Pumping stations and water transport

Practical applications: distribution networks

ct5550

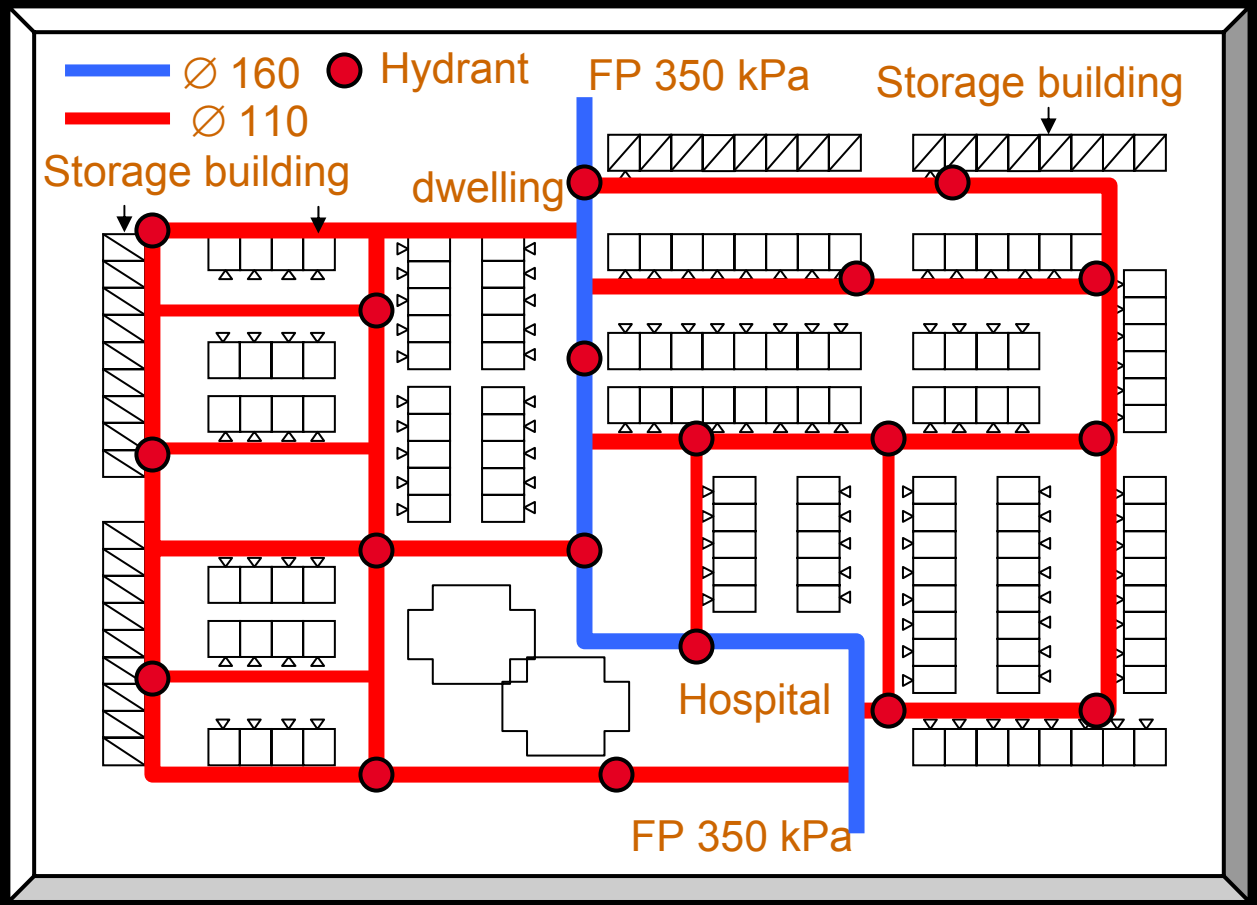
Introduction

- Distribution networks represent the majority of pipe line length
- Design criteria are historically dominated by fire flows and needs for loops
- Recent developments demand for new starting points for design and operation.

Traditional distribution networks

- Continuity supply
  $\Rightarrow$ looped networks
- Conventional fire fighting demand
  $\Rightarrow$ Hydrants on Ø110 mm
- This principal is applied for more than 150 years…….

Conventional lay out

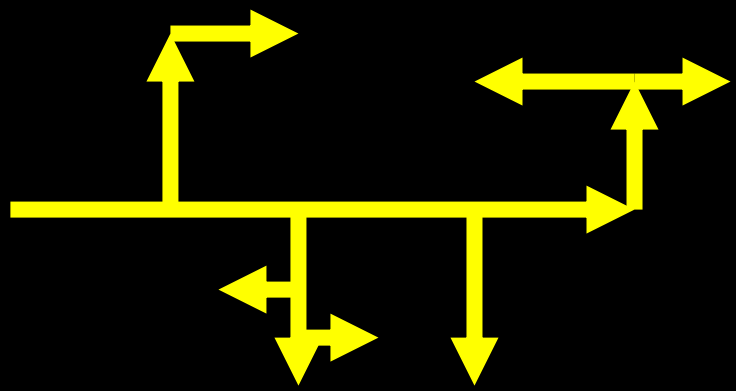


Characteristics conventional design

- Conventional fire fighting capacity prescribes diameter and consequently
  - Low velocities
  - ‘Shuttling’ water
  - Long retention times
  - Accumulation sedimentary deposits
    - Water quality problems because:
      deposits cause discolouration
      deposits are breeding ground for bacteria
- Design is ‘connecting fire hydrants’

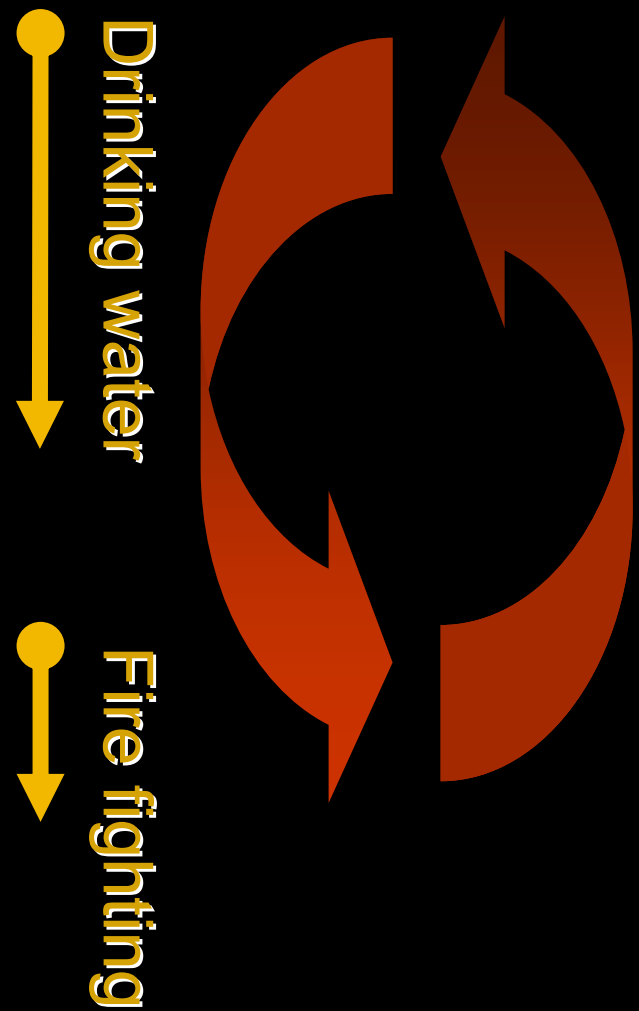
Alternative distribution network

- Design networks on:
  - The actual drinking water demand
  - Once a day a velocity of 0.4 m/s
  - Branched structure (unidirectional flow)



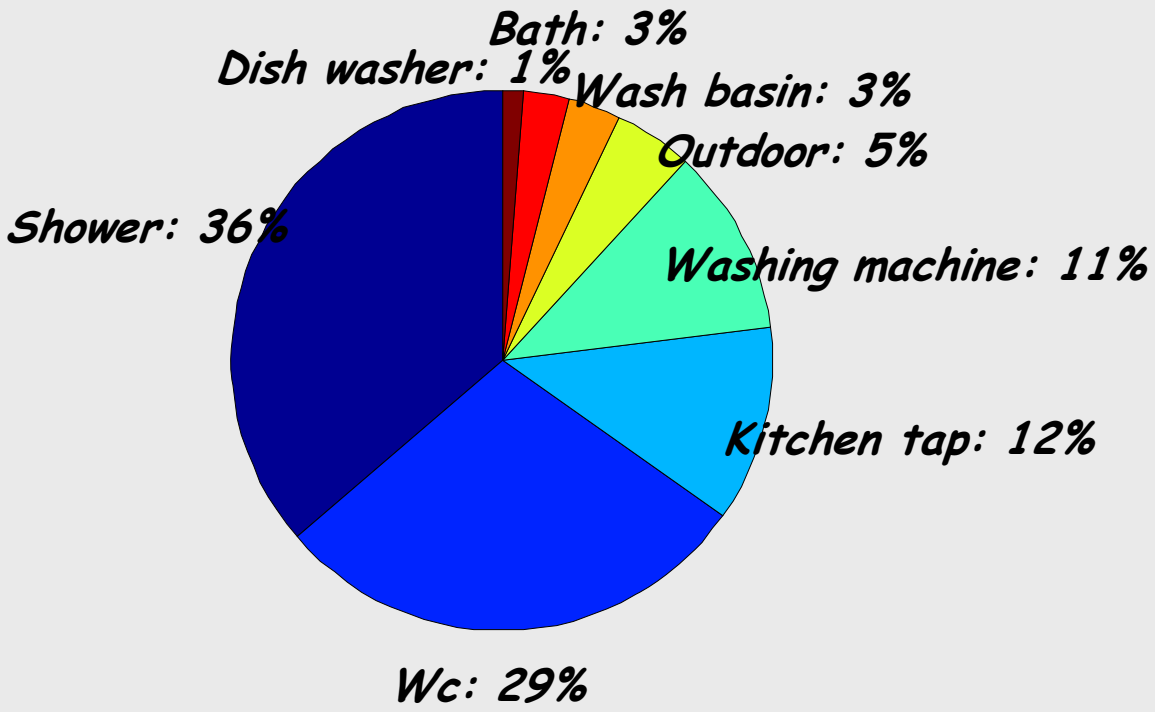
Design distribution network

- Determine drinking water demand
- Arrange sections
- Design main structure
- Design sections
  - ⇨ *check pressure drops*
- Fitting fire fighting demand
  - ⇨ *check pressure drops*



Household demand

tap	liter pppd
Bath	3.5
Brtap	4.0
Dw	1.6
Ktap	14.8
Ostap	5.9
Shower	45.9
Wc	36.6
Wm	14.2
sum	126.4



Drinking water demand (up to proximally 1000 dwellings)

- q√n method:

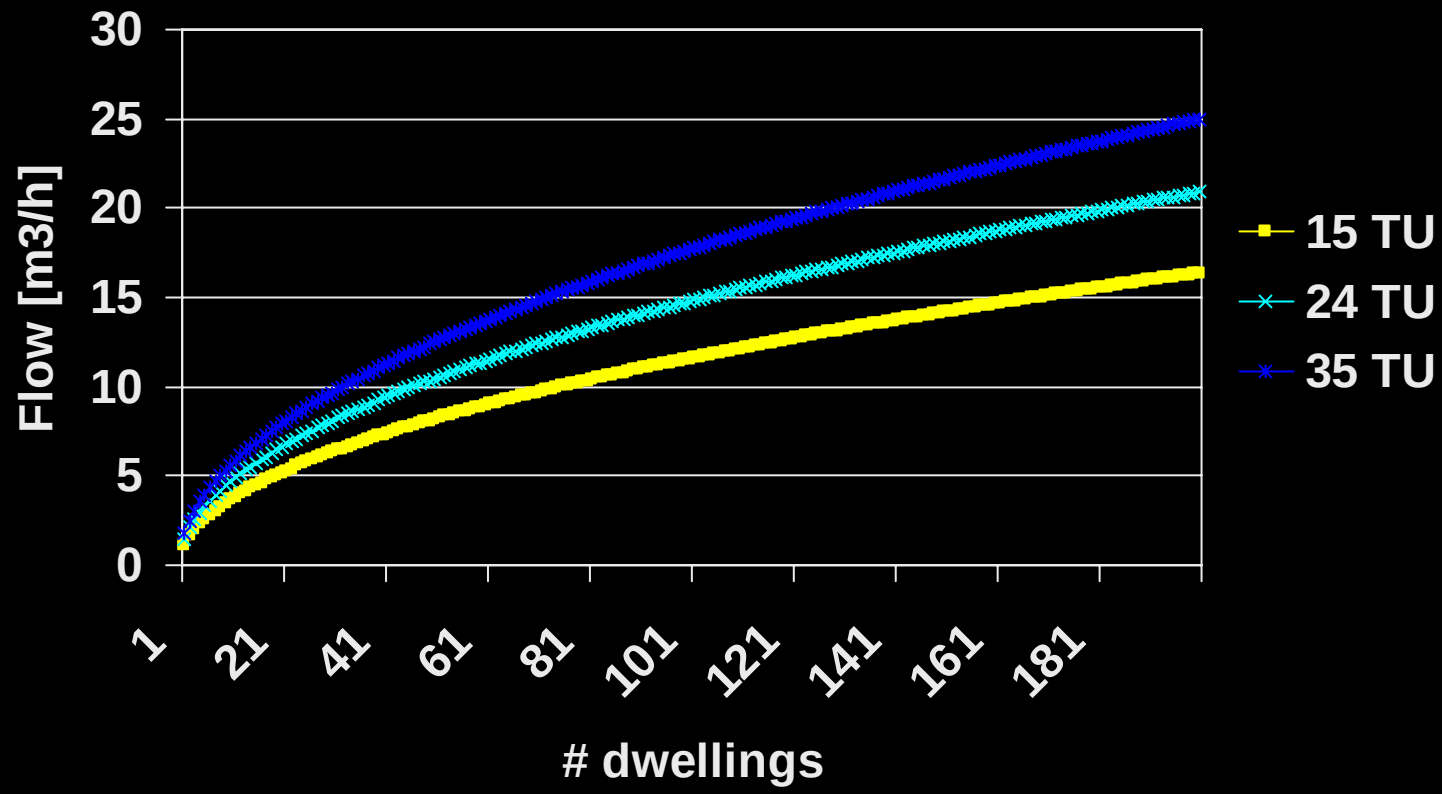
$$Q_{\max} = 0,083 \cdot \sqrt{n \cdot TU_{dweling}}$$

  - Q_{max} : maximum demand n dwellings [l/s]
  - n : # of dwellings
  - TU : # of TU per dwelling
  - 0.083 : Capacity 1 TU (300 l/h)
- TU varies 20-25

q√n method

Tap points	# tap units
Toilet cistern	0.25
Toilet washbasin	0.25
Kitchen sink	4
Dish washer	4
Bath/shower mixer tap	4
Washbasin tap	1
Washing machine tap	4
Total average house	14-28

Maximum flow with several dwelling types



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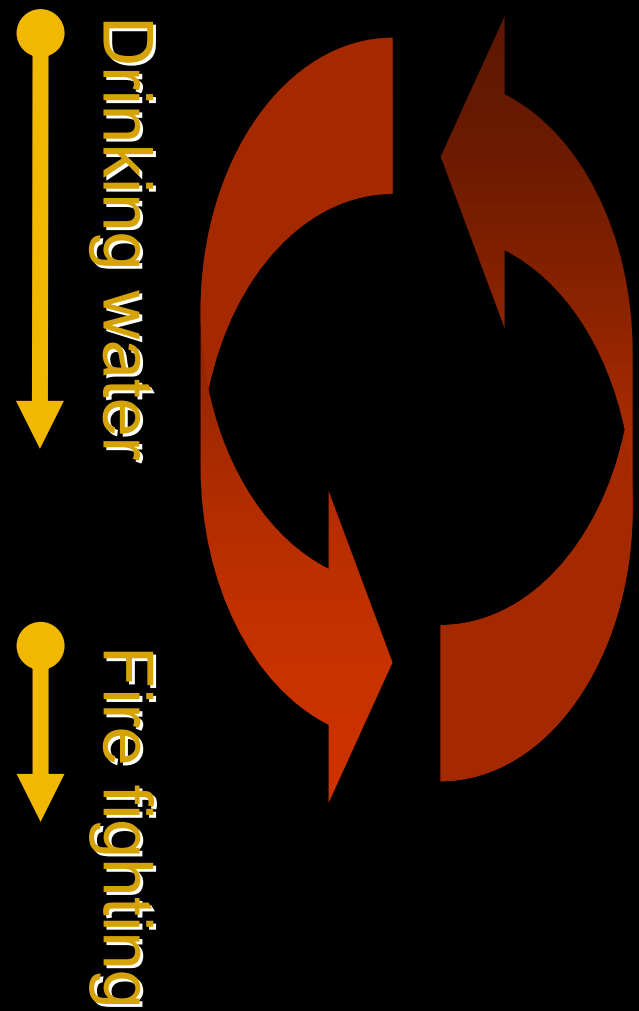
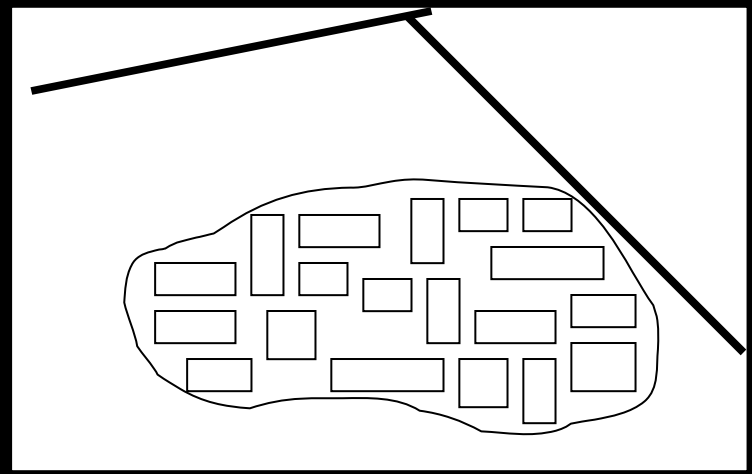


Arrange sections

- Determine size section
- Identify special connections/buildings (large fire fighting capacity)
- Cluster dwellings to sections
  - Limit pipe length by branching



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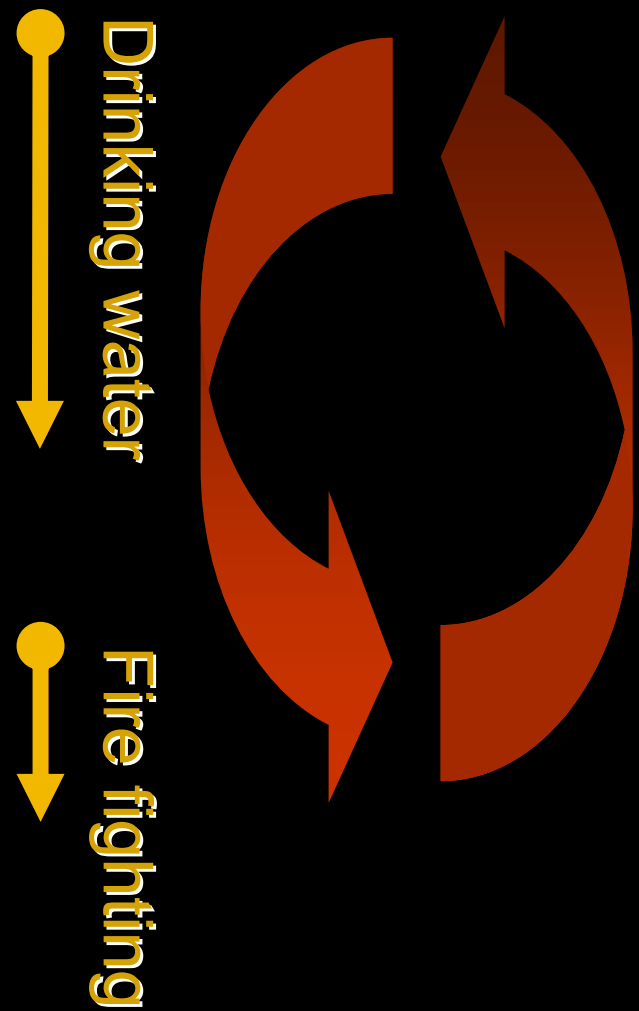
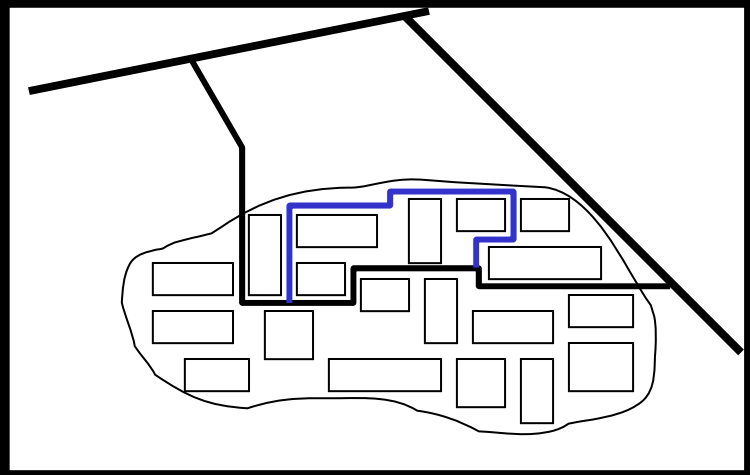


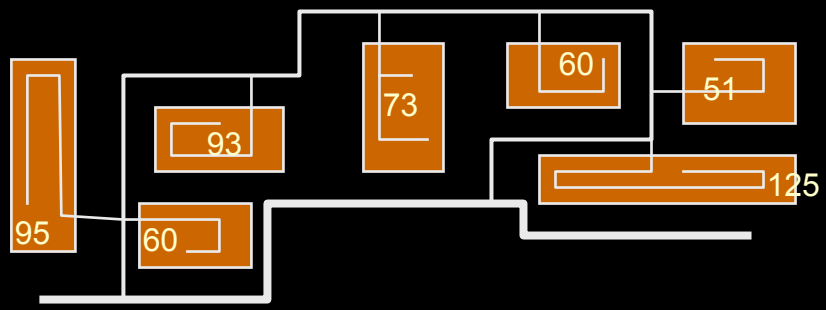
Design main structure (1)

- Identify main structure
- Connect section to main structure
- Determine volume flows

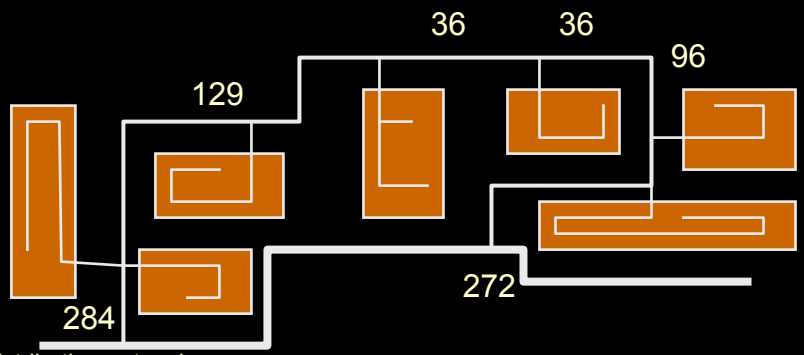


Design main structure (2)

- Determine paths main structure
- Connect sections

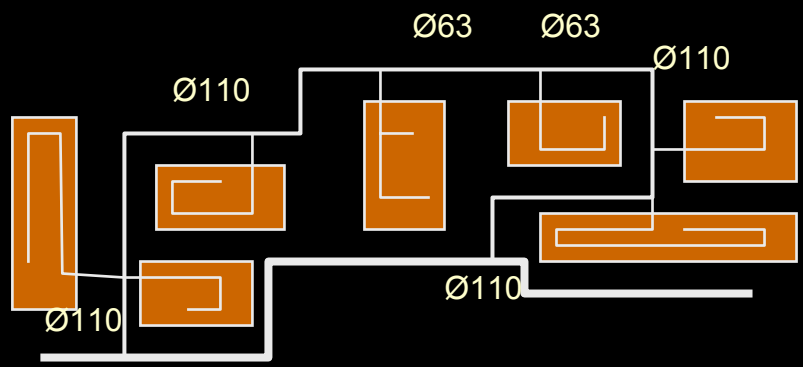


- Calculate volume flows (n $\Rightarrow$q)



Design main structure (3)

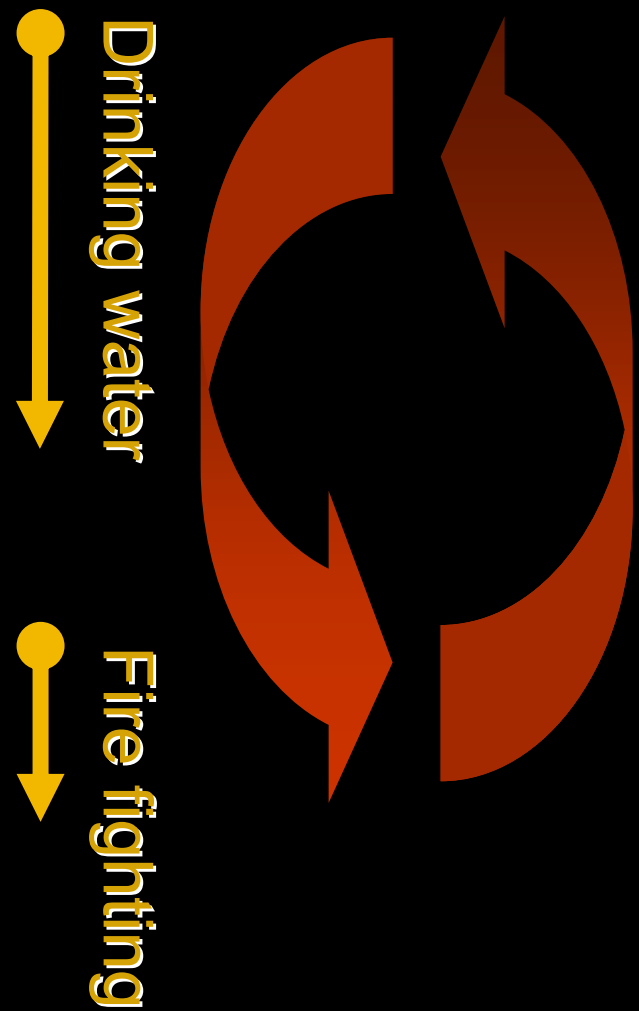
- Determine diameters



- Calculate pressure loss at maximum demand
- Calculate pressure loss at fire flows

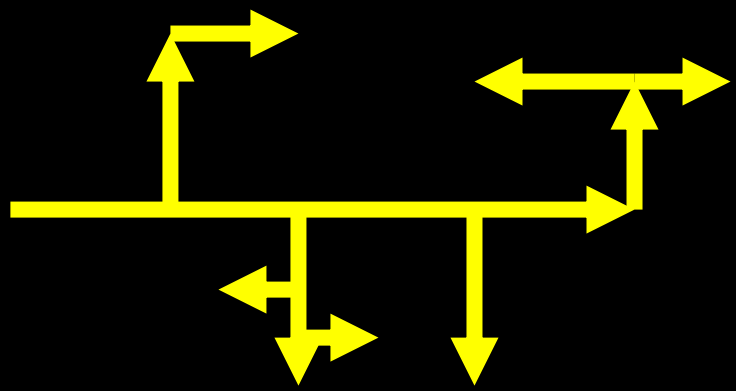
Design distribution network

- Determine drinking water demand
- Arrange sections
- Design main structure
- Design sections
  - ⇨ *check pressure drops*
- Fitting fire fighting demand
  - ⇨ *check pressure drops*



Design sections (1)

- Pressure at beginning
  - Pressure trunk main minus friction losses in main structure
- Flow direction in branched structure



Design sections (2)

- Design section based on available diameters, # connections and velocities (0,4 – 1,5 m/s)
- Check pressure losses with Darcy Weissbach

- Redesign if necessary

Design distribution network

- Determine drinking water demand
- Arrange sections
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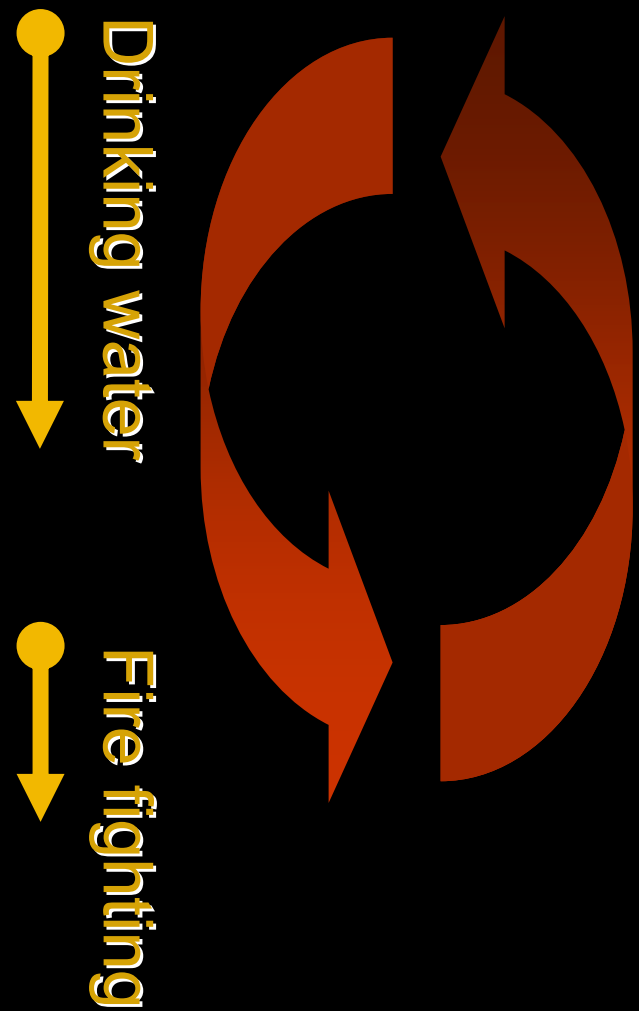


Fire demand + last checks

- Determine locations hydrants (last one on Ø63)
- Check distance to buildings
- Check pressure drops with maximum fire flows (pressure may drop to almost zero)

- Redesign is necessary

Restrictions on design

- Number of tap units per dwelling
- Maximum number of connections per section
- Diameter range pipes (e.g.PVC, Ø 110, Ø 63, Ø40)
- Minimum velocity 0.4 m/s
- Maximum velocity 1.5 m/s
- Fire fighting demand
  - 30 m^3/h at modern buildings
  - More at special buildings
  - Max 50 m distance to buildings

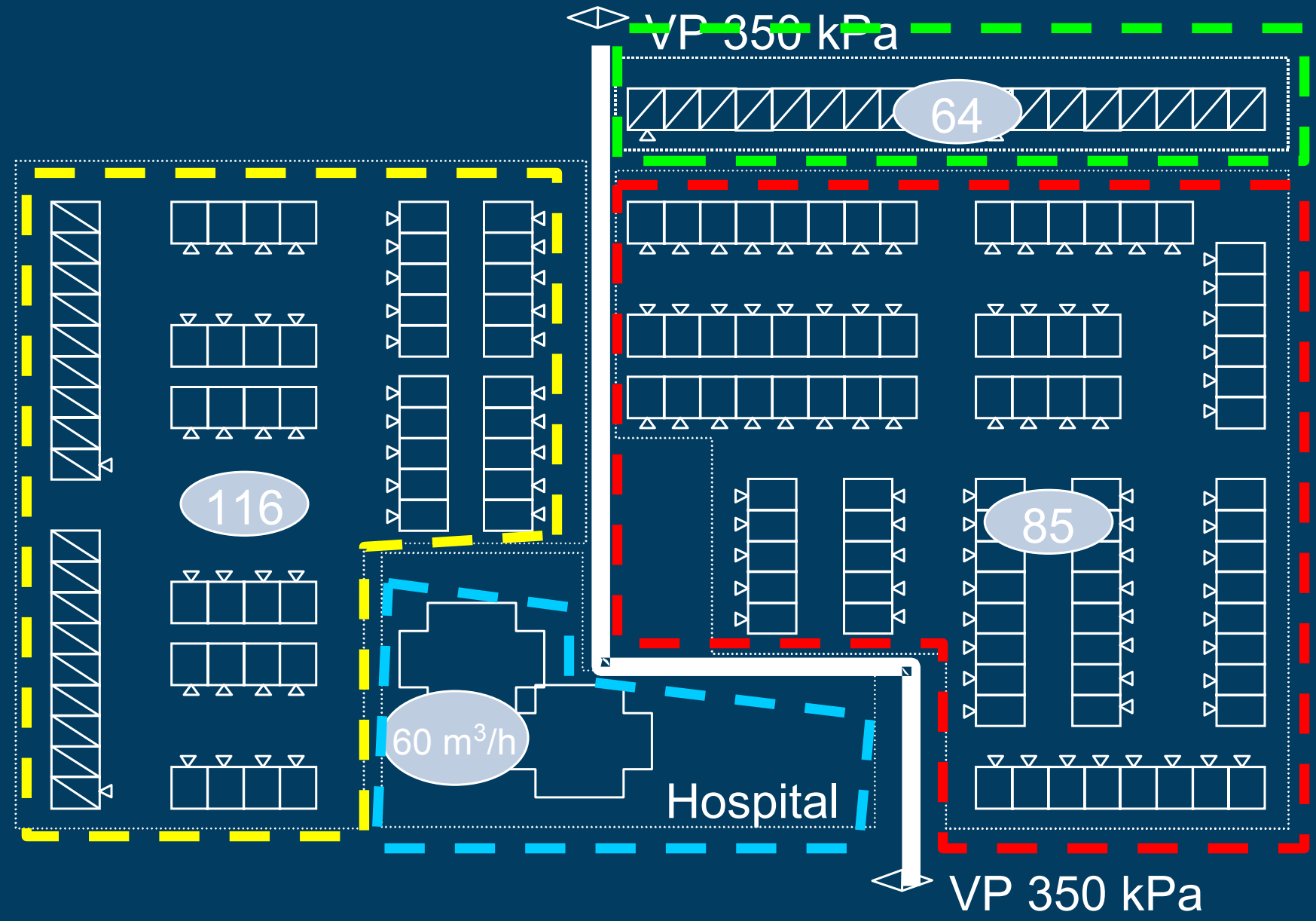
“Pipe table”

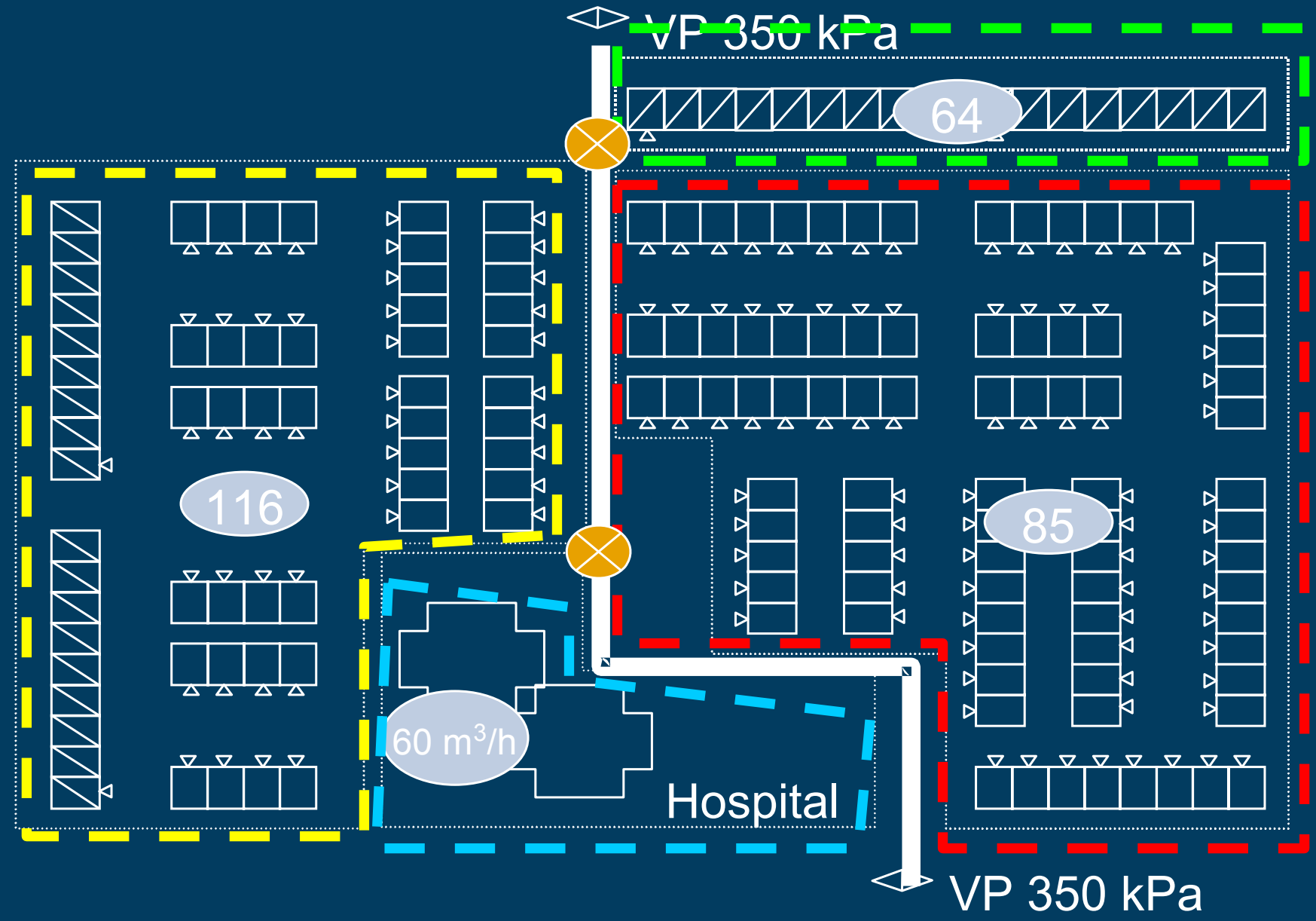
Diameter pipe	# houses (TU=22)
40	1
50	3
63	7
75	15
90	32
110	68

$$\sqrt{n} = \frac{v \cdot \frac{1}{4} \cdot \pi \cdot D^2}{0{,}083 \cdot 10^{-3} \sqrt{TU_{house}}}$$

$v_{max} = 1.5$ m/s

$v_{min} = 0.4$ m/s


VP 350 kPa
64
116
85
60 m3/h
Hospital
VP 350 kPa


VP 350 kPa
64
116
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Hospital
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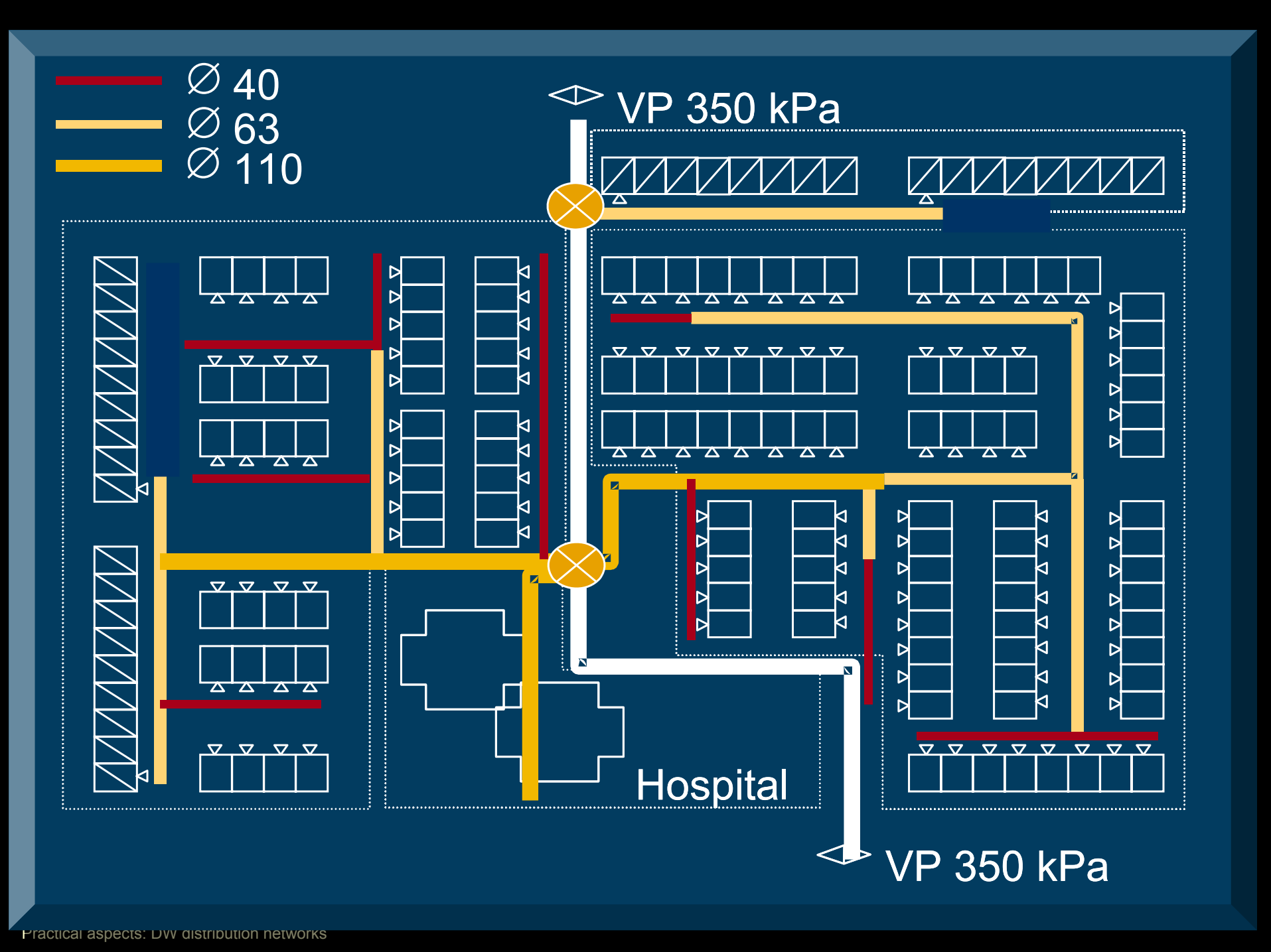
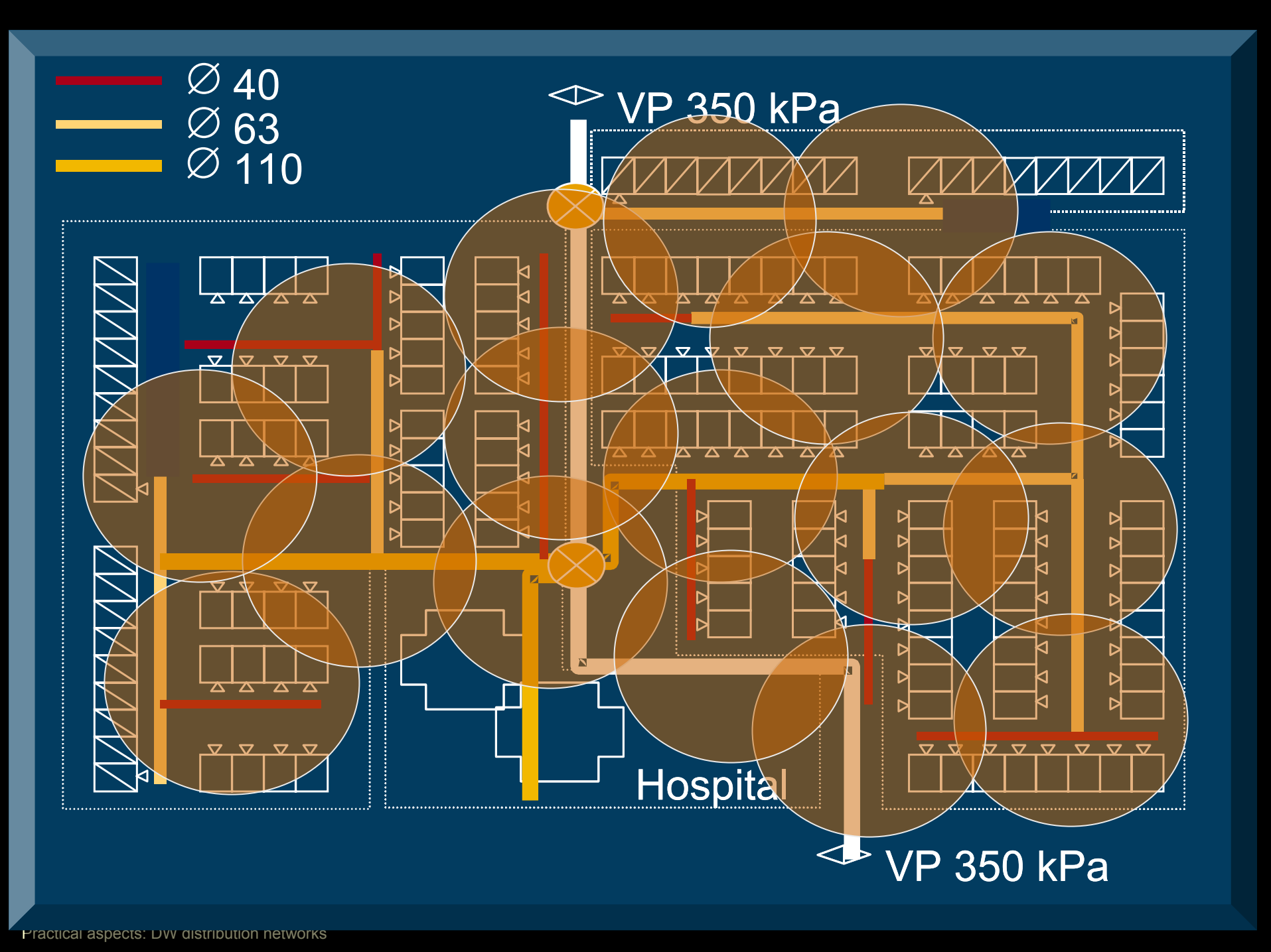
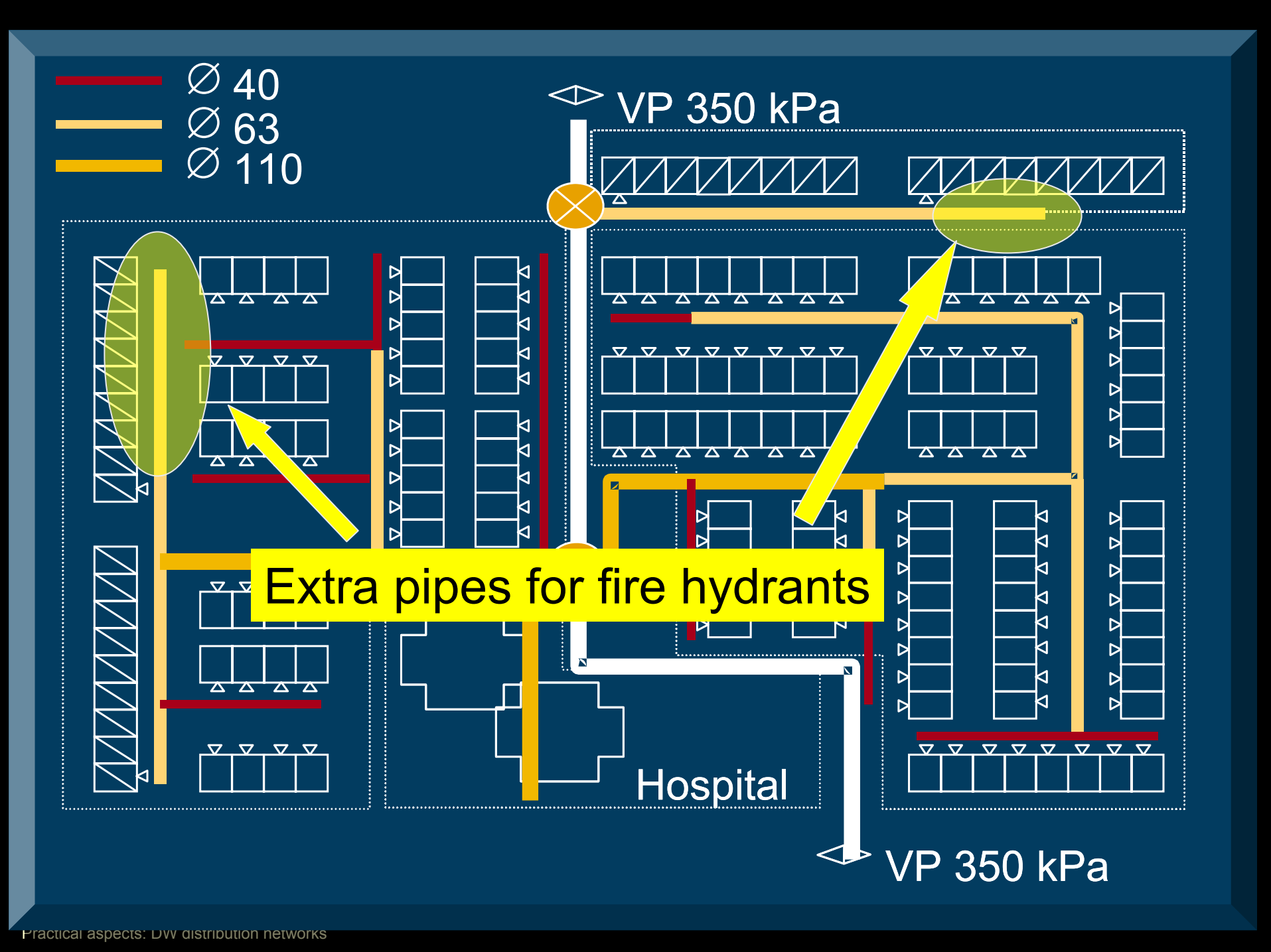
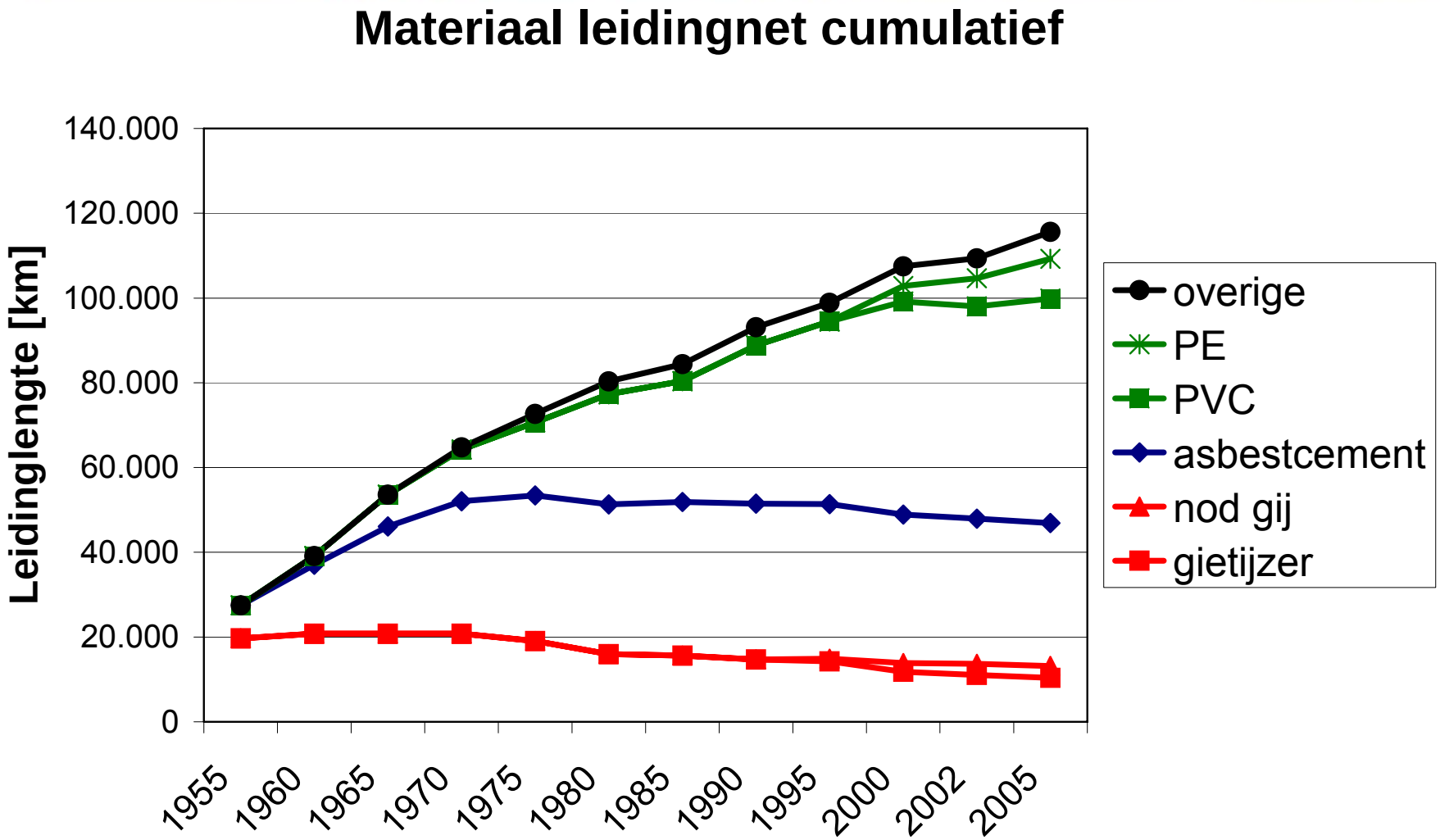

Ø 40
Ø 63
Ø 110
VP 350 kPa
Hospital
VP 350 kPa

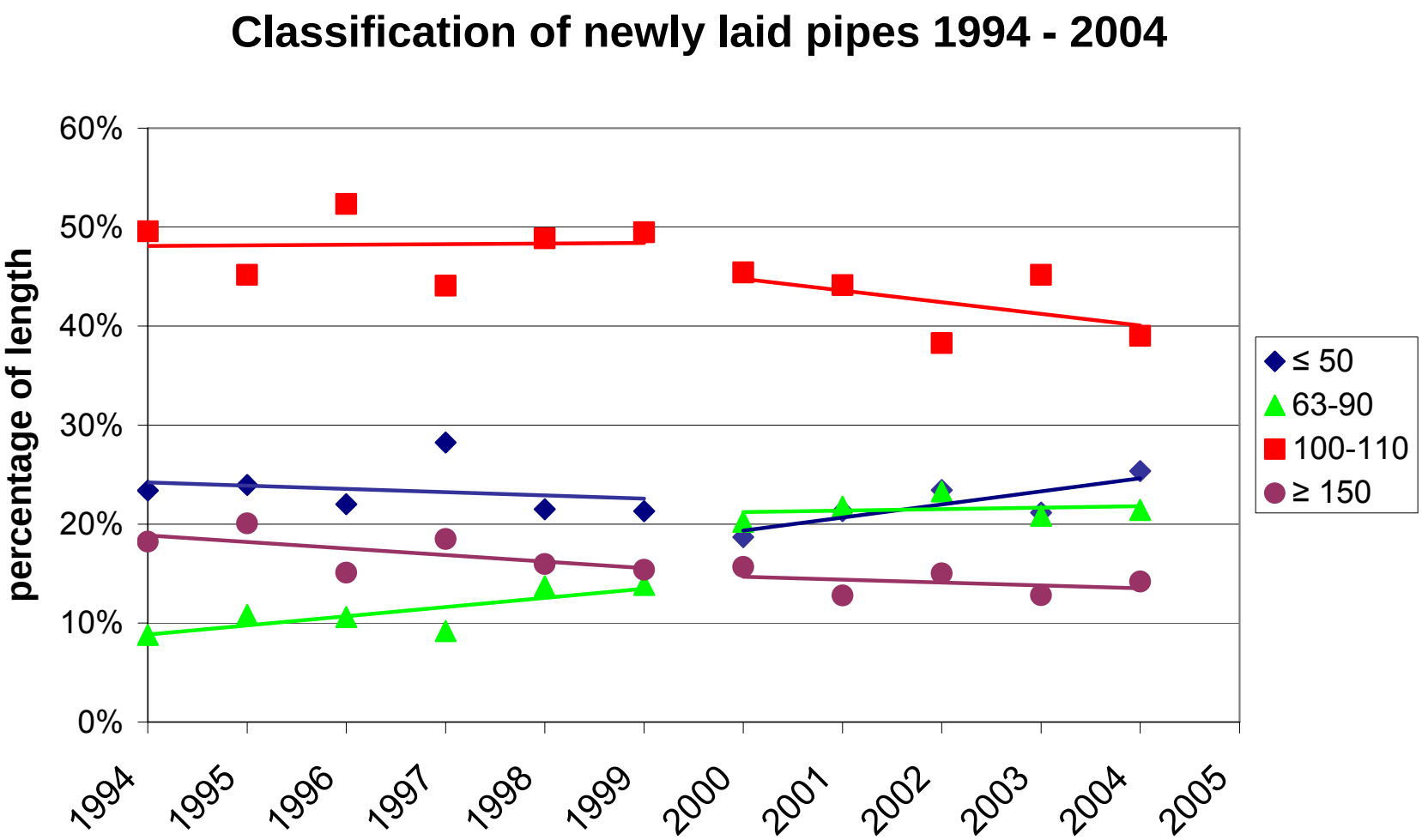

Ø 40
Ø 63
Ø 110
VP 350 kPa
Hospital
VP 350 kPa


Ø 40
Ø 63
Ø 110
VP 350 kPa
Extra pipes for fire hydrants
Hospital
VP 350 kPa

Network composition



Classification newly laid pipes in the Netherlands



Proving the concept of self cleaning networks

Measurement locations – area 1

- **Branched PLUS network, 2nd generation – small diameters**

	Internal diameter (mm)	Minimum # of houses
ZPE 40	35,2	1
ZPE 50	44,0	4
U-PVC 63	58,2	12
U-PVC 90	83,0	46
U-PVC 110	101,6	100
U-PVC 160	147,6	250

Based on:

$Q = 0.083 \cdot \sqrt{15} \cdot N$

$v_{design} = 0.4$ m/s

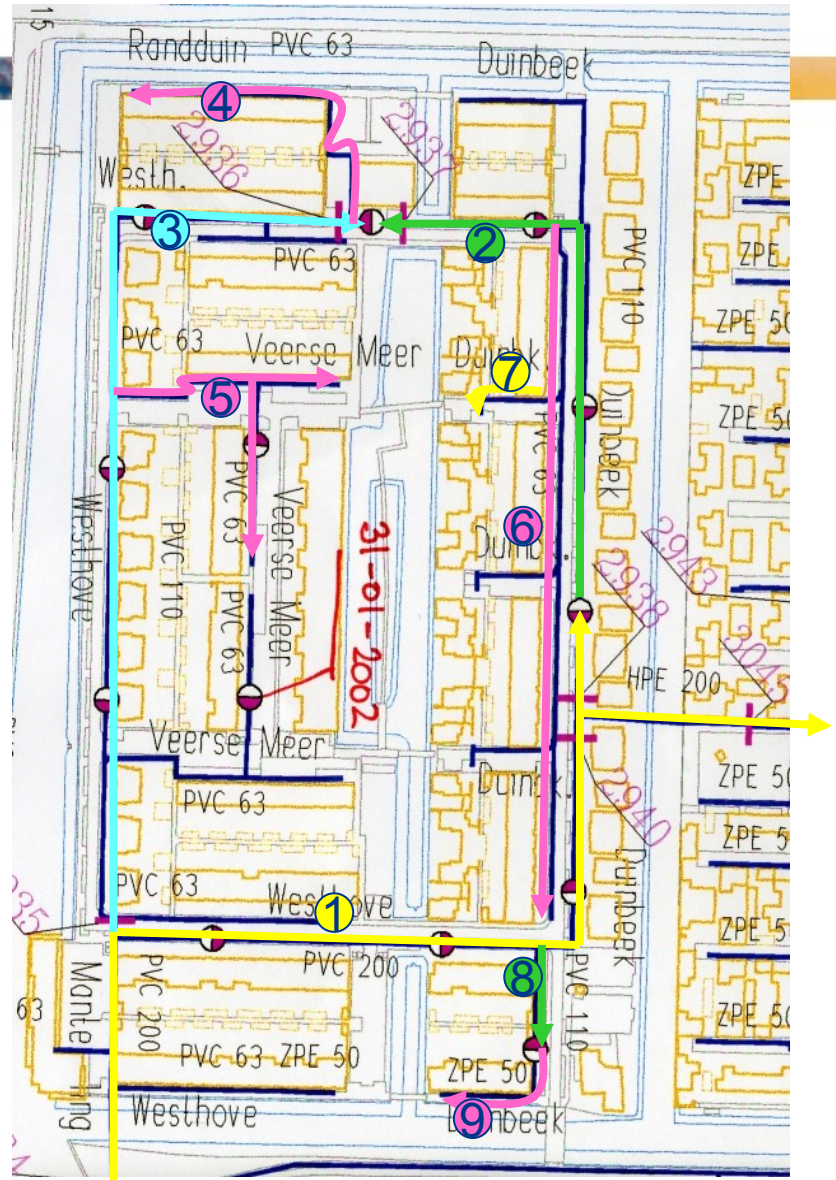
Q-measurement

Particle counters

Flushing point

Measurement locations – area 2

- Branched network, 1st generation, larger diameters



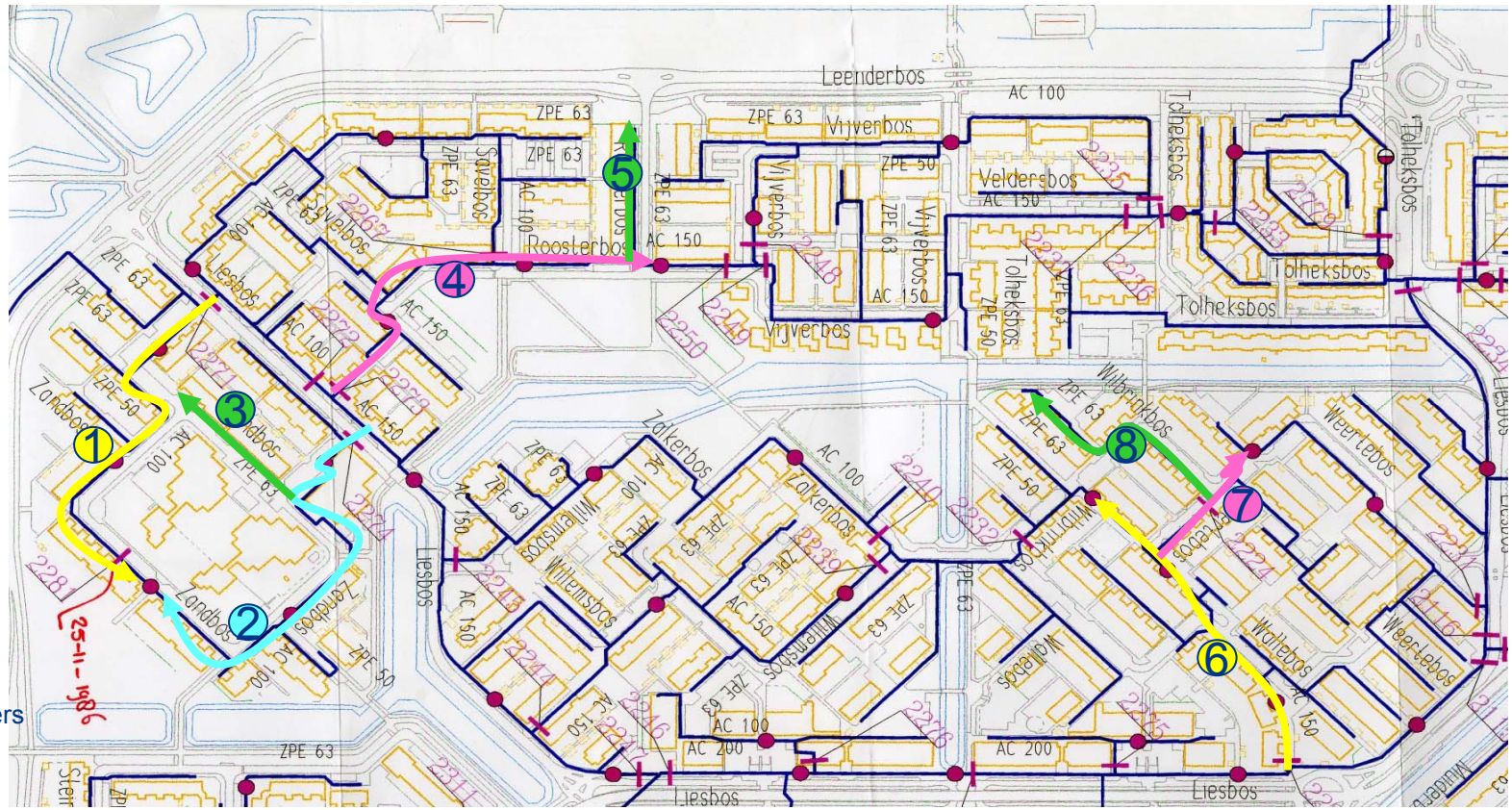
Q-measurement

Particle counters

Flushing point

Measurement locations – area 3

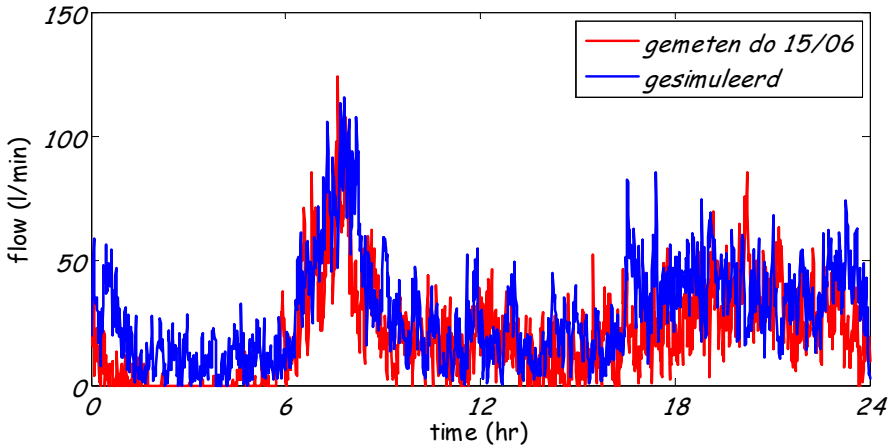
- **Looped network**

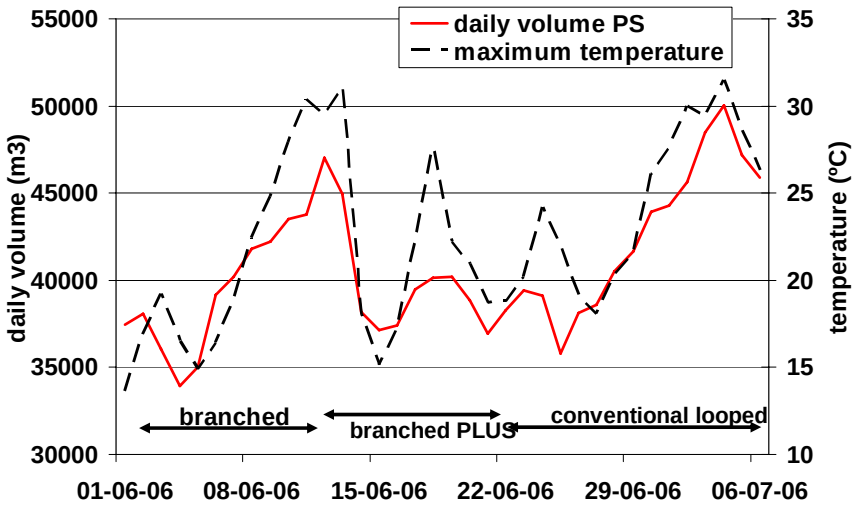


Particle counters

Flushing point

Measurement results – flows

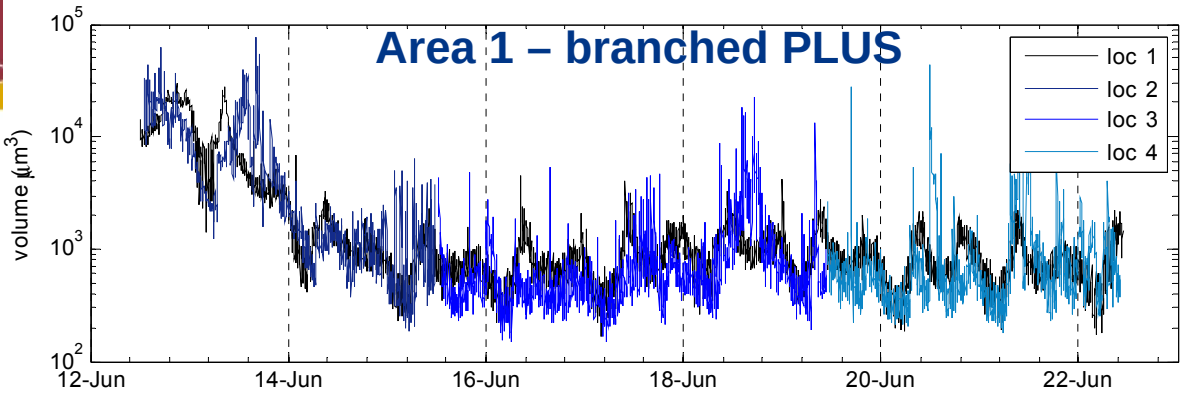




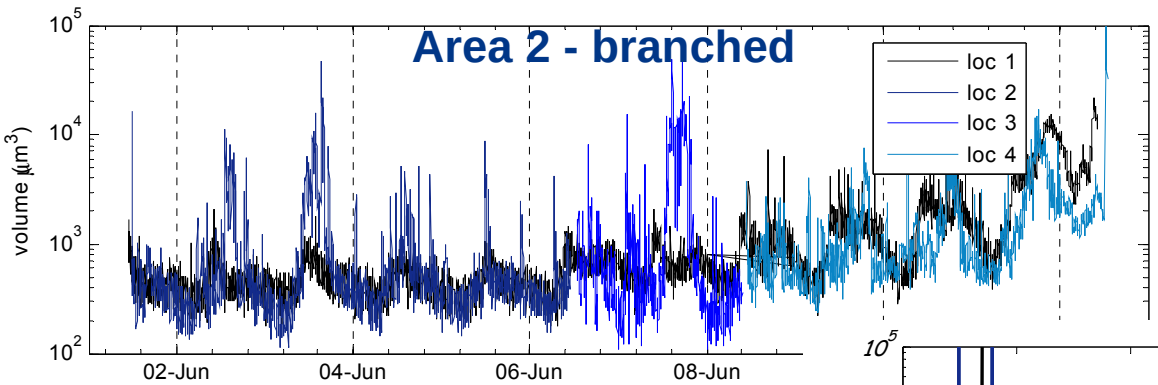
- Q measured in area 1 and 2
- Q simulated with demand model SIMDEUM®

- Extreme temperatures, extreme water uses

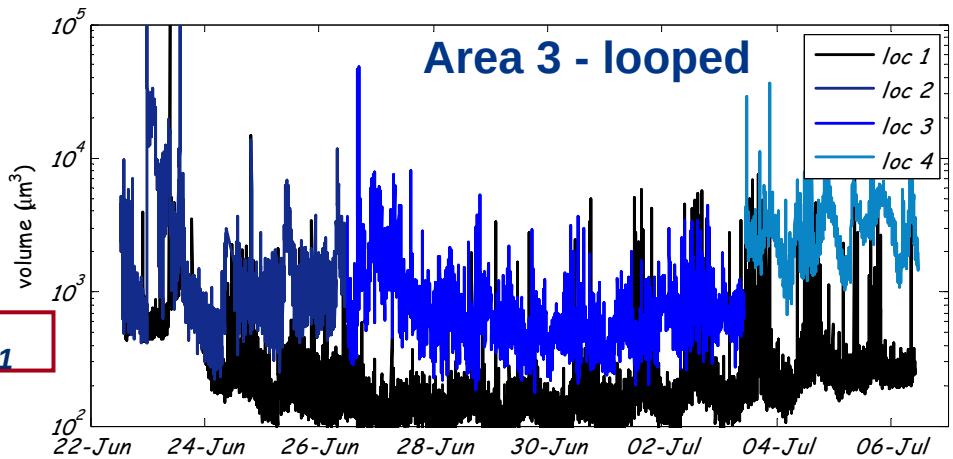
Measurement results– particle counters



$pc_{234} = pc_1$

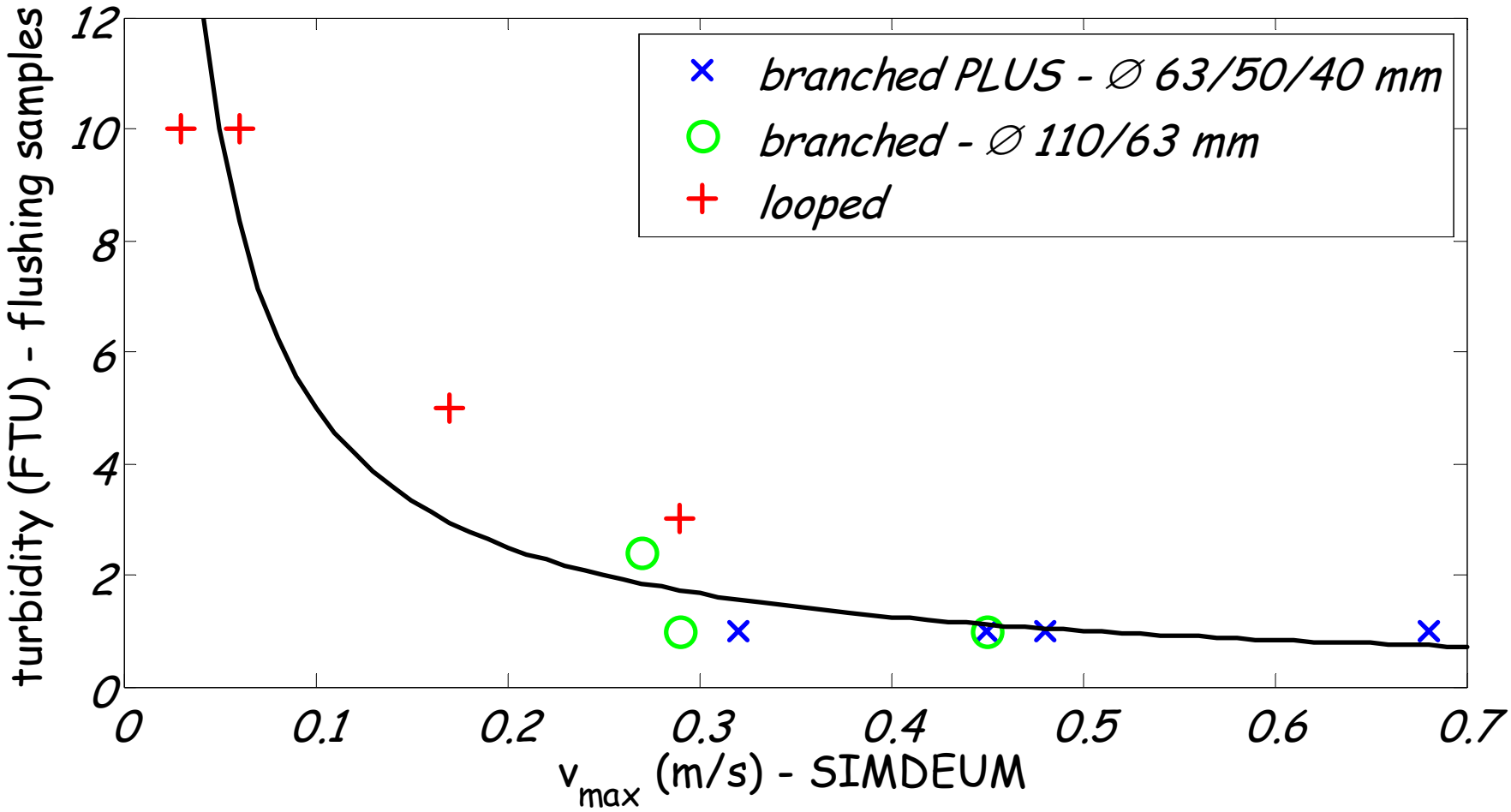


$pc_{234} >= pc_1$



$pc_{234} > pc_1$

Relation velocity - turbidity



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