Groundwater Hydrology and Management
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Lecture: 33
Runoff conservation for recharge

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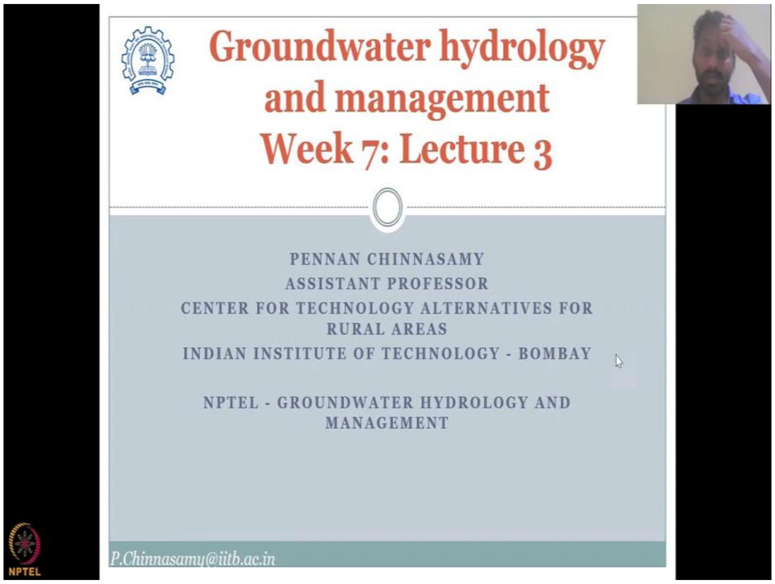

Hello, everyone. Welcome to NPTEL course on Groundwater hydrology and management. This is Week 7, Lecture 3. In this week, we are looking at multiple methods in increasing the recharge rate. This is because India has being seen an unprecedented use of groundwater and with it, there is a lot of recharge needed to sustain groundwater use.

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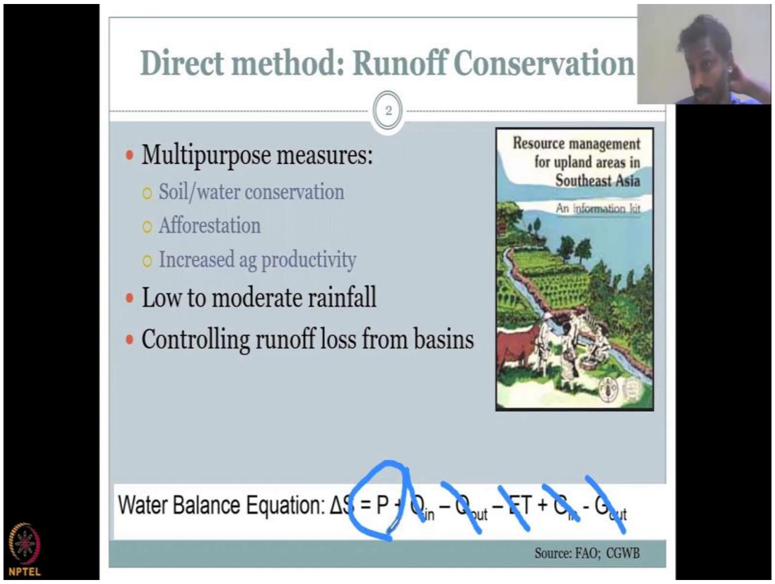

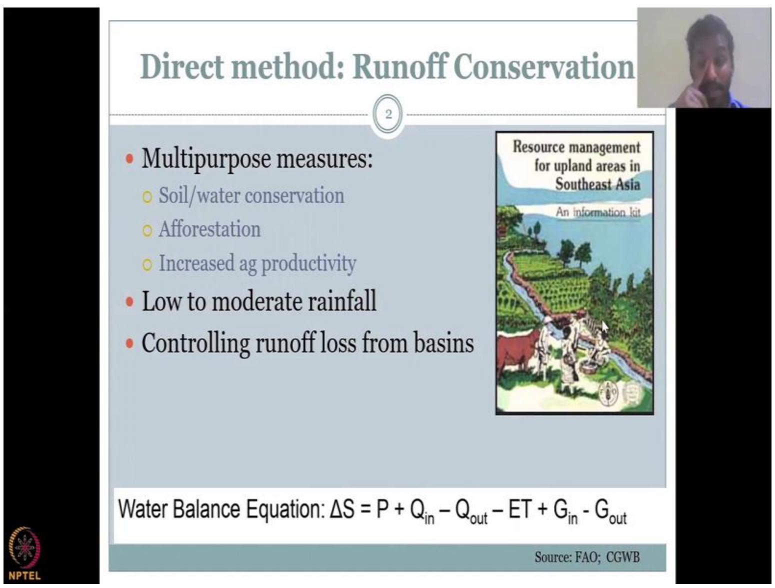

In the last lectures, we looked at how the methods are devised, it is direct methods, indirect methods, and a combination of both. In today's lecture, we will look at the direct method and most important methods for India. The first one is the runoff conservation. As the name suggests, runoff is from your water balance equation, we can get, which is the water which comes from rainfall, which is not going into the ground as groundwater recharge or storage, it just goes on the surface as runoff.

There is a need to conserve the runoff, prevent the runoff from escaping the watershed. And it has multi-purpose measures. For example, the runoff conservation can help in soil water conservation. It can help in afforestation because it can give water to forested regions and improve the forest cover. It can increase the agricultural productivity because now you have more water, you are lessening the loss of water from the watershed, you are keeping the water within the basin. And so there is more use of increased agricultural productivity.

These are mostly preferred on low to moderate rainfall because excess rainfall you do not need to capture the runoff, let us, let it go. Because if you capture runoff, then flooding will happen. So these runoff conservation measures are mostly needed for the low and moderate rainfall. In other words, in India, it is the arid or semi-arid conditions. Let us take Rajasthan for example. There is only limited rainfall occurring in very short timeframe. If you do not capture the rainfall as runoff and storage et cetera, it just leaves the watershed.

So it is very important to capture it. And also there is a need of controlling runoff loss from basins across the world. This book, if you see here, it is a famous book on resource management for upland areas in Southeast Asia. Upland means it has a good slope. High, hilly regions et cetera. There is good rainfall in hilly regions. And if you do not manage it properly, then the runoff will just flow down downstream and without any use for the upland communities, upland, uphill, all these higher elevation lands or same, maybe.

So where does this understanding come from? The basic understanding comes from your water balance equation, where you have your precipitation, runoff in, runoff out, ET, groundwater in, groundwater out, and change in storage. If you do not, the point here, which are discussing is, if you do not reduce your groundwater out, that means you are reducing your storage because it is a negative. And assuming, like for example, in this area, you do not have ET, So let us ET be 0, groundwater in is equal to groundwater out, so let it be 0, and there is no water coming in.

So groundwater in is 0, and surface water and no pipe connection, nothing is coming in. This is the upland. So what happens is your storage is nothing else but your precipitation minus the runoff, which means if you say there is zero runoff, you close your basin, you control your basin without preventing water in, losing, then the entire runoff is basically your precipitation or your storage is basically your precipitation that you are catching and keeping within the basin. These are called 0 or closed basins because it does not let the water out.

And to be honest, in some regions, these are needed because the water is not enough for the upland people. So moving on, we have these water balance equations and other equations that support, that we need to capture the rainfall and also manage the rainfall variable. So these are runoff conservation. So basically, catch the rainfall, runoff et cetera. If we catch directly rainfall it is rainwater harvesting, if you let rainfall convert to runoff and then you conserve runoff, then it is runoff conservation.

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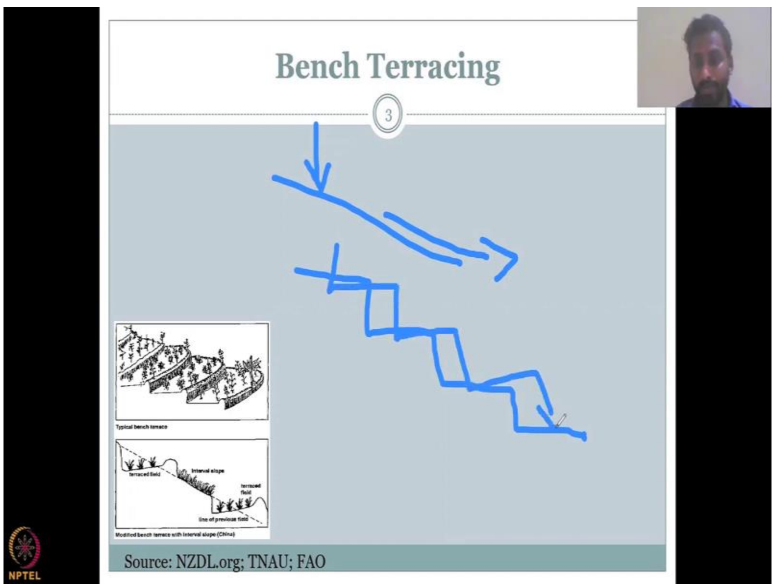

Bench Terracing

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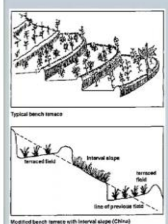
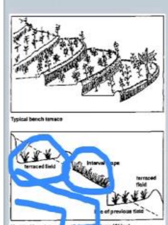


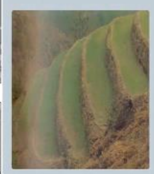
Source: NZDL.org; TNAU; FAO

Bench Terracing

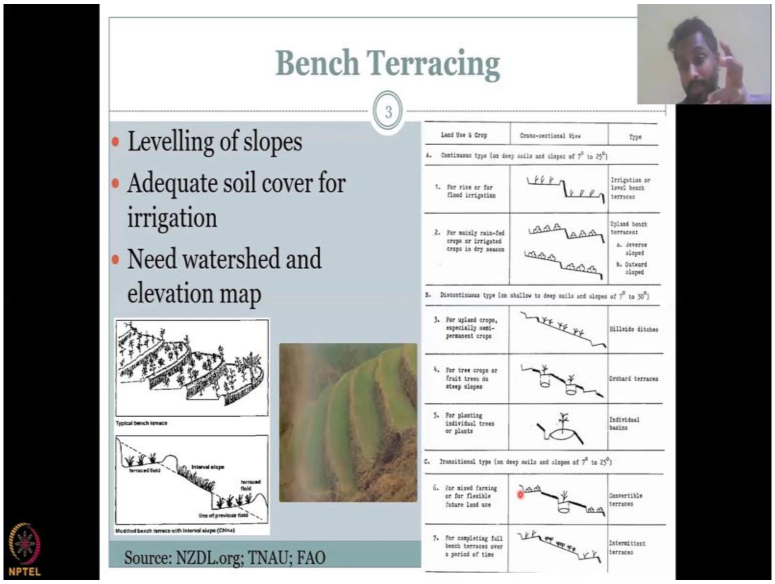
3

- Levelling of slopes
- Adequate soil cover for irrigation





Source: NZDL.org; TNAU; FAO



So let us look at some methods. The first method is the Bench Terracing. I am using the methods given in the CGWB manual, and I will be taking some references from TNAU, FAO et cetera. So what you, he here, have his bench terracing or, terracing is converting a slopy land into terraces. You cut through in between so that you slow down water.

So if you have it like this and water is falling, water flows down on the slope, It is much faster rather than going in steps. So if water is for example here, you have a slope and water hits, rainfall hits, then it quickly goes down the slope. However, if you make the surface as a terraced, cut-through in between, then water would flow and then go down like this, go down like this, go down like this. Maybe, I will use a different color.

So this is land surface, and then you have, so water will go like this. So what is happening is you are delaying the water and by delaying the water and hitting down, down, because it goes down, goes down, goes down, then here there is good recharge happening and net groundwater is recharged. So, let us see what is a quick example. We have these locations mostly in the high upland regions or high elevation regions where there is good rainfall.

But because of the slopey land, water just goes down. So it is kind of a runoff conservation, where you wait till the rainfall converts to runoff, and then you capture it, slow, make it slowly go down, and then recharge it. So it starts with leveling of slopes. First, you make sure the slope is leveled, and then remove the, any unleveling patterns like ditch or a gap et cetera. So you make it leveled, so that water can run smoothly, and adequate soil cover for irrigation is also needed.

So you cut and then use some land where you can put the soil. So you need to get soil so that you can grow native species of vegetation or agriculture. Remember, in the example I showed, when you cut it, you can further reduce the speed of the runoff if you have vegetation because vegetation can act like a buffer, and that buffer would make the water goes slow. So here is what is happening. If you have just plain land, then cut the land, and some water will move down a little bit slower. But if you have your agricultural slope along with terrace farming and or native species, water will slow down. Once it slows down, it goes into the recharge.

Need watershed area, boundary of the watershed, and elevation map. That watershed area gives you how much rainfall is going to come, and the elevation gradient gives you how many contours you can space. So because I know how the elevation changes, I can say every 10-meter elevation difference I can put. If I do not know that, then what would happen is you will randomly put in these terraces and it will not work well. So like this, you convert a slope into cutting, by terracing activities, and then put soil there because initially there will not be any soil, bring agriculture-related soil up and then put it there so that crops or new vegetation can grow.

Once vegetation starts to grow, water will automatically slow down and then recharge and also support the vegetation that is on the land. So everyone has given you multiple examples of these types and which land uses you could use. For example, all these are cross-sectional view. So you have a land like this, you cut the land and then you can see from the cross-section, what is the relevant construction. So if you look at here, you could see that first initially dashed line is the initial line, is a sloppy slope.

And then you cut it, take the soil, put it down in the next terrace or you can remove it and put agriculturally active soil and then you can make some field, agricultural field or trees something that can help slow down the water. So for rice or for flood irrigation you can keep it gently sloping, not high sloping along the thing, along the slope because you do need water to stay there for long. Rice takes a lot of water. So mainly rain-fed crops or irrigated crops in dry season when there is more steeper slopes. It is okay to have a steeper slope.

Remember, to convert a slope to a straight land you have to do a lot of work, and a lot of machinery or construction is needed like in terms of removing the soil and cutting, terracing. So understand, if you have that bandwidth. These are the continuous type. Discontinuous type include for upland crops, especially semi-permanent crops, small-small crops, you can put, you can have trees in between the crops like fruit trees, orchard terraces and then you have individual plants, big trees or big plants can be kept, and then you can also have a mixed farming.

So you can have both a terrace and a tree and a terrace and a tree. So if you go to regions like Ooty in South India, in Tamil Nadu, you could see that along the slopes they make tea plantations, and to keep the soil holding on better and also to help the slowing down the water you have eucalyptus or other trees in between the tea plantation. So yes, you have to sacrifice a bit of the land, but it is good on the overall cycle.

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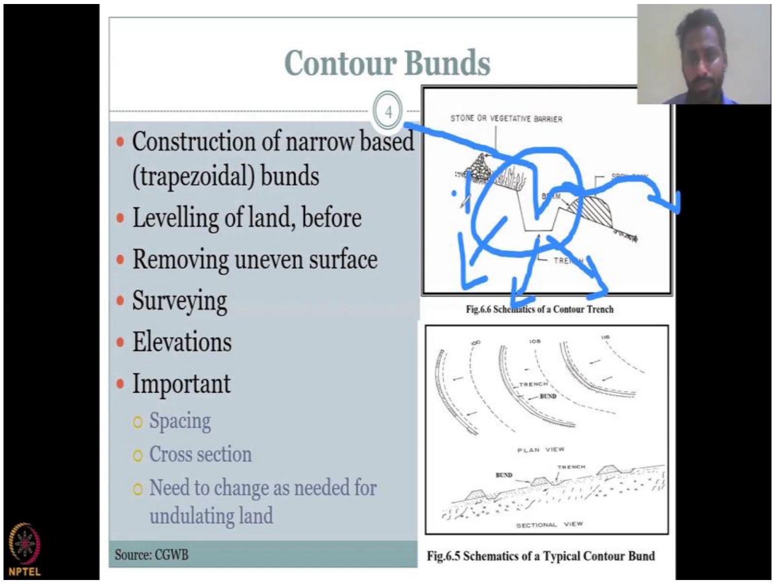

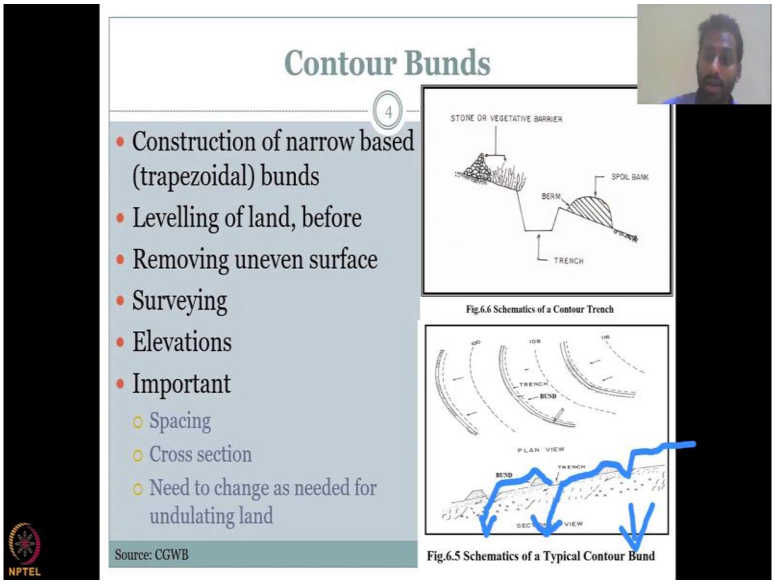

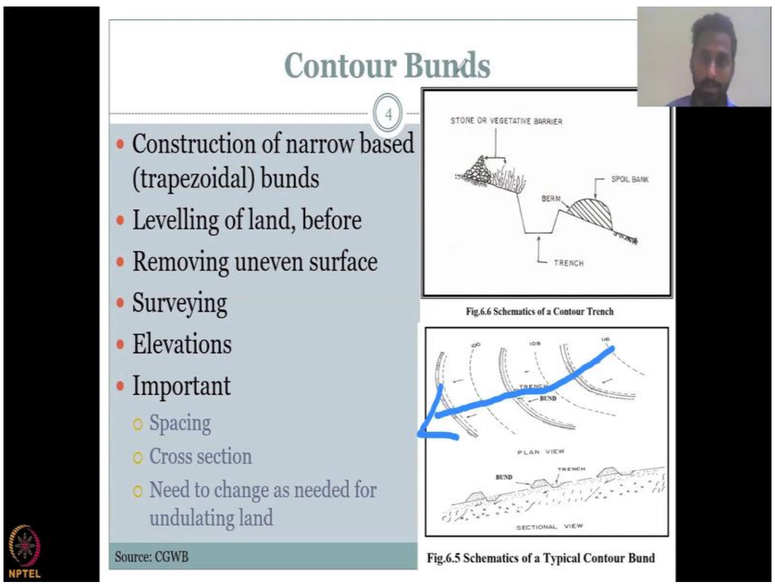

The next one we want to see is Contour Bunds. So similar to your terracing, however, this is not along the hill slopes. Terracing is a very, very high elevation, whereas contour bunds are construction of narrow-based trapezoidal bunds, just a bund around the semi-sloping land, not high sloping land, semi-sloping. Let us see how they make it. So you have a slope or a land, piece of land, you make a trench or ditch. You have to dig a little bit. Put the soil out along the, after the ditch or trench. So when water comes, and you can also have stone or vegetative barriers to slow down the water. So the idea is to slow down the runoff or capture the runoff.

So if runoff comes, it first slows down and then goes into this trench. Here is where water starts to rise, and then it is also not overflowing because you have this bund which is slowing down the release of water. So once this ditch is full of water and the enough water is available for going over, it goes over. Now the point is, how does water recharge? Along the trenches, water recharges, along the trenches, water recharges. In the previous I, said every step there is a recharge. Here, every trench or a ditch, there is a recharge.

Leveling of land is needed before you start these processes because you want to remove the irregularities, uneven surface, you need to remove, otherwise water would go somewhere else, not into the ditch. Your whole idea is to get water into this ditch. From here, it recharges. When you slow down here, yeah, there is some recharge happening, but most of the recharge would happen here in the ditch. So a lot of surveying is needed to get the elevations correctly to level it. And elevations are very, very important for these kinds of studies.

And it is also important to consider the spacing between the trenches. If you have too much trenches, then the land is lost, the stability is gone. And the cross-section has to be done well to capture how many interspacing of trenches has to be there. Need to change as needed for undulating land. Sometimes the spacing is not the same. If I say, for example, I have 10 elevations, so do I have 10 trenches? No. It depends on the land also not, only the elevation. So, the land is also important.

The cross-sectional view here shows how this is done by CGWB. For example, the water is coming, it goes into the trench, recharges down. And then the water was prevented from moving readily out, but still, water would go slowly out, and then another trench goes down, recharge, and then it goes up again and then recharges again. So the recharge happens along the trenches and along where the water flows, but especially in the trench, there is more water recharge.

Let us take this example. You have 116 which is your elevation, and then 100 is another elevation. Water runoff flows from high elevation to low elevation. So from 116 to 100, water is moving slowly. And while it moves, these trenches are there to capture the water. And after the water, there is a bund. So these bunds actually prevent more water from flowing.

So water is flowing like this, and this is where we capture it in the cross-sectional view. It goes in, and then the bund, and then goes in and over the bund. While it goes into the trench, it is recharging. This is clear, more schematics are given in the CGWB handbook, which I have shared earlier in the last class.

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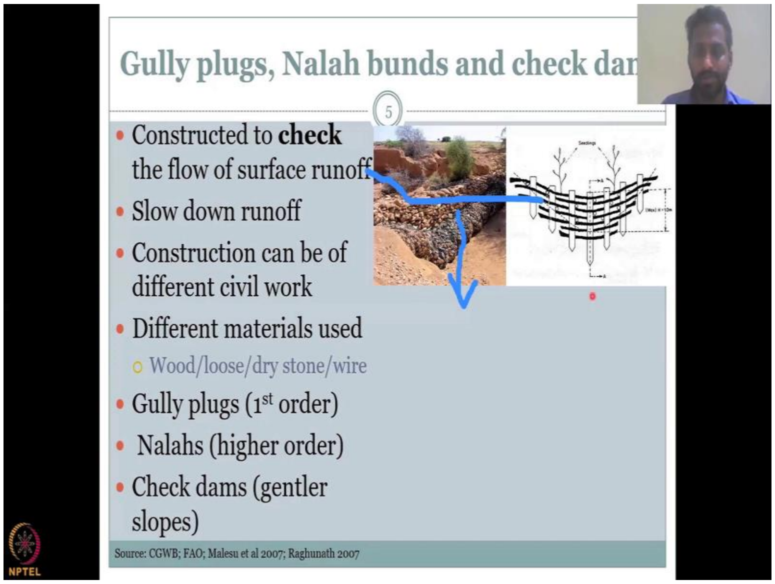

Then we move on to Gully plugs, Nalah bunds, and check dams. The spellings of nalah is different in different regions. N A L L A H, but the meaning is the same. So there are certain similarities between a Gully plugs, Nalah bunds, and check dams, but there are also some certain differences. I will go through this in detail. And more importantly, these all work on the principle of if you reduce the runoff, if the runoff is reduced, slowed down, or conserved, conservation of runoff, then water will go into the recharge.

Let us look at the definitions. Constructed to check the flow of surface runoff, hence the word check dam is. It is made to check or slow down the flow of surface runoff. While you check, there is a checkpoint, there is a traffic moving, and when there is a checkpoint, people move slow. So that is where you temporarily slow down the runoff, and the runoff goes in as recharge. So here you could see, water can come and then the gully is plugged.

What is the gully? A gully is a sudden dip in the elevation where water is flowing. It could be a stream order, very small stream order et cetera. So along the stream order, if you put stones and other things that is plugging, like a plug you put for leaking water, like a tap, so if here you put a gully plug, then water will go through and recharge, and then still go through the horizontal wave. Our aim is to get water vertical from horizontal.

So for example, here, water will be flowing, and then hit this rock, still it will flow, but some water is gone into the groundwater recharge because you are slowing down the water. And what you put in the gully depends on what materials you have. It can be rocks, pebbles, and other soil materials or it can also be some seedlings and saplings, wood et cetera. So that is a beauty of this technique. It is not that expensive. Just community participation can help in building these structures, mainly to slow down the water and get the runoff in.

Construction can be of different civil work and levels. Civil means civil engineering or machinery where you can have multiple constructions or less construction. Very important to understand, the bank of these gullies or stream orders. If the stream or the gully is not stable, then when you slow down the water what happens is, all these material can collapse. Some collapse is happening here. But mostly, this is where the maintenance is very much needed.

Different materials can be used, ranging from wood, loose or dry stone, big, big rocks or very loose stone, they can be clumped together and used. You can use wire, woven wire, like wire net, nets can be used to slow down the water, and a combination of rock and wire can be seen here in this diagram. So all these can be lined up across the gully and, so that water can move and then slowly get infiltrated. As I said, you can also put saplings and seeds as FAO as recommended on the top figure.

So what is the big difference between the other methods. So gully plugs are of the first-order stream, which means it is a very, very small river or a stream network that connects to a river and so the water volume and the discharge velocity is small. So even though it is low, you are trying to reduce it, so that you can have more recharge.

Nalahs would be of a higher-order. It is the same technique, but higher-order, So once the order is higher, you will expect to not use the same wood or dry stone, but you would use more like cement and rocks. In other words, if you look at where these are more appropriate, the gully plugs are more appropriate in the forested zones, where you have water coming slowly. Rainfall happens and the stream is just starting, the starting of a stream is around the forest.

So there, the stream the 1st order stream, you can put a gully plug. And right there, water can be used. In fact, beavers, it is an animal called beaver, you can go google out B E A V E R, so these beavers actually stop these small, small forest rivers by making these dams, gully plugs. And in that, they can catch fish or also they get more water so that they can enjoy the environment.

So check dams are of higher stream orders and it has a gentler slope. If it is too much slope, the water cannot stay. So it is gentler slope. Let us look at some examples. So this is a nalah, a small nalah, built across the river as shown in the CGWB report. And check dams are much bigger. It is smaller than a dam, large irrigation dam where you cannot walk and turn like the kid is walking. However, it is bigger than the nalah. Nalah is much, much smaller.

And also, please remember all these are expensive. There is money needed for these. So it depends on not only the water which is coming but also how much money is available for these types of activities. And if your village or Panchayat has enough money then mostly they go for check dams. Lesser money, they will choose the gully plugs or nalahs, as and when needed.

And also these check dams can be in a cascading effect. So these are called cascading check dams, which means one after the other after the other, same way you did look at the terrace farming, where you had a terrace, another terrace, and another terrace. So, or a trench contour trench. A trench, a trench, and then another trench along the elevations.

Here, what happens is you have small check dams, where water is stored and then overflows and then store and then overflows. So wherever it is stored, that is where the recharge is happening. So here, groundwater recharge is happening. Here it is slowed down. Not much is saved behind the gully plug but still, some recharge is happening. Whereas, here also, there is recharge.

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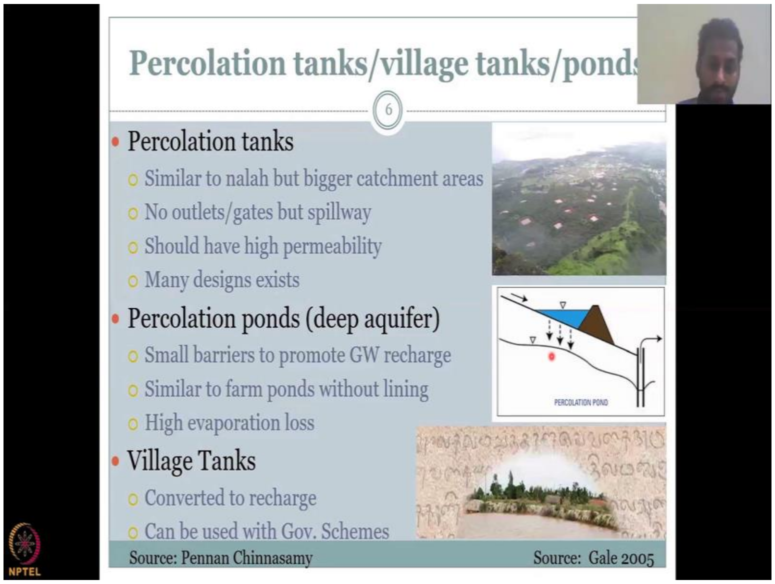

Let us look at the next one, to slow down the runoff and capture, is percolation tanks, village tanks, and ponds. What you see on the top is farm ponds are small, small village farm ponds were along the Konkan region Maharastra, you can see that big, big ponds are created to capture the runoff. So while runoff is coming down the hills, for example, this is a hill and where it is, when water is coming down, it is getting stored in these farm ponds. And from there, the ponds the water recharge is happening.

It is basically evacuated land along the slope or along the land surface where water runoff can be captured. But make sure that enough comes there, otherwise there is nothing to store. So percolation tanks, how they work is, a small check along the river, and it has good gravel and material underneath the dam to enhance percolation. This is the difference between a check dam and a percolation pond. Whereas, a check dam would allow the water to go and then it overflows and goes.

Here, you are trying to create a pond. You do not see a pond overflowing, not often. So it is, you take water from the main channel and then you put it in the pond. So similar to nalah, but bigger catchment areas. It has much, much bigger catchment areas. No outlets, gateways, but spillway. As I said, you do not have a gate to open and release the pond water, but the spillways are there. A small embankment and along the embankment, the water can go.

Should have high permeability there. The soil or the land underneath the pond has to have high permeability. So it is not just evacuating the soil and then you put the water in. Here, what mostly is done is, you can line certain types of soil, rocks and materials which have high permeability so that when you put the water in, it starts to increase the infiltration. Many designs exist, so we will see some of them.

So in this percolation pond, what is you can see is, it is along the slope and water is being first shunted into the pond area. Once the water is ponded up, then water starts slowly to recharge. Percolation tank is along the river and a tank can also be off the river. You can just take the water and put it in the tank. So mostly when, what is difference between a tank and a pond is, tanks can also be along the river channel, whereas ponds are normally kept away.

And they can not, may not be just fed by the river but it can also be fed by rainfall. Small barriers to promote groundwater recharge, similar to farm ponds without lining. So normally, farm ponds have lining, which means cement line underneath. So when water flows, it can not go groundwater where village tanks and farm ponds need not want recharge. All they want is to store the water, and then they use the water later for irrigation.

Whereas, percolation pond, the aim is to get water in the groundwater. There is evaporation loss because when you pond the water, there is evaporation loss, but you are also augmenting the percolation. Not infiltration, percolation. Infiltration is just going in very slowly. This, we saw in the previous lectures, whereas percolation is going into deep aquifer.

Village tanks are somewhat outside of the main river channels. It is a tank. So normally, tanks are also away from the river channel wherein water can be put in from the main channel, or runoff can be routed into the tanks, whereas a pond is similar to a tank but smaller in size, and also, water can be put in through runoff routing.

So we route the runoff into the percolation pond. So the village tank, what is new about this is, Village tanks were never for groundwater recharge. It was a water body that the village would use for drinking, bathing domestic use, and or taking the livestock for water.

However, the CGWB manual and many studies have recommended the use of village tanks as groundwater recharge. So what do you need to do is make sure you remove the cement lining on the ground, underneath the tank. So when you expose the tank to the natural soil, then water recharge can happen, rather than having a cement line.

So normally a village tank is like a large swimming pool, very, very large swimming pool if it has cement. Otherwise, it is just made of tarp, some people put plastic sheets underneath to prevent the recharge. But the idea here it is if you manage the runoff to capture all the runoff effectively and put it in the village tank, you could still get recharge going down, and also use the water for domestic or the surface.

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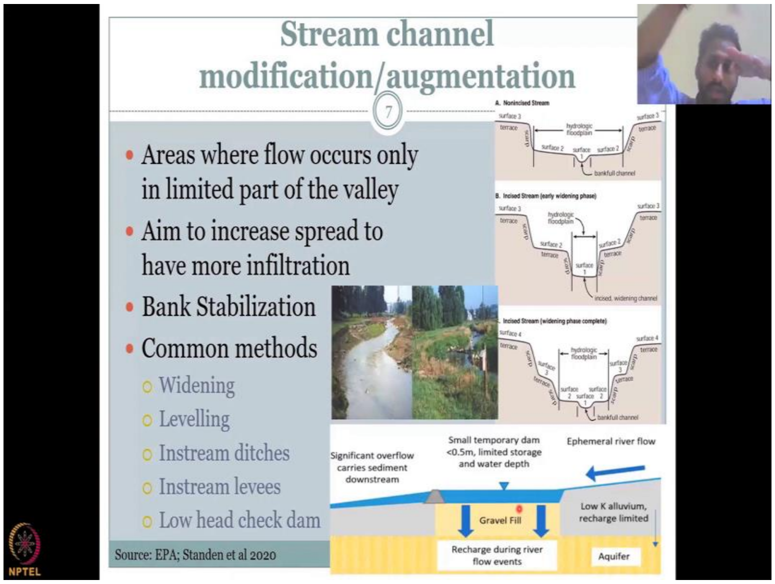

The next one I would like to touch upon is modification. So a modification of streams channel and augmentation is also very necessary for successfully reducing the runoff, and conserving the runoff for recharge. So what does it mean? So here what you see from the EPA book is that when a river is flowing, when a stream is flowing, when a water runoff is flowing, if it is made to flow in a very concentrated way, then fast, it will go and less recharge is happening.

If it goes in a torturous way, there is some water that can be recharged. However, still, the water can go fast. However, if you make the stream go in a wide channel, rather then a small channel, if it goes in a wide channel, then water will be spread across and then recharge can happen. Just look at this image. So here what is happening is the river is flowing in a very small, concentrated way even though the land is available, so there is less recharge happening

But in this system, all the other banks are not protected and dug deep, then the water spreads. Once you spread the water, there is more connection between water and land area, surface area, and then recharge happens. So like this. Initially, this was all full water flowing, but slowly what happens is at this part, it gets deeper. When it gets deeper, then the other land is not having water for recharge. Only water recharge happens here.

So the idea is to modify or manage the stream channel to increase the connectivity of water and land to the recharge. Area where flow occurs only in limited part of the valley. For example, valleys along the slopes also, but it happens only in a limited section. If you see a valley, even the Ganges valleys and basin, the bank is so big, however, water flows in a very small area. And only in that area, water is recharging. However, if you make the water flow, like in a spreaded fashion, then more recharge will happen.

Aim is to increase spread area to have more infiltration. So you spread out the water to have more infiltration. It is similar to the flood irrigation method. Now here, you are you are doing it inside a river channel. Bank civilization is important. So as and when this happens, you need to make sure that you clear the sediment. So what is happening here is when water is flowing, here sediments are depositing, and only water is flowing in this area. Slowly, the sediment deposit is high, and water only flows in the central region.

What the idea is, to make sure you push all the sediment out so that water can still flow, and that is called Bank stabilization. The common methods are widening, you widen the area of where the water can flow or widen the stream channel. Leveling, you keep it on the same level, like here, all the water is on the same level. Instream ditches, So along the stream you can have multiple ditches where sediments can be deposited, rather than at one location depositing. Instream levees, like this example.

A levee is a small, check dam kind of thing but not like a dam. It is just a small, it like a speed breaker within the river. So when the water is flowing, it slowly goes above and then goes down. And while it goes up and down, there is some gravel fill here. A different material is filled so that water can recharge. Low head check dams is the same as I said, it is instream levees. So you can have a small check dam but not like a check dam, where it is big, and then it stops the water. It is just there to, so the water can go over, and then slow down while it goes.

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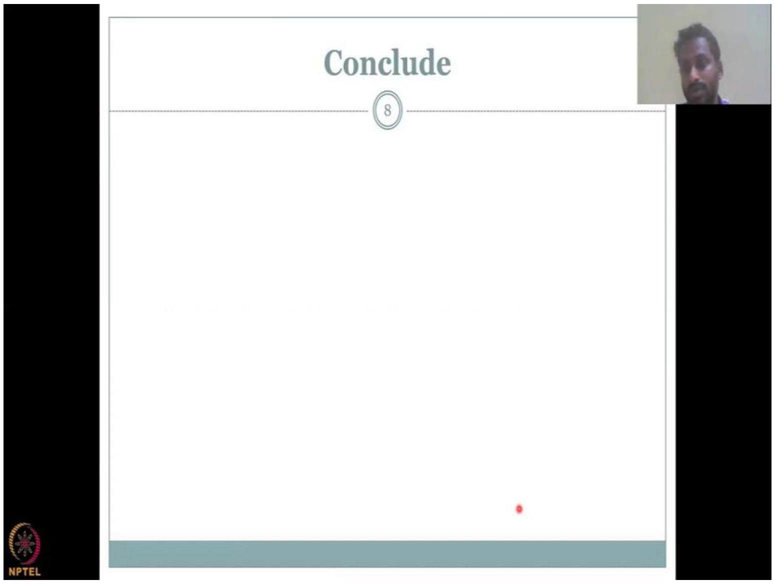

So with this, I think we have covered the major, major factors for conserving runoff and recharging it through direct methods. I will see you on the indirect methods, and other methods for groundwater recharge in the next class. Thank you.