Ekologie tekoucích vod
Stream Ecology

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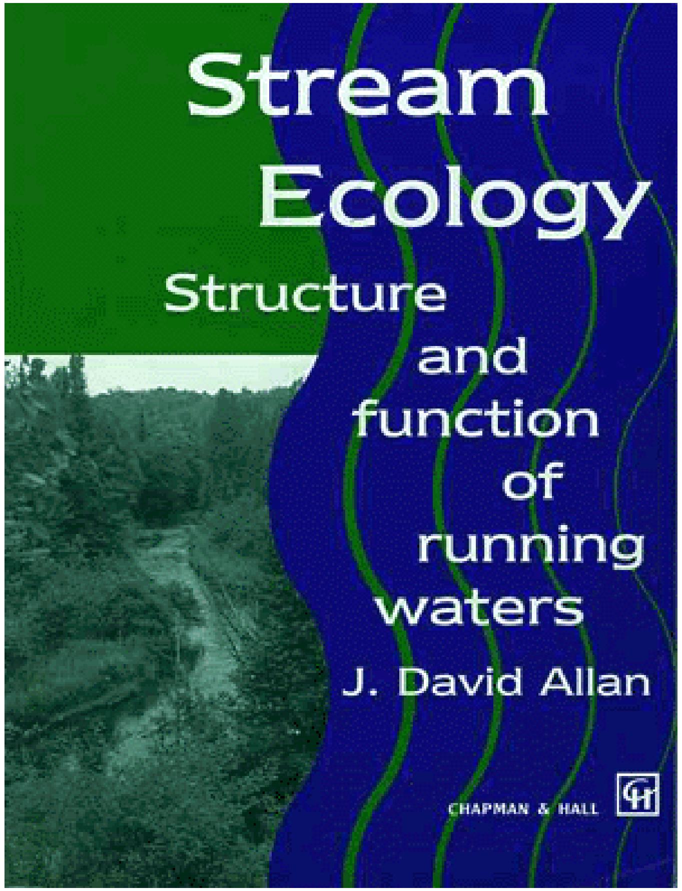
References


Stream
Ecology
Structure
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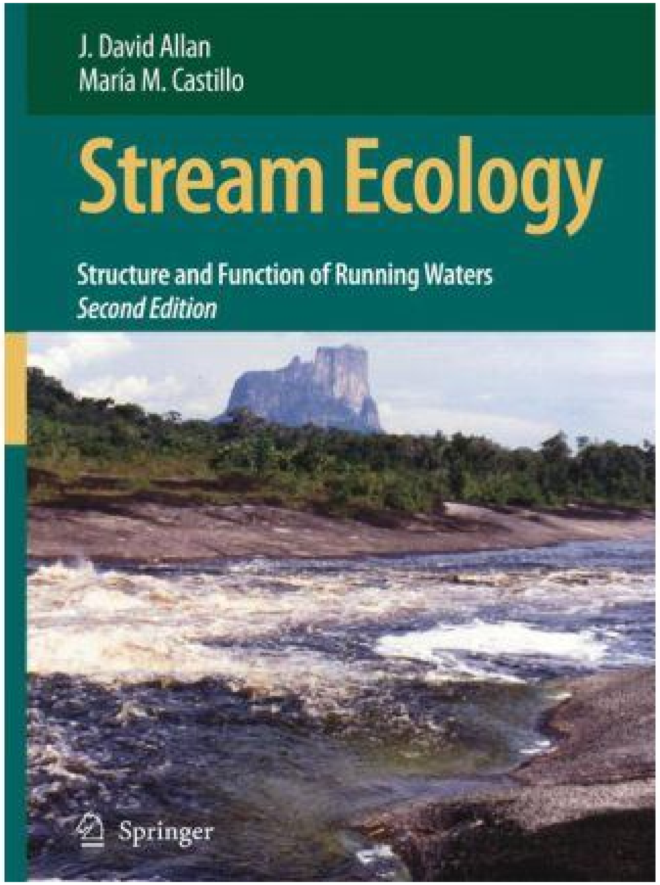
CHAPMAN & HALL


J. David Allan
María M. Castillo
Stream Ecology
Structure and Function of Running Waters
Second Edition
Springer

Hydrology: History

- rain-water as the source for springs and streams – since the 16th century

Bernard Palissy
(1510-1589)

Pierre Perrault
(1608-1680)
„On the Origin of Springs"

Water volume

Total water volume	
Inland water	2.80 %
Ice caps, glaciers	2.24 %
Groundwater	0.61 %
Lakes	0.009%
Atmosphere	0.001%
Running waters	0.0001%

- renewal time: 12-20 days

Water cycle

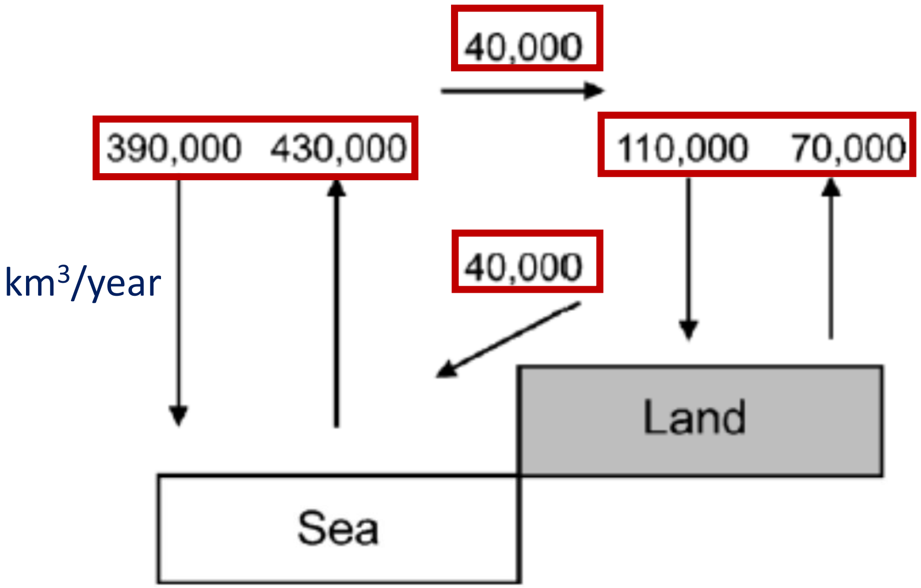
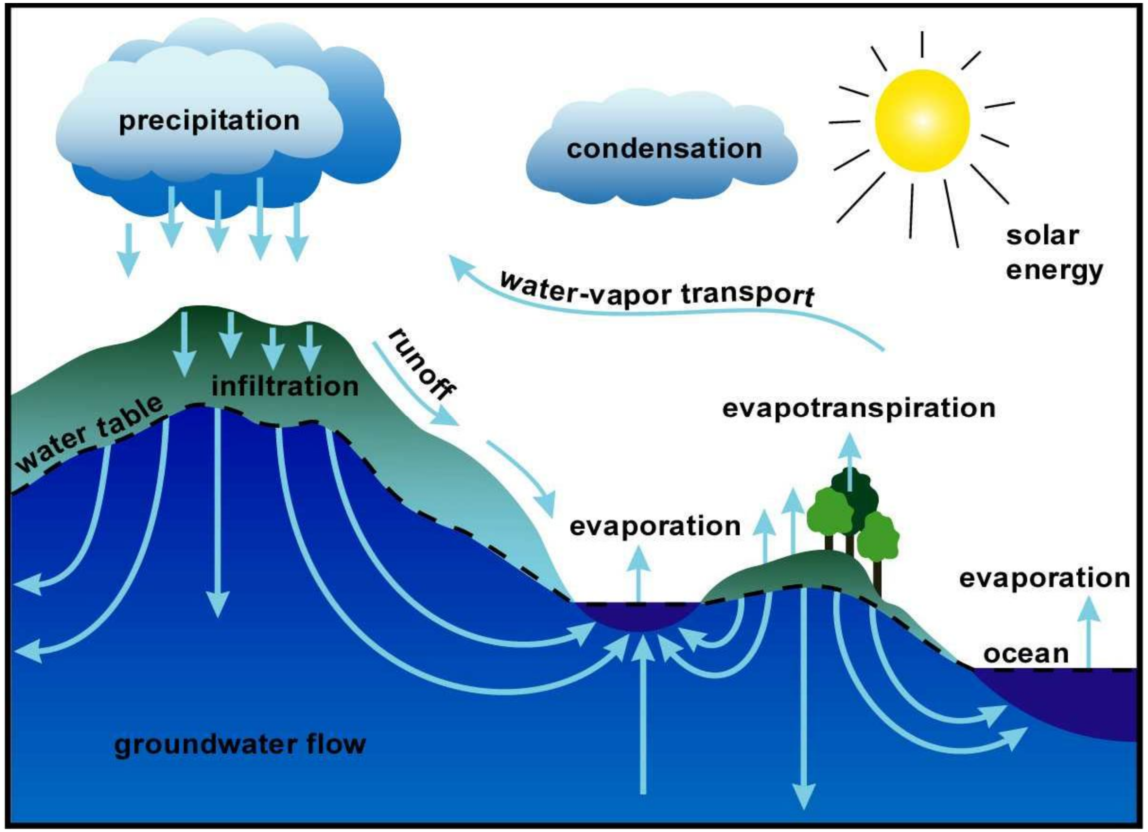


FIGURE 2.2 A simplified depiction of the global water cycle. Flows are approximate, in cubic kilometers per year. Downward arrows signify precipitation, upward arrows evapotranspiration (ET). The upper horizontal arrow represents the transfer of moisture from sea to land; the lower arrow represents runoff from land to sea. (Reproduced from Postel et al. 1996, after Gleick 1993.)



Water balance on continents

TABLE 2.1 Water balances of the continents. (From Dingman 2002.)

Continent		*Precipitation*		*Evapotranspiration*		*Runoff*	
	Area *(10^6 km^2)*	*(km^3 $year^{-1}$)*	*(mm $year^{-1}$)*	*(km^3 $year^{-1}$)*	*(mm $year^{-1}$)*	*(km^3 $year^{-1}$)*	*(mm $year^{-1}$)*
Europe	10.0	6,600	657	3,800	375	2,800	282
Asia	44.1	30,700	696	18,500	420	12,200	276
Africa	29.8	20,700	695	17,300	582	3,400	114
Australia[a]	7.6	3,400	447	3,200	420	200	27
North America	24.1	15,600	645	9,700	403	5,900	242
South America	17.9	28,000	1,564	16,900	946	11,100	618
Antarctica	14.1	2,400	169	400	28	2,000	141
Total land[b]	148.9	111,100	746	71,400	480	39,700	266

[a] Not including New Zealand and adjacent islands

[b] Including New Zealand and adjacent islands

Pathways of water from land to streams

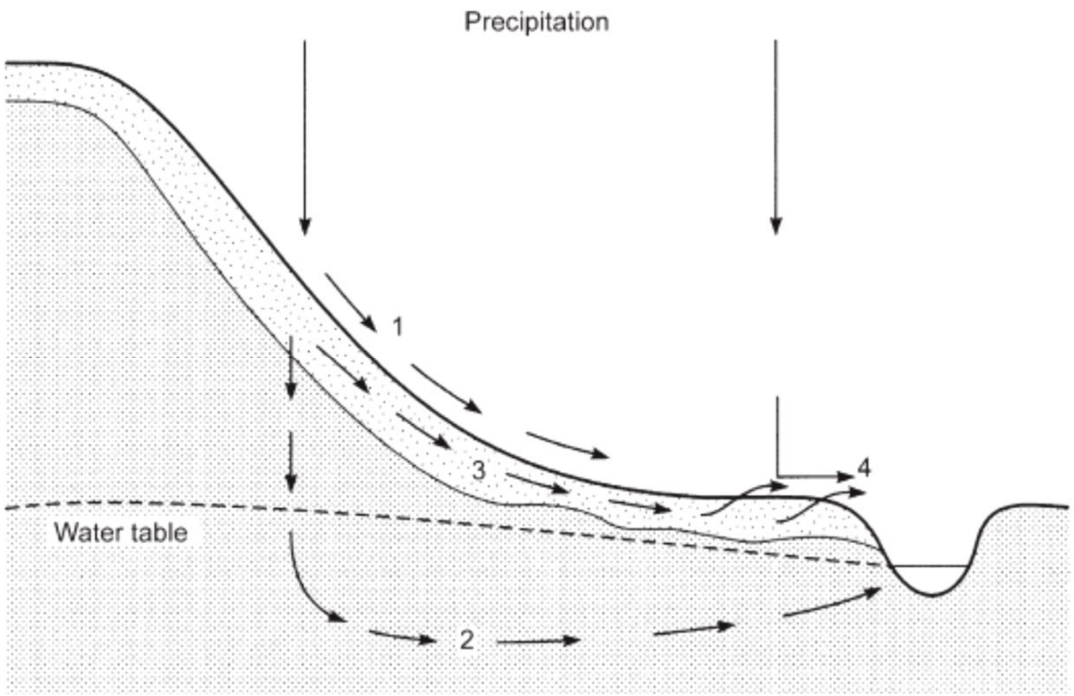


FIGURE 2.5 Pathways of water moving downhill. Overland flow (1) occurs when precipitation exceeds the infiltration capacity of the soil. Water that enters the soil adds to groundwater flow (2) and usually reaches streams, lakes, or the oceans. A relatively impermeable layer will cause water to move laterally through the soil (3) as shallow subsurface stormflow. Saturation of the soil can force subsurface water to rise to the surface where, along with direct precipitation, it forms saturation overland flow (4). The stippled area is relatively permeable topsoil. (Reproduced from Dunne and Leopold 1978.)

- infiltration capacity of soil
- depression storage capacity
- 1... Overland flow (plošný splach, sklonový odtok) – a part of surface runoff, Horton's model (1933)
- 2... Groudwater flow (podzemní odtok) → river's baseflow (základní odtok)
- 3... Shallow sub-surface stormflow (podpovrchový, hypodermický odtok)
- 4... Saturation overland flow or return flow (Hewlett & Hibbert, 1967)

Movement of water between channel and groundwater

- perennial vs. intermittent streams
- a... Gaining or effluent streams
- b... Losing or influent streams

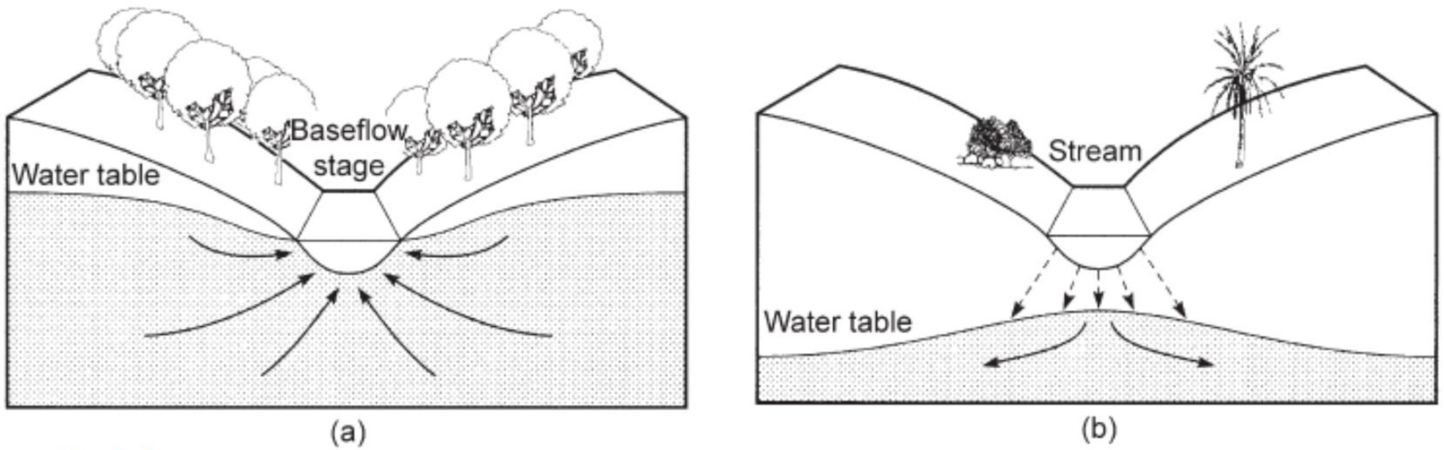


FIGURE 2.6 (a) Cross section of a gaining stream, typical of humid regions, where groundwater recharges the stream. (b) Cross section of a losing stream, typical of arid regions, where streams can recharge groundwater. (Reproduced from Fetter 1988.)

Streamflow

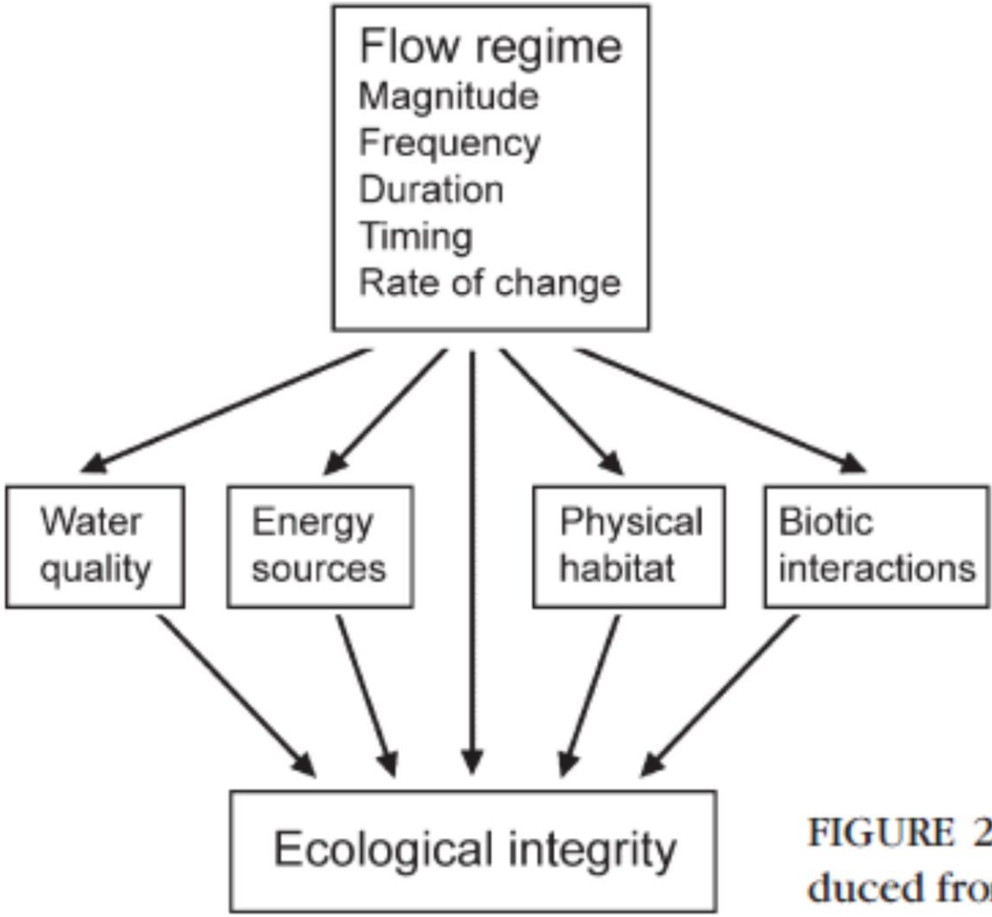
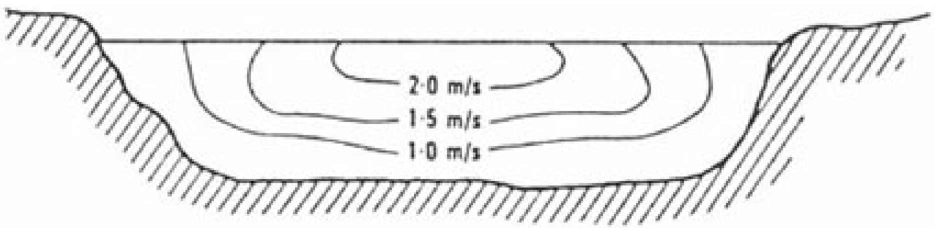


FIGURE 2.14. Streamflow as a master variable. (Reproduced from Poff et al. 1997.)

Current velocity

- U [m s^{-1}]
- channel slope, sinuosity and obstructions in the channel, friction with bed, banks, and atmosphere
- velocity measurement
  - mechanical, electromagnetic flowmeters
  - acoustic methods
- mean velocity
  - float (plovák): × 0.8
  - in turbulent waters – at each 0.1× of depth



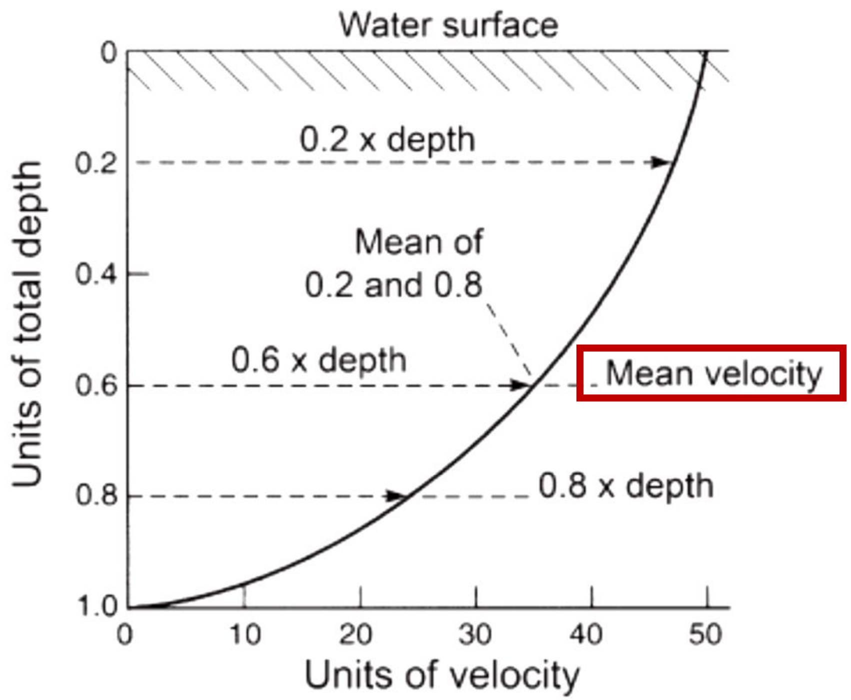


FIGURE 2.8 Current velocity as a function of depth in an open channel. Mean velocity is obtained at a depth of 0.6 from the surface when depth is <0.75 m, and from the average of measurements at 0.2 and 0.8 depth in deeper rivers.

Discharge (= flow)

- Q [m^3 s^{-1}] = width × depth × U

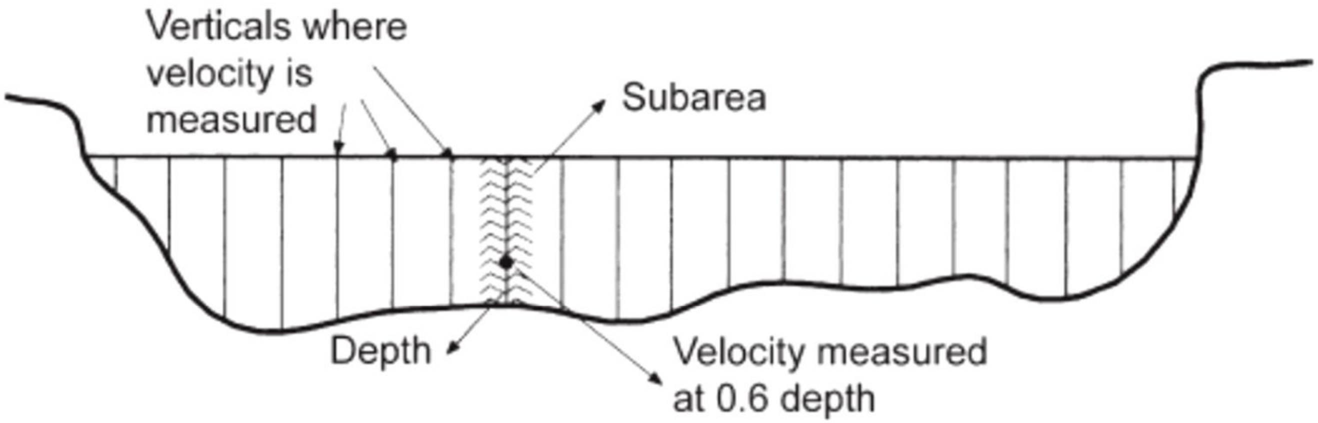


FIGURE 2.7 Estimation of discharge from the integration of point measurements of velocity and associated area of flow in subsections of the channel cross section. Velocity is measured at 0.6 depth from the surface in shallow streams. (Reproduced from Whiting 2003.)

Hydrograph

- wide variation over time, river size and geographic region (distribution of precipitation, snow storage, and basin, soil and vegetation characteristics)
- flashy streams vs. streams in humid areas
- broader and less sharp flood peaks with increasing number of tributaries and downstream
- natural connection with floodplain

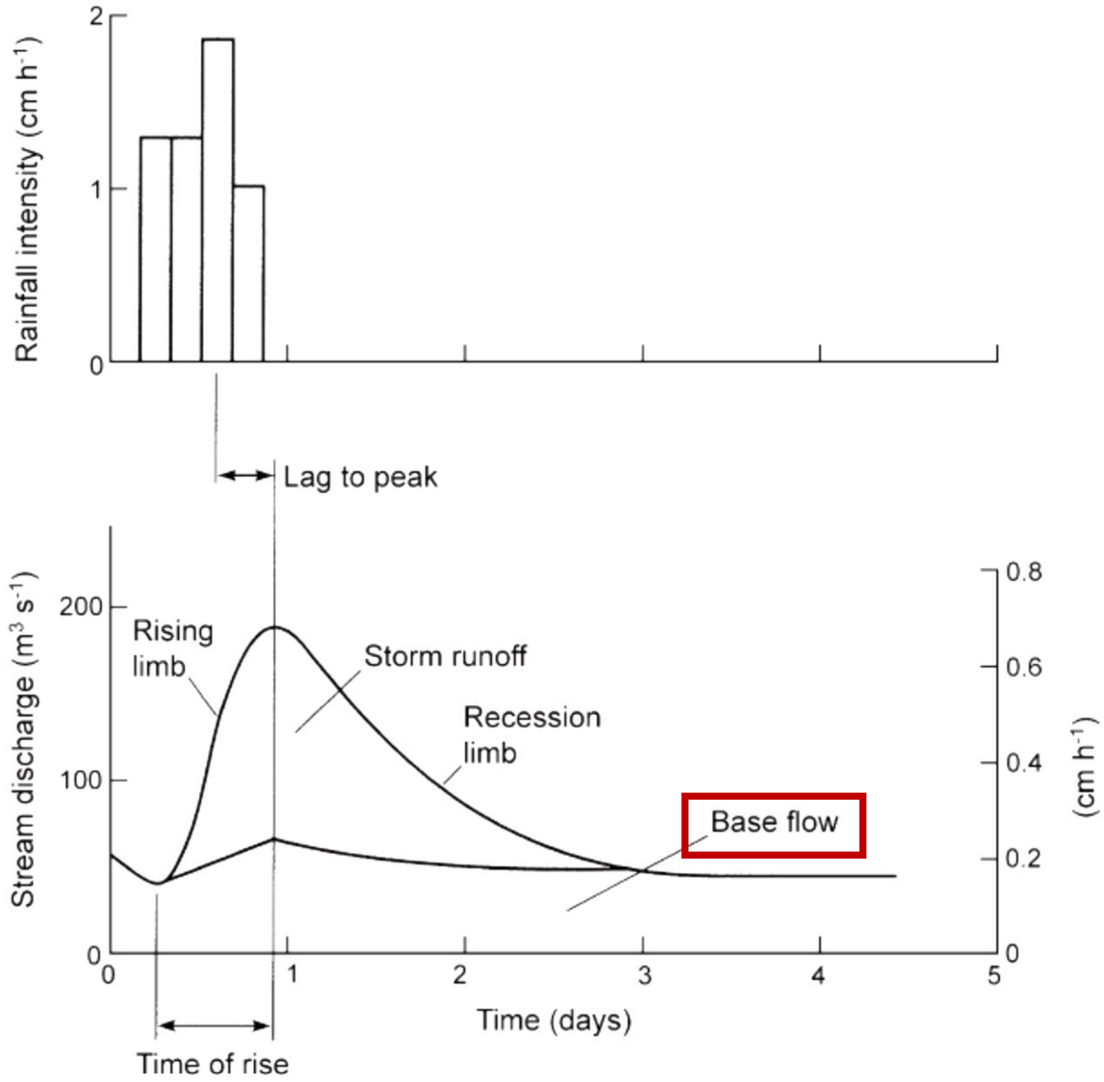


FIGURE 2.9 Streamflow hydrograph resulting from a rainstorm. (Reproduced from Dunne and Leopold 1978.)

Flow regime

- characteristic of regions
- magnitude of a flow event vs. its probability → **flow duration curve**
  - daily records
  - median flow ($Q_{0.5}$)
  - extremes:

    $Q_{0.05}$ – exceeded in 18 days in a year

    $Q_{0.95}$ – exceeded in 347 days in a year
  - comparisons of flow regime stability between streams - after normalizing flow for drainage area
  - indicator of water availability but not timing

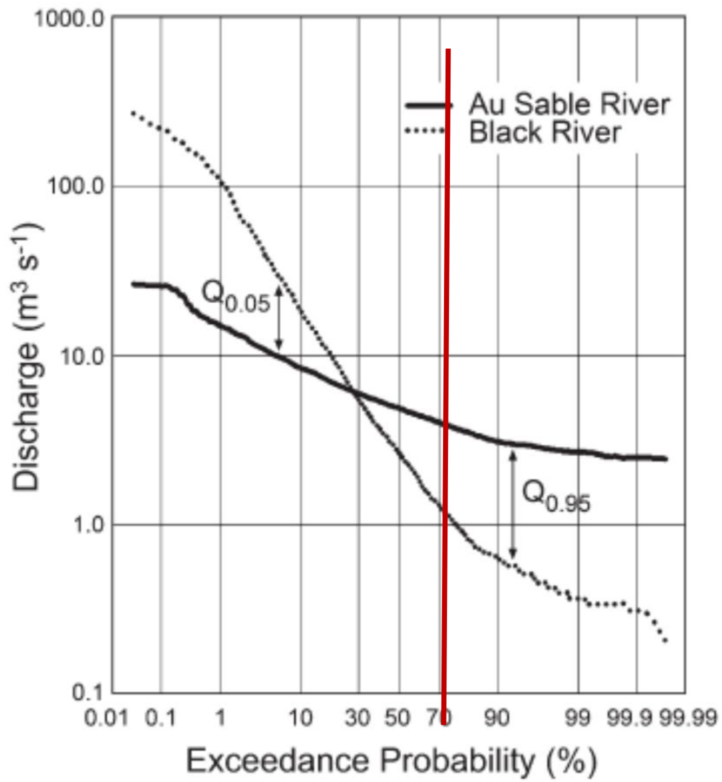


FIGURE 2.10 Flow duration curves for two rivers in Michigan, showing the high flow discharge ($Q_{0.05}$) that is exceeded only 5% of the time, and the low flow discharge ($Q_{0.95}$) that is exceeded 95% of the time. Because the two watersheds are of similar area, discharge was not normalized to drainage area. Graphs were constructed from daily records for 1990–2000.

Flood frequency analysis

- timing of flood events
- counting the peaks of the flood hydrograph (esp. in small streams)
- T (reccurrence interval) = (n+1)/m
  n...years of record, m...rank of the flood magnitude (max.=1)
- **probability of a „1-in N-year“ flood** of a given size or larger
  = 1/average reccurence
- bankfull flood

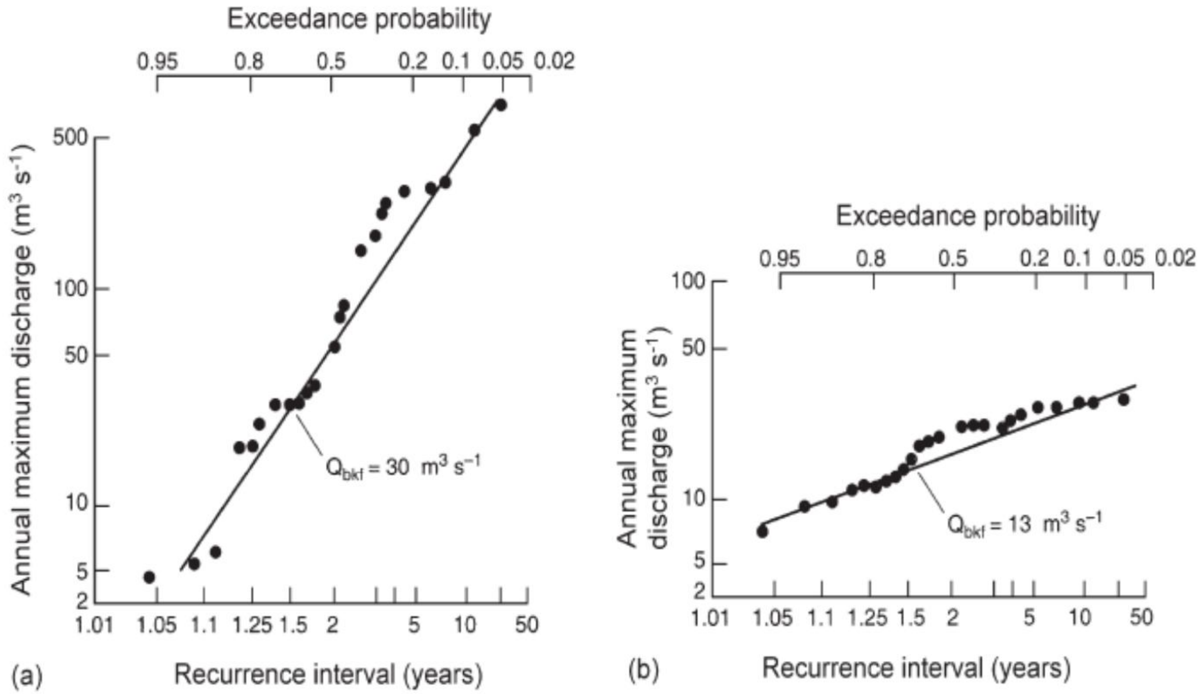


FIGURE 2.11 Example of a flood-frequency analysis for two rivers, based on annual peak instantaneous flows from a 20-plus year gauge record. The bankfull flood (Q_{bkf}) is estimated using $T = 1.5$ years, and the probability or recurrence interval for more extreme events (e.g., 20- and 50-year floods) can be read from the graph. Lines are fitted by eye. (a) Sycamore Creek, Arizona, is an arid land stream subject to flash floods. (b) The Colorado River in its upper reaches, near Grand Lake, Colorado, has a highly regular snowmelt-driven hydrograph. Note the steeper slope of the graph for Sycamore Creek.

Fluvial geomorphology

- hydraulic processes
- a tendency to reach a dynamic equlibrium between erosion and deposition
- slope, chanell width and depth, flow velocity, grain size of sediment load, bed roughness, sinuosity and braiding
- cross section symetrically trapezoidal in straight reaches

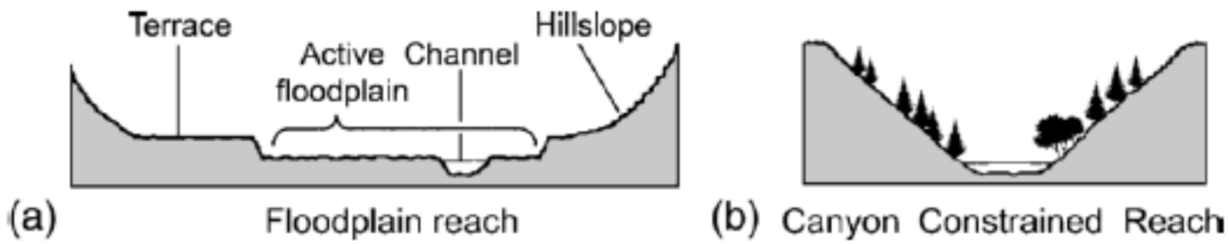


FIGURE 3.2 (a) Diagrammatic cross section of a valley showing present channel, the floodplain occupied in modern time, and a terrace representing a previous floodplain. (Reproduced from Dunne and Leopold 1978.) (b) A constrained river channel with little opportunity to develop a floodplain. (Reproduced from Ward et al. 2002.)

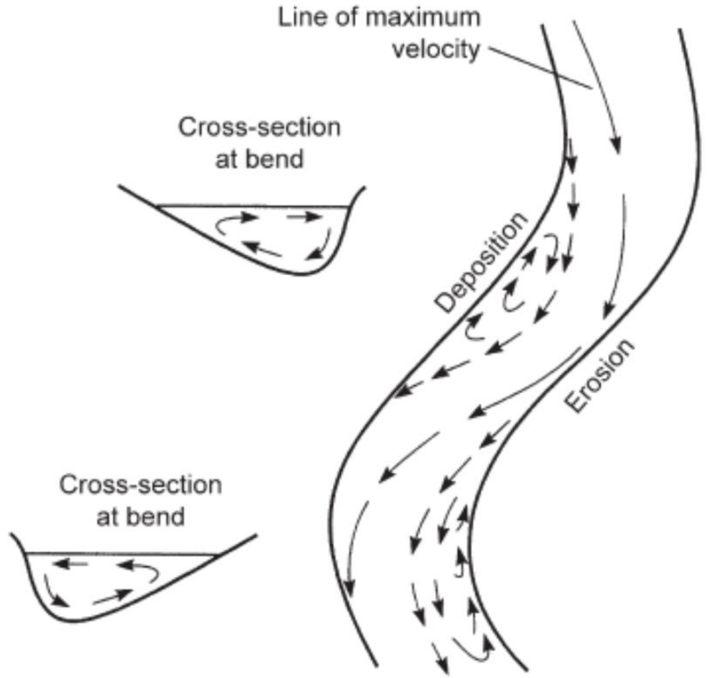


FIGURE 3.1 A meandering reach, showing the line of maximum velocity and the separation of flow that produces areas of deposition and erosion. Cross sections show the lateral movement of water at bends. (Reproduced from Morisawa 1968.)

Hydraulic geometry

- power equations – Leopold & Maddock (1953)

  $w = aQ^b$

  $d = cQ^f$

  $v = kQ^m$

  $Q = w \times d \times v \rightarrow a \times c \times k = 1, \; b + f + m = 1$
- overgeneralization
- after overflowing of banks, „w“ increases rapidly with increasing „Q“
- „v“ may remain nearly constant at a site
- highest „v“ usually at the lowest and flattest downstream parts

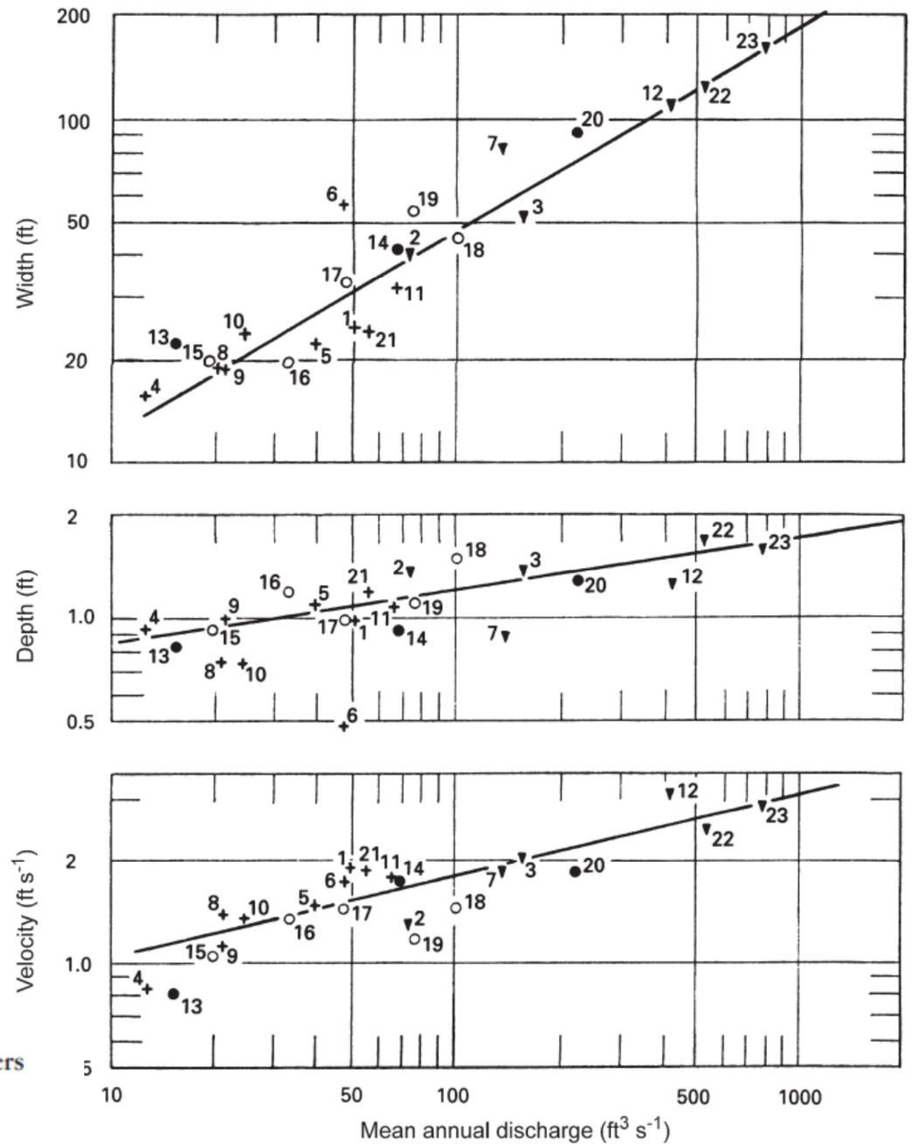
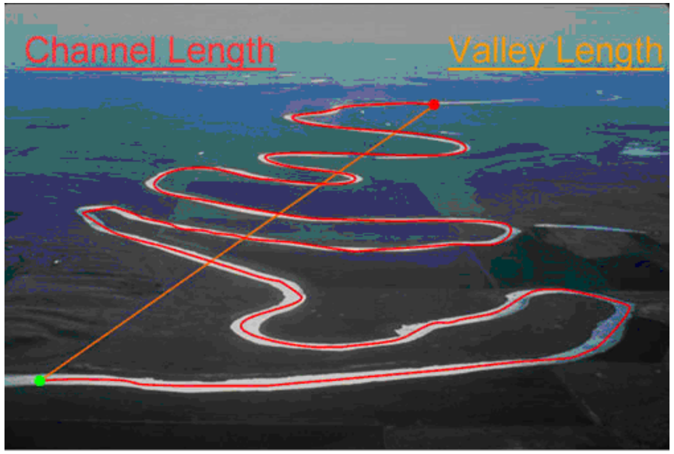
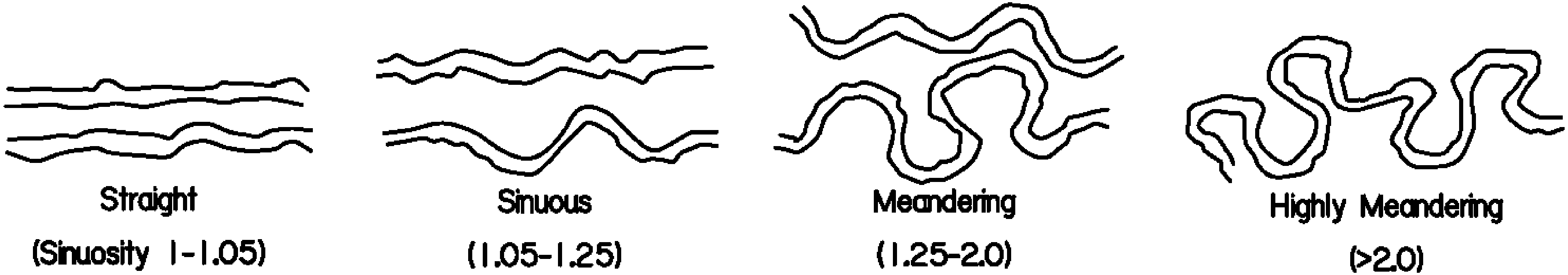


FIGURE 3.3 Width, depth, and velocity in relation to mean annual discharge as discharge varies downstream. Numbers refer to sites on the Powder River and tributaries, Wyoming and Montana. (Reproduced from Leopold 1994.)

Sinuosity



- **sinuosity index (SI)**
  = channel thalweg (údolnice) distance / downwalley distance
  - values: 1-4
- a consistent pattern of bends accross all streams:
  wave length 10-14 × w
  mean radius of curvature 2-3 × w



Sinuosity II

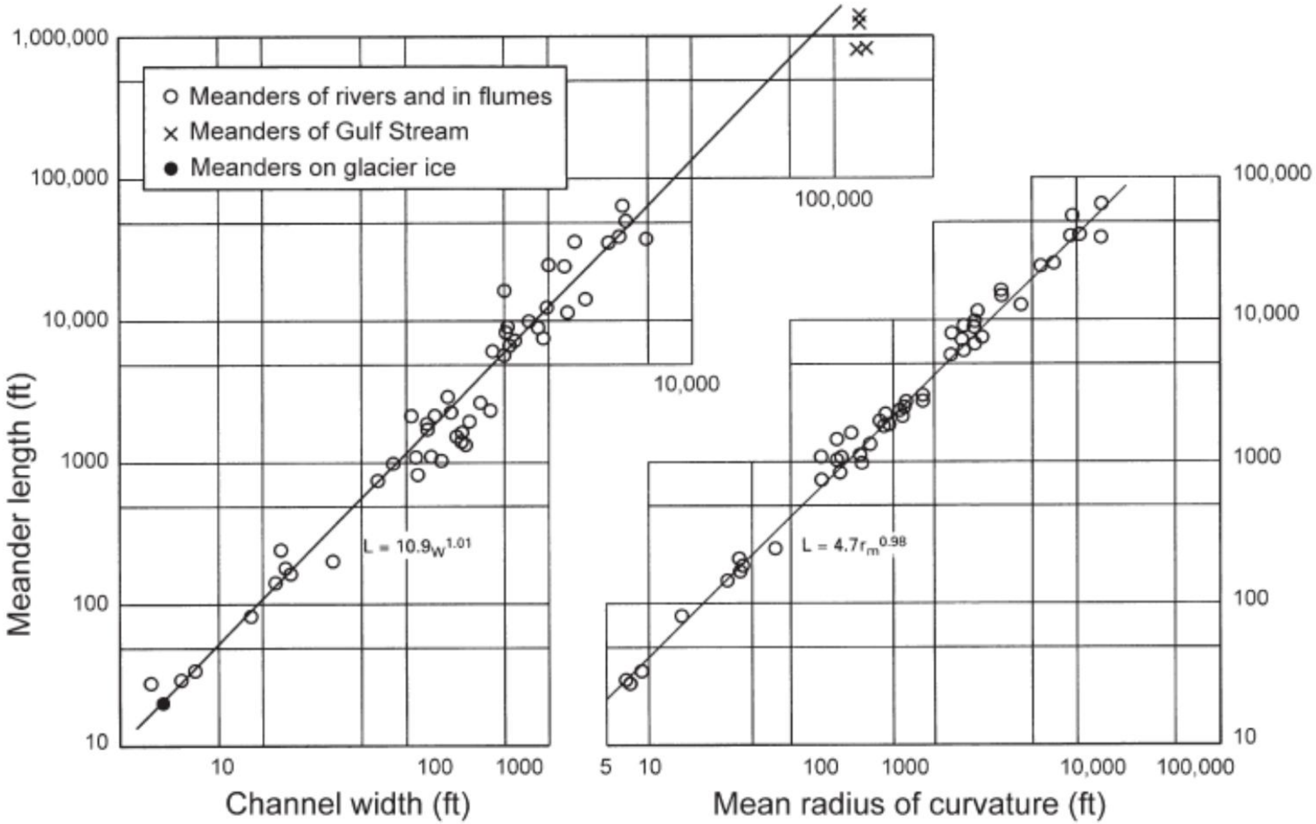


FIGURE 3.4 Relations between meander length and channel width, and between meander length and mean radius of curvature (Reproduced from Leopold 1994)

Pool-riffle sequence

- usually at moderate and low gradient, unconfined, poorly sorted gravel streams
- riffle – shallow, high velocity, gravel-cobble
- pool – deeper, lower velocities, finer sediment
- alternating at intervals of ca 5-7× w
- a change in distribution of forces at high discharge
- the role of log wood in some geographic regions (Pacific Northwest)

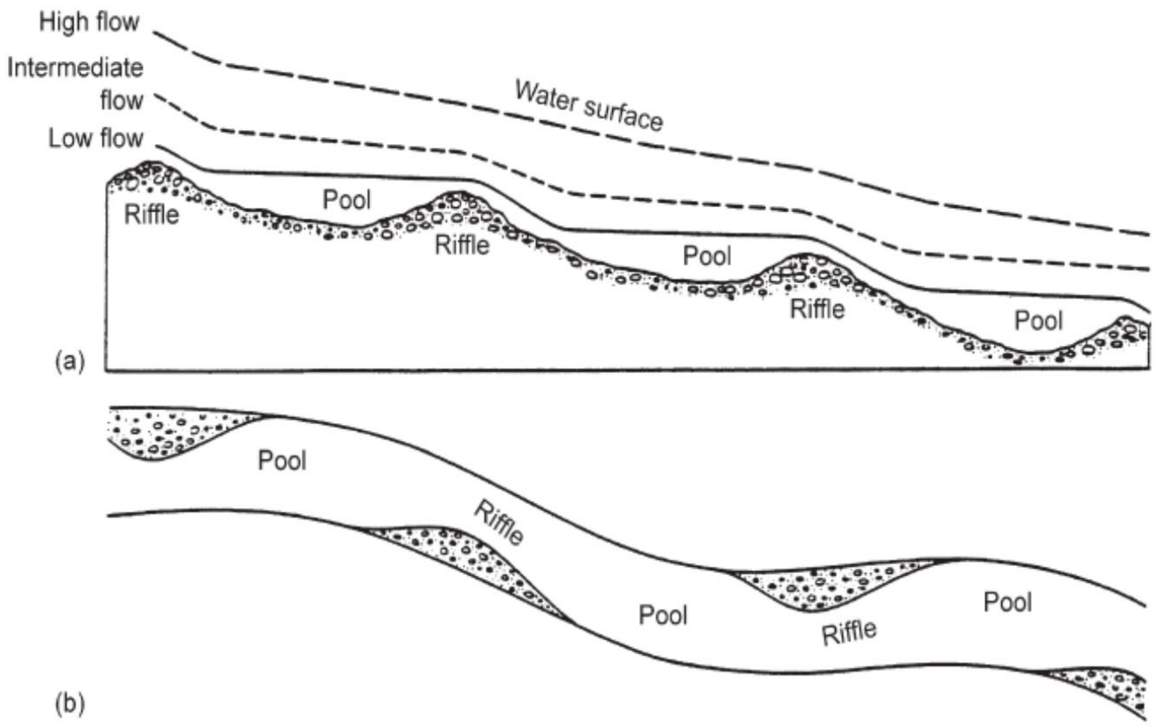
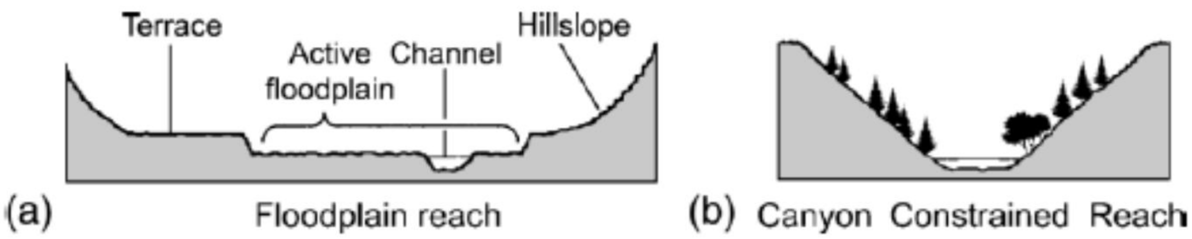


FIGURE 3.5 A longitudinal profile (a) and a plan view (b) of a riffle-pool sequence. Water surface profiles in (a) depict high-, intermediate-, and low-flow conditions. (Reproduced from Dunne and Leopold 1978.)

Floodplain

- a flat area adjacent to a river, formed mainly of river sediments and subject to flooding
- only less frequent larger flows inundate the floodplain (with a 1.5 year frequency, sometimes several times annually)
- degradation - river cut downwards, old floodplain → terrace
- aggradation - increase in land elevation due to the deposition of sediment



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Grain size

- given by the sizes introduced from upstream, tributaries and hillslopes, by abrasion and sorting
- The canonical definition by geologist **Chester K. Wentworth** (1922): "A Scale of Grade and Class Terms for Clastic Sediments„ - *The Journal of Geology*.

(1891-1969)

Millimeters (mm)		Micrometers (µm)	Phi (ϕ)	Wentworth size class	
	4096		-12.0	Boulder	Gravel
	256		-8.0	Cobble	
	64		-6.0	Pebble	
	4		-2.0	Granule	
	2.00		-1.0	Very coarse sand	Sand
	1.00		0.0	Coarse sand	
1/2	0.50	500	1.0	Medium sand	
1/4	0.25	250	2.0	Fine sand	
1/8	0.125	125	3.0	Very fine sand	
1/16	0.0625	63	4.0	Coarse silt	Silt
1/32	0.031	31	5.0	Medium silt	
1/64	0.0156	15.6	6.0	Fine silt	
1/128	0.0078	7.8	7.0	Very fine silt	
1/256	0.0039	3.9	8.0	Clay	Mud
	0.00006	0.06	14.0		

Grain size analysis