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Working with water

# Methods to estimate flood flows

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# Estimating flows

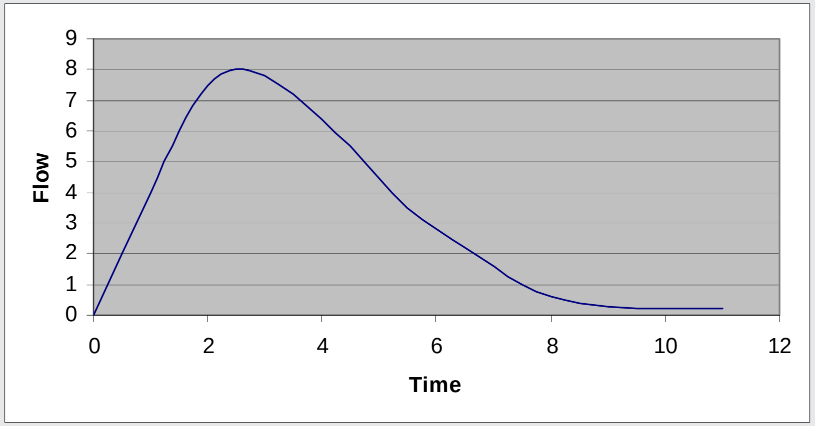
Estimates of peak flows (magnitude)

Statistics

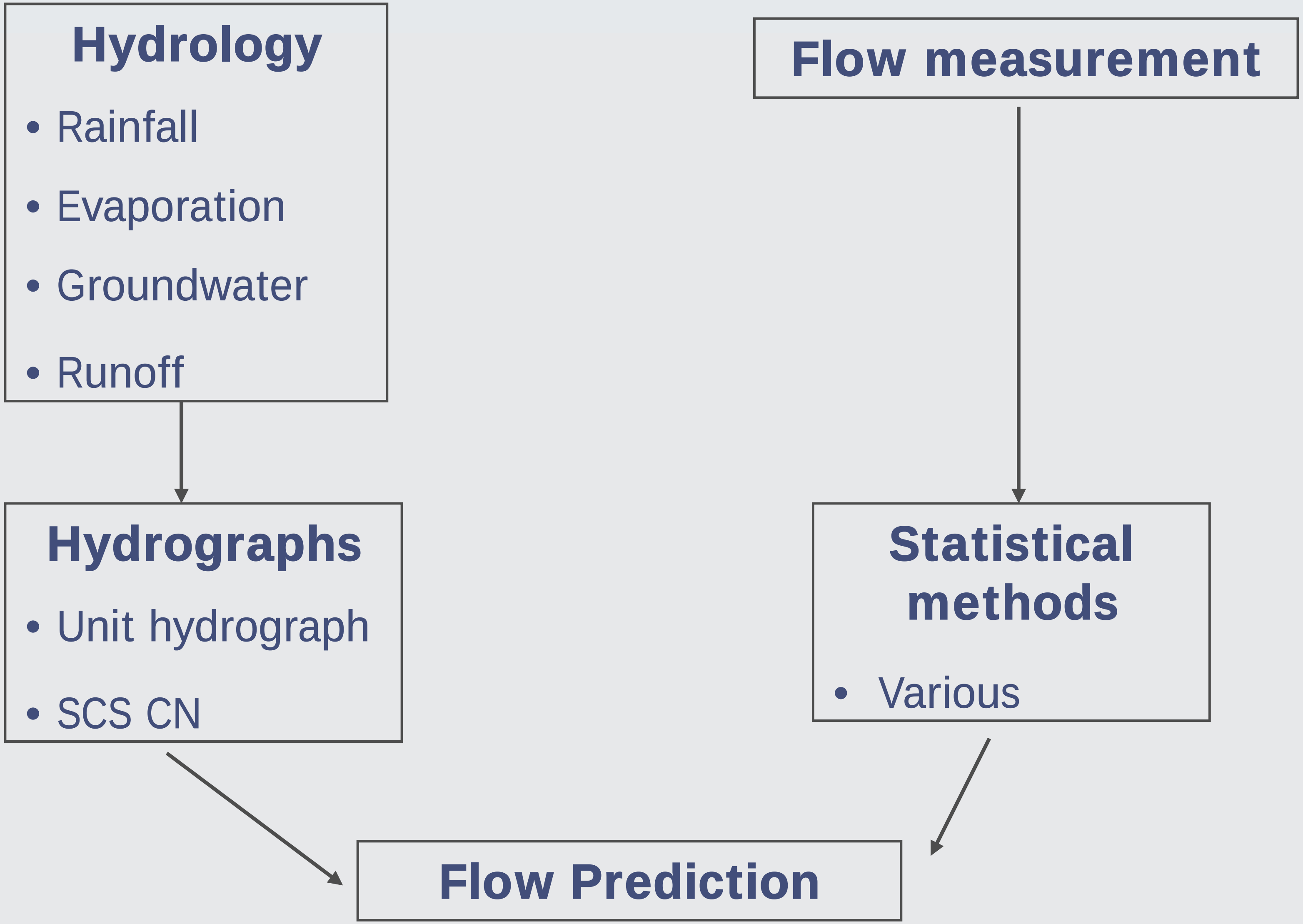
e.g. peak flow during extreme event

Prediction of timing, shape and volume (hydrograph)

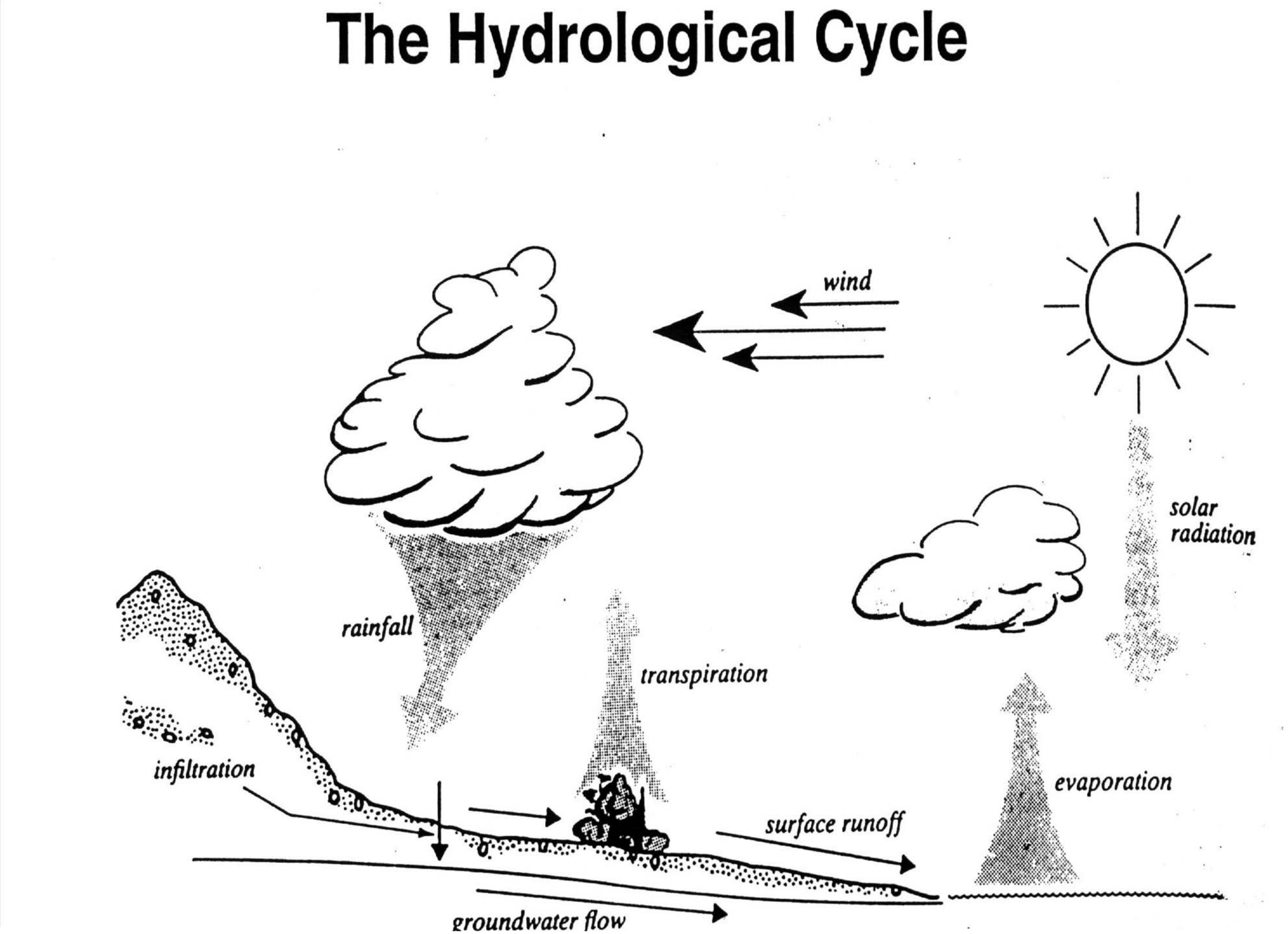
Hydrological rainfall-runoff modelling



# Hydrology and flow estimation



# The hydrological cycle



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# Hydrological modelling

Nature of flood-producing system is complex interaction of:

> Atmosphere

> Land geology

> Vegetation

> Geomorphology

> Soils

> Activities of mankind

# Therefore...

Modelling can only provide generalised estimates

Local information on observed floods is essential to calibrate models

Best information on future flood magnitudes is obtained from historical records

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# STATISTICAL METHODS

# Return period

The return period, T, is the average interval (in years) between years containing a flood exceeding a given magnitude

The flood with return period T is referred to as the T-year flood

The probability, P, of a T year flood happening in any one year is (1/T)

# Statistical analysis of data (1)

Produces flood estimates based on recorded historical pattern of runoff events

1) Select ‘annual maximum’ floods from the period of record

> Ensure ‘independence’

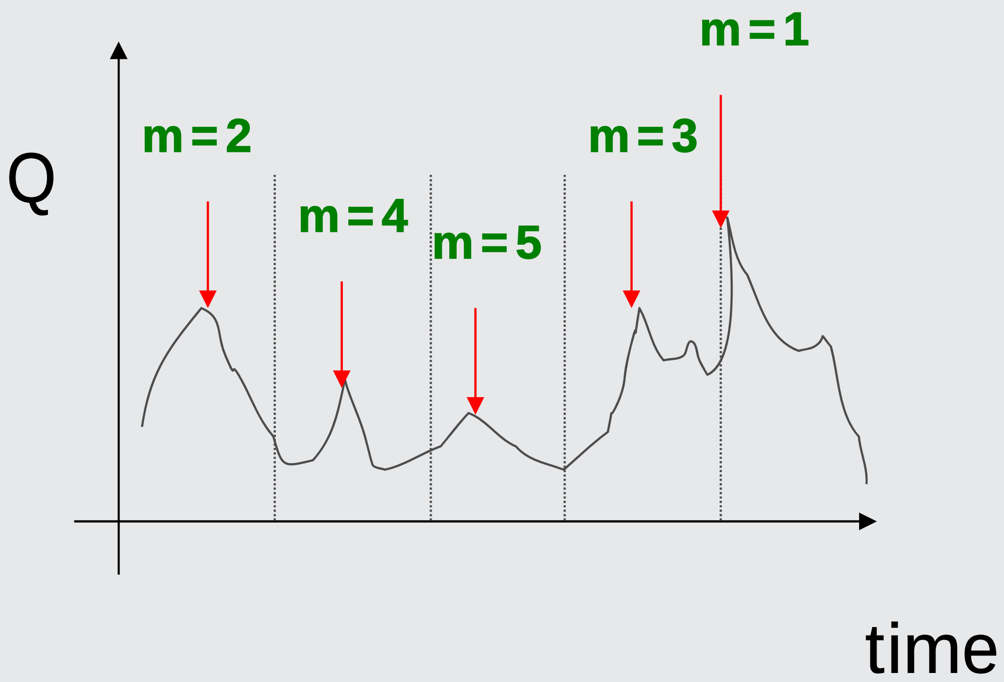
> Use ‘water’ years

2) List events in descending order, and give rank, ‘m’

3) Count total number of events in series = ‘n’

# Statistical analysis of data (2)

n = 5



# Statistical analysis (3)

> Probability ‘P’ associated with each event can be computed from a number of formulae e.g. Gringorton:

$$P = \frac{m - 0.44}{n + 0.12}$$

> To predict flows for any return period, need a graph

> But… plotted on graph paper, P against Q is unlikely to follow a straight line.

> Several theoretical distributions have been proposed e.g. Gumbel, Generalised Logistic

# Statistical analysis (4)

> If, instead of plotting 'P' against Q, you plot the 'reduced variate' 'y' against Q

where $y = -\ln(-\ln)(1-P)$

> Then (for Gumbel), the points should be a straight line

> Extrapolate line to predict design floods

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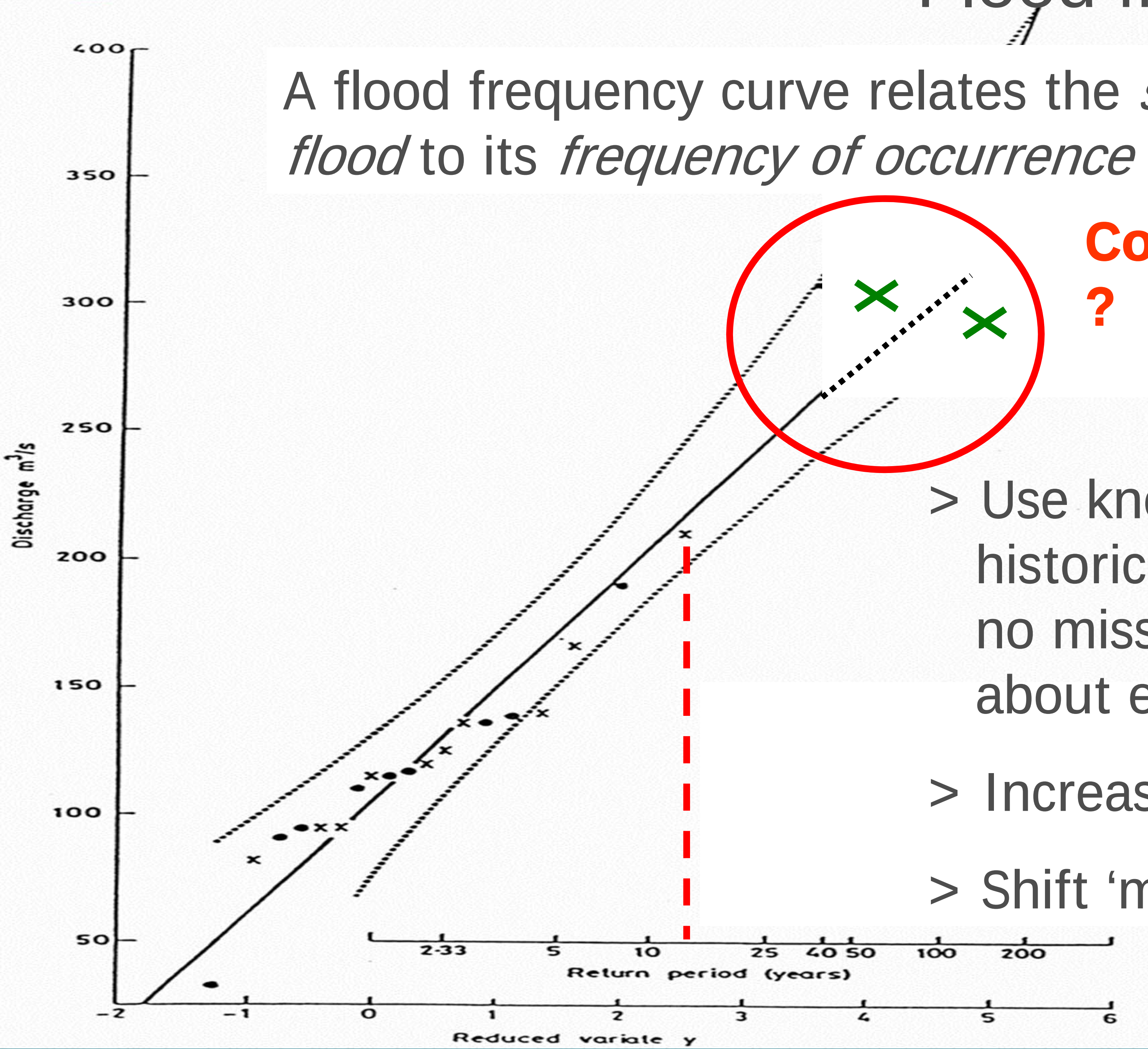
# Flood frequency plot

A flood frequency curve relates the *size of a flood* to its *frequency of occurrence*




**Confidence ?**

- > Use knowledge of historical floods (providing no missing information about extreme floods)
- > Increase 'n'
- > Shift 'm'

# Some useful y values

| | |
|---|---|
| **T = 1000 years** | **y = 6.91** |
| **T = 100 years** | **y = 4.60** |
| **T = 50 years** | **y = 3.90** |
| **T = 25 years** | **y = 3.20** |
| **T = 10 years** | **y = 2.25** |
| **T = 5 years** | **y = 1.50** |

# Sources of uncertainty

Choice of statistical distribution, fitting procedure etc

Duration of records normally so short that it is difficult to extrapolate with confidence

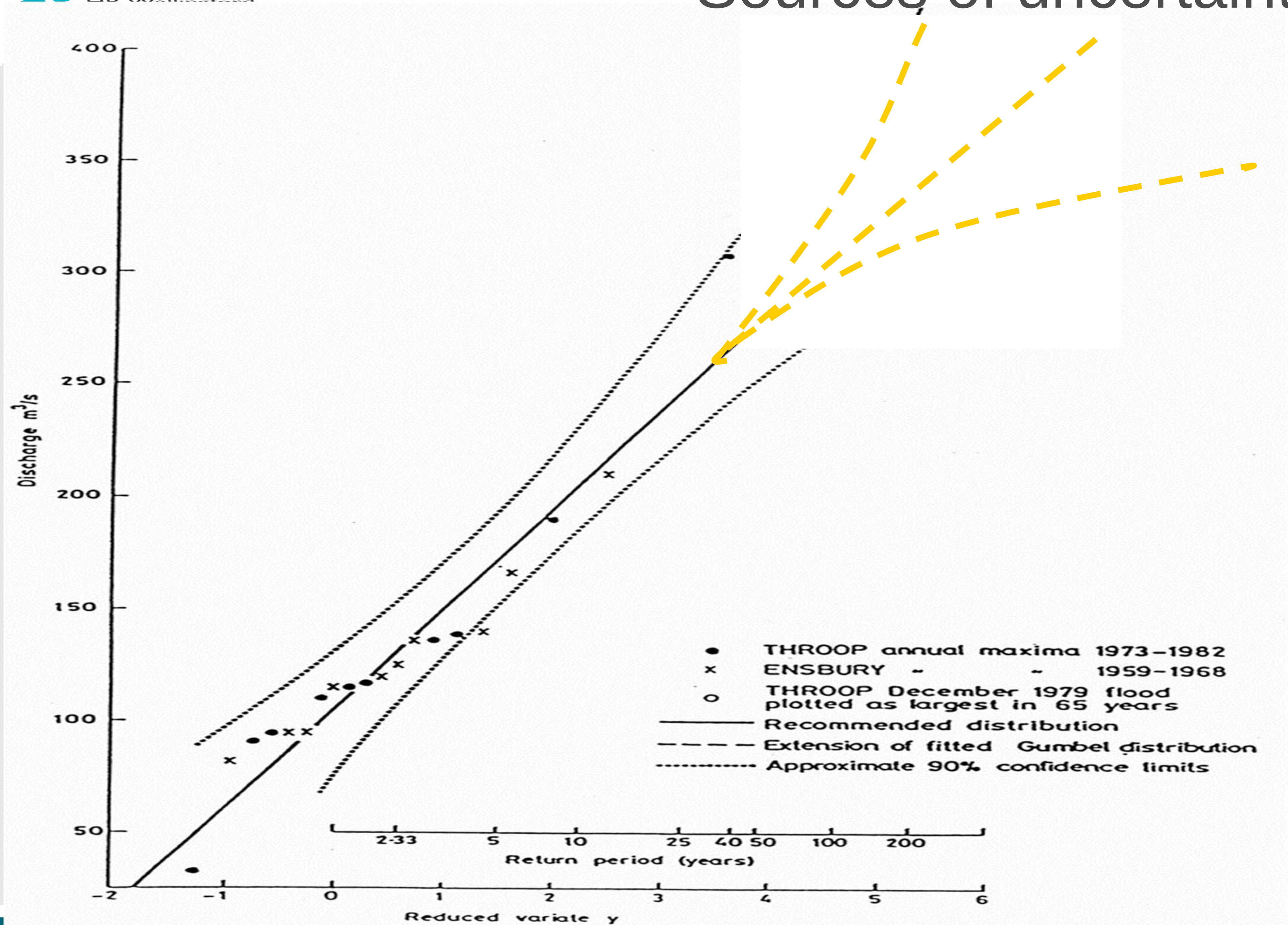
Flow series may not be ‘homogeneous’, e.g.

> Change in data collection method, position, datum

> Land use change in the catchment (e.g. development)

> Climate change

# Sources of uncertainty

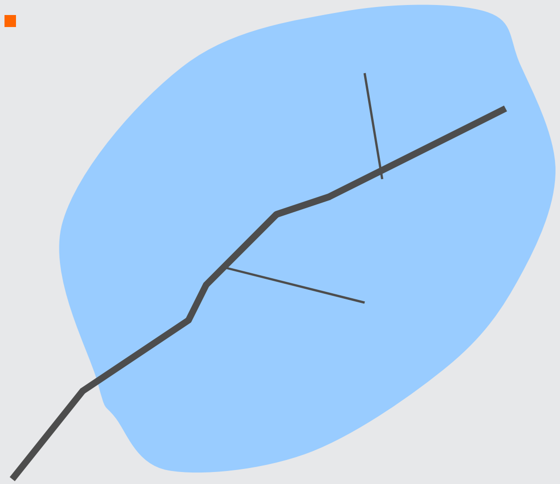


# RAINFALL - RUNOFF METHODS

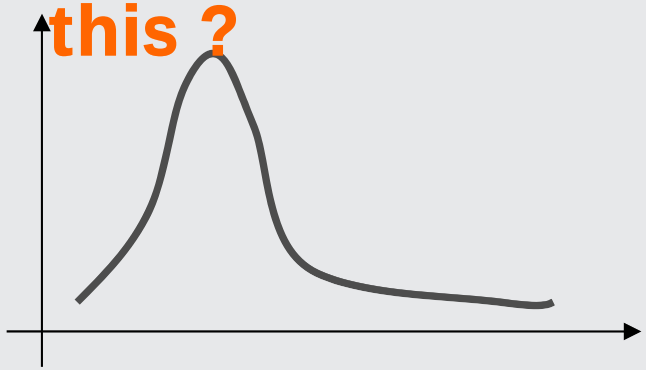
# Rainfall-runoff method

When shape and timing of flood hydrograph is to be determined

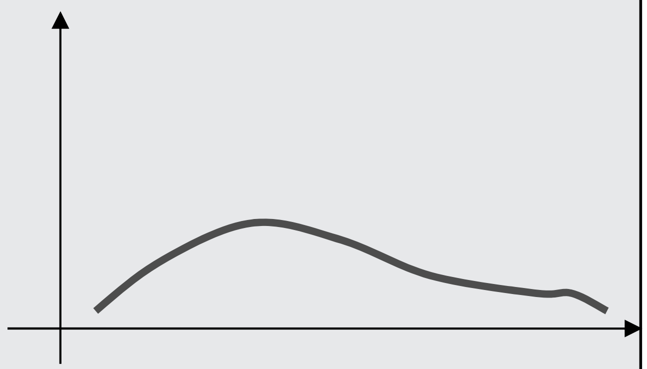
**Does this ….**



**Give you this ?**

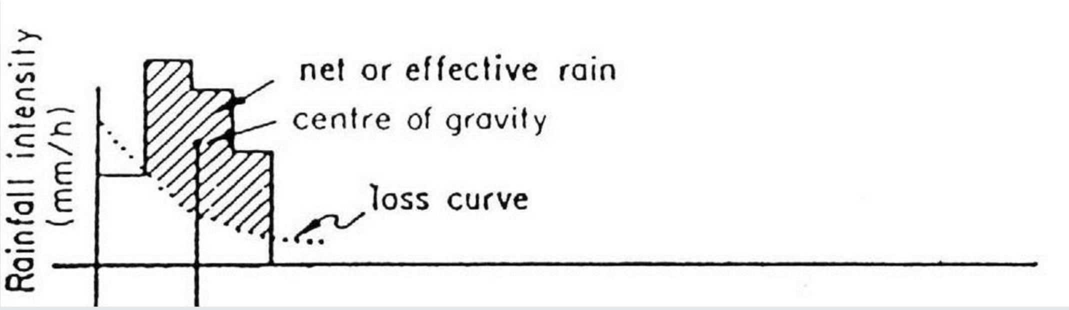


**Or this ?**



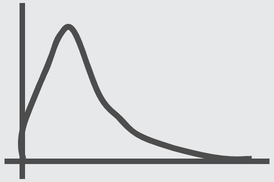
Technique for relating the runoff to the rainfall that caused it is the Unit Hydrograph (UH) method

# Rainfall-runoff approach

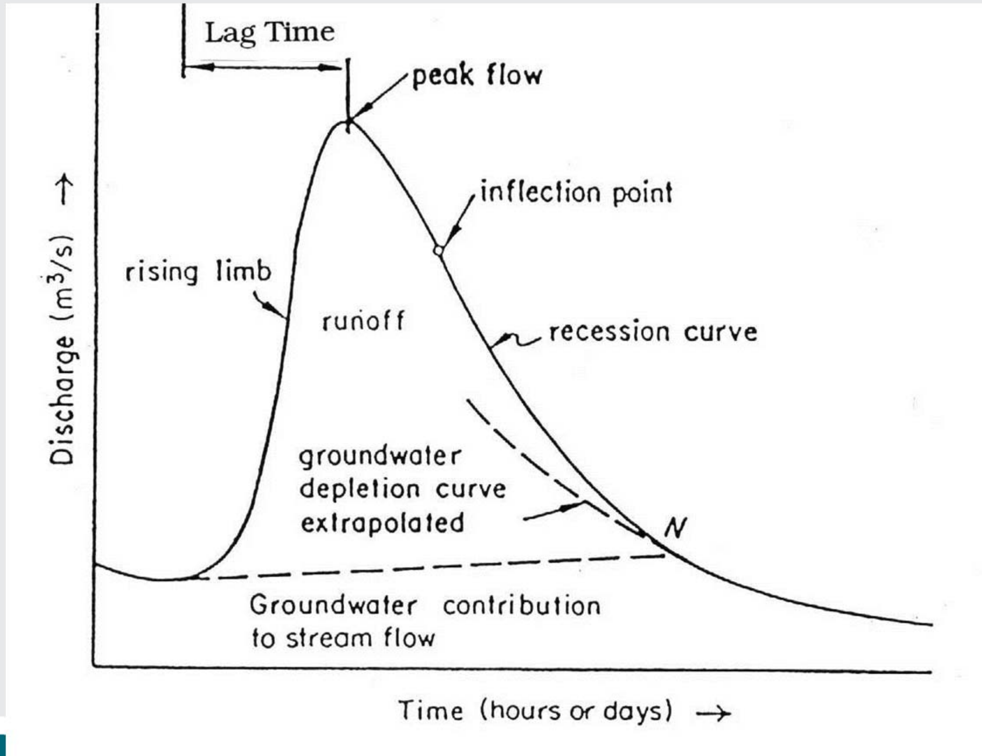



Net Rainfall

X



Unit Hydrograph




Runoff Hydrograph

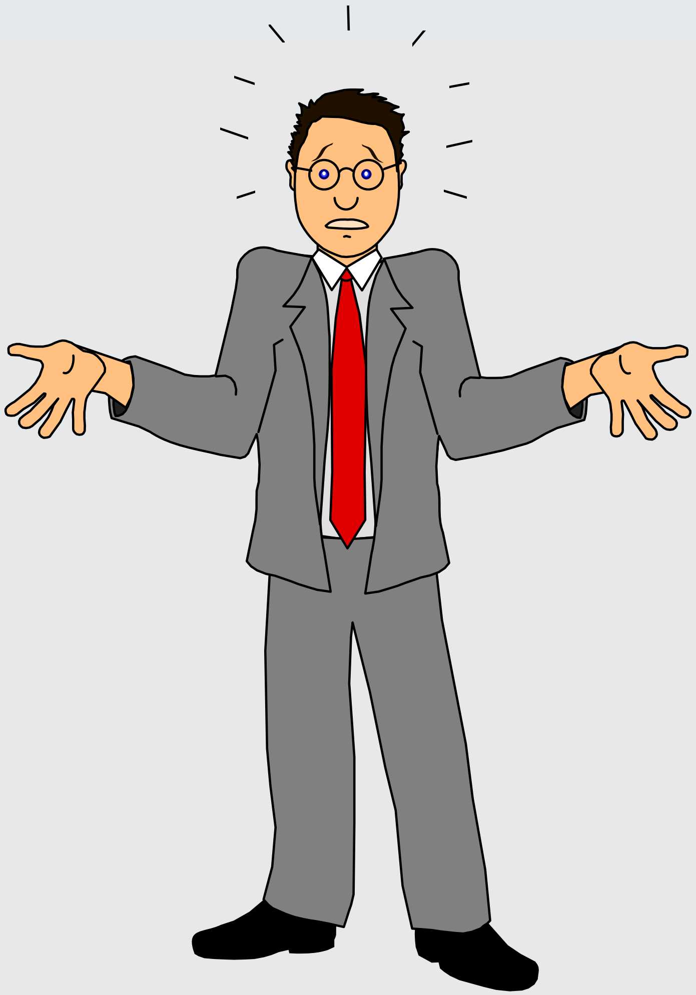
# Unit Hydrograph theory

UH is the rapid response of the catchment to unit depth of effective rainfall falling in unit time

The concept makes three main assumptions:

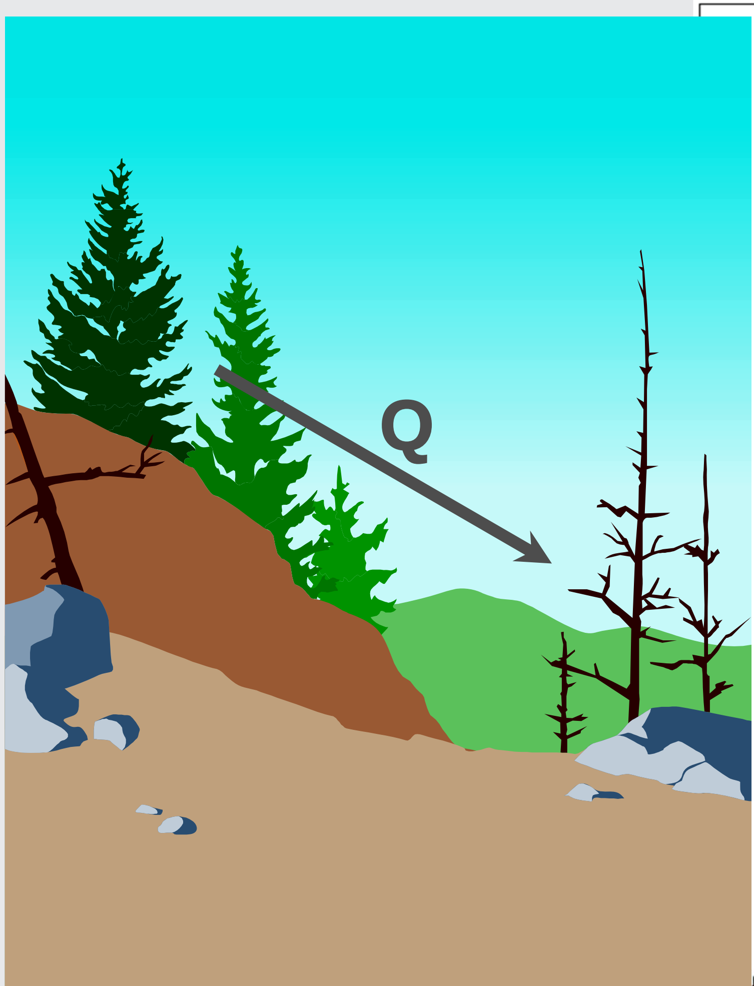
- > Time invariance (unique and constant rainfall-runoff relationship)
- > Linearity (increase in rainfall causes proportional increase in runoff)
- > Superposition (total runoff is sum of individual runoff hydrographs)

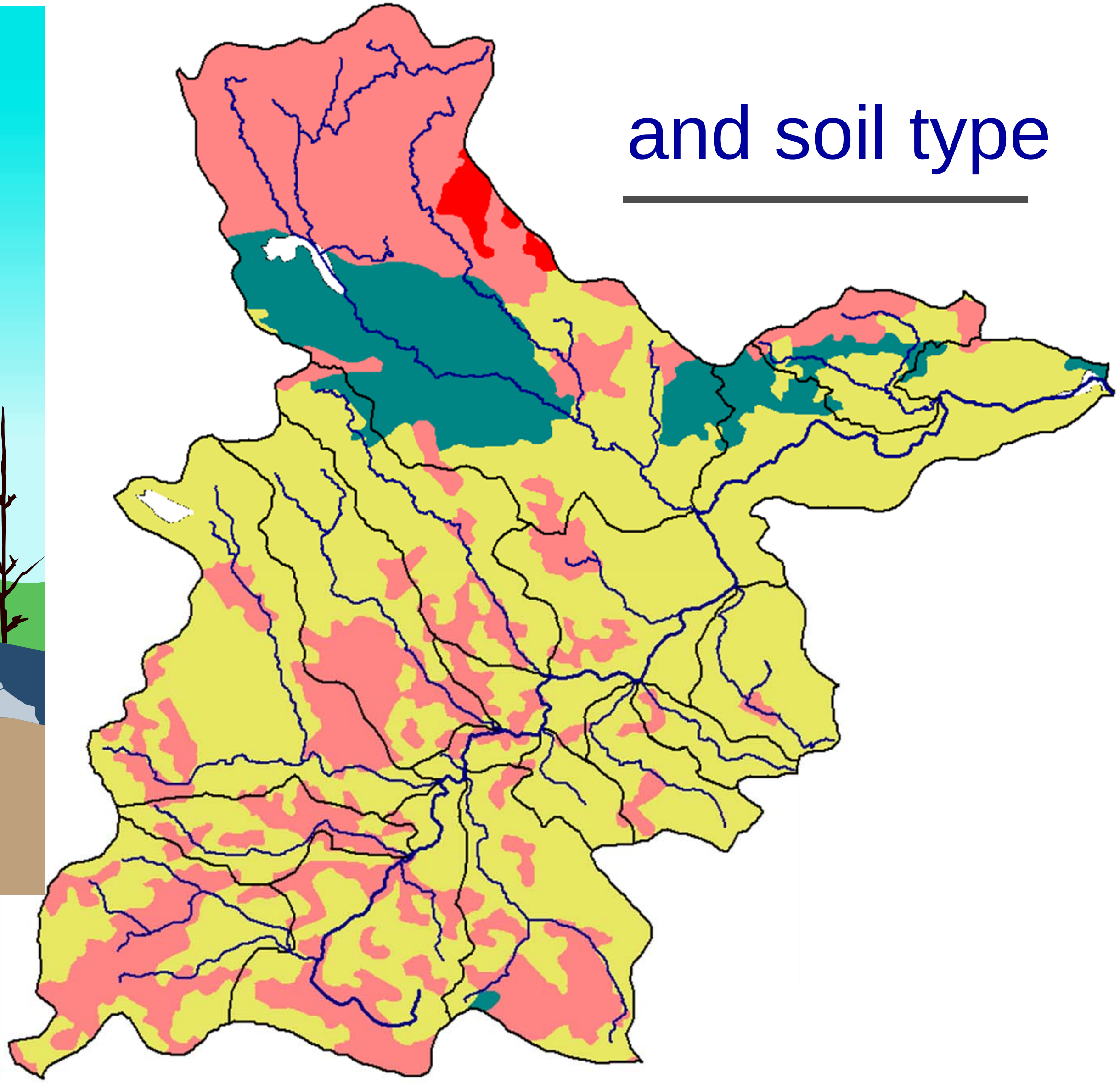
# What affects the flood generation process ?



**CATCHMENT FEATURES WITH SIGNIFICANT INFLUENCE ON THE FLOOD GENERATION PROCESS**

# Catchment size, slope



and soil type

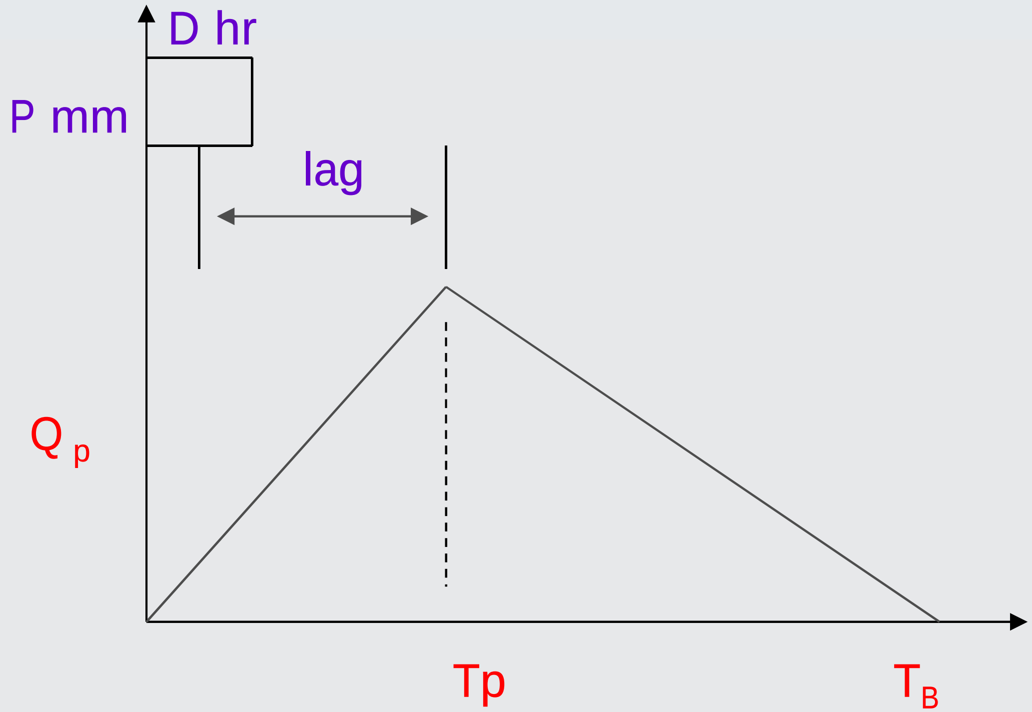
# Degree of urbanisation

# Catchment wetness

# Attenuation from lakes and reservoirs

# 1) Construct unit hydrograph

# Unit Hydrograph




Often the UH has a simple triangular form, where the UH peak and timebase are both functions of the time-to-peak, Tp

# Estimating Tp

From equations (the example below is for the UK)

$Tp = 4.27 DPSBAR^{-0.35} PROPWET^{-0.80} DPLBAR^{0.54} (1+URBEXT)^{-5.77}$

From observed values of ‘lag’ time between centroid of rainfall and flow peak

$Tp = 0.879\ LAG^{0.951}$

# Hydrograph computation

1) Construct unit hydrograph

2) Estimate percentage runoff

# Percentage runoff

From catchment descriptors (equation below is for the UK)

$$SPR = SPR_1 HOST_1 + SPR_2 HOST_2 + SPR_3 HOST_3 + .... + SPR_N HOST_N$$

From observed values of ‘baseflow index’ (ratio of baseflow to total flow)

# Percentage runoff

Percentage runoff is the proportion of the total rainfall input which shows up as rapid response runoff in the river

# Hydrograph computation

1) Construct unit hydrograph
2) Estimate percentage runoff
3) Calculate design storm event rainfall
4) Distribute according to chosen profile

# Design storm event

Design storm duration, D

Design storm depth, P

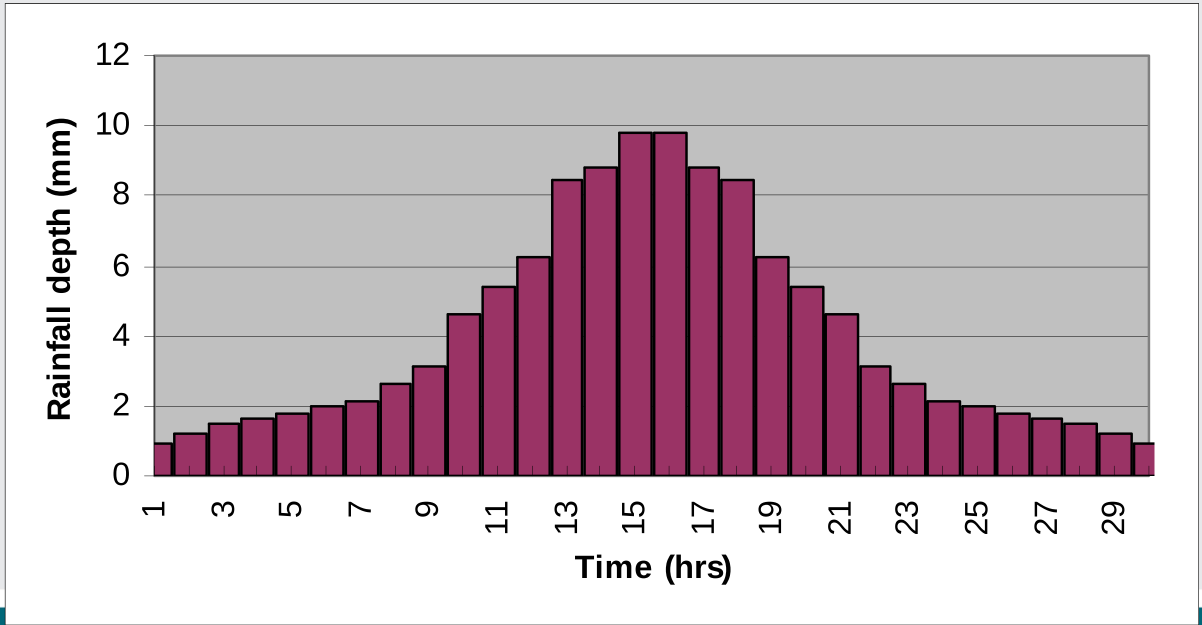
Design storm profile

# Design storm event

Critical Storm Duration (hours)

Storm Depth, P (mm) is taken from a rainfall model

Profile is dependent on climate



# Hydrograph computation

1) Construct unit hydrograph

2) Estimate percentage runoff

3) Calculate event rainfall

4) Distribute according to chosen profile

5) Convolute net rain and UH

# Problem catchments

> Small (< 0.5 $km^2$)

> Large (> 500 $km^2$)

> Permeable catchments e.g. chalk

> Urban

> Flat and low-lying, possibly with pumped drainage

> Diversion/extensive channel works

# Any questions?

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