NRW Assessment and Management

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Understanding and assessing NRW

… and why this is so important for you!

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History of modern NRW management

- In the past, water loss reduction activities were done in an un-coordinated way
- Interrelations were not properly understood
- The changing point: Privatization of the UK water industry (1989) - the need to become more efficient
- Significant research was done in the UK
- This work formed the basis for most modern NRW management concepts and tools
- In 1997 IWA started with international standardization of terminology and performance indicators – one important outcome was the Water Balance

The next big water loss event

Water Loss 2020

Nov 8-11, 2020 Shenzhen, China

2020年11月8-11日 中 国·深 圳

www.waterloss2020.org

The Water Balance

The basis for everything

<table>
<tr><td rowspan="10">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</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="8">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="6">Water Losses</td><td rowspan="2">Commercial (Apparent) Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Meter Inaccuracies and Data Handling Errors</td></tr>
<tr><td rowspan="4">Physical (Real) Losses</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows from the Utilities Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to the Customer Meter</td></tr>
</table>

Calculating a water balance

- Step 1 – determine system input volume
  - The accuracy of the system input volume (SIV) is the single most important factor for the accuracy of the water balance!
- Step 2 – determine authorized consumption
  - Billed consumption – ideally 12 months billing data (metered and unmetered)
  - Unbilled metered consumption – if any, get records
  - Unbilled unmetered consumption – use estimate: 0.8% of SIV
- Step 3 – estimate commercial losses
  - Water theft – discuss magnitude of the problem, estimate range of potential losses
  - Meter under-registration and (too) low estimates for unmetered customers
- Step 4 – calculate physical losses

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Indicative examples of bulk meter accuracy

Equipment/method	Approximate accuracy range
Electromagnetic flow meters	< 0.15 – 0.5 %
Ultrasonic flow meters	0.5 – 1 %
Insertion probes	≥ 2 %
Mechanical meters	1 – 2 %
Venturi meters	0.5 – 3 %
Measuring weirs in open channels	> 5%
Volume calculated based on pump curves	10 – 50 %

The numbers in the table are "best case"

Actual meter accuracy will depend on many factors (like flow profile, calibration, meter installation, maintenance) and has to be verified case by case.

Calculating Physical Losses

- **Definition:** Losses from pressurized system up to the point of customer use
- Simple mathematically:

	System Input Volume
–	Authorized Consumption
–	Commercial Losses
=	Physical losses

- But, results sometimes inaccurate and unreliable
- Especially in systems with
  - Poor accuracy of SIV
  - Unknown customer meter accuracy
  - High levels of water theft

Probability analysis in the water balance calculations

- Water balance elements have different accuracy levels
- Some elements are even estimated
- Probability analysis allows judging the overall reliability of the Water Balance
- Confidence intervals express relative accuracy:

a 95 % confidence level means that I am 95% confident that an input value is within X% of the true value

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95% confidence intervals - an example

Water Balance Components	Volume (m3/day)	Confidence Interval
System Input Volume	300,000	**2%**
Billed Consumption	200,000	**0%**
Non Revenue Water	100,000	???
Unbilled Authorized Consumption	5,000	**+/- 50%**
Water Losses	95,000	???
Commercial Losses	30,000	**+/-30%**
Physical Losses	65,000	???

Applying 95% confidence intervals to the water balance

	Volume (V) [m^3/d]	95% Confidence Interval (CI)		Standard Deviation (SD) [=V x CI /1.96]		Variance (Va) [= SD^2]	
System Input Volume	300,000	+/- 2 %	→				
Billed Author. Consumption	200,000	+/- 0 %	→				
Non-Revenue Water	100,000						
Unbilled Author. Consumption	5,000	+/- 50 %					
Water Losses	95,000						
Commercial Losses	30,000	+/- 30 %					
Real Losses	65,000						

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System Input Volume	300,000	+/- 2 %	→	3,061	→		
Billed Author. Consumption	200,000	+/- 0 %	→	0	→		
Non-Revenue Water	100,000						
Unbilled Author. Consumption	5,000	+/- 50 %					
Water Losses	95,000						
Commercial Losses	30,000	+/- 30 %					
Real Losses	65,000						

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System Input Volume	300,000	+/- 2 %	→	3,061	→	9,369,721 +	
Billed Author. Consumption	200,000	+/- 0 %	→	0	→	0	
Non-Revenue Water	100,000						←
Unbilled Author. Consumption	5,000	+/- 50 %					
Water Losses	95,000						
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Billed Author. Consumption	200,000	+/- 0 %	→	0	→	0	
Non-Revenue Water	100,000		←	3,061 [=√ Va]	←	9,369,721	
Unbilled Author. Consumption	5,000	+/- 50 %					
Water Losses	95,000						
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System Input Volume	300,000	+/- 2 %		3,061		9,369,721 +	
Billed Author. Consumption	200,000	+/- 0 %		0		0	
Non-Revenue Water	100,000	+/- 6 % [=SD/V*1.96]		3,061		9,369,721	
Unbilled Author. Consumption	5,000	+/- 50 %					
Water Losses	95,000						
Commercial Losses	30,000	+/- 30 %					
Real Losses	65,000						

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Billed Author. Consumption	200,000	+/- 0 %	→	0	→	0	
Non-Revenue Water	100,000	+/- 6 %	←	3,061	←	9,369,721 +	
Unbilled Author. Consumption	5,000	+/- 50 %	→	1,275	→	1,626,926	
Water Losses	95,000						
Commercial Losses	30,000	+/- 30 %					
Real Losses	65,000						

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Unbilled Author. Consumption	5,000	+/- 50 %	→	1,275	→	1,626,926	
Water Losses	95,000	+/- 7 %	←	3,316	←	10,996,647	
Commercial Losses	30,000	+/- 30 %					
Real Losses	65,000						

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Applying 95% confidence intervals to the water balance

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Water Losses	95,000	+/- 7 %	3,316	10,996,647 +
Commercial Losses	30,000	+/- 30 %	4,592	21,084,965
Real Losses	65,000			

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Unbilled Author. Consumption	5,000	+/- 50 %	→	1,275	→	1,626,926	
Water Losses	95,000	+/- 7 %	←	3,316	←	10,996,647 +	
Commercial Losses	30,000	+/- 30 %	→	4,592	→	21,084,965	
Real Losses	65,000	+/- 17 %	←	5,664	←	32,081,612	

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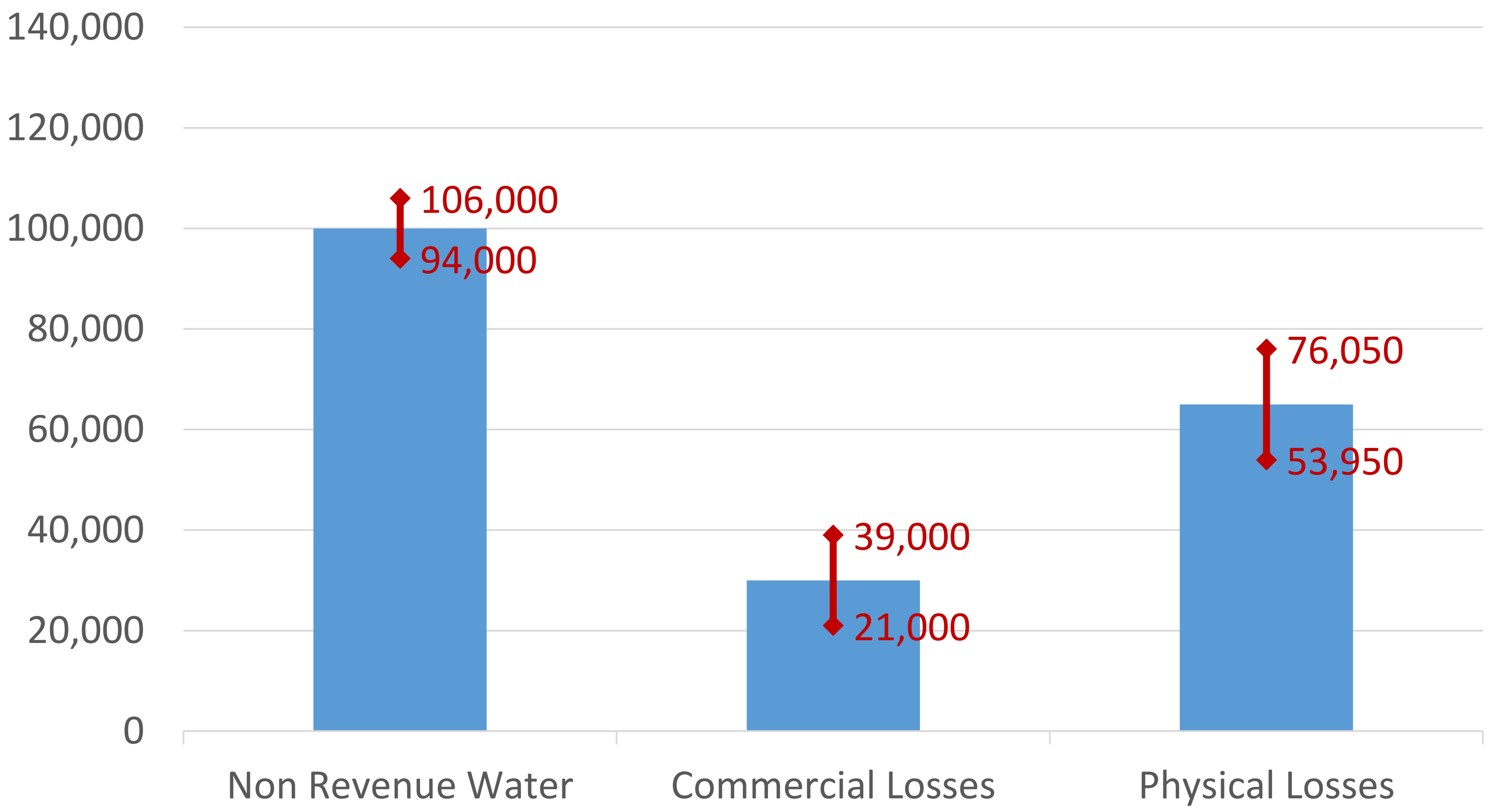
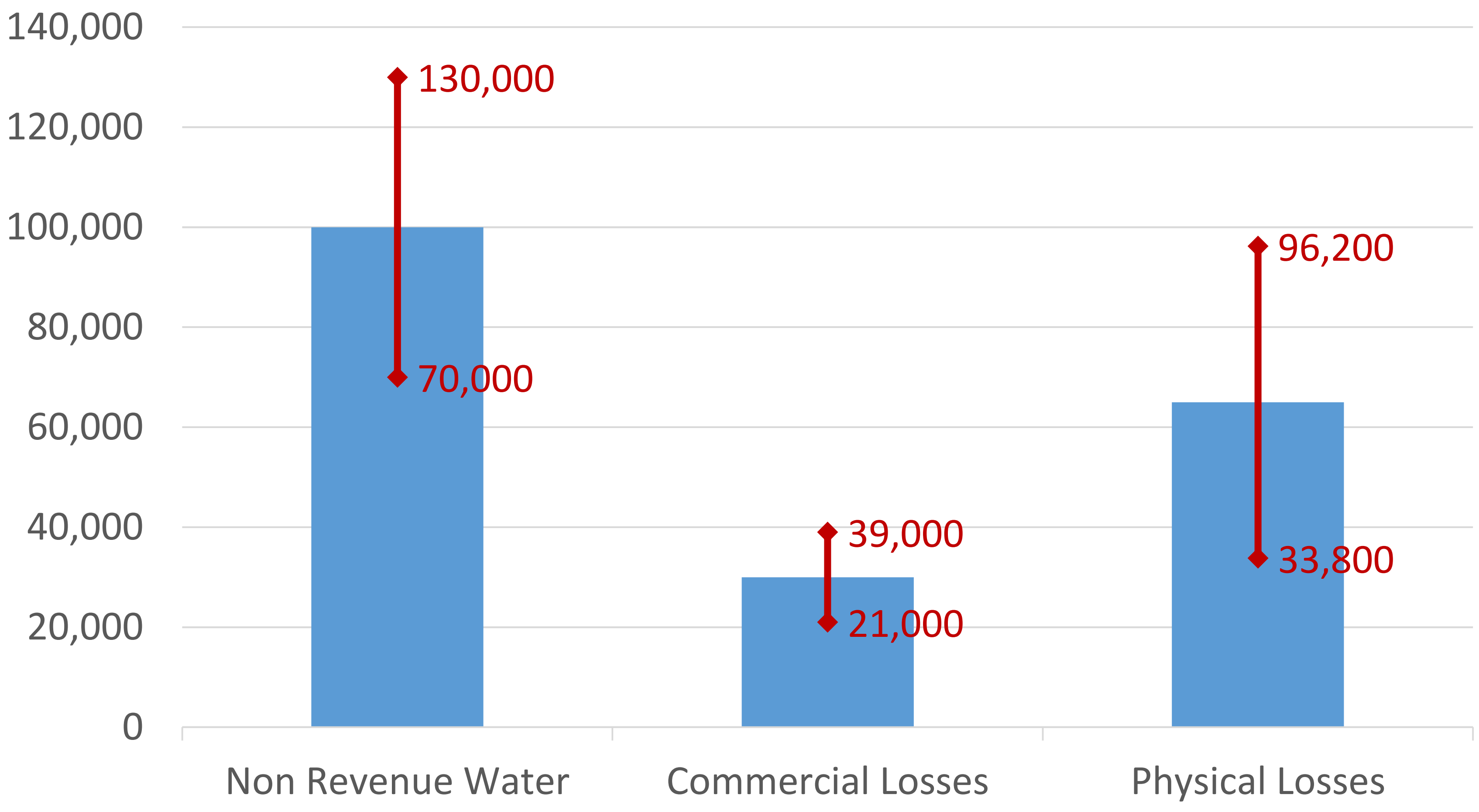
Interpreting the results



But if system input volume +/- 10%



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Many production meters – better accuracy!

Meter #	Volume	Confidence Interval	Standard Deviation SD =V x CI/1.96	Variance V = SD^2
1	1,000	10%		
2	1,000	10%		
3	1,000	10%		
4	1,000	10%		
5	1,000	10%		
6	1,000	10%		
7	1,000	10%		
8	1,000	10%		
9	1,000	10%		
10	1,000	10%		
	10,000			

Many production meters – better accuracy!

Meter #	Volume	Confidence Interval	Standard Deviation SD =V x CI/1.96	Variance V = SD^2
1	1,000	10%	51.02	
2	1,000	10%	51.02	
3	1,000	10%	51.02	
4	1,000	10%	51.02	
5	1,000	10%	51.02	
6	1,000	10%	51.02	
7	1,000	10%	51.02	
8	1,000	10%	51.02	
9	1,000	10%	51.02	
10	1,000	10%	51.02	
	10,000			

Many production meters – better accuracy!

Meter #	Volume	Confidence Interval	Standard Deviation SD =V x CI/1.96	Variance V = SD^2
1	1,000	10%	51.02	2,603.08
2	1,000	10%	51.02	2,603.08
3	1,000	10%	51.02	2,603.08
4	1,000	10%	51.02	2,603.08
5	1,000	10%	51.02	2,603.08
6	1,000	10%	51.02	2,603.08
7	1,000	10%	51.02	2,603.08
8	1,000	10%	51.02	2,603.08
9	1,000	10%	51.02	2,603.08
10	1,000	10%	51.02	2,603.08
	10,000			**26,031.82**

Many production meters – better accuracy!

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1	1,000	10%	51.02	2,603.08
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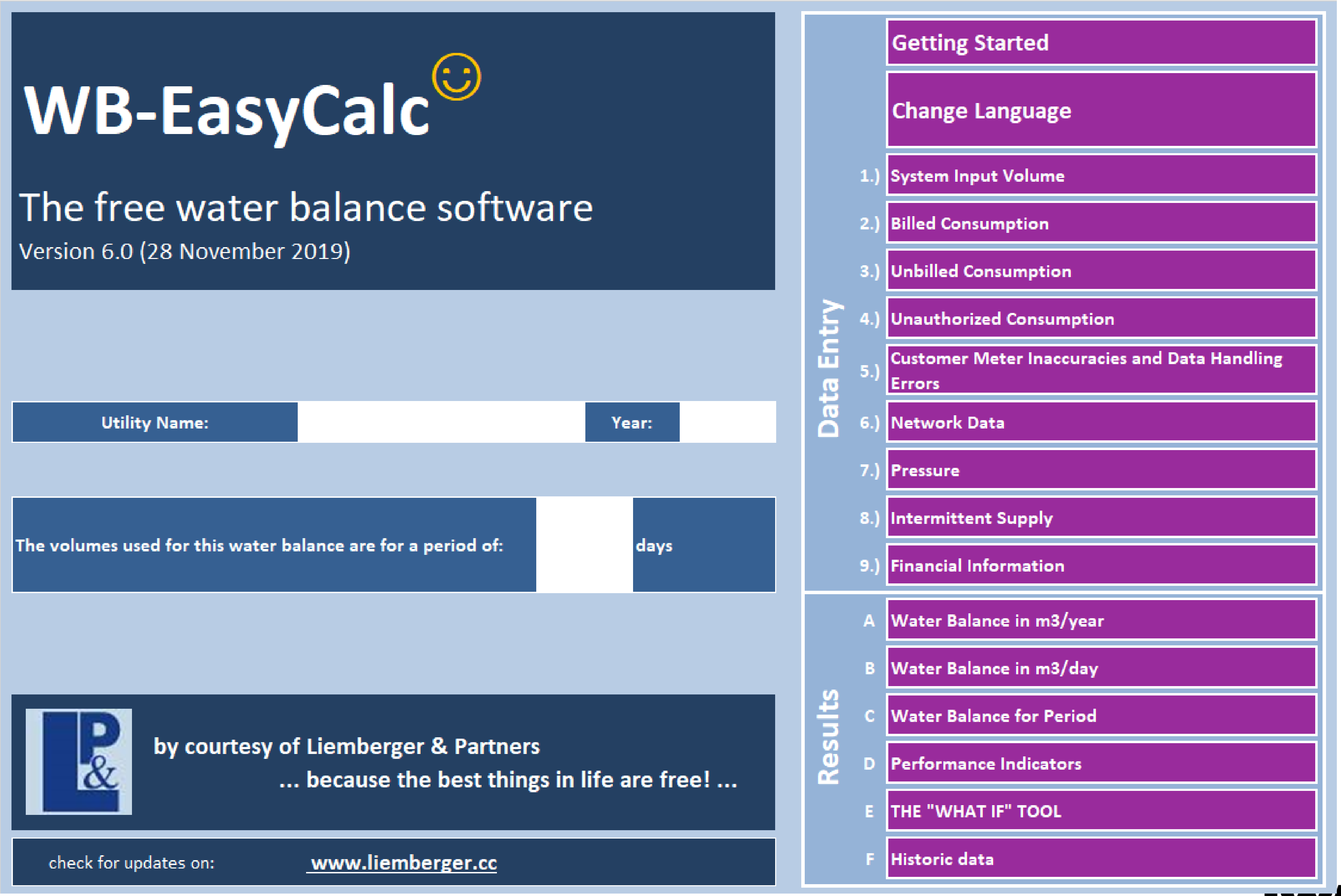
3	1,000	10%	51.02	2,603.08
4	1,000	10%	51.02	2,603.08
5	1,000	10%	51.02	2,603.08
6	1,000	10%	51.02	2,603.08
7	1,000	10%	51.02	2,603.08
8	1,000	10%	51.02	2,603.08
9	1,000	10%	51.02	2,603.08
10	1,000	10%	51.02	2,603.08
	10,000		**161.34**	**26,031.82**

Many production meters – better accuracy!

Meter #	Volume	Confidence Interval	Standard Deviation SD =V x CI/1.96	Variance V = SD^2
1	1,000	10%	51.02	2,603.08
2	1,000	10%	51.02	2,603.08
3	1,000	10%	51.02	2,603.08
4	1,000	10%	51.02	2,603.08
5	1,000	10%	51.02	2,603.08
6	1,000	10%	51.02	2,603.08
7	1,000	10%	51.02	2,603.08
8	1,000	10%	51.02	2,603.08
9	1,000	10%	51.02	2,603.08
10	1,000	10%	51.02	2,603.08
	10,000	**3.2%**	**161.34**	**26,031.82**


WB-EasyCalc
The free water balance software
Version 6.0 (28 November 2019)
Utility Name:
Year:
The volumes used for this water balance are for a period of:
days
by courtesy of Liemberger & Partners
... because the best things in life are free! ...
check for updates on:
www.liemberger.cc
Getting Started
Change Language
Data Entry
1.) System Input Volume
2.) Billed Consumption
3.) Unbilled Consumption
4.) Unauthorized Consumption
5.) Customer Meter Inaccuracies and Data Handling Errors
6.) Network Data
7.) Pressure
8.) Intermittent Supply
9.) Financial Information
Results
A Water Balance in m3/year
B Water Balance in m3/day
C Water Balance for Period
D Performance Indicators
E THE "WHAT IF" TOOL
F Historic data

Takeaway #1

We always need a water balance and we need to understand its accuracy!

Understanding Physical Losses

What you need to know before talking about performance indicators

Leakage Classification

- **Reported Bursts**
  - visible, phoned in by public, observed by water utility staff, normally large flow rate and short run- time
- **Unreported Bursts**
  - non-visible, located during a leak detection survey, often smaller but long run-time
- **Background Leakage**
  - very small leaks; difficult and uneconomic to detect and repair individually

Most Leaks are Invisible

- Majority of all leaks
  - does **NOT** come to the surface
  - is caused by leaking service connections
- Absence of an **ACTIVE** program to detect invisible leaks is a good indication for high levels of leakage
- In general: small leaks are the biggest problem

But sometimes it's also the big leaks!

About 5 million liters per day!

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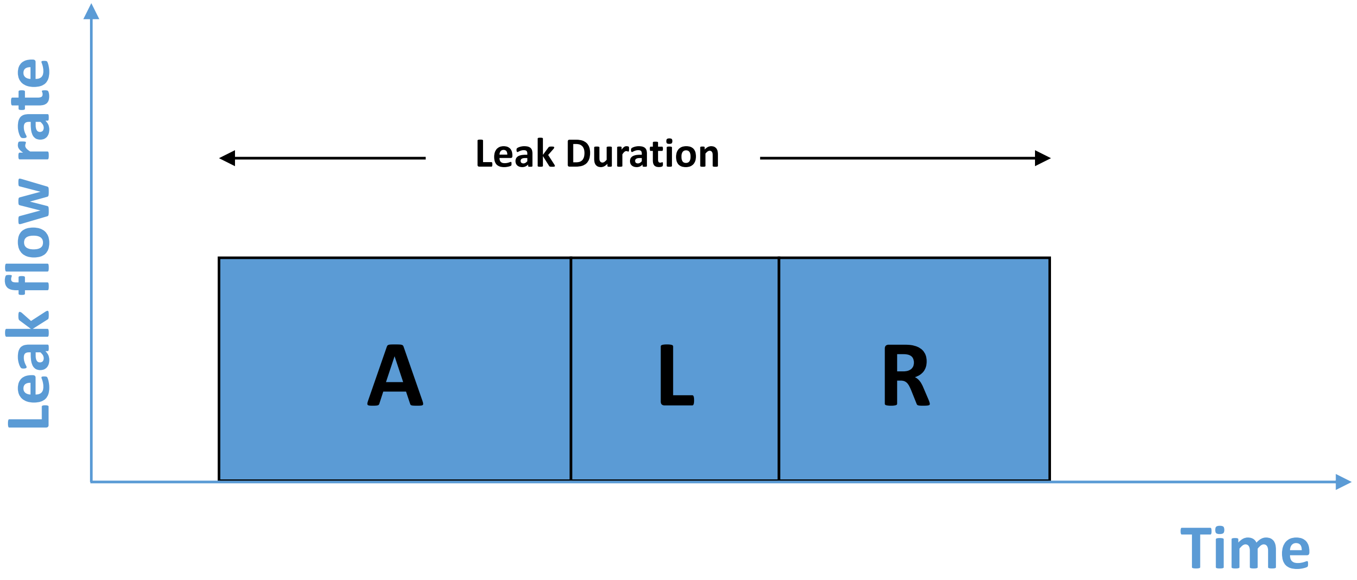
Leak volume:
A function of time and flow rate



Leak Volume = Time (A+L+R) x Flow Rate

A: Awareness L: Localization R: Repair

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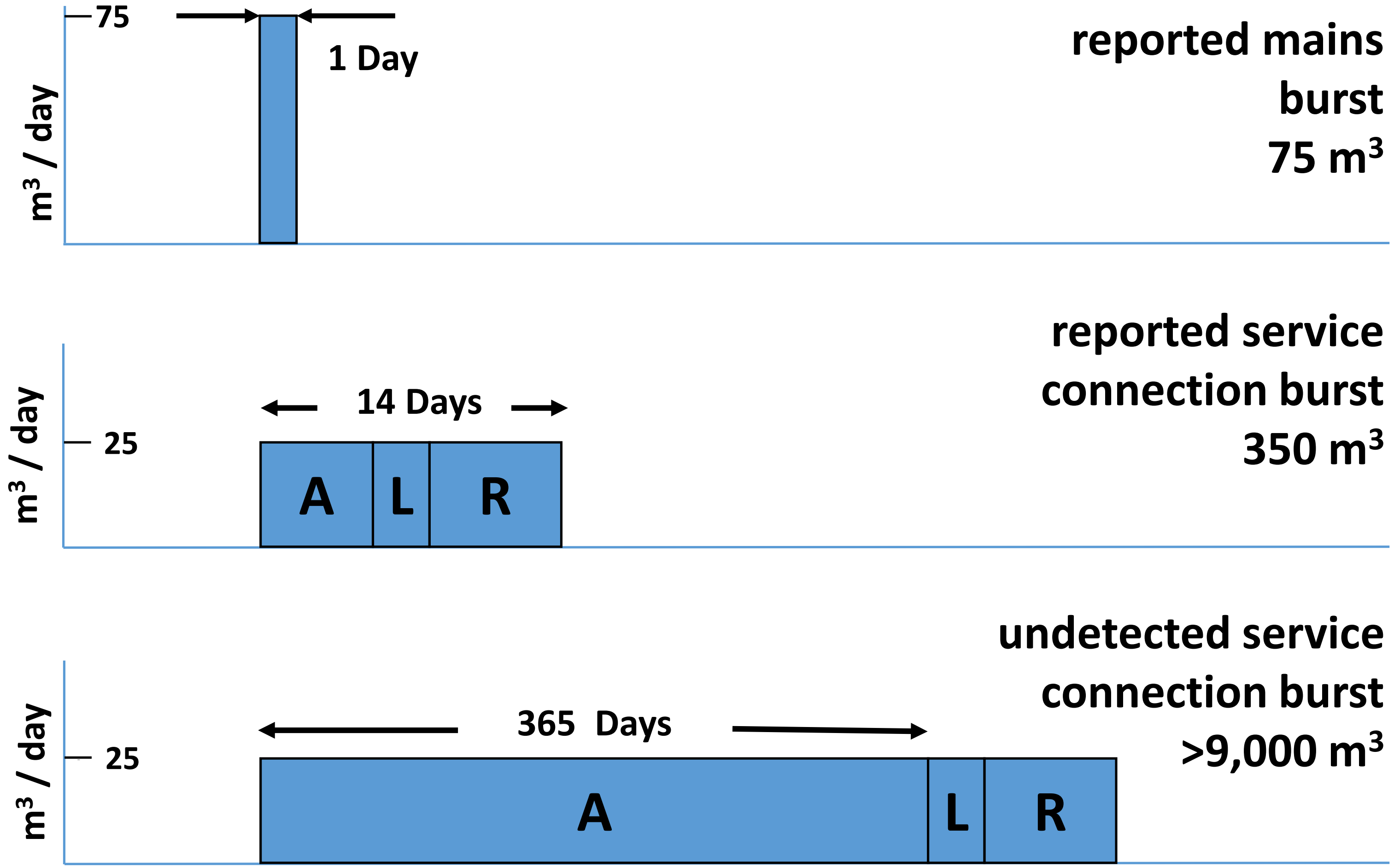
Time makes a big difference



Pressure:leakage relationship in distribution networks

- Leakage is more pressure sensitive than traditional hydraulic theory suggests
- Because leakage in distribution networks is complex:
  - irregular shape of holes, multiple hole patterns
  - size of holes changes with pressure depending on pipe material
- FAVAD (Fixed and Variable Area Discharge) methodology allows to calculate pressure:leakage relationship:

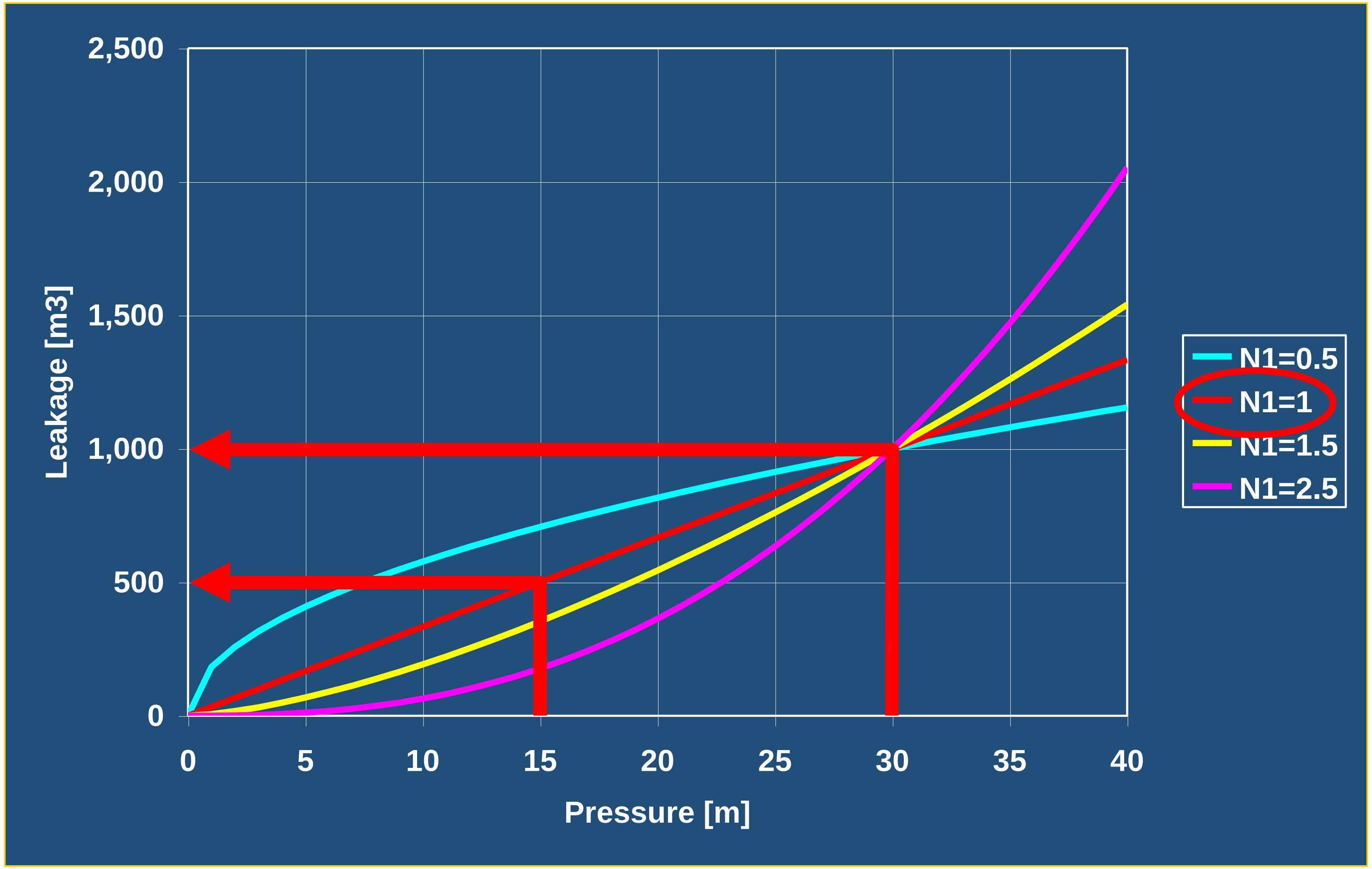
But what to use for N1?

$$L_1/L_0 = (P_1/P_0)^{N1}$$

or

$$L_1 = L_0 \times (P_1/P_0)^{N1}$$

Pressure/Leakage Relationship



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Importance of correct pressure:leakage relationship simulation

- FAVAD methodology allows relating changes in pressure to changes in leakage
- Leakage can be calculated for different pressures, for example:
  - How much will leakage increase if a new source (pumping station, treatment plant) will be added?
  - What is the potential for leakage reduction through pressure reduction?
- Relationship complex, but a good first assumption is a linear relationship:

  10% more pressure = 10% more leakage

Direct impact on physical losses: Average supply time

- Average supply time
  - Needs to be measured/recorded
  - Is essential for the calculation of water loss performance indicators
  - Only 12h supply ➔ only 50% leakage!

No water, no leak, no problem! ☺

In summary

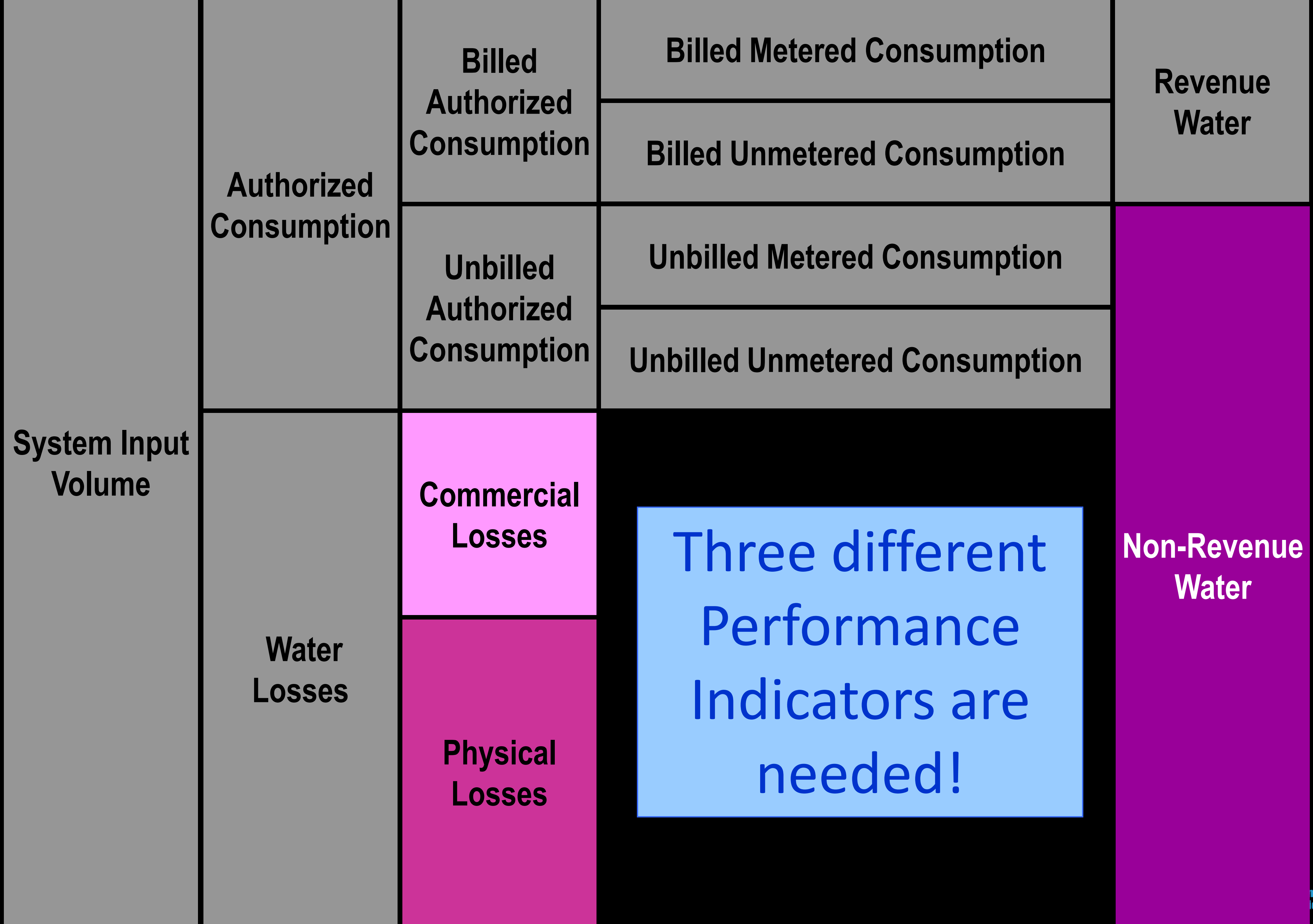
- 90% of all leaks are not visible on the surface
- Leakage volume from bursts depends on flow rate and time from occurrence to repair
- Undetected smaller bursts are most serious
- Leakage is more sensitive to pressure than traditional wisdom suggests
    - First assumption: linear relationship
- Average supply time must always be taken into account!

Takeaway #2

We don’t know anything if we don’t have information on supply time and pressure!

Water Loss Performance Indicators

What you need to know before talking about performance indicators



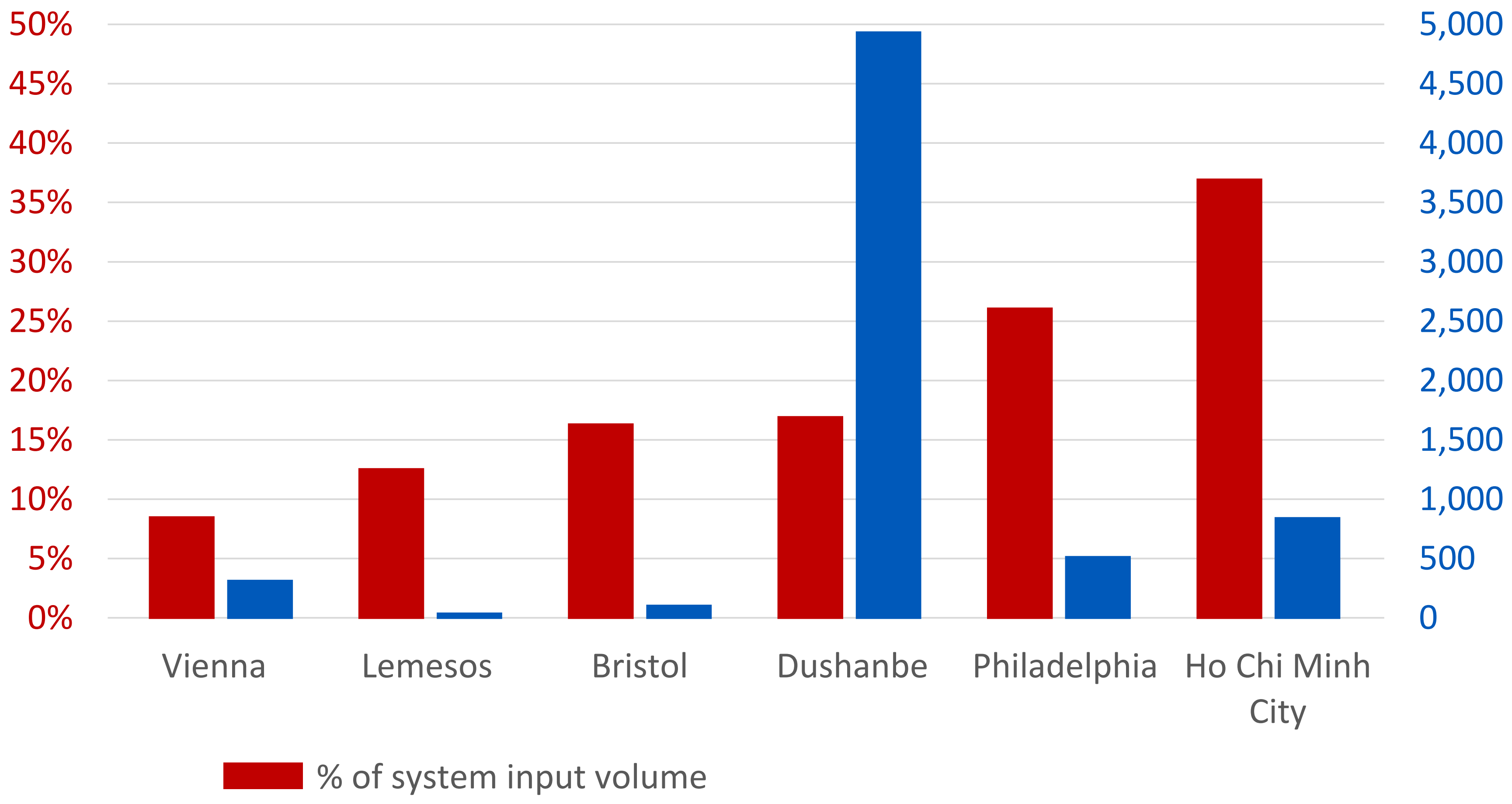
Three different Performance Indicators are needed!

miya

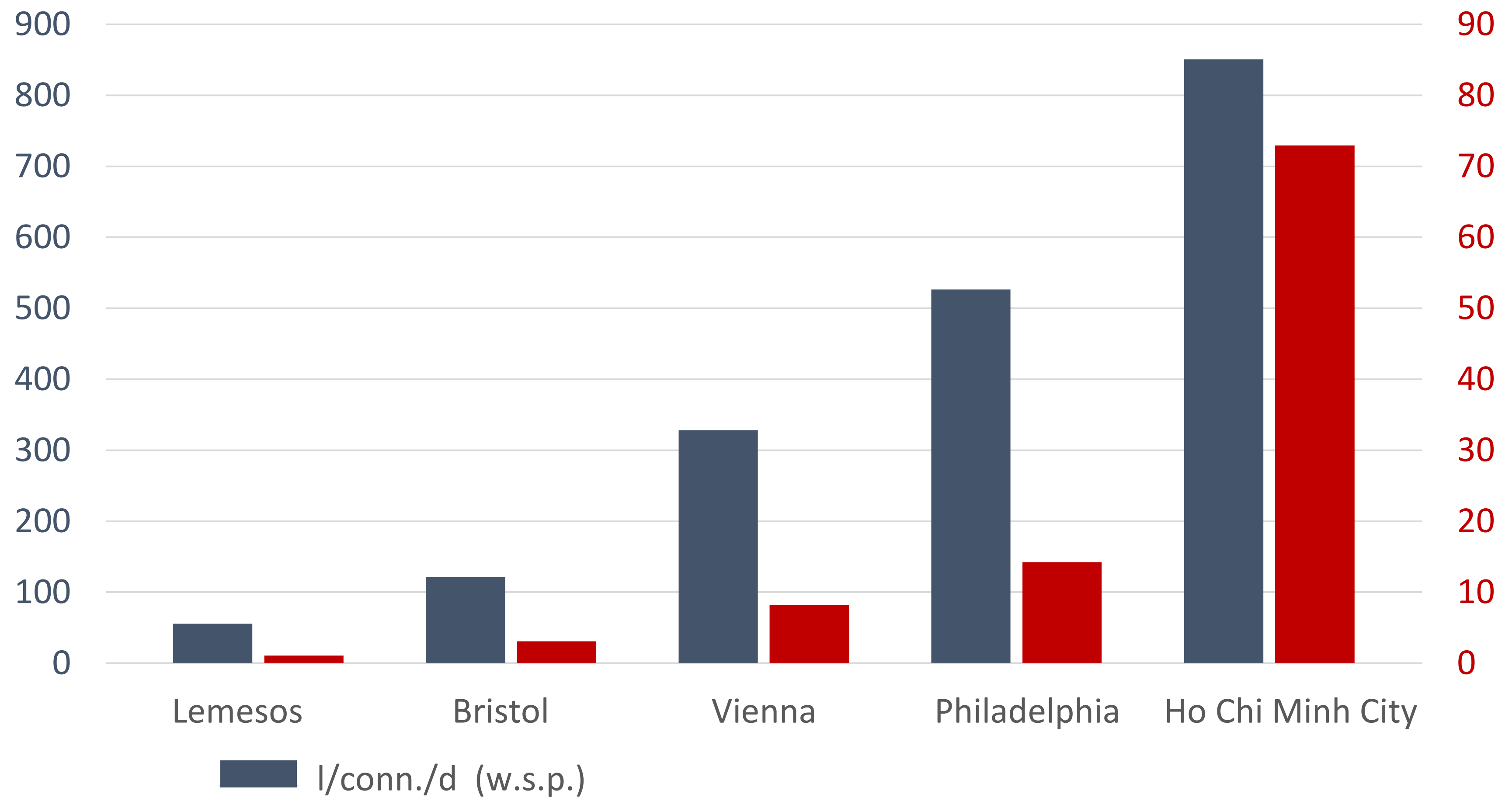
NRW as % of System Input is a very misleading Indicator

- % NRW is a poor technical indicator: why?
  - Does not work in the case of intermittent supply
  - misleading: “favours” utilities with high consumption
  - Is not suitable to compare utilities with different pressure levels
  - lumps together two unrelated water loss components:
    - physical and commercial losses
- All international and many national water associations advise against using percentages
- Politicians, media and many others still use it (and will continue to do so ☹)
  - But we should not!

Physical losses – how wrong can % be?



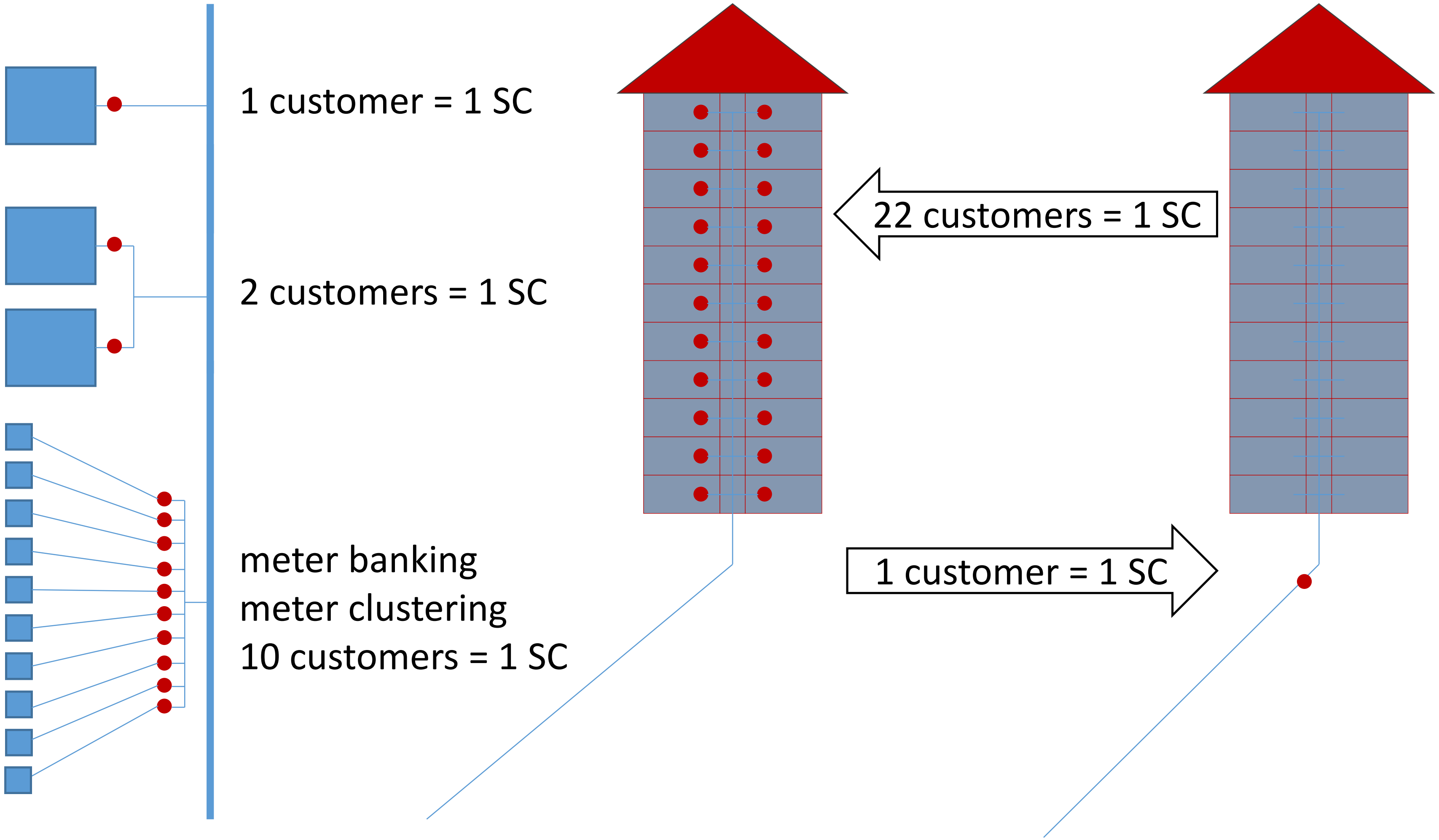
The importance of pressure



Number of service connections

- Number of service connections (SCs) often confused with the number of customers, for example:
  - Indaqua: 250,000 customers but only 185,000 SCs, mainly caused by:
  - Matosinhos: 87,000 customers and 41,000 SCs
- Leakage (and NRW) is expressed per SC
- Number of SCs essential for the calculation of PIs and for project cost estimates
- Water utilities should identify, geo-locate and record (GIS) service connections
- Number of connections may initially have to be estimated

Customers versus service connections



Water Loss Performance Indicators

- Physical Losses
  - Liters/connection/day (w.s.p.)
  - Liters/connection/day per meter pressure (w.s.p.)
  - Infrastructure Leakage Index (ILI)
- Commercial Losses
  - % of Authorized Consumption
  - Liters/connection/day
- NRW
  - **NOT** % of system input volume;
  - Liters/connection/day (w.s.p.)
  - Value of NRW as % of operating cost

Average pressure

- Most water utilities do not record pressure in the distribution network
- In the best case, spot measurements with pressure gauges
- Pressure is often only measured at pumping stations and trunk mains (where it is significantly higher)
- Gravity systems: night pressure is higher than daytime pressure
- 24h average values are needed – and a weighted average has to be calculated
- Intermittent supply: use only pressure during supply hours to calculate the average

Adjusting performance indicators for intermittent supply situations (w.s.p.)

Average Supply Time	Number of service connections in the concerned area	Calculate:
24 h/d	10,000	240,000
12 h/d	20,000	240,000
6 h/d	5,000	30,000
~ 14.6 h/d	**35,000**	**510,000**

Correct indicator for measured 200 l/conn./d (Water Balance):

200 /14.6 x 24 = 329 l/conn./d (w.s.p.)

w.s.p. = when the system is pressurized

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Infrastructure Leakage Index (ILI)

one number capturing a utility's leakage management performance

Infrastructure Leakage Index (ILI)

- Developed by the International Water Association (IWA)

ILI = CARL / UARL

CARL	=	Current Annual Real Losses
UARL	=	Unavoidable Annual Real Losses, level of losses that one would expect from a utility with network in good condition and which practices intensive active leakage control

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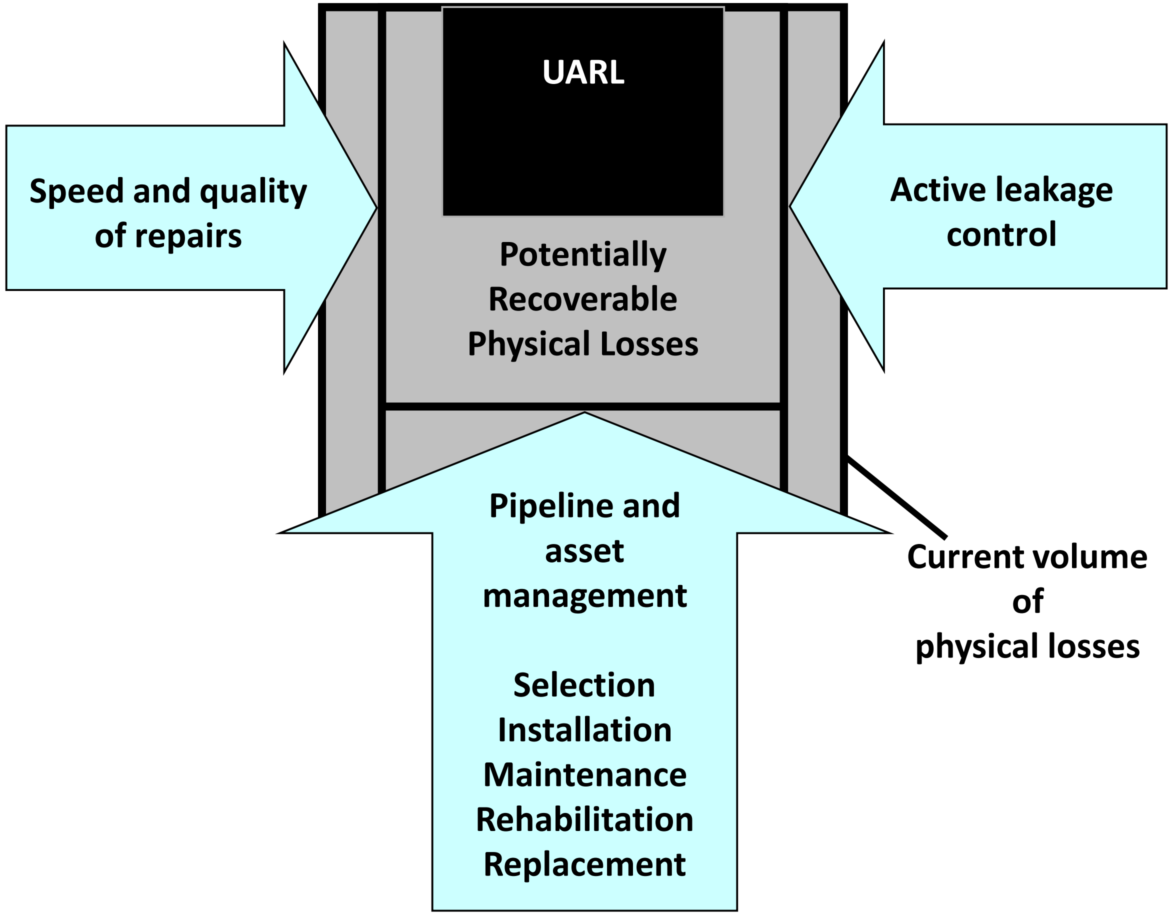
Illustrating the ILI Concept



Calculating the ILI

- Step 1: Calculate UARL using the IWA formula

UARL (l/day) = (18 x LM + 0.8 x NC + 25 x LP) x P

LM = Length of Mains (km)

NC = Number of service Connections

LP = Length of Service Connections from property boundary to customer meter (Length of pipe on Private land) *(not to be confused with total length of Connections) (km)*

P = average Pressure (meters)

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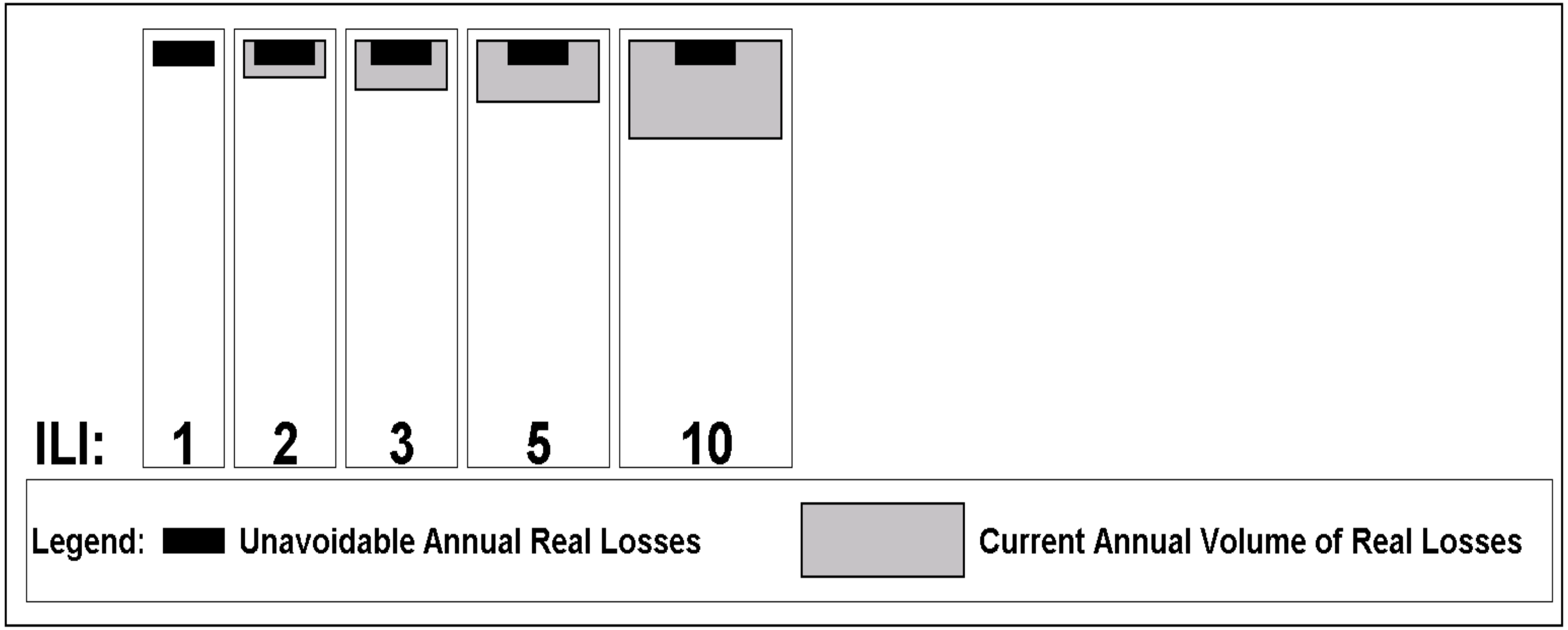
Calculating the ILI (continued)

- Step 2: Calculate current physical losses per day (e.g. from Water Balance)
- Step 3: adjust for intermittent supply

  $UARL_{(adjusted)}$ = UARL /24h x actual supply hours

- Step 4: Calculate ILI = CARL / $UARL_{(adjusted)}$

ILI from 1 to . . . .?


ILI:
1
2
3
5
10
Legend:
Unavoidable Annual Real Losses
Current Annual Volume of Real Losses

The physical loss matrix

Technical performance category		ILI	Physical Losses in Litres/connection/day when the system is pressurized at an average pressure of:				
			10 m	20 m	30 m	40 m	50 m
High Income countries	A1	< 1.5		< 25	< 40	< 50	< 60
	A2	1.5 - 2		25-50	40-75	50-100	60-125
	B	2 - 4		50–100	75–150	100–200	125–250
	C	4 - 8		100–200	150–300	200–400	250–500
	D	> 8		> 200	> 300	> 400	> 500
Low and Middle Income Countries	A1	< 2	< 25	< 50	< 75	< 100	< 125
	A2	2 - 4	25-50	50-100	75-150	100-200	125-250
	B	4 - 8	50–100	100–200	150–300	200–400	250–500
	C	8 -16	100–200	200–400	300–600	400–800	500–1,000
	D	> 16	> 200	> 400	> 600	> 800	> 1,000

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The NRW Matrix

NRW Management Performance category		Non-Revenue Water in Liters/connection/day when the system is pressurized at an average pressure of:				
		10 m (15 psi)	20 m (30 psi)	30 m (45 psi)	40 m (60psi)	50 m (75 psi)
High Income Countries	A1		< 50	< 65	< 75	< 85
	A2		50-100	65-125	75-150	85-175
	B		100-200	125-250	150-300	175-350
	C		200-350	250-450	300-550	350-650
	D		> 350	> 450	> 550	> 650
Low and Middle Income Countries	A1	<55	<80	<105	<130	< 155
	A2	55-110	80-160	105-210	130-260	155-310
	B	110-220	160-320	210-420	260-520	310-620
	C	220-400	320-600	420-800	520-1000	620-1200
	D	> 400	> 600	> 800	> 1000	> 1200

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Takeaway #3

It is impossible to calculate water loss performance indicators without knowing the number of service connections!

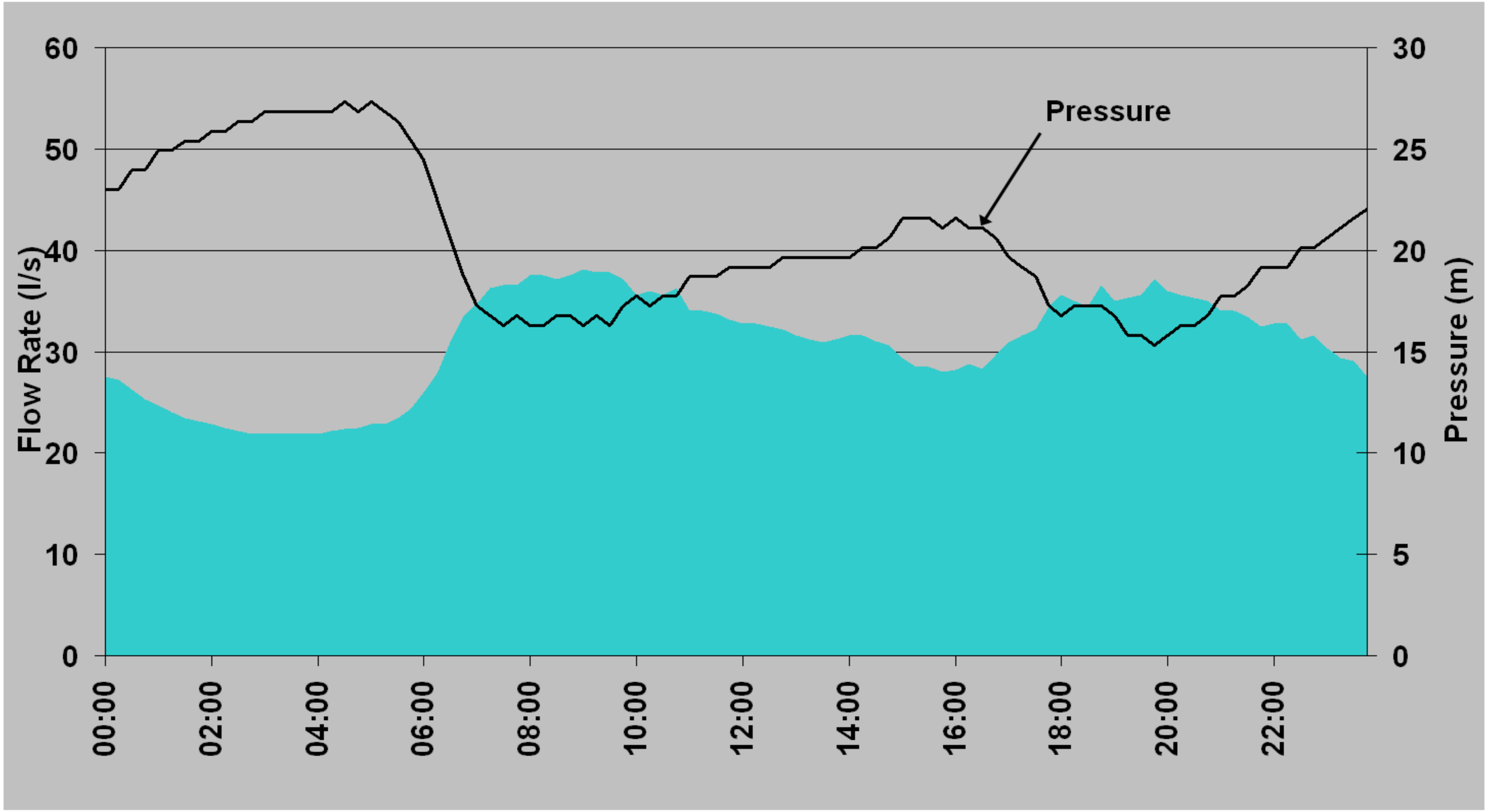
Bottom-up water loss assessment

… if you need very accurate data

24 hour flow and pressure measurements

- Identify hydraulically discrete zone (or create one)
- 24h flow and pressure measurement (better several days)
- Data required:
  - Inflow
  - Pressure
  - Length of mains
  - Number of service connections
- Customer data
- Billed consumption of previous month
- Ideal: customer meter accuracy testing

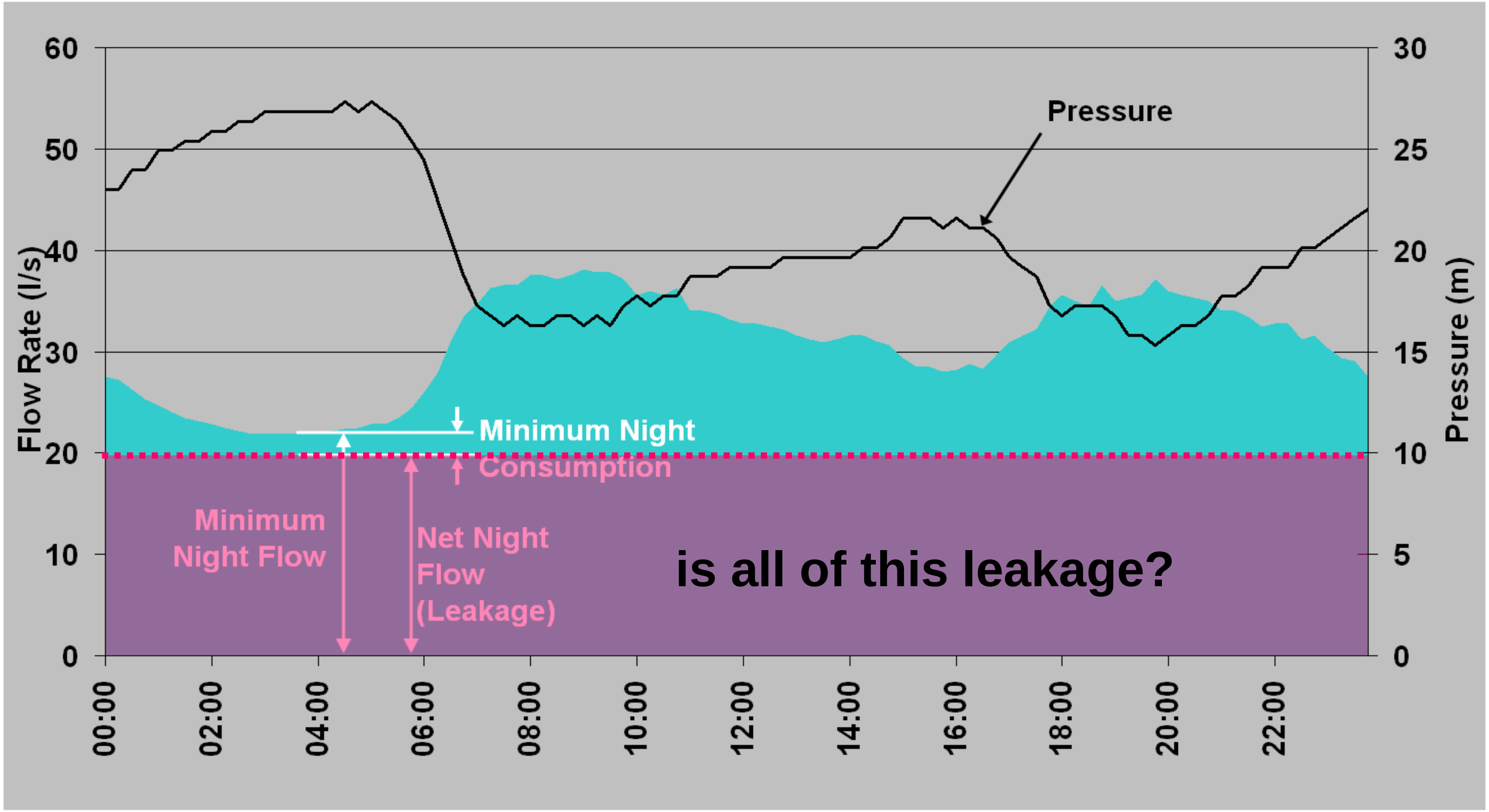
24 hour flow and pressure measurement



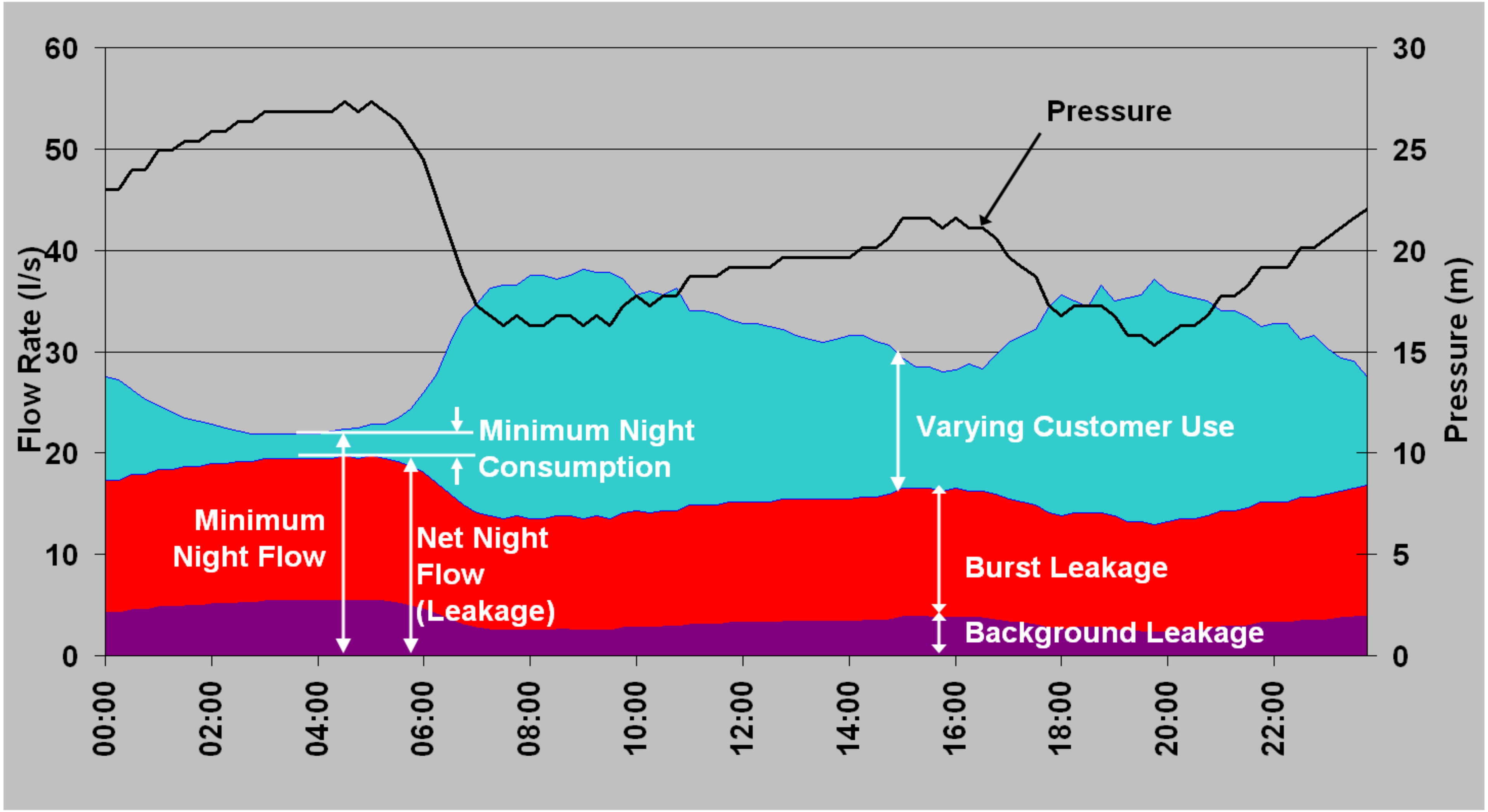
Minimum night consumption assessment

- Household consumption:
  - sample measurements of individual houses and extrapolation
  - can vary substantially depending on local conditions, season (irrigation!)
  - attention: ground and roof tanks!!!
- Commercial customers to be assessed separately
- Meters of large customers to be read during night hours of measurement

Leakage modelling



Leakage modelling



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Calculating results

Total inflow volume

\- calculated physical losses

= consumption

\- billed consumption

= commercial losses

\- estimated meter under-registration

= potential illegal consumption

Water loss PIs can now be calculated

- Physical Losses
  - Liters/connection/day (w.s.p.)
  - Liters/connection/day per meter pressure (w.s.p.)
  - Infrastructure Leakage Index (ILI)
- Commercial Losses
  - % of Authorized Consumption
  - Liters/connection/day
- NRW
  - Liters/connection/day (w.s.p.)

Example: Ho Chi Minh City, Vietnam

- First draft water balance (2003) showed high leakage (660 – 790 l/connection/day, at 12m pressure)
- This figure was questioned – nobody believed leakage was so high
- Therefore bottom-up leakage assessment was done in 10 zones
- Result: Average value: 805 l/connection/day
- Conclusions:
  - Initial accuracy of the water balance was okay
  - Only small corrections needed

Takeaway #4

To understand the magnitude of the NRW problem, we need to know:

1. Volume of NRW
2. Length of mains
3. Number of service connections
4. Average supply time
5. Average pressure

NRW reduction and management

A brief introduction to this complex topic

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Why public water utilities fail with NRW reduction

- **No management focus**
- No water audit, no real problem analysis
- Therefore: no strategy – or at least no good strategy!
- Because: lack of experience and skills
- Totally **unrealistic** cost estimates (especially OPEX)
- Insufficient **funding** – NRW reduction always needs upfront investment

Accurate GIS – the basis for everything!

Customer census

Asset survey

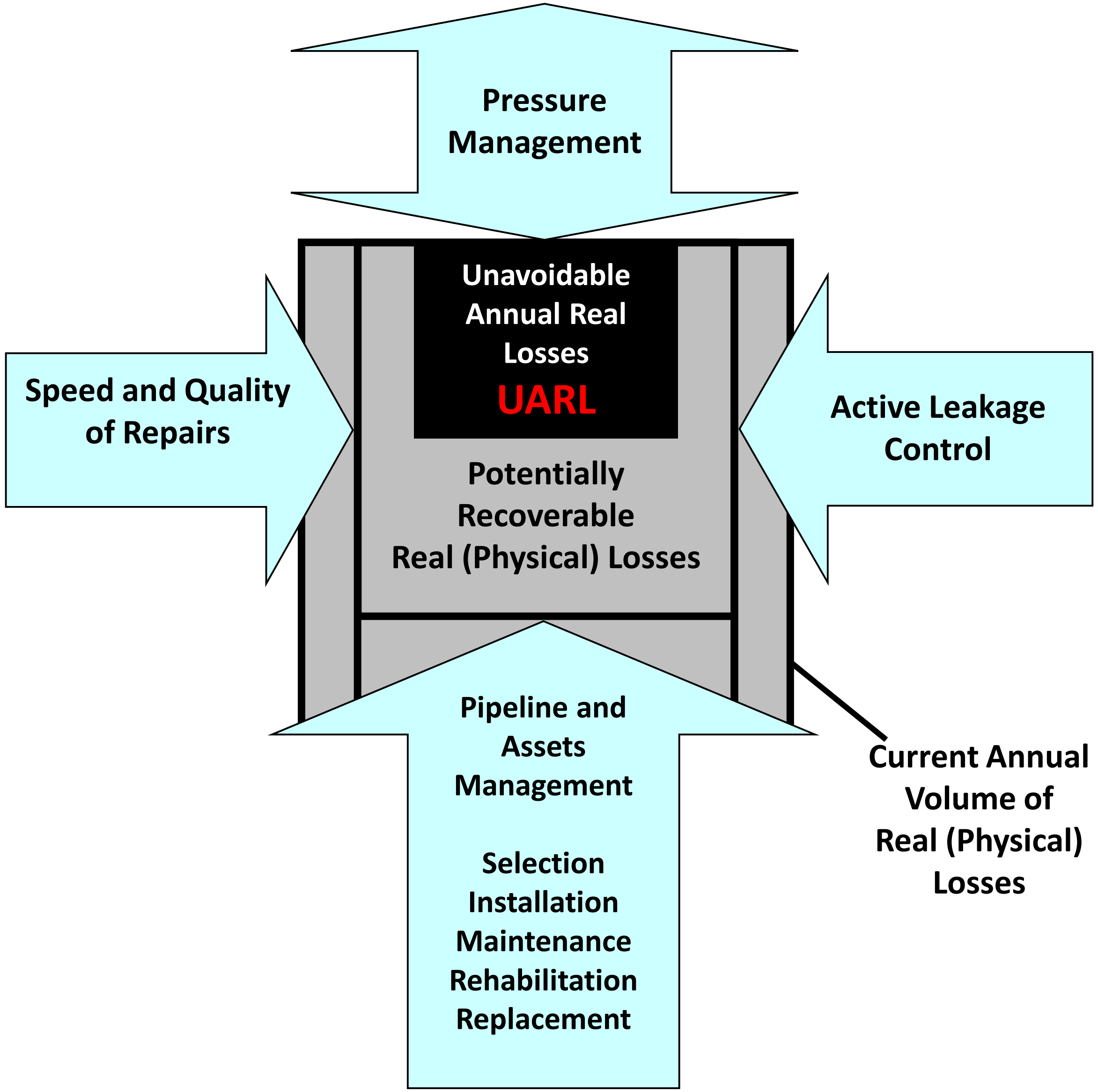
As-built drawings and knowledge of old staff!

Takeaway #5

Customer census, asset survey and establishment of an accurate GIS must be right at the beginning of any project!

Reducing Physical Losses

… always the most time consuming, difficult and expensive part …



The 4 Elements of a Sustainable Leakage Control Strategy

A challenge for many utilities: move from passive to active mode!

Three levels of sophistication

1. Doing the obvious (simple and cheap): Identifying, locating and repairing visible leaks

   But do it fast and in good quality!

2. Second level of action: Localizing and repairing non-visible leaks (**A**LC – **Active** Leakage Control)
3. Third, the advanced and sustainable stage: Establishing district metered areas (DMAs) and introducing pressure management

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The physical loss reduction checklist

- **Change management focus**
- Improve speed and quality of repairs
- Introduce active leakage control
- Review, improve operating practices
- Introduce network zoning and DMAs
- Practice pressure management
- Start with asset management (selective infrastructure replacement)

Quality of Repairs

- Too often leaks are repaired in sub-standard quality - with sub-standard materials
  - wrapped-around plastic bags (or pieces from rubber tubes of tires)
  - wooden plugs
  - sub-standard, non-stainless steel repair clamps

Quality of Service Connections

- Service connection is the weakest part of the system
- A leaking service connection (e.g. corroded steel pipe) should be entirely replaced and not repaired
- PVC is not an appropriate material for service connections (better use HDPE, copper, stainless steel, ...)
- High quality pipe saddles and fittings are the most cost effective long term solution due lower life cycle costs

How are leaks detected

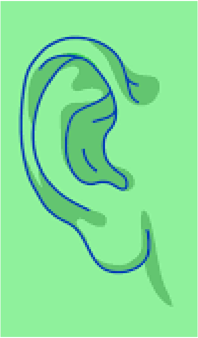
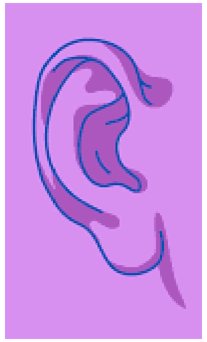
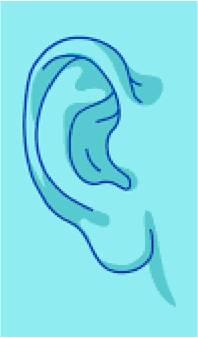
- “Walk the line” – just looking for visual leaks (the most basic)
- Tethered devices for in-pipe inspection (especially for trunk mains, expensive)
- Gas (helium) detection (specialized, expensive, time consuming)

But MOST leak detection techniques are based on acoustics
– hearing the leak noise!

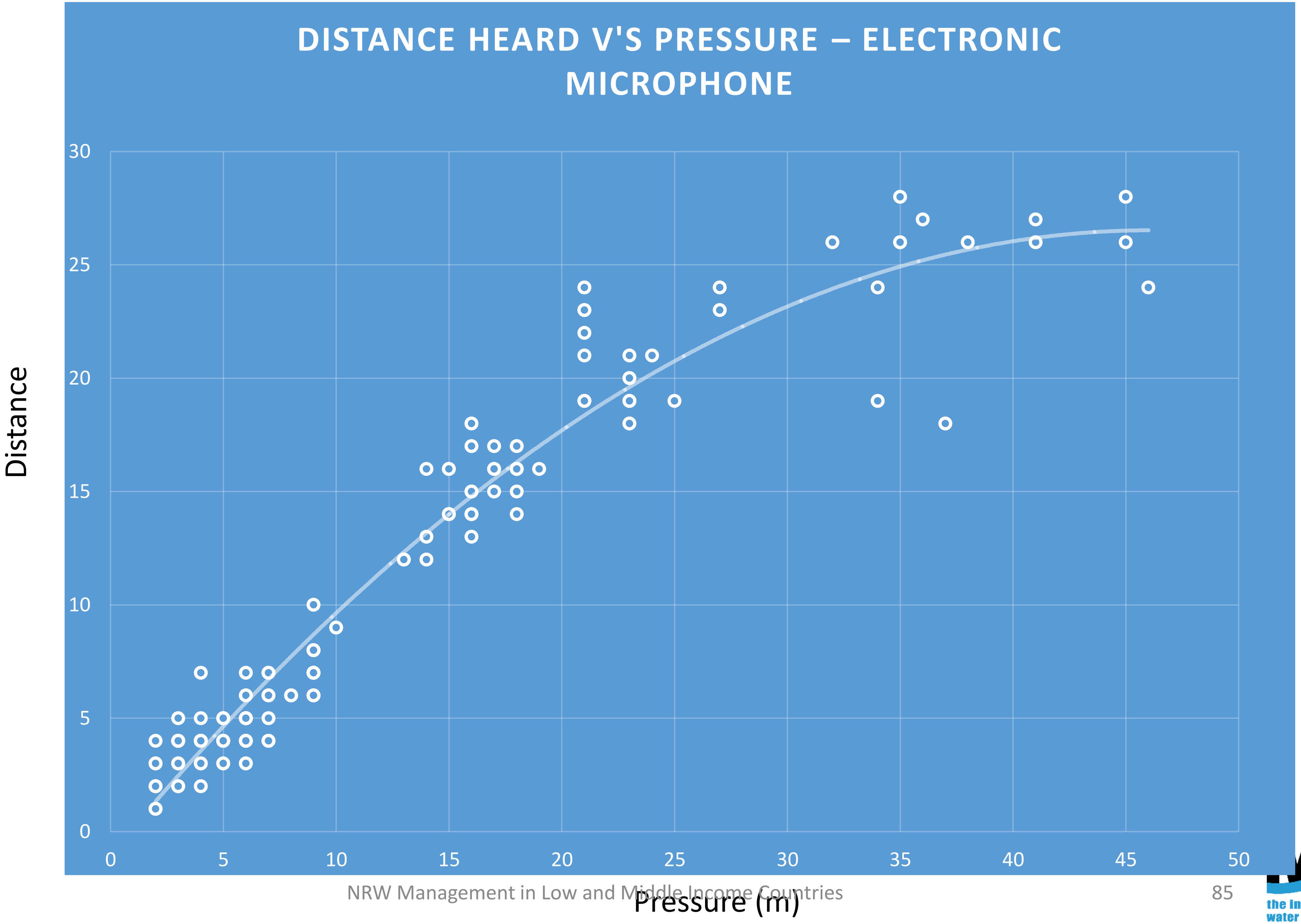
- Manual listening stick
- Ground microphone and electronic listening stick
- Leak noise correlator
- Leak noise loggers

Listening sticks and ground microphone

Human Hearing

- Average range is generally between a low of 20 hertz and a high of 20,000 Hz but is most sensitive between 1,000 Hz and 4,000 Hz.
- Already at an age of 8 years the hearing starts to deteriorate
- As a teenager the high range has dropped to 16,000 Hz - at 30 years it is down to 12,000 hertz.
- At the age of 60 you are near deaf to a lot of sounds of high and low frequency! (but also depends on your exposure to loud noises when you were young)



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Jakarta, Indonesia

- Before we started: everyone said leak detection can’t be done in Jakarta
- When we started: even our teams did not find most of the leaks
- The problem: wrong strategy!
- Only once we understood the low pressure issues we developed a new strategy
- A painful and time consuming job – but very successful!

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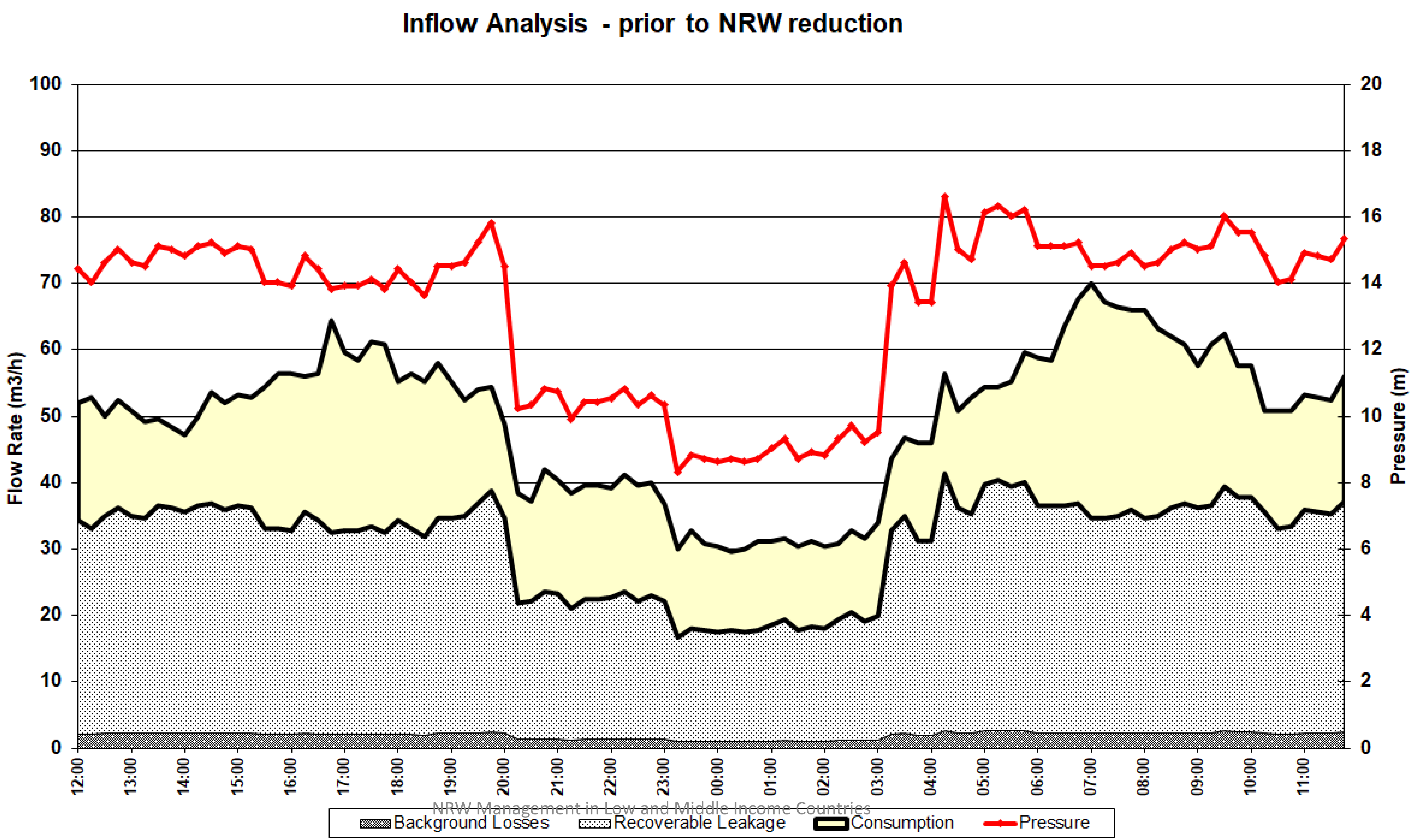
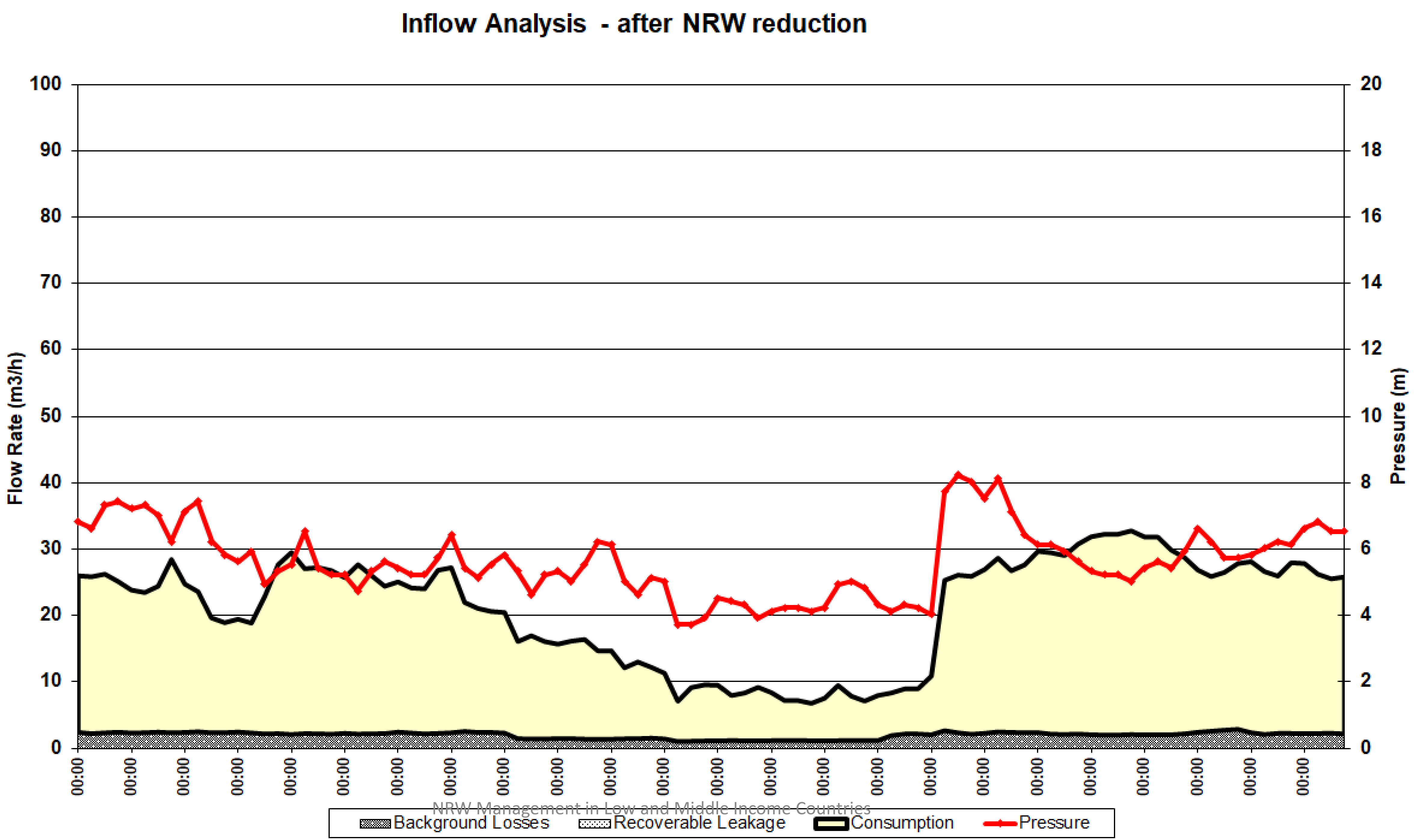
Example: NRW reduction in one of the DMAs

	Baseline
Date	June 2018
Inflow (m^3/day)	1,203
Billed Consumption (m^3/day)	440
NRW %	63 %
NRW Volume (m^3/day)	763
Leakage Indicators	
Litres/connection/day (w.s.p.)	1,102
Litres/connection/day per m pressure (w.s.p.)	84
m^3/km mains per hour (w.s.p.)	1.0
Unavoidable Physical Losses (m^3/day)	14
Infrastructure Leakage Index (ILI)	53

- 28.8 km main pipes
- 682 service connections


Inflow Analysis - prior to NRW reduction
Flow Rate (m3/h)
Pressure (m)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
Background Losses
Recoverable Leakage
Consumption
Pressure



Inflow Analysis - after NRW reduction
Flow Rate (m3/h)
Pressure (m)
100
90
80
70
60
50
40
30
20
10
0
20
18
16
14
12
10
8
6
4
2
0
00:00
Background Losses
Recoverable Leakage
Consumption
Pressure

Results achieved

	Baseline	After the project	Savings
Date	June 2018	December 2019	
Inflow (m^3/day)	1,203	492	
Billed Consumption (m^3/day)	440	437	
NRW %	63%	**11%**	
NRW Volume (m^3/day)	763	**55**	**708**
Leakage Indicators			
Litres/connection/day (w.s.p.)	1,102	28	
Litres/connection/day per m pressure (w.s.p.)	84	5	
Infrastructure Leakage Index (ILI)	53	3.2	
Leaks detected and repaired		**84 (!)**	

Note: Billed consumption hasn't changed!!!!

Summary

- Pressure is an issue and affects results, equipment & methodology
  - Electronic listening devices must be used on non-metallic mains
- Do not rely on manual sticks with deaf staff !!
- Adopt your strategy to the situation – there isn't the magic "one approach suits it all" (not even within one utility for the entire network)
- Work when you have highest pressure and lowest background noise
- Mandatory hearing test for all staff
- Rule of thumb for plastic pipes AND low pressure:

1m pressure – 1m leak detection distance

Takeaway #6

Every system is different – every system needs a tailored leak detection strategy and methodology!

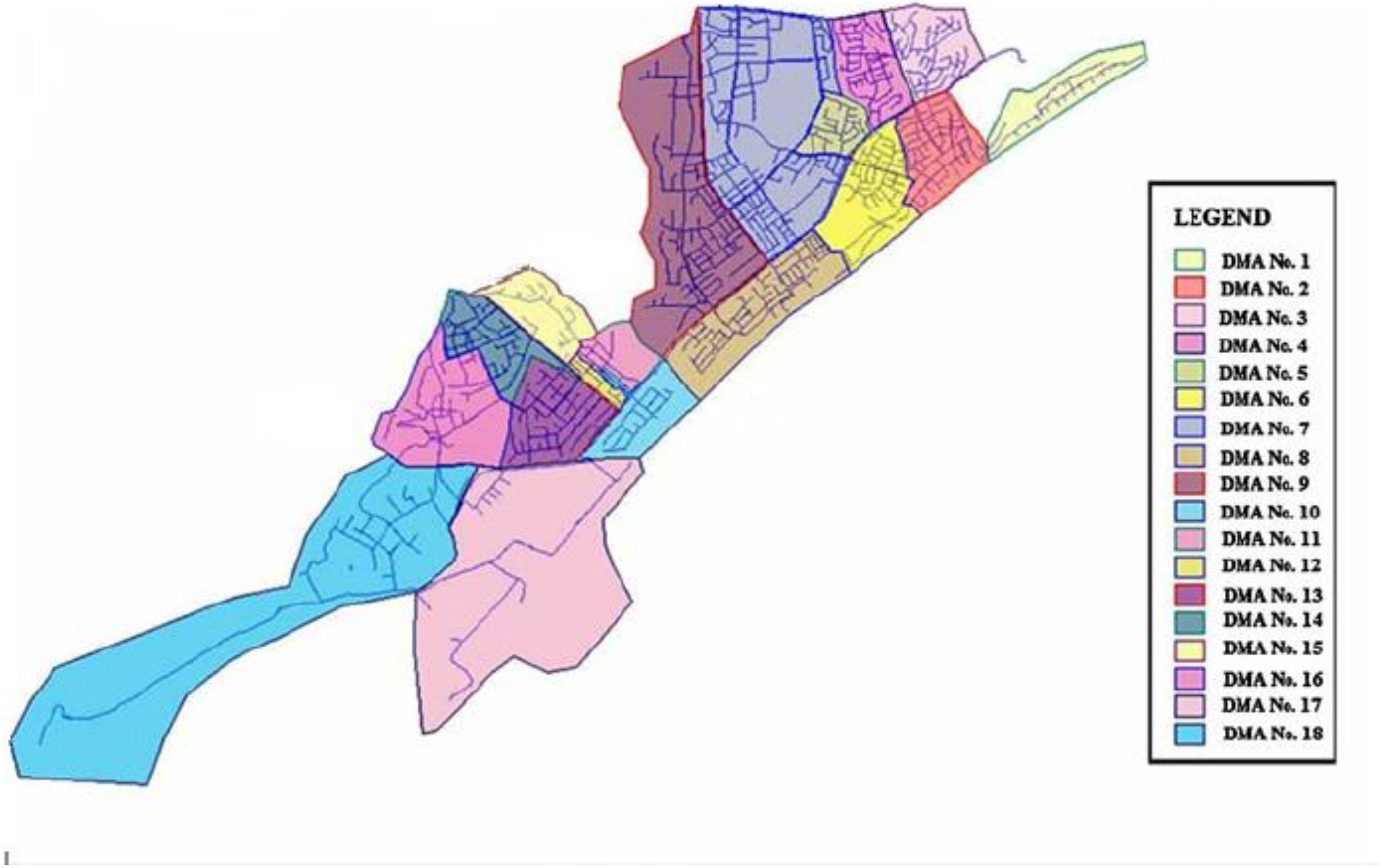
Reviewing and improving O&M practices

- Avoid wide pressure fluctuations
- Intermittent supply: try to (re)establish 24x7 supply DMA by DMA
- Inspect and maintain valves and hydrants regularly
- Operate reservoirs and pumping stations properly
- Keep GIS continuously up to date

DMA – District Metered Area

- Principles of DMA approach
  - ♦ division of network into small hydraulically discrete zones
  - ♦ continuous measurement of flow and pressure
- Objectives
  - ♦ Reduction of leak awareness time
  - ♦ Prioritization of leak detection activities
- An excellent basis for pressure management
- The way forward for utilities with fragile networks

District Metered Areas



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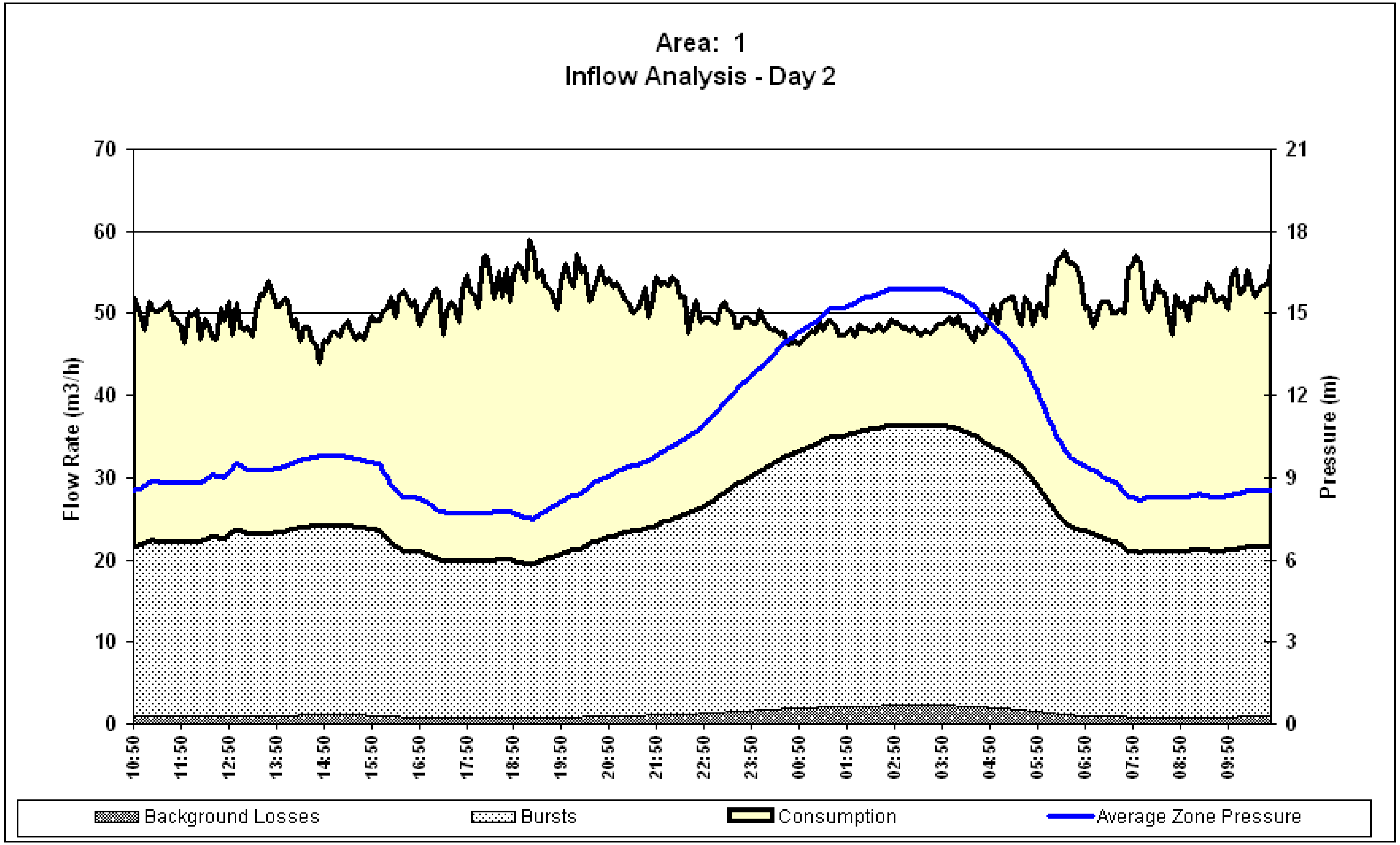
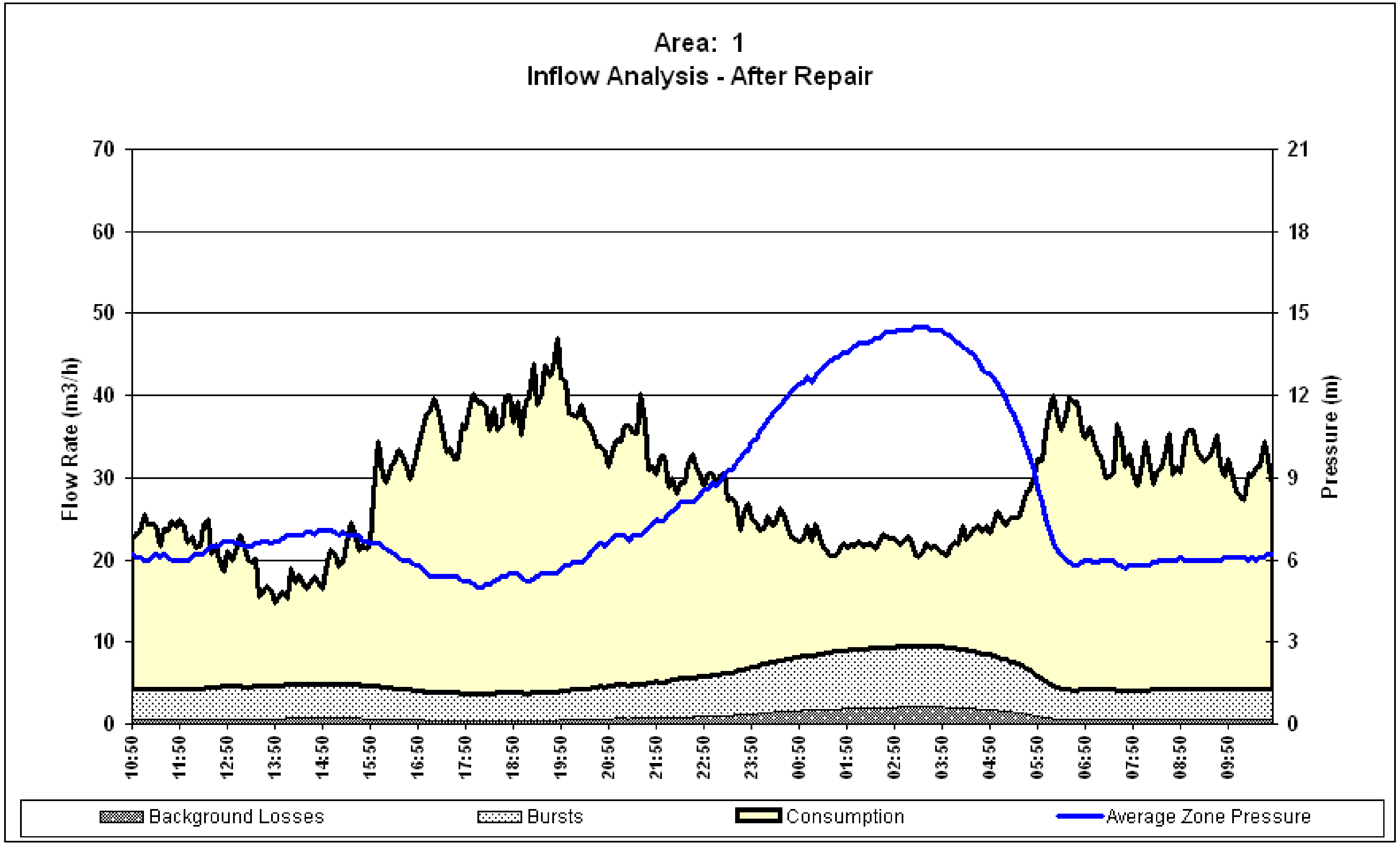
Designing, establishing DMAs

- Ideally: Based on a calibrated hydraulic model
- Design criteria:
  - one inflow point only (if at all possible)
  - size: between 500 and 1,500 service connections
    - The poorer the network condition the smaller the DMA
- Electromagnetic flow meter at the inflow point, with flow and pressure data logger (automatic data transfer)
- Pressure logger at the “critical point”
- DMA needs to be commissioned after a successful Zero Pressure Test (ZPT)

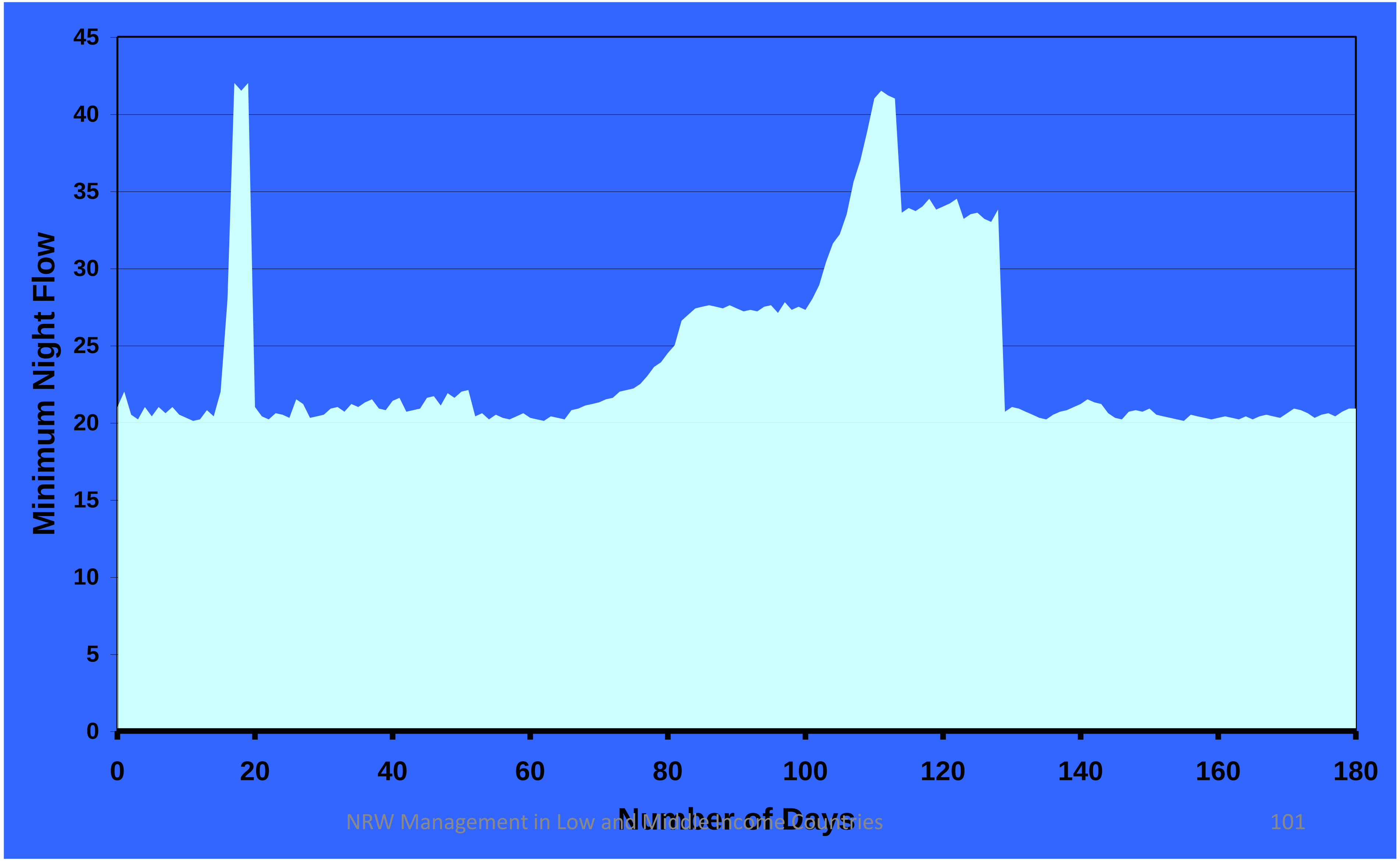
Data analysis
before leak detection and repair



Data analysis after leak detection and repair



Using DMA night flow data



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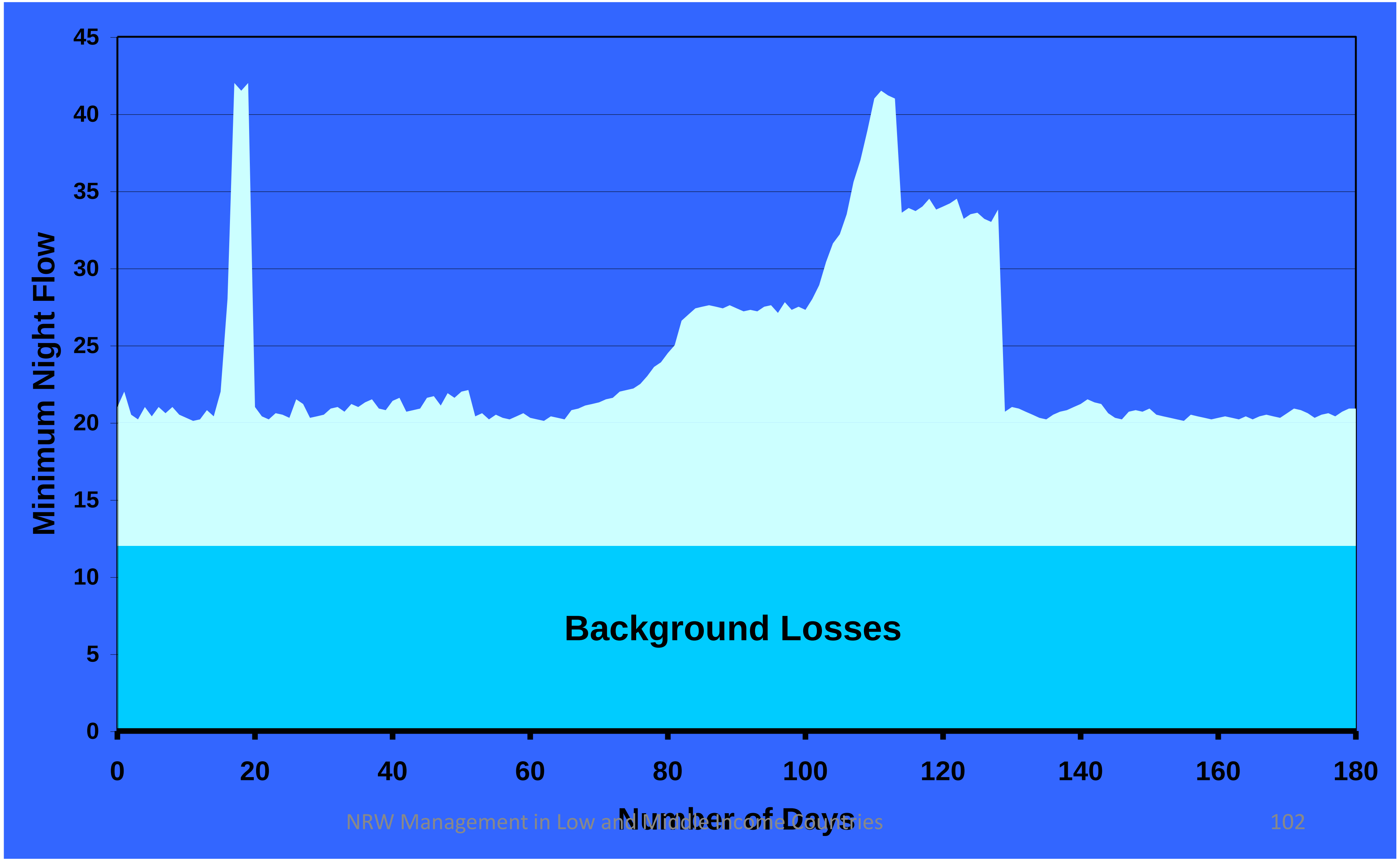
Using DMA night flow data



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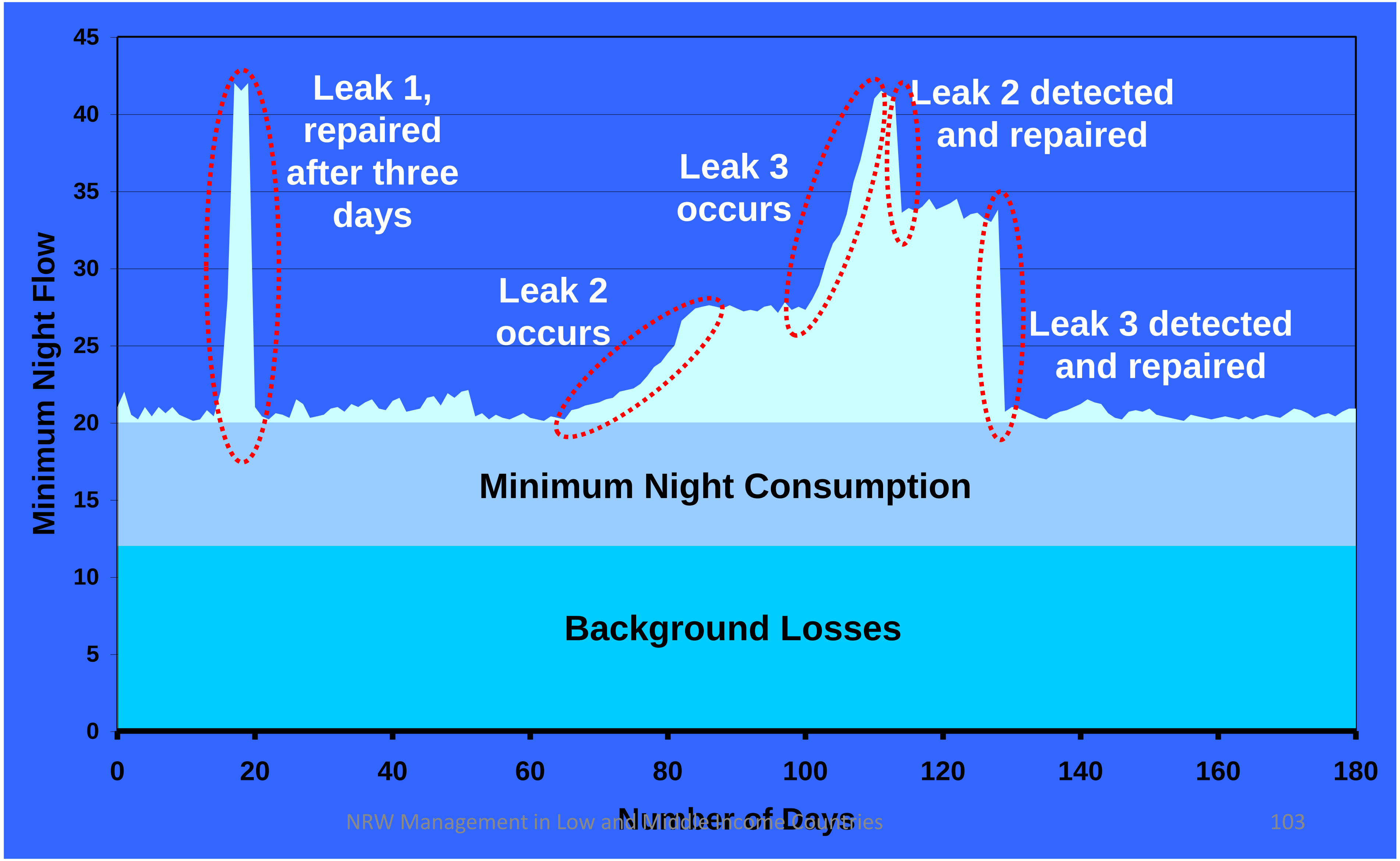
Using DMA night flow data



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Pressure management

- High pressure
  - High leakage
  - Reduced asset lifetime
  - High burst frequency
- Pressure fluctuations
  - High bust frequency
  - Sometimes impact on the quality of service
- Pressure transients
  - Extremely bad for the distribution network

Ways of reducing network pressure

- Zoning by elevation
- Throttled gate valves (not recommended, due to wear on the gate and poor control)
- Pump control - variable speed drive (VSD)
- Pressure Reducing Valves (PRVs)





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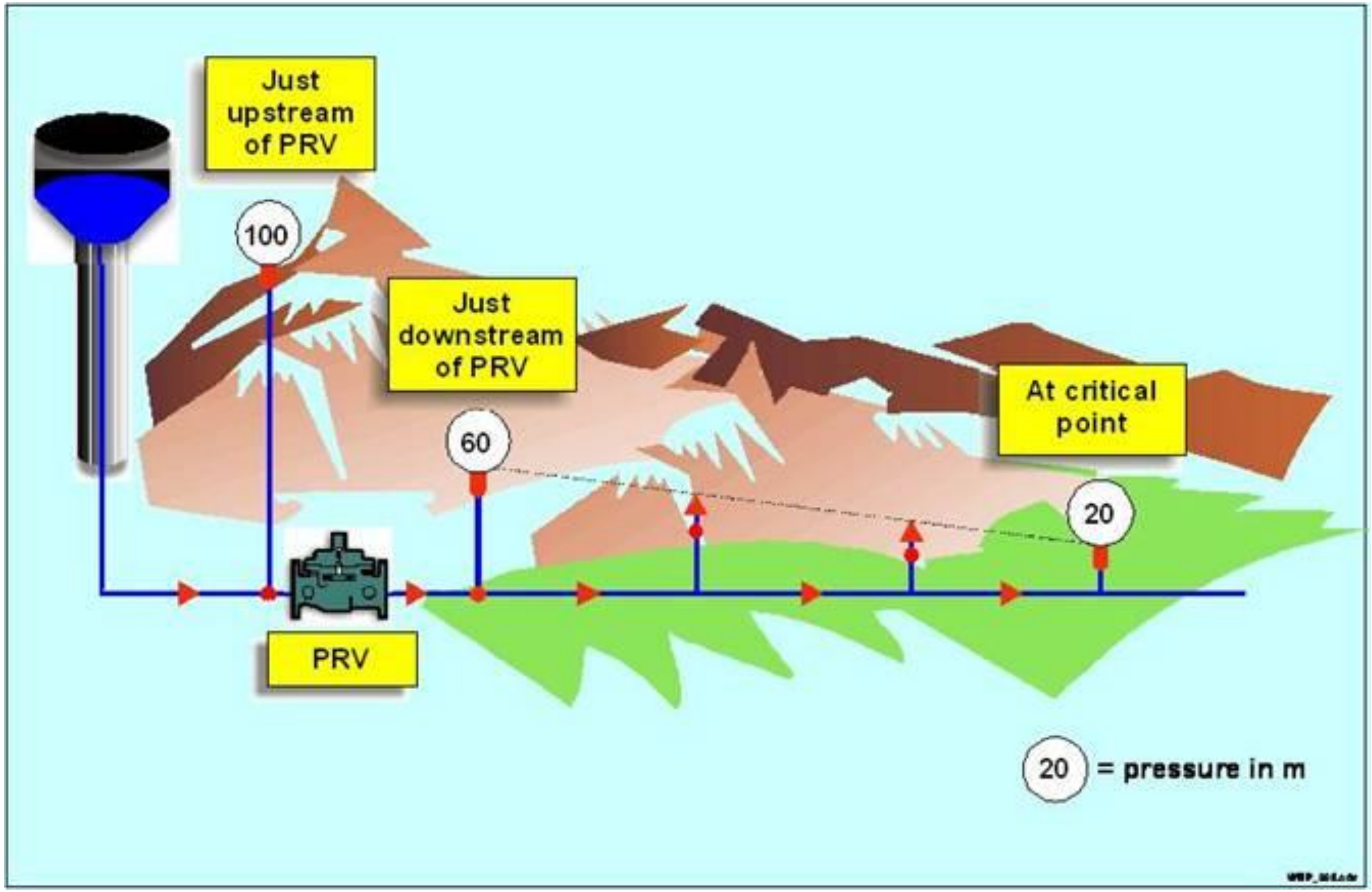
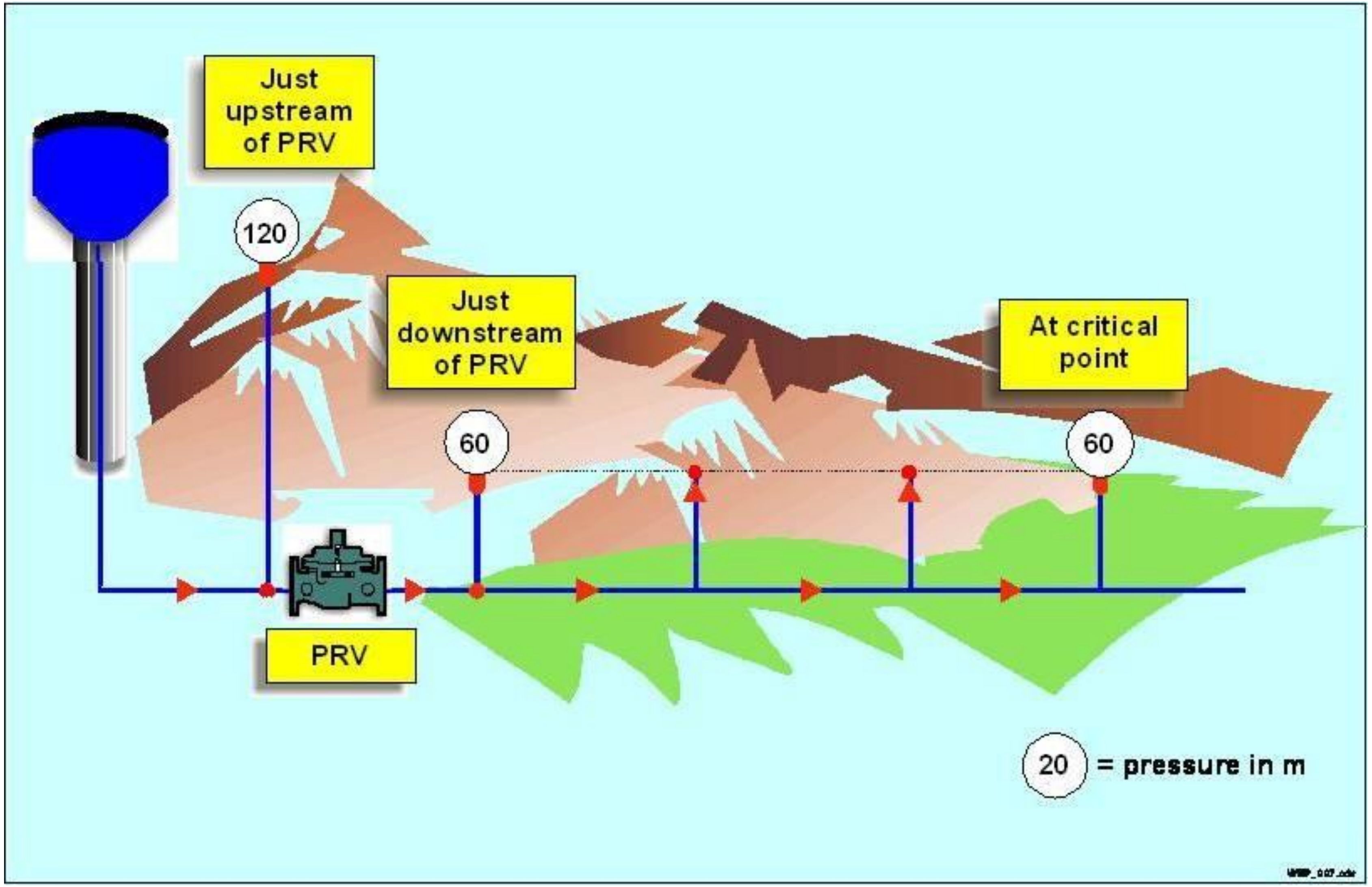
Peak demand period



Low demand period



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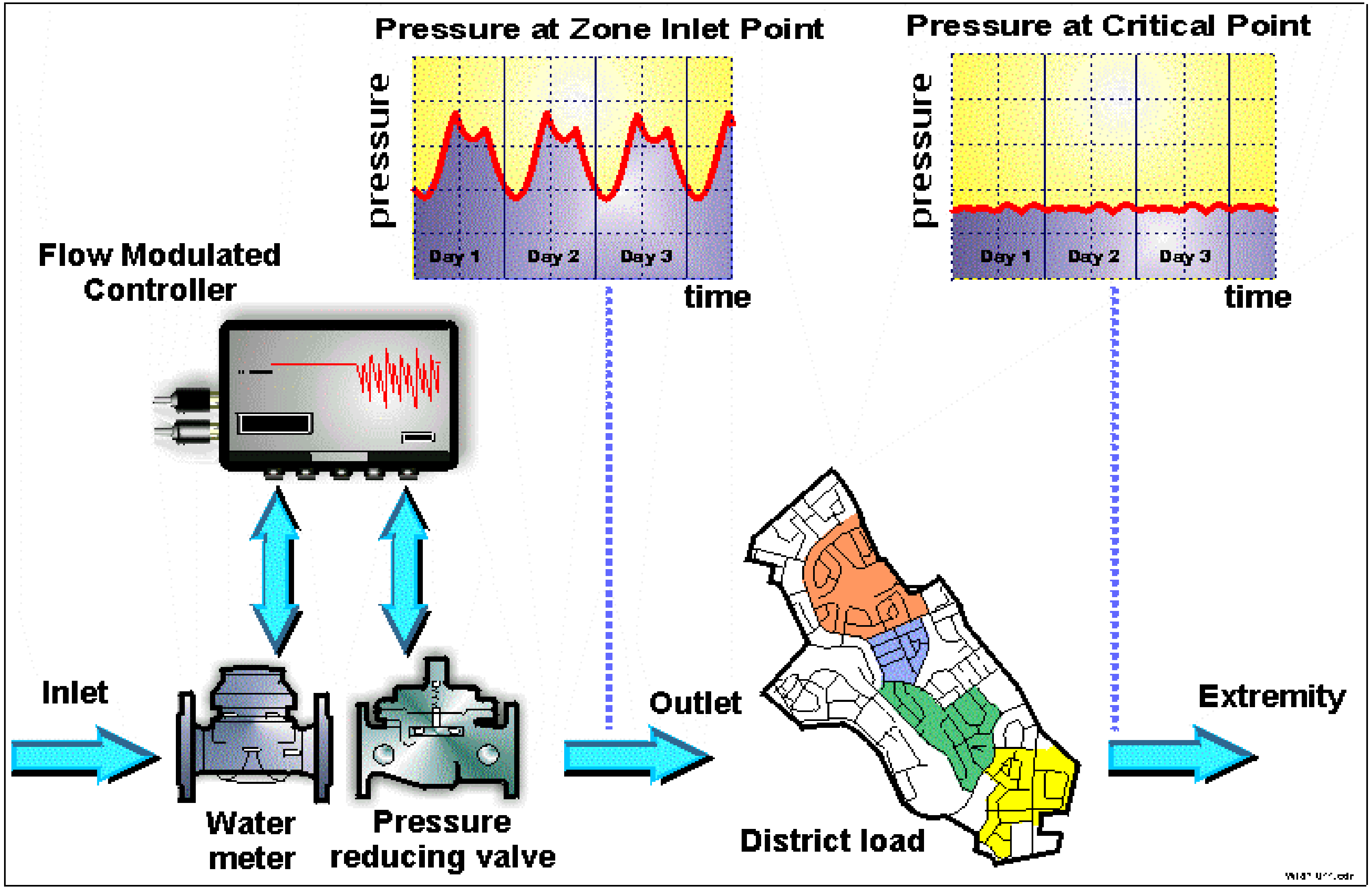
Flow modulated PRV control: pressure at critical point constant



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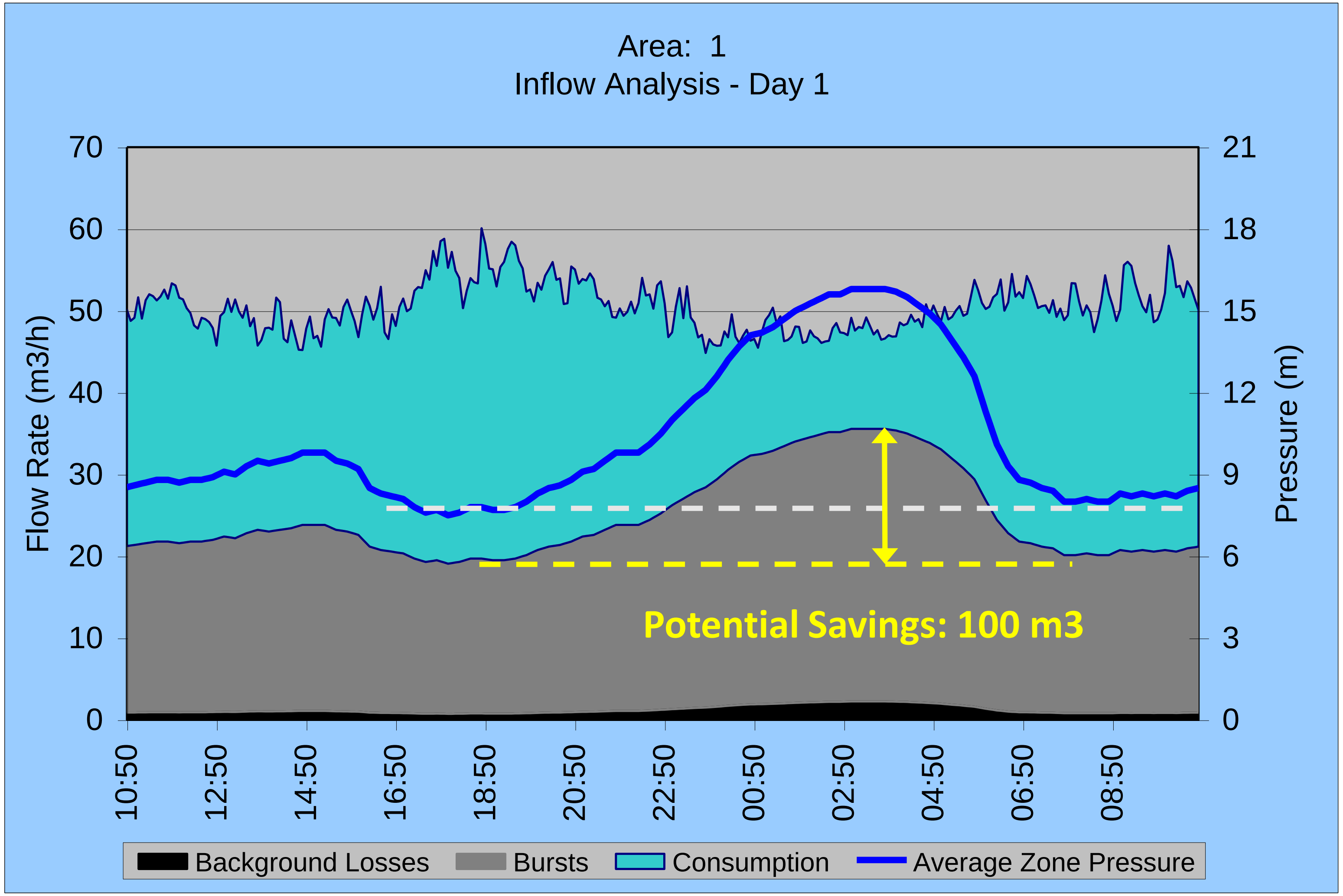
Even in low pressure situations, pressure management is beneficial

- Normally not done – PRVs were traditionally installed to reduce excessively high pressures; but: pressure management also beneficial in low pressure situations
- 10 m (1 bar) pressure: a 2 m (0.2 bar) pressure increase results in about 20% more leakage!!
- In poor quality networks pressure increases caused by leak repair might compensate all savings!

Example: Capping of night time pressure



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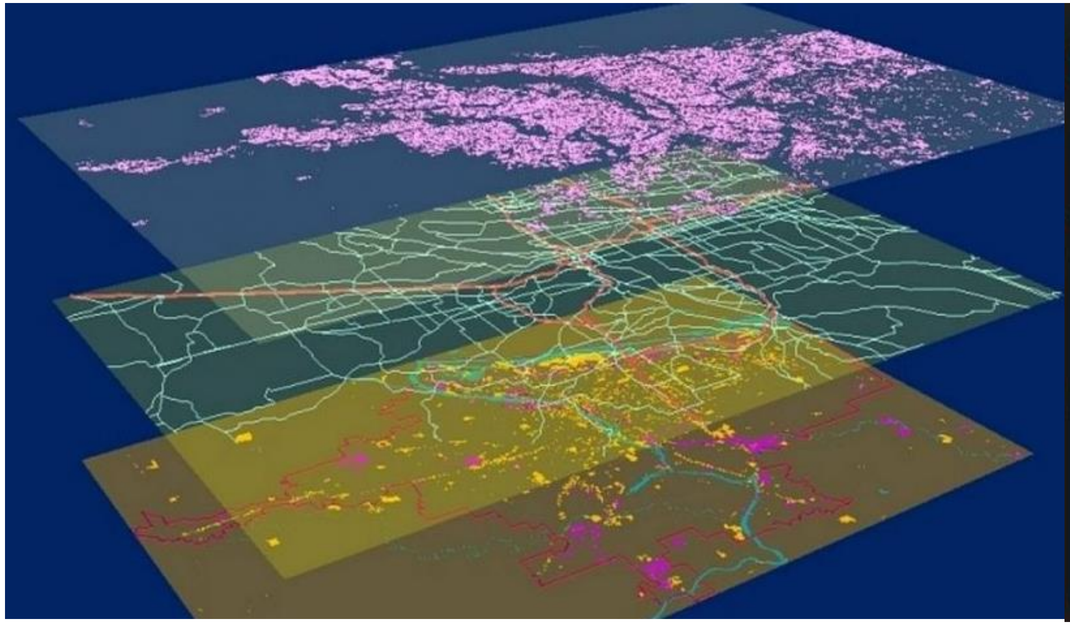
Geographical Information System (GIS)

- Everything you need to know about the company's assets
- What, How, When and Where
- Only as good as the data it holds



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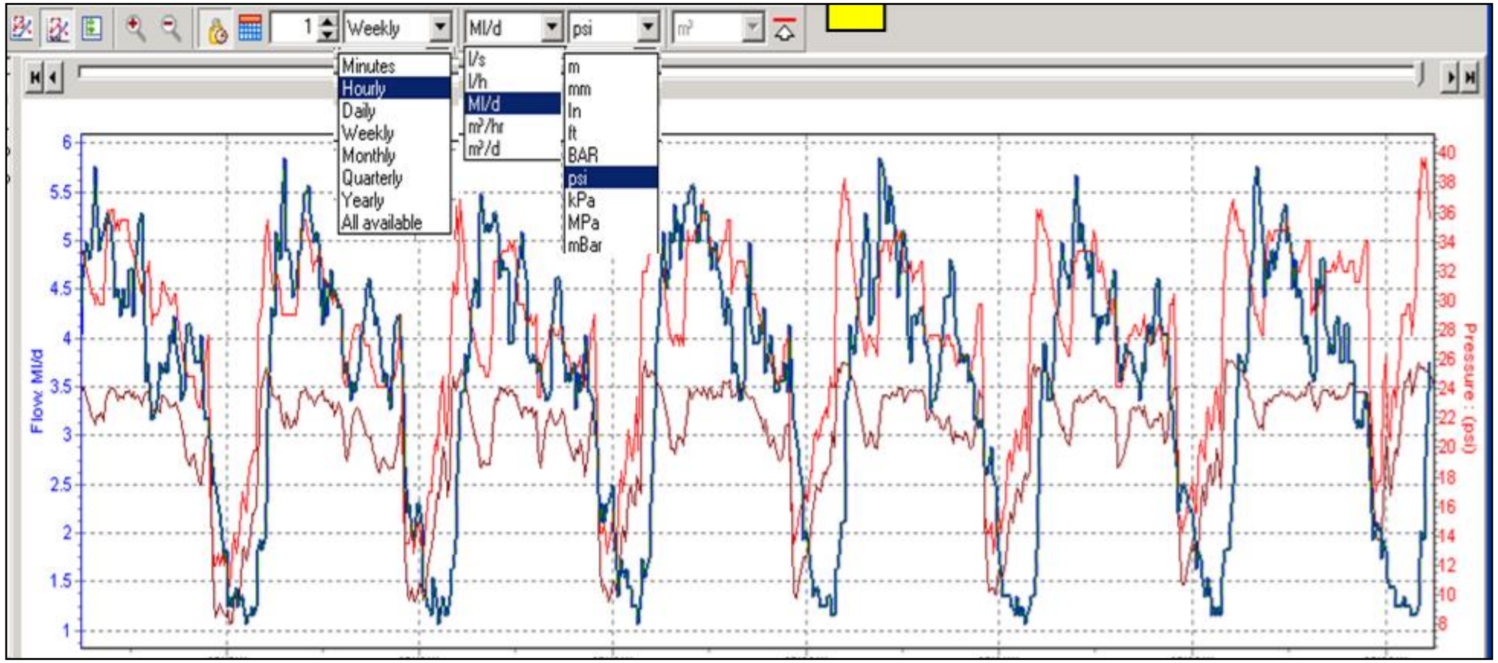
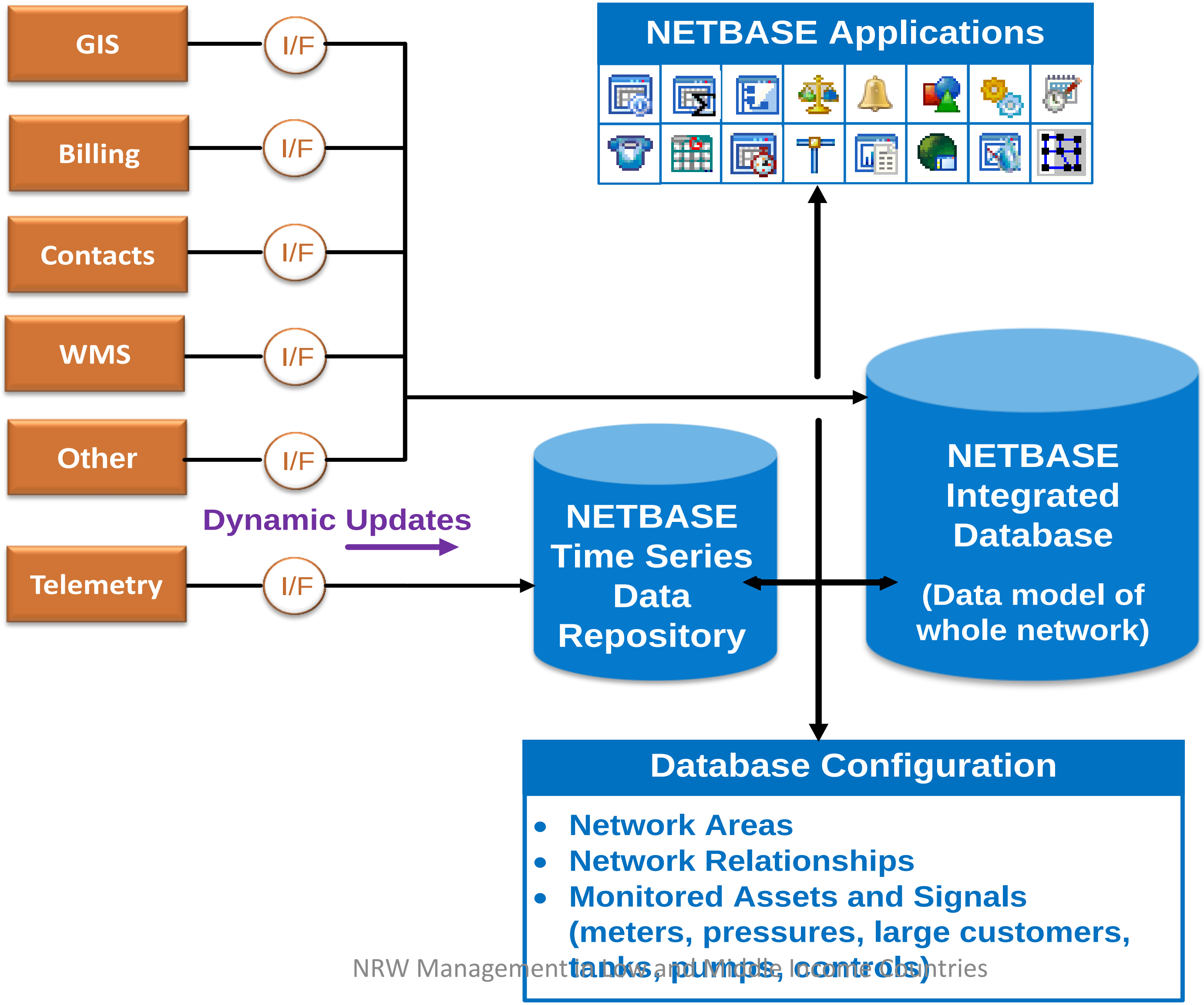
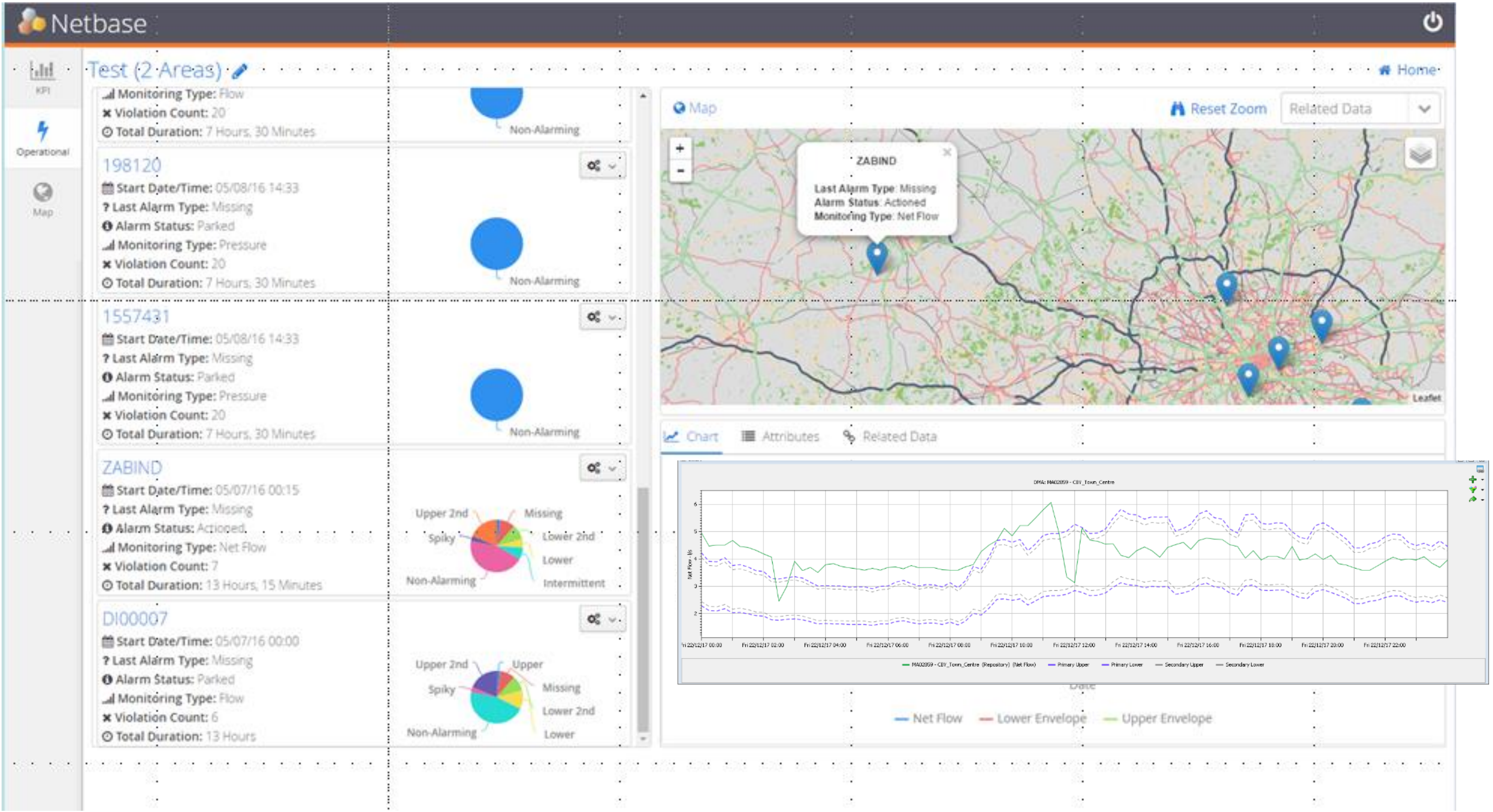
Data Logging – flow and pressure



NRW Management Software (Netbase)



Network Alarms

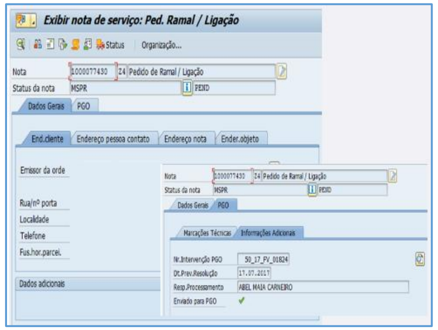


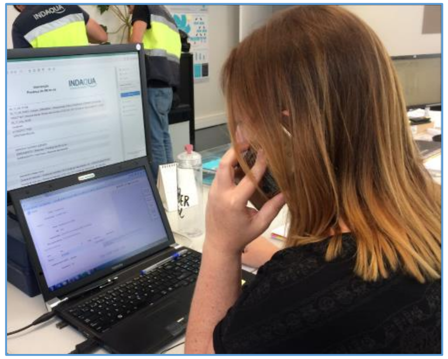
Work Management Systems

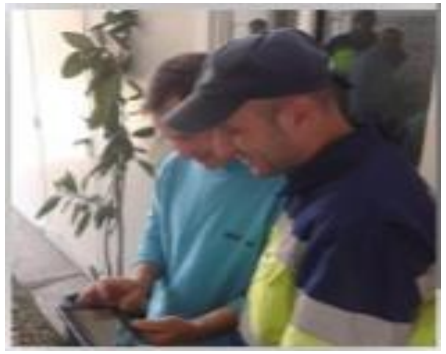
Job Order

Dispatching

Mobile Team



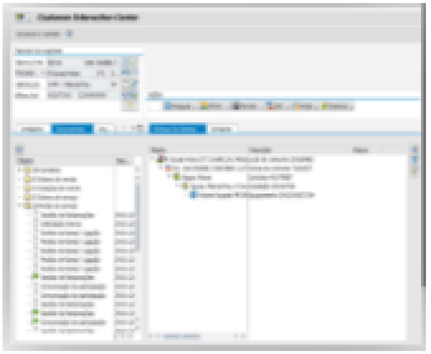




Sync/Integration

Inspection

Field Work



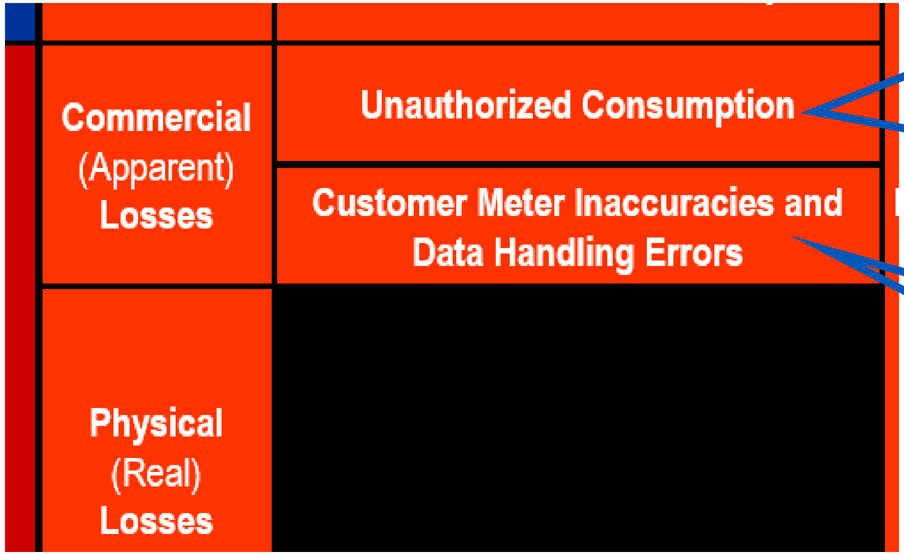
Takeaway #7

Reduction and management of physical losses is complex, a managerial challenge and requires a lot of know-how and experience!

Reducing Commercial Losses

… the fastest return on investment …

Elements of Commercial Losses



- Any form of water theft
  - Illegal connections
  - Illegal hydrant use (tanker filling!)
  - Customer meter bypasses
  - Customer meter tampering

- Customer meter inaccuracies
- Billed unmetered consumption based on underestimates
- Data collection and transfer errors
- Meter reader corruption
- Billing system errors

Let's start with this!

Different meter types

- Mechanical meters
  - ♦ Velocity meters
    - Single jet
    - Multi Jet
  - ♦ Volumetric meters - Positive displacement
- Solid state meters (no moving parts)
  - ♦ Electromagnetic flow meters
  - ♦ Ultrasonic meters

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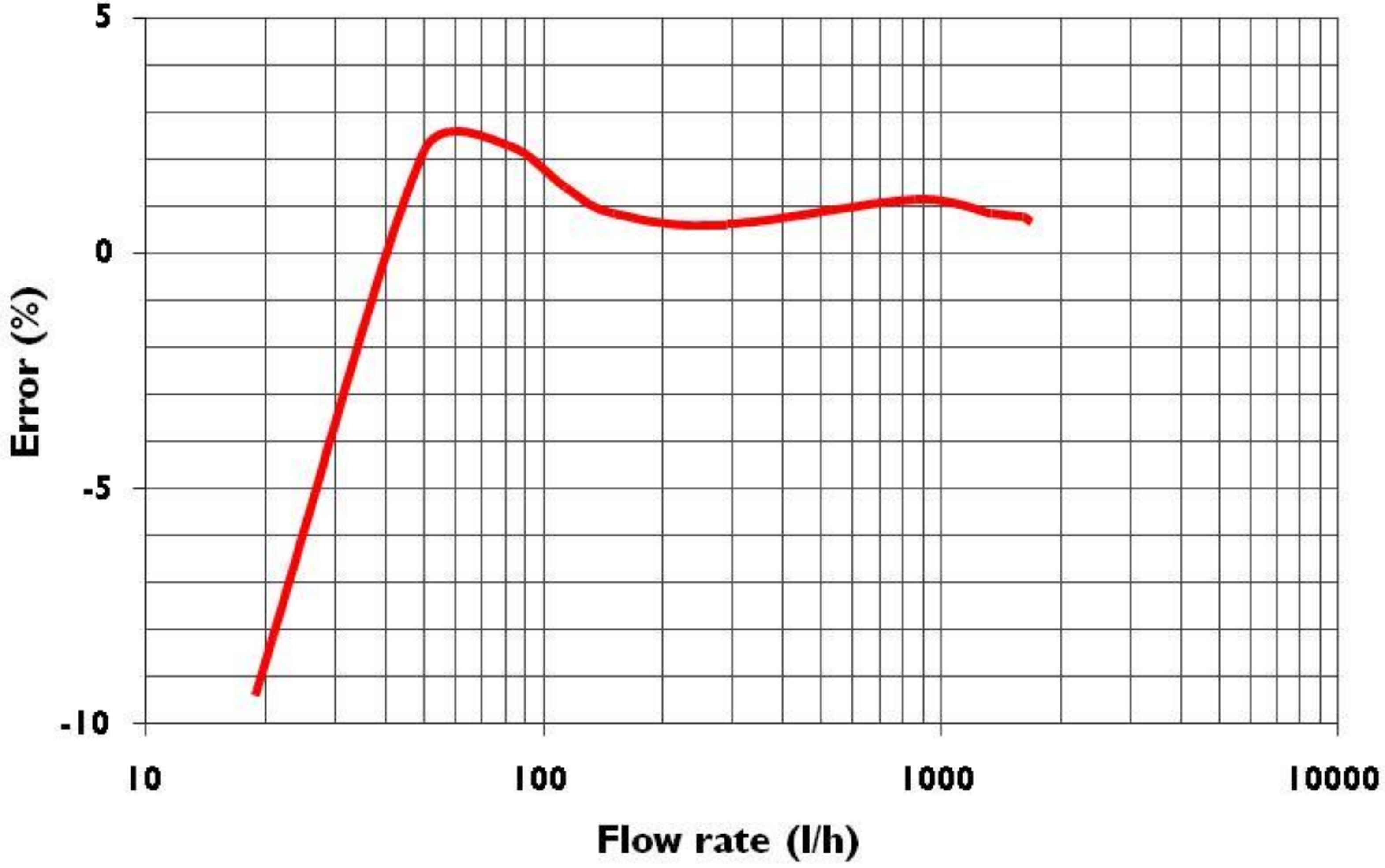
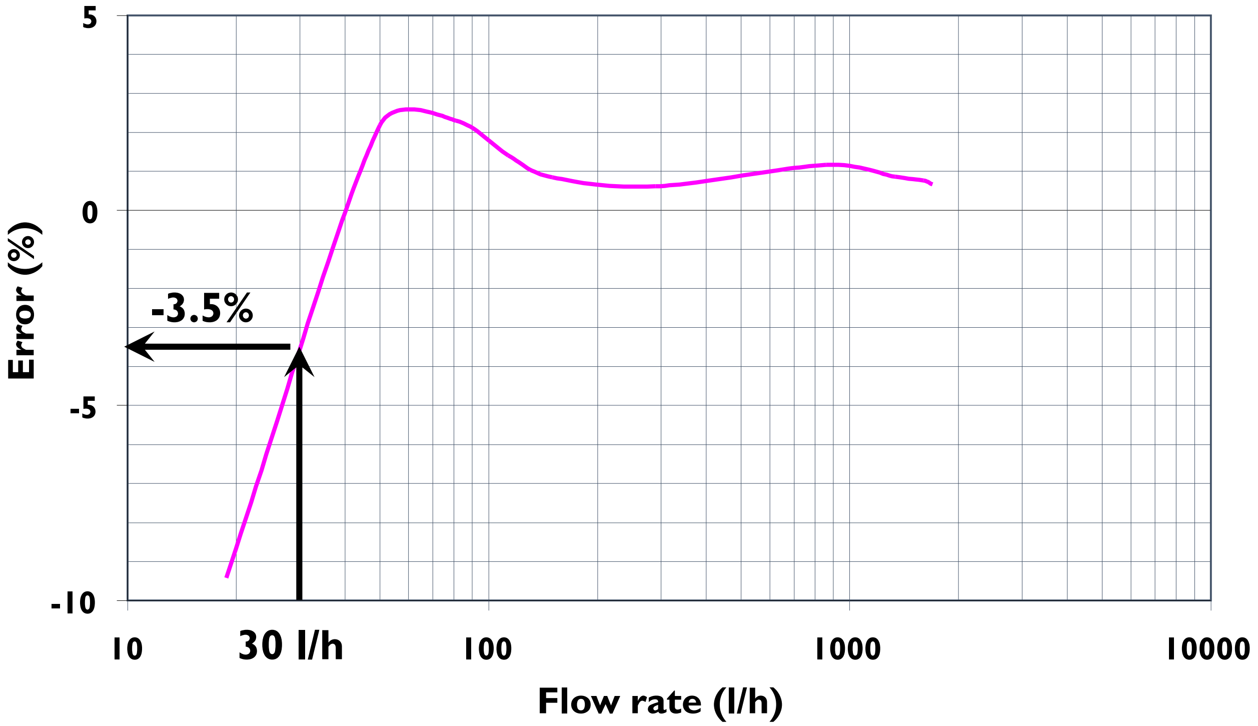
The many causes of inaccuracies of mechanical meters

- Inappropriate meter specification
- Wear and tear
- Poor meter quality
- Wrong/improper installation
- Poor water quality
- Intermittent supply
- Wrong sizing
- Spinning or jetting
- Roof Tanks
- Lack of proper maintenance/replacement

Metrological characteristics: Error curve of a mechanical meter

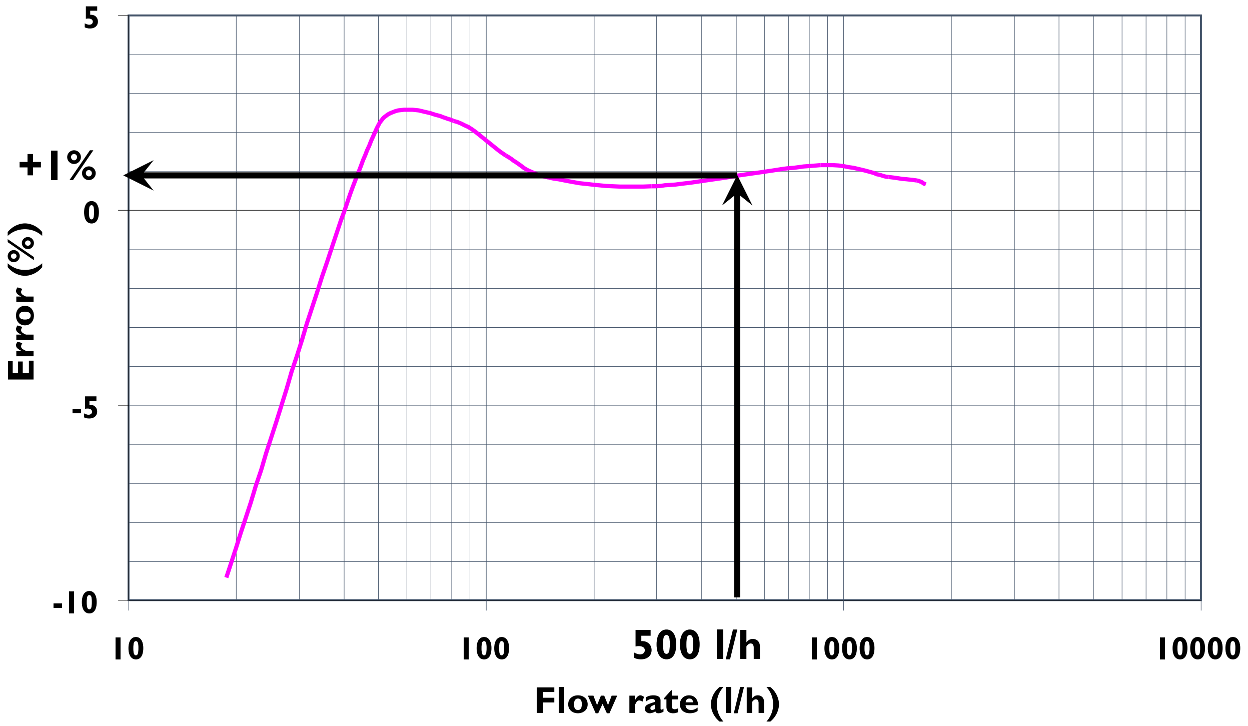


Metrological characteristics: Interpreting the error curve (1)



- For a flow of 30 l/h the error is - 3.5%
- This means:
  - For every 100 l consumed at 30 l/h the meter registers 96.5 l

Metrological characteristics: Interpreting the error curve (2)



- For a flow of 500 l/h the error is +1%
- This means:
  - For every 100 l consumed at 500 l/h the meter registers 101 l

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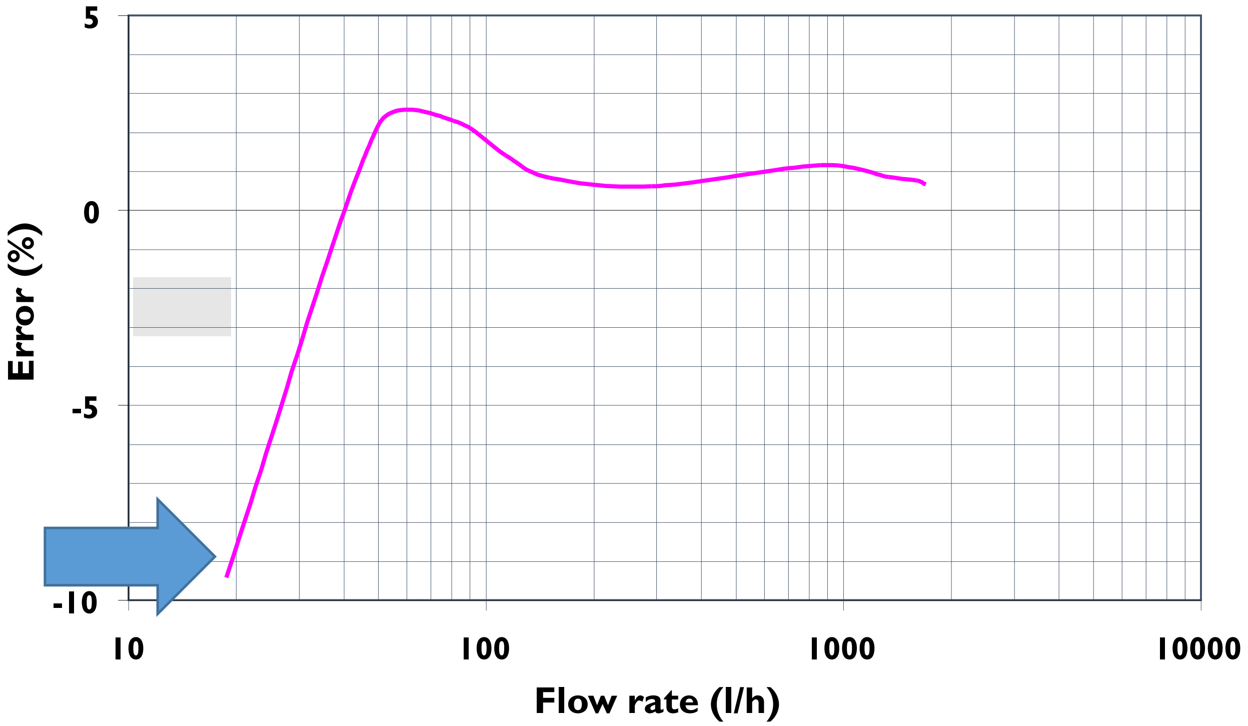
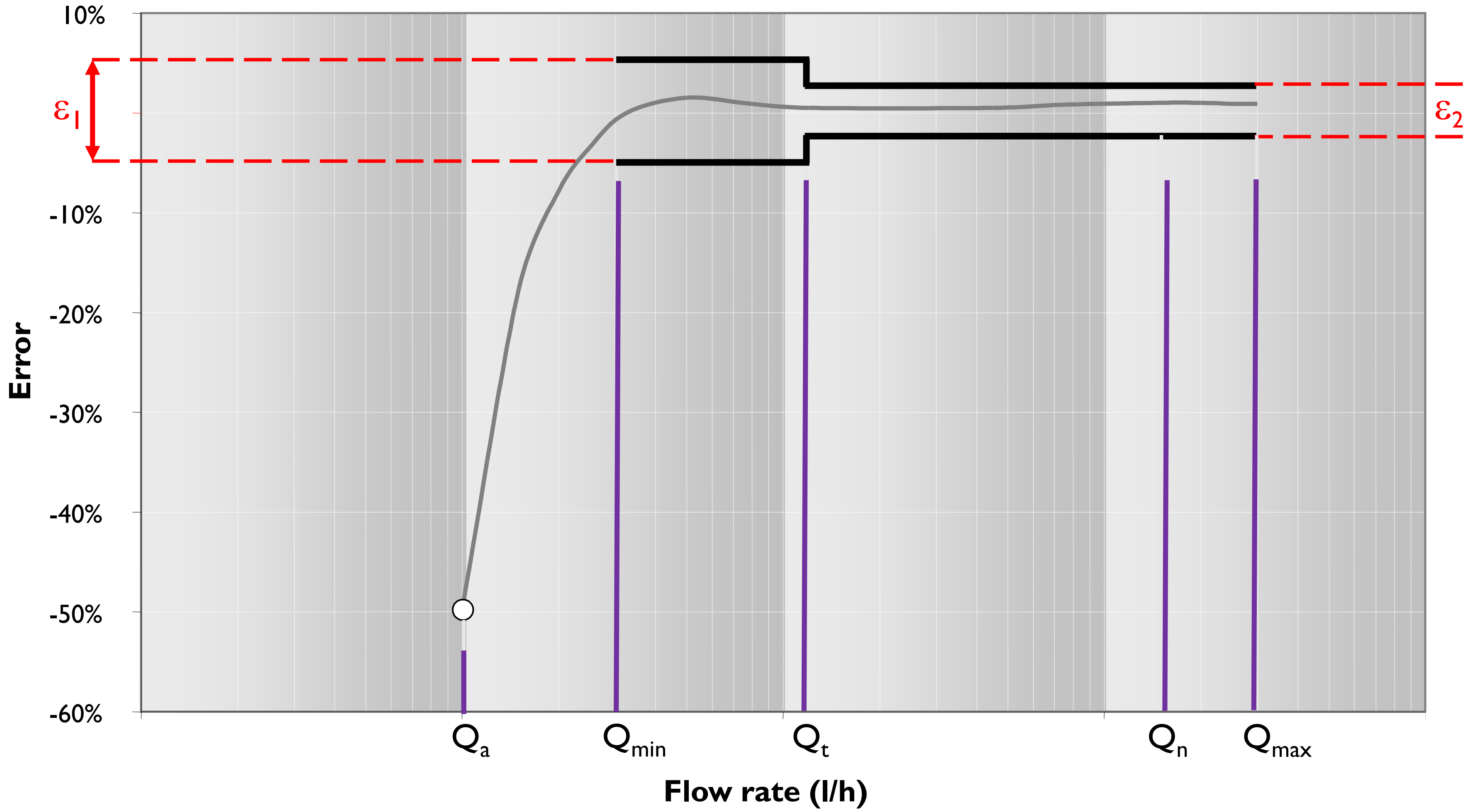
Metrological characteristics: Interpreting the error curve (3)



- All water used below the starting flow it is not measured
- The error is -100%

Metrological Characteristics

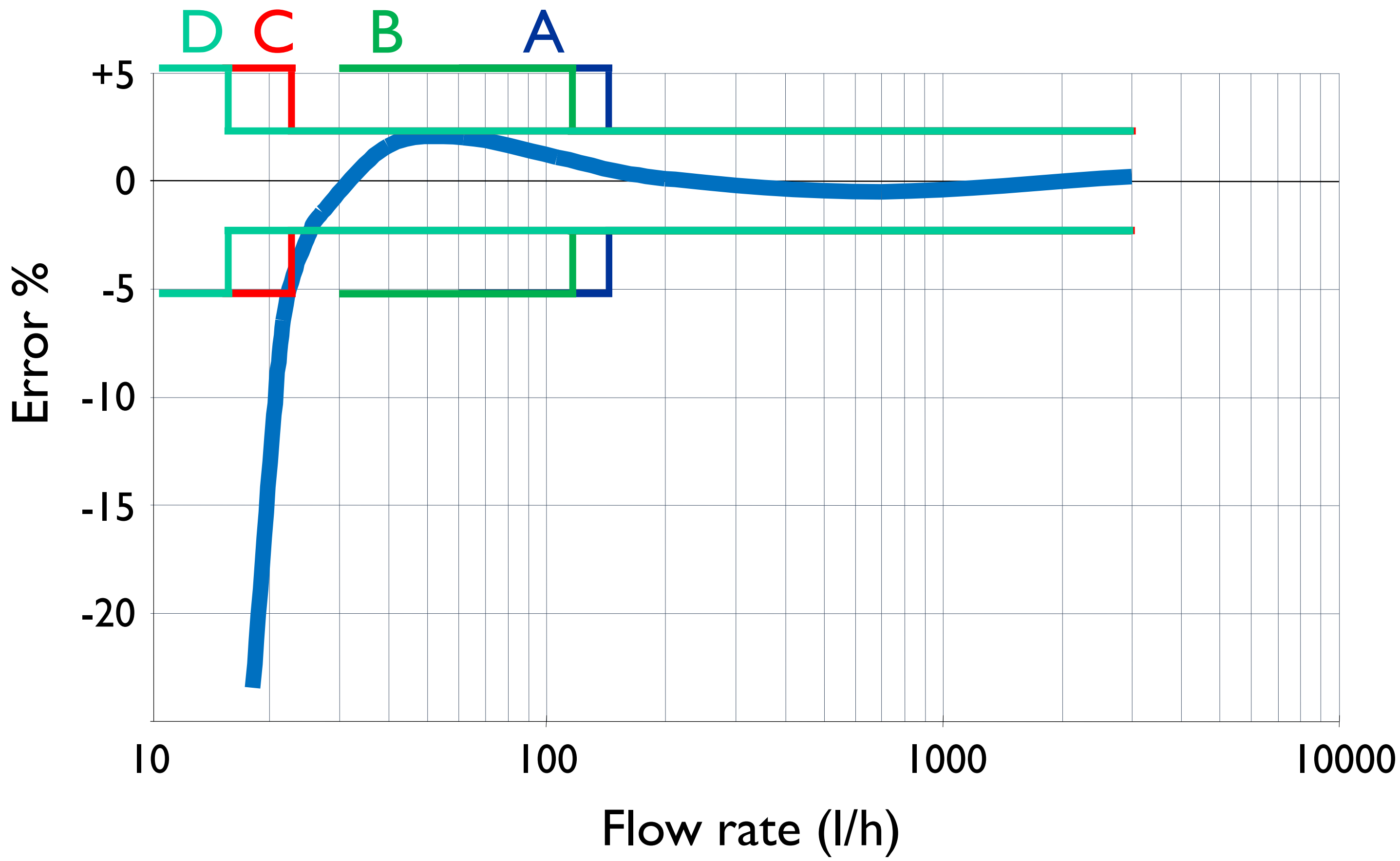


- Q_a Starting Flow
- Q_{min} Minimum Flow
- Q_t Transitional Flow
- Q_n Permanent Flow
- Q_{max} Maximum Flow

Meter accuracy - ISO 4064

- Old ISO standard (1993) : Meter Classes are from A – D
  - (still widely used when people talk about meters)
  - The higher the class, the lower the flow at which the meter starts to register
- New ISO standard (2005): Meter designation (latest update published 2018)
  - R=Q3/Q1
  - Q3= permanent flow Q1= minimum flow
  - The higher R the bigger the measuring range of the meter
- More accurate mechanical meters are less robust and more expensive

Metrological Characteristics (ISO 4064:1993)



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Comparison: ISO4064:1993 vs. ISO4064:2005

Class B

Minimum	Transitional	Permanent	Maximum
30 l/h	120 l/h	1500 l/h	3000 l/h

R80

Q_1	Q_2	Q_3	Q_4
31.3 l/h	50 l/h	2500 l/h	3125 l/h

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Comparison: ISO4064:1993 vs. ISO4064:2005

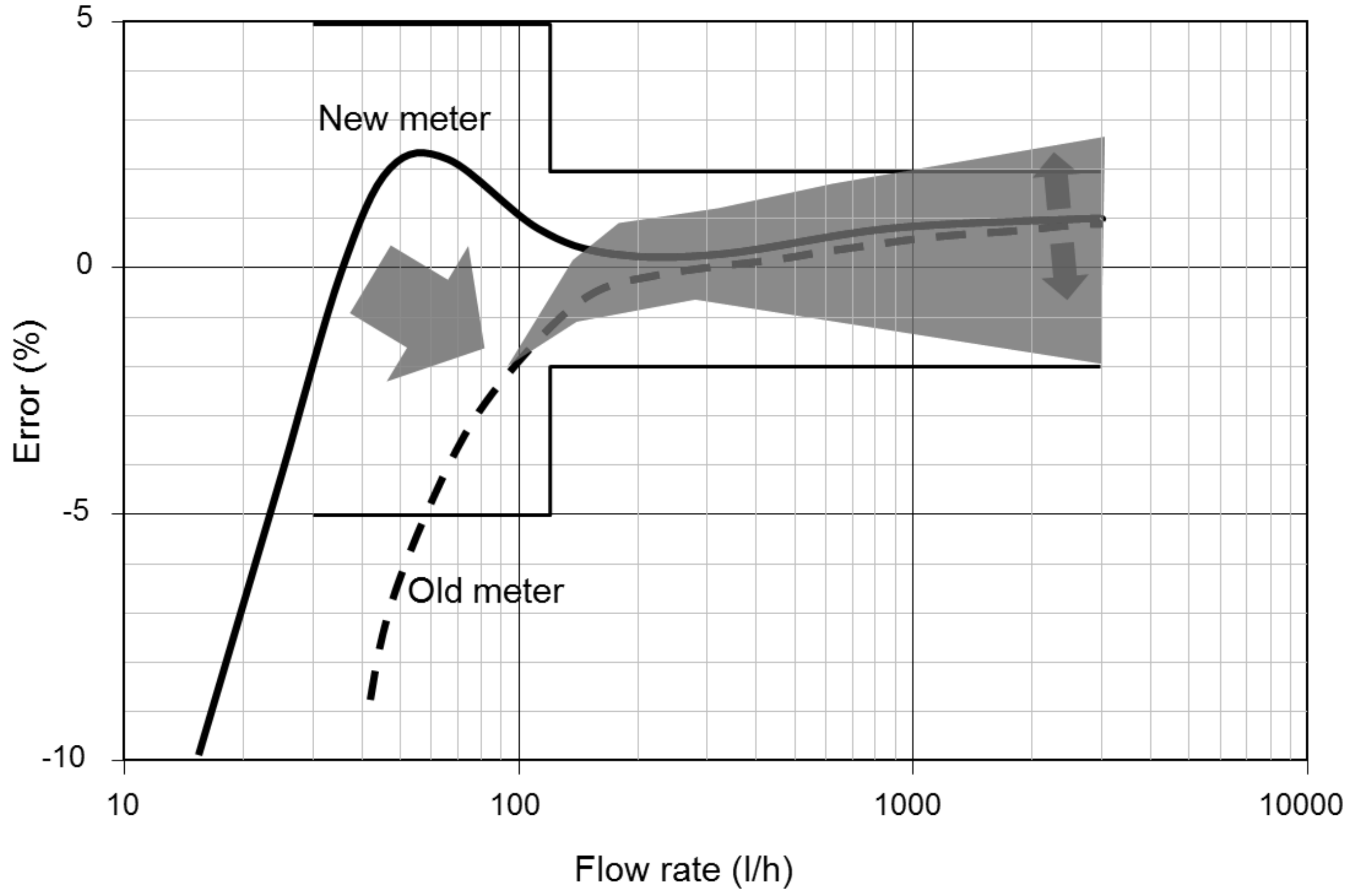
Class C

Minimum	Transitional	Permanent	Maximum
15 l/h	22.5 l/h	1500 l/h	3000 l/h

R160

Q_1	Q_2	Q_3	Q_4
15.6 l/h	25 l/h	2500 l/h	3125 l/h

Typical meter degradation (single jet meter)



Source: Francisco Arregui

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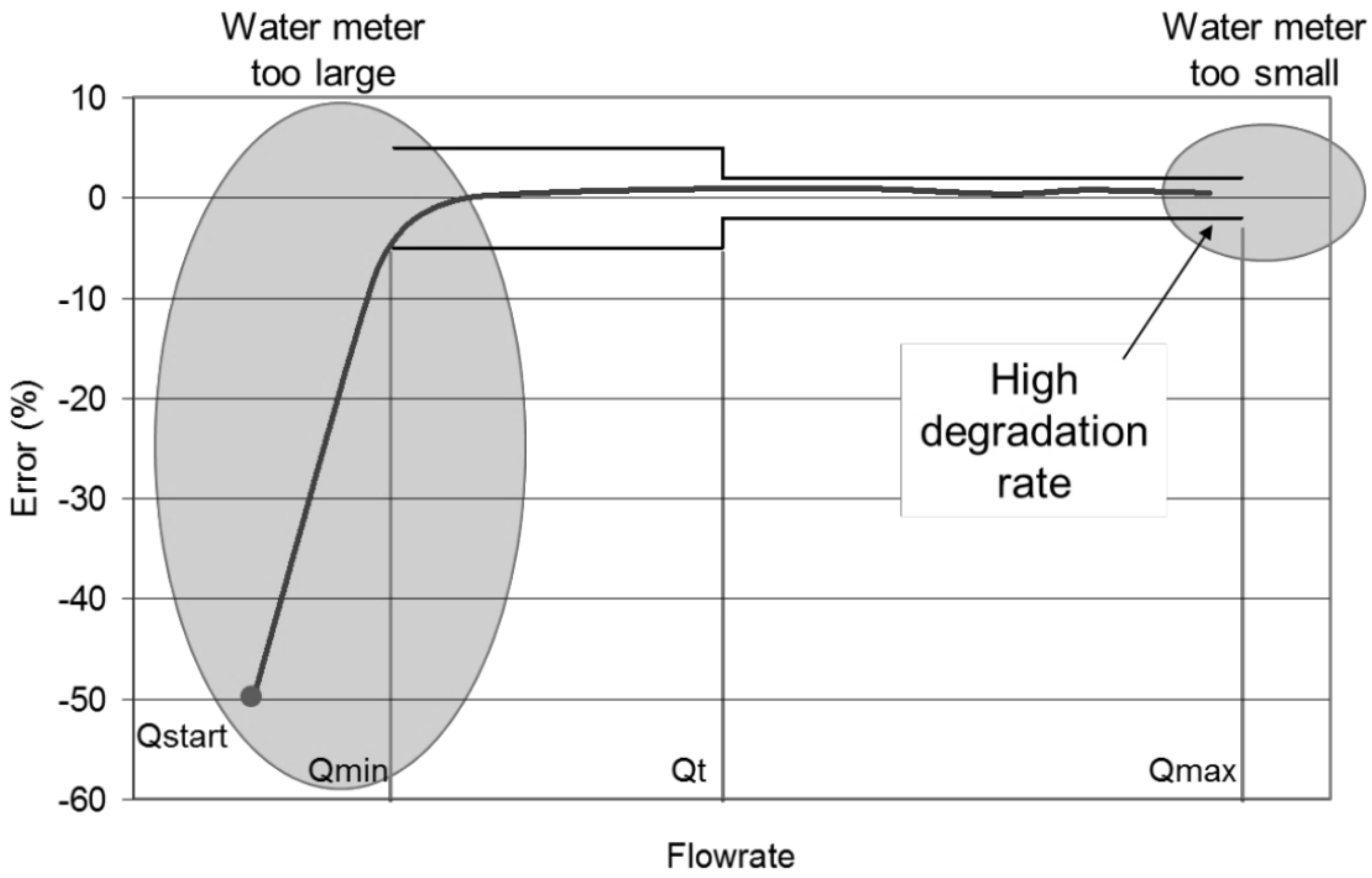
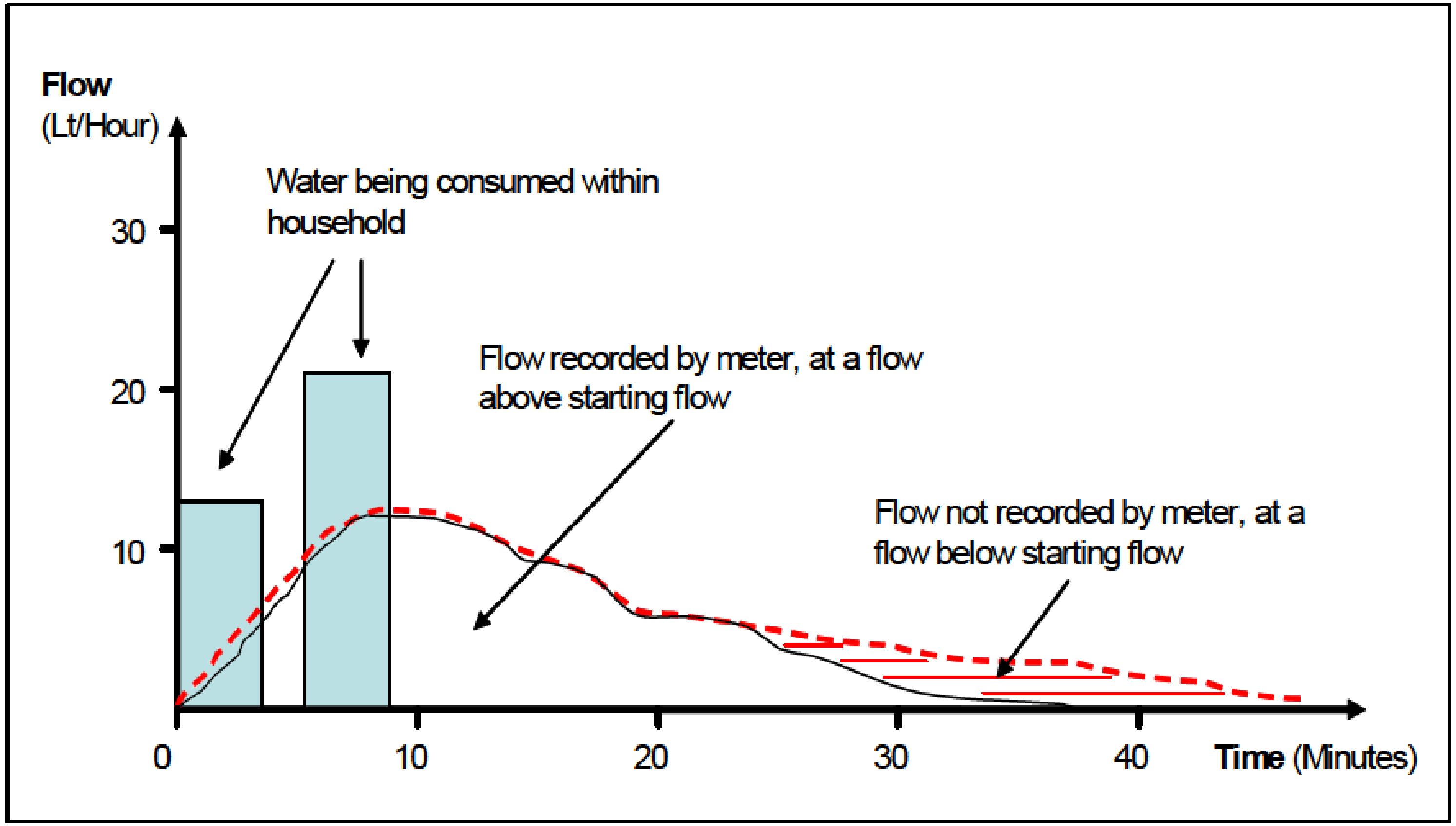
Sizing of mechanical meters – so important!



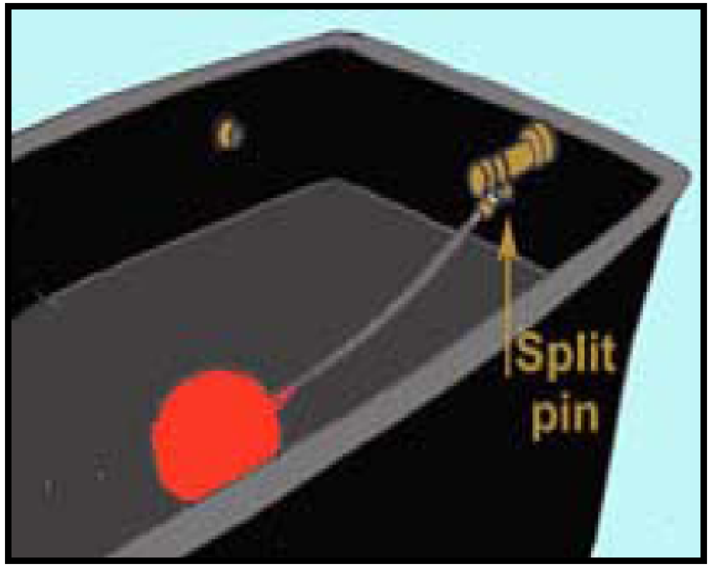
Source: Francisco Arregui

- Specially for key account meters this is a serious problem
- A large % of these meters is often incorrectly sized
- Right sizing has often extremely short payback times (months)

Roof tanks – the problem with the closing phase



Ball or Float Valve



Source: Alex Rizzo

Note: this problem wouldn't exist if the valve had only 2 positions – open and closed

How shall these meters generate revenues?

Philippines

Greece

Tanzania

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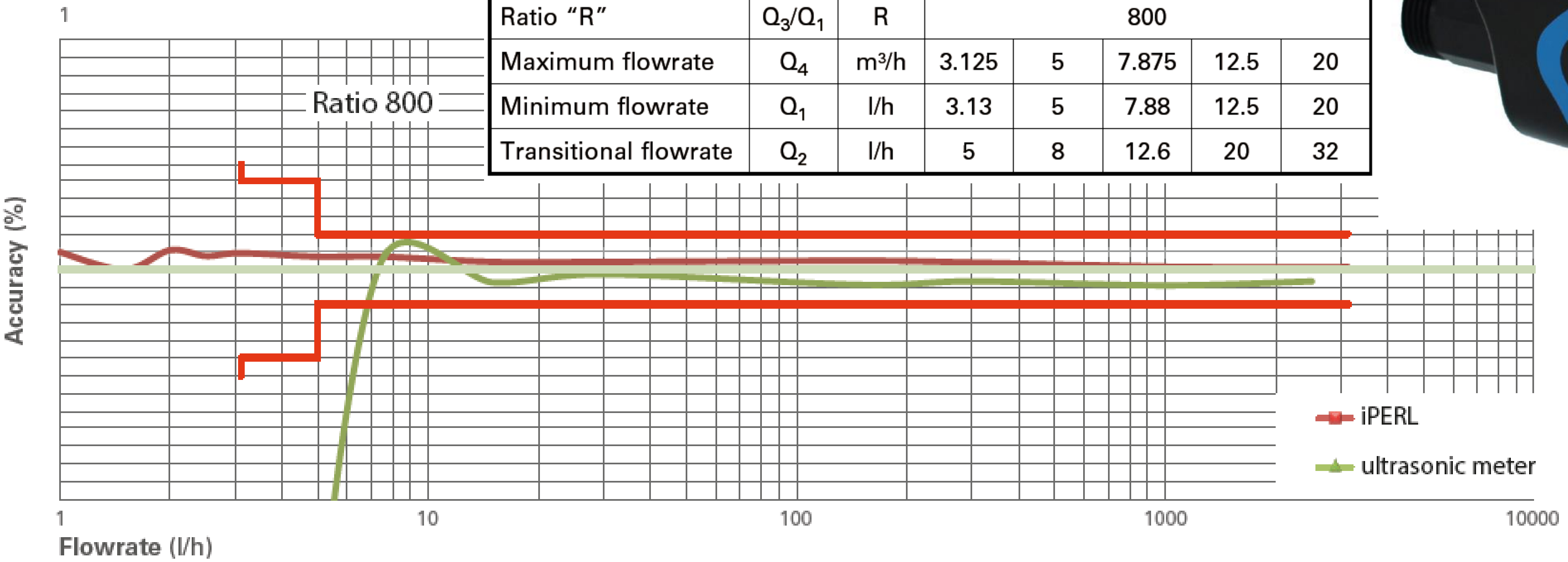
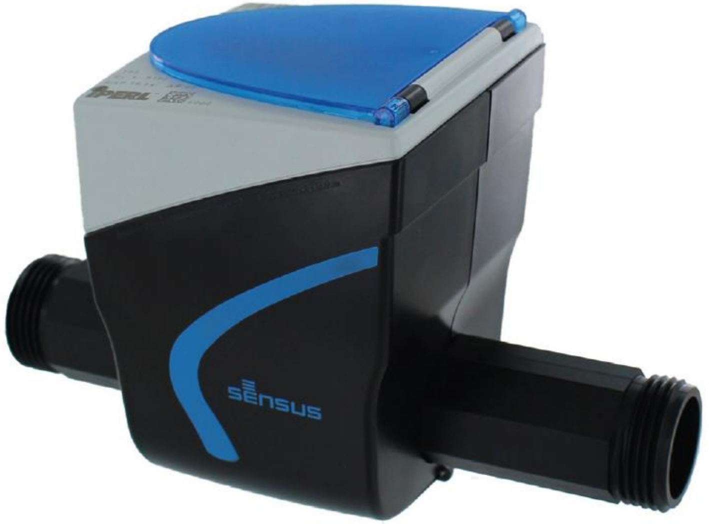
The (still expensive) future – Solid state meters

Nominal size	DN		DN (mm)				
			15	20	25	32	40
Permanent flowrate	Q_3	m³/h	2.5	4	6.3	10	16
Starting flowrate		l/h	1	1.6	2.5	4	6.4
Ratio "R"	Q_3/Q_1	R	800				
Maximum flowrate	Q_4	m³/h	3.125	5	7.875	12.5	20
Minimum flowrate	Q_1	l/h	3.13	5	7.88	12.5	20
Transitional flowrate	Q_2	l/h	5	8	12.6	20	32





But there are still many concerns

- How reliable will be the electronics?
- How robust are the meters in tough weather conditions?
- Will the battery life be really as long as promised?
- How will the meters behave in real life (unsteady flow conditions)?
- In summary: not enough experience yet
- Suggestion: we should start to test different brands in our projects

Immediate focus must be on key accounts

- This was the situation at the beginning of the Maynilad NRW project:

7% of the customers generated

25% of the total billed volume which accounted for

48% of the total revenue

Takeaway #8

A thorough customer meter accuracy study can yield significant financial benefits!

Elements of unauthorized consumption

- Illegal connections
- Meter tampering, bypasses
- Illegal use of water from hydrants (e.g. tanker filling, construction works)
- Irrigation by breaking mains
- Illegal commercial and industrial consumption

More illegal connections!

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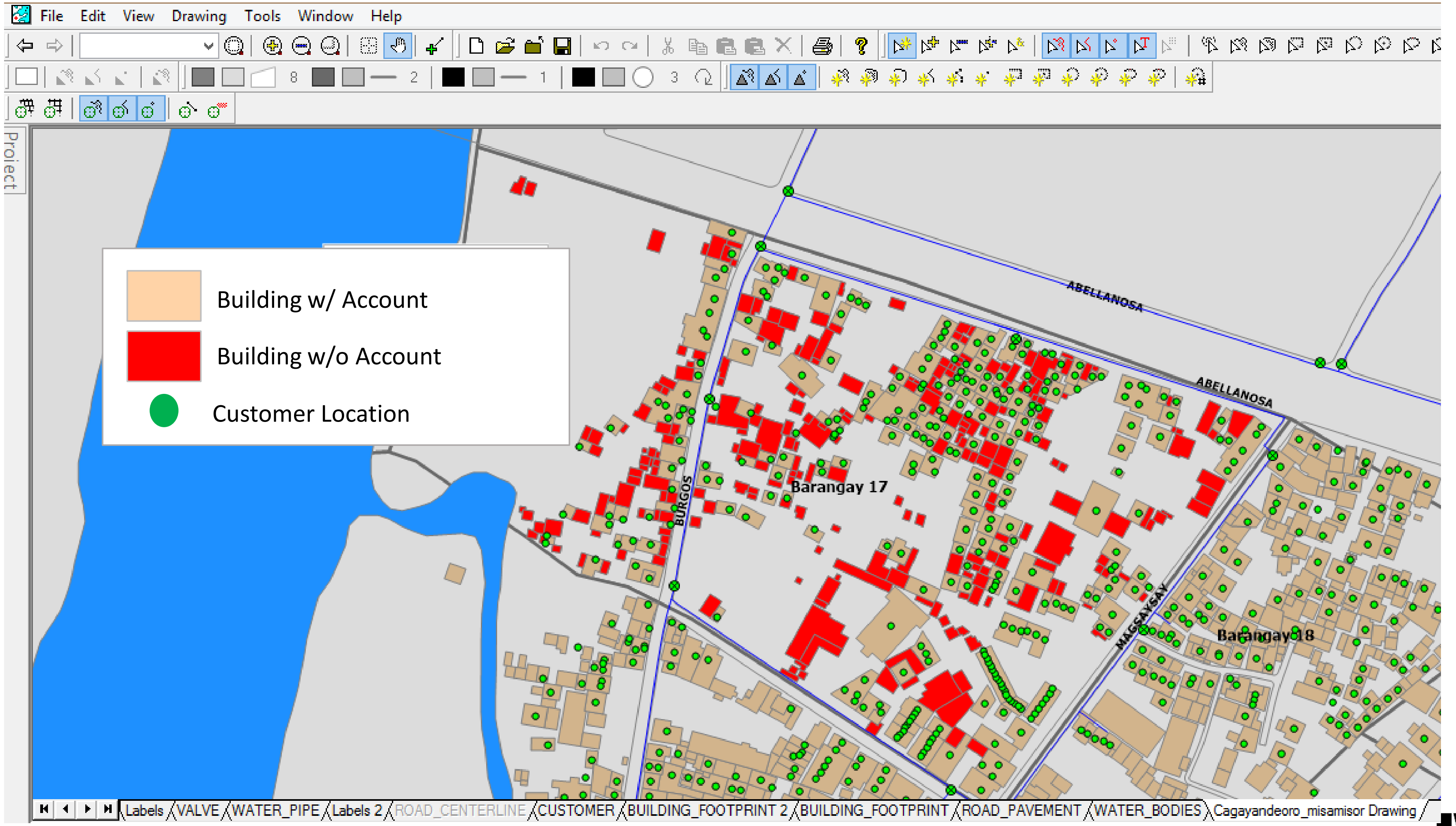
GIS based on house-to-house survey as basis for the identification of potential illegal connections



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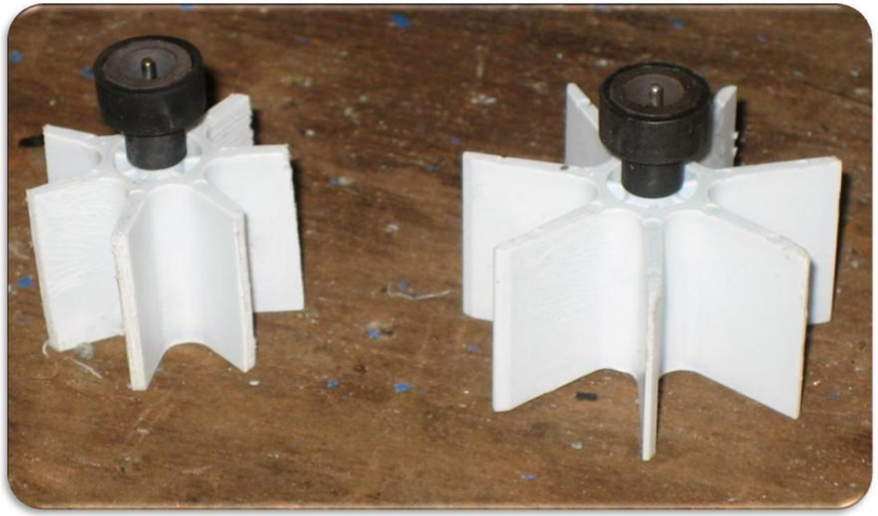
Illegal Connections and Informal Settlements

- Poor quality of installations cause also physical losses
- Informal settlements can be measured as a whole (district meter)
- Work with community to improve and regularize service

Meter bypasses

- Regular visual inspection
- Look for flags, anomalies in billing records
- Comparison of consumption to average values

Meter tampering



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Keep customer data base up-to-date

- Detect and register illegal connections
  - House to house customer survey
  - Work with community; awareness campaigns
  - Keep customer records up to date
- Keep data base up to date
  - Visit customers
  - Check category
  - Check number of people; garden; irrigation
- All customers to be included in GIS!

Tackling problems with meter reading, data handling and billing

- Effective supervision, rotation of meter readers, spot-checks
- Automatic meter reading (AMR, AMI)
- Periodic auditing of the entire meter reading, data processing, billing, collection chain
- Statistical analysis, monitoring, verification
- Appropriate billing system operated by competent management and personnel

Takeaway #9

Up-to-date GIS and customer data base are a prerequisite for reduction of unauthorized consumption!


New Sources of Water
1. New Dams
2. River Sharing
3. Rain Water Harvesting
4. Desalination
5. Icebergs
JUST PLUG THE LEAKS!!