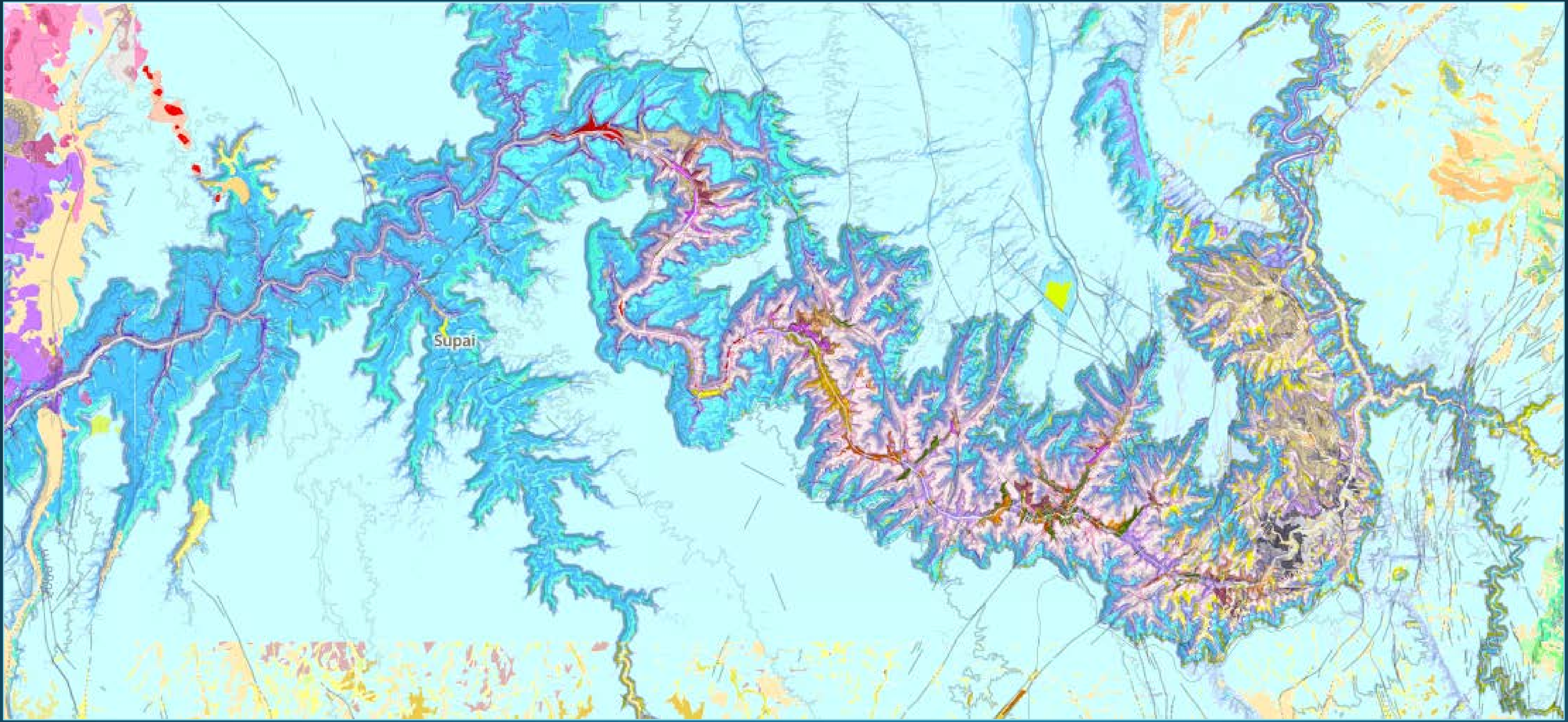
Geologic controls on the evolution of rapids in the Grand Canyon

George Snyder



Outline:

1. Overall river morphology, large scale fluvial pattern in the Grand Canyon section of the Colorado River.

2. Lithologic influences and depositional processes behind the formation of rapids.

3. Late Quaternary evolution of alluvial production and deposition.

4. Evolution of rapids over the last century and the influence of Glen Canyon Dam on rapid aggradation.

The Colorado River: “Rapids and Pools”

150+ named rapids in the Grand Canyon

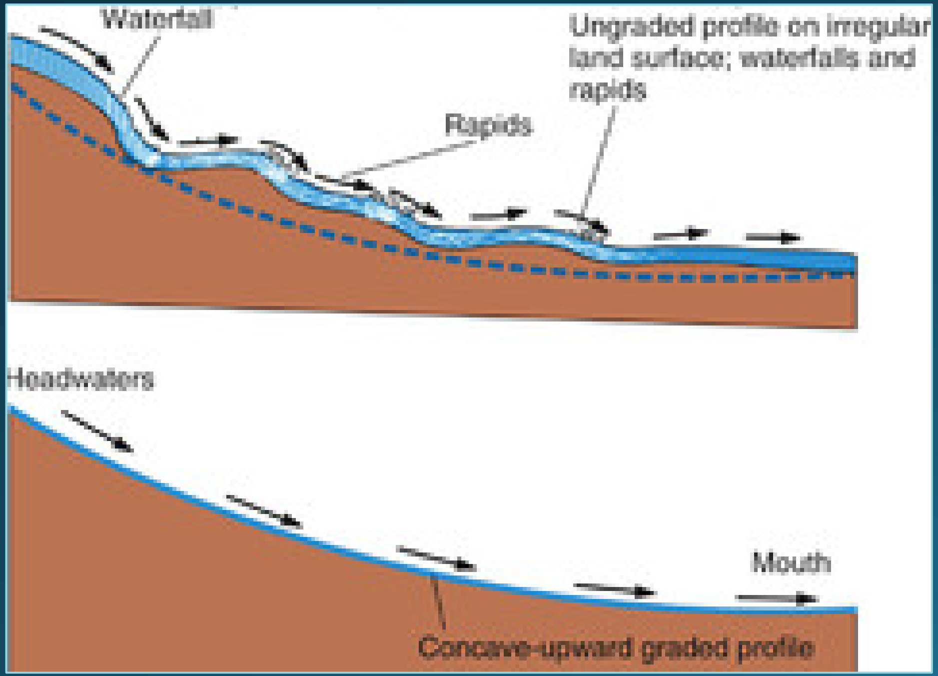
Given 1 - 1 0 difficulty rating. Approximately I – IV on the international scale.

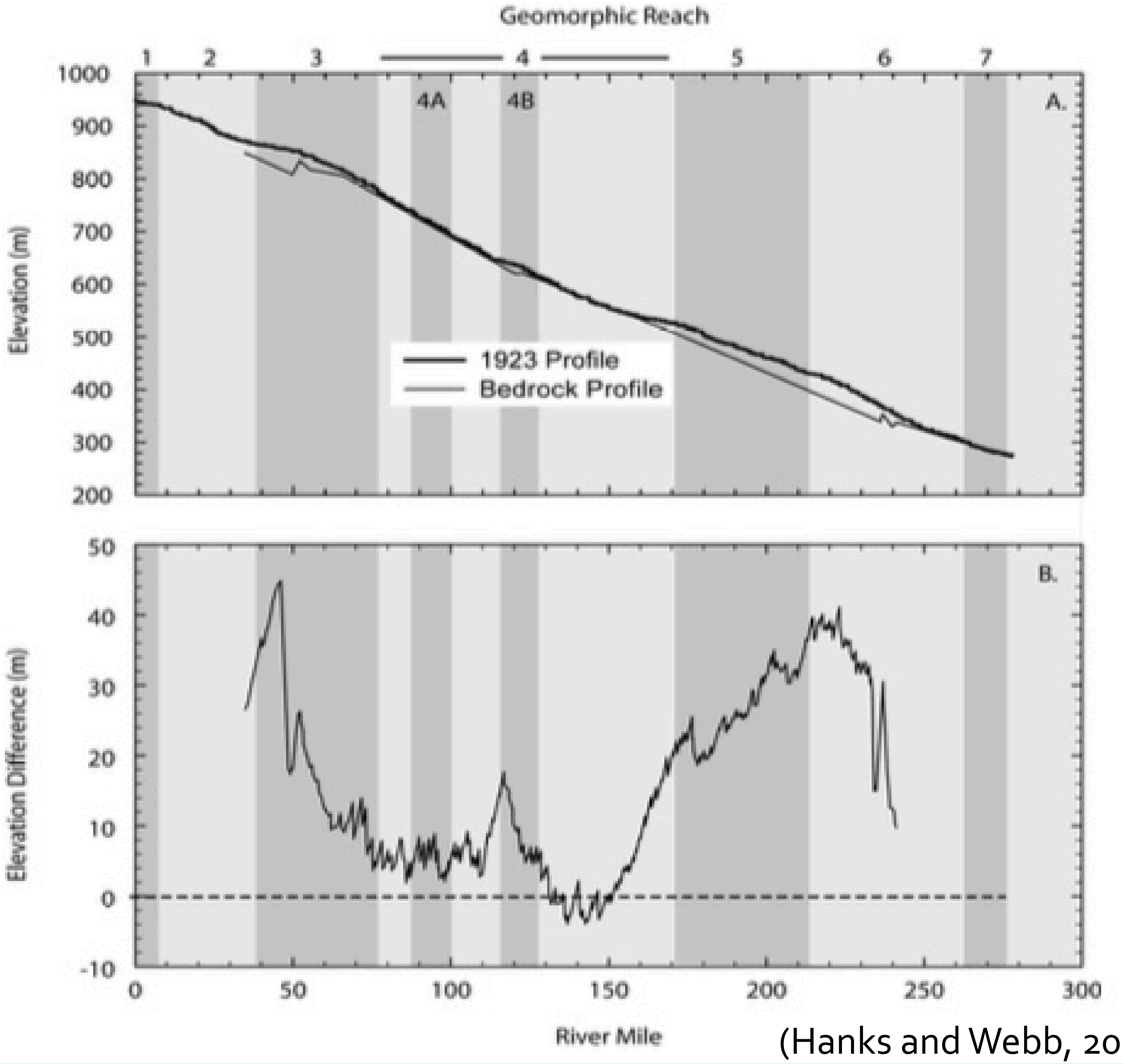
66% of vertical drop occurs over 9% of the river.

Longitudinal Profiles

Rivers in erosional-depositional equilibrium adjust into a predictable “graded” longitudinal profile.

Deviations from a graded profile indicate active geological processes are countering fluvial adjustment.





(Hanks and Webb, 2006)

Debris flows

Dense, 10-40% vol. water, clay rich slurries

High cohesion

High shear stresses on flow boundaries

High density = greater buoyant forces on entrained boulders.

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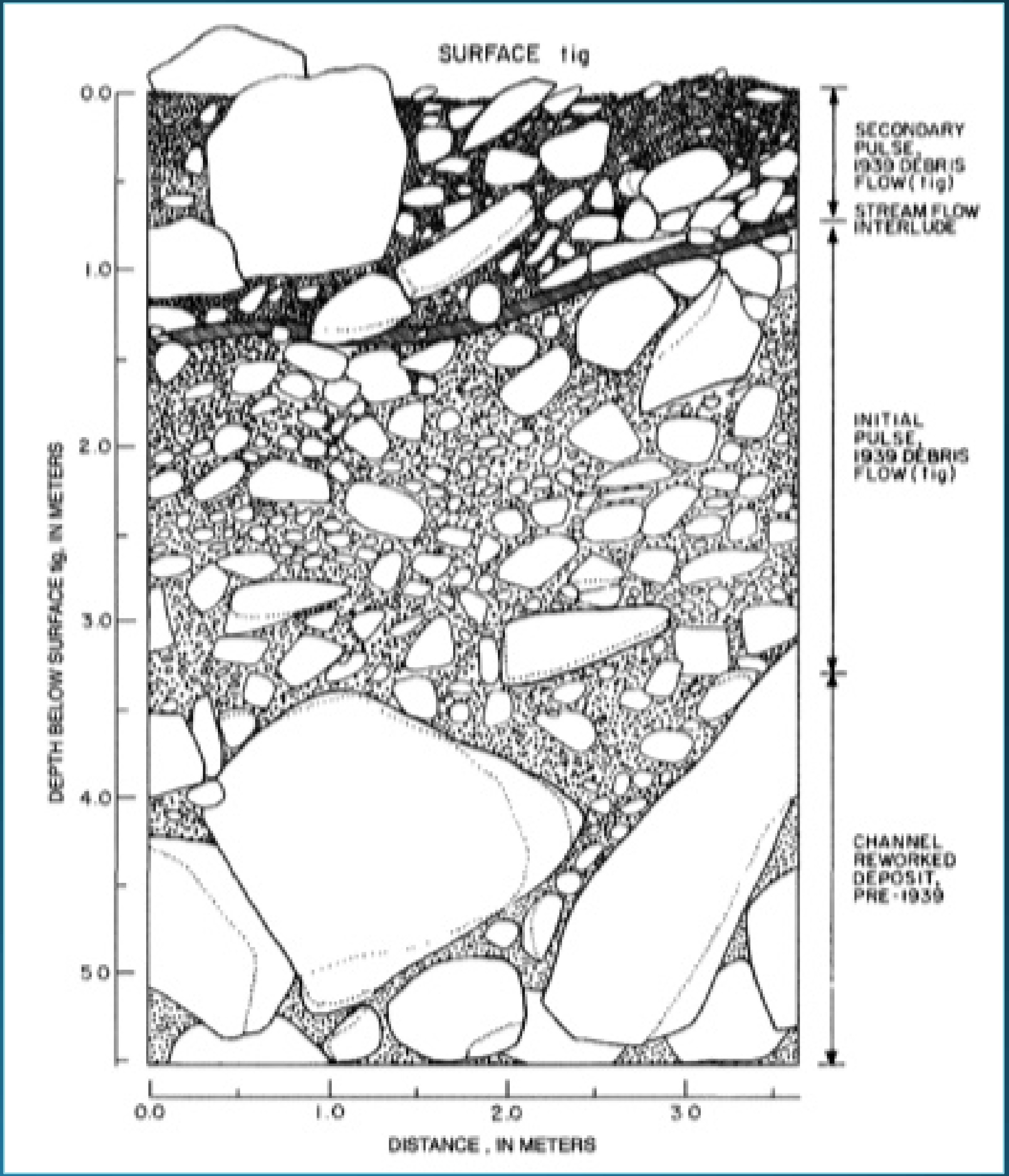


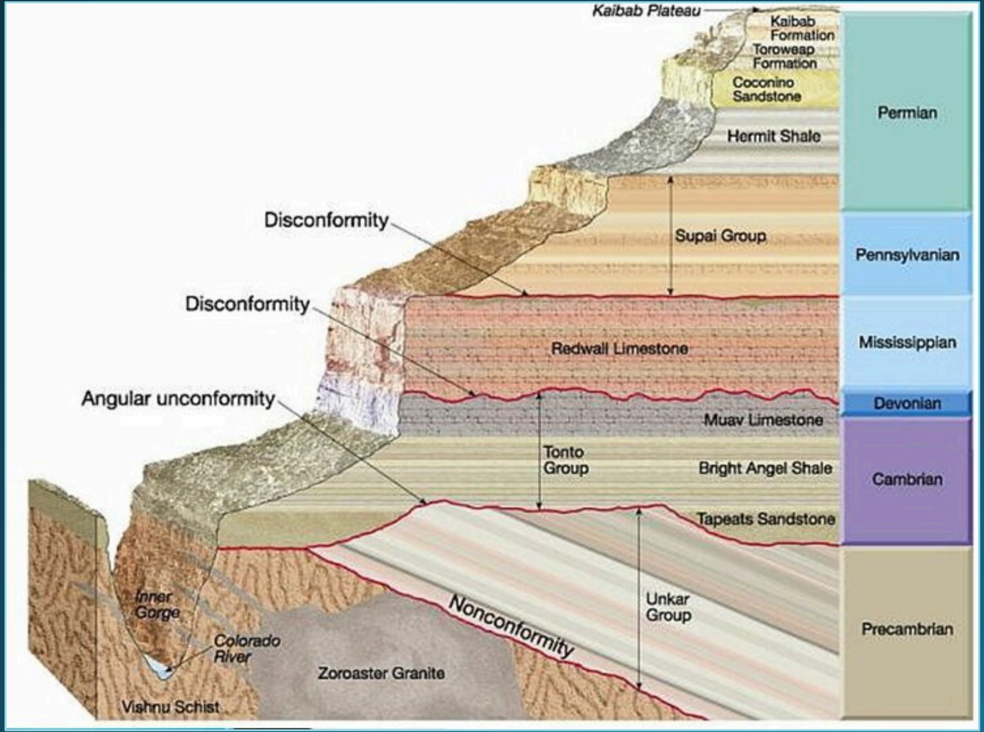
Debris flow sources

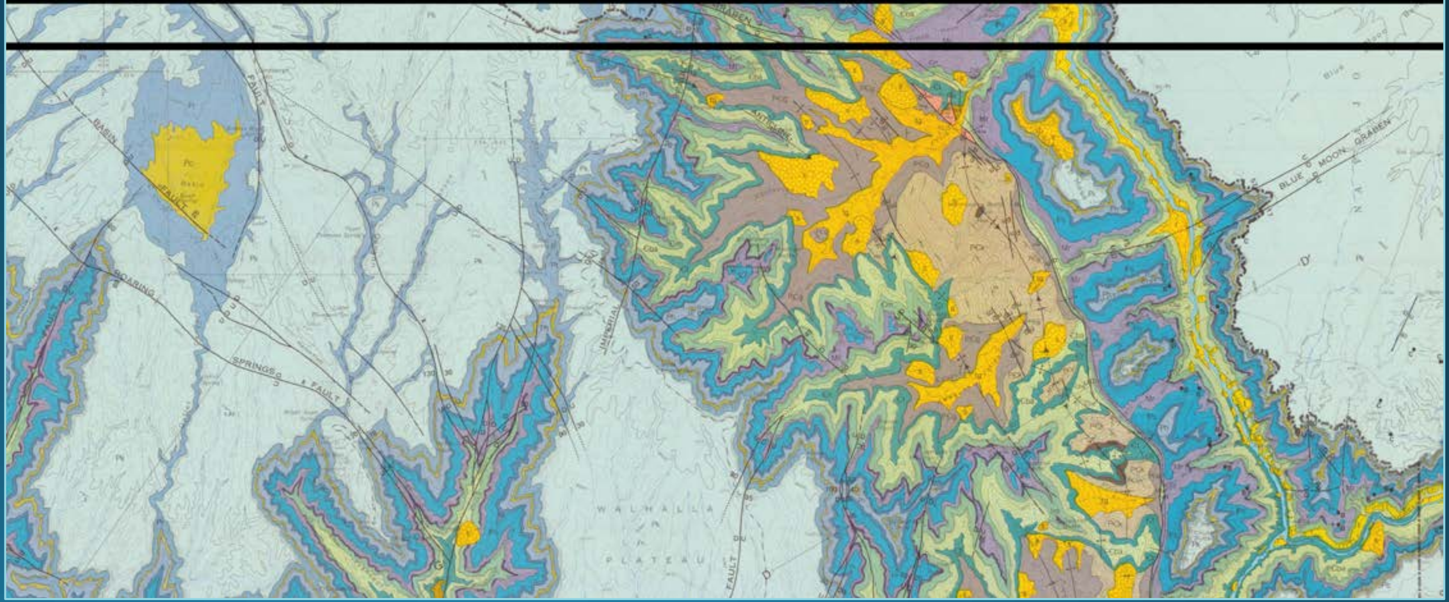
4 formations account for 75% of slope failures: Bright Angel Shale, Muav Limestone, Supai Group, Hermit Shale.

Key characteristics include:

Clay/silt rich lithology – provides fine grained matrix necessary for initiating debris flows.

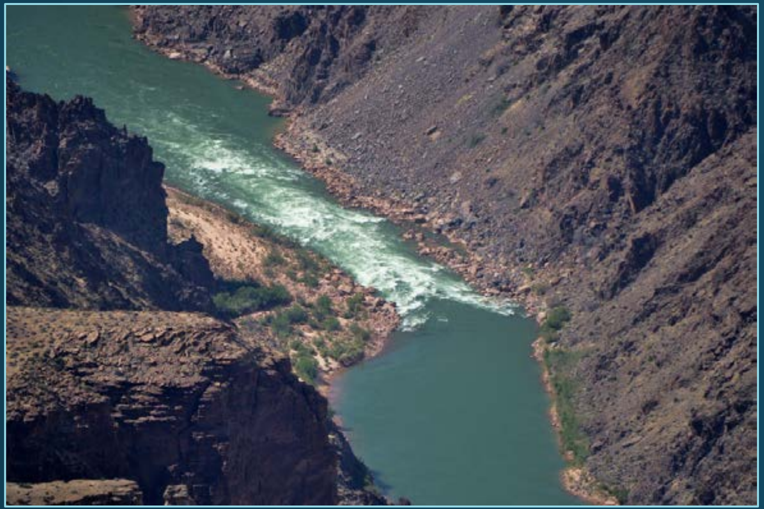
Ledge forming units – Ledges act as repositories for boulders sourced from cliff forming units.

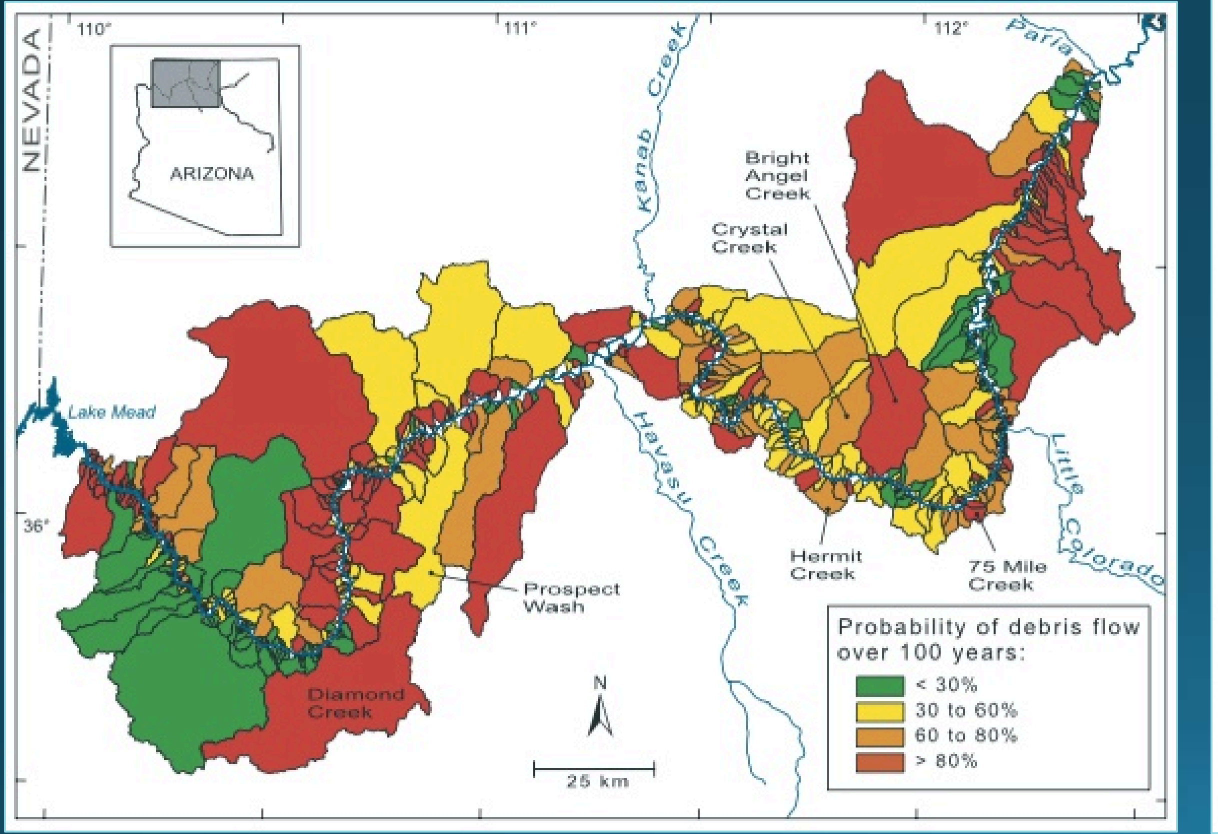




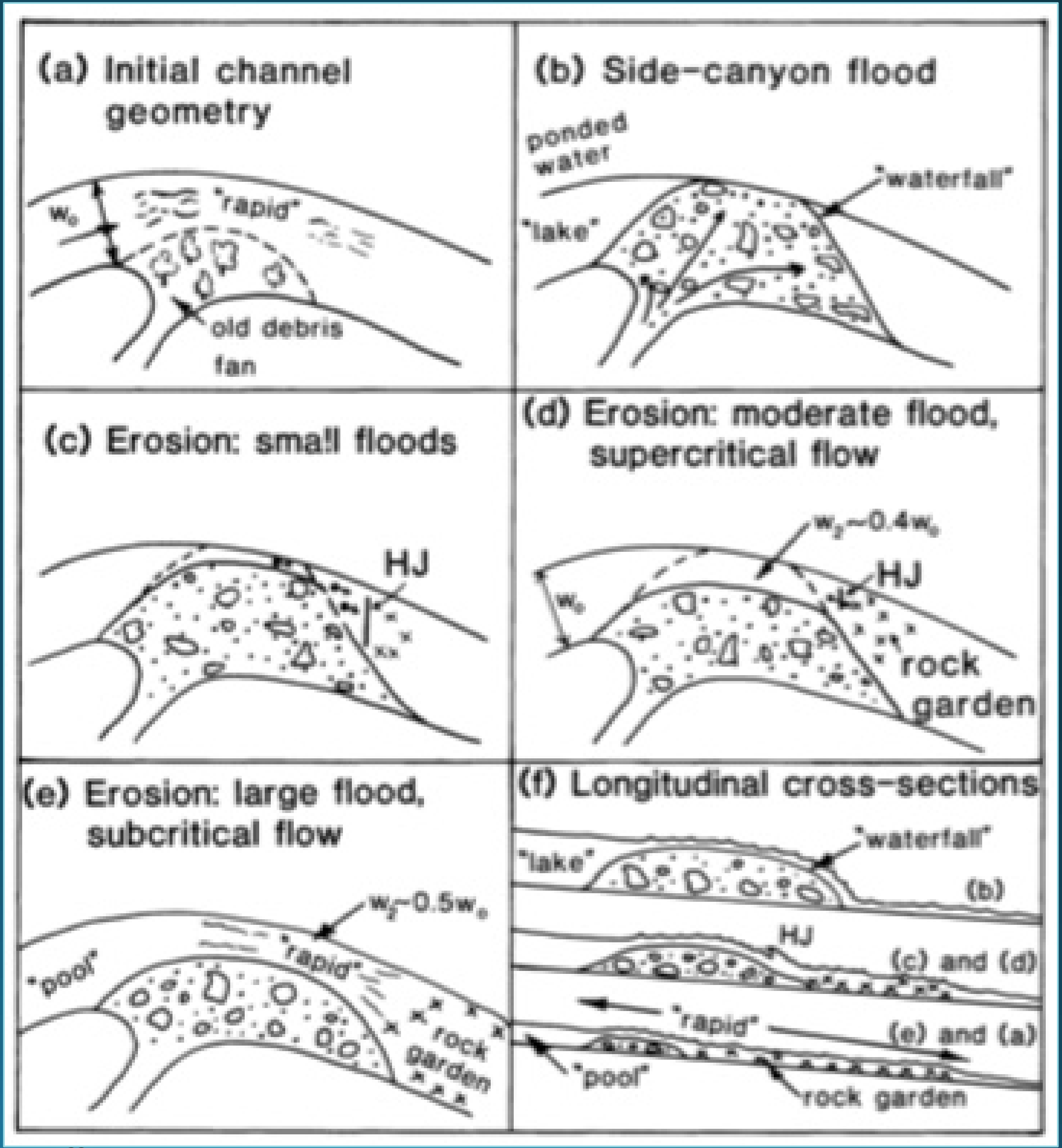
Rapid formation:

~5 events/year average in the Grand Canyon over the last century.





(Griffiths et al., 2004)

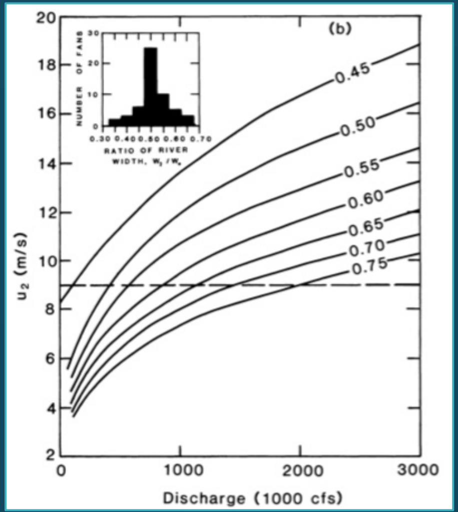


(Kieffer, 1983)

Rapids: Relict or Recent?

Wetter climates in the Pleistocene are thought to have accelerated main stem canyon incision.

Hillslopes and tributaries, however, appear to have been more stable, accumulating regolith, to later be eroded and deposited after the onset of a warmer climate and the development of summer monsoons.

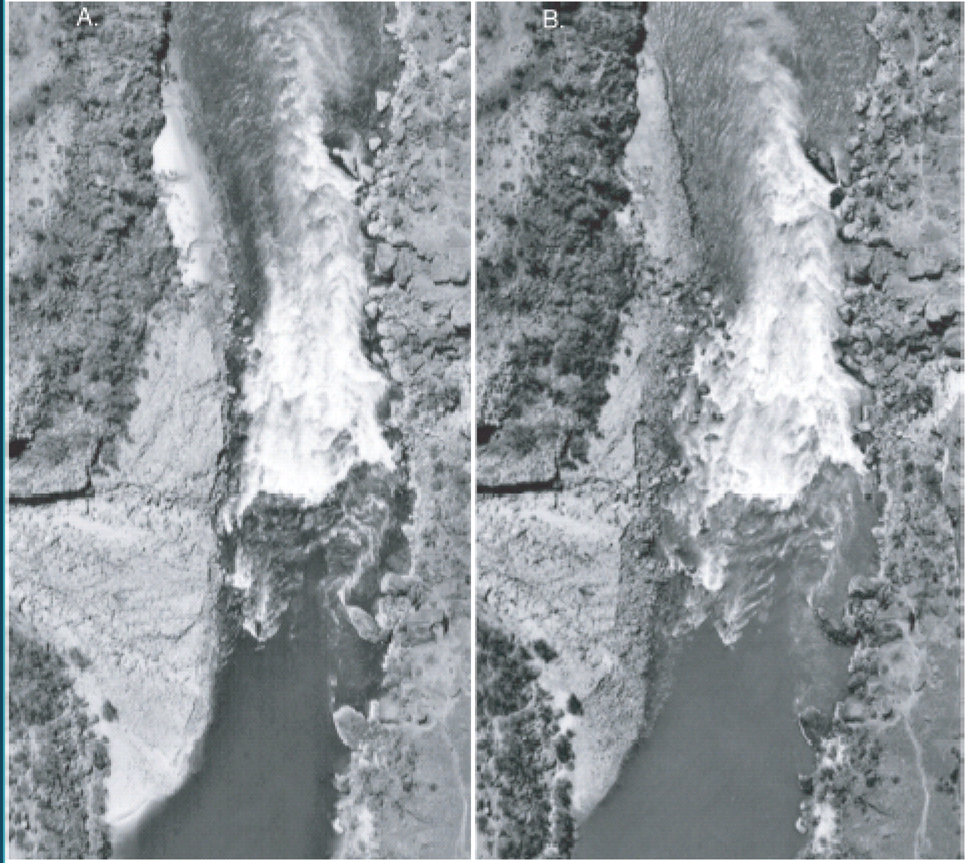


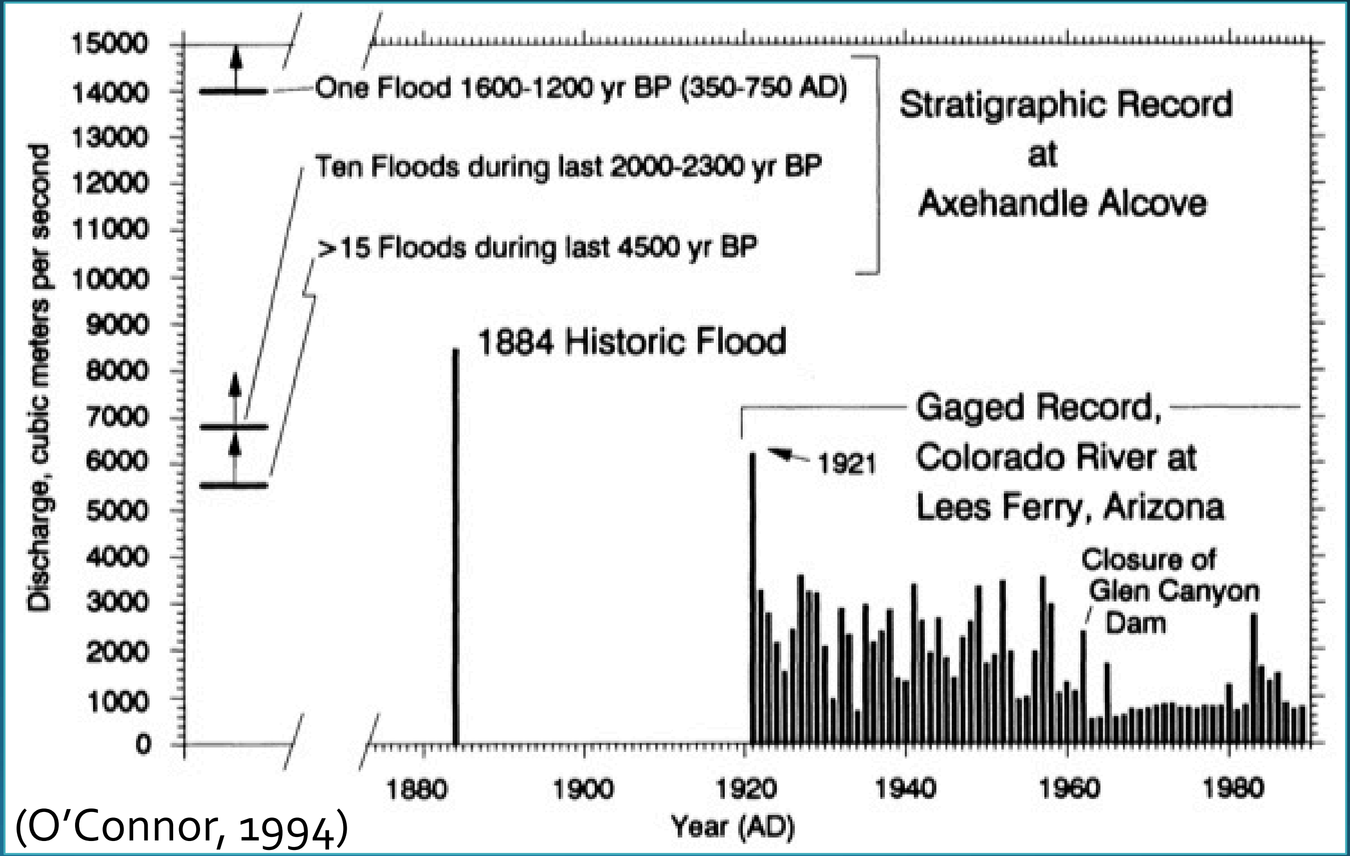
Most major rapids constrict the main stem to 0.5 the average width.

Widening of Crystal Rapid after the 1983 flood suggests past discharges of >11,320 m³/s are required to erode channel to 0.5 main stem widths.

Large floods are crucial for maintaining rapids.

(Kieffer, 1983)





(O'Connor, 1994)

Aggradation 1923-2000:

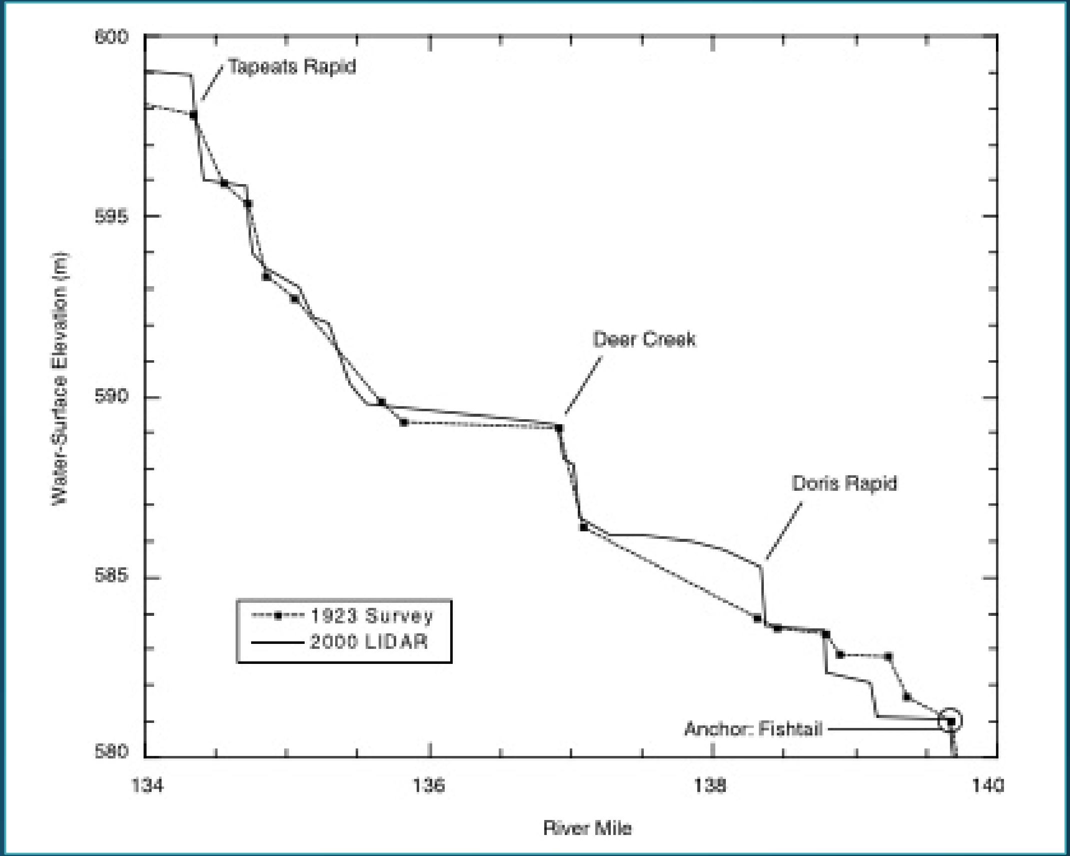
Lidar surveys in 2000 found net aggradation of rapids(+ 0.25 m) since 1923.

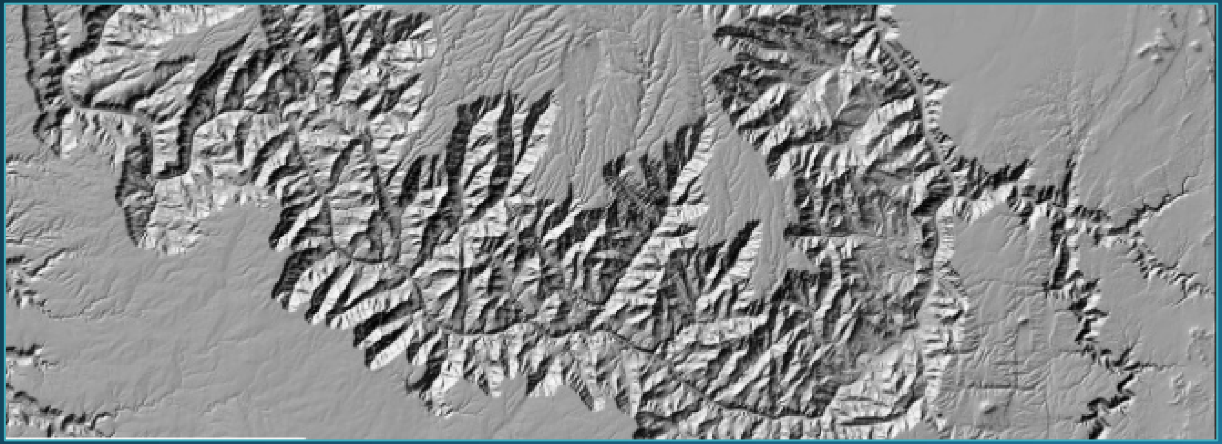
In 1923, 50% of drop occurred over 9% of river, in 2000 that number rose to 66%.

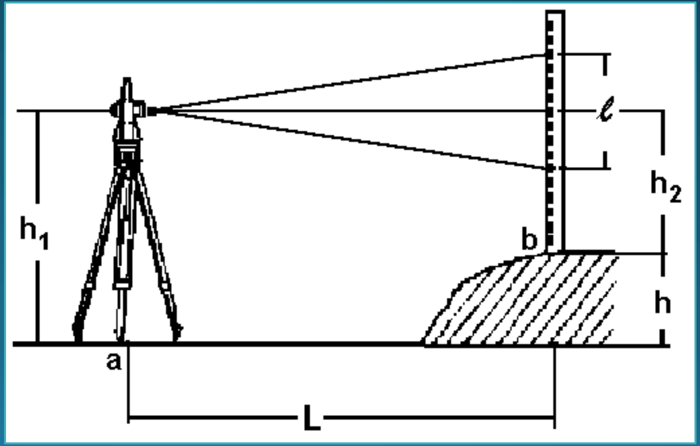
Exceptionally large floods are not required to refresh rapids. Modest floods can clear debris.

The 1983 flood of ~2750 m^3/s was capable of widening the two largest rapids on the river. Crystal Rapid had become nearly unnavigable.

One rapid (Doris) was completely removed following the 1921 flood of ~4800 m^3/s.







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Questions?