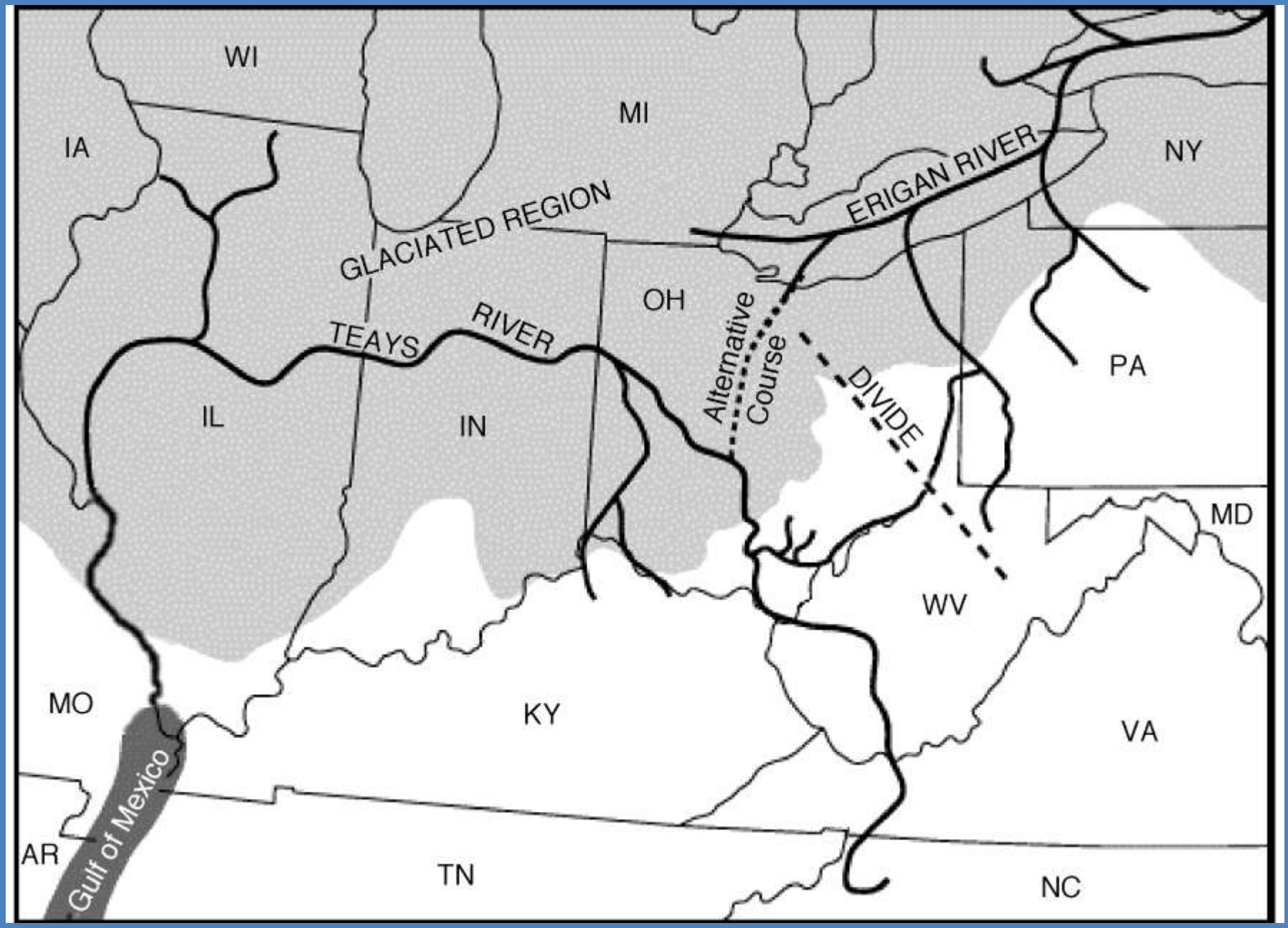
# Some Basic Concepts of Fluvial Geomorphology


WI
MI
IA
NY
ERIGAN RIVER
GLACIATED REGION
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MO
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Gulf of Mexico
AR
TN
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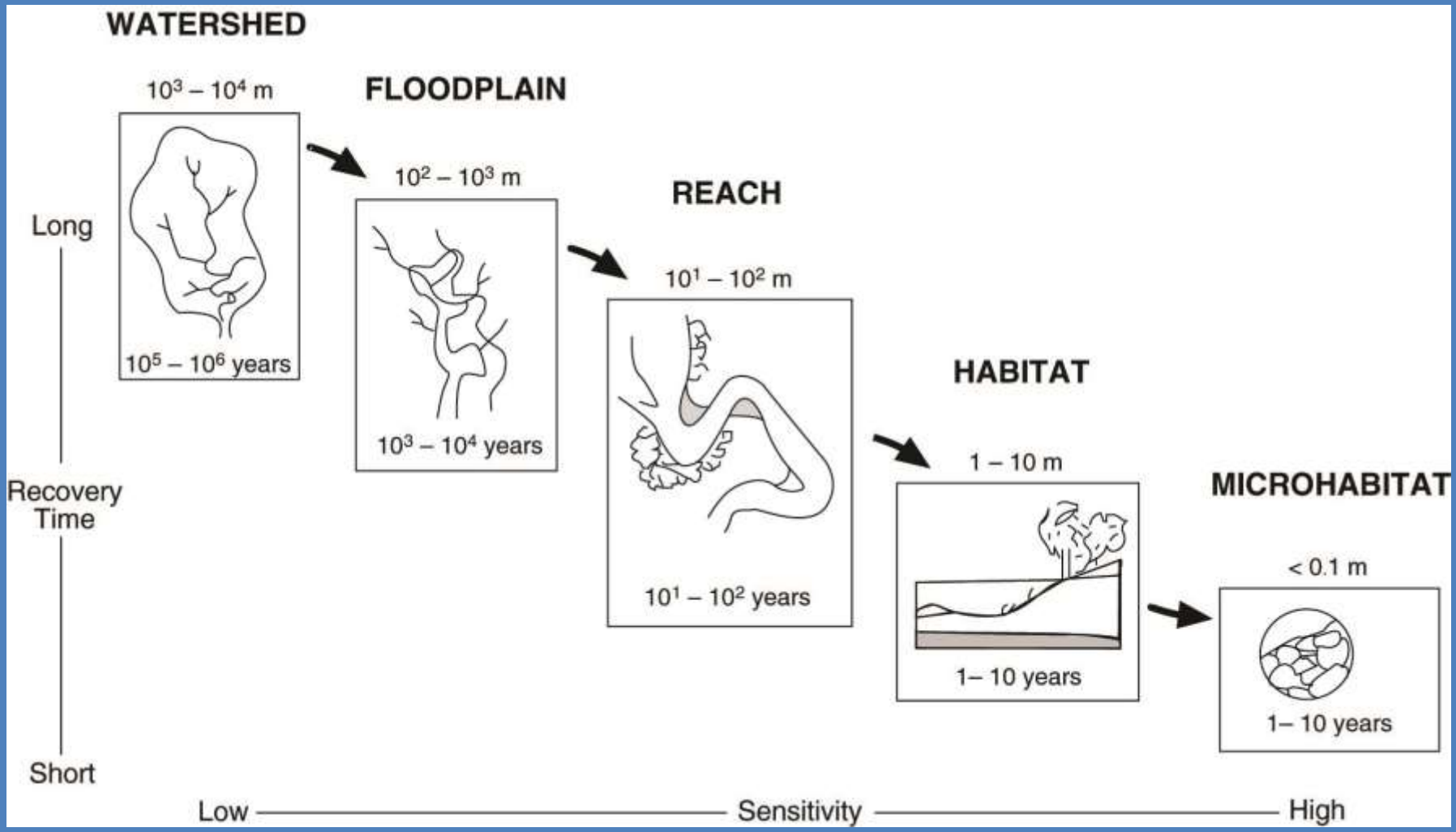
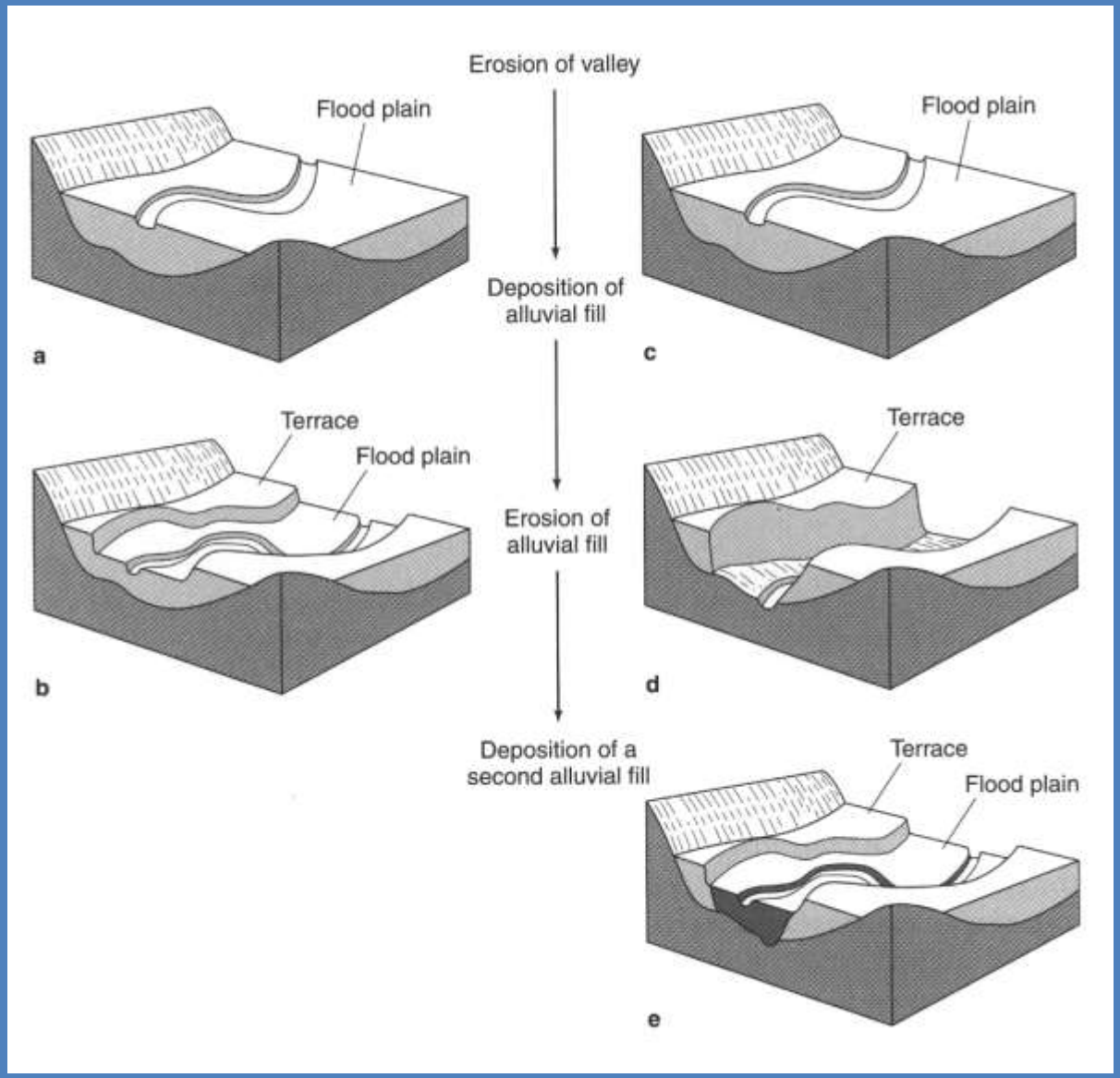

WATERSHED
$10^3 - 10^4$ m
$10^5 - 10^6$ years
FLOODPLAIN
$10^2 - 10^3$ m
$10^3 - 10^4$ years
REACH
$10^1 - 10^2$ m
$10^1 - 10^2$ years
HABITAT
1 – 10 m
1– 10 years
MICROHABITAT
< 0.1 m
1– 10 years
Long
Recovery Time
Short
Low
Sensitivity
High

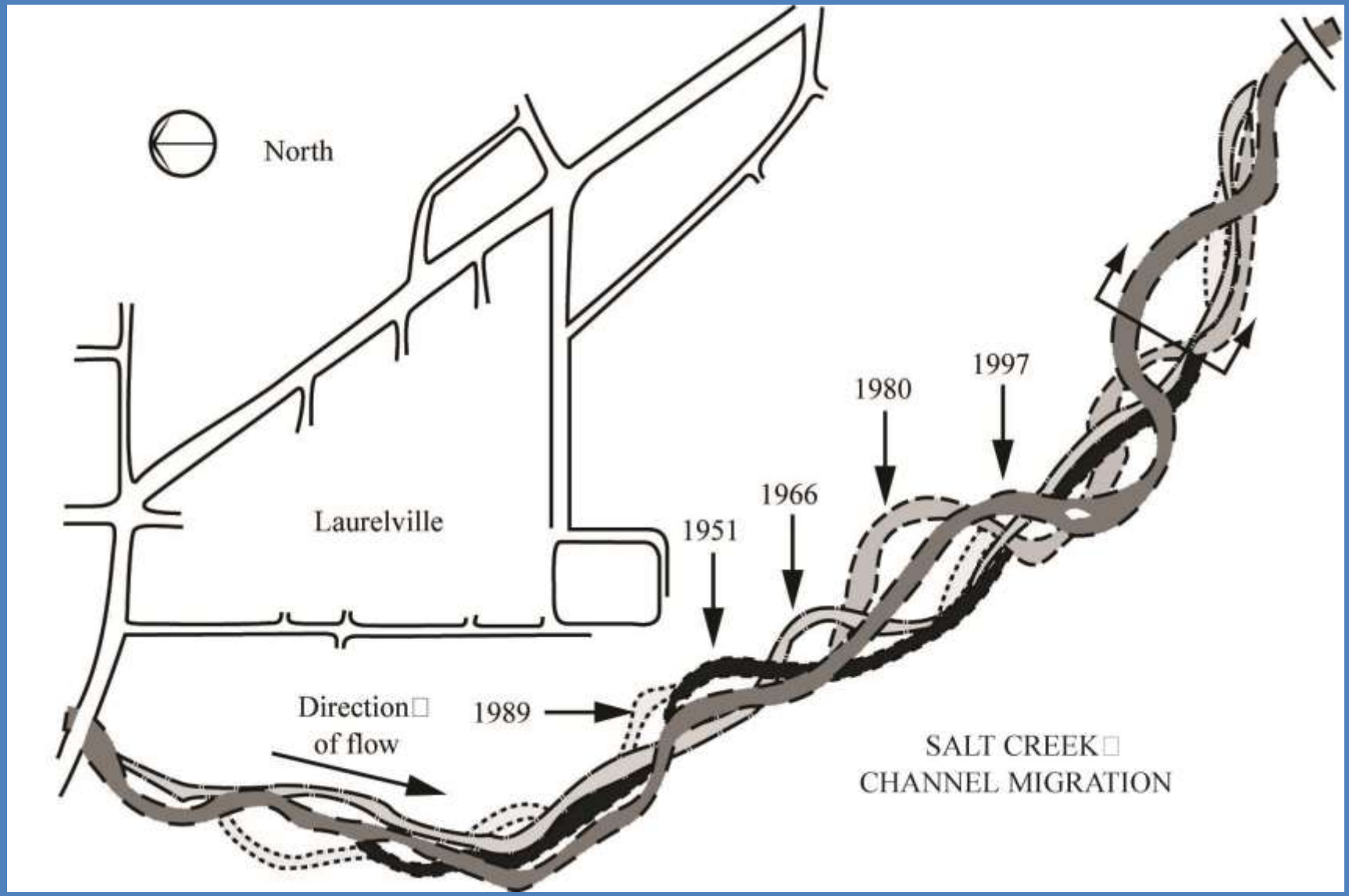
# Changes in valley morphology over "geologic time"

(Leopold, 1997, p 106)



# Channel changes over years or decades

(Ward and Trimble, 2004, p 181)



# Basic Concepts

- Force and resistance
- If exerted force is less than resistance, no change
- If exerted force is greater than resistance,
  there is a change to the channel or gradient
- Channel stability does not = rigidity
- Stable channels are in dynamic equilibrium; that is:
  - Channels don't change rapidly with time
  - The import and export of sediment is in balance
  - The channel is neither aggrading or degrading
  - Excessive mass wasting is not occurring

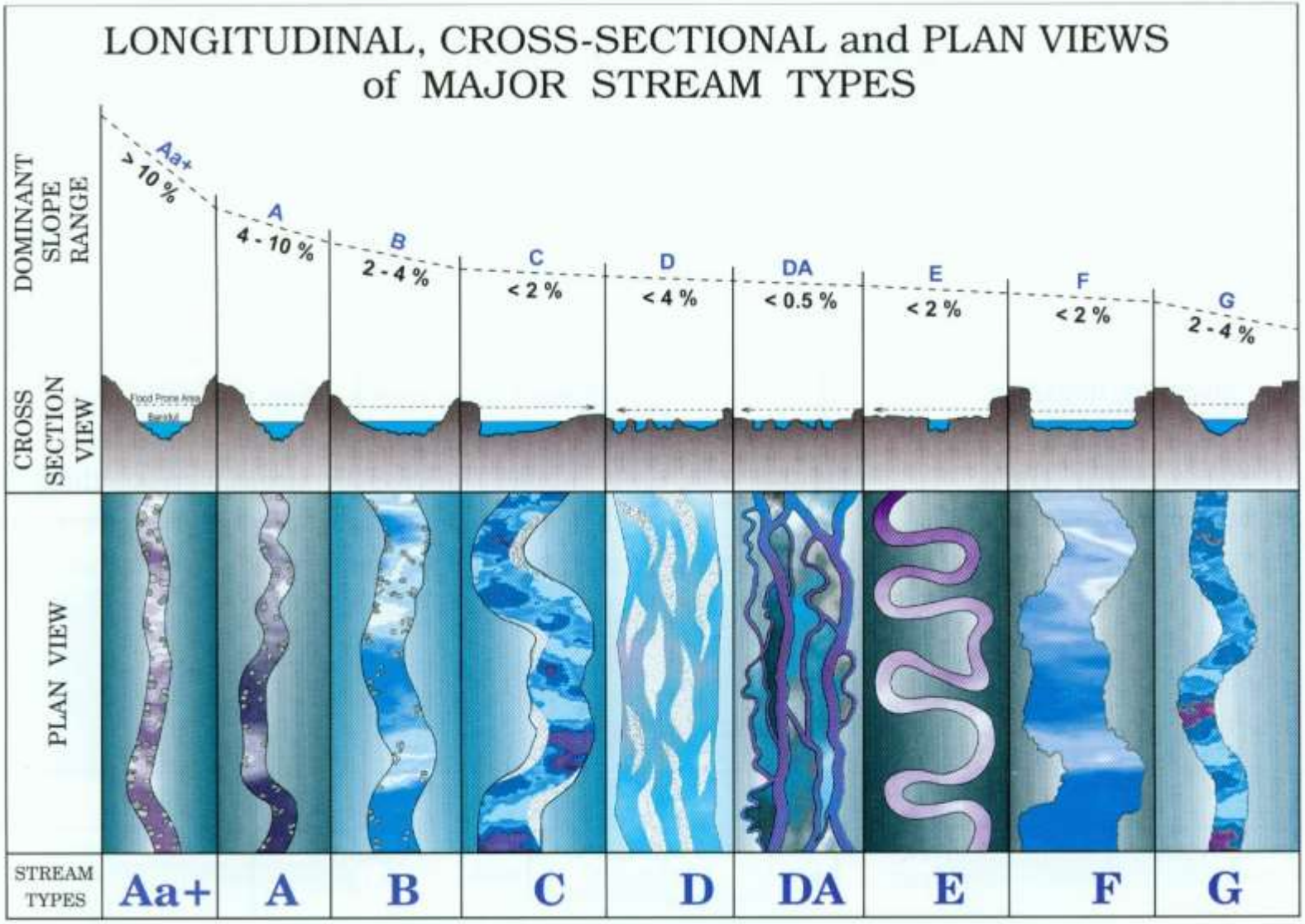
# Morphological Characteristics

**Channel shape is primarily a function of 8 variables (Leopold, Wolman and Miller, 1964):**

**channel slope,**
**width,**
**depth,**
**discharge,**
**velocity,**
**roughness of the channel materials,**
**sediment load,**
**and sediment size.**

# Basic Stream Channel Shapes

(Rosgen, 1996, p 4-4)




Meanders

# Sinuosity

- The ratio of channel to down valley distance
- Ranges from 1 to 4 in streams.
- Streams with a sinuosity of 1.5 or greater are called meandering streams.
- Streams with a sinuosity of less than 1.5 are called straight streams.
- Even in straight streams the thalweg tends to meander somewhat.

# Meanders

- Water will follow the path of least resistance
- Pipe flow experiments have shown that bends that have a ratio of curvature to width of 2 exhibit minimum resistance to curvature.
- Meanders tend to follow a sine-generated curve shape:

$$\Theta = \omega \sin (S/M)\, 2\pi$$

Where:

$\Theta$ = the angle between direction and main valley direction at a given point

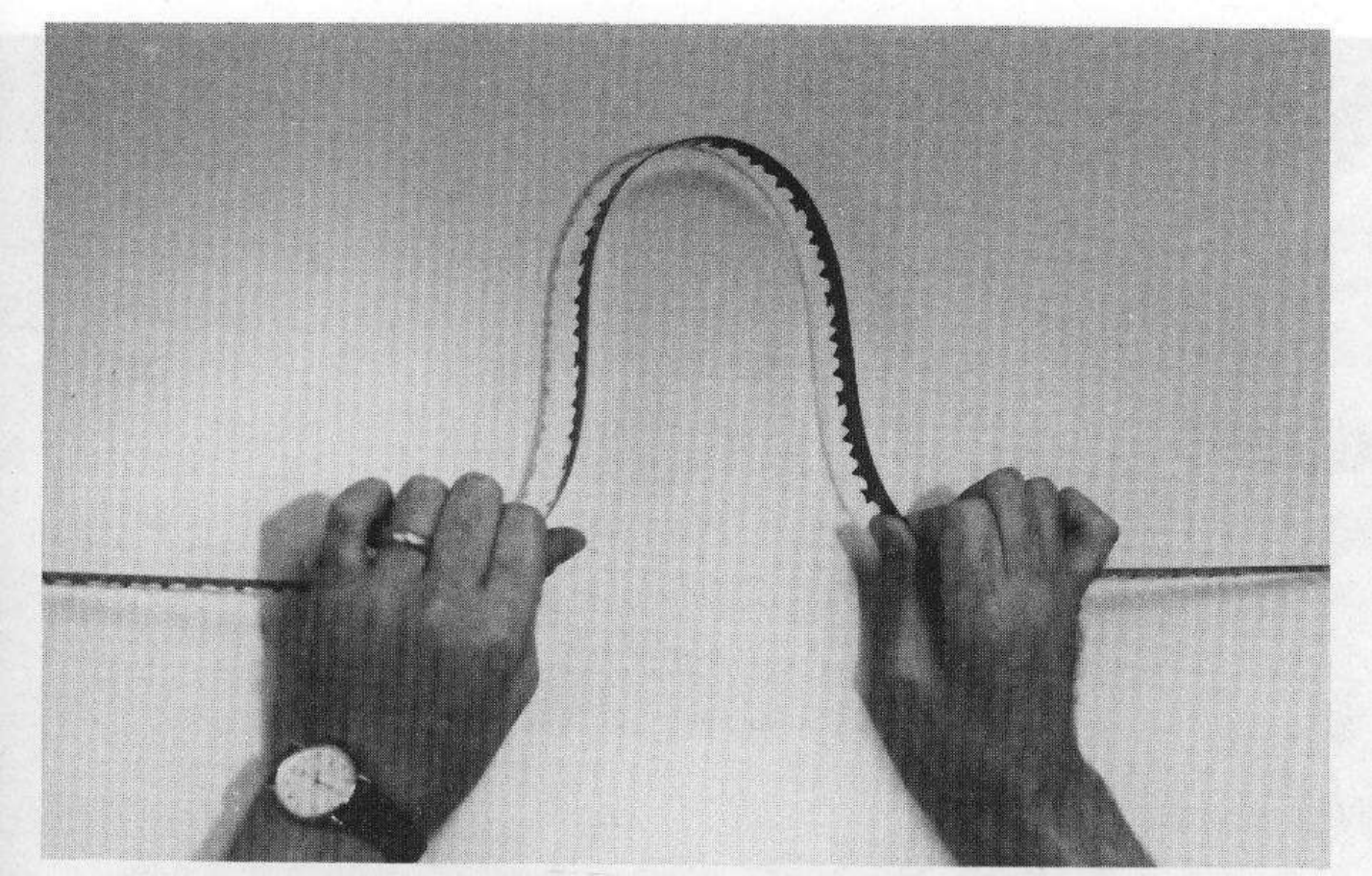
$\omega$ = the maximum angle of deviation

S = point distance along the path

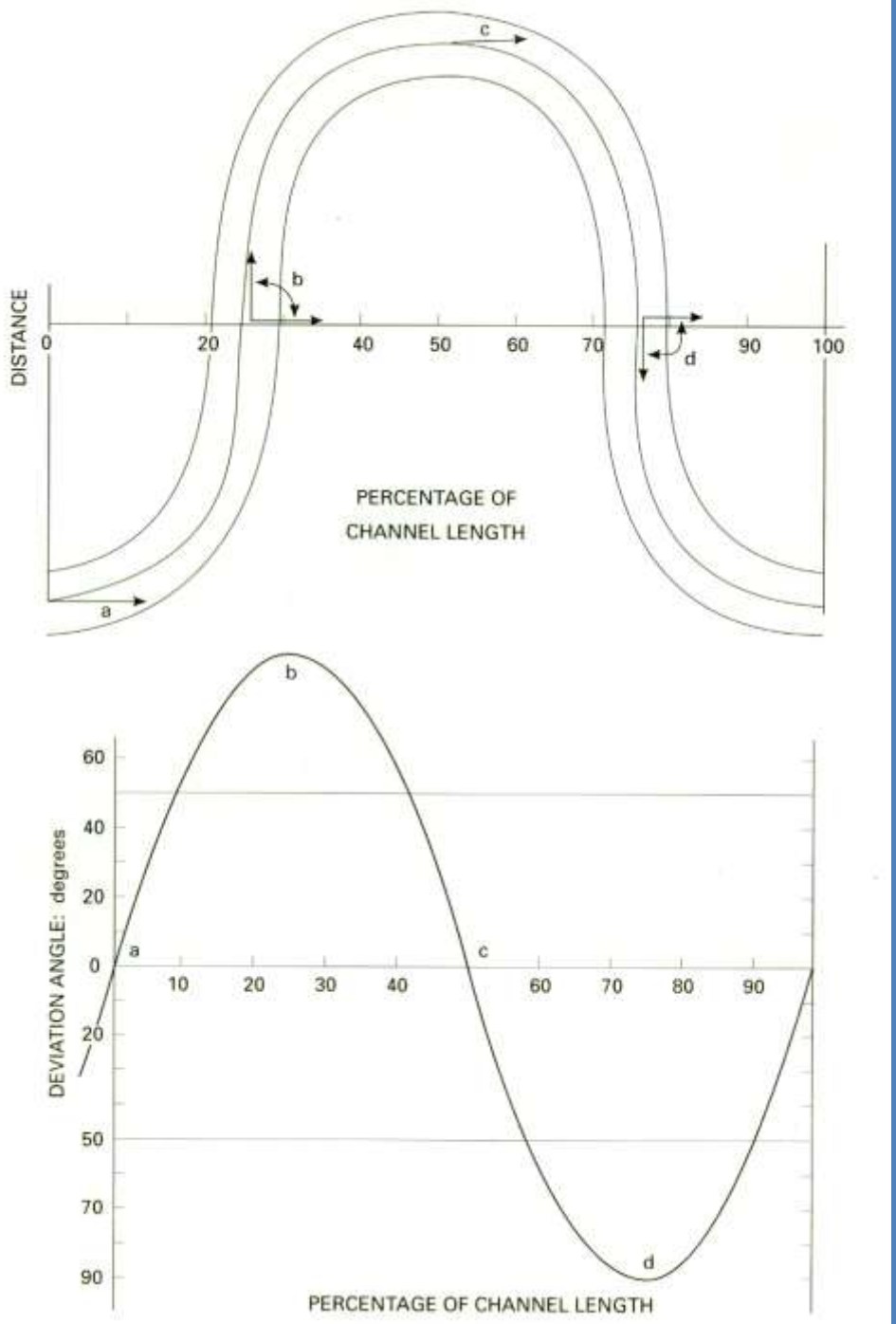
M = total path distance along a unit wavelength

# Meanders (cont.)

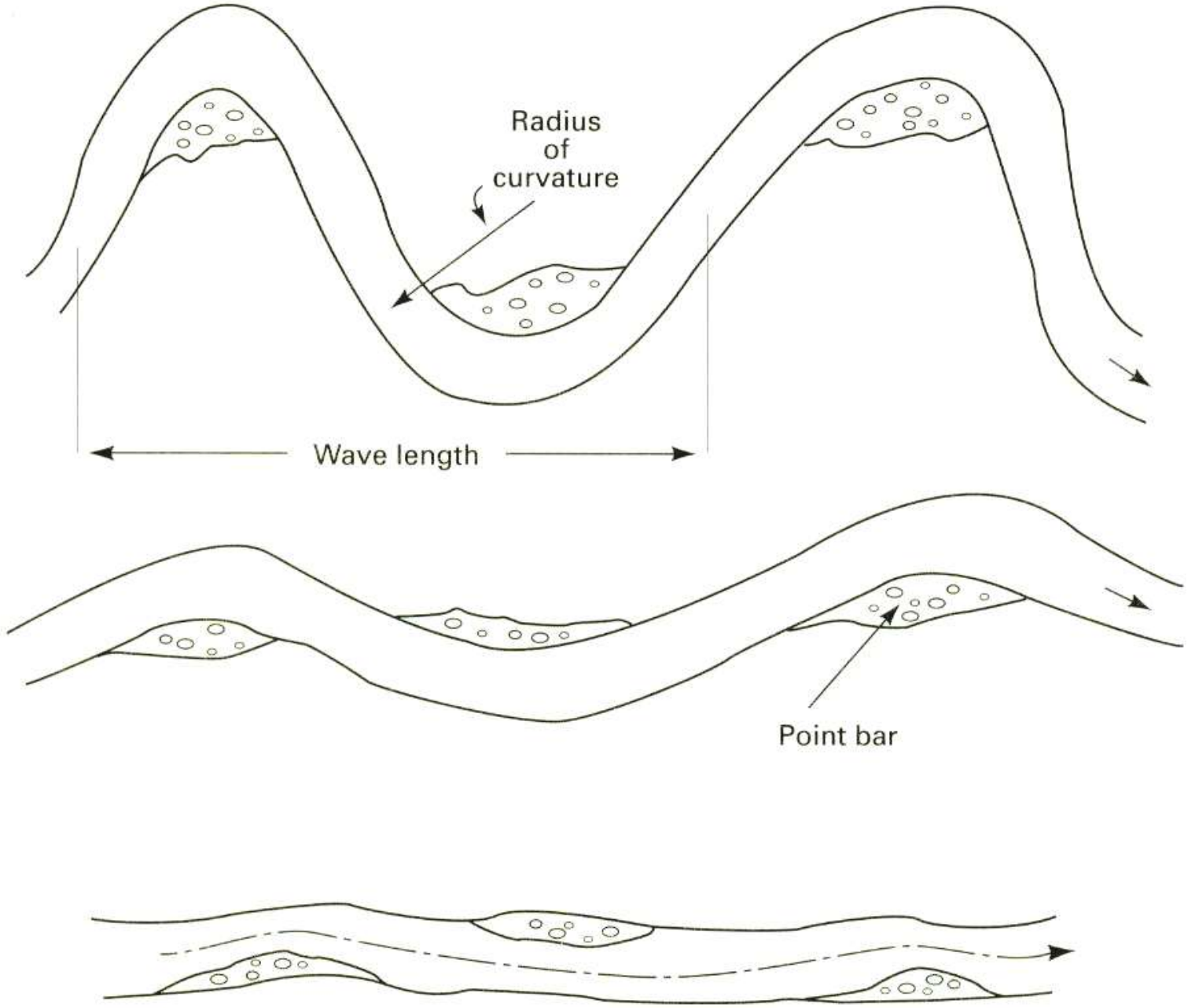
**Sine-generated curves represent the most uniform distribution of stress along a curve.**

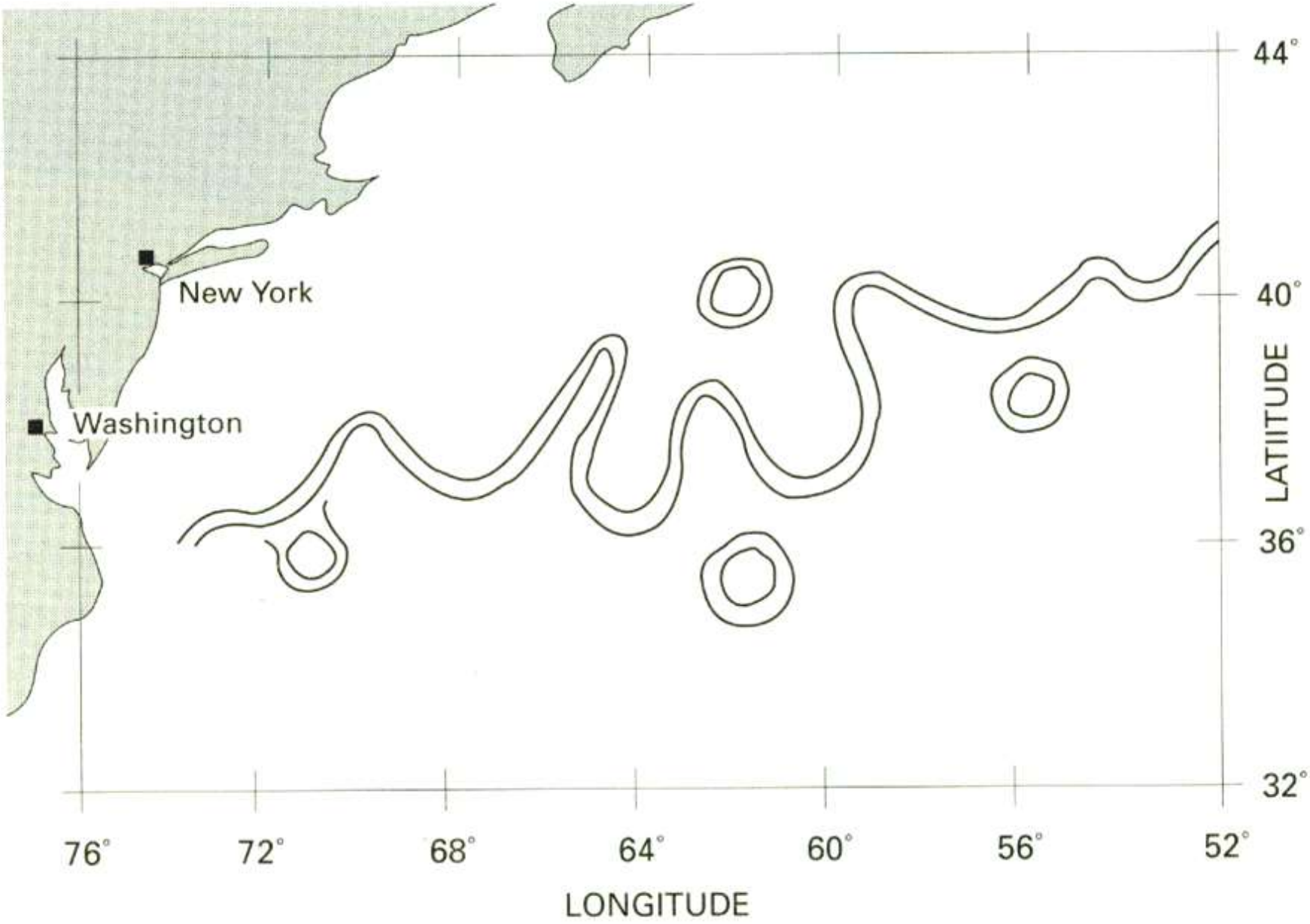


From Leopold, 1994, p. 67




From: Leopold 1994, p. 66


Radius
of
curvature
Wave length
Point bar




(From: Leopold 1994, p. 62)

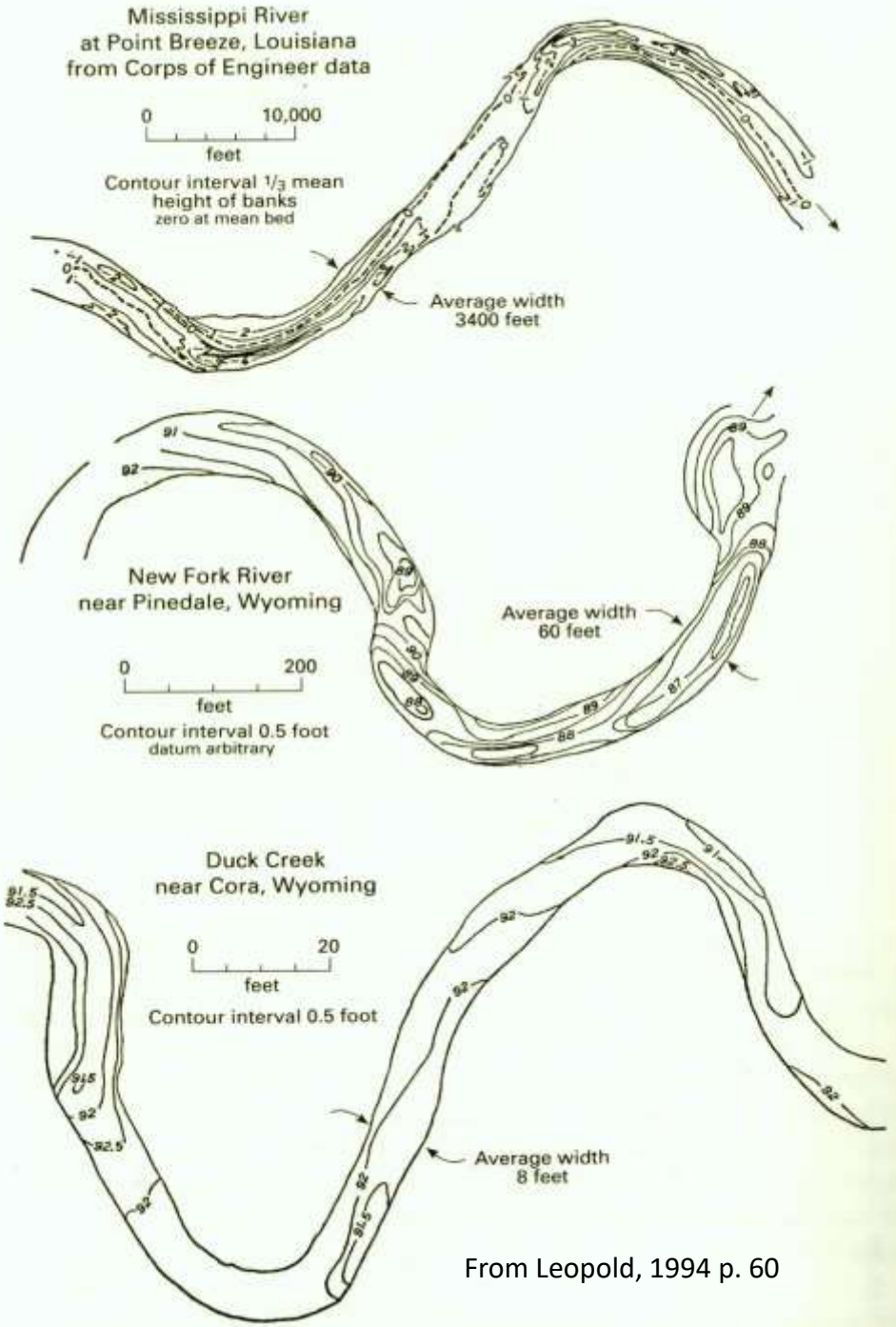

Meandering of a road ditch
on deposited sediment
(flat gradient).

# Meander geometry

Repeated measurements of meanders across many stream sizes has shown a consistent relationship among the wavelength, width and radius of curvature:

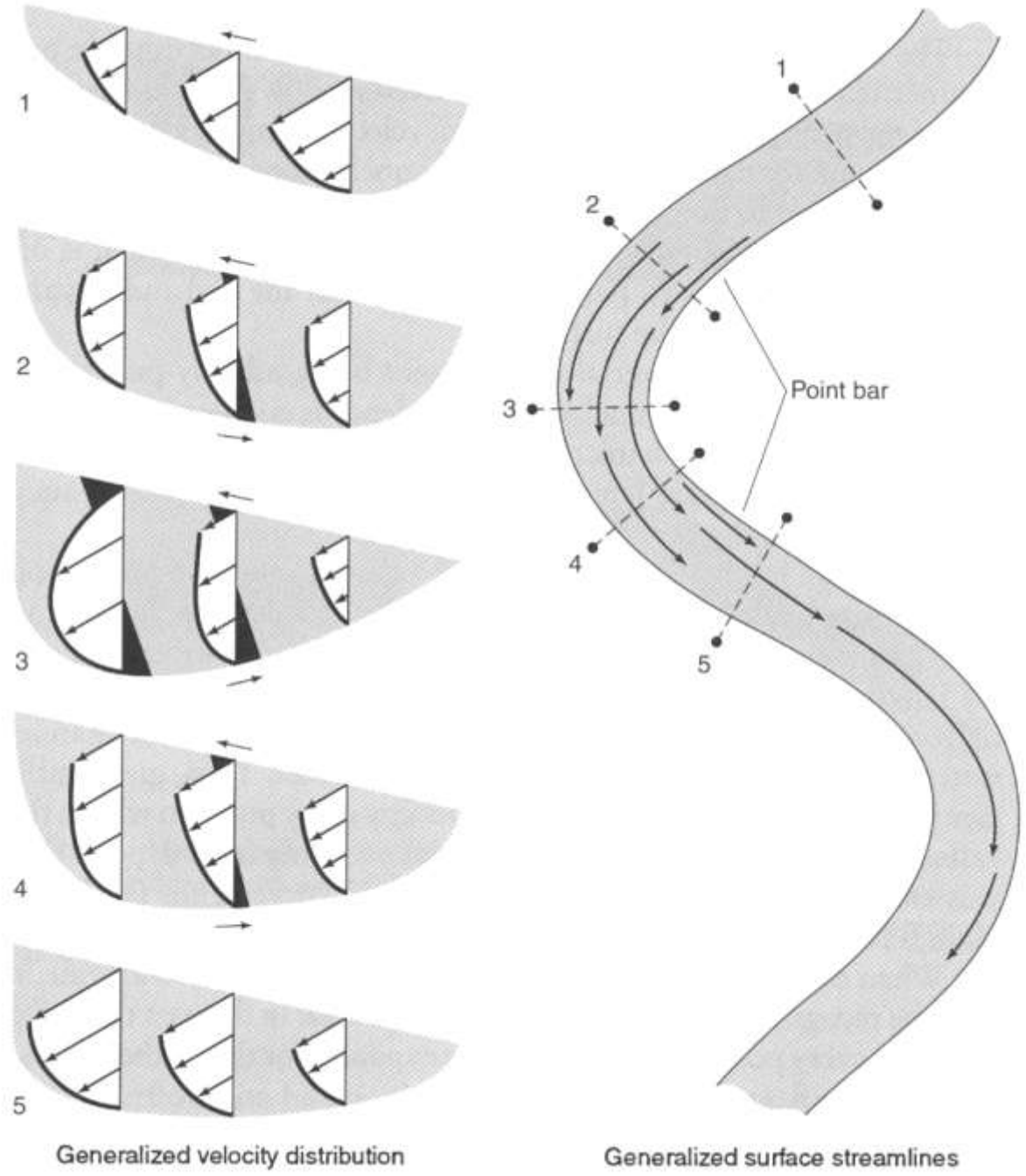
- wavelength is nearly always between 10 – 14 channel widths.
- wavelength averages 11 times channel width.
- the radius of curvature in the central part of the bend averages 1/5 of the wavelength.
- based on the relationships above, the radius of a meander is 2.3 times the channel width (1/5 x 11 channel widths = 2.3)

**The similarity of meander geometry across streams of different sizes is demonstrated by the 3 streams to the right that are drawn to the same size on the page.**

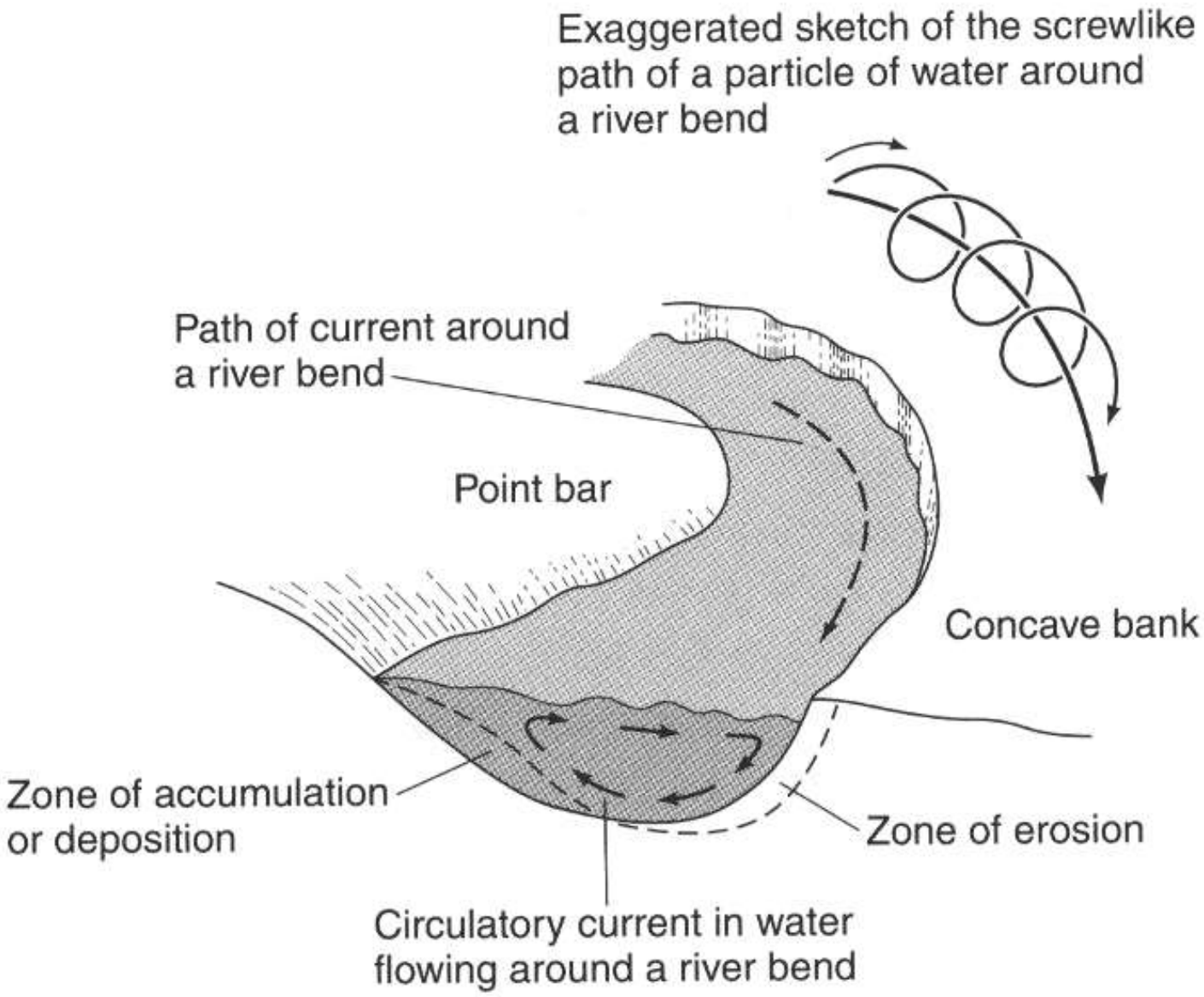



From Leopold, 1994 p. 60

# Velocity Profiles in Meanders



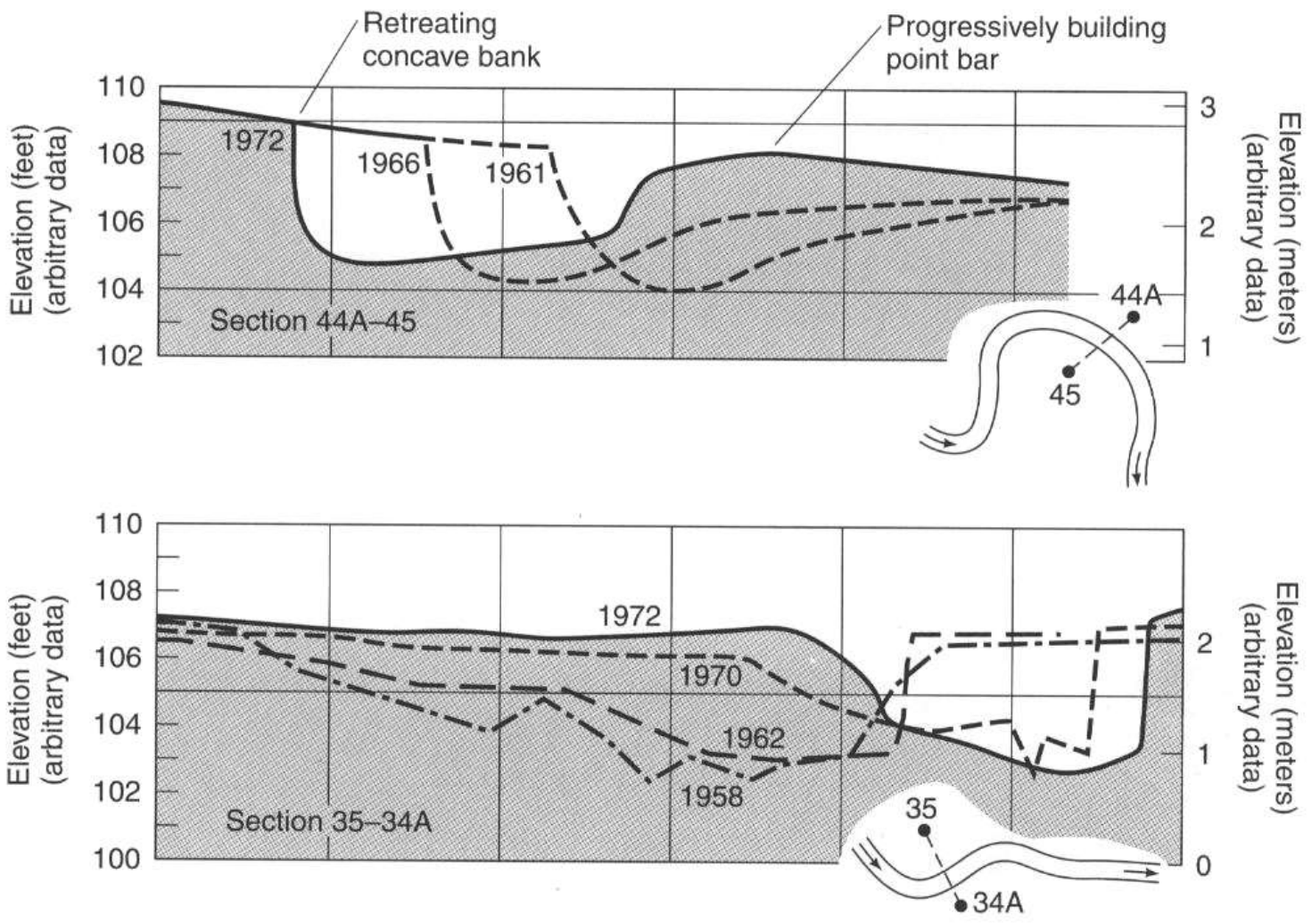

From Leopold, 1997, p. 77

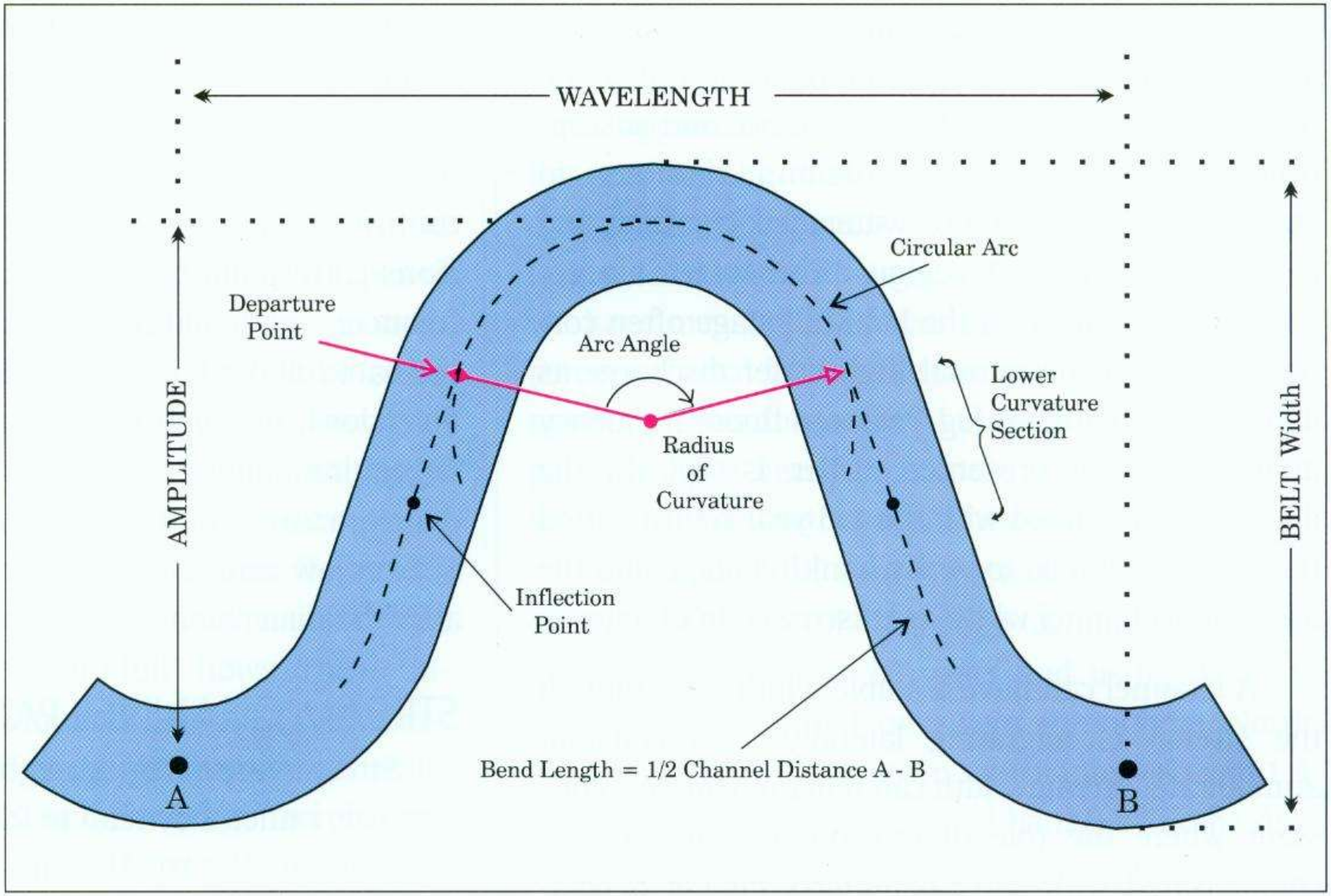



From Leopold, 1997, p. 76

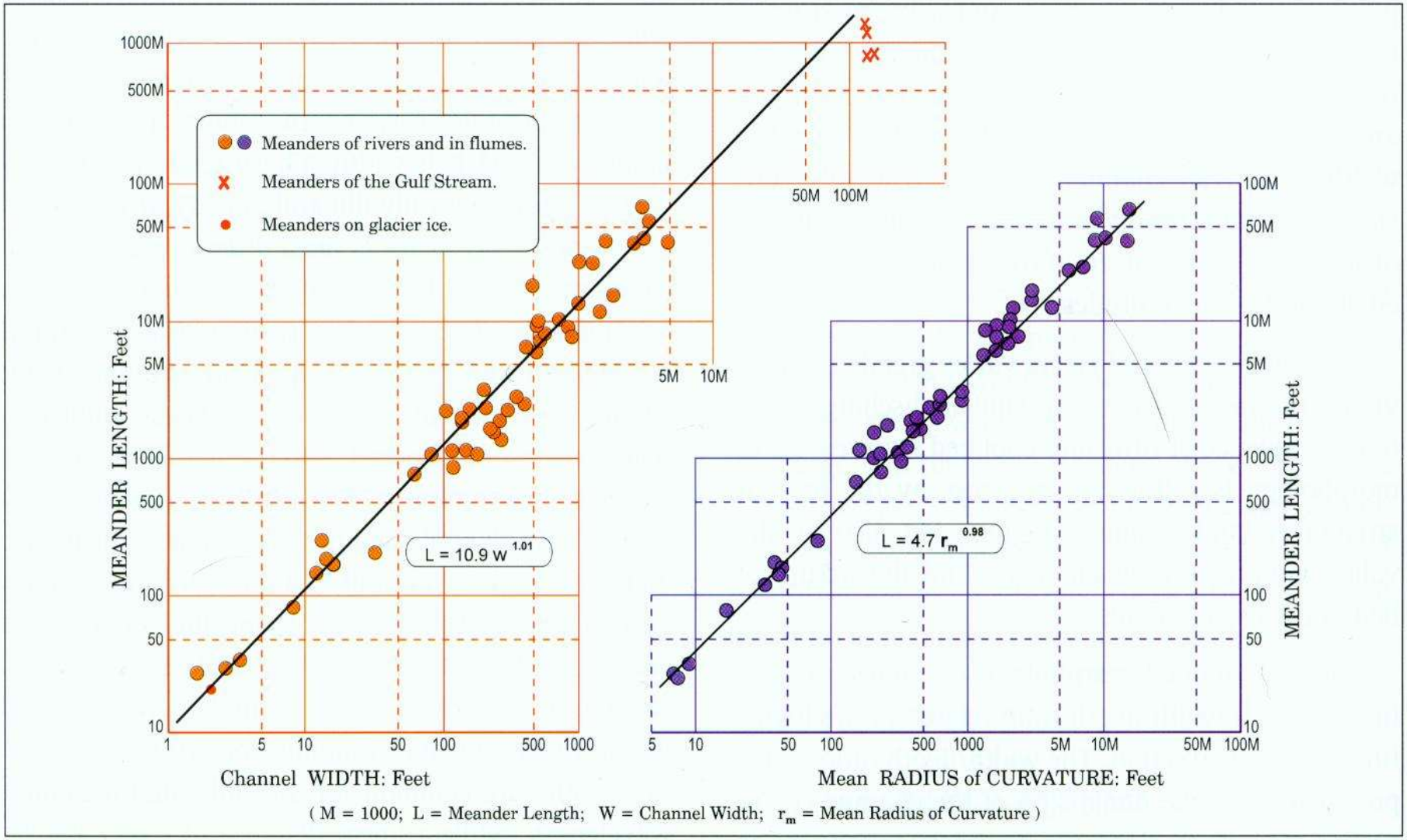
# Build up of a flood plain near meander point bars

(Leopold, 1997, p 79)

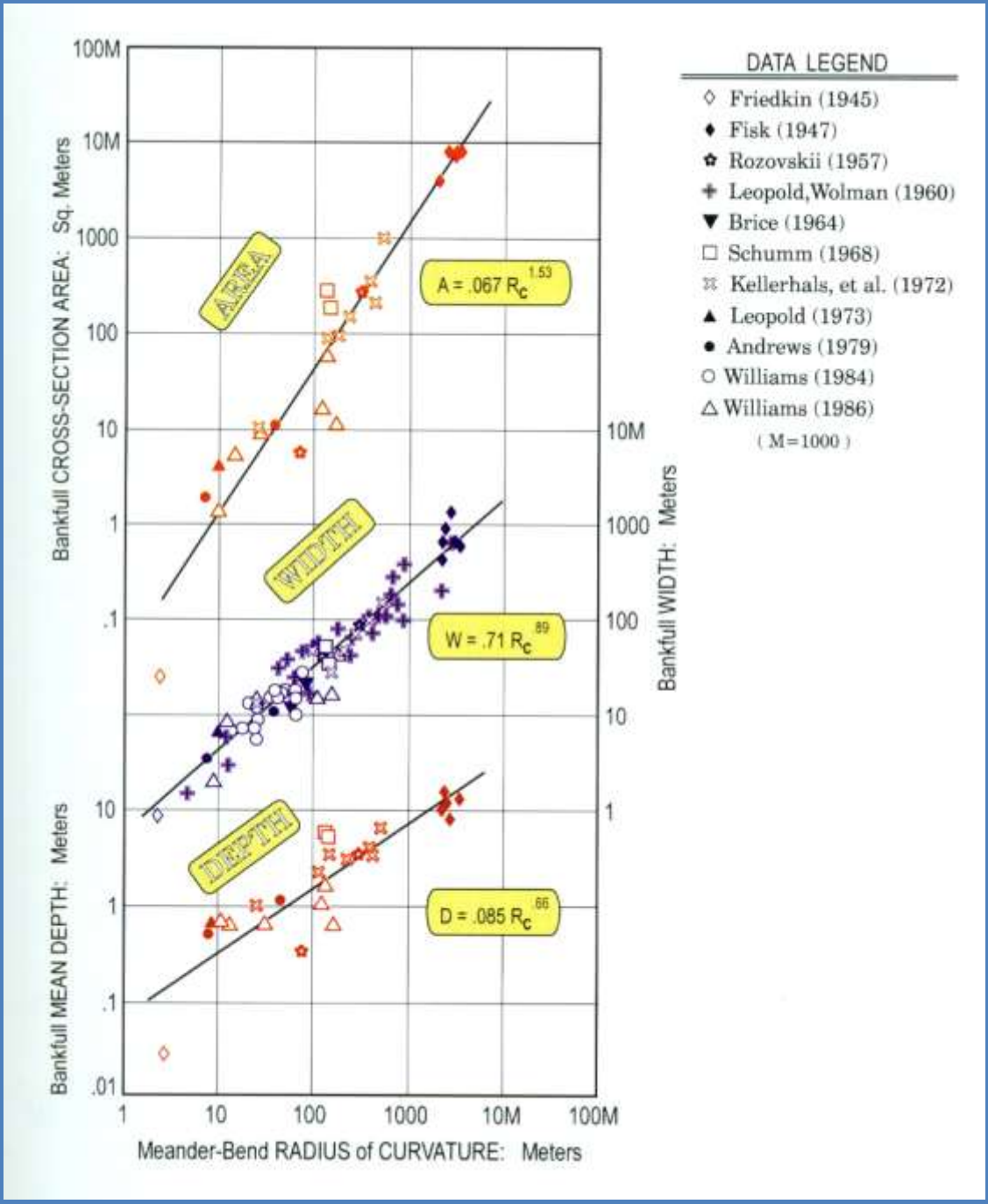




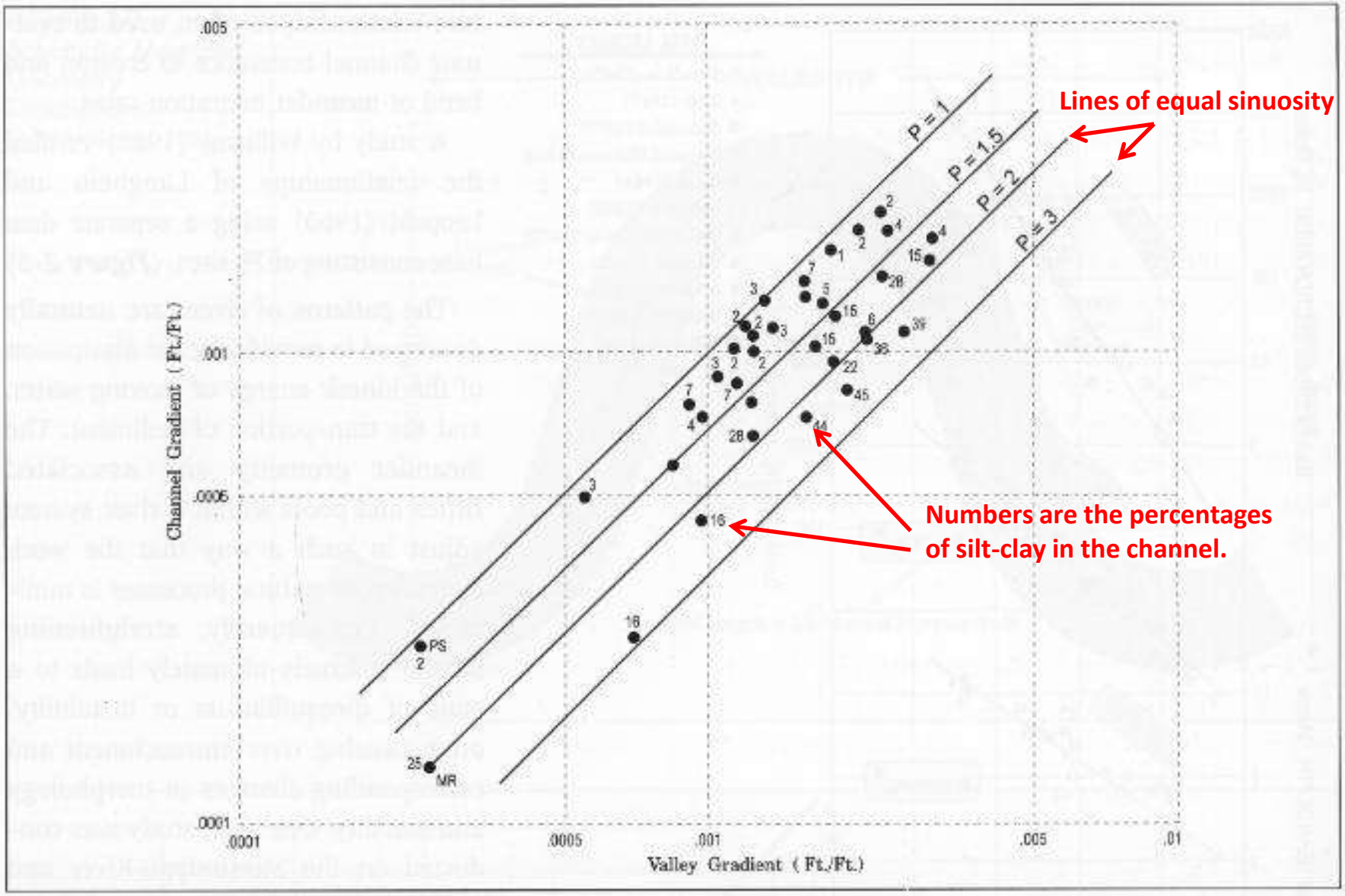

From: Rosgen, 1996




From: Rosgen, 1996




From: Rosgen, 1996




(From: Rosgen, 1996; after Schumm, 1968)

# Straight Channels

- Straight channels have a sinuosity of less than 1.5
- Channel gradients tend to be close or equal to valley slopes.
- Stream energy is dissipated by the pool-riffle sequence. (and sometimes other structures)

# The Pool and Riffle Sequence

Swiftcurrent River GNP, Montana


Cedar Creek, McCurtain County, OK

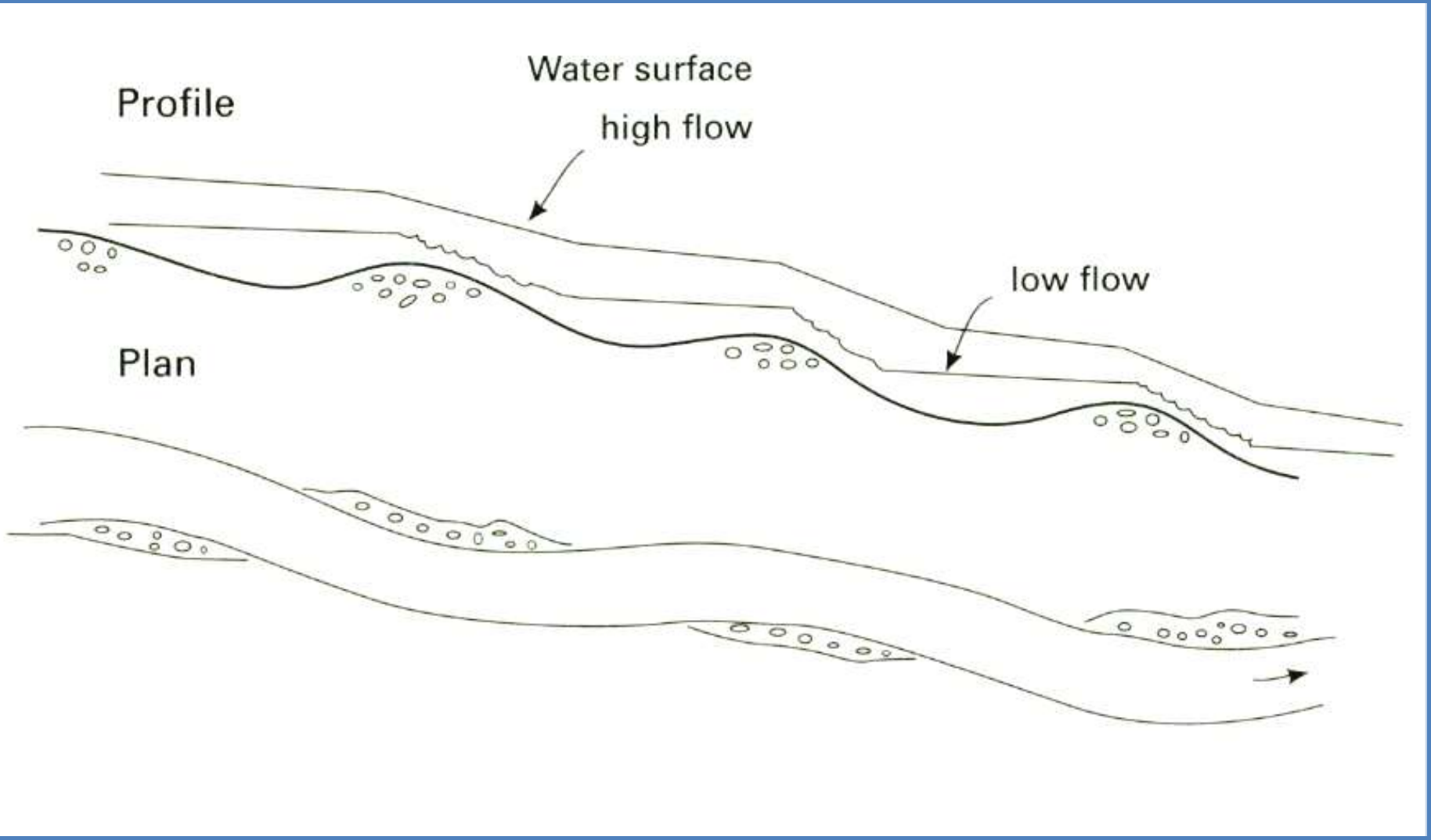

Rio Pueblo, Tres Ritos, NM


Colorado River, Canyonlands NP, Utah
Q = 60,000 cfs

# Pool and Riffle Geometry

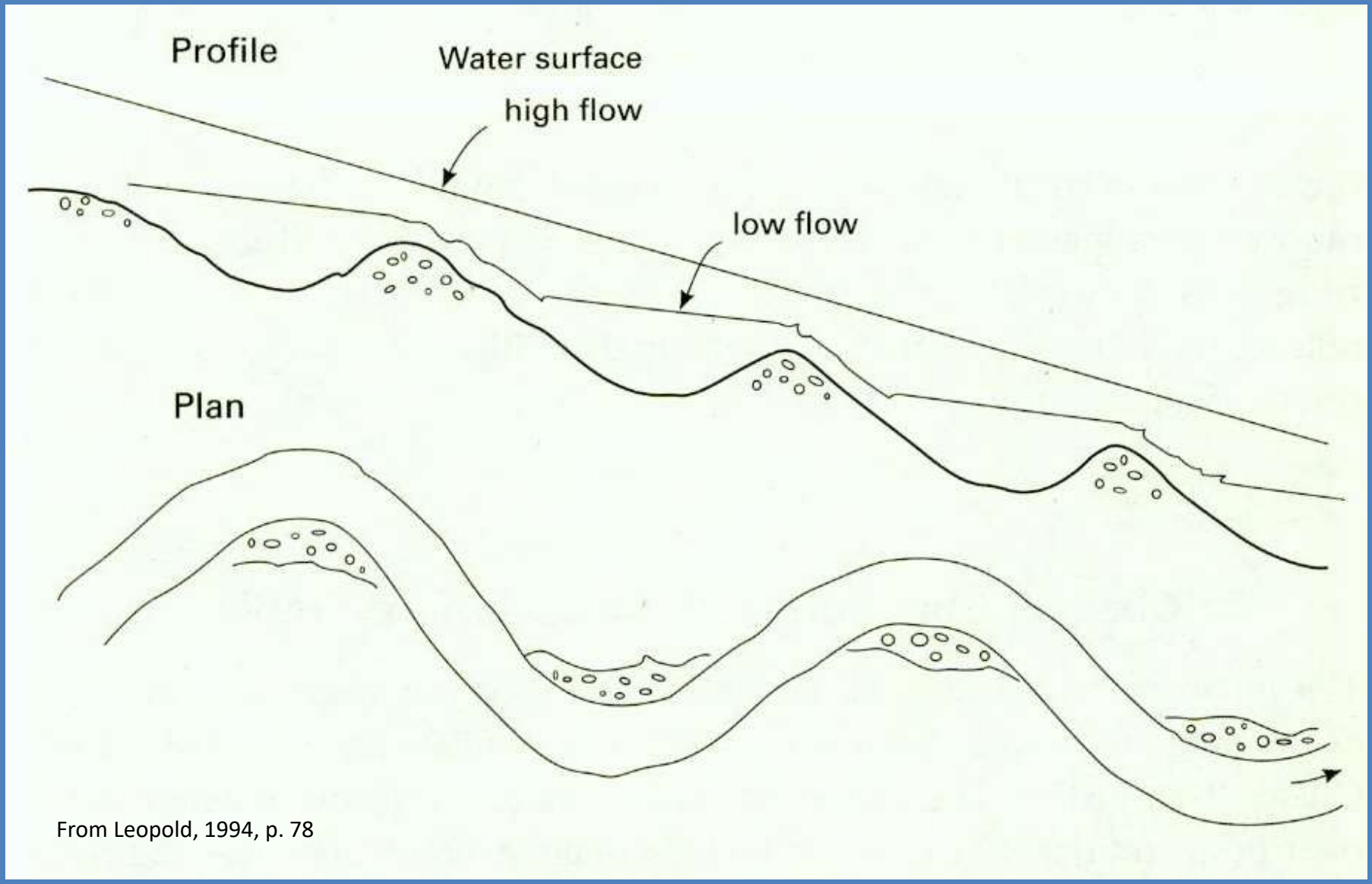
- In a very general sense, the pool-riffle is a sequence of alternating deep and shallow water.
- Is another form of resistance to flow that dissipates stream energy.
- They form in gravel-bedded streams.
- In sand-bedded streams deep and shallow water and resistance to flow are provided by dunes and ripples.
- Riffle/pool spacing occurs at frequency of 5 to 7 bankfull widths.

# Straight stream channels




From Leopold, 1994, p. 78

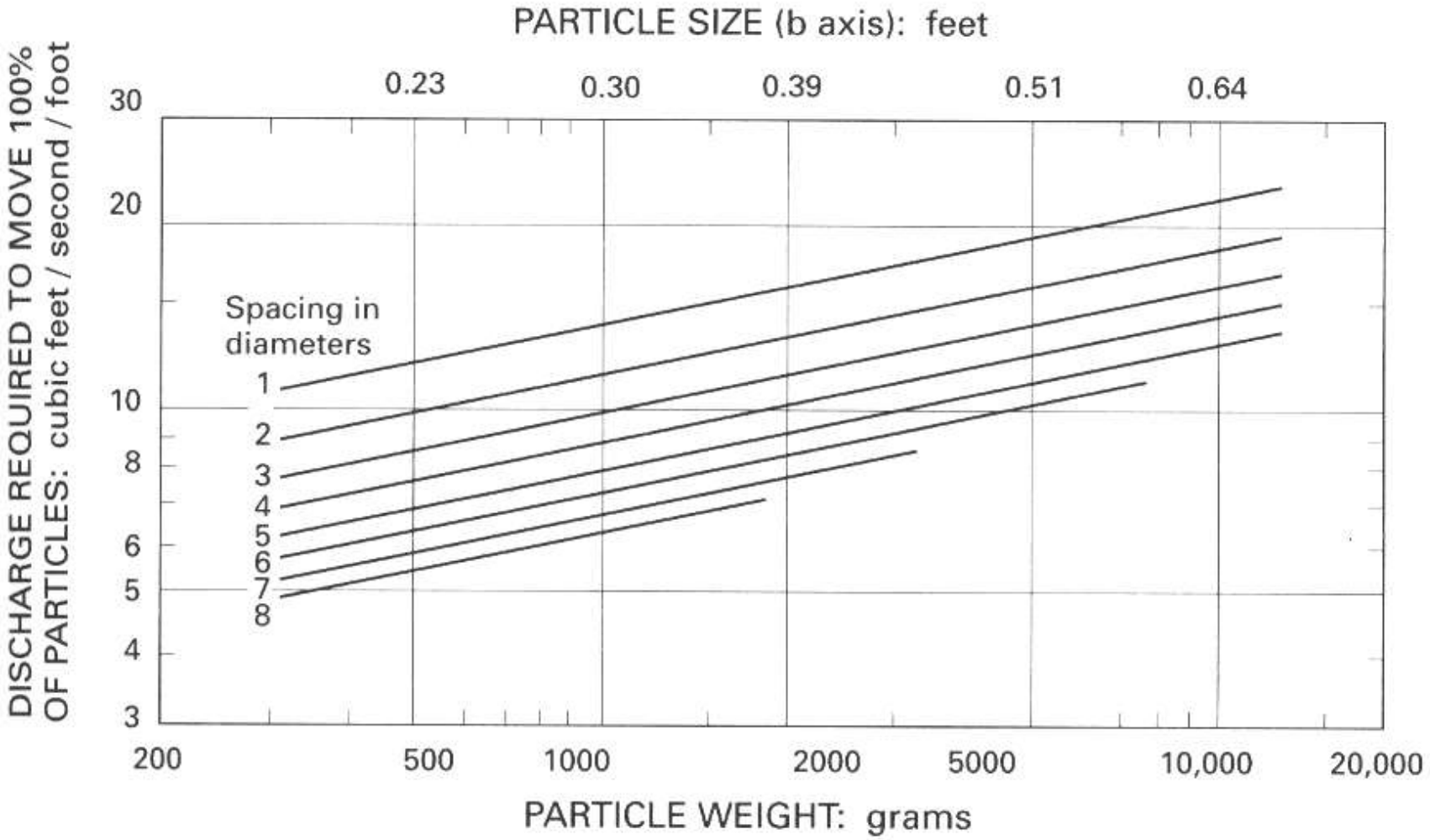
# Meandering or curved channels




From Leopold, 1994, p. 78

# How do pools and riffles form?

- The actual physical process is still unknown.
- In theory, as depth (discharge) increases, smaller particles should move first. If discharge continues to increase, larger particles will be transported (winnowing).
- Individual rocks interact with one another and influence their collective movement.
- Closely spaced rocks move downstream at a slower rate than those spaced further apart.
- They tend to bunch up in “platoons” which form riffles.



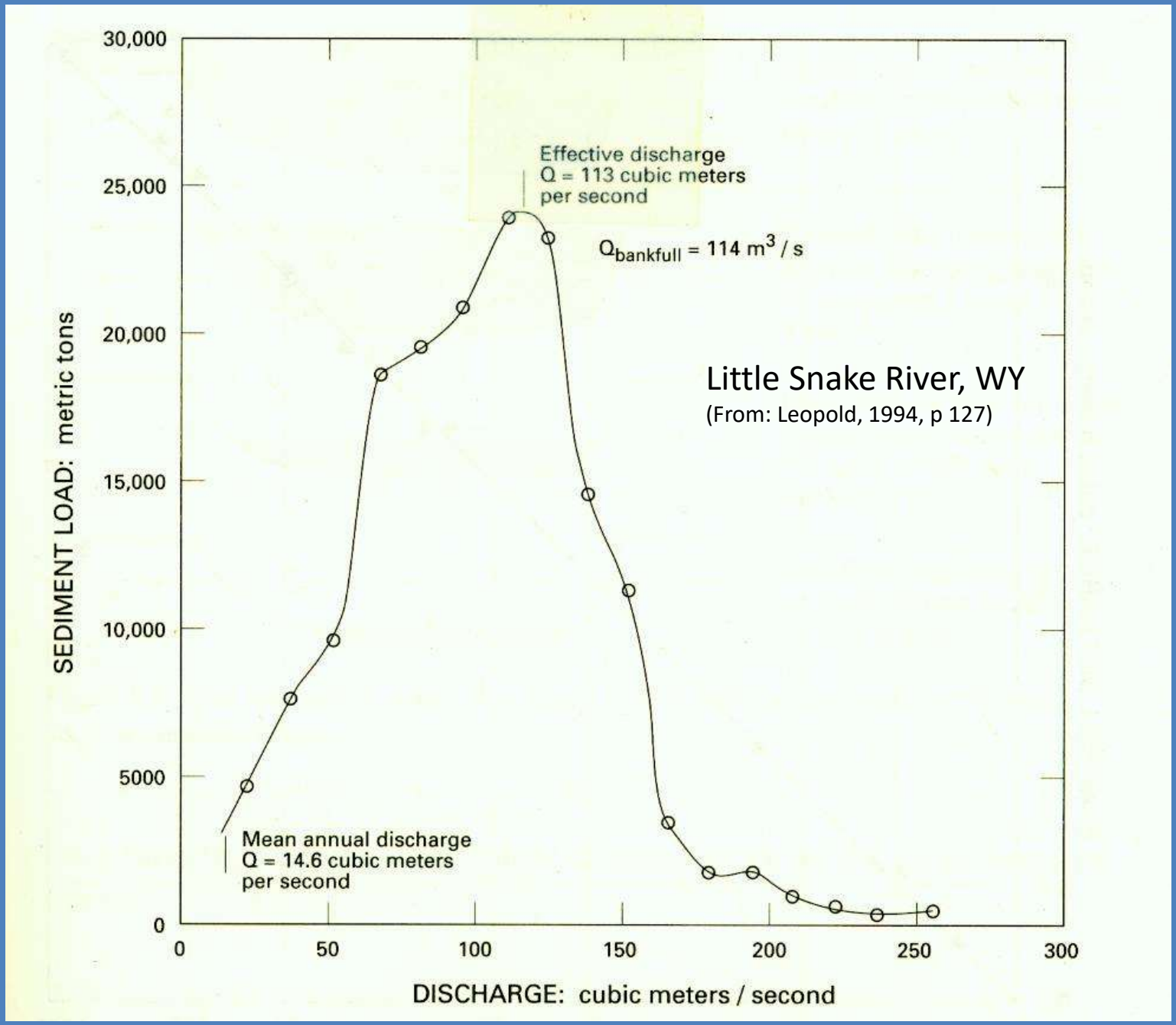

From: Leopold 1994, p 77

# Bankfull and Effective Discharge

# Bankfull and Effective Discharge

**The concept of effective discharge:**

- **The effectiveness of erosion and deposition in forming stream channels increases with discharge.**
- **Low discharges occur frequently, but are ineffective in transporting sediment.**
- **High flows are effective in transporting sediment, but occur infrequently.**
- **An intermediate flow occurs often and is capable of transporting significant quantities of sediment.**
- **Effective discharge is the discharge that carries the largest amount of sediment over a long period of time.**

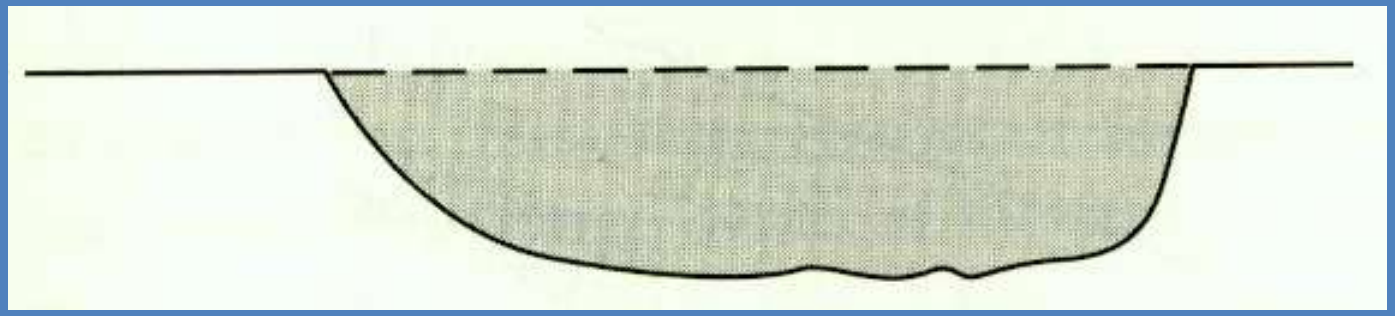



Little Snake River, WY

(From: Leopold, 1994, p 127)

# Bankfull and Effective Discharge (cont.)

- Bankfull discharge is the flow that just fills the channel to the top of its banks and at a point where the water begins to overflow onto a flood plain.
- It occurs (exceeded) on average once every 1-2 years
- Or it has a return interval of 1.5 years



- Bankfull stage (or depth) is the incipient elevation on the bank where flooding begins.


Bluff Creek, Battiest, OK

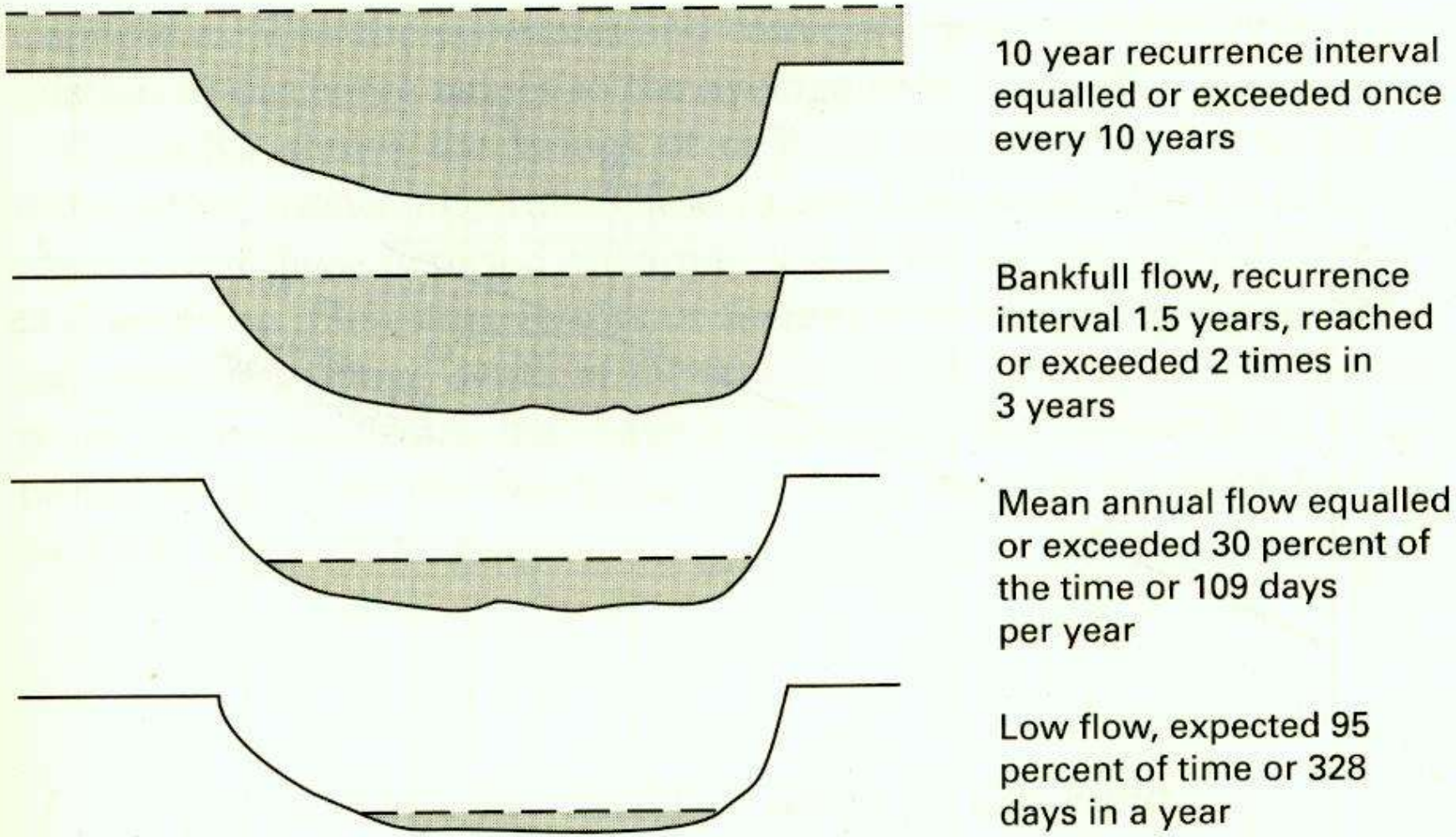
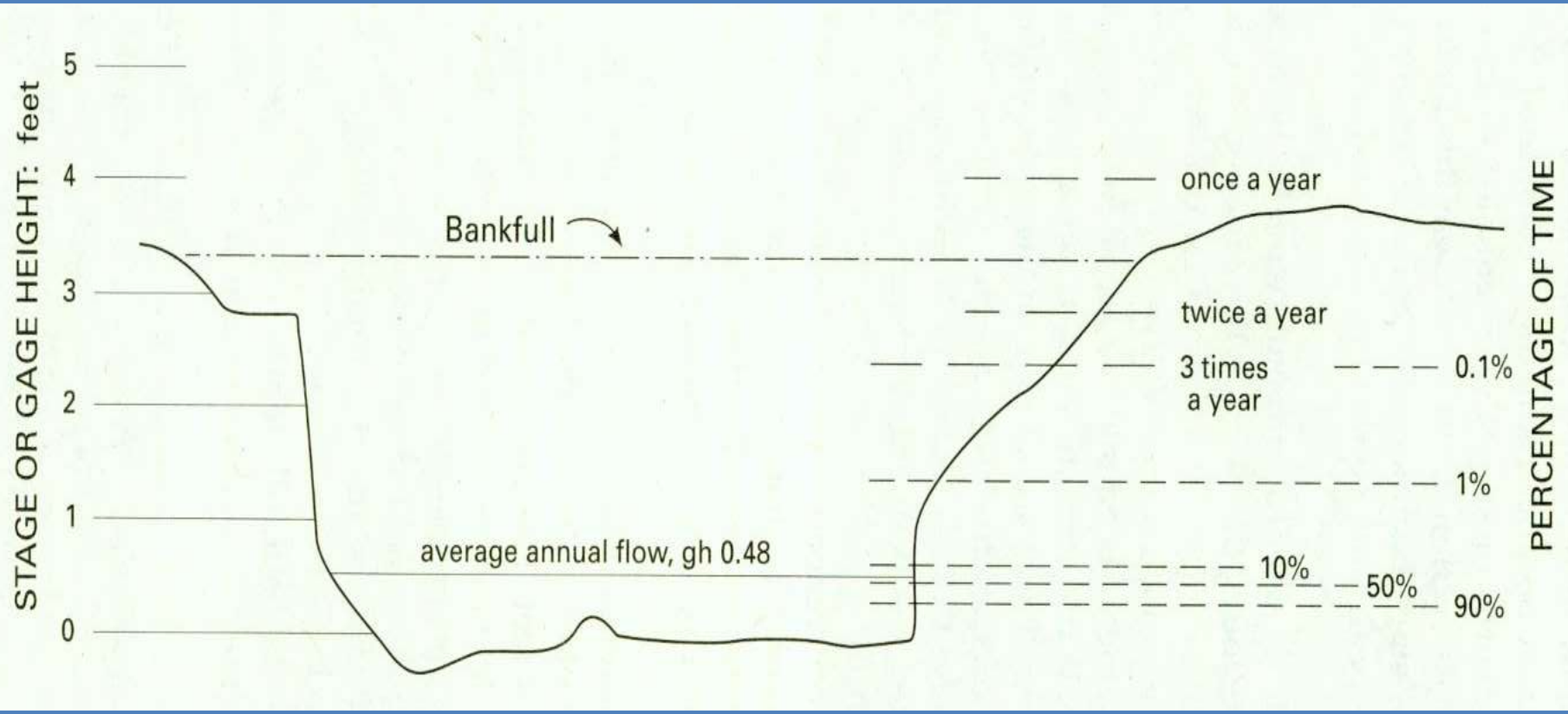



*Figure 8.3* The amount of water in a river channel and the frequency with which such an amount occurs.

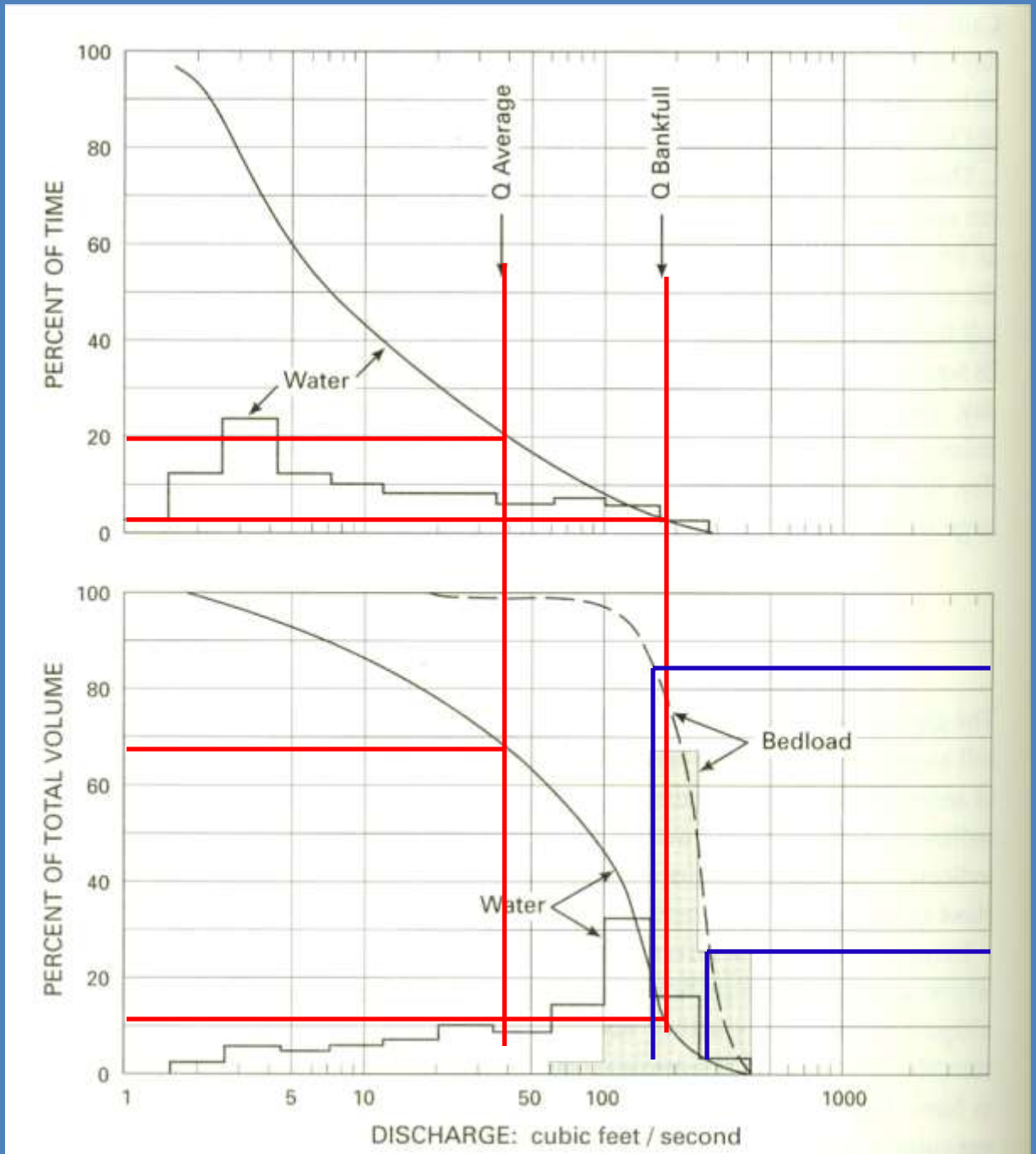
From Leopold 1994, p. 129


For most streams, bankfull
and effective discharge are the same




**Watts Branch, Maryland**

**(From: Leopold 1994, p. 152)**

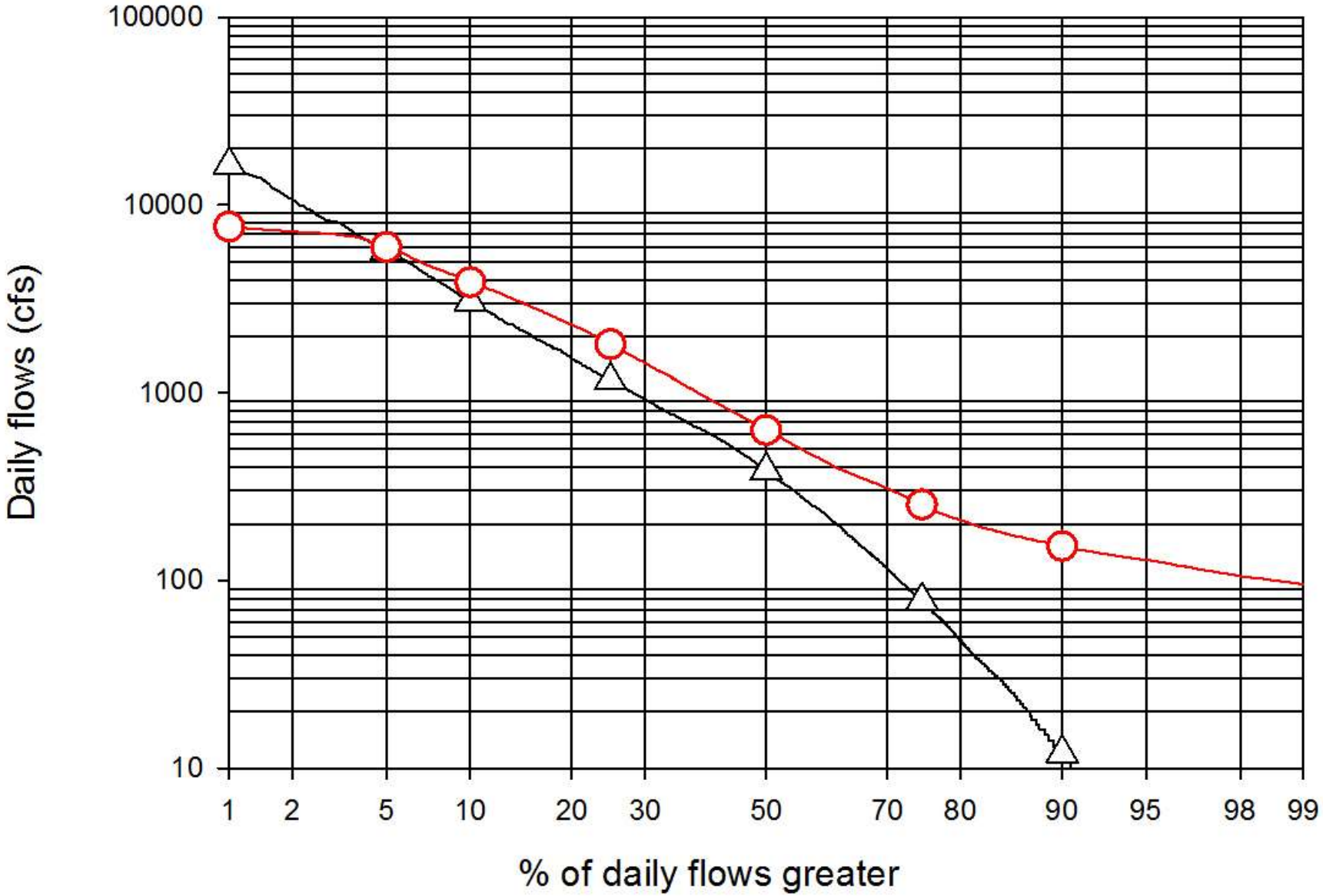


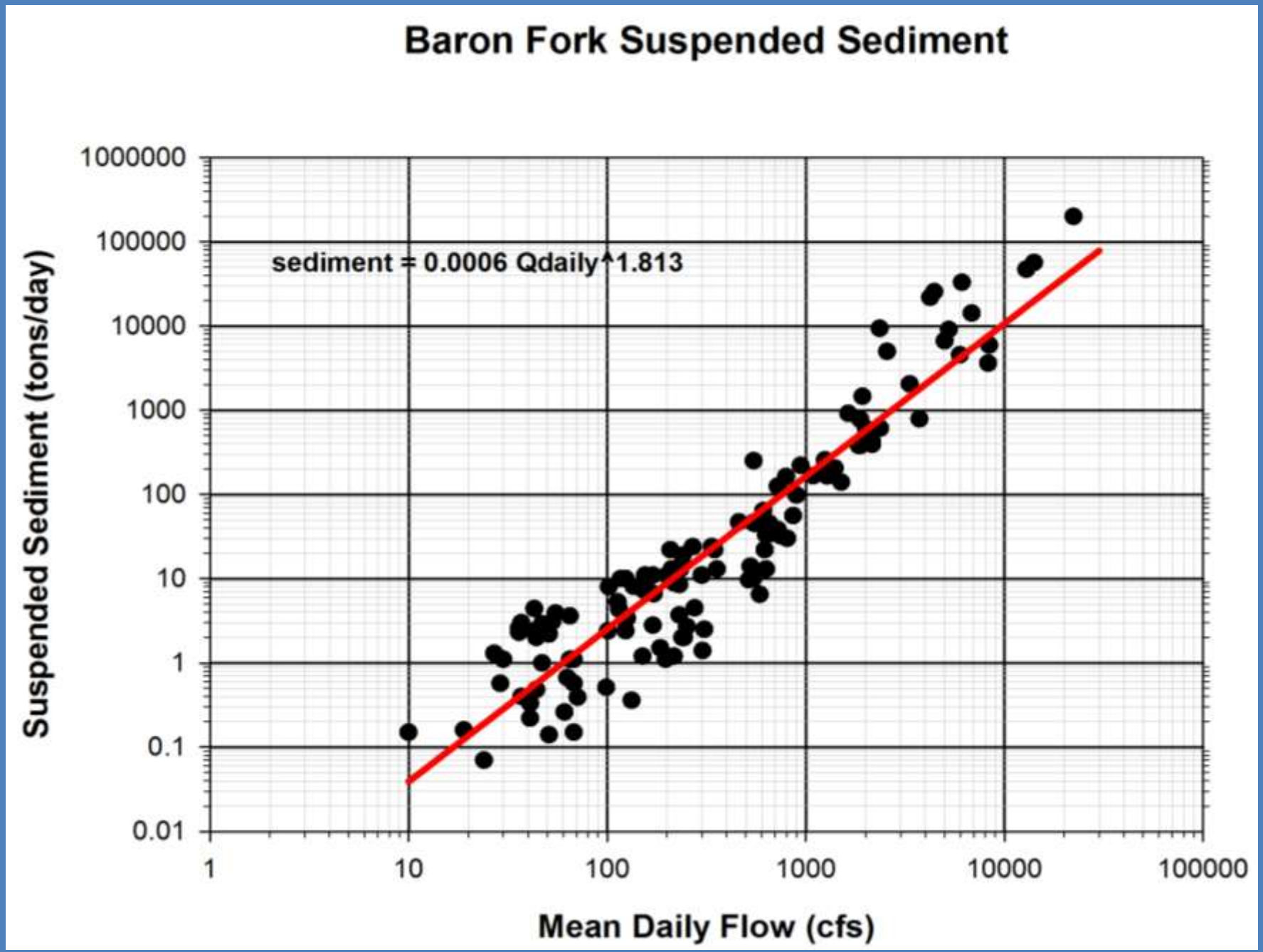

**Left Hand Creek, CO**

(From: Leopold, 1994, p 210)

# Mountain Fork River, Oklahoma

flow duration curves before (black triangles)
and after (red circles) Beaver's Bend Dam




Baron Fork Suspended Sediment
sediment = 0.0006 Qdaily^1.813
Suspended Sediment (tons/day)
1000000
100000
10000
1000
100
10
1
0.1
0.01
1
10
100
1000
10000
100000
Mean Daily Flow (cfs)