Basin characteristics

From hydrological processes at the point scale to hydrological processes throughout the space continuum:

- **point scale → river basin**

The watershed characteristics (shape, length, topography, ...)

- **control the response of the river basin**
  - shape of the hydrograph
  - soil water dynamics

- **can be used to identify similarity of response among different basins**
  - extrapolation and regionalisation of models

**NB**

River basin, drainage basin, watershed, catchment are used as synonymous
Basin characteristics

**Lecture content**

Quantitative characterization of

- topographic features
- river network characteristics
- soil
- land cover
- interrelationships between watershed features

Skript: Ch. IV.1, IV.1.1, IV.1.3, IV.1.4
Watershed definition

**watershed**: area of land draining into a **river network** converging to an **outlet**

The area of the watershed is delimited by the **topographic (=drainage) divide** outlined on a topographic map.
Topographic vs phreatic divide

- the area contributing to water balance corresponds to that delimited by the \textit{topographic (=drainage) divide}

- the area contributing to water balance \textbf{DOES NOT} correspond to that delimited by the \textit{topographic (=drainage) divide}

\[ \text{Closing the water balance requires the knowledge of the \textit{phreatic divide}} \]
Hypsometric curve

<table>
<thead>
<tr>
<th>elevation range [m]</th>
<th>ΔA [km²]</th>
<th>$A_{tot}$ [km²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1685 – 1500</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>1500 – 1250</td>
<td>4.9</td>
<td>8.3</td>
</tr>
<tr>
<td>1250 – 1000</td>
<td>7.6</td>
<td>15.9</td>
</tr>
<tr>
<td>1000 – 750</td>
<td>4.1</td>
<td>20.0</td>
</tr>
<tr>
<td>750 – 500</td>
<td>2.8</td>
<td>22.8</td>
</tr>
<tr>
<td>500 – 443</td>
<td>1.3</td>
<td>24.1</td>
</tr>
</tbody>
</table>

$H_{tot} = \sum_i h_i A_i = 1108 \text{ m}$

- cumulative frequency distribution of areas with elevation
  - watershed steepness
- use
  - watershed similarity
  - hydropower potential (identifies large contributing areas with high elevation difference)
Watershed average slope (Alward-Horton’s)

\[ l_i = \text{length of the average elevation line between two subsequent contour lines} \]

\[ d_i = \text{distance between two subsequent contour lines} \]

- **local slope** \( s_i = \frac{\Delta h_i}{d_i} \) **vs** **basin slope**, \( \bar{s} \)

- **local slope** for approximately rectangular areas between two subsequent contour lines of difference \( h \):

  \[ s_i = \frac{h}{d_i} = \frac{hl_i}{d_i l_i} = \frac{hl_i}{a_i} \quad \text{where } a_i = \text{area between two contour lines} \]

- **basin slope** for regularly spaced elevation ranges (contour lines difference = \( h \)):

  \[ \bar{s}_i = \frac{hl_1}{a_1 A} + \frac{hl_2}{a_2 A} + \ldots + \frac{hl_n}{a_n A} = \frac{h}{A} \left( l_1 + l_2 + \ldots + l_n \right) = \frac{hL}{A} \]

  where \( L = \text{total length of average elevation lines} \)

  \( A = \text{total area} \)

**NB**

the degree of accuracy depends on the contour line spacing and on the accuracy of the rectangular areas approximation
Watershed average slope (grid method)

- **local slope**
  
  \[ s_i = \frac{\Delta h_i}{d_i} \]
  
  with \( \Delta h = \) contour lines interval
  \( d_i = \) minimum distance between two contour lines in different gridboxes

- **basin slope**
  
  \[ \bar{s}_i = \frac{\sum_{i} s_i}{N} \]
  
  where \( N = \) number of grid nodes where local slopes \( s_i \) are computed

**NB**

the accuracy of the method depends on the number \( N \) of local slope estimates
Watershed characteristics (automatic methods)

- modern surveying techniques (airborne laser altimetry, satellite radar altimetry, ...) make available digital terrain models (DTMs)

- most commonly DTM are available in raster format → grid of squares with elevations associate to each node

DTMs can be manipulated by means of Geographical Information Systems (GIS) to extract basin characteristics:

- watershed delineation
- local and basin slope
- digital river network
  - flow direction
  - flow accumulation (drainage area)
- river profile
- aspect
  ...

Shaded relief representation of the DTM of the Maggia River basin (grid size 25×25m)
Digital River Network (DRN)

Example of DRN extracted by GIS from a DTM

actual drainage network ("blue lines")
Other watershed characteristics – Soil

Example of Digital Soil Map (Maggia river basin, Tessin, CH)

- **use**
  - delineation of infiltration and soil storage characteristics
  - parameterisation of infiltration models

- **problems**
  - accuracy of information
  - different classification / resolution used by different countries
Other watershed characteristics – Land use

Example of Digital Land Use Map (Maggia river basin, Tessin, CH)

- use
  - parameterisation of models
    - infiltration (e.g. SCS-CN)
    - evapotranspiration

- problems
  - representativeness of map depends on raster size
  - different classification / resolution used by different countries
Other watershed characteristics – Drainage Density

\[ D = \frac{\text{total length of streams}}{\text{area}} = \sum_i \frac{L_i}{A} \]

- it measures the efficiency of the basin drainage (i.e. of how well or how poorly a watershed is drained by rivers)
- it depends upon both climate (e.g. rainfall regime) and physical characteristics (e.g. geology, slope, soil, land cover) of the drainage basin
- for equal climatic characteristics can be used as proxy information for permeability
  - high \( D \) \( \rightarrow \) low permeability
  - low \( D \) \( \rightarrow \) high permeability
Interrelationships of watershed characteristics

[Graphs showing relationships between watershed characteristics such as length, area, drainage density, and relative relief]