

## Fluvial Geomorphology – the Shape and Function of the Verde River - ChatGPT – 3/5/23

“I” = Interviewer, “G” = ChatGPT AI

**I:** Hi G. Let's discuss fluvial geomorphology, specifically the geomorphology of Arizona's Verde River.

**G:** Sure! I'd be happy to discuss fluvial geomorphology and the geomorphology of Arizona's Verde River with you. What specific questions do you have?

**I:** First, how about defining the term "fluvial geomorphology."

**G:** Fluvial geomorphology is the study of how rivers shape and change the landscape over time through erosion, transportation, and deposition of sediment. It is the branch of geomorphology that focuses on the processes and landforms associated with running water, such as rivers, streams, and floodplains. Fluvial geomorphology explores how rivers interact with their channels, banks, and floodplains to create a dynamic and complex system that is constantly changing in response to various environmental factors such as climate, geology, vegetation, and human activity.

**I:** So, the geomorphology of the Verde River would be the study of its physical form and how that form changes over time?

**G:** Yes, that's correct. The geomorphology of the Verde River would be the study of its physical characteristics, such as its channel geometry, sediment transport, and erosion and deposition patterns, and how these features change over time in response to natural and human factors. This includes examining the river's past, present, and future morphology, such as how the river has evolved over time and how it is likely to change in the future. Understanding the geomorphology of the Verde River is important for a variety of reasons, including water management, flood control, ecological health, and recreation planning.

**I:** OK, let's start with sediment transport and deposition. Explain to our readers why understanding these is important to understanding how the Verde works.

**G:** Understanding sediment transport and deposition in the Verde River is important because it plays a crucial role in shaping the river's channel morphology and floodplain characteristics. The Verde River carries sediment, including sand, gravel, and other materials, downstream through the river system. As the river flows, it transports sediment along its bed and banks, and deposits it in areas where the flow velocity slows down, such as on the inside bends of meanders or in the floodplain during flood events.

The deposition of sediment can create new landforms, such as sandbars, islands, and point bars, and can influence the river's channel width and depth. The composition and size of the sediment can also affect the river's ecology, as different types of sediment support different plant and animal communities.

Changes in sediment transport and deposition can have significant impacts on the river system. For example, increased sedimentation can cause the river channel to become shallower, which can increase the likelihood of flooding during high-flow events. Sediment deposition can also impact water quality, as the sediment can contain pollutants or nutrients that can affect the ecology of the river. Therefore, understanding sediment transport and deposition in the Verde River is important for managing the river's ecology, flood risk, and water quality.

**I:** I've often heard the terms "competent" and "incompetent" applied to rivers. Can you explain these as they relate to sediments?

**G:** Yes, "competent" and "incompetent" are terms used to describe the ability of a river to transport sediment of a certain size.

A "competent" river is one that has enough flow velocity and energy to move sediment of a certain size, such as sand, gravel, or boulders. When sediment is being transported by a competent river, it is typically carried along the river bed or within the water column, and can be deposited in areas where the flow velocity slows down, such as in eddies or on the inside bends of meanders.

In contrast, an "incompetent" river is one that does not have enough flow velocity or energy to move sediment of a certain size, and sediment is deposited in the river bed or along the banks.

Incompetent rivers typically transport finer sediment, such as silt and clay, which can be suspended in the water column and transported downstream for longer distances.

The competence of a river is influenced by various factors, such as the river's slope, discharge, sediment supply, and channel characteristics. In general, a river's competence is higher during periods of high flow and lower during periods of low flow. Understanding the competence of a river is important for managing sediment transport and deposition, as well as for predicting the potential impacts of sediment on the river's ecology and infrastructure.

**I:** So, the competence of the Verde depends on the energy of the flow -- it would normally increase in higher flows and decrease as flows decrease?

**G:** Yes, that's correct. The competence of the Verde River depends on the energy of the flow, which is related to the river's discharge, channel slope, and channel characteristics.

During high-flow events, such as during spring runoff or monsoon season, the river's discharge increases, which in turn increases the energy of the flow. This increased energy allows the river to transport larger sediment particles, such as sand and gravel, and can lead to increased erosion and sediment transport along the river bed and banks. As the flow velocity decreases, such as in eddies or on the inside bends of meanders, the sediment can be deposited, creating new landforms.

Conversely, during low-flow periods, the river's discharge decreases, which reduces the energy of the flow. This can result in the river being less competent, meaning that it is unable to transport larger sediment particles and instead deposits sediment on the river bed or banks.

However, it's important to note that the competence of the Verde River is not solely determined by flow energy. Other factors, such as the sediment supply, channel geometry, and riverbed roughness, also play a role in determining the river's competence.

Then, the geomorphology of the river's banks and flood plains would reflect past conditions, by the composition of the sediments. Large boulders would indicate high, fast floods and sandy or muddy areas indicate low-flow times.

Yes, that's correct. The geomorphology of the Verde River's banks and floodplains can provide clues about past river conditions, such as the size and frequency of floods, the sediment transport and deposition patterns, and the history of the river's evolution.

For example, large boulders and cobblestones on the banks and floodplain can indicate that the river has experienced high-energy, high-flow events in the past, such as flash floods or intense monsoon storms. The presence of sand or silt on the banks and floodplain can indicate that the river has experienced periods of lower flow, when sediment was deposited along the banks or in the floodplain.

In addition, the sediment composition and structure of the banks and floodplain can provide information about the age and evolution of the river system. For example, layers of sediment may represent different periods of deposition, and can be used to infer the history of the river's geomorphic changes over time.

Overall, studying the geomorphology of the Verde River's banks and floodplain can provide valuable insights into the river's past, present, and future characteristics, and can help inform management decisions related to flood control, water management, and ecological restoration.

**I:** I notice that the closer I am to the river, the larger the sediments, and as I walk farther from the water, there is more sand, small rocks, and silt. Why is that?

**G:** The change in sediment size and composition that you're noticing as you move away from the river is due to the way that sediment is transported and deposited by the river.

As the river flows downstream, it erodes sediment from the riverbed and banks, and transports it downstream. The largest and heaviest sediment particles, such as boulders and cobblestones, require the highest energy to be transported, and are therefore typically found closest to the river channel. Smaller sediment particles, such as sand and silt, require less energy to be transported and can be carried farther away from the channel by the river flow.

As the river slows down and the flow velocity decreases, it loses its ability to transport the sediment, causing the sediment particles to be deposited on the riverbed and banks. This process of sediment deposition occurs first in areas where the flow velocity slows down, such as in eddies or on the inside bends of meanders. Over time, this process can create bars, islands, and other landforms that are composed of sediment.

As the sediment is deposited farther from the channel, it continues to be influenced by processes such as wind and water erosion, and can be further broken down into smaller particles, such as sand and silt. This can result in the finer sediment being deposited even farther away from the channel, creating a gradient of sediment size and composition as you move away from the river.

Overall, the distribution of sediment size and composition in the area surrounding the Verde River is a reflection of the complex interplay between the river flow, sediment transport, and deposition processes, as well as other environmental factors such as climate, geology, and topography.

**I:** OK, let's move to another fluvial geomorphology topic: incision.

**G:** Sure, incision is an important process in fluvial geomorphology, and it refers to the lowering of the river bed or channel over time. Incision can occur due to a variety of factors, such as changes in discharge, sediment supply, or channel geometry.

In the case of the Verde River, incision has been a significant process in shaping the river's geomorphology. The river has cut down into the underlying bedrock and sedimentary layers over time, creating a series of terraces and steep-sided canyons that are characteristic of the Verde River valley.

One factor that has contributed to incision in the Verde River is changes in the river's discharge regime. As the climate in the region has fluctuated over time, the river's flow regime has also changed, with periods of high and low flows. During periods of high flow, the river can erode more sediment and cut down into the bedrock, leading to incision. Conversely, during periods of low flow, the river may deposit sediment and build up the river bed, slowing down or reversing the process of incision.

Another factor that has contributed to incision in the Verde River is the geology of the region. The river flows through a mix of sedimentary and igneous rock formations, which vary in their resistance to erosion. The more resistant rock formations can create natural barriers to erosion, causing the river to cut down into the softer, more easily eroded formations around them.

Overall, incision is an important process in shaping the geomorphology of the Verde River, and is influenced by a complex interplay of factors related to climate, geology, and river flow dynamics.

**I:** One of the mechanisms that can lead to incision is head cutting. What is head cutting and how can it affect the ecosystem of the river?

**G:** Head cutting is a type of stream erosion process that occurs when a channel incises rapidly upstream and the head of the channel migrates upstream at a faster rate than the tail of the channel. This can lead to a rapid lowering of the stream bed and the formation of a steep-sided, V-shaped channel.

In the case of the Verde River, head cutting can be a significant process that contributes to incision and the formation of canyons. When a channel incises rapidly, it can expose underlying sediment and

bedrock layers that were previously buried, leading to a greater potential for erosion and sediment transport downstream. This can increase the amount of sediment that is carried downstream by the river, and can also lead to changes in the river's morphology and ecosystem.

One way that head cutting can affect the ecosystem of the river is by altering the physical habitat of the river channel. As the channel incises and deepens, it can alter the flow dynamics of the river, creating new habitat niches for aquatic organisms. For example, deep pools and riffles can provide habitat for fish species that require specific flow regimes and water depths.

However, head cutting can also have negative impacts on the ecosystem of the river. Rapid incision can destabilize the river banks and increase the potential for erosion and sediment transport downstream. This can result in increased turbidity, reduced water quality, and loss of aquatic habitat. In addition, head cutting can also lead to changes in the vegetation and wildlife communities that depend on the river ecosystem, as the physical characteristics of the river channel change over time.

Overall, head cutting is an important process that can contribute to incision and the formation of canyons in the Verde River, but it also has the potential to affect the ecosystem of the river in complex and sometimes unpredictable ways.

**I:** And how does incision affect the streamside riparian forest?

**G:** Incision can have significant effects on the streamside riparian forest ecosystem along the Verde River. Riparian forests are important habitats that provide critical ecological functions, such as filtering pollutants, stabilizing the riverbanks, and providing food and shelter for a variety of wildlife.

As the river incises and cuts down into the underlying bedrock and sediment layers, the water table may also be lowered. This can affect the availability of water for riparian vegetation and wildlife that depend on the river ecosystem for survival. In addition, the exposed riverbanks and sediments can be more vulnerable to erosion, which can increase the potential for the loss of riparian vegetation and the destabilization of the riverbanks.

Furthermore, as the river channel changes and shifts, it can alter the physical characteristics of the riparian forest habitat, such as water flow, sediment deposition, and soil moisture. These changes can affect the composition and structure of the riparian forest community, with some species being favored while others may decline.

In the case of the Verde River, the riparian forest ecosystem has been impacted by incision and other factors, such as altered water flow and land use practices. These changes have contributed to the loss of riparian vegetation, the destabilization of riverbanks, and the decline of some wildlife species that depend on the riparian ecosystem.

To mitigate these impacts, restoration efforts along the Verde River have focused on restoring riparian vegetation, stabilizing riverbanks, and improving water management practices. These efforts aim to promote the health and resilience of the riparian ecosystem and ensure its continued ecological functioning.

**I:** What other things can destabilize the Verde's banks and lead to erosion?

**G:** There are several factors that can contribute to the destabilization of the Verde River's banks and lead to erosion. Some of these include:

1. Increased water flow: High water flows can erode riverbanks by increasing the force and velocity of the water. This can lead to undercutting and collapse of the bank, especially if the bank is composed of loosely consolidated sediment.
2. Changes in water flow: Alterations to the natural flow regime of the river, such as changes in water volume, timing, or sediment load, can also destabilize riverbanks. This can occur when water flows are increased or decreased, leading to changes in sediment transport and deposition.
3. Land use practices: Human activities such as land development, agriculture, and livestock grazing can also contribute to the destabilization of riverbanks. These activities can increase sedimentation, alter the natural flow regime, and disturb riparian vegetation, all of which can contribute to bank instability and erosion.
4. Natural erosion processes: Natural erosion processes, such as head cutting, mass wasting, and landslides, can also contribute to bank instability and erosion. These processes can be triggered by factors such as changes in water flow or sediment load, or by natural geological processes.
5. Climate change: Climate change can also impact the stability of riverbanks by altering the timing, volume, and intensity of precipitation events, and by contributing to changes in vegetation cover and soil moisture.

Overall, a combination of natural and human-induced factors can contribute to the destabilization of the Verde River's banks and lead to erosion. Understanding and managing these factors is critical for maintaining the health and resilience of the river ecosystem.

**I:** What is "mass wasting?"

**G:** Mass wasting is a term used to describe the movement of soil, rock, and sediment downslope under the influence of gravity. It is a natural process that occurs in many landscapes, including those along the Verde River.

Mass wasting can take many forms, including landslides, rockfalls, and debris flows. The specific type of mass wasting that occurs depends on factors such as the type of rock and soil present, the steepness of the slope, the amount of vegetation cover, and the amount of water present.

In the case of the Verde River, mass wasting can be triggered by a variety of factors, such as heavy precipitation events, changes in water flow, and alterations to the natural flow regime of the river. These factors can contribute to the destabilization of the riverbanks and increase the likelihood of mass wasting events.

The impacts of mass wasting can be significant, including damage to infrastructure, loss of property, and threats to human safety. In addition, mass wasting can also impact the health and resilience of the river ecosystem by altering sediment transport, water flow, and riparian vegetation.

Understanding the factors that contribute to mass wasting and managing these factors is critical for reducing the impacts of mass wasting and maintaining the health and resilience of the Verde River ecosystem.

**I:** You mentioned livestock as a factor in stream bank destabilization. Can you tell us more about how livestock can destabilize banks and cause erosion?

**G:** Livestock grazing can contribute to the destabilization of riverbanks and lead to erosion in several ways:

1. **Trampling:** Livestock grazing can result in the trampling of riverbank vegetation, which can weaken the soil and make it more susceptible to erosion. The loss of vegetation cover can also reduce the ability of the bank to absorb and dissipate the energy of flowing water.
2. **Compaction:** Livestock hooves can compact the soil, reducing its permeability and increasing runoff. This can increase the amount of water flowing over the riverbank and increase the likelihood of bank erosion.
3. **Removal of riparian vegetation:** Livestock grazing can also result in the removal of riparian vegetation, which can contribute to bank instability and erosion. Riparian vegetation plays an important role in stabilizing riverbanks by anchoring the soil and absorbing the energy of flowing water.
4. **Soil erosion:** Finally, livestock grazing can also increase soil erosion by exposing bare soil to flowing water. This can lead to the loss of soil, nutrient depletion, and reduced soil fertility.

Overall, livestock grazing can contribute to the destabilization of riverbanks and increase the likelihood of bank erosion. Management practices that limit livestock access to riparian areas, control grazing intensity and timing, and encourage the growth of riparian vegetation can help to reduce the impacts of livestock grazing on riverbank stability and erosion.

**I:** I see. Let's talk about the sinusoidal nature of meanders in a riverbed. What can you tell me about this phenomenon?

**G:** Meanders are the sinuous bends or curves that occur in a riverbed. They are a common feature of many rivers, including the Verde River.

The formation of meanders is driven by a combination of factors, including the velocity and volume of water flowing in the river, the characteristics of the river channel, and the type of sediment present.

As water flows through a river, it naturally seeks the path of least resistance. In areas where the river channel is uneven or where sediment is present, the flow of water can become uneven, with faster

water on the outside of bends and slower water on the inside. Over time, this uneven flow can cause erosion on the outside of bends and deposition on the inside, leading to the formation of meanders.

The sinuous nature of meanders is the result of the interplay between the flow of water and the channel characteristics. As the river flows around a bend, the faster water on the outside of the bend causes erosion, while the slower water on the inside causes sediment to be deposited. This process can cause the bend to become more pronounced over time, creating the characteristic sinuous pattern of meanders.

Meanders are important features of river ecosystems, as they create diverse habitats for aquatic species and provide important ecological functions, such as nutrient cycling and sediment storage. However, they can also pose risks to human communities, as they can cause changes in water flow patterns and increase the likelihood of flooding.

**I:** And these s-shaped meanders often move downstream, rather like a snake slithering, right?

**G:** Yes, that's correct. Meandering rivers like the Verde River can undergo a process called lateral migration, in which the entire meander loop gradually migrates downstream over time. This can happen due to a variety of factors, including changes in the flow of water, sediment deposition and erosion, and natural events like floods and landslides.

During lateral migration, the outer bank of the meander loop experiences erosion, while the inner bank experiences deposition. This can cause the meander to become more pronounced and eventually cut off, forming an oxbow lake.

Lateral migration can have both positive and negative impacts on river ecosystems and human communities. On the one hand, it can create new habitats and increase the diversity of aquatic species. On the other hand, it can increase the risk of flooding and cause changes in water flow patterns that can have negative impacts on human infrastructure and land use.

**I:** So, an oxbow or an oxbow lake is a section of a meander that the river no longer flows through?

**G:** Yes, that's correct! An oxbow lake is a U-shaped body of water that forms when a meandering river cuts off one of its meanders. Over time, the river erodes through the narrow strip of land that separates the meander from the rest of the river, creating a new channel that bypasses the meander loop. The meander loop is then filled with sediment and eventually becomes an oxbow lake, disconnected from the main channel of the river. Oxbow lakes can be important habitats for aquatic species, as they provide still water areas for fish and other organisms. They can also be important sites for wetland vegetation and nutrient cycling.

**I:** I notice that the largest cottonwood trees along the Verde occur farther from the river than small cottonwoods. Why might that be?

**G:** The distribution of cottonwood trees along the Verde River can be influenced by a variety of factors, including water availability, sediment deposition, and competition with other plants. Generally, larger cottonwood trees can tolerate drier conditions than smaller trees, which may explain why they occur farther from the river channel. Larger trees may also have deeper root systems that allow them to access water from deeper soil layers.

Additionally, cottonwood trees require periodic flooding to maintain healthy growth and reproduction. During floods, cottonwood seeds are dispersed and new seedlings can establish on newly deposited sediments. However, frequent or severe floods can also damage or uproot established trees, which can create gaps in the forest canopy and promote the growth of smaller cottonwood trees. So the distribution of different size classes of cottonwood trees along the river can reflect a combination of past flood events, competition with other plants, and differences in water availability and soil conditions.

**I:** Might large trees be less susceptible to uprooting by floods than smaller trees?

**G:** Yes, that's correct! Larger trees are generally more resistant to uprooting and damage from flooding than smaller trees. This is because they have larger root systems that anchor them more firmly in the soil, and their trunks and branches are more robust and less likely to break or bend under the force of the water.

However, even large cottonwood trees can be vulnerable to flooding during particularly severe or prolonged events. In addition, the frequency and severity of flooding can also affect the overall health and survival of cottonwood trees. Too frequent or too severe floods can lead to erosion, sediment deposition, and changes in the river channel that can damage or destroy cottonwood habitats. So while larger trees may be more resistant to individual flood events, the long-term health and survival of cottonwood forests along the Verde River depends on a complex interplay of factors, including flood frequency and intensity, sediment dynamics, and plant-soil interactions.

**I:** So, floods transport sediments, create meanders, affect the distribution of vegetation, and might lead to incision. What happens to a river that doesn't experience flooding?

**G:** A river that doesn't experience flooding can have a different geomorphic and ecological character compared to a river that does. Floods play an important role in shaping river channels and floodplains by eroding and depositing sediments, carving new channels, and creating habitats for riparian vegetation and wildlife.

Without flooding, a river may have a more stable channel with a smoother gradient and fewer meanders or braided sections. Sediments may accumulate in the channel and floodplain, leading to shallower water depths and changes in the types of plants and animals that can live there. Riparian vegetation may also be affected, as many species of trees and shrubs rely on periodic floods to disperse their seeds and create new habitats.

However, it's important to note that not all rivers experience flooding, and some rivers have adapted to more arid or stable conditions by developing specialized ecosystems and geomorphic features.

For example, desert rivers like the Colorado River in the southwestern United States have evolved unique adaptations to low-flow conditions, such as the formation of sandbars and pools that support a diverse array of plant and animal species. So the characteristics of a river depend on a complex interplay of factors, including climate, geology, hydrology, and biotic interactions.

**I:** The Verde River is often referred to as a "flashy" river because it's prone to flash flooding. How can flash floods affect a river geomorphology?

**G:** Flash floods can have a significant impact on the geomorphology of a river, particularly in the case of a "flashy" river like the Verde. These floods are characterized by their rapid onset and short duration, and can result in high water velocities, large sediment loads, and erosive power that can reshape the river channel and floodplain.

Flash floods can cause significant erosion of sediment from the river banks and channel, leading to downstream deposition and changes in the river's profile. They can also lead to the formation of new channels or the avulsion of existing channels, where the river suddenly changes course and creates a new channel, leaving the old channel abandoned and filled with sediment.

Flash floods can also impact the vegetation along the river, uprooting trees and shrubs, and depositing sediments that may alter the nutrient composition of the soil. As a result, flash floods can have both positive and negative impacts on the river ecosystem, creating new habitats and niches for some species while disrupting the natural balance for others.

Overall, the frequent occurrence of flash floods in the Verde River can contribute to the dynamic and ever-changing nature of its geomorphology, creating a complex and diverse system that supports a wide range of plant and animal species.

**I:** OK, how do ephemeral tributaries, like washes, affect the river's form and function?

**G:** Ephemeral tributaries, such as washes, can have a significant impact on the form and function of the Verde River. During periods of heavy rainfall, ephemeral tributaries can rapidly transport large amounts of sediment and water downstream, which can alter the shape of the river channel and floodplain.

When ephemeral tributaries enter the Verde River, they often bring with them large amounts of sediment and debris, which can increase the sediment load of the main channel. This can lead to changes in the river's profile, such as the formation of bars or islands, and may affect the river's capacity to transport sediment downstream.

Additionally, the inflow of water from ephemeral tributaries can cause rapid fluctuations in the water level of the Verde River, leading to erosion and deposition along the riverbanks and channel. This can lead to changes in the shape and depth of the river channel, affecting the flow velocity and patterns.

The vegetation along ephemeral tributaries can also impact the Verde River, as changes in land use, such as grazing or development, can alter the amount of sediment and nutrients that are transported downstream. This can impact the health of the riparian vegetation and the wildlife that depend on it.

Overall, ephemeral tributaries can play an important role in shaping the form and function of the Verde River, contributing to its dynamic and ever-changing nature. However, changes in land use and increased development in the watershed can also lead to negative impacts, such as increased erosion and sedimentation, that can threaten the health and sustainability of the river ecosystem.

**I:** I like the term "dynamic and ever-changing nature" as applied to the Verde River. It is certainly one of the most dynamic ecosystems in Arizona, wouldn't you say?

**G:** Yes, I would definitely say that the Verde River is one of the most dynamic ecosystems in Arizona. Its constantly changing form and function, shaped by various geomorphological processes and environmental factors, make it a unique and fascinating system to study and experience. The river supports a diverse array of plant and animal species, and provides important ecosystem services, such as water supply and recreation opportunities, to the surrounding communities. However, the river also faces numerous challenges, such as water scarcity, habitat degradation, and invasive species, that threaten its health and resilience. It is important to continue studying and monitoring the Verde River, and to work towards sustainable management practices that balance the needs of humans and the environment.

**I:**

That's a great place to leave this fascinating subject, G.

**G:** Yes, it has been a pleasure discussing fluvial geomorphology and the Verde River with you. Don't hesitate to reach out if you have any more questions or topics you'd like to explore!