CIE4491

Lecture. Quantifying stormwater flow – Rational method

27-5-2014

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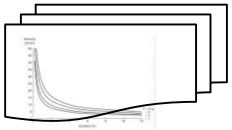
Robust method stationary modelling

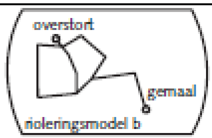
IDF curves



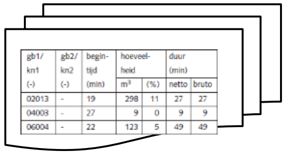
Rainfall runoff modelling

Rational method

Branched networks (few loops)



Stationary hydraulic calculations

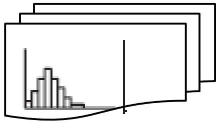


gb1/ kn1 (-)	gb2/ kn2 (-)	begin-tijd (min)	hoeveel-heid m³	(%)	duur (min) netto	bruto
02013	-	19	298	11	27	27
04003	-	27	9	0	9	9
06004	-	22	123	5	49	49

Water levels in nodes

Storm event dynamic modelling

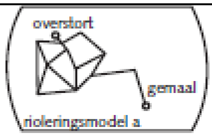
Design storms



Rainfall runoff modelling

Hydrodynamic model calculations

Detailed branched and looped networks

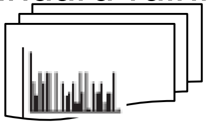


Dynamic hydraulic calculations

Q-t diagram per node per storm event

Rainfall series dynamic modelling

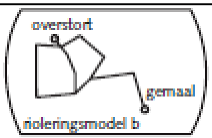
Standard rainfall series



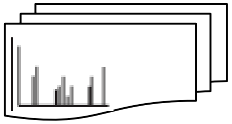
Rainfall runoff modelling

Hydrodynamic model calculations

Simplified branched and looped networks



Dynamic hydraulic calculations



Q-t diagram per node for series of storm events

Rational method for stormwater drainage system design

Rational method: $$Q(t) = C.I.A$$

Q = inflow into manhole (m^3/s)

C = Runoff coefficient, representing runoff losses (-)

I = rainfall intensity (mm/h or l/s/ha)

A = catchment area connected to urban drainage system (m^2)

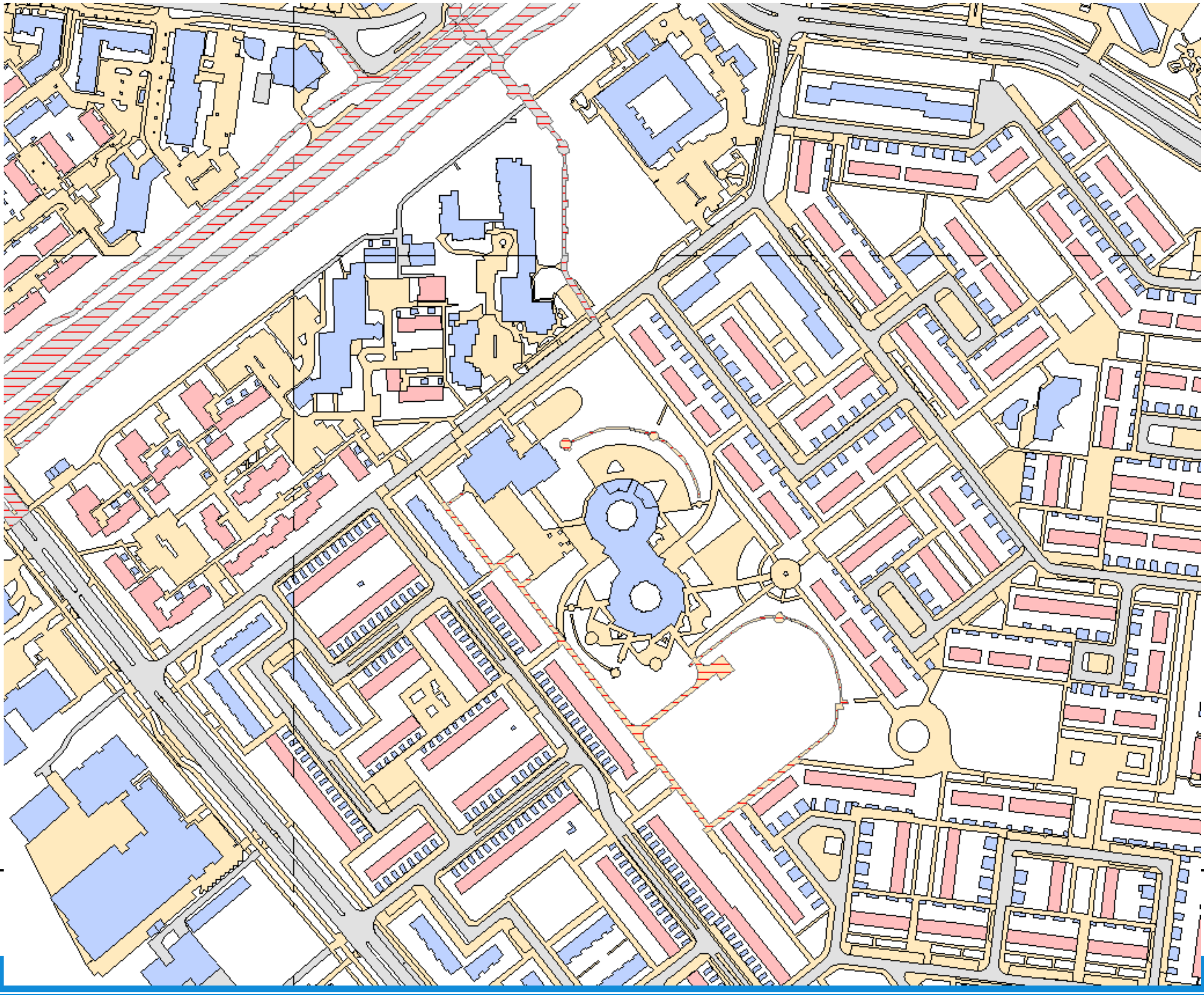
Rational method for stormwater drainage system design

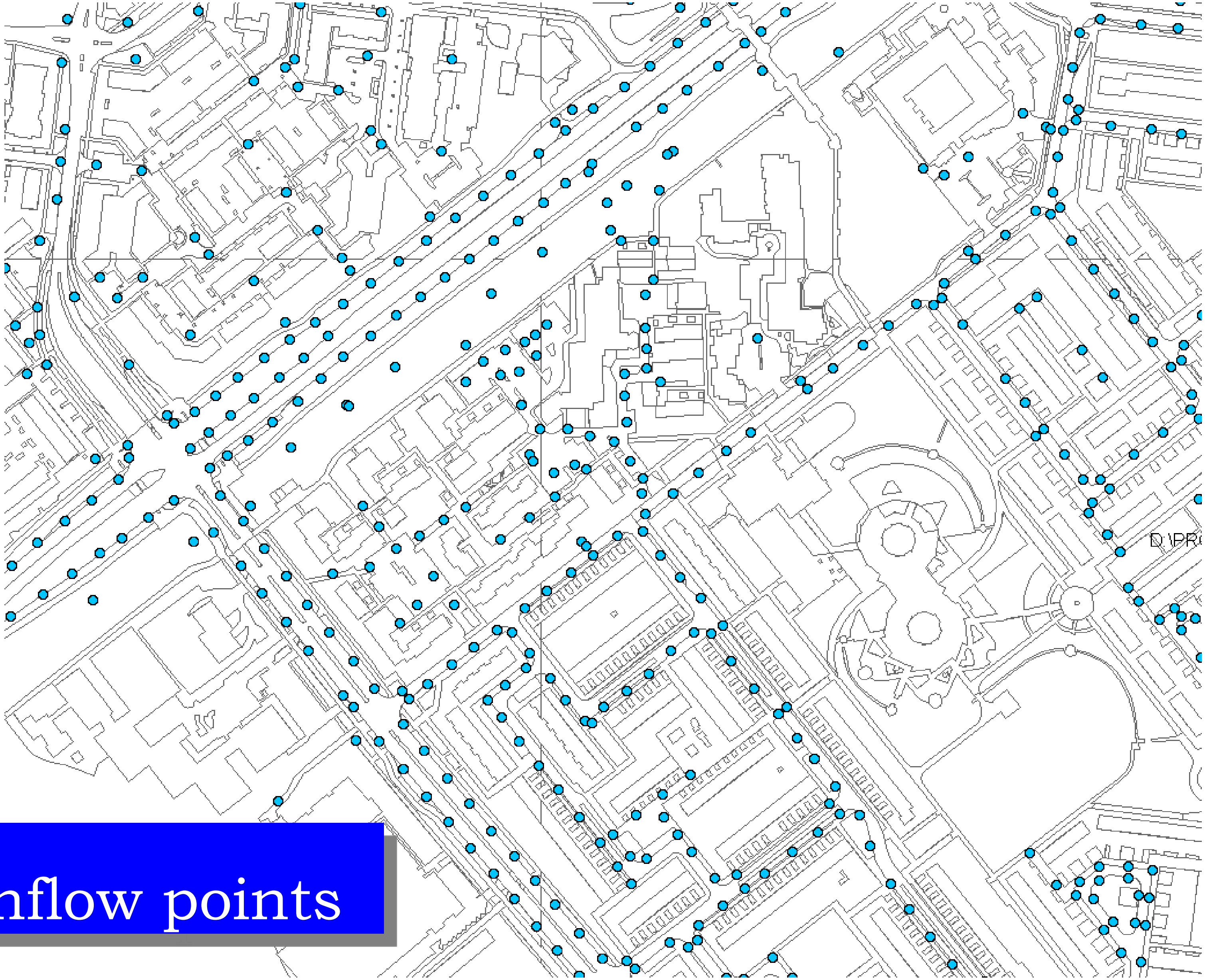
Rational method: $Q(t) = C.I.A$

1. Determine size and characteristics of subcatchment areas
2. Determine runoff coefficient C for subcatchment areas
3. Calculate concentration time at critical inflow points in drainage system
4. Determine critical rainfall intensity based on concentration time and IDF curve
5. Calculate Q at all critical inflow points

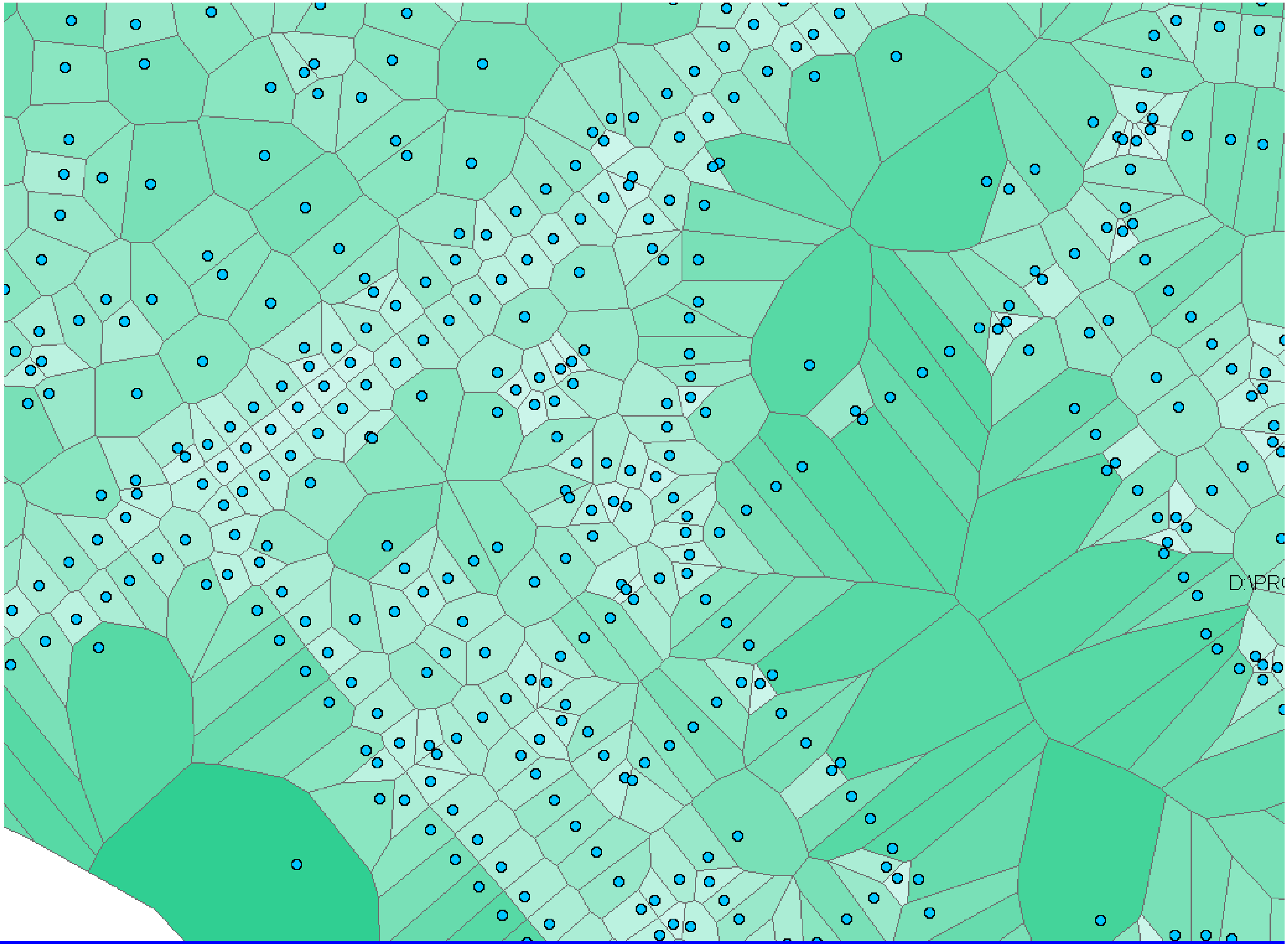
Runoff coefficient C: dependent on catchment type

Flat roofs
Inclined roofs
Impervious area
Pervious area

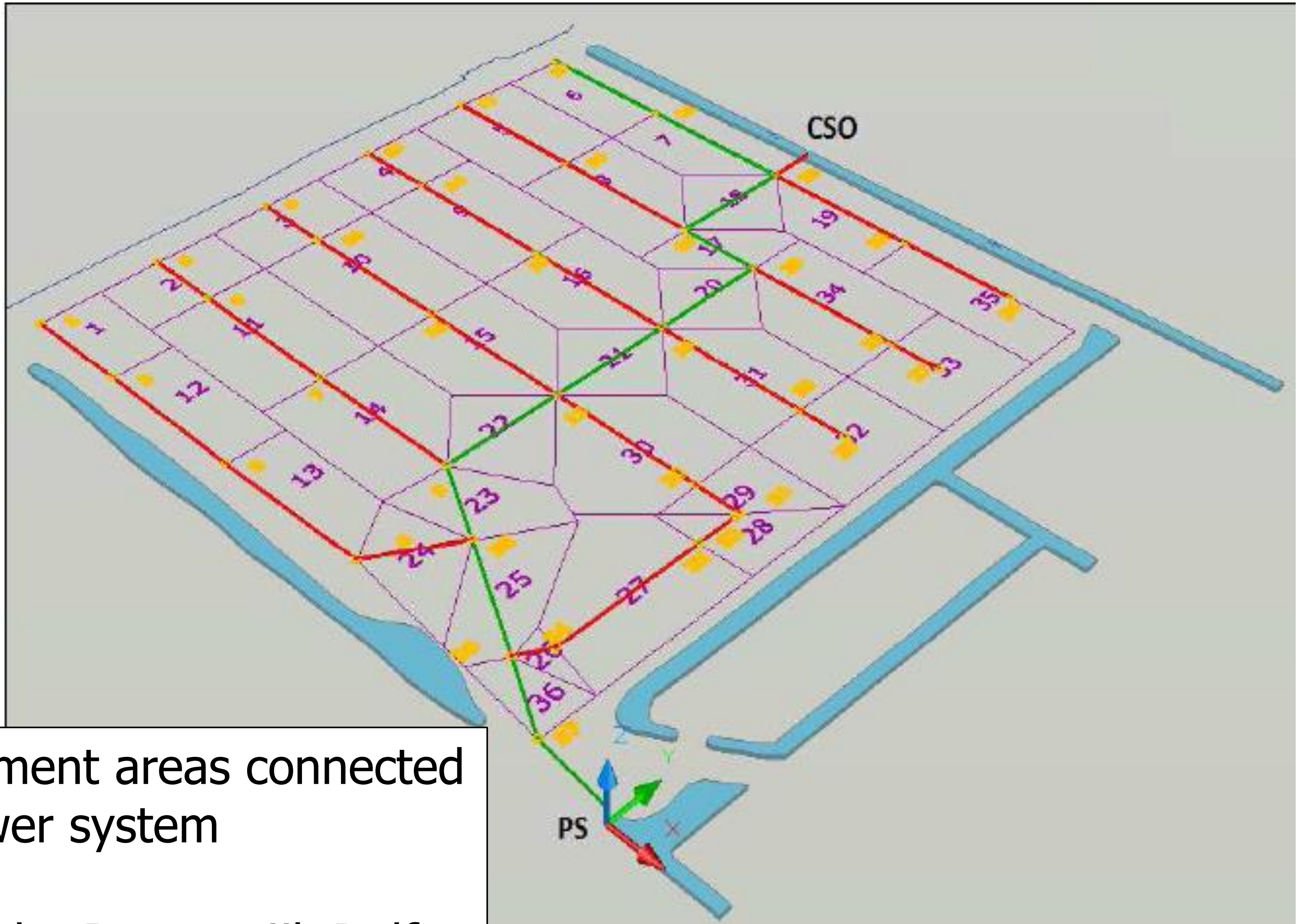




Inflow points



Contributing area per inflow point (manhole)



Catchment areas connected to sewer system

Example: Bomenwijk Delft

Time of concentration

- Time required for surface runoff to flow from remotest part of catchment to inflow point under consideration

- Two components
  - time of entry (t_e)
  - time of flow (t_f)

$$t_c = t_e + t_f$$

Return period (y)	Time of entry (min)
1	4-8
2	4-7
3	3-6

Time of entry & time of flow

- In reality, time of entry varies with
  - surface roughness
  - slope & length of flow path
  - rainfall intensity
- Time of flow depends on
  - Hydraulic properties of pipe – flow velocity
  - Length of flow path

Rational method for urban drainage design

Steady state stormwater flow:

$$Q_n = i \times \sum_{m=1}^{n} C_m A_m$$

Q_n = flow at location with n upstream sections (l/s)

i = **critical rainfall intensity** (l/s/ha (or mm/h)) for return period T and concentration time t

C_m = runoff coefficient of catchment discharging to section m

A_m = catchment area discharging to section m (ha)

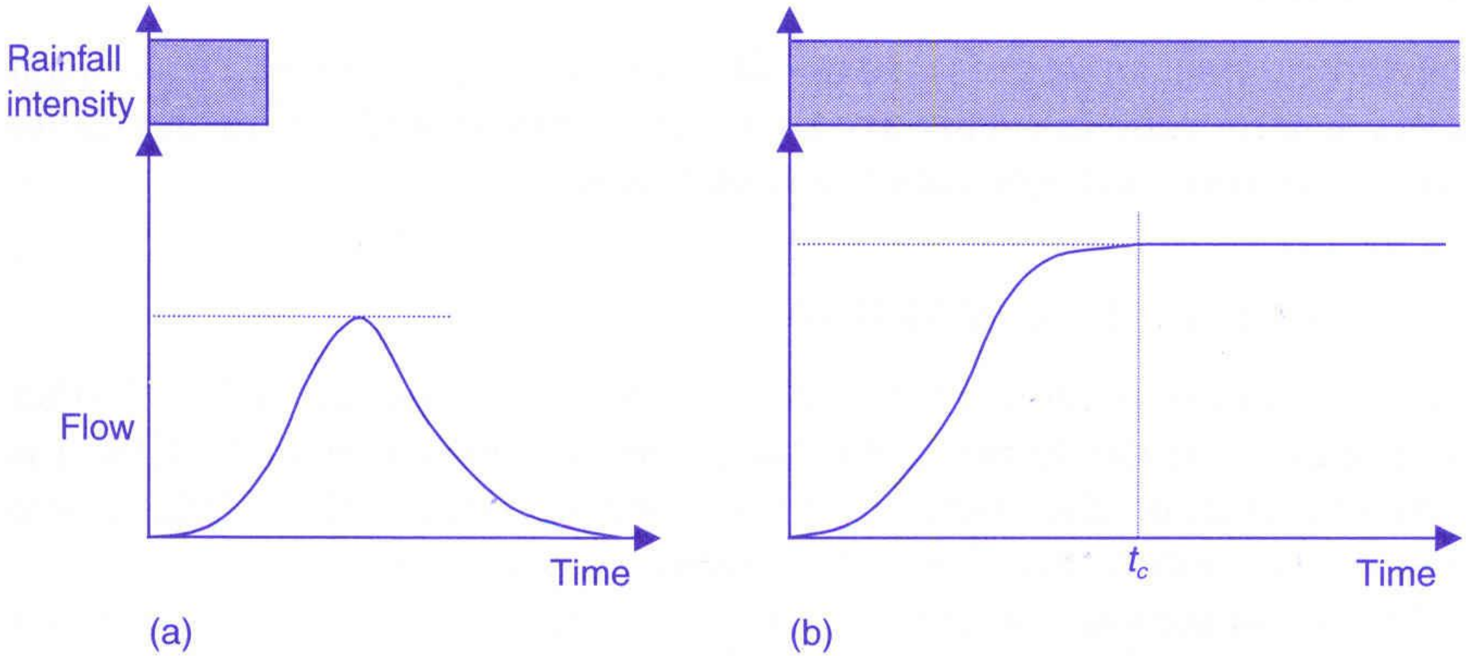
Rational method

Assumptions:

- Rainfall is uniform over the whole catchment area
- Catchment imperviousness remains constant throughout storm
- Flow in the system is at constant velocity throughout t_c
- Steady state flow reached when $t_{storm} \geq t_c$

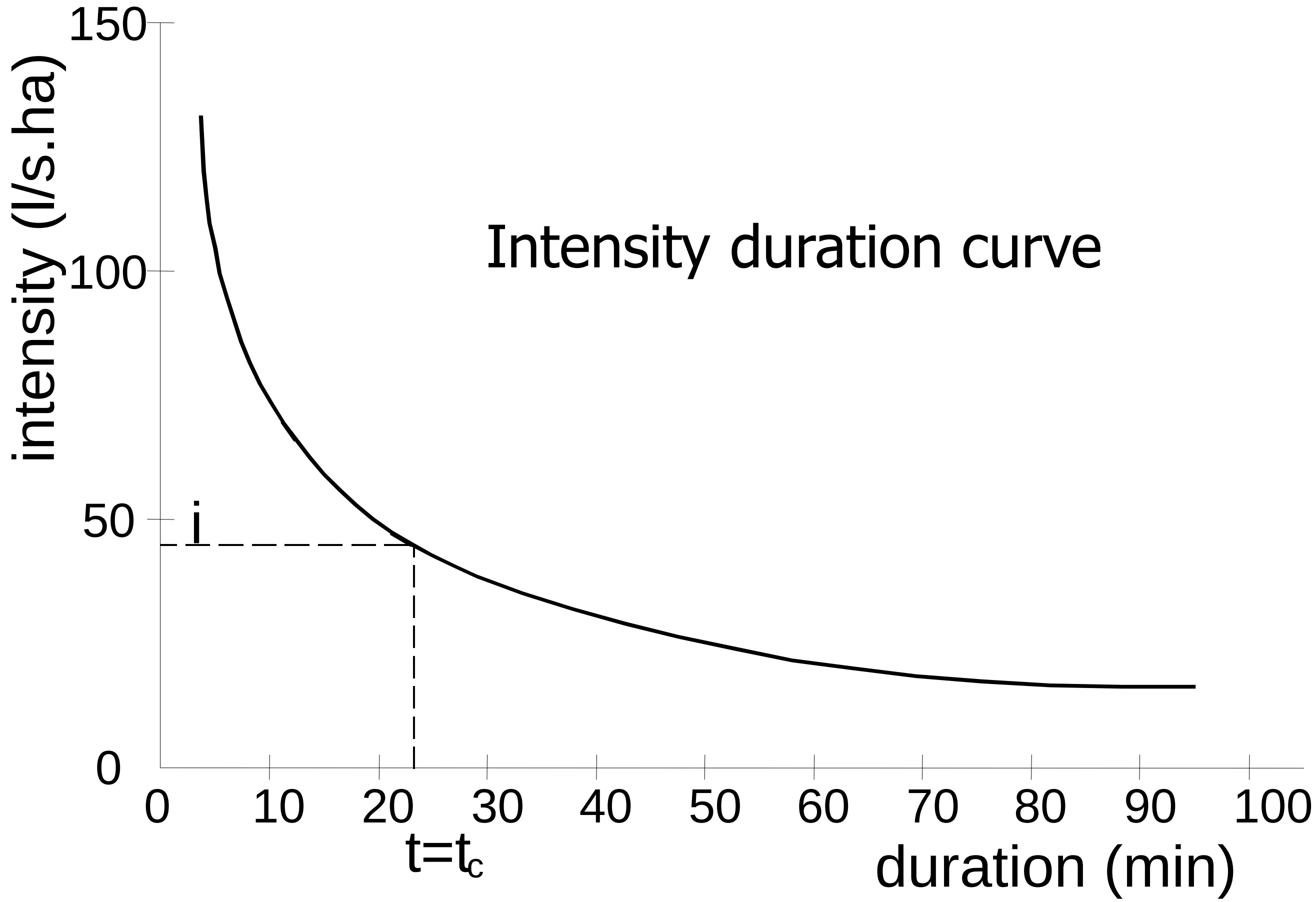
- Critical rainfall intensity for at points in system at time t = t_c

Rational method: stationary conditions



Hydrograph response to continuous rainfall (graph b)

Critical rainfall intensity



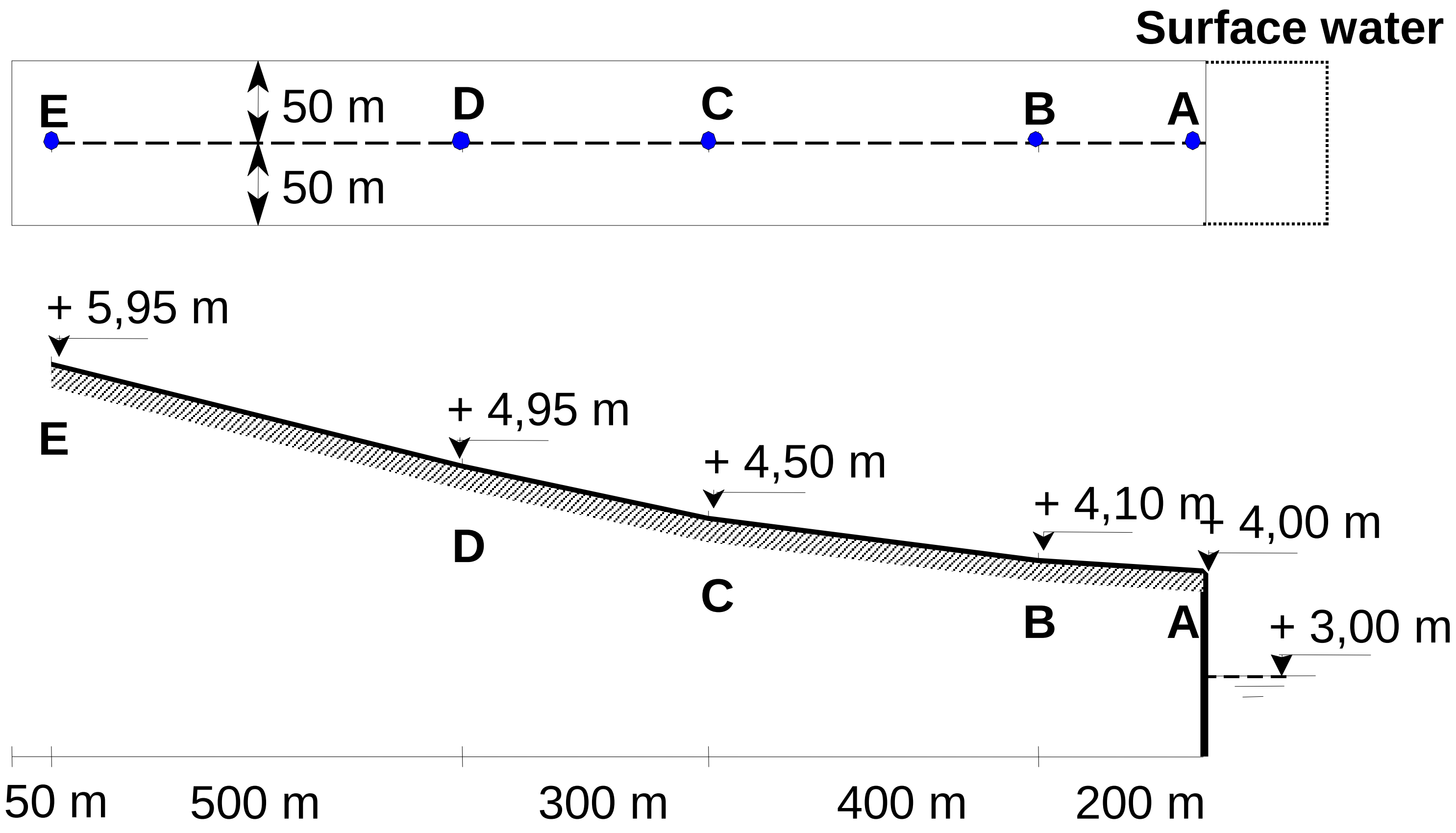
Summary rational method for stormwater system design

- Choose return period of rainfall (T)
- Estimate contributing areas for each pipe and run-off coefficient
- Assume flow velocity of 1 m/s
- Estimate maximum time of concentration (t_c) for connected catchment areas
- Read critical rainfall intensity from IDF curve
- Calculate flow rate in each pipe according to:

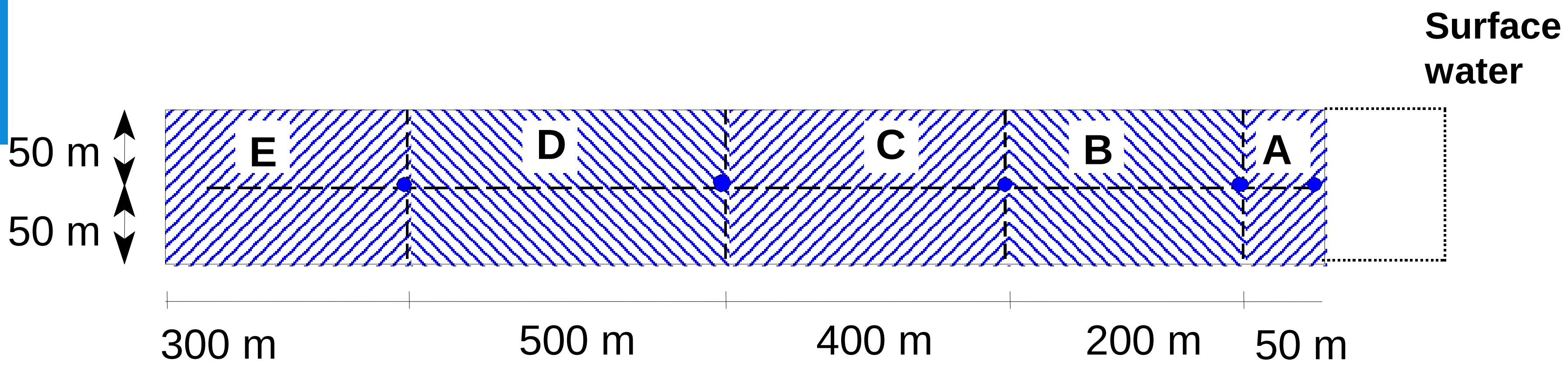
$$Q_n = i \times \sum_{m=1}^{n} C_m A_m$$

- Adjust diameters of pipes if necessary
- Check flow velocity and concentration time

Example: calculate design flow for each node

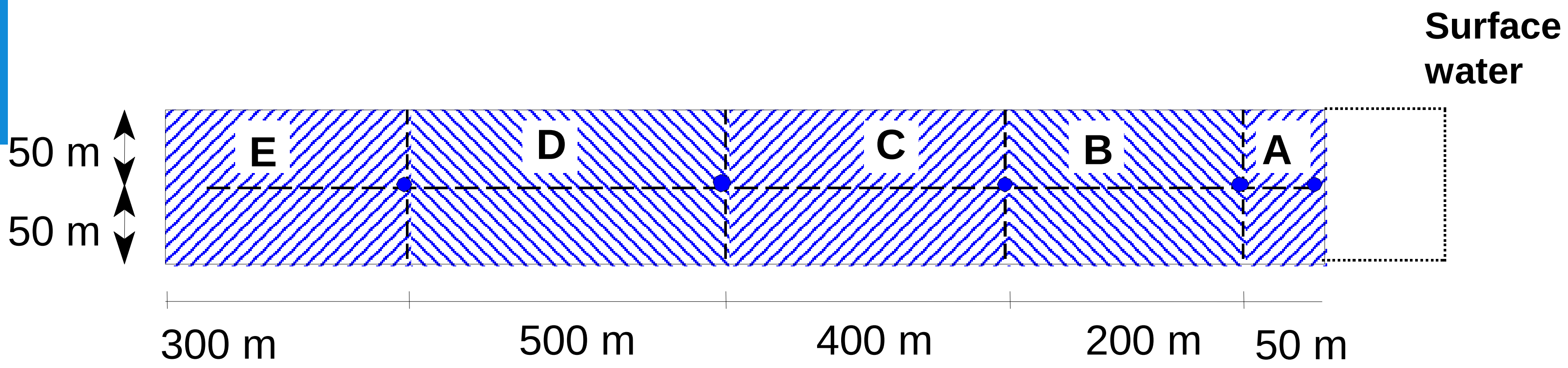


Determine contributing area



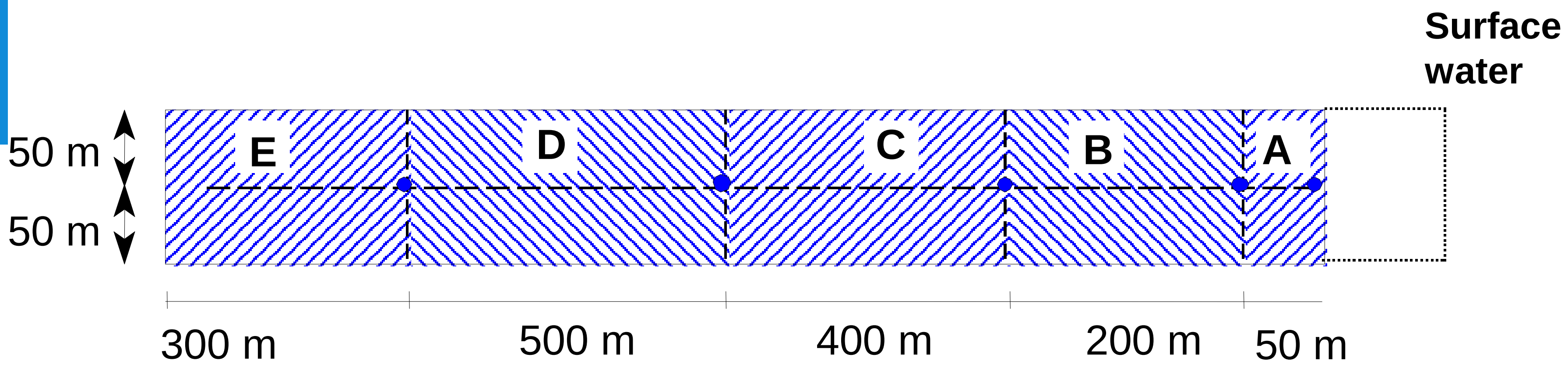
Area	A	B	C	D	E
Area per node (ha)	0.5	2	4	5	3
Impervious area (%)	50	60	40	30	30
Impervious area per node (ha)					
Cum. Area per node (ha)					

Determine contributing area



Area	A	B	C	D	E
Area per node (ha)	0.5	2	4	5	3
Impervious area (%)	50	60	40	30	30
Impervious area per node (ha)	0.25	1.2	1.6	1.5	0.9
Cum. Area per node (ha)	5.45	5.2	4.5	2.4	0.9

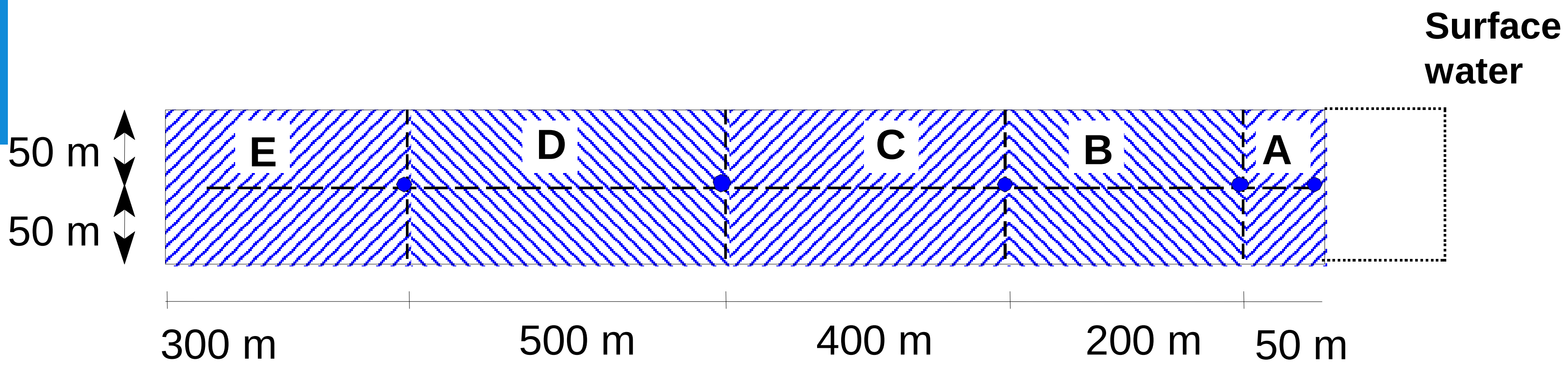
Time of concentration



Assume flow velocity 1 m/s

Area	A	B	C	D	E
Time of concentration (min)					

Time of concentration

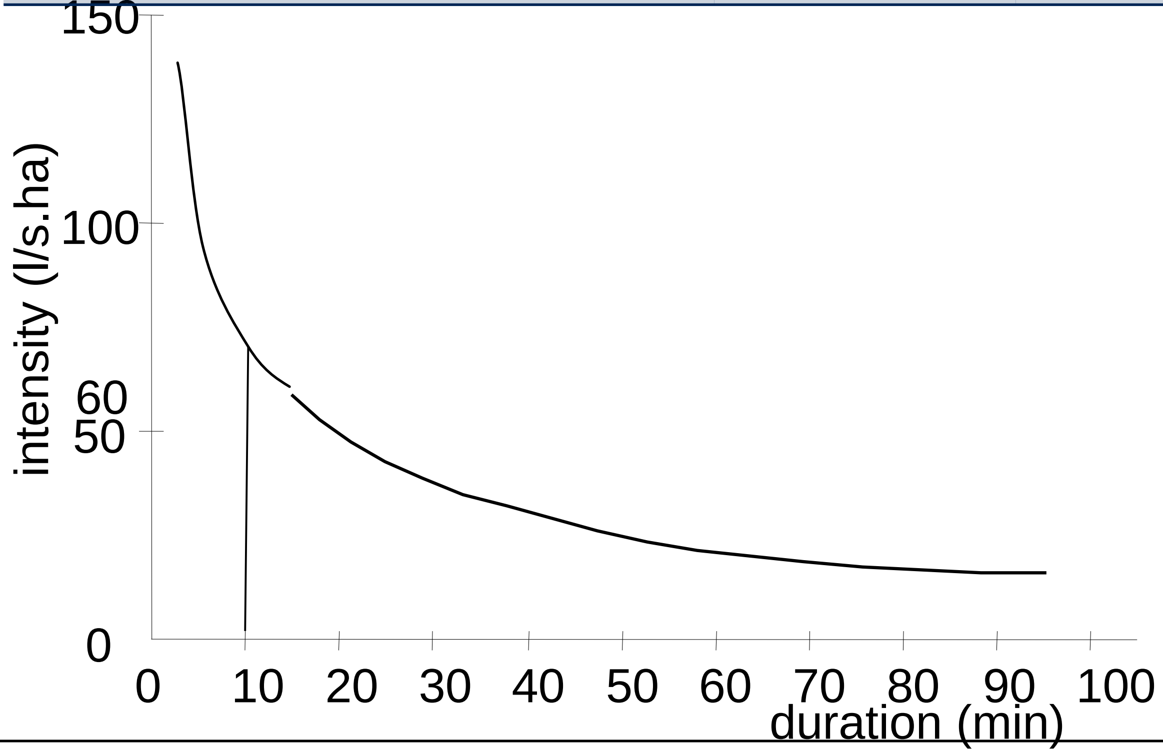


Assume flow velocity 1 m/s

Area	A	B	C	D	E
Time of concentration (min)	29	28	25	18.3	10

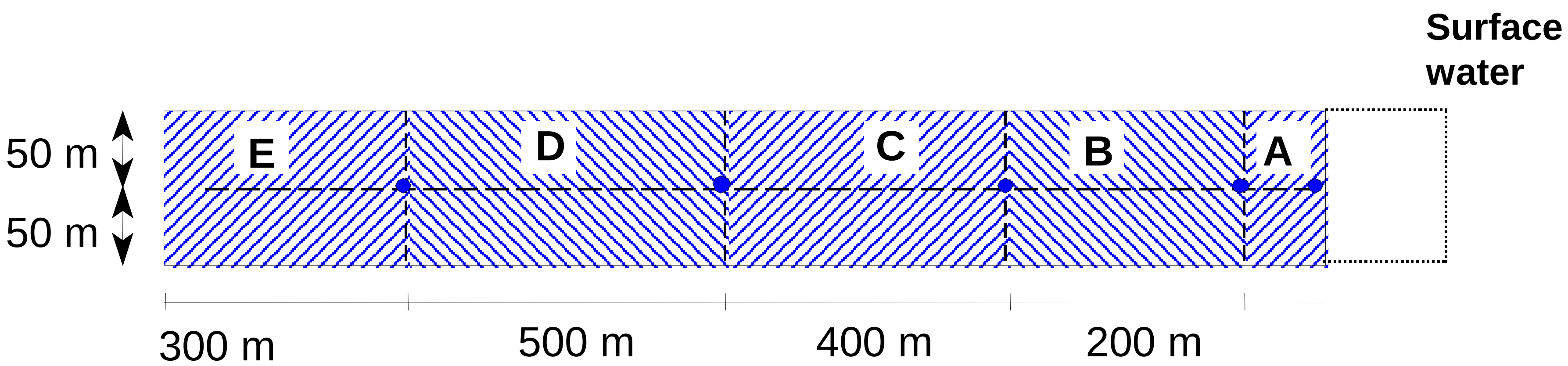
Critical rainfall intensities from IDF curve

Area	A	B	C	D	E
Time of concentration (min)	29	28	25	18.3	10
Rainfall intensity (l/s/ha)	40	40	45	50	70



Design flow for each node

Area	A	B	C	D	E
Time of concentration (min)	29	28	25	18.3	10
Rainfall intensity (l/s/ha)	40	40	45	50	70
Cumulative area (ha)	5.45	5.2	4.5	2.4	0.9
Design flow (l/s)	218	208	202	120	63



Rainwater flow, remember:

- Highly variable (0 – extreme): no system can cope with all possible rainfall intensities
- High rainfall intensity is critical
- Stormwater flow is large compared to wastewater flow
- Translation into design values : statistics and assumptions