Water Science for Schools

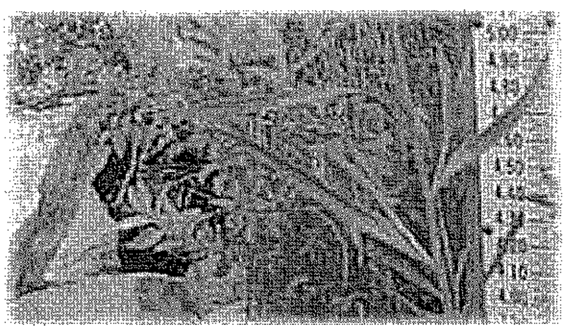
How streamflow is measured

If you're a teenager, I imagine your favorite activity is to sit with your parents on a quiet river bank, drink your glass of lemonade, and ponder the complexities of life. Probably the first question you ask is "How much water is flowing in this river?"

You've come to the right place for an answer. The U.S. Geological Survey has been measuring streamflow on thousands of rivers and streams for many decades. It is a process involving two concepts:

(1) Stream stage
(2) Streamflow

Stream stage

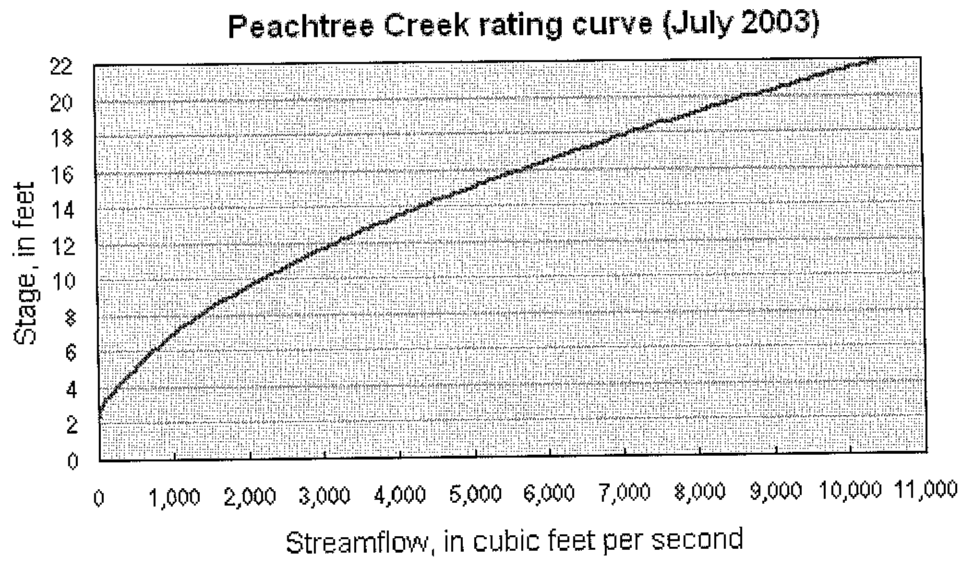


Often during a large rainstorm you can hear an announcement on the radio like "Peachtree Creek is expected to crest later today at 14.5 feet." The 14.5 feet the announcer is referring to is the stream stage. Stream stage (also called stage or gage height) is the height of the water surface, in feet, above an established datum plane where the stage is zero. The zero level is arbitrary, but is often close to the streambed. You can get an idea of what stream stage is by looking at this picture of a common staff gage, which is used to make a visual reading of stream stage. The gage is marked in 1/100th and 1/10th foot intervals.

Streamflow

Streamflow, or discharge, is the volume of water flowing past a fixed point in a fixed unit of time. For water flow in streams, the U.S. Geological Survey expresses the value in cubic feet per second (ft^3/s). For example, when rain has not fallen for a while, Peachtree Creek often is at a baseflow stage of about 3 feet. The rating curve (see chart below) shows that at a stage of 3 feet streamflow is 76 ft^3/s. Since one cubic foot of water contains 7.48 gallons, it might be easier to understand this streamflow value if you consider that 76 ft^3/s is about 568 gallons of water flowing each second.

Rating curve defines stage/streamflow relation



This chart, known as a rating curve, shows that there is a relation between stream stage and streamflow. The stage-streamflow relation is used to relate water level to an associated streamflow. The rating curve for a specific stream location is developed by making successive steamflow measurements at many different stream stages to define and maintain a stage-streamflow relation. These steamflow measurements and their corresponding stages are then plotted on a graph. Continuous streamflow throughout the year can be determined from the rating curve and the record of river stage.

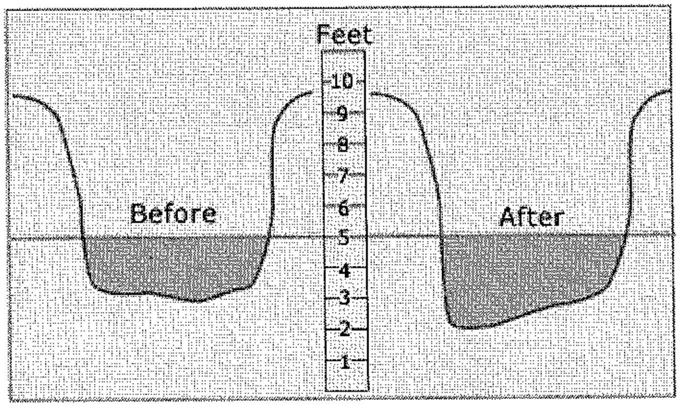
The rating curve is crucial because it allows the use of stream stage, which is usually easily determined, to estimate the corresponding streamflow at virtually any stream stage.

Relation of stream stage to streamflow is always changing

In July 2003, a stage of 6 feet at Peachtree Creek translated into a streamflow of 727 ft^3/s, but that number could change by July 2004. Rating curves are not static - they occassionally must be recalculated. Rating curves frequently shift due to changes in the factors that determine the relation between stream stage and streamflow. These factors are:

- Slope of the stream (affects velocity)
- Roughness of the channel
- Area of the channel at each stream stage
- Backwater effects (when a tributary enters a larger river)
- Filling in, scouring out, channel changes of river banks

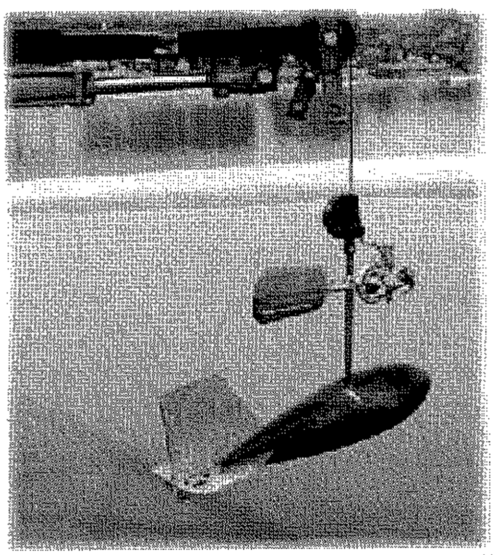
Consider what can happen to a stream channel during a large flood. The diagram below shows a streambed before and after a flood, thus changing the relation between the stream stage, in feet, and the amount of water flowing at that stage. The colored area represents how much water is flowing. Both diagrams show the same 5-foot stage, but more water is flowing after the flood because the streambed profile has changed and now there is more area for water to flow. Scouring occurs more often on the outside edge of a curve in a stream, whereas sand buildup occurs on the inside edge.



How streamflow is determined

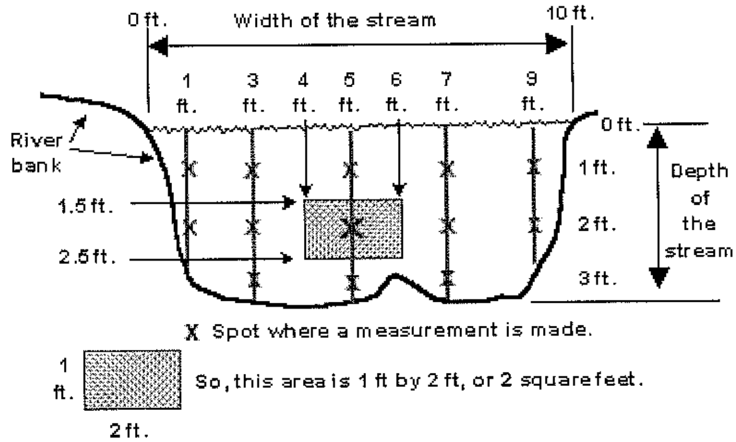
Measuring streamflow

In order to accurately determine streamflow, measurements must be made of its width, depth, and speed (velocity) of the water at many horizontal and vertical points across the stream. To develop a stream-stage/streamflow relation (rating curve), streamflow must be measured at many different stages. The well-developed rating curve allows for estimation of streamflows at virtually any stream stage. More simply, if a stream is measured at stages of 3.5, 6, 7.1, 9, and 10.2 feet, then an estimate can be made for a streamflow at 8 feet -- that is the goal.



For example, let's say we need a measurement of Example Creek when it is at a stream stage of approximately 3 feet. First, someone has to go out to the stream when the stage is near 3 feet. The diagram below shows a cross-section of Example Creek at a 3-foot stage. Note that the stream stage does not necessarily correlate to the actual depth of the stream. Example Creek is about 10 feet wide. The stream-measurement procedure is to go across the stream at selected intervals and measure the total depth and the velocity of the water at selected depths at each interval across the stream. The picture shows a current meter (attached above the torpedo-looking weight), which is lowered into the stream and measures water velocity. The spinning cups on the current meter measure velocity.

In the diagram, the hydrologist would take a measurement of how fast the water is moving at every green 'X', and would then determine the areas between all of the measured intervals, such as the one shown by the purple box.



In the diagram, water depth/velocity measurements are obtained horizontally across the stream at 1, 3, 5, 7, and 9 feet (the vertical lines in the diagram). At each location, measurements of velocity and total depth are obtained. Depending on the depth and flow conditions, one or more velocity reading(s) are obtained in each vertical. For our example, a water depth/velocity measurement is obtained at a point 5 feet from the edge of the stream. The total depth is slightly more than 3 feet and velocity readings are obtained at depths of 1, 2, and 3 feet (the 'X's on the 5-foot vertical line). The purple box represents an area that is midway between this measurement point and the measurement points on either side. The purple area is 2 feet across and one foot high, or 2 square feet. The measured velocity at the big X in the purple box is is 2 feet per second. To compute the amount of water flowing in that purple area each second, multiply the area of the purple box times the velocity of the water:

(1) 2 feet wide x 1 foot high = 2 square feet
(2) 2 square feet x 2 feet per second = 4 cubic feet per second.

To compute the total stream streamflow the hydrologist has to create imaginary purple boxes between all of the 'X's and, using the velocity of the water in every box, compute the streamflow for each purple area. Summing the streamflows for all the purple areas will give the total streamflow. Actually, the example above is a simplified explanation of how streamflow is measured. When an actual measurement is made, the hydrologist takes measurements at about 20 points across the stream. The goal is to have no one vertical cross-section contain more than 5 percent of the total stream discharge.

Read a personal account of measuring flow during a flood in California.

Sources and more information

- Discharge measurements at gaging stations, USGS Techniques manual
- A Day in the Life of a USGS Water Scientist
- Willie Takes a Field Trip, a coloring book that introduces tomorrow's scientists to water

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Related Topics

How the stream height (stage) relates to the amount of water flowing in a stream
Real-time USGS streamflow data
Earth's Water → Water Science home page
The water cycle: Streamflow

Water movement in channels

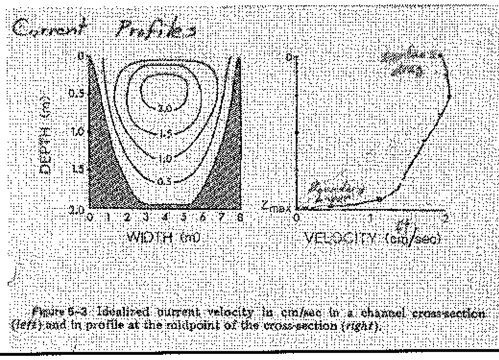
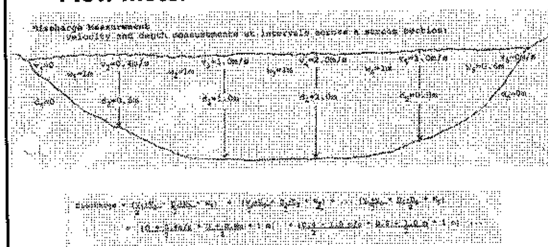


Figure 5-3 Idealized current velocity in cm/sec in a channel cross-section (left) and in profile at the midpoint of the cross-section (right).

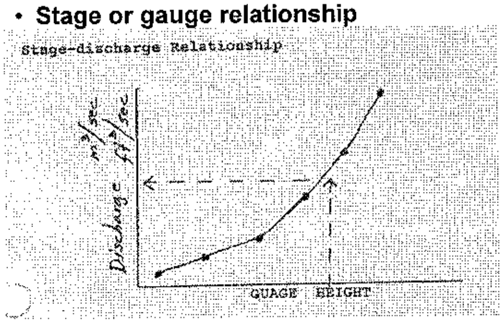
Measuring Discharge

- Flow meter



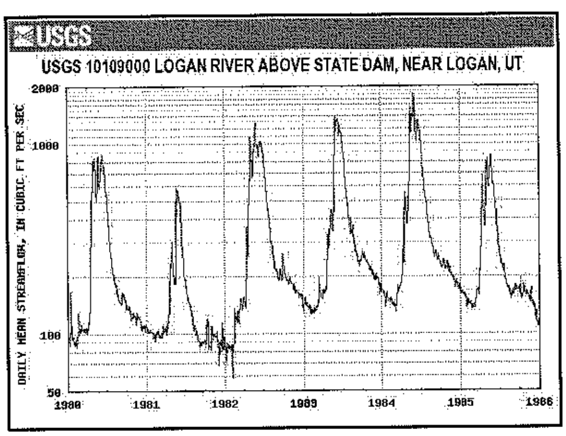
Measuring Discharge

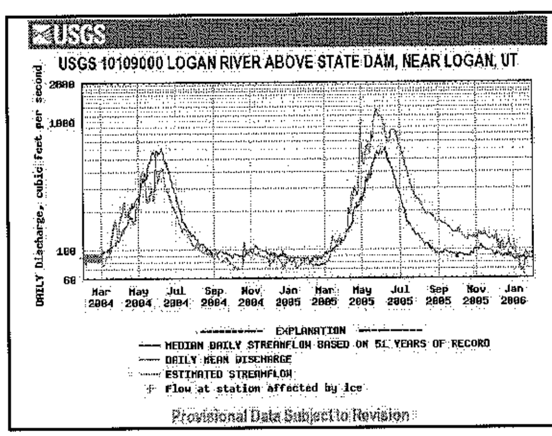
- Stage or gauge relationship



US Stream and River Discharge Data USGS

http://water.usgs.gov/data.html





Stream Geomorphology

2 Feb 2006
AWER 4500

What is Fluvial Geomorphology?

- Geomorphology – the study of landforms, including their origin, evolution, and the processes that shape them
- Fluvial geomorphology – study of river form, formation and evolution, focusing on the movement and redistribution of sediment

Sediment Movement

- Erosion
- Transport
- Deposition

Flow & transport of materials

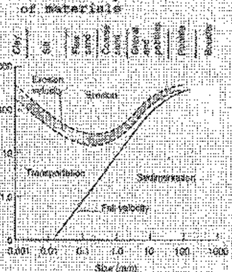


FIGURE 1.7. Relation of mean current velocity in water at least 1 m deep to the size of mineral grains that can be eroded from a bed of material of similar size. Below the velocity sufficient for erosion of grains of a given size (shown as a band), grains can continue to be transported. Deposition occurs at lower velocities than required for erosion of a particle of a given size. (Redrawn from Morisawa, 1968.)

Sediment Transport and Size

- Dissolved load
- Suspended load
- Bed material load

Particle Size Classification

Name of particle	Range of size in mm
Boulder	>256
Cobble	64–256
Pebble	32–64
	16–32
Gravel	8–16
	4–8
	2–4
Very coarse sand	1–2
Coarse sand	0·5–1
Medium sand	0·25–0·5
Fine sand	0·125–0·25
Very fine sand	0·0625–0·125
Silt	0·0039–0·0625
Clay	<0·0039

Table 1.4. Suggested terminology, categories

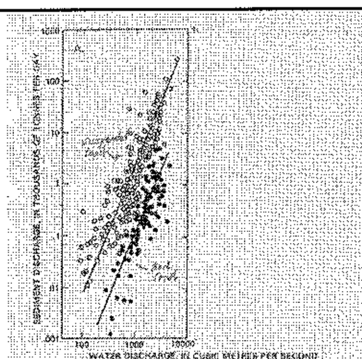
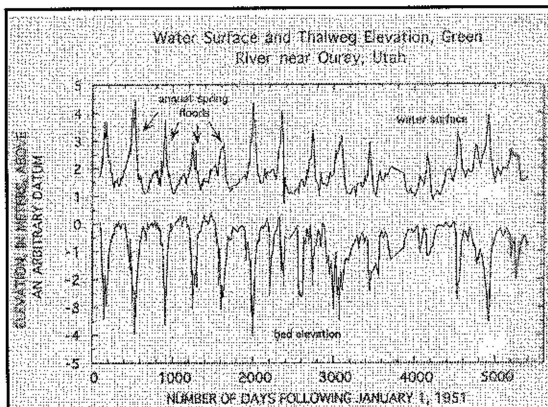
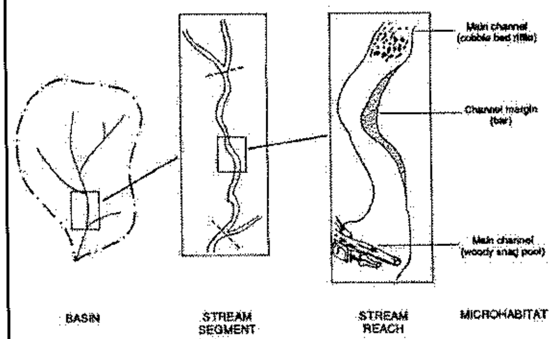


Figure 4. Comparison of measured discharges of suspended load (open circles) and bed load (dark circles) A: Clearwater and Snake Rivers at Lewiston, Idaho, 1972-1979 (Emmett, 1981, p. 14). Drainage area approximately 266,000 km².



Annual variability in sediment load

Figure 3. Annual suspended-sediment discharge of three rivers showing variations between years and frequencies within individual years.



Stream reach features

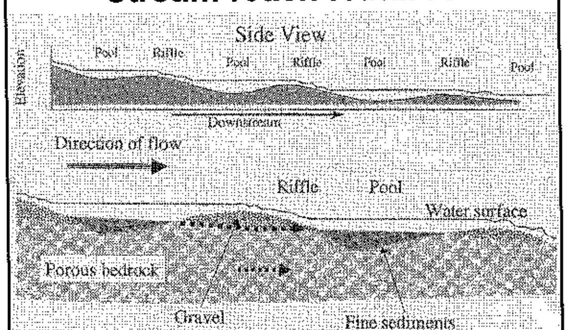


FIGURE 5.11 Cross-sectional diagram of a stream showing the riffle-pool sequence, accumulation of fine sediments, and water flow through the shallow subsurface (hyporheic).

Stream segment features

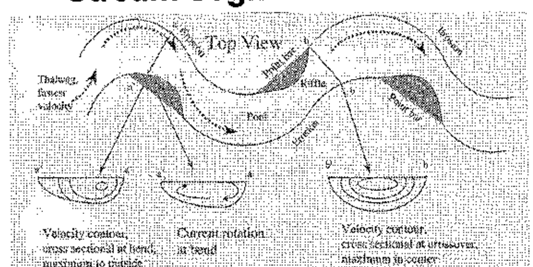
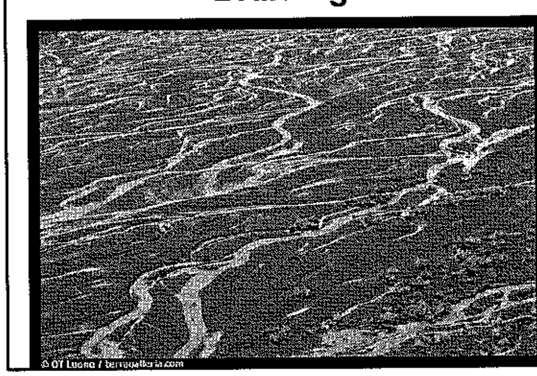


FIGURE 5.10 Conceptual diagrams of stream geomorphology. (Top) The side view is a cross-sectional lengthwise view showing pool and riffle sequence. (Middle) The top view shows a meandering stream, the thalweg (line of maximum velocity), and zones of erosion and deposition (point bars). (Bottom) The water velocity contours (cross-sectional across the channel) show how the maximum velocity is outside of the bend and the lateral current direction. When the thalweg crosses the channel, the maximum velocity is in the center of the channel.

Rio Achicachi, meander bend
Titicaca Basin, Bolivia

Braiding



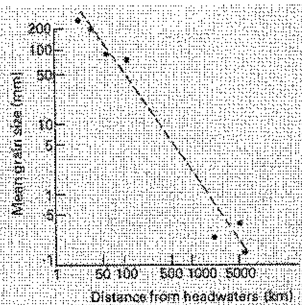
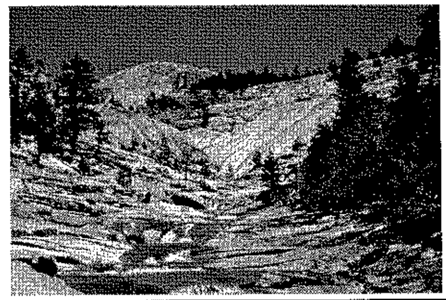


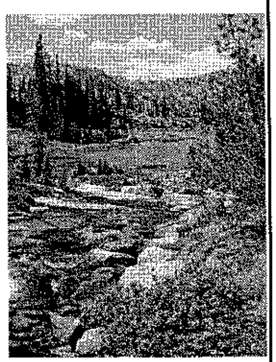
Fig. 2–5 Relationship between mean grain size of bed material and distance from headwaters in the Yellowstone–Missouri–Mississippi river system. (After LEOPOLD, L. B. *et al.* (1964). *Fluvial Processes in Geomorphology*. W. H. Freeman, San Francisco.)

Headwater, bedrock stream,
Sierra Nevadas. Dinkey Cr.
- **Note lack of riparian vegetation**
- **Bedrock substrate**



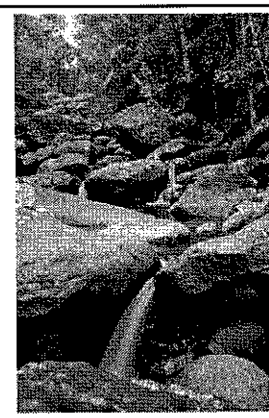
Yellow Belly Creek and pond
Above Toxaway Lake
Sawtooth Mountains, ID

--Note course substrates
--Limited Riparian Vegetation



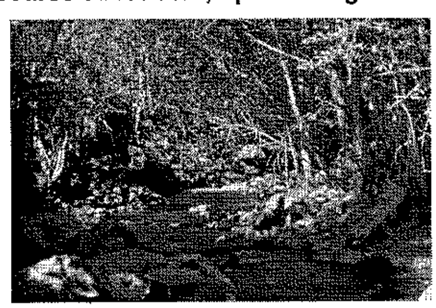
Puerto Rican Tropical Stream

Note:
- **High gradient**
- **<u>Large</u> substrates**
- **Riparian Vegetation**
- **Shading**



Nobe-Young Creek
Tulare Co., Calif. – Note Riparian Shading

Thompson Creek
Siskiyou Co., CA –
Note course substrates, riparian vegetaion



Large Woody Debris
Andrews Forest
Cascade Range, OR

Coastal Siskiou Mountain River,
California – Note bank erosion

Green River, Utah
Note meander,
sediment deposition
on inside bend

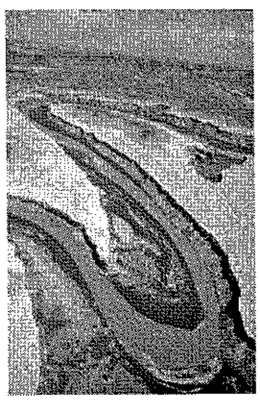
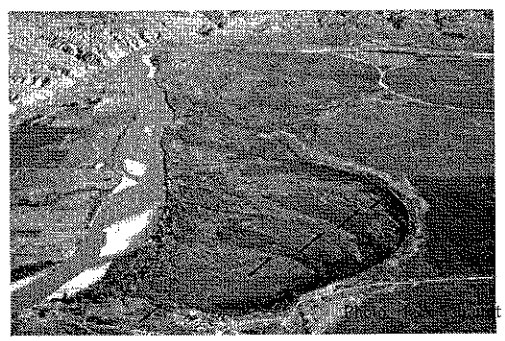


Photo: Jack Schmidt

Green River
Note series of meander channels



Green River
-Sand Bed Channel
-Note sand bar
deposition

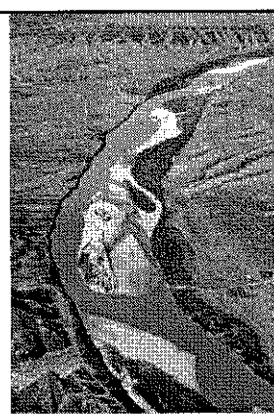


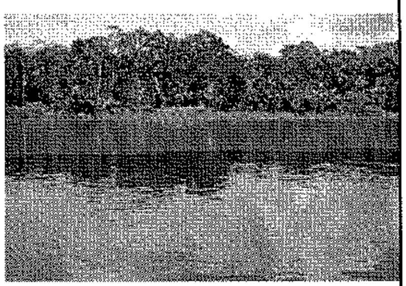
Photo: Jack Schmidt

Amazon River, Peru
--Note meanders

Peruvian River during large flood
-- note sediment load, bank erosion

Rio Ramis, Titicaca Basin, Peru
– note low gradient, fine sediments

Rio Cayeru
Leticia Columbia
- Note riparian vegetation
  (& distance to vegetation)
- Note merging of black-water, and sediment-laden
  rivers



Los Angeles "River"