Sustainable River Basin Management

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Module - 2-2

Lecture - 12

Part – 02

Welcome everybody to Sustainable River Basin Management, part two of module two-two, second week. Today, we will be speaking about Stream Morphology and I want to demonstrate you some of the basics of science based ((Refer Time: 00:33)).

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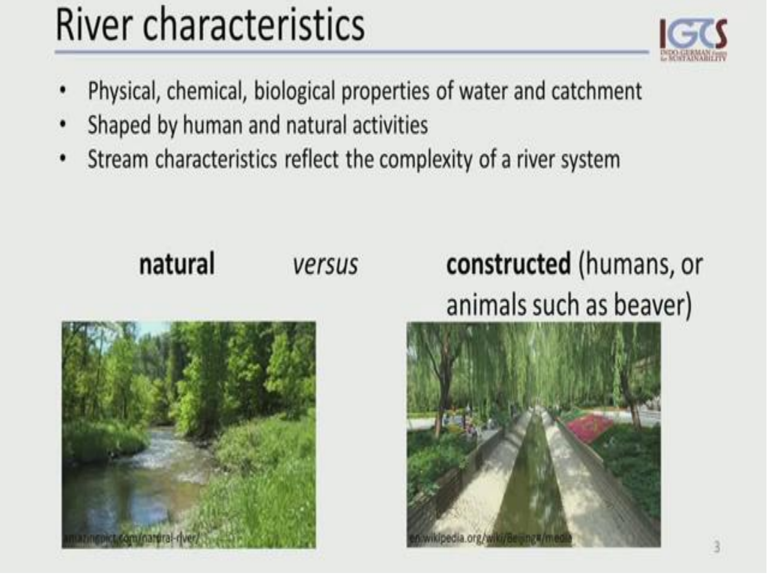

Let us first talk about river characteristics and remember, what we have been saying when I introduced river systems as such. The river characteristics are described by the physical, the chemical, biological, properties of water and the catchment in which this water appears. It is shaped by human and natural activities and the stream characteristics reflect the complexity of our river system.

We can differentiate between natural river systems, just an example here. Although, it may be shaped by our use of the forest before or the use of water somewhere upstream, it appears to us as natural. And then, what we can call constructed and this constructed could be due to our human interventions, it could also be due to animals shaping and constructing river streams, parts of a stream. For instance, beavers, an example of how we humans construct and still perceive as nice or beautiful or appealing is shown here.

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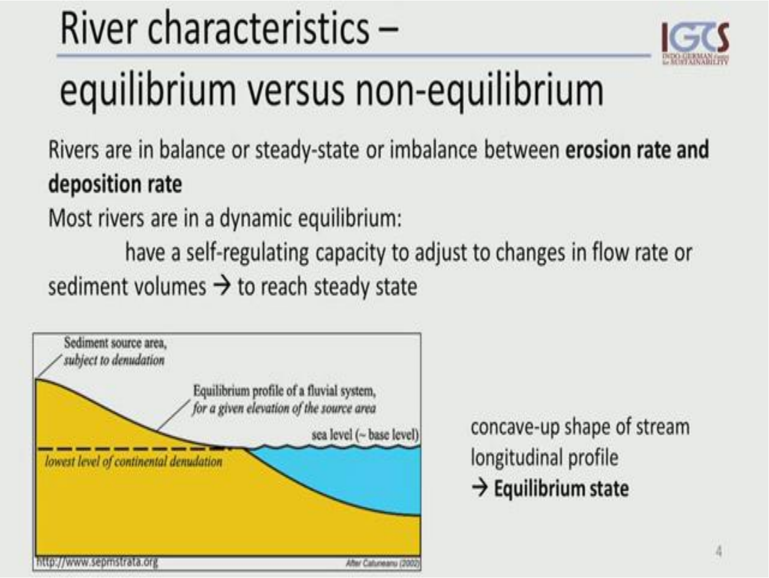

We can usually describe rivers being in equilibrium or being in non-equilibrium and what we mean by this we want to discuss now. Rivers are in a balanced or steady state or imbalanced between the erosion rate and the deposition rate. So, we are speaking of the removal of sediments and the deposition of sediments at somewhere else.

This figure here shows us a model of a river. You could see the river source somewhere here, the water shed boundary or the catchment boundary here and then, the course of the river along this profile, this surface and reaching the sea eventually, the ocean. So, the sea level usually is our base level, that is, the lowest level to which erosion can take place and to which sediments can be carried and transported and deposited.

So, when we speak of equilibrium, we mean that our profile would look like this and we have reached the stable state, where ((Refer Time: 03:42)) erosion rate and deposition rate are in a balance. We can identify such river systems being in an equilibrium state by their concave, up shape of the longitudinal profile, this one here.

However, as you may imagine, most of the rivers are not in equilibrium. So, we speak of a dynamic equilibrium instead, which also is a description of the self regulating capacity of the streams, with just two changes and those changes may be in flow rate or in sediment volumes. And we speak then, of the steady state instead of an equilibrium as such. Most of our rivers are in a steady state equilibrium.

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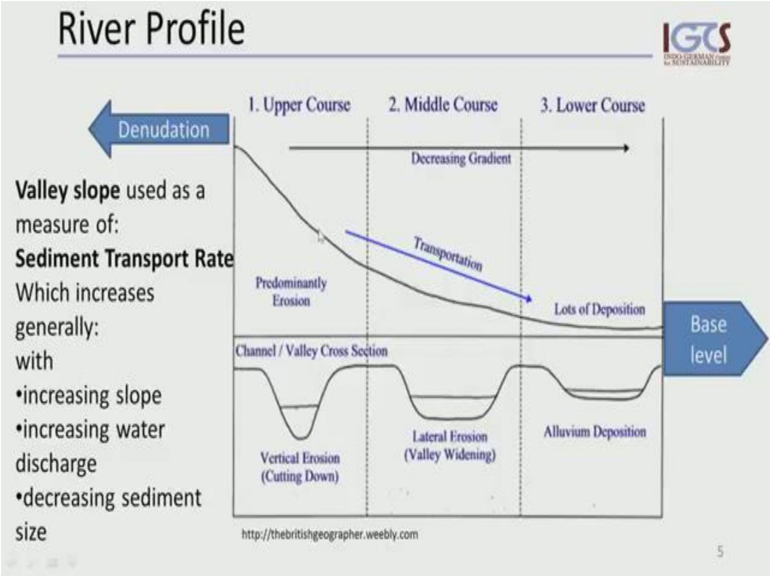

Let us look into the river profiles and you are familiar with usual division that we also do for water management purposes. We speak of an upper course, we speak of a middle course and the lower course. The upper course is where are source areas of the water, our springs. Maybe most of rainfall occurs somewhere in opulent area and then we have a middle course, where our, if slower velocity is if less steep, slopes in our profile may have higher water volumes over and then, we reach lower courses where most of the deposition takes place, where we will observe our floodplains and eventually our water will join the ocean and by that we have reached its base level. Now, this base level can shift, as you can, you know yourself, that sea levels have been rising and decreasing over the geological time scales and by that we change, influence the dynamics of this profile. We can identify for each of these sections of our river system, according a vertical or valley cross sections.

And in the upper course we have steeper slopes and higher energy, higher velocities, stream velocities. We usually will see v shaped valley, where primary vertical erosion will shave and dominate the landscape and the evolution of such a valley. In the middle course, we probably will observe more widening, we will see wide vast valleys. And most, its most prominent is lateral erosion, erosion taking place along the flanks of the river valley. And in the lower courses, we will observe move of the deposition of these flue sediments and refilling of the level of the floodplain level. So, our valleys slopes are therefore, a good measure of the sediment transport rates and those transport sediment rates are influenced by the slope, the amount of water, water discharge and the sediment size.

So, we can use all of these as indicators of a, where we are in a river profile, if you can only see a part of it from a satellite image, for instance. And we can identify it, draw conclusions on what type of a river system behind from some of these properties. Now, this is not stable as such. The base level, base level is changing, our sea levels are rising at the moment, our continents are not stable, they are uplifting in many cases as a result of the ice age.

So, there is upper course head erosion taking place, denudation taking place. So, this point is shifting and more and more of the land is not currently part of the water catchment, will essentially be caught and involved into one river system expanding that water shed and changing slopes and velocities and erosion again here.

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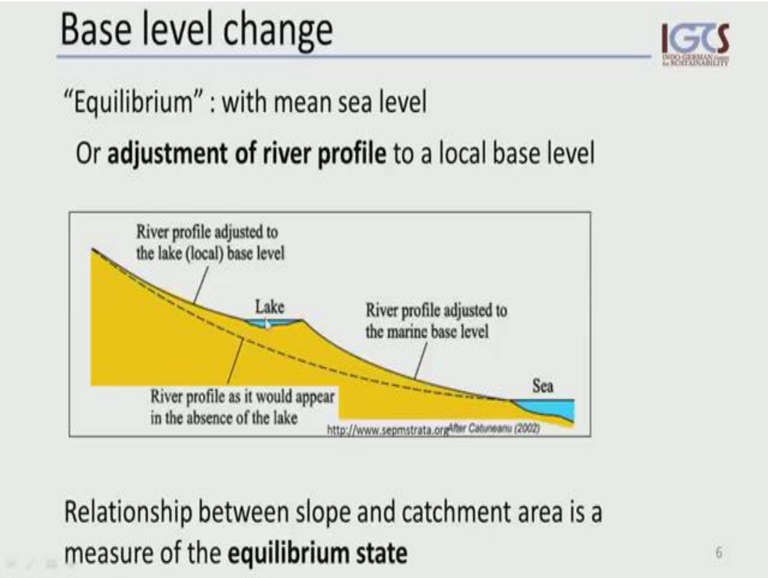

Base level changes are very important and we will be talking about this throughout this class and the next class as well. And it is essentially, the relationship between slope and catchment area, which we can use is a measure of equilibrium state. Now, well, equilibrium meaning was regard to a mean sea level and we have been saying, that this is changing. So, the river can however adjust its own river profile to local base level.

And what such a local base level could be is, for instance, a lake, a water reservoir, a surface where water, where flow velocities are slowed down to such a level, that sedimentation, sediments will be trapped on this part. And if there is an overflow, again we will have the formation of a new slope and new river profile downstream of this lake system down to the next base level. That base level could be again a lake or a dam. It could be the final destination, it could be the ocean.

Now, this shows us here, this line here shows us what the natural, so to say, natural profile of this river would be and we have seen, what it is as a beside of lake, which could be natural lake, could could be a manmade reservoir. Now, this is very important and we can, we will see how deep we already influence our hydrological processes by simply adding such base level to a landscape.

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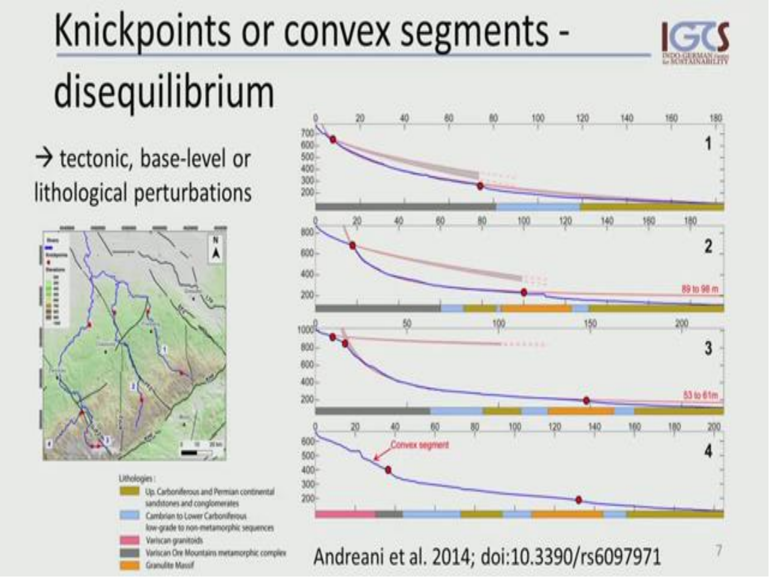

Now, we usually talk about knick points or convex segments in, occurring in river profile and those indicate this equilibrium in a river. And those could be the result of tectonic events, they could be the result of base level changes, they could be the result of some lithological, perturbations.

And I found an interesting example, which I want to present you here. You have region in middle Europe at the border of Germany and Czech Republic and river system, draining from south towards the north here. And we have major garden structure here in this area, the ((Refer Time: 12:42)) system.

Now, the red dots here indicate such knick points, which were identified by remote sensing techniques and by analyzing river profiles. So, we have 1, 2, 3, 4 rivers here and the same shown here in this map and you can see clearly here, where these knick points occur, where such change in the profile occur. And we can see here, or projections were made from, in this publication, this work, what the actual natural profile should have been, if not a specific event would have come in this disturbed these natural processes. And in this case, mostly tectonic events, because we also go quite back into our geological history and we can link it to specific tectonic phases, evolutions of this mountain area, this and the rift area that we are talking that I mentioned earlier. So, this is one way of analyzing the evolution of rivers, but also the geological history of certain areas in combination this remote sensing techniques.

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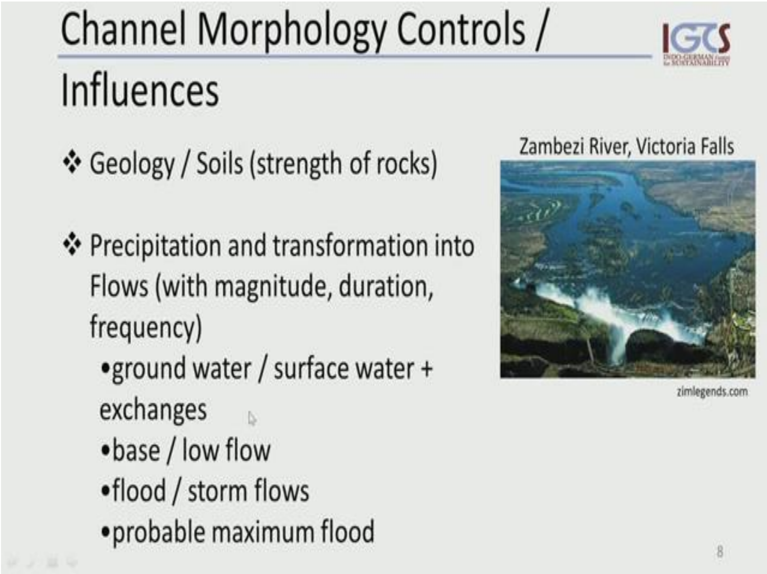

Now, let us, now focus on the controls of channel morphology, what influences it? Most of all it is geology. The type of soils that we have in certain terrain and what we mean by that is mostly the strength of rocks, how resistant this rock is to erosion and just an example here, the Victoria Falls, one of the major rivers, the Zambezi River. We see this huge stream, which has been interrupted by a major fault or several falls here and which have shifted rocks of different strengths next to each other. And for that reason created a differential erosion and falls with the result, the Victoria Falls is the result of that. We can also see on one side a very greenish, very wet soil, whereas on the other side of the river bank you see the entire area, which also indicates quite some influence of falls and tectonic features in influencing hydrology here.

The second important control element of morphology is the rainfall precipitation and the transformation of that precipitation into flows. That could be in terms of magnitude, it could be in terms of duration in the terms of frequency. We come back to this and it includes all of the different flows, our ground water, surface water, that linkage between ground water and surface water, our base flows, our low flows, our flood and storm flows and the maximum floods occurring in such a system.

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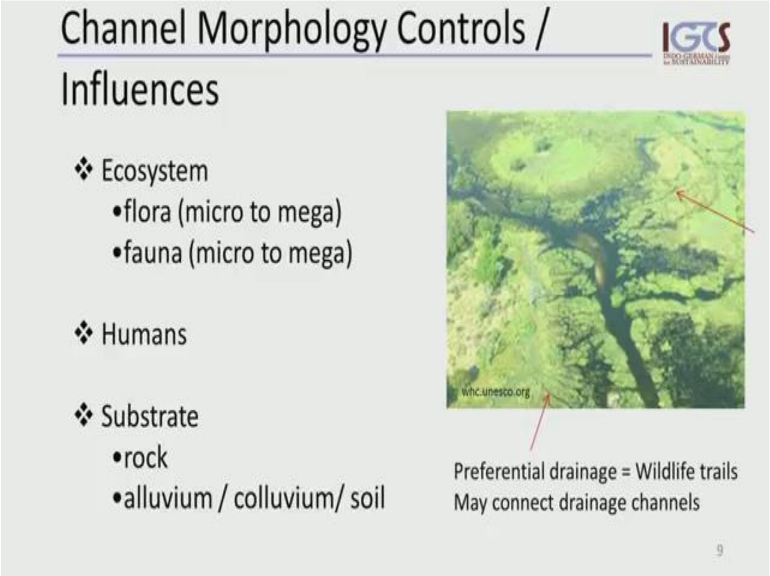

In addition, to these already mentioned primary, very important controls, ecosystems are very important. The flora in terms of, from base, form micro to mega and fauna from micro to mega. And let us just take an example here of a floodplain region. And you can see here drainages, where water joins the major stream, major canal here. And you can, in many cases, those are preferential drainages because wildlife uses those as the shortest lines to access the main canal to cross or to get to the source of water or to get to the water as such.

So, elephants, buffalo or large herbivorous, hippopotamus use those and using them all the time they increase the drainage and they also may even create connecting drainages between some secondary or some other stream channels far apart from the main channel here. So, they are quite important in shaping the drainage and shaping the landscape. And then, of course, humans and we shape the morphology and have influence on our river systems. The substrate rock or the alluvium, colluviums, soil that occurs at the bottom of our streams is quite important, and lastly the sediment budget..

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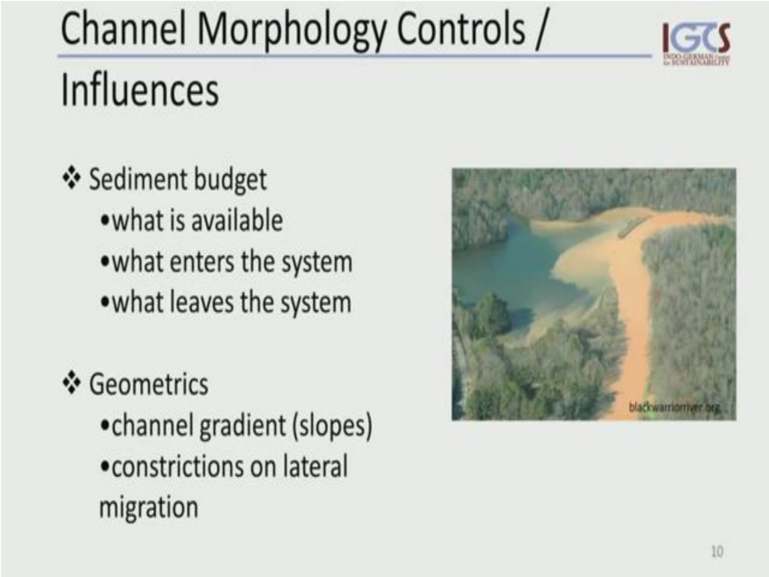

What is available, what enters the system, what leaves the system? As an example here, a stream, we have two rivers joining this river, joining another large one and this tributary here brings a lot of sediment and quite some time those two water masses are not able to mix and this is quite substantial impacts on the aquatic life, but also in the flow patterns.

The velocities will slow down here, most sedimentation with take place in this area, may have more bottom erosion taking place due to this tense flow of suspension in this main stream. So, there are various processes influencing this. Yet another general morphology control is the geometrics, we will come back to this the channel gradients slopes, we talked about this and constrictions for instance the lateral migration.

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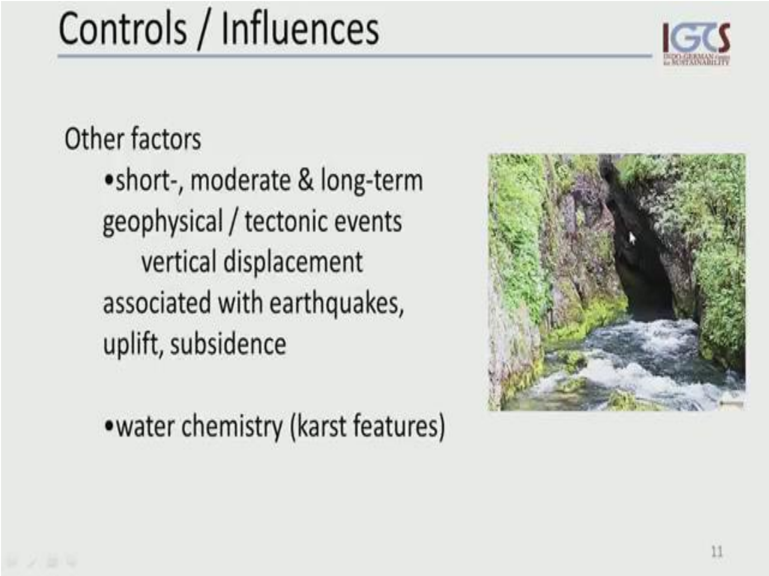

And then, we have some other factors, which we sometimes think much more relevant, but actually more underlying and secondary. This could be short term, geophysical or tectonic events, some displacement of geological layers as a result of earthquakes or uplift or subsidence or it could be water chemistry processes such as cost features forming such large caves, openings where rivers increase and the chemical processes, which have formed this as a small space.

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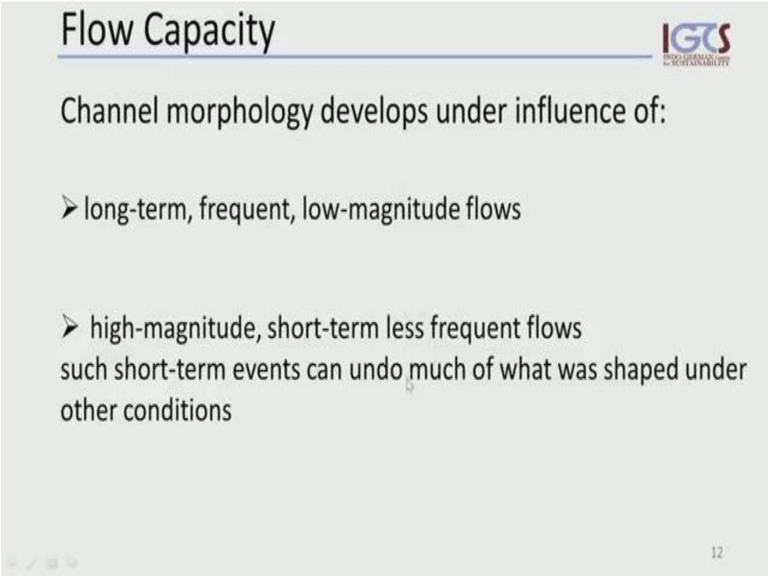

So, important is in, on the flow systems, the flow capacity as such and that develops and the influence of long term, frequent, low magnitude flows on one hand inside and on, as a result of high-magnitude, short-term and usually less frequent flows. And this high-magnitude events can very often undo the processes, which where shaped under these low flow conditions and this is very important to keep in mind.

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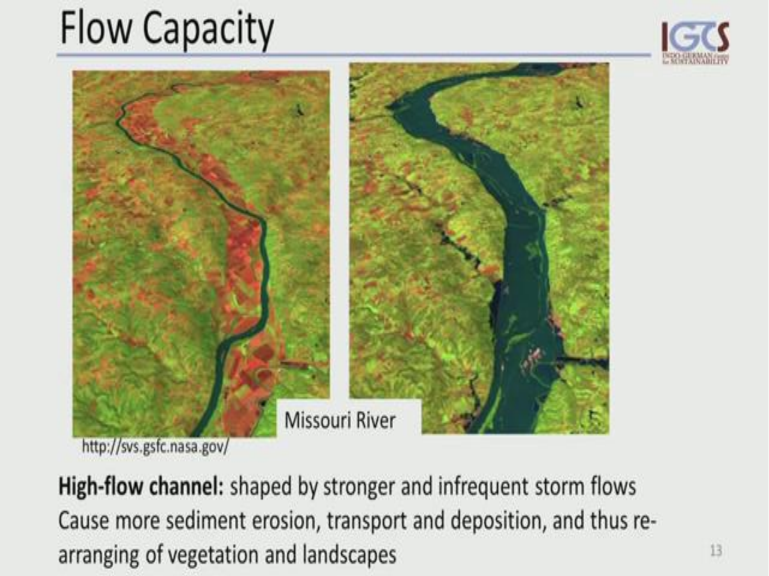

Now, we observe high flow channels for which accommodate large volumes of water, which shape is strong and infrequent storm flows and usually cause a lot of sediment movement, sediment erosion, transportation and deposition and as such, really, shape and rearrange vegetation and landscapes. So, it is a very important event in terms of landscape changes.

An example here of the Missouri river this is the satellite image. You see a different land use is taking place here. Some agricultural large fields here and we have the Missouri river valley here. This is the low flow channel here, but you also can see here a wider valley, which corresponds to this high flow channel. We see, that those river floodplains are used very much for agricultural, very important, very fertile zones.

And we have on the other side the same part here, this river, which is dry and on this image here now carries water as a tributary. We see this entire high flow channels filled with water. All of these agricultural fields are underwater in this image. So, this has a major, has major impact on, demonstrates these major forces executed by such high flows.

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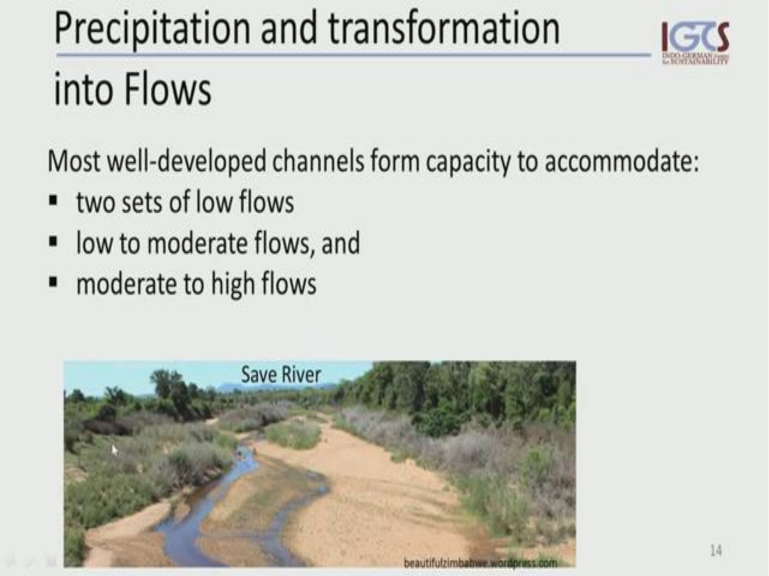

Now, let us look into the precipitation and transformation into flows. And we can see, that most of the river channels have capacity to accommodate all those different flows. They have usually the capacity to accommodate two different types of low flows and they have the space capacity to accommodate moderate and high flows.

Just an example here, one of the rivers in southern Africa here, the Save River coming from Zimbabwe. And here, this is the low flow, one of the low flow channels here. This entire part is, part of the low flow to moderate. This channel can migrate, it can move, can be one year here, was somewhere closer to this bank here. It could be somewhere here; it could split and be distributed. So, this is changing very much. And then, we have this sand part here, which will be the active part and the moderate flows. And then, we have the river bank here, which you can see here where this ((Refer Time: 25:28)) vegetation starts, which will be active under high flow conditions. And then, we may have extreme events, which may even go above bank flow here and spill over.

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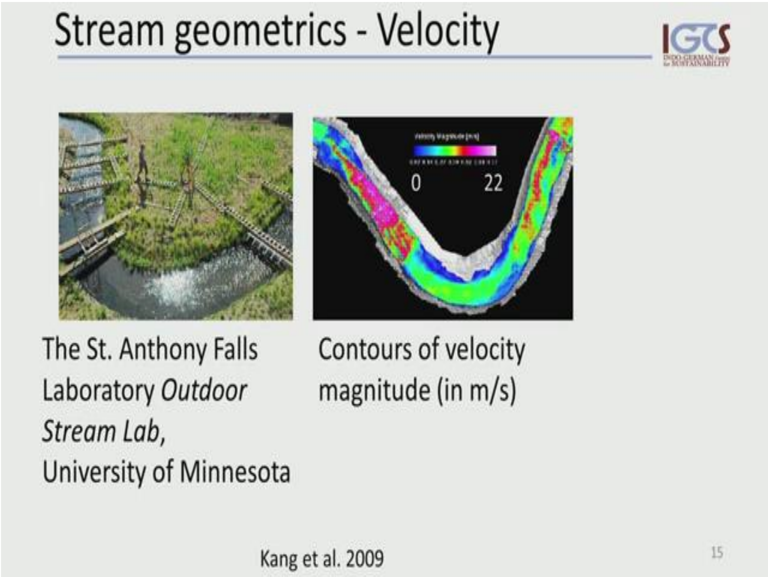

Now, having said this, let us look into these stream geometrics and their velocity and this is an interesting example of an outdoor laboratory at the University of Minnesota. And you see, a person here as a scale and they use that to analyze the impacts of stream geometrics on different interventions and give inputs to river to stream restoration interventions.

And here, we have that same stretch here and a measurement of the velocity magnitudes in meter per second. And we see, that this starts from a blue, no flow to a purple, whitish, where we have higher flows reaching in this case 22, about 22 meters per second. And what we can see here, that in a river bend, was bend, bending the curves here very much influence flow velocities.

So, we can expect sedimentation to take place in areas where the energy is low, velocity is low, where sediments can be deposited. And we can expect certain grain sizes here, probably the smaller particle sizes being deposited here, whereas in those parts where our stream channel is most late or more narrow. We can observe higher velocities, which will allow only larger sediment particles to settle or deposit or in most cases, probably will remove larger particles and take them along and deposit them in some other downstream area.

So, those scientific approaches are very important to define interventions. How we shape the river, if, where should be boulders, where should be, how should, them, the banks and the latter parts of a river be shaped to achieve what we want was the, was our intervention.

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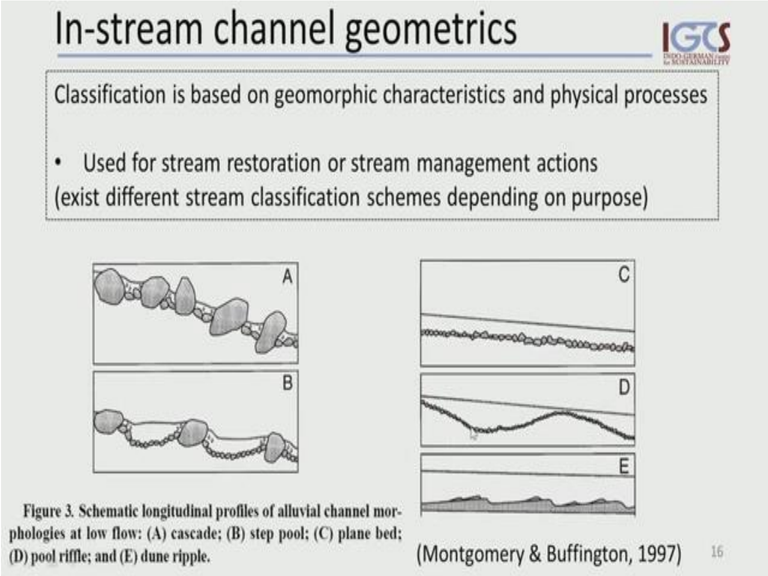

Now, let us continue on in-stream channel geometries, take from the outside into what happens inside a stream channel itself and that classification and that, which is most commonly used is based on the geomorphic characteristics and physical processes. And those are used for stream restoration and also for stream management actions. So, we may use different classification schemes for different purposes.

So, keep this in mind, this is not the only one existing, not only one, which you may find useful for your specific applications. Those are the most basic schemes of in-stream morphologies. We may have this large boulders here, you may have boulders and pools where the velocities may slow down. Also, temperatures may increase here and allow for different processes to take place.

There may be a spill over into the next and so on, cascading or step-wise movement. We may have incline, but pebble size sediments, we may have some refill structure, large refills here, which also slow down velocity and may foster sedimentation, may create deeper parts and more shallow parts, which could be penetrated better by light or some others may have lower temperatures and more oxygen, maybe, may be placed into the water due to those effects.

And we may have something like this, we, where we have changing flow velocities and higher velocities take shaping the bottom like this. So, this is our basic classifications and we may use those to actually, to place such features and create such features artificially to achieve certain benefits for our water system.

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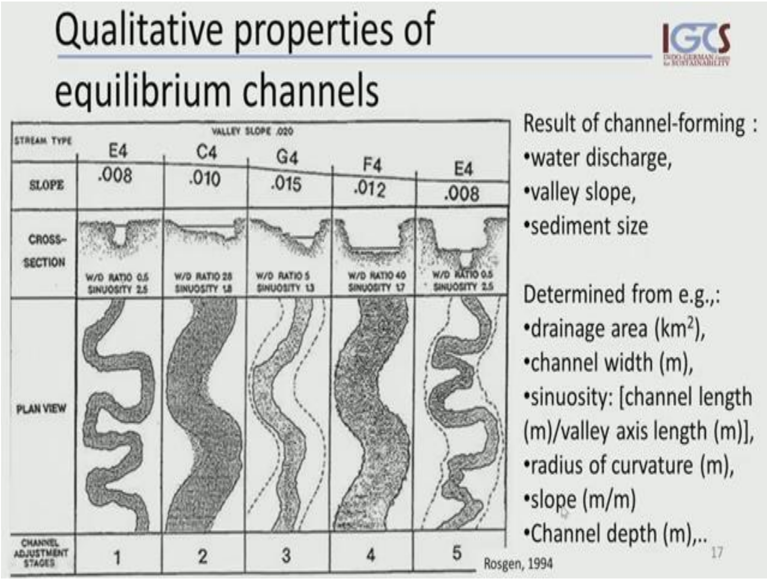

Let us look into the qualitative properties of these equilibrium channels and let us recap, that the channels are formed as a result of the water discharge and the amount of water, the valley slope and sediment sizes. There are many different schemes again in classifications and I am just showing you one here, which shows us here the adjustment stages in channels and the different cross-sections, which are typical for these stages associated with certain slopes, more shallow or plane, almost not existing slope and steeper slopes here.

And how the plain few of these rivers will look like if we, for instance, take an aerial picture or a satellite image to look into this. So, we can see, that there is a process, which starts from very curvy way, very pronounced sinuosity towards the straightening widening. And then, coming back to and out developed wide channel was in which we again have a very curved and very sinuous shape of river in a floodplain for influence. So, this could be a mountain area head water and this could be a floodplain.

Now, what are the parameters that we use to analyze those properties? We look into the drainage area, how big it is. When it is very small, we usually can assume, that it is a young, it is a young river system. We may look into the channel widths, we may use the channel depths just like here in this ratio here as a description of typical river system. We may look in to the sinuosity, the radius of curvature and we may you use the slope of the river. So, those are some of the approaches and not or may be in all cases appropriate, but we can use them to characterize entire countries or regions.

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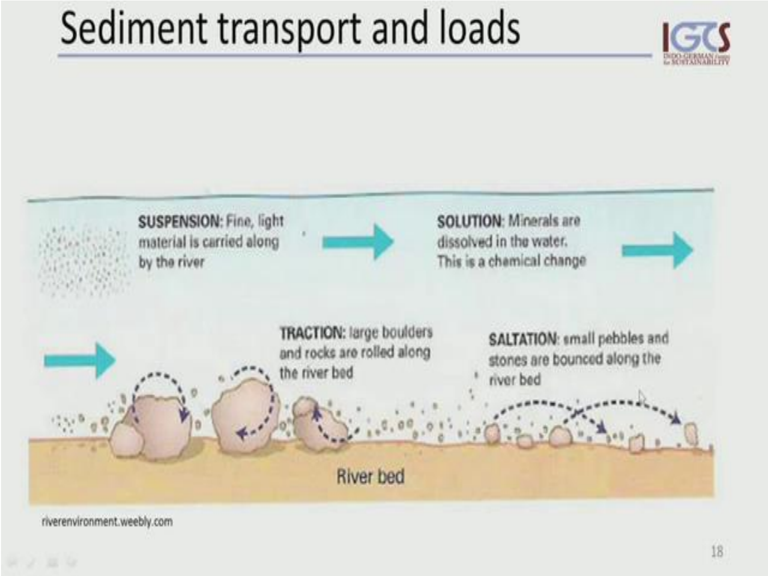

Now, let us look in to the last one today, into sediment transport and loads, which we have not talked about yet and I just want to show you the different ways in which sediments can be transported and loads can be transported.

So, we have our water here and we have our river bed here and what we have seen in one of the pictures earlier was a suspension, where sediments are occurring in very fine particles, which take very long time to settle to deposit somewhere. So, they are usually carried in suspension along the flow of the river. Contrary to suspensions we also have solutions. This means, that minerals or particles or chemicals or chemical elements are dissolved in the water in the form of ions. And in that way carried, was in the water to some other places, where may be, due to evaporation they may precipitate again and form minerals again.

And then, we have different sizes of larger particles of sediments, of boulders, of sands, of pebbles, which depending on the flow velocity would be able to be tracked along, to all along, spin along. And by that way the road, the surface of the river bed, they may form water minerals, deep holes here for instance, or such rocks could be jumping flow energy. Kinetic energy may be accumulating here and then, after some time, these pebbles could jump and change their position, could this call saltation and be tracked along the river bed and deposited by changing the velocity here. You can imagine, that those processes change here and those large boulders may be easily moved and deposited somewhere else under extreme conditions. We will stop here and I will see you in next time again.

Thank you.