The basic means of water measurement is metering. The smaller the area being metered, the more accurate the results and the easier they are to analyse.

6.4.1.2 When minimum night flow is being metered, the flow rate should exceed the lower accuracy range of the bulk meter; otherwise the measurements will be unreliable and should be discarded. In such an event, metering of the minimum night flow will have to be done via a bypass meter or a potable meter, with a compatible lower accuracy range.

6.4.2. The use of reservoirs to determine minimum night flow

Where no convenient bulk meter that is integral with the outflow pipe exists, the following procedure can give an indication of the minimum night flow for the area (or for an isolated section of the area) served by the reservoir, but shall not be deemed to be a substitute for the more accurate methods of direct metering such as step-testing:

a) Determine the structure leakage for the reservoir expressed in litres per hour or in kilolitres per hour (see **12.1.2**). This task can be done at any convenient time.

b) Between the hours of approximately midnight and 4:00 (or earlier in areas where workers rise very early), with the reservoir full or nearly full, close the valve on the inlet pipe to cut the inflow to the reservoir, keeping the outlet pipe open.

c) Measure the drop in surface water level over a period of time, and express in litres per hour or in kilolitres per hour.

d) The difference between the flow obtained in (c) above and the structure leakage (in litres per hour or kilolitres per hour) is the minimum night flow into the isolated area of the water distribution system.

NOTES
1. Smaller meters downstream in the system can be used to further segregate the minimum night flow into smaller zones or areas.

2. **Caution** needs to be exercised in the use of reservoirs for purposes of determining the minimum night flow or checking a bulk meter, either inflow or outflow, and the practicalities need to be carefully considered. Accuracy is influenced by a number of factors, such as the size of the reservoir compared with the outflow, the possibility of reverse flow or backflow, the accuracy of the measurements (1 mm error in the top water level could be a relatively large volume of water), a hook gauge is recommended as it is a simple and sensitive device for the measurement of changes in level, and the regularity
of the wall dimensions of the reservoir.

6.4.3. On-site storage

On-site storage is usually a prerequisite for institutional, commercial or industrial buildings where a disruption in service will endanger the lives of occupants, or will cause inconvenience or damage. If the on-site storage facility is filling over night, accurate minimum night flow rate determinations will not be possible. However, if current metered consumption is compared with historical meter readings, sites requiring investigation can be identified. The water services provider can also determine typical volumes of water that should be used per capita, per square metre or per unit of production from similar consumer categories elsewhere, and can compare those with the volumes used for the particular site.

7. A MANAGEMENT APPROACH FOR THE IMPLEMENTATION OF WATER LOSS CONTROL (see figure 18)

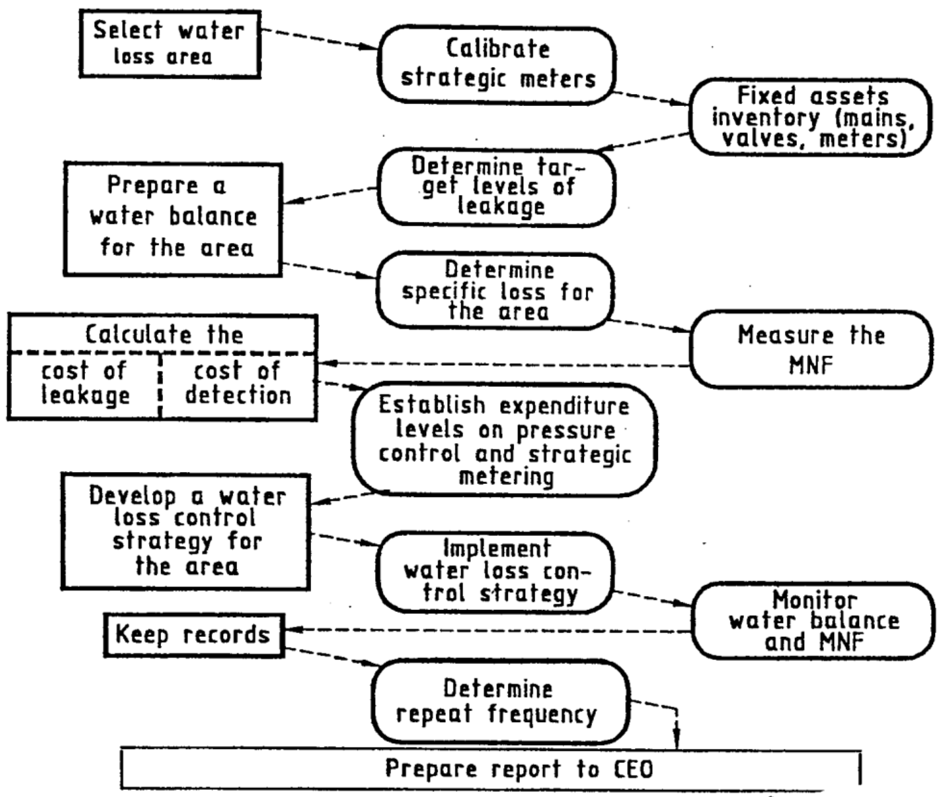


Figure 18 — A management approach for the implementation of water loss control

7.1 Survey goals

7.1.1. Before a single leak is found and repaired, unaccounted-for water can be reduced quite considerably through the simple expedient of improving flaws in the accounting systems, such as faulty meters, dyslectic meter readers, booking errors and billing errors.

7.1.2. Any water loss control initiative shall be preceded by a check of all water meters, especially the larger sizes, and faulty meters shall be replaced or repaired. The effectiveness of this exercise will be reflected in the results of a before-and-after water balance of the particular zone or sub district or portion thereof.

7.1.3. When determining a strategy for a water loss programme, decision makers should aim to survey and service the entire water distribution system over a period of one year, after which the survey is repeated. This will enable decision makers to ascertain the impact of the programme and to identify areas where leak propagation is high.
Surveys taking longer than one year will not enable the water services provider to get the leakage problem under control, but rather will place management in an "always-trying-to-catch-up" role.

7.1.4. System surveys can be done superficially or in-depth, with the obvious advantage of savings in the former but a better success rate in the latter case.

7.1.4.1 Superficial system surveys comprise visual inspection and sounding of all hydrants and isolating valves only.

a) The benefits are

1) the survey is rapid (few valve boxes have to be opened),
2) progress can be as much as 12 km a day,
3) the work is easily accomplished by a one-man team,
4) only low cost and robust equipment is used,
5) only medium level of skills is required, and
6) surveys can be done during daylight hours.

b) The disadvantages are

1) contact points can be far apart (more than 250 m),
2) the work is susceptible to interference from external noise (aircraft, dogs and traffic) and requires a great level of skill and patience,
3) smaller leaks are mostly missed, and
4) the method is not suitable for plastics pipes.

7.1.4.2 In-depth surveys will comprise area metering, with sectoring or step-testing and visual inspection, followed by intensive sounding (i.e. each and every pipe, fitting, fixture or component) and, where necessary, leak noise correlation.

a) The benefits are

1) a more effective operation,
2) the work is less affected by external noise,
3) the system is inspected at the same time, and
4) the method justifies a higher level of monitoring and control, probably utilizing extensive personal computer (PC) software.

b) The disadvantages are

1) a longer planning lead time is necessary,
2) the area needs to be prepared, incurring not insignificant costs,
3) normally some midnight work will be required,
4) the progress is slower (typically 3 km to 5 km a day),
5) disruption to supplies occurs, albeit during the early hours,
6) the work requires a 2 to 3 person crew,
7) costly scientific equipment and instrumentation are required,
8) a high level of skills is required, and
9) high dedication is required.

7.2 Factors that affect water loss surveys

The following factors affect water loss surveys:

a) The length of the distribution system determines the number of personnel required to cover the area over a two-year period.

b) Conversely, the number of personnel available determines the number of kilometres that can be covered.

c) Environmental factors can impede a crew's progress, for example
   1) climatic conditions such as extreme temperatures (both high and low) and inclement (stormy) weather,

   2) topographic circumstances, and

   3) urban factors such as inaccessibility of fittings for sounding, interference from traffic (heavy traffic will shorten the time available to do surveys), parked vehicles, pedestrians and ambient noise.

d) Various aspects of the system infrastructure play a role, for example

   1) pipe materials,
   2) pipe diameters,
   3) pressure,
   4) paved or unpaved overburden,
   5) the thoroughness of the documentation, and
   6) the degree of area preparation.

7.3 Factors that affect leak detection operations

Leak detection operations are affected by

a) environmental aspects, such as

   1) the water table,
   2) the soil material,
   3) the soil moisture,
   4) the surface material, and
   5) the character of the urban area,

b) the infrastructure of the system, such as

   1) pipe materials,
   2) pipe-bed material,
   3) pressures,
   4) the age of pipes and fittings,
   5) the use of cathodic protection,
   6) the depth to pipes,
   7) the size of leaks,
   8) the nature of access points, and
   9) whether covered valve boxes and other fittings are used, and

c) certain operational factors, such as

   1) the operators' ability (training level),
   2) the operators' keenness and dedication,
   3) the equipment used,
   4) the traffic noise, and
   5) the mapping and documentation.

7.4 Factors that affect specific techniques

7.4.1. Factors that affect LNC operations (see also **10.8.3** and **Annex F**)

These factors include the following:

a) the pipe material;
b) the pressure (i.e. audibility of the leak);
c) the size of leaks;
d) the equipment used;
e) the operators' ability (training level);
f) the access to contact points; and
g) the accuracy of the mapping.

7.4.2. Factors that affect noise propagation

The propagation of the noise generated by a leak in a pipe is affected by:

a) Dispersion. Noise generated by a leak travels in the water column, reflecting off the pipe wall as it proceeds away from the point of the defect. Each time the noise reflects from the pipe wall, a very small amount of the noise is lost. This phenomenon is referred to as noise dispersion. Softer pipe materials absorb a greater part of the noise than do harder pipe materials. Leak noise will therefore travel further along a hard steel walled pipe than it will in a plastics pipe.

b) Attenuation. Noise attenuation is the small loss of sound signal which takes place continuously as sound waves travel through water.

c) Diameter. Because the angle of reflection is flatter in a small diameter pipe than in a large one, noise will travel further in a small diameter pipe.

Therefore, for leak noise propagation, hard pipe materials of small diameter perform better than hard pipe materials of large diameter, as follows:

- steel, best– least attenuation
- black iron,
- copper,
- ductile iron
- cast iron good
- fibre cement (also asbestos cement)
- pre-stressed concrete
- concrete
- PVC and uPVC inferior
- high density polyethylene
- polypropylene
- polybutylene
- rubber worst – highest attenuation

7.5 Precautions during field operations

7.5.1. General operational precautions

The following precautions shall be followed during water loss survey work:

a) The relevant sections of the National Occupational Health and Safety Regulations shall be observed at all times.

b) When work is to be undertaken within a road reserve, the necessary traffic warning signs shall be deployed.

c) Road cones or equivalent shall be used to divert traffic from working sites.

d) It is preferable to walk down one side of the street and up the other side, rather than to cross back and forth across the road.

e) The laying of cables, fire hoses or other equipment across a road should be avoided.

7.5.2. Opening and closing of access cover

The following rules should always be adhered to:

a) Do it quietly, have consideration for the neighbourhood. Do not slam the cover.

b) Beware of bees, spiders and snakes in valve boxes and meter boxes or elsewhere.

c) Open the cover with the correct key, a large size screwdriver or similar tool; never use the ignition key of your vehicle!

d) Carry your organization ID with you at all times.

7.5.3. Entering a manhole

The following rules shall always be adhered to:

a) Never enter a manhole if you are working alone.

b) Do not enter a manhole chamber before aerating the chamber adequately. If it is deeper than 2 m or if there is water present in the chamber, do not enter without a safety harness with rope and without one or more members of the team standing by to assist in the event of an accident.

c) Never play the fool by replacing the manhole cover while someone is still inside the chamber.

d) Never smoke inside a manhole chamber.

7.5.4. Excavations

The following important safety rules shall always be adhered to:

a) Establish the location of all power cables, telephone cables, gas lines and other services (see **4.4.5.2**) before leaving the water depot or commencing to excavate.

b) Hand dig "cross-cuts" to verify the positions of other services before using heavy equipment to excavate.

c) Observe the appropriate safety regulations whenever excavations are made. Beware of wet soils which collapse sooner and with far more dramatic effect than do dry soils.

8. MONITORING AND EVALUATION OF THE SYSTEM

8.1 Water audit

8.1.1. A PC-based program for an effective water audit is provided, complete with PC disks.

8.1.2. A water audit is an accounting system that refines the water balance, which traces the path of water supplied through a water distribution system, from the point of production or ingress through to the end user or consumer, by comparing the volume of water entering a specific, discreet zone through the zone meter, with the volume of water registered by the consumer meters.

8.1.3. As for any other auditing system, the purpose for doing a water audit is to discover fraud, negligence, incompetence, etc., as well as to achieve the more positive aims of efficiency, proactive avoidance of water shortages, low loss levels and profitability and non-inflated water tariffs, and to identify good and bad management practices, and generally to account for the water.

8.1.4. Correct water auditing will require an account of relevant decisions taken, or not taken, by those in positions of responsibility. It will require the water services provider to justify those decisions and its actions. Explanations will be required of the extent of the unaccounted-for water, the amount of resources spent on combating the unaccounted-for water and the achievements of the water department of the water services provider in containing the unaccounted-for water.

NOTE – In Annex A an example is given where the incorrect presentation of statistical results creates an entirely erroneous perception of the water services provider’s performance. A well-conceived water audit will clarify the true situation and prevent such inaccurate representations.

8.1.5. The term “audit” implies inspection or evaluation by an outside body, institution or legal arbitrator, and it needs to be standardized to enable comparisons to be made with other audits.

NOTE – A suitable computer program for conducting a water audit in a standardized manner is included in the pocket at the back of this standard (see Annex M).

8.1.6. Water audits shall take place at regular intervals of not longer than a year.

8.1.7. The water services provider should regularly monitor the midnight sewer flows as an indicator of possible on-site leakage, especially in unmetered areas. The midnight sewer flow should then be compared with the minimum night flow rate for the area. Allowance should be made for the lagging effect of transport through the sewers.

8.1.8. Individual site audits can assist in controlling water wastage through consumption benchmarking. Even though no water may be leaking from the pipe work, high wastage of water could nevertheless be occurring. This could be leaking fittings downstream of the consumer meter. Typically, this occurs in residential areas where payment levels are low and through wasteful user habits when the cost of water is included in the rent or in the rates, or where the cost of water is insignificant compared with the running costs of the establishment such as at hospitals, airports, mines and manufacturing/processing plants, etc. By auditing downstream usage, norms can be determined from similar activities elsewhere and compared with actual consumption.

8.2 Information required for a meaningful water audit report (WAR)

8.2.1. A diagrammatic layout sketch of the water distribution system shall form part of any water audit. It enables the auditor to know what it is that is being audited.

8.2.2. The diagrammatic layout referred to in 8.2.1 should show, *inter alia:*

a) reservoirs, with, in an adjacent block, a description of their size and capacity;

b) source/supply bulk meters, with a description of their size and readings;

c) district meters, with a description of their size and readings;

d) where sub district and zone meters are permanently installed, a description of their size and readings;

e) a tabulation of the size, character and development type of each zone, sub district and district, which reflects the physical nature of the development (residential, industrial, commercial and the numbers of each) within each sector being served by the meter, and indicates the number of metered and unmetered connections and the expected design consumption for each of these areas, the minimum night flow rate, unaccounted-for water, the V_{add}/V_b ratio and the extent of universal metering, the date of installation of the consumer meters and an estimate of the average inaccuracy of these meters, based on local spot tests;

f) a tabulation of the type, size, description and the readings of each type of meter (other than a consumer meter), when it was last calibrated, when it is due for further calibration and the manner of the calibration (whether in situ or on a laboratory test bench), the extent of refurbishment, whether an in-situ test was done after reinstallation to check installation effects; and

g) similar information to that given in (f) above in the case of bulk meters that measure the outflows from the water distribution system.

8.2.3. Essentially, a water audit is an information system that helps the water services provider to become more aware and the auditor to make an accurate evaluation of each authority's performance.

8.3 Financial analysis (see also 5.5)

8.3.1. The cost of leakage control includes expenditure on policy implementation (by-laws) and on specialized loss detection crews, and the cost of the water lost. These are all recoverable in the form of consumer charges. Other immediate costs include electricity, chemicals and bulk supply charges. Longer-term costs are associated with volume related capital expenditure.

8.3.2. Generally, as a first approximation, unaccounted-for water should not exceed somewhere between 15% and 25% of the annual volume of water produced in any twelve-month period. The water services provider should determine what is a reasonable amount of money to spend on water loss control, given the total production cost of water for the same twelve-month period. The availability of water, and therefore the value of water, will be a significant factor in the equation.

8.3.3. To find the economic level of leakage, one determines the financial costs of active leakage control, the total losses for a specific area and the marginal cost of available water and pressure management options. These factors can be combined into various assessment formulas.

Cost/benefit relationships are based on historic records, whereas the IRR and the NPV analyses (see **4.2.4.1** and **4.10.2.16**) look at future scenarios.

8.4 Benefits of a water loss control programme

8.4.1. Under semi-arid conditions, the primary benefit of a water loss control programme lies in the volume of water not wasted, financial benefits being secondary by comparison. Some further benefits are

a) reduction of water losses,

b) more efficient use of existing water supplies,

c) deferred construction of new facilities,

d) increased revenues,

e) reduction or increase of tariffs on the basis of the economic environment(prevailing economic conditions), and

f) decreased expenditure on purchasing or producing water, owing to, for example

  1) lower volumes of water required,

  2) reduced power costs,

  3) reduced chemical costs for waste water treatment, and

  4) reduced pollution of the environment.

The above points are all proactive objectives of the water services provider**.**

8.4.2. On the operational side, the resulting improved knowledge of the water distribution system also leads to

a) quicker response to call-outs,

b) better knowledge of where the water goes,

c) improved system efficiency/optimization through reduction of meter errors and better maintenance,

d) reduction of non-physical losses through a better understanding of the system and a broader outlook on community needs,

e) reduced property damage, such as from water seeping into basements, etc.,

f) improved public relations,

g) acceptance of demand management principles and options, and

h) renewed interest and motivation of the water department staff, leading to improved productivity.

8.4.3. A water loss control programme should be seen as an ongoing activity because, as mentioned in the introduction (see page 1), the cost of water is going to rise, making the cost/benefit of such programmes even more favourable. In addition, if an annual water audit has to be prepared, a water loss control programme will reduce the deficit. In the absence of even a rudimentary water loss control programme, the water services provider will have to resort to crisis management, which is both highly undesirable and inefficient.

9. OPTIMIZATION AND PRIORITIZATION OF CORRECTIVE MEASURES

9.1 Passive leakage control

9.1.1. Passive leakage control consists of dealing only with those leaks and bursts which are reported to the water services provider by members of the public (see **10.6.6**).

9.1.2. If a water services provider performs only passive leakage control, underground leakage will continue to occur and remain undiscovered until, eventually, the input to the system fails to meet the consumer demands plus the losses, and consumers do not receive adequate supplies.

9.1.3. Passive leakage control will usually result in losses in excess of 25 l/h per connection.

9.2 Active leakage control

9.2.1. Active leakage control comprises a logical series of steps which the water services provider takes to aggressively reduce water losses through the systematic eradication of leaks. These steps include the following:

a) placing and preparation, which covers

   1) bulk metering or the measurement of the bulk water put into supply,

   2) pressure control and reduction,

   3) district, zone and area metering, and

   4) sectoring.

b) detection, which covers

   1) visual inspection,

   2) step-testing,

   3) sounding,

   4) pipe location,

   5) leak noise correlation,

   6) ground moisture determination by radar (“ground radar”),

   7) infrared scanning,

   8) gases and sniffers, and

   9) pinpointing the leak position, and

c) remedial action, which covers

   1) excavation, and

   2) replacement or repair.

9.2.2. The objective of active leakage control is to limit the duration of underground leaks, and comprises any ongoing activity that is specifically aimed at the location and repair of underground leaks.

9.2.3. An active leakage control programme includes the introduction of PRVs and flow-modulated pressure-control valves to reduce the operating pressure.

9.2.4. As shown in figure 19, the cost of moving from an intensive active leakage control programme to no action, i.e. passive leakage control, does not follow a straight line. Moreover, doubling up the active leakage control activities will not halve the losses. The number values on the curve will differ from place to place but the form of the line will remain largely the same.

The cost increase for an active leakage control programme accelerates as the level of leakage approaches the level of background losses. Conversely, the level of leakage will be high if the cost of active leakage control approaches zero, i.e. passive leakage control.

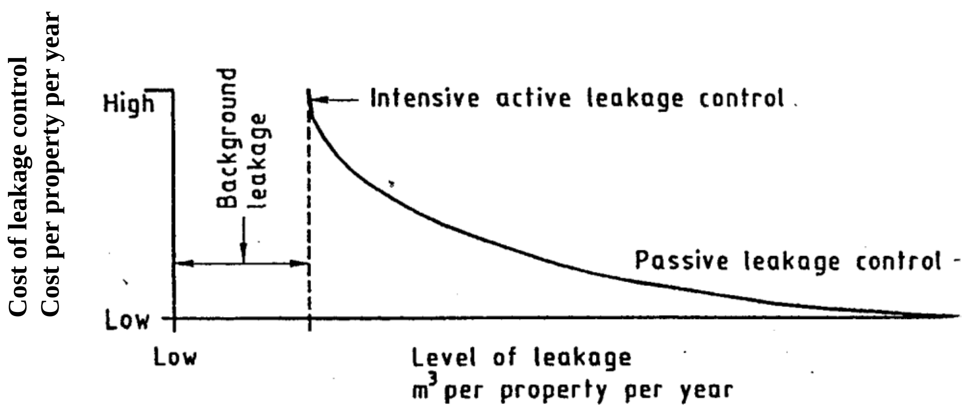


Figure 19 — Costs of active leakage control vs passive leakage control

9.3 Design considerations

9.3.1. Water distribution systems

9.3.1.1 Designing water distribution systems for water management is the first priority of any water management programme. Leakage will claim top priority over all other consumers. In any system, first the leaks are filled and what is left goes to the rest of the consumers.

9.3.1.2 Water-wise reticulation will keep water conservation in mind. This requires that there be sufficient and, most importantly, strategically positioned valves, pressure-control devices, meters and monitoring points so that each zone or area can be monitored accurately to observe the rate of growth in night flows. This implies a compatible monitoring system, a water balance spreadsheet and the software capability to analyse incoming data.

9.3.1.3 The conventional design of a large diameter main with multiple feed points into a development area does not lend itself to good water loss management practice.

9.3.1.4 Although difficult to achieve in the planning for future developments, excessively sized pipes should be avoided since this will result in lower velocities which will enhance sediment accumulation (insufficient scouring power) and also promote corrosion of metallic materials in contact with the water. While the pipeline is underutilized, the district meter will effectively be oversized, with consequent cost and accuracy penalties (see **10.2**).

9.3.1.5 Dead-ends (see **3.1.17**) should be avoided because they will enhance corrosion and affect the quality of the water standing in the pipe.

9.3.2. Materials, components, fixtures and fittings

9.3.2.1 The inappropriate selection of materials, components, fittings or fixtures can lead to leaks and water wastage, and also to fruitless expenditure by and adverse criticism of the water services provider.

9.3.2.2 Materials acceptable for use in water distribution systems comprise

a) plastics,

b) stainless steel,

c) galvanized steel,

d) black iron piping,

e) cast iron,

f) steel suitably coated and lined for corrosion protection,

g) fibre cement,

h) glass-reinforced plastics,

i) pre-stressed concrete, and

j) copper.

9.3.2.3 Materials, components, fittings and fixtures used in a water supply system shall be in accordance with the relevant ZABS specification and approved for use in Zambia. Items shall be so selected that they are suitable for the expected conditions of use.

9.3.2.4 In order to ensure the correct selection of materials and consequent corrosion protection mechanism, such as coatings, cathodic protection or alternative low-corrosion materials, extensive soil resistivity tests and analysis need to be done before the design is finalized and a pipe material selected.

9.3.2.5 Proof of quality and performance of materials, components, fittings and fixtures not covered by this standard or by another appropriate standard, shall be established by tests or by reference to other standards.

9.3.2.6 When materials, components, fittings and fixtures are being selected, the following factors shall be considered:

a) life cycle costs;

b) internal and external corrosion;

c) compatibility of different materials;

d) aging, fatigue and temperature effects;

e) mechanical properties;

f) compatibility with various water loss control techniques;

g) durability;

h) availability;

i) periodic service availability;

j) possible need for back-up service;

k) standardization of manufacture (to enable efficient maintenance to be carried out); and

l) training for water management division personnel in the installation and use of the equipment.

9.3.2.7 Non-metallic pipes cannot, currently, be easily traced using conventional pipe locating devices. Systems should therefore be designed with this in mind. Non-metallic pipes should be installed with a straight line of sight between valves, hydrants or other visible fittings. Where this is not possible, a plastics strip incorporating a stainless steel thread should be placed above the pipe and fixed to the pipe work at either end, to enable the use of conventional metal-detecting pipe locators. It is unlikely that convenient technology to trace non-metallic pipes underground will be developed in the foreseeable future. One available technique impresses a high frequency noise vibration into the pipe and a device traces this on the surface.

9.3.2.8 The plastics strip mentioned in **9.3.2.7** is also available without the stainless steel thread. Such a strip that is placed 300 mm above a pipe will give warning to contractors that a water pipe is buried below. It is recommended that such warning strips be placed above all pipes of diameter larger than 50 mm and any other pipe deemed to be of a strategic nature, such as a pipe serving a hospital or clinic. The installation of warning strips is particularly recommended in cases where the distribution water mains are installed before development takes place in an area.

9.3.2.9 All materials, components, fittings and fixtures in every part of a water distribution system shall operate effectively under all normal conditions likely to be experienced.

9.3.2.10 The selected fittings or components or any other apparatus shall not induce pressure surges that can cause damage to any part of the water distribution system under normal usage.

9.3.2.11 The use of dissimilar metals shall be avoided wherever practicable, especially in below-ground installations. Special measures shall be taken to prevent corrosion where pipes, pipe joints or connected fittings are of dissimilar metals.

9.3.2.12 Fire hydrants serve a valuable function in water management. For this reason, the selection of a particular pattern shall be carefully considered (see **10.8.1.2** and **10.8.1.3**).

9.3.2.13 Waterworks valves in an active water loss control area will be operated many times. Correct valve selection, therefore, could result in significant cost savings through lower maintenance costs. The selection of valves that have the same closing direction will be an advantage, as will the avoidance of "fragile" types of valve.

9.3.2.14 Flow in water distribution mains can be impaired by

a) air pockets forming at high points in the system,

b) sediment accumulation at low points,

c) defective valves or other fittings (PRVs, NRVs and meters),

d) rust tubercles (also resulting in “red water” and staining),

e) scale formation and lime deposits in pipes, and

f) bad workmanship, such as non-alignment, badly made connections, etc.

9.3.3. Designing for meter testing

NOTE – Meter testing procedures are dealt with in 10.3.

Preferably, all water meters should be tested in situ (see **10.3**). In the case of larger size meters (>100 mm), special structures involving a bypass facility to enable the periodic installation of a test meter or pitot tube need to be designed into the system. This requirement applies equally to district, sub district and zone meters, and also to meters supplying large consumers. The detailed procedures are described in Annex **G**.

9.3.4. Designing for meter protection against unrecorded reverse flow situations

9.3.4.1 Few, if any, water meters are designed to measure reverse flow accurately and to indicate that such a reverse flow has taken place.

9.3.4.2 The meter itself may not be damaged by reverse flow but unless such a reverse flow is accurately recorded, it will cause havoc with any endeavours to determine an accurate water balance within the system and will render results meaningless.

9.3.4.3 All meters, especially bulk supply meters, where the possibility of reverse flow during the night or during low pressure situations (when the mains are being worked on) exists should be protected against a reverse flow occurring by the installation of a suitable reverse flow limiting device.

9.3.4.4 Ideally, district metering points should be designed as control stations to control both flow direction and pressure.

9.3.4.5 Before a reverse flow control is installed, the system should be analysed to determine whether reverse flow occurs on a regular basis. If that is the way the system is meant to operate, the installation of the control could lead to water shortages in some areas, depending on demands elsewhere in the system.

9.3.5. Designing for pressure control

NOTE – Pressure-control devices are dealt with in 9.4.

9.3.5.1 A crucial and fundamental design consideration is that of maintaining pressures at adequate levels, ideally not less than 200 kPa and not more than 500 kPa.

NOTE – In areas where non-affordability suggests that a lower level of service would be more appropriate, normally occurring (uncontrolled) pressures could be as low as 150 kPa for individual consumer connections and still deliver an adequate supply of water. In the case of community standpipes that serve a number of households, such pressures could result in unacceptably long waiting times and queues, and communities should be consulted whether the extra cost to raise the pressure is acceptable to the community. Fire-fighting requirements should also be seriously considered before such a low pressure is accepted.

9.3.5.2 Excessive system pressures accelerate the flow rate through defects in a pipeline, boosting unaccounted-for water considerably. Conversely, reducing pressure will cause a proportionate reduction in leakage, as shown in figure 20. Although the scope for pressure reduction might be limited by a number of physical factors, reductions in pressure are likely to be worthwhile where it is appropriate to effect them. Typically, pressures rise during the night when consumption reduces. If a high night flow rate into an area is observed, consideration should be given to the fitting of a pressure control device to reduce pressure at night, thus reducing the losses considerably. Such a device could be either a permanent or a temporary feature.

NOTE – Experience has shown that pressures vary widely from as high as 1 500 kPa to below 200 kPa. The average pressure in water supply systems is of the order of 500 kPa. This value is used internationally as a universal reference pressure for comparison purposes.

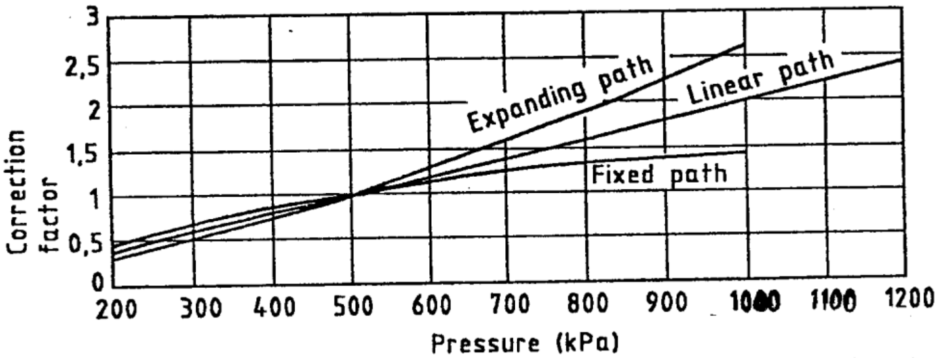


Figure 20 — Correction factor vs pressure for expanding, linear and fixed leakage paths

9.3.5.3 Water services authorities are well advised to urgently address the problem of excessive pressures in their water distribution system, with a view to reducing the unaccounted-for water and attaining a more favourable water balance in the process, before finding or repairing even a single leak.

9.3.5.4 The effect of pressure on leakage will be different for different pipe materials. A split in a plastics pipe will expand when subjected to increased pressure, causing more water to escape. The same applies to leakage through O-rings, valve packings, etc., and the pressure/leakage relationship will follow an expanding leakage path. In the case of corrosion damage in steel mains, the defect remains "fixed" over the short term and a fixed leakage path will dominate.

9.3.5.5 Report 26 of the Water Research Centre in Stevenage in the UK proposes correction factors based on an expanding leakage path. Table 6 gives the appropriate correction factor to compare water losses in an area at one pressure with the losses in another area at a different pressure, by converting them both to the equivalent loss rate at the reference pressure (500 kPa). For example, a loss rate of 4.3 m^3 /h in one area at 300 kPa pressure is equivalent to 4.3/0.529 = 8.13 m^3 /h at 500 kPa. Similarly, a loss rate of 9.7 m^3 /h at 700 kPa in a second area is equivalent to 9.7/1.565 = 6.19 m^3 /h at 500 kPa. Clearly, the first example is a "worse" case than the second, although that may not have appeared so initially.

NOTE – While the above pressures remain unaltered for both areas, there will always be more water lost in the second area than in the first. However, should the water services provider decide that the 300 kPa pressure is too low and raise it, or decide that the 700 kPa pressure is too high and lower it, they need to be aware of the possible consequences of their actions. This technique of using pressure correction factors is also aimed at predicting the probable nature of the leakage in any area (see Annexes B and C).

Table 6 — Correction factors for various pressures (expanding path model)

Pressure (KPa)	Correction factor
200	329
300	529
400	753
500	1000
600	1271
700	1565
800	1884
900	2226
1 000	2592

9.3.5.6 From figure 20 and Table 6, it is possible to quickly assess the savings that would arise from introducing or refining pressure management.

9.3.5.7 Fringe effects of pressure reduction are reduced consumer consumption, lower consumer bills (and therefore also reduced income), lower burst frequency and repair costs, and lower total water losses.

NOTE – The considerable influence of pressure on the flow rates through leaks and bursts and on burst frequencies, is well known. It is therefore surprising that no attempt has previously been made to introduce pressure as an explanatory factor when comparing leakage control performance measures or setting targets for night flows or annual losses.

9.3.5.8 In any water distribution system, both "expanding" and "fixed" leakage paths will exist, with the pressure/leakage relationship depending on the proportion of each in the network at any particular time. There is therefore no single relationship that can be universally applied. The actual relationship can be identified by night calibration tests in which the night pressure into a system, or portion of a system, is changed and the corresponding changes in night flow are analysed.

9.3.5.9 The proportionate reductions in leakage that arise from a reduction in pressure are, therefore, in practice, more likely to fall within the upper and lower limits of the curves shown in figure 20, which represent "all fixed paths" and "all expanding paths". The central line is a linear relationship midway between these two extremes. The linear relationship would be an appropriate assumption for pressure/ leakage calculations where no calibration tests have been undertaken and little is known about the types of pipe in the system.

In cases where plumbing losses are known to be low, bursts are speedily located and repaired, and leakage is close to predicted background levels, the relationship could be closer to the "expanding paths" curve. Where a large proportion of losses is from fixed-size holes (typically, corrosion holes in metal pipes or broken plumbing fittings), the relationship could be closer to the "fixed paths" curve.

9.4 Pressure-control devices

NOTE – Designing for pressure control is discussed in 9.3.5.

9.4.1. Pressure reducing valves (PRVs)

9.4.1.1 PRVs release water at a constant pressure; moreover, recent developments such as pressure-sustaining valves or preset flow valves can sustain a constant pressure and flow respectively. These valves can be mechanically, hydraulically or electronically activated.

9.4.1.2 As with any other valve or fitting, a PRV should be carefully and correctly selected in order for it to performe its design function within its specification.

9.4.1.3 The ability of a PRV to be repaired or serviced in situ could be an important aspect in the selection of a valve. For reasons of standardization, a water services provider should endeavour to use only one make of valve for each type of installation.

9.4.1.4 The most common types of PRV are

a) spring-loaded diaphragm valves,

b) weight-operated control valves,

c) piston-operated control valves,

d) diaphragm-operated control valves, and

e) flexible sleeve PRVs, which include:

   1) collapsing diaphragm control valves, and

   2) rolling diaphragm control valves.

9.4.1.5 Most PRVs come with specific installation and operating requirements set by the manufacturer, which shall be adhered to at all times. Other considerations in the selection of a PRV comprise the following:

a) sizing;

NOTE – A PRV that is too large will be unstable at low flows, resulting in pressure surges, and a PRV that is too small will impair service delivery.

b) failure mode; and

NOTE – Failure in the fully open or partially open position renders the downstream pressure equal to the upstream pressure. This could have serious implications, especially for private plumbing installations.

c) cavitation, taking the following factors into consideration:

1) Cavitation in PRVs is a complex issue. Where alternative sites are available for installing the valve, the site with the higher resultant outlet pressure will reduce the likelihood of cavitation.

2) When the outlet pressure is set close to atmospheric pressure (about 0.75 bars), cavitation can occur. Cavitation results in destructive wear to both the valve and the downstream pipe work.

3) Cavitation creates high noise levels.

4) At low pressures when the valve oscillates between open and shut positions, severe water hammer will occur, with the risk of major damage.

5) Accurate performance requirements shall be provided when enquiries are directed to potential suppliers.

9.4.1.6 The outlet pressure setting of a fixed outlet pressure-control valve is determined by downstream conditions, which include

a) the required level of service at the "worst case" point,

b) the elevation difference between the valve and this point, and

c) friction losses under peak flow situations.

9.4.1.7 For more complex systems a variable outlet-pressure control valve might be preferable to the fixed outlet pressure type. These valves can modulate the outlet pressure according to the flow rate, and no external power source is required. The cost of a variable outlet-pressure control valve is only marginally more than the fixed pressure type. The variable outlet-pressure types are, however, difficult to set up. Setting the valve is best achieved by installing the valve in a test rig that is capable of delivering the peak design flow and, after setting, installing the preset valve in the field. Alternatively, fire hydrants downstream of the valve can be opened until the peak design flow is achieved and the valve is set accordingly, in situ.

9.4.1.8 In more advanced systems, electronic controllers can decrease the diurnal pressure variation by monitoring either time of use or system demand.

9.4.1.9 A variety of different makes are available commercially and an in-depth study of the available models shall be made prior to selection. Expert opinion is advisable.

9.4.2. Pumps

9.4.2.1 Two types of pump are available:

a) fixed-speed pumps; and

b) variable-speed pumps.

Each type of pump has a unique application and each choice needs to be carefully considered. Again, expert opinion is advisable.

9.4.2.2 For on/off use such as filling a tank or reservoir (usually operated by a float switch), the fixed speed pump is ideal. The variable-speed pump offers increased flexibility, especially when installed direct into the supply main.

9.4.2.3 Broadly, three categories of variable-speed pumps are available:

a) electromechanical drives;

b) variable-speed motors; and

c) electronic variable-speed drives.

9.4.2.4 The main considerations for the selection of a variable-speed pump are:

a) the availability of higher operational flexibility;

b) savings in power consumption;

c) the decrease in pump costs;

d) the improvement of the efficiency of units, which results in longer pump life; and

e) the avoidance of excessive system pressure when consumption is low.

9.4.3. Notification of pressure change

9.4.3.1 Before embarking on an exercise to reduce pressures, it is advisable to notify the affected consumers of the proposed change, to facilitate the pressure reduction programme. By pointing out the advantages to consumers beforehand, one can ensure that few will object once the programme has been completed.

9.4.3.2 The following notification procedure is recommended to notify affected consumers:

a) In the case of high-rise buildings and other circumstances where pumps or other special equipment might have to be installed, give three months notice prior to pressure change.

b) In the case of a fire brigade, give three months notice.

c) For all other consumers, give six weeks notice.

d) If the pressure change is to be more than 200 KPa, preferably alter the pressure, at intervals of one week apart, in steps of not more than 200 KPa, until the target pressure is achieved.

e) Investigate and possibly readjust pressures in the light of valid consumer complaints. In some instances, consumers might have to be served from an adjacent zone where the pressure is higher. In such cases, the necessary amendments have to be made to the verification survey database, the zone boundary has to be changed and the address and other details have to be transferred to the new zone.

10. Implementation of corrective measures

10.1 Specific requirements for metering

10.1.1 Mechanical meters for use in water distribution systems shall comply in all respects with the requirements of the relevant ZABS specifications, and with the relevant requirements of the Weights and Measures Act CAP 403 of the laws of Zambia

10.1.2 All meters shall be installed strictly in accordance with the manufacturer's instructions.

10.1.3 Because of the large volumes of water that could be involved, all bulk meters, including the bulk supply meters should be capable of accurately metering any reverse flow that might occur, and should be fitted with a monitoring device capable of reporting the reverse flow condition and the volumes of water involved. Failure to install such a system could play havoc with the meter readings (and make any attempts at a water balance ludicrous). Plots of the flow rate over a period of a week should indicate the occurrence of a reverse flow condition, if it occurs on a regular basis.

10.2 Sizing of meters

10.2.1. All meters larger than 15 mm (identified when undertaking the district, sub district or zone inventory (see 4.4) shall be checked for correct sizing.

10.2.2. It is very important that when the minimum night flow rate is being measured, the lower end of the accuracy range of the meter used is lower than the minimum flow rate, otherwise the indicated flow rate will, to all intents and purposes, be meaningless. In such an event, a smaller, temporary meter connected to fire hoses on either side of an isolating valve and thereby bypassing the larger meter, should be used.

10.2.3. When developing new areas over an expected long period, it makes economic sense to taper down the supply pipe from say 300 mm and install a 200 mm meter until development has reached between half and two-thirds of the full development. To upgrade the meter at that time is a simple task which could coincide with the need to replace the meter.

10.3 Meter testing

NOTE – Designing a system to enable in-situ testing of water meters are discussed in 9.3.3. Detailed meter testing procedures are described in Annex G.

10.3.1. The following test methods are not intended to replace the verification tests required in terms of the Weights and Measures Act CAP 403 of the laws of Zambia and no seals may be broken or adjustments effected. The purpose is purely to give the water services provider an indication of the in-situ accuracy of the water meters, for purposes of water balance reporting.

10.3.2. In-situ testing of water meters is necessary to determine their accuracy under installed rather than test-bed conditions. Meter accuracy is influenced by age, conditions of installation and correct sizing. (The volume and the quality of the water passing through the meter both influence the significance of the age of the meter.)

10.3.3. The in-situ testing of meters over time will indicate a deteriorating trend in meter accuracy. This trend is used to optimize the replacement period for meters under the particular field conditions.

10.3.4. The recommended method (see **9.3.3**) for testing all water meters is in-situ testing. This can be achieved using an in-line comparative test with laboratory calibrated equipment, preferably placed at a distance equal to 30 pipe diameters downstream or 15 pipe diameters upstream of any bends, obstructions, fittings or other flow obstacles in the pipe. Where this cannot be achieved, distances of 10 pipe diameters and 5 pipe diameters respectively are the absolute minima for the above distances. Below these the test becomes meaningless.

Alternatively, the volumetric method described in Annex **P**, which provides for in-situ testing by means of open test measures that can hold at least one minute's flow at the flow rate being tested, might be preferred.

10.3.5. Mechanical meters of diameter 50 mm up to 800 mm are available. The smaller size meters (of diameter 50 mm up to 300 mm) need to be tested at least every two years and the larger meters (of diameter 400 mm up to 800 mm) even more frequently. Experience might suggest longer periods for new meters and a shorter period between tests for older meters. This calibration is best carried out in situ and the facility for this requirement should be incorporated at the design stage (see **9.3.3).**

10.3.6. Non-mechanical meters shall be recalibrated in accordance with the manufacturer's instructions, but not less than annually.

10.3.7. Various types of insertion meters can be used to test large meters in situ. These include turbine insertion meters, considered the preferred device by the World Bank (Technical Paper No. 72, 1987), electromagnetic meters and the pitot tube, which is a simple differential pressure meter that measures the rate of flow by determining the square root of the difference between the upstream and downstream pressures. This difference is measured on a manometer and is converted into flow units. According to Stewart Scott Inc, single-point pitot tubes will require a velocity profile to be determined. The advantages of insertion meter testing are

a) portability,

b) simplicity,

c) good accuracy (3 %, depending on the skill of the operator), and

d) the fact that internal pipeline conditions can be determined when measuring the inside diameter of the pipe.

10.3.8. To ensure accuracy, the following shall be avoided:

a) upstream turbulence,

b) velocities below 0,3 m/s,

c) air in any of the equipment,

d) leakage,

e) blocked apertures, and

f) human error in taking measurements.

10.3.9. Subject to the conditions in **10.3.4**, the test meter can be placed either upstream or downstream of the meter being tested/calibrated. The actual distance between the two meters is, within reason, not important.

10.3.10. Meters of diameter less than 100 mm can be tested by metering the flow from a fire hydrant, using laboratory calibrated equipment and a fire hose to achieve the required straight sections (see **10.3.4**).

10.3.11. Consumer meters of diameter 15 mm and 20 mm can be similarly tested by using a garden tap and a laboratory meter or weighing device. Procedures for in-situ testing of meters are described in Annex G.

10.3.12. As it is not uncommon for up to half of the water supplied to go to only 10 % or 20 % of the consumers, it is especially important to keep the larger size meters calibrated.

NOTE – A small discrepancy (5 %) on a 100 mm diameter meter would normally "lose" far more water than a large error (20 %) on a 15 mm diameter meter.

10.4 Unmetered water

10.4.1. The components of unmetered water use, authorized or unauthorized, are listed in **6.2.1.**

10.4.2. The use of unmetered water shall not be tolerated by any water services provider, whether within its own area of supply or to any other area where it supplies in bulk only.

10.4.3. Even in areas where universal (individual) metering cannot be implemented, or is impractical or uneconomical to implement, some sort of zone, block, street, building, site or other type of group metering shall be installed, whether to recoup revenue or merely to keep record of where the water goes and in what per capita quantities, for purposes of comparison.

10.4.4. In cases where unmetered water is delivered, unaccounted-for water can be drastically reduced by the simple expedient of installing consumer, group or mini-bulk meters upstream of the unmetered consumers. For each case an inventory of the consumers shall be done and an estimate made of the expected consumption, based on the number of residents. Monthly meter readings are then compared with this estimate to determine wastage or leakage. If the actual consumption exceeds the estimated consumption by more than 20 %, the water services provider shall immediately establish the reason and take any remedial measures necessary. A minimum night flow rate test will indicate the likelihood of leakage.

10.4.5. The local Authorities shall submit monthly a fire water audit report to the CEO of the water Utility, indicating an estimate of the amount of unmetered water used by the fire utility, for what purpose it was used (fires, drills, hydrant flushing, testing, etc.), and the method of estimation.

10.4.6. The location and nature of all fires that were fought with water, whether metered or unmetered, shall be listed.

10.4.7. Even water used during maintenance operations shall be measured. However, if this is not the case the following values can be used to estimate the volumes of water used for each operation:

Mains:

- flushing: 3,0 times the volume of the pipe section to be flushed
- swabbing: 2.5 times the volume of the pipe section to be swabbed
- air scouring: 2.0 times the volume of the pipe section to be scoured
- scraping and relining: 4.0 times the volume of the pipe section to be relined
- commissioning: 3.0 times the volume of the pipe length to be commissioned

Service reservoirs:

- cleaning: 20 % of the full volume of the reservoir
- commissioning: the full volume of the reservoir
- fire fighting training: 0.5 m^3 per fire drill

NOTE – The above figures are intended only to bring these aspects to the attention of the water services provider. Each authority should establish its own techniques and procedures from which design norms for each operation can be established.

10.5 Equipment

10.5.1. Choice of equipment

10.5.1.1 When the equipment for installation into a district manifold is being chosen, it should be kept in mind that, generally, the most suitable meter/logger combination is not the cheapest.

10.5.1.2 Compatibility between the meter and the logger (or any other device to which the meter might be connected) shall be ascertained prior to purchase and installation.

10.5.1.3 If the water services provider's policy in any district, sub district or zone follows the operational procedure described in **4.7.5(b),** then, because the meter and logger are to be installed as and when required and left there only for as long as it takes to get the necessary information, and because the equipment is likely to be moved about from one manifold to another, robust construction of the meter and other equipment is a primary consideration.

10.5.2. Safe use of equipment

From figure 17, (see **6.3.3**) time is a water demand management tool. Damage to equipment is not only very costly, but could also take weeks or even months to repair thus delaying the discovery, location or repair, of a leak. The safe use of equipment is central to good water loss management and control, for example:

a) place equipment well out of the way of vehicles (especially your own) when working in a street;

b) load equipment carefully (do not just throw it into the rear of a vehicle);

c) secure equipment during transportation;

d) use the equipment for the purpose for which it was designed (for example, do not open valve box or meter box lids with the tip of a sounding stick);

e) water and electronics are incompatible (use plastics to cover the equipment, especially cable connections, whenever there is a danger of moisture);

f) ensure a firm magnetic contact before releasing your grip on a transducer;

g) do not drop transducers onto a pipe to get a better contact; and

h) do an inventory check not only of the equipment but also of tools as they are loaded after a job (it is very easy to forget some piece of equipment when loading up after a long frustrating work period).

10.5.3. Maintenance of equipment

10.5.3.1 Operators of leak detection equipment should not endeavour to undertake the maintenance of their own equipment. Most devices are protected by one or more fuses. If the device should suddenly go dead, especially upon switching on, it is good practice to check the fuses first. If the problem persists, take the device to the servicing agent or, failing that, to another expert familiar with the type of device.

10.5.3.2 Even the very best equipment requires regular and periodic maintenance. Cables, especially at the point where they enter the housing, are notorious for fatigue breaks. *Ad hoc* on-site repairs are not only irritating but also time-consuming, which is costly.

10.5.3.3 Weak batteries will reduce performance and cause instruments to be less sensitive, resulting in incorrect conclusions.

10.5.3.4 Certain electronic instruments such as pressure transducers, load cells and the LNC that uses radio links will require periodic recalibration. Special care should be taken to follow the instructions of the manufacturer. This might seem superfluous, but if it is not done, erroneous results will be generated and the entire leak location industry could come into disrepute because of the irresponsible practices of a few operators.

10.5.4. Operation of equipment

All instrumentation demands and deserves gentle treatment. Persons not trained in the use of leak detection equipment (or in anything else for that matter) should be discouraged from handling the equipment. This is particularly true when the equipment is being packed up at the end of a job, when inexperienced helping hands are overeager, simply to get the things loaded.

10.6 Public relations and public involvement

10.6.1. The public can expect that the water services provider which serves them is efficient. This will occur when the water services provider implements sufficient measures to ensure that the combined cost of active leakage control and the cost of water lost are at a minimum.

10.6.2. Consumers, in general, trust the water services provider that serves them.

10.6.3. Consumers firmly believe that it is the responsibility of the water services provider to promote water loss control.

10.6.4. Consumers are opposed to the concept of simply raising water tariffs to cover water losses.

10.6.5. Consumers are concerned about their water accounts and the level of control they have over their bills.

10.6.6. The general public should be encouraged to participate in the water management programme by reporting visible leakage (see **9.1.1**).

10.6.7. Staff members, bus drivers, postal delivery service people, meter readers and others should be encouraged to observe and to report unusual occurrences, such as the one or two trees in an avenue which are considerably larger than the rest, or green patches of grass or veldt against an otherwise dry background. However, do not dig without first confirming the existence and location of a water pipe, followed by sounding or correlating to confirm the existence of a leak.

10.6.8. It is good practice to give the public recognition for their participation. This is best achieved through the medium of municipal newsletters, notices accompanying the water account, media interviews and press releases.

10.6.9. A public "water report" desk and telephone help-line service shall be continuously manned at least during normal office hours. In larger towns and cities this could be extended to a twenty-four hour service

10.6.10. A standard procedure shall be developed in the case of incoming reports, to enable a report back to be made. This is particularly good practice in the event that no defect is found and consequently no sign of activity in the street is apparent to the person who made the report and who might otherwise perceive that "nothing was done".

10.6.11. The loss detection crew or contractor shall be capable of responding quickly to such public reports, to keep the public awareness drive motivated. This response shall not take longer than 48 hours.

10.6.12. The activities and statistics of the "water report" desk will form an integral part of the water service provider's report to its Board of Directors.

10.6.13. Public participation will not simply "just happen" as the right of the water services provider, but will need to be developed by active public awareness campaigns and through education. These initiatives are not done in isolation but are planned with central government initiatives. Water services authorities should also build alliances with local industries, so that the industry's advertising campaign and the message being given out by the water services provider, coincide. A united front of: "We support water conservation" needs to be promoted as a sort of ethic or culture within the area of supply.

10.7 Costing evaluation

10.7.1. Because of the scarcity of potable water in Zambia, benefits will outweigh costs as long as the cost of leakage reduction is below the marginal cost of developing new sources of water needed to replace the water lost. Additional benefits (see also **8.4.1**) include:

a) reduction in running costs,

b) deferment of expenditure on capital works, and

c) the extended availability of existing water.

10.7.2. Items to be considered when the cost of leakage control is being determined include

a) district manifold construction, either permanent or temporary,

b) cost of district meter (proportional),

c) cost of data-logging,

d) cost of analysing data,

e) performance of step-test operations,

f) necessity to the step tests of prior maintenance to the valves and fittings,

g) sounding of consumer meters,

h) sounding of mains and fittings,

i) pipe location,

j) additional consumer meter reading,

k) location and repair of backlog of leaks found during the sounding survey,

l) installation of PRV,

m) use of LNC or other detection technique,

n) repair of indicated leaks,

o) cost of capital equipment, such as vehicles, sounding apparatus, correlator, pipe and valve locators, excavator, etc.,

p) updating of water distribution system plans and drawings,

q) transportation costs, and

r) staff costs (operational and administration).

10.8 Water loss control methods

10.8.1. Step-testing

10.8.1.1. Step-testing still forms the backbone of many water management operations. Some operators prefer to carry out step-testing at night when consumption is at its lowest and the pressure consequently high. Others, however, prefer to operate during the day. Using modern state-of-the-art equipment and top-trained operators, step-testing can be very successfully applied during the day.

NOTE – It is recommended that, if a water services provider is unable or not prepared to service all of the isolating valves and to install hydrants with a rising jumper or a foot valve, step-testing should not be contemplated.

10.8.1.2. In water loss management areas that are likely to be monitored through the same point regularly, the water services provider should consider installing two permanent fire hydrants, one inside and the other one outside the area, bridging a boundary valve that will be used as the supply point. These hydrants should be within a metre or two of each other and specifically placed there for conducting the step test.

10.8.1.3. Any water services provider contemplating using the step-testing method should take the following inconveniences into consideration:

a) The valves, hydrants and other fittings that are shown on drawings can often not be found in the field. It is recommended that the entire area to be tested be surveyed during the day, to verify the drawings. This should take place simultaneously with the servicing of these fittings prior to step testing.

b) Ideally, all valves in the area should be serviced before step-testing is carried out. As servicing is a routine maintenance function, it shall in any case be done periodically every five years, irrespective of any water loss control programmes.

c) Vehicles are often parked over the fittings to be operated. Where this is likely to be a problem, the area or fittings to be tested should be cordoned off at an opportune time before the test.

d) Valve gland packings often start to leak when the valve is operated, thus causing more leaks to exist after the step test than before. This can often be detected during a step-test procedure, by an increase in flow rate when the valve is closed.

e) Hydrants that are used to feed or receive water can present problems because they are not always suitably located.

f) Often, a permanent step-testing facility needs to be created by cutting-in a prefabricated test point in the pipe work that comprises two hydrants and an intervening valve.

g) Owing to the higher incidence of noises generated from many sources during the day, when step testing is carried out during the day, the length of pipe per test needs to be correspondingly shorter to maintain accuracy.

10.8.1.4. When step-testing is carried out at night, the following additional points need to be considered:

a) Step-testing is typically carried out between midnight and about 04:00 hours.

b) Experience has shown that night step-testing is limited to an area comprising approximately 30 to 40 valves, which is the practical maximum number of valves that can be closed, and reopened, in a 4 h to 5 h night shift.

c) The hour and the night temperature can make step-testing unpopular amongst staff.

d) Residents in the area could be disturbed by operations noise at the inconvenient hour.

e) Night testing is more costly than daytime testing and it is therefore essential that more care be taken to ensure that the test does not have to be aborted owing to a lack of preparation.

f) Often valves do not close completely and such test areas are difficult to isolate. Therefore, before a test area is entered at midnight, the area should be isolated during the day to iron out such difficulties and to obtain a pressure drop that confirms isolation.

g) Refilling the water distribution system after step-testing can cause serious damage if it is done negligently.

h) Working at night could be hazardous.

10.8.1.5. Connections serving consumer installations where continuous after-hours flow through the meter can be expected should be treated as isolating valves for the purposes of conducting a step test.

10.8.1.6. Before proceeding with the step-test programme, check that a pressure drop is attained. The rate at which the pressure drops can give a rough indication of the outflow from the water distribution system. However, the outflow is not necessarily all due to leakage.

10.8.1.7. After closing an isolating valve, use a sounding device to check that the valve is no longer allowing water to pass through.

10.8.1.8. If, after closure of an isolating valve, the flow rate increases, there could be three main causes:

a) the valve gland has started to leak;

b) inflow from another source has been cut off and this is now being compensated for by increased flow through the step-test monitoring meter; or

c) the valve was in a closed position and is now open, allowing additional flow to occur.

10.8.1.9. Counting the number of rotations of the valve key can, to an experienced operator, confirm the diameter of the pipeline and also indicate whether the valve has travelled the full reach of the gate**.**

10.8.1.10. After closing an isolating valve, re-open the valve marginally to flush out dirt caught in the pocket of the gate, before closing the valve again.

10.8.1.11. Check the direction of closing of the isolating valve. Waterworks valves close anticlockwise (left-hand) and, when a clockwise (right-hand) closing valve is used, most water services authorities will paint the valve box lid with a prominent colour (see **4.3.1.3**).

10.8.1.12. RSVs are known to be less robust than cast iron and other valves. Most water services authorities paint the valve box lid of a RSV a specific colour (see **4.3.1.3**) to indicate the presence of such a valve. Be on the lookout for these and handle them accordingly.

10.8.1.13. After the conclusion of a step test, the water distribution system shall be refilled in accordance with normal procedures. Hydrants need to be open at high points in each sector to allow the egress of air and to prevent water hammer. Failure to do so could result in serious damage to both pipes and fittings on both public and private property.

10.8.1.14. When refilling the water distribution system, open the isolating valve only partially, to control the velocity of the inflow into the pipe and so limit the severity of any shock wave that might occur, particularly if no hydrant is suitably positioned.

10.8.2. Sounding

10.8.2.1. The fundamental requirement with regard to sounding is that each and every pipe, fitting and fixture available has to be located and sounded.

10.8.2.2. Sounding cannot be hurried. Only great patience and dedication will yield satisfactory results.

10.8.2.3. All leaks do not make suitably audible noises, since many leaks (such as splits, glands, rubber seals, air release valves, open taps and loose threads) are not typical holes in the pipe.

10.8.2.4. Not all leak noises propagate equally well along the pipe length. (See also **7.4.2**.)

10.8.2.5. During sounding, extreme interference can be experienced from aircraft, barking dogs, traffic, transformers and substations, electrical motors, swimming pool cleaning equipment, etc., and if these cannot be stopped, great patience will be required.

10.8.3. Leak noise correlation

10.8.3.1. The factors that affect leak noise correlation are listed in 7.4.1. The operation of the leak noise correlator is described in Annex **F.**

10.8.3.2. The leak noise correlator is not a magic wand that will locate each and every leak on a water distribution system. It works only within certain parameters and is subject to fixed criteria.

10.8.3.3. Experience and dedication of the operator are crucial.

10.8.3.4. The transducers should make good, firm contact with the pipe or fitting.

10.8.3.5. When contact onto a non-metallic material is to be made, use a clamp, vice-grip pliers or a similar device to ensure a good contact.

10.8.3.6. The location, diameter and material of the pipeline should be known.

10.8.3.7. The total length of the pipeline between the transducers should be accurately measured. The accuracy of the final indicated leak position will depend on the accuracy of this information. Each time a leak position has been indicated, the operator should ensure that the correlator is not merely indicating the position of a junction. This requires further correlations, using alternative contact points, visual observations, or sounding that uses both direct and ground microphones.

10.8.3.8. A rod driven into the ground at the indicated position is also useful to indicate the likely existence, or otherwise, of a leak. However, be careful of other underground services.

10.8.3.9. Correlation can only take place if the leak noise travels.

10.8.3.10. Correlation is not simple. The operator requires intensive training and, above all, a unique dedication.

10.8.4. Fast Fourier transform (FFT) method

The FFT method is a process that after analysing the noise frequencies that fall within the leak noise band, selects the most prominent frequency. This facility is currently built into all modern-day LNCs.

10.8.5. Gas injection

Various approved gases can be injected into the pipeline and, combined with a compatible "sniffer" detector, can give a relatively quick and effective way of finding leaks of all sizes.

10.8.6. Ground radar (subsurface interface radar)

10.8.6.1. Ground radar apparatus is used to detect changes in density below the surface. It is most useful when mains are inaccessible for attaching transponders (microphones), when the pipe material is non-metallic, or when the location of the pipe is unknown.

10.8.6.2. Subsurface interface radar "sees" into the ground by means of radar frequency signals emitted from a transmitter. Depending on the dielectric nature of the ground into which the emissions are made, the signals are returned from the various interfaces in the ground to an antenna, and a computer enhanced picture is built up, which can be infinitely adjusted to highlight the features that are being searched for.

10.8.6.3. Water reflects radar particularly well, making radar eminently suitable to the task of leak detection. Because some rock and concrete are also reflective to a degree similar to the reflectance of water, it is essential to sink a probe into the ground when a leak is suspected, in order to confirm the presence of water.

10.8.6.4. The main advantages of ground radar are that it is entirely non-intrusive and is totally unaffected by external interferences such as noise or electrical interferences. This latter feature makes subsurface interface radar particularly suitable for use in busy city centres during normal working hours.

10.8.6.5. Hard surfaces do not significantly hamper its effectiveness but simplify its movement over the pipe trajectory.

10.8.6.6. When using radar it is often difficult to distinguish between leakage water and natural water stored in fissures or in the pipe trench, and other dense materials.

10.8.7. Infrared

10.8.7.1. Differences in surface temperatures can be distinguished using infrared technology.

10.8.7.2. Infrared is more suited to finding larger leaks than smaller leaks because a larger leak is more likely to reduce the surface temperature locally.

10.8.7.3. Solid surfaces such as tarred or concreted surfaces hamper the usefulness of infrared.

10.8.7.4. A model aircraft provides an ideal instrumentation platform for mounting an infrared video or a still camera. It is especially useful for over-flying pipelines laid through difficult terrain, such as water board trunk mains and delivery mains to remote mining operations. The method can also be applied to trace leakage from canal systems.

10.9 Effecting repairs on consumer installations

10.9.1. All detected leaks, whether on the distribution side of the consumer's meter or on the installation side, shall be repaired quickly and effectively. A maximum time of 48 h after the leak has been discovered shall be adhered to.

10.9.2. When a leak is discovered on the installation side of the consumer's meter, it is in the interest of the consumer to carry out the repair as soon as possible. In the interests of keeping water demand to a minimum, the water services provider might consider implementing a programme for the repair of leaks that occur on consumers' properties.

10.9.2.1. Should the repair not be done within seven days (irrespective of whether the water is being paid for or not), the water services provider will issue a notice to the consumer. In this instance, three actions are open to the water services provider:

a) After the leak has been discovered, the consumer is informed of its existence by a note being left in the letter box (or by the note being handed to someone who is apparently over the age of 16 years, and is on the premises at the time). The note will instruct the consumer to ensure that the leak is repaired within seven days.

b) Should the leak not be repaired within the stipulated seven days, an official notice will be issued, instructing the consumer to effect the repairs and that failure to do so within seven days will entitle the water services provider to carry out the repair and recover the costs from the consumer. If the consumer is not the owner of the premises, the consumer will have to make private arrangements to recoup the costs of the repair from the legal owner of the premises.

c) If, at any stage the leak should cause an emergency, the water services provider will disconnect the water supply and issue a notice, stating the nature of the emergency and informing the consumer that his water supply has been temporarily disconnected owing to the emergency and will remain cut off until the consumer has repaired the leak.

10.9.2.2. In terms of its agreement to supply water to a consumer, the water services provider shall ensure that it retains the right to enter premises at any reasonable hour in the pursuance of its water supply obligations and responsibilities, so that the actions described in **10.9.2.1** (a) to (c), can be performed legally and without hindrance.

11. Charging for water loss control services

11.1 General

11.1.1. Expectations

11.1.1.1 Because of the inevitable existence of background leakage, it is not normally economically feasible to achieve zero losses in any district, sub district, zone or other area.

11.1.1.2 Each water services provider will need to determine and set realistic, economically feasible and achievable water loss target levels for each district, sub district, zone or other area.

11.1.1.3 There will always be "ghost" losses. These are inexplicable losses or phenomena that would take a lot of time and cost a lot of money to solve. Each water services provider will have to decide how much time and money, if any at all, it will spend on solving such imponderables. Often it is best just to live with them and allow time to solve the problem; typically, such occurrences are not of very great magnitude.

11.1.1.4 Finding "ghost" losses usually entails activities such as manhole searching, storm water drain incursions, air-conditioner surveys, fire service overflows (unmetered fire services filling a storage tank with a faulty ball valve), and of course, uncharted draw-offs. "Ghost" phenomena could be attributable to air-locks, sticking valve gates and jumpers, gates with holes in them, broken spindles, blocked or partially blocked pipes (debris, bricks concrete, broken valve gates, etc.).

11.1.2. Alternative charging rates

11.1.2.1 An hourly rate basis (including all time, mileage, insurances, indemnities, etc.) is suitable for smaller *ad hoc* type jobs. There should be built-in checks for progress determination. A target rate per kilometre should be indicated.

11.1.2.2 If an overall rate for the job is used, contractors will probably submit a high quotation to cover the eventuality of difficult sections.

11.1.2.3 A rate per kilometre of water distribution mains is arguably the most equitable charging method. Allowance should be made for known complex areas such as the Central Business District (CBD) and old areas where documentation is suspect, for large-size bulk mains with a dearth of contact points or valves, and for pipelines that cannot be closed for any time, not even for short periods.

11.1.2.4 For casual *ad hoc* work, where the contractor is "on call", an hourly rate is recommended, since this type of call typically only takes 2 h to 4 h. Alternatively, a "per call" fee can be negotiated. A water services provider is advised to have an "on call" or "‘per call" contract with one or more contractors, to cover non-routine reports of atypical water-related phenomena.

11.1.2.5 Performance based contracts or bounty payments to contractors (i.e. payments assessed according to the amount of water saved or the number of leaks found) are strongly discouraged. Such contracts are usually based on the reduction of the minimum night flow rate as a benchmark, and invariably end up with both parties on bad terms.

NOTE – Unless the client has installed a number of newer meters, strategically placed and adequately logged to ensure accurate measurements, the likelihood is that the instrument by which savings are to be measured is twenty years old, either under- or over-sized, is of 800 mm diameter and a leak of 26 kl/h is being claimed for. Furthermore, the client is unlikely to be concerned if the contractor is directed to an area where major leakage is improbable, thus putting the onus of risk fully upon the contractor, who will not be long in the business, to the mutual detriment of both parties.

11.2 Prepayment metering systems

11.2.1. As with any other measuring/metering system, prepayment metering systems are subject to the requirements of the Weights and Measures Act CAP 403 of the Laws of Zambia. Worldwide, prepayment systems are gaining in prominence, driven largely by the increased convenience for the consumer and reduced costs to the water services provider. Complex systems, often referred to as "intelligent" systems, are interrogatable by the water services provider and also have the capability to send messages to the consumer. Such devices can cater for prepayment of any or all of the water, sewage, electricity, gas, rates and taxes, refuse, telephone, banking and account payments. Prepayment in this instance constitutes the automatic downloading of a preset amount of money from the consumer’s account from which each service authority can withdraw the required amount automatically. At the end of the month, when the next round of payments becomes due, the balance of the preset amount is again downloaded, to return the total to the preset amount. The cost associated with the conversion from existing systems, rather than operating costs or the availability of technology, is likely to be the decisive parameter in delaying the introduction of remote and prepayment metering systems.

11.2.2. Many variations of non-interrogatable prepayment devices exist. These can be operated with a “smart card”, where the consumer purchases a credit for water, and inserts the smart card into a monitoring device in the home, which is connected via a link to the water meter, which is fitted with a pulse output or an encoder device. Similar systems are used for standpipe applications.

11.2.3. A number of non-electronic prepayment metering devices are also currently available. These are used for bulk supply, community taps, yard taps, house connections and distributed storage tanks. Non-electronic prepayment metering devices can be mechanically controlled pressure-equalizing volumetric devices for community standpipes, or simply the filling of on-site fixed-volume tanks, referred to as regulated distributed storage tanks.

11.2.4. Regulated distributed storage tanks are very effective in helping households to manage water usage, since they control the maximum daily water usage of the household connected to such tanks.

12. Leakage from water storage structures

12.1 Reservoirs

12.1.1. Leakage from reservoirs occurs in two ways:

b) through faults in the structure itself (see **12.1.2**); and

c) through overflow resulting from a faulty inlet control valve (see **12.1.3**).

12.1.2. Leakage from reservoirs can be determined in three ways:

a) by observing and quantifying the under-floor drainage;

b) by isolating both inflow to and outflow from the reservoir and measuring the drop in surface level over a period of time, preferably with the aid of a hook gauge. Normally this can be done after midnight, with minimal disruption to consumers. However, when this is not possible, the leakage check has to be well planned because the flow into the area served by the reservoir will then have to be redirected from another source for the duration of the test, which could take anything from a few minutes (for a small reservoir) to a few hours (for a large reservoir with very little structural leakage). If an alternative feed direction is not available, the water services provider will have to embark on an extensive and intensive awareness campaign to advise all consumers in the affected area to store sufficient water for the number of hours that the test is expected to take and to promote a "we are working for you so please work with us" image; and

c) by metering the inflow and outflow accurately over a specific period, which could be a week. The difference between the two measurements indicates the leakage from the structure, but both meters have to be accurate. The initial water level and the final water level should be as much the same as possible and the actual water level difference should be carefully measured and converted into a volume measurement to complete the assessment.

12.1.3. Overflow leakage is easily visible and is typically the result of a faulty inlet control valve.

12.2 On-site storage facilities

12.2.1. On-site storage facilities should be tested regularly for leakage by closing off the inlet pipe and converting any drop in the water level to a flow rate expressed in litres per hour or kilolitres (cubic metres) per hour.

12.2.2. Overflow from on-site storage facilities (both from underground sumps and from roof top tanks) usually occurs via an overflow pipe that leads direct into a drain and such leakage is, therefore, often not visible.

12.2.3. If the water bill becomes excessive or if the meter is found to be running in the early hours of the morning, without obvious reason, the on-site storage facility should be one of the first places to check for a fault, using a tank-level-drop test (see **12.2.1**).

12.3 Fire services

12.3.1. Properties with separately metered fire services need to be closely watched for meter drift or movement.

12.3.2. Stagnant water promotes corrosion and products of corrosion build up on infrequently used control valves, making them difficult to operate when there is an emergency. This could result in the breaking off of the spindle or even the breaking of the valve itself.

12.3.3. Water stored for any significant period of time will become unwholesome and even toxic. Care shall be taken at the design stage to prevent this situation from occurring.

12.3.4. Use of fire services for car washing, for the washing of buildings, premises and driveways and even for cooling down buildings on hot summer days is not permitted.

12.3.5. Possible leakage from fire storage tanks should also be checked by closing off the inlet valve and observing the drop in the water level.

NOTE – There is a real danger that the person doing this might forget to open the inlet valve again, with the result that, when there is a fire, the storage tank will be empty.

12.3.6. Unmetered fire services shall be tested for leakage at least every second year.

NOTES
1. Unmetered fire services can also be abused (theft of water from on-site fire hydrants and fire hose reels), and should therefore be fitted with at least a "tell-tale" meter. A combination meter could also be installed, even if this means that the meter will be destroyed in the event

of a fire, since the cost of a new meter after every fire will be negligible compared with the control measures achieved in the interim. This is in accordance with the policy that no water supply should be unmetered.

2. An alternative to the use of a combination meter would be the installation of a reflux valve of the necessary size, together with a bypass meter of diameter 15 mm or 20 mm, to record if, and how much, water was used off the fire service. Such an installation should be more robust than a combination meter.

12.3.7. New installations shall be tested twice a year until the water services provider is satisfied that the system is good (probably after two consecutive satisfactory tests).

12.3.8. Older systems (more than about 20 years old) shall be tested annually for leaks.

12.3.9. Properties whose fire service is fed through the revenue meter shall be treated as a normal installation and fire storage as normal on-site storage.

Annex A
(Informative)

The choice of quantities to describe water losses and unaccounted-for water

Determination of the extent and, therefore, the quantity of losses from a water distribution system is not an exact science that can easily be described in terms of dimensions, mass and molecular structure. The question of how many and which parameters are needed requires attention. The problem posed here would in fact only be answered completely by an algorithm, or at least by a check list, that leads systematically to the determination of all of the relevant parameters that are necessary for the description of a system. For the water industry, such an approach is not deemed practical. A compromise therefore needs to be sought between the two extremes of an exact description on the one hand and the indecisive term "percentage" on the other, which is based on inexact measurements of two variables, all of which change, semi-randomly, with time.

A.1 The following examples illustrate the inadequacy of some of the measures used in the context of water losses:

Example 1 The total consumption for a given period is 100 units of water. The losses are 10 units. The percentage losses are therefore 10 %. But this was a very wet period. In the following period, the consumption goes up to 200 units of water owing to extensive garden irrigation, a small fire that had to be extinguished, increased air-conditioning, etc. The losses remain at 10 units. Although the value of the losses remains unchanged, they have halved when expressed as a percentage of the total consumption.

Example 2 Year 1 has a very wet summer after a period of water restrictions, so consumers have used very little water on their gardens. Year 2 is a dry year but dams are full so no water restrictions are implemented. The local authority has no water loss control programme and applies only passive leakage control. The following report is submitted to the water services provider's Council:

> "During the year under review, the water department was able to reduce water losses by almost a third, from 42 % to 30 %."

Such a report would in all likelihood enjoy extensive media coverage. However, the report is based on the following actual water balance results:

Year	Units supplied	Units sold	Losses (units)	losses%
1	100	58	42	42
2	145	98	47	30

Thus it would appear that the local authority has reduced losses by 12 %, which would be magnificent. And they didn't have to do a thing to achieve it! But in reality, the losses went up by 12 %. Not quite the same picture, is it?

Example 3 Another common and equally unacceptable practice is that of expressing loss rates in terms of only one parameter, such as l/h per house or only in terms of l/h/km. In the first case, a street has housing with frontages of 40 m, i.e. 25 houses per kilometre, on either side of the street, or 50 properties per kilometre of pipeline. If a loss rate averaging 2 l/h per house, is acceptable, then acceptable losses will total 100 l/h/km. However, in the case of a low income area, property frontages could be as little as 15 m, or about 134 houses per kilometre. At the same acceptable 2 l/h per house, losses are now up to 268 l/h/km. This illustrates a ludicrous situation where, for the same length of pipeline, acceptable losses (if measured in litres per hour per kilometre) could vary by a factor of close to 3.

A.2 The examples given in clause A.1 serve to demonstrate the usual need to express loss as a function of more than one parameter. In any given distribution system, the usual constants are the length of the mains pipes, the number of connections and the measuring time. The only plausible quantities for expressing loss rates are therefore cubic metres per hour per kilometre and litres per hour per house. For water reticulation systems, these quantities are largely independent of pipe size (circumferential leaks such as at pipe joints and valve stems are exceptions), water consumption, and other variables (but not pressure). Because the behaviour of the system is determined by several independent variables, using only one parameter is insufficient for comparison purposes, unless the values of the other important parameters are also noted. Pipe material and the age and length of connections all have an influence on the loss rate and should also be mentioned. Occasionally, other parameters such as population, number of consumers per supply point, per room or per unit, etc., could also be used.

A.3 In all cases, pressure compensation to the international norm of 500 kPa should always be applied for comparison purposes. By using this reference convention, towns all over the world can be better compared with one another. No consensus for an acceptable loss figure has been achieved internationally, although a figure in the region of 200 l/h/km to 700 l/h/km seems generally acceptable as a starting point. Local experience will indicate what target is achievable realistically. If the measured figure is too high, unnecessary wastage is taking place and, if it is too low, unnecessary cost might be incurred. Once a figure has been determined for an area, a process of sectoring should take place to determine whether the measured loss is evenly distributed over the whole area, or whether one or more discrete leaks exist, which can be located and repaired. (See Annex **C**.)

NOTE – It is interesting to note that both the Water Research Centre report and the UK Water Industry reports avoid reference to the term unaccounted-for water. This is probably attributable to their addressing the individual components of unaccounted-for water as separate issues and therefore avoiding the need to refer to unaccounted-for water generically.

Annex B
(Informative)

Example calculation for estimating minimum night flow rate

Base data for a hypothetical area is as follows:

Length of mains:		116 *Km*
Number of connections:		2790
Number of properties:	Household:	2787
	Non-household	3
Estimated population @ 3.2 persons per property		8900
Average night pressure		900 KPa

Default values (see 5.4)

Background losses from mains (@ 500 KPa):	35 *l/h/Km*
Background losses from connections (@ 500KPa):	3 *l/h* per property
Background losses from dwellings (@ 500KPa):	2 *l/h* per house
% people active at night:	2% each hour
Volume of toilet cisterns:	9 l
Average consumption by non-household[1]:	1.2 *K l/h* per property

Calculations:

A Background Leakage

• Mains: 116 Km x 35 l/h/Km	= 4.06 *K l/h*
• Connections: 2,790 x s l/h per connection	= 8.37 *K l/h*
• Properties: 2,787 x2 l/h per property	= 5.57 *K l/h*
Total expected leakage (@ 500KPa)	= 18.00 *K l/h*

Correction to 900 KPa[2]: 18 x 2,226 (see Table 6)	= 40,068 *K l/h*

B Normal night use (insensitive pressure):

• Consumer: 8,900 x 2% x 9 l/h	= 1,602 *K l/h*
• Non-consumer: 3 x 1.2 K l/h per property	= 3.6 *K l/h*
Total expected night use	= 5,202 *K l/h*

Total night flow you could expect to measure:	= 48.58 *K l/h*

1) 1 x primary school, 1 x hotel, 1 x high school.
2) A PRV reducing the pressure from 900 KPa would save 22.86 *K l/h* and at K2,272 per *K l* for water, would pay for itself in less than a year, including installation. Reducing pressure to 500 KPa would reduce Q_d by 200 l/h, suggesting that high pressure is the single most significant water loss parameter in any water supply system.

NOTES

1. For the full report, refer to Water Research Commission report No. WRC 803/1/98
2. The converse calculation, when the minimum night flow rate has been measured and the nature of the leakage has been determined, is presented in Annex C.

Annex C
(Informative)

A calculation method to determine the likely number of leaks from the minimum night flow measurements

NOTE – All of the default values for leakage used in this example have been taken from 5.4.

Base data for a hypothetical "Anytown" is as follows:			
Length of mains:			9 630 m
Number of connections:			645
Number of properties:	Household		695
	Non-household		3
Estimated population (nights):			3 200
Average zone night pressure:			660 kPa (66 m)
Measured MNF:			12,8 k ℓ/h

Default (target) values		
Background losses from mains @ 500 kPa:		40 ℓ/h/km
Background losses from connections @ 500 kPa:		2 ℓ/h per connection
Background losses from dwellings @ 500 kPa:		1 ℓ/h per house
% people active during the night flow exercise:		4 % each hour
Volume of toilet cisterns:		9 ℓ
*Average quantity water used by non-households:		120 ℓ/h per property
Power law index for:	Background losses:	1,5
	Leaks/bursts:	0,5

* Schools with auto-urinals.

NOTE – Automatic flushing urinals are notorious water wasting devices and should be summarily replaced with appropriate user-activated devices.

Calculations:	
A Background leakage (@ 500 kPa):	
• mains: 9,63 km × 40 ℓ/h/km	= 0,385 k ℓ/h
• connections: 645 × 2 ℓ/h per connection	= 1,29 k ℓ/h
• properties: 695 × 1 ℓ/h per property	= 0,695 k ℓ/h
Total: Background leakage (@ 500 kPa)	= 2,37 k ℓ/h

B Normal night use:	
• consumer: 3 200 × 4 % @ 9 ℓ per flush	= 1,152 k ℓ/h
• non-consumer: 3 × 120 ℓ/h per property	= 0,36 k ℓ/h
Total: Normal night use	= 1,512 k ℓ/h

NOTE – Night use is usually where a person gets a drink of water, fills the kettle, uses the toilet or runs a bath after coming home late. The consumer obtains a certain volume of water and then shuts the water off. To all intents and purposes, therefore, pressure does not enter the equation.

C Pressure correction to background leakage:		
• correction factor to 660 kPa: $(66/50)^{1,5}$	= 1,516	
• total background leakage @ 500 kPa:	= 2,37	k ℓ/h
Estimated background leakage @ 660 kPa = 2,37 × 1,516 = 3,6		k ℓ/h

D Night flow normally expected:	
• background leakage + normal night use	
= 3,6 k ℓ/h + 1,512 k ℓ/h	= 5,112 k ℓ/h

E Evaluation of MNF:		
• recorded MNF @ 660 kPa:	= 12,8	k ℓ/h
• calculated night normal night flow rate:	= 5,112	k ℓ/h
Resultant leakage	= 7,688	k ℓ/h

F Equivalent service pipe leaks:

A typical distribution main leak would lose approximately 1,6 k ℓ/h at 500 kPa pressure. This flow rate has been accepted internationally and is referred to as "equivalent service pipe leak".

• equivalent pipe leak @ 500 kPa:	= 1,6	k ℓ/h
• correction factor to 660 kPa $(66/50)^{0,5}$:	= 1,15	

Equivalent service pipe leaks @ 660 kPa (1,6 × 1,15) = 1,84 k ℓ/h

G Results. What you should be looking for:

There are approximately 8,688/1,84 = 4,7, say 5, equivalent service pipe leaks in the area. These could be various mixes of valve glands (± 800 ℓ/h), ferrules/connections (± 600 ℓ/h), joints at valves, pipes or tees (600 ℓ/h to 1,2 k ℓ/h) or holes in the pipe, etc. Age, material and general condition of the system will dictate probable proportions of each defect type.

Hydrants, SVs, air release valves, reservoir overflows, illegal connections, auto-sprinklers, forgotten hosepipes into pools or lawn watering, undetected automatic urinals, etc., could also be the reason for unexpected flows in the middle of the night and should be anticipated.

Annex D
(Informative)

Inventory schedule

Water services authority

Date of this investigation (Y M D)

Date of last investigation (Y M D)

Type of area under investigation:

District   Subdistrict   Zone

Area name   Code No./Area ref. No.

Property information:

Last update of information (Y M D)

Number of properties:

Households   Commercial   Industrial

Medical   Institutional   Other

Total population:

Permanent   Growth since last update

Infrastructure information:

Mains: Total length of distribution mains (km)

Connections: Average length (km)   Number

Total length of connections (km)

Flow information:

Last MNF (m³/h)   This MNF (m³/h)   % Change (+ or -)

How determined: Bulk meter   Last calibrated (Y M D)

Estimated   Method used

Is pressure control applied   Average night pressure (kPa)

Actions taken since last investigation:

Pressure control introduced   Unmetered water reduced

Meters:

In-situ testing of meters   Meter replacement programme

Meter survey: Domestic   Larger meters

Leakage:

Number of leaks found   Reduction in MNF

Leak detection methods used: Active   Passive

Step-testing   Sounding   Correlation   Visual

Radar   FFT   Gases   Other

Position of leaks:

Distribution mains No.   Connection pipes No.

On property No.   Volume of water lost per day

Annex E
(Informative)

Costing schedule for loss detection crew

NOTE – Some water authorities might prefer to tabulate this information in a spreadsheet.

Number of personnel

Controller [ ]
Administration [ ]
Supervisory [ ]
Artisan [ ]
Labourer [ ]
Other [ ]

Total number of personnel [ ]

Costs for active leakage control personnel

Salaries/wages [ ]
Bonuses [ ]
Overtime [ ]
Staff insurances [ ]
Pension/Provident funds [ ]
Other [ ]

Total personnel costs [ ]

Allowances:

Tools [ ]
Clothing [ ]
Other [ ]

Total allowances [ ]

Transport costs

Running [ ]
Insurance [ ]
Other [ ]
Maintenance [ ]
Plant and equipment [ ]

Total transport costs [ ]

Daily charge-out rate for loss detection crew [ ]

Annex F
(Informative)

The leak noise correlator and how it works

The leak noise correlator is a device that determines the position of a leak by measuring, at two different points on the pipe, the noise that arrives at these points having travelled along the pipe from the defect. Microphones (known in this context as transducers) are placed in contact with the pipeline, and detect the leak noise over a considerable distance. The distance that leak noise will travel is determined by the pipe material, the pipe diameter, the condition of the pipe wall, and the loudness of the leak noise, which in turn is determined by the pressure in the pipeline and the shape and sharpness of the defect in the pipe.

In figure F.1, the leak noise travels through a distance d_1 to reach the closer transducer. Simultaneously, the noise has travelled in the other direction through a similar distance d_2. The time taken for the leak noise to travel the remaining distance *s*, at velocity *v*, to reach the more remote transducer**,** is then measured by the correlator in milliseconds and is referred to as the time delay, t_d. Thus $s = t_d \times v$. 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 $d_1 = \frac{L - vt_d}{2}$

During a correlation scan, the leak noise will reach the closer transducer first and the signal is progressively delayed until a similar leak noise is received by the more remote transducer. By this means the time delay, which is the difference between the times at which the leak noise reaches the two transducers, is measured, and the position of the leak can be computed.

The velocity *v* of sound through water is affected by the pipe material and the pipe diameter. The following values of *v* for various pipe materials can be used as approximate indicators:

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

At least three correlations should be done, using different points and bracketing the leak on each occasion. Care should also be taken to ensure that the correlator is not merely indicating the position of an intersection with a branch pipe on which the leak is actually located.

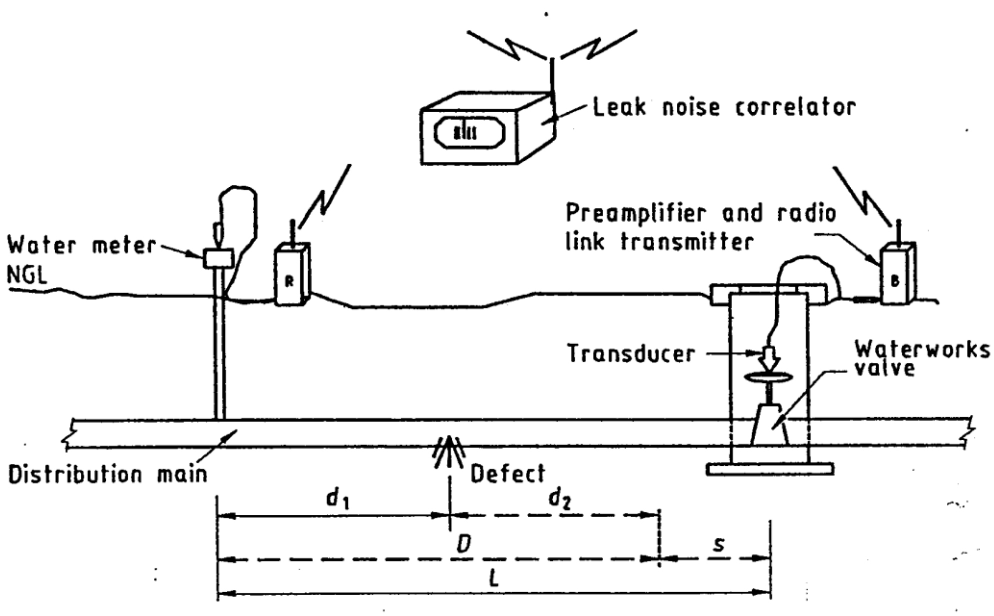


Figure F.1 — Location of a leak by leak noise correlation

Annex G
(informative)

In-situ meter testing

NOTE – These tests are not intended to replace the verification requirements in terms of the Weights and Measures Act CAP 403 of the laws of Zambia and its relevant regulations. Seals may not be broken or adjustments effected.

G.1 In-situ testing of consumer water meters

G.1.1 Recommended procedure

The following is the recommended procedure:

a. From the water distribution drawings, a random sample of plots (houses) is selected in the area to be tested.

b. Field report sheets are prepared (see Annex **L**).

c. Two or three days before the tests are due to take place, the affected consumers are notified in writing and on the water services provider's letterhead, explaining the purpose of the test and giving other pertinent information on the exercise. These notices can be delivered by an inspector walking down a street and giving notices only to those properties where someone is at home. This will save access time when the test is actually being carried out.

d. During delivery of the above notices, the meter is located and checked to ensure that it is working and stops completely when no water is used on the premises. Leaking garden taps can be tightened or repaired and other leaks reported to the household for repair.

e. On the day of the test, one crew member goes ahead of the test crew and checks that the meters to be tested are working and ascertains that there are no leaks on the property by checking that the meter is completely stopped. If leaks are found, they are either quickly repaired/tightened, or the test is passed over for that site. Residents are requested not to use any water for the duration of the test.

f. Three tests each for slow, medium and fast flow rates are carried out and recorded on the data sheets. At least two test results at each flow rate should be consistent; otherwise the test is repeated until similar results are attained.

g. On completion of the series of tests, the residents are informed that they may resume using water and are thanked for their co-operation. The test crew moves on to the next site.

h. The test sheets are transferred to a spreadsheet and analysed.

G.1.2 Meter testing apparatus

Two basic types of test apparatus can be used for testing consumer water meters as shown in figures G.1 and G.2. The first type is based on mass, and uses an electronic scale to determine the volume of water that has passed through the consumer meter; the second is based on volumetric flow, using an in-line check meter to test the consumer meter.

All of the above methods have their advantages and their disadvantages. The electronic scale is a delicate instrument and requires very careful and accurate setting up to ensure that it is level. The scale is also sensitive to wind.

The check meter apparatus is generally preferred since it does not limit the volume of water used for each test and it is relatively robust.

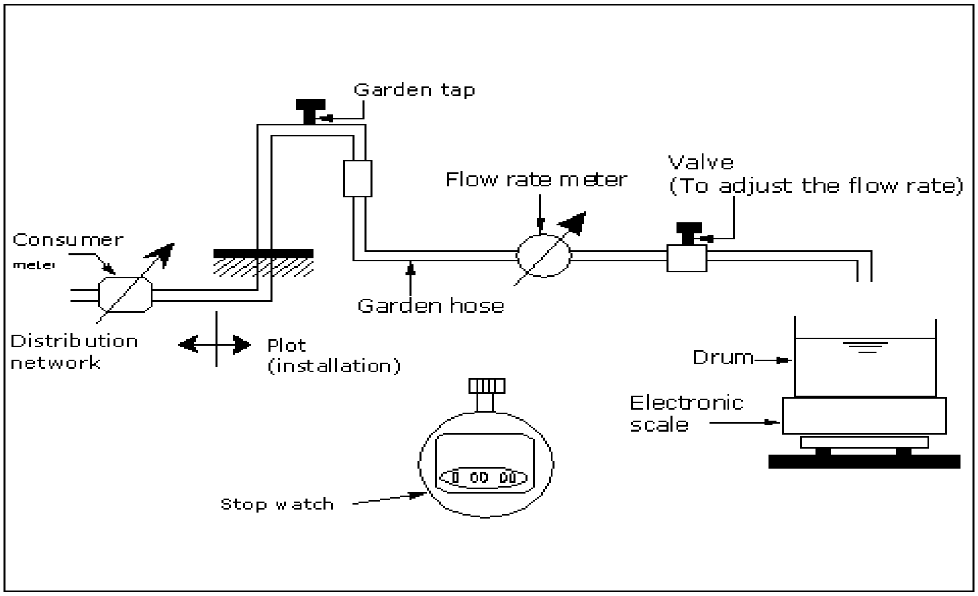


Figure G.1 — Test apparatus for use with an electronic scale

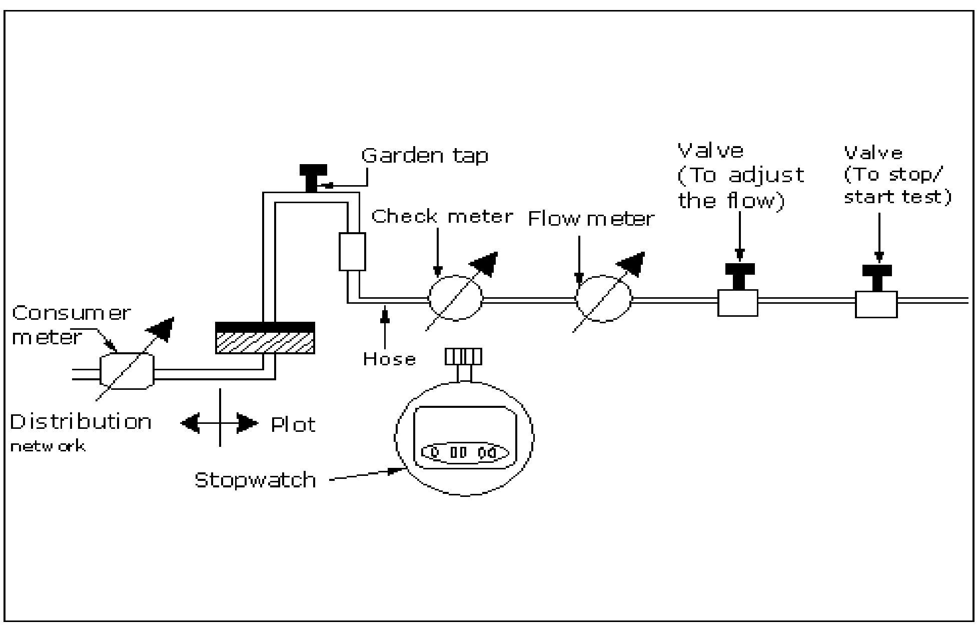


Figure G.2 — Test apparatus incorporating a calibrated check meter

The stopwatch is used to take the time, in seconds, for 1 l to flow at the low flow rate (30 l/h for a size 3 water meter, and 60 l/h for a size 5 water meter). Instead of comparing volumes by reading the water meters, those carrying out the test take the times for 1 l to flow through each meter and these times are then compared. For "two digit" meters (i.e. those having only two digits registering decimals of a cubic metre), the time for 10 l has to be taken, since the resolution for 1 l or even 5 l is too indecisive to measure accurately.

G.1.3 Reading of meters being tested in situ

The small volume of water used for each test necessitates the accurate reading of the decimal graduations of the meter.

It is imperative that the person reading the meters be acquainted with reading the litre graduations on the meter counter. Generally, meter readers are accustomed to reading whole numbers only (kilolitres or cubic metres), and often experience great difficulty in reading the decimal graduations accurately or consistently. The problem is aggravated by the juxtaposition of meters with two digits, three digits and four digits, to read one hundred litres, ten litres and one litre respectively. This results in spurious readings, especially for the low flow rate tests, which then have to be discarded.

It is essential that meter readers used to assist in this exercise be comprehensively instructed in the correct reading of decimal graduations on each of the different types, makes and models of meters used in the area.

G.1.4 Analysis of test results

Meter errors are calculated using the following formula:

$$\text{Error (\%)} = \frac{V_{\text{in situ}} - V_{\text{check}}}{V_{\text{check}}} \times 100$$

Where,

$V_{\text{in situ}}$ is the volume of water read on the consumer meter being tested, and

V_{check} is the volume of water measured by the check meter on the test apparatus.

A positive error indicates that the consumer meter reads fast. (Less water has passed through the meter than is indicated on the consumer meter.)

A negative error indicates that the meter reads slow. (More water has passed through the consumer meter than indicated.)

G.2 Testing of large meters

G.2.1 The procedures for the in-situ testing of large meters are similar to those used for consumer water meters, with the exception that test points have to be installed in the consumer connection prior to the test (see figure **G.3**). This installation is best done at the design and construction stage (see **9.3.3**). The installation allows the continuous monitoring of the installed meter against the check meter over extended periods of time, without inconvenience to the consumer.

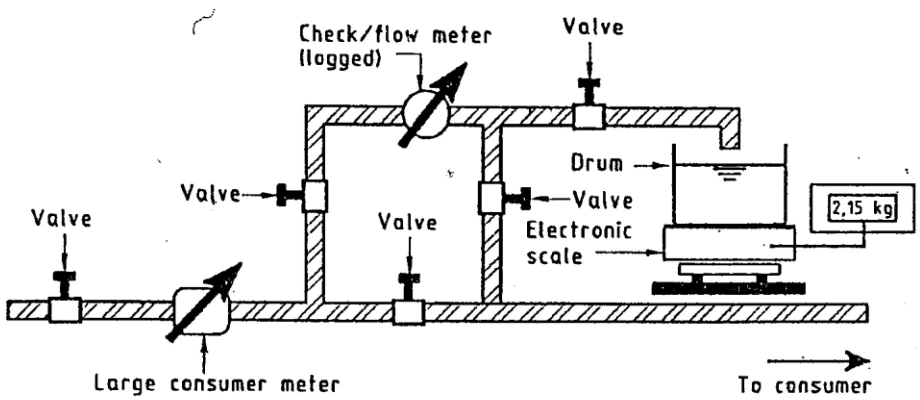


Figure G.3 — Installed test apparatus for large meters

G.2.2 Two different types of test should be carried out at each meter:

e) A meter accuracy test to determine the accuracy of the meter at the low, medium and high flow rates. The principles used for this test are identical with those used for the consumer water meter tests using the check meter.

f) A meter size and type test to determine the correct size and type of meter for the individual consumer. Water delivered is diverted through the check meter and logged for a 24 h period, or longer if flow rates vary from day to day. The recorded demand pattern is analysed to ascertain the correct size and type of meter for the particular circumstances. This is a once-off test and need not be repeated unless a change in the consumption pattern is observed.

G.2.3 The procedure for the in-situ testing of meters of diameter exceeding 250 mm includes the following:

d) Install an insertion point on the pipe, such as an access tee, on a straight length of pipe, at a distance equal to at least 30 but preferably 50 times the pipe diameter away from any turbulence causing devices upstream and at least the same distance from the permanent in-line meter downstream. Ensure that there are no take-off points between the insertion point and the permanent meter.

e) Insert the meter, taking velocity measurements at various depths across one plane of the pipe. The position of these measurements can be established with the aid of a velocity-area method known as the log-linear method. Computer software packages are available to assist the user (see **4.4.5.7**).

f) Once the average velocity has been determined, the flow rate is calculated and compared with that of the permanent in-line meter. The test can be repeated for the various flows by throttling a control valve on the pipeline, provided the valve is situated beyond the limits indicated above.

Annex H
(informative)

Job report card for leakage repair

Water Utility — **Leakage Repair Report**

Date: | Time: to = h | Job No.:

Town | Suburb | Street | Street No.

Description of damage

Location of burst

- ☐ Supply main
- ☐ Distribution main
- ☐ Service connection
- ☐ In street
- ☐ Under sidewalk
- ☐ Other

Pipe diameter mm | Depth to pipe mm

Nature of the fault

- ☐ Previous repair
- ☐ Hole
- ☐ Lateral split
- ☐ Radial split
- ☐ Crushed pipe
- ☐ Broken coupling
- ☐ Blown gasket
- ☐ Connection
- ☐ Other ....

Pipe material

- ☐ Steel
- ☐ uPVC
- ☐ HDPE
- ☐ Cast iron
- ☐ Fibre cement
- ☐ Galv. mild steel
- ☐ Polypropylene
- ☐ Prestressed concrete
- ☐ Ductile iron
- ☐ Glass fibre
- ☐ Other .....

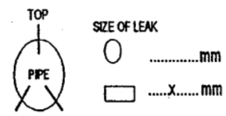
What was damaged

- ☐ Pipe
- ☐ Joint
- ☐ Previous repair
- ☐ Connection
- ☐ Ferrule
- ☐ Valve
- ☐ Hydrant
- ☐ Other ....

Evidence of previous repairs apparent

☐ Yes ☐ No

Position of leak
(Indicate closest to leak)



Problems experienced during repair

- ☐ Unable to isolate
- ☐ Impaired access to valves
- ☐ No. of valves to isolate
- ☐ Other ....

Condition of pipe

- ☐ Bad (Replace)
- ☐ Good (Repair)
- ☐ Unsure

Description of repair

Damage was:

Repaired ☐ Replaced ☐ Material used ....

What repairs were made

- ☐ Leak clamp
- ☐ Welded
- ☐ Spiked/pegged
- ☐ Repaired joint
- ☐ Repacked valve/hydrant
- ☐ Other ....

Cause of damage

- ☐ Corrosion
- ☐ Impact
- ☐ Pressure
- ☐ Other ....
- ☐ Ground movement
- ☐ Abuse

Sketch of repair location

Indicate:
- Street names
- Stand numbers
- Isolating valves
- Leak position

Comments:

Annex I
(Informative)

Correlation sheet

Location……………………………					Anyone Leak Detection Services P.O. Box 00001 ANYTOWN Tel(260) 123456		
	Red	Blue	Length M	l_d ms	V m/ms	Indicated Position From red	Remarks
Leak location Experts							

Annex J
(Informative)

A simplified spreadsheet for bulk meter readings, water consumption and water balance

	A	B	C	D	E	F	G	H	I	J
7	Meter	Date: 1	Date: 2	Water	Date: 3	Water	Date: 4	Water	Date: 5	Water
8	Reference	*16.03.96*	*13.04.96*	measured	*16.05.96*	measured	*12.06.96*	measured	*14.07.96*	measured
9	Number	Reading	Reading	in 28 days	Reading	in 33 days	reading	in 27 days	Reading	in 32 days
10	Zone 1									
11	In 2311	*114633*	*114971*	C11 - B11	*115306*	E11 - C11	*115714*	G11 - E11	*116109*	I11 - G11
12	In 2312	*61341*	*61502*	C12 - B12	*61791*	E12 - C12	*62049*	G12 - E12	*62334*	I12 - G12
13	Total in			D11 + D12		F11 + F12		H11 + H12		J11 + J12
14	Consumption			*427*		*529*		*570*		*585*
15	Balance			D13 - D14		F13 - F14		H13 - H14		J13 - J14
16	UAW (%)			D15/D13*100		F15/F13*100		H15/H13*100		J15/J13*100

18	Zone 2									
19	In 123									
20	Consumption									
21	Balance									
22	UAW (%)									

Zone 3									
In 124									
Consumption									
Balance									
UAW (%)									

Zone 4									
In 131									
Consumption									
Balance									
UAW (%)									

Zone 5									
In 132									
Consumption									
Balance									
UAW (%)									

Zone 6									
In 1411									
In 1421									
Total in									
Consumption									
Balance									
UAW (%)									

NOTES
1 The numbers in *italics* are data that are filled in at the time of taking the readings.
2 The column/row references in the spreadsheet represent the calculations that will be performed by the spreadsheet.
3 The meter reference number follows the sequence described in 4.3.1.2
4 Zones 1 and 6 are each supplied through two metered supply pipes. There could be multiple supply points.

Annex K
(Informative)

Spreadsheet for in-situ checking of water meters that serve industrial premises

Test No.	Run No.	Slow				Medium							Fast				
		Meter	Time	Error	Mean	Meter	Readings		Difference	Error	Mean	Meter	Readings		Difference	Error	Mean
			s/ℓ	%	%		Initial	Final	kℓ	%	%		Initial	Final	kℓ	%	%
03-01	1	In situ	35,28			In situ	2317,01615	2317,03116	0,01501			In situ					
		Check	41,92	18,82		Check	0,05972	0,07475	0,01503	-0,13		Check					
	2	In situ	26,85			In situ	7,03915	7,04935	0,0102			In situ					
		Check	27,04	0,71		Check	0,08214	0,08238	0,01024	-0,39		Check					
	3	In situ	26,12			In situ	,80559	8,0652	0,0093			In situ					
		Check	27,4	4,9	8,14	Check	0,0986	0,10792	0,00932	-0,21	-0,25	Check					
03-02	1	In situ	30,42			In situ	15956,0647	15956,0735	0,0088			In situ	15960,03570	15960,05100	0,008800		
		Check	31,15	2,41		Check	0,21901	0,22786	0,00885	-0,56		Check	0,19706	0,21055	0,01349	13,42	
	2	In situ	34,4			In situ	6,13321	6,14701	0,0138			In situ	6,1761	6,194			
		Check	38,35	11,5		Check	0,28798	0,30179	0,01381	-0,07		Check	0,31925	0,33702			
	3	In situ	27,29			In situ	6,1961	6,2095	0,0134			In situ			0,0179		
		Check	27,19	-0,37	4,52	Check	0,33924	0,35247	0,01323	1,28	0,22	Check			0,01777	0,73	7,07
03-03	1	In situ	27,83	0,92		In situ	1792,96865	2,98105	0,0124			In situ					
		Check	28,09	0,92		Check	0,46301	0,4753	0,01229	0,9		Check					
	2	In situ	28,01			In situ	2,98905	3,00055	0,0115			In situ					
		Check	26,98	-3,66		Check	0,48436	0,49613	0,001177	-2,29		Check					
	3	In situ	28,11			In situ	3,01205	3,02635	0,0143			In situ					
		Check	28,98	3,11	0,12	Check	0,50701	0,52135	0,01434	-0,28	-0,56	Check					

Annex L
(Informative)

Typical report sheets for consumer meters tested in situ

L.1 Report sheet for consumer water meters tested in situ

Authority: .... Tested by: ....

Date/test No.:

Year	Month	Day	Test No.

Consumer details					Meter details			Remarks
*Type	Domestic	Industrial	Institutional	Commercial	Make			
					Model			
Suburb					Size			
No. & Street					Number			
Stand No.					*Units	Kilolitres	Gallons	

Test type		Slow flow	Medium flow		Fast flow	
Run No.	Meter	**Time in seconds For 1 ℓ, 5 ℓ or 10 ℓ	Meter reading Initial	Final	Meter reading Initial	Final
1	In situ					
	Check					
2	In situ					
	Check					
3	In situ					
	Check					

Flow range in ℓ/h		
Test	Meter size	
Type	15 mm	20 mm
Slow	55-65	110-130
Medium	450-550	900-1 100
Fast	1 500-1 600	2 300-2 700

*Tick selected box
**Depends on number of decimal places

L.2 Report and calculation sheet for consumer water meters tested in situ

Tested by: ....

Year	Month	Day	Test No.

*Tick selected box
**Depends on number of decimal places

Full meter reading:

Flow range in ℓ/h		
Test type	Meter size	
	15 mm	20 mm
Slow	55-65	110-130
Medium	450-550	900-1 100
Fast	1 400-1 600	2 300-2 700

	Consumer details				Meter details		Remarks
*Type	Domestic	Industrial	Institutional	Commercial	Make		
	Other:				Model		
Suburb					Size		
Street & No.					Number		
Erf No.					*Units		

Test type		Slow flow			Medium flow					Fast flow				
Run No.	Meter	**Time for 1 ℓ, 5 ℓ or 10 ℓ			Meter reading					Meter reading				
		s	Difference	%	Initial	Final	ℓ	Difference	%	Initial	Final	ℓ	Difference	%
	In situ													
	Check													
	In situ													
	Check													
	In situ													
	Check													

Annex M
(Informative)

Basic steps to implement a water loss management programme

Introduction
The following phased procedure can be applied to any area comprising some or all districts, sub districts and zones. The approach has been kept simplistic by intent, to encourage confidence through understanding. Complications will arise in areas that are neglected areas, areas without meters, areas where non-payment is rife, areas with illegal connections, and areas that have complex and highly developed networks.

Phase 1: Preparation

Step 1: Develop a plan for the envisaged water loss management programme, which will include the following:

a. verification of all major water pipe routes and interconnections on plans;

b. demarcation of districts, sub districts and zones, and identification of each;

c. determination of size and type of management meters required;

d. identification of bidirectional flow meters;

e. indication of locations where the meters will be installed;

f. determination of size and type of isolating valves required;

g. indication of locations where the valves will be installed;

h. planning and design of a monitoring/reporting system to be compatible with the existing water meters, data loggers and PC software to analyse the data; and

i. cost estimate of carrying out the measures given in (a) to (h) above.

Step 2: Obtain approval for the plan.

Phase 2: Installation and monitoring

Training of local operation and maintenance staff forms an integral part of any water management programme. For each step of the exercise, intensive and ongoing training should be provided for.

Step 1: Select, order, purchase and install the meters, valves and monitoring system.

Step 2: Monitor the entire installation to test the integrity of the management system:

a. develop a spreadsheet of bulk supply information;

b. establish background information;

c. determine minimum night flow rates for each of the various zones;

d. survey each zone for night time consumption and determine the net minimum night flow rate;

e. determine specific losses for each zone; and

f. prioritize zones.

Phase 3: Water loss control

Step 1: Implement an intensive water loss and leak detection procedure for the whole area on a zone-by-zone basis:

a. locate leaks in streets (this can be commenced during the integrity test period);

b. repair all of the identified leaks, one zone at a time, as rapidly as possible, using contractors if necessary; and

c. prepare and maintain a leak repair report file.

Step 2: Monitor the effect of the leak repair programme and make a before and after comparison to determine the net benefits, on a zone-by-zone basis.

Phase 4: Assessment

Step 1: Analyse results:

a. determine the cost/benefit relationship for the exercise;

b. determine a water balance for the distribution system; and

c. monitor each zone to determine the growth in leakage (deterioration) over a six month period.

Step 2: Prepare and supply any training or operating manuals that might be required for the efficient running of the system.

Phase 5: Water audit

Phases 1 to 4 represent a procedure for the implementation of a water loss management programme.
The next logical step will be to prepare a water audit (see clause **8** for each zone:

To verify consumer information against the billing list for each zone:

a. Ensure that each property which appears on the billing list actually exists in the zone, and that each property in the zone appears on the billing list. Ideally, each water services provider should have only one address list to serve all services, post office, rates and taxes, etc.

b. Ensure that each property on the billing list is served through the particular zone meter. This might entail turning off the water at the valve and checking that no property within the zone then has water. At the same time, check that all adjacent properties bordering on the outside of the zone do still have a water supply. This exercise could be quite labour intensive in order to keep to a minimum the inconvenience of turning off the water.

Sample consumer meters in situ (see Annex **G**) to determine whether the accuracy falls within acceptable limits. This is crucial for the success of a water audit. Depending on the quality of the water supplied, consumer water meters can be expected to have an acceptable operational life of 7 to 12 years.

Annex N
(Informative)

Management structures to develop a policy and to implement sustainable and meaningful water management within a water services provider

Sub clause **4.2** of this standard describes the establishment of a UFW committee to develop a policy on water management for the water services provider and to determine a strategy to ensure that the policy is implemented. The implementation aspects, however, will require competent staff who have unique skills and dedicated functions to perform.

N.1 Establishment of management structures

In the case of a city or town and in some district, a liaison/policy committee comprising members from the commercial, administration, finance, legal and technical departments, needs to be established to guide the water loss management programme.

N.1.1 The Water Loss Management Division will be staffed by dedicated personnel who should not necessarily be Utility Division employees but rather highly trained, experienced specialists. Figure N.1 is a functional chart. Smaller local authorities might have one person responsible for many of the disciplines mentioned, while a better staffed organization could have one person for each responsibility.

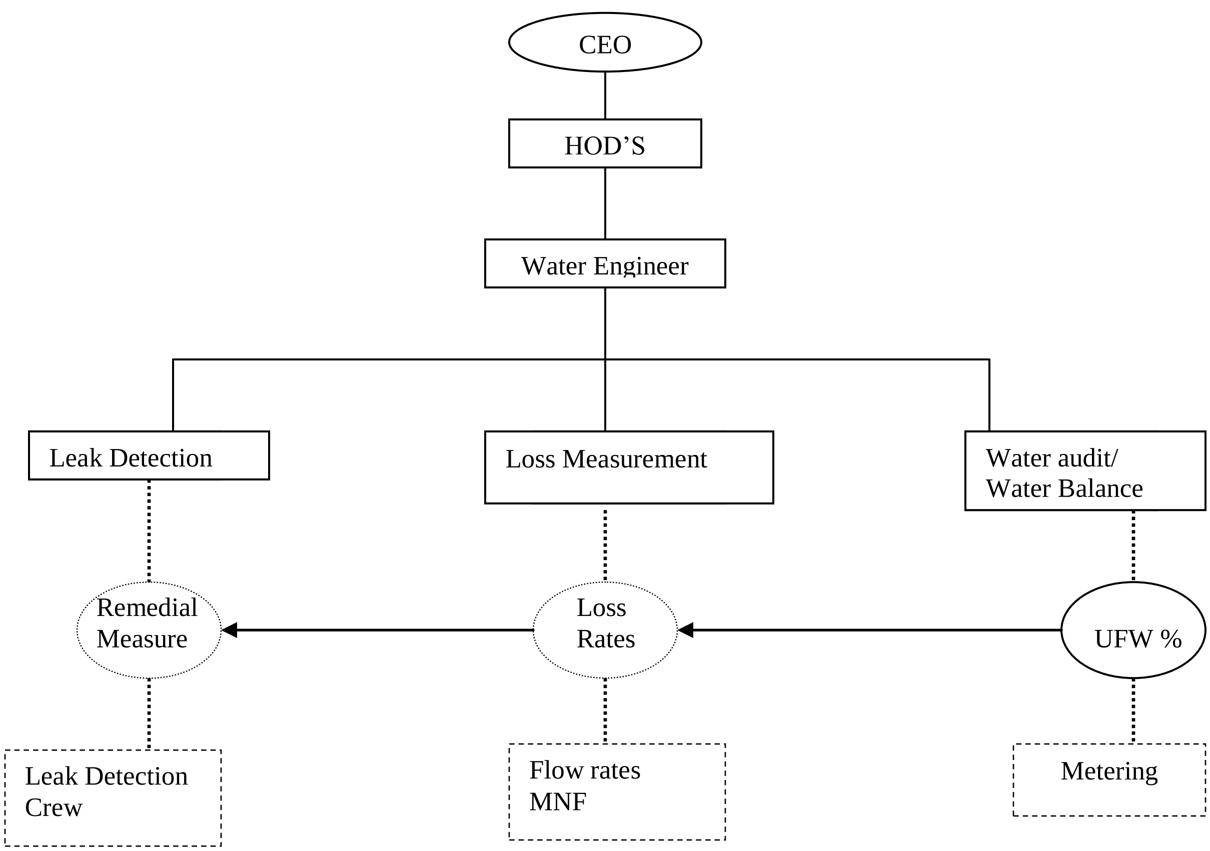


Figure N.1 — Typical management structure for a water services provider

N.1.2 In order to operate efficiently, the Water Loss Management Division will be an autonomous division and distinctly separate from the operation and maintenance section, although probably still reporting to the same

Technical/ Operations Manager, since the success of a water loss survey depends largely on how quickly repair work can be done. Very close co-operation between these two divisions/sections is therefore imperative.

N.1.3 In the case of communities and districts responsible for their own water supply, a community water committee should be elected to undertake the tasks mentioned in **N.1.1** and **N.1.2**. Training in the various tasks will be an essential part of the establishment of any such water committee.

N.2 Staffing levels

N.2.1 General

N.2.1.1 The control and reduction of unaccounted-for water is a primary function of the entire water department staff. They will actively support and be guided by a core of specialists who are permanently employed and trained for the express purpose of managing unaccounted-for water.

N.2.1.2 Alternatively, a water services provider which is embarking on a unaccounted-for water programme could appoint dedicated staff (or the private sector) to initiate the process and set up appropriate unaccounted-for water systems, etc. With time, this operation would be integrated into the general operations of the department and water loss management would then become an operational philosophy of the department.

N.2.1.3 As a rule of thumb for larger water services authorities, an average of 5 % to 10 % of water branch staff, at all levels, should be assigned full time to the function of unaccounted-for water management, depending on the age, maintenance history and general condition of the water distribution system. A smaller water services provider might have an even greater proportion of persons on this task.

N.2.2 Staff qualities and responsibilities

N.2.2.1 The most important qualities, or attributes, required of staff involved with unaccounted-for water are

- dedication,
- being methodical,
- being meticulous, and
- enthusiasm,

in their approach to their task. Much of the work, such as in-situ meter testing, step-testing, sounding, etc., is tedious and laborious. Boredom or lack of interest will have a decisive negative impact on results.

N.2.2.2 The qualities given in N.2.2.1 will need to be supported by appropriate training for the various tasks. Staff should be fully conversant with the operation of the GIS, if one exists, the system database, procedures, recording processes and the correct operation of all of the sophisticated equipment required for the control of water losses.

N.2.3 Senior management level

The Water Loss Management Division will be the responsibility of the Division Head, who should be dedicated to the water management programme and who will be chiefly responsible for the financial management and strategic planning of the division, through the liaison/policy committee.

N.2.4 Supervisor level

An engineer level, reporting directly to the Division Head, responsible for the planning and implementation of the water loss management programme.

N.2.5 Operations level

Technician level, or alternatively junior engineer, responsible for data management.

N.2.6 The loss detection crew

The loss detection crew will comprise one or more teams, each made up of one or more of the following:
- a technician,
- a plumber, and
- a labourer,

Who are responsible for the physical/practical execution of all water loss management activities.

N.3 Duties

N.3.1 Division Head

N.3.1.1 The Division Head will develop a strategic management plan (see **4.1.1**) and will have the following responsibilities:

- decide whether to implement a water loss control programme or not
- decide on the degree of involvement of such a programme, such as decide on whether to implement passive/active/continuous/*ad hoc* leakage control, etc.
- decide on whether to create an entirely new division or simply add on to the functions of one or other existing division within the water department
- review existing links between meter reading, billing and accounting infrastructures
- upgrade the management job description to include water loss control as a discrete management function
- promote recognition for the Division, its aims and activities
- obtain funding from the Council, Board or Management, as the case may be, for the Division, for the proper implementation of all levels of its activities
- develop a short-term, medium-term and long-term strategic plan for the water services provider. The strategic plan will determine the target levels (see **5.4**) for total losses (unaccounted-for water), financial limitations (how much are you prepared to spend to achieve your unaccounted-for water target level?), conservation targets, exploitation and augmentation of resources and long-term consumption demand goals
- the amount of money needed to be spent
- the time scale over which the programme is to be phased
- define districts, reservoir zones and areas
- compile a water balance annually to form part of the Engineer’s report to the Council, Management, or Board, as the case may be
- prepare performance audits for submission to the Council, Board of Directors or NWASCO, upon request, and to compare one water management section with that of a similar section of another water services provider

- appoint, motivate and train staff serving in the division
- determine target levels of the minimum night flow rate for each district
- determine target expenditure levels

NOTE – International literature suggests a figure around US$0.25 per house per year, or US$12.75/km per year, as a starting point, but concedes that a more achievable figure will need to be determined depending on the state of the water distribution system and the financial resources of each water services provider. Having this target level available will enable the engineer to know how much money to budget for, or how far his budget allocation for water loss control will go, and he can adjust his staff levels accordingly.

N.3.1.2 The Administrative Section will also have increased functions to add to its work load:

- the addresses appearing in each district, sub district and zone will have to be physically checked in the field to ensure that every address indicated does in fact exist in the particular area and that water is not being supplied to addresses that fall outside of the area
- cross-checks will need to be made between departments billing the same area such as water, electricity, sewage, refuse collection and rates and taxes (if they are billed through different departments either within or outside of the organization) reading of the water meters should become the function of the water department (if it is not already so)
- the water accounts database should automatically compare the current account with the previous month's account and the account of the same month a year ago and discrepancies of more than 25% should be flagged for investigation
- water bills should be designed more innovatively so that consumers are encouraged to take notice of their water bill and to be aware of how much water is being used on the property and what the average for that area is. This will facilitate the early indication of a leak on the property

N.3.2 Engineer level

The responsibilities at engineer level should be

- planning and installing metering and data acquisition locations
- operating the water network management PC software program and any other software packages which the water services provider is using

NOTE – No great sophistication is required to develop a water situation display. Simply plotting the average daily demand, minimum night flow rate and revenue on a wall chart will reveal a host of information and show tendencies.

- designing monitoring equipment facilities
- selecting monitoring/data acquisition equipment and devices
- storing and analysing of data obtained or generated
- generating monthly reports for Division Head
- verifying water reticulation drawings through continuous updating of information and making the corrections promptly

NOTE – A system should be developed where the making of corrections cannot be inadvertently overlooked (verification report).

- archiving of data, information and results on a GIS or, failing that, on a system ensuring ease of access and recall
- determining a suitable period between repeat tests for each area but not longer than every two years

NOTE – This repeat period will be adjusted from time to time as more experience in each area is gathered.

- comparing current data with previous data and determining growth in leakage rate which relates to deterioration of the system

- using permanent district meters for ongoing monitoring to identify those areas that are deteriorating most rapidly. When the reasons for the deterioration are being checked, the instrumentation should be checked first and the meter calibrated

- preparing cost/benefit reports annually or more frequently in marginal or problematic areas, (i.e. when approaching the point where the engineer has to make the decision whether to repair or replace any given section of the pipe work)

N.3.3 Technician level

The responsibilities at technician level are

- installing temporary data-logging, metering (and, as required, telemetry) equipment into existing monitoring facilities

- checking the correct functioning of the above-mentioned equipment

- checking the "as installed" accuracy of the above-mentioned equipment and any other fittings, fixtures or equipment, such as pressure gauges, which may have been installed

- downloading information gathered on data-loggers into software programs or spreadsheets, as the case may be

- determining the minimum night flow rate for each area

- instructing the Loss Detection Crew on the various areas that need attention, listed in order of priority

N.3.4 Loss Detection Crew

N.3.4.1 The Loss Detection Crew is the interface between the "Accounting for" and the "Corrective" actions.

N.3.4.2 The responsibilities of the Loss Detection Crew are:

- undergoing speciality training in the art of leak detection techniques and the use of leak detection instrumentation and equipment such as data-loggers, sounding devices, LNCs, ground radar, metallic pipe and valve cover location, mobile advanced step-testing (MAST) and procedures for opening and closing valve boxes and meter boxes and for entering manholes

- responding to work orders received from engineer level

- planning a water loss control procedure for each area and retaining or archiving for future reference

- carrying out water loss control procedures, as required, in highest priority areas first

- in larger areas or in complex areas (such as CBDs), subdividing the area into two, three or four sections (sectoring), to determine whether the minimum night flow rate recorded earlier is evenly distributed over the whole area or whether the rule of 80-20 applies to the area (the Pareto principle)

- undertaking step tests, sounding surveys, leak noise correlations, visual inspections, or MAST surveys, as required. Optional Loss Detection Crew tasks (recommended for water audit purposes):

- measuring the approximate size of the leak defect, using the water loss gauge, and, with known pressure, estimating the volume of water lost through the defect (The pressure occurring at night can be considerably higher than at times of peak demand. To estimate the volume of water escaping through a defect in the pipe, a pressure somewhere between these two extremes should be used. Typically, a pressure between half and two-thirds of the difference is selected, depending on the nature of the area.)

NOTE – International convention suggests assuming a one year period to determine the amount of water lost for accounting purposes. Because the size of the leak has grown over the year, a size between half and two-thirds of the size measured should be used to estimate the volume of water leaked from the system, using the accompanying table to estimate the rate of water loss. It has to be remembered constantly that this is not an exact science.

- comparing the gross cumulative losses found, as measured above, with the change in minimum night flow rate.

NOTE – If the figures do not agree, the cumulative totals should be adjusted proportionally.

N.3.5 Contractors

N.3.5.1 Many of the leak detection functions of the Loss Detection Crew can be put out to tender. Doing all of it in-house is especially difficult for medium to small towns.

N.3.5.2 When going out on contract, tender procedures should be followed.

N.3.5.3 The water loss procedures should be formalized into an industry so as to encourage and recognize an industry sector.

N.3.5.4 All first time or new contractors will need to undergo a training period to ensure that they are familiar with the operating and safety procedures of the water services provider and the relevant provisions of existing safety regulations.

N.3.5.5 The water services provider should take a policy decision on whether the contractor will be permitted to operate valves and fittings on the water distribution system and, if so, under what terms of indemnity.

N.3.5.6 Ideally, a contractor would be accompanied by one or more water services provider officials at all times to, *inter alia*, operate valves and fittings, liaise and make contact with the public and generally ensure an amiable image.

N.3.5.7 Consideration should be given to the practice that all leaks located should preferably be repaired by the water department staff of the water services provider.

N.3.5.8 The success of the contractor should be measured against the minimum night flow rate measured previously and the ongoing minimum night flow rate and unaccounted-for water figures. It is essential that the water services provider ensure that all parties have a clear joint understanding and acceptance of, and agreement on, each party's responsibilities.

N.3.5.9 Administrators are advised against the temptation to pay contractors in accordance with the amount of water saved or number of leaks found. This is known as bounty hunting.

Annex O
(Normative)

Verification of used water meters when tested in the installation in which they are used in trade

In order for a water meter to be verified as correct in terms of the Weights and Measures Act Cap 403 of the Laws of Zambia, the following requirements shall be complied with.

O.1 Permissible tolerance of indication on used water meters

When a used meter is tested in accordance with clause **O.2**, the difference between the indicated volume and the actual volume of water that passed through the meter shall not exceed:

a) 8 % of the actual volume passed at actual flow rates of less than q_t; and

b) 3,5 % of the actual volume passed at actual flow rates of not less than q_t.

O.2 Efficiency test

O.2.1 Test flow rates

Meters shall be tested at the following flow rates:

a) between q_{min} and 1,1 q_{min};

b) between q_t and 1,1 q_t; and

c) at least 90 % of the maximum attainable flow rate for the installation but not exceeding q_s of the meter.

O.2.2 Test apparatus

O.2.2.1 Calibrated reference device, consisting of one of the following:

a) standard volumetric measures capable of measuring at least the volume of water delivered in 1 min at the flow rate being tested but large enough to ensure that the error in the reading of the meter does not exceed 0.5 % of the volume delivered. The measures comply with the statutory requirements for such volumetric measures for use by verification officers;

b) any other test method that is acceptable to the Director of Weights and Measures and that conforms to the accuracies required for the testing by means of volumetric measures.

O.2.2.2 Any take-off valve, after the meter, for example a garden tap, for starting and stopping the test.

O.2.2.3 Flow rate control valve, to accurately control the flow rate of the water if the take-off valve cannot perform this function.

O.2.2.4 Means to measure the flow rate, in order to ensure that it is within the parameters for each flow rate given in **O.2.1**.

O.2.3 Procedure

O.2.3.1 Check the operation of the test apparatus and equipment and ensure compliance with **O.2.2.1**.

O.2.3.2 By inspection, observation or some other means, take precautions to ensure that there are no leaks in the plumbing system or usage of water during the test so that all water metered during the test enters the calibrated reference device.

O.2.3.3 Bleed any air from the pipe work connecting the meter to the calibrated reference device. Where applicable, wet the calibrated reference device and drain for 15 s.

O.2.3.4 Ensure that pipes are filled to the same extent at the beginning and at the end of the test.

O.2.3.5 Ensure that precautions are taken to avoid the effects of vibration and shock.

O.2.3.6 Open the water supply and adjust the flow rate to any of the flow rates given in **O.2.1**, and determine the error of the water meter indication at that flow rate.

O.2.3.7 Repeat O.2.3.6 for each of the remaining flow rates given in **O.2.1**.

O.2.3.8 If the error determined after any of the tests lies outside the tolerance band, the test may be repeated twice (i.e. to a total of three tests)..

O.3 Sealing and application of verification mark

If the meter complies with the above requirements, it shall be sealed as follows:

A meter shall have a device or other means of protection such that, after the meter or measuring assembly (as applicable) has been verified, it can be so sealed or protected that there is no possibility of dismantling the measuring element from the indicator or altering the meter or its adjustment device before or after installation, without damaging the seal or component parts of the meter. A seal or means of protection, which is located inside the meter body while in use, need not bear any markings.

The verification mark shall be incorporated in the seal or applied to the dial face in a permanent manner, for example, by embossing after verification, or by means of a permanent waterproof sticker that cannot be removed without damage to the sticker. When the verification mark is applied to the dial face, it shall not obscure the volume indication or the markings required as follows:

Each water meter shall be clearly and indelibly marked with the following information, either grouped or distributed on the body, on the indicator dial or on an identification plate or waterproof label permanently affixed to the meter, unless otherwise prescribed in special cases. The hinged cover of the water meter dial shall never be used for this purpose.

a. the manufacturer's name or trade name or registered trade mark;

b. the permanent flow rate, in cubic metres per hour (which may be combined with a thread or flange size, provided that the permanent flow rate remains conspicuous);

c. serial number (which may include the year of manufacture);

d. the direction of flow, applied to the body of the meter and indicated (for example) by an arrow;

e. on meters incorporating verified measuring assemblies, an identification mark, marked on the body, to indicate compliance with type approval documentation;

f. an approval number (This number will be allocated after type approval of a specific model of meter);

g. metrological class(es), e.g. A, B, C or D, as appropriate, and, where relevant, the letter V (vertical) or H (horizontal)

h. the nominal working pressure if other than 1 600 KPa; and

i. the pressure loss (either the group, or in kilopascals).