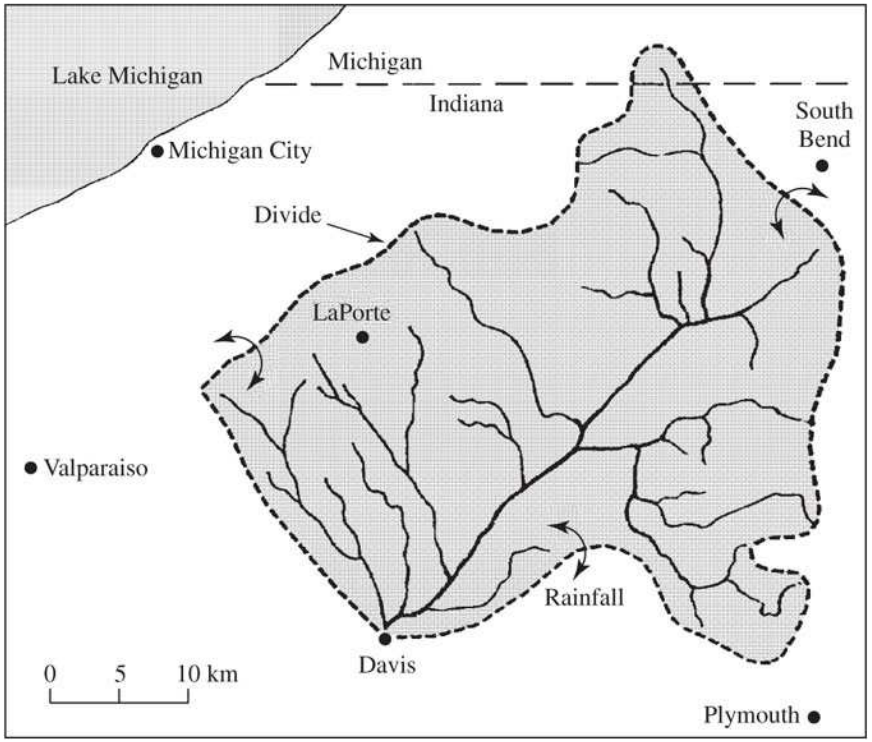
Watershed

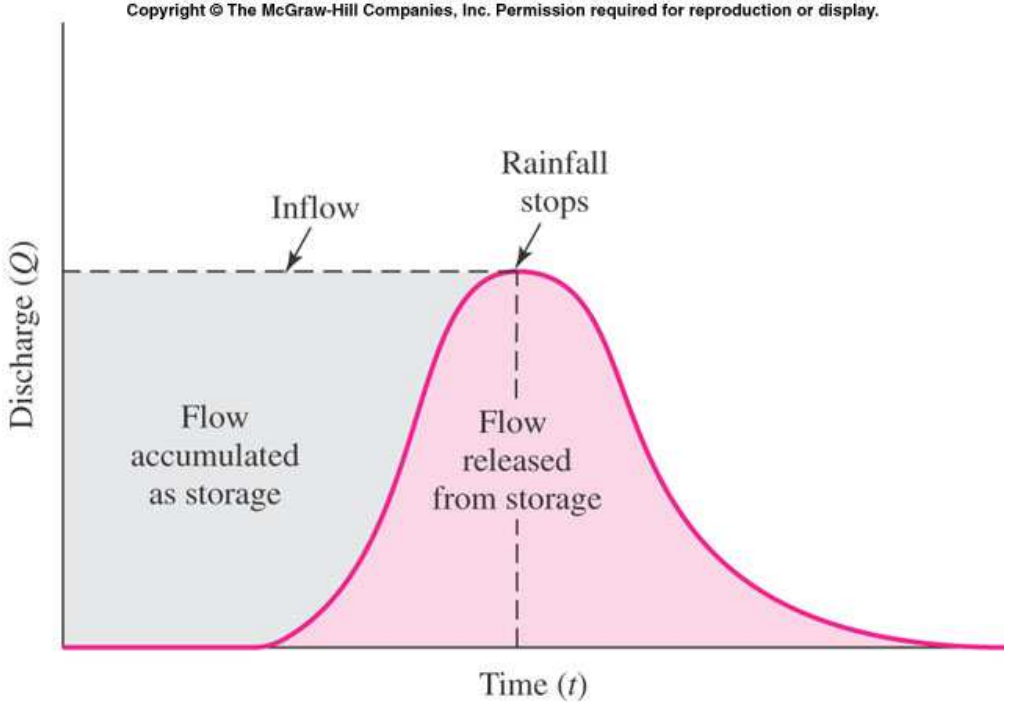
- **Watershed (basin)**: the area of land where all of the water that is under it or drains off of it goes to the same place

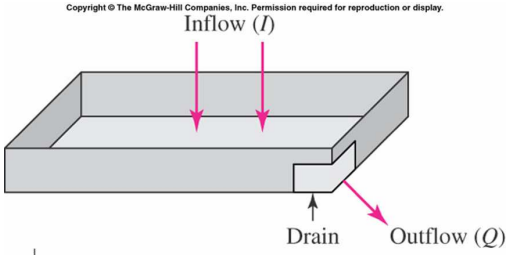
- **Divide**: the boundary of the watershed



Hydrograph

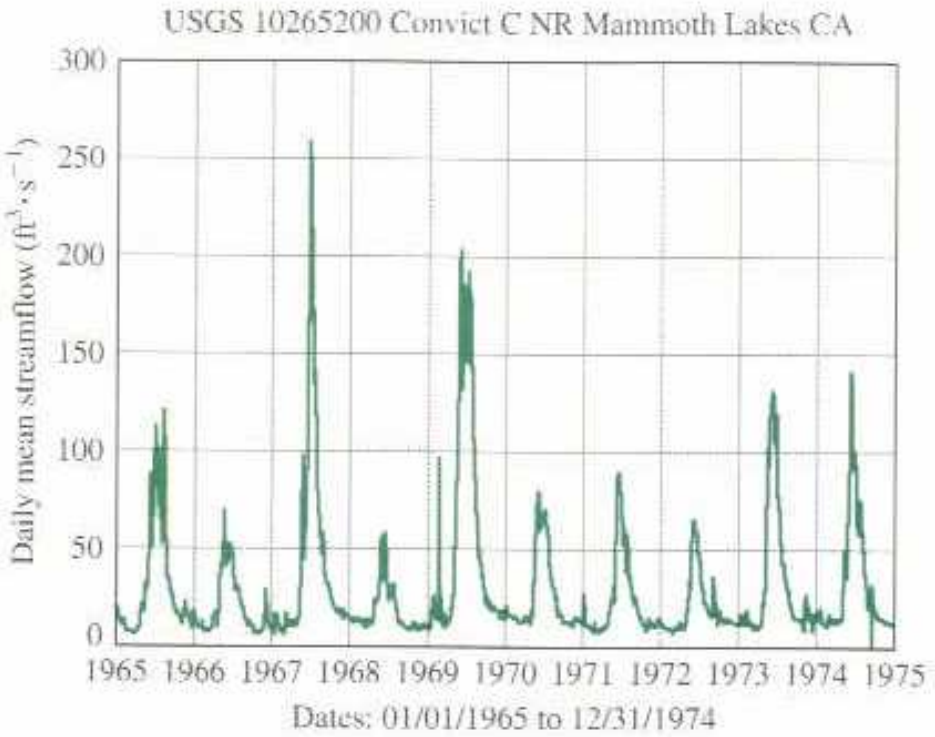
- A chart in which flow rate is plotted vs. time





An example hydrograph for a simple parking lot

Hydrograph



10-year hydrograph for a creek (example)

- The shape of the hydrograph is affected by various factors such as: precipitation, weather, topography of the watershed, density and type of ground cover, …

Runoff coefficient

- Runoff coefficient

  = {rate of runoff (R)} / {rate of precipitation (P)}

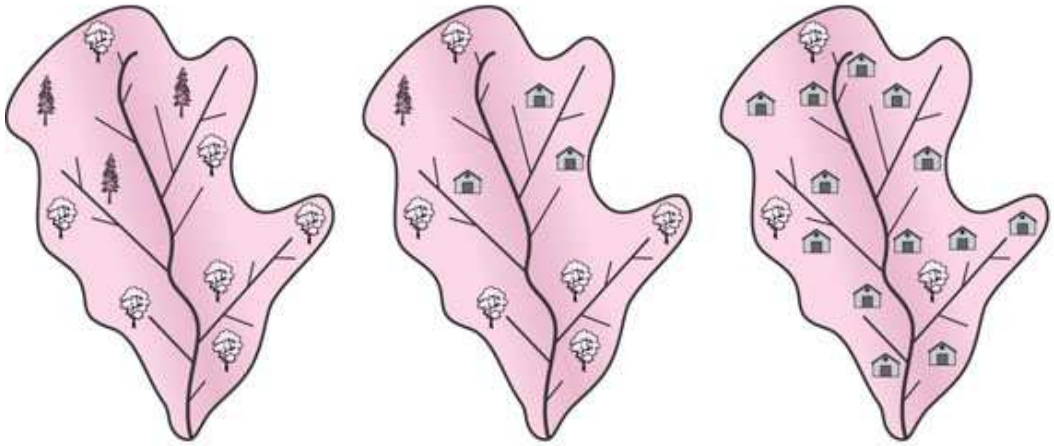
Typical Runoff Coefficients

Description of Area or Character of Surface	Runoff Coefficient	Description of Area or Character of Surface	Runoff Coefficient
Business		Railroad yard	0.20–0.35
Downtown	0.70–0.95	Natural grassy land	0.10–0.30
Neighborhood	0.50–0.70	Pavement	
Residential		Asphalt, concrete	0.70–0.95
Single-family	0.30–0.50	Brick	0.70–0.85
Multi-units, detached	0.40–0.60	Roofs	0.75–0.95
Multi-units, attached	0.60–0.75	Lawns, sandy soil	
Residential, suburban	0.25–0.40	Flat (<2%)	0.05–0.10
Apartment	0.50–0.70	Average (2–7%)	0.10–0.15
Industrial		Steep (>7%)	0.15–0.20
Light	0.50–0.80	Lawns, heavy soil	
Heavy	0.60–0.90	Flat (<2%)	0.13–0.17
Parks, cemeteries	0.10–0.25	Average (2–7%)	0.18–0.22
Playgrounds	0.20–0.35	Steep (>7%)	0.25–0.35

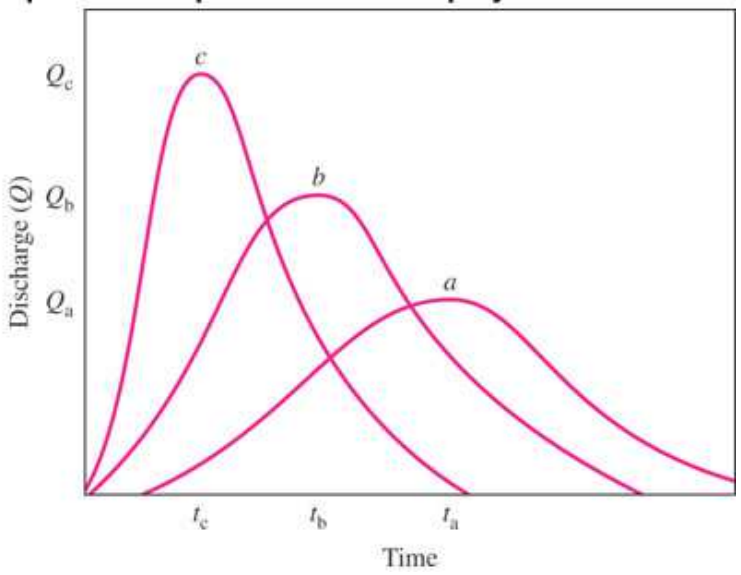
Source: Joint Committee of the American Society of Civil Engineers and the Water Pollution Control Federation, 1969.

The more developed, the bigger runoff coefficient

Runoff coefficient



(a) Undeveloped (b) Partially developed (c) Fully developed



$Q_c > Q_b > Q_a$, $t_c < t_b < t_a$

- Urban & industrial development increases the impact of flood

Runoff coefficient

Q: A watershed with an area of 4530 km^2 received 77.7 cm of precipitation in 2013. The average rate of flow measured in a river which drained the watershed was 39.6 m^3/s. Infiltration occurred at an average rate of 9.2 x 10^{-7} cm/s and evapotranspiration was estimated to be 45 cm/year. What was the change in storage in the watershed in 2013? What was the runoff coefficient?

Low impact development (LID)

- A developing area of study and practice
- A land planning and engineering design approach to minimize the hydrological impact of urban development
- Some effect on the treatment of stormwater pollutants is also expected

An LID project in Seattle, USA
(*http://www.mapc.org*)

LID practices

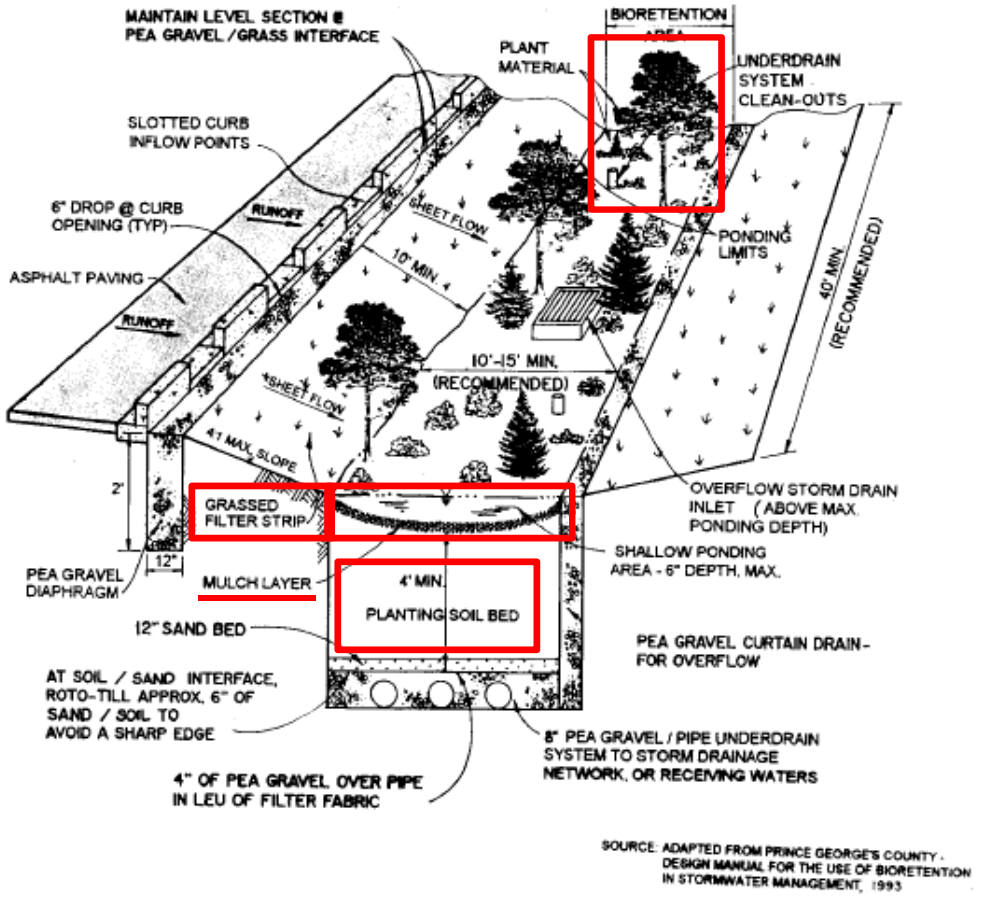
- Bioretention zone

Grass buffer strips: reduce the velocity of runoff, filter particulate matter

Plants: take up nutrients, transpiration

Organic layer: support microbial growth (organic material degradation), sorb pollutants

Planting soil: water retention, sorb pollutants



http://www.georgiastormwater.com

LID practices

- Green roofs

LID practices

- Permeable pavements
  - sidewalks, bike roads, parking lots
- Grass swales and channels
  - Redirect runoff from stormwater drains
- Rain barrels, cisterns
  - Collection of stormwater and use for irrigation / toilet flushing

Grass swale in Ottawa, Canada (*http://www.ottawa.ca*)

Reading assignment

- Textbook Ch 7, p. 263-266, 296-298