Center for Environmental Research at Hornsby Bend

Fluvial Life: the Ecology of Flowing Water

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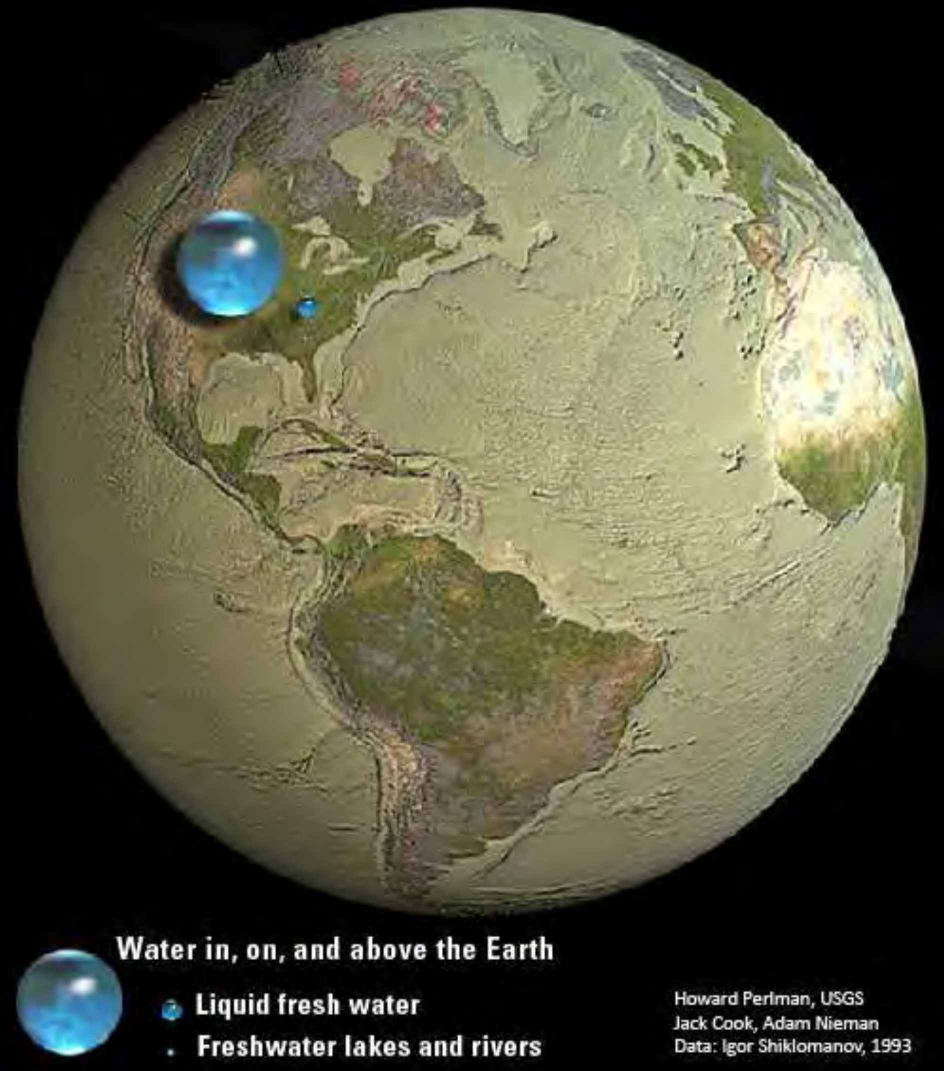
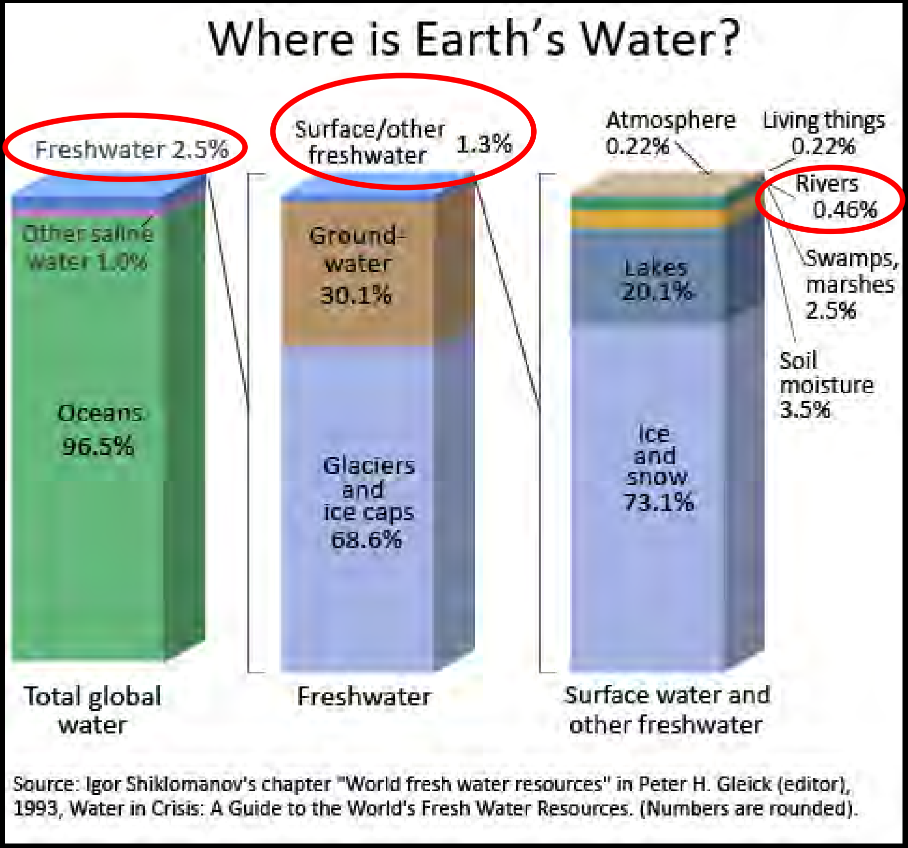




Spheres showing:

(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) vs	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

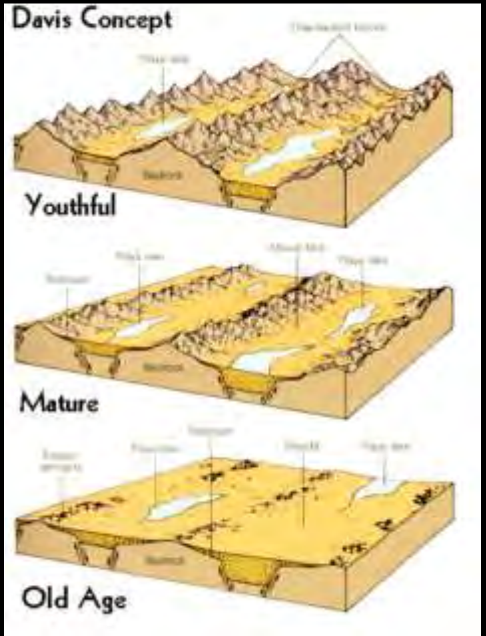
The Life of a River – Physical Geography - Abiotic

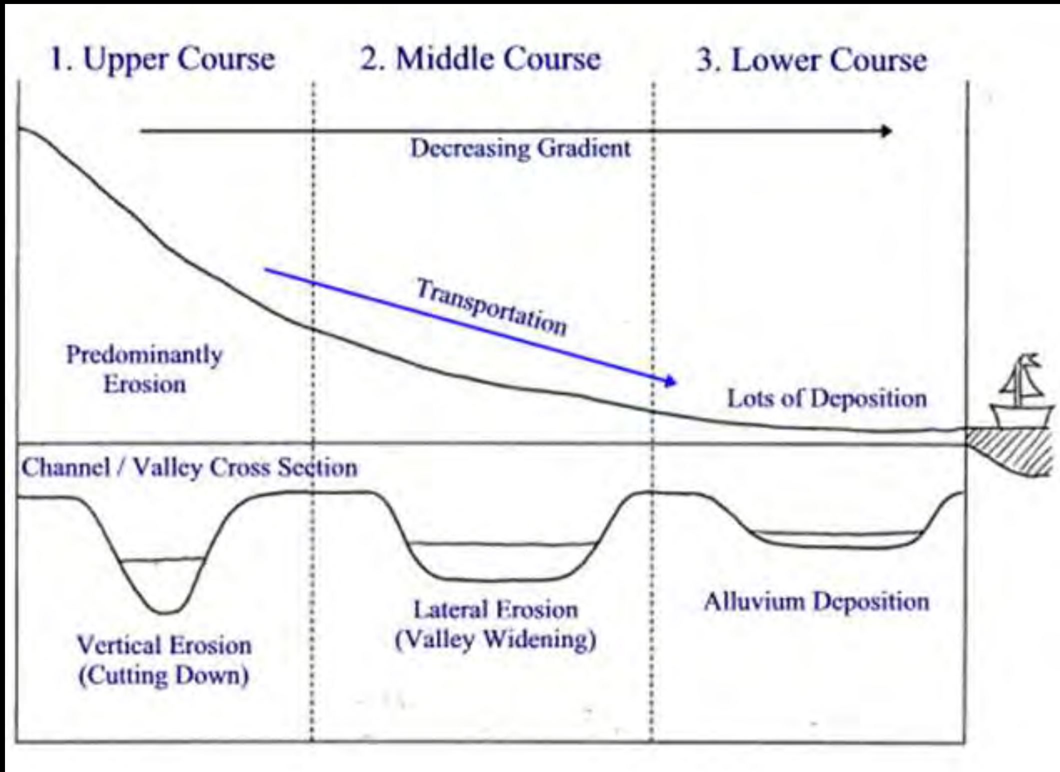
William Morris Davis “viewed the river system as having a life of its own.

- 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.”

(1850 - 1934)

Luna Leopold “A Reverence for Rivers” 1977



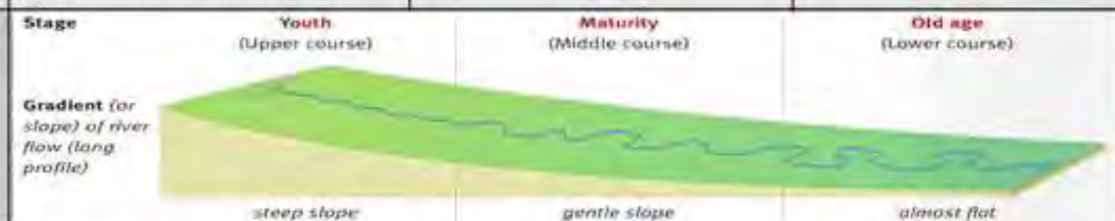


A Fluvial Life and Physical Geography – Waterway Ecosystem

The Upper Course: steep and rugged

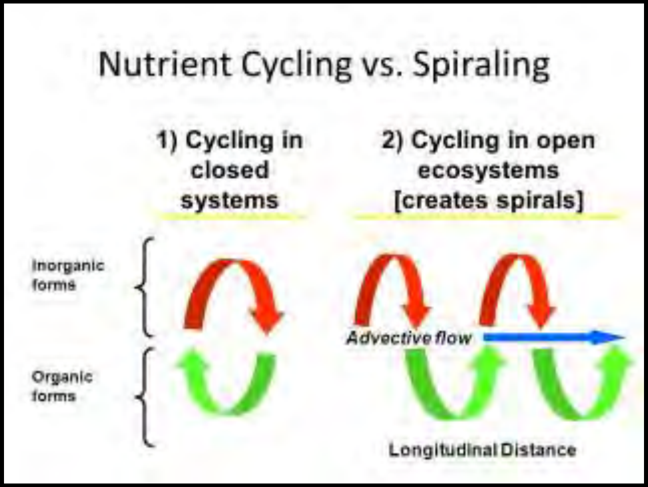
The Middle Course: winding sedately through wide valleys

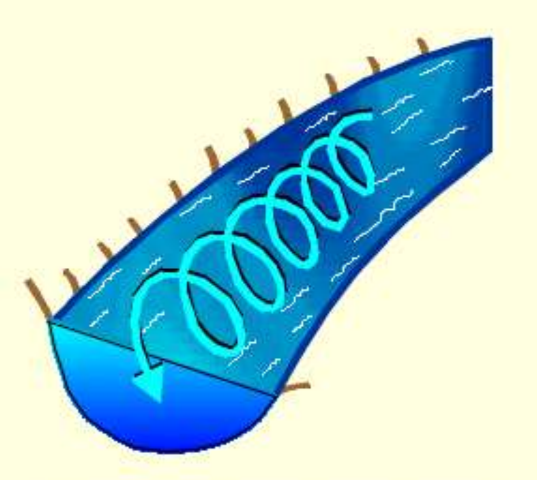
The Lower Course: a somewhat aimless course toward final extinction

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)

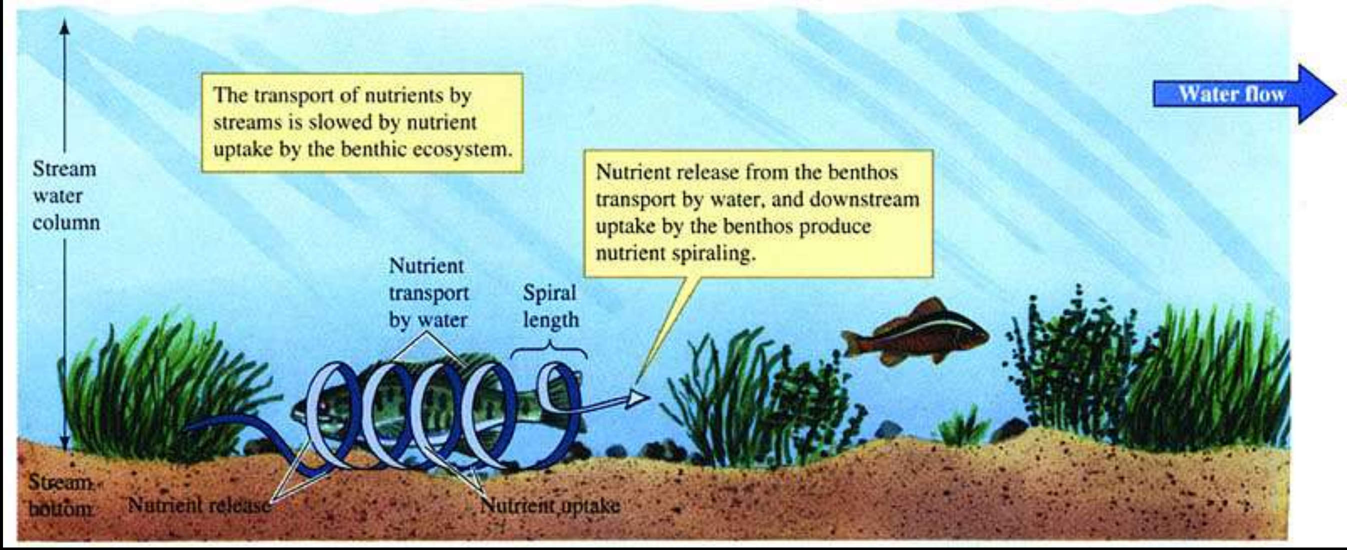
Terrestrial Ecology vs. Fluvial Ecology
Nutrient Cycles and Nutrient Spiraling

- Nutrient cycles describe changes in nutrient states through time and usually do not consider a spatial component
- But water in streams have a strong spatial component.
- Because these nutrient cycles occur simultaneously with downstream transport, nutrient transformations in streams are conceptualized as "spiraling"
- The spiraling length represents the distance over which the average nutrient atom travels as it completes one cycle of utilization from a dissolved available form, passes through one or more metabolic transformations and is returned to a dissolved available form.





The nutrient cycle, in conjunction with downstream transport, describes a spiral.



Freshwater Ecology - Food Webs

Freshwater ecosystems begin with the consumption of living or dead plant material

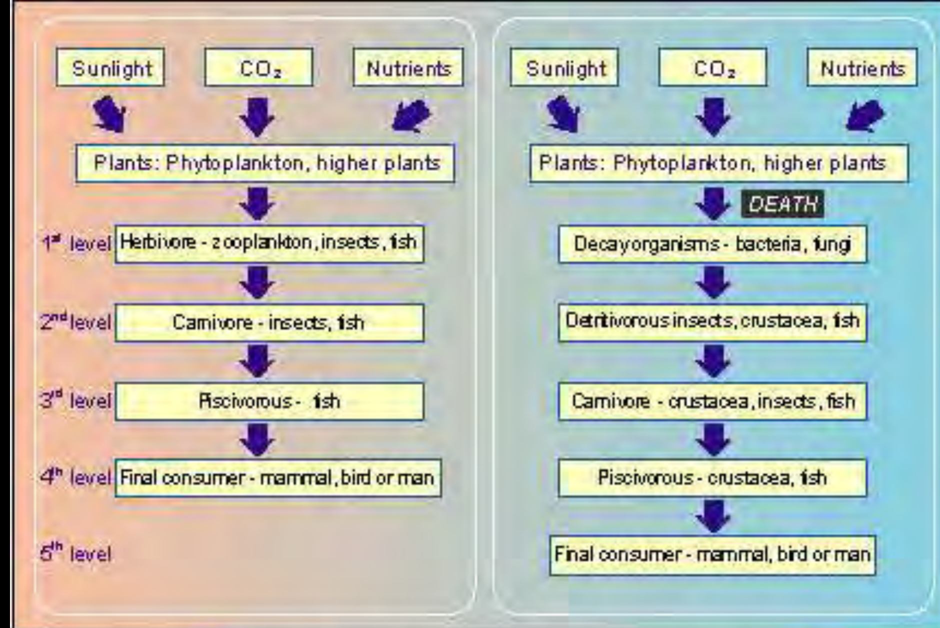
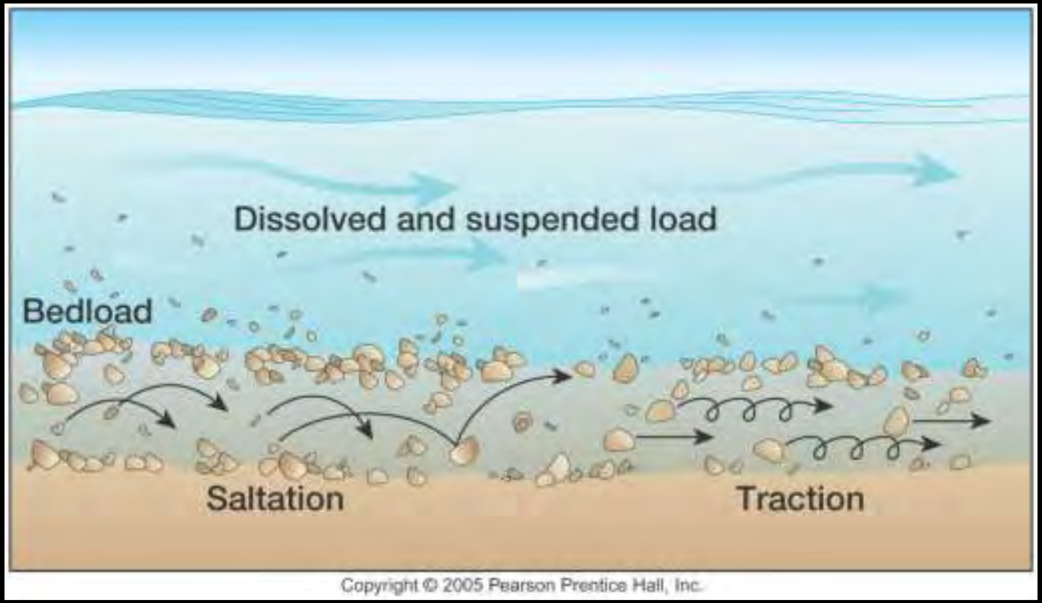


Figure: Alternative pathways for energy and nutrient flow among river organism.

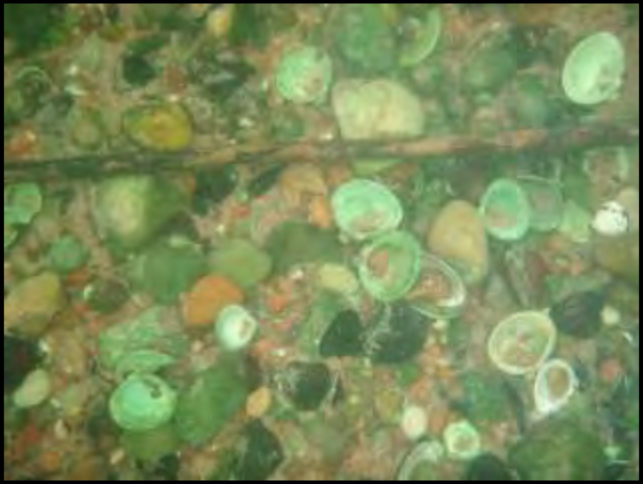
Fluvial Transportation
Water, Sediment, and Organic Material

- Rivers transport three main materials downstream – water, sediment, and organic material.
- The abiotic components – water and sediment – most directly affect the shape of the river channel [Fluvial Geomorphology].
- The biotic components of a river's transported load range from dissolved organic matter to large woody debris.



Dissolved Organic Matter (DOM)

- Very small particles (<0.5 microns in diameter) but the fundamental component of the organic material in rivers.
- Sources: some of it enters via subsurface drainage and originates from terrestrial decomposition processes - other sources are detrital leaching and exudates and excreta from aquatic organisms. [Everything Poops!]
- DOM tends to increase in concentration downstream. The highest levels occur in blackwater rivers, especially those draining peat swamps, which are rich in humic substances that color the water.
- DOM is taken up directly by microorganisms – especially bacteria – in biofilms , and can be flocculated into larger particles by mechanical forces such as turbulence whereupon they become available to animals.

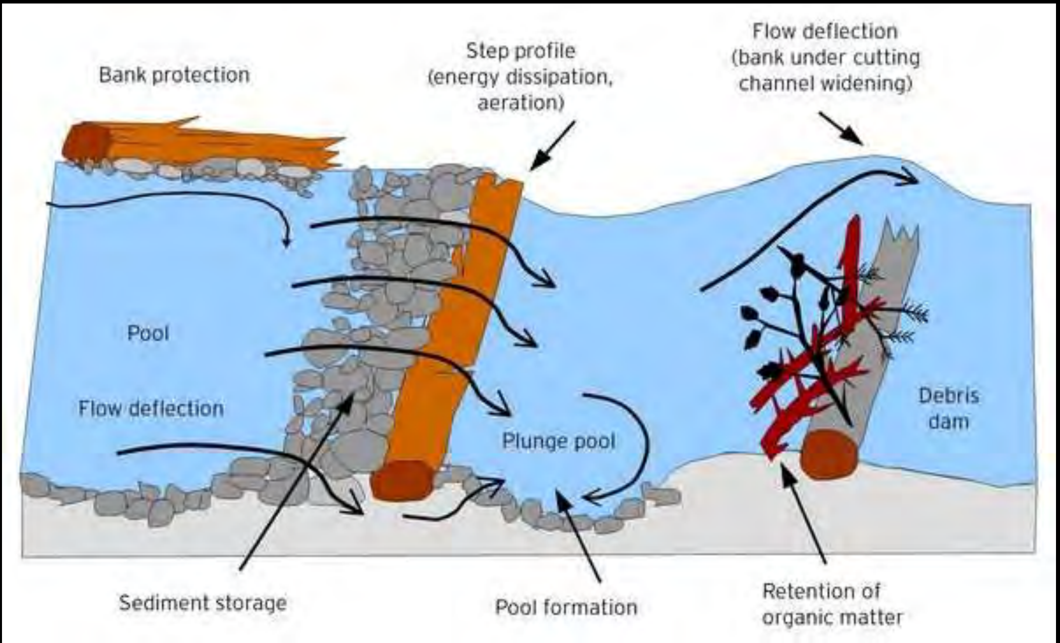

Large Organic Matter - Woody Debris

Trees and tree limbs that fall into streams and rivers increase habitat heterogeneity.

Submerged woody debris persists for long periods in streams and rivers.

Woody debris can –

- stabilize river beds,
- modify erosion and deposition,
- create essential fish habitat,
- help form pools that retain organic matter.



The River Continuum Concept [RCC]
An Ecological Model

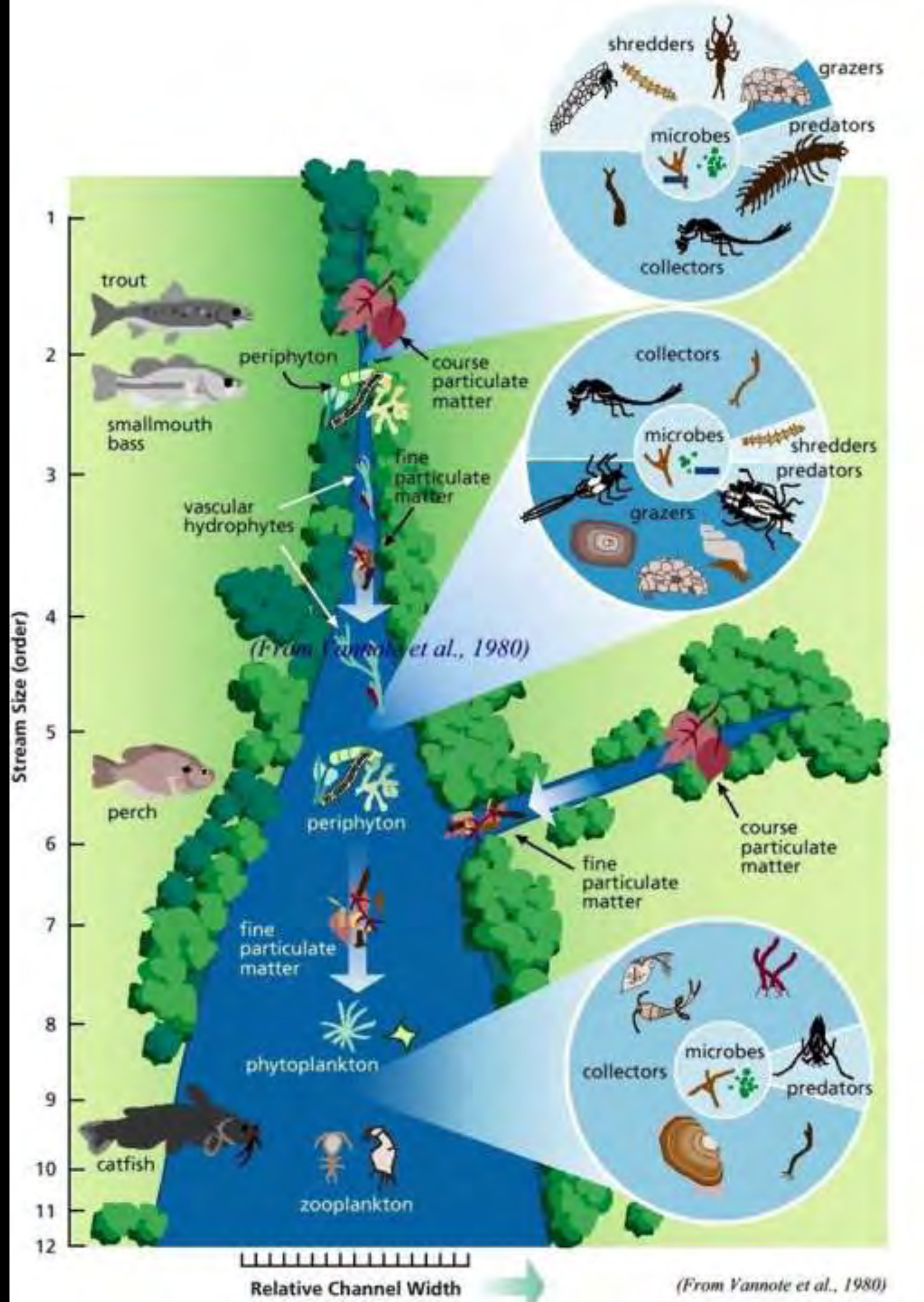
The River Continuum Concept is a model that tries to explain how the physical and biological characteristics of a river change in a downstream direction.

The foundation concept of the RCC states that rivers have physical gradients which are influenced by the surrounding environment, natural disturbance regime, local hydrology, and upstream conditions.

They in turn impact and define the biological components of the stream within the river as the river increases in size and moves downstream.

The RCC largely focuses on the interaction of stream invertebrates with their habitat and food resources.

Developed by Dr. Robin Vannote
The Stroud Water Research Center
Avondale, Pennsylvania

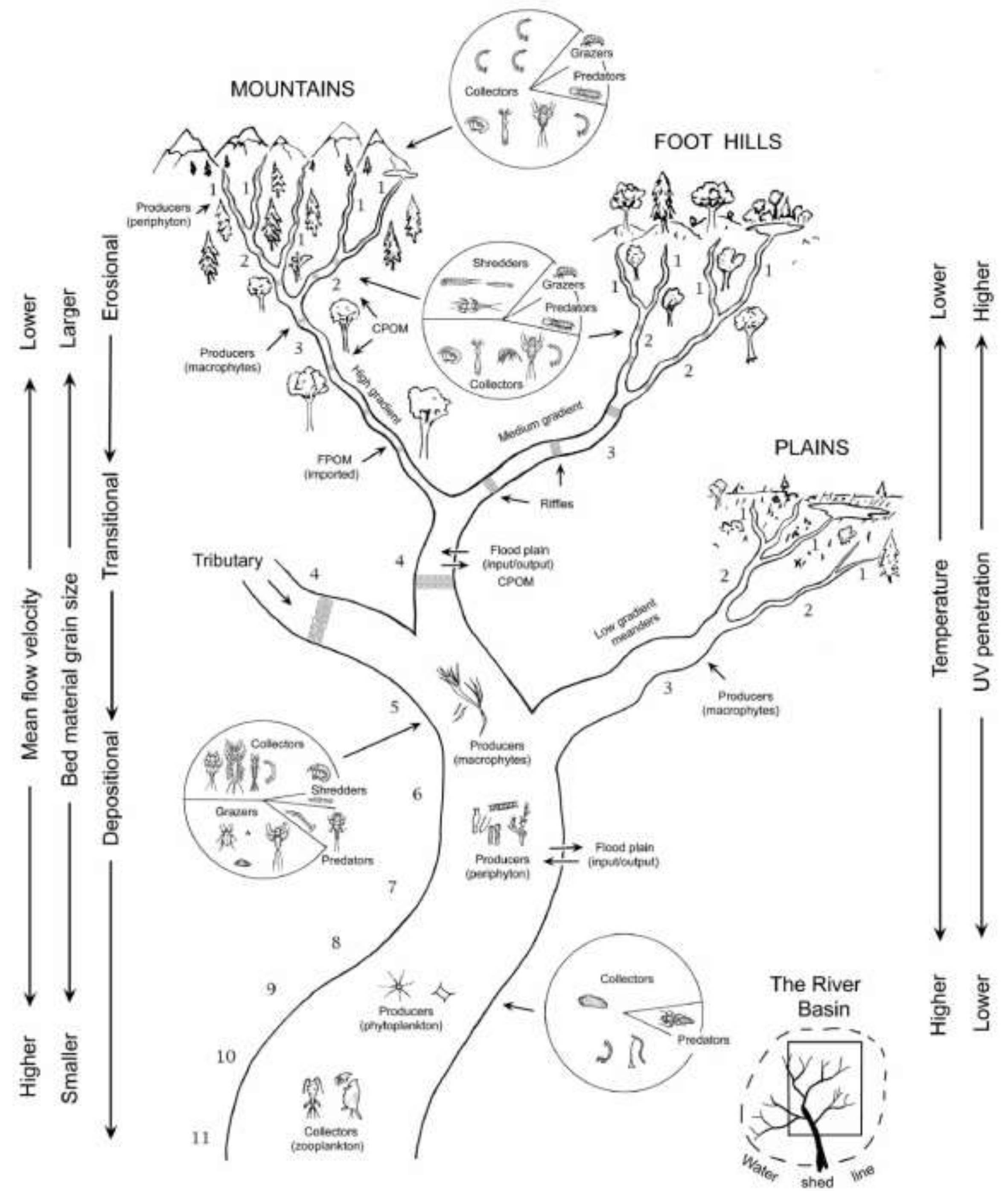


The River Continuum Concept (RCC)

Throughout the continuum of the river, the proportion of the four major organism types change -

- shredders
- collectors
- grazers (scrapers)
- predators

With the exception of the predators, all these organisms feed directly from plant material



Biological Types and Food Types

Predators are organisms that eat each other and the following organisms –

Shredders are organisms that feed off of coarse particulate organic material (CPOM) such as small sections of leaves. They ingest the organic matter along with volunteer organisms (fungi, microorganisms) attached to the source. The preferred size of the CPOM is about one millimeter, therefore shredders must break it up into a finer particulate. In the process of shredding, much of the now fine particulate organic matter (FPOM) is left in the system, making its way further downstream. Some common shredders of North American waters include the mayfly and stone fly larvae

Collectors are designated by their use of traps or other adaptive features to filter and catch organic matter. The preferred particle size for collectors lies between 0.5 and 50 micrometers (UPOM = Ultrafine particulate organic matter and FPOM). This group includes fly larvae, nematodes, and many other animal groups.

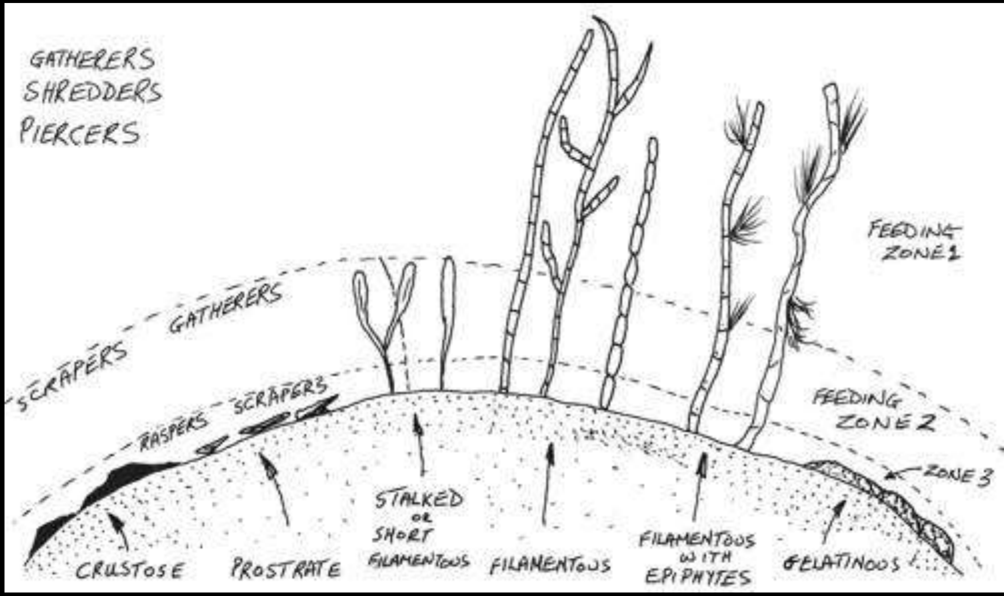
Grazers (scrapers) feed off of periphyton that accumulates on larger structures such as stones, wood or large aquatic plants. These include snails, caddisflies, and other organisms.

Surface Habitat

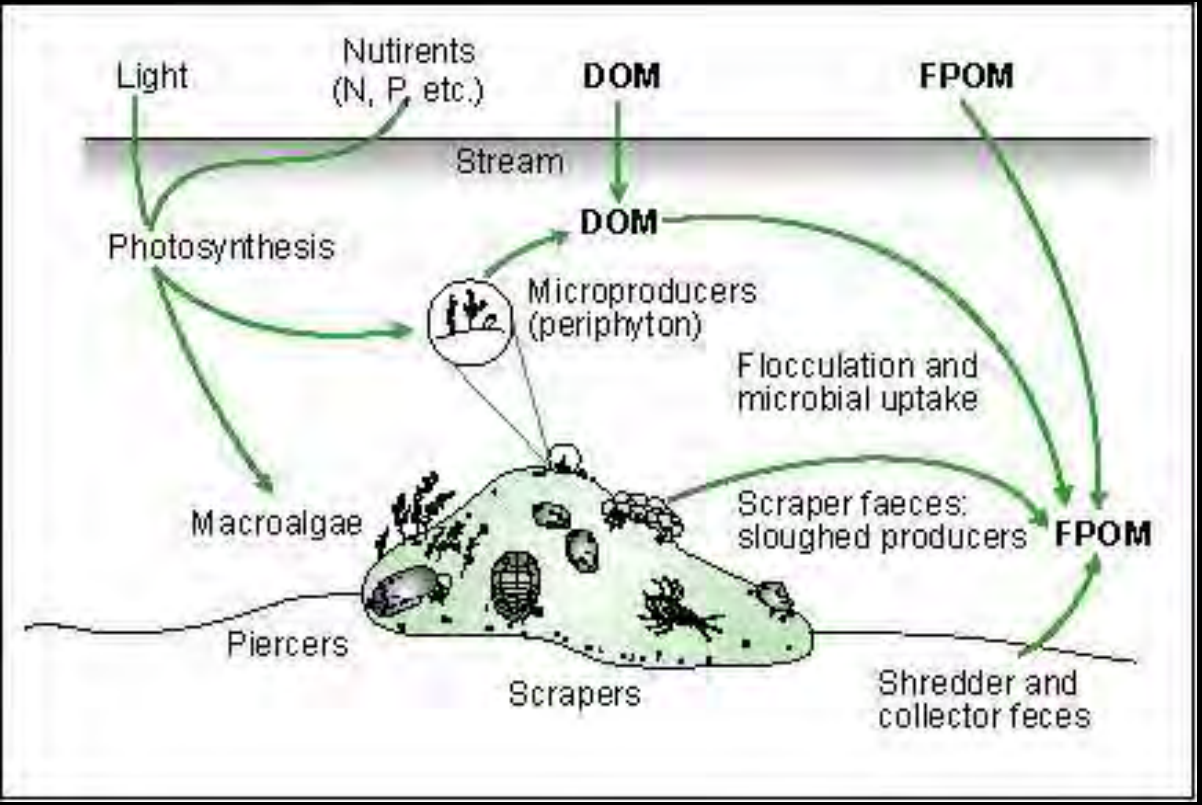
Periphyton is a complex mixture of algae, cyanobacteria, and detritus that are attached to submerged surfaces in most aquatic ecosystems.

The three zones of Periphyton on stones ⟶

Zones relate to the ability of the animals to consume the material



Surface Habitat



By a variety of mechanisms, the periphyton-bacteria-organic microlayer on substrate surfaces is scraped or browsed.

Diatoms are a prominent constituent of this matrix. Small Trichoptera larvae (Hydroptilitae) pierce the cell walls of macroalgea and suck out cell fluids.

Subsurface Habitat

The Hyporheic Zone

Streams exchange water, nutrients, and organisms with surrounding aquifers.

The interstitial, water-filled space beneath river beds, where most active aquifer-river water exchange occurs, is termed the hyporheic zone, and is an important habitat for a number of aquatic organisms and for fish spawning.

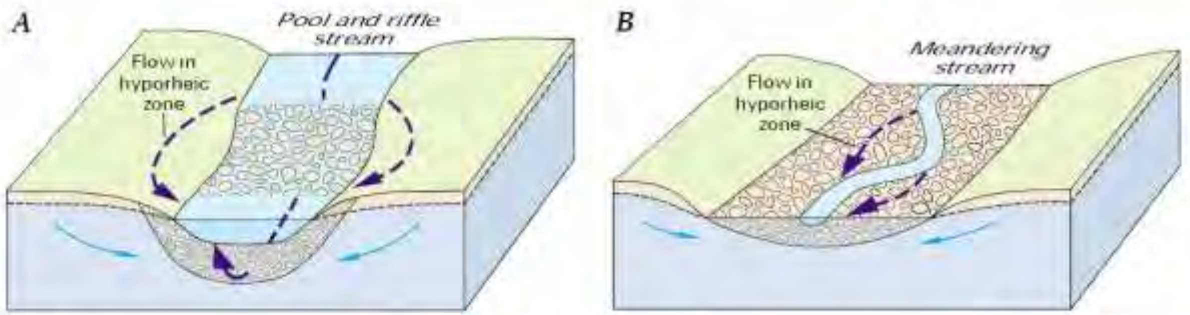
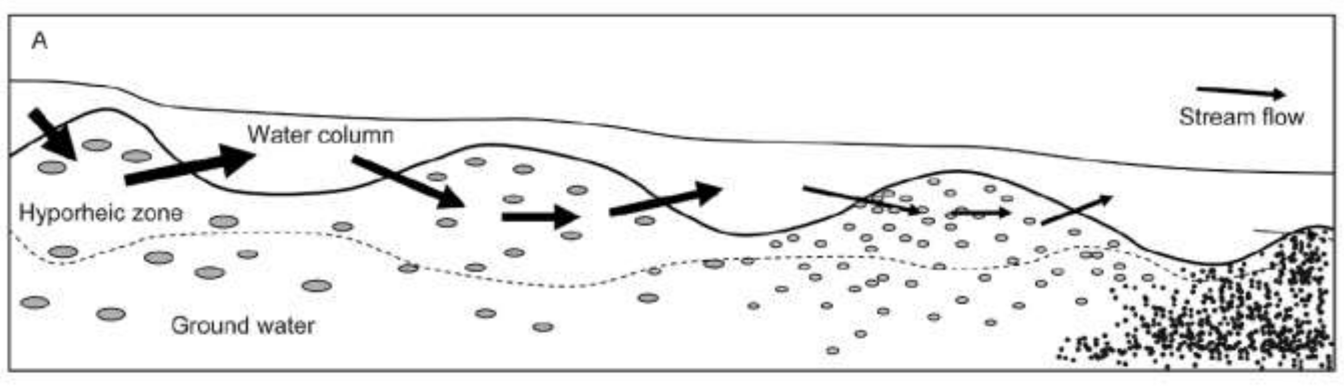
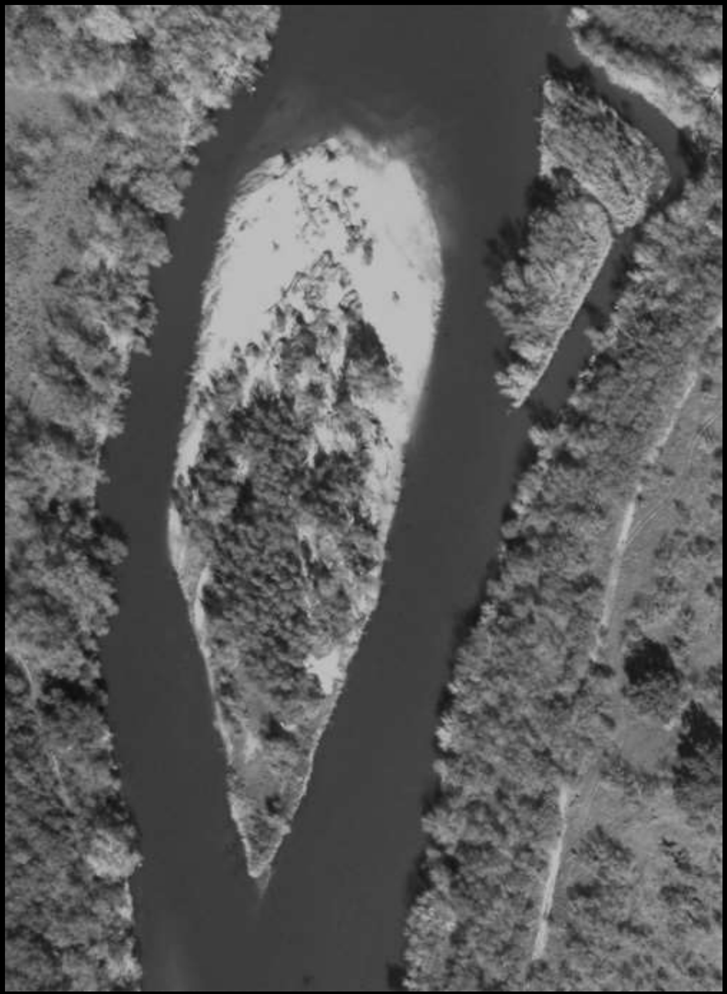
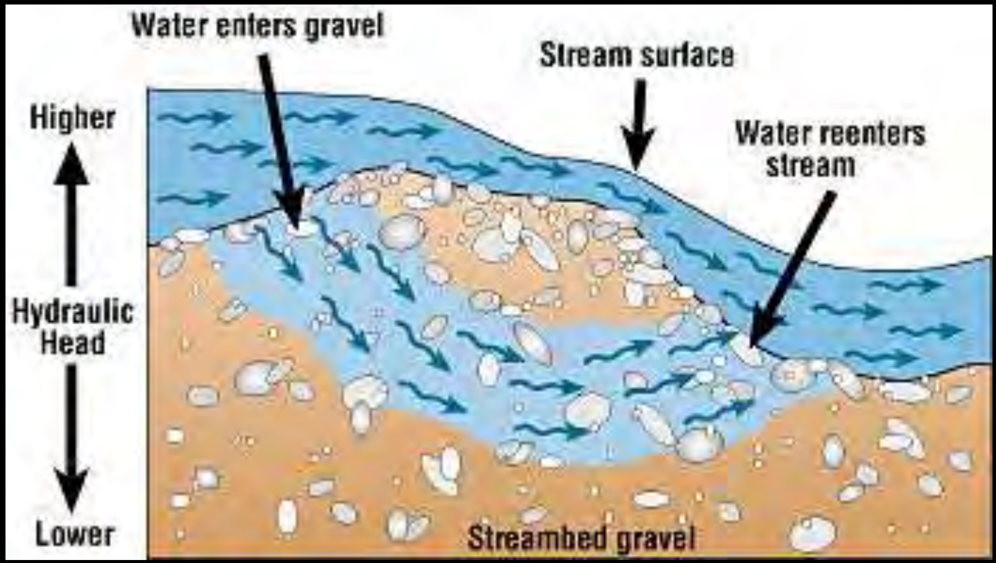


Figure 14. Surface-water exchange with ground water in the hyporheic zone is associated with abrupt changes in streambed slope (A) and with stream meanders (B).



The Hyporheic Zone





The Hyporheic Zone Research at Hornsby Bend

THE UNIVERSITY OF TEXAS AT AUSTIN
JACKSON
SCHOOL OF GEOSCIENCES

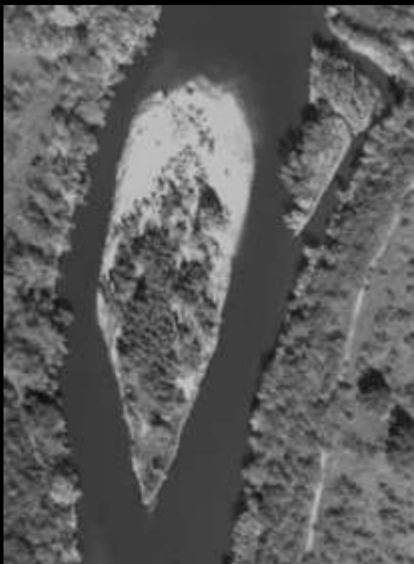
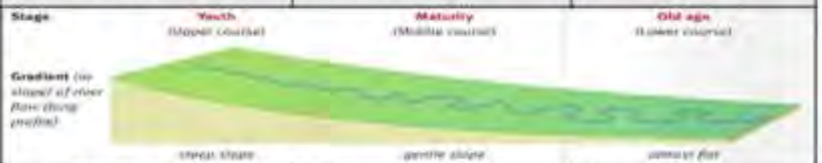
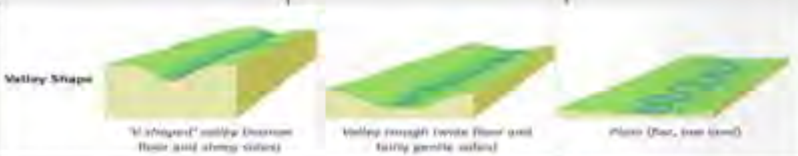


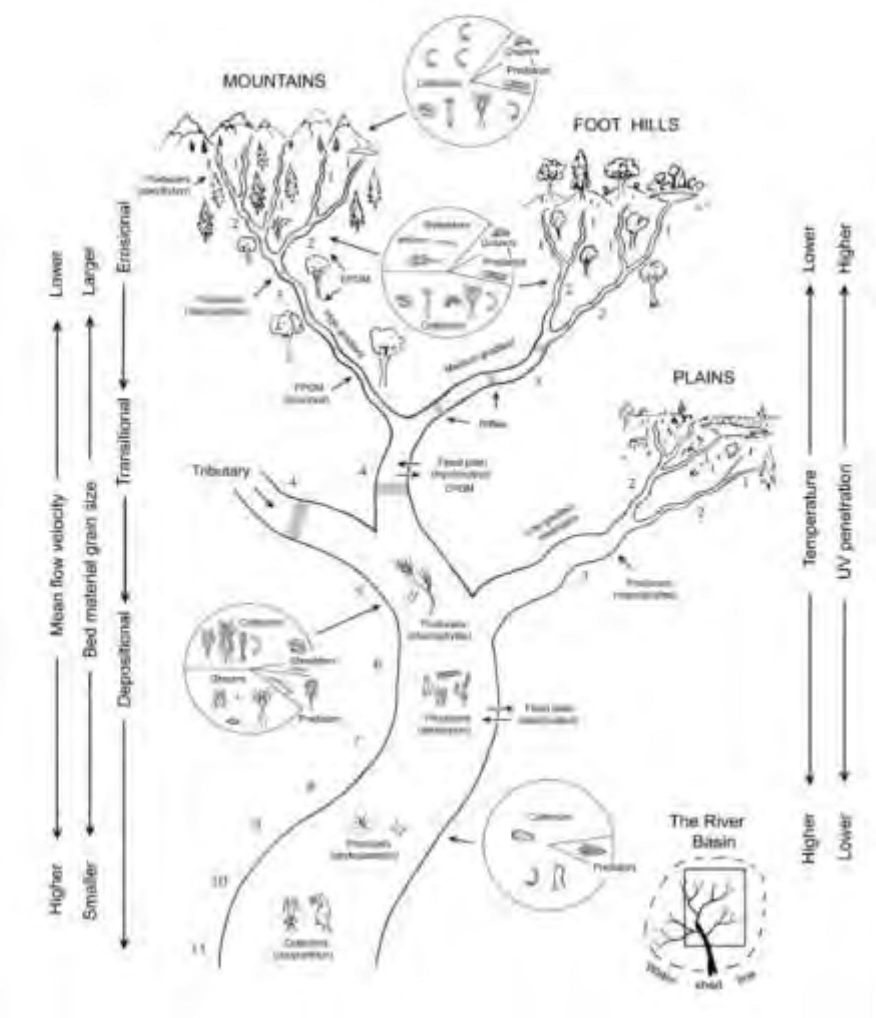
Figure 1. Location of study site on the Colorado River in relation to Austin, Texas, USA. USGS gaging station 08158000 is 2 km downstream from Longhorn dam, and the study site is another 13 km downstream

Figure 2. Map of Hornsby Bend piezometer transect. Bank piezometers are numbered in order of distance from the river, and the river stage recorder is denoted as (R). Dashed lines indicate the estimated extent of dam influence on the water table

The Life of a River

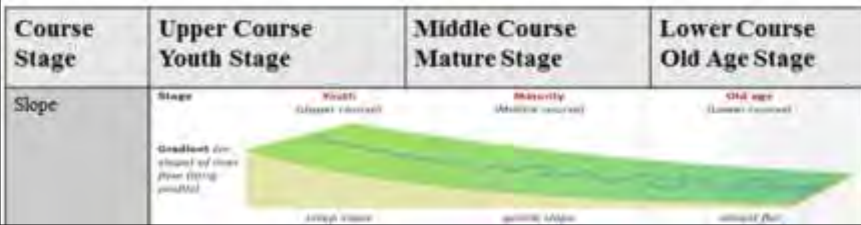
The Geography of Fluvial Life

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)



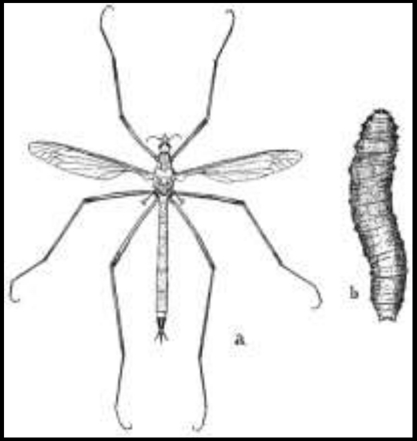
The Upper Course - Youthful Headwaters

Upper Course - Source



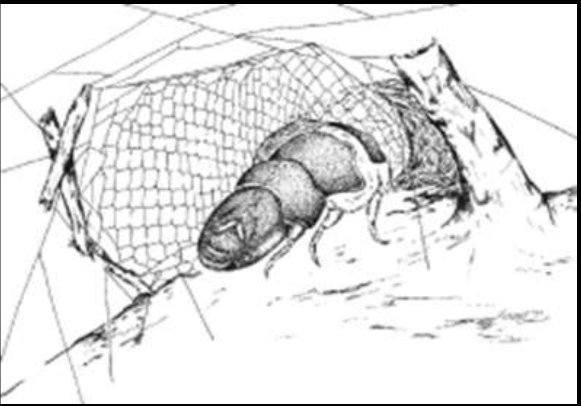
- River sources are usually small and, in the case of mountain streams, steep and erosional.
- In temperate environments, small streams tend to be shaded by an interlocking, overhead tree canopy.
- Such conditions result in cool, well-oxygenated streams that are abundantly supplied with a food base of leaves.
- Fine particles of organic matter are released as the leaves are broken down by biological communities in the streams

Upper Course Food Web



Leaf fall from the forest canopy in small streams are used by Shredders who get nutrition primarily from the fungi and bacteria that colonize the leaf surface. Craneflies, stoneflies, caddisflies and aquatic sow bugs are important members of this group.

Small fragments of leaves and feces from shredders are captured by another group of macroinvertebrates called Collectors - Netspinning caddisflies and blackflies are examples of this group.



The Leaf Pack Network is a network of citizens, teachers, and students investigating their local stream ecosystems.

- Create an artificial leaf pack and place it in a stream for 3-4 weeks.
- Collect and examine the packs in the classroom.
- Discover aquatic insects that indicate stream health, showing the connection between trees and streams.
- Share data through the network.

STROUD WATER RESEARCH CENTER

Leaf Pack Network

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.

Upper Course – Rapids and Pools

Macroinvertebrate communities in rapids are typically more diverse than communities in pools.

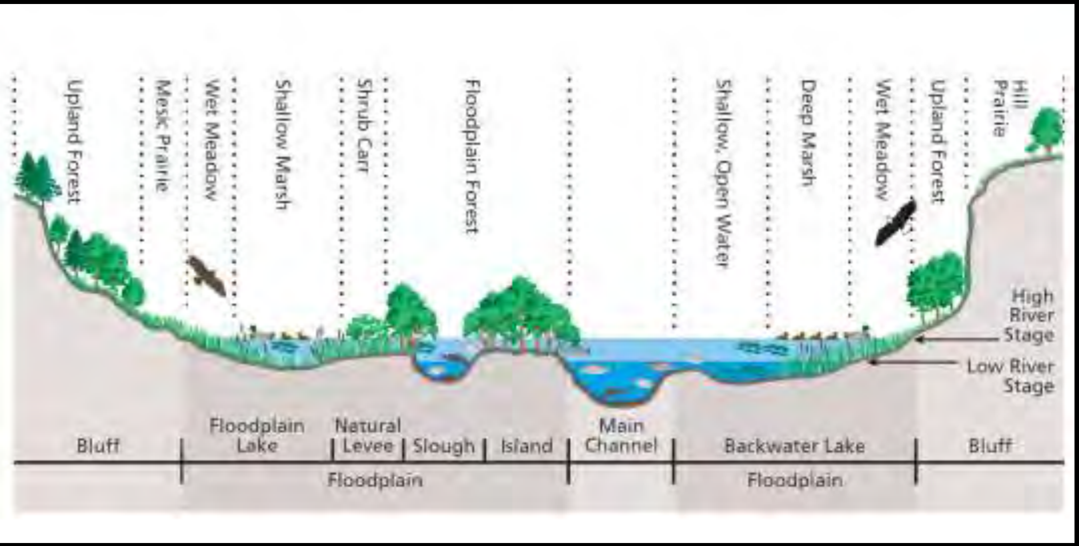
The pattern in fish communities is reversed, with pool fish communities tending to be more diverse than those in rapids.

Brook trout – state fish of PA and Laurel Run, Perry County, PA

The Middle Course: Life in the Meander Belt

Habitat Diversity

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

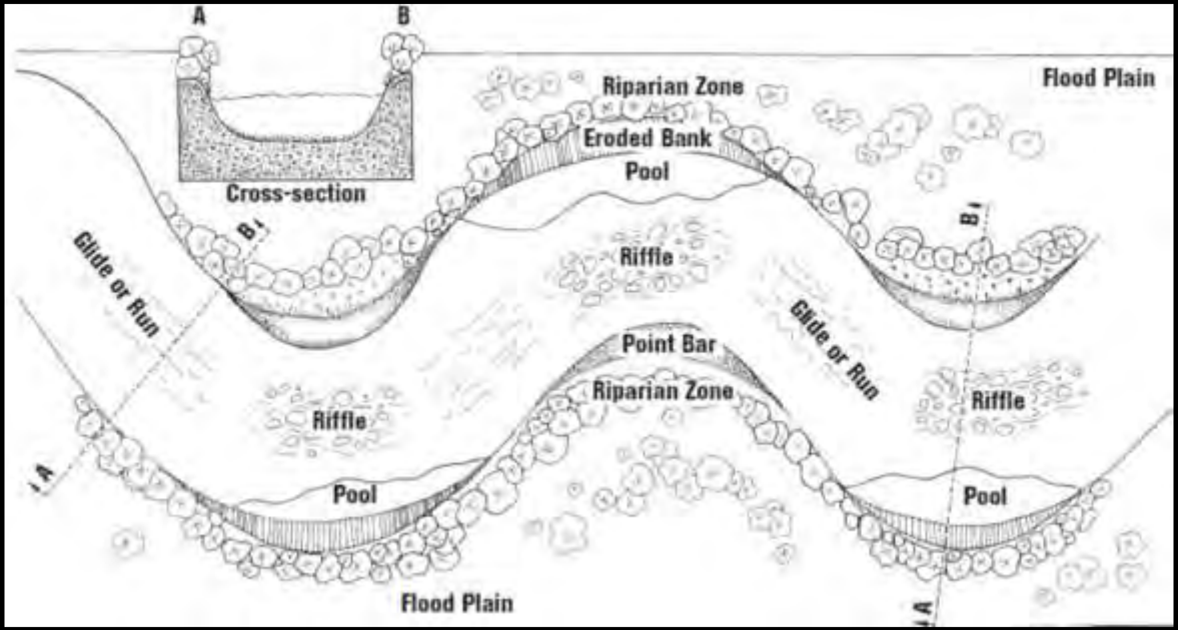


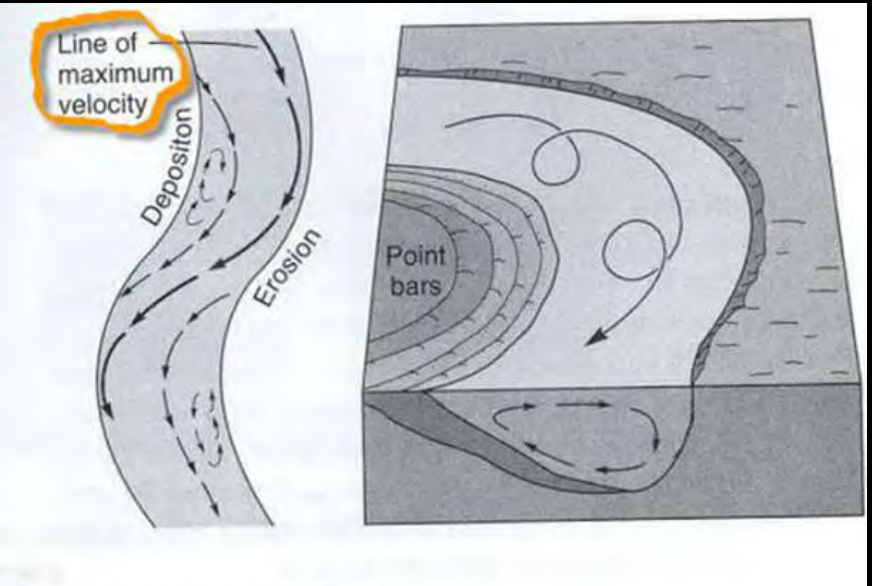
The Middle Course

Wider Channel = More Solar Energy

- At some point along their path to the sea, rivers have typically gained enough water and width to preclude interlocking tree canopies.
- Streams at this point are warmer and less abundantly supplied with leaves than was the case upstream.
- Open canopy, and fairly shallow water, means that light can reach the river benthos, increasing in-stream primary productivity.

Aquatic Life Worlds: Erosional Zone and Depositional Zone





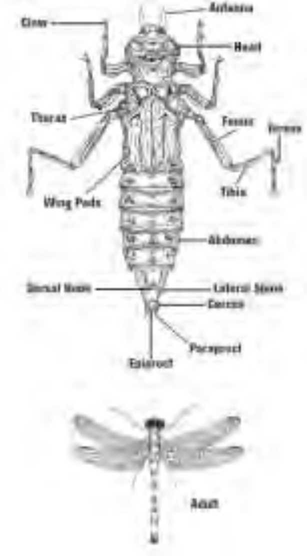
Helical flow in a meander.

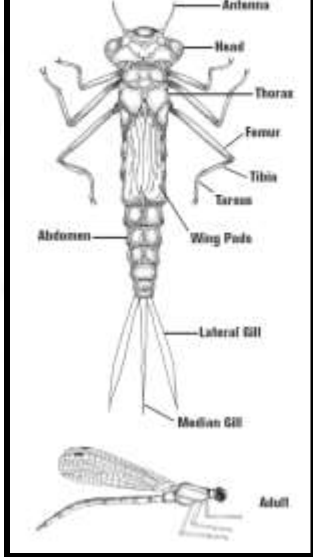
Erosional and Depositional Zone – Pools

A pool is relatively deep and wide with slow-moving water compared to riffle, run, or glide areas. Pools often contain large eddies with widely varying directions of flow compared to riffles, glides, and runs, where flow is nearly all downstream.

Deposition - Reduced velocity allows suspended materials to settle to the bottom. Sediment in most pooled areas of streams and rivers is composed of sand, silt, clay, and organic matter, compared to the coarser sediment of riffles, runs, and glides.

The slower-moving water supports organisms similar to those found in lakes and pond systems (dragonflies, damselflies, water striders) and shelter fish out of the strong downstream flow.



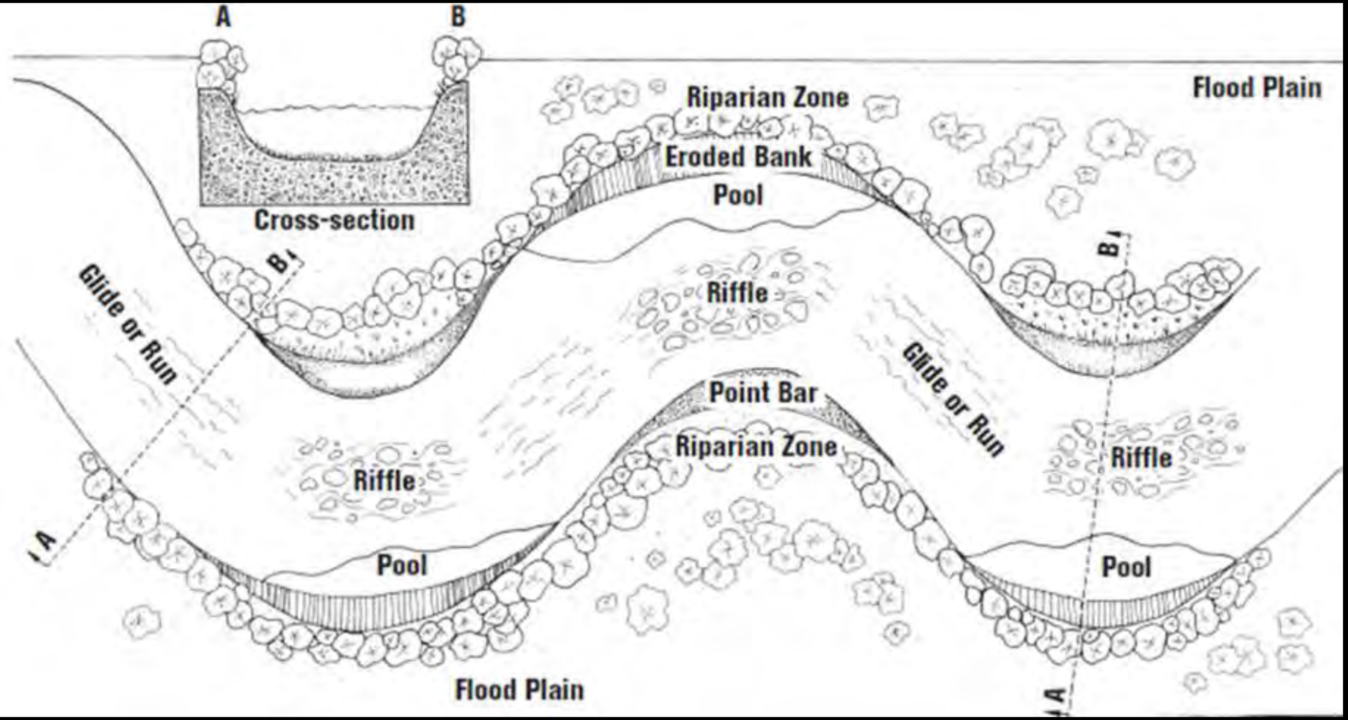


Erosional Zone – Riffles

Riffles are the shallow portions of a stream characterized by relatively fast-moving, turbulent water with bottom materials composed of cobble, gravel, or bedrock.

Riffle areas of streams are important habitats for many aquatic insects and small fish that require flowing water for feeding and high oxygen levels

Few plants grow in the fast-moving water of a stream, but some may be adapted for living in the current of smaller streams. Riffle areas commonly support those organisms adapted to life in fast-moving waters, such as algae, plants, and invertebrates that can anchor themselves to rocks, logs, and other stream debris. (mayflies, caddisflies, riffle beetles, water pennies)



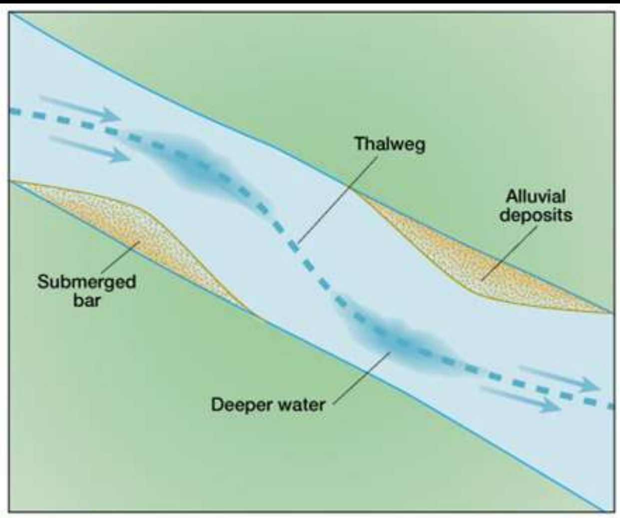
Erosional Zone – Runs and Glides

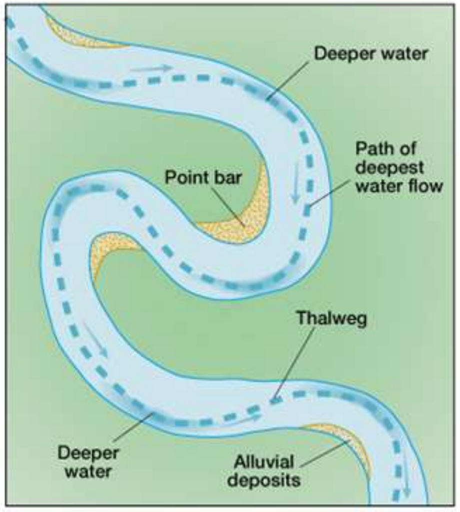
Some fish prefer the fastest part of a stream (darters). Many fish spawn in the riffles of streams.

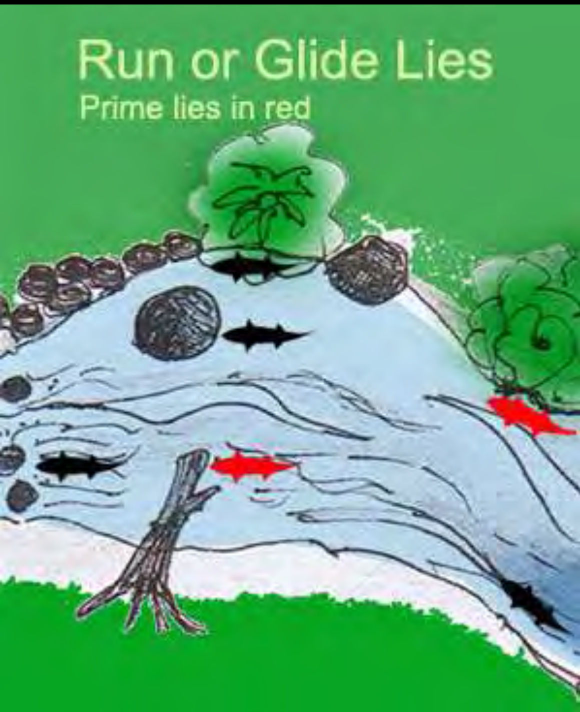
- Glides and runs are intermediate habitat types that fall between riffles and pools.
- A glide is an area where the flow is characterized by slow-moving, nonturbulent flow referred to as laminar, similar to that in a shallow canal. A glide is too shallow to be a pool, but the water velocity is too slow to be a run.
- A run is a relatively shallow portion of a stream characterized by relatively fast-moving, nonturbulent flow.

Depositional Zone – Gravel Bars

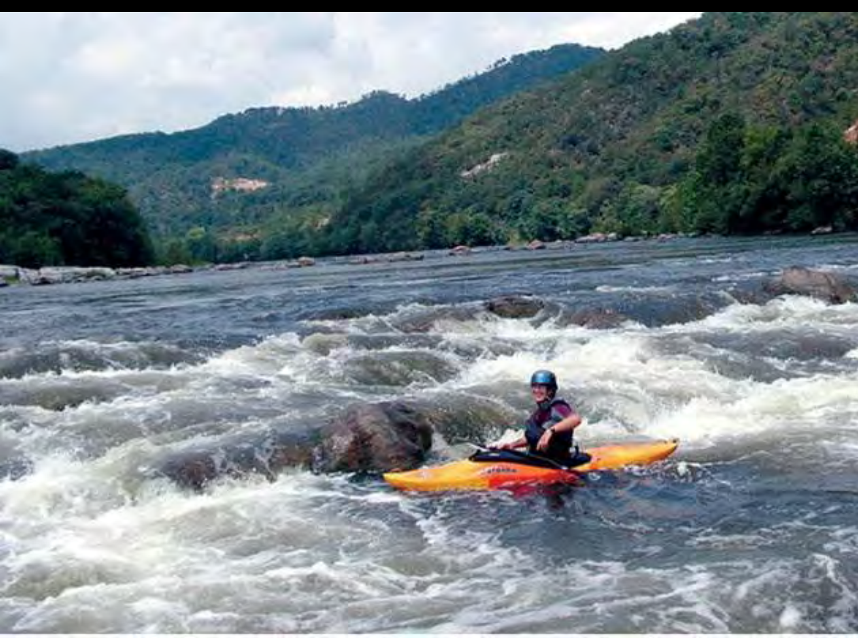
- The depositional zone refers to the inner bank of a stream where velocity is at a minimum.
- The slower velocities allow for the deposition of suspended sediment and bed materials (gravel, pebbles), which form bars.
- These bars often support emergent aquatic vegetation and, as the bars grow larger, they are colonized by terrestrial plants and trees, to form islands.

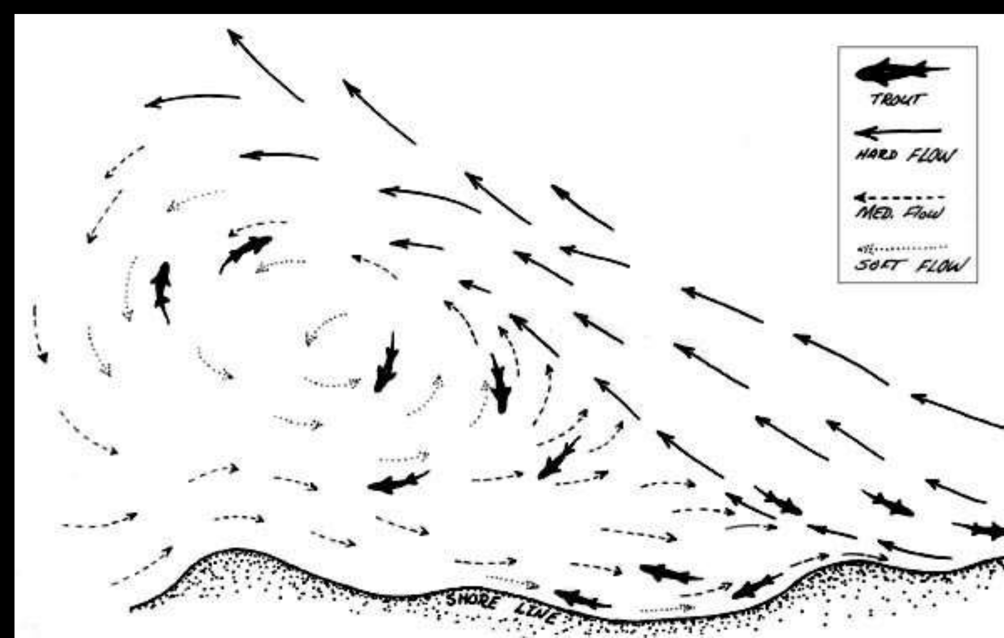






Eddies are currents that move in a direction other than downstream, usually in a circular motion.





Aquatic Stream Habitats

General Aquatic Habitat Types	Characteristics	Description
Lotic–erosional	Flow	Relatively shallow area of a stream. Three areas defined by flow: Riffle–fast-moving, turbulent water Run–fast-moving, nonturbulent water Glide–slow-moving water
	Sediment	Coarse sediment comprised of cobble, pebble, and gravel
	Aquatic plants (macrophytes)	Plants typically grow on or in coarse sediment (pondweed)
	Aquatic animals	Aquatic insects and small fish that require high oxygen levels, flowing water for feeding, and are adapted to living in swift water through the ability to swim or cling to rocks in riffle areas
	Organic materials (detritus)	Comprised of leaf litter, twigs, and other coarse particulate matter, usually trapped in stream riffles behind large rocks or logs; also known as *leaf packs*
Lotic–depositional	Flow	Relatively deep and wide with slow moving water compared to riffles, runs, or glides
	Sediment	• Primarily found in pools and backwater areas of streams • Fine sediment comprised of sand and silt
	Aquatic plants (macrophytes)	Submergent vegetation growing in fine sediment *(Hydrilla, Potamogeton)*
	Aquatic animals	• Organisms similar to those found in lakes and pond systems (dragonflies, damselflies, water striders) • Many fish use the deeper water of the pools and areas along the banks for cover and find food easier to catch in slower moving water
	Organic materials (detritus)	Comprised of leaf litter and other particulate matter found at the bottom of pools and backwater areas of streams

Adapted from Merritt and Cummins, 1995.

Diversity of Life in The Middle Course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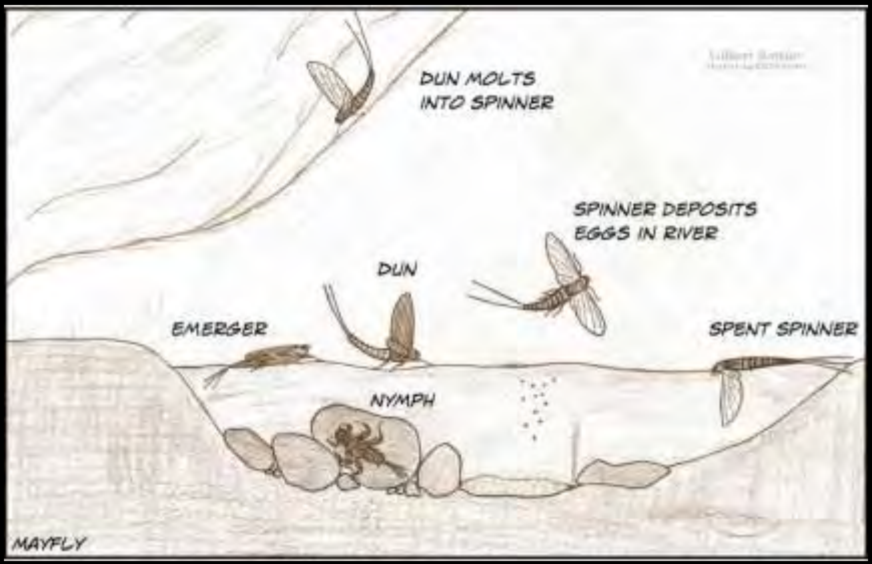
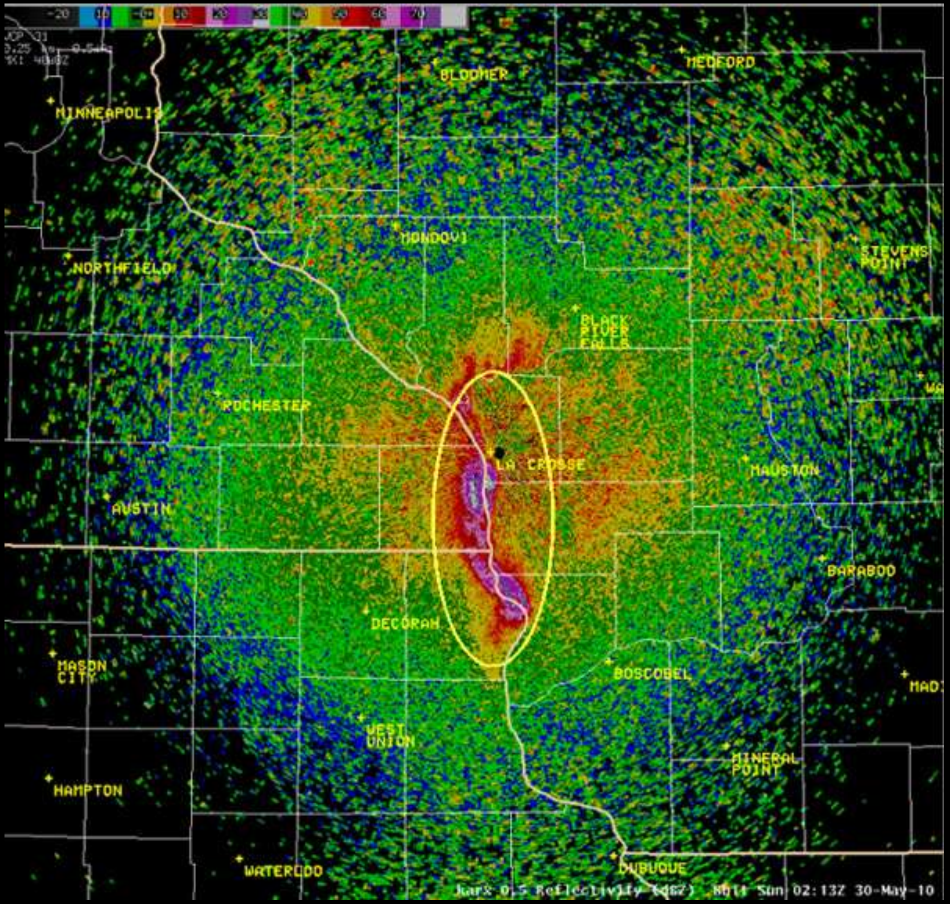
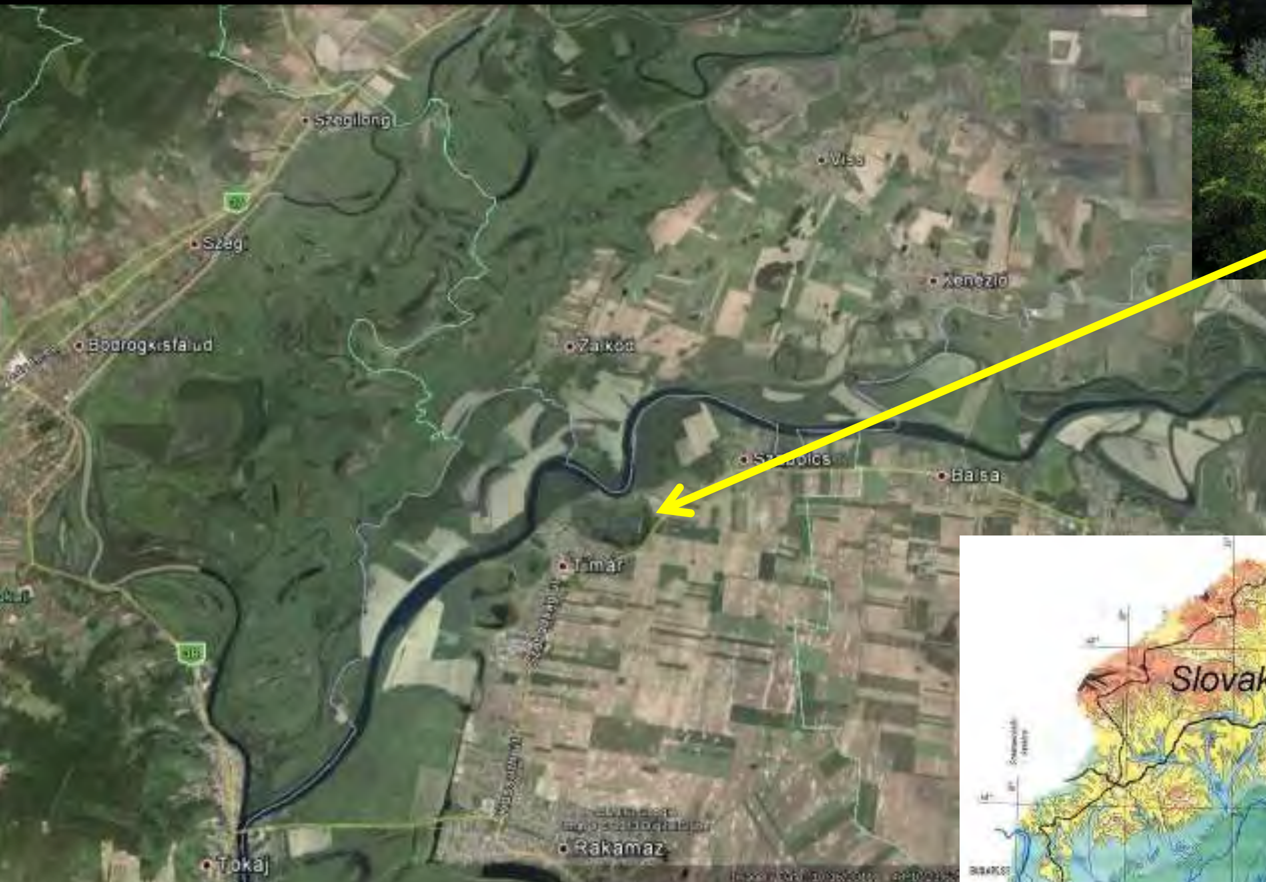


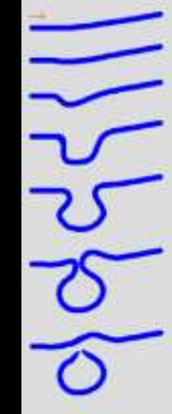


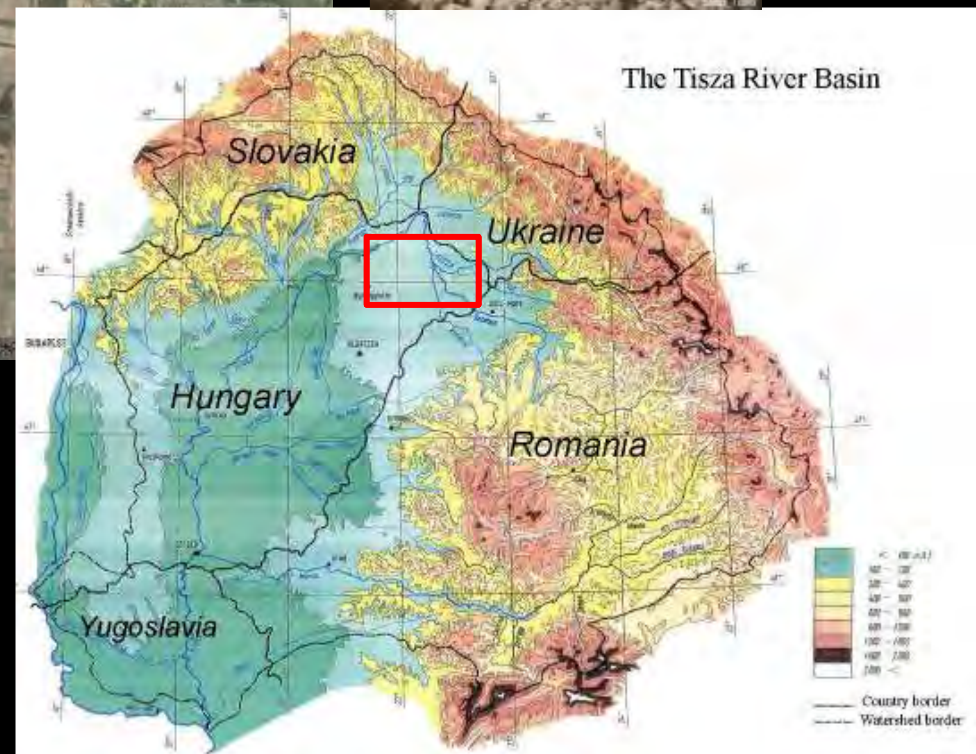
A mayfly mass emergence or hatch from the Mississippi river captured by the National Weather Service Doppler radar in La Crosse Wisconsin (USA) in May 2010

The adult mayflies in flight are represented by the bright pink, purple, and white.

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







The Bodrogköz lowland region lies between the Bodrog and Tisza rivers. 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

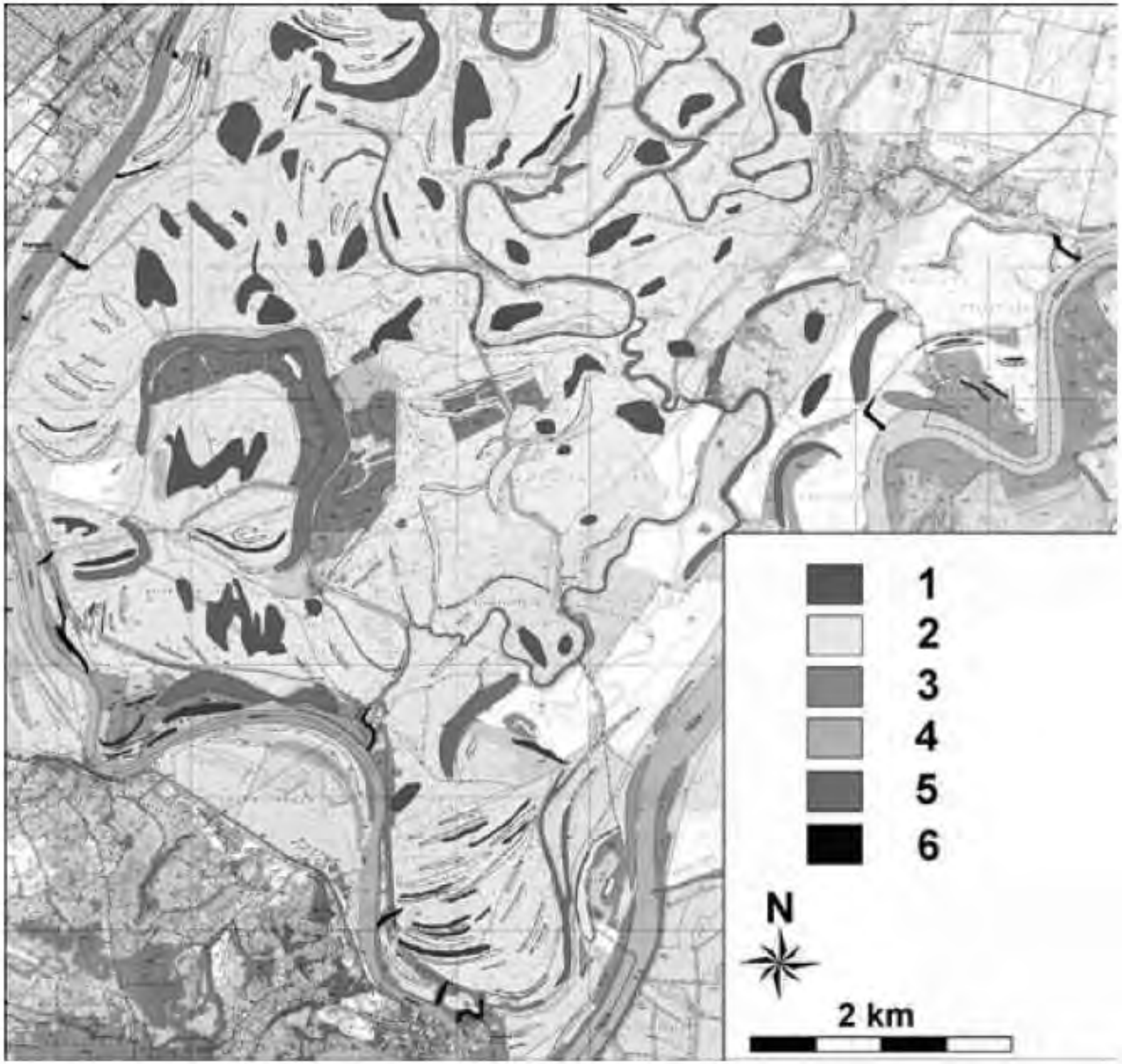
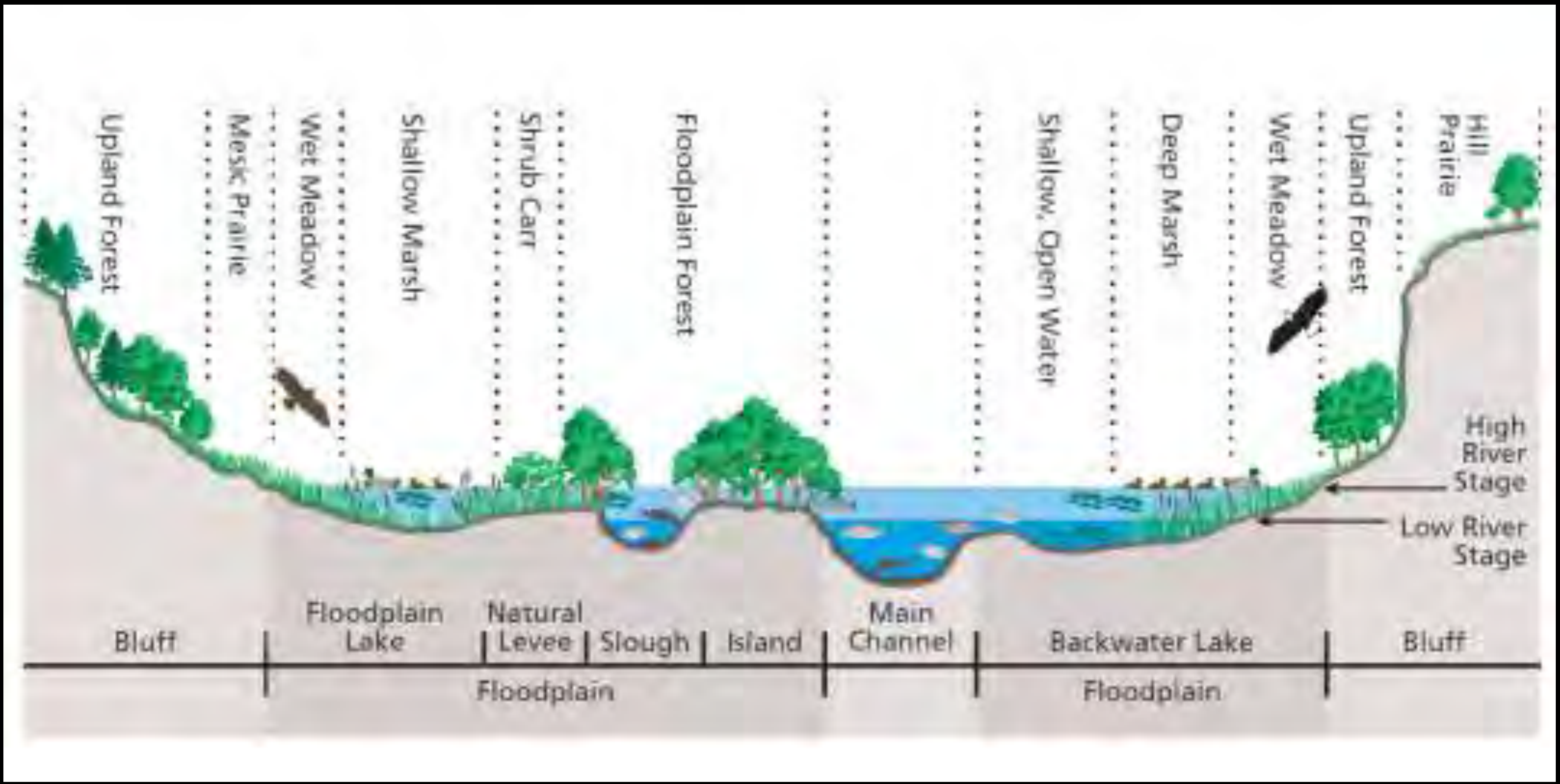


FIG. 2 - Landforms of the SW Bodrogköz (In: Szabó & *alii*, 2004). 1: fluvial ridge, 2: swale, 3: abandoned cut-offs, 4: present natural levee, 5: backswamps, 6: (remnants of) one-time flood-plain ditches.

The Middle Course: Life in the Meander Belt

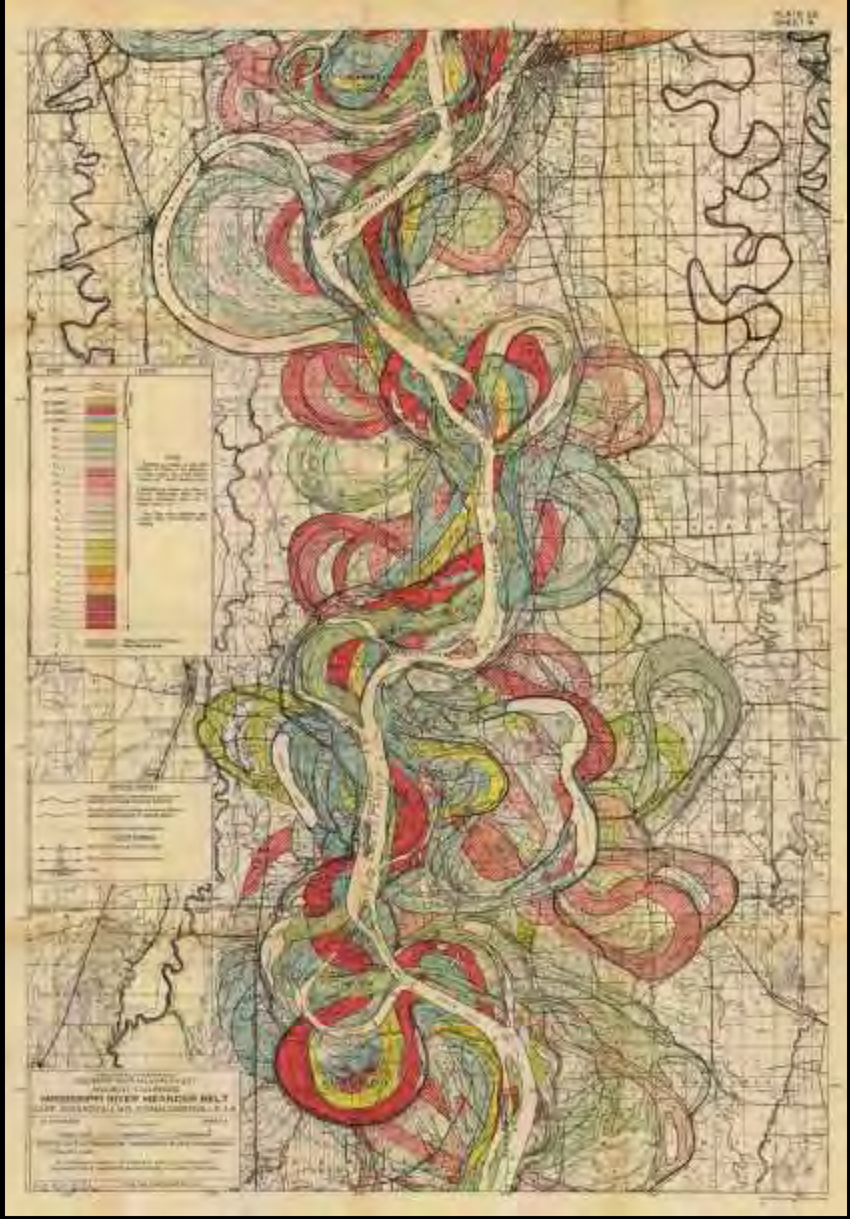
Habitat Diversity = Biodiversity

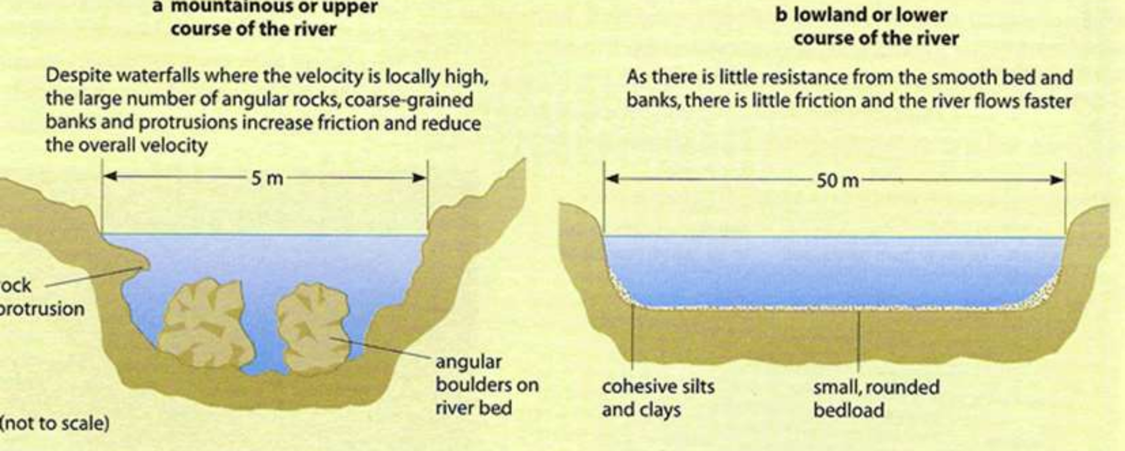


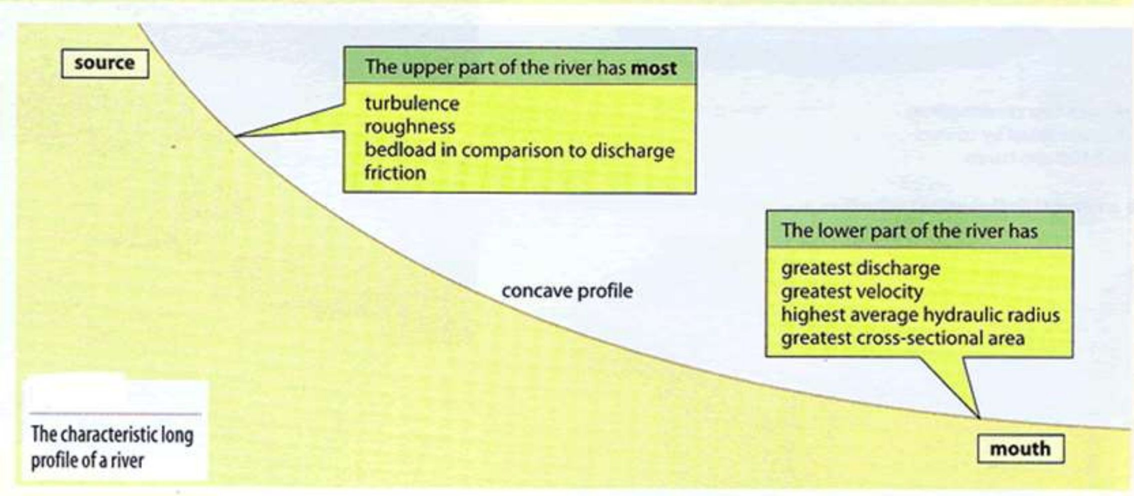
The Lower Course: From River to Sea
Old Age and Final Extinction

- Very large rivers are usually low gradient and very wide, resulting in negligible influence of riparian canopy in terms of shading and leaf-litter input.
- Water currents keep fine solids in suspension, reducing light penetration to the benthos.
- Organic matter in suspension is by far the largest food base in these very large rivers.
- Larger alluvial rivers in their natural state are diverse habitats with side channels, sand and gravel bars, and islands that are formed and reformed on a regular basis. →

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.

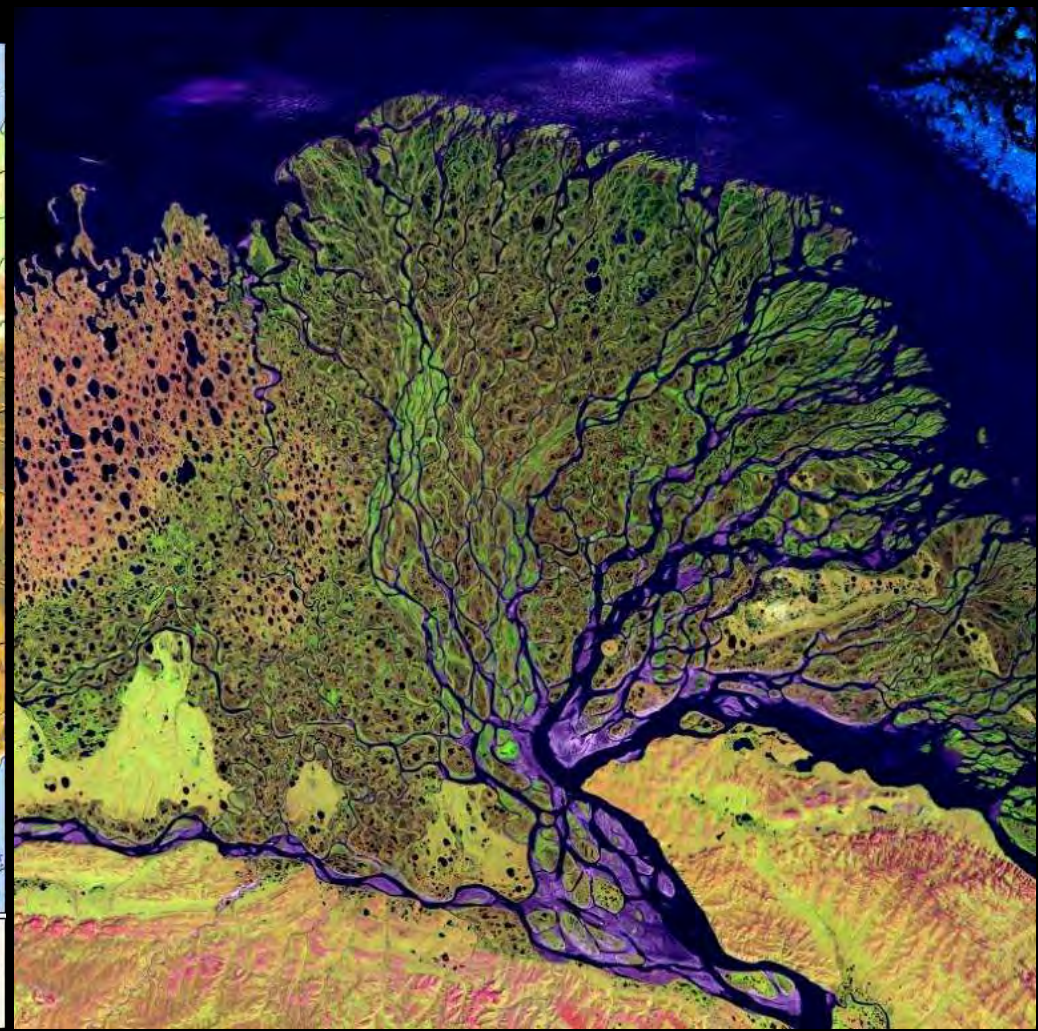
Analysis of some of the large number of velocity measurements made at stream-gaging stations demonstrates that mean velocity generally tends to increase downstream.

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

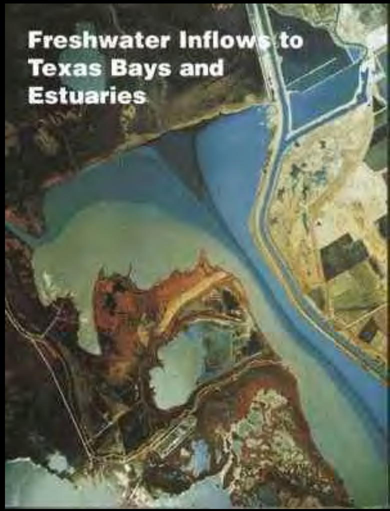
This downvalley decrease of shear implies decreasing competence downstream.

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

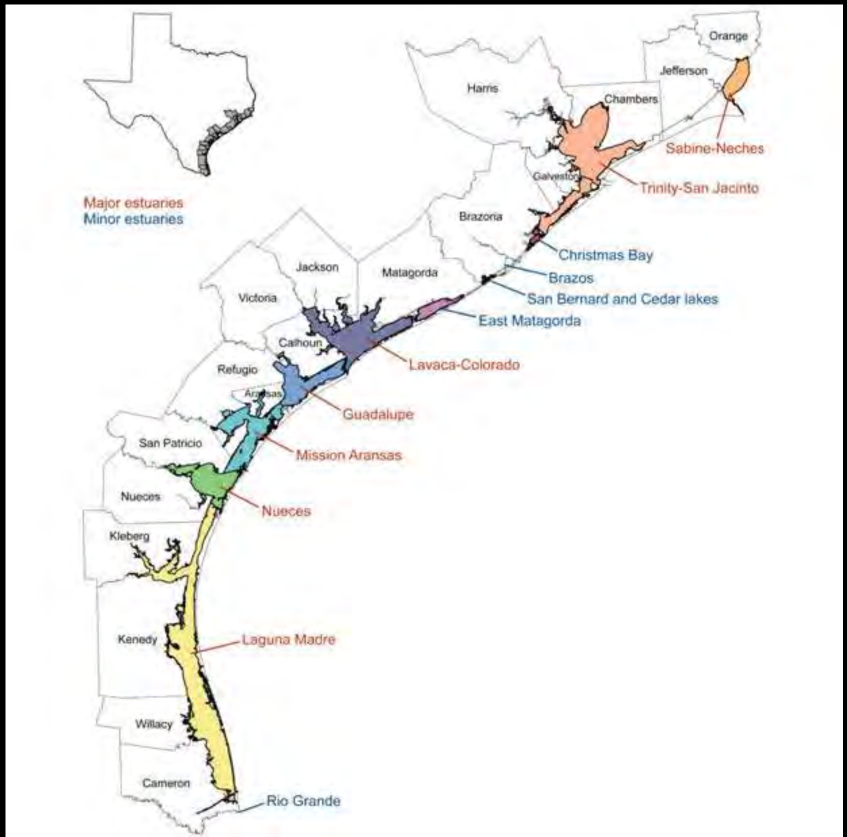
- At the end of the Lena River there is a large delta that extends 100 km into the Laptev Sea and is about 400 km (250 mi) wide.
- The delta is frozen tundra for about 7 months of the year, but in May transforms the region into a lush wetland for the next few months.
- The Lena Delta Reserve is the most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



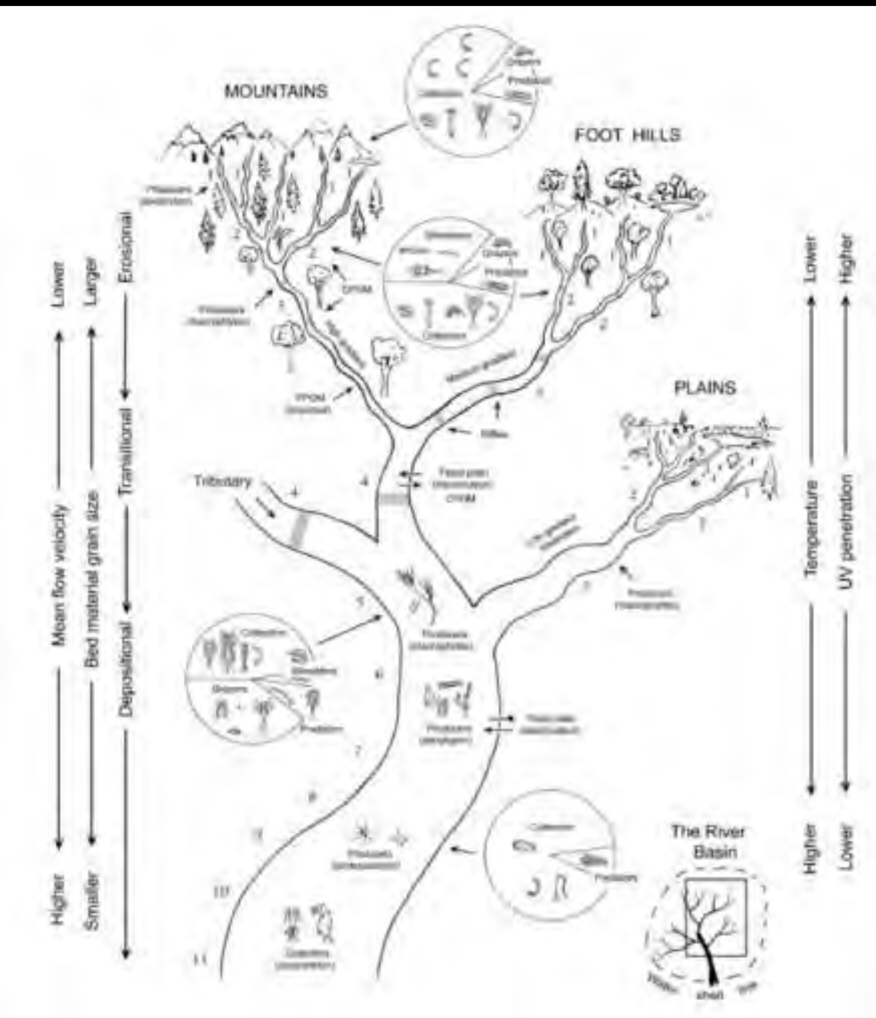
Estuary - An estuary is fresh water meets salt water and in Texas is a partly enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open sea.

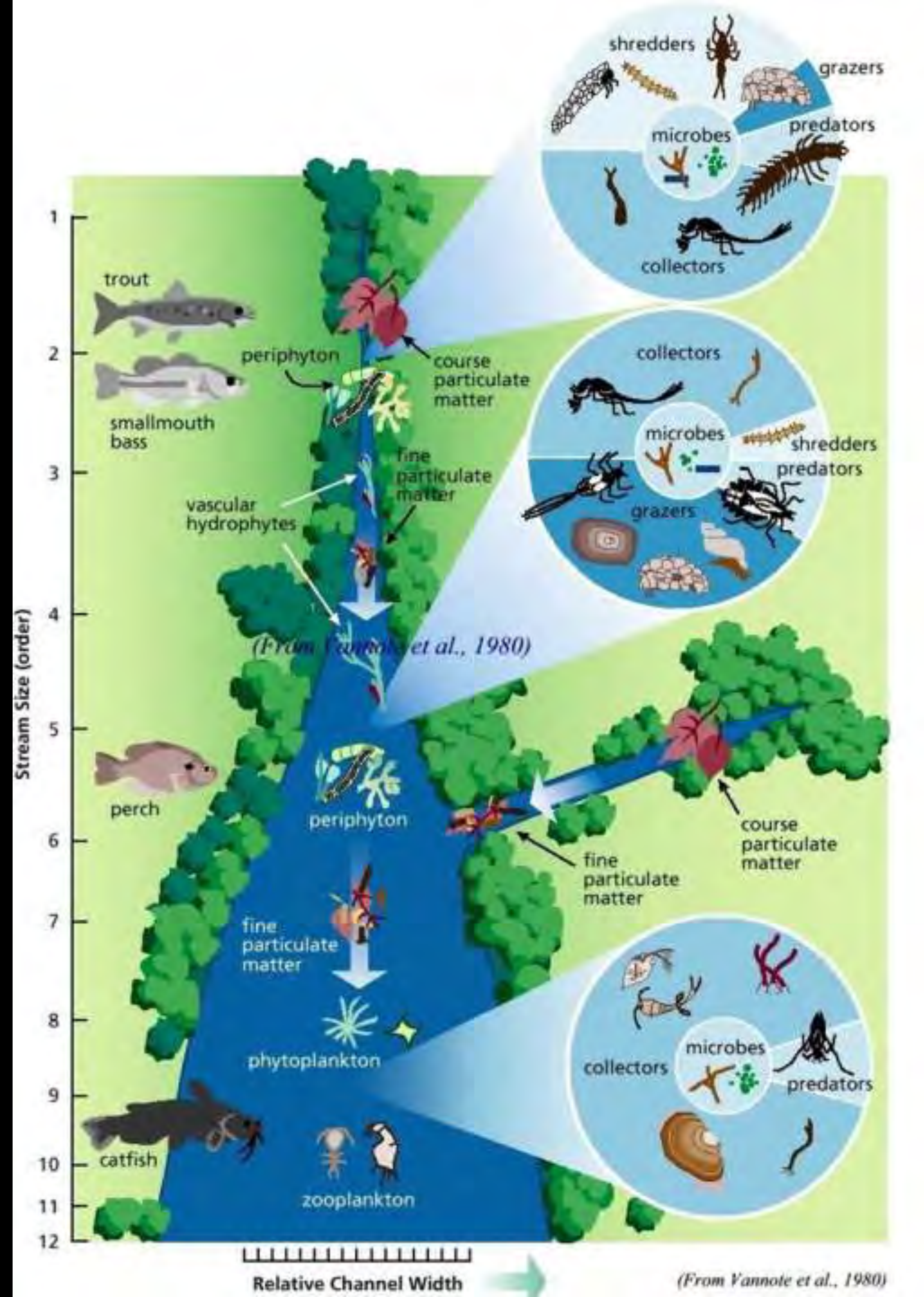


Estuaries form a transition zone between river environments and maritime environments and are subject to both marine influences, such as tides, waves, and the influx of saline water; and riverine influences, such as flows of fresh water and sediment. The inflows of both sea water and fresh water provide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

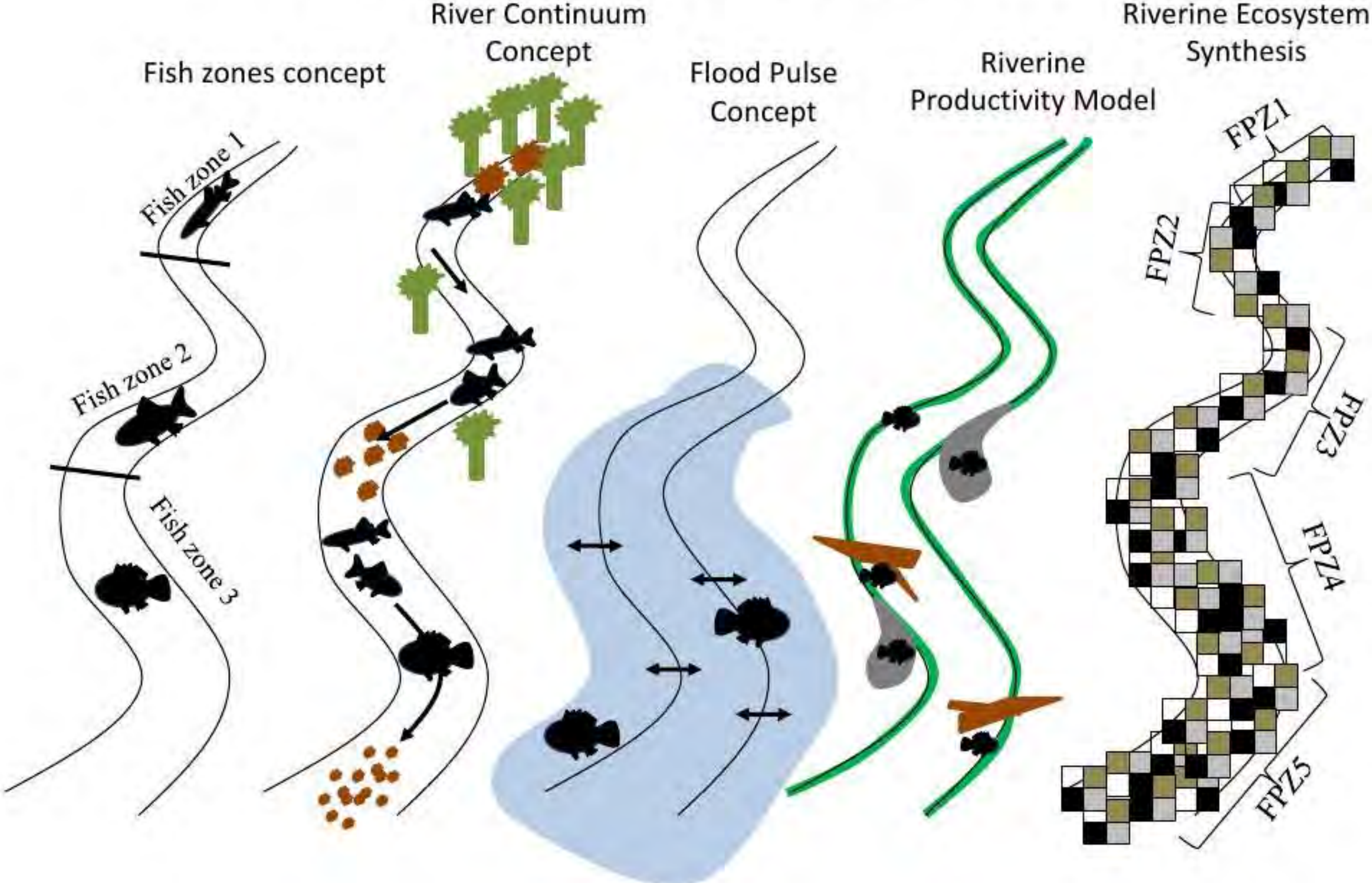


The River Continuum Concept [RCC]





River ecosystem concepts



The Serial Discontinuity Concept

The RCC is a model that might apply to pristine rivers, but few rivers remain unchanged or unaffected by human activities.

Dams are certain to have an impact on the organization of aquatic communities, since the flow is blocked and the longitudinal transition of conditions along the river is altered.

The dam creates a 'serial discontinuity' in the river because the gradual downstream transition in conditions is disrupted, and the longitudinal transfer of material is prevented.

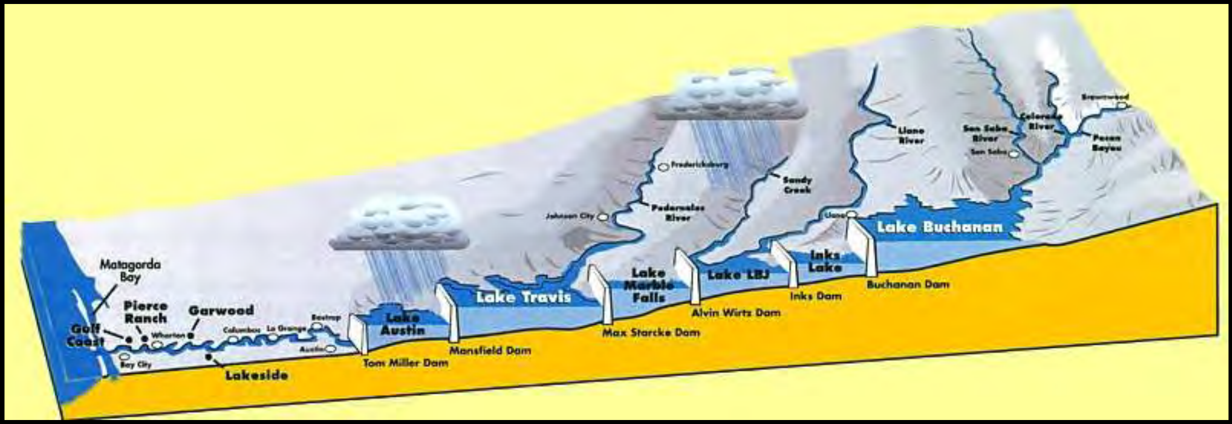
Suspended sediments are deposited behind the dam.

Water released from the dam will pick up a 'normal' sediment load downstream where it may erode the riverbed and banks.

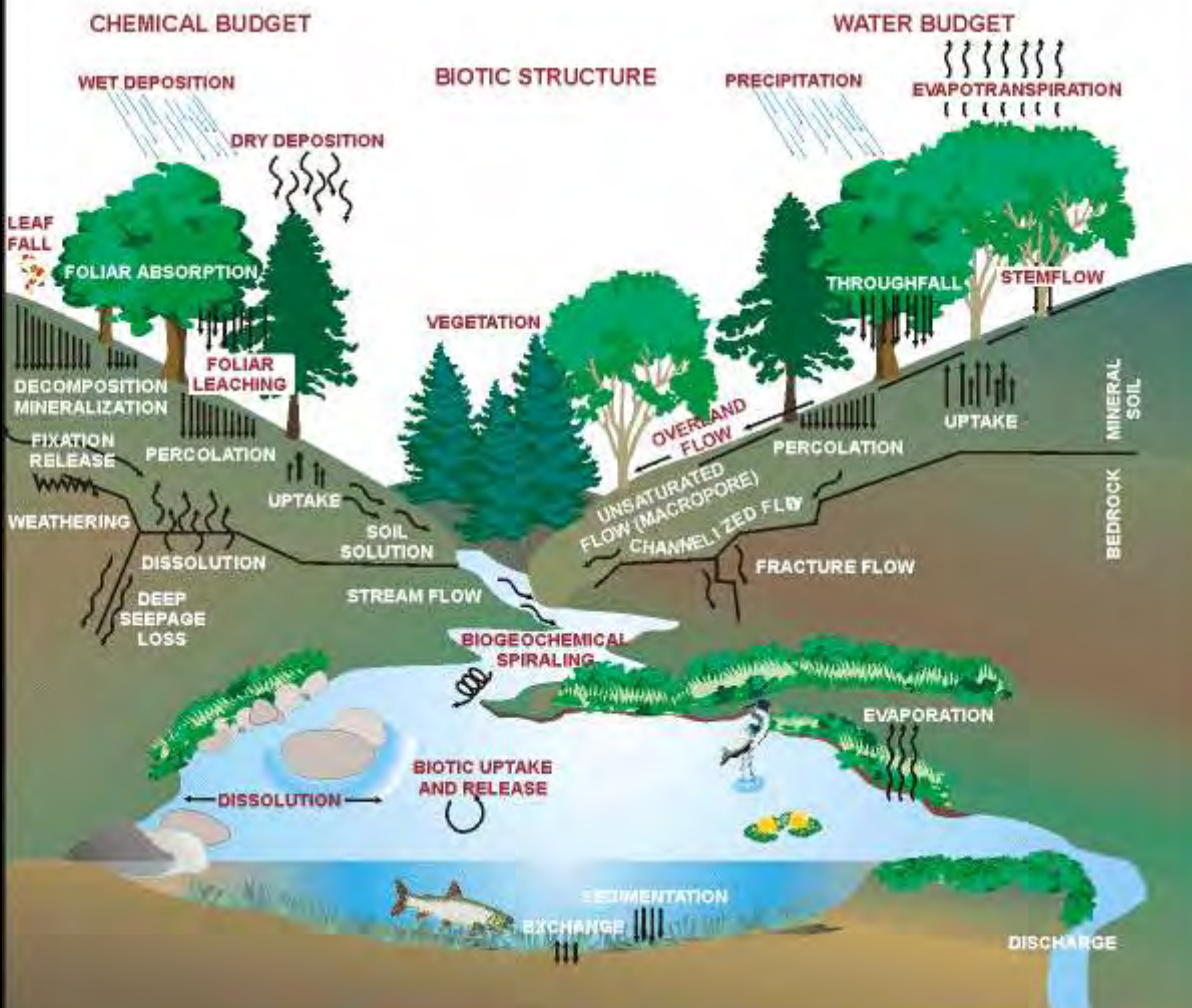
- The downstream transition of water temperature is altered, and water released from the dam may be either warmer (if it is taken from the surface) or cooler (if it is taken from the depths) than natural conditions. Concentrations of dissolved oxygen may be changed also.

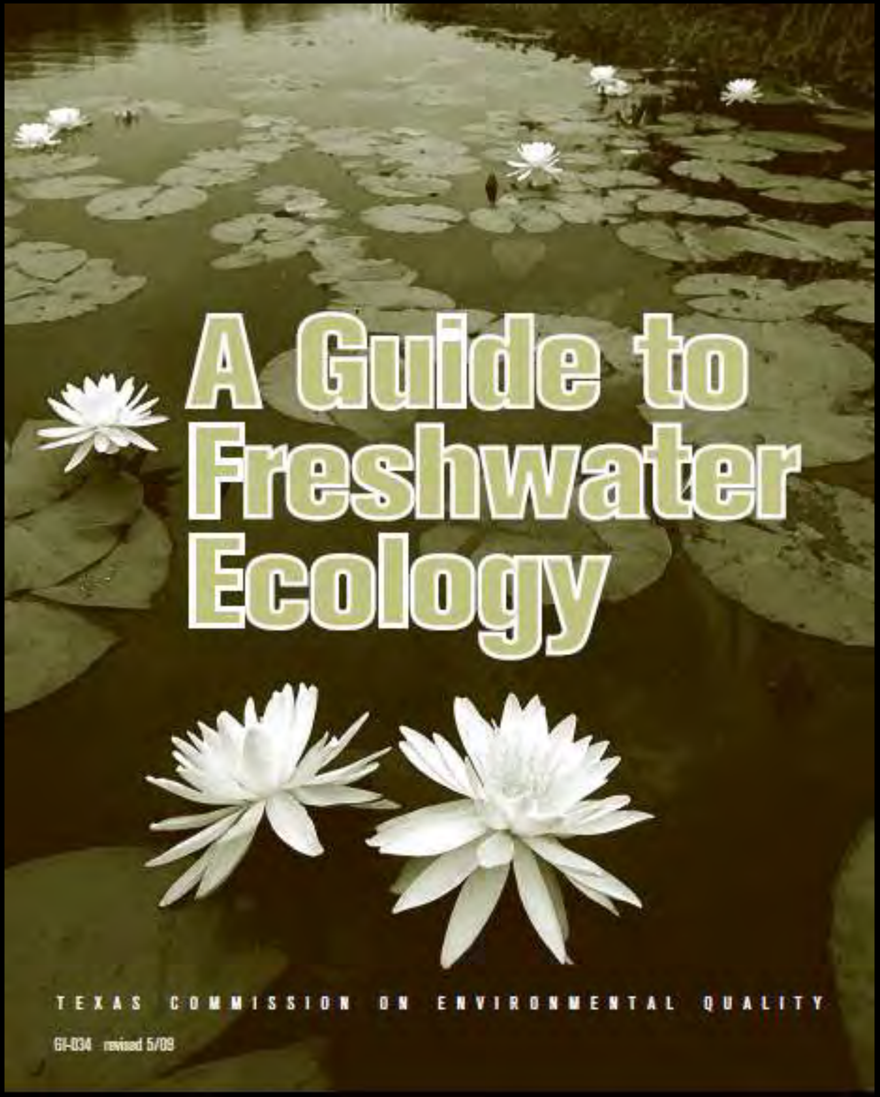
- Phytoplankton that develops behind the dam may be released downstream providing a food resource for filter-feeders that would be unavailable under natural conditions.

- The seasonal patterns of flow will be altered, especially if the function of the dam is to provide water for irrigation (in which case dry-season flows downstream will be reduced) or to control flooding (in which case wet-season flows and floodplain inundation will change).



WATERSHED ECOSYSTEM DYNAMICS




A Guide to Freshwater Ecology
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
GI-034 revised 5/09

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