CE 361A : Engineering Hydrology

Precipitation

Lecture -8

Revision

Data collected from rain gauges

1. Present rainfall data
2. Check consistency
3. Estimate missing values
4. Areal average rainfall
5. Adequacy of raingauge
6. Frequency analysis: Intensity-duration-frequency (IDF) curves
7. Depth-area-duration relationships (DAD)
8. Probable maximum precipitation
9. Variability, Periodicity and Trends

special topic

Revision

- Analysis of Rainfall
  - Design storm
    - Intensity
    - Duration
    - Frequency
    - Areal distribution
  - Frequency
    - Annual series
    - Exceedance probability, p
    - Non-exceedance probability, q
    - Return period or recurrence interval, T

Revision

- Estimation of frequency
  - To estimate rainfall magnitude of a given frequency
  - To estimate frequency of a given rainfall magnitude
  - Plotting position formula
- Intensity duration frequency (IDF) or depth duration frequency (DDF) curves
  - To estimate IDF/DDF curves from raw data
  - IDF /DDF curves by IMD – Isopluvial maps

Areal distribution

- A storm of given duration over a certain area rarely produces uniform rainfall depth over the entire area.
- The storm has a centre, where the rainfall P_0 is maximum
- P_0 is always greater than the average depth of rainfall $\overline{P}$
- The difference between P_0 and $\overline{P}$ *is given by the Areal Reduction Factor (ARF)*

Areal Reduction Factor (ARF)

Factors influencing ARF

1. Type of rainfall
   - Convective, frontal, orographic or cyclonic
   - Summer or winter monsoon
2. Duration of rainfall
   - Longer the duration less will be the areal reduction

Areal Reduction Factor (ARF)

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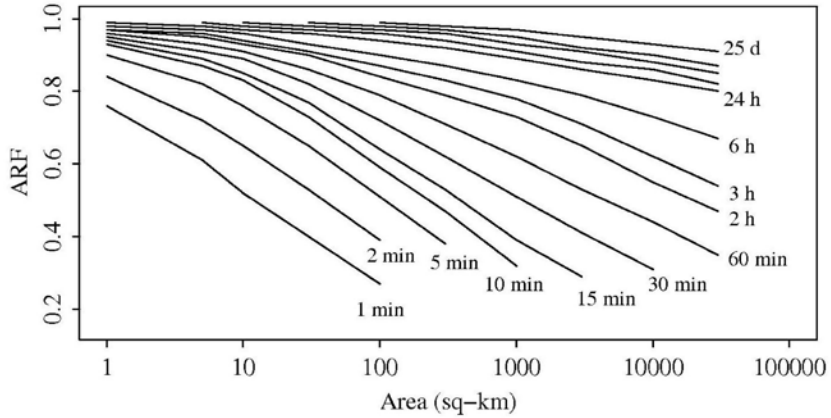


Figure 1. *Areal reduction factors for precipitation in the United Kingdom presented in the Flood Studies Report (diagram derived from tabulated values in NERC (1975))*

Area Reduction Factor (ARF)

Factors influencing ARF

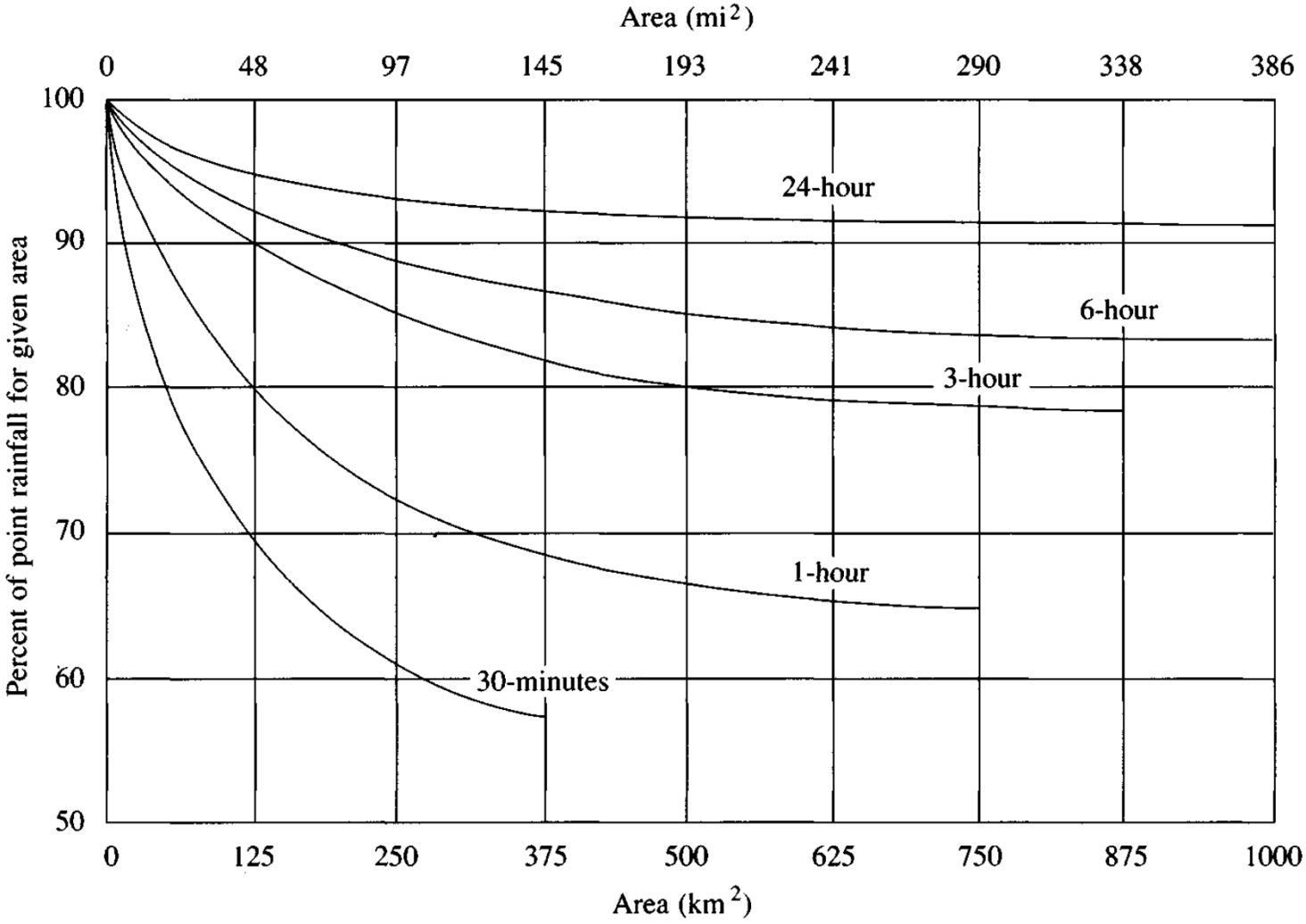
1. Type of rainfall
   - Convective, frontal, orographic or cyclonic
   - Summer or winter monsoon
2. Duration of rainfall
   - Longer duration smaller will be ARF
3. Characteristic of area
   - Shape of area and alignment of isohyets
   - Urban vs rural areas

Estimation of Areal Reduction Factor (ARF)

1. Empirical methods
   - Storm centered analysis
   - Fixed area analysis
2. Analytical methods
   - Spatial correlation, scaling and storm movement

Reference: Svensson and Jones (2010), “Review of methods for deriving areal reduction factors”, Journal of flood risk and management

Areal Distribution



Source: World Meteorological Organization (1983) & Chow et al. (1988)

Area Reduction Factor (ARF)

Example: Dhar and Bhattacharya (1975) developed a relationship for North India

$$\bar{P} = P_0 \exp(-KA^n)$$

$\bar{P}$ is average depth in cm over an area A (in km^2)

P_0 is highest amount of rainfall at storm center

K and n are constants for a given region

Duration	K	n
1 day	0.0008526	0.6614
2 days	0.0009877	0.6306
3 days	0.001745	0.5961

Exact determination of P_0 is not possible;

Highest station rainfall is taken as average over 25 km^2.

Source: Subramanya (2008)

Maximum Depth-Area-Duration curves

Based on severe-most storm

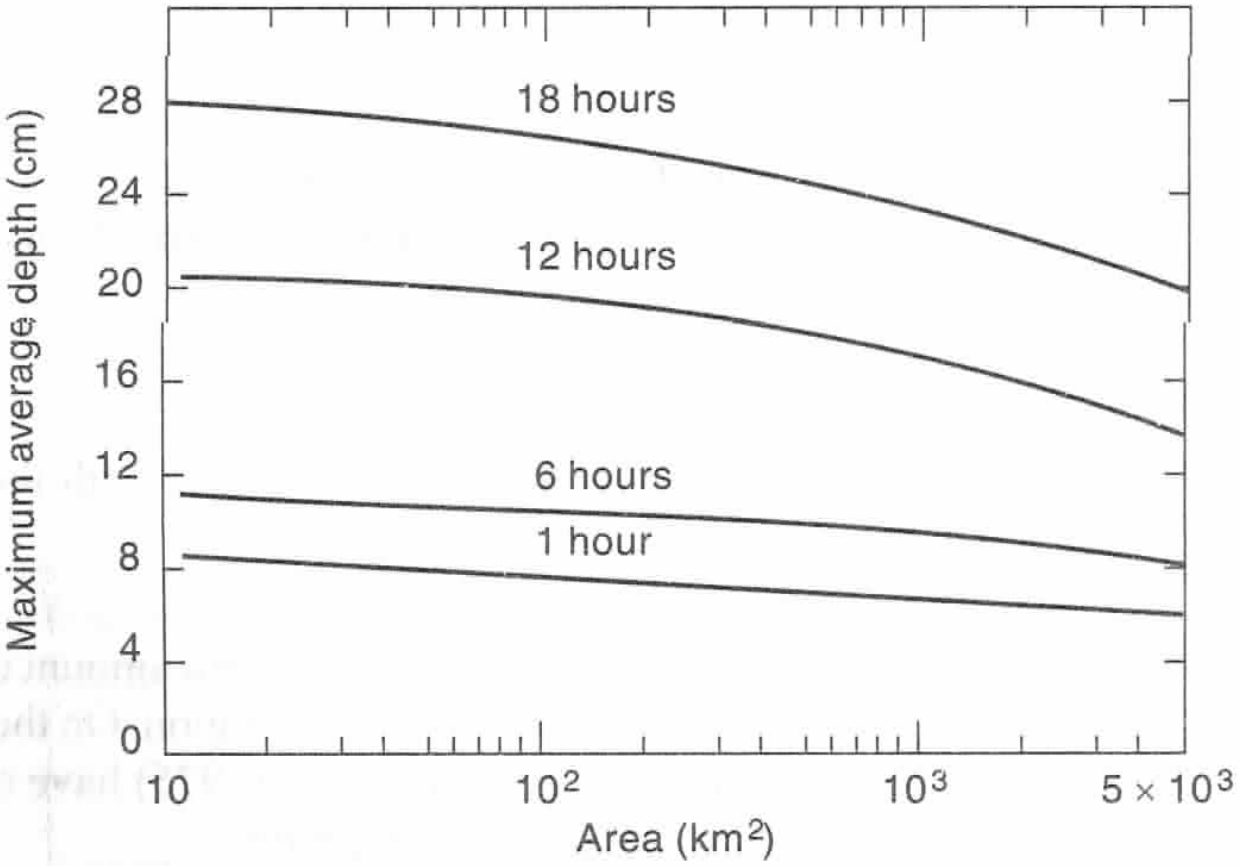


Fig. 2.16 Typical DAD Curves

Source: Subramanya (2008)

Probable Maximum Precipitation

Maximum (meteorologically) possible precipitation that can be expected at a location

How to determine?

- Meteorological method
- Statistical method

Probable Maximum Precipitation over India

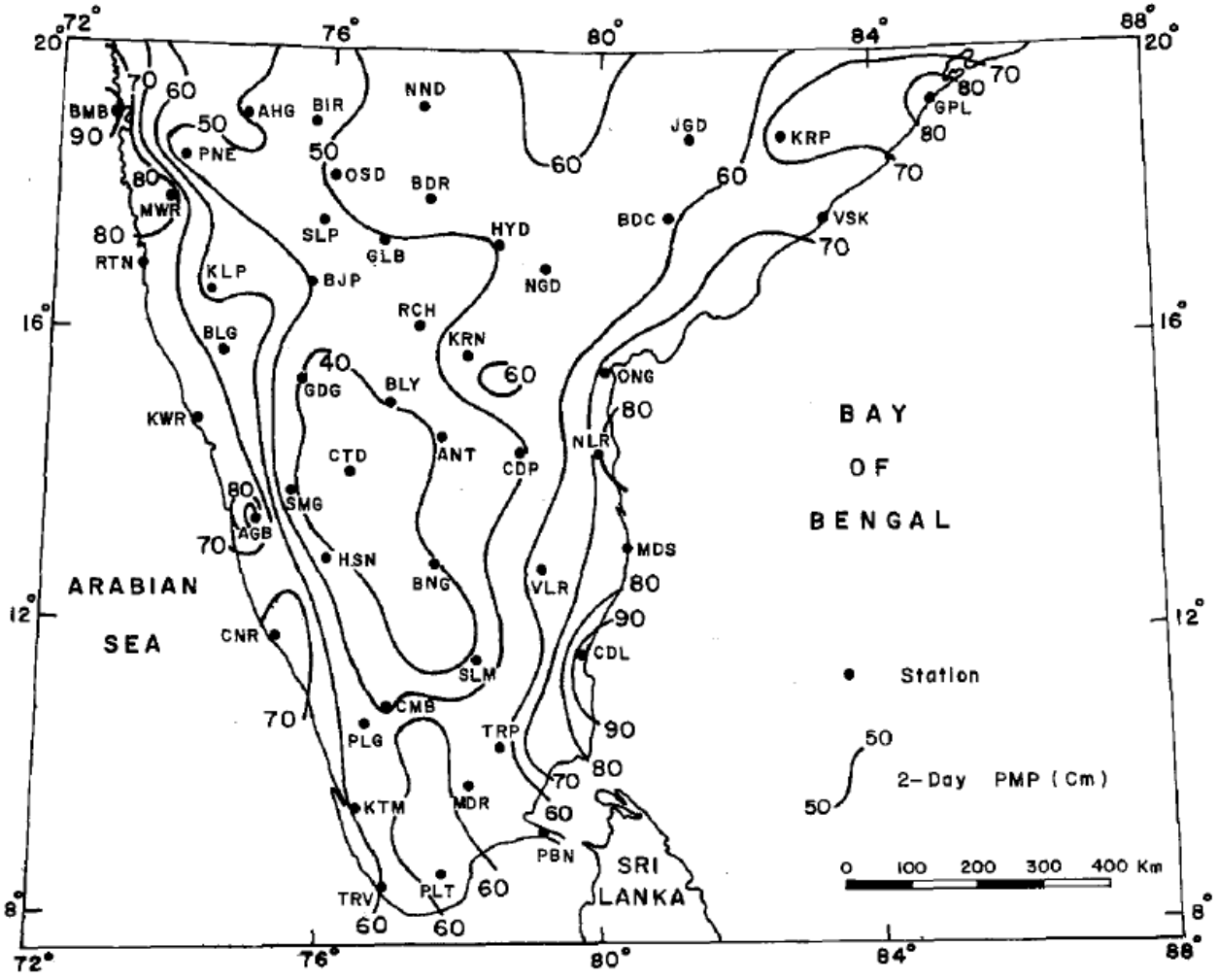


Fig. 2. Generalised map of 2-day PMP (cm) over Indian peninsula

Probable Maximum Precipitation over India

Mumbai July 26, 2005

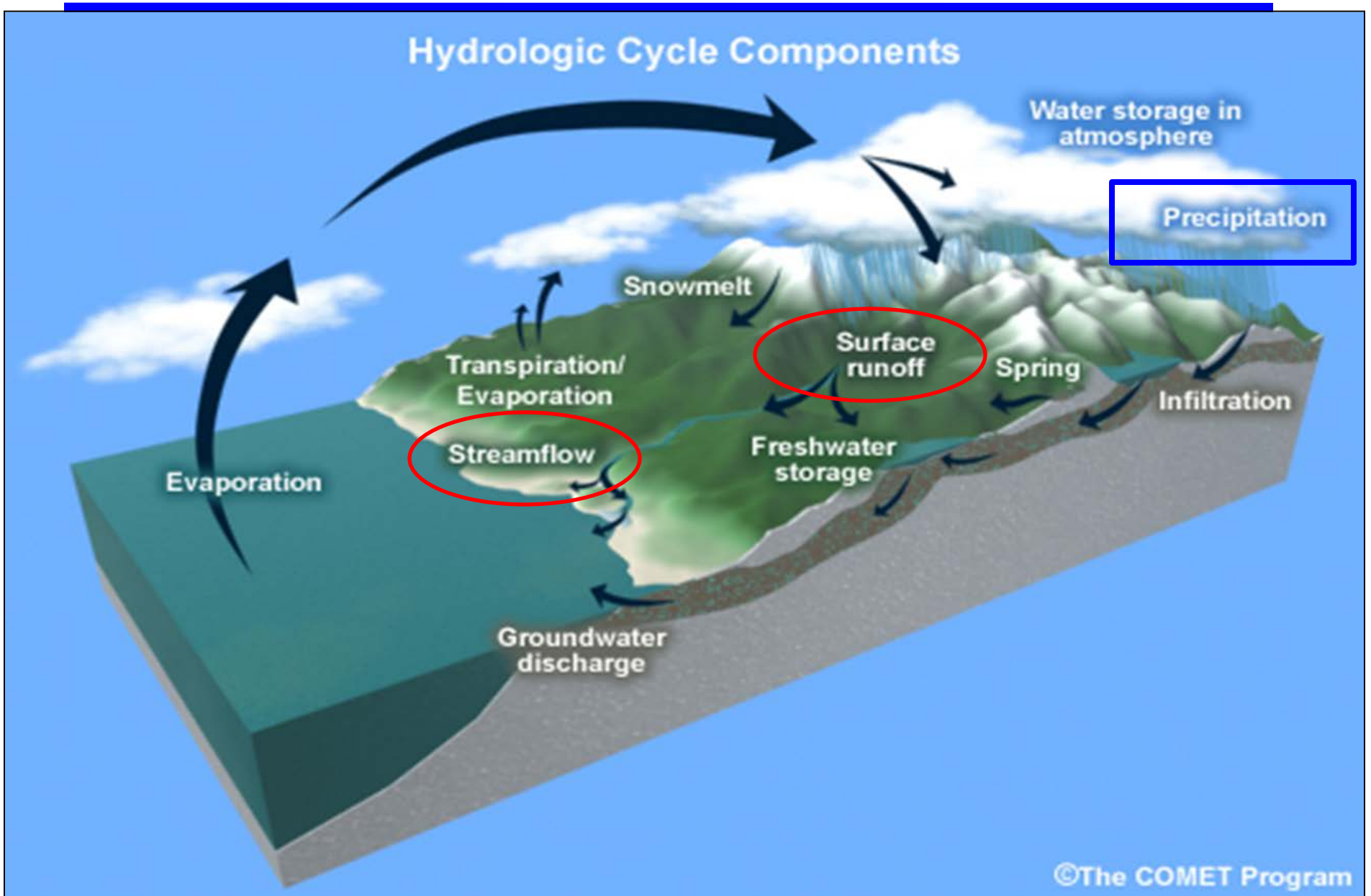
- 994 mm rainfall in a day
- 664 mm in 12 hours
- 100 million USD
- Loss of life !!!
- No prior warning

Criteria for design storm

Type of structure	Return period OR PMP
Highways culverts	5 – 10 yrs
Highway bridges	50 – 100 yrs
Farm drainage	5 – 50 yrs
Urban drainage	25 – 50 yrs
Airfield	50 – 100 yrs
Levees around cities	50 – 200 yrs
Small dams with no likelihood of loss of life	50 -100 yrs
Small dams with significant loss of life	100+ yrs or 50% of PMP
Large dams with considerable loss of life	100 % of PMP

Abstraction from Precipitation

Hydrologic Cycle



Water balance

Runoff = Precipitation - Abstractions

Abstractions or losses

1. Interception
2. Evaporation
3. Transpiration
4. Depression storages
5. Infiltration

Objective

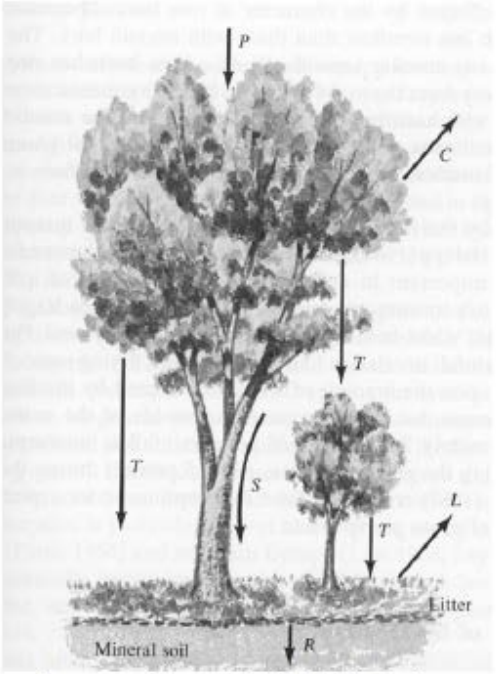
- What are these losses?
- What factors effect them?
- How are they measured?
- How are they estimated?

Interception

The volume of precipitation that is retained by vegetation and subsequently evaporated

Terms

- Precipitation (P)
- Throughfall (T)
- Stemflow (S)
- Canopy interception (C)
- Litter interception (L)
- Net rainfall (R)



Dunne and Leopold (1978, Fig. 3-1)

Interception (I) = C + L

Factors effecting interception

Three major factors

1. Type of vegetation
2. Precipitation characteristics
3. Meteorological variables

Factors effecting interception

Type of vegetation

1. Deciduous vs Coniferous forest

In general, coniferous trees have more interception losses than deciduous trees

Source: wikipedia.org & panoramio.com

Factors effecting interception

Type of vegetation

2. Trees vs grasses

- Dense grasses can have nearly same interception losses as a full grown tree
- Grasses may have more storage but less evaporation

Source: http://mother-natures-son.com

Factors effecting interception

Type of vegetation

3. Natural vegetation vs agricultural crops

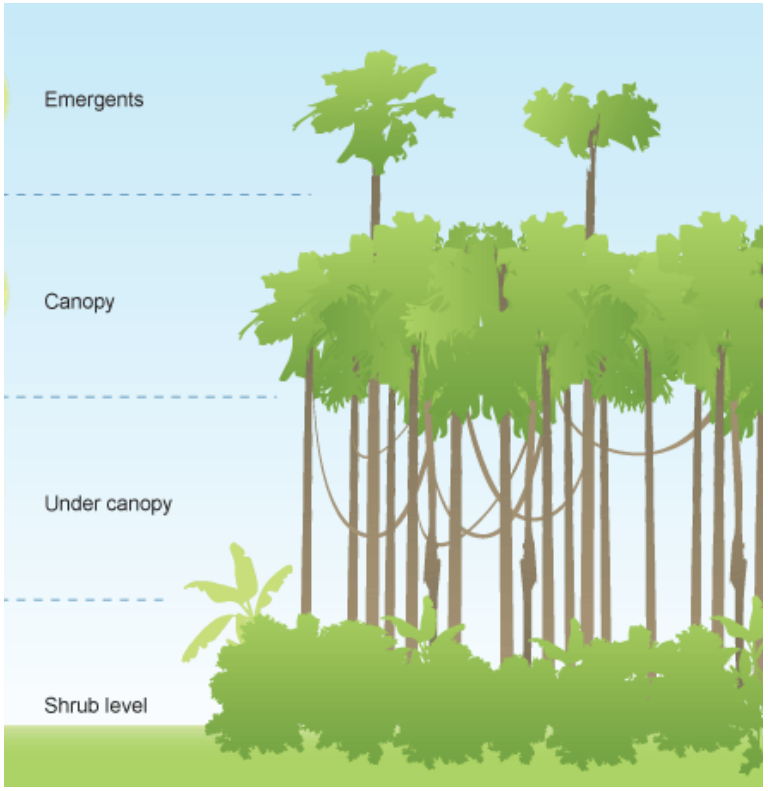
- In general agricultural crops have less interception losses
- The interception is more during the growing season

Source: wikipedia

Factors effecting interception

Type of vegetation

4. Multilevel vs single level vegetation



Source: http://bbc.co.uk

Factors effecting interception

Precipitation characteristics

1. Intensity
2. Duration
3. Frequency
4. Type of precipitation – rain or snow

Factors effecting interception

Meteorological variables

1. Wind
2. Temperature

Measurement of interception losses

One of the most difficult parameter to reliably measure

Throughfall measurement

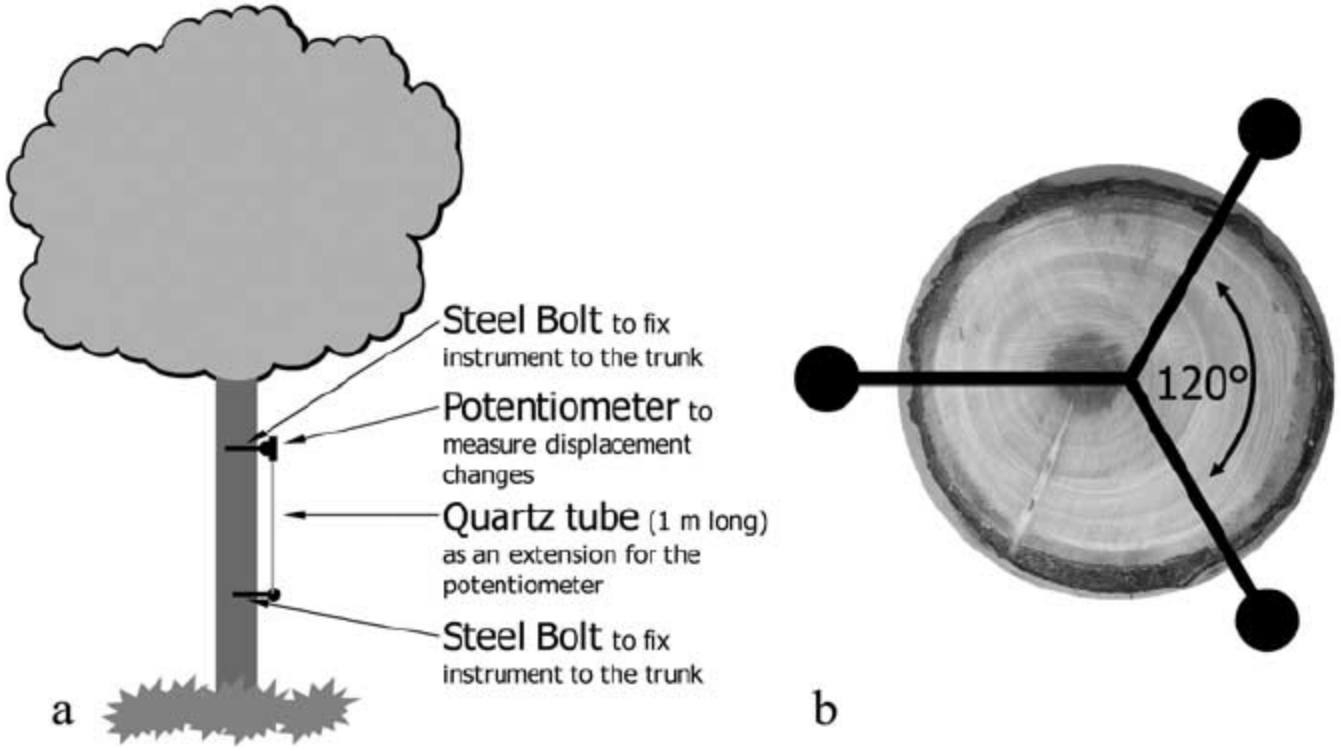
Measurement of interception losses

Stemflow measurement

Measurement of interception losses

Litter interception

Measurement of interception losses



Interceptometer

Estimation of interception losses

Main author	Model type	Interception element:			Time scale
		canopy	stem	forest floor	
Rutter	Conceptual	x	x		$\leq$ hourly
Gash	Analytical	x	x		event
Calder	Stochastic	x			$\leq$ hourly
De Groen	Concept./Stoch.	x	x	x	monthly
Keim	Concept./Stoch.	x			6-hourly

Table 1.3: Characteristics of interception models.

How important are interception losses?

TABLE II

Distribution of incident rainfall in different forests during the monsoon season (values were averaged for two years, 1981 and 1982)

Forest	Gross rainfall (mm)	Stand throughfall (mm)	Stand stemflow (mm)	Stand interception (mm)
Sal forest	1,153	950 (82.4)	10 (0.85)	193 (16.7)
Pine—mixed-broadleaf forest	1,179	1,079 (91.5)	5 (0.42)	95 (8.0)
Pine forest	1,234	922 (74.7)	3 (0.28)	308 (25.0)
Mixed-oak—pine forest	915	758 (82.8)	3 (0.35)	154 (16.8)
Tilonj-dominated mixed-oak forest	1,364	1,155 (84.7)	5 (0.38)	204 (14.9)
Rianj-dominated mixed-oak forest	1,240	1,002 (80.8)	11 (0.89)	227 (18.3)

Values in parentheses are percentages of gross rainfall. Gross rainfall for the monsoon seasons of 1981 and 1982 was measured and reported in Pathak et al. (1984).