Aalto University
School of Engineering

Water demand management & leakage

WAT-E2110 – Design and Management of Water and Wastewater Networks
Lecture 3: Water demand management and leakage

Doctoral candidate Suvi Ahopelto 4.3.2019

Today

8:30–9:30 Thematic lecture

Break 15 min

9:45–12 We work on assignment 3 together

Me – Suvi Ahopelto

- **Doctoral candidate at Water and environmental engineering research group**
- **Research themes:**
    - Resource efficiency in water distribution:
        - *water and energy efficiency, leakage management, water use management, renovation of pipe networks*
- **suvi.ahopelto@aalto.fi**

Covered in this lecture

- **Something about water demand management from the water utilities perspective (in Finland)**

- **Water loss due to leakage**
  - Physical basis
  - Estimating and managing leakage levels
  - Assignment 3: Modeling leakage

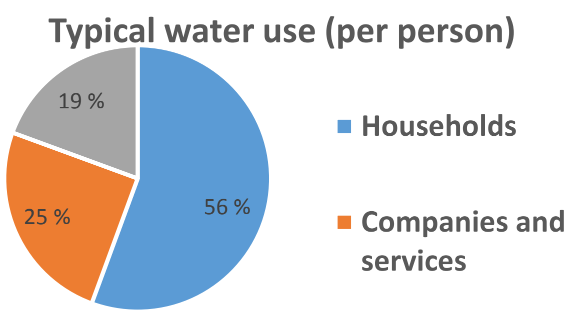
Water demand management

- **Long-term demand:** Planning investments and preparing for the future (20-40 years)
- **Short-term demand:** Operating the water supply network efficiently, peak demand
- **Five Components of WDM (Brooks 2006)**
  1. reducing the quantity or quality of water required to accomplish a specific task;
  2. adjusting the nature of the task so it can be accomplished with less water or lower quality water;
  3. reducing losses in movement from source through use to disposal;
  4. shifting time of use to off-peak periods;
  5. increasing the ability of the system to operate during droughts.

Water use

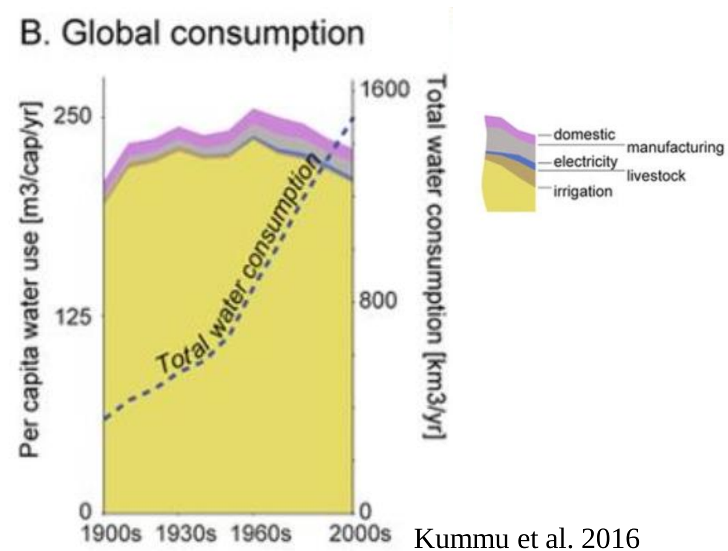
Finland

- **We abtract around 2-3% of renewable water resources annually**
  - For example Belgium uses around 72% and Italy 32%
- **Only seasonal/occasional/regional water stress**
- **Public water supply:**



Global

- **Water scarcity is a major issue**

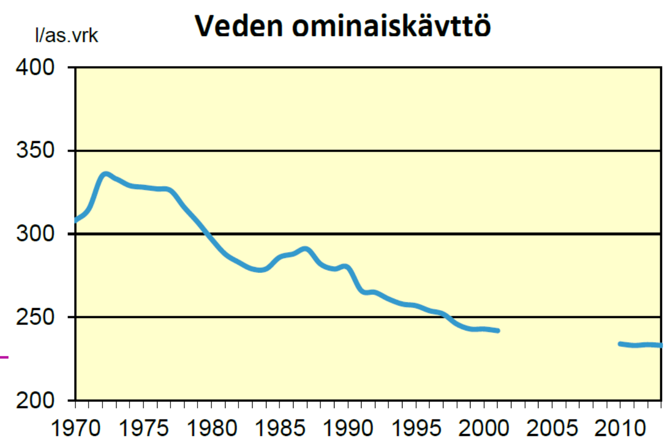


Kummu et al. 2016

- **Consumptive use**
- **Non consumptive use**

50-years (residential) water use trend in Finland

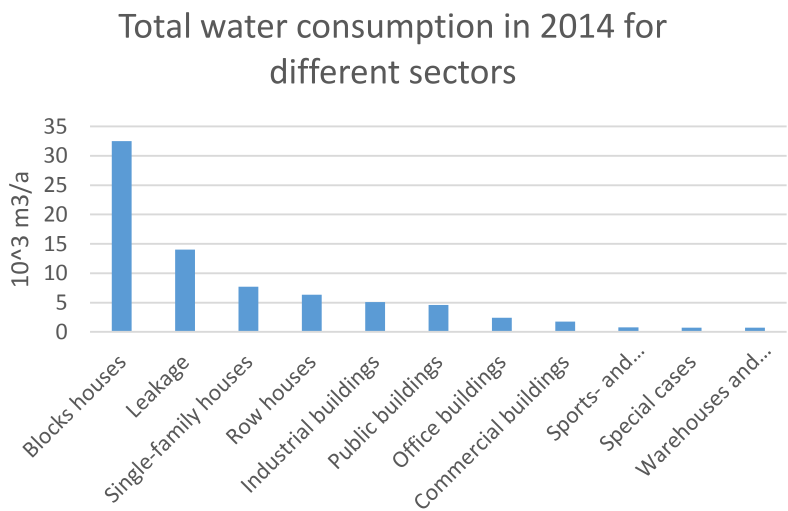
- **Until mid-1970s, water use was thought to increase ”indefinitely”**
- **Water use started to decrease after the energy crisis in 1972 and new waste water tariffs in 1974**
  - Efforts by the water utilities to reduce leakage etc.

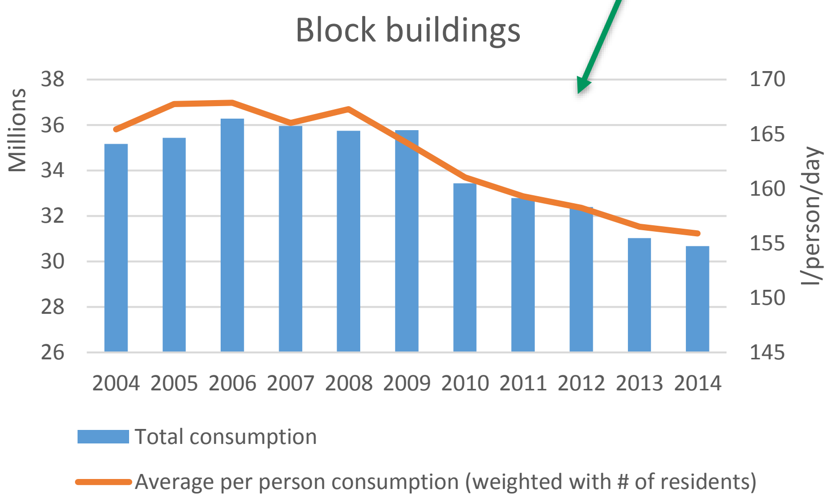


Source: SYKE

Water consumption trends in one city

The trend is -0.8%/year
in block buildings





- **Around one third of the decreasing trend can be explained by new and renovated buildings**

Question (5 min)

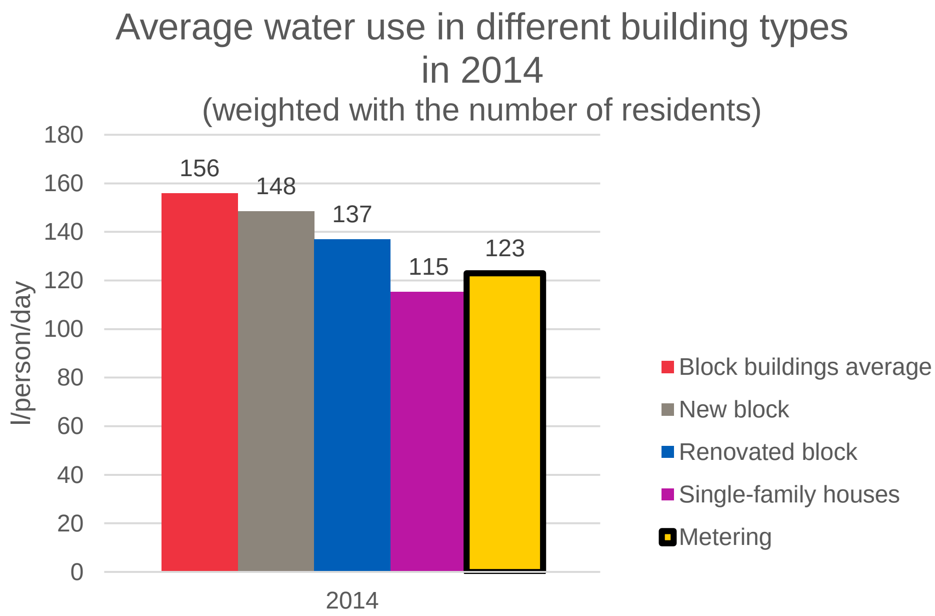
Discuss in groups of 2-4 people:

How could water demand (water supplied by water utilities) be reduced?

Question (5 min)

How could water demand (water supplied by water utilities) be reduced?

- Reduce leakage
- Tariff policy, metering
- Reduce hydraulic pressure – in pressure zones or at the property
- *Encourage people to reduce less*
- Consumption feedback
- More efficient water fixtures and devices
- Water reuse

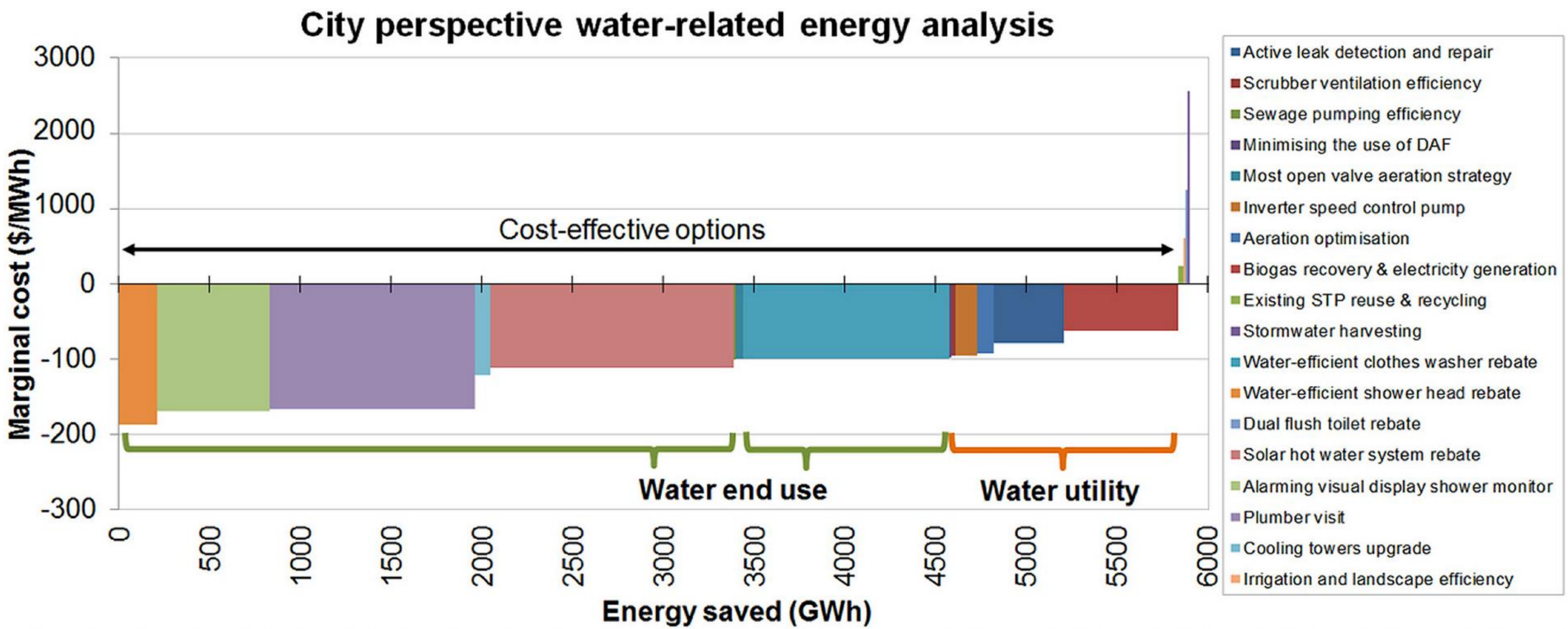

Average water use in different building types
in 2014
(weighted with the number of residents)
180
160
140
120
100
80
60
40
20
0
l/person/day
156
148
137
115
123
2014
Block buildings average
New block
Renovated block
Single-family houses
Metering

Benefits of WDM in practice

- **Consumers**: ***e.g.*** **installing water-saving faucets and toilets can reduce water and energy (heating water) bills**
- **Communities and utilities**: ***e.g.*** **can avoid constructing new larger facilities for treatment and storage**
- **Companies**: **more efficient water use can reduce operational costs**
- **Environment**: **pumping and heating needs energy => greenhouse gas emissions, excessive water intake harms the environment**
- **Economy**: **more efficient use of natural resources increases productivity**

Costs and benefits need to be balanced!

Weighting benefits and costs



Lam et al. (2017)

Water use, water demand management

Other courses dealing with water demand and use:

WAT-E2100 Urban Water Systems (period II)

- Water supply systems, water demand, benchmarking

WAT-E2090 Water and people in a changing world (period V)

- Global scale water scarcity
- Food security, water footprint

WAT-E2080 - Water and Governance (period III)

- Governance, political framework and legislation related to water resources

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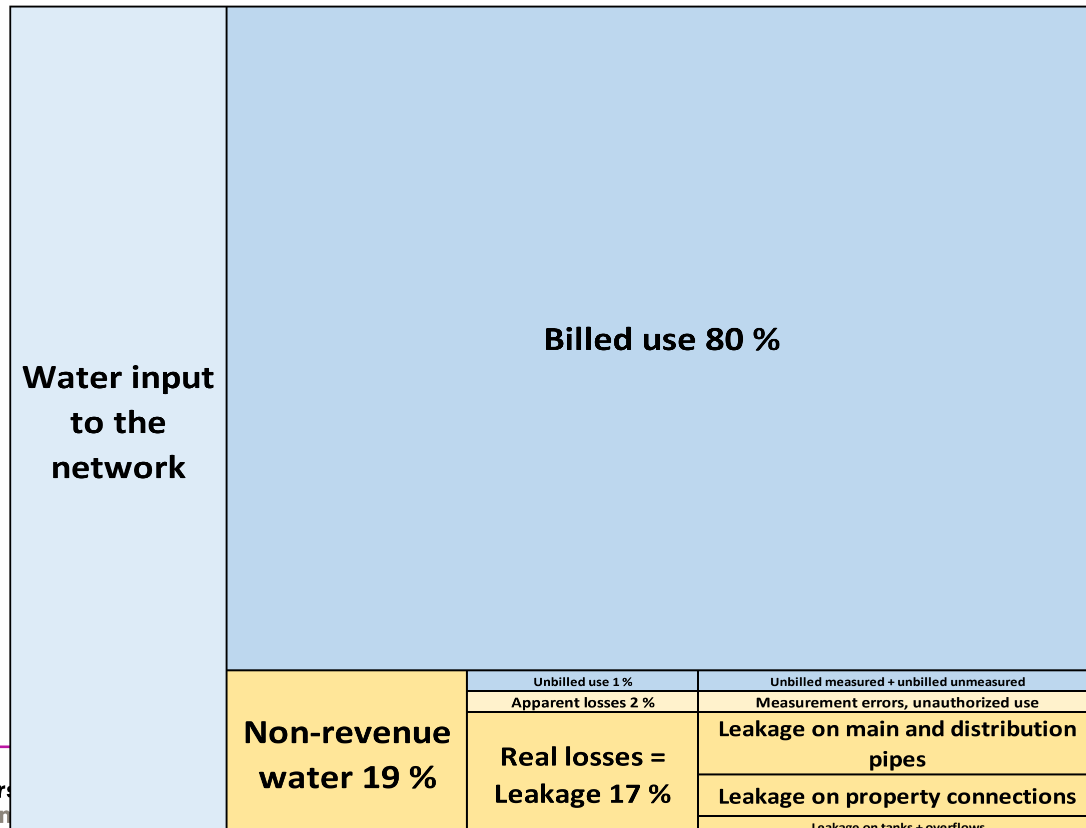
Helsingin sanomat, 7.2.2016. Image: Heikki Saukkomaa / Lehtikuva.

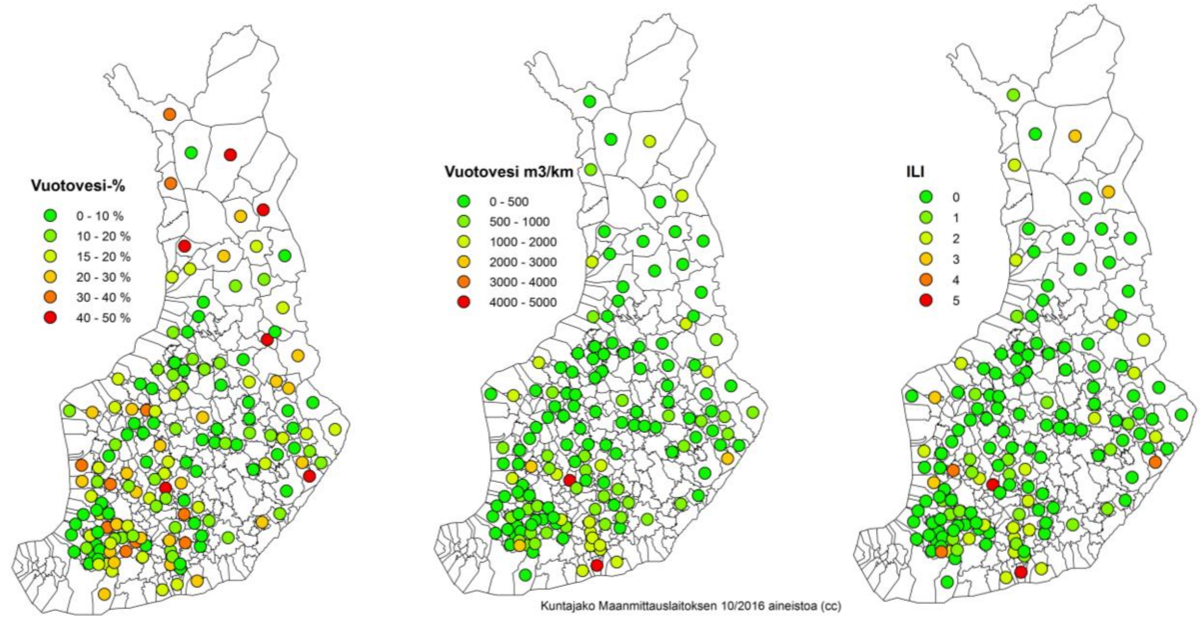
Water loss/Leakage

Water balance for a Finnish water supply system



Water loss in Finland

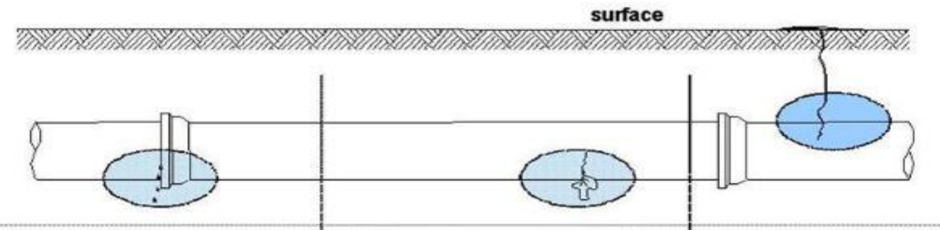
- ILI (Infrastructure leakage index) $= \frac{current\ leakage}{theoretical\ minimum}$



Low and Middle Income Countries ILI range	High Income Countries ILI range	Leakage Performance Category LPC	Calculated ILI for this System	General description of Leakage Performance(LPC) Categories (LPC limits for Low and Middle Income Countries are double those for High Income Countries)
Less than 3	< 1.5	A1	1.3	Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective improvement
3 to < 4	1.5 to < 2	A2		
4 to < 6	2 to < 3	B1		Potential for marked improvements; consider pressure management, better active leakage control practices, and better network maintenance
6 to < 8	3 to < 4	B2		
8 to < 12	4 to < 6	C1		Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts
12 to < 16	6 to < 8	C2		
16 to < 24	8 to <12	D1		Very inefficient use of resources; leakage reduction programs imperative and high priority
24 or more	12 or more	D2		

Table 8 – International Leakage Performance Categories based on ILI.

Where is the water leaking from?



Background leakage

Un-reported and un-detectable using traditional accoustic equipment.

Tools

- Pressure stabilization
- Pressure reduction
- Main and service replacement
- Reduction in the number of joints and fittings

Un-reported leakage

Often does not surface but is detectable using traditional accoustic equipment.

Tools

- Pressure stabilization
- Pressure reduction
- Main and service replacement
- Reduction in the number of joints and fittings
- Proactive leak detection

Reported leakage

Often surfaces and is reported by the public or utility workers

Tools

- Pressure stabilization
- Pressure reduction
- Main and service replacement
- Optimized repair time

Acknowledgement: Jairo Tardelli Filho (SABESP, Brazil)

Leakage management

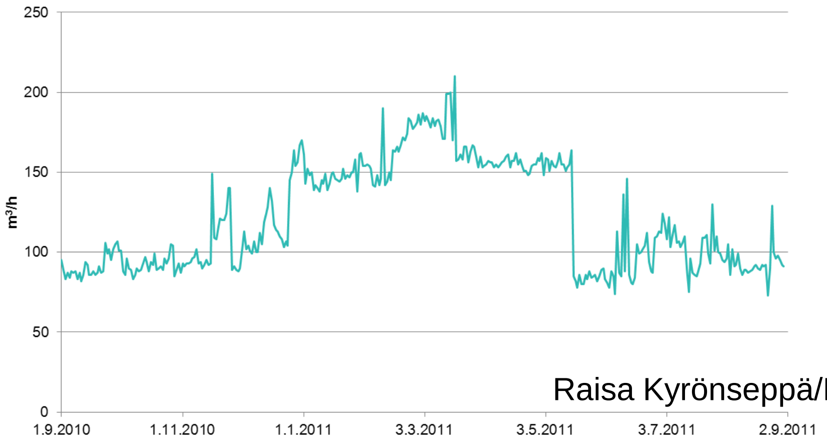
- **Active leakage control**
  - Monitoring
  - Leak detection
  - Repair
- **Asset management**
- **Pressure management**

Monitoring

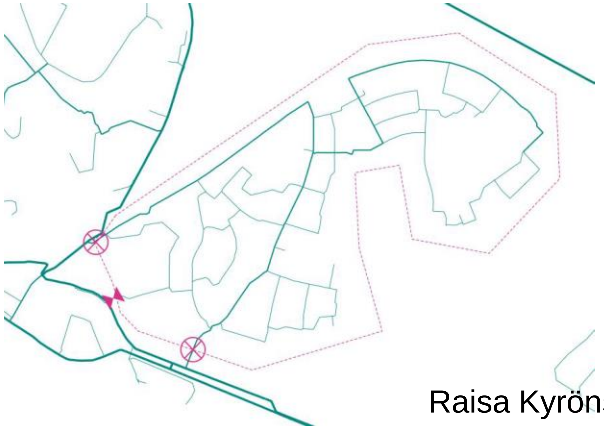
District metering areas (DMAs)

- Network is divided into areas
- Metering (flow + pressure) at every inlet

Flow measurement



Raisa Kyrönseppä/HSY 2018



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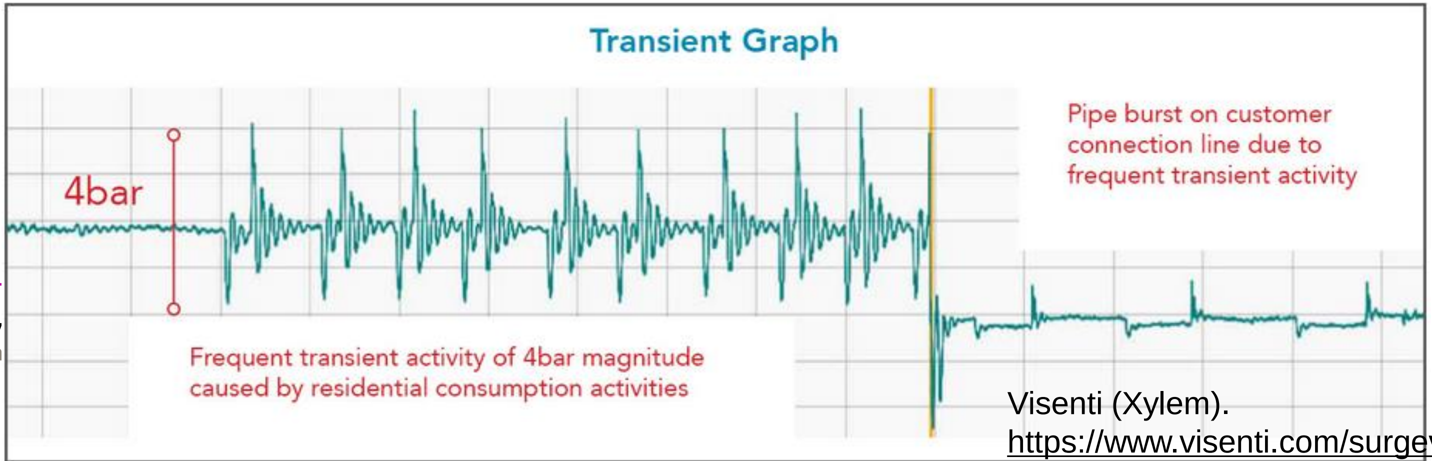
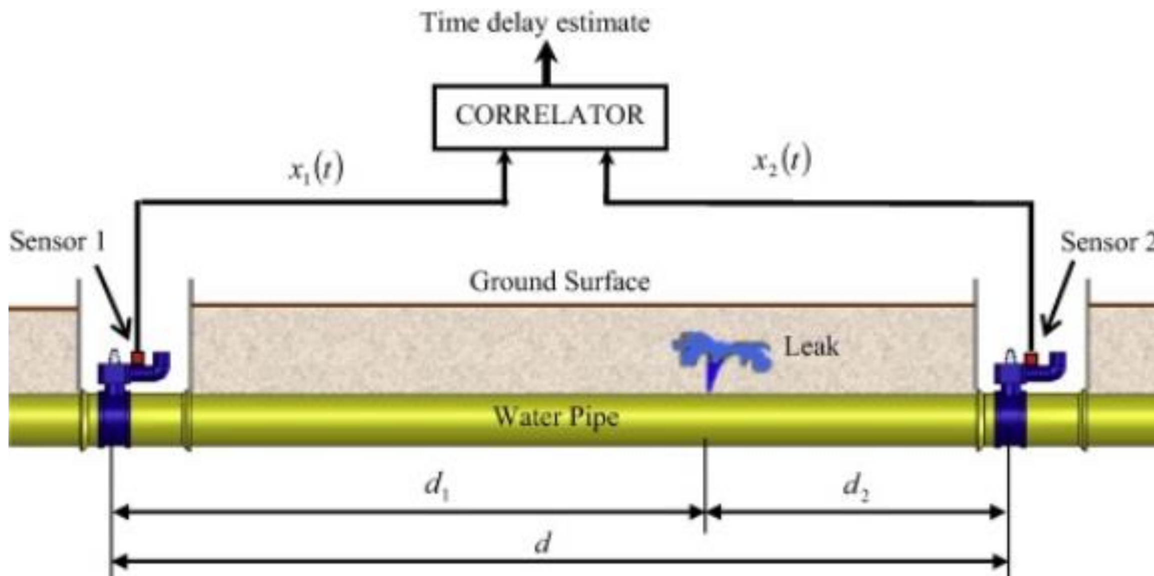


Visenti (Xylem). https://www.visenti.com/surgeview

Leak detection

- **Mainly acoustic techniques**
  - Noise loggers & correlators
  - Inline inspection techniques (tethered & free-swimming)
  - Ground radar
  - Ground microphone
  - Listening stick

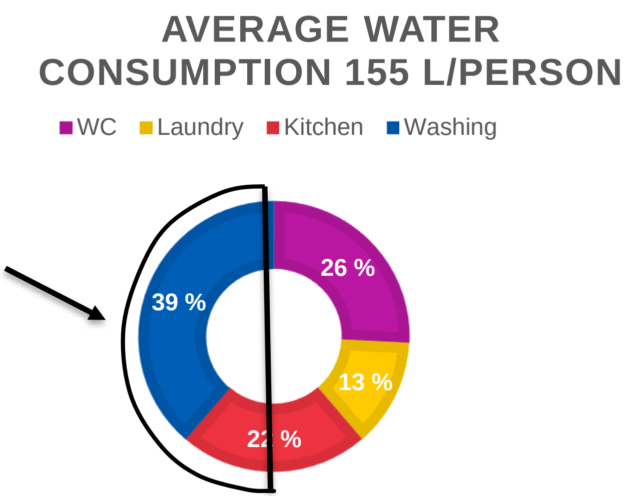


Brennan et al. 2016

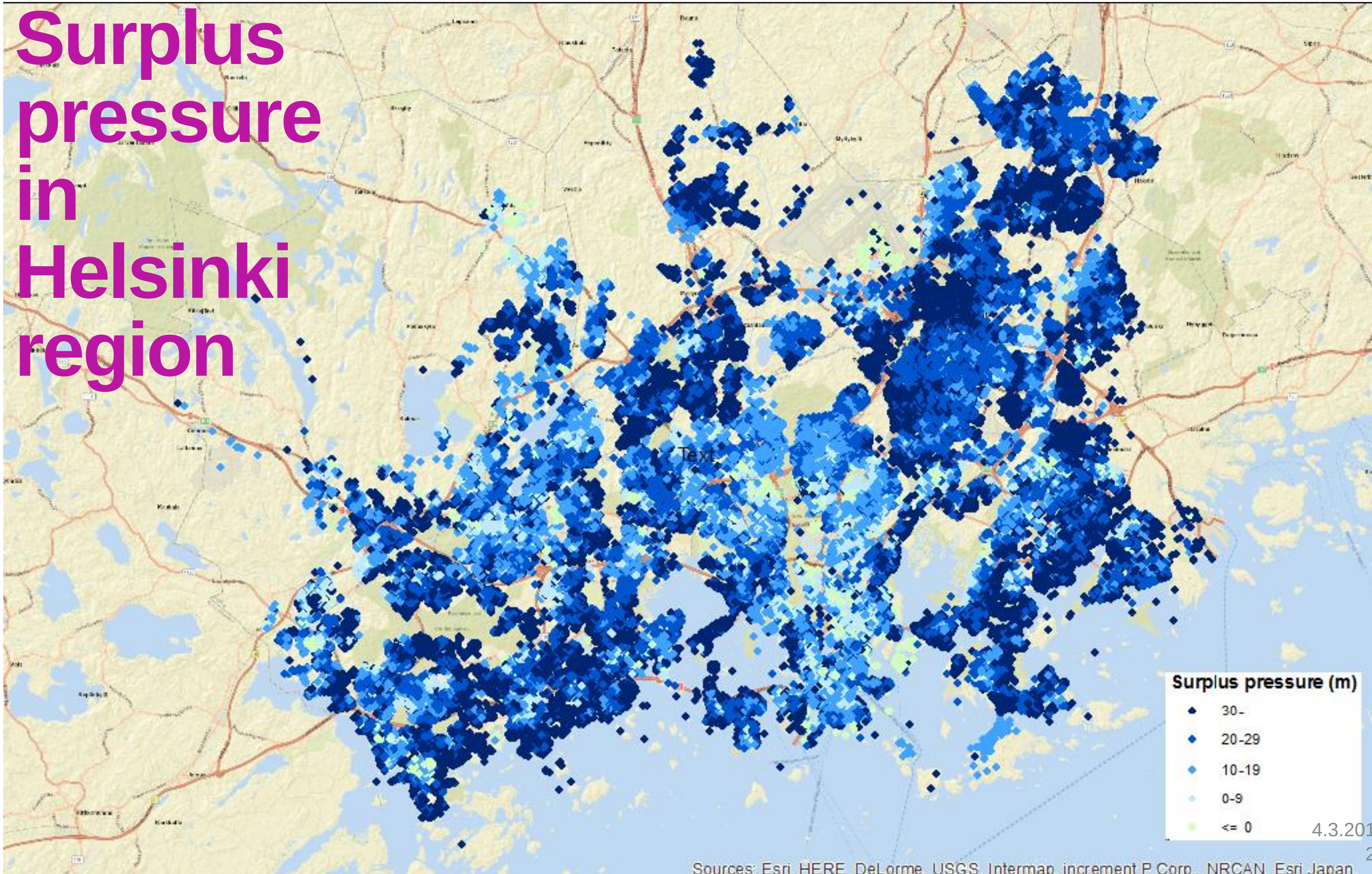
Pressure, water demand and leakage

- We looked into how leakage is affected by pressure…
- The same thing applies to water consumption

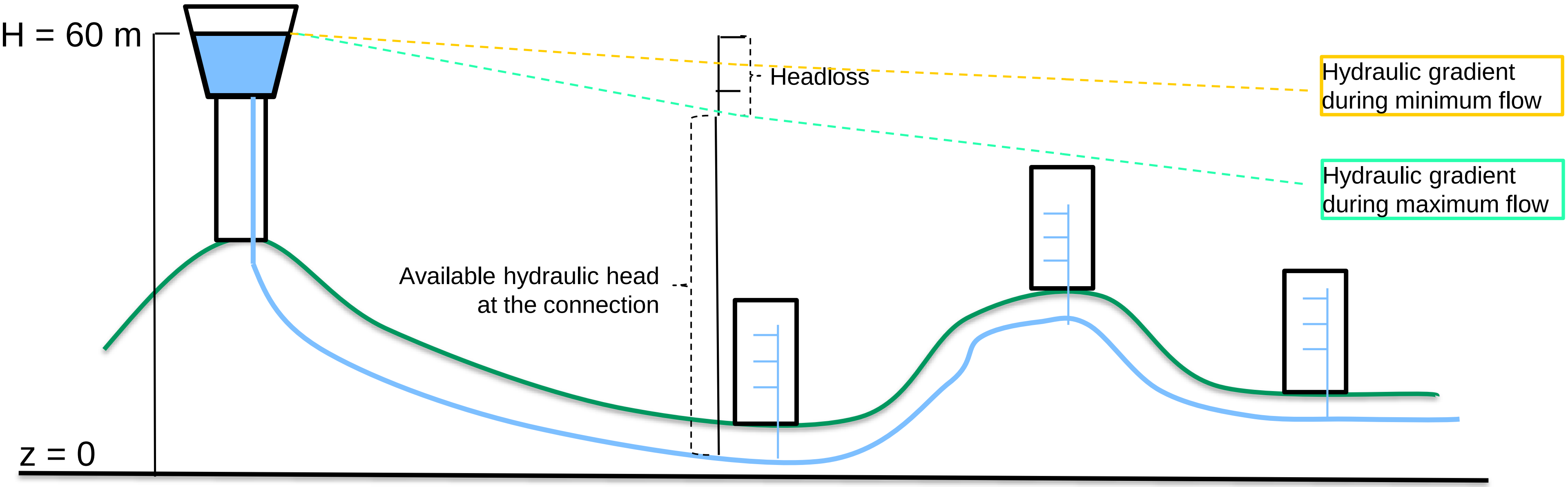
Roughly half of household consupmtion is pressure-dependent



Surplus pressure in Helsinki region

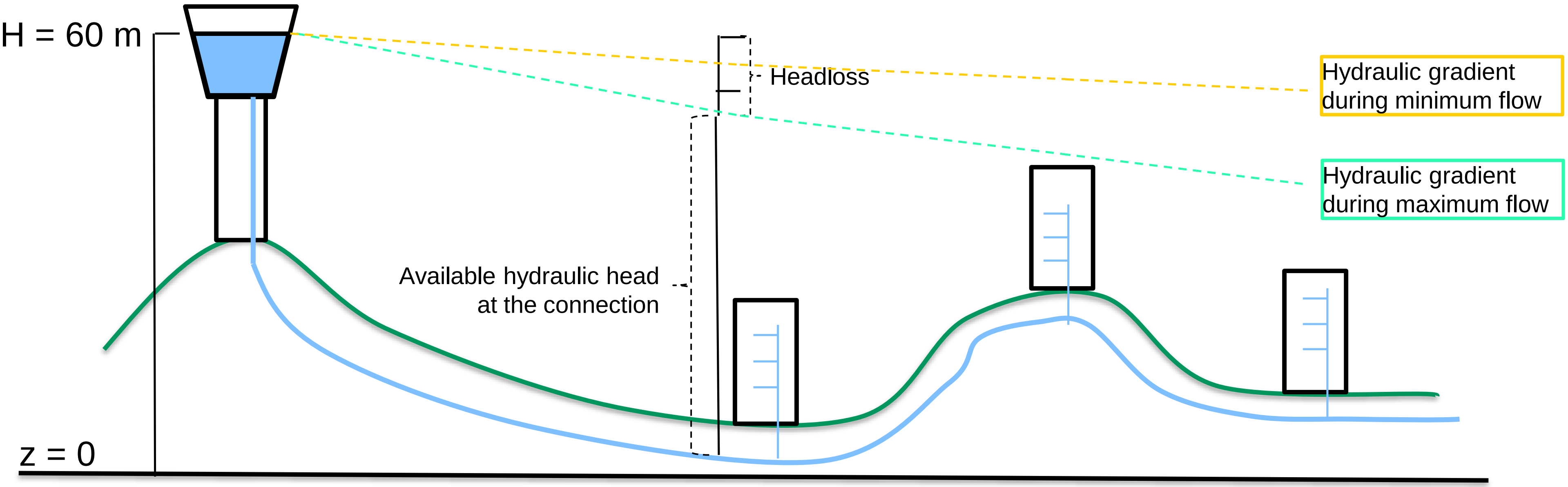


Hydraulic pressure



Hydraulic pressure

Q: Why the pressure gradient slope is steeper during the peak hour?

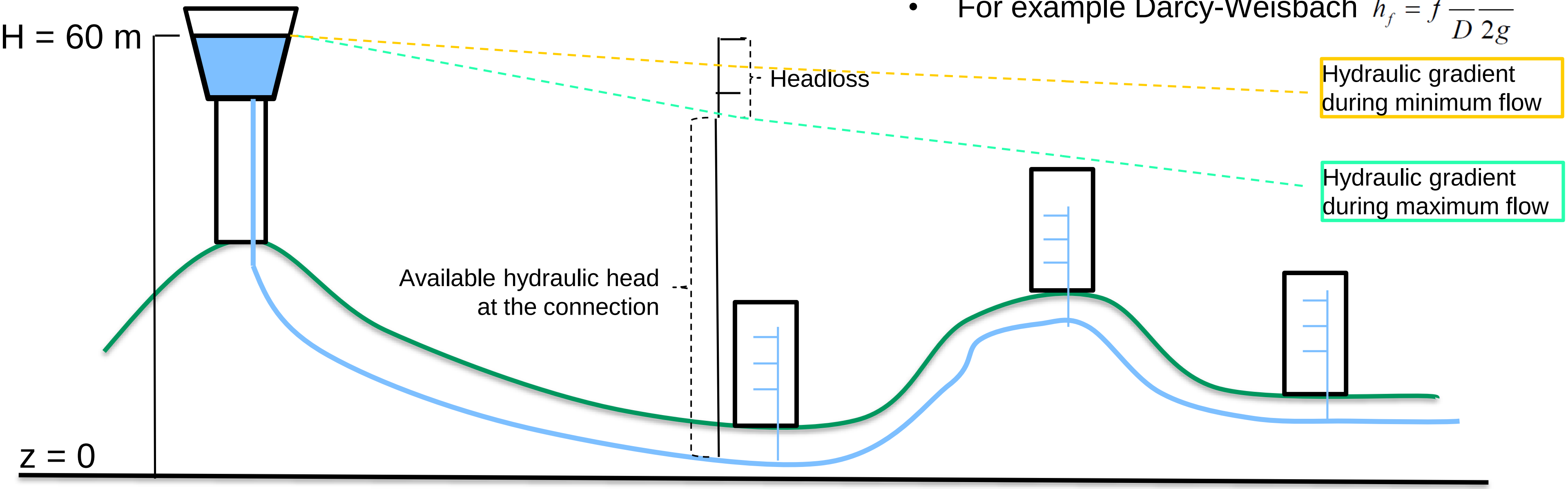


Hydraulic pressure

Q: Why the pressure gradient slope is steeper during the peak hour?

A: Because the friction headloss is dependent on the flow velocity v, and thus the flow rate Q.

- For example Darcy-Weisbach $h_f = f\frac{L}{D}\frac{v^2}{2g}$



In the model, leakage is represented as…

- **So called emitters, representing pressure-dependent outflow**

$$\mathbf{Q} = \boldsymbol{C}\boldsymbol{p}^{\gamma}$$

where Q = outflow, p = pressure, C = discharge coefficient, and γ = pressure exponent

- **Emitters:**
  - Are associated with junctions
  - Can also be used to model sprinklers or available fire flow

In the model, leakage is represented as…

- **So called emitters, representing pressure-dependent outflow**

The discharge coefficient can be calibrated to match the measured leakage volumes

$$Q = Cp^{\gamma}$$

Depends on the pipe material, that is, whether the size of the orifice is pressure-dependent or not. For rigid materials, γ = 0.5.

where Q = outflow, p = pressure, C = discharge coefficient, and γ = pressure exponent

- **Emitters:**
  - Are associated with junctions
  - Can also be used to model sprinklers or available fire flow

Derivation of the emitter equation (1/3)

- Conservation of energy (Bernoulli eq.)

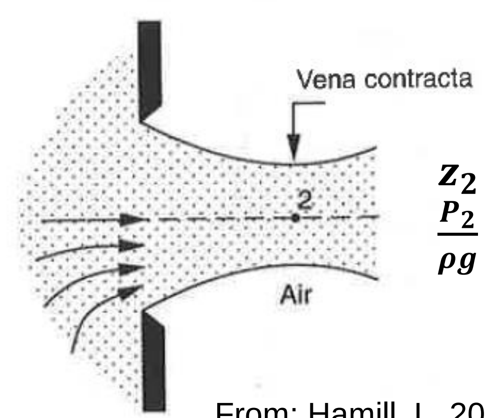
$$z_1 + \frac{v_1^2}{2g} + \frac{P_1}{\rho g} = z_2 + \frac{v_2^2}{2g} + \frac{P_2}{\rho g}$$

- The discharge Q from an orifice can be obtained by applying the energy equation to a streamline between the pipe and the 'outside' (where atmospheric pressure is assumed)

$$z_1 = 0$$

(we assume no kinetic energy on this direction) $\frac{v_1^2}{2g} = 0$

(hydraulic pressure is denoted with H) $\frac{P_1}{\rho g} = \mathrm{H}$



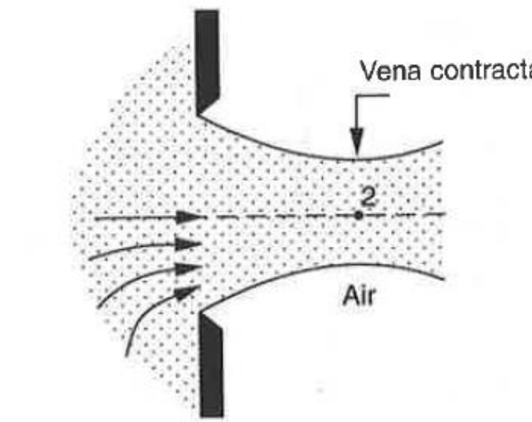
$z_2 = 0$ (streamline is level)

$\frac{P_2}{\rho g} = 0$ (atmospheric pressure is the datum)

From: Hamill, L. 2011. Figure 5.4

So we are left with

$$\frac{P_1}{\rho g} = \mathrm{H} = \frac{v_2^2}{2g}$$



By adding the continuity equation $\mathbf{Q} = \boldsymbol{Av},$

we get

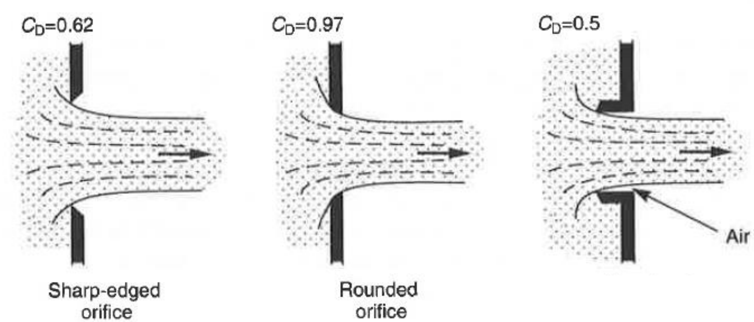
$$\boldsymbol{Q = A\sqrt{2gH}}$$

However, the theoretical equation is not accurate, because:

1. The area of the jet at the *vena contracta* is less than the area of the orifice, A.
2. In reality, there is a slight reduction in velocity as the jet passes through the orifice.

That is why need the coefficient C_d and get to the equation:

$$Q = \boldsymbol{C_d} A\sqrt{2gH}$$



From: Hamill, L. 2011.
Figure 5.5

With leakage, we lump all the unknowns and constants together:

$$Q = C_d A\sqrt{2gH} \quad -> \quad Q = C_d A\sqrt{2g}\sqrt{H} \quad -> \quad Q = C\sqrt{H}$$ (almost the emitter equation)

- **For simplicity and because flow through cracks, for example, and background leakage don't follow the physical basis of orifice flow as round holes do**

More…

- The emitter equation is represented as a power law equation, because the area of the orifice (hole, crack) may change if the hydraulic pressure change (in elastic materials)

$$\mathbf{Q} = \boldsymbol{C}\boldsymbol{p}^{\gamma}$$

Depends on the pipe material, that is, whether the size of the orifice is pressure-dependent or not. For rigid materials, $\gamma = 0.5$.

- Often γ = 0.5 is used for rigid pipe materials and γ =1.5 for elastic materials

- According to some field studies on real water distribution networks, γ is 0.5-2.8….

Assign leaks tool in the Fluidit software

- **Tools-Demands-Assign Leaks**
- **Press the assign-button multiple times to iterate the wanted NRW (non-revenue water) value**
- **Leakage is assigned to each pipes upstream node**
- **” Each conduit's share of the total NRW is calculated by dividing the total NRW with the total conduit length and average diameter in the zone and multiplying by the conduit's length and diameter”**
- **Junction-Properties-Emitter – that’s the emitter coefficient for the pipe downstream of the junction**
- **Base model – Properties – Emitter Exponent (that’s the γ)**

References

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