Introduction to urban hydrology

Prof. Gabriele Manoli
gabriele.manoli@epfl.ch

https://www.architecturaldigest.com/story/architect-new-yorks-central-park-incredibly-unexpected-legacy

Today’s session

Outline

- **Urban water cycle**
- Modeling runoff
- Flooding and drainage

Urban Water Cycle

Urban hydrology

Access to drinking water is indispensable and a primary determinant of the location of a city. Unfortunately building a city always disrupts the pre-existing drainage patterns and hydrology.

Rivers and streams are channelized, diverted or covered; systems of pipes and storm sewers are linked to the road and building network. Wetlands are drained or filled-in; natural soils are covered by buildings, concrete or asphalt, which reduces infiltration and enhances runoff.

Water is added, removed, diverted, constrained, pumped and piped as needed to achieve various practical goals: to prevent flooding, irrigate, supply drinking water, cool buildings, dilute heat pollution, remove waste, generate electricity or operate industrial processes.

The Shibuya River in Tokyo, Japan

Oke et al. (2017)

Urban Water Cycle

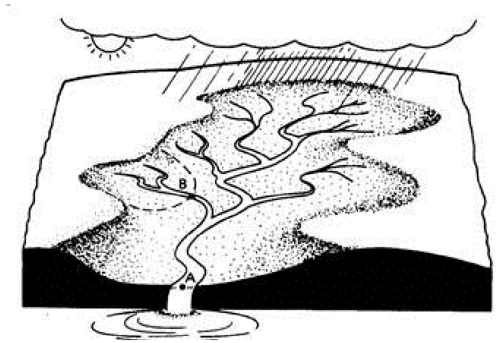
Definitions and concepts

Hydrology: occurrence, quantity, distribution of water

- flow rates and volumes as a function of time and with a probability of exceedance
- processes in watersheds

Hydraulics: conveyance of fluids (can be storm water, can also be sewerage)

- depth and velocities of flow in space and time
- processes in pipes, channels, culverts, rivers

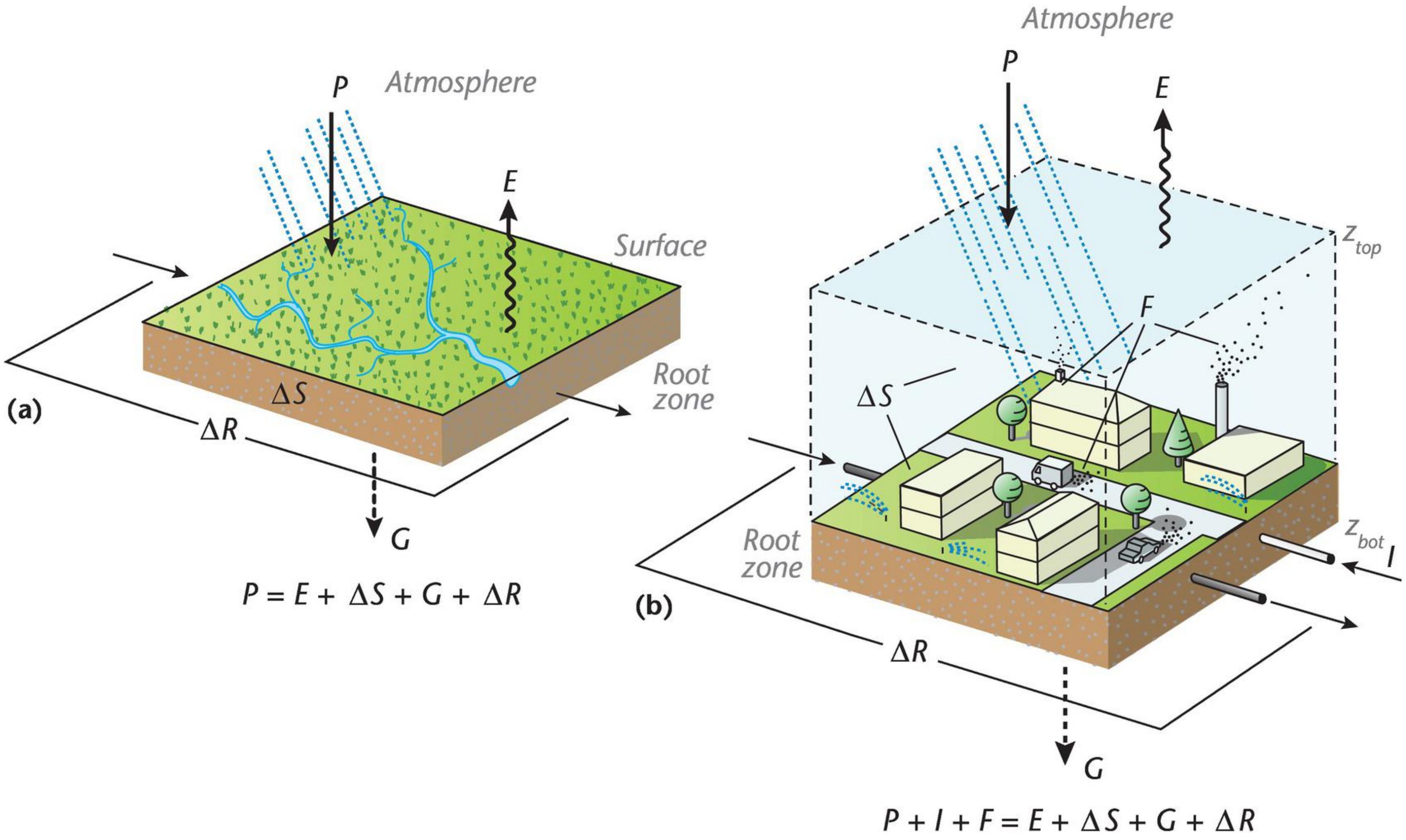


Drainage Basin: area of land draining to the same lowest hydrographic feature (e.g., river or lake). Other terms:

- Catchment (UK)
- Watershed (USA)
- River basin (international)

Urban Water Cycle

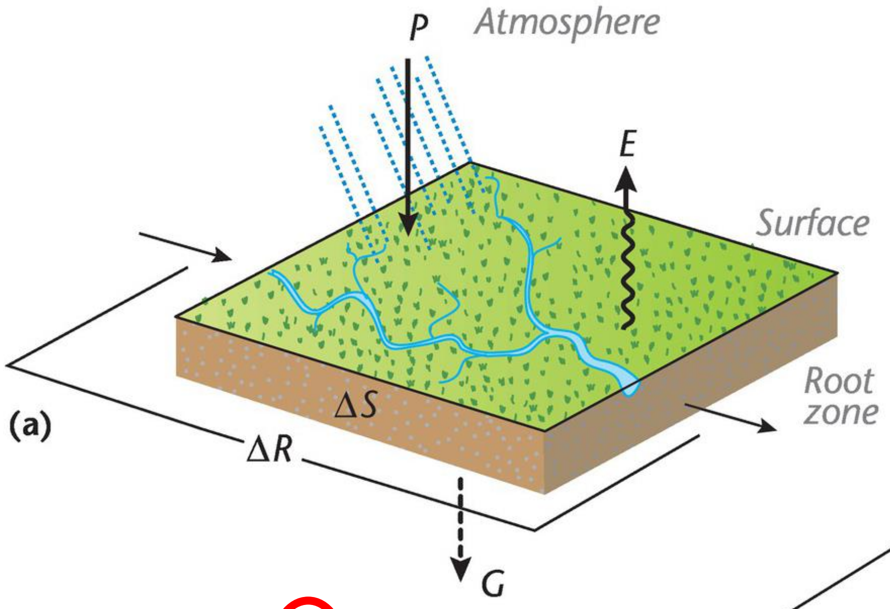
Surface water balance



Oke et al. (2017)

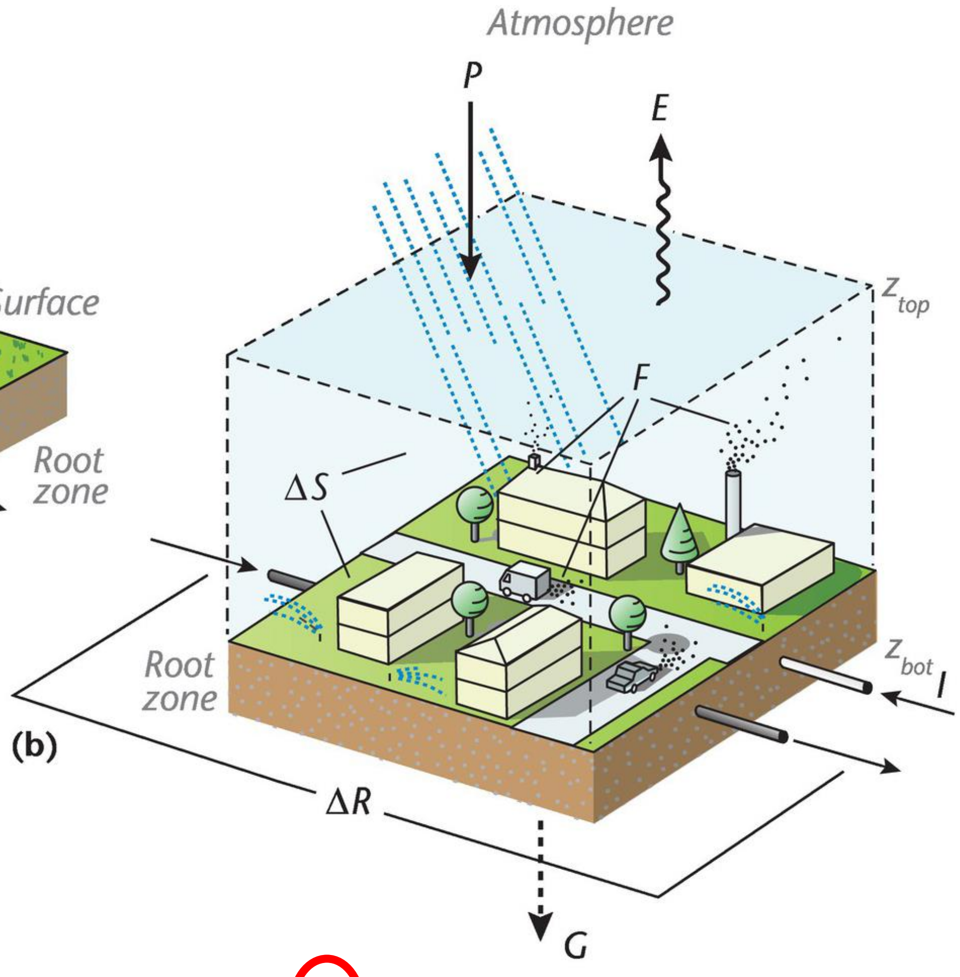
Urban Water Cycle

Surface water balance



$$P = E + \Delta S + G + \Delta R$$

Precipitation



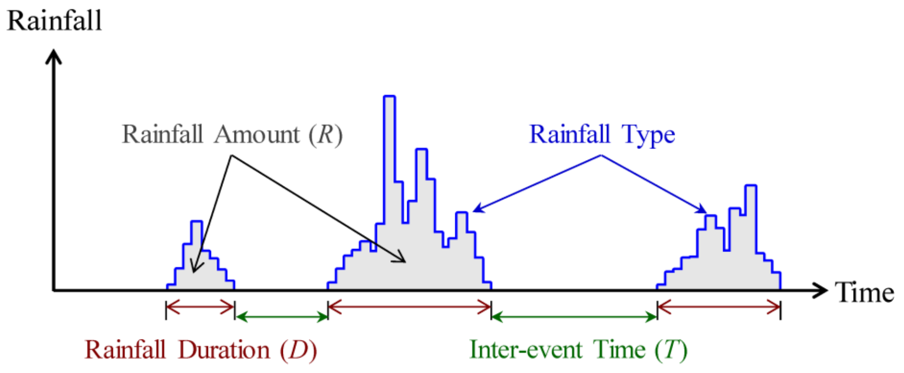
$$P + I + F = E + \Delta S + G + \Delta R$$

Oke et al. (2017)

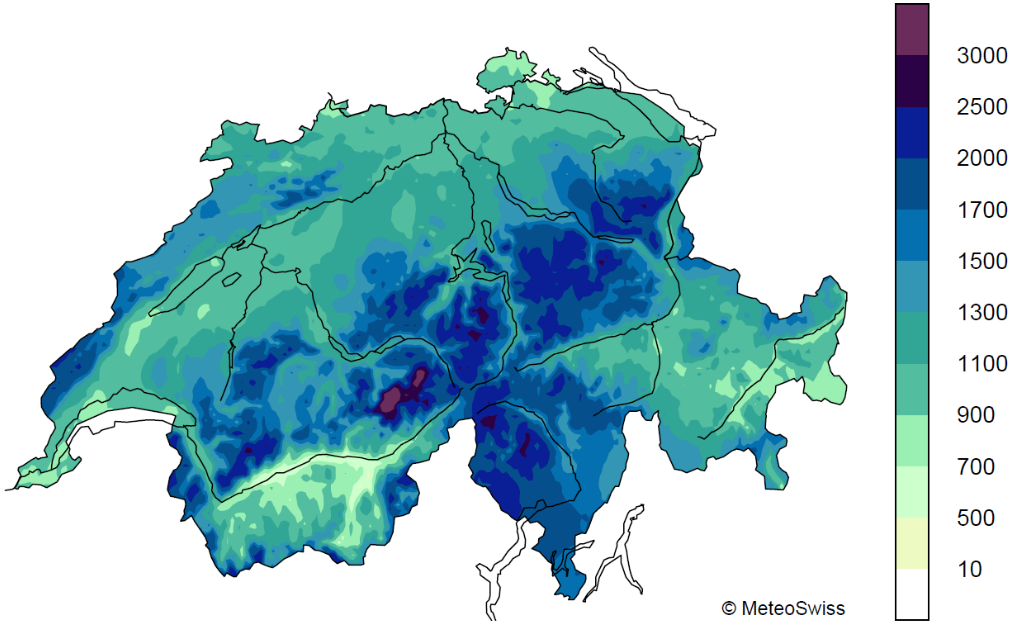
Urban Water Cycle

Precipitation (rain or snowfall)

- **Main input into the hydrological cycle**
- **Key parameters:**
  - Amount (volume or depth per unit area)
  - Rate (volume falling or flowing per unit time)
  - Duration (period with and without precipitation)
- **Measurement**
  - Rain gauge, radar, satellite remote sensing
- **Effective rainfall** = rainfall – losses



Source: Google Images



Annual total precipitation (mm) for the period 1991-2000

Urban Water Cycle

Precipitation (rain or snowfall)

- A **return period (T)** is an estimate of the likelihood of an event, such as an earthquake, flood or a river discharge flow to occur.
  - It is a statistical measurement based on historic data
  - Usually used for risk analysis
  - Assumes that the probability of the event occurring does not vary over time and is independent of past events.
- In terms of rainfall or flooding, a return period is the **average length of time in years for an event of given magnitude (e.g., extreme rain, flood or river level) to be equalled or exceeded**.
  - For example, if the river level with a 50 year return period at a given location is 2m above flood stage, this is just another way of saying that a river level of 2 m above flood stage, or greater, should occur at that location on the average only once every 50 years.
  - the **probability of occurrence** of the 50 year flood in one year is **$p=1/T$**=0.02

Urban Water Cycle

Precipitation (rain or snowfall)

In general, the probability that an event of specified magnitude will be equalled or exceeded within a period of *N* years is:

$$p_N = 1 - (1 - p)^N$$

Where the probability of occurrence (*p*) is the probability that an event of the specified magnitude will be equalled or exceeded during a one year period. This is equivalent to:

$$p_N = 1 - \left(1 - \frac{1}{T}\right)^N$$

Where *T* is the return period.

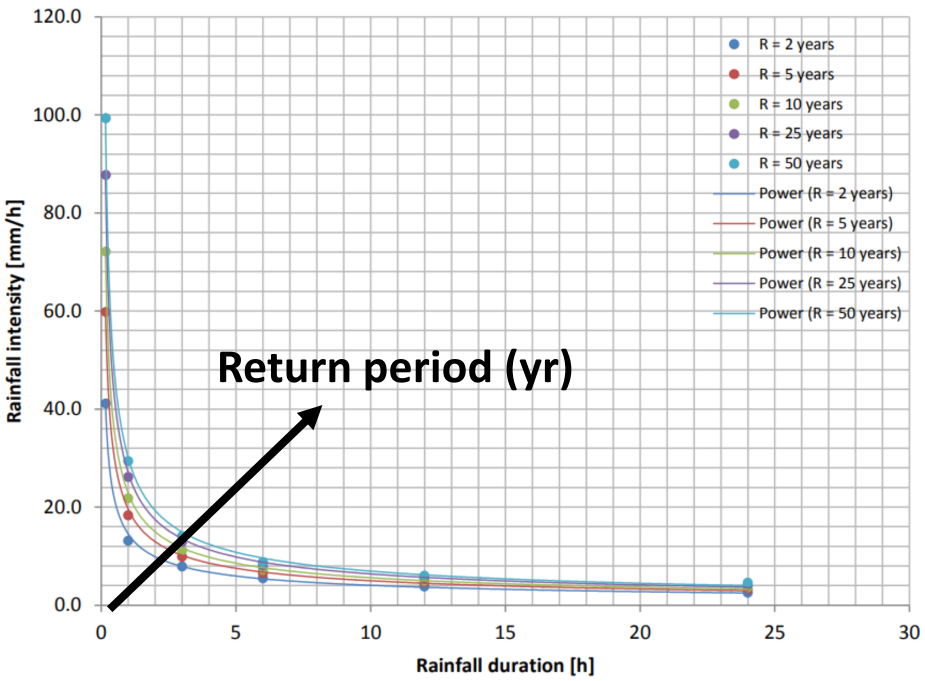
Urban Water Cycle

Precipitation (rain or snowfall)

- **Intensity-Duration-Frequency (IDF) Curves:** a graphical representation of the probability that a given average rainfall intensity will occur.
- Derived using a procedure known as rainfall frequency analysis (see Butler and Davies, 2011)

During the design of urban drainage systems, a **design rainfall intensity** is to be estimated based on the IDF curve and the drainage regulations (i.e., estimation of the rainfall intensity for a specific hazard frequency and runoff concentration time).

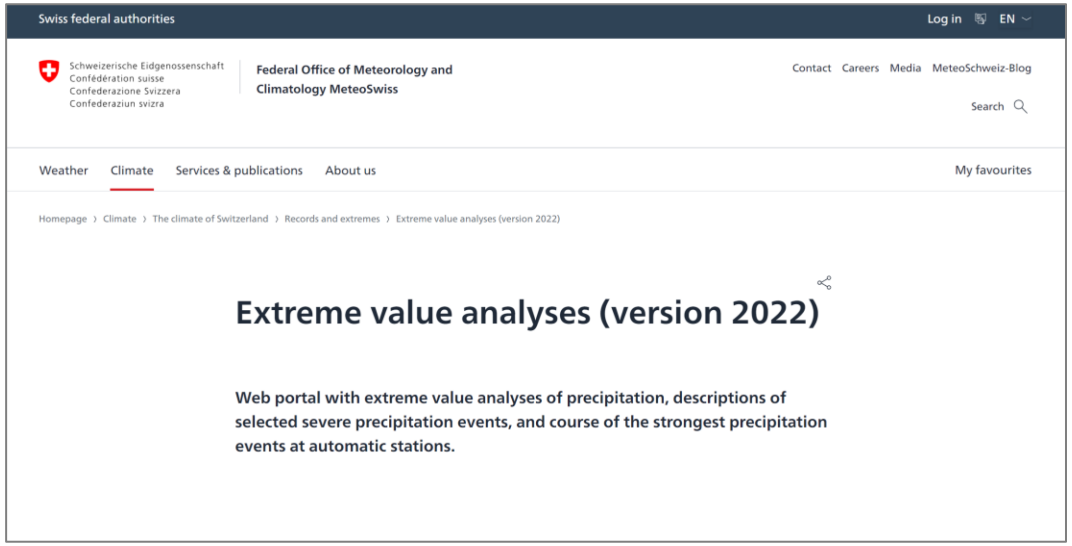
Rainfall intensity-duration-frequency curve for the station of Davos (ETH Zurich)

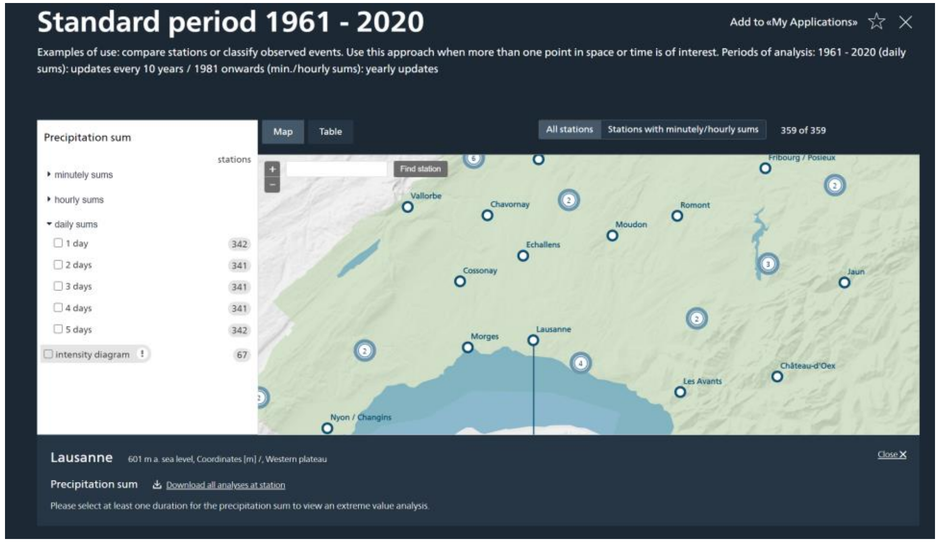


Urban Water Cycle

Precipitation (rain or snowfall)

- **Intensity-Duration-Frequency (IDF) Curves:** a graphical representation of the probability that a given average rainfall intensity will occur.
- Derived using a procedure known as rainfall frequency analysis (see Butler and Davies, 2011)



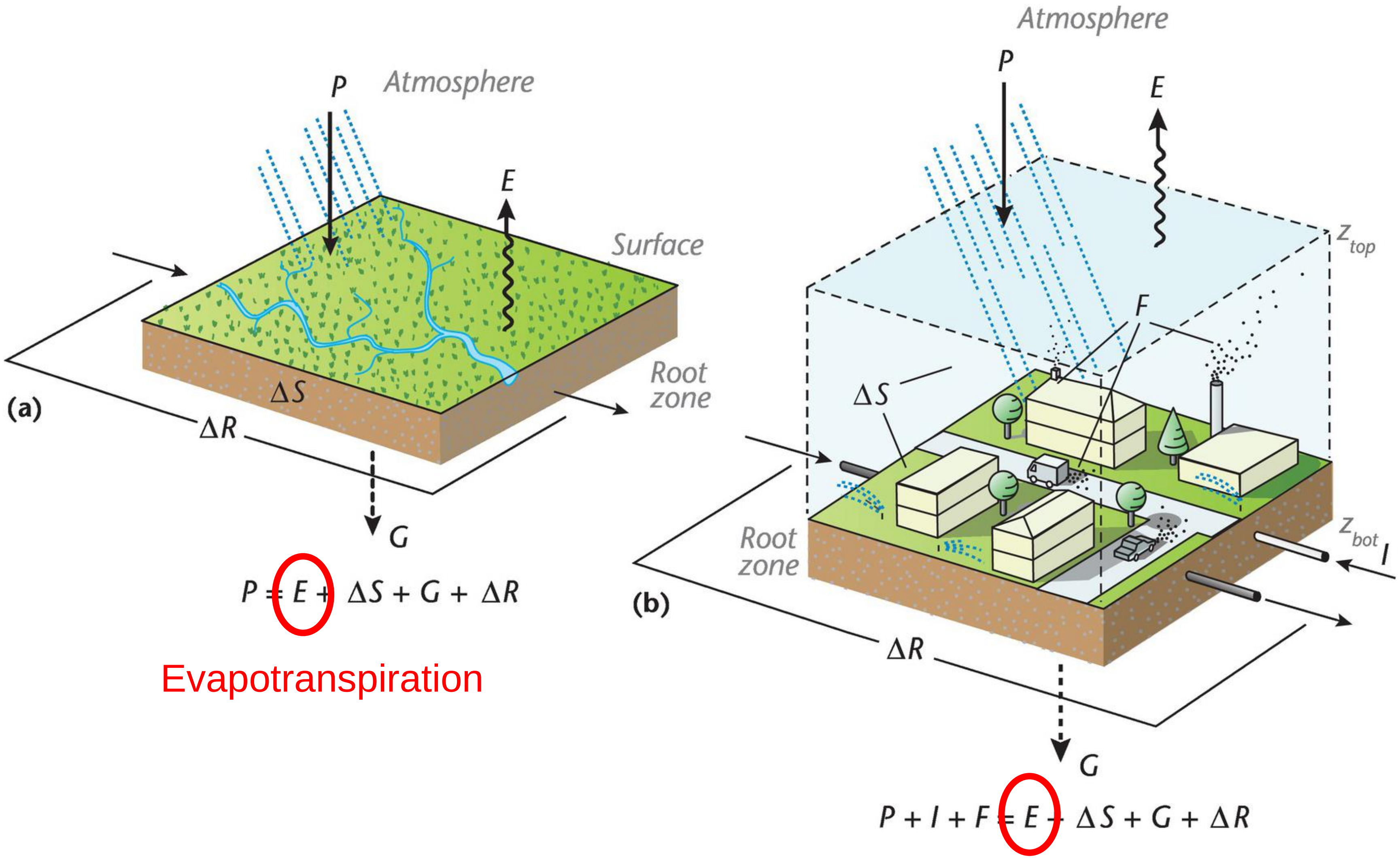


Extreme value analyses (version 2022) - MeteoSwiss (admin.ch)

Urban Water Cycle

EPFL

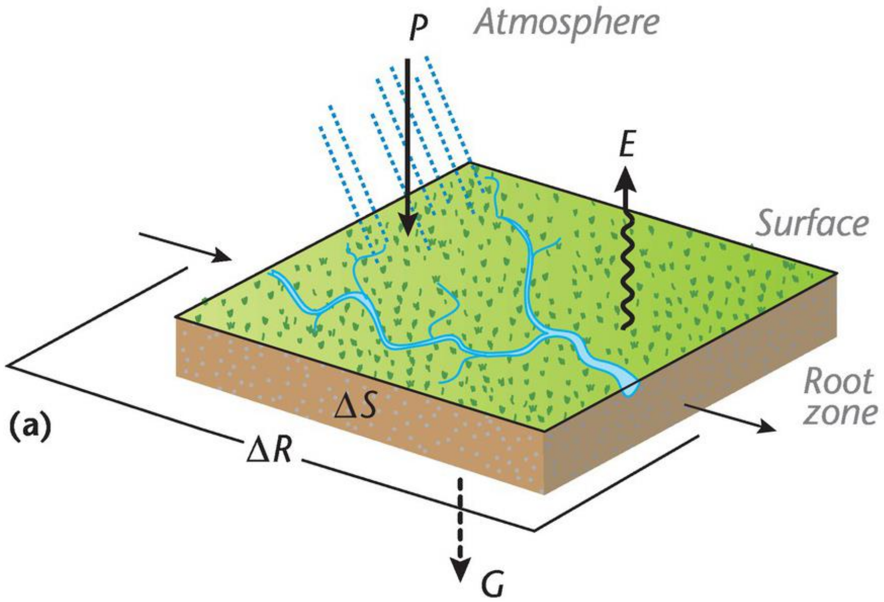
Surface water balance



Oke et al. (2017)

Urban Water Cycle

Surface water balance

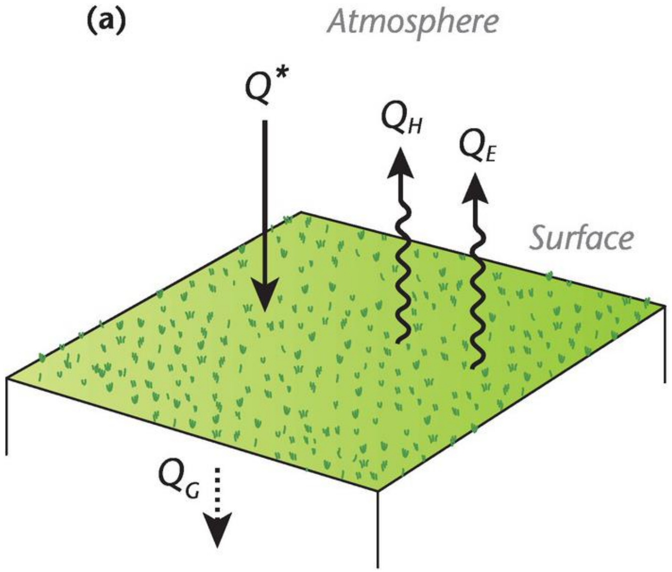


$$P = E + \Delta S + G + \Delta R$$

Evapotranspiration

Coupling

Surface energy balance



$$Q^* = Q_H + Q_E + Q_G$$

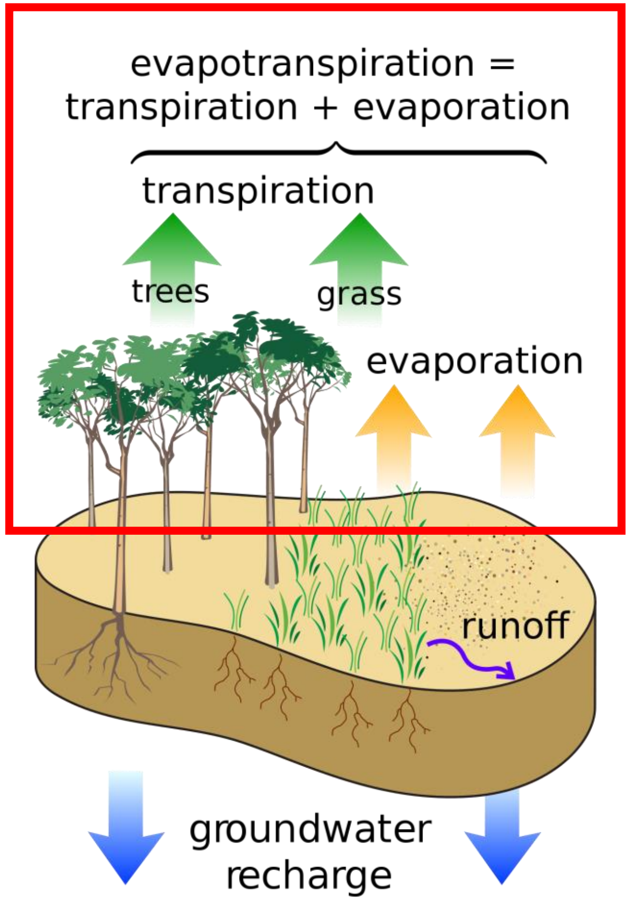
Laten heat flux $= L_v \cdot E$

Oke et al. (2017)

Urban Water Cycle

Evapotranspiration

- **Evapotranspiration:** soil/water bodies (Evaporation) + vegetation (Transpiration)
- **Factors affecting transpiration:** plant's maturity, % soil cover, solar radiation, humidity, temperature, and wind speed
  - **Potential evapotranspiration (PET)** is rate when moisture supply is unlimited
  - Actual evapotranspiration drops below PET as soil dries out



https://en.wikipedia.org/wiki/Evapotranspiration

Urban Water Cycle

EPFL

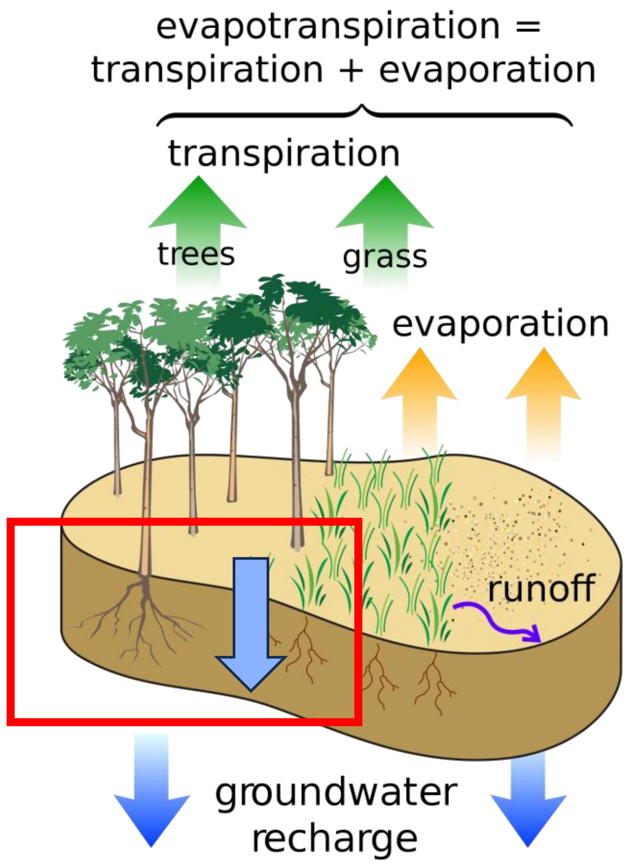
Infiltration & groundwater recharge

- After a rainfall event, the infiltration rate decreases with time as the soil becomes saturated
- The infiltration rate can be estimated e.g. using Horton equation:

$$f_p = f_c + (f_o - f_c)\ e^{-kt} \quad (11)$$

where f_c is the final or equilibrium infiltration rate ($mm \cdot s^{-1}$), f_o is the initial infiltration capacity at $t = 0$ ($mm \cdot s^{-1}$), and k is a constant dependent on soil type and the initial moisture content.

Conceptual Hydrological Models



https://en.wikipedia.org/wiki/Evapotranspiration

Urban Water Cycle

Infiltration & groundwater recharge

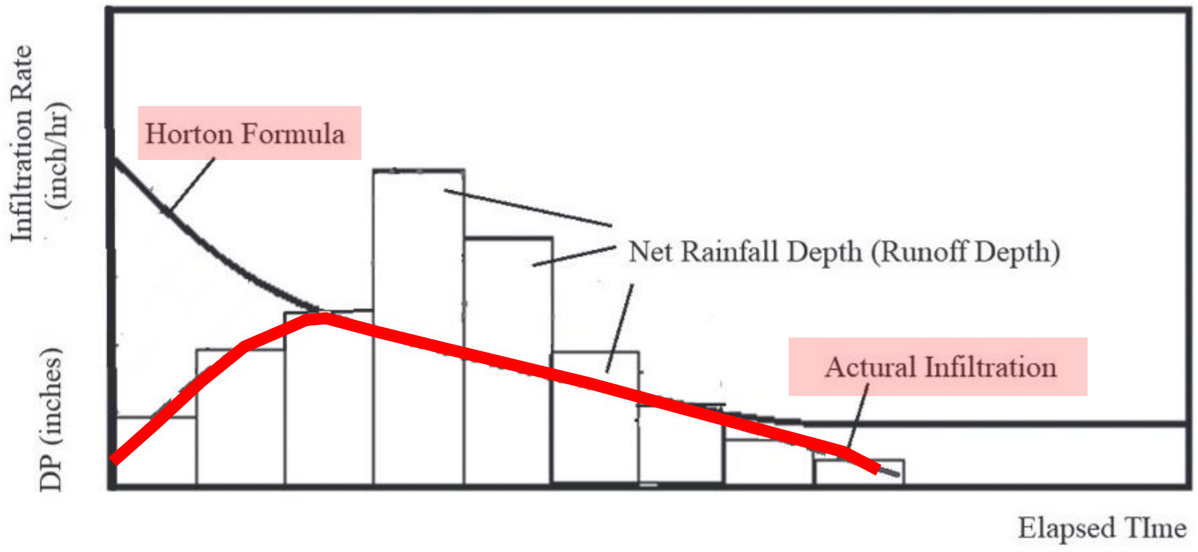
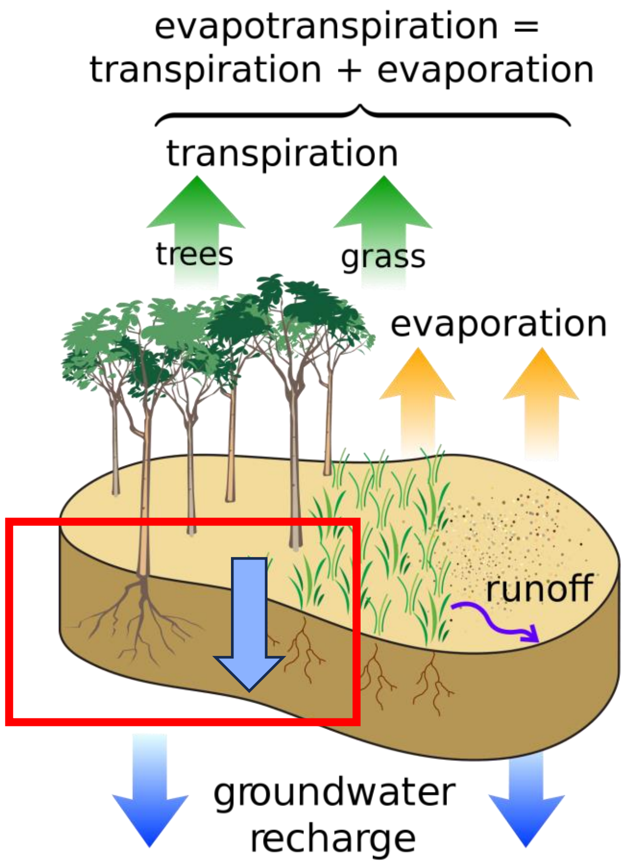


Figure 3.4 Seepage flow model to estimate net rainfall depth

Guo et al. (2022)



https://en.wikipedia.org/wiki/Evapotranspiration

Urban Water Cycle

Runoff

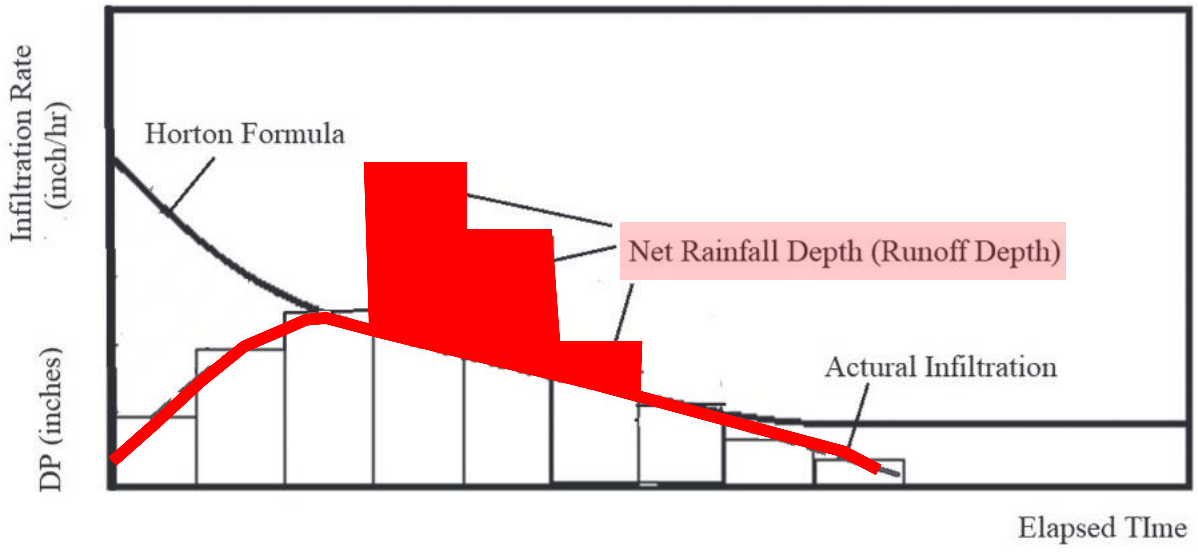
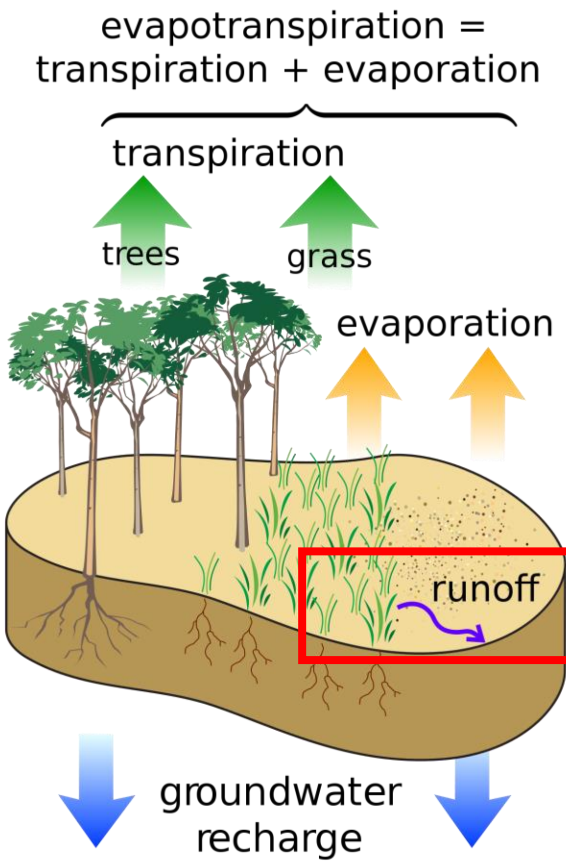


Figure 3.4 Seepage flow model to estimate net rainfall depth

Guo et al. (2022)



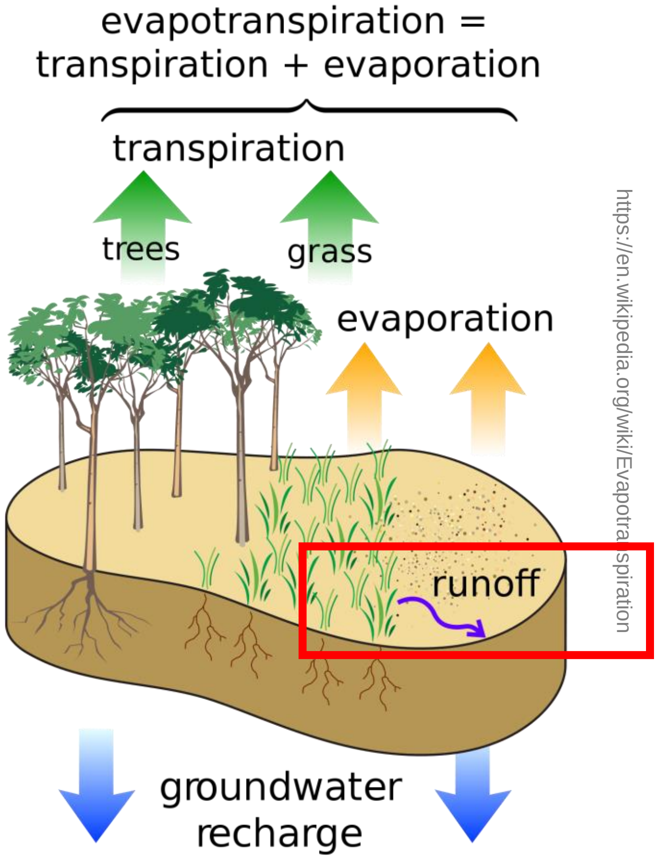
https://en.wikipedia.org/wiki/Evapotranspiration

Urban Water Cycle

Runoff

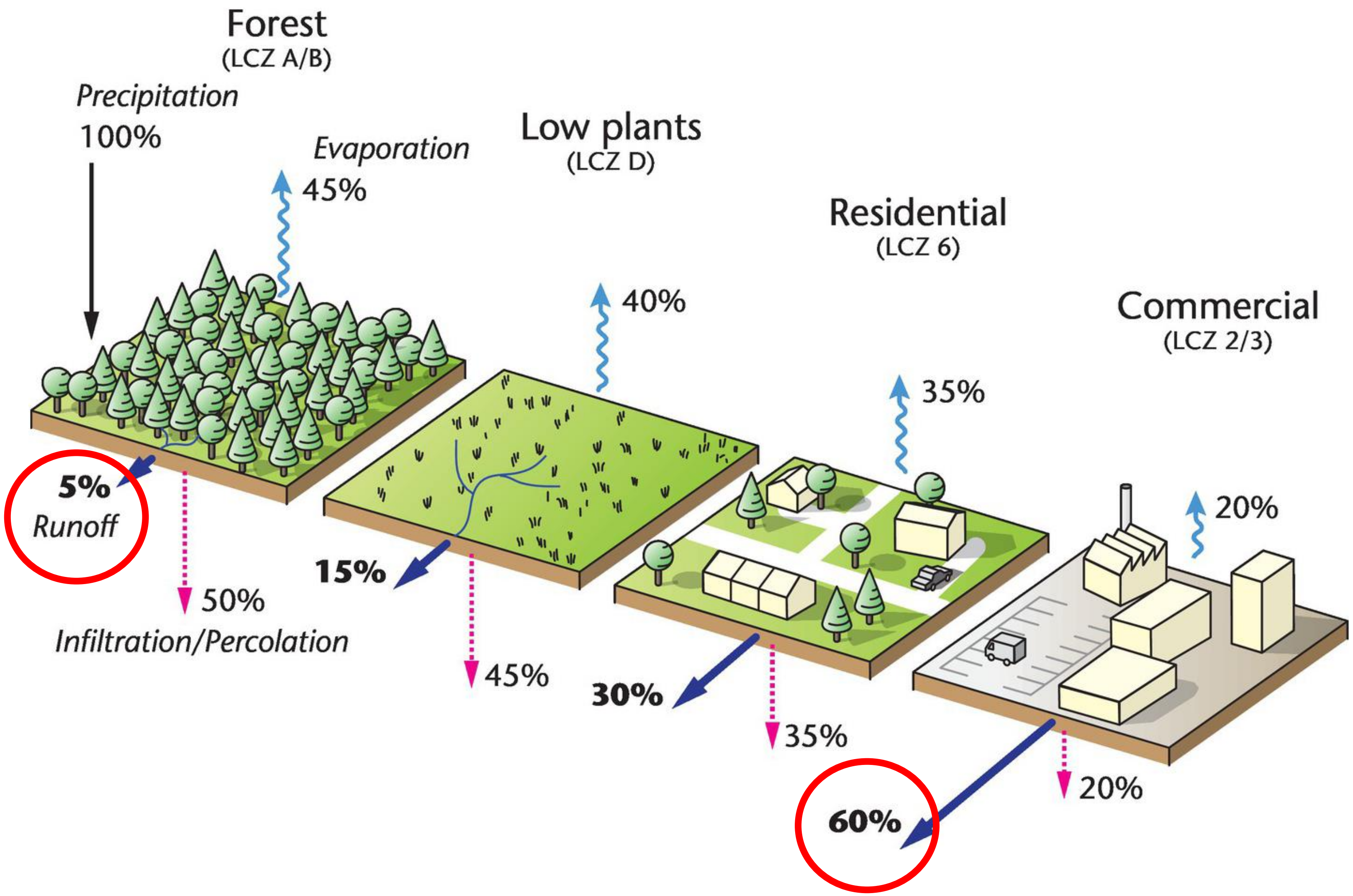
- Runoff that flows over land before reaching a watercourse is referred to as surface runoff or overland flow.
- Once in a watercourse, runoff is referred to as streamflow, channel runoff, or river runoff.
- Urban runoff is surface runoff created by urbanization.

Source: Google Images



https://en.wikipedia.org/wiki/Evapotranspiration

Urban Water Cycle



Generalized approximation of the effect of land cover on the partitioning of precipitation (100%) between evaporation, infiltration and percolation and runoff over periods as long as a year, so that storage change in the root zone is negligible.

Oke et al. (2017)

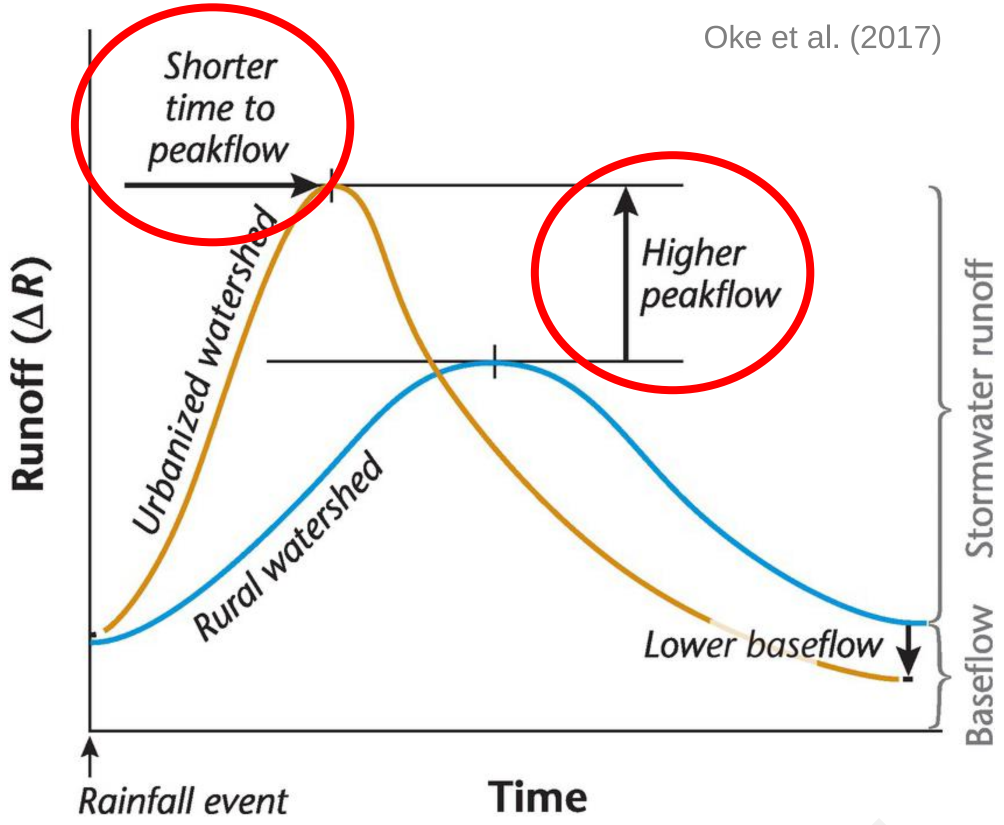
Urban Water Cycle

Discharge curves

The main result of urban development on streamflow is threefold:

- Following a storm event a much **greater volume** of runoff is generated.
- The **time taken** before water input appears in gutters, drains, culverts, streams and rivers is **shortened**.
- The **base flow** is usually **lower** as less water infiltrates into the substrate.

Oke et al. (2017)



Typical storm hydrograph depicting the relation between stream discharge (*R*, left axis) and time, starting with a major input of rainwater (*P*) due to a storm event. One curve is typical of flow from a rural catchment, the other after urban development. Comparing the two curves, note that after development: the increased value of peak flow; the shortened time before arrival of that peak, and the drop in the baseflow.

Today's session

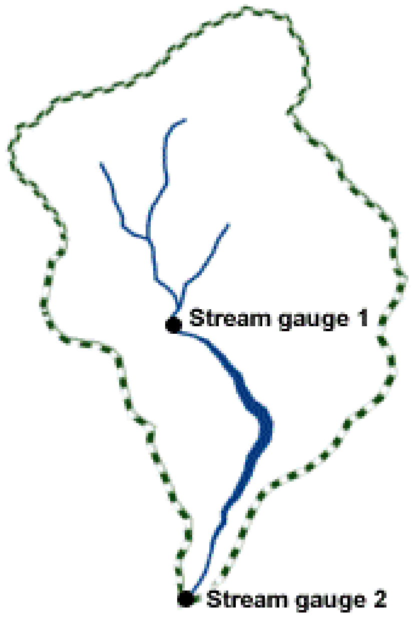
Outline

- Urban water cycle
- **Modeling runoff**
- Flooding and drainage

Modeling runoff

Modeling runoff

- Predict **flows** at catchment outlet
- Estimate **peak rates** or time-series of flows known as a **hydrograph**
- Modelling approaches:
  - **Lumped** – whole catchment as one ‘black box’ element
  - **Distributed** or gridded



©The COMET Program

Modeling runoff

Lumped runoff and catchment size

- **Small catchments** (≤ 1 km2): **Rational Method** if you can assume constant rainfall in space and time. Only overland flow occurs.

- **Medium catchments** (≤ 25 km2): **unit hydrograph method** when you can assume rainfall is spatially constant but temporally varied (since slower response to rainfall)

- **Large catchments:** both spatial and temporal variation in precipitation must be considered. **Routing methods** must be used since channel flow occurs.

Modeling runoff

Rational method:

$$Q = C \cdot i \cdot A$$

where:

- Q = **Peak** runoff in m^3/s
- C = Runoff coefficient (dimensionless)
- i = Rainfall intensity (mm/hr)
- A = Drainage area (ha)

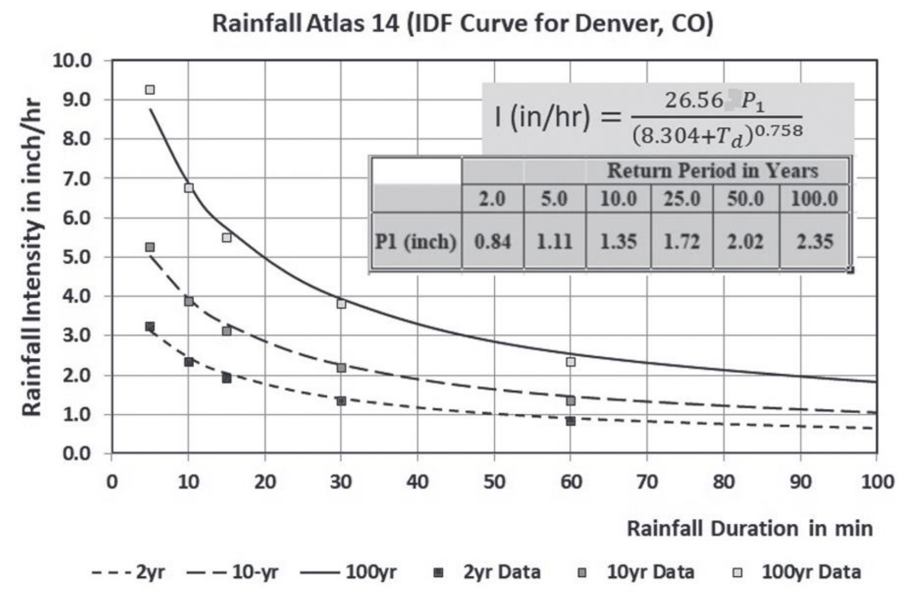


Figure 4.1 IDF curves and formula for Denver, Colorado

Guo et al. (2022)

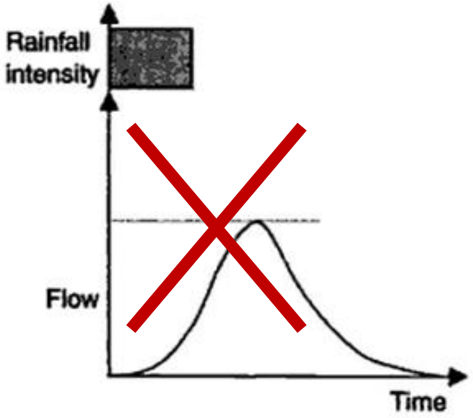
The **rainfall intensity** (i) is typically found from Intensity/Duration/Frequency curves for rainfall events in the geographical region of interest.

Modeling runoff

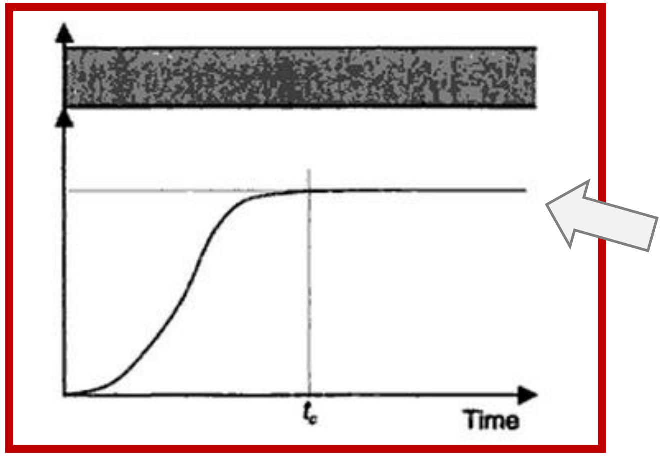
Rational method (assumptions):

- Steady state, rainfall rate must be constant
- Duration of the storm must be greater or equal to the **time of concentration** t_c

NO



YES



Peak runoff

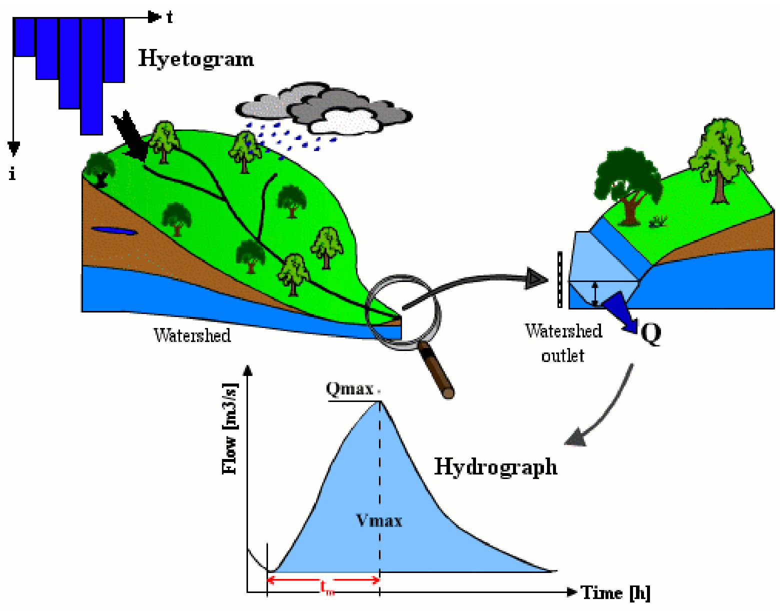
whole catchment is contributing runoff

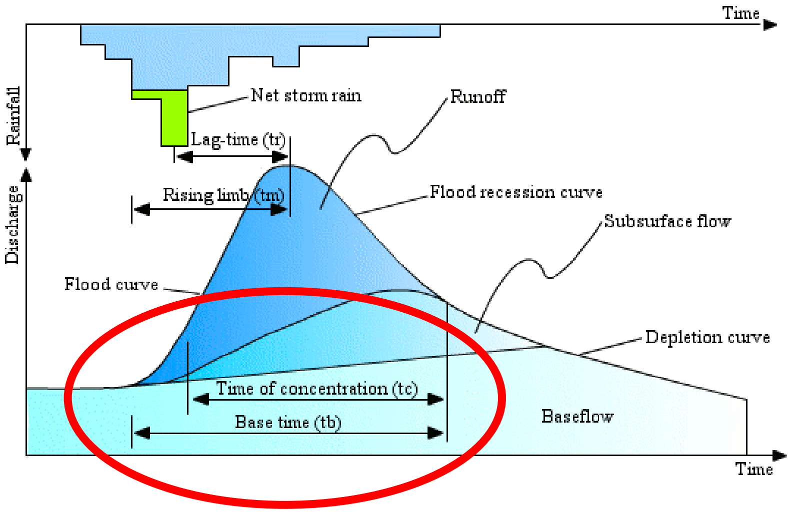
Modeling runoff

Rational method (assumptions):

- Steady state, rainfall rate must be constant
- Duration of the storm must be greater or equal to the **time of concentration** t_c

time for a drop of water to flow from **remotest point** in catchment (‘up-catchment’) to the **point of interest** (‘outlet’).





Modeling runoff

Rational method (assumptions):

- Steady state, rainfall rate must be constant
- Duration of the storm must be greater or equal to the **time of concentration** t_c

Note:

The Rational Model is simplistic and **depends on the user** to compensate for most of the factors that influence peak runoff (e.g., antecedent rainfall, spatial variability). Users must:

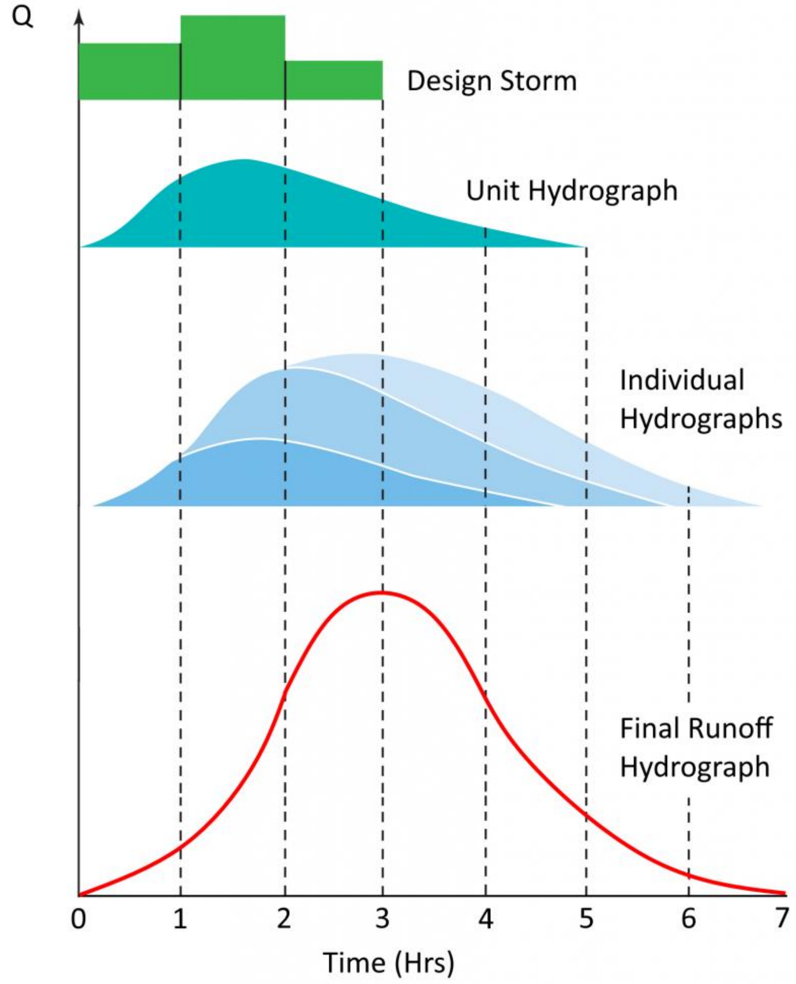
- choose the appropriate **runoff coefficient(s)** and
- determine the **time of concentration** based on plan information (which will include hydrologic changes due to construction/urbanization)

Modeling runoff

Unit hydrograph method

Considers a basic unit of rainfall that creates a pulse of runoff:

- This pulse is quantified by a **unit (flow) response function**
- If the hydrologic system can be approximated as **linear**, response function is called unit hydrograph
- Linear systems follow 2 principles:
  - **Proportionality** (all results are proportional)
  - **Superposition** (all results are additive)



NRCS (SCS) Hydrographs

Modeling runoff

Unit hydrograph method

- **Unit hydrograph (UH)** of a catchment is runoff generated by a 1mm depth rainfall that falls uniformly over the drainage area at a constant rate for a specific duration (e.g. 1 hour)
- These can be generated from observed data or "synthetically" if data are not available

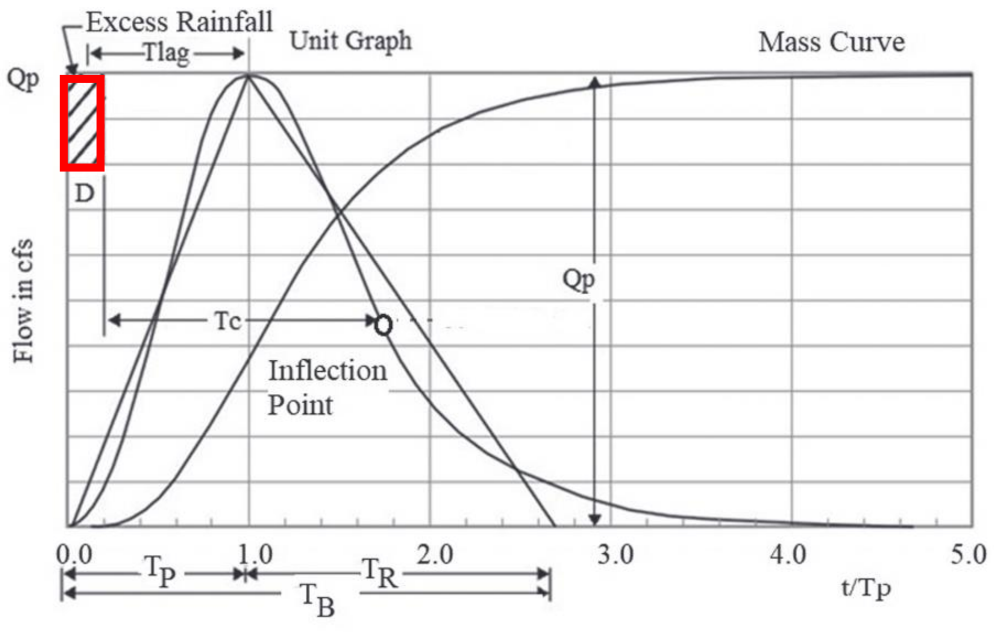


Figure 5.1 SCS triangular unit hydrograph

See Guo et al. (2022)

Modeling runoff

EPFL

Unit hydrograph method

$$Q_p = \frac{2V}{3600\,(T_P + T_R)}$$

$$T_{lag} = \frac{L^{0.8}(S+1)^{0.7}}{1900\sqrt{S_0}} \quad \text{(for large rural and forest areas)}$$

$$S = \frac{1000}{CN} - 10$$ = maximum soil retention volume

Table 5.1 SCS curve number for various land uses

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	*Average percent impervious area*[2]	*A*	*B*	*C*	*D*
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3/]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98

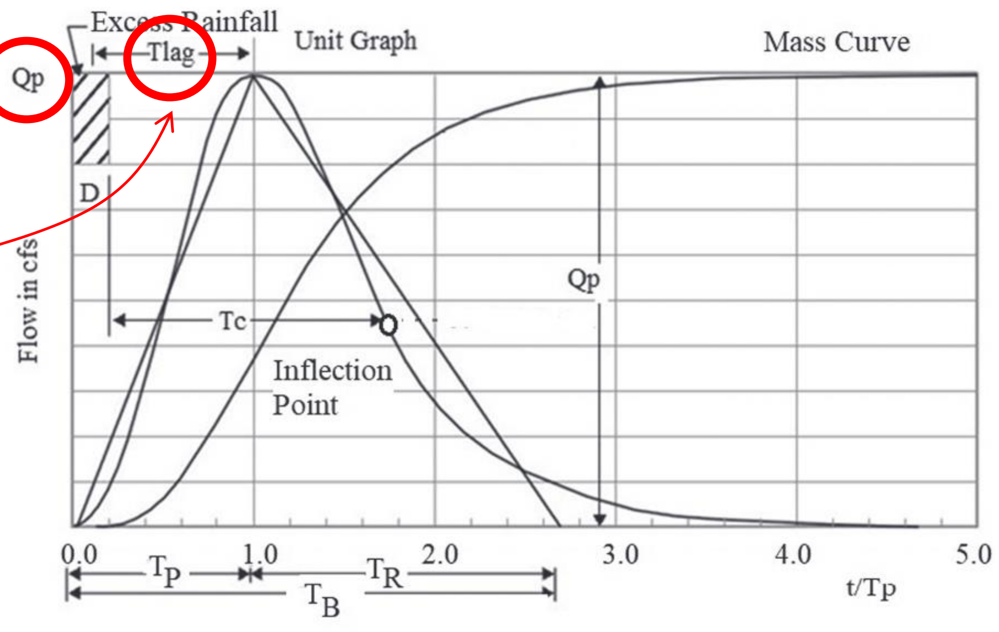
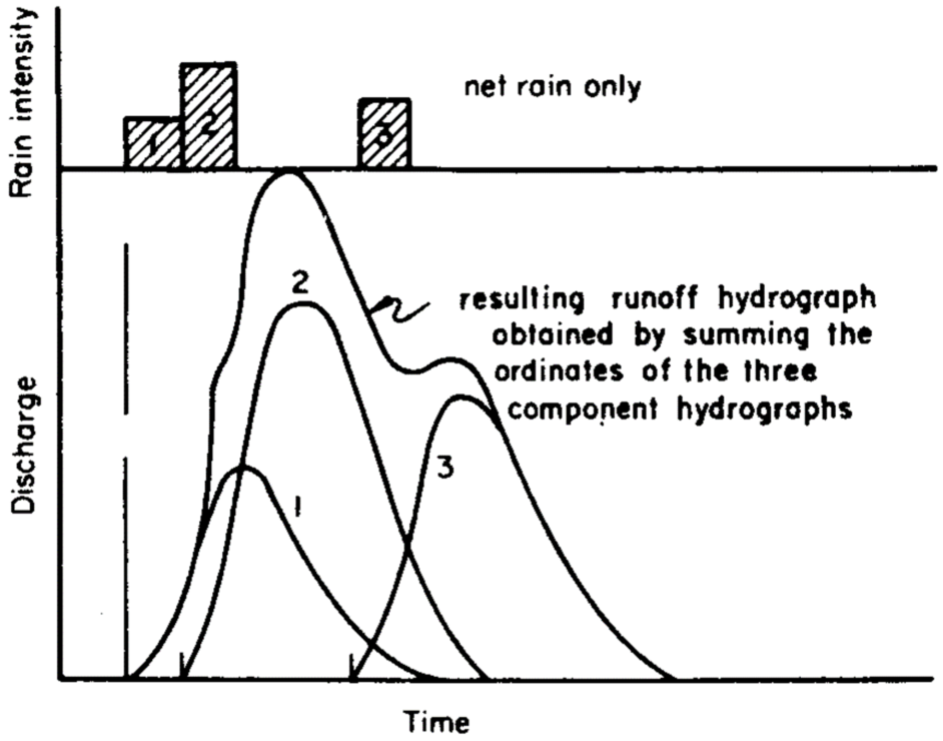


Figure 5.1 SCS triangular unit hydrograph

See Guo et al. (2022)

Modeling runoff

Unit hydrograph method



Application of UH to real storms:

$$Q(t) = \sum_{\omega=1}^{N} u(D,j)\, I_\omega$$

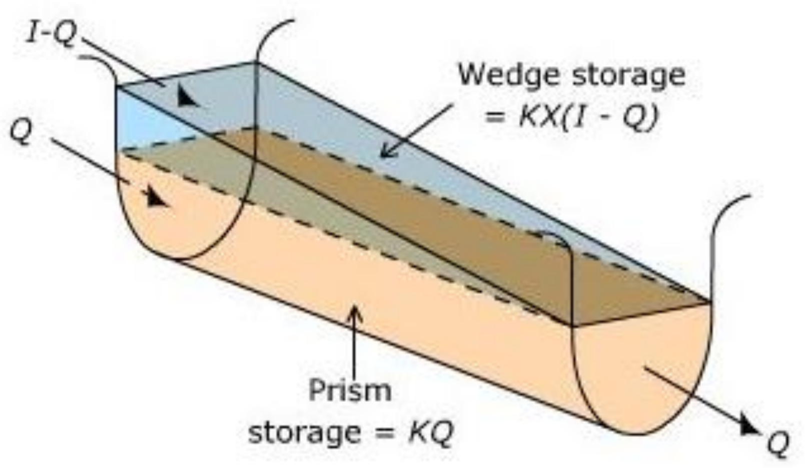
$$Q(t) = u(D,t)\, I_1 + u(D,t-D)\, I_2 + \ldots + (D,t-(N-1)D)\, I_n$$

$Q(t)$	runoff hydrograph ordinate at time t (m^3/s)
$u(D,j)$	D-h unit hydrograph ordinate at time j (m^3/s)
I_ω	is the rainfall depth in the ωth of N blocks of duration D (m)
j	$t-(\omega-1)D$ (s)

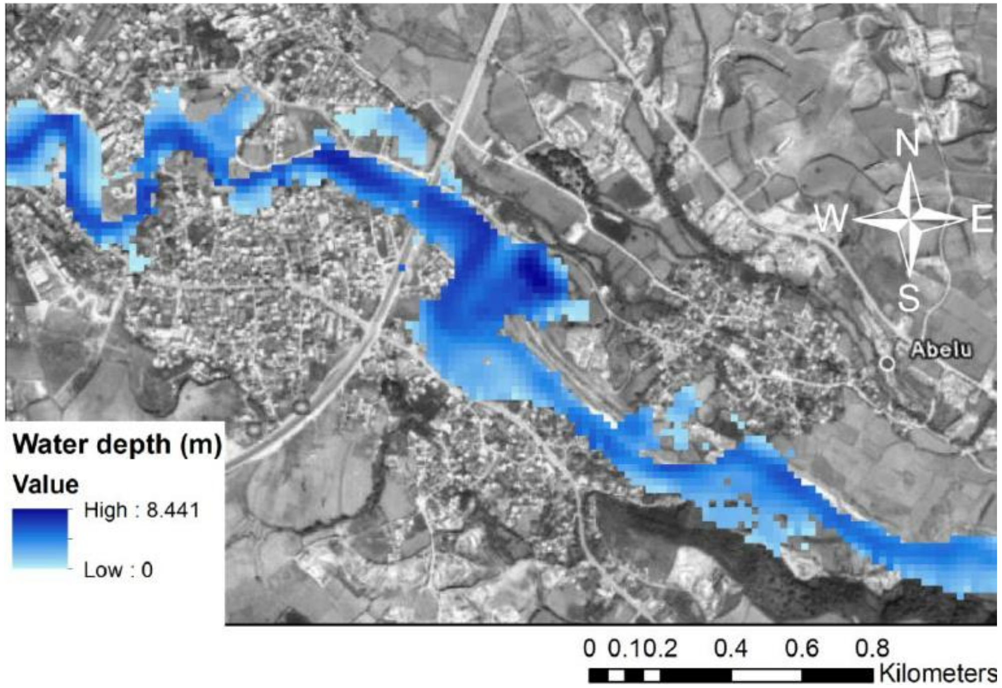
See Butler and Davies (2011) & Guo et al. (2022)

Modeling runoff

Large catchments: flow routing



Muskingum hydrologic flow routing



Ghanbarpour et al. (2013)

Modeling runoff

InVEST Urban Flood Risk Mitigation

InVEST
Integrated Valuation of Ecosystem Services and Tradeoffs

Watch 8

Table of Contents

Quick search

Go

Urban Flood Risk Mitigation

Introduction

Flood hazard comes from different sources, including: riverine (or fluvial) flooding, coastal flooding, and stormwater (or urban) flooding - the focus of this InVEST model. Natural infrastructure can play a role for each of these flood hazards. Related to stormwater flooding, natural infrastructure operates mainly by reducing runoff production, slowing surface flows, and creating space for water (in floodplains or basins).

The InVEST model calculates the runoff reduction, i.e. the amount of runoff retained per pixel compared to the storm volume. For each watershed, it also calculates the potential economic damage by overlaying information on flood extent potential and built infrastructure.

The Model

How it works

Runoff production and runoff attenuation index

For each pixel i, defined by a land use type and soil characteristics, we estimate runoff Q (mm) with the Curve Number method:

$$Q_{p,i} = \begin{Bmatrix} \frac{(P-\lambda S_{max_i})^2}{P+(1-\lambda)S_{max,i}} & if \quad P > \lambda \cdot S_{max,i} \\ 0 & otherwise \end{Bmatrix} \qquad (118)$$

Where P is the design storm depth in mm, $S_{max,i}$ is the potential retention in mm, and $\lambda \cdot S_{max}$ is the rainfall depth needed to initiate runoff, also called the initial abstraction ($\lambda = 0.2$ for simplification).

S_{max} (calculated in mm) is a function of the curve number, CN, an empirical parameter that depends on land use and soil characteristics (NRCS 2004):

$$S_{max,i} = \frac{25400}{CN_i} - 254 \qquad (119)$$

InVEST Urban Stormwater Retention

InVEST
Integrated Valuation of Ecosystem Services and Tradeoffs

Watch 8

Table of Contents

The Model

The model calculates annual stormwater retention volume and the associated water quality benefits (i.e., avoided transport of nutrients or pollutants to lakes, streams, or estuaries that receive runoff). The value of the retention service may be calculated using a replacement cost of stormwater infrastructure. Optionally, the model can also provide estimates of potential groundwater recharge to the aquifer, as well as the stormwater exported in surface runoff (as volume and mass of pollutants or nutrients). An overview of the urban rainfall-runoff water balance, illustrating these major fluxes of water, is shown in Fig. 18 below.

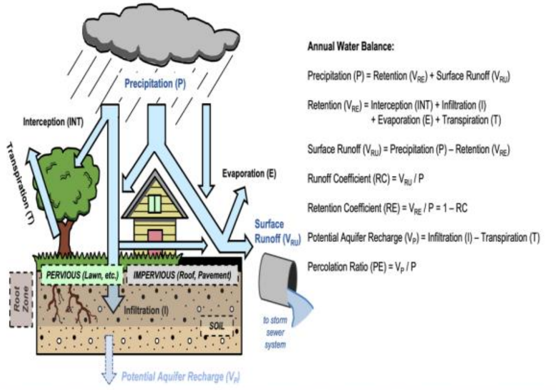


Fig. 18 **Major hydrologic fluxes in the urban stormwater balance**, illustrating potential fates of incoming precipitation as it falls on pervious surfaces (soil or vegetation, such as lawns and trees) and impervious surfaces (rooftops and paved surfaces). Potential aquifer recharge is estimated during dry weather periods as the difference between the volume of infiltrated rainfall and the volume of water transpired by vegetation over a soil depth in which most plant roots may be found.

Today's session

Outline

- Urban water cycle
- Modeling runoff
- **Flooding and drainage**

Flooding and drainage

Urban flooding

https://www.citylab.com

https://www.dawn.com

Flooding and drainage

What is urban flooding?

- Pluvial (**rain**)
- Fluvial (**river**)
- Storm surge (**sea**)
- Groundwater
- Sewer

What causes urban flooding?

- Increase in impermeable surfaces
- Inadequate drainage
- Heavy rain / Overbank flows
- Natural disasters (e.g. hurricanes)
- Dumping of solid waste in open drains




Source: Google images

Flooding and drainage

Urbanisation and drainage

Urban drainage systems are those which are needed to drain water in developed urban areas because of the interaction between built surfaces, human activity, and the natural water cycle

Urban Drainage systems handle two key types of water: **wastewater** and **stormwater**:

- Wastewater is very small compared to stormwater.
- Wastewater does nor cause floods.
- Urban drainage is mainly designed for stormwater

Bazalgette sewer, North Kensington. Constructed c. 1861

Flooding and drainage

Urbanisation and drainage

A very old profession, dating back to around **3000 BC**!

Lothal, ca 3000 BC - Wikipedia

Cloaca Maxima, ca 600 BC - Science

Flooding and drainage

Removing urban water

- Convenience
- Public health (e.g. diarrheal and mosquito borne diseases)
- Prevent flooding (surface water and sewer)
- Protect environment

Where does it go?

- Drainage network
  - Separate or combined
  - Gravity and pumped
- Treatment
  - Sewage treatment
  - Wetlands or ponds
- Receiving environment (Groundwater, Rivers, Ocean)

An open sewer in Kibera, Nairobi

Slums near a garbage dump in Jakarta

Flooding and drainage

Approaches to urban drainage

- **Traditional approaches:** Piped networks and intensive treatment (using combined or separate systems)
- **Modern approaches:** Sustainable Drainage Systems (SuDS) or Water Sensitive Urban Design (WSUD)

https://www.thames21.org.uk

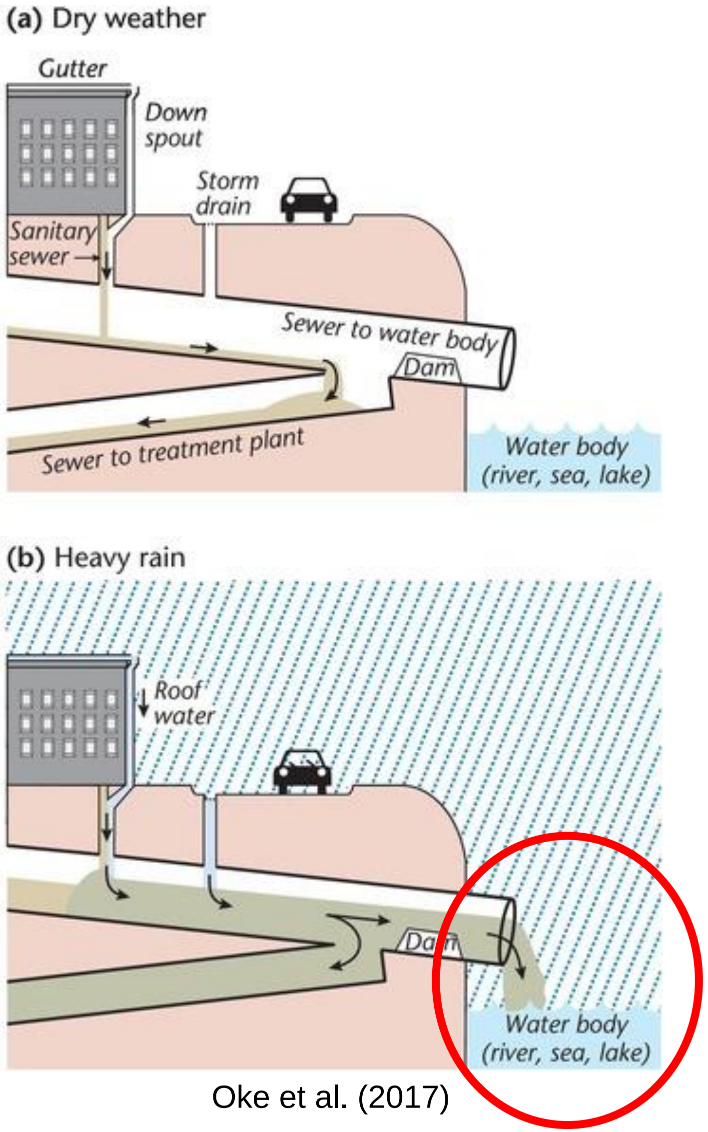
Flooding and drainage

Piped networks: Combined Sewers

- Storm water and wastewater **combined**
- Highly **variable** flow and quality
- **Overflows** during storm events (dilute **untreated** sewage discharged into environment)
- Treated at wastewater treatment plant
  - Variable flow, larger plant
  - Control for variable quality inflow

Cheaper construction (1 pipeline only) but …

- More expensive treatment facilities
- Overflows during storm events have serious environmental impacts (worse during summer)



Oke et al. (2017)

Flooding and drainage

Piped networks: Combined Sewers

CSO pipe, London (Google Images)

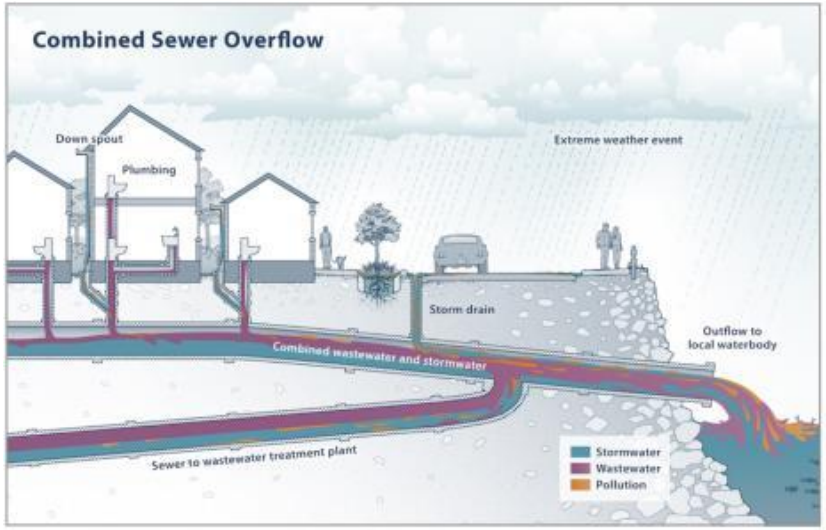
Thames Tideaway Tunnel project (Google Images)

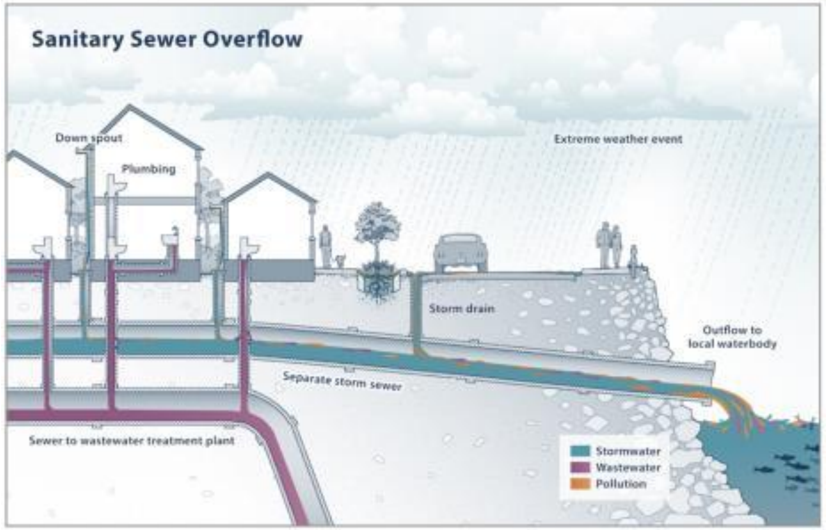
Flooding and drainage

Piped networks: Separate Systems

Separate networks for storm water and wastewater:

- Intensive treatment of wastewater
- Low intensity treatment of storm water
- Higher capital and maintenance costs
- Lower operating costs
- Better environmental protection





https://toolkit.climate.gov/

Flooding and drainage

Sustainable Urban Drainage Systems (SuDS)

SuDS mimic nature and typically manage rainfall close to where it falls. SuDS can be designed to **reduce** peak flow transport (convey) surface water, **slow** runoff down (attenuate) before it enters watercourses, **store** water, increase **infiltration**.

Possible techniques include:

- Ponds
- Swales
- Rainwater harvesting
- Green roofs

Images: CIRIA, http://www.ciria.com/suds/

Flooding and drainage

Sustainable Urban Drainage Systems (SuDS)

Benefits:

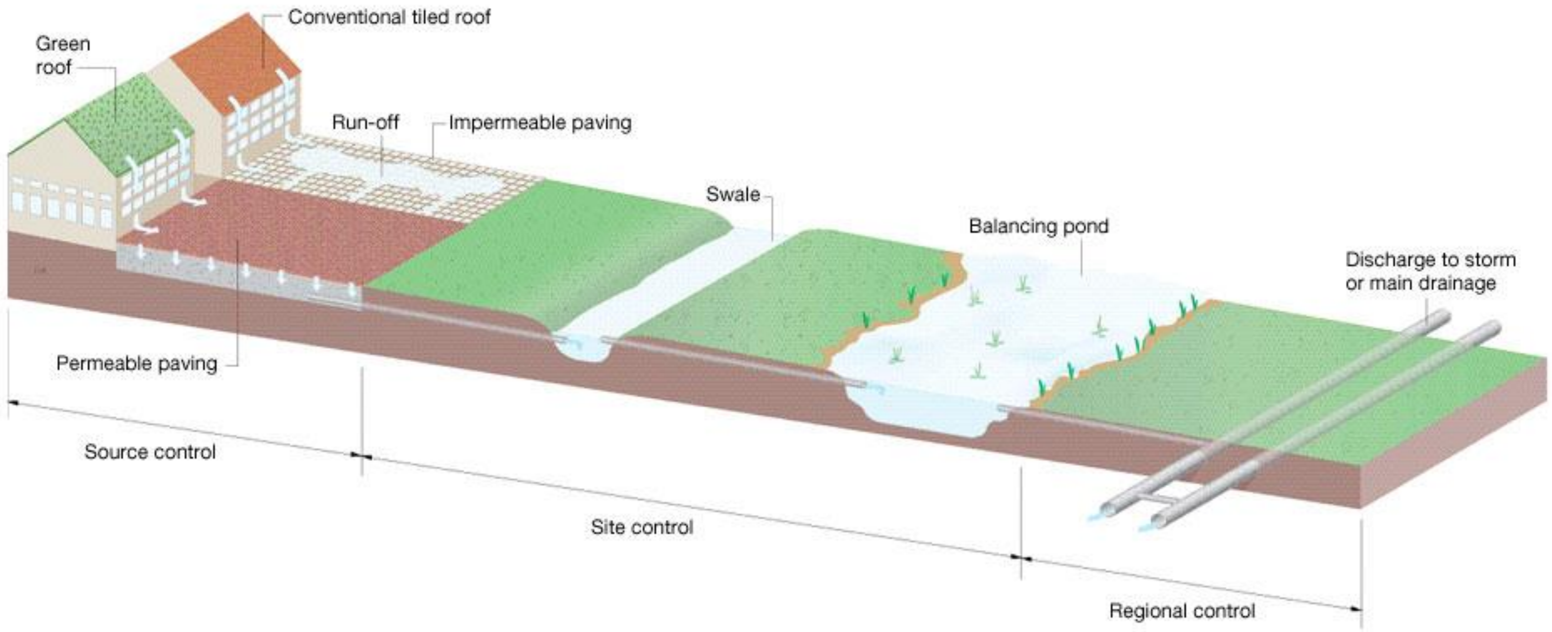
- Reduce inputs into drainage networks
- Reduce overflows into the environment
- Improve water quality
- Restore urban water courses
- Reduce carbon emissions
- Utilise storm water and waste water
- Build resilience to flooding
- Reap social benefits

Images: CIRIA, http://www.ciria.com/suds/

Flooding and drainage

Sustainable Urban Drainage Systems (SuDS)

The **SuDS management train** concept promotes division of the area to be drained into sub-catchments with different drainage characteristics and land uses, each with its own drainage strategy.



The management train starts with prevention (preventing runoff by reducing impermeable areas), or good housekeeping measures for reducing pollution; and progresses through local source controls to larger downstream site and regional controls.

Image source: http://www.permcalc.co.uk/why-suds/sudsmanagement-train/

Flooding and drainage

EPFL

Sustainable Urban Drainage Systems (SuDS)

The Federal Council › DETEC › FOEN   Homepage Media Contact

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Office for the Environment FOEN

Topics | Publications, media | Data, indicators, maps | The FOEN

Homepage › Topics › Topic Water › Information for specialists › Measures › Wastewater › Urban drainage

‹ Measures

Wastewater

Urban drainage

Drainage on transport routes

Industrial and commercial waste water

Urban drainage

Switzerland has a reliable urban drainage infrastructure. Drainage plans help to maintain and develop this service. As a result of climate change, new approaches to dealing with rainwater are also necessary, e.g. 'sponge cities'.

Switzerland has a comprehensive, efficient and reliable drainage infrastructure. A General Drainage Plan (GEP) is required to ensure that these remain functional and up to date going forward. Climate change is resulting in more frequent heavy precipitation, heat waves and dry periods, so we need to rethink the way we deal with rainwater. The 'sponge city' model provides a promising approach. It allows large quantities of water to be stored in urban areas during heavy precipitation and then slowly released into the environment. This relieves urban drainage systems and has a positive impact on the microclimate in these areas.

⌄ The General Drainage Plan GEP

⌄ Sponge cities

Sponge cities

The climate is changing and so are precipitation patterns. Extreme events such as heavy precipitation and prolonged periods of heat and drought are becoming more frequent. This has an impact on drainage systems in Switzerland's towns and cities, where more than 60% of the ground area is sealed over, so water cannot easily drain away. The sponge city model can mitigate this negative impact. It provides the greatest possible benefit for waters protection with the least possible damage to property during flood events. It also creates a more balanced climate in urban areas.

Like a sponge, the city of the future will store as much rainwater as possible during heavy precipitation, and then slowly release it again. This brings multiple benefits. During heavy rain events, sewerage systems come under extreme pressure. This results in flooding, and waste water may be discharged from the sewerage system or waste water treatment plants into water bodies. With more water retention and storage possibilities in urban areas, such as temporary ponds and green spaces on squares and roofs, the rain can then flow out of the urban area more slowly, seep into the ground, be absorbed by plants or evaporate. Larger areas covered in vegetation also counteract the urban heat island effect. A sponge city experiences less flooding and less pollution and has a more balanced climate.

Initial steps have already been made to promote the notion of a sponge city by the Swiss Water Association (VSA), which has drawn up guidelines on integral rainwater management, or good precipitation waste water management (Abwasserbewirtschaftung bei Regenwetter (2019)).

VSA: Abwasserbewirtschaftung bei Regenwetter

Flooding and drainage

EPFL

Sustainable Urban Drainage Systems (SuDS)

The Federal Council › DETEC › FOEN

Homepage Media Contact

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Office for the Environment FOEN

Topics | Publications, media | Data, indicators, maps | The FOEN

Homepage › Topics › Topic Water › Information for specialists › Measures › Wastewater › Urban drainage

‹ Measures

Wastewater

Urban drainage

Drainage on transport routes

Industrial and commercial waste water

Urban drainage

Switzerland has a reliable urban drainage infrastructure. Drainage plans help to maintain and develop this service. As a result of climate change, new approaches to dealing with rainwater are also necessary, e.g. 'sponge cities'.

Switzerland has a comprehensive, efficient and re
infrastructure. A General Drainage Plan (GEP) is r
remain functional and up to date going forward.
in more frequent heavy precipitation, heat waves
need to rethink the way we deal with rainwater.
provides a promising approach. It allows large qu
stored in urban areas during heavy precipitation
into the environment. This relieves urban drainage systems and has a positive impact on the microclimate in these areas.

⌄ The General Drainage Plan GEP

⌄ Sponge cities

Sponge cities

The climate is changing and so are precipitation patterns. Extreme events such as heavy precipitation and prolonged periods of heat and drought are becoming more frequent. This has an impact on drainage systems in Switzerland's towns and cities, where more than 60% of the ground area is sealed over, so water cannot easily drain away. The sponge city model can mitigate this negative impact. It provides the greatest possible benefit for waters protection with the least possible damage to property during flood events. It also creates a more balanced climate in urban areas.

Like a sponge, the city of the future will store as much rainwater as possible during heavy precipitation, and then slowly release it again. This brings multiple benefits. During heavy rain events, sewerage systems come under extreme pressure. This results in flooding, and waste water may be discharged from the sewerage system or waste water treatment plants into water bodies. With more water retention and storage possibilities in urban
temporary ponds and green spaces on squares and roofs, the
flow out of the urban area more slowly, seep into the ground,
y plants or evaporate. Larger areas covered in vegetation also
urban heat island effect. A sponge city experiences less
ess pollution and has a more balanced climate.

Initial steps have already been made to promote the notion of a sponge city by the Swiss Water Association (VSA), which has drawn up guidelines on integral rainwater management, or good precipitation waste water management (Abwasserbewirtschaftung bei Regenwetter (2019)).

VSA: Abwasserbewirtschaftung bei Regenwetter

Guest speaker (Week 8)

+

ENV-417 (Urban hydrology)

Flooding and drainage

Sustainable Urban Drainage Systems (SuDS) & Co.

Nature-based stormwater management approaches, including Blue-Green Infrastructure (BGI), Green Infrastructure (GI), Water Sensitive Urban Design (WSUD), Sustainable Urban Drainage Systems (SUDS), Low Impact Development (LID), ABC Waters, and Sponge Cities may all reduce runoff but differ in their primary focus and approach.

[Exploring the Differences between Nature-Based Stormwater Management Approaches]

Research articles

SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage

Tim D. Fletcher, William Shuster, William F. Hunt, Richard Ashley, David Butler, Scott Arthur, ...show all

Pages 525-542 | Received 09 Sep 2013, Accepted 14 Apr 2014, Published online: 23 Jul 2014

Cite this article https://doi.org/10.1080/1573062X.2014.916314 Check for updates

https://www.tandfonline.com/doi/full/10.1080/1573062X.2014.916314