Unit 3. Performance Indicators of Water Losses in Distribution System

Contents:

Understanding and managing losses in water distribution system

Step 1: Analysis of network characteristics and operating practices

Step 2: Use appropriate tools and mechanisms to suggest appropriate solutions

Component of water loss

- Water loss
  - Physical loss
    - House connection leaks
    - Pipe break and leaks
    - Storage overflow
  - Commercial loss
    - مفارقات Billing anomalies
    - Metering error
    - Water theft

Standard Terminologies

(Source: IWA, 2000)

<table>
<tr><td rowspan="9">System Input volume</td><td rowspan="4">Authorized consumption</td><td rowspan="2">Billed authorized consumption</td><td>Billed metered consumption (including water exported)</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Billed unmetered consumption</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption</td><td>Unbilled metered consumption</td><td rowspan="7">Non- Revenue water</td></tr>
<tr><td>Unbilled unmetered consumption</td></tr>
<tr><td rowspan="5">Water losses</td><td rowspan="2">Apparent losses</td><td>Unauthorized consumption</td></tr>
<tr><td>Metering inaccuracies</td></tr>
<tr><td rowspan="3">Real losses</td><td>Leakge on transmission and/or distribution mains</td></tr>
<tr><td>Leakage and overflows at utility storage tank</td></tr>
<tr><td>Leakage on service connections up to point of consumer metering</td></tr>
</table>

What is Unaccounted-For-Water (UFW)?

Definition: Unaccounted-for water (UFW) represents the difference between "net production" (the volume of water delivered into a network) and "consumption" (the volume of water that can be accounted for by legitimate consumption, whether metered or not).

UFW = “net production” – “legitimate consumption”

Non-revenue water (NRW) represents the difference between the volume of water delivered into a network and billed authorized consumption.

NRW = “Net production” – “Revenue water”
=UFW + water which is accounted for, but no revenue is collected (unbilled authorized consumption).

Calculating Water Loss

Water loss is expressed as

• percentage of net water production (delivered to the distribution system)

• as m^3/day/km of water distribution pipe system network (specific water loss)

• Others

- m^3/day/connection

- m^3/day/connection/m pressure

- **Water loss as % of net water production is the most common.**

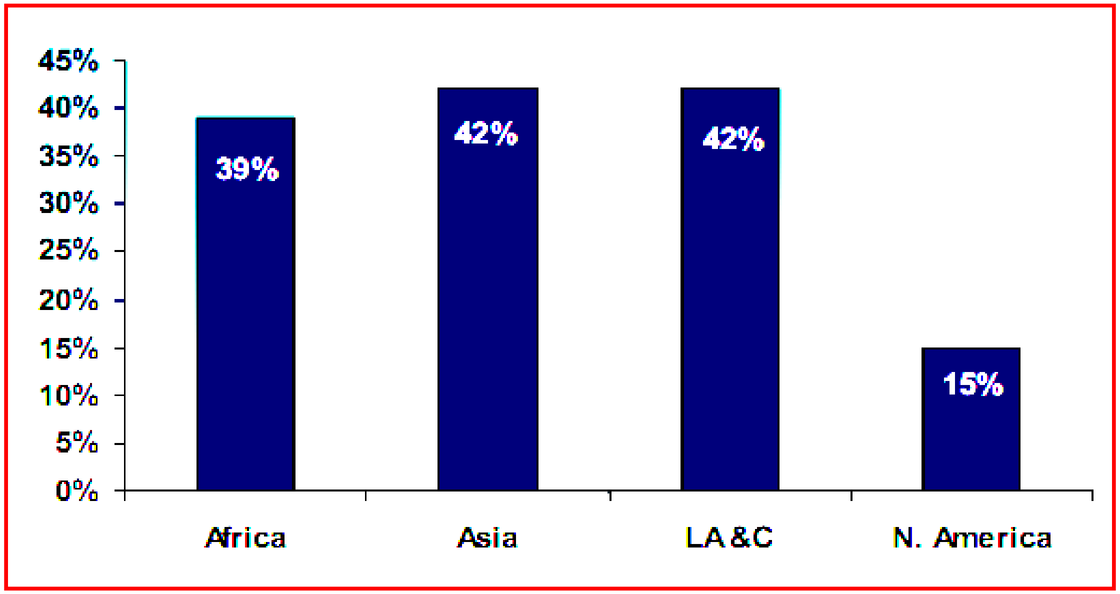
-It could be misleading for systems with different net productions with same amount of real & apparent losses.

Magnitude of Water Losses

• Water loss levels (UFW or NRW) vary widely per country and within one country per city.

• UFW values ranging from 6% to 63% have been reported

• A certain level of water losses can not be avoided from a technical point of view and /or is considered acceptable from an economic point of view.



Mean UFW in Large Cities in Africa, Asia, Latin America and the Caribbean and North America

What is an Acceptable Water Loss?

1. It is a compromise between the cost of reducing water loss and maintenance of distribution system and the cost (of water) saved.

2. American Water Works Association (AWWA) Leak detection and Accountability Committee (1996) recommended 10% as a benchmark for UFW.

3. UFW levels and action needed

< 10% Acceptable, monitoring and control

10-25% Intermediate, could be reduced

> 25% Matter of concern, reduction needed

Components of Water Losses

Good understanding of the relative weights of different components is important for development of a sound water loss reduction program.

Component of UFW (%)		Indonesia	Thailand	Malaysia
Physical losses	Trunk mains, distribution system	21	2	2
	Service connections	10	34	17
Non-Physical losses	Illegal connections	6	2	2
	Under registration and billing	6	8	15
Total UFW %		43	46	36

Leakage distribution (% of total volume)

Country	Trunk mains	Distr. pipes	Service reserv.	Service conn.
Sweden	10.4	43.8	-	45.8
Britain	10.9	43.5	4.4	41.2
USA	9.0	77.7	5.0	8.3
Israel	12.5	47.5	5.0	35.0

Breakdown of Distributed Water Volume Nuremberg, Germany as example

<table>
<tr><td rowspan="9">Distribution water 100%</td><td rowspan="3">Accounted for water 91.3%</td><td colspan="2">Charged water 84.8%</td></tr>
<tr><td colspan="2">Bulk supply water 6.2%</td></tr>
<tr><td colspan="2">Other meters water (park, fountains etc.) 0.3%</td></tr>
<tr><td rowspan="6">Unaccounted for water 8.7%</td><td rowspan="3">Apparent losses 3.5%</td><td>Unmetered usage 0.5%</td></tr>
<tr><td>Own water works consumption 1%</td></tr>
<tr><td>Meter errors 2%</td></tr>
<tr><td rowspan="3">Real losses 5.2%</td><td>Pipe breaks 3.5%</td></tr>
<tr><td>House connection corrosion 1%</td></tr>
<tr><td>Other losses 0.7%</td></tr>
</table>

Unavoidable Annual Real Losses (UARL)

• It is impossible to eliminate all real losses from a distribution system

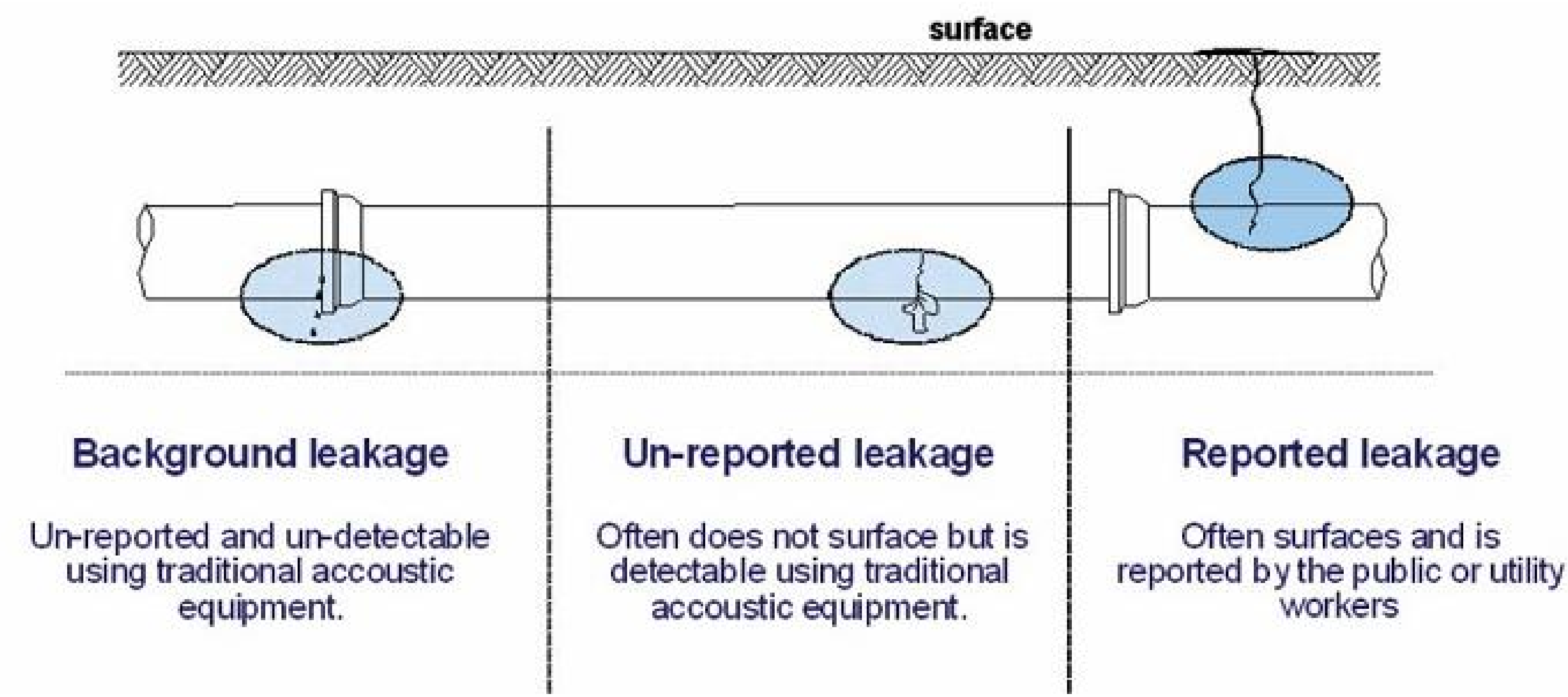
- some losses are “unavoidable”

- some leakages are believed to be undetectable (too small to detect) or- uneconomical to repair

• An estimate of Unavoidable Annual Real Losses (UARL) can help to evaluate the feasibility of real loss minimization (provides better understanding of real loss components).

Unavoidable Annual Real Losses (UARL)

- **The UARL is computed based on Background and Burst Estimates (BABE) concept.**



Unavoidable Annual Real Losses (UARL)

$$\boxed{\text{UARL (L/day)} = (18 \times L_m + 0.80 \times N_c + 25 \times L_p) \times P}$$

where

L_m = Length of mains in km

N_c = Number of service connections

L_p = Total length in km of underground connection pipes (between the edge of the street and customer meters)

P = Average operating pressure in m

Unavoidable Annual Real Losses UARL in liters/service connection/day for customer meters located at edge of street

Density of connections N_c $/L_m$ (per km mains)	Average operating pressure (P) in meters				
	20	40	60	80	100
20	34	68	112	146	170
40	25	50	75	100	125
60	22	44	66	88	110
80	21	41	62	82	103
100	20	39	59	78	98

Unavoidable Annual Real Losses (UARL)

Generalized Equation

$$\boxed{\text{UARL (L/day)} = (A \times L_m + B \times N_c + C \times L_p) \times P}$$

where

A = specific real losses for mains (L/day/km/m pressure)

B = specific real losses for service connections (L/connection/m pressure)

C = specific real losses for underground service pipes (L/day/km/m pressure)

Typical UK distribution system background leakage levels at 50 m pressure

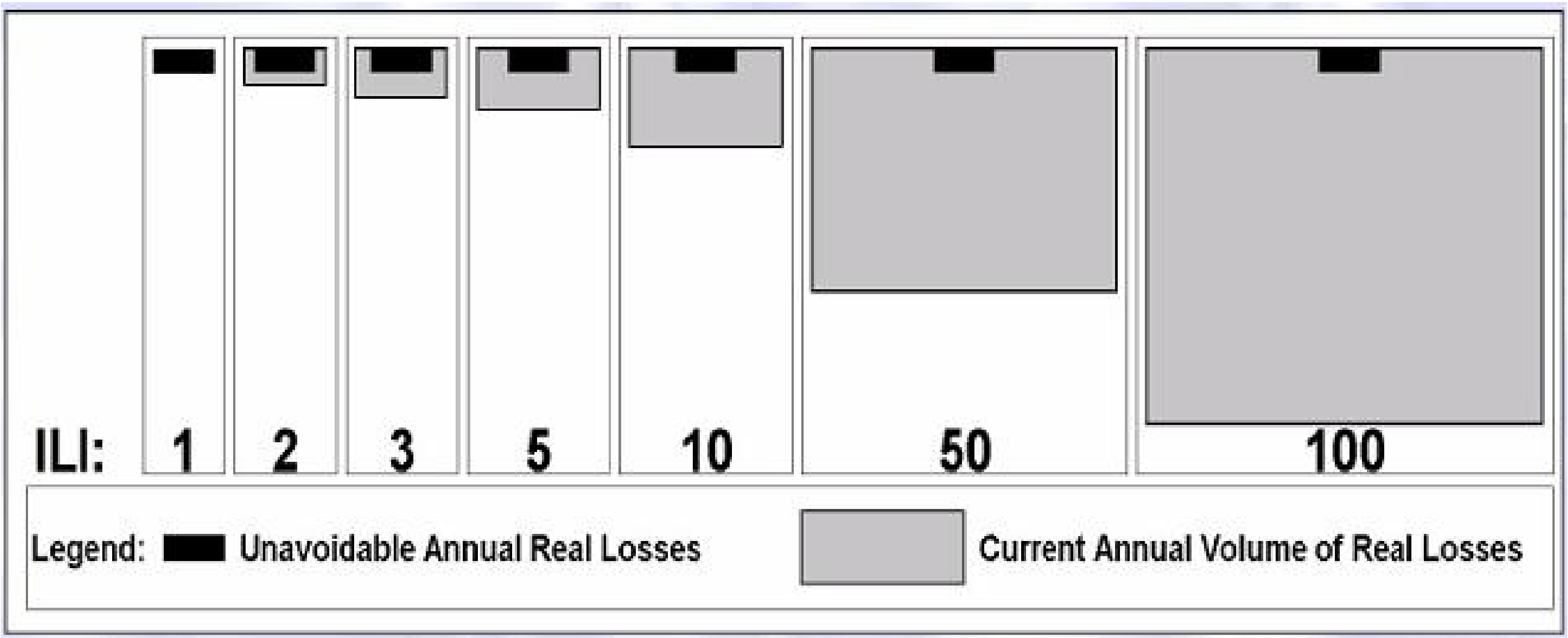
Infrastructure element	Estimated leakage level		
	low	average	high
Distribution main (l/km/h)	20.0	40.0	60.0
Average for all metered service pipes: • meter at property boundary (l/connection/h) • meter in - house (l/connection/h)	 1.50 1.75	 3.00 3.50	 4.50 5.25
In house plumbing losses • Average over all houses (l/property/h)	 0.25	 0.50	 0.75

Source: Twort et al. 2000

The Infrastructure Leakage Index (ILI)

- **A better indicator**
- **Describes the quality of infrastructure management**
- **Is the ratio of Current Annual Real Losses to Unavoidable Annual Real Losses**

$$ILI = \frac{CARL}{UARL}$$



World Bank Institute Banding System

- to Interpret ILIs
- ILI is classified into Bands A to D
- Different limits for developed & developing countries
- Each Band has a general description of performance
- Each Band suggests a range of recommended activities

Developing countries	**Developed countries**	**BAND**	**General description of real loss performance management categories**
ILI Range	ILI Range		
< 4	< 2	A	Further loss reduction may be uneconomic unless there are shortages; careful analysis is needed to identify cost effective improvement
4 to <8	2 to <4	B	Potential for marked improvements; consider pressure management, better active leakage control practices, and better network maintenance
8 to <16	4 to <8	C	Poor leakage record; tolerable only if water is plenty and cheap; even then analyze level and nature of leakage and intensify leakage reduction efforts
16 or more	8 or more	D	Very inefficient use of resources; leakage reduction programs imperative & high priority

WBI Recommended Activities

WBI Recommendations for BANDS	A	B	C	D
Investigate pressure management options	Yes	Yes	Yes	
Investigate speed and quality of repairs	Yes	Yes	Yes	
Check economic intervention frequency	Yes	Yes		
Introduce/improve active leakage control		Yes	Yes	
Identify options for improved maintenance		Yes	Yes	
Assess Economic Leakage Level	Yes	Yes		
Review burst frequencies		Yes	Yes	
Review asset management policy		Yes	Yes	Yes
Deal with deficiencies in manpower, training and communications			Yes	Yes
5-year plan to achieve next lowest band			Yes	Yes
Fundamental peer review of all activities				Yes

The Apparent Loss Index (ALI)

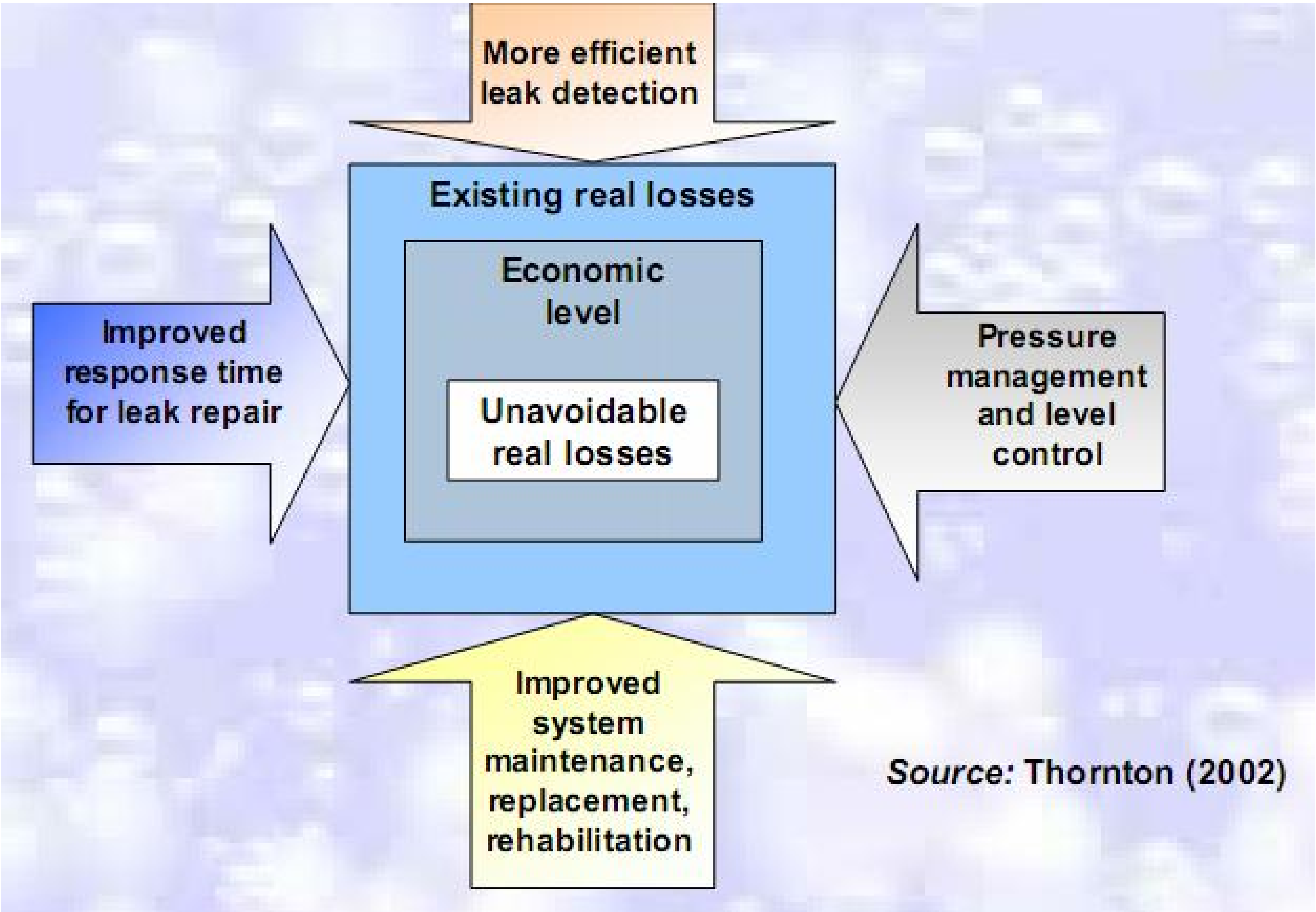
Similar to the concept of ILI, a index for apparent loss has been recommended by IWA task force.

$$\text{Apparent Loss Index (ALI)} = \frac{\text{Apparent Loss}}{\text{5\% of Water Sales}}$$

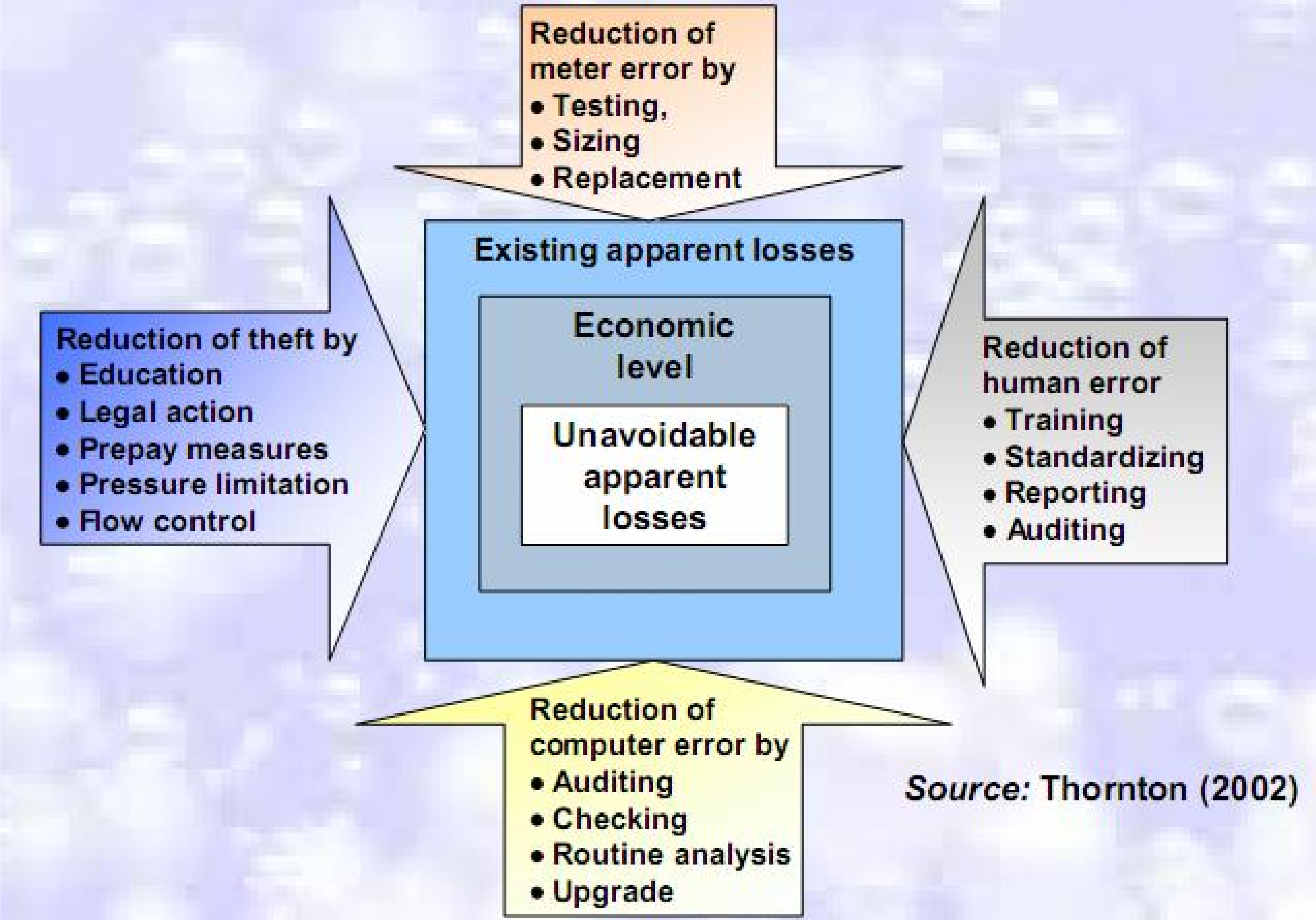
Controlling Water Loss

- Water audit or Water balance
- Meter testing and repair/replacement, improving
- billing procedure
- Leak detection and control program
  - network evaluation
  - leak detection in the field and repair
- Rehabilitation and replacement program
- Corrosion control
- Pressure reduction
- Public education program; Legal provisions
- Water pricing policies encouraging conservation
- Human resources development
- Information system development

Four components of an active real loss management program



Four components of an active apparent loss management program



Guideline for Water Loss Level

For systems with per capita consumption of less than 150l/day the general rule for water loss level is:

Good condition of system	**< 250 Litre/connection /day**
Average condition	**250 - 450 Litre/connection/day**
Bad condition of system	**> 450 Litre/connection/day**

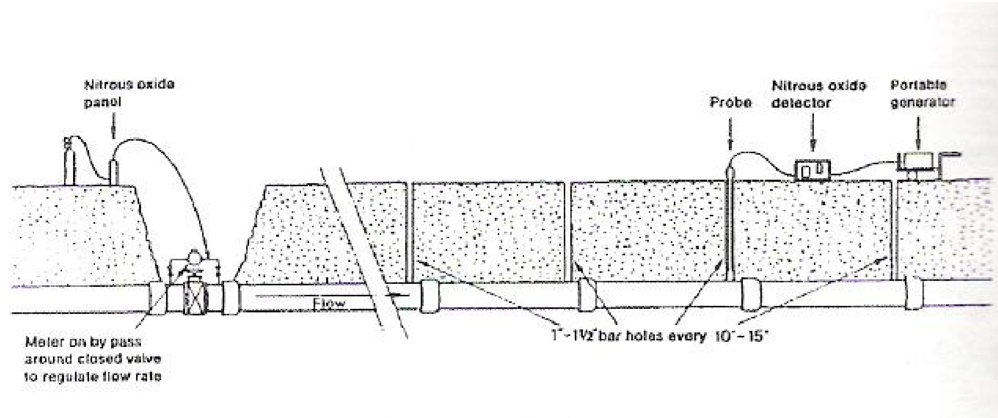
Another guideline for the water loss level is the “Benchmark” Liter/km mains/day:

Good condition of system	**< 10,000 Litre/km main/day**
Average condition	**10,000 – 18,000 Litre/km main/day**
Bad condition of system	**> 18,000 Litre/km main/day**

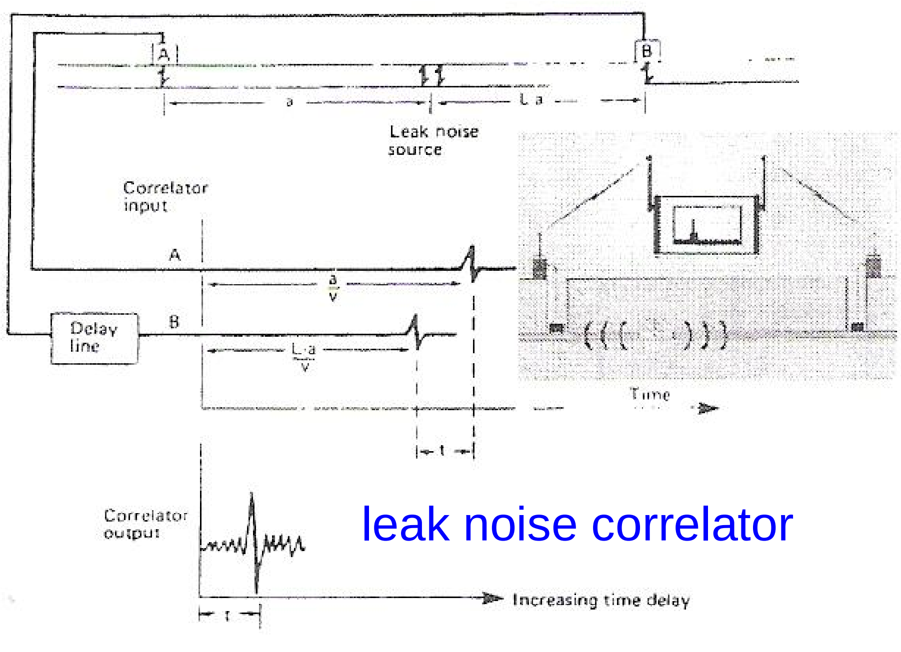
Source: Kfw funded programs

Leak Detection Methods

Acoustic (sound) method



Tracer techniques (N_2O)



leak noise correlator

Field Tests in Water Distribution Systems

- Provides insight into the system performance

- Data collection is the first step in the model calibration process.

Field test campaigns comprise:

- Pressure measurement on the network
- Fluctuations in reservoirs levels
- Network flow rates

Pressure measurements are located on the basis of the following criteria:

1. Good spatial coverage
2. Optimized use of available equipment

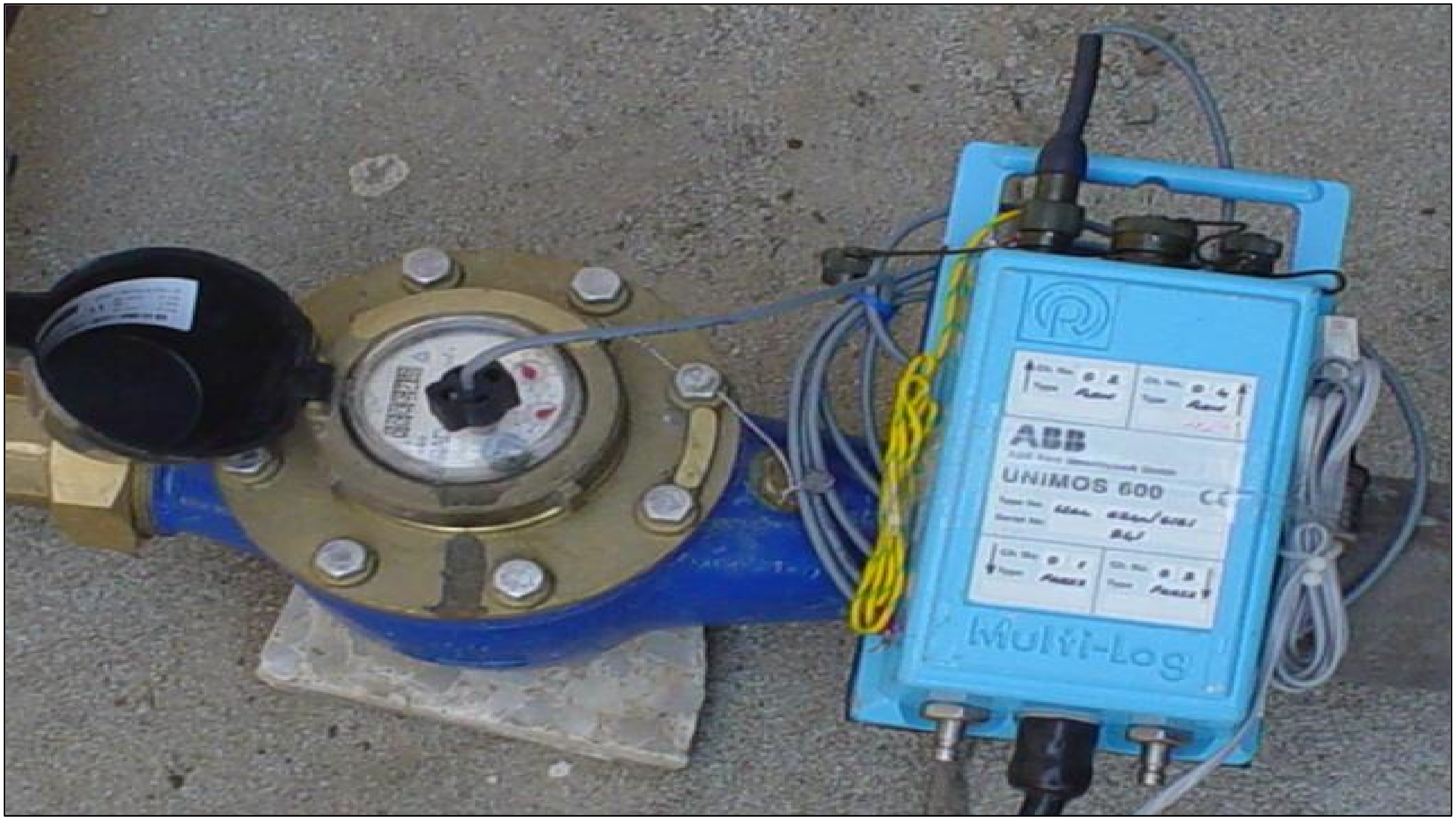
- All of the measurements must be performed simultaneously
- Accurate topographical readings to all pressure measurement points

Field Test Equipment

Pressure	Flow	Reservoirs Levels
Pressure gauges	Flow meters with pulse heads	Level meters
Pressure sensors /transducers	Insertion electromagnetic flow meters	Some tanks are equipped with electronic level measurements

Data loggers / recorders

are very useful tool in field tests



Data logger introduction and physical sample

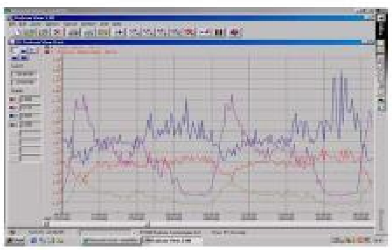
INTRODUCTION

RadLog for Windows™ software is the generic term for an extensive range of software modules and specialist applications designed and supported by RADCOM, primarily for operational data logging.

RADLOG for Windows™ offers Icon driven communications, data storage and graphing for the acquisition of data from Radcom Data Loggers and controllers. Full use is made of the various Windows™ facilities, including graphics, print manager and help screens.

Sample screen from graphical display module in RADLOG View

TYPICAL APPLICATIONS



Flow & Pressure Monitoring and Control Software

Logger setup & data download
RadLog for Windows software is ideal for setting up and downloading data from any Radcom data logger on site using a Laptop PC, in the office using a desktop PC, or via PSTN or GSM telemetry links.

Data analysis
RadLog for Windows provides a simple to use extensive graphing package for data analysis with windowing and zooming functionality. Data can also be examined in table format on screen, or exported into other packages.

GIS interface
RadLog for Windows can be linked to proprietary GIS Graphical Information Systems, or can be used with Radcom's Easy GIS software.

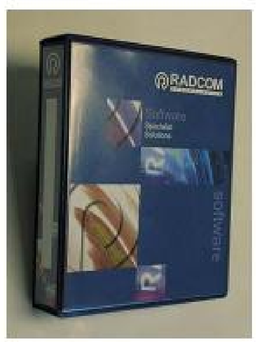
ADVANCED DESIGN

RadLog software has been developed by Radcom over the last 15 years, and is widely known as the market leader in the water industry.

RadLog for Windows also provides full support for Radcom's more recent range of PRV Controller products. Thereby offering a single package that can control and monitor critical systems.

RadLog for Windows can be used on Server based systems, where the downloaded data is available for multiple users across the LAN or Wide Area Network.

RADCOM has adopted a continuous review and update philosophy based on the feedback from operational users, resulting in regular releases of the software, adding enhancements and solutions. Details of the latest software can be obtained from RADCOM's Help Desks on Telephone Nos:-
UK:+44(0)2380 682 320 or USA : +1 800 723 2066



Software Operations Manual complete with diskettes / CD

INTRODUCTION

Multi Log is the most cost effective, advanced and flexible data logger yet. It can be supplied with up to four inputs for monitoring any combination of digital or analogue signals.

Each input has a primary recording channel and secondary "fast sampling" channel and can be supplied in portable mode or with a telemetry link.

Multi Log is completely water proof, submersible and battery powered and will require no maintenance for at least five years.

A telemetry link can be provided either by telephone line using an internal PSTN modem or by using the cellular communications network with an internal GSM modem.

Alternatively, portable Multi Log units can be upgraded in the field to cellular communications with the addition of **Rad Net GSM.**

TYPICAL APPLICATIONS

District and Zone Monitoring
Multi Log is ideal for monitoring flow, pressure and or water quality parameters to assess demand, leakage and conformance

Network Analysis Investigations
Multi Log can perform dynamic flow & pressure analysis of network models together with the facility to investigate unusual events with "fast sampling".

Key Account Customers
Multi Log confirms levels of service and enables extra data to be provided to key customers, even in real time using telemetry links.

ADVANCED DESIGN

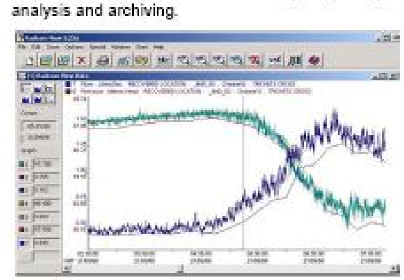
Multi Log can be supplied with up to four inputs of any type. Each input is logged in two channels; a primary channel and a secondary channel. Both channels can be programmed independently.

This enables, for example, the primary channel to be used for normal recording and reporting purposes while the secondary channel is used diagnostic purposes.

When monitoring pressure, the secondary channel can record transients that would be missed using conventional recording methods.

Alternatively, the secondary channel can be used to measure the time interval between flow meter pulses. This enables flow data to be interpolated to fixed time intervals and therefore 'smoothed' for analysis.

All of Radcom's data loggers and controllers are compatible with **Rad Log for Windows**™, the industry-standard for data trending, reporting, analysis and archiving.



Typical Rad Log display showing primary and secondary channels from Multi Log

Field Test at Water Well Outlet

The field test campaign

- Pre-field Test activities
- Main field Test activities

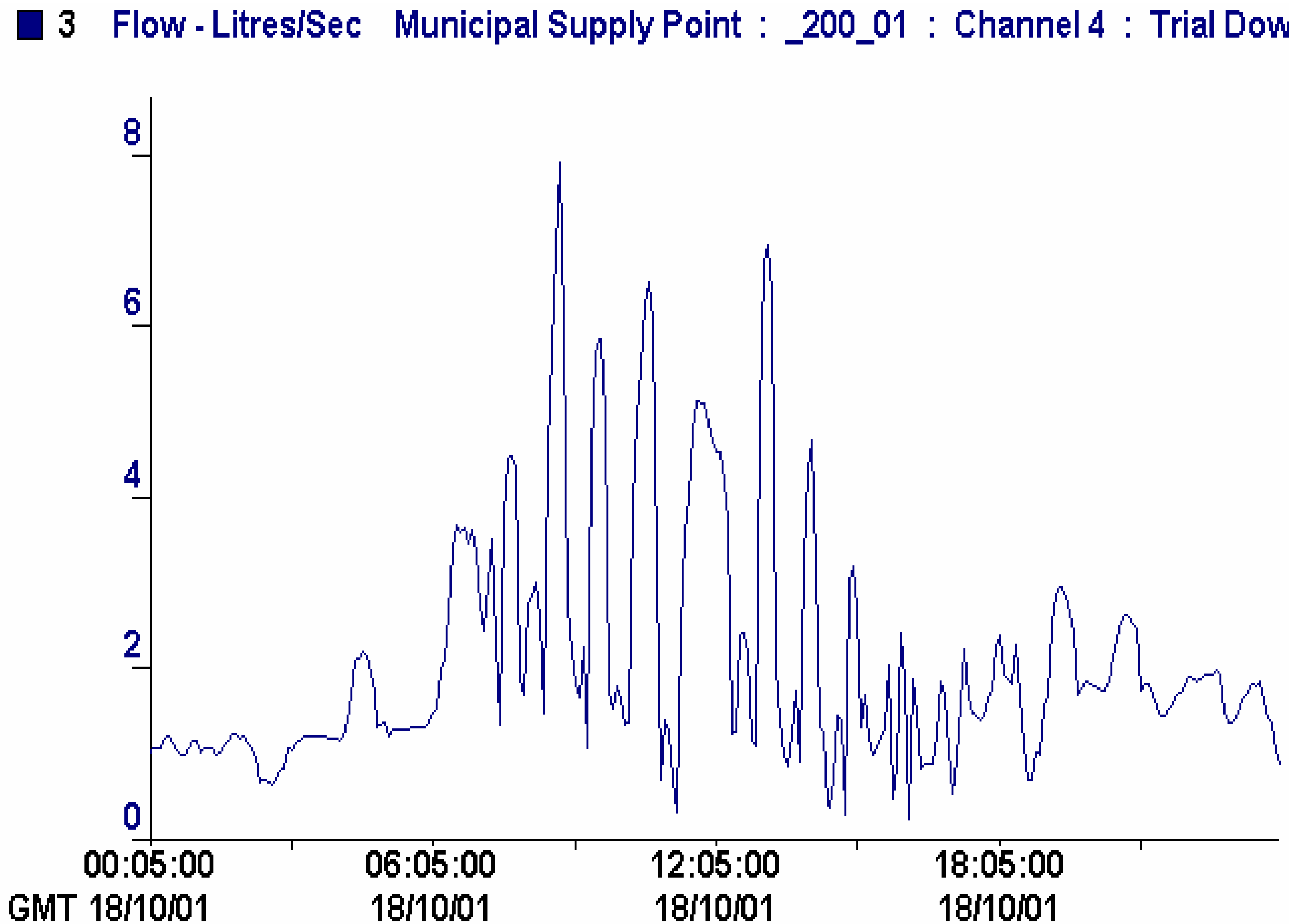
Pre-field Test activities

1. Selection of the measurement points
2. Determination of ground levels of pressure measurement points - contour map / conventional levelling techniques (if needed).
3. Definition and execution of site works needed to conduct the field tests.
4. Fabricating tapping points for pressure measurements.
5. Inspection & maintenance of water meters.
6. Installation of water meters for flow measurements as needed.
7. Identification of strategic valves within the distribution system.

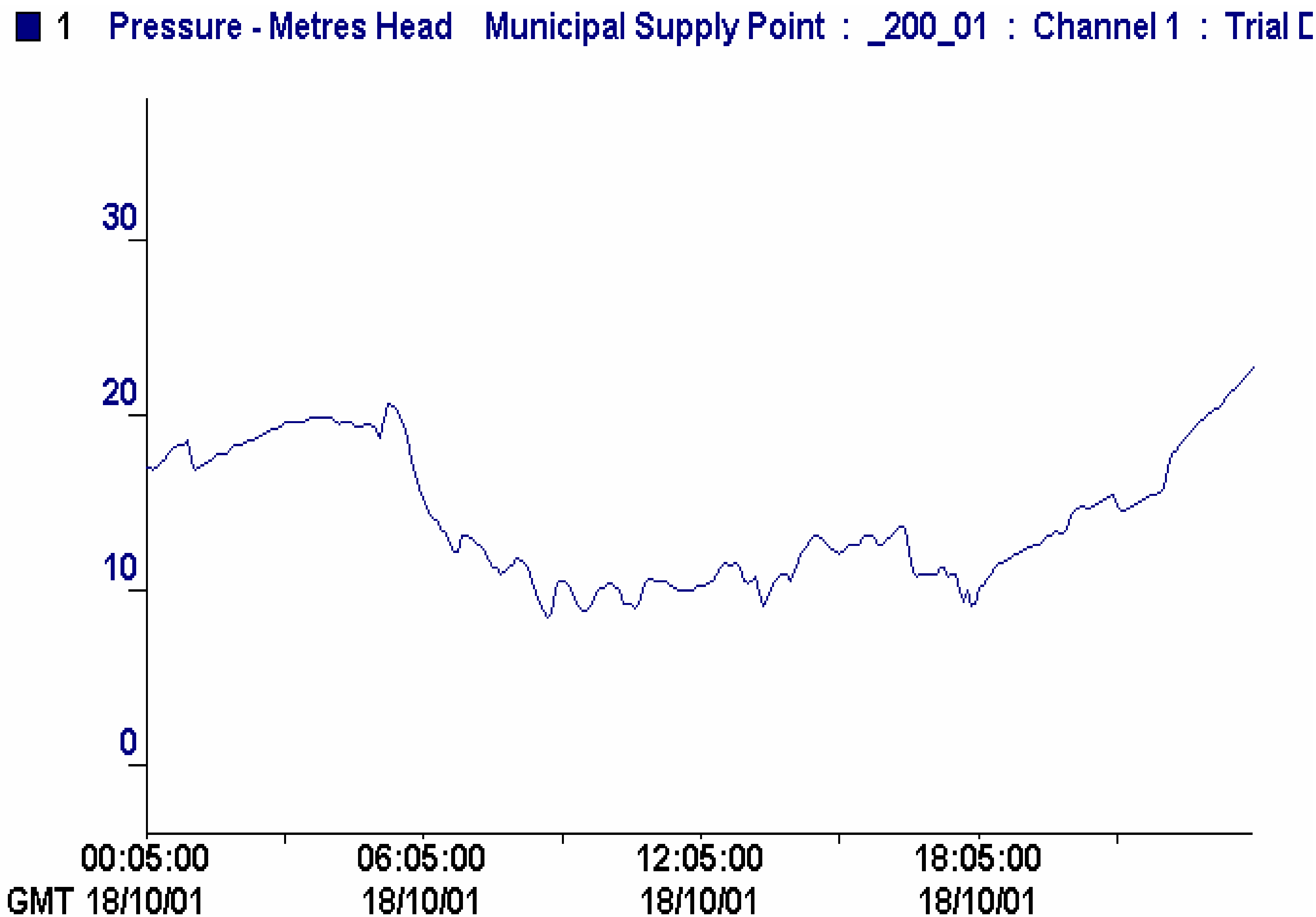
Main field Test activities

1. Definition of test period and sampling rate.
2. Programming data loggers for flow and pressure measurement.
3. Installation of data loggers
4. Collecting manual reading as needed.
5. Tracking the status of valves during the field test.

Field Test Results



Field Test Results, continue



- **DISTRICT METERING:**

A water distribution network will, by definition, supply water to consumers, both domestic and commercial/industrial.

Depending on the country, varying amounts of water are "lost" or "unaccounted for" between the reservoir or storage facility or the operating well and the consumer.

Unaccounted For Water (UFW) is expressed as the difference between the volume of water entering the distribution system and the volume of water billed to customers. Depending on the country, UFW figures can range from single figure percentages to more than 40% in Gaza Strip.

- Apparent losses arise from the continued use of old consumer water meters. Almost any type of water meter will under read with time: the magnitude of this under-reading depends on the manufacturer, type and age of the meter. Under-reading obviously has a negative impact on the revenue accruing to the water utility and contributes to the overall UFW figure.

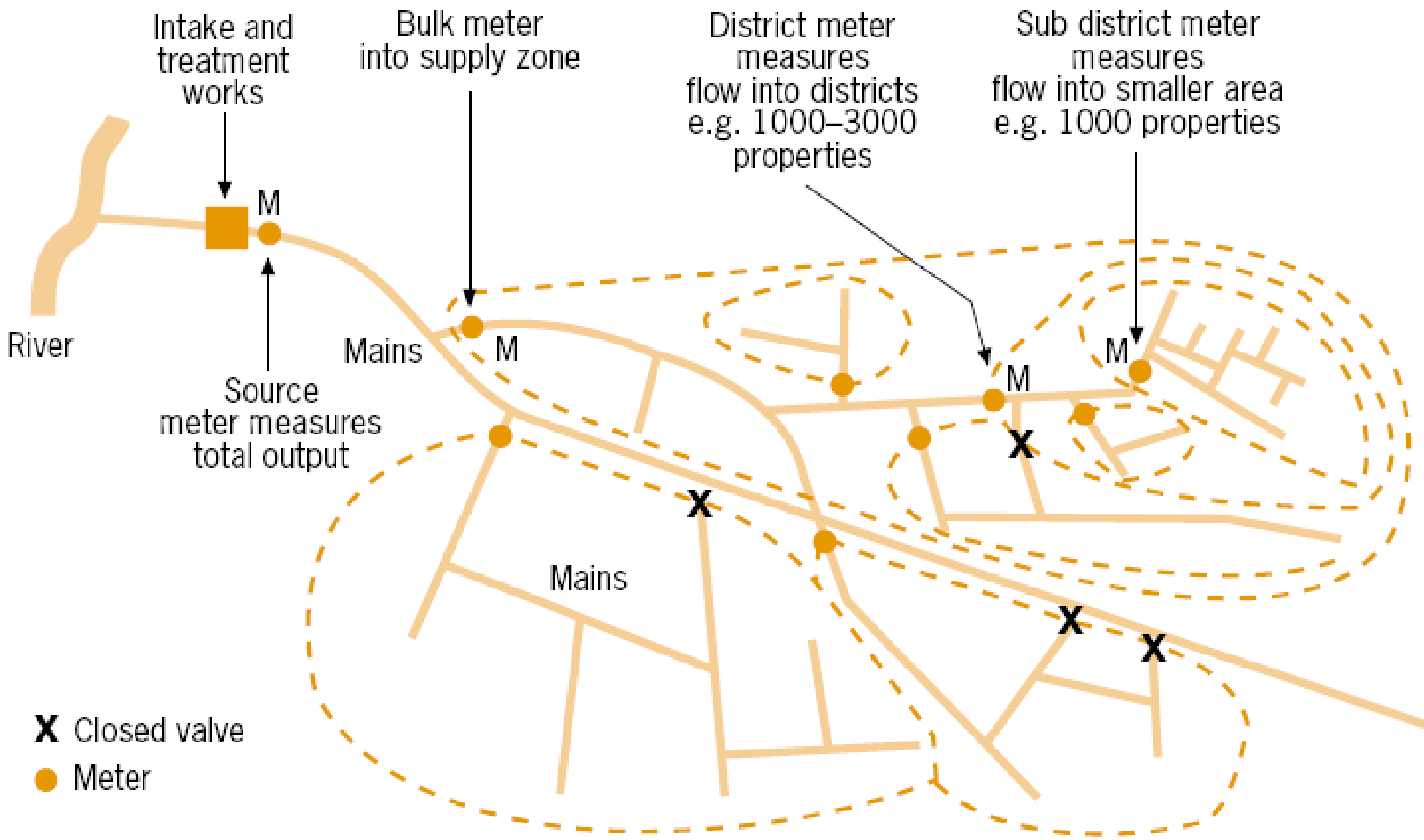
- It should also be noted that certain types of meter may over-read with time, depending on the condition of the water. The continued use of these meters could mask a potential UFW problem, as the apparent sum of the billed consumption may equal or exceed the amount of water entering the network, whereas in fact an unknown amount of water may be lost due to leakage or theft.

- **In order to localize the problem areas, it is recommended that the network be divided into several District Meter Areas, (DMA), and that accurate bulk water meters be installed at the entry point into these districts. Ideally, the sum of the flow totals recorded by the district meters should equal the quantity of water measured at the outlet of the water well sources, allowing for recognized meter uncertainties as defined in international standards. If there are significant differences between the source reading and the sum of the district meter readings, the upstream network needs immediate investigation. However, as the pipe sizes, flow rates and pressures are likely to be greater in this part of the network, leaks are more likely to be obvious.**

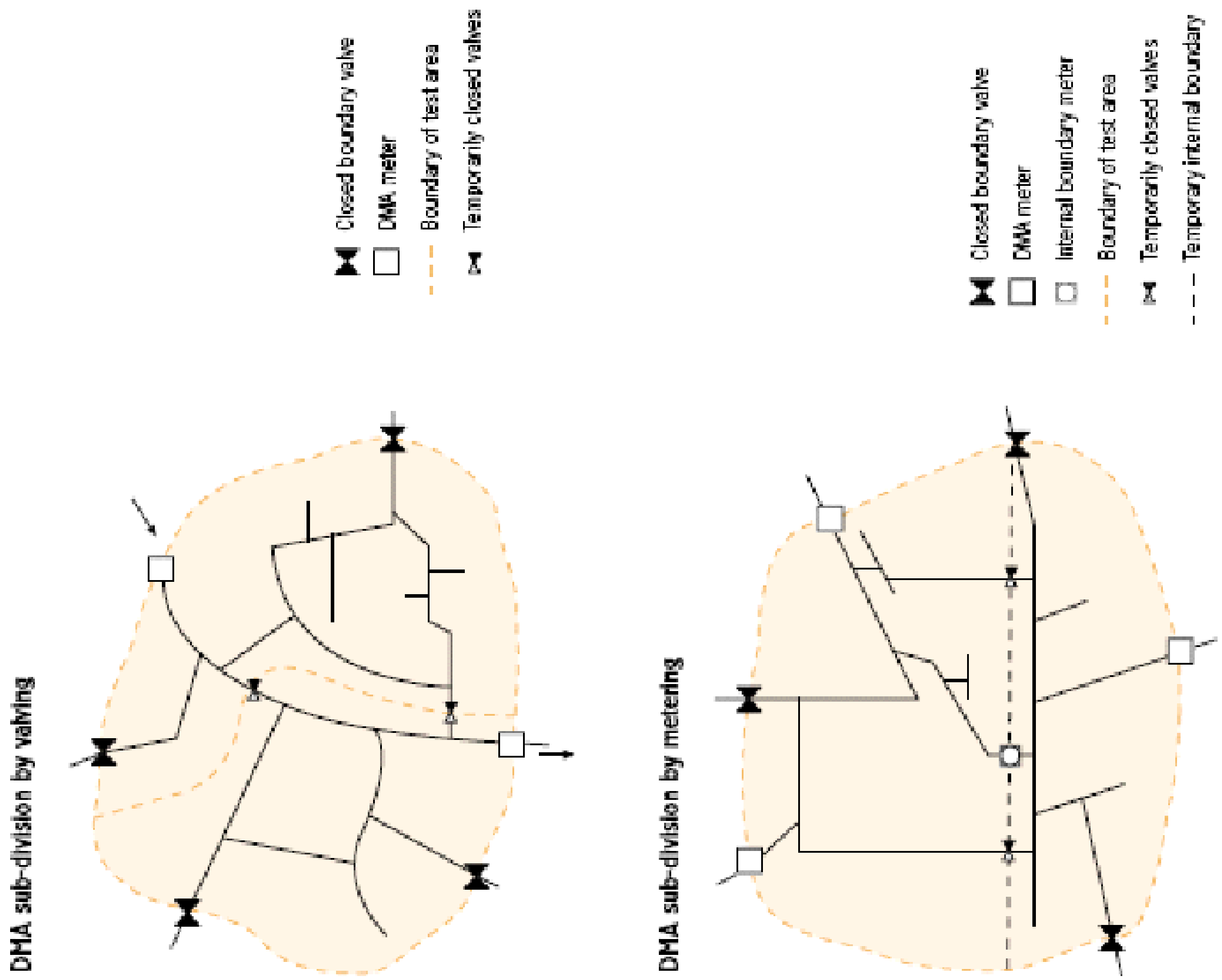
- In some networks, district meters are already installed. In these cases, a meter evaluation and, if necessary, replacement program is an essential part of the UFW reduction exercise. This should be implemented at an early stage and should include meters installed at large commercial and industrial customers which .may represent a significant source of revenue for the utility. A detailed study needs to be conducted into the age, size and type of meter installed. A meter change-out program has the combined benefit of;
- (1) Producing more reliable information for the UFW evaluation team and
- (2) Increasing the revenue for the utility, as older under-reading meters are replaced with newer, more accurate meters.

Typical metering hierarchy and DMA design options

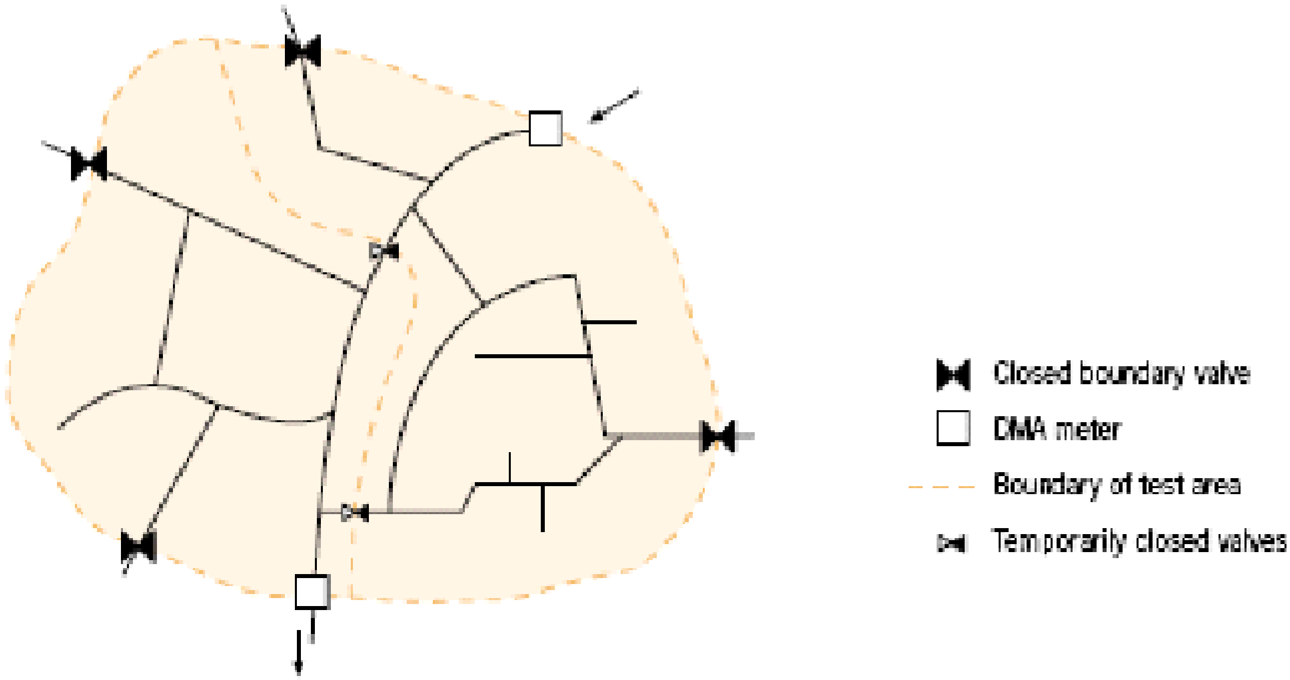
(reproduced from *Managing Leakage—Report J*)



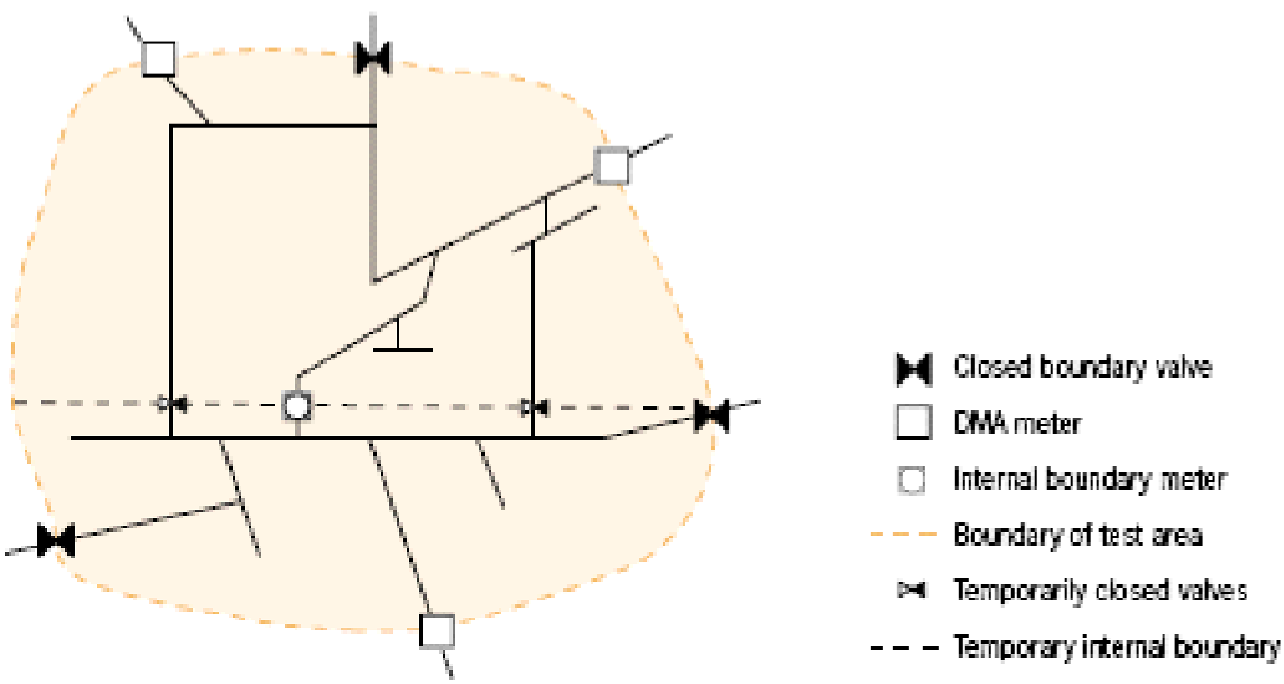
sketch illustrating the DMA and other valves' location with the boundary of the proposed district zone



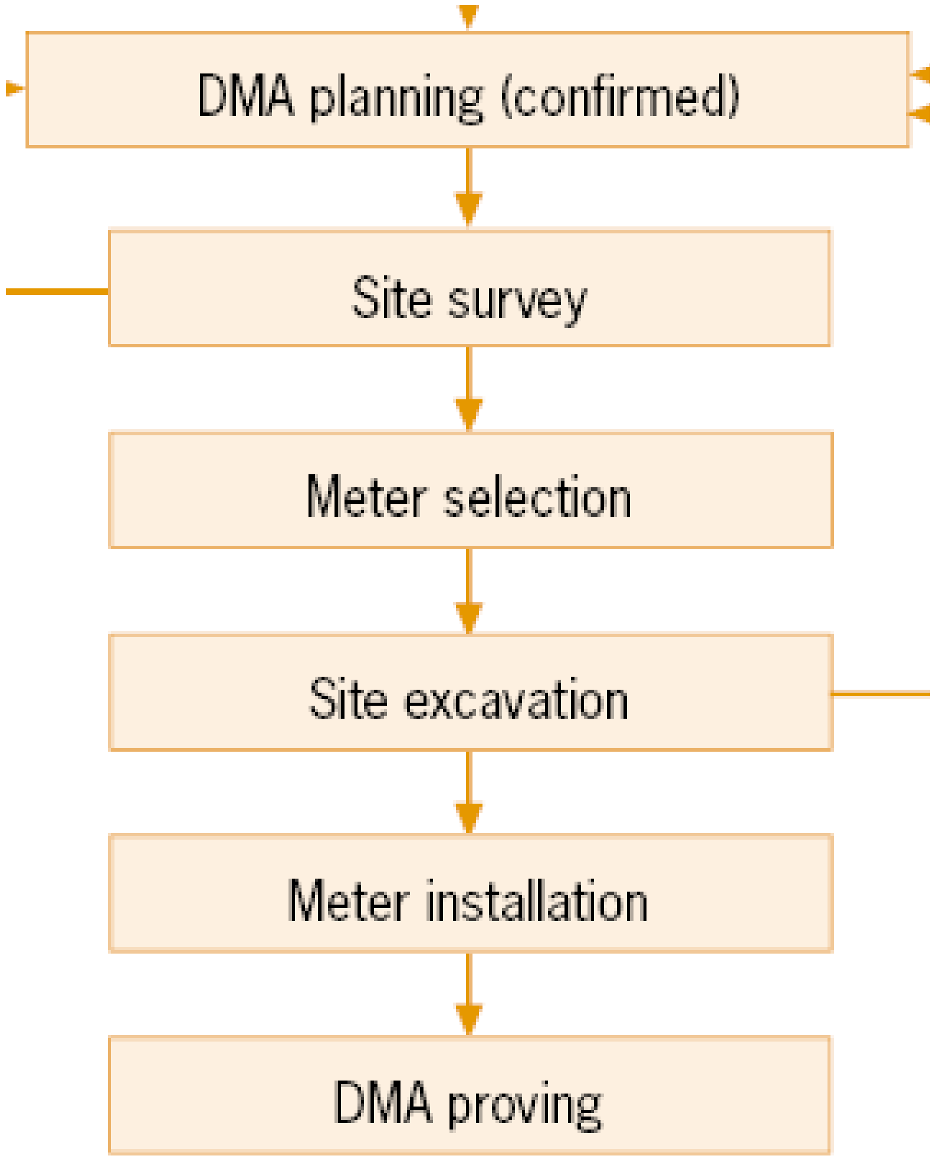
DMA sub-division by valving



DMA sub-division by metering



Following is a chart summarizing the stages in designing and installing DMAs

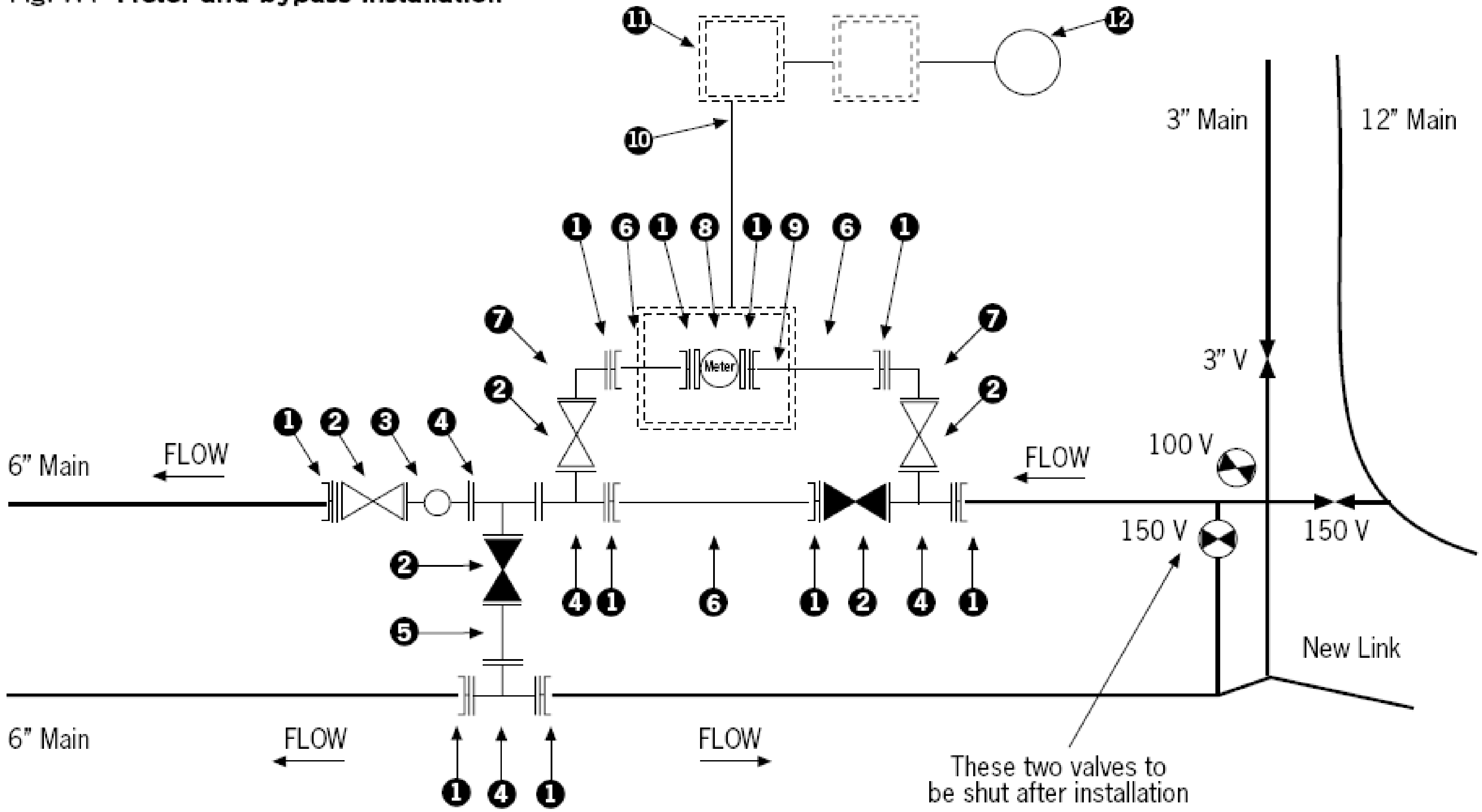


Several key considerations in such a design or re-design a DMA is that it should include the followings;

1.Separate trunk mains from subsidiary networks
2.Limit the number of recording meters (ideally single-feed)
3. and Whenever possible each district should be fed by one and only one meter. Multiple meters will be allowable where no other network arrangements are practicable.
4. Best use of the existing network structure in order to limit additional network.
5. Existing billing zoning (readers rounds), if any, so that the reading of a particular district meter is comparable to the reading of the pertinent district meter.

• Following is an example of installation of standard district meter and its accessories;

Fig. 7.4 **Meter and bypass installation**



Meter and bypass installation: schedule of materials

Ref. No. (see Fig. 7.4)	Materials	Quantity
1	150 flange adapter	10
2	150 SV	4
3	150 x 150 x 80 mm tee with W/O	1
4	150 x 150 x 150 mm tee	2
5	150 ductile iron pipe—length to suit	3
6	150 mm 90° elbow	2
7	150 mm ductile iron pipe—length 0.75 m	1
8	150 mm meter	1
9	Pressure tapping	1
10	150 mm ductile iron pipe—length to 1.5 m	1
11	50 mm ducting	As required
12	Boxes	2
	Antenna	1
	Grade A chamber cover	1
	GSM communications (temporary)	

References

- Water Supply. Twort A.C, Law, F.M, Crowley and Ratnayaka. John Wiley &sons.Inc. Fifth edition 2000

- Global Water Supply and Sanitation Assessment 2000 (WHO-UNICEF)

- International water association (IWA) http://www.iwahq.org

- American Water works Association (AWWA) http://www.awwa.org