Kevin M. Anderson, Ph.D, Coordinator

Center for Environmental Research at Hornsby Bend

Austin WATER

MISSION

<u>Urban Ecology and Sustainability</u>

- Community
- Education
- Research

PARTNERS

- Austin Water Utility
- University of Texas
- Texas A&M University

RESEARCH AREAS

- Soil Ecology, Sewage Recycling and Reuse
- Hydrogeology of the Alluvial Aquifer
- Riparian Ecology
- Avian Ecology

HBBO
Hornsby Bend Bird Observatory

Texas Riparian Association

Center for Environmental Research at Hornsby Bend

Austin WATER

The CER Lunchtime Lectures 2019

The Geography of Flowing Water: Rivers, Streams, Nature, and Culture

The 2019 CER Lunchtime Lectures will explore the geography of flowing water – rivers and streams.

Water writes it way across the surface of the Earth, inscribing deeply or shallowly depending on how resistant the surface is to the flow of water and sediment carried across the land.

This morphology of the physical geography of the Earth is the starting point for geography, but geographers go beyond the physical shapes and shaping of rivers and streams and, also, study their cultural roles and impacts in order to fully understand the geography of flowing water.

Locations and Day of the Month –
Every 1st Tuesday - University of Texas Norman Hackerman Building (NHB). 100 E 24th St Room 1.720
Every 2nd Tuesday - Austin Water Center for Environmental Research (CER) at Hornsby Bend
Every 2nd Wednesday – Senior Activity Center-Lamar (SAC-Lamar) at 2874 Shoal Crest Ave, South Room

The Geographer

Geography

A literal translation would be

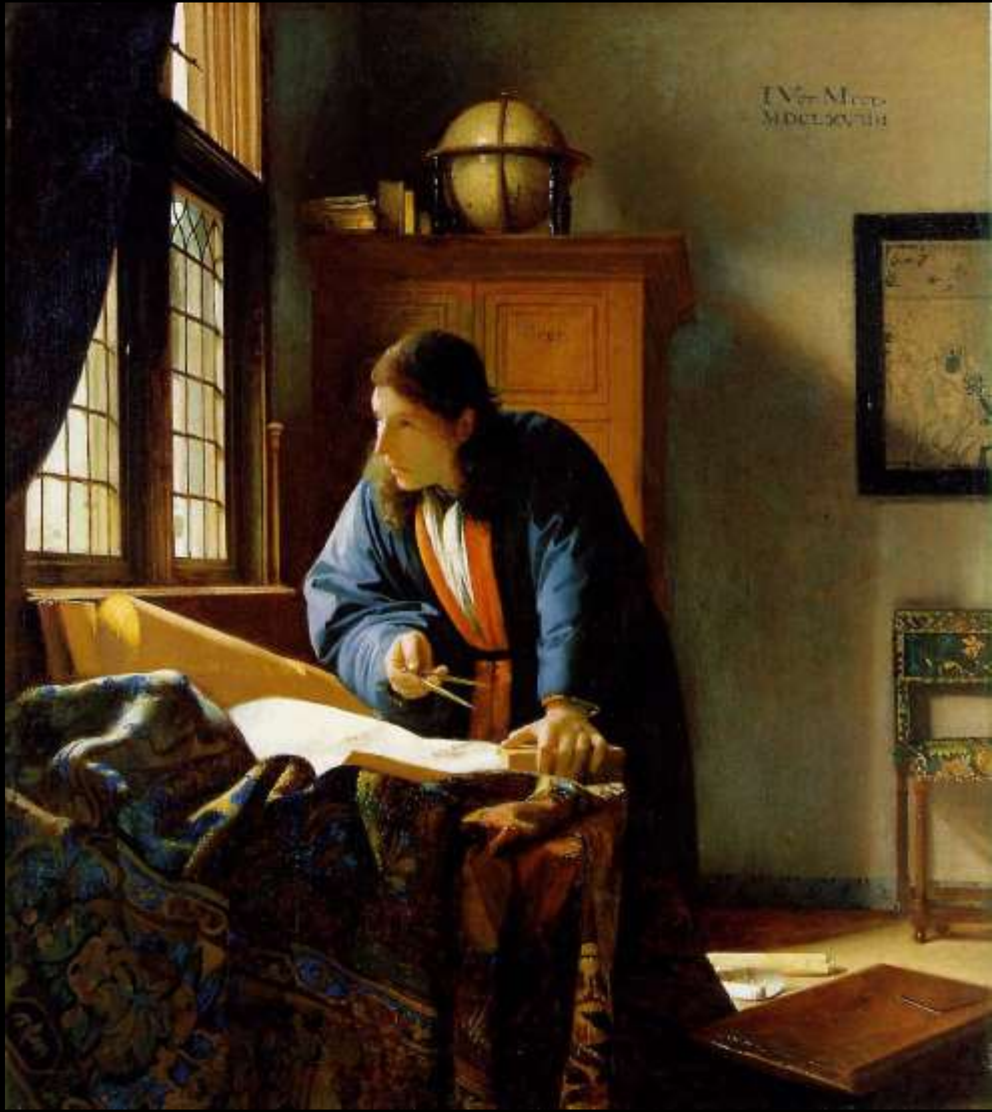
"to describe or write about the Earth".

As the bridge between the human and physical sciences, Geography is divided into two main branches –

- human/cultural geography
- physical geography

The common focus of both branches of

Geography is the Landscape



Vermeer “The Geographer”
1668–1669

The Philosopher

Heraclitus 540-480BC "No man ever steps in the same river twice."

- "Heraclitus, I believe, says that all things go and nothing stays, and comparing existents to the flow of a river, he says you could not step twice into the same river" (Plato *Cratylus*)
- We call it a "river" precisely because it consists of changing waters. If the waters should cease to flow it would not be a river, but a lake or a dry streambed.
- There is a sense, then, in which a river is a remarkable kind of existent, one that remains what it is by changing what it contains.

Everything Flows – Everything stays the same only by changing.

Fluvial Language

A Linguistic Journey

Riverside	Aquifer	Downstream
Riparian	Floodplain	Upstream
Riverine	Erosion	Midstream
Bottomland	Aggrading	Fork
Shoal	Degrading	Hydraulic
Eddy	Downcutting	Terrace
Whirlpool	Reach	Flume
Bar	Channel	Gradient
Rapid	Drainage	Slope
Bank	Watershed	Gravel
Bed	Catchment	Gully
Riffle	Basin	Hydrological
Ripple	Sediment	Hyporheic
Bend	Branch	Thalweg
Pool	Stream	Sweep
Hole	Current	Sinuous
Bankful	Surface	Tributary
Snag	Submerge	Inflow
Backwater	Depth	Outflow
Alluvial	Sounding	Headwaters
Fan	Groundwater	Mouth
Braid	Surfacewater	Delta
Oxbow	Discharge	Estuary
Meander	Peak Flow	Flood

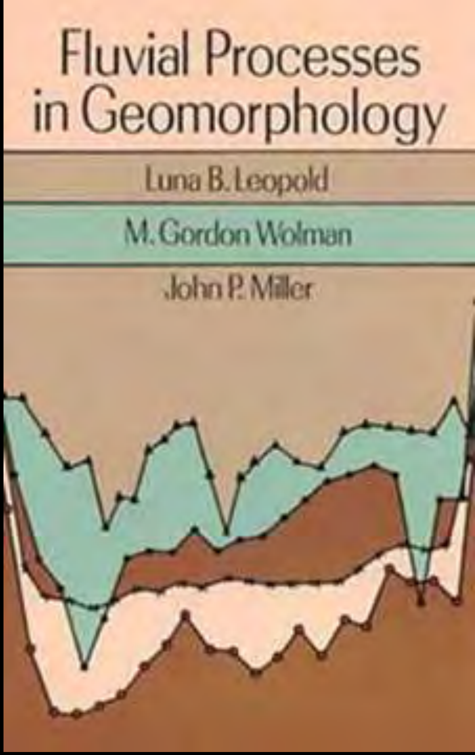
The Physical Geography of Flowing Water

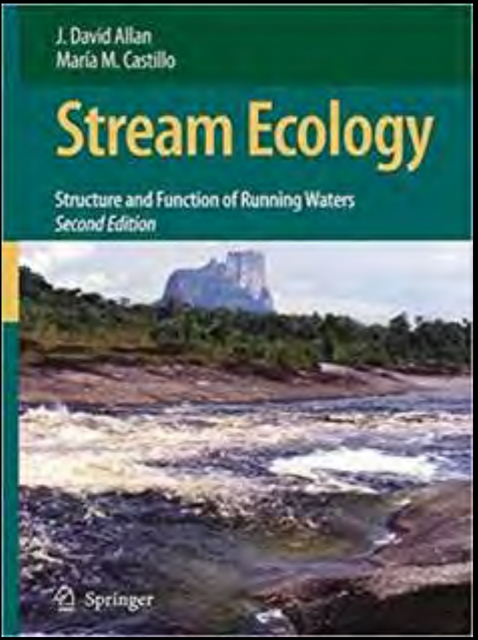
January - Fluvial Process: Streams and Hydrology

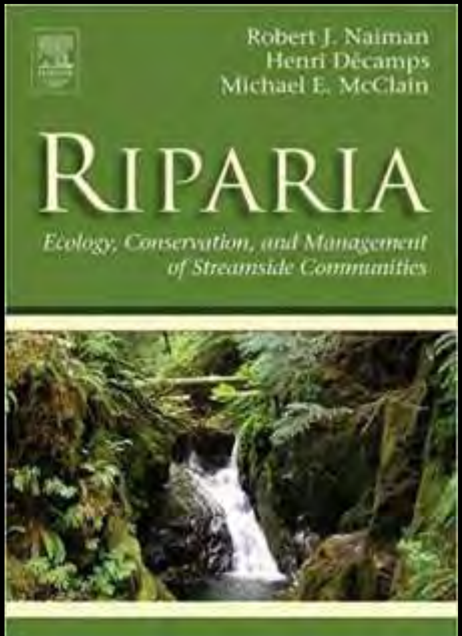
February - Fluvial Life: the Ecology of Flowing Water

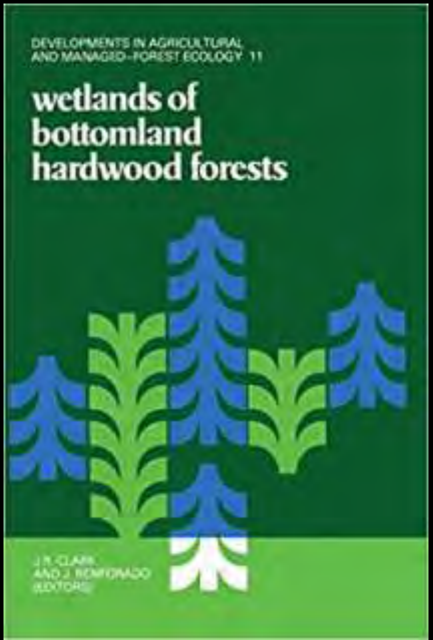
March – Riparia: Life at the Edge

April – Bottomland: Life on the Floodplain

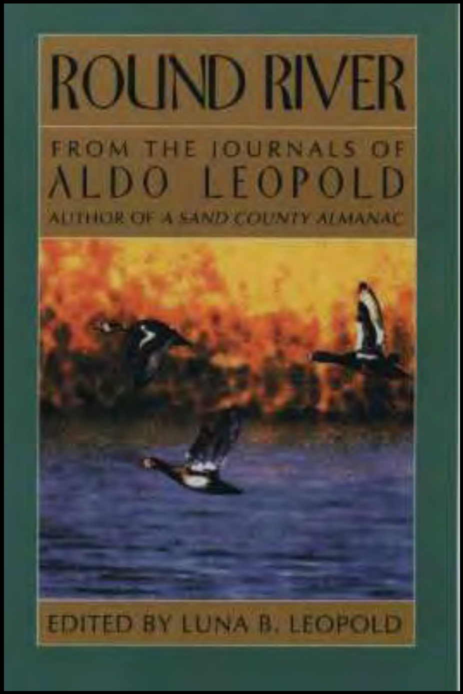








The Meaning of Flowing Water

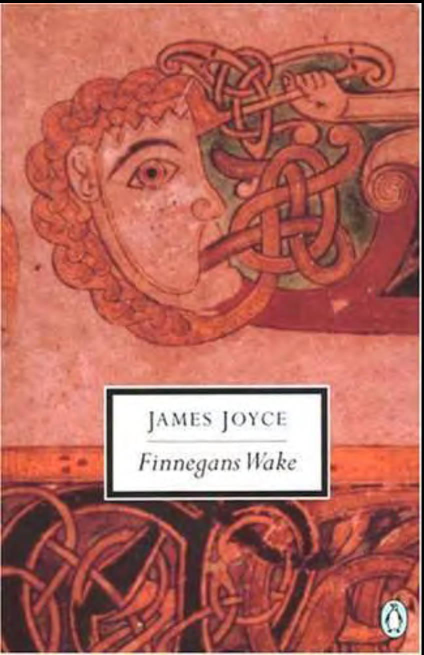


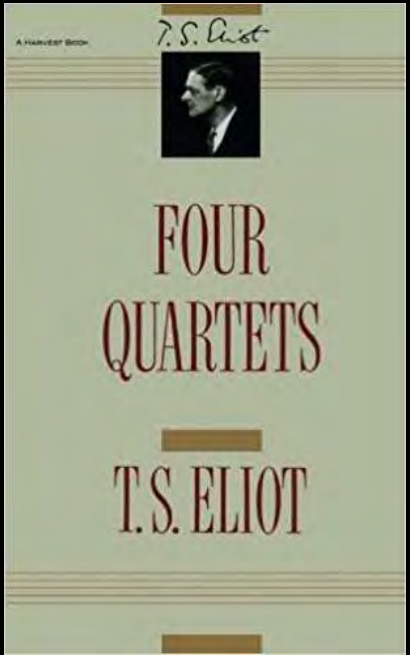
May - The Round River: Myth, Meaning, and Flowing Water

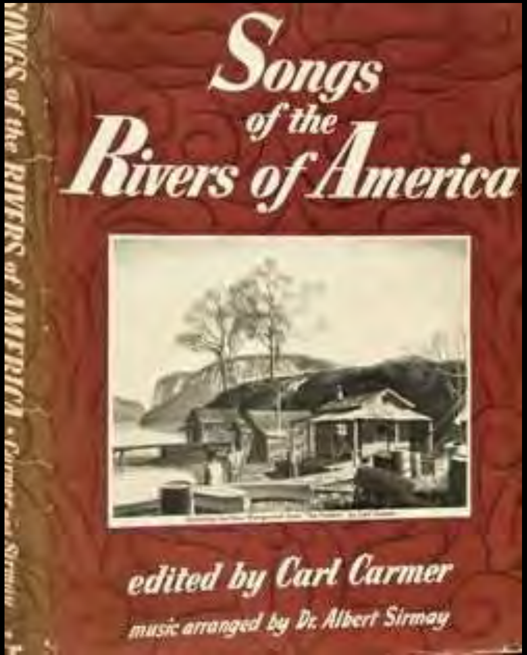
June – Riverrun: Language, Art, and Waterways

July – Water Music: American Music and Rivers

August – Strong Brown God: Poetry of Flowing Water







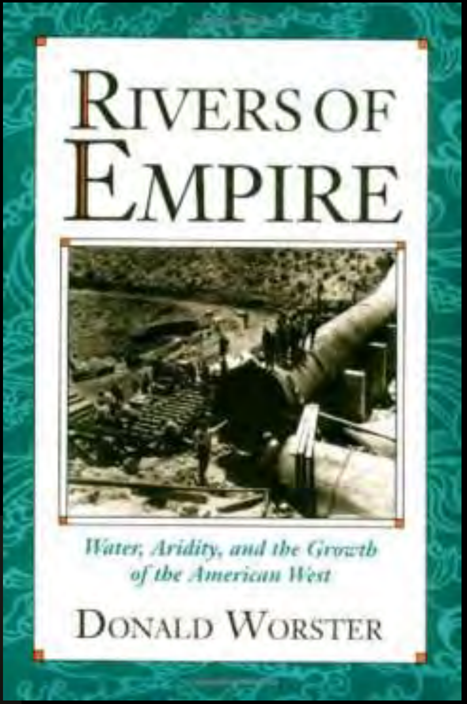
The Cultural Geography of Flowing Water

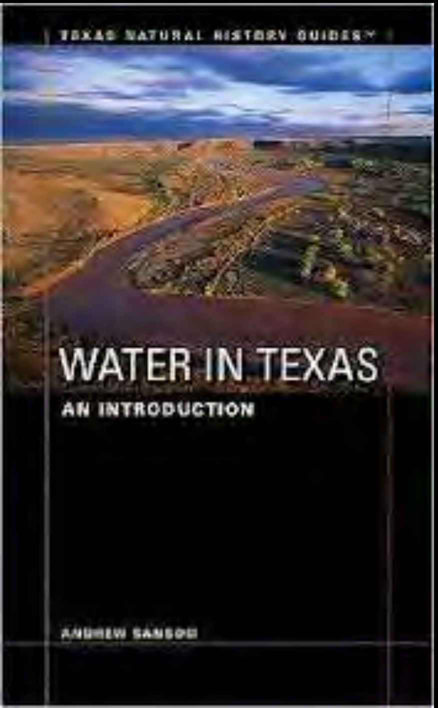
September - Rivers of Empire: American Environmental History and Waterways

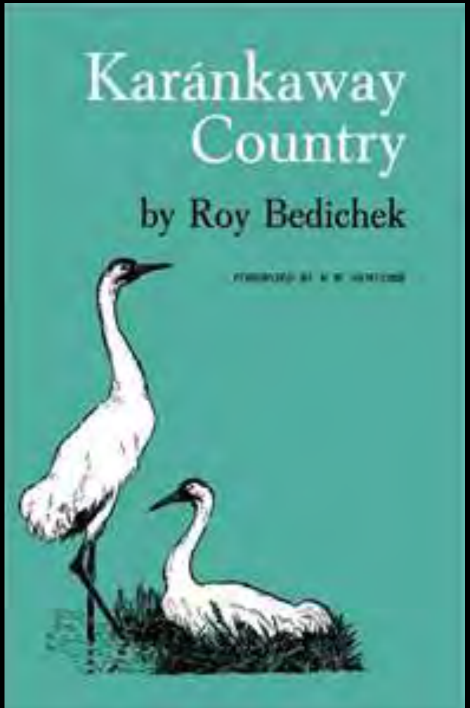
October - Waters the Land: Rivers and Water in Texas

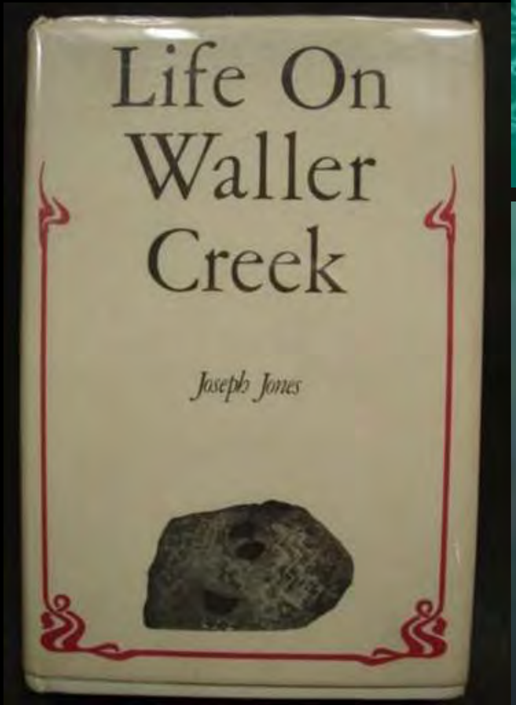
November - Another Colorado: Austin and the River

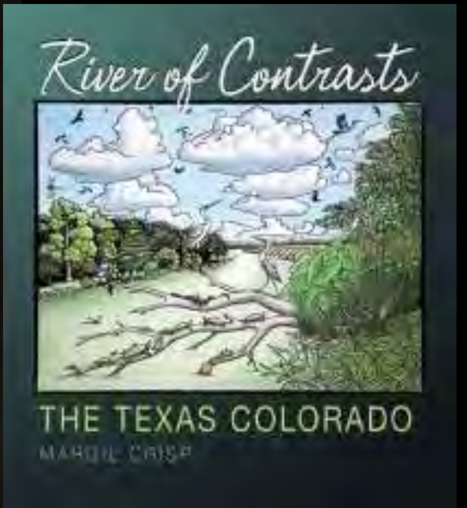
December – The Urban Stream: Life on Waller Creek











Center for Environmental Research at Hornsby Bend

Austin WATER

The CER Lunchtime Lectures 2019
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NATURE in the CITY

Nature In The City Podcast

http://austineconetwork.com/nature-in-the-city/

AUSTIN ECONETWORK

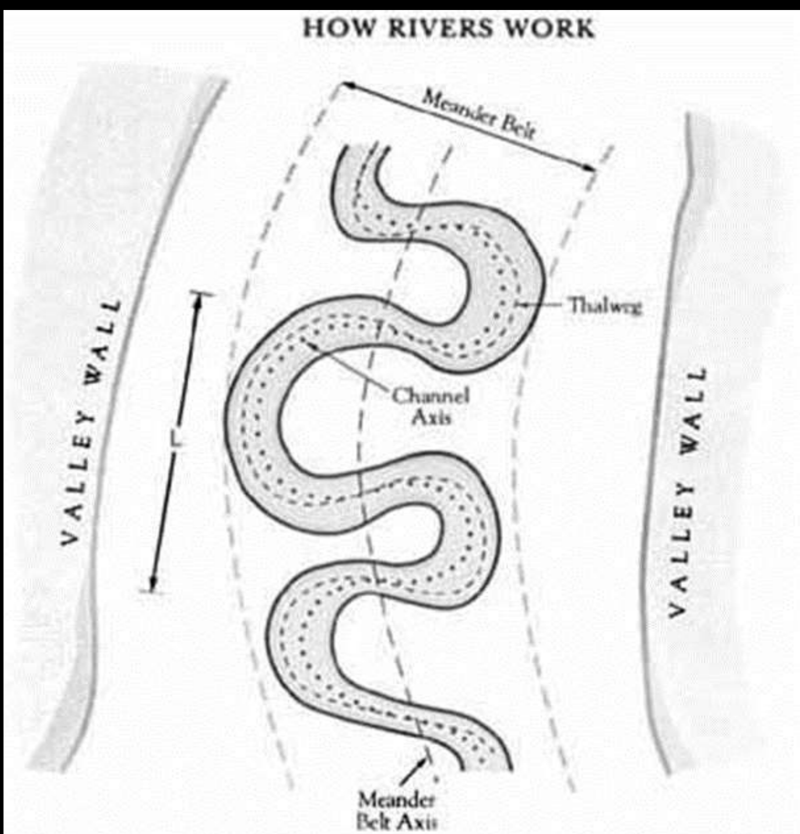
CITY OF AUSTIN Development SERVICES DEPARTMENT

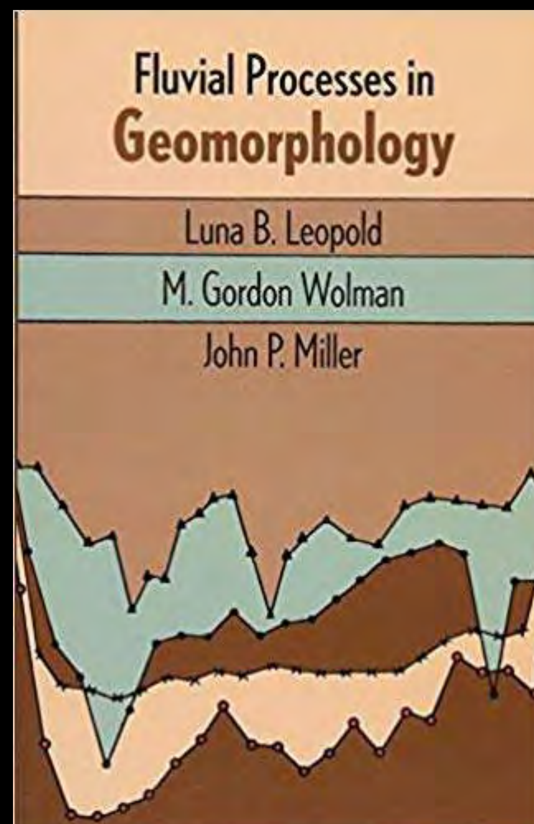
Community Tree Preservation Division

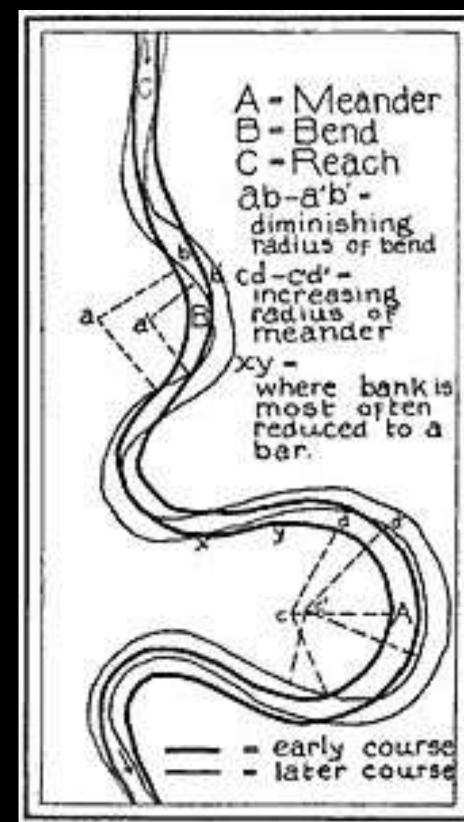
Center for Environmental Research at Hornsby Bend

Fluvial Process: Streams and Hydrology

Kevin M. Anderson, Ph.D.
Austin Water – Center for Environmental Research







A Fluvial Journey

Fluvial - of, relating to, or living in a stream or river

Fluvial Geomorphology is the study of how moving water shapes a landscape over time

Sinuosity is inversely proportional to slope

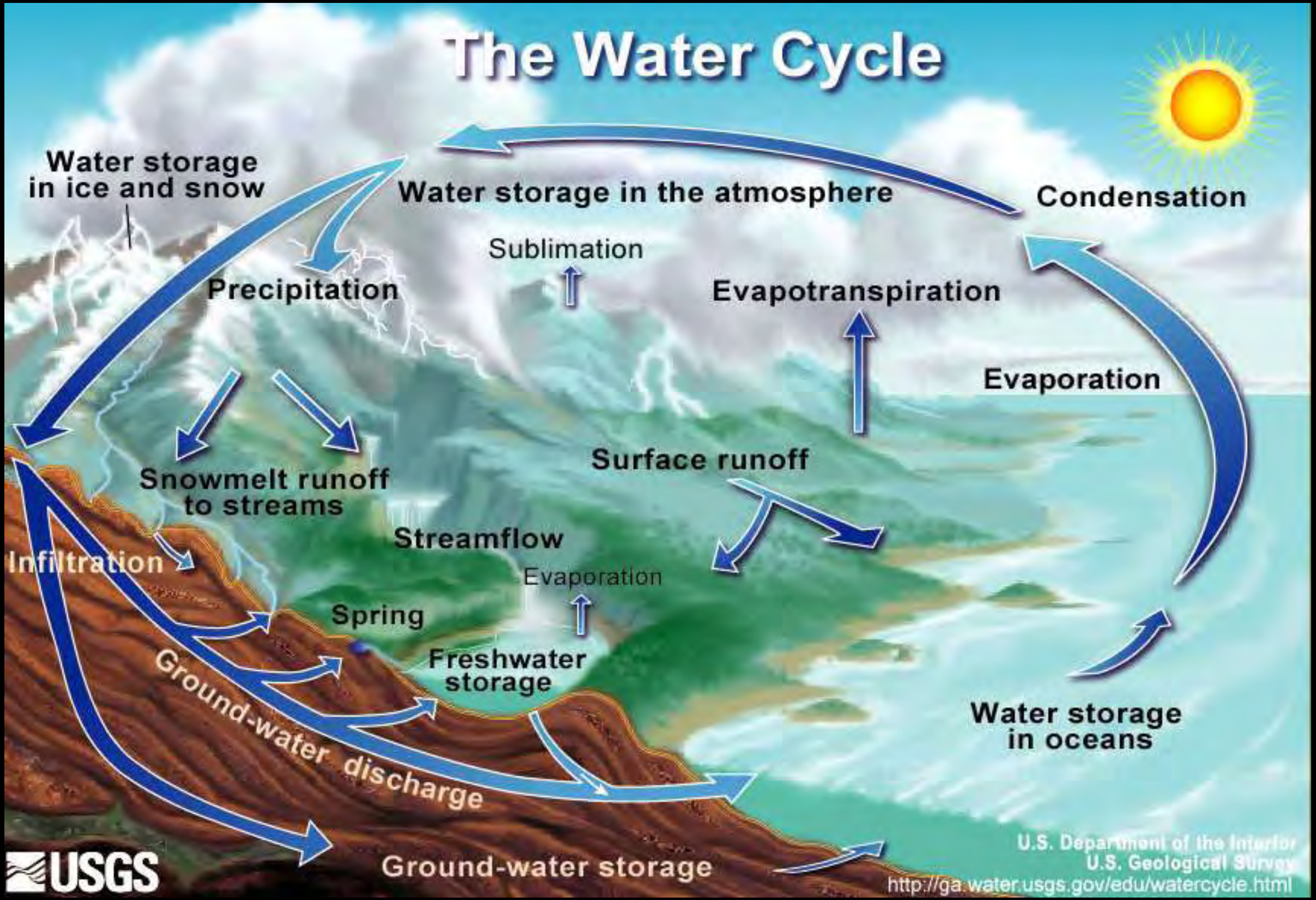
The Grand Circle – <u>The Water Cycle</u>

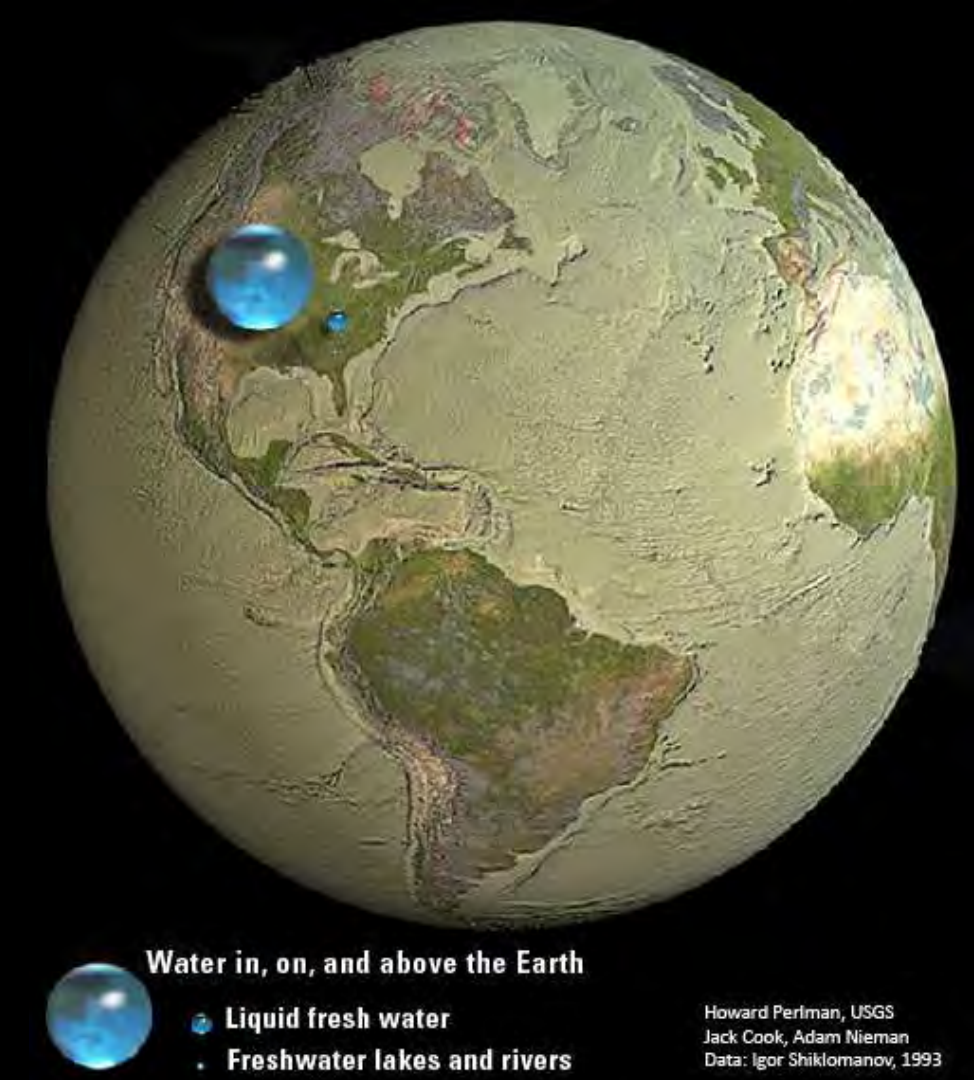
Water evaporates from water bodies such as rivers, lakes and seas, and from plants and trees. The water vapor rises, cools and condenses to form clouds. Rain falls from the clouds . The rain water is intercepted by plants , seeps into the ground before reaching surface streams, or runs off the land surface into streams and rivers. The rivers enter lakes, seas, or oceans.
The water cycle is then repeated.

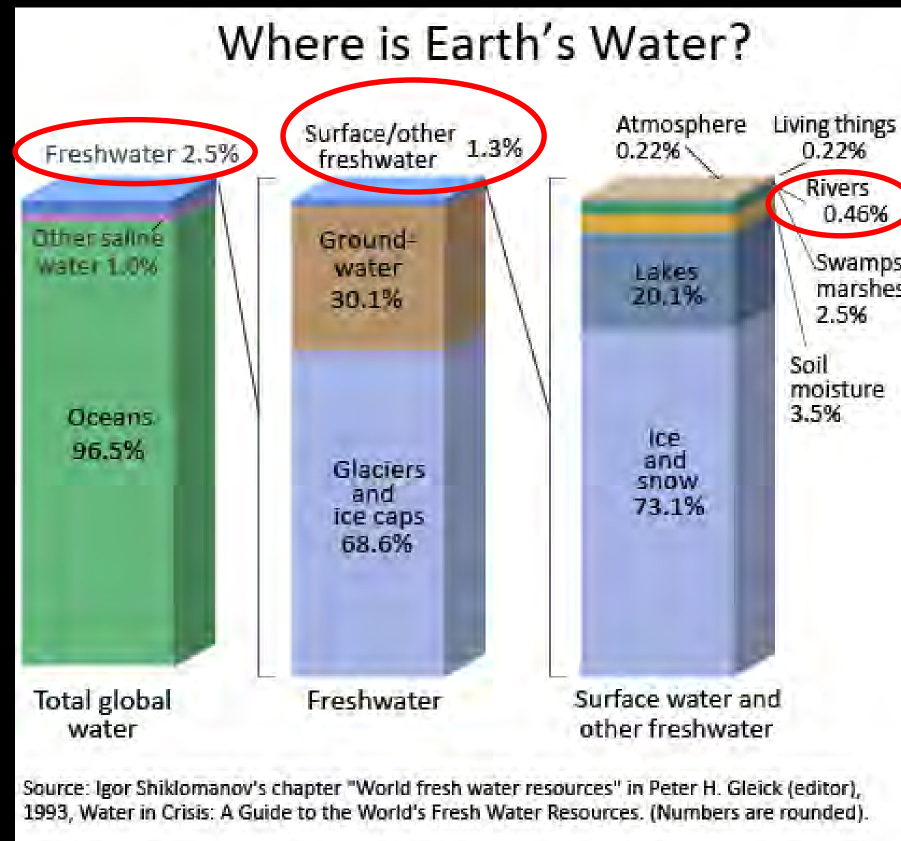
Avg US Precipation 30”

Evaporation and Transpiration to Atmosphere 21”

Groundwater and Rivers 9”







Spheres showing:

(1) All water (sphere over western U.S., 860 miles in diameter)
(2) Fresh liquid water in the ground, lakes, swamps, and rivers (sphere over Kentucky, 169.5 miles in diameter)
(3) Fresh-water lakes and rivers (sphere over Georgia, 34.9 miles in diameter).

General Differences Between Streams and Lakes

Streams (Lotic)	Lakes (Lentic)
One direction of flow, upstream to downstream	Various flows, no particular direction
Normally oxygen rich	Oxygen depletion exists at times in deeper water
Shallower	Deeper
Narrower and longer	Wider and shorter
Various effects from different terrestrial environments along the stream's course. The shoreline has more potential to affect water quality because a larger portion of the water body is near shore.	Terrestrial environment similar all around the lake shore. A smaller portion of the water is in close proximity to the shore.
Stream continually cuts into the channel, making it longer, wider, and deeper	Lakes become shallower over time from depositing sediments
Age progression of a stream goes from young stream, narrow and shallow, to mature stream, wider and deeper	Age progression of a lake or pond goes from lake to marsh or swamp to land
Shorter retention time for water	Longer retention time for water
Top and bottom waters generally have the same temperature	May have different temperatures from the top to bottom

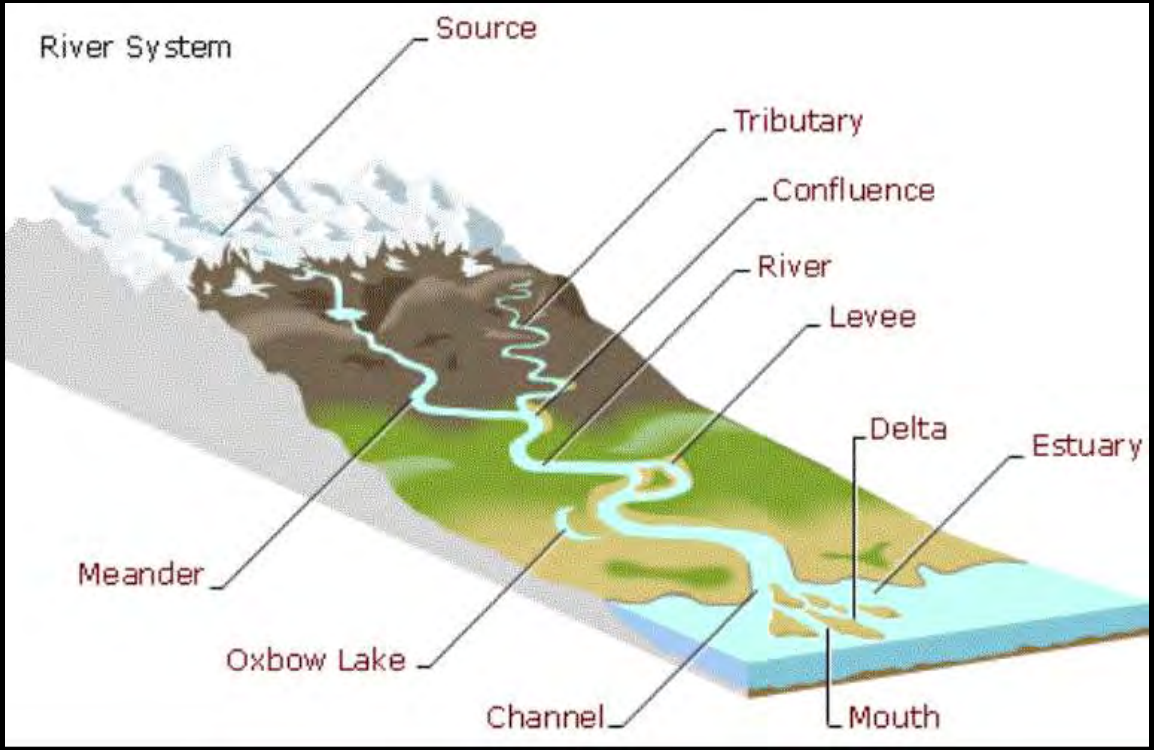
Flowing Water vs. Nonflowing Water
Lotic vs. Lentic

The Geography of Waterways

A river or stream - a body of water flowing along a natural channel

Fluvial Anatomy

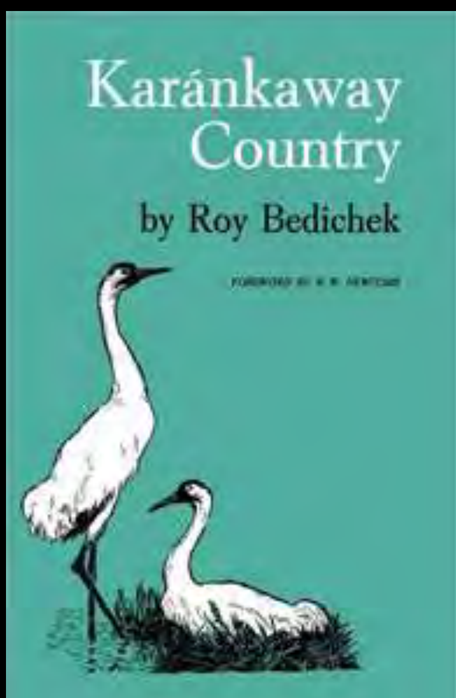
A river or stream starts at the source or headwaters and flows along its course ending in a confluence with another stream or river or drains into a lake, sea, gulf, or ocean at its mouth



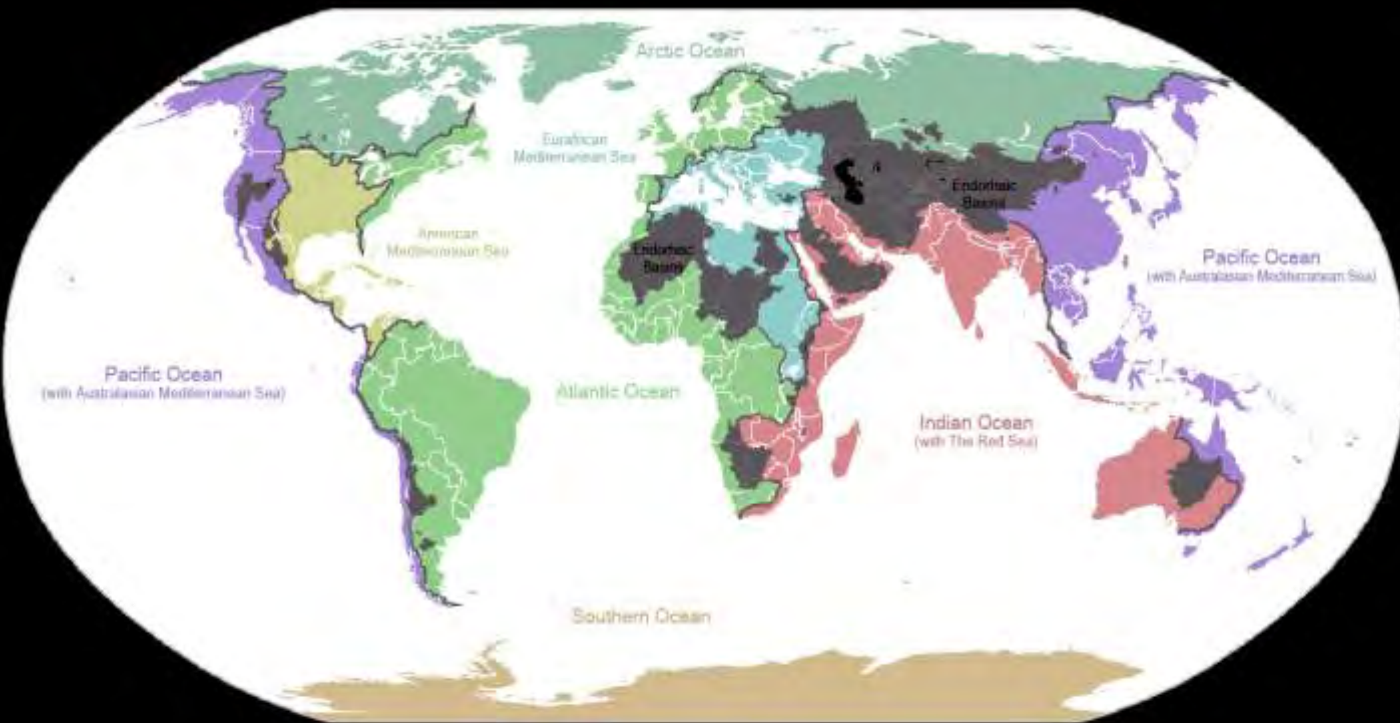
Problem of Anatomy and River Terminology – mouth, head, source

"I think that ancient misnomer 'mouth,' which we use to designate the place where a river empties, has done the cause of conservation incalculable harm. Our river imagery is muddied at its source. We speak of the head of a river, but there is no mouth in the head. That orifice in our curious anatomy is at the other end. We speak of *the* source of a river, but a river has a thousand sources.

There is no better place than at the so-called 'mouth' of a diseased river to diagnose its ailment, for there we find out what it is being fed, whether it is digesting what it is taking in, the condition of its circulatory system, and whether or not its eliminations are normal. By the same token, there is generally no worse place to begin the treatment of the disease after its nature is discovered." 233-4



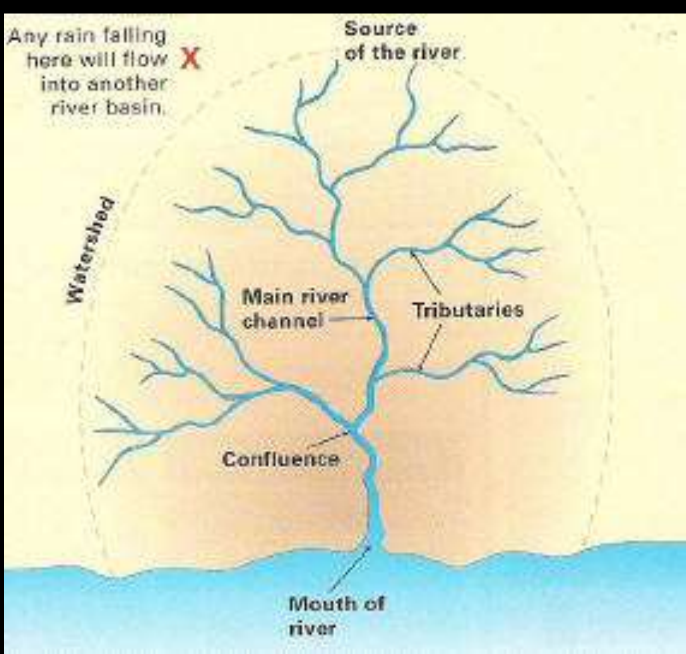
Roy Bedichek (left) with Frank Dobie at Barton Springs Pool

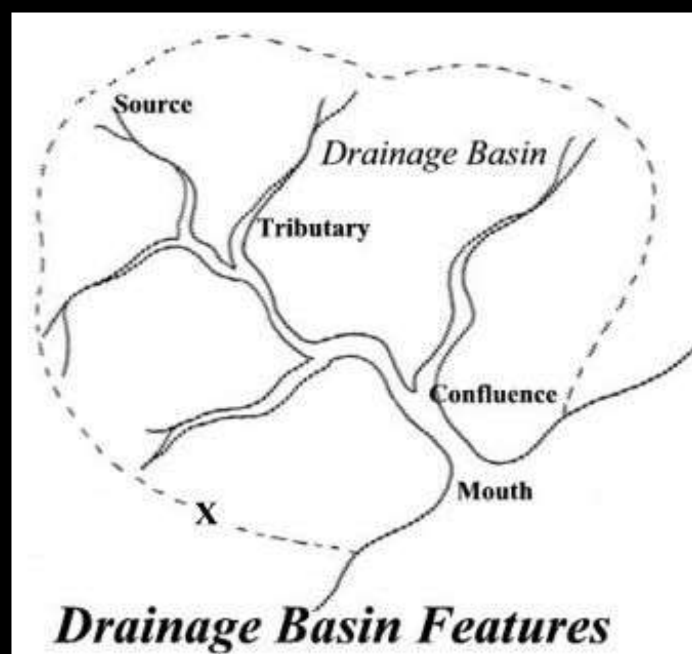


Watersheds vs. Drainage Basin Catchment Area

A watershed (US usage) or drainage basin/catchment area (British usage) is an area of land which is drained by a river and its tributaries.

In British usage, a watershed is the boundary separating one drainage basin from another. It usually follows the ridge or crest of a hill or mountain.

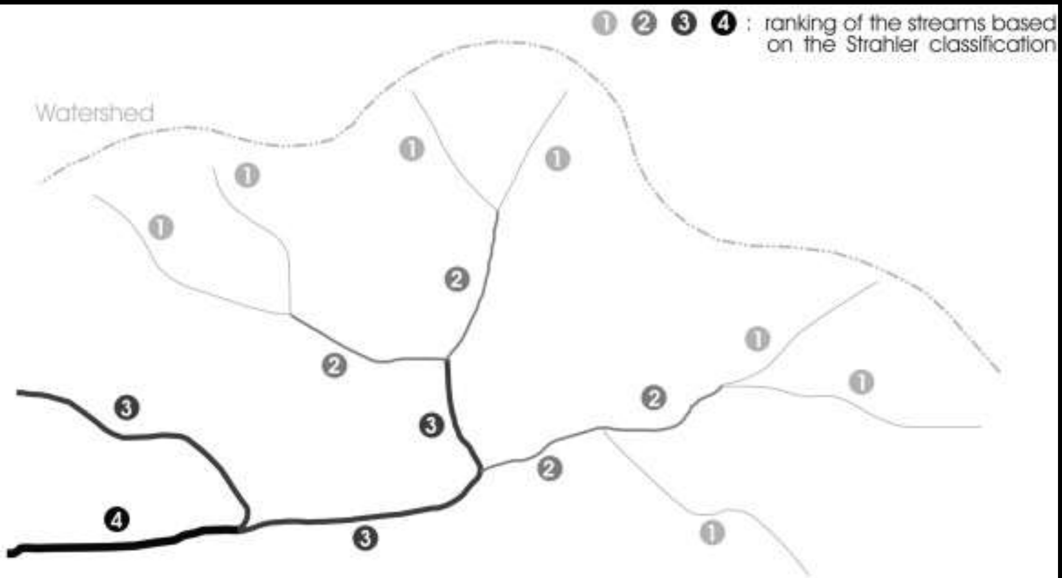


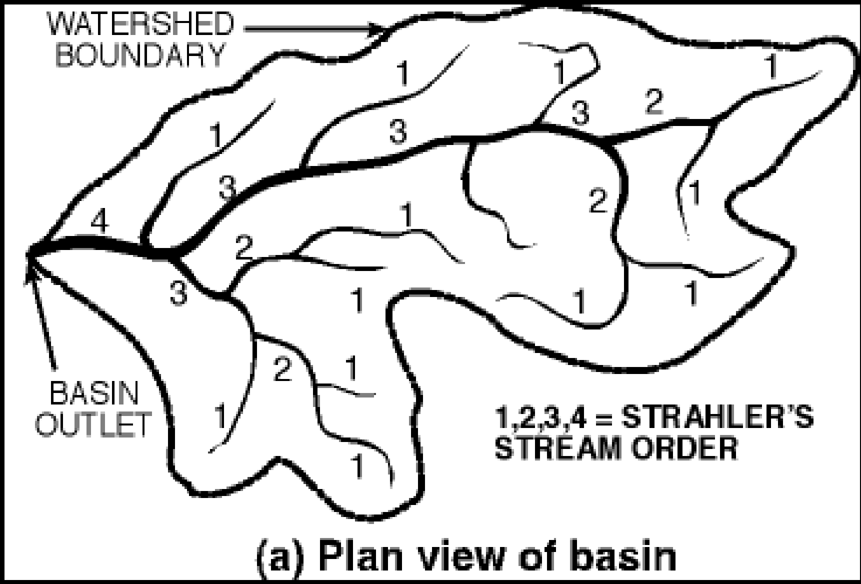


River Network – The Strahler Stream Order

Strahler number or Horton–Strahler number

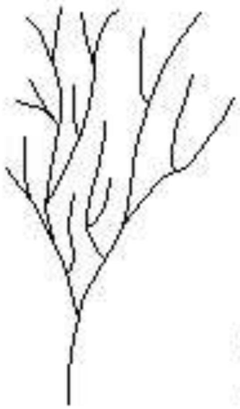
- a mathematical tree with a numerical measure of its branching complexity
- These numbers were first developed in hydrology by Robert E. Horton (1945) and Arthur Newell Strahler (1952, 1957)
- They are referred to as the Strahler stream order and are used to define stream size based on a hierarchy of tributaries.





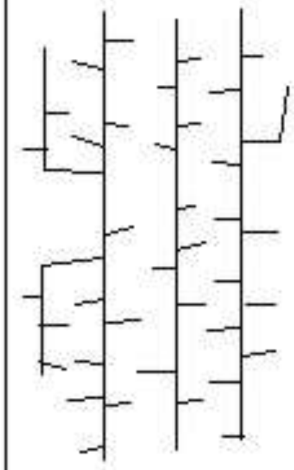
Fluvial Landscapes

Drainage Patterns



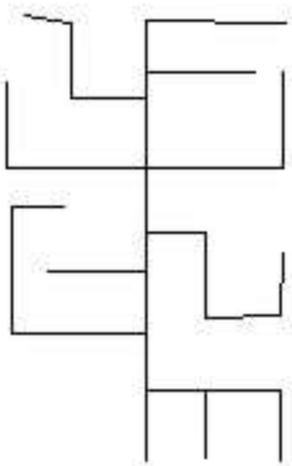
DENDRITIC – tributaries meet at low angles and branch in random, tree-like pattern. Form on roughly planar surfaces of conmsistently erodable rocks or sediment.

FLINT/CHATTAHOOCHEE/ APALACHICOLA SYSTEM



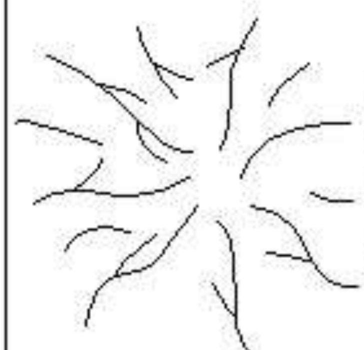
TRELLIS – Short tributaries meet long trunk streams at near right angles. Few connections between trunks. Form on folded or tilted sedimentary rocks of different resistances to erosion.

POTOMAC SYSTEM



RECTANGULAR – Straight tributaries meet straight trunk streams. Bends approximate right angles. Form on faulted or otherwise fractured bedrock. (**ANGULAR** drainage is similar but bends/junctions are at some angle other than 90°).

COTTONWOOD CREEK, UTAH (ANGULAR DRAINAGE)



RADIAL – Flow outward from a well-defined central point. Form on volcanoes and other round uplifts of the land.

DRY VALLEYS ON NORTH MENAN BUTTE, IDAHO

Flowing Water and Erosion – Earth Writing

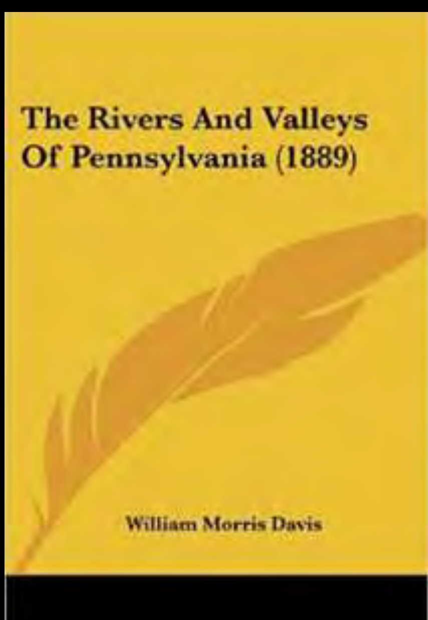
Flowing water always wants to carry a sediment load

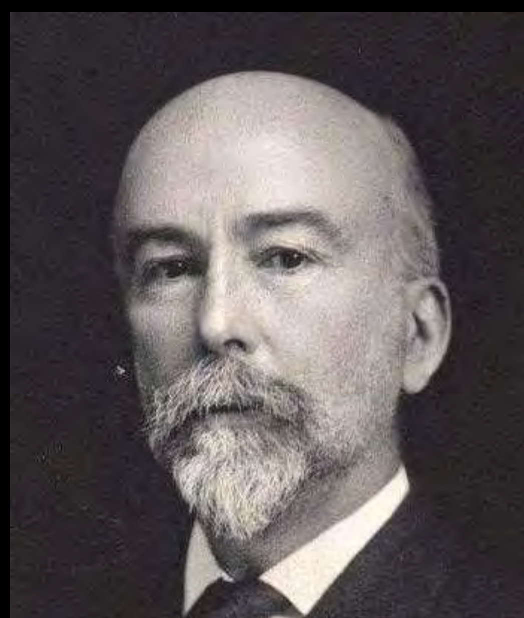
William Morris Davis (1850 - 1934)

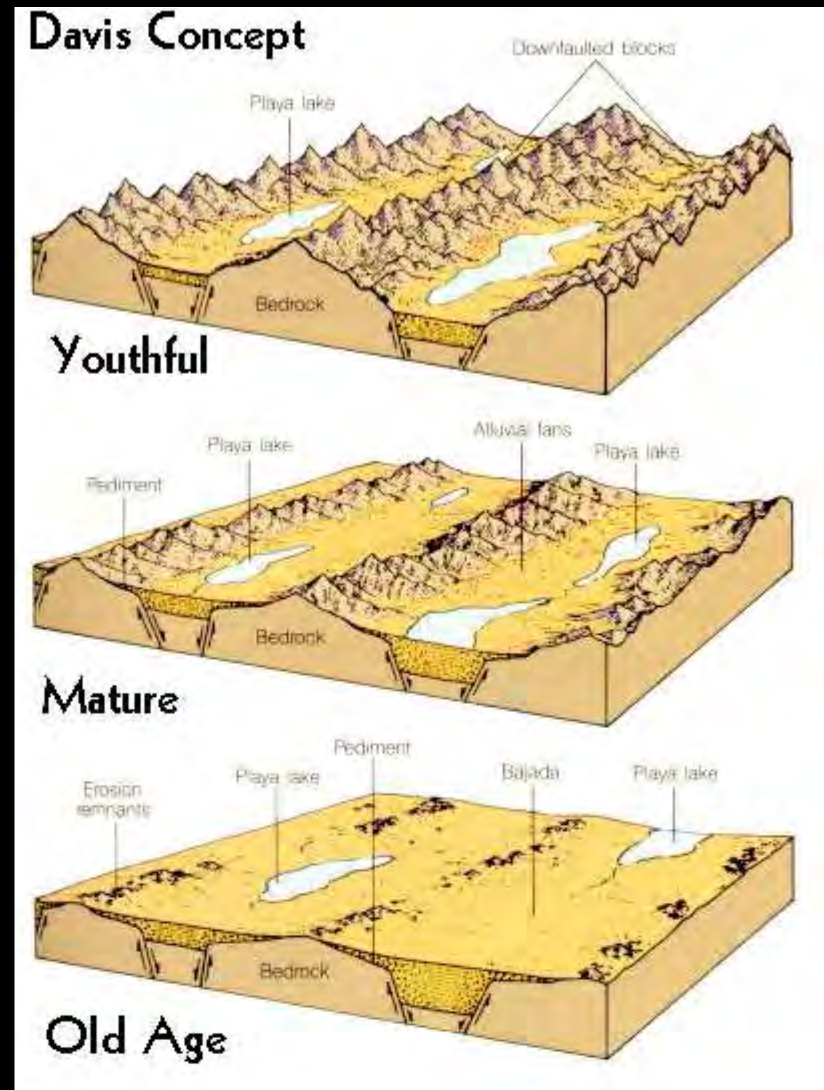
An American geographer, geologist, geomorphologist, and meteorologist, often called the "father of American geography".

The Geographical Cycle – Erosion

His most influential scientific contribution was the “geographical cycle” or the cycle of erosion, first defined around 1884, which was a model of how rivers create landforms.





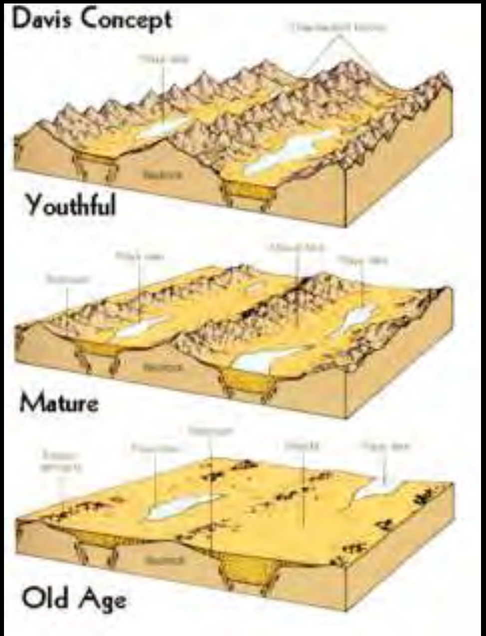


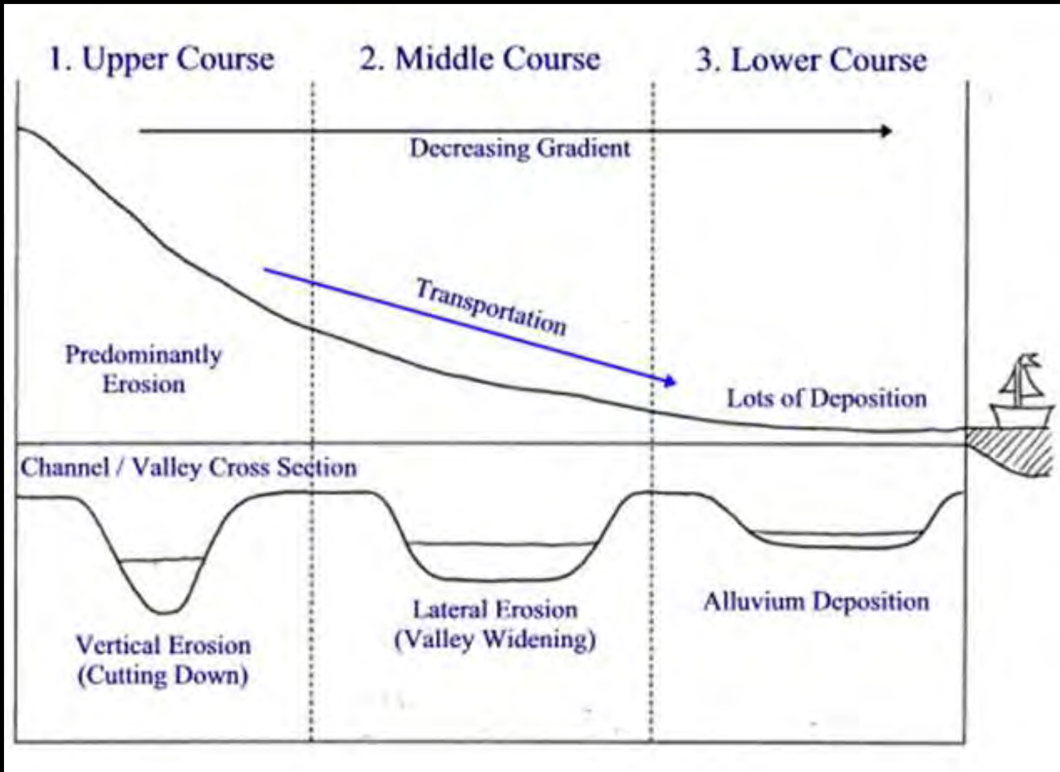
The Life of a River – William Morris Davis

Davis "viewed the river system as having a life of its own.

- Its youthful headwaters are steep and rugged. It rushes toward the sea, eroding bed and bank on its way.
- In its central part, it is mature, winding sedately through wide valleys adjusted to its duty of transporting water and sediment.
- Near its mouth it has reached, in its old age, a nearly level plain through which it wanders in a somewhat aimless course toward final extinction as it joins the ocean that had provided the sustaining waters through its whole life span."

Luna Leopold "A Reverence for Rivers" 1977





A Fluvial Life

The Upper Course: steep and rugged

The Middle Course: winding sedately through wide valleys

The Lower Course: a somewhat aimless course toward final extinction

<table>
<tr><th>Course Stage</th><th>Upper Course
Youth Stage</th><th>Middle Course
Mature Stage</th><th>Lower Course
Old Age Stage</th></tr>
<tr><td>Slope</td><td colspan="3">
</td></tr>
<tr><td>Main processes</td><td>Hydraulic Action
Abrasion

Erosion</td><td>Erosion and Deposition</td><td>Deposition</td></tr>
<tr><td>Valley shape</td><td colspan="3">
</td></tr>
<tr><td>Main features</td><td>V-shaped Valleys
Interlocking Spurs
Waterfalls</td><td>Meanders and Ox-Bow lakes</td><td>Deltas
Levees
Flood Plains
(and m+ob lakes)</td></tr>
</table>

The Upper Course - Youthful Headwaters

Speed of Flowing Water (velocity)

The velocity of a river is the speed at which water flows along it. The velocity will change along the course of any river, and is determined by factors such as the gradient (how steeply the river is losing height), the volume of water, the shape of the river channel and the amount of friction created by the bed, rocks and plants.

Gradient of river - the steeper the slope, the faster the flow.

Steep V-Shaped Valley
Narrow/Shallow Channel

<u>River Competence</u> - Rivers and streams carry sediment that ranges in size from clay (smallest) to boulders (biggest). The <u>biggest sized particle</u> that a river could carry at <u>a specific point</u> is called the river's <u>competence</u>.

<u>Bed Load</u> – sediment that is transported along the bed of a river or stream

<u>Wetted perimeter</u> refers to the wetted length of bed and bank. Larger wetted perimeter (banks and bed in contact with water), the river has to overcome <u>more friction</u> and is <u>slowed down</u>.

The Upper Course – Rapids and Roughness

Rapids are most commonly found in the upper course of the river and form as a result of the river cutting down rapidly in a localized section of the river.

The main characteristics of rapids are distinctly steeper gradients marked by steps in the channel and high turbulence, which is the result of large bedload in the channel.

Due to the roughness of the channel, flow is turbulent and known as whitewater.

The velocity of the river is noticeably faster at rapids but not efficient in its flow.

The Upper Course vs. Lower Course – Apparent Velocity, Capacity, and Channel Efficiency

The channel in the upper course is more often shallow and punctuated with large angular bedload. The rougher the channel, the slower is the flow, because the water has to overcome the friction of the river bed and banks.

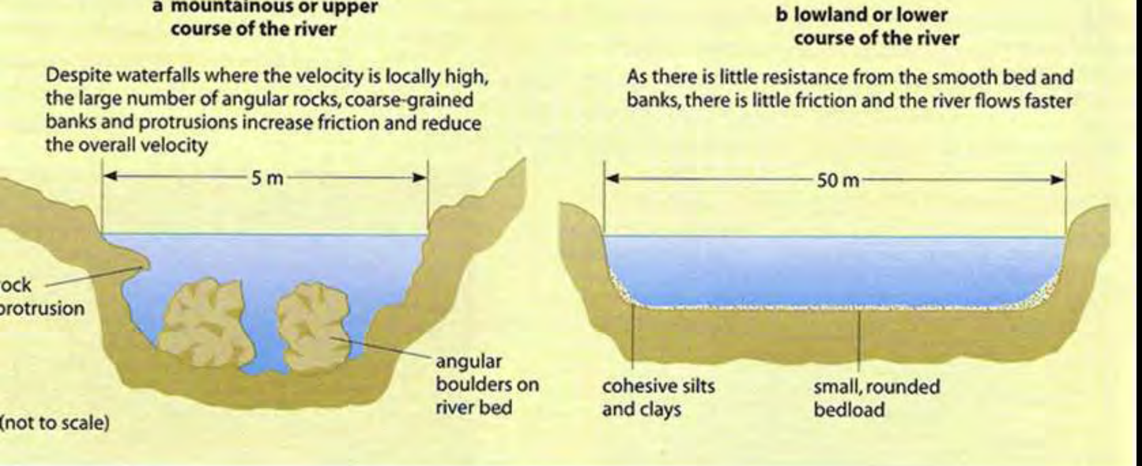
As a consequence it has low channel efficiency and therefore the quantity of transported bedload is lower.

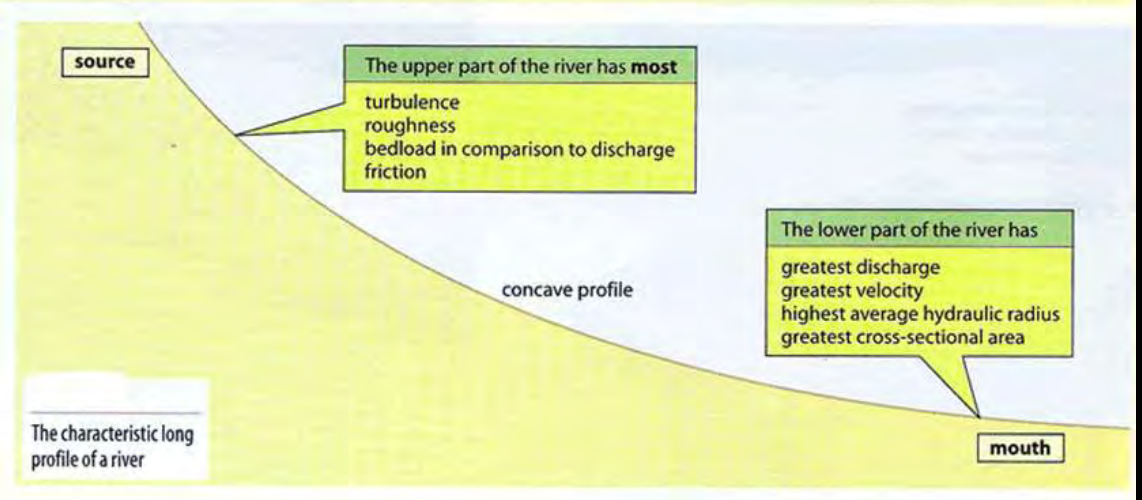
Hydrologists use the term channel efficiency to describe the river's ability to transport bedload and discharge. Smooth semi-circular channels are the most efficient channels and are located more often further downstream.

Capacity - Rivers can only carry so much load depending on their energy. The maximum volume of load that a river can carry at a specific point in its course is called the river's capacity.

Capacity of a river increases downstream.

Course Stage	Upper Course Youth Stage	Middle Course Mature Stage	Lower Course Old Age Stage
Slope			





Apparent vs. Mean Velocity
Competence vs. Capacity

"Downstream Change of Velocity in Rivers"

Luna Leopold *American Journal of Science*, VOL. 251, August 1953

Because river slope generally decreases in a downstream direction, it is generally supposed that velocity of flow also decreases downstream.

Analysis of some of the large number of velocity measurements made at stream-gaging stations demonstrates that mean velocity generally tends to increase downstream.

Near the streambed, shear in the vertical profile of velocity (rate of decrease of velocity with depth) tends to decrease downstream.

This downvalley decrease of shear implies decreasing competence downstream.

The Dean of American Fluvial Geomorphology
Luna Leopold (October 8, 1915 – 2006)

- He was a leading U.S. geomorphologist and hydrologist, and son of Aldo Leopold.
- USGS 1950-72, UC Berkeley 1972-86

A View of the River. (1994, reprinted 2006).
Water, Rivers and Creeks. (1997).
Fluvial Processes in Geomorphology. (1964, reprinted 1995).
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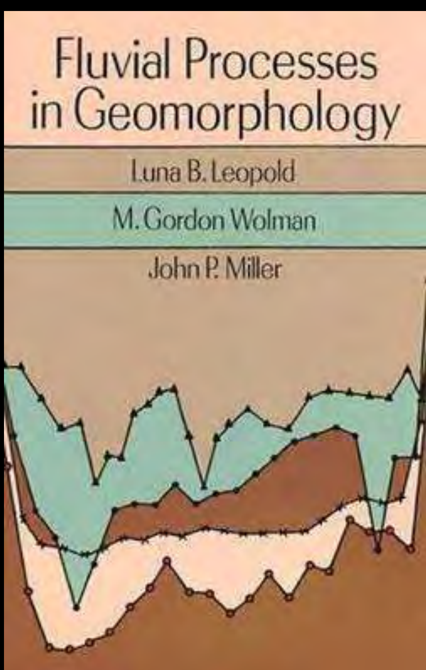
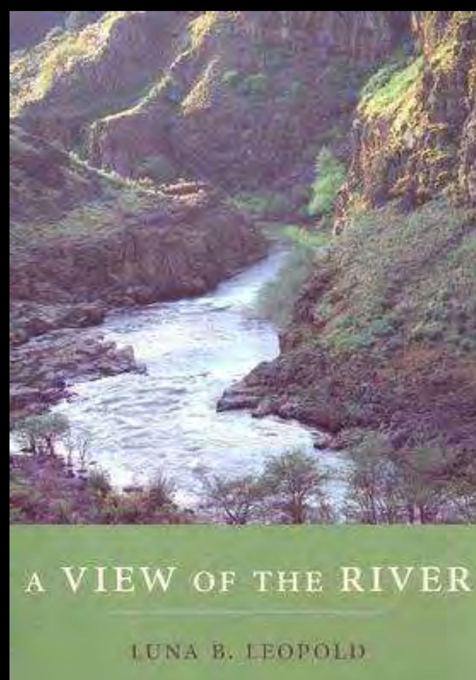
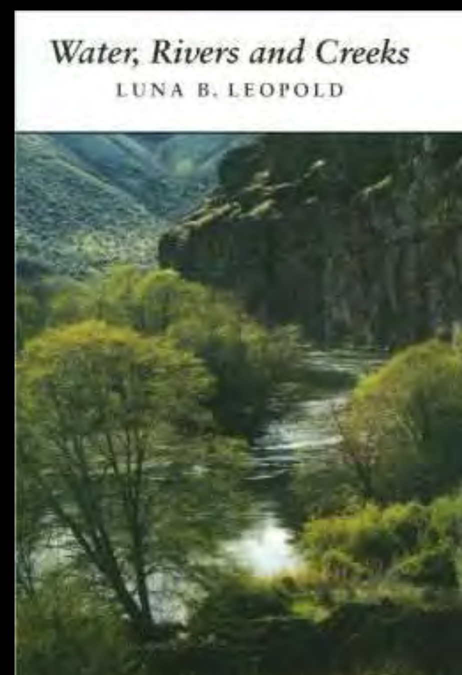
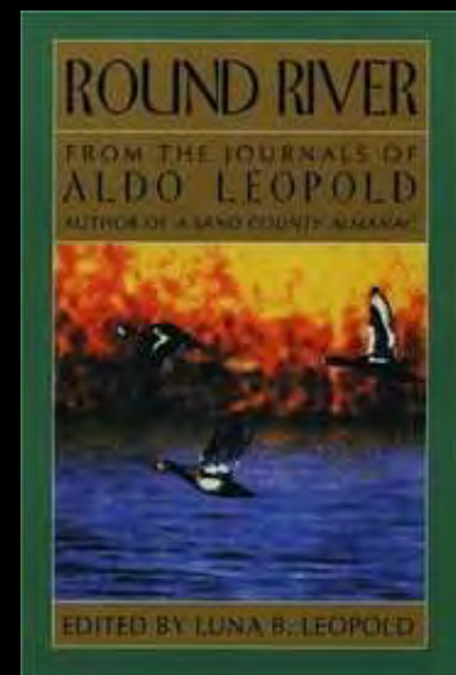
The Virtual Luna Leopold Project
http://eps.berkeley.edu/people/lunaleopold/









The Work of Flowing Water

Erosion – Earth Writing

The Upper Course → Middle Course
eroding bed and bank on its way

Erosion → Transportation → Deposition

Erosion - the gradual removal of rock material from the river banks and bed.

There are four types of erosion within the river.

1. Hydraulic action refers to the force of the water flow against the banks and bed. Sometimes the bank becomes over saturated and just slumps into the river.

2. Abrasion refers to the way in which the suspended load, transported by the flow collides with the bed and bank. This is sometimes anecdotally referred to as the 'sandpaper effect'.

3. Solution is the chemical reaction between carbon acid in the water and mineral elements in the rock.

4. Attrition is unique because it directly relates to erosion of bedload rather than the bed and bank. Attrition takes place through small collisions between bedload material.

Abrasion, hydraulic action and solution all erode the bed and banks of the river, hence deepening and widening the river.

Santa Elena Canyon

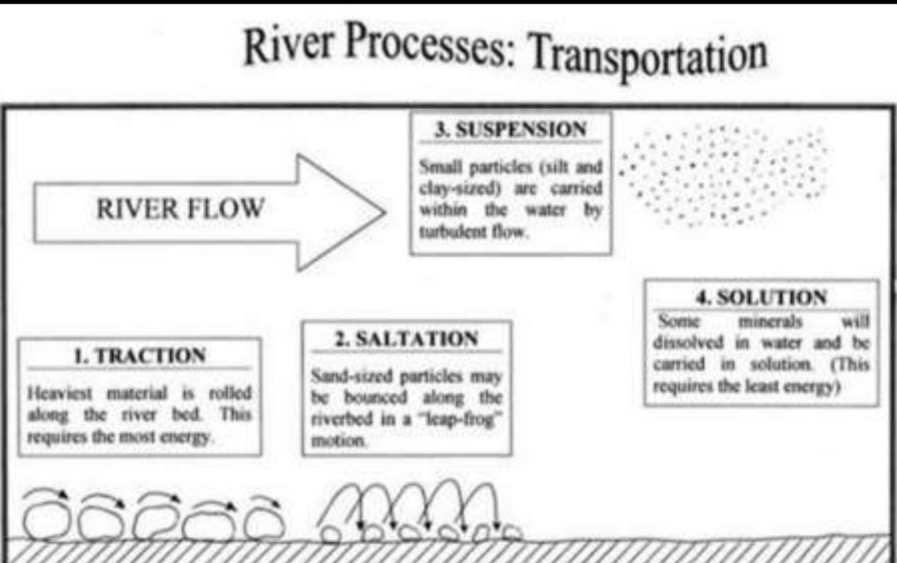
Fluvial Process - Four Modes of Transporation

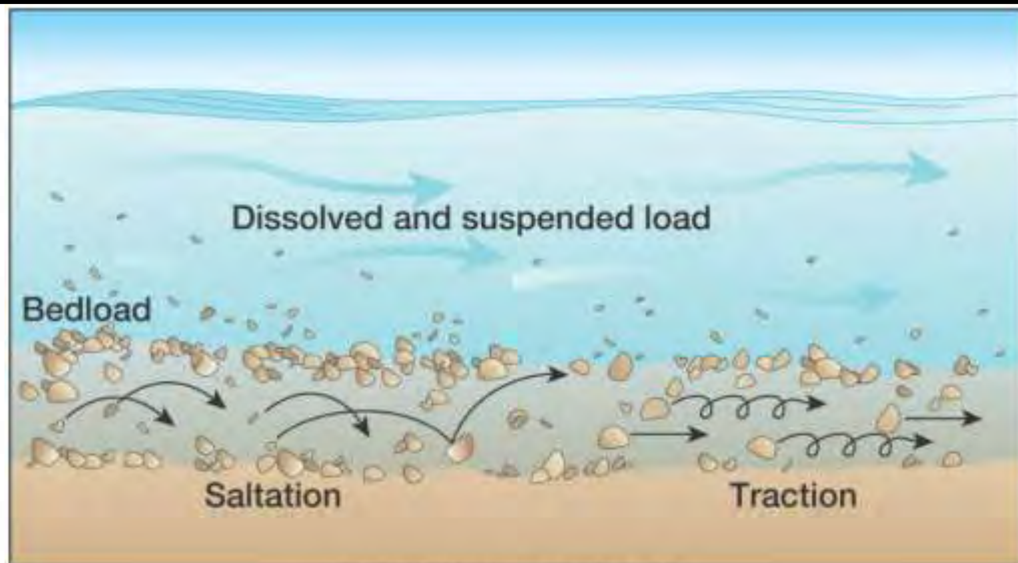
1.Traction - The largest of particles such as boulders are transported by traction. These particles are rolled along the bed of the river, eroding the bed and the particles in the process, because the river doesn't have enough energy to move these large particles in any other way.

2.Saltation - Slightly smaller particles, such as pebbles and gravel, are transported by saltation. This is where the load bounces along the bed of the river because the river has enough energy to lift the particles off the bed but the particles are too heavy to travel by suspension.

3.Suspension - Fine particles like clay and silt are suspended in the water. Most of a river's load is transported by suspension.

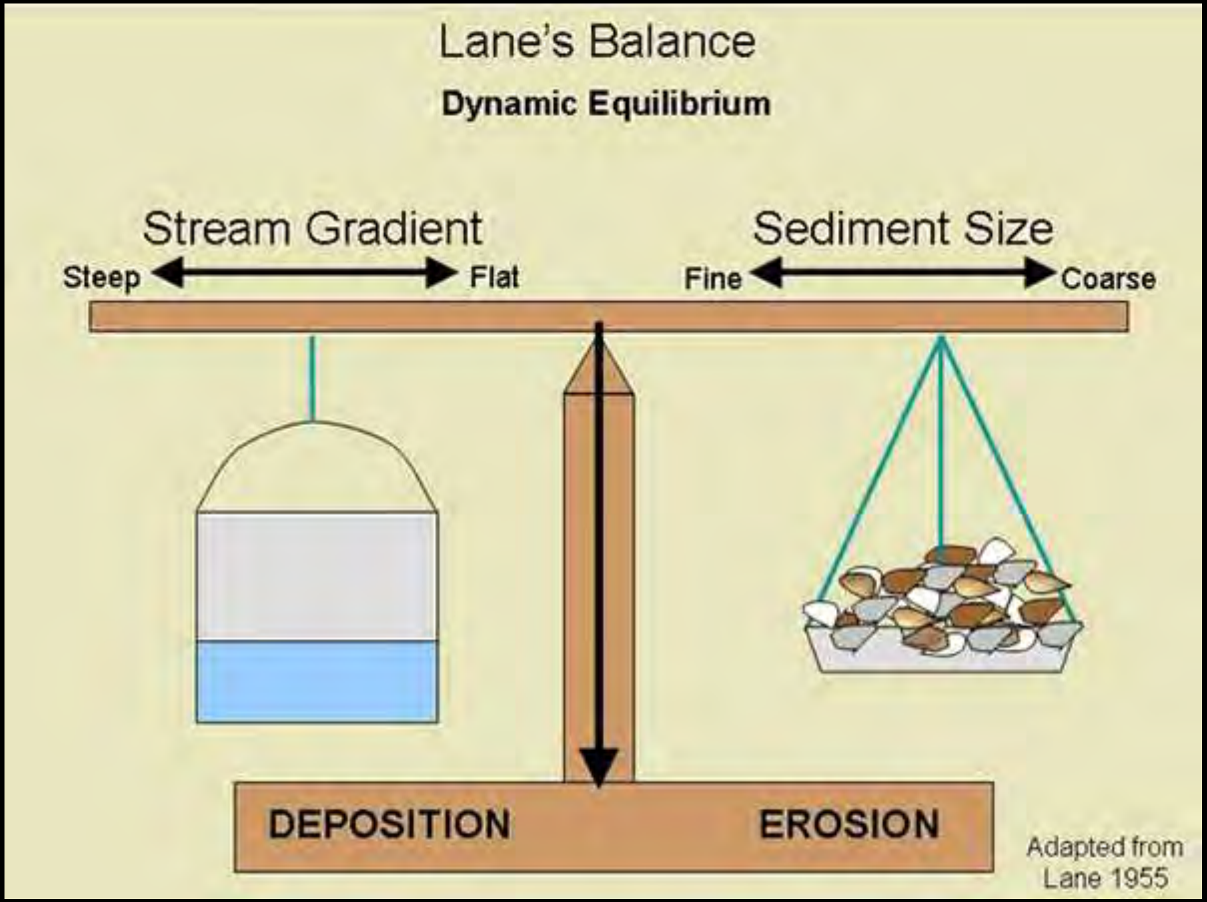
4.Solution - This is where particles are dissolved into the water so only rocks that are soluble, such as limestone or chalk, can be transported in solution.





Erosion → Transportation → Deposition

All Flowing Water Wants To Carry Sediment

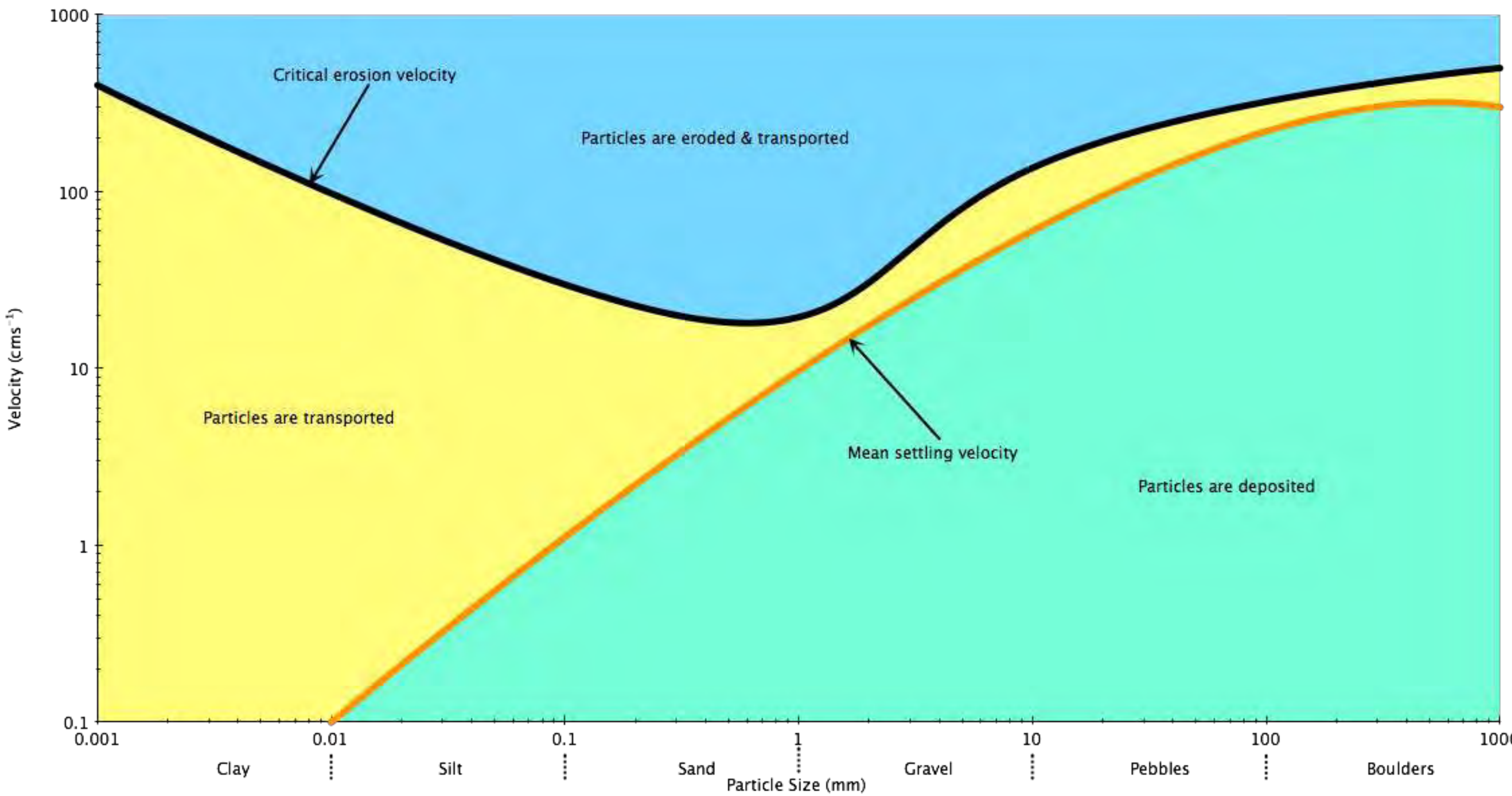


Hjulstrom Curve

For each grain size there is a specific velocity at which the grains start to move, called <u>entrainment velocity</u>.

However the grains will continue to be transported even if the velocity falls below the entrainment velocity due to the reduced (or removed) friction between the grains and the river bed. Eventually the velocity will fall low enough for the grains to be deposited.

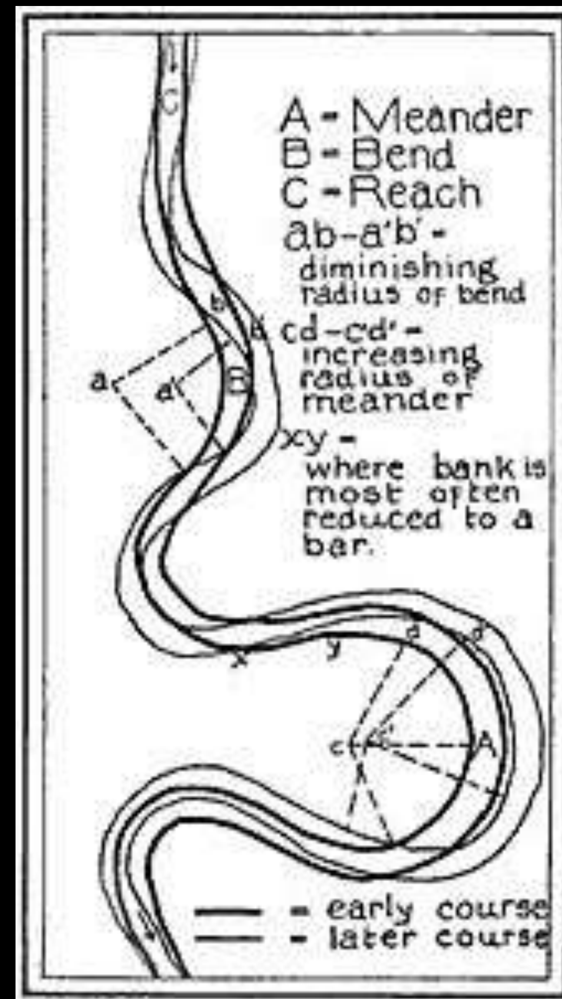
This is shown by the Hjulstrom curve.



Middle Course - Winding sedately through wide valleys

Sinuosity is inversely proportional to slope

Course Stage	Upper Course Youth Stage	Middle Course Mature Stage	Lower Course Old Age Stage
Slope			
Main processes	Hydraulic Action Abrasion **Erosion**	**Erosion** and **Deposition**	**Deposition**
Valley shape			
Main features	V-shaped Valleys Interlocking Spurs Waterfalls	Meanders and Ox-Bow lakes	Deltas Levees Flood Plains (and m+ob lakes)

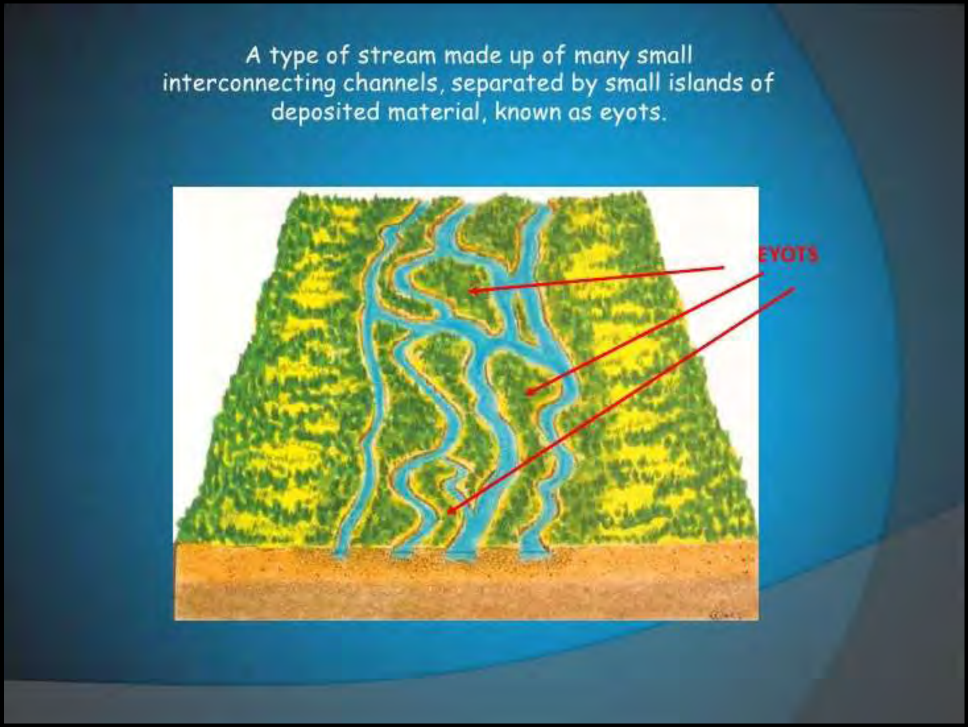


Upper Course to Middle Course - Deposition and Channel Patterns

Braided channels are dominated by multiple channels (braids) and sediment bars (eyots).

This unique channel characteristic develops due to changes in velocity and discharge, and often form as the slope decreases and river competence lowers, so the river deposits course sediment.

During periods of increased discharge, the capacity of the river to transport sediment increases and eyots become eroded. The competence of the river to transport larger bedload also increases. The braids widen and merge.

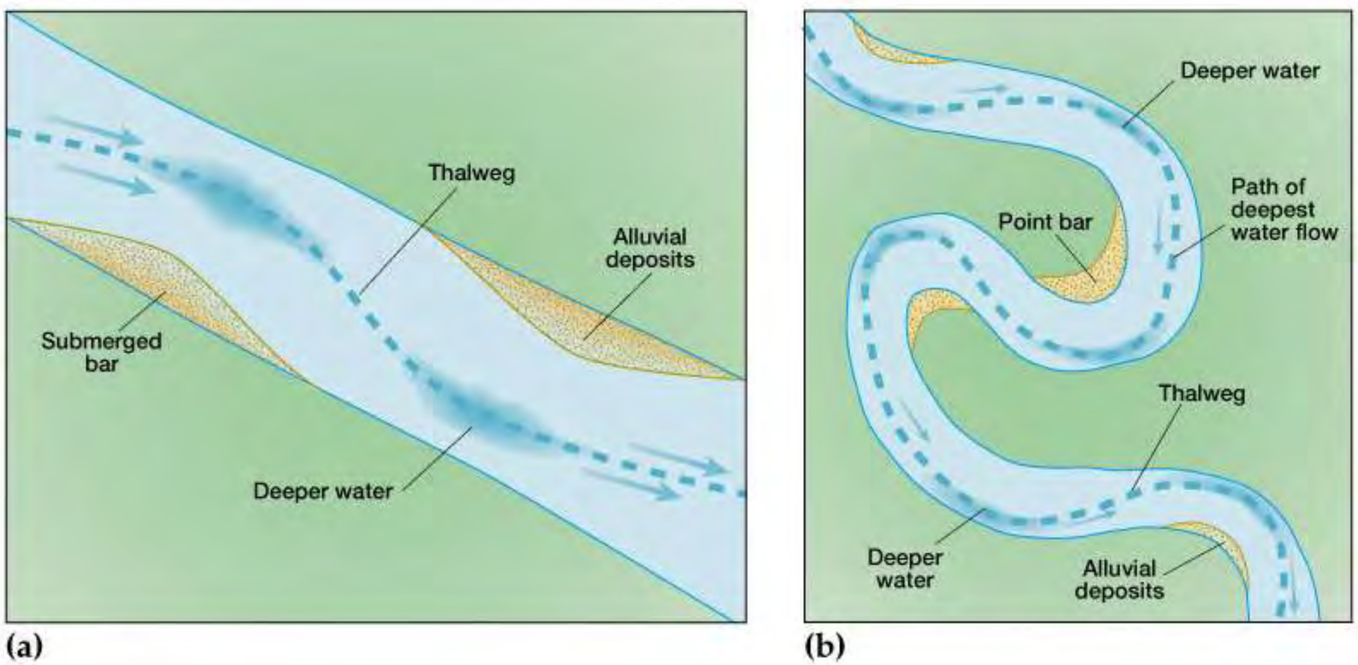


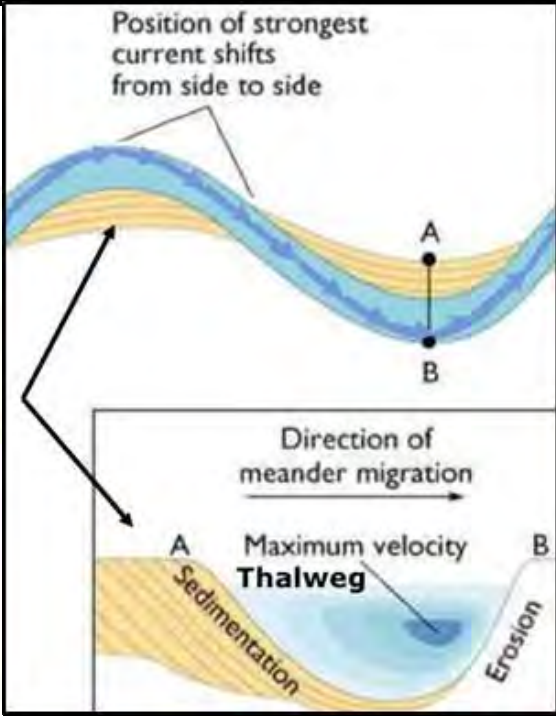
The Thalweg - Line of Fastest Flow

The word derives from German "Talweg" meaning "valley way".

In hydrological and fluvial landforms, the thalweg is a line drawn to join the lowest points along the entire length of a stream bed or valley in its downward slope, defining its deepest channel.

The thalweg is almost always the line of fastest flow in any river.

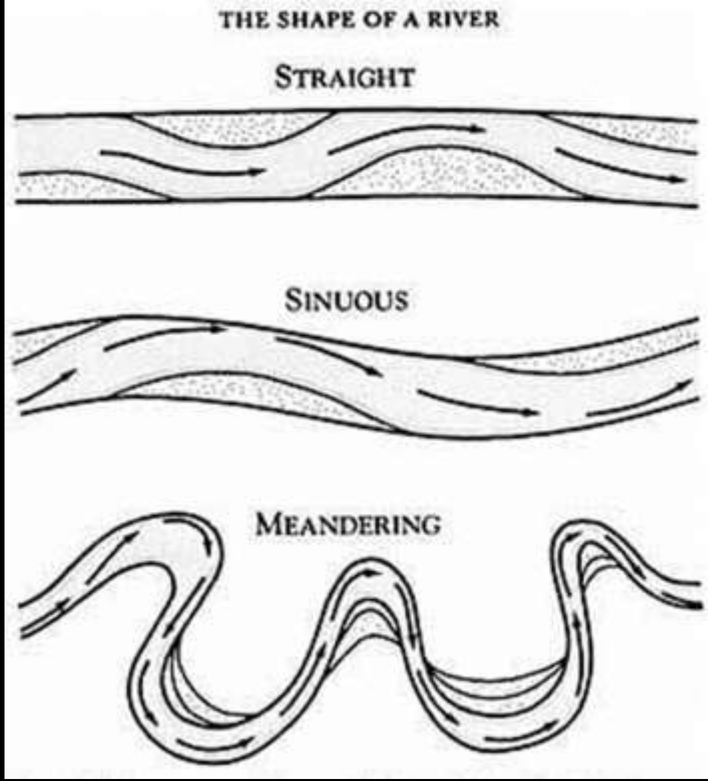




Meanders - Winding sedately through wide valleys

Meanders are loop-like bends in a river.

- The water flows round the meander in a spiral manner.
- This causes erosion to take place on the outer bank and deposition on the inner bank.

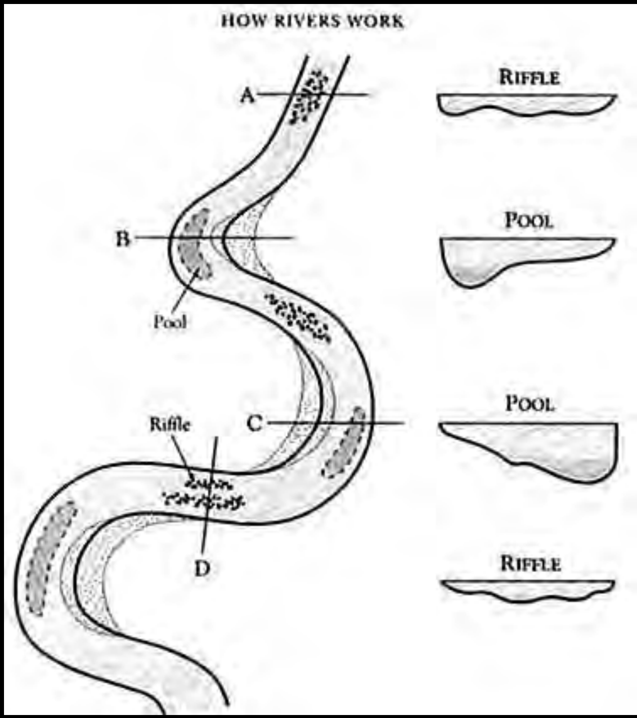


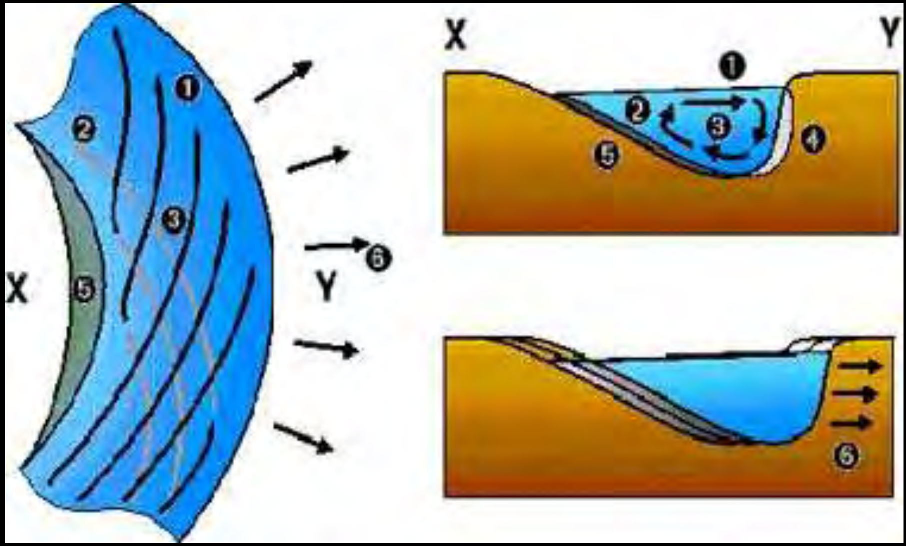
Fluvial Process – Helical Flow, Erosion, Deposition

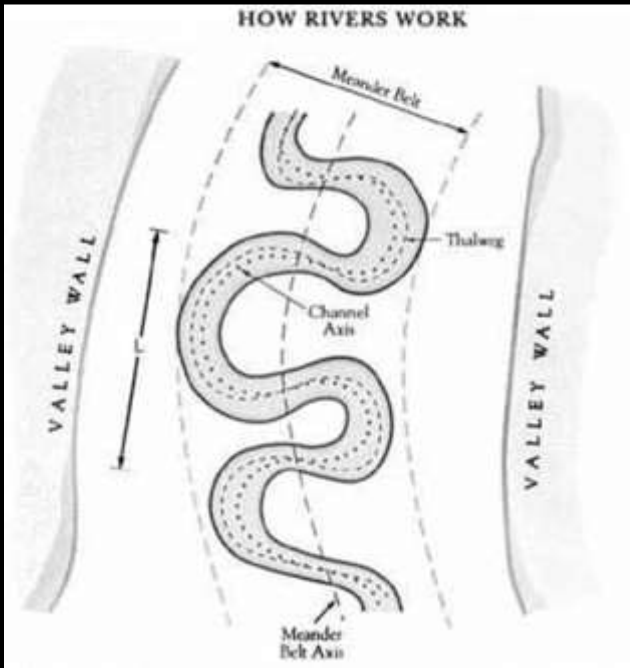
Higher velocity chutes within a stream tend to be driven to the outside of a meander seen at point 1. On the outside of the meander, the surface of the water has a tendency to be slightly higher because it has gained momentum and acceleration, in the same way as centrifugal force works.

Here, the flow is forced down the outer bank which results in the scouring of the bank and bed. It returns to the surface toward the inside of the meander where flow is less turbulent, seen at point 2.

The helical flow of water plays an important role in the formation of meanders, especially in the developing river cliffs and slip-off slopes.

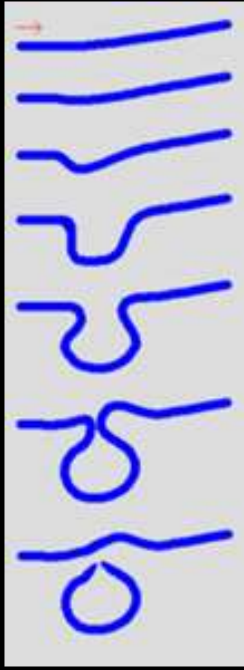


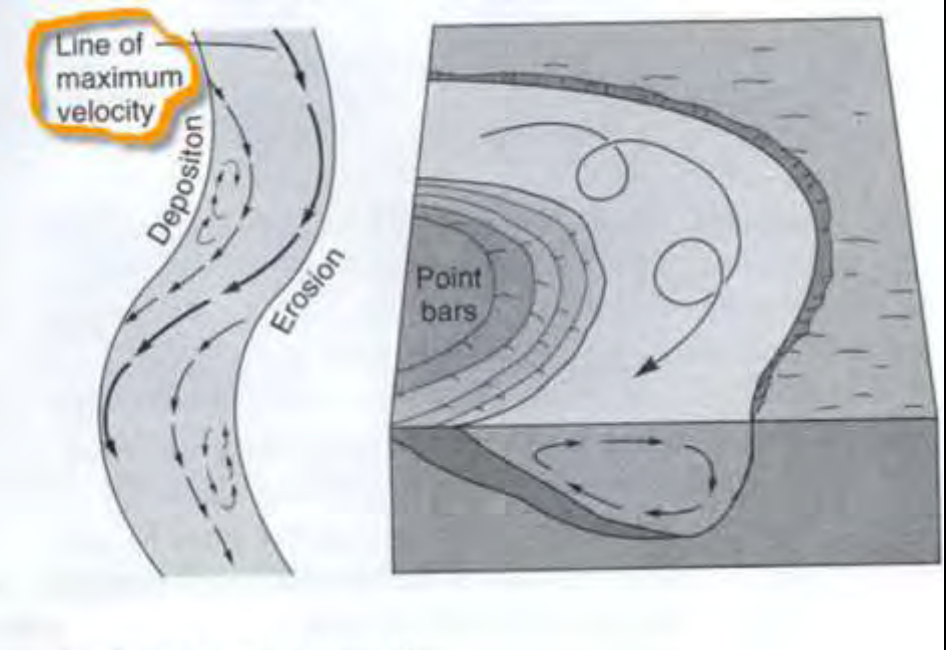




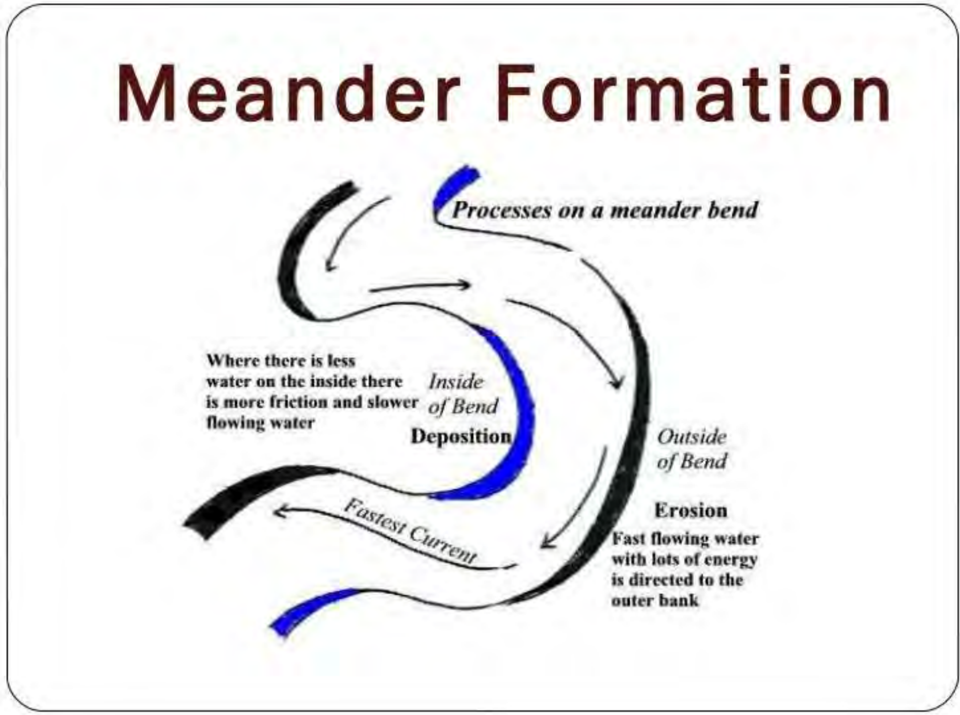
The Life of a Meander – River to Lake to Wetland to Scar

- The helical flow erodes the outside of the bend and deepens the pool.
- At the same time it redistributes scoured material and deposits it on the slip-off slope and riffle section.
- This continuous process cause meanders to migrate and contract at their neck.
- When a river meanders in very big loops, the outer bank is so rapidly eroded that the river cuts through the narrow neck of the meander. The river then flows straight through the channel. When deposition seals off the cut-off from the river channel, an oxbow lake is formed. It may silt up and eventually dry up.
- This leaves meander scars on the floodplain that simply mark the old channel.

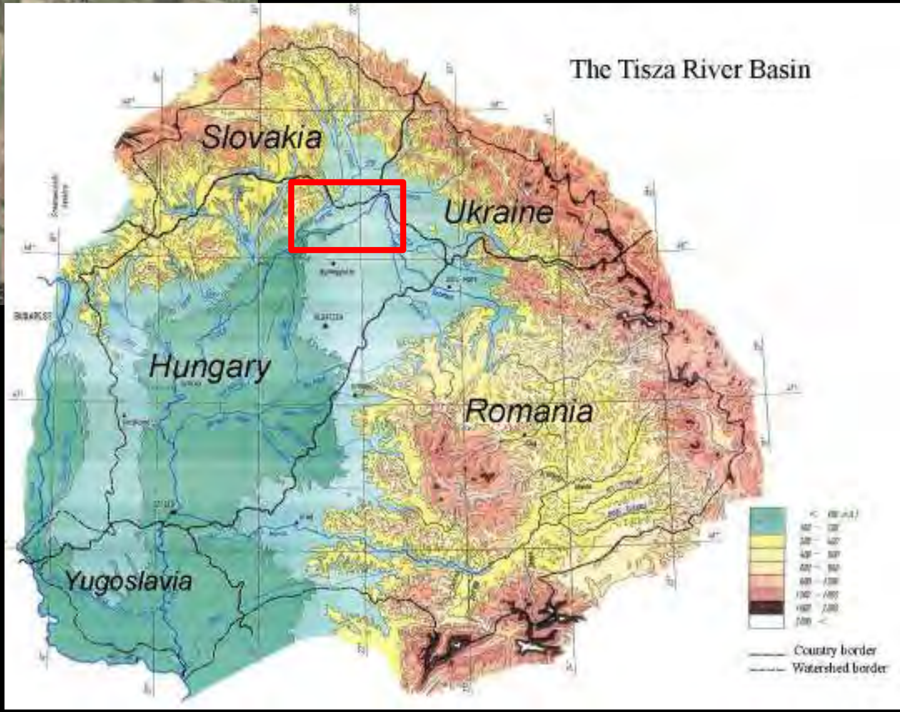




Helical flow in a meander.



Oxbow Lakes and Meander Scars – The Bodrogköz
The Tisza and Bodrog Rivers – Northeastern Hungary



The Bodrogköz lowland region between the Bodrog and Tisza rivers is separated from the area up north by yet another river called Latorca. The southern part belongs to Hungary and the upper Bodrogköz is on the other side of the border in Slovakia. Now a cross-border UN Ramsar Wetland of International Importance

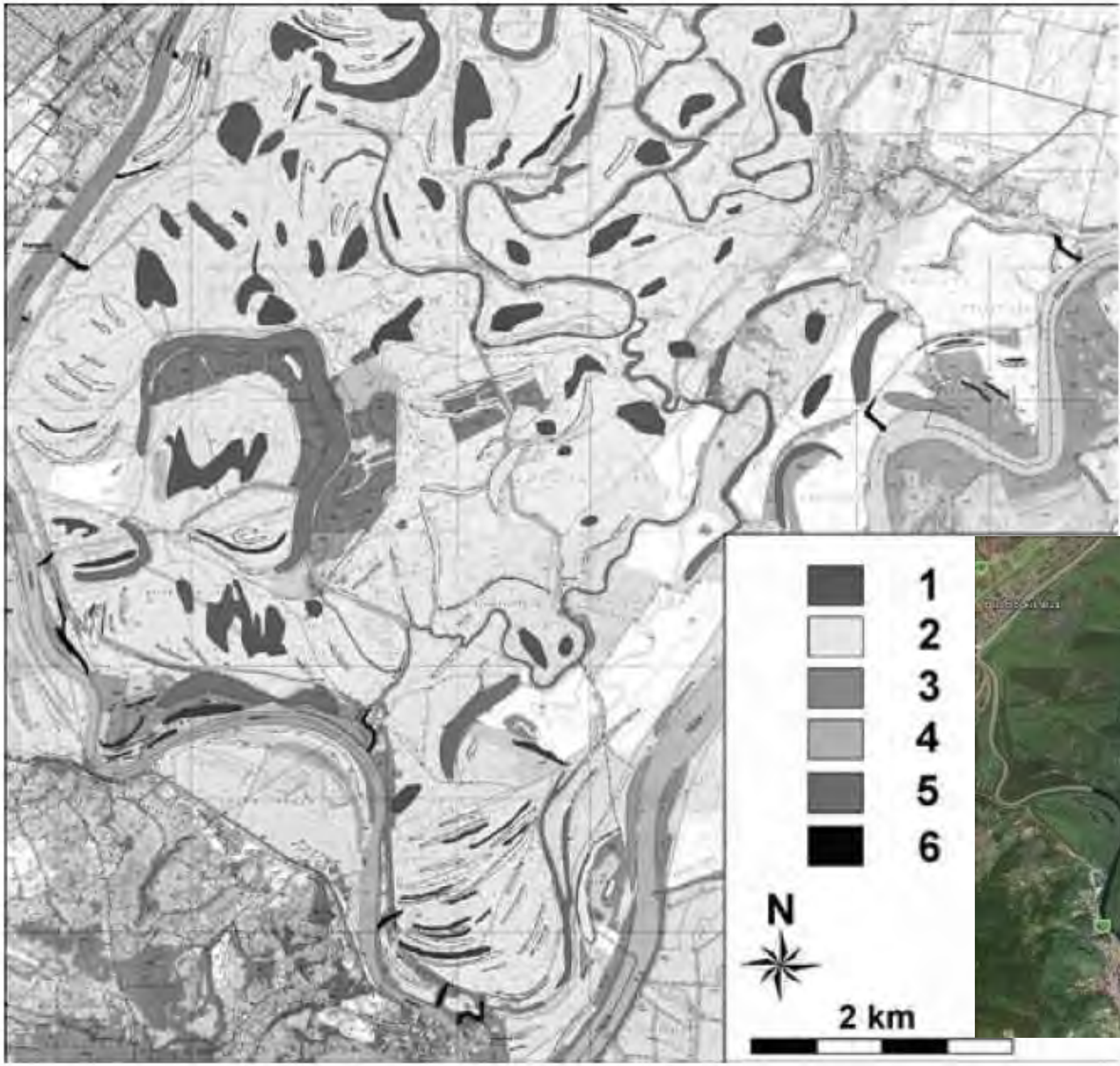
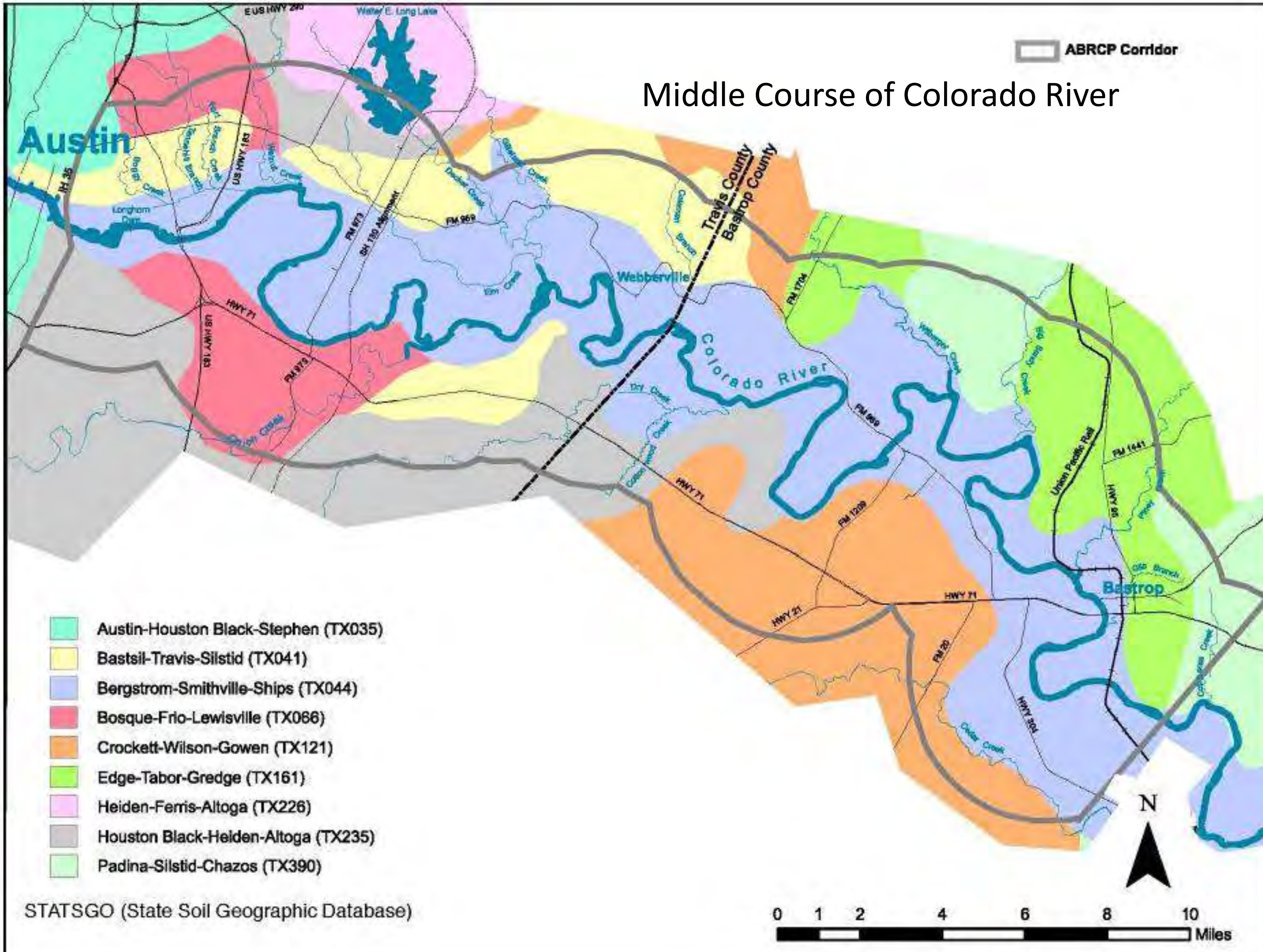


FIG. 2 - Landforms of the SW Bodrogköz (In: Szabó & *alii*, 2004). 1: fluvial ridge, 2: swale, 3: abandoned cut-offs, 4: present natural levee, 5: backswamps, 6: (remnants of) one-time flood-plain ditches.

Middle Course of Colorado River




Old Mining Pit
2003

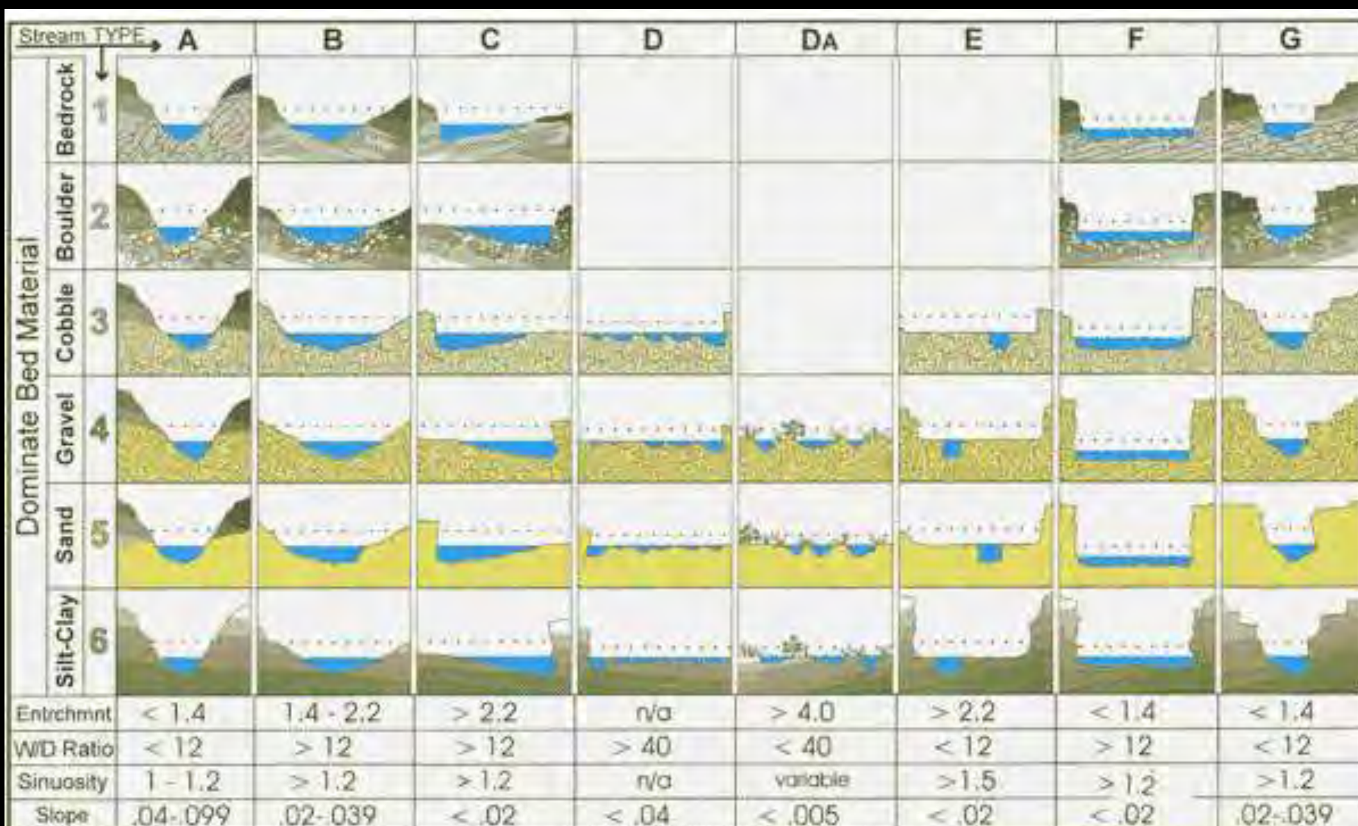

2006


80 feet
130 feet
Breach
Mining Pit
2006

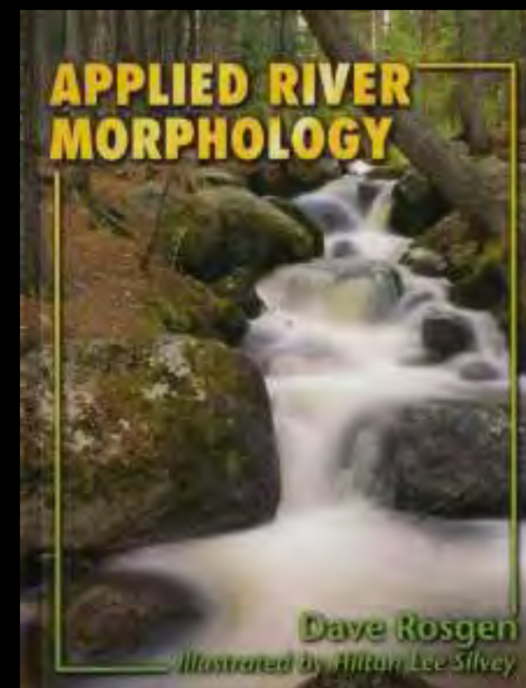
River Morphology – Complexity and Patterns

Dave Rosgen, a former hydrologist with the U.S. Forest Service and now Principal Hydrologist of Wildland Hydrology Consultants.

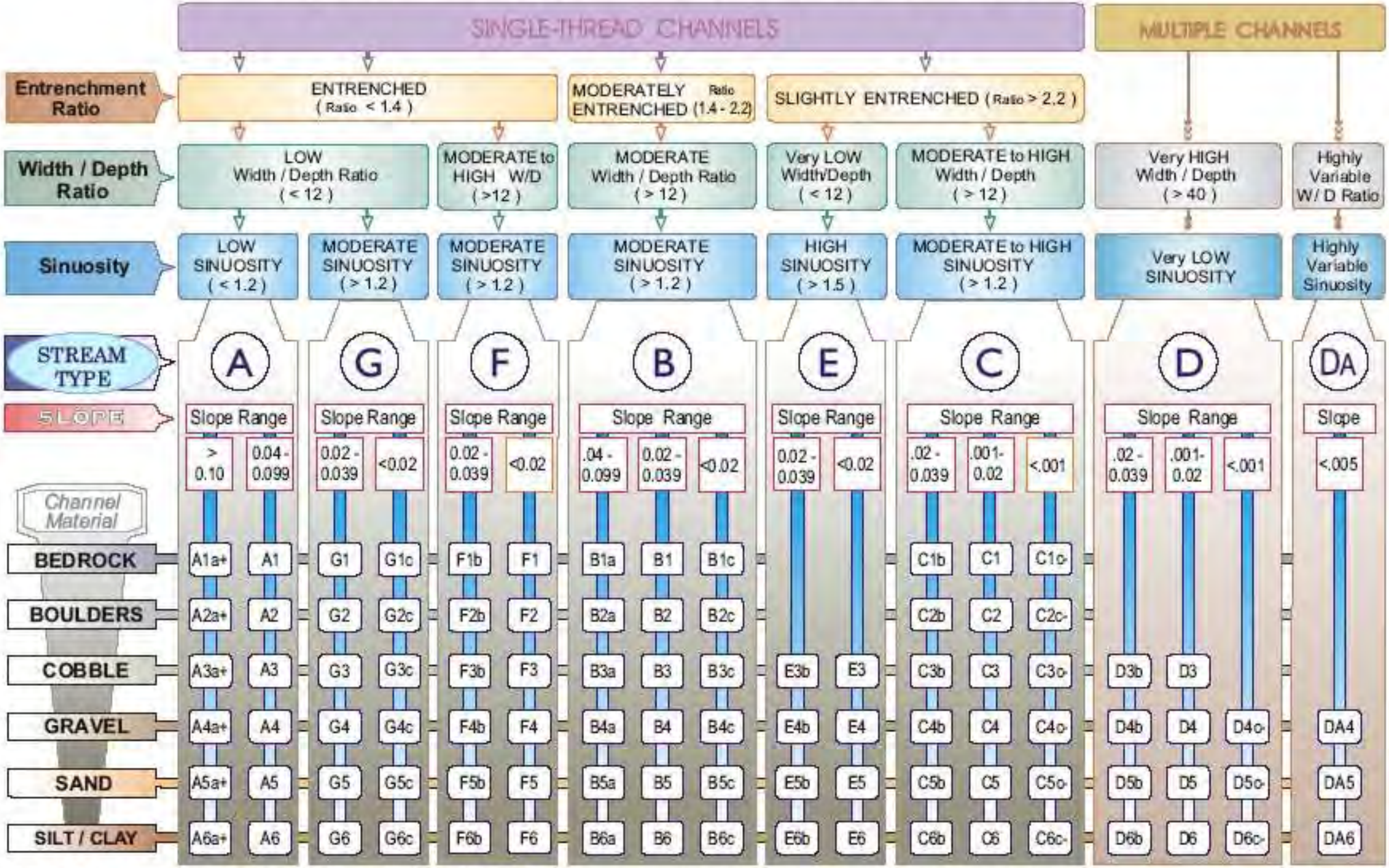
The objective of classifying streams on the basis of channel morphology is to set categories of discrete stream types so that consistent, reproducible descriptions and assessments of condition and potential can be developed.



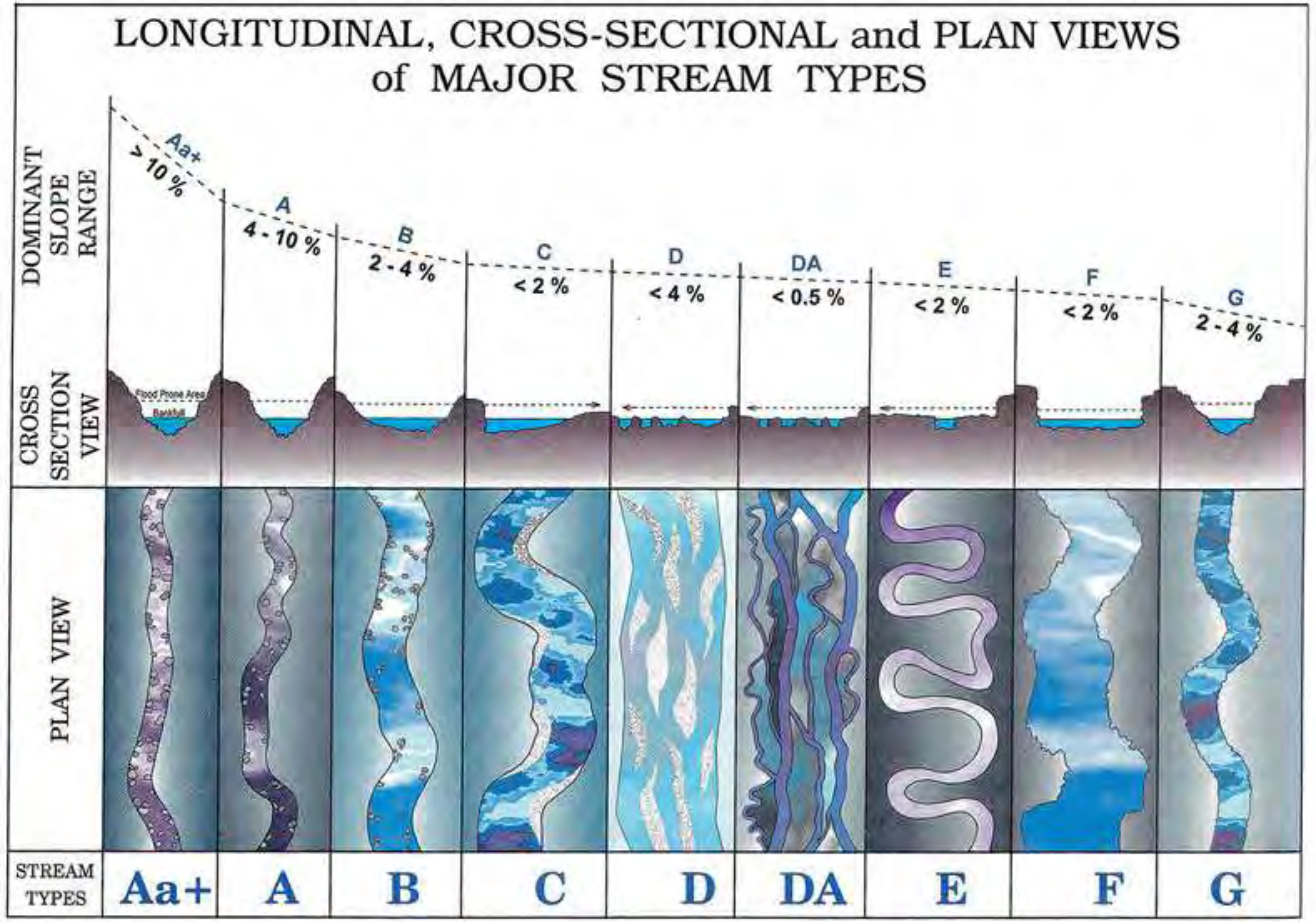
Applied River Morphology . Pagosa Springs: Wildland Hydrology Books, 1996. www.wildlandhydrology.com



The Key to the Rosgen Classification of Natural Rivers



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

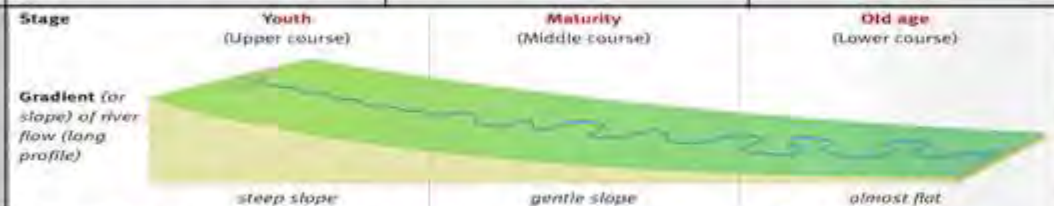


Sinuosity is inversely proportional to slope

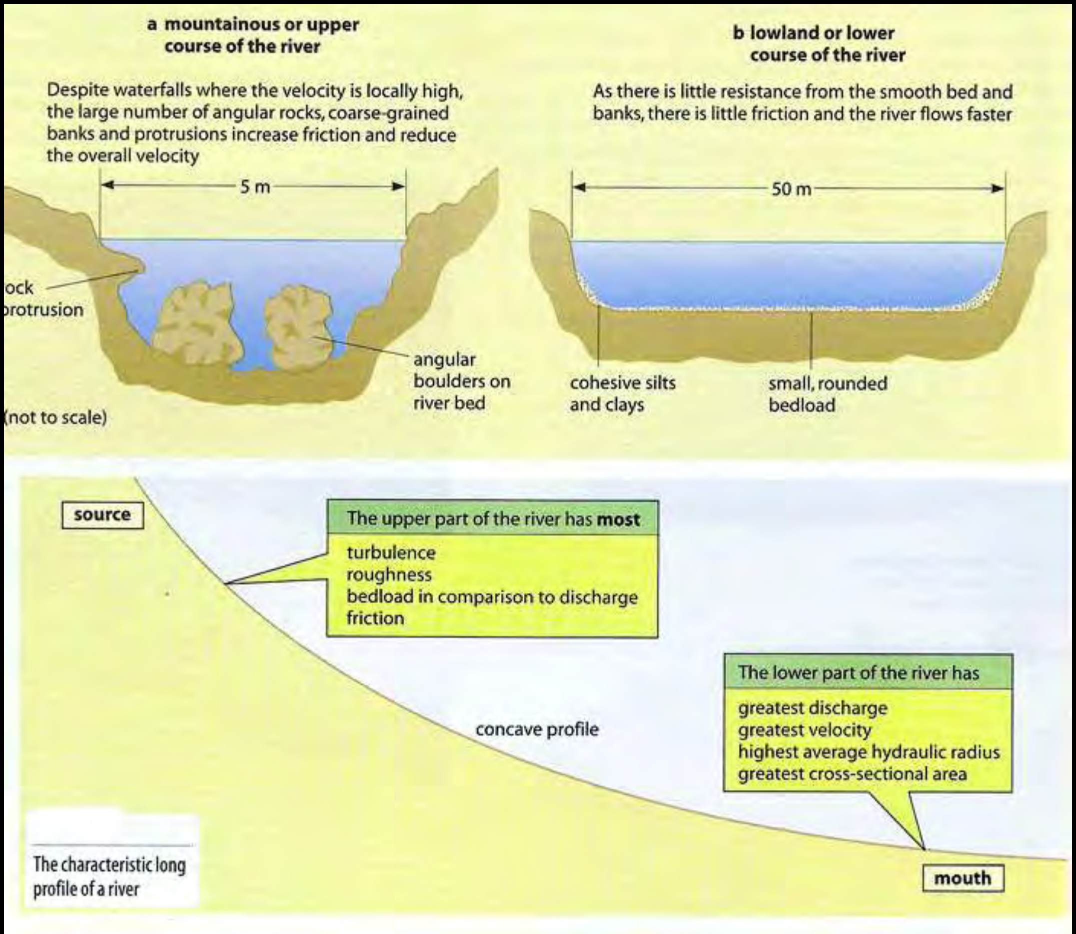
The Lower Course – Old Age

a somewhat aimless course toward final extinction

Wandering and Deposition

Course Stage	**Upper Course Youth Stage**	**Middle Course Mature Stage**	**Lower Course Old Age Stage**
Slope			
Main processes	Hydraulic Action Abrasion **Erosion**	**Erosion** and **Deposition**	**Deposition**
Valley shape			
Main features	V-shaped Valleys Interlocking Spurs Waterfalls	Meanders and Ox-Bow lakes	Deltas Levees Flood Plains (and m+ob lakes)

“Downstream Change of Velocity in Rivers” Luna Leopold



The characteristic long profile of a river

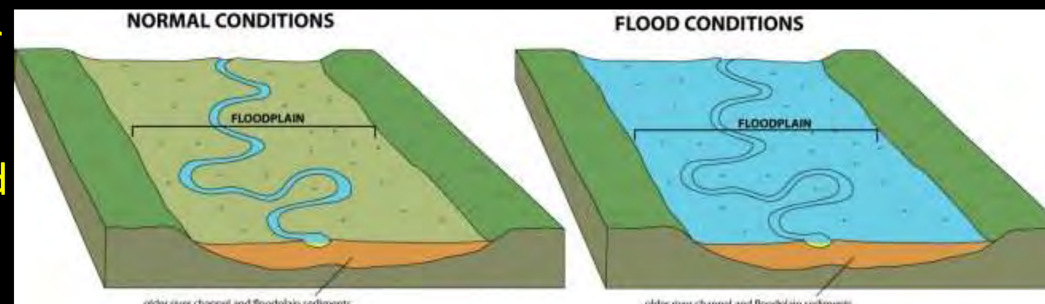
Floodplains and Levees

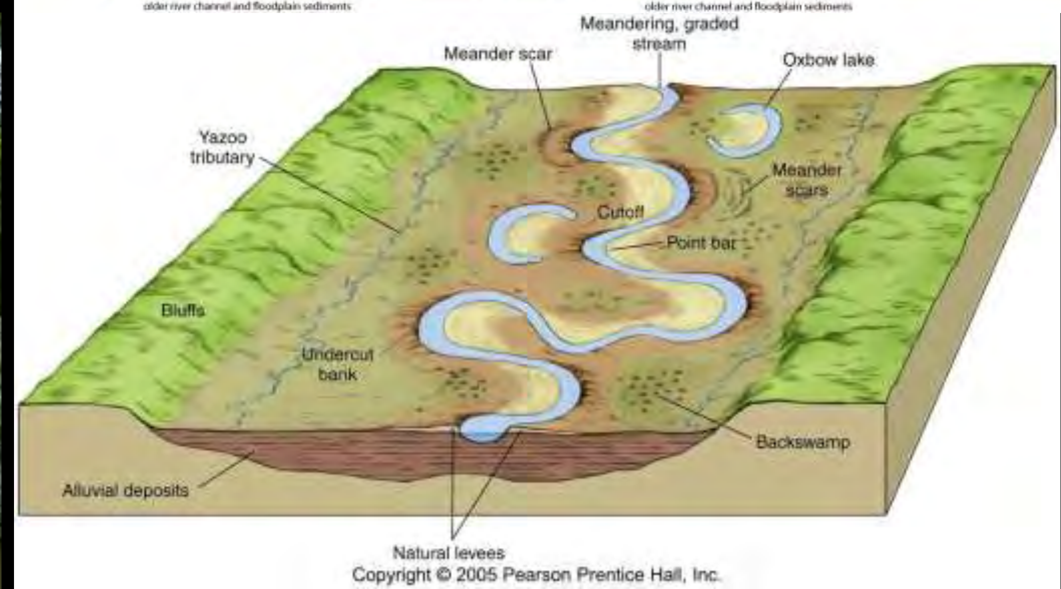
A floodplain is a low-lying plain on both sides of a river that has repeatedly overflowed its banks and flooded the surrounding areas.

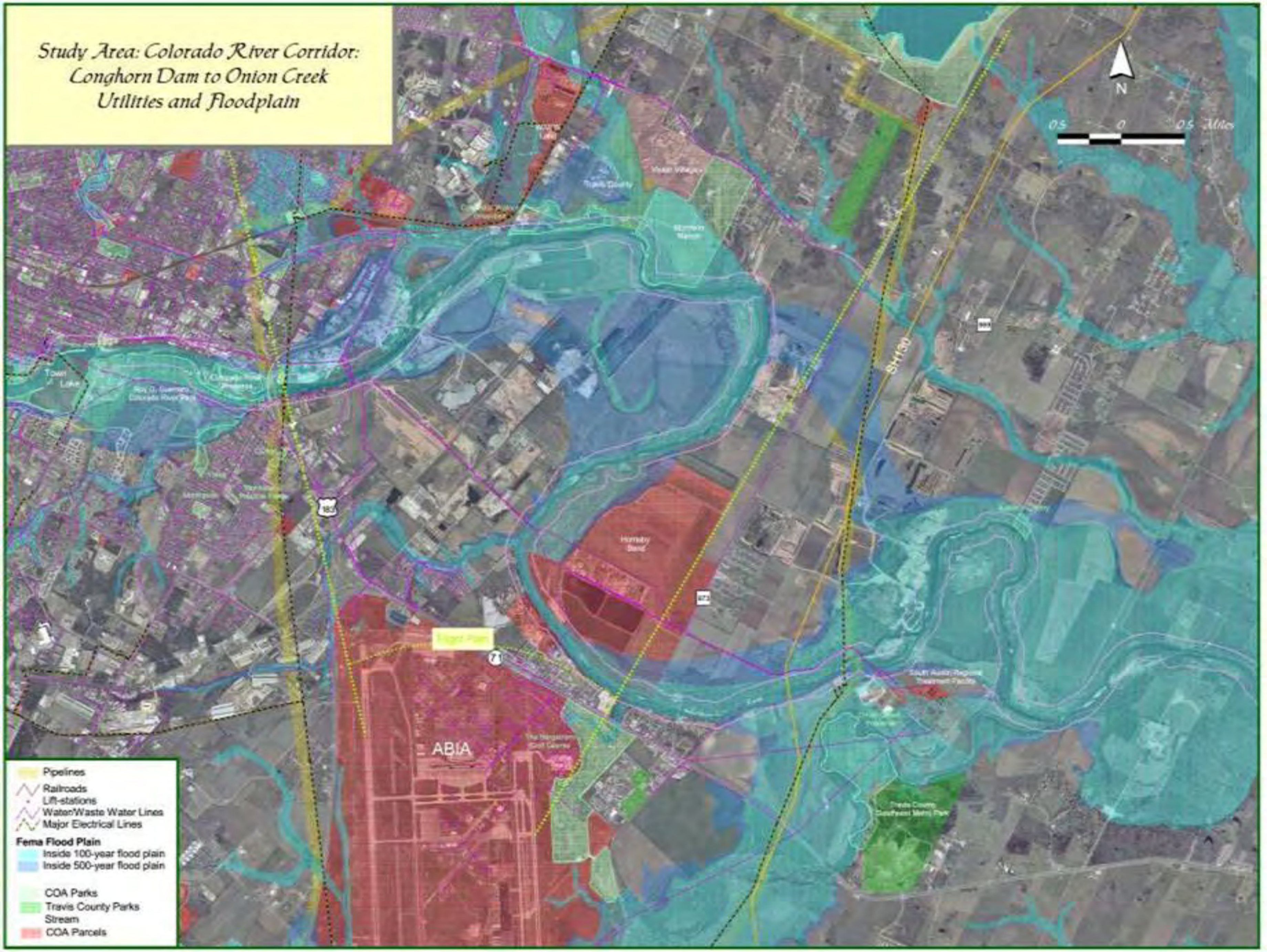
When the floods subside, alluvium is deposited on the floodplain.

The larger materials, being heavier, are deposited at the river banks while the finer materials are carried and deposited further away from the river.

The larger materials at the river banks build up into embankment called levees.






Study Area: Colorado River Corridor:
Longhorn Dam to Onion Creek
Utilities and Floodplain
N
0.5
0
0.5 Miles
SH130
ABIA
Pipelines
Railroads
Lift-stations
Water/Waste Water Lines
Major Electrical Lines
Fema Flood Plain
Inside 100-year flood plain
Inside 500-year flood plain
COA Parks
Travis County Parks
Stream
COA Parcels

Delta - final extinction as it joins the ocean

River deltas form at the mouth of the river or inland on the approach to lakes.

There is great variation in the shapes of deltas due to the complex interaction between fluvial and marine systems.

Their shape is influenced by the amount and type of sediment being transported by the river, the velocity, discharge and capacity of the river and the strength of marine tides and waves.

Arcuate deltas like that found on the Nile are the most common type of delta. They are characterized by a gently curving shoreline, smoothed by longshore currents. They have a distinct pattern of branching distributaries and tend to be dominated by courser material.

Bird-foot deltas have long finger-like projections that reach out to the sea, like the Mississippi River's delta. These deltas might have broad, shallow shelves.
The bird-foot delta is named for its long thin shape, much like a bird's toe.

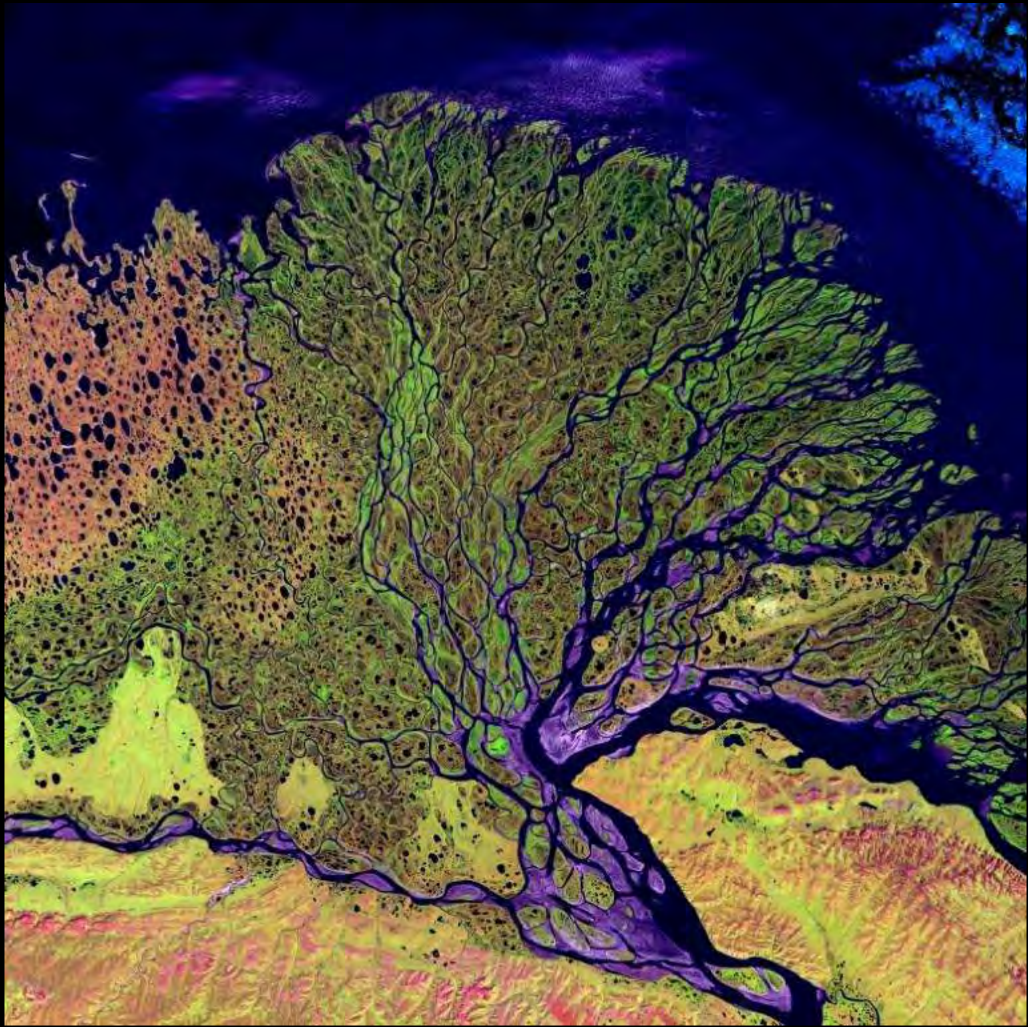
The Danube Delta is the second largest river delta in Europe, after the Volga Delta.

The greater part of the Danube Delta lies in Romania, while its northern part, on the left bank of the Chilia arm, is situated in Ukraine .

The approximate surface is 4,152 km², of which 3,446 km² are in Romania.

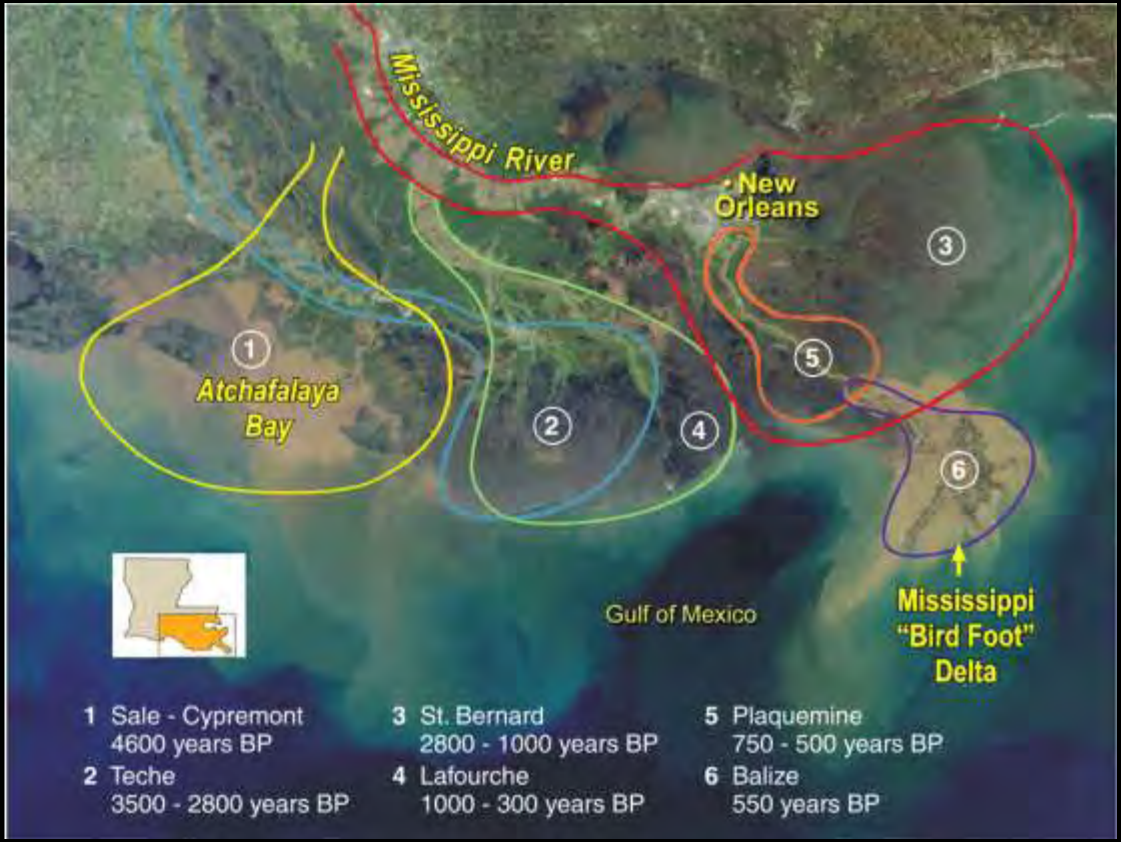
The Lena River, some 2,800 miles (4,400 km) long, is one of the largest rivers in the world.

- At the end of the Lena River there is a large delta that extends 100 km into the Laptev Sea and is about 400 km (250 mi) wide.
- The delta is frozen tundra for about 7 months of the year, but in May transforms the region into a lush wetland for the next few months.
- The Lena Delta Reserve is the most extensive protected wilderness area in Russia. It is an important refuge and breeding ground for many species of Siberian wildlife.



Avulsion - the rapid abandonment of a river channel and the formation of a new river channel

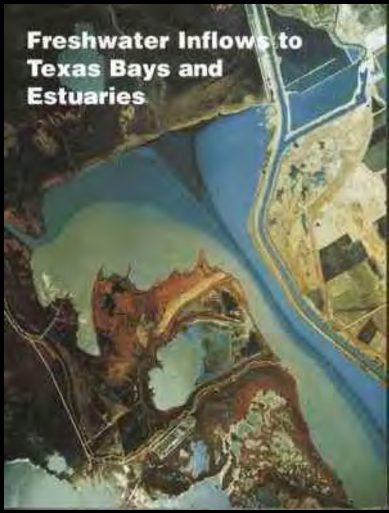
Avulsions are common in deltaic settings, where sediment deposits as the river enters the ocean and channel gradients are typically very small. This process of avulsion in deltaic settings is also known as delta switching. When this avulsion occurs, the new channel carries sediment out to the ocean, building a new deltaic lobe. The abandoned delta eventually subsides

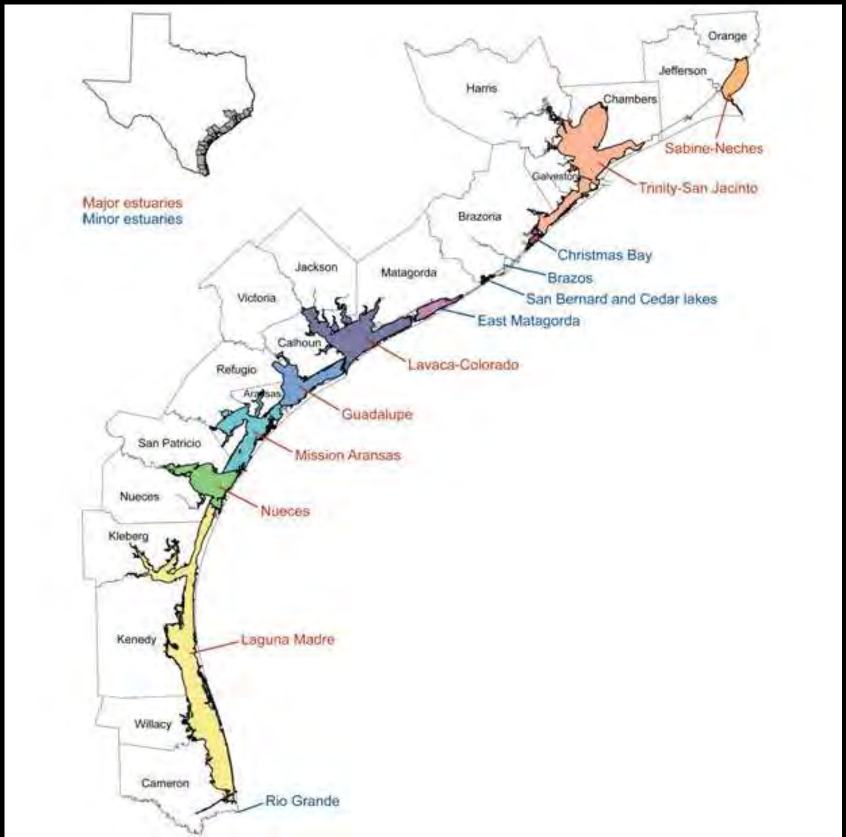


Location of Mississippi River channels discharging water into the Gulf of Mexico over the past 5000 years. Notice the location changes from time to time, keeping all areas of the delta supplied with sediments that balance the natural sinking of the delta. Today, two-thirds of the flow are through the Bird Foot Delta (6) and one third through the Atchafalaya

Estuary - An estuary is fresh water meets salt water and in Texas is a partly enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open sea.

Estuaries form a transition zone between river environments and maritime environments and are subject to both marine influences, such as tides, waves, and the influx of saline water; and riverine influences, such as flows of fresh water and sediment. The inflows of both sea water and fresh water provide high levels of nutrients in both the water column and sediment, making estuaries among the most productive natural habitats in the world





Fluvial Process - A Fluvial Life

The Upper Course: steep and rugged

The Middle Course: winding sedately through wide valleys

The Lower Course: a somewhat aimless course toward final extinction

Course Stage	Upper Course Youth Stage	Middle Course Mature Stage	Lower Course Old Age Stage
Slope			
Main processes	Hydraulic Action Abrasion **Erosion**	**Erosion** and **Deposition**	**Deposition**
Valley shape			
Main features	V-shaped Valleys Interlocking Spurs Waterfalls	Meanders and Ox-Bow lakes	Deltas Levees Flood Plains (and m+ob lakes)

Sinuosity is inversely proportional to slope


Applause!


Questions?

The Physical Geography of Flowing Water

January - Fluvial Process: Streams and Hydrology

February - Fluvial Life: the Ecology of Flowing Water

March – Riparia: Life at the Edge

April – Bottomland: Life on the Floodplain