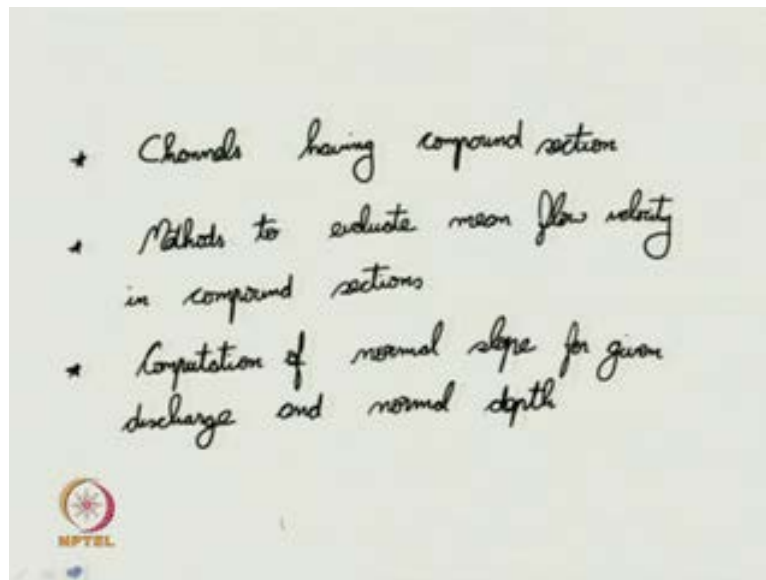


Advanced Hydraulics
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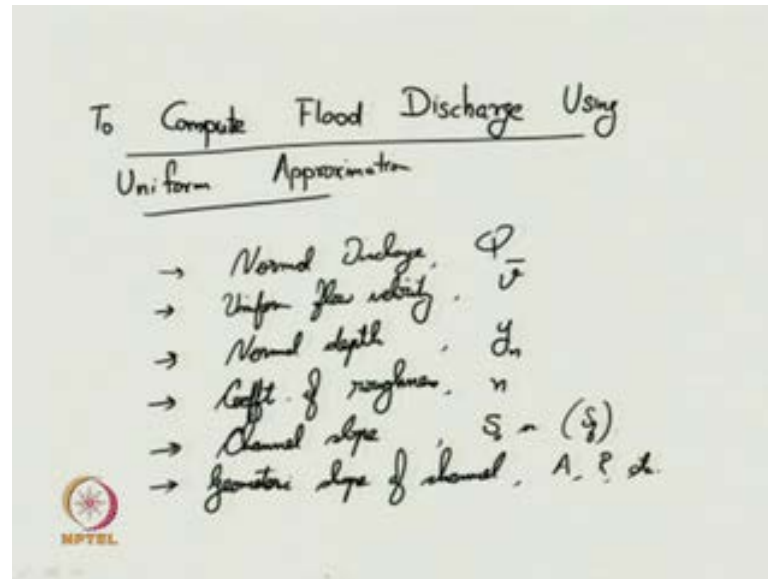
Module - 2
Uniform Flows
Lecture - 5
Uniform Flow Approximation for Flood Discharge

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Very good morning to everyone, we are back into our lecture series on advanced hydraulics. We are for last few classes going through the module two on uniform flows. In the last class, we discussed on the channels having compound sections, how the compound section was defined, how to evaluate mean flow velocity for compound sections; that was also discussed in the last class. We also suggested on how to evaluate normal slope, suppose if normal, if discharge and normal depth if it is given for a channel, how to evaluate the normal slope of the channel, that was also discussed.

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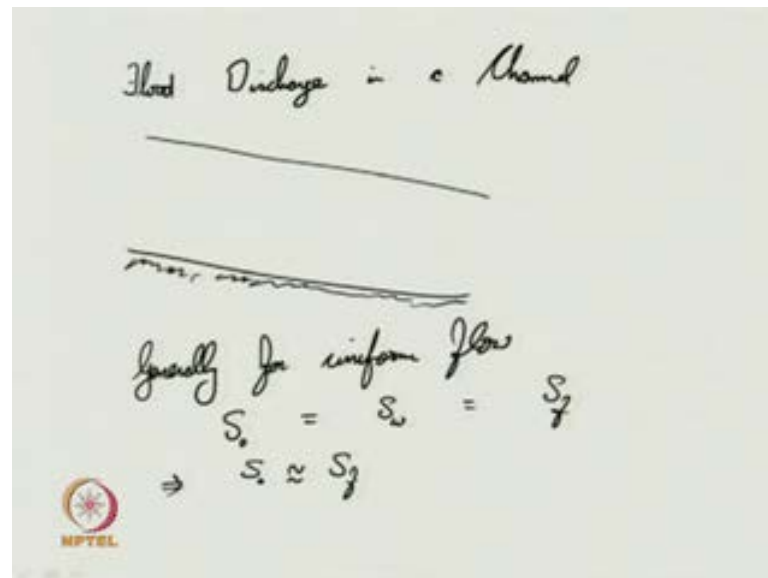


Today, we will see on how to compute flood discharge, using uniform flow approximation. To compute flood discharge, using uniform flow approximation. So let us just go back, before going into the concept what is meant by flood discharge and all, and you have to use the uniform flow approximation and all. Let us recall in the uniform flow computations and all, what are the various variables, or what are the various things you have gone through. If you want to use manning's uniform flow approximation and all, what are the various quantities in those equations? I will just briefly enumerate them, you have already seen normal discharge, we gave it as symbolically Q . We have seen the uniform flow velocity; we gave it as \bar{v} . We have seen the concept called normal depth y_n , manning's coefficient of roughness. In the manning situation, you have also seen the channels slope, or bed slope, or energy slope, coming into picture s_{naught} , or s_f coming into the picture, the geometric shape of the channel, that give rise to cross sectional area A , hydraulic radius R etcetera.

So, if these parameters, if these six quantities are related in manning's equation for uniform flow computation, so for example, if you are given the, all other parameters, say normal depth y_n , coefficient of roughness n , channels slope s_{naught} , and the geometric shape of the channel a and r . If they are provided to you, you can easily compute the normal uniform flow velocity, as well as the normal discharge Q in the channel. Similarly, if normal discharge Q , if it is given to you, you can and if the other parameters normal depth, coefficient of roughness, and geometry of the channel if they are also

provided, you can easily compute the normal slope of the channel. So these, some of the problems related to them also we have computed and all. So you have to recall them, you have to use those concepts.

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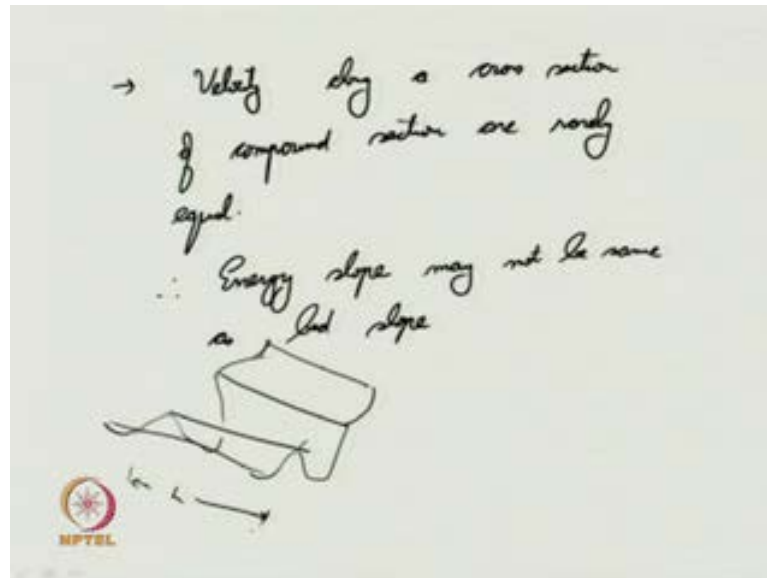


Now, to evaluate flood discharge, or to compute flood discharge, to compute flood discharge in a channel, what do you mean by that, what do you mean by flood discharge in a channel? You have to take a considerable reach of the channel. Earlier we were dealing only with one cross sectional area of the channel. Now you may need to take the considerable reach of the channel, and along with reach of the channel, where ever it is flooded, or where ever it is over flowed, although all those quantities how you can measure the corresponding discharge and all, you need to take into account. Going back into the uniform flow computation, you have seen that.

Generally for uniform flow, your bed slope, your slope of the water surface, and the energy slope, all of them are equal. Approximation is quite valid for general shift channels, or even for laboratory experiment channels and all. However if you go through the natural streams rivers and all, you may seldom see, where all this parameters are equal, means exactly equal. To approximate uniform flow in those natural streams, or rivers and all, you need to approximate, you have to suggest that your bed slope is approximately equal to you energy slope, or like that or it is approximately equal to the

water surface slope and all; like that you need to use certain approximation, then only the uniform flow approximations can be employed for natural flow.

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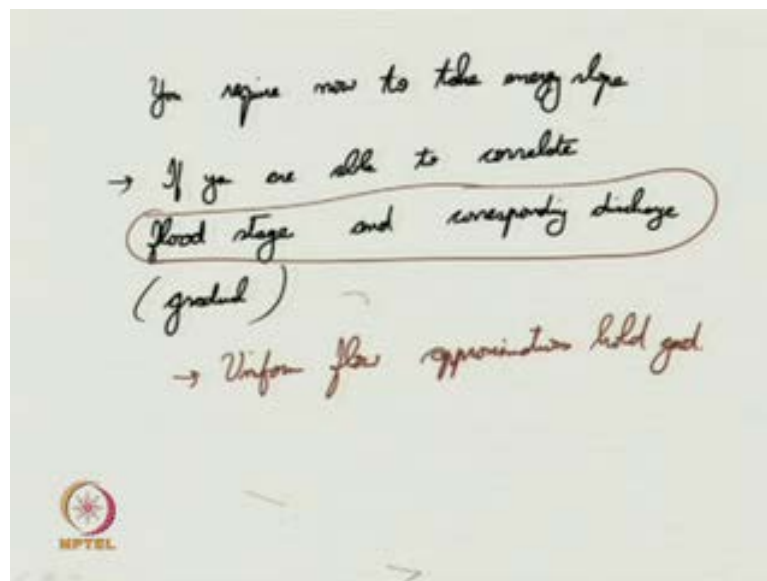
So as you have seen in compound section, compound sections channels and all, most of the natural streams may be having compound sections. So the velocity, so the velocity pattern along with the same cross section of the channel, it may not be uniform, it may be having different winds, along the flood plains the velocity may be quite different, along the main driver channel, or main channel of the carrier channel, main portion of main body of the channel, it may be having different velocity, so that we have seen in the last class, we have already gone through them. So you have to now think on certain approximation here, as velocity is may be rarely equal along compound sections, along the same cross sections in a compound section and all.

You may have to give some approximation, certain approximation. Definitely the computation of energy is low, means if an a if along a cross section veloc... along a cross section of compound section, are rarely equal; therefore, energy slope may not be same as bed slope, it is quite possible in natural stream. Then you need to incorporate correction factors, or we have seen certain things and all, even if you do that, you will see the energy slope and bed slope, they are somewhat not exactly equal and all, so you need to device certain method. So here comes the portion, rather than taking only one

section of the channel. For computing flood discharge now, you have to think in terms of the stretch, or reach of the channel, along which the flooding is getting occurred.

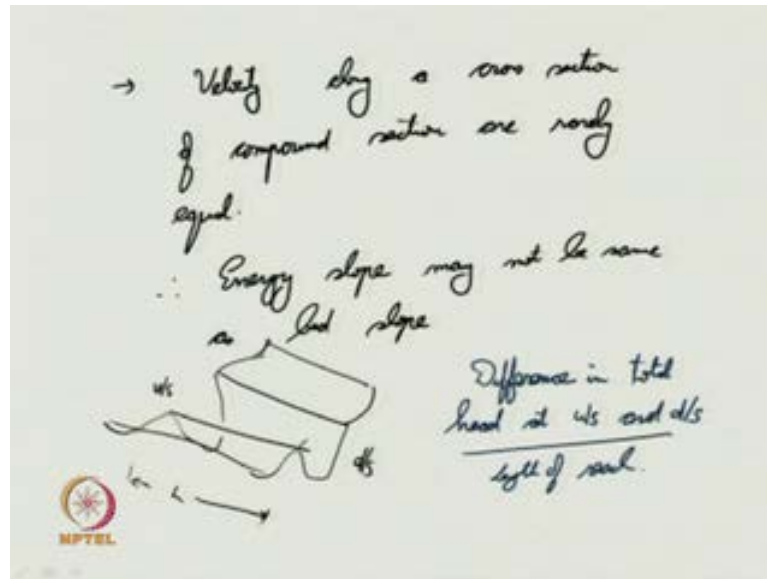
See if you have say a channel reach like this, so its cross section may be like this, and it is flooding along these portions also, let us approximate it like this. So in such a type channel portion, along the flood plains, or along the over side channel portion channel and all, you may have to incorporate difference velocity, in the main body it will be different velocity. Subsequently along this entire reach, how much quantity, how much discharge is available from the flood, flood plain, as well as along the main body; the combined discharge and all, how to evaluate them. You are going to take the stretch or reach of the channel; you have to do certain averaging along the reach, and then try to evaluate the discharge. Let us go through them.

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So for such type of figure, you may see that, you require now to take energy slope, rather than the bed slope. You need to think in terms of energy slope first, because the energy parameters energy head and all, it is quite different in the upstream.

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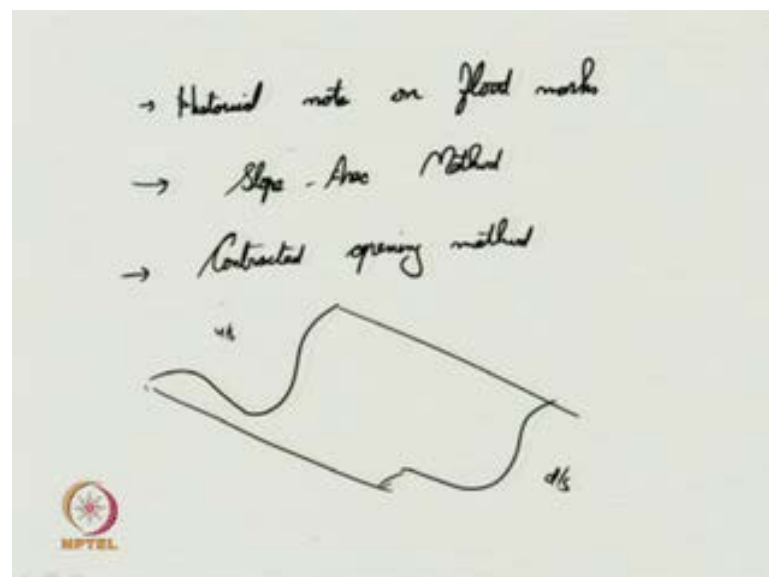
For example, here this is the upstream portion, and this is the downstream portion. So the energy head, the difference in the energy head, divided by the length of the reach; that will give you the energy slope, the bed slope correspondingly. And if they are not equal, you have to first evaluate the energy slope; you have to think in terms of energy slope here first. So the difference between the total heads at the, you may calculate the total head at the upstream, you may calculate the total head at the downstream, subsequently the difference in head divided by. So, difference in total head at upstream and downstream, divided by length of reach. This will give you the energy slope, I hope you know what is mean by total energy head; that is it is consisting of pressure head, section head or datum head, what you say is datum head, as well as pressure head, datum head and velocity head. So, most of the uniform flow computation, you were able to avoid the energy, sorry velocity head to compute the energy head, because then we know velocity in most of the cases if it is a regular section and all, they are quite equal.

And the magnitude of velocity head at upstream and downstream, they would have been almost same, and it may not be creating any change in the energy slope; that is not going to cause you any change in the energy slope. However, for such compound sections, or such flood discharge flood causing channels and all, you may need to take into account the total energy at the upstream, total energy at the downstream, you have to evaluate the energy slope first, then you have to compute the corresponding discharge. So, here then you will see that, during the flood when it enters the flood plain and all, the velocity will

be drastically changed along the flood plain, in the main body it will be different. So the flood stage and the discharge, they may be... if you want to if you are, if you are, if you are able to correlate the stage in the flood plains; that is a flood stage, and corresponding discharge.

So if you are able to correlate flood stage and corresponding discharge, and if they are having some gradual changes, or gradual changes and all if they are there; that is if the flood stage if it is changing gradually, then the discharge is also, flood discharge along the flood plains; that is also changing gradually, or like that if you are able to correlate them. Then you will be able to give uniform flow approximation for the flood discharge also. Otherwise for natural streams, where ever flood is occurring flood is components are there. It is quite difficult to give uniform flow approximation, so this is quite essential. That is this portion suggesting that, you have to correlate flood stage, and it is corresponding discharge, if you are able to do that, then that is fine. Then uniform flow approximations hold good. So what are some of the methods which you can use, how you can see. So mostly for such this thing, when we suggested that, if there is a gradual change in flood with respect to the flood discharge, with respect to the stage of the flood and all.

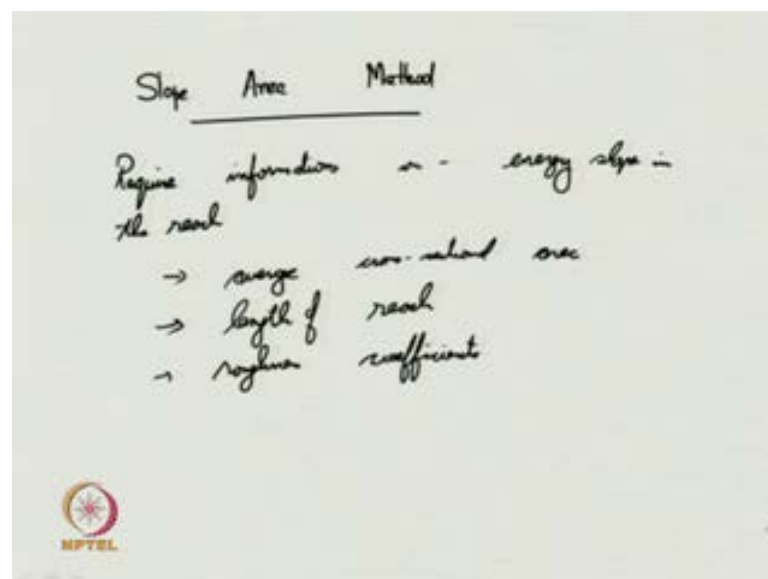
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You are required to have historical note on flood marks in the channel. So, various historical, no means you have to give elaborate, you have to note the various flood marks

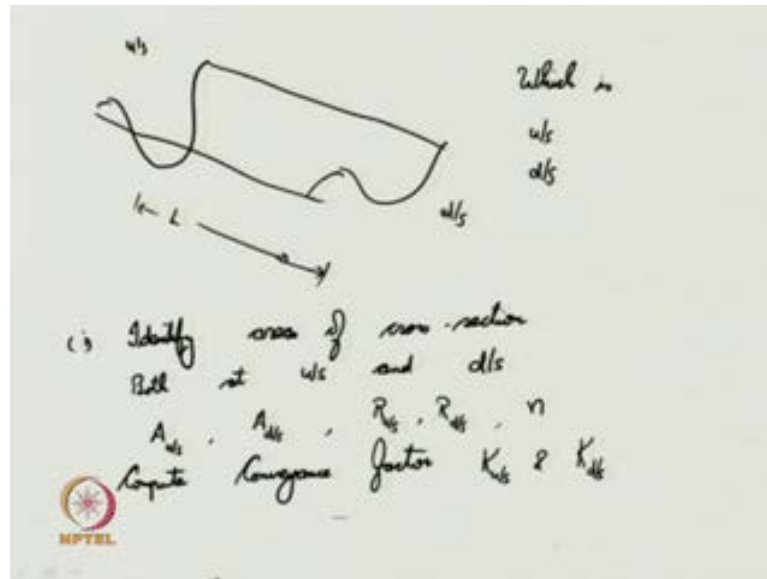
in the channel and all. So at the during the peak rainy season, and during the peak flow of the river, this was the mark of the flood at that time, during the lean period this is the mark, or means at various situations and all, what are the different flood marks and all, you can just either capture them in photograph, or you can note it, you do the survey related to the marks and all, you can just obtain it as a data. So once you obtain the corresponding data, then you can use; say for example, slope area method, which we will see today, to evaluate flood discharge. Then there is another method called, contracted opening method. So here as we mentioned in the earlier portion; so in such a channel portion such a type of channel listing, in the upstream and downstream. The upstream and downstream, you are directly applying the energy equation. Here in the contracted opening method, in the downstream and all, principle of energy conservation and all is being directly employed, and you are trying to evaluate the corresponding discharge, so that we are not going to see in today's lecture and all, definitely we are going to explain you on the slope area method.

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So, the thing is that, we require information on, for this slope area method. We first require information on the energy slope; we require certain informations, so that is energy slope in the reach. You may also require, or your average cross sectional area of the reach, length of the reach, roughness coefficients. So, like this some of the parameters are required, so we will just briefly see, what is the thing?

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Say, if the channel reaches like this, the upstream portion downstream portion, length of the reach is l ; length of the reach. Then the methodology involves, you have to understand, which is first identified, which is upstream portion, and which is downstream portion, that you need to understand first, by seeing the direction of flow and all, based on that, you have to now first evaluate. So the procedure for the slope area method it in was the first step is, identify area of cross section, both at upstream and downstream. So in the first method, you will be identifying areas of the cross section, not only that you will be identifying areas of cross section at upstream, area of cross section at downstream, you are able to, you have to evaluate the hydraulic radius at upstream, hydraulic radius at downstream. You can see if manning's coefficient if it is same at upstream and downstream, well good you can take it like that n itself, or you can suggest n at upstream and n at downstream, like this you can suggest them. Now using these parameters what you have to do is that, you have to compute conveyance factor, both at upstream and downstream. The conveyance factors at upstream and downstream, you need to evaluate them.

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$$K = \frac{1}{n} AR^{2/3}$$

(i) Average conveyance factor of the entire reach

$$K_{avg} = \sqrt{K_{up} K_{down}}$$

(ii) Assume velocity head is not having prominent role in energy slope

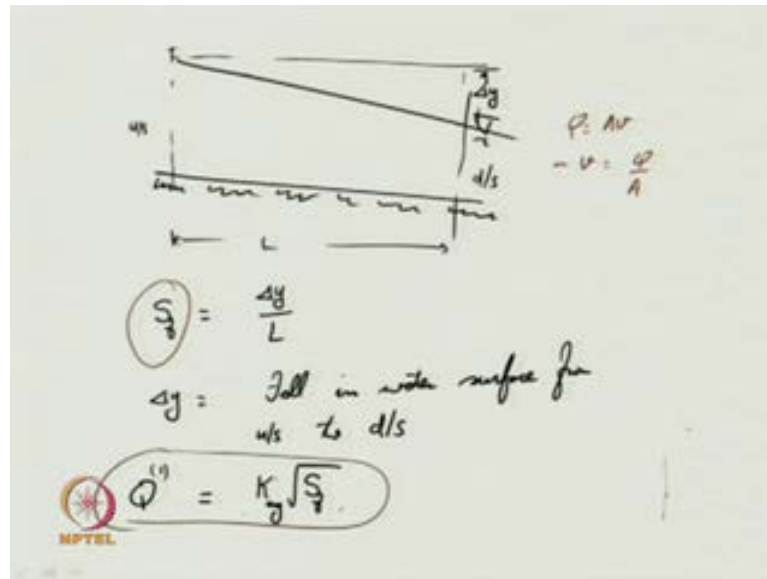
Slope of energy $S_f = \frac{\Delta h}{L}$



I hope you are aware how to obtain conveyance factor, this is $\frac{1}{n} AR$ to the power of 2 by 3. So, for the upstream common section or simple section, what will be, you evaluate the corresponding conveyance factor, in the downstream of the reach what is the conveyance factor, both you need to take into account. Now for the entire reach, you are. The second step is, you are now obtaining average conveyance factor, for the entire reach. So this average conveyance factor for the entire reach, it can be given as k average, this is nothing but, the geometric mean of the conveyance factor at upstream and downstream respectively. This is the form of formula for geometric mean, so that has been directly employed here.

So, once you get the average conveyance factor, the third steps involved is, you have to first assume; that is, in this method first you are assuming, velocity head is not having prominent role in energy head computation, just it does not brief assumption, initial assumption, or you can as you might have seen in solution of various differential equations, with respect to time and all, initial conditions or like that. So this just a initial approximation, we are suggesting that, velocity head initially we are assuming that, it is not having prominent role in the computation of energy head, or rather then that you can see that, it is not having prominent role in computation of energy slope, so that will be better terminology, not having in energy slope, this is a initial assumption. In that way you can find slope of energy s_f , this is nothing but equal to $\frac{\Delta y}{L}$, I will tell you what is mean by $\frac{\Delta y}{L}$.

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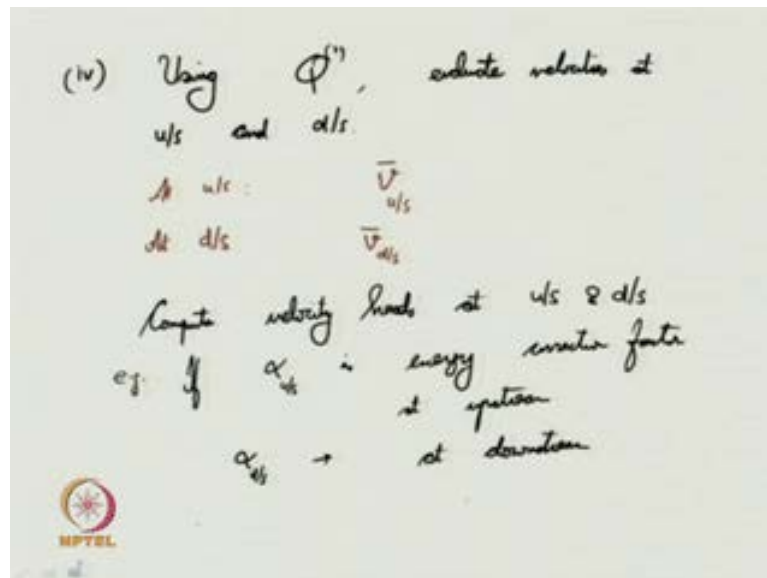


So, the reach, if I just draw the front view of the thing, and if this is the channel distinct; say this is the upstream section, this is the downstream section. Now whatever drop in water surface is there, we are now approximating that. You know that for uniform flow, water surface slope, bed slope, or energy slope, all of them are approximately equal in general channels, or in regular shape channels and all. Right now we have come into dealing with the natural streams, where flood discharges occur. So there is a difference in level of water surface at the upstream and downstream, that difference is given by Δy . So this Δy by l , whatever is there, we can initially approximate this as energy slope; that is not (()) correct, but that is the initial approximation, we are suggesting that, the component of velocity head in this case is very negligible, in determining the energy slope; therefore, the energy slope s_f is given by Δy by l . If this is the case, Δy is equal to fall in water surface, from upstream to downstream in the reach.

Now based on this particular value of slope, based of this particular value of slope based on this particular value of slope you can evaluate, and you give a first approximation for the discharge in the entire channel q . The discharge in the entire channel reach, from the entire channel reach the discharge, it can be given as Q is equal to k average into s_f to the power of half or root of s_f . So please note that, we had given an approximation for the energy slope, and you are substituting it. So let me give this as a first approximation, and this is not the correct discharge actually from the, correct flood discharge from the channel, this is just a first approximation. Now using this value of q , you can easily now

evaluate what are the velocities at the upstream and downstream; that is called possible. Uniform flow means generally the discharge is same at upstream and downstream, so you can easily evaluate.

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So the fourth step is, using the first approximation of discharge. Now evaluate velocities at upstream and downstream, you evaluate them, as shown in the figure here, at the upstream, and at the downstream, whatever are the velocities, how will you compute them, you know the formula for that. So Q is equal to $a v$, or v is equal to Q by a , directly substitute them. So we will get, at upstream location, you will get the corresponding velocity $v_{u/s}$, at the downstream section you will get the corresponding velocity $v_{d/s}$, based on this you can easily now compute. Velocity heads at upstream and downstream, just compute them. For example, if $\alpha_{u/s}$ is energy head correction factor; that is energy correction factor, for velocity at upstream section. Similarly, $\alpha_{d/s}$ energy correction factor at downstream. So if you have this data, then you can easily evaluate.

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At u_1 $\rightarrow \alpha_{u_1} \frac{V_{u_1}^2}{2g}$

At d_2 $\rightarrow \alpha_{d_2} \frac{V_{d_2}^2}{2g}$

You have drop in water surface = Δy



So at upstream the section, the velocity head will be now alpha u s v u s square by 2 g. Similarly, at downstream section, the corresponding, section corresponding head will be alpha d s v d s square by 2 g. So once you have these quantities, now you require to use these two heads, in the energy correction factor, in the energy slope. You have already determine the energy slope earlier, so that was the first step approximation. Now you know, dropping water surface; that is a measured quantity, so that is not going to change.


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Energy slope $S_f = \frac{h_f}{L}$

$h_f = \Delta y + k \left(\alpha_{u_1} \frac{V_{u_1}^2}{2g} - \alpha_{d_2} \frac{V_{d_2}^2}{2g} \right)$

$k \rightarrow 1.0$ if you reach in entirely
(i.e. $V_{u_1} < V_{d_2}$)

If $V_{u_1} > V_{d_2}$ channel is expanding
 $k = 0.50$



Therefore, energy slope for the entire reach, can be given as s_f , this is equal to the change, in this change in energy head h_f , drop or drop in energy head, total energy head h_f by the length of the channel. This h_f includes now, here drop in water surface, plus a factor small k into $\alpha_u v_u^2$ square divided by $2g$ minus v_d^2 square by $2g$. Once you obtained this corresponding form of the energy drop, this is the energy drop in the entire channel reach, and head of energy drop in the entire channel reach. This k factor, it is an empirical, if there is obtain form empirical this thing and various experimentation and all, its scientist has suggested that, k can be give as one, if your channel reach is contracting. If your channel reach is contracting that means, v upstream is less then v downstream, if you channel reach is contracting, in that case you can give k is equal to one. If v upstream is greater than v downstream, channel is expanding you have to take k is equal to 0.5. This also there many scientist experimentally obtain those things and all, or experimentally doing some analytic and all, so we will just incorporate them in our analysis here.

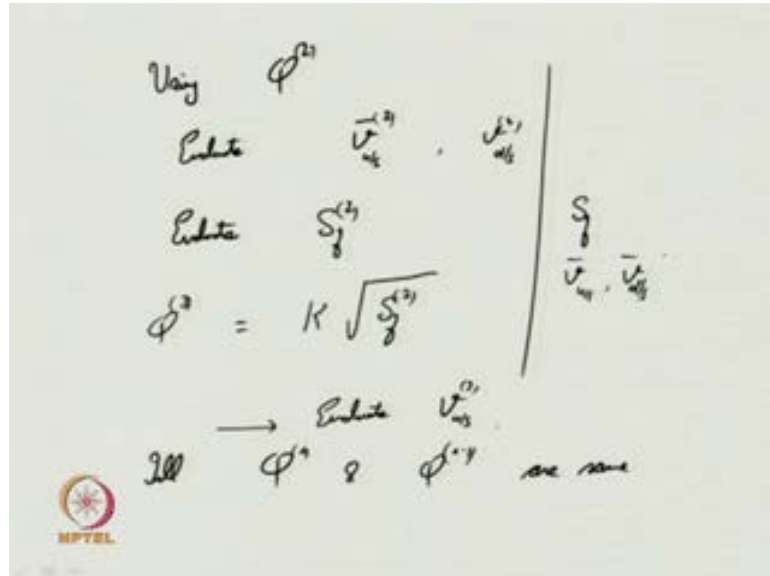
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The image shows handwritten mathematical derivations on a whiteboard. At the top, it says "for the new gully = modified energy slope". Below this, the modified energy slope $S_f^{(1)}$ is defined as $\frac{h_f}{L}$, which is equal to $s_f + k \left(\frac{\alpha_u \bar{v}_u^2}{2g} - \frac{\bar{v}_d^2}{2g} \right)$. Then, the modified discharge $Q^{(2)}$ is given as $k \sqrt{S_f^{(1)}}$. In the bottom left corner, there is a logo for NPTEL.

So once you get thing quantity, now you get a, you are now getting a modified energy slope, as mentioned earlier. So s_f , let me give this as 1. This is equal to s_f of 1 is equal to now Δy plus k into $\alpha_u v_u^2$ square by. Based on this, you can evaluate the modified discharge, or you can give a new value for discharge, Q is now equal to $k \sqrt{s_f}$; that has been modified. So this you can give as the second

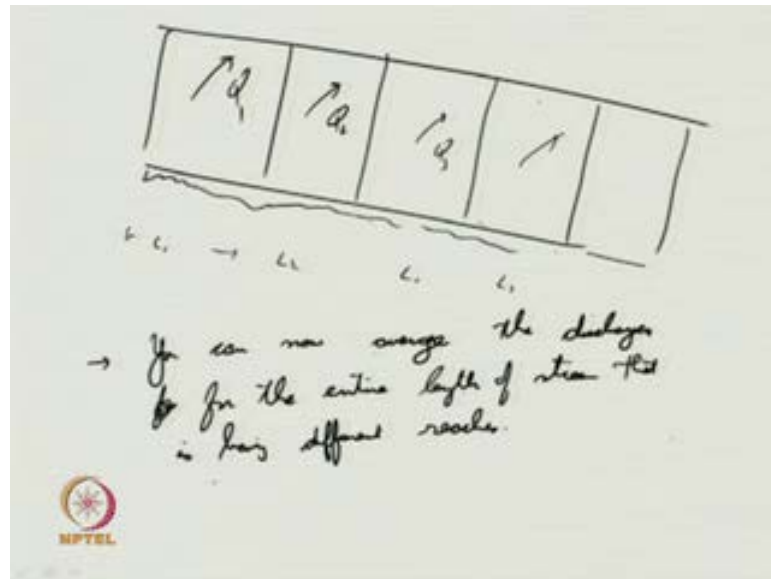
approximation for discharge. Once you get this second approximation for discharge, again go back.

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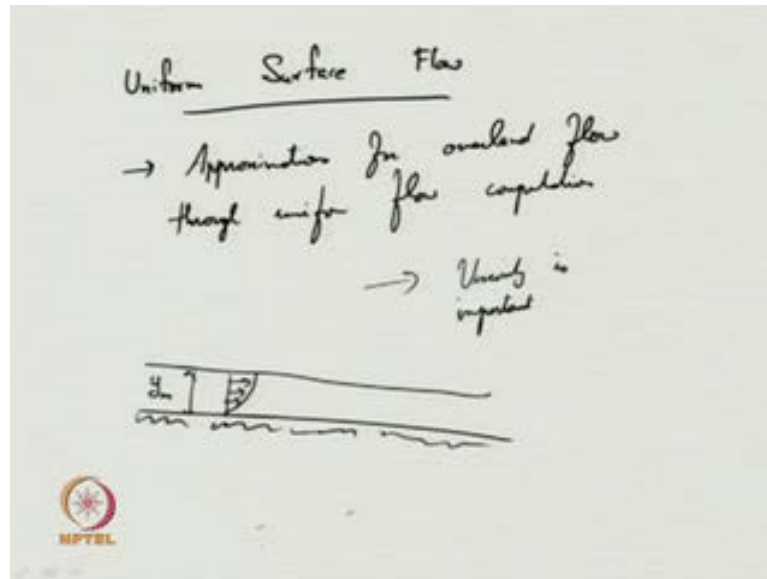
You just go back using, so using now Q_2 evaluate v upstream, and that also you can give it as two v downstream, to evaluate s_f^2 . Now so once you get s_f^2 , the same procedure as I adopted. You can compute Q_3 , this is nothing but, ketians root of s_f^2 . So once you get Q_3 go back, again evaluate, just check it that is we are going back again, because we are finding that Q_2 and Q_3 they are not same. Similarly, Q in the first approximation, Q in the second approximation obtain, they are not same. So we are going back like this, till two of the conjugative approximations, are giving you the same discharge. So evaluate like this, till say Q in the i eth approximation, and Q in the i minus one th approximation are same. So once you get this thing, the corresponding values of s_f has to be noted, the corresponding values of v in the upstream, and v in the downstream, those things also have to be noted, and now you have got the discharge, flood discharge. So this is how you compute, means this is how you compute the flood discharge, using uniform flow approximation for the natural streams.

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So as I mentioned earlier, you are dealing with the entire channel reach. So if you are having many such reaches, if there are many such reaches of different lengths; say this is L_1 this is L_2 L_3 L_4 L_5 etcetera, and like this you have many reaches. Then for the entire natural stream, you can now average the discharges. So using the slope area discharge method, you have evaluated the corresponding Q from this reach. Similarly you can give it as Q_1 , what is the slope using slope area method, what is the average discharge from this thing Q_2 , Q_3 it is not average, it is the slope area method by approximation, means by iterating you have arrived at Q_2 as the discharge from this reach, Q_3 also discharge from this reach, like that several reaches are there. You can average the discharges, for the entire length of stream; that is having different reaches. like this you can submit for the entire this thing, and you can just average it and get the average discharge for the entire natural stream; that is the why you can compute you can use appropriate weights also to compute the discharge.

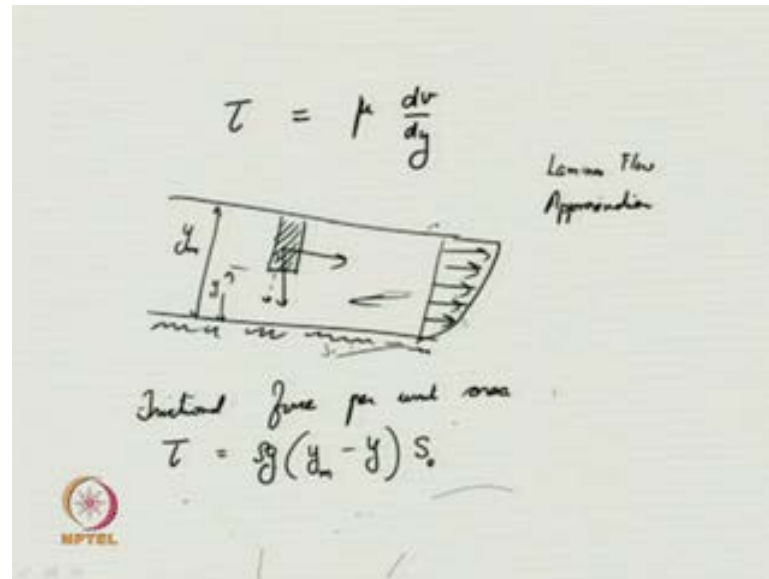
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Next we will just go through what is meant by, uniform surface flow. You have heard the word uniform surface flow, or especially during the rainy season and all, you may see various, mean in on the overland flow of water occurs form the overland, in the form of thin sheet. Means the depth of flow will be considerable small, but still there is some flow of water in a sheet form, through the surface, whether it will be the same, says if whether it will be like this along the sheet, it may be going like these and all, various type of flow you might have observed it in nature. You can even give approximations for overland flow, through uniform flow computations; that is also quite possible. Say this is your land surface, so before the water reaches, when the rain fall of occurs, afer some quantity getting infiltrated, and before it reaches the main channel, or before it reaches any channel, it flows along the ground in a form of thin sheet.

So, this depth, it is quite small, so let me say this depth as y m, sums very small depth y m. And it may not go beyond this depth also, mostly it is a very thin this thing. So in this case, if you observe that, again your basic furead mechanism principles and all are coming into picture, the depth of flow is small of course. So it may be having some velocity distribution of this form, with respect to depth. You will observe that, for such type of flow, friction or the resistance due to viscosity and all, is prominent in such type of flow. So viscosity is important in overland flow. So if viscosity is important, how will you compute the uniform flow now. So you have to use the newtons law of viscosity, i hope you know what is newtons law of viscosity.

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We suggest that, the shear stress along with the bed of the channel, or shears stress along with the bed of the pipe, is nothing but praportional to the gradient of velocity, and the prapostionality constant is called, a dynamic coefficient of viscosity view. So the same thing we need to apply here, so therefore let me just give the overland flow in a magnefied form. Here this is your depth y m, so it is having a velocity distirbution. So in such cases, just take a small elementry strip from the top surface, from the top surface of water, you just take the small elementry strip, and this strip is at height y from the bottom of the ground. Now in this strip, whatever is there, means you will see, that what happenes is there, for such type of overland flow, viscosity is from suggested that, so there will be a considerable amount of friction, that causes, that friction force will be acting in the apposite direction, and that causes, or that opposes the motion of flow in the down stream direction. So, how the viscus flow affects these things, should take this elementry strip, it has its weight acting down wards.

So the component in the flow direction, whatever is there. Now that is now being compsated, or you can suggest that is being now delt with the frictional force, along the bed, so you have to equate it now. So what is the frictional force along this direction now, what is a frictional force. You will see that, the frictional force here. Please note that, we are taking laminar flow approximation. So the frictional force per unit area along the perpendicular direction of the screen here given to you per unit area, whatever frictional force if it is there. Let us consider that, as your shear streff. You know that

force per area, gives you the stress component in many of the situations. So are stress having the units of force per area, so let us give that as shears stress. This is nothing but, ρg into, see what is the thing here. The depth here is y m minus y , and you know that ρg , is a weight of the liquid in this thing, within this particular depth. So $\rho g y$ m minus y into the slope, means you need to take into account the slope here. So we are equating the component of the gravity force in this direction, with respect to the friction force; that is what we are doing it here, that can be given it like this.

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$$\tau g (y_m - y) S_s = \tau \frac{dv}{dy}$$

$$\therefore \frac{dv}{dy} = \frac{\tau g S_s}{\tau} (y_m - y)$$

$$\therefore v = \int \frac{\tau g S_s}{\tau} (y_m - y) dy$$

$$v = \frac{\tau g S_s}{\tau} (y y_m - \frac{y^2}{2})$$

So this is nothing but, if you again go through the same in equation $\rho g y$ m minus y s naught this is equal to you use the newtons law of viscosity. You are equating with with respect to newtons law of viscosity. From this equation, just rearrange the terms so $d v$ by $d y$ is nothing but equal to $\rho g s$ naught by μy m minus y , or you can use this relationship now to obtain the intergril, say v the velocity in that portion of the small, portion of that overland flow and the. It is nothing but integral $\rho g s$ naught by μy m minus y into $d y$, you will see that all these contities are concerned $\rho g s$ naught by and μ are constant with respect to y , you are going to get this equation as v is equal to $\rho g s$ naught by μy into y m minus y square by 2. So, you are getting a quadratic expression for the velocity, in the overland flow. You can now compute the average flow, this is with respect to any height y .

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Average velocity at any section of overland flow

$$\bar{v} = \frac{1}{y_m} \int_0^{y_m} v \, dy \quad \left(\text{how} \right)$$

$$\bar{v} = \frac{\rho g S_0}{3\mu} y_m^2$$

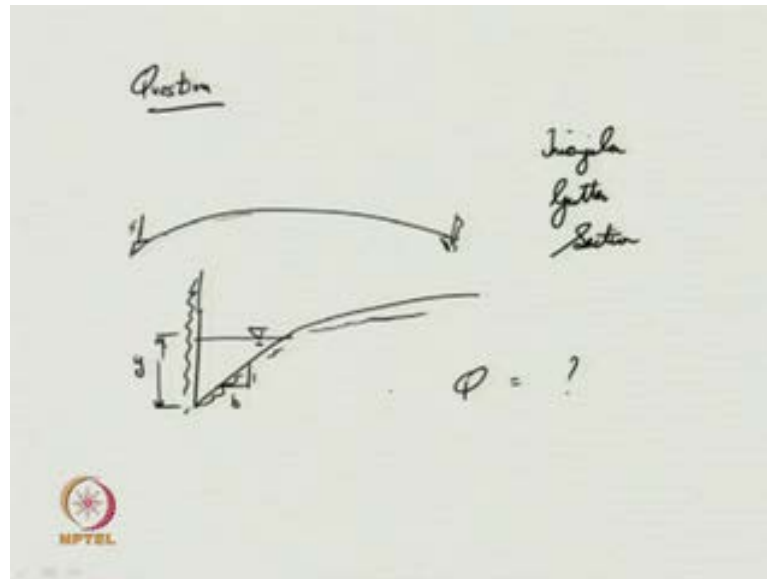
Discharge per unit width = $q = C_L y_m^3$

$$C_L = \frac{\rho g S_0}{3\mu}$$



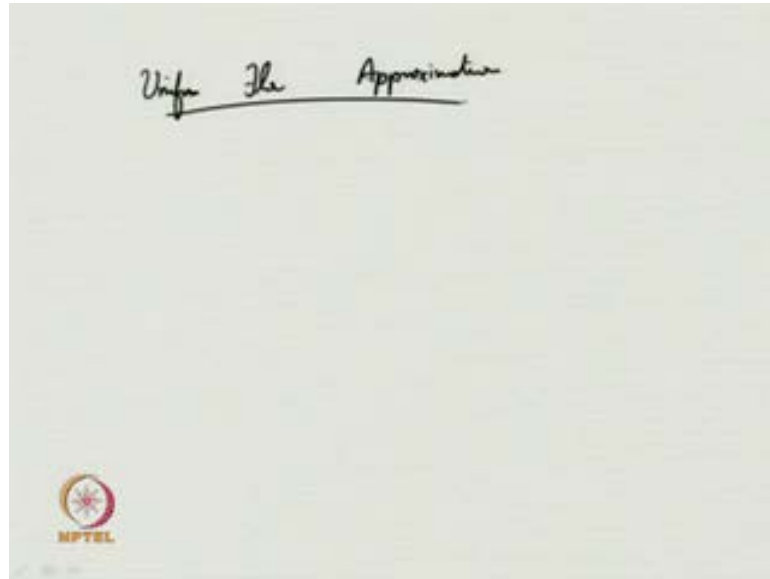
So you can compute average velocity, at any section, for overland flow, can give this as \bar{v} , this is 1 by y_m , is the depth of the overland flow, v d y . You just substitute the quantity of v whichever we are given it here, you will get this as $\rho g S_0$ naught by three times μ into y_m square. So we are this portions and all, we have referred the text from venticher on open channel hydraulics, so this average overland flow velocity is computed in this way. So this is as good as your uniform flow, means this velocity is same as uniform flow. You can also suggest that the discharge per unit width; discharge, this is velocity, so discharge per unit width, in the uniform for the overland flow, you can give this as equal to q , and this is given as some coefficient C_L into y_m cube isent it. What we have done, we have just C_L into y_m cube, because here this is velocity, and velocity into the width, means which ever we discharge your talking about discharge per unit width, so you have to take the sections appropriately, rather than unit area, you are taking unit width, so C_L into y_m cube, it will be a third degree equation with respect to your depth of overland flow. So your C_L is nothing but, the coefficient seeing coefficient $\rho g S_0$ naught by 3μ , it may be observed like that also, you may see such phenomanaon and all. Like this way, you can compute uniform flow for overland flow cases also.

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So today, we will like to stop it here, as a portion of interest or curiosity, I can just ask you one question. You have seen in road sections, you have seen in various road section, roads and all. So the road is having a gradual slope, and at the two end portions of the road; say this is your road, and at the two end portions, you may see small gutters on the road, at the this portion, and at this portion, like this you may see gutters in the road. Now you can use your uniform flow approximation to compute flow along this gutter; that is also quite possible. You can also use your overland flow approximations along these portions, to find the discharge, or discharge per unit width along this thing, and then arrive at the discharge quantity here, then subsequently incorporate uniform flow along this main triangular gutter channel and all. If I just elaborate it, if I just show it in an elaborated way, it may look like this, something like this, like this, then like this. So this is your triangular main channel, water may be there. A question, as a part of today's quiz, today in the today's quiz, we are just asking you one question only. For the same triangular gutter section, for the triangular gutter section, there is depth is given as y , and the slope is given as 1 to b , if this is provided to you how will you evaluate, or how will you evaluate discharge Q , in the triangular section.

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So, you use uniform flow approximations, so you should be aware with the geometry of of the triangular section, then you try to compute it.