Sustainable River Basin Management

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Module - 02
Lecture - 08
Part 3

Welcome everybody to Sustainable River Basin Management, module two, part three. Today we will be talking about, what appliances are, what are budgets.

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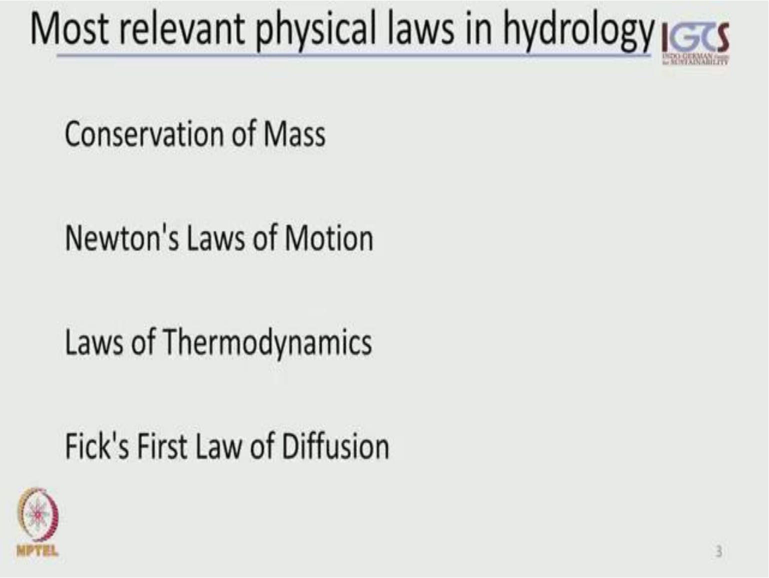

Let us first of all come back to our most relevant physical laws in hydrology. We have touched upon the importance of physical laws when we spoke about hydrological models in our previous class. Important laws that you should be aware of and you should have an idea in your head are: conservation of mass, Newton’s law of motion, the laws of thermodynamics and Fick's first law of diffusion. We come back to one or the other throughout the class.

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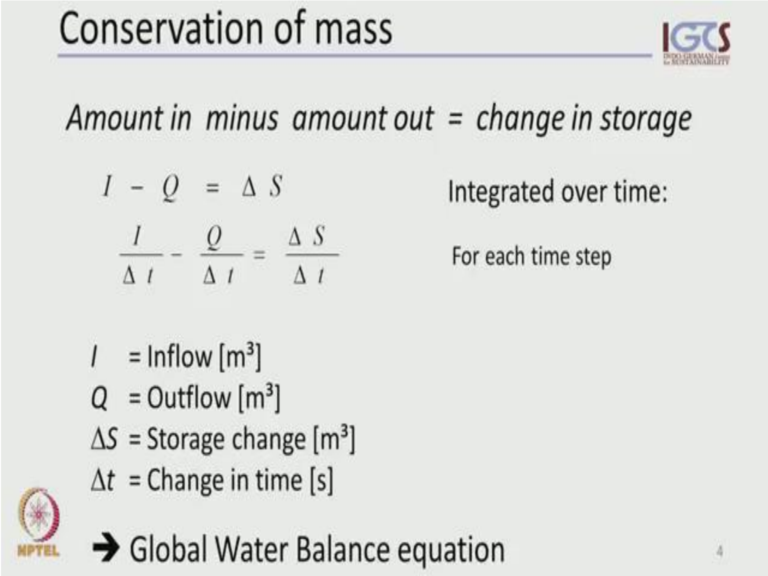

Now, let us start with, today we are talking about water balance, let us talk about the conservation of mass. In very brief it states, the amount that goes in minus the amount that leaves the system equals the change in storage. Now, this can be expressed in a mathematical form and I is inflow, Q our outflow and delta S our change in storage. And it has, this has to be observed as a changing state, so it has to be integrated over time and we can express it in this way.

And again, we have to resolve this for each of the time steps that when we monitor a system, it changes constantly. Now, this is fairly simply looking equation is our, is a very important one because it exercise our global water balance equation.

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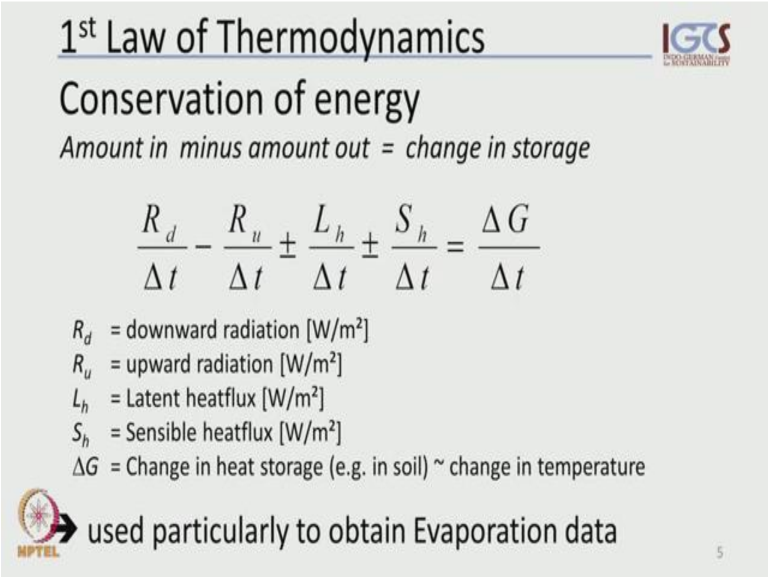

Now, the second which is important for today's class is the conservation of energy. Its entry starts from the same amount of energy minus incoming minus the amount of energy going out of our system equals to change in storage. And this can be put into a mathematical relationship again where we express our downward or inward radiation change over time minus t, outgoing radiation over time plus the change plus minus the latent heat flux and sensible heat flux equals the change in heat storage or change in temperature that heat storage could be. For instance, soil, the soil layer or water body. And this is, this range is extremely important for the, for the calculation or to obtain evaporation data, unless we try to measure evaporation.

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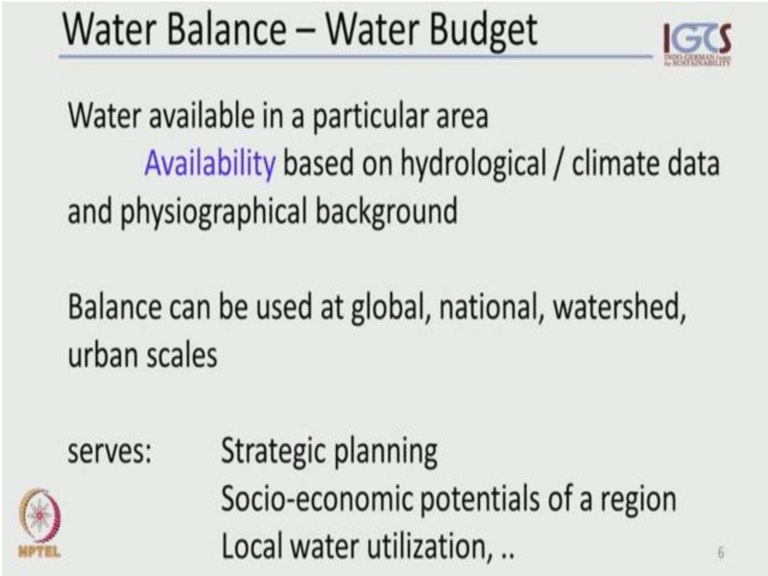

Now, talking about water balance or water budget, let us define what we mean by this. Essentially, we express, we are able to express in the form of the water balance, the water, amount of water that is available in a particular area and that availability essentially is based on hydrological, climate data and physiographical background. So, means, we will be talking about water availability in our next lecture where we will use a slightly different definition for water availability.

Now, when we talk about water availability and water budget, that is manly based on hydrological and climate data and physiographical backgrounds of our catchment. So, net balance can be used at a global national watershed open scale. We can come up with some water balance at any required geographical and temporal scale.

And what do we need this for is, essentially serves for strategic planning of water, resources for socioeconomic potentials of region, to determine poverties should we go for tourism for instance in a particular area or garden produce, cash crops in a particular area. It could be served, could be used for to come up with this budgets for local water utilization and others. So, it is a very basic and very important component of water management.

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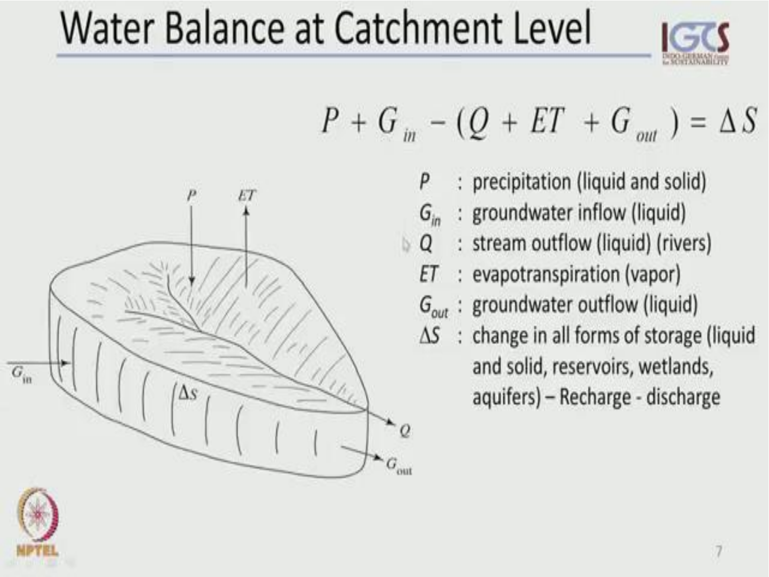

How do we come to a water balance in a catchment? Let us just use a box model, a catchment, any type of catchment and our basic input components, precipitation and count water inflows into our, into our catchment. And our outgoing components, our evapotranspiration and our runoff in the form of surface runoff or in the form of sub surface, ground water, outflows and in, in our, within our catchment our storage changes.

Now important to a catchment level water budget, this equation will look like this. The sum of incoming minus the sum of outgoing amounts equals the change in storage. So, what we mean by a precipitation? It summarizes liquid and solid, so we have to measure both liquid and solid. If this is applicable, ground water in the form of liquid, speaking of the stream outflows, we speak of rivers and the evapotranspiration, we speak of water vapor, the ground water outflows as a liquid again.

The change in storage and we refer to any form of storages, in the form of liquid or solid and state and this would entail our reservoirs, our wetlands and our aquifer systems. So, this gives us already an idea of how quickly it becomes very complex to express, to measure, to observe the ((Refer Time: 07:19)), that we need to calculate our water balance.

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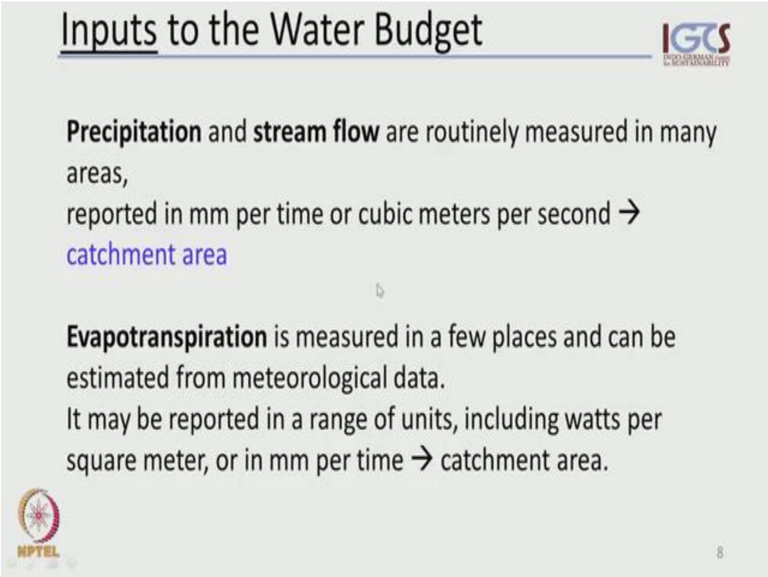

Now, let us talk about the inputs to the water budget, I am not going to discuss the details of how to measure each of those, we can, you should read about this, you should have that information as a working knowledge, but you are not talking about this in our class. Just an overview, precipitation and stream flow are routine measurements. Assume, maybe a way of, in many areas it is important in either millimeter per time or cubic meters per second for a particular catchment area. So, we need to know what our catchment area is.

Evapotranspiration is measured in some places, in very few places only and also, in very few places just evaporation is measured, potential evaporation is measured. It can be estimated from meteorological data, from climate data based on the law that we introduced in this class. It may be reported also in a wide range of units, which could be watts per square meter, it could be a millimeters per time and again, it has to be based upon particular area, a catchment area or sub catchment area.

So, keeping all those, this already in mind, we have to work in single units if we want to come up this water budget, which could already in itself be a challenge, because it is being recorded in such, so many different units.

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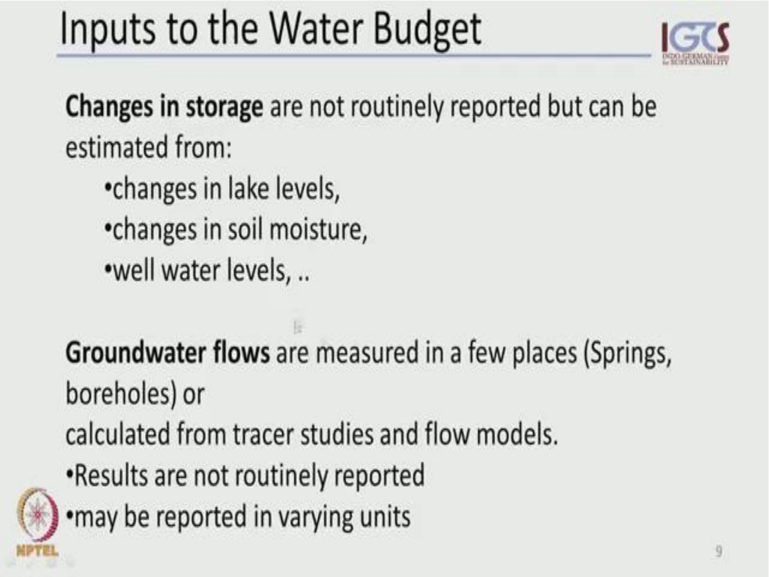

Another important input component is the change in storage, which is not being routinely reported, but can be estimated. So, for instance, so measurements of lake levels, changes in lake levels, the measurements of soil moisture and measurements of water well levels. And you can only see how, let as an additional challenge comes, that we measured only in one point, whereas we have to relate the storage to an area or catchment area.

And a very important, yet other input to our water budgets are groundwater flows, inflows and outflows and those are equally measured only in very, very few places and some we can measure it directly. In springs, for instance, where we have direct access, a window to our groundwater or boreholes, again it is just a point measurement as we need this to relate to a catchment as an area.

And or we could, in most of cases we just calculated from, for instance, tracer studies or from flow models and that is a major missing piece in the many water budget because it is not being reported regularly or routinely and it again may be measured in various units, which not facilitate the calculation in one in the same water budget.

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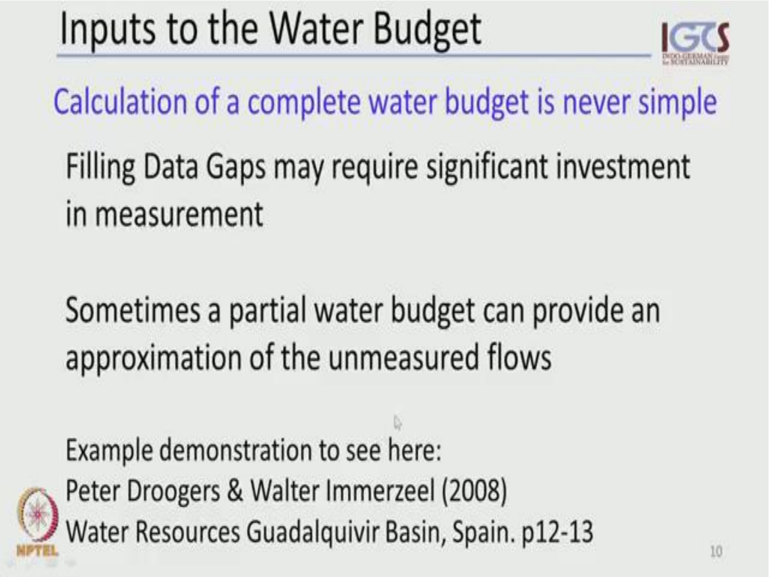

So, what we want to make clear here is, that the calculation of a complete water budget is not at all a simple exercise. It is never simple and it requires a lot of data and filling those data gaps usually require the significant investment in measurement, which means, having equipment available, having a monetary network in place and possibilities to collect those data and analyze those data in the needed frequency.

Sometimes a partially existing water budget can be used to estimate or calculate unmeasured flows, for instance, groundwater or evapotranspiration. But, that is only sometimes and I would like to point you to this example here from the literature, which you can later also access from our portal this exercise of putting different sources together. All this is being nicely demonstrated how difficult it becomes to come as a proper water budget.

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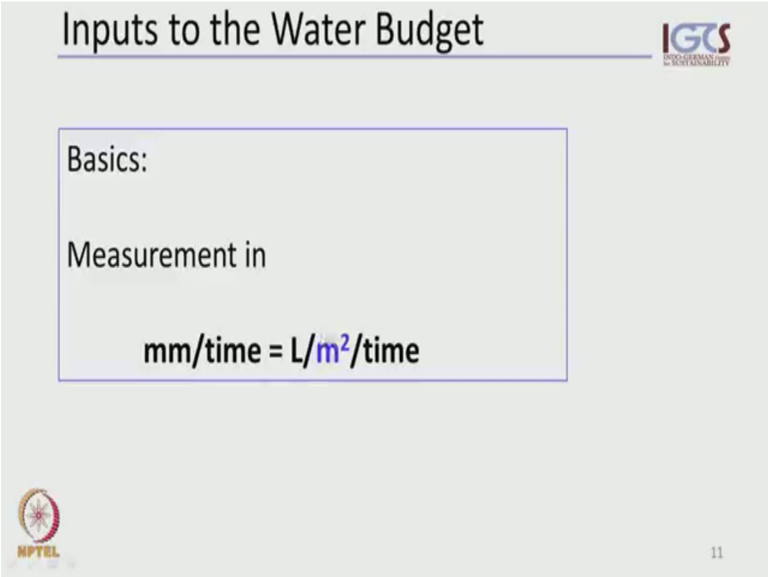

Another very basic relationship that you should know and be able to handle at any time is the relationship between height per time as a way of measuring rainfall and our rain gauges to a volume to area per time unit. We will then come up with budgets at catchment scale or sub catchment scale.

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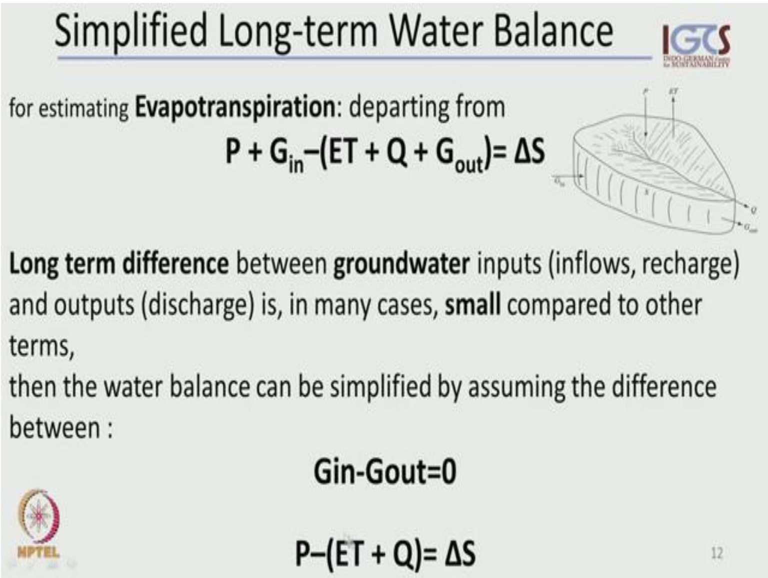

Now, there are ways of working with simplified versions of the water budget, which I want to briefly demonstrate here in this case, in the case of the evapotranspiration, which is very often the missing part, one of the missing parts.

So, when we work with long term a long term like this, this is the emphasis here. We can simplify, we can assume, that the long term differences between ground water inputs on this side and which means, inflows and recharge of ground water and the ground water outflows, ground water discharge may not vary much, they are small and for that reason we may assume that our ground water inputs and ground water outputs may become 0. And in that case, we can simplify our water budget equation to the one lined out here below.

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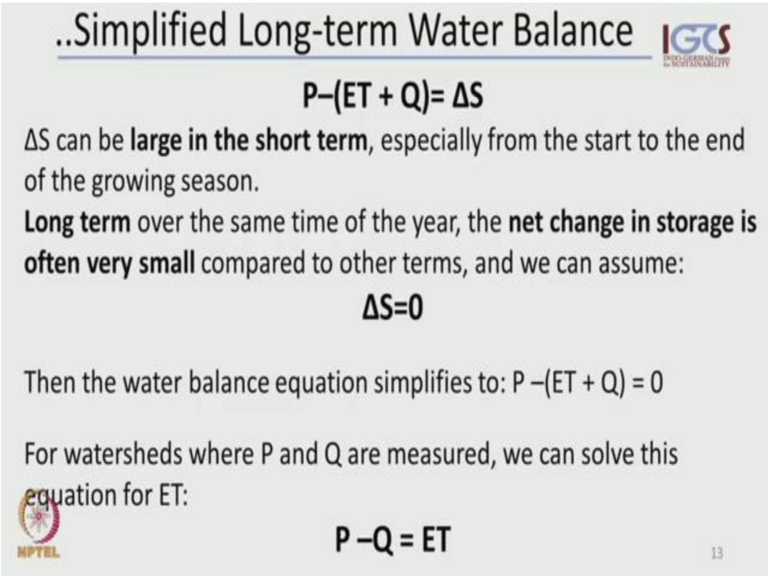

Now, the next step would be the difficulty on the storage change to estimate or determine this. And again, we know, that at very short term the changes in our storage our quite, quite big and quite essential. Just think of the beginning of going season, the end of the going season, the situation of our water storage before the rainy reason and after the rainy season, you see, that the change in storage is very relevant and very large.

However, if you take long term records over and compare over its periods, same periods, for instance, hydrological years, then the net change in storage becomes very small. And in such cases, we can set our change in storage to assume own in such cases. And then, we can simplify a water balance equation to this version, which helps us to calculate ET. All come up with this regional long term balance, which can help us analyze a water situation to quiet an interesting and elaborate point. We will come back to this equation at a later stage.

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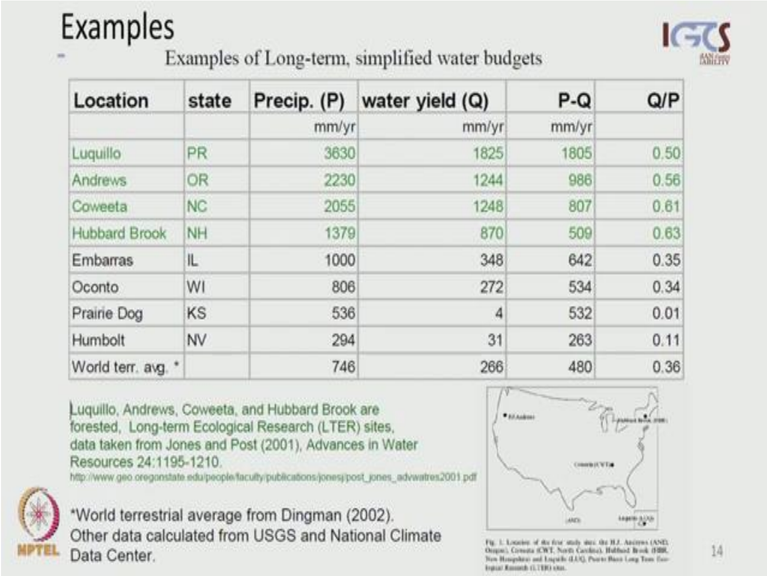

Now, I want to show you a few examples of water budgets to give you an idea how this looks like and how it has been applied. First example is basin, river basins in, in the US. Source of information is here and what we have in this table is rainfall, we have discharge and then we have a relationship of P of precipitation minus discharge for each of these river basin and we have a ratio.

This ratio is or can be characteristic for river basin, for climate, specific climate condition, for specific geographical regions, geological conditions and for that reason can give a vague, vague first overview of what the water budget situation is in a large, over a large area like a country. So, this is one example and which gives us already an idea of, what, where we have difficulties in our, in water supply probably and limitations. And we also can see, how much of the water, that is, rainfall transforms actually into available discharge into water that can be abstracted and may be used or is available for biological activity.

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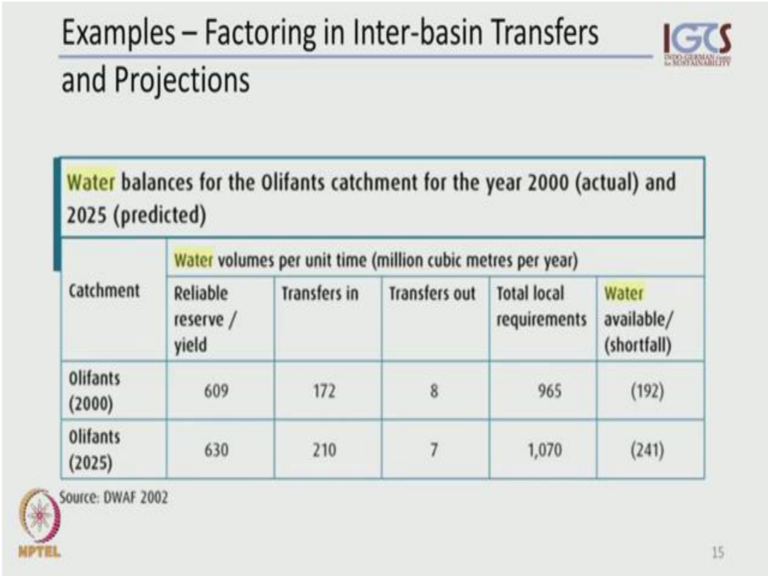

Catchment	Water volumes per unit time (million cubic metres per year)				
	Reliable reserve / yield	Transfers in	Transfers out	Total local requirements	Water available/ (shortfall)
Olifants (2000)	609	172	8	965	(192)
Olifants (2025)	630	210	7	1,070	(241)

Another example that I want to show here is to, that the importance, some way and ever becoming more important to factoring the inter-basin transfers, to conduct projections of water availability. Now, this is an example from South Africa, the Olifant river catchment and we have data sets from the year 2000 and projection for 2025.

What we, what summarize here is the water budget, is the reliable water resource, the inter-basin transfer taking place in to the Olifant river and the basin transfers that take place out of the Olifant river catchment. Water requirements are in terms out of water, which means there is a human factor. How much water is needed for all of the different usages and how much water is actually available and what we see here is that already in the year 2000, summing, summing our reliable local research and our inter-basin transfers minus our transfers out of the basin we already see, that we have a negative balance here.

So, that is a very important information planning purposes when our water balance is negative and this does not become better in for the future projections. So, this gives, is a, is already a useful management information based on which planning and strategic decisions can be taken.

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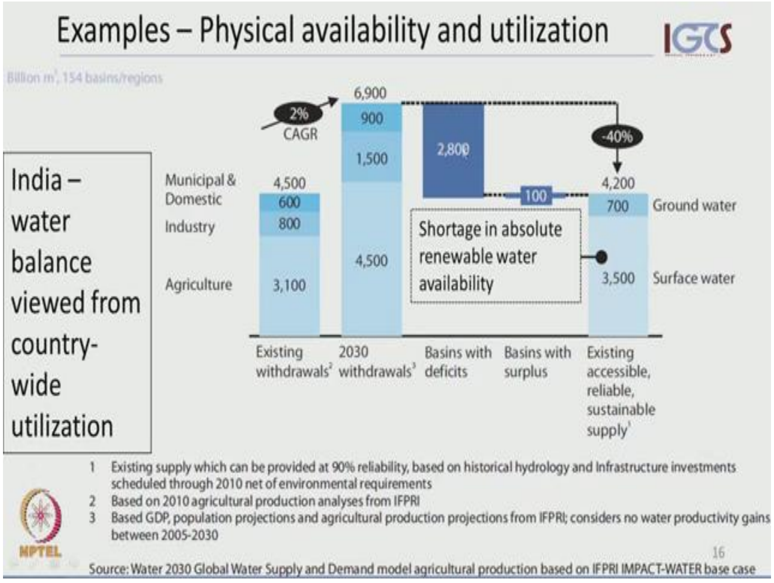

Another example, a way of physical availability and utilization are brought together, water budget again, in this case from India and India wide, not based on catchment, but based on what the country as such has available. We can already here see what is available or existing today, what has been used for the different purposes, agriculture, industry and domestic, municipality and what the projections are for the year 2030. And you can see, that this is going, the demand is going, but our available existing water resources may not go. If we only look into what is available in India itself and that there will be a water deficit that has to be covered already, very soon.

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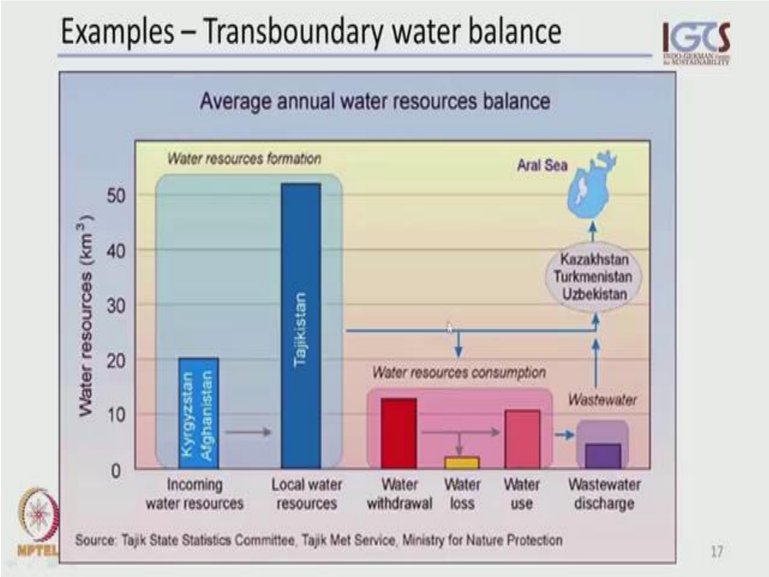

Now, is a last example, a very important part also, the times boundary water balance. We have looked at India as a case, as a country, water balance and now a transboundary water balance. We have our water resources here and then the different components. The water resources available in two countries in the Asian region, which and the amount, that is been passed on to the country of interest. So, the sum of the two water resource columns here would be the amount of water available in this country.

Then, we have this blue flow indicating that an amount of this water has been passed on across the border to another free countries, and been used there and eventually been discharge into the Aral Sea. And within this country there are different usages or consumptive usages of this water for withdrawal, there is a water loss and water use, which have to be deducted from this, this amount. And we have a waste water discharge out of this, which again joins the trans, transboundary flow towards the Aral Sea. So, that is the way, efficient way also of analyzing regional water packets and also efficient ways to communicate and prepare also negotiations between those countries sharing water resources.

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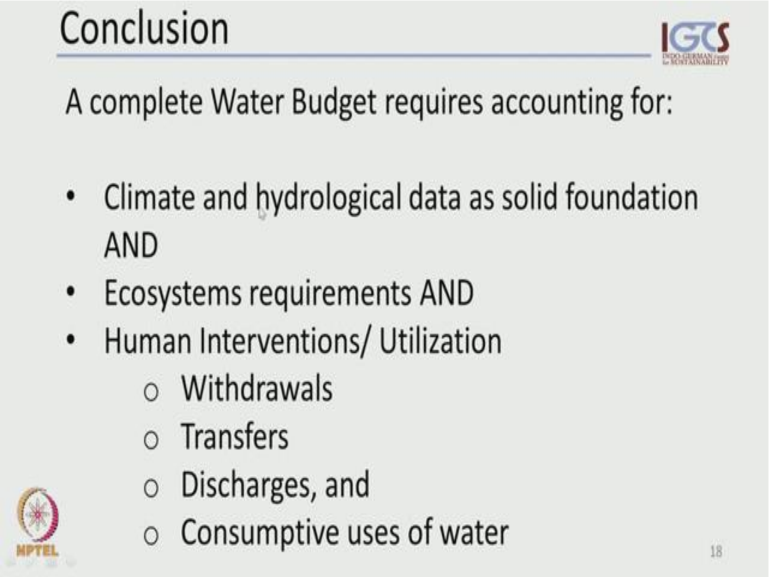

Now, let us conclude here. A complete water budget requires accounting for a number of elements. First of all, we have to start from solid climate and hydrological data. And this is the first point, stepping point, where the difficulties start. Hydrological data may not be available at this scale that we require, at the frequency that we require. The consistency may not be there, may not, may not be able to have the same consistency across the entire catchment. The catchment is being shared by these countries for instance. This is the starting point.

And then, we need to budget into account for the ecosystem's requirements of our in terms of water use, water, water utilization and we have to factor human interventions or human utilization, which means our withdrawals, our transfers into our, into our catchment, out of our catchment, the discharges and consumptive uses of water. All of this make up our water budget far beyond the hydrological model, which we have been talking about in our previous class. And at this point I want to stop and next time we will be talking about water availability and following up on water budget discussion today.