water and sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Guideline for the preparation of an IWA water balance to determine Non-revenue Water and Water losses

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LIST OF DEFINITIONS AND ABBREVIATIONS

Definitions or abbreviation	Description
CARL	Current Annual Real Losses
Connection	Any accepted (informal) or formal point of water supply. A connection can metered or unmetered.
Formal connection	Any point of water supply, which has been installed by the water utility and is controlled with a service level agreement.
Informal connection	Any point of water supply, which has been installed by the user but the water utility has no intension of removing.
Unauthorised (illegal) connection	A water connection to a user which was not installed and accepted by the water utility or a water connection which has deliberately been tampered with to reduce or eradicate the metered consumption.
User	A user includes any person, business, institution, etc. that is supplied with potable water by the water utility. A user includes consumers and customers. A consumer is a person or group of people (household) that are the final users of products and/or services generated within a social system. A customer (also known as a client, buyer, or purchaser) is the recipient of a good, service, product, or idea, obtained from a seller, vendor, or supplier for a monetary or other valuable consideration. Water utilities should endeavour to make all users customers.
Deemed or flat rate consumption	Deemed or flat rate consumption is an unmetered fixed volume of water sold to a user on a monthly basis. Users are deemed to use this volume of water but the actual consumption may be more or less.
DWS	Department of Water and Sanitation
ILI	Infrastructure Leakage Index
IWA	International Water Association
KPI	Key Performance Indicator
NRW	Non-Revenue Water
SIV	System Input Volume
UARL	Unavoidable Annual Real Losses
UFW or UAW	Unaccounted for Water
WCWDM	Water Conservation and Water Demand Management
WTW	Water treatment works
WWTW	Wastewater treatment works

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1 INTRODUCTION

Water loss in water distribution systems has been studied for many years in many countries and is continuously leading to the development of new concepts and theories. The Water Loss Task Force (WLTF) of the International Water Association (IWA) was established in 1995 to develop standards and best practice guidelines. The WLTF has subsequently grown to the largest specialist group within the IWA, and their best practice guidelines have been adopted by more than 15 % of water utilities across the world (Waldron, 2010).

Some of the key concepts developed by the WLTF to date include:

- abandoning the ambiguous concept of un-accounted for water (UAW or UFW) and providing improved concepts for defining water loss and non-revenue water (NRW)
- development of the standard IWA water balance which provides a breakdown of authorised consumption, water losses and NRW
- development of the infrastructure leakage index (ILI) as physical water loss indicator
- discouraging the use of % water losses, as the use of percentages can be misleading
- adopting the burst and background leakage estimate (BABE), fixed and variable area discharges (FAVAD) and unavoidable annual real loss (UARL) concepts which were developed by the South African and United Kingdom water industries, providing a systematic and component based technique to assess water loss in a water distribution system
- various guidelines and initiatives on performance benchmarking of water losses, pressure management, leak detection, district metered areas (DMA), physical losses and commercial losses.

The South African Water Services Act (Act 108 of 1997) requires all spheres of Government to ensure water services are provided in an efficient, equitable and sustainable manner, which is sufficient for subsistence and sustainable economic activity. This can only be achieved through a detailed understanding of the system input volume, authorised consumption, water losses and non-revenue water (NRW) of all urban and rural potable water distribution systems. The water balance, developed by the IWA for this purpose, has been actively promoted in South Africa since 2002 by the Department of Water and Sanitation and the Water Research Commission through the following publications:

- 2002 – Development of a simple and pragmatic approach to benchmark real losses in potable water distribution systems in South Africa. WRC Report TT 159/01 by Mckenzie and Lambert.
- 2005 – Benchmarking of Leakage from Water Reticulation Systems in South Africa. WRC Report TT 244/05 by Mckenzie and Seago.
- 2007 – Non-Revenue Water in South Africa. WRC Report TT 300/07 by Seago and Mckenzie.

Although the IWA, DWS and WRC have gone to great lengths to standardise the water balance calculations and terminology, there still remains considerable confusion and varying opinions on how to deal with certain aspects of the water balance calculation.

The Minister of Water Affairs introduced the No Drop Certification Programme for Water Use Efficiency and Water Loss Management on 21 May 2013 at the Budget Vote Speech. The No Drop certification scorecard is an incentive-based regulatory programme aimed at improving water losses and NRW. Regulation has the primary task to set and/or interpret rules, standards and, where relevant, grant approvals for the water sector, monitor compliance, analyse and publish results, promote transparency and confidence in the actions of the Regulator, make determinations, enforce decision and intervene where necessary. To ensure that the evaluation of Water Services Authorities is equal and just, they need to report on their water balance calculations in the same way.

The purpose of this guideline document is to discuss the technicalities and standardise the water balance calculation for the country and provide a guideline, which can be used and understood by politicians, officials and the public. This guideline follows the terminology, methodologies and requirements of the IWA and the No Drop programme and will assist utilities to comply and thus avoid audit queries. Utilities are encouraged to prepare a water balance that is a true reflection of - their current efficiency, water loss and NRW status. Preparing a water balance that looks good on paper should at all costs be avoided, as problems cannot be addressed if they are "hidden" somewhere in the calculations.

1.1 Importance of water conservation and water demand management

Water conservation and water demand management (WCWDM) is critical in the water services sector and could influence the

- available water resources that are under pressure and are highly influenced by population growth, short and long term climate change, economic trends, water quality, environmental considerations and huge cost to develop, operate and maintain new infrastructure
- financial sustainability of the water utility if proper metering, billing and cost recovery is not properly implemented
- water security if the water demand exceeds the reliable supply
- level of service delivery. Excessive leakage often results in deteriorating and inequitable level of service. The result of such leakage is usually intermittent supply and rationing as the water authority cannot pressurise the bulk supply. Intermittent supply can result in water borne diseases as contaminants are sucked into the pipeline during drainage
- service delivery. Water supply infrastructure assets which are not maintained will result in poor service delivery and increased leakage

Repairing leaks will reduce physical losses

- micro environment by creating unnatural wetlands, a breeding ground for mosquitoes and health hazards to the community
- macro environment by necessitating augmentation schemes such as large dams
- economy by assisting in alleviating poverty, improving the economy and job creation through awareness, plumbing and maintenance job creation opportunities
- reduced production, pumping, pipe failure and chemical costs with subsequent reduced greenhouse gasses
- reduce the impact of severe droughts and climate change

- decisions taken at national, provincial and local government level, as they cannot make sound judgements with regards to water resources and water services without the IWA water balance. The water balance should form the basis of licence applications, approvals and conditions, planning and implementation of water resources, WCWDM strategies and business plans, operation and maintenance programmes, monitoring and evaluation of WCWDM projects and regulation (No Drop).

1.2 Modified IWA water balance

The IWA developed the standard water balance to benchmark and evaluate the performance of water distribution systems and it is being promoted across the world as best practice. The IWA standard water balance was slightly modified for South Africa to allow for free basic water. The modified IWA water balance is shown in **Figure 1**.

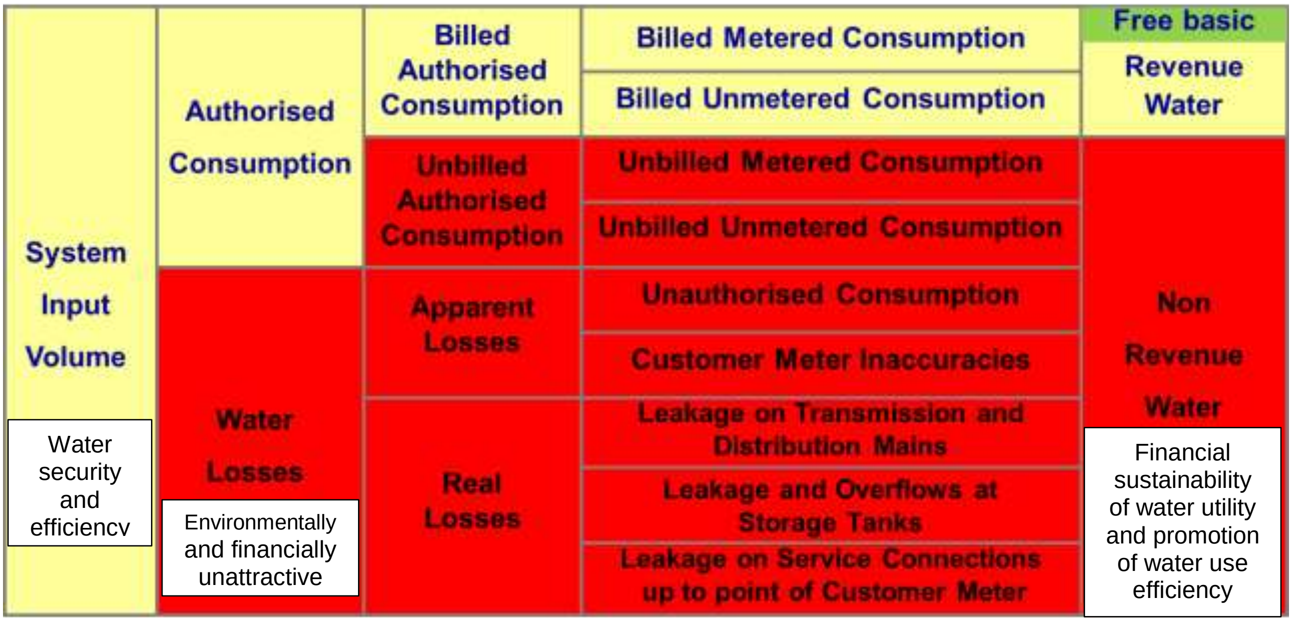


Figure 1: Modified IWA water balance

Each component of the water balance is significant as it highlights various important aspects. The system input volume provides an indication of the water security, if compared to the licensed abstraction, and the water use efficiency in terms of litres per capita per day. The water losses are financially and environmentally unattractive and cannot be allowed while the NRW provides an indication of the financial sustainability of the water utility. Payment for water services promotes water use efficiency as it has been shown all over the world that people who pay for water tend to use it more sparingly.

The following definitions are adopted from the *State of Non-revenue Water in South Africa* (Seago & McKenzie 2007):

- *System input volume (SIV)* represents the potable volume input to the water supply system from the water utility's own sources, as measured at the water treatment works (WTW) outlet, allowing for all known errors (i.e. errors on bulk water meters) as well as any water imported from other sources, also corrected for known bulk metering errors

- *authorised consumption* is the volume of metered and/or unmetered water used by authorised users, the water utility and others who are implicitly or explicitly authorised to do so by the water utility, for residential, commercial and industrial purposes
- *water loss(es)* is the sum of the physical and commercial losses and is calculated as the difference between the SIV and the authorised consumption. In most countries, water losses are also considered to be unaccounted for water (UFW) although the exact definition of UFW can vary from country to country
- *billed authorised consumption* is effectively the revenue water, and is the volume of authorised metered and unmetered consumption which is billed by the water utility and paid for by the user
- *unbilled authorised consumption* is the volume of authorised metered and unmetered consumption that is not billed or paid for
- *commercial losses or apparent losses* are made up of the unauthorised consumption (theft or illegal use), plus all technical and administrative inaccuracies associated with user metering. If commercial losses are reduced, generally more revenue will be generated by, and for, the water utility
- *real losses* are the physical water losses from the pressurised system, up to the point of the metered or unmetered connection. In most cases, real losses represent the unknown component in the overall water balance. The purpose of most water balance models is therefore to estimate the magnitude of real losses so that the water utility can gauge whether or not it has a serious leakage problem. Real losses are generally calculated as the difference between total losses and estimated commercial losses
- NRW is the volume of water supplied by the water utility but for which it receives no income. NRW incorporates unbilled (metered or unmetered) authorised consumption, apparent / commercial losses and real / physical losses.

Community awareness creates jobs and educates the community

1.3 Legal requirements

Non-revenue water and water loss benchmarking are required under the Regulations relating to Compulsory National Standards and Measures to Conserve Water (R509 of 2001) under the Water Services Act (Act No. 108 of 1997). The aforementioned regulations require the following:

- Clause 10 states that a water services authority **must include a water services audit in its annual report** on the implementation of its Water Services Development Plan required in terms of section 18(1) of the Act
- Clause 11 states that a water services institution **must prepare a water and effluent balance analysis on a monthly basis** and determine their water losses by comparing the measured quantity of water provided to each supply zone with the total measured quantity of water provided to all user connections within that supply zone

- Clause 13 states that a water services institution must, within two years after promulgation of these Regulations, **fit a suitable water volume measuring device or volume controlling device to all user connections** provided with water supply services.

The Regulations relating to Compulsory National Standards and Measures to Conserve Water (R509 of 2001) are included in the Department's No Drop incentive-based regulatory system to improve service delivery and water security and to reduce water losses and non-revenue water.

Water loss benchmarking is also required in terms of the following legislation:

- **The Water Services Act, Act No 108 of 1997**, makes provision for the preparation and adoption of water services development plans by water services authorities and the promotion of effective water resource management and conservation to ensure efficient, affordable, economical and sustainable access to water services.
- **The Water Act, Act No 36 of 1998**, recognises that sustainability and equity are central guiding principles in the protection, use, development, conservation, management and control of water resources.
- **Municipal Systems Act, Act No 32 of 2000**, that provides for the core principles, mechanisms and processes that are necessary to enable municipalities to move progressively towards the social and economic upliftment of local communities, and ensure universal access to essential services that are affordable to all.

1.4 Water Distribution System Terminology

Key components of the water distribution system are shown in **Figure 2**.

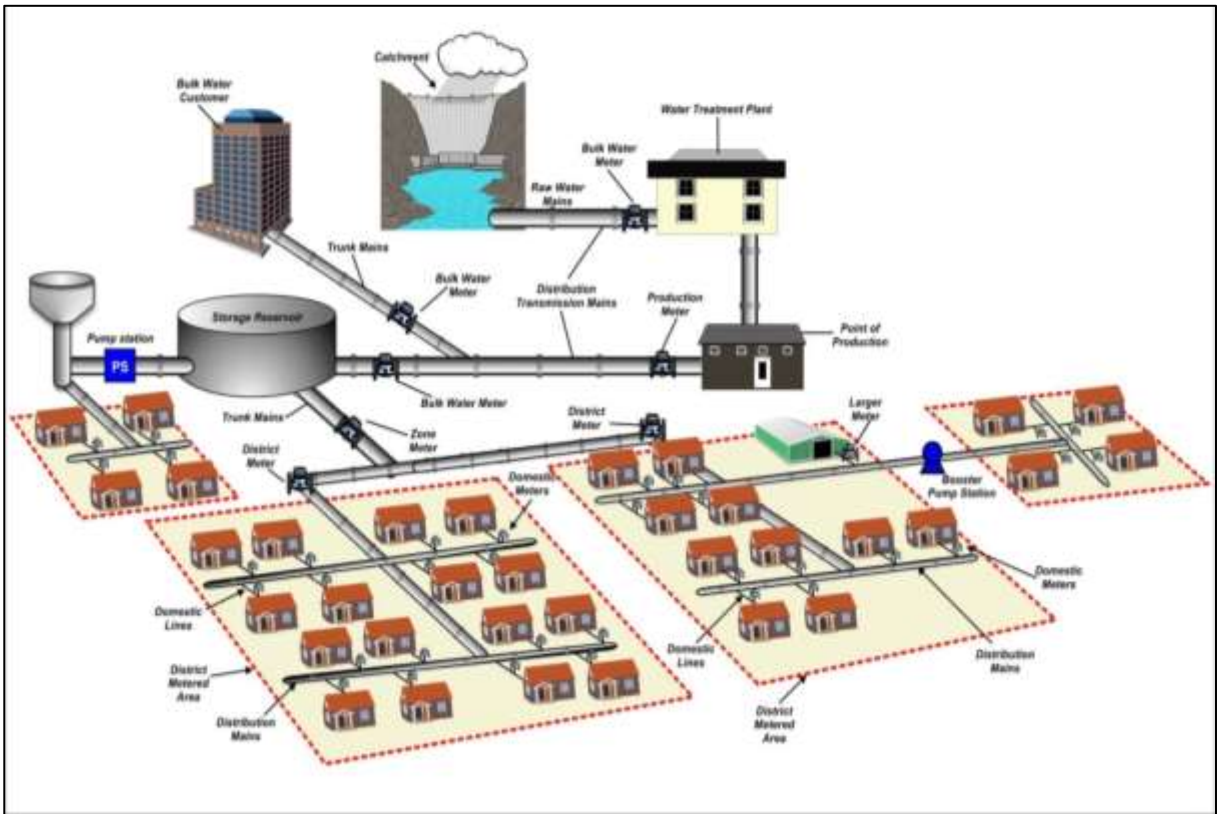


Figure 2: Components of a water distribution network

- **Water sources** include springs, wells, boreholes, rainwater, surface water – rivers and dams, bulk-supply pipelines or a combination of these
- **Water treatment works (WTW)** are used to treat raw water to acceptable standards for domestic and non-domestic consumption
- **Bulk water transmission mains** are used to transmit raw or potable water; are often long and of large diameter and are designed to supply water at the average demand flow rate. Usually there are limited or no user connections on a bulk water transmission pipeline
- **Storage reservoirs** provide balancing storage to meet daily demand, emergency storage for interruptions in bulk supply, balancing storage for pump operation and fire-fighting
- **Storage towers** serve high-lying areas adjacent to the reservoir, provide emergency storage for interruptions in supply and fire-fighting
- **Pump stations** are required to boost pressures in transmission mains and to supply towers when natural pressures are too low
- **Bulk distribution mains** feed from reservoirs into the reticulation and are usually the biggest pipes in the system because they are sized for peak flows
- **Reticulation** is the network of pipes (150 mm diameter and smaller) which connects the system to individual users, the network has service valves for maintenance and hydrants as required for fire-fighting
- **District metered areas (DMA) or zones** are set up to enable effective management and monitoring of system losses
- **Connections** are subject to a Service Agreement between the user and the utility. The connection (saddle, lead, stop tap and meter) is part of the reticulation system and belongs to the utility whereas fittings on properties (after the meter) belong to the user and are their responsibility.

2 BASIC INFORMATION REQUIRED

Certain basic information is required to prepare a water balance. Most of the information required should be provided by the engineering and finance departments of the water utility and it is important that these departments work together to develop a single water balance which accurately reflects the volumes of water distributed and not a department specific water balance which gives different answers. Information used in the water balance should be the same as presented in the Integrated Development Plan (IDP), Water Services Development Plan (WSDP), annual report, and other official documents.

The water balance calculation should be based on traceable and credible information which could be verified during an audit. Credible and verifiable information includes monthly bulk or user meter readings and official reports from the municipal billing system to justify billed metered and unmetered consumption. A typical audit trial for the system input volume is shown in **Figure 3**.

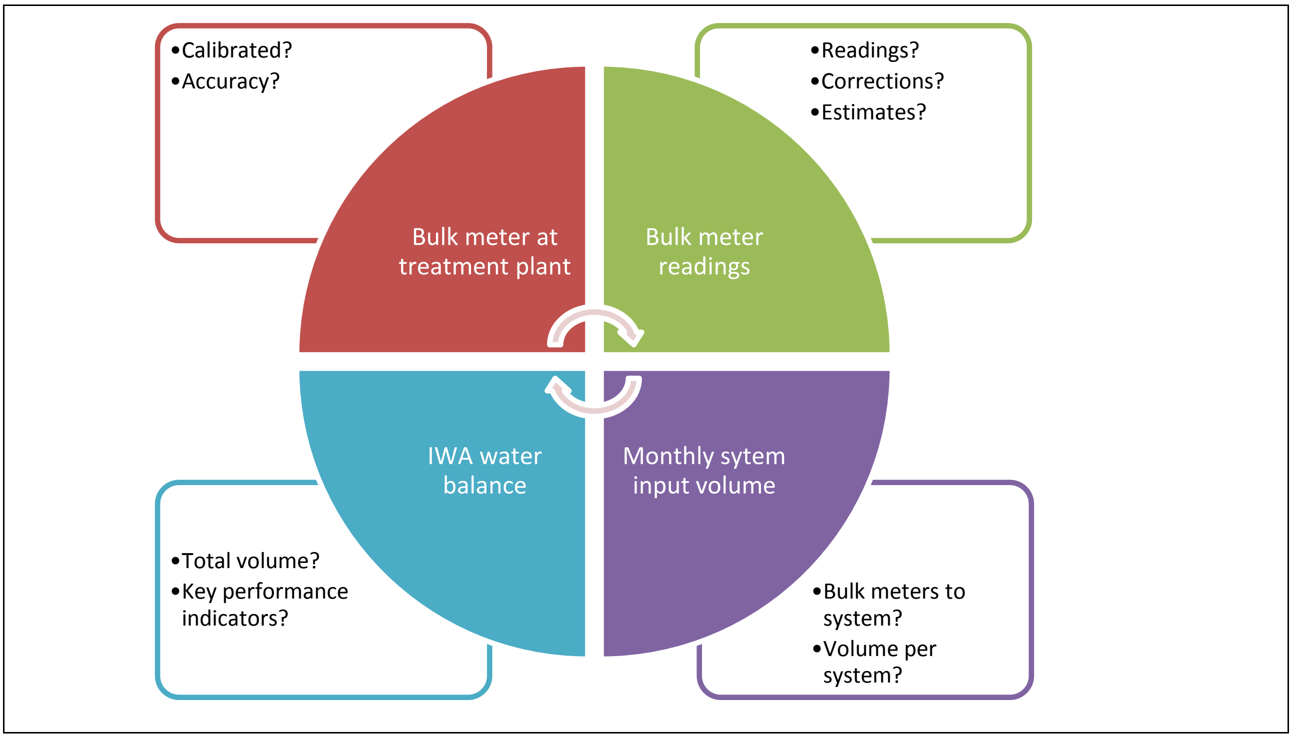


Figure 3: System input volume audit trail

The basic information required to prepare an IWA water balance and calculate KPIs is discussed in the following sections.

2.1 Supply area and schematic

A water supply system is defined as an area with defined physical water infrastructure, including, but not limited to pipes, valves, meters and potable water storage facilities such as reservoirs or boreholes, for which the system input volume and authorised consumption could be measured and a water balance prepared. A water supply system could be any size and made up of several smaller water supply systems. The sum of several smaller water supply systems should add up to the water balance for the whole water utility's supply area.

To enable management of these systems, the engineering department should develop a layout drawing of the supply area supported by a schematic layout. The infrastructure should be recorded in a comprehensive asset register, which can provide information pertaining to the age of infrastructure, replacement due dates and the replacement value of the infrastructure.

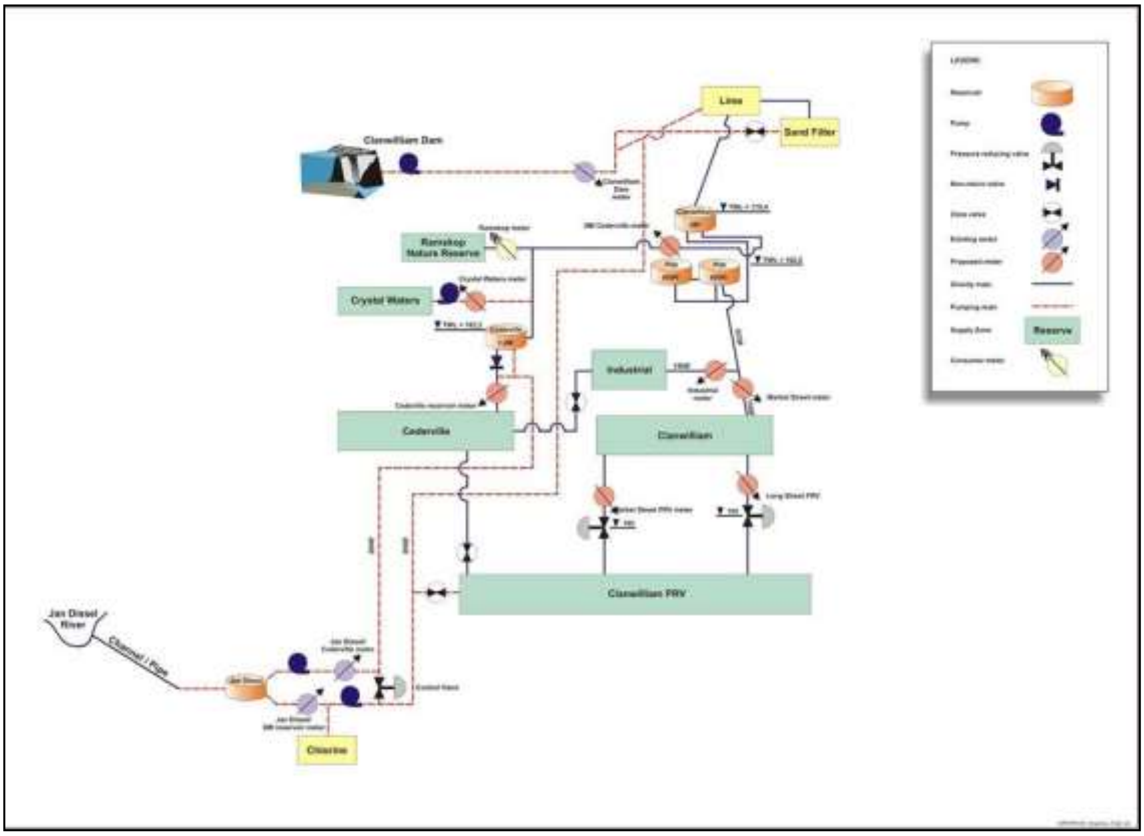


Figure 4: Typical schematic layout drawing

> **Audit requirement:** Layout drawing of distribution network covering all areas supplied by the water utility. The layout drawing must be supported by a schematic layout indicating all key infrastructure components such as reservoirs, towers, bulk meters, WTW and WWTW.

2.2 Population and households served

The population and households served should be obtained from a reliable source such Statistics South Africa (StatsSA) Census data. StatsSA data is considered the official source of demographic information by the DWS, and any deviation from StatsSA data must be verified. Water utilities are encouraged to use the demographic information presented on the Department's National Water Services Knowledge System (www.dwaf.gov.za/wsks) which is used for WSDPs, national planning and information and is based on the latest Census data.

> **Audit requirement:** Latest population and household served and growth figures based on justifiable sources.

2.3 Number of connections

A connection is defined as any point of water supply by the utility and can be formal, informal or unauthorised. A formal connection has been installed by the water utility and is controlled with a service level agreement. An informal connection has been installed by the user but is accepted by the water utility. All users, supplied with potable water by the utility, should therefore be included in the water balance and should either have a metered or unmetered connection. All informal connections that are accepted, and therefore authorised, by the water utility should be considered unmetered connections, unless the utility intends to remove these connections. Connections that are not accepted by the utility should be considered unauthorised (illegal) and removed or formalised, which usually involves a legal process of informing the user, imposing a fine and possible prosecution. The connection decision flow diagram is shown in **Figure 5**.

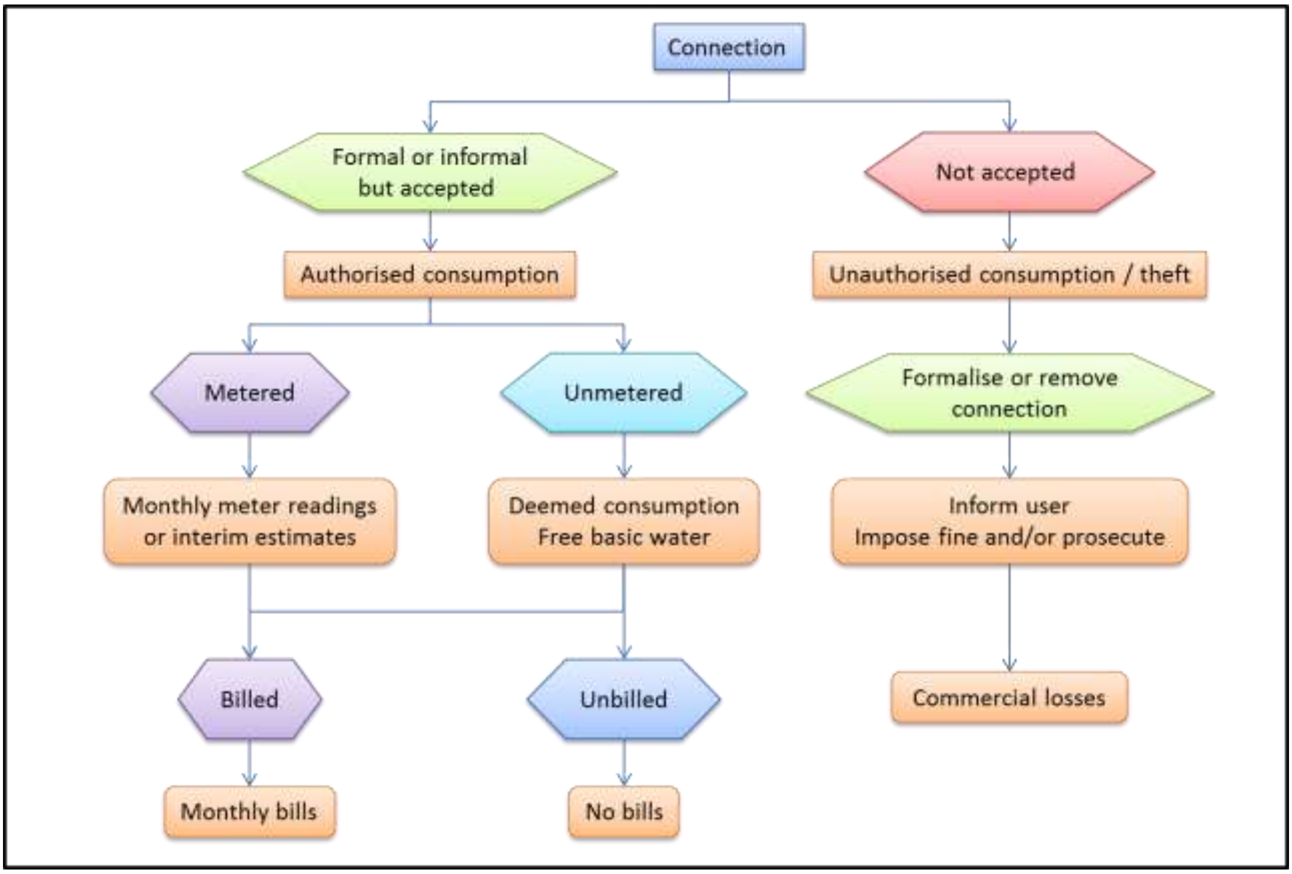


Figure 5: Connection decision flow diagram

If the approach above is aligned with the IWA water balance, the connection is considered the divide between water losses and authorised consumption as shown in **Figure 6**.

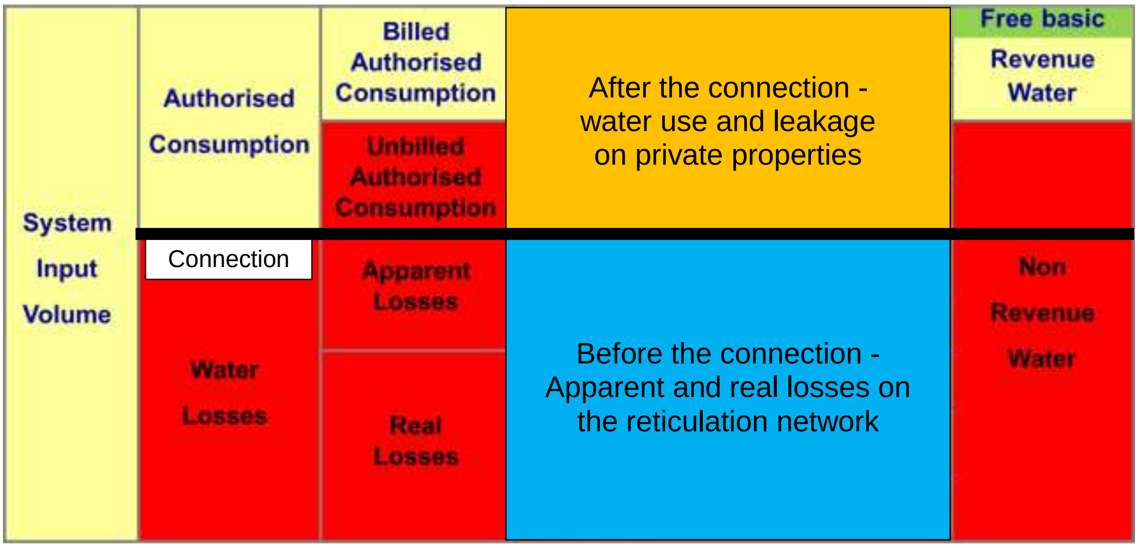


Figure 6: Authorised consumption versus water losses

2.3.1 Metered connections

Double meter box considered as two connections

A metered connection is defined as a connection which has a water meter, which is read on a regular basis and an account may be issued by the water utility based on actual metered consumption. Usually water utilities can provide the number of meters and accounts distributed from the billing system. Taking into consideration the physical complexities of connections in differing water supply systems, for the purposes of No Drop, the number of water accounts has been adopted as the auditing tool to determine the number of connections, as this can easily be audited and obtained from the municipal billing system. It is accepted that there might be more than one user on a property, multiple connections per account or a connection which supplies more than one property, however, this should not have a significant impact on the overall result. A townhouse development is a good example of a single account and water connection. The number of meters could be equal to the number of connections but if the system has a large number of combination meters, the figures could become distorted.

Audit requirement: Provide the number of accounts sent out on a monthly basis for water users.

2.3.2 Unmetered connections

An unmetered connection is defined as a formal or informal connection without a water meter and for which bills may be produced. Typical unmetered connections include areas where consumption is based on an estimate (or deemed consumption) determined by the water utility, informal connections and unmetered standpipes. The balance between the total number of connections and metered connections should be equal to the number of unmetered connections.

Unauthorised connections should be treated as unmetered connections or removed

Audit requirement: Provide details of the number of unmetered connections based on registered users, number of deemed consumption users, informal but accepted connections, indigent users, etc.

2.3.3 Unauthorised connections

An unauthorised connection is defined as a water connection to a user, which was not installed and accepted by the water utility or a water connection which has deliberately been tampered with to reduce or eradicate the metered consumption. Removing an unauthorised connection, often involves:

- immediately notifying the user in terms of the local bylaws
- removing or formalising the connection
- imposing a fine and possible back dating of estimated water consumption
- possible prosecution

Any existing connection, which the utility has no intension of following the actions mentioned above, should be considered an unmetered connection.

2.3.4 Correlation between number of connections, level of service and households

Census data provides information on water services in the municipality. To ensure all users, supplied by the water utility, are captured in the water balance, the water utility must ensure there is a correlation between the number of connections, level of service and households. For example, all households with water inside the dwelling and yard are expected to have a water connection, and the municipality shown in Table 1, is expected to have approximately 6 253 + 3 745 = 9998 connections.

Table 1: Typical Census data for a municipality

Service category	Level of service	Number of households	Total no of households	Percentage
RDP or better level of access to water	Inside dwelling	6 253	10 246	98.0%
	Inside yard	3 745		
	Communal <=200m	248		
Access to a water infrastructure	200 < Communal <= 500	111	135	1.3%
	500 < Communal <=1000	20		
	Communal >1000	4		
No access	No access	77	77	0.7%
Total Households		10 456	10 456	100.0%

Statistics have shown that on average there are 1.0 to 1.5 households per connection in most local municipalities. In high-density areas, like large metros, this could go up to 3.0 households per connection if the area is characterised by large townhouse developments and blocks of flats with a single connection.

Audit requirement: Ensure that all users supplied by the water utility are captured in the water balance by identifying all households in the supply area. Each household supplied by the utility should form part of the system input volume and have a metered or unmetered connection.

2.4 Length of mains

The length of mains, measured in kilometres, is the total length of pipe, excluding transmission mains, that supplies potable water to users and is obtained from the municipal asset register, hydraulic models, GIS or CAD systems or as-built drawings. If the length of mains is not available, it can be estimated as follows:

Long sections of transmission mains should be excluded from the length of reticulation

Option 1 (low accuracy): Divide the total number of connections by the average number of connections per kilometre. In South Africa, there is an average of 50 connections per km of mains for most urban areas.

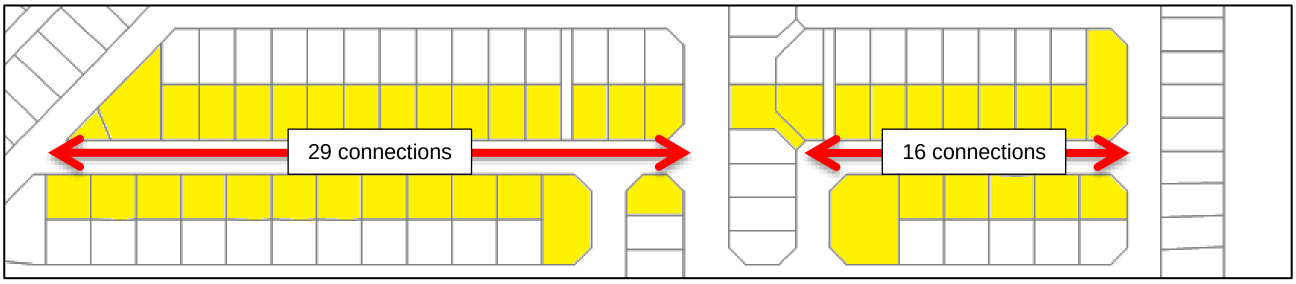
Option 2 (low accuracy): The estimated number of connections per km can also be calculated using the formula below:

$$Estimated\ number\ of\ connections\ per\ km = \frac{1000 * 0.9 * 2}{Average\ length\ of\ property\ street\ front\ (m)}$$

Using the formula above will provide the following results:

Average property size (m^2)	350	1000	2000	3000
Average length of property street front (m)	15	25	36	45
Expected number of connections per km	120	72	50	40

Option 3 (improved accuracy): The density of connections can also be calculated by driving various distances in an area and counting all the connections along the way as shown in the figure below. Dividing the number of connections by the distance driven will provide the density of connections, which can then be used to calculate the total length of mains as shown in the table below.



Area	(A) Distance driven (km)	(B) Number of connections counted	(C = B / A) Density of connections (Conn/km)	(D) Total number of connections in area	(E = D ÷ C) Estimated length of mains (km)
Supply area 1	1.3	70	54	5434	101
Supply area 2	0.9	61	68	3476	51
Supply area 3	1.2	62	52	1289	25
Supply area….	0.9	55	61	6742	110
System total	**4.3**	**248**	**58**	**16941**	**294**

The definition of a transmission main is not always clear but generally has a clearly defined start and end point with limited or no connections in-between. Transmission mains typically include pipelines from water treatment plants, boreholes, springs, etc. to reservoirs. Transmission mains should be excluded from the length of mains as it could distort KPIs and should be analysed separately to determine bulk transmission losses.

Audit requirement: Provide details of the length of mains from the municipal asset register, GIS or CAD systems or as-built drawings. If no such systems exist, provide details of the estimated length of mains calculation.

2.5 Average system pressure

The average system pressure is the average operating pressure of the reticulation network. The average operating pressure could be obtained from an hydraulic network analysis, logging results, spot pressure readings taken during normal operations or sampling. The spot pressure readings or logging results should be summarised as shown in the table below:

Supply area	Address	Description	Date and time	Pressure (m)
A	Stand 1	Average zone point	23-Mar 08h34	45
A	Stand 2	Average zone point	12-Sep 11h23	36
A	Stand …	Average zone point	13-May 14h53	64
Average A				**48**
B	Stand 1	Average zone point	19-Aug 12h37	27

B	Stand 2	Average zone point	30-Apr 07h50	45
B	Stand …	Lowest point	06-Nov 20h21	38
Average B				**37**
…	Stand 1	Average zone point	08-May 23h46	67
…	Stand 2	Critical point	06-Jul 14h10	64
…	Stand …	Lowest point	11-Dec 16h52	50
Average…				**60**
System average				**48**

Care should be taken to ensure the samples are representative of the pressures in the supply area and preferably include the highest and lowest point. The average system pressure can also be calculated using the difference in elevation as shown in the table below. The static pressure will always be higher than the spot pressure readings usually taken during the day.

Pressure point	Elevation (m amsl)	Static pressure (m)
Reservoir top water level (TWL)	1345	
Pressure point		
Critical / high point	1297	48
Average zone point 1 (AZP1)	1278	67
Average zone point 2 (AZP2)	1283	62
Low point	1267	78
Average		**64**

The static pressure is calculated as the difference in elevation between the reservoir top water level and the pressure point. For example, Reservoir TWL – AZP2 = 1345 – 1283 = 62 m.

Audit requirement: Provide details of average pressure calculation from hydraulic network analysis, logging results or spot pressure readings.

2.6 Intermittent supply and time pressurised

Water distribution systems should at all times be pressurised, but if this is not the case, the system input volume and authorised consumption must be adjusted accordingly to ensure key performance indicators are not distorted. For example, the table below illustrates the impact of supplying 10 million m^3/annum to a population of 100 000 over 365 days (100%) and 200 days (60%) respectively.

System input volume (m^3/annum)	% time pressurised	Population served	Litres / capita / day
10 000 000	100% (365 days)	100 000	274
10 000 000	60% (200 days)	100 000	475

Intermittent supply should at all costs be avoided for the following reasons:

Isolating valve which had to be replaced after continuous opening and closing

- During system drainage, negative pressures inside the pipeline will damage the pipe seals which were designed for positive pressures. Continuous negative and positive pressure fluctuations will damage pipe seals to such an extent that they can only be repaired by total replacement of the network
- During system pressurisation, the air in the pipelines dissipates through the users' water meters. Air passing through a water meter will damage the mechanism, as the air causes the meter to spin excessively which exceeds the maximum flow rate of the meter. The air passing through the meter also distorts the meter readings and corrupts the billing database, as the consumption is in fact air. This could have a profound effect on the water balance calculation in times of drought
- The negative pressures inside the pipeline, during system drainage, will suck any contaminants (sewer, soil, storm water, chemicals, etc.) into the pipeline which can cause water borne diseases such as cholera and typhoid
- Water distribution systems are designed for stable pressures and continuous drainage, and pressurisation will increase burst pipes, operational problems, overtime claims, user dissatisfaction and general disruption in supply
- Isolating valves in water distributions systems are not designed for daily operation and will inevitably get damaged over time when improperly operated. This will increase maintenance costs
- If the water supply becomes uncertain, users will start leaving taps open and wait for the water to fill buckets, baths and tanks. Once users start leaving taps open, it becomes increasingly difficult for the water services teams to fill reservoirs and pressurise the system. Service delivery will become worse, resulting in an increased reluctance to pay for services
- Users quickly adapt to their new supply conditions and inevitably revert to on-site storage to mitigate the inconvenience caused by the disruption in supply. Once on-site storage is established, users revert back to their usual lifestyle, oblivious of the disruption in supply. This practice results in very little reduction in actual demand.

Audit requirement: Provide details of system downtime, disruption in supply, logging results, etc. to show time pressurised.

3 COMPONENTS OF THE WATER BALANCE

3.1 Key considerations

The water balance calculations are simple if the system input volume and authorised consumption volumes are known. Once these values have been determined, any of the other indicators can be calculated through simple arithmetic.

The following key issues should be taken into consideration during the water balance calculation:

- The water balance is based on the potable water supplied to the system and does not make allowance for water treatment losses. Water treatment losses are typically between 5 and 10% of system input volume and must not be included in the IWA water balance
- Free basic water is considered billed metered or unmetered consumption, billed at a zero rate, and forms part of the billed consumption and revenue water. Care must be taken not to duplicate free basic water where it has already been included in the billed consumption
- Billed consumption is considered the consumption for which an invoice is issued by the utility to the user. Revenue water refers to the volume of water for which revenue should be received, and can be "Billed Metered" as well as "Billed Unmetered" water. The issue of payment of the bill is not addressed under the water balance as this is considered to be a cost recovery (legal) issue and not a technical water balance issue
- NRW water is becoming the standard term replacing unaccounted-for water (UFW or UAW) in the water balance calculation and is the term recommended by the IWA, in preference to UFW. It is a term that can be clearly defined, unlike the unaccounted-for water term which often represents different components to the various water suppliers
- Any losses on the reticulation network, before the metered or unmetered connection, should be considered commercial or physical losses, whereas any leakage and water use after the connection should be considered authorised consumption. The objective in this approach is to highlight unbilled or unmetered consumption and should not be confused with commercial or physical losses which occur on the reticulation network.

3.2 Collaboration between finance and technical departments

Figure 7 shows the typical metering, reading, billing and cost recovery cycle for a water utility. The technical department is responsible for the installation, management and maintenance of the water meters while the finance department is responsible for the meter readers, preparation and distribution of the monthly water bills and will pursue legal recourse if the bill is not paid. The meter readers gather pertinent information during the meter reading process. This information on cycled, illegible, broken, no access, no meter, reading errors, leaking, reticulation leaks, high or low consumption, etc. must be shared with the technical department for action otherwise the meter readers will continue recording the same errors at huge cost to the water utility. The cycle emphasises the importance of close collaboration between the technical and finance department to ensure effective metering, reading, billing and cost recovery systems.

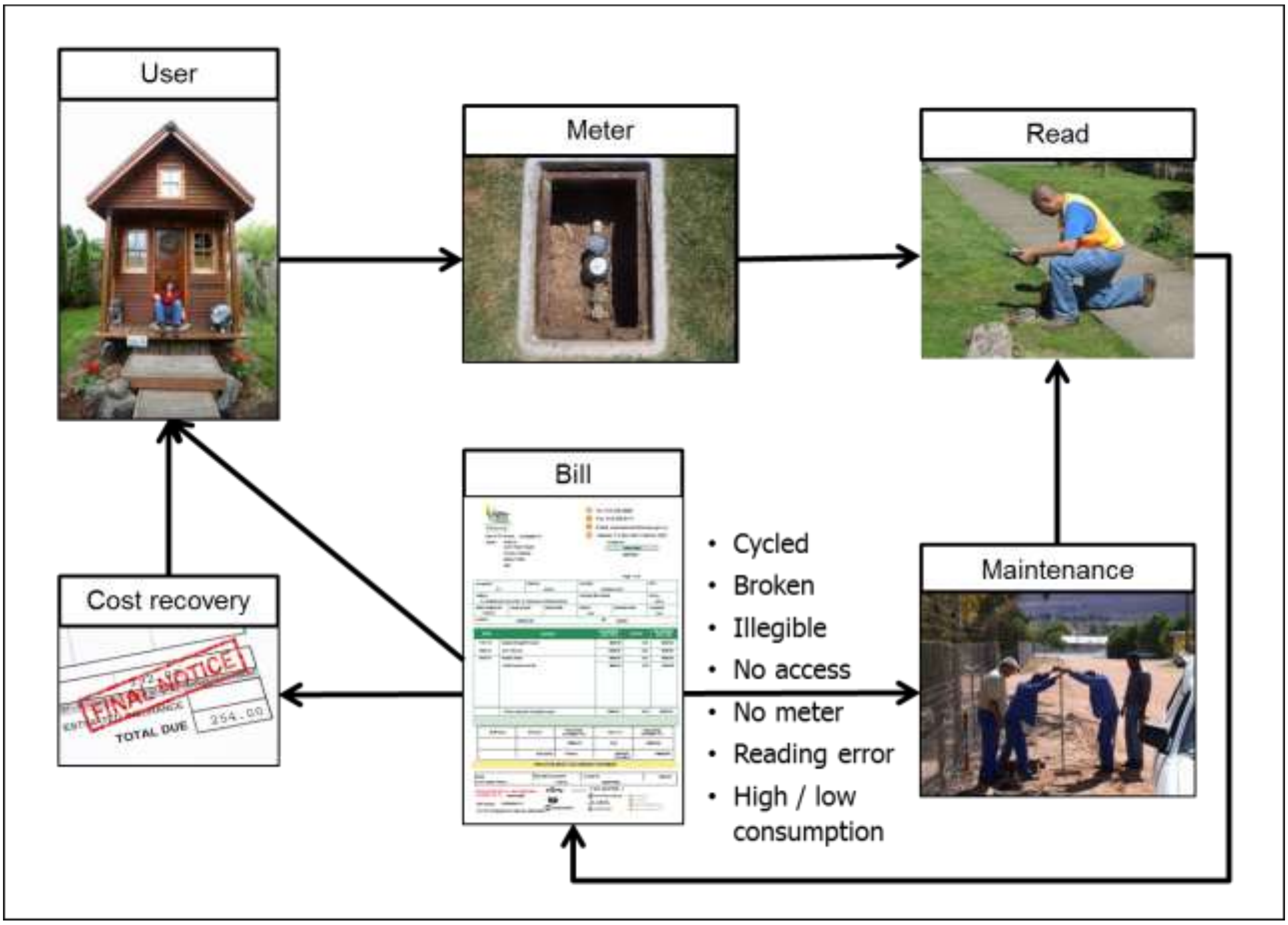


Figure 7: Metering, reading, maintenance, billing and cost recovery cycle

3.3 System input volume

The system input volume (SIV) is the volume of potable water supplied from surface and ground water resources and bulk service providers to the water supply system and is calculated as follows:

System input volume =

Potable supply from water treatment plant (sum of meter/s on plant outlet)

+ supply from bulk or other water services providers (sum of meter/s used for billing purposes)

+ supply from boreholes, springs, fountains if not supplied through water treatment plant (meter/s on each borehole or bulk supply point)

The system input volume should be obtained from actual meter readings or alternatively estimated from the average operational capacity of the water treatment works or average pumping times.

Water treatment works operational capacity (poor accuracy)

Month	Design capacity (Mℓ/day)	Operational capacity (%)	Operational capacity (Mℓ/day)	Days in month	Volume (m^3/month)
January	100	80%	80	31	2 480 000
February	100	70%	70	28	1 960 000

The operational capacity is estimated based on up and down time, imposed water restrictions, general performance of the treatment works, etc.

System input volume based on pump capacities (medium accuracy)

Pump capacity	25 m^3/h @ 55m head		
Pump start	**Pump stop**	**Pumping hours**	**Volume pumped (m^3)**
01/07/2017 06:00	01/07/2017 22:00	16.0	400
02/07/2017 05:30	02/07/2017 23:10	17.7	442
…….	……	….	…..
31/07/2017 06:00	03/07/2017 20:30	14.5	363
Month total			**13804**

Audit requirement: Provide bulk meter reading and consumption records complete with estimates and corrections. The audit trail should include the system input volume calculation, meter readings and inspection of the bulk meters to ensure they are accurate, operational and that the meter readings correlate.

3.4 Authorised consumption

Authorised consumption is the volume of metered and unmetered water used by users, the water supplier and others who are implicitly or explicitly authorised to do so by the water services authority, for residential, commercial and industrial purposes. Authorised consumption can only be metered or unmetered and billed or unbilled. All consumption by any user within the municipal system must fall within one of these four categories otherwise, it should be considered unauthorised consumption which forms part of water losses.

3.4.1 Billed metered consumption

The billed metered consumption volume is the actual metered volume of water provided to the user, through a metered connection which should be read and billed at accepted intervals determined by the water utility. The metered consumption is calculated by subtracting the meter reading for the current month from the previous month or estimating the consumption based on patterns of historical consumption. This volume will already include the free basic water component and should not be added again. Estimated readings should be reconciled every 3 to 6 months to ensure users are billed based on actual consumption.

Water exported to neighbouring utilities forms part of billed metered consumption as these users are authorised to use the water, supplied through a metered connection which should be read and billed on a monthly basis. Water used for parks, swimming pools, etc. which is metered and billed internally between departments is also considered billed metered consumption although payment will happen through journal entries. These departments are expected to budget and "pay" for water. Water used for fire-fighting that is metered and billed to the user is considered billed metered consumption.

Domestic metered connection

The billed metered consumption is obtained from the municipal billing system.

Billed metered consumption =

Metered water supply and billed to users inside the utility's supply area

+ Metered water supply and billed to users outside the utility's supply area (if applicable)

+ Metered water supply and billed to internal departments (if applicable)

+ Metered water supply and billed to users used for fire-fighting

Audit requirement: Provide records of monthly meter readings and calculations to determine billed metered consumption.

3.4.2 Billed unmetered consumption

The billed unmetered consumption volume is the deemed or free basic volume of water which the user is authorised to use, supplied through an unmetered connection which cannot be read on a monthly basis, and the user is billed based on a deemed consumption. Flat rate or deemed consumption will already include free basic water and should not be added again.

Any volume of water used by the user in excess of the predetermined deemed or free basic volume of water, should be considered unbilled unmetered consumption. For example, a user uses an estimated 24 kℓ/month and is billed based on a deemed consumption of 15 kℓ/month. The 15 kℓ/month is considered billed unmetered consumption while the balance of 9 kℓ/month is considered unbilled unmetered consumption.

Unbilled unmetered consumption from a public standpipe

Another example is a user receiving 6 kℓ/month free basic water but uses an estimated 15 kℓ/month. The 6 kℓ/month is considered billed (at zero rate) unmetered consumption while the balance of 9 kℓ/month is considered unbilled unmetered consumption. It is unlikely that the water utility would distribute bills for free basic water at zero rate but the free basic water allocation should be included in the water balance. Ideally, areas billed on deemed consumption should be monitored through zone meters and the estimated actual consumption should be based on the total supply, after allowing for reticulation losses, as opposed to a purely theoretical estimate. Calculations would typically look as follows:

Area	(A) Households	(B) Deemed consumption or FBW	(C) System input volume (m³/month)	(D) 15% reticulation losses (m³/month)	(E) Billed unmetered consumption (m³/month) (A x B)*	(F) Unbilled unmetered consumption (m³/month) (C – D – E)	(G) Actual monthly consumption (m³/household /month) (C + D) / A
1	10 000	15 kl/month	282 353	42 353	150 000	90 000	24
2	5 000	6 kl/month	88 235	13 235	30 000	45 000	15
3	1 000	6 kl/month	5 882	882	5 000	0	5
Total	**16 000**		**376 470**	**56 471**	**185 000**	**135 000**	**20**

* The billed unmetered consumption is equal to the number of households x the deemed consumption or FBW unless the actual consumption is less as for Area 3.

The first two examples are discussed in the section above while the third example is an area that uses less than the allocated free basic water. In this case, there is no unbilled unmetered consumption. The billed unmetered volume is obtained from the municipal billing system while the system input volume and estimated reticulation losses are obtained from the engineering department. Estimated reticulation losses include water lost through leaking pipes and connections and not water lost through leaking public standpipes or private taps and toilets. A public standpipe is considered a connection which should be metered. Any losses or usage beyond the standpipe connection are considered authorised consumption.

Billed unmetered consumption =

Unmetered and billed deemed water supply to users

+ Unmetered and billed (at zero rate) free basic water to users

Audit requirement: Provide records of monthly deemed consumption bills distributed, bulk meter readings and calculations to determine billed unmetered consumption.

3.4.3 Unbilled metered consumption

The unbilled metered consumption volume is the volume of water which the user is authorised to use, supplied through a metered connection which is read or estimated on a regular basis but users do not receive a bill. These users typically include the utility's own use such as parks, buildings and swimming pools and water used for fire-fighting, if metered.

The metered consumption can be used to calculate the actual reticulation losses in cases where the user is billed a deemed or free basic volume of water. Calculations would typically look as follows:

Area	Households	System input volume (m^3/month)	Metered consumption (m^3/month)	Deemed consumption or FBW	Billed metered (deemed) consumption (m^3/month)	Unbilled metered consumption(m^3/month)	Percentage reticulation losses (%)
1	10 000	280 000	240 000	15 kl/month	150 000	90 000	14%
2	5 000	85 000	75 000	6 kl/month	30 000	45 000	12%
3	1 000	5 500	5 000	6 kl/month	5 000	0	9%
Total	**16 000**	**370 500**	**320 000**		**376 471**	**135 000**	**14%**

Unbilled metered consumption can also include the volume of water used in excess of the free basic or deemed consumption volume in cases where users are metered.

Fire-fighting

Address	Description	Date	Tanker supply (m^3)	Hydrant supply (m^3)	Volume (m^3)
123 Street	5 storey building	12-May	2 x 5000 ℓ = 10 m^3	2.353	12.353
345 Street	Residential household	23-May	2341 ℓ = 2.341 m^3	0	2.341
Month total			**12.341** m^3	**2.353**	**14.694**

This volume is obtained from the municipal billing system.

Unbilled metered consumption =

Metered water supply and unbilled to users inside the utility's supply area

+ Metered water supply and unbilled to users outside the utility's supply area (if applicable)

+ Metered water supply and unbilled to internal departments (if applicable)

+ Metered water supply and unbilled used for fire-fighting

Audit requirement: Provide records of monthly meter readings and calculations to determine unbilled metered consumption.

3.4.4 Unbilled unmetered consumption

Unbilled authorised consumption

The unbilled unmetered consumption volume is the volume of water which the user is authorised to use, supplied through an unmetered connection which cannot be read on a monthly basis, and users do not receive a bill. This consumption typically includes water used in excess of the deemed or free basic volume of water which the user is authorised to use and water used for fire-fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, building water, etc.

Water used for fire-fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, building water, etc. should be supported by evidence as summarised in the tables below.

Fire-fighting:

Address	Description	Date	Tanker supply (m^3)	Hydrant supply (m^3)	Volume (m^3)
12 Industry Road	Factory warehouse	12-May	2 x 5000 ℓ = 10 m^3	Pump @ 5 ℓ/s for 2 hrs	46
Provincial Road	Truck accident	23-May	0.5 x 5000ℓ = 2.5 m^3	None	2.5
Month total			**12.5**	**36**	**48.5**

Mains flushing:

Address	Description	Date	Length (m)	Diameter (mm)	Volume (m^3)
67 Street	Mains burst	05-May	1500	200 mm	47
12 Street	Install new bulk meter	15-May	500	150 mm	9
			1000		**49**

Unbilled unmetered consumption =

Unmetered unbilled water used for fire-fighting, mains flushing, parks, buildings, etc.

+ Unmetered unbilled consumption in excess of deemed or free basic water allocation

Audit requirement: Provide records of estimates and calculations to determine unbilled unmetered consumption.

3.4.5 *Typical examples*

The following table summarises typical examples of authorised connections.

Scenario	Authorised connection	Metered	Billed	Outcome
 Metered house connection	Yes	Yes	Yes	Metered billed consumption
 Unmetered house connection	Yes	No	Yes	Volume <= deemed or flat rate consumption = unmetered billed Volume > deemed or flat rate consumption = unmetered unbilled
 Metered yard connection	Yes	Yes	No	Volume <= free basic water consumption = metered billed (at zero rate) Volume > free basic water = metered unbilled
 Metered tanker supply	Yes	Yes	No	Metered unbilled
 Unmetered livestock watering point	Yes (The connection is informal but the utility has no intension of removing it)	No	No	Unmetered unbilled

Scenario		Authorised connection	Metered	Billed	Outcome
	Metered public standpipe	Yes	Yes	No	Volume <= free basic water consumption = metered billed (at zero rate) Volume > free basic water = metered unbilled
	Unmetered informal connections	Yes (The connections are informal but the utility has no intension of removing it)	No	No	Volume <= Free basic water consumption = unmetered billed (at zero rate) Volume > Free basic water consumption = unmetered unbilled

3.5 Water losses

Water losses are calculated as the difference between the system input volume and the authorised consumption. Water losses are broken down into commercial or apparent and physical or real losses. Commercial losses are not visible, except for unauthorised use, and are usually as a result of poor or lack of metering. Physical losses are visible losses and are usually as a result of burst pipes, overflowing reservoirs and leaking connections.

Burst pipes contribute to physical losses

Water losses = System Input Volume – Authorised Consumption

where Authorised Consumption = Billed metered + billed unmetered +unbilled metered + unbilled unmetered

3.6 Commercial or apparent losses

Commercial or apparent losses are made up of unauthorised connections (theft), plus all technical and administrative inaccuracies associated with user metering and billing. If commercial losses are reduced, generally more revenue will be generated by, and for, the water utility.

Traditionally, commercial losses were accepted as 20% of water losses but this assumption was revised in the WRC Report TT300/07 (WRC, Jan 2007) as shown in **Table 2**, which provides a more pragmatic approach to calculating commercial losses.

Unauthorised water connections

The percentage unauthorised connections, meter error and data transfer errors should be added to obtain the total percentage of commercial loss. The volume of commercial losses is then calculated as a percentage of the total water losses.

Table 2: Percentage commercial loss guideline

Unauthorised connections	%	Meter age and accuracy	Good water	Poor water	Data transfer	%
Very high	10%	> 10 years	8%	10%	Poor	8%
High	8%					
Average	6%	5- 10 years	4%	8%	Average	5%
Low	4%					
Very low	2%	< 5 years	2%	4%	Good	2%

*Source: WRC Report TT300/07, 2007

% Commercial losses = % Unauthorised Connections + % Meter Error + % Data Transfer Error

Volume commercial losses = Water losses x % Commercial losses

Audit requirement: Provide evidence or basis of percentage unauthorised connections, meter accuracy and data transfer errors.

3.7 Advanced commercial or apparent loss calculations

Table 2 generally provides a very conservative approach to calculating commercial losses but it is a good start. It is recommended that water utilities that are at an advanced stage of water balance calculations should adopt a more pragmatic approach as described in the following sections.

Excluding the x10 factor on bulk meters increases commercial losses (Meter reading = 583849 x 10 = 5838490)

3.7.1 Unauthorised connections (theft)

An unauthorised connection is defined as a water connection to a user which was not installed and accepted by the water utility or a water connection which has deliberately been tampered with to reduce or eradicate the metered consumption. The percentage unauthorised connections is determined by dividing the number of unauthorised connections by the total number of connections. 10 % unauthorised connections translates into 10 unauthorised connections for every 100 connections.

$$\% \, Unauthorised \; connections = \frac{Number \; of \; unauthorised \; connections}{Total \; number \; of \; connections}$$

Water utilities should preferably document unauthorised connections as found during operations and maintenance procedures. Alternatively, the water utility should randomly perform audits in supply areas to determine the number of unauthorised connections and document the results as summarised in the table below.

Area	Total number of connections	Total number of unauthorised connections found	% unauthorised connections
Supply area 1	2000	100	5.0%
Supply area 2	5000	150	3.0%
Supply area 3	8000	200	2.5%
Supply area….	15000	1200	8.0%
Total	**30000**	**1650**	**5.5%**
Audit requirement: Provide evidence of the number of unauthorised connections identified during normal operations and maintenance or sample testing.			

3.7.2 Meter error and under registration

Metering inaccuracies differ significantly for utilities and depend on the water quality, class of meter, type of meter, meter sizing, installation requirements and air surges.

The utility should continuously perform in-situ meter testing during normal operations and maintenance procedures or randomly perform in-situ tests in supply areas. The test should be performed by temporarily installing two higher class meters in series with the existing meter as shown

Figure 8. The existing meter should not be disturbed during the test. A different accuracy will be obtained once the meter has been removed and tested in a laboratory as debris or scale deposits might have come loose.

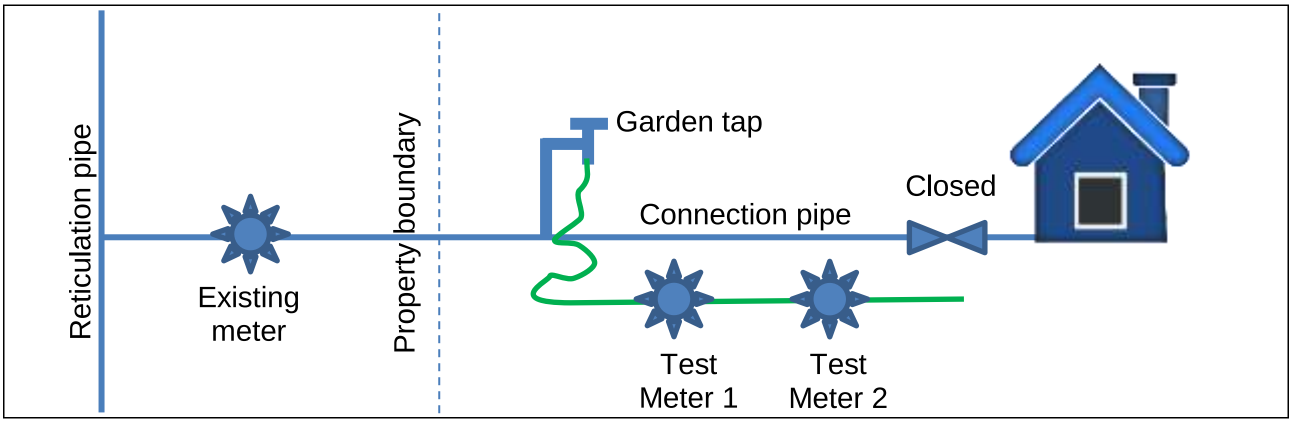


Figure 8: In-situ water meter testing

The meter accuracy is determine by comparing the three meter readings as summarised in the table below:

Date	Meter serial no & address	Status	In-situ meter		Test meter 1		Test meter 2		% meter error
			Reading	Volume passed m³	Reading	Volume passed m³	Reading	Volume passed m³	
23-Jun	MN767	Before	3456.7245		45.5456		24.5667		
	Street 123	After	3456.7666	0.0421	45.5956	0.05	24.6167	0.05	16%
12-Aug	SZR542	Before	5676.2674		45.5956		24.6167		
	Street 456	After	5676.3167	0.0493	45.6456	0.05	24.6667	0.05	1%
23-Aug	THA2330	Before	6567.2652		45.6956		24.7167		
	Street 789	After	6567.3165	0.0513	45.7456	0.05	24.7667	0.05	-3%
09-Sep	HRZ469	Before	9863.2354		45.7956		24.8167		
	Street 123	After	9863.2813	0.0459	45.8456	0.05	24.8667	0.05	8%
Total				**0.1886**		**0.20**		**0.20**	**6%**

Audit requirement: Provide evidence of meter accuracy tests performed.

In-situ meter testing is described in detail in SANS 10306:2010 Code of practice – The management of potable water in distribution systems – Annexure G.

3.7.3 Data transfer and management errors

Data transfer and management errors are the difference between the actual metered consumption and the metered consumption billed. Data transfer and management errors typically occur as a result of data entry errors, estimated readings, meters not captured on the billing system, meter factor errors and financial billing corrections without volume corrections.

It is accepted that many utilities do not read their meters on monthly basis and work on estimated readings. In this case, the data transfer error will be high on estimated months but is expected to be reconciled once the meters have been read.

Debris caught in the meter mechanism will cause meter error

The percentage data transfer error is determined through sample testing and calculated as follows:

$$\%\ Data\ transfer\ error = \frac{Actual\ consumption - Consumption\ on\ billing\ system}{Actual\ consumption}$$

The billed consumption could be higher than the actual consumption, as shown in the example below, in which case the apparent losses will reduce. This should not be a problem if the differences are small but could lead to user dissatisfaction if the differences are large. Large differences suggest readings are over estimated and users over charged.

User	Meter reading end year 1	Meter reading end year 2	Actual consumption for past year	Billed consumption	% error
User 1	68653	69307	654	655	-0.2%
User 2	76869	77147	278	250	10.1%
User 3	89986	94341	4355	4574	-5.0%
User….	43455	44217	762	732	3.9%
Total			6049	6211	-2.7%

Audit requirement: Provide evidence of data transfer accuracy tests performed.

3.8 Current Annual Physical or Real Losses (CARL)

Physical or real losses are the physical water losses from the pressurised system, up to the metered or unmetered connection point. Real losses include leaking mains, reticulation pipes, connection pipes, overflowing reservoirs and bursts.

Physical losses are calculated as the difference between the total losses and commercial losses. If real losses are reduced, more water will be available for distribution to users or the total system input volume will reduce.

Physical water losses

Physical or Real losses = Water losses - Volume Commercial Losses

3.9 Unavoidable Annual Real Losses (UARL)

Although not shown explicitly in the water balance, the Unavoidable Annual Real Losses (UARL) is the expected minimum level of physical losses from the water distribution system. The leakage from a water distribution system can never be zero and is calculated as follows:

Unavoidable Annual Real Losses (UARL) = (18 x Lm + 0.8 x Nc + 25 x Lp) x P

Where Lm = length of mains in km; Nc = Number of connections; Lp = Length of underground pipe in m and P = average operating pressure in m.

Lp is considered zero if the meter is on the property boundary otherwise it is the length of pipe from the property boundary to inside the household where the meter was installed.

3.10 Volume Non-Revenue Water

Non-revenue water is the volume of water for which the water utility receives no income and is calculated as follows:

Non-revenue water = System input volume – Billed (metered and unmetered) consumption

3.11 Potential real loss saving

The potential real loss saving is the difference between the Current Annual Real Losses (CARL) and the Unavoidable Annual Real Losses (UARL)

Potential real loss saving = CARL – UARL

Where CARL = Physical or Real losses = Water losses - Volume Commercial Losses

4 WATER BALANCE ASSESSMENT

4.1 Key Performance Indicators

Once the water balance has been calculated, various key performance indicators can be calculated to assess the performance of the water supply system. It is recommended that several KPIs are calculated as no single indicator can be used to assess the performance of the distribution network. KPIs should also be used to verify and cross check results, for example, a system with a high NRW but low physical leakage might be possible or suggest a calculation or estimation error.

4.1.1 Percentage non-revenue water (NRW)

Although the use of percentages to define water losses is not recommended by the IWA, this indicator remains widely accepted and used in most parts of the world including the South African water industry and for this reason, it has been retained although it should be used with caution in the knowledge that it can sometimes be misleading. It does however remain a useful indicator in communicating the extent of non-revenue water distributed, which reflects on both the technical and finance departments in the utility. The percentage NRW is calculated as follows:

$$\%\, NRW = \frac{SIV - (Billed\ Metered + Billed\ Unmetered)}{System\ Input\ Volume} \times 100$$

4.1.2 Unit consumption or efficiency

Litres / capita / day provides an indication of the efficiency or gross volume of water used per capita (person) per day. Although the calculation is based on the total system input volume and not just the domestic component, it does provide a useful indicator. In most utilities, there is very little difference between domestic and commercial water use as most people use water at the work place (commercial use) as they would have at home. Care should be taken in areas where there is a large wet industry and if necessary, it should be excluded from the calculation in order to derive a more realistic per capita consumption.

$$\ell/c/d = \frac{(System\ Input\ Volume - Export\ Volume - Wet\ industry) \times 1000 \div 365}{Population\ Served}$$

Where:

"System input volume" and "export volume" are in m^3/annum

The "export volume" is the volume of water supplied to users and utilities outside the utility's boundary

Typical "wet industry" water use includes liquor, beverages, food, paper, etc. factories

4.1.3 Real loss indicators

The use of percentages as an indicator for real losses (physical leakage) should also be discouraged although, it is again, accepted that percentages will always remain in use since few water utility managers are prepared to discard percentages completely from their list of KPIs. It is therefore important when using percentages to quantify physical leakage, to highlight the potential pitfalls and to ensure that other KPI's are also provided.

Litres/connection/day – metric units

This water loss indicator will be suitable for most systems where the density of connections is greater than 20 connections per km mains. In cases where the density of connections drops below 20 per km of mains, it is often appropriate to use the following indicator instead:

m^3/km mains/day – metric units

4.1.4 Infrastructure Leakage Index

The Infrastructure Leakage Index (ILI) provides an indication of the physical leakage in the distribution system and can often be used to benchmark one system against another. The ILI provides an indication of the current level of leakage (CARL) versus the expected minimum level of leakage (UARL). An ILI of 5 therefore means that the current level of leakage (CARL) is five times higher than the expected minimum level of leakage (UARL).

Infrastructure Leakage Index ILI = CARL/UARL

Where:

- ILI = Infrastructure Leakage Index (non-dimensional)
- CARL = Current Annual Real Losses (litres per connection per day)
- UARL = Unavoidable Annual Real Losses (litres per connection per day)

4.2 Benchmarks

Interpreting the results from the water balance calculation and key performance indicators are critical to assess the performance of the water supply system. The results vary significantly across water utilities and usually depend on the level of service and development.

Basic information typical range

KPI	Metros	Local municipalities
Population	750 000 to 5 000 000	7000 to 750 000
Length of mains (km)	5 000 to 15 000	50 to 5 000
Pressure (m)	30 to 60	30 to 60
Households / connection	1.0 to 3.0	1.0 to 1.5
Density of connections	40 to 80	30 to 70

The No Drop performance based regulatory programme has adopted the following KPI performance criteria which are in line with international best practice.

Overall No Drop Score:

	90-100%	Excellent situation, need to maintain via continued improvement
	80-<90%	Good status, improve where gaps identified to shift to 'excellent'
	50-<80%	Average performance, ample room for improvement
	31-<50%	Very poor performance, need targeted intervention towards gradual sustainable improvement
	0-<31%	Critical state, need urgent intervention for all aspects of water use efficiency

ILI (Physical water loss) performance categories

	>8	Extremely high physical water loss
	6-8	Poor performance in physical water loss
	4-6	Average physical water loss performance
	2-4	Good physical water loss performance but some improvement may be possible subject to economic benefit
	<2	Excellent physical water loss management

Apparent / Commercial loss (%) performance categories

	>40%	Extremely high commercial water loss
	30-40%	Poor performance in commercial water loss
	20-30%	Average commercial water loss performance
	10-20%	Good commercial water loss performance but some improvement may be possible subject to economic benefit
	<10%	Excellent commercial water loss management

Non-Revenue Water (%) performance categories

	>40%	Extremely poor non-revenue water management
	30-40%	Poor non-revenue water performance
	20-30%	Average performance with potential for marked improvement
	10-20%	Good performance but some improvement may be possible subject to economic benefit
	<10%	Excellent non-revenue water management

Water Use Efficiency (l/cap/day) performance categories

	>300	Extremely high per capita water use
	250-300	Poor per capita water use
	200-250	Average per capita water use with potential for marked improvement
	150-200	Good per capita water use but some improvement may be possible subject to economic benefit
	<150	Excellent per capita water use management

The results for most utilities fall within these performance criteria and should be used to assess the performance of the utility. It the results are not within range, the water balance calculations should be checked or there should be very good reasons for the anomaly.

4.3 KPI limitations

There is no perfect key performance indicator and KPIs must be used with caution to avoid misleading results.

4.3.1 Litres per capita per day

The impact of including or excluding wet industries and water exported from the litres per capita per day is shown in the table below.

System	Unit	Small town	Small Industrial town	Large Industrial town
Population	number	20 000	20 000	20 000
System input volume	**m^3/day**	**4 500**	**9 000**	**13 500**
Authorised consumption	m^3/day	3 500	5 000	6 500
Wet industry	m^3/day	0	2 000	5 000
Water exported	m^3/day	1 000	2 000	2 000
Litres per capita per day				
SIV	l/c/d	225	450	675
Authorised consumption	l/c/d	175	250	325
SIV less wet industries	l/c/d	225	350	425
SIV less water exported	l/c/d	175	350	575

The authorised consumption provides the most realistic indication of the user's actual water consumption. Water exported and wet industries are not applicable in most utilities or form a very small portion of the total consumption and have a minimal impact on the overall result.

4.3.2 % Non-revenue water

Percentage non-revenue water is a function of the system input volume and volume non-revenue water where non-revenue water consists of water losses and unbilled authorised consumption. In the example below the water losses and unbilled consumption for the two towns are the same but because the system input volume in Big Town is double that of Small Town, the non-revenue water halves.

System	Unit	Small town	Big town
System input volume	m^3/annum	5 000 000	10 000 000
Water losses	m^3/annum	1 000 000	1 000 000
Unbilled consumption	m^3/annum	1 000 000	1 000 000
Non-revenue water	m^3/annum	2 000 000	2 000 000
% Non-revenue water	%	40%	20%

The same result would be obtained if Small Town could establish a large wet industry within its supply area that would, for example, double the system input volume. Without fixing any leaks or addressing unbilled consumption, the non-revenue water would be halved.

4.3.3 Infrastructure leakage index

The ILI is a function of the CARL, length of mains, number of connections and average system pressure. Figure 9 shows the impact of the density of connections if the CARL, length of mains, losses per connection and average pressure remain the same. The results indicate that the ILI would reduce if the density of connections increases.

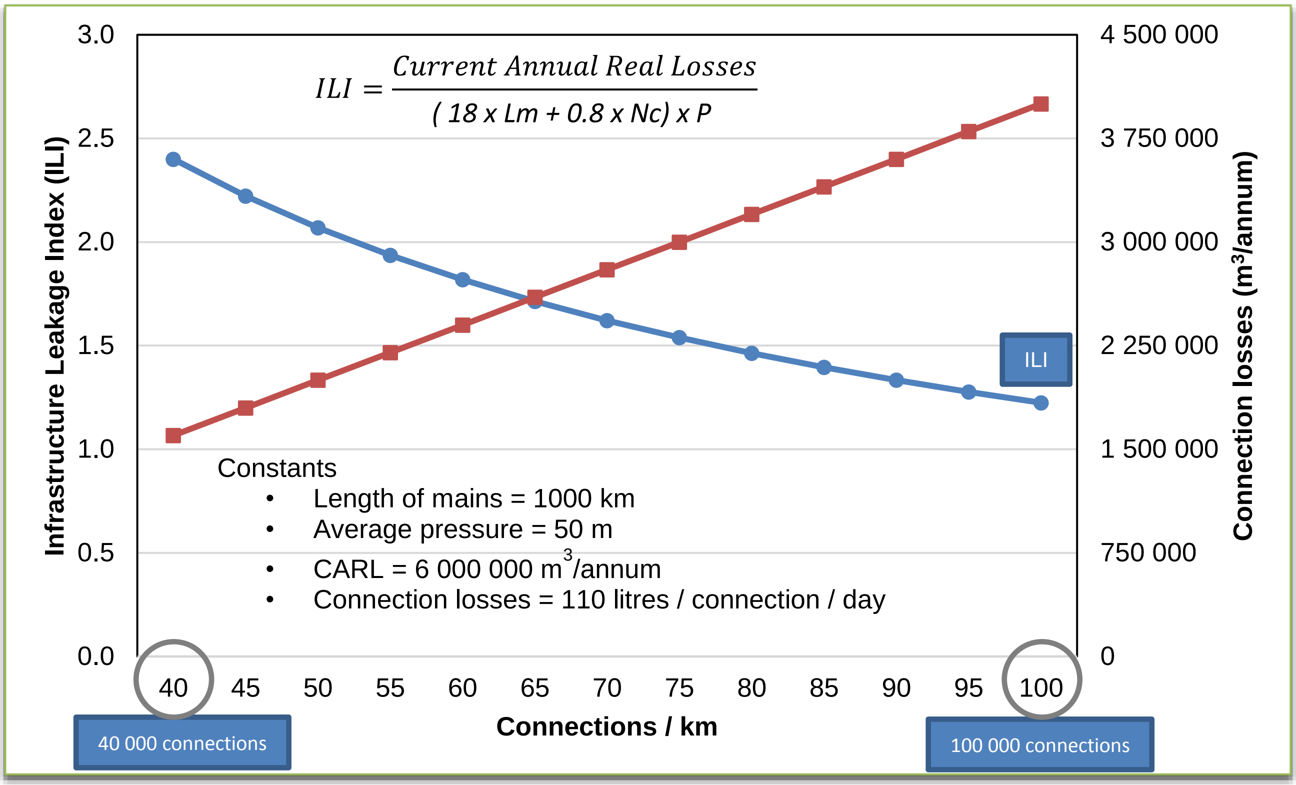
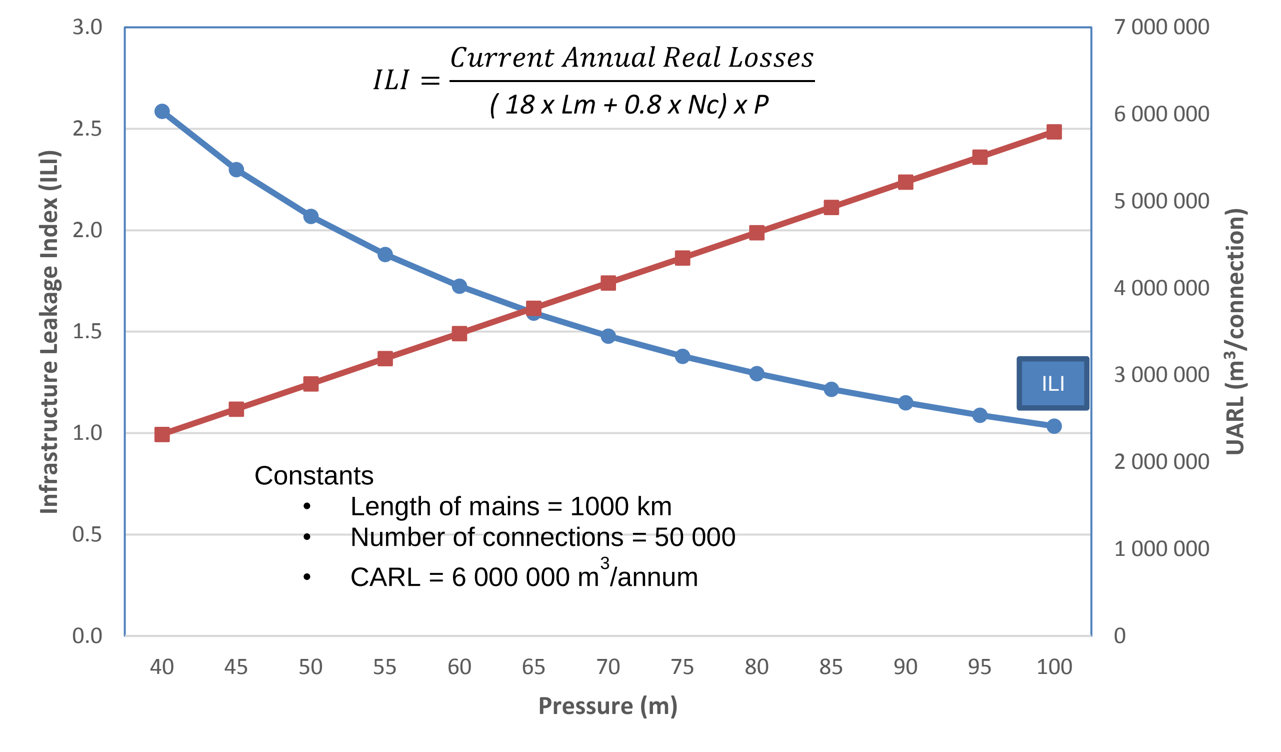


Figure 9: Impact of density of connections on the ILI

The impact on different systems is shown in the table below. The ILI for Big Town is half of that of Small Town although the connection losses in Big Town are more than double those of Small Town. The reason for this is that Big Town has an average of 100 connections per km whereas Small Town has only 40 connections per km.

System	Unit	Small Town	Big Town
Average pressure	m	50	50
Length of mains	km	1 000	1 000
Connections	number	40 000	100 000
Density of connections	No/km	40	100
Mains losses	m³/annum	900 000	900 000
Connection losses	m³/annum	1 600 000	4 000 000
UARL	m³/annum	2 500 000	4 900 000
Current water losses	m³/annum	6 000 000	6 000 000
ILI	-	2.4	1.2
Connection losses	l / connection / day	110	110

Similarly, the impact of pressure can be shown if the CARL, length of mains, losses per connection and number of connections remain the same. The results indicate that the ILI would reduce if the pressure increases.

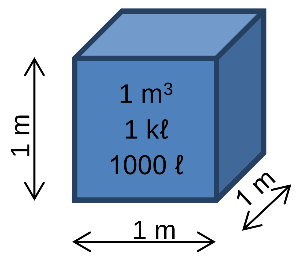


5 COMMON MISTAKES AND RECOMMENDATIONS

5.1 Unit errors

The units used to calculate the water balance must remain consistent. The following should be kept in mind to avoid errors:

- Ensure the volumes are provided per month or per year as required.
- mega litres = Mℓ = 1 000 000 litres and is typically used to define the capacity of a treatment plant in Mℓ/day. 1 Mℓ = 1000 kℓ
- kilo litres = kℓ = 1000 litres = 1 m^3 and is typically used to calculate the water balance
- The length of mains must be provided in kilometres (km) and not metres (m).
- The average system pressure must be provided in metres (m) where 100 kPa = 1 bar = 10 m pressure.

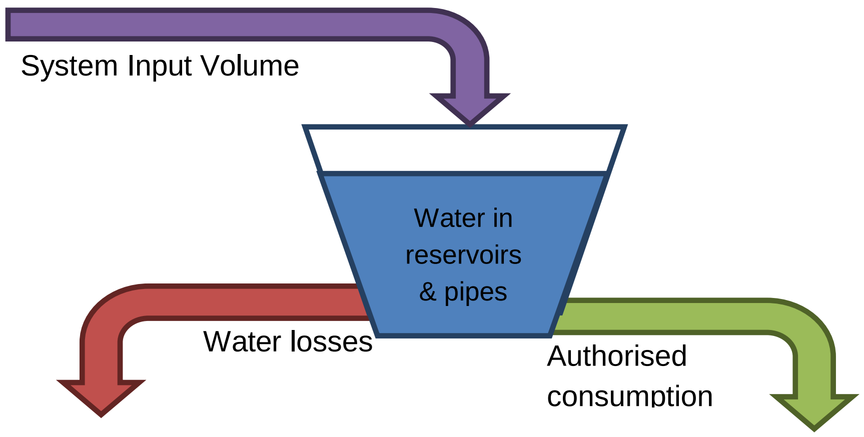


1 m^3 = 1 kℓ = 1 m x 1 m x 1 m block of water

5.2 Storage volume included in water balance

Some water utilities want to include the volume of water stored in reservoirs and pipes in the water balance. The volume of water stored in reservoirs and pipes is an asset and therefore assumed that it must be included in the water balance.

To explain this misconception, the water distribution system could be compared to a bucket full of water, where the water in the bucket is equal to the water stored in reservoirs and pipes. The inflow is equal to the system input volume, the outflow is equal to the authorised consumption and any holes in the bucket are equal to the water losses.



It is accepted that the water level in reservoirs fluctuates on a daily basis and pipes are drained to perform maintenance, but for all practical purposes the reservoir and pipes remain full and therefore the water level in the “bucket” or water distribution system remains the same. For the water level in the bucket to remain the same, the system input volume (inflow) must equal authorised consumption plus water losses (outflow) and the “SIV = Authorised consumption + water losses”. The volume of water stored in pipes and reservoirs must therefore be excluded from the water balance calculation. Any losses from overflowing and disinfection of reservoirs, scouring of pipelines are included in the water losses or unbilled unmetered consumption.

5.3 Monthly or annual water balance

All meter readings and water balance calculations should be performed on a monthly basis to ensure discrepancies are immediately resolved. Any estimates or data changes should be properly documented to ensure institutional memory.

It is accepted that the metered consumption could fluctuate depending on seasonal changes, meter reading problems, interim estimates, meter corrections, etc. to the extent that the demand could exceed the supply in some months. To allow for these changes, it is recommended that the water balance is prepared on a 12 month rolling basis. The water balance should therefore always be based on the last 12 months of data. The difference between a monthly and 12 month rolling water balance is shown in Figure 10 and Figure 11.

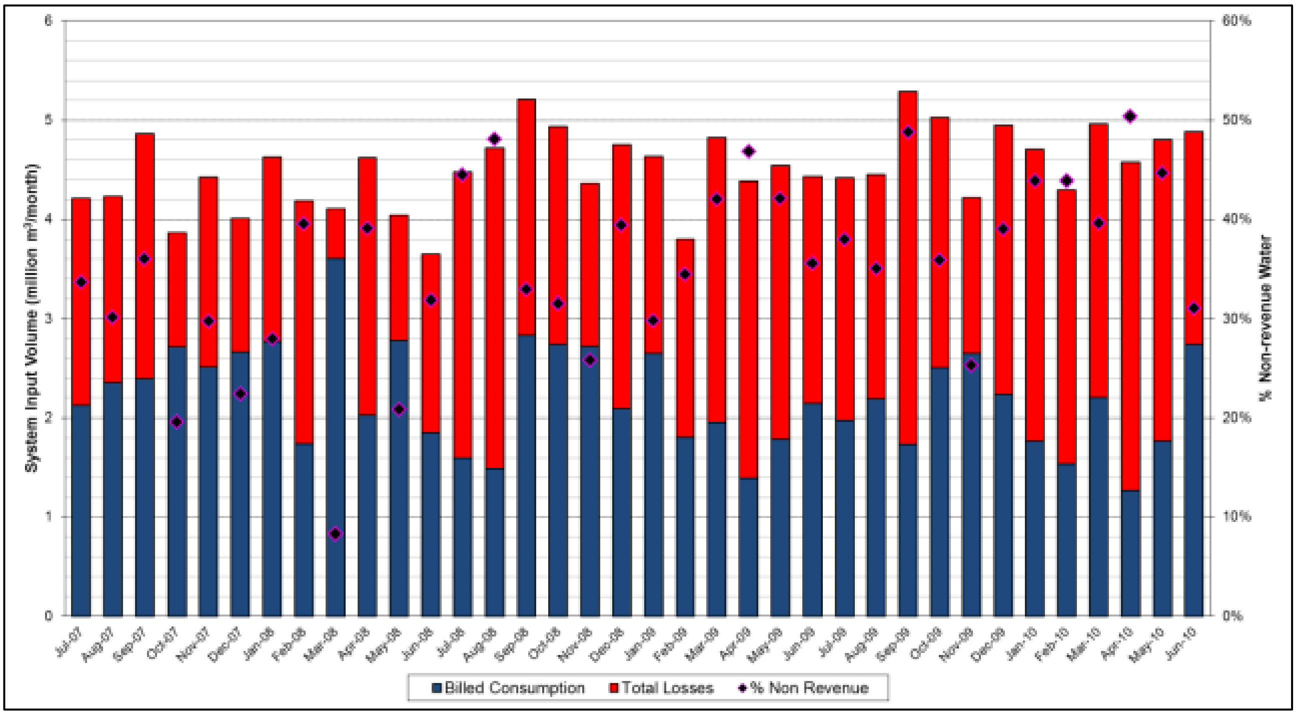


Figure 10: Monthly water balance calculation indicating huge fluctuations in NRW

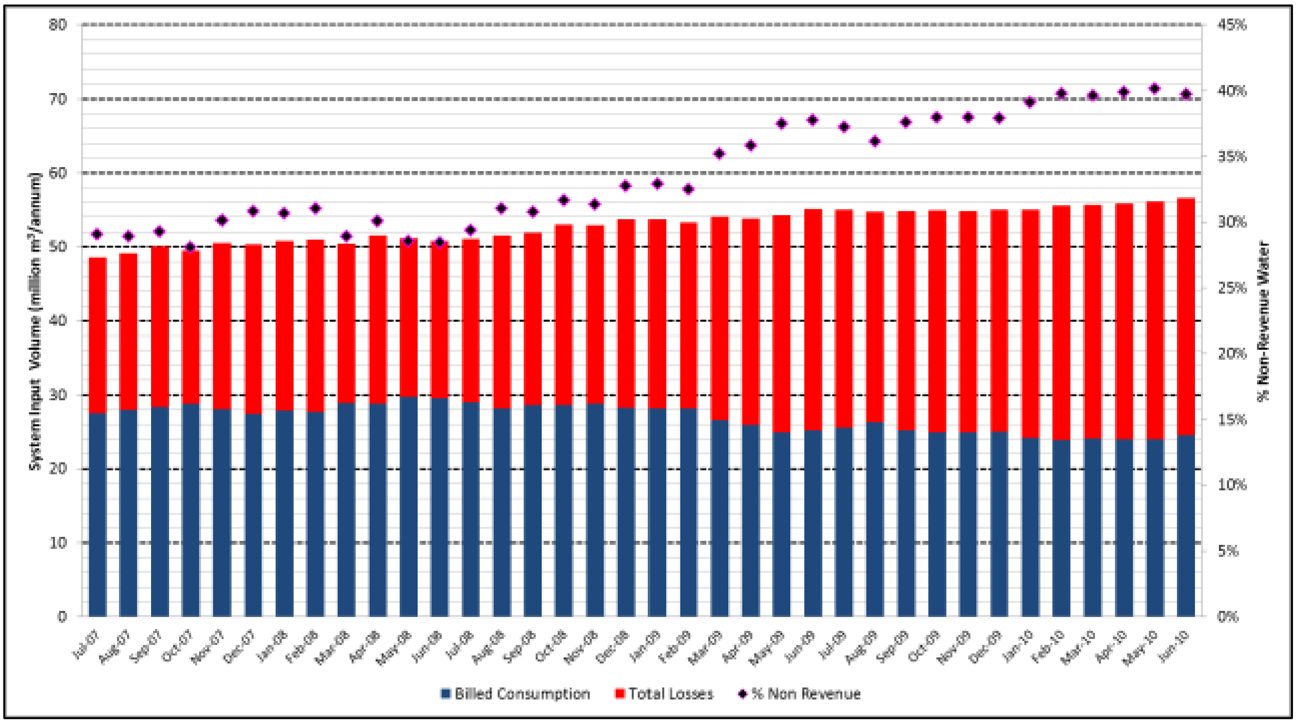
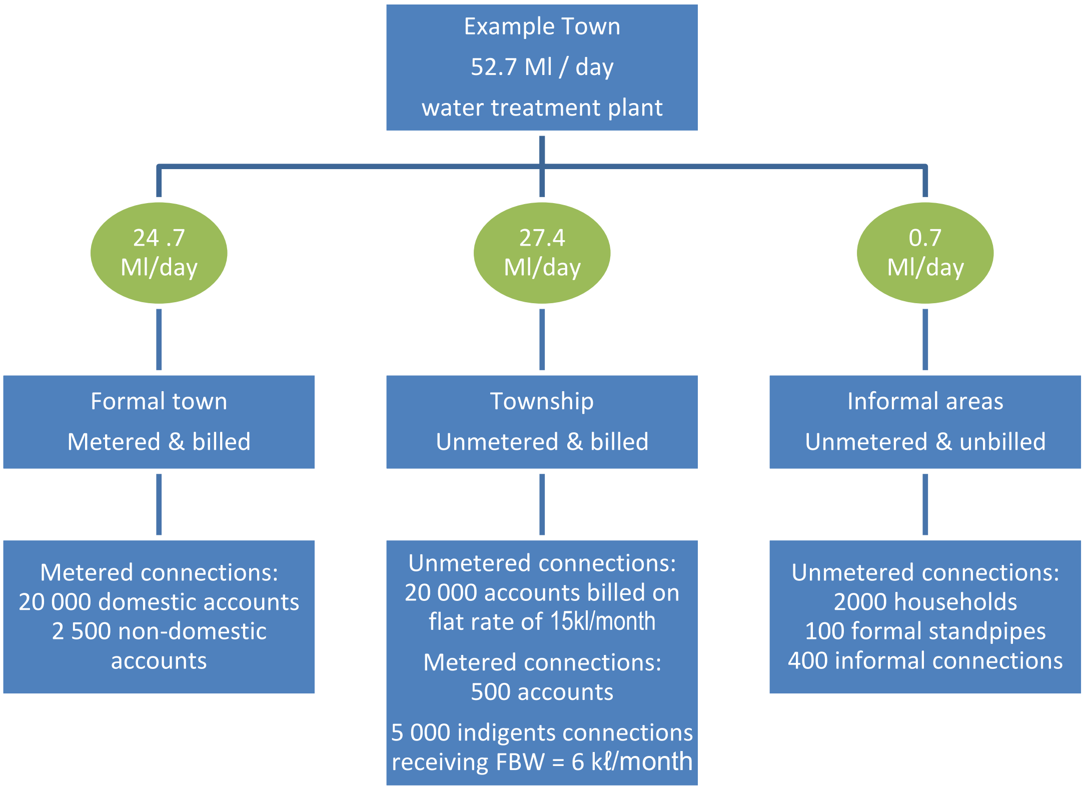


Figure 11: Twelve month rolling water balance calculation indicating gradual NRW increase

6 EXAMPLE

The following example illustrates most of the concepts and methodologies described in this guideline:



Basic information

		Area	Town	Township	Informal	Total
Basic information	**Population served**	**No**	**100 000**	**150 000**	**10 000**	**260 000**
	Households served	**No**	**25 000**	**30 000**	**2 000**	**57 000**
	Connections - total	**No**	**22 500**	**25 500**	**500**	**48 500**
	Connections - metered	**No**	**22 500**	**500**	**0**	**23 000**
	Domestic	No	20 000			20 000
	Non-domestic	No	2 500	500		3 000
	Connections - unmetered	**No**		**25 000**	**500**	**25 500**
	Households / connection	**No**	**1.1**	**1.2**	**4.0**	**1.2**
	Length of mains	**km**	**400**	**350**	**15**	**765**
	Connections / km	**No/km**	**56**	**73**	**33**	**63**
	Average system pressure	**m**	**55**	**45**	**40**	**47**
	Time system pressurised	**%**	**100%**	**100%**	**100%**	**100%**
	Apparent losses	**%**	**22.0%**	**0.5%**	**0.0%**	**7.5%**
	Consumer meter age	%	10.0%	0.2%	0.0%	3.4%
	Illegal connections	%	4.0%	0.1%	0.0%	1.4%
	Data transfer	%	8.0%	0.2%	0.0%	2.7%

Notes:

- 6 kℓ/month free basic water only to indigent users
- System input volume obtained from bulk meter readings
- Authorised consumption obtained from the financial billing system
- Unbilled metered consumption is water used by the utility
- **Town:** All connections are metered. Domestic and non-domestic split obtained from water tariffs. There is close correlation between the number of households and connections. Apparent losses estimated from Table 2.
- **Township:** All domestic connections (20 000) are unmetered and billed on a flat (deemed) consumption of 15 kℓ/month. Indigent connections are unmetered and supplied with 6 kℓ/month free basic water. Actual consumption for domestic and indigent users is estimated at 23 kℓ/month based on sample testing. Non-domestic connections are metered and users billed on actual consumption. The weighted apparent losses are summarised in the table below. Apparent losses for domestic and indigent users are 0% as there are no meters.

Connections	Unmetered connections	Metered connections	Total
Number of connections	25 000	500	25 500
% of total	98%	2%	100%
Apparent losses	**Unmetered connections**	**Metered connections**	**Weighted average***
Consumer meter age	0%	10%	0.2%
Illegal connections	0%	4%	0.1%
Data transfer	0%	8%	0.2%
Total % apparent losses	**0%**	**22%**	**0.4%**

* Weighted average consumer meter age = 0% unmetered x 98% + 10% x 2% = 0.2%

- **Informal:** All standpipe connections are unmetered. Apparent losses are equal to zero as there are no meters and all connections (formal and informal) are considered authorised.

Water balance calculations

		Area	Town	Township	Informal	Total
Water Balance Calculations	**System input volume**	**kl/annum**	**9 000 000**	**10 000 000**	**250 000**	**19 250 000**
	Own sources	kl/annum	9 000 000	10 000 000	250 000	19 250 000
	Other sources	kl/annum				0
	Authorised Consumption	**kl/annum**	**6 600 000**	**7 560 000**	**216 000**	**14 376 000**
	Billed authorised	**kl/annum**	**6 100 000**	**4 210 000**	**144 000**	**10 454 000**
	Billed metered	**kl/annum**	**6 100 000**	**610 000**	**0**	**6 710 000**
	Domestic	kl/annum	5 000 000	360 000		5 360 000
	Non-domestic	kl/annum	1 000 000	250 000		1 250 000
	Export volume	kl/annum	100 000			100 000
	Billed unmetered	kl/annum		3 600 000	144 000	3 744 000
	Unbilled authorised	**kl/annum**	**500 000**	**3 350 000**	**72 000**	**3 922 000**
	Unbilled metered	kl/annum	500 000	50 000		550 000
	Unbilled unmetered	kl/annum		3 300 000	72 000	3 372 000
	Water Losses	**kl/annum**	**2 400 000**	**2 440 000**	**34 000**	**4 874 000**
	Commercial / Apparent losses	**kl/annum**	**528 000**	**12 200**	**0**	**365 550**

Area		Town	Township	Informal	Total
Physical / Real losses	kl/annum	1 872 000	2 427 800	34 000	4 508 450
UARL	kl/annum	505 890	438 548	9 782	895 442
Potential real loss saving	kl/annum	1 366 110	1 989 253	24 218	3 613 008
Revenue water	kl/annum	6 100 000	4 210 000	144 000	10 454 000
Non-Revenue water	kl/annum	2 900 000	5 790 000	106 000	8 796 000

Key performance indicators

	Area	Town	Township	Informal	Total
Key Performance Indicators	Indicator as % of system input volume				
	% Revenue water	67.8%	42.1%	57.6%	54.3%
	% Non-revenue water	32.2%	57.9%	42.4%	45.7%
	% Water Losses	26.7%	24.4%	13.6%	25.3%
	System input volume unit consumption				
	Litres / capita / day	244	183	68	202
	m³ / household / month	30	28	10	28
	m³ / connection / month	33	33	42	33
	Authorised Unit Consumption				
	Litres / capita / day	178	138	59	150
	m³ / household / month	22	21	9	21
	m³ / connection / month	24	25	36	25
	Domestic m³ / connection / month	23	24	36	24
	Non-domestic m³ / connection / month	33	42		35
	Water loss indicators				
	Litres / capita / day	66	45	9	51
	m³ / household / month	8	7	1	7
	m³ / connection / month	9	8	6	8
	UARL : Losses (litres / connection / day)	62	47	54	51
	CARL : Losses (litres / connection / day)	228	261	186	255
	Infrastructure Leakage Index (ILI)	3.7	5.5	3.5	5.0
	CARL : Losses (m³/ km mains / day)	13	19	6	16

KPI interpretation

Using the No Drop scoring the performance of the each system can be interpreted as follows:

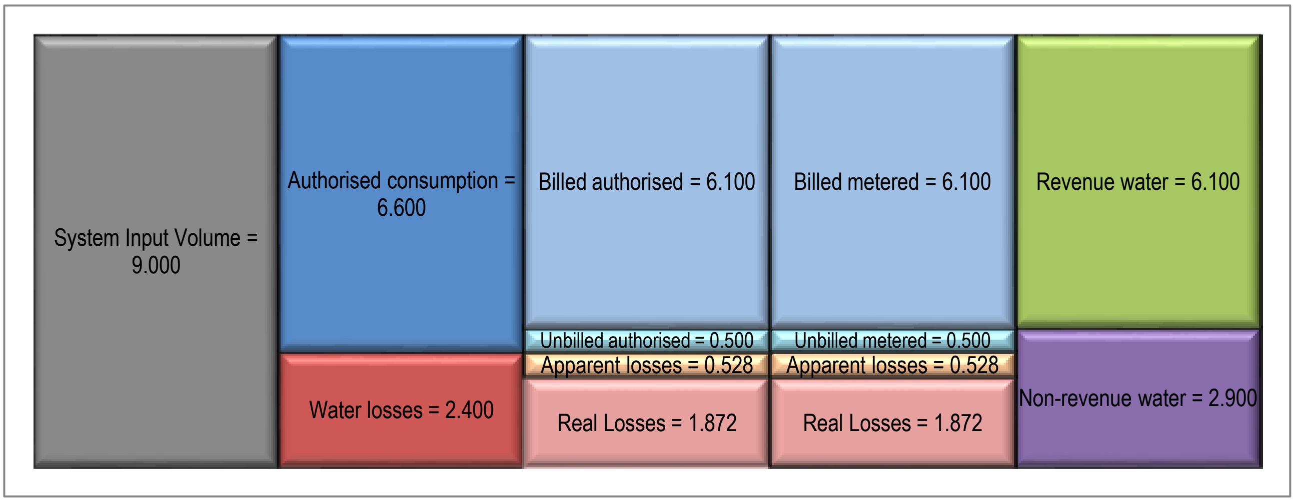
KPI	Town	Township	Informal	Total
ILI	3.7	5.5	3.5	5.0
Apparent loss	22.0%	0.5%	0.0%	7.5%
% NRW	32.2%	57.9%	42.4%	45.7%
Efficiency	244	183	68	202

Legend

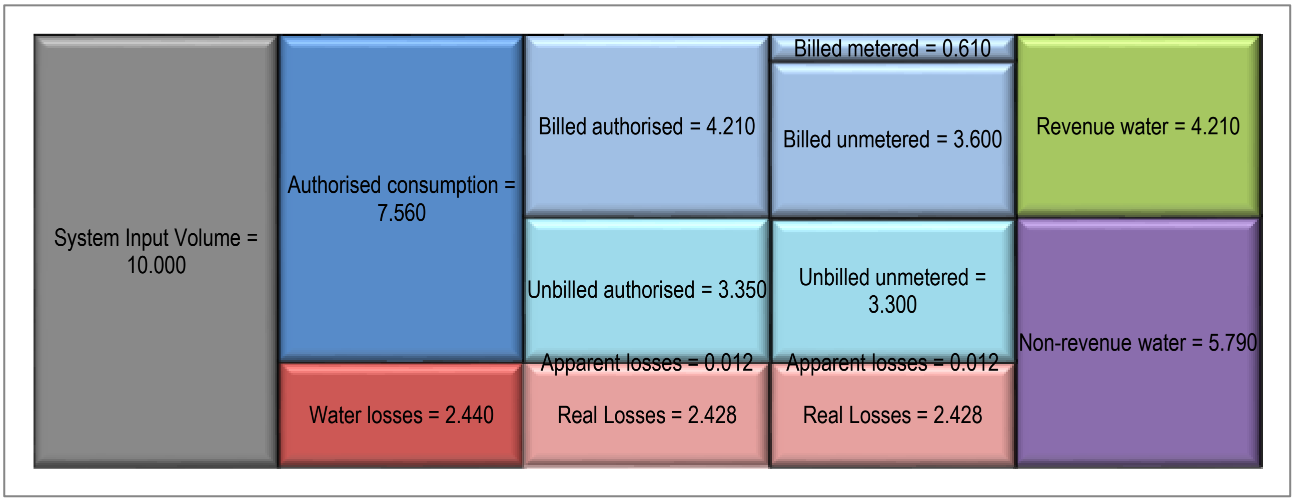
Very good	Good	Average	Poor	Extremely poor

Water balance diagrams

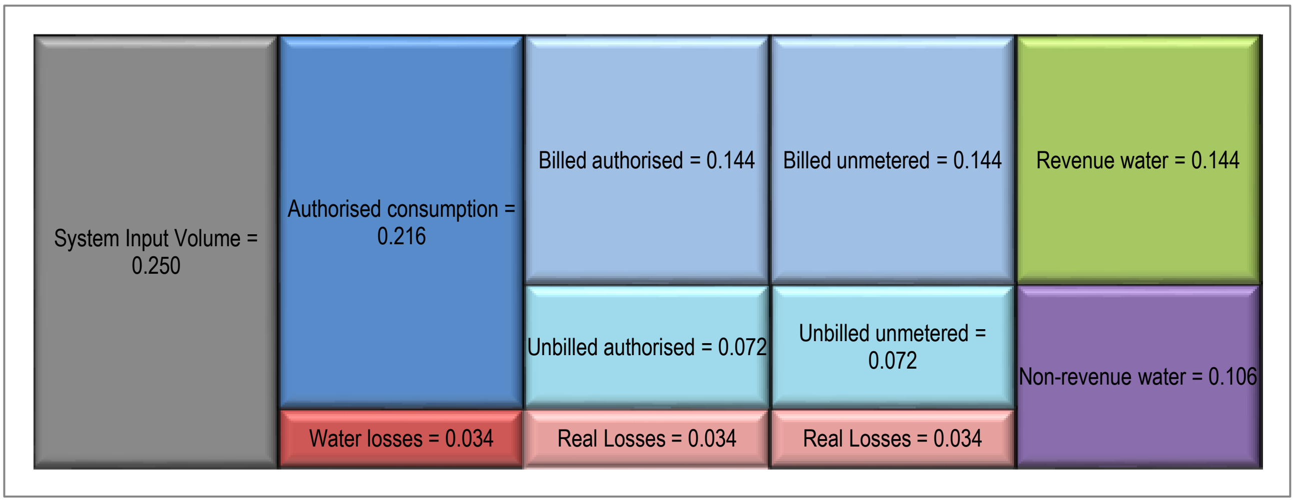
Town water balance diagram



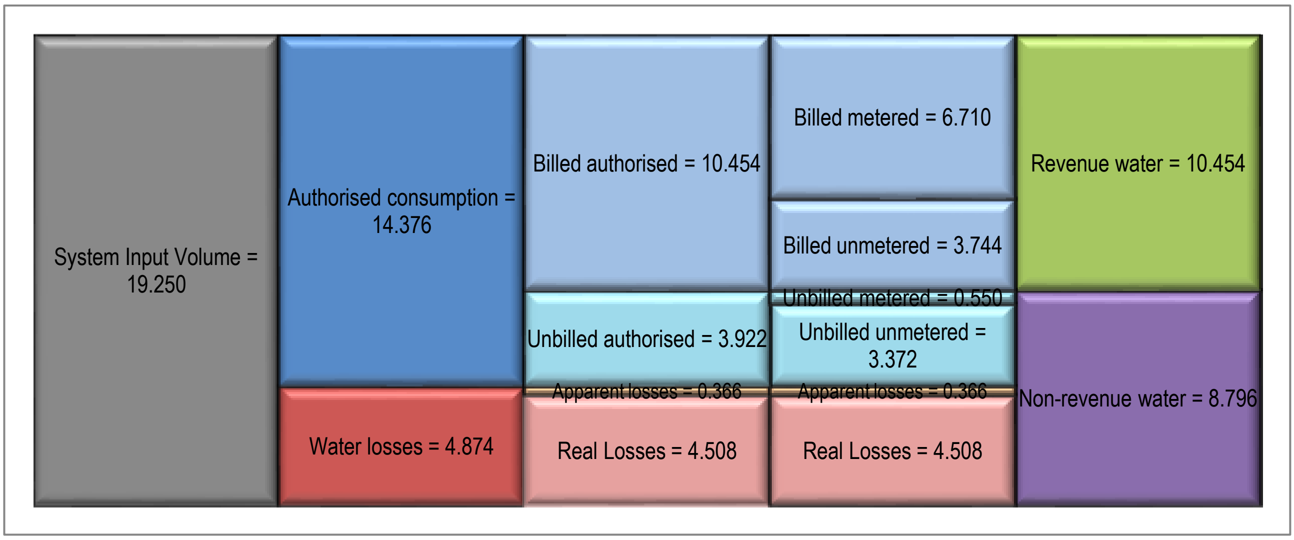
Township water balance diagram



Informal area



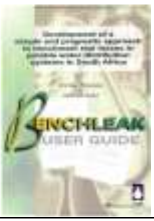
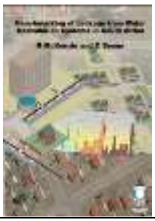
Total water balance



Comments on the results

- The No Drop benchmarking criteria highlight that the utility has a NRW (45.7%) problem as a result of the high unbilled authorised component in the water balance and not because of water losses
- Water losses are (25.3%) in line with average performing systems. Apparent losses form a very small component due to the high number of unmetered connections. Water losses (ILI = 5.5) should be addressed in the Township area
- Apparent losses in the Town area are high as a result of aging meters and should be addressed by introducing a meter replacement programme
- The water balance highlights that the municipality should focus on reducing the unbilled authorised consumption component by installing meters and reducing or controlling the demand on private properties.

7 FURTHER READING

	**"Development of a simple and pragmatic approach to benchmark real losses in potable water distribution systems in South Africa. WRC Report TT 159/01 by Mckenzie and Lambert, 2002"** This report introduced the standard International Water Associations water balance methodology to South Africa and recommended that it be implemented.
	**"Benchmarking of Leakage from Water Reticulation Systems in South Africa. WRC Report TT 244/05 by Mckenzie and Seago, 2005"** The study included assessment data from approximately 60 water supply systems and after careful screening the sample data set was reduced to 30 systems.
	***"Non-Revenue Water in South Africa. WRC Report TT 300/07 by Seago and Mckenzie, 2007"*** The study included water balance information from 62 systems which was extrapolated to provide an indication of the overall water losses from municipal reticulation systems for the whole of South Africa."
	**"SANS 10306:2010 The management of potable water in distribution systems. SABS Standards Division, 2010"** This 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 water losses.