Rural Water Resources Management
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Week 07 - Lecture 04
Watershed delineation

Hello everyone, welcome to NPTEL course on Rural Water Resource Management. This is week 7 lecture 4. In this week, we have been looking at the hydrological water balance approach, which has been called by different names, example, mass balance, water balance or hydrological balance equation. It is a very important equation to understand what is the net storage in the system after considering the major inputs and outputs and the storage then can be transferred into a rural water resource.

So, this can be actually used for agriculture or livelihood options, give the farmers a sustainable irrigation pattern etcetera. The past lectures in this week, we have been looking at how the water budgets can be established, what are the units? what are the different parameters that are key to establishing these equations and also arresting a unit to start.

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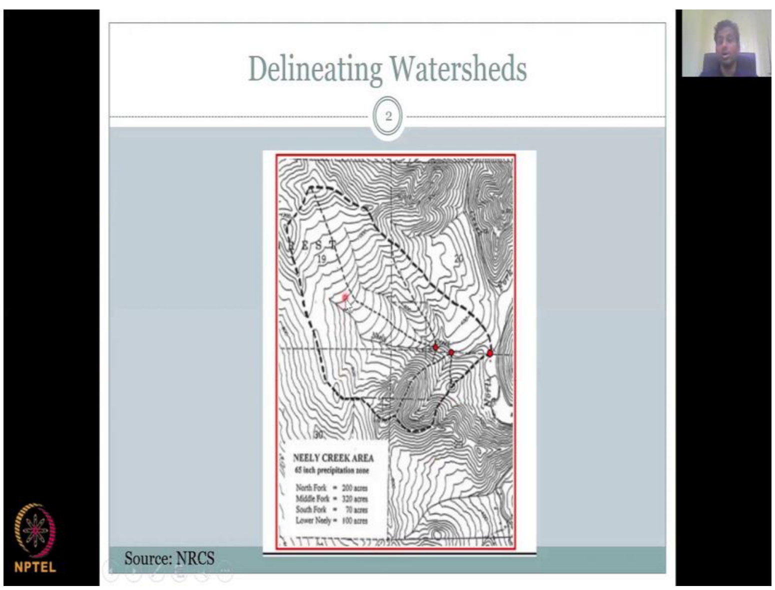

Moving on, we understood that watershed-scale basin-scale or the catchment-scale is very important because a watershed by definition, it catches water and sheds water so, watershed. A catchment catches water basically catches water, a watershed would catch the water and shed the watershed mean it will give it off and that is what is very important for the hydrological cycle because the water continuity would happen. If all the water was stored here, then how will the water go to the oceans, lakes, plants and then evaporate or evapotranspiration and then go back to atmosphere. Again, rainfall without all those things the cycle would be incomplete if the watershed loses the property of shedding the water.

So, some people do say let the rivers flow correct. And that is the meaning of also incorporated in the watershed approach. Basically, all the area within a watershed would capture the water and bring it to one point through channels through drainage networks or streams. So, these are like streams that you could see. And they are bringing the water through all these channels.

And to the last point of the watershed where all the water would come from your watershed and get out. There are some storage is groundwater storage, soil moisture storage, some check dams, big dams, etcetera. And those should be accounted for. We have known how to account this in this surface water balance. But here, what we are going to see today is how do you define the unit for your analysis, especially the watershed approach. This is an example image from the US government or NRCS.

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And we will be seeing how to use a map, basically a topographic map to understand and delineate a watershed. Let us look at the methods there is need for info on elevation. So, the basic criteria for defining a watershed is elevation, because it runs on the principle that water flows from high potential to low potential. So, in a given area, you need to find the highest potential and the highest potential is given or triggered by the height in which the water sets which is eventually the elevation of the ground, the trees. So, if you know the elevation of the ground and the multiple elevation points along your area, then you could establish this high potential to low potential connection.

So, in an area if everything is flat, everything is the same height and I put water here and water here would they flow? They will not flow. Because it is the same potential. But if I have a undulating surface a slope, and this is the nature? It is a slope, normally you do not see flatland in natural system.

So, if a water falls here and water falls here, will this water, let us call it B and this water A. Will B go to A or A to B? A will go to B because A is at a higher potential and B is at a lower potential. If you have undulating surface like this A B C, so A will go to B, C will go to B, B will not go to C, you see the point that you have a high potential, a low potential and a middle potential, C will not go to A, but C will go to B because B is the lowest potential and water would want to go.

So, given this understanding of land and elevation, we understood that elevation is the key in driving this potential difference, and to understand how water flows, which is what is needed inside the watershed. So, what do you need in a watershed to delineate a watershed is a info on the elevation. Maps, so where do get this info?

From Maps, Cadastral and Toposheets, manual. And also, it could be available from state and federal survey departments. It is basically a survey department a mandatory to have these images or maps and most of them are paper maps. And if you go to these offices, they will be willing to give you a photocopy of it, but not the actual map. And there are some other methods that I can share with you coming time.

So, it was manually done. So, which is very, very long time ago, they will send surveyors to monitor the elevation from one point to the other. Where is the lowest elevation point we have had this in the groundwater class, we have had this across many other classes in this lecture series, the lowest elevation point is your sea level, sea level is at 0. So, we have 0.

So, what would a surveyor do, they will go to the 0th location because that is where they know and from there, they will use a differential scale to actually put points along the tree and then measure the elevation difference, you cannot measure the elevation difference at zero level, for example, Mumbai coast and Delhi.

You cannot because you cannot see the elevation level. So, you have to break it into multiple smaller points. That is what a survey is, and then go to every point and use these instruments to see the differential elevation. And then at the end of the day, you do have a map, I will show you a map how it looks like. So, that is the manual method.

The automatic method or digital method I would call more is from the digital elevation models, which are models driven by satellite and remote sensing data. There is other ways also you can digitize a topo sheet. So, the maps that have been made using surveyors and manual, which are more accurate, but spatially you cannot have many points because not every meter or kilometer they would have, so those maps can be digitized, which means converted into digital format. I said it is available as a paper, but you can convert it to a digital format.

The other things are, you could use a satellites which are remote sensing, satellite payloads, which are going above the Earth's atmosphere. Or you can use smaller remote sensing methods like radar, like planes, planes can take elevation using LIDAR technology, all those things. So, you could understand basically, there are two ways one is your manual Topo sheet method. And your digital elevation models procure by remote sensing data. Either way, your goal is to have a map with elevation points.

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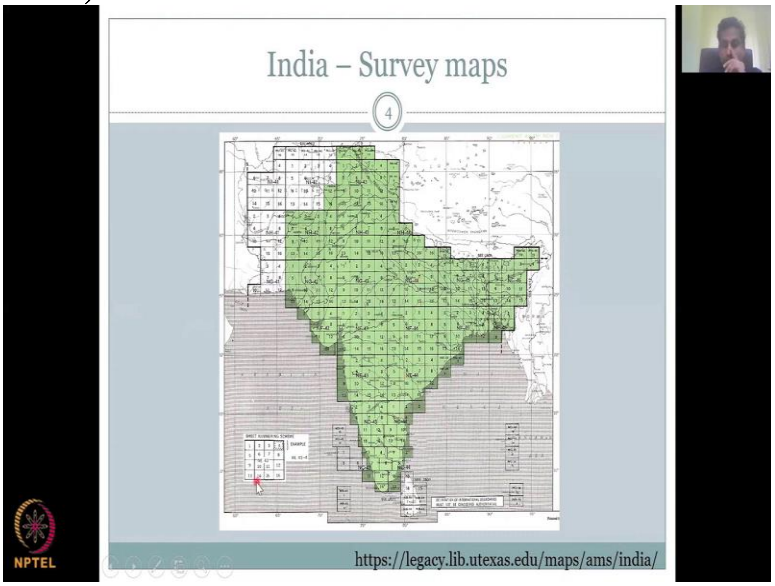

And this is a very interesting website in University of Texas, it houses all the important toposheets for entire India. All you have to do is go to this link, and then click which is your area of interest. And they have divided India into grids or tidals, more importantly, and just click on the tidal number and scheme. So, given an example how to do it, is it North East, North West, etcetera, etcetera. So, you can have the region here, and the number on this sheet along with the sheet number sequence. So, this is a ND-44. This is nemg44. So, in the ND44. Which one do you want?

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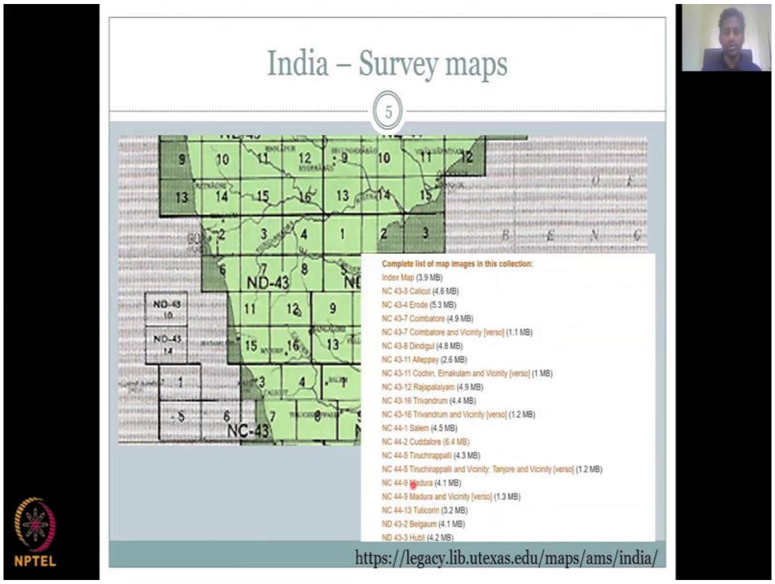

And then if you click it, you can go to the actual map. I am zooming in to show you another view of it. So, these tidals have the same number. You could see that oh, why am I seeing another two another three which is the same is because this is ND-4433 and ND-43 3, so there is big difference between the ND and ND, so this is ND-43, ND44.

So, use these numbers in particular, or if you cannot use the scale, just go to this and click it, they have actually linked each box style to the accurate toposheet. I will show you an example. Before we see that NC 43, so NC 43 is Calicut, NC 43-40, which is these areas, and then you have all NCs HC's and ND's are here.

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So, you could see that you have an image of the toposheet by just clicking on the toposheet. And what you see inside is if you zoom in, you will see elevation data, and the names of the important locations and water bodies. So, the blue water bodies are available, these are mapped way long ago. So, if you go now and check these water bodies, it may not exist, maybe it is converted to urban setting, maybe it has been small, because of encroachments on the side.

But this is a very important map to show how many water bodies we had, and in what time. So, if you look at the name spellings are very different from the conventional use, because it is done by US people and they use in 1962 1929 data. So, this is before independence. And so, who did these exercises? It was done by the Britishers.

So, Britishers did very extensive mapping of these elevations along India's boundaries, and for a particular reason that they wanted to see how the elevation radiated so that they could build railroads, roads, etcetera, to take out the possessions of India faster through ports and stuff. So, if you look at very closely, you could see the numbers of the elevation, what is the elevation and what is the unit.

Read the information here, which is given in this box, it gives you clearly what is the unit used, what is the data that has been used to make these maps and the location of the style is given here. So, all the information you need is given and each one is divided into tidals. So, this is one way of getting your data, I will also show you some remote sensing data, but this lecture is mostly to show what do you do to delineate a watershed.

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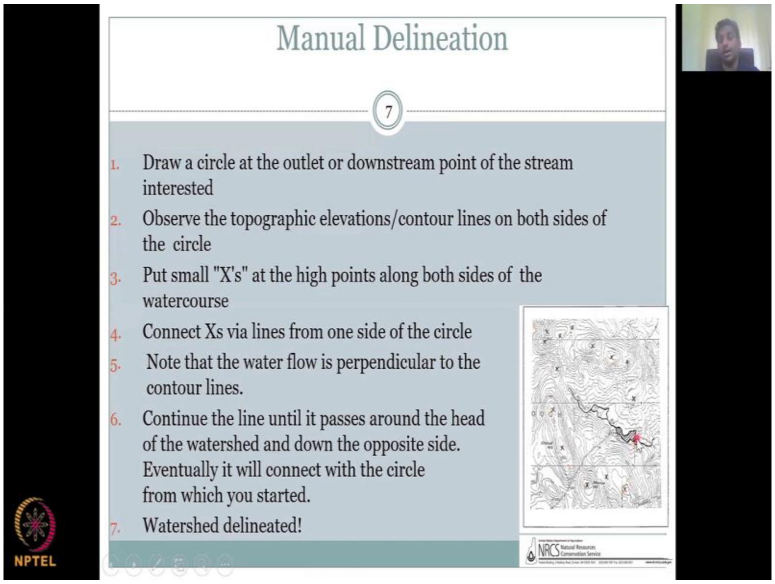

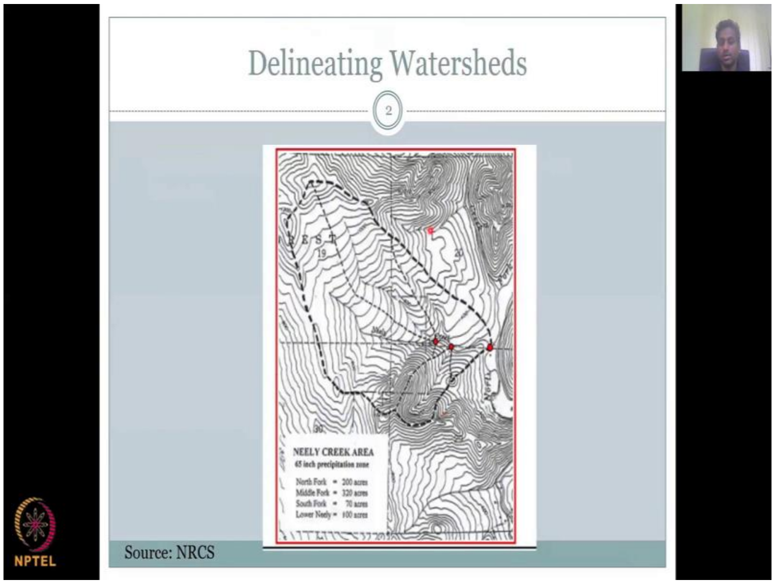

So, basically, you need an elevation map, an elevation map is nothing but lines which tell you the elevation of the region, so it will have points or lines which are called contour lines, which actually tell you the location and the elevation of that point. So, if you have this line, for example, along the line, the elevation is same. So, this one is at 400 meters. So, along this line all the wherever the line goes, it is 400 meters, that is how you should understand. So, they have divided the land into contours and contours would have the same elevation along the same line, the next contour would have a different. So, you see differences of elevations.

So, this point, what do you see on the as a center point is the highest elevation, because it has smaller circle. So, if you look at a mountain or a hill, it will be like this. And the center point is smaller area, because see the area is very small. that is why the circle is small. And then if you come down the mountain, you can put concentric rings of equal elevation. And that is why you see a concentric ring. And then after some time it joins to next hill.

Because the hills do not stand by itself, they might have Hill range, Himalayan range, Western guards range, so they actually are close together. So, you will see multiple hills with different elevation points, but at one point, they can coincide because the elevations are the same. For example, here elevations are the same; the base of the hill is almost the same.

So, how do you delineate? Now, I have given you a topo sheet using a topo sheet or a method? How do you use manual method and not using here satellite data? Because satellite data there are tools open source that can quickly delete the watershed for you. You do not have to give a lot of input, but it is always good to understand the methodology. So, let us get into the methodology and draw a circle at the outlet or downstream point of the stream. Those who are interested you can print this out from the slide, and then do the exercise. The basic exercise is given in this slide.

This one. Good, So, all you could take the previous India image and take a slide, take a topo sheet out and then you can do this exercise. The first thing you should do is draw a circle at the outlet or downstream point of the stream interested. So, every watershed is defined by an outlet see that is where the water would be collected and it will be shed outside your watershed outside the area. So, that watershed outlet point is very important and that is where you should determine this is my point of interest. So, that is the information that is needed from your end.

So, you are giving an outlet point. Then it could be above the dam below the dam so if you see here there is a big lake performing there is a stream running and a river and it forms lakes or and there is a dam or something because there is more water here. So, then the level of what was high and below right below it, you put the outlet so all the water is collected and taken out then what do you do is observe the topographic elevations contours lines on both sides of the circle, which means from here you should look up and from here you should look down.

So, both the sides, you should look at the topographic elevations or contour maps because some maps would have a point and the point would have a elevation. So, here what the book is saying NRCS is saying is just look on the side of your point and then find the highest elevation put a small x at the high points along both sides. So, I am putting one x here, which is the highest point and then I move up to see where is an isolated high point it should not be a connected line it should be a small circle and a high point.

So, then you go on marking. So, if you see here clearly you see a hill and on the top of it I put the X. Here also hill hill, so isolated points. So, along the isolated points a small x can be put and then you connect the X via lines on one side of the circle. So, now I put all the x's and I now join the line from one side. So, I go up go like this to delineate the boundary, I cannot go the side because there is no nearest high elevation isolation point it is here.

So, I come down and go here, then connect, connect, connect and connect all these points out of the watershed outlet point. So, connect x's via lines from one side to the circle note that water flows is perpendicular to the contour lines. I have figured to show what do I mean perpendicular it cannot flow along because if it flows along a line, the elevation is the same. I have already told you if the elevation is the same water will not flow from one point to the other point, it is same only when it is elevation is different.

So, this point is a higher elevation this point is a lower elevation high to low. So, how will this be? This will be one contour line and this will be one contour line. So, it flows perpendicular to the contour line. Note that water flow is perpendicular the contour line and not parallel, or along, continue the line until it passes around the head of the watershed, which is this, this is called the head of the watershed and eventually it will come connect to the circle which you started.

So, a many times here, a lot of errors when you do it manually because you might miss a point, which is high elevation, but you did not notice it or the data on the paper did not capture. So, there are some errors in delineating watersheds, which is where an automatic method is much, much more useful. And then once you have connected the line, so from here I draw the line connecting all the x's and then from across the boundaries Yes, then I have made my watershed.

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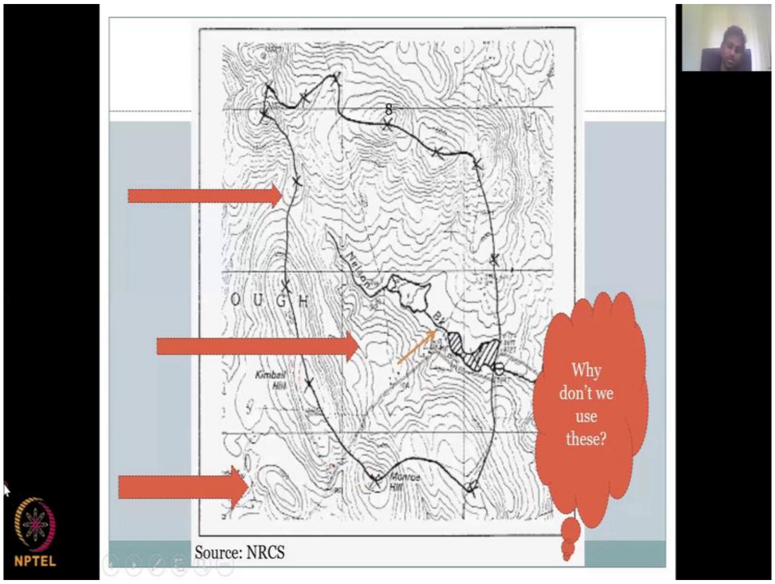

So, this is how the watershed looks. For example, as I said, you started here with the outlet point and then I moved up to see where the nearest high elevation point. So, I have a high elevation point here and here, which one would I take? I will take this point because from here this is the closest and then I move on there is a high elevation point here, but then this one is much more higher and or within one side of your river. So, you have to go closer to the river as much as possible do not go away from the river, closest to the river, which is the highest point.

Because if what falls on the ridge, what will happen, it will fall 50 percent on the side, and 50 percent on the other side, because it is like this, the point, as I am saying the highest elevation point is this one. And if water falls on this one, it has 50 percent chance to go left and 50 percent chance to go. but all the water inside the watershed will flow to you. So, all the watershed would do is collect the water from all the area and put it into the drainage which is your stream or river and bring it out to the outlet point.

So, that is why it is important to have an angle from your river. So, you already know where the river is. And from your river, you should look up to see or down to see which is the closest high elevation isolated point. So, here it is this one so I put a point. And then again I move up and side walls I found this point 230 and then here a small point here, there is no other point just look down because all they do is running lines, it is not closing, you see here it is not closing. The circle is closed, then that is an isolated high elevation point.

So, I have one point here, one point here one point and then come up down, and then go through the watershed boundary and come here. Let us take some key important points, this is called the head of the watersheds. This is called downstream or the watershed. Head stream downstream. The downstream is where most of the water would come because it concentrates all the water and brings it to the outlet point.

So, the flow is always greater at the downstream point compared to the head, but the headstream point will give you where the river originates. So, the river is originating here, along the headstream along the head watershed, not downstream. So, you would see all these locations where it is and then this watershed also gives you an understanding of where the elevation gradient is and where the land use land covers.

So, you can also move it here that totally depends on you where you want to put your outlet point. I want it here because it will be good to see how much water comes into this dam, how much water comes into this river, if you put it above that dam, then the water is mostly from here and coming around and this dam water drainage all these areas would not be captured.

So, let us see these concerning points and why we do not use them. So, the first point, we do see a Saddle. This is called a saddle point. And you could see the lines run perpendicular or cut through the contour lines, they do not go along the contour line, so never go along. So, I did not use this point because it will go this way and then come whereas I have very nearer, very nearer to the stream I have a high isolation point.

Why would I not use this point? Because it is not closed. Only when it is closed it forms a full circle, it forms a full circle and hence you can have an X mark. But here since the elevation is there, it is a high elevation, but it is not close, which means water from here can still enter this path and that you need to accommodate. Why will I not use this point? It is a high elevation dig, it follows your methodology. However, from your stream, if I go outwards, this is the first elevation point this is isolated. So, I should stop here and come down this elevation is for the next watershed boundary.

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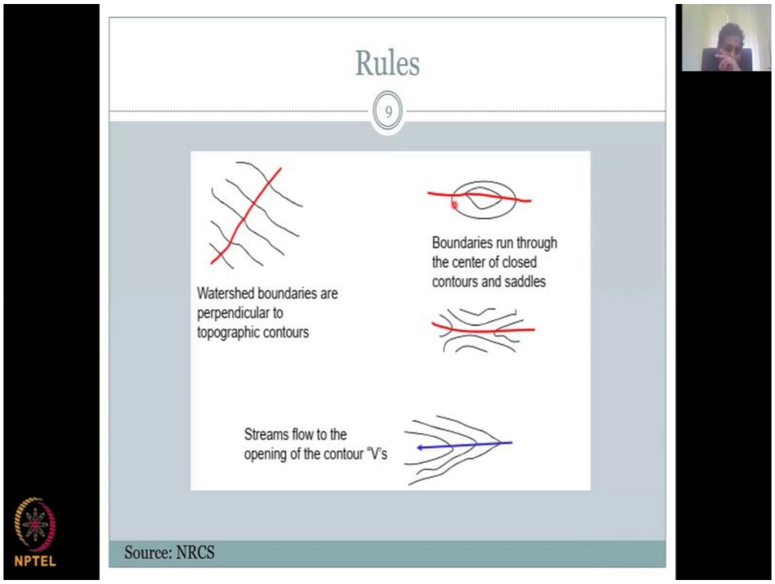

So, we saw how we need to use and neglect some of these points and the rules and concerns we did mention earlier and I will show you how it is available on a contour line. So, if you have contour lines from the topo sheet, remember that the watershed boundary which is red runs perpendicular to it, watershed boundaries are perpendicular to the topographic elevation, why? Because this one is at a higher elevation, another elevation, lower lower lower and this is the lowest. So, that is how the watershed boundary is created.

You cannot have along the watershed boundary to be along the contour line because then it is the same elevation where you do not have much difference in waterflow. Boundaries run through the center of close contours and saddles. So, you have this high elevation point the boundaries will run through it not along it not around it and also saddle points.

Saddle points are between two high elevation points. So, there is a high elevation point here and a high elevation point there, so between that there will be a saddle. So, this is your saddle. So, you have a high elevation mountain, high elevation mountain and in between you have a saddle and the watershed boundary would run through it. So, look at how it runs through it.

Streamflow to the opening or contour these. So, you see how the streamflow will occur is along the contours the V's towards the opening. So, the flow direction the opening of the contour. So, this is your opening of the contours and water would flow along this side along this direction. So, this is within your watershed, blue is not the watershed boundary it is the stream. So, once you have this stream network created you also notice that it flows on the downward. So, this one is flowing downwards the stream from north to south and all the contours are at opening, like opening like this.

So, water is flowing through and why because you are high high elevation to low elevation. So, this part is your high elevation and of the V and this part high elevation, this is lower elevation water falls from high to low potential and it cuts through. So, this is within, there is no high elevation point isolated here because that is at the boundary at the boundary of your watershed. So, the high elevation point isolated is for your boundary of the watershed.

So, with this, I think we have covered the need for Watershed as a unit of analysis, we understood how a watershed is delineated using the elevation points, you have an high elevation along your topographic map, a topographic map is a manual map, where they have the elevations and using that you can manually delineate the watershed by identifying your first your stream of interest and along the stream where do you want an outlet and from the outlet you put the elevation points in with a boundary this is a manual task.

But in nowadays, it is very easy to do this exercise within 5 minutes on your PC using GIS software. And the data is also free. The next class I will show you some data and some watershed boundaries that have been created using your open source DEM'S and open source GIS software. So, that it is free open source is free for everyone you are not required to do it by hand you can do it by the software because a computer access is getting better nowadays.

So, and this is the starting unit of analysis for your water balance, once you do the watershed, then within that all the parameters you can take, you cannot take outside like a district boundary you cannot take because now you are working at a watershed boundary. So, watershed's are very important to understand how the water flows and within the watershed, all the water would concentrate precipitation into runoff.

But if you take it from a district boundary, it can take from water from outside the discharge point may be outside your district boundaries. So, that is where district boundaries are not used for water balance equations. First you do it at a watershed-scale. And then maybe you can apply it to the district state national scale if needed.

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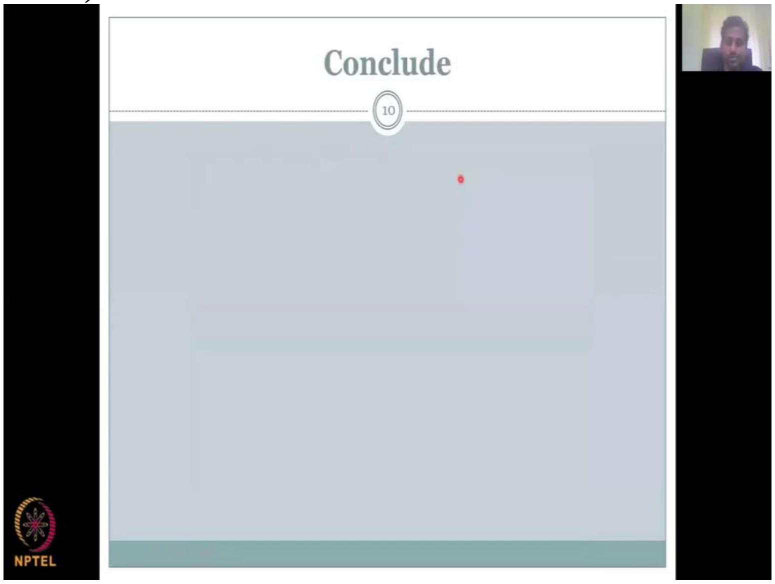

With this I would like to conclude today's lecture on the watershed Analysis Unit, which is your watershed area delineated from elevation maps. And we will see in the next class to wrap up the watershed balance equation lecture series and I will see you in the next one. Thank you