Advanced Hydraulics
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Module - 5
Channel Transitions
Lecture - 1
Channel Transitions Part 1

Welcome back to our lecture series on advanced hydraulics. So, till now, we have covered four modules on various parts of this course. Today, we will start the fifth module on channel transitions or flow through channel transitions.

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If you recall, in the last module and all, we have discussed on hydraulic jumps, especially hydraulic jumps in rectangular sections. We also covered how to control the hydraulic jumps. We also discussed on how to use jumps as energy dissipaters. We have discussed briefly on jumps in sloping channels. We also discussed on surges, which are called unsteady hydraulic jumps or moving hydraulic jumps, right.

So, with these things and all, in your mind, we can now go into the next portion; that is, that is also quite significant for the, at this level of the course; that is, flow in channel transitions.

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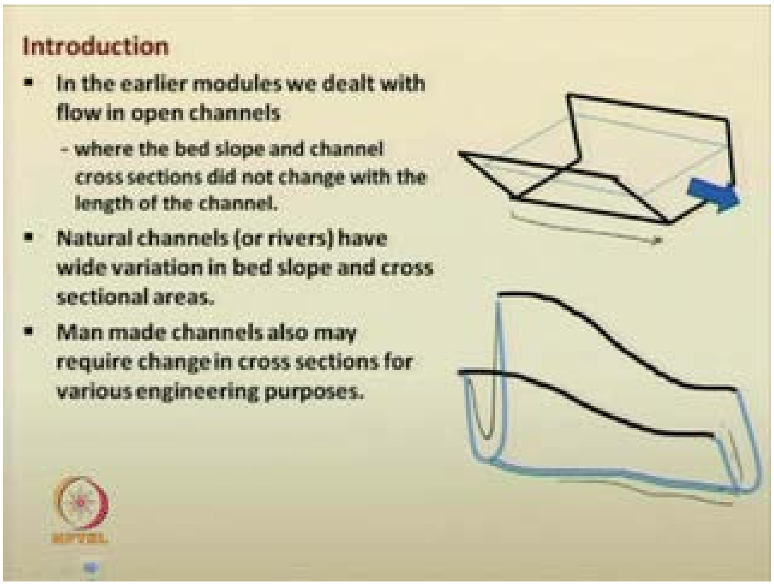

So, today is the first lecture on this particular module. So, if you look back into the previous modules, what did we observe, that is, related to the channel bed and the channel width as cross sectional width and all, you have seen that the prismatic nature; means, in most of our analysis, we have followed the prismatic nature or the prismatic section; it is being carried forward.

The width; for example, if it is a trapezoidal channel, the bed width, or if it is a rectangular channel, the width of the channel, they were not changing quite significantly; that is the thing, which we employed in many of our analysis. Similarly, the slope of the channel is not changing quite significantly; means, we assume the, this slope of the channel from the upstream section to the downstream section, they are having the same bed slope; they are not quite different slopes and all.

But, in the natural conditions, especially in rivers, or even in the manmade channels and all, we may encounter several situations, where the cross section of the channel changes rapidly; even the bed elevations changes rapidly. For example, if you can see here; here the bed is, the beds condition is entirely different; the cross section of the channel, it is entirely different from one reach to the another reach. So, in the natural rivers and all, mostly in natural rivers, you will encounter such situations.

So, whichever analysis we have done using the prismatic nature or prismatic conditions and all, may not be that much useful, although we will get a preliminary picture on the idea of discharge and all. But it may not be the exact analysis. So, here, what we will do is that, we will see how some of the transitional features affect the flow in the open channels.

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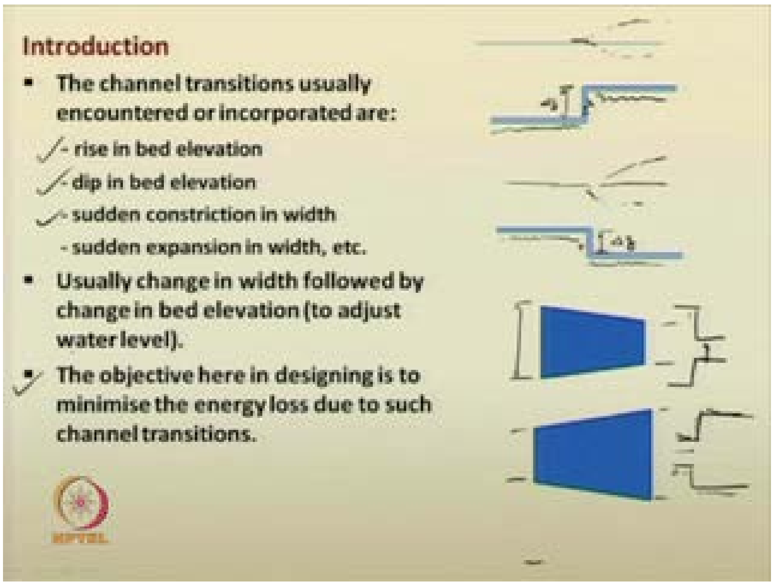

Some of the, some of the channel transitions that we normally see in engineer channels are: see, rise in bed level; that is, the bed level; here, you can see the channel bed; it is, all of a sudden raised at a particular location. So, what happens due to this rise in the bed level? How the flow occurs? Say, if this was the flow depth, whether it will further rise as the bed increases, or whether it will decrease, or whether it will remain same, that we do not know; we have to use our analytical methods to understand, what could be the depth there.

Similarly, dip in bed elevation; that is also normally encountered in channels. Here you see, there is a sudden dip of high delta z; here also, here also we can say high delta z. So, there is sudden dip in the channel bed. And, we have to see, whether the flow, again it will increase, or whether it will remain same, or whether it will decrease; we have to check the situation again.

Another type of channel transition that may be encountered is, the width of the channel get decrease. Here, say, the width is quite large, and here the quite is, it is quite less. You may also see the similar situations; say, a quite wide rectangular channel getting constricted into a narrow rectangular channel. Similarly, you may also see sudden expansion in width. Here, you can see there is an expansion in the width from this location to this location, or you will also see channels where; see, this is the top view, this is not the top view of the channel; so, these are the sides of the channel; so, a narrow rectangular channel getting expanded; like that also situations change.

So, usually the change in width is followed by some change in bed elevation, because they are interrelated, or, means, it may be required, so that the flow or water level is maintained. So, in, as you have seen that open channels are mostly engineered one; or, that it means we have used our engineering principles to design and to implement the thing. So, we do not want much fluctuation in the water level. Therefore, to maintain the water level, almost in a similar way, you; if, one thing, if the channel width is increase, then it may be followed by decrease in, or the bed elevation or means, the bed elevation will be provided, or some sort of things will be there.

So, we, our objective mainly is, while designing we have to minimize the energy loss during the channel. That, with that objective, one will be starting designing; or, they will be going for designing the channels in flow; means, or flow in the transitional forms of the channels. So, let us keep these things in mind, and see how we can analyze.

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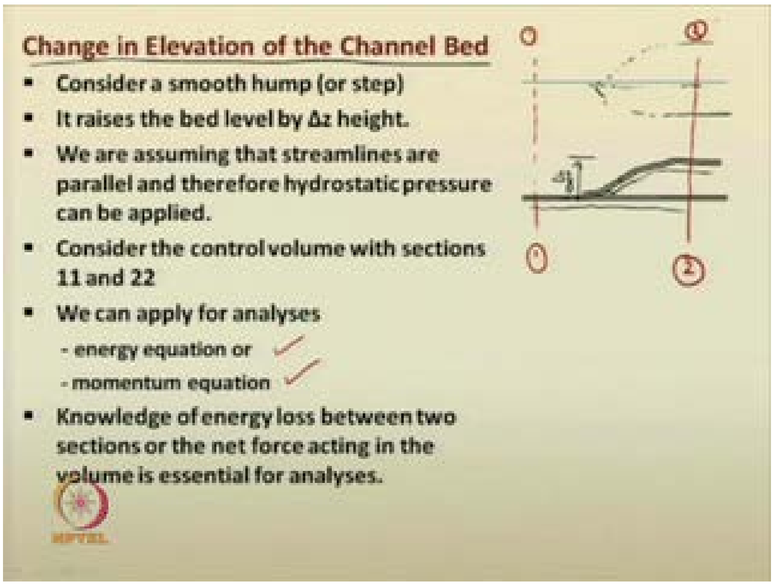

First, we will go for change in elevation of the channel bed. You see here; there is a channel bed; it has increased now towards this location; say, let this height be delta z. So, initially the water was slowing, at this level. Now, due to encountering of this raise in bed level; so, we do not know, whether water level will increase, whether it will remain same, or whether it will decrease; how will you analyze the thing?

So, again, just to get a preliminary idea or to continue our scientific insight into the problem, we are simplifying the cases; that is, we want to know how the elevation enter; rather than going deep into the all the aspects of a multidimensional problem and all, we are just simplifying the situation in such a way that, we are assuming now the stream lines are; we are suggesting a smooth hump here; the raise in the bed level is smooth, so a smooth hump is being provided; streamlines are not bifurcated, or means they are not disjointed; so, streamlines, we are considering, say, again it is parallel in that particular flow; thereby, we can use hydrostatic pressure conditions; to evaluate the pressure in the liquid and all, we can use the hydrostatic conditions and all, that way.

So, let us consider 2 sections. Consider 2 sections here, as the bed is elevated. So, I am considering 2 sections; this is section 1 1, and let this be section 2 2. So, 2 sections we are considering in this particular rectangular channel flow, where the bed is being elevated by a height del z. So, we can use energy equation for analysis, or we can use momentum equation for analysis; that is, you can compare the energies at the 2 sections, or you can use the momentum equation for the entire control volume and closed in this sections; the, so, thereby, the net forces in the system or the control volume, whatever is there, that can be understood. Based on those things, one can start the analysis.

So, if use the energy equation, you need to understand what could be the energy loss between the 2 sections. If you are using the momentum equation, you should know the, what is the net force acting in the system, based on those thing the flow will be occurring.

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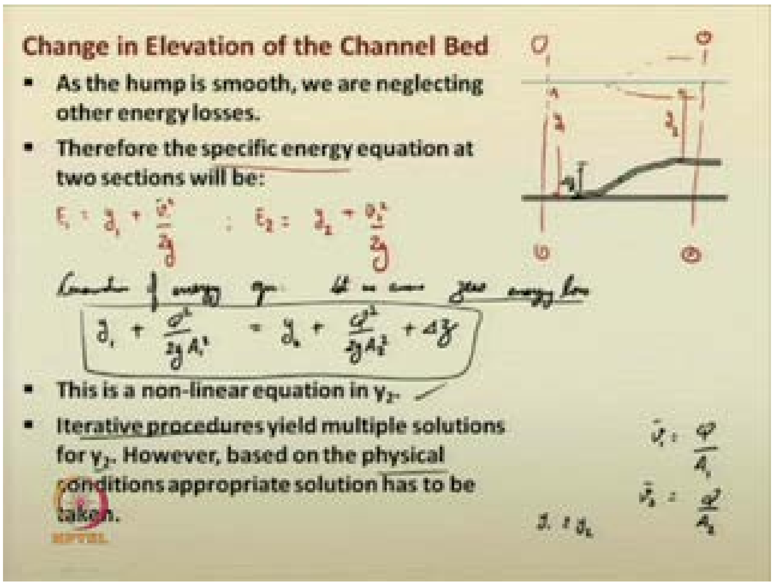

Let us assume that; here, we are suggesting the hump to be very smooth, in this case. In these two sections, the hump is very smooth. So, therefore, the energy between the 2 sections, we are assuming them, that the loss in the energy is not that much significant. Let us assume; in that way, we are trying to progress the analysis.

So, if you recall the specific energy equation; say, at section 1, even this will be nothing but, equal to the depth of the flow y 1; say, if this is the depth of the flow here, and here if this is the depth of the flow y 2. So, y 1 plus; you know it is, v 1 square by 2 g. So, similarly, the specific energy at section 2 2, it is nothing but depth of flow y 2 plus, v 2 square by 2 g. So, we do not know the elevation; say, whether it is here, whether it is here, y 2, that has to be analyzed.

The energy equation; so, if you take the energy equation, consideration of energy equation, let us assume 0; energy loss between 2 sections- 1 1, section 1 1 and section 2 2. Therefore, the energy equation can be represented as the conservation of energy equation y 1 plus; v 1 you know, what is v 1? The average velocity v 1 is nothing but, the discharge by A 1; similarly, v 2 is equal to Q by A 2.

So, we can write the same thing now; Q square by 2 g A 1 square is nothing but, equal to y 2 plus, Q square by 2 g A 2 square; again, to consider this as, there is zero energy loss, this equation will be satisfied if you incorporate this particular height del z, all right. So, then, this is the conservation of energy equation. You know that the bed, bed is elevated by a height del z, so that also you need to take into account here. So, what will you get? You know that relationship between, means, y 1 and y 2, are related. So, this equation becomes a non-linear equation in y 2, fine.

So, you, as we have done in our earlier analysis and various analysis, you have to use the iterative procedures. So, we will get a multiple type of solutions for y 2; from that, which is the practically feasible solution that you need to understand. And, we, we will be using these particular solutions. So, based on the physical condition, you need to take the appropriate solutions.

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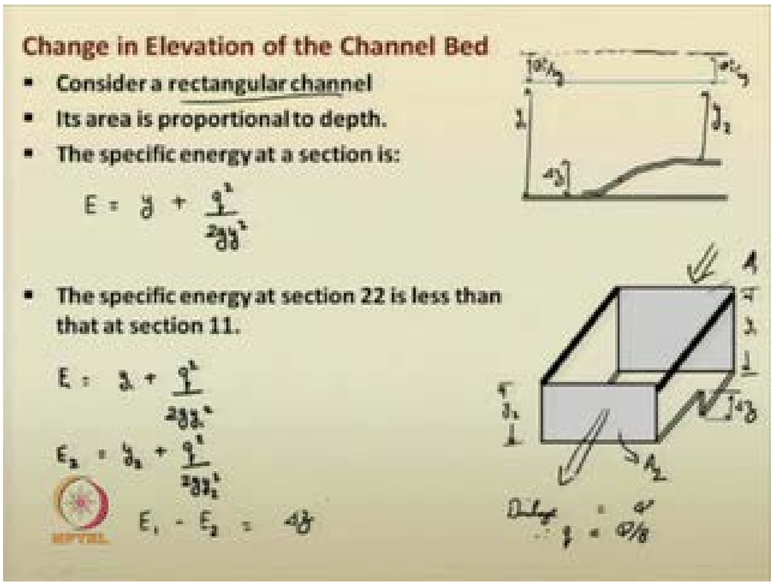

So, as we mentioned for a general channel, consider a rectangular channel, as given here, in the 2 portions. So, here, this is the upstream side; flow occurs from this direction to this direction like this. Here, the height of the section, it is y 1, and here, it is y 2, fine. There is a change in bed elevation; this height is given as del z, similarly, I can give it here also.

So, you know that the area, this A 1, sorry; this is A 2 and this is A 1, both the areas are proportional to the depth of the flow; that is B into y 1, here it is B into y 2, is area A 2. So, that is, the depth of the area is now coming into picture there. What is the specific energy at any section? At any section, the specific energy E is given by, depth of the flow plus, a quantity; means, earlier we have seen it, v 1 square by 2 g. This can be for a rectangular channel. That is for a rectangular channel, if the discharge is equal to Q, then discharge per unit width Q can be given as Q by B; this we have done it, in many of our previous analysis.

So, I will be using that small q here; q square by 2 g y square, for the rectangular channel. So, E 1 will be now, y 1 plus q square by, 2 g y 1 square. E 2 is equal to y 2 plus, q square by, 2 g y 2 square. How are they related now? How can we relate E, E 1 and E 2? Can you have a guess? If you see here, you know the specific energy diagram will be looking like this; so, this is the depth of flow y 1, and this is the velocity head v 1 square by 2 g; here also, we do not know exact location, v 2 square, and this is y 2.

So, from both of these diagrams, it is quite obvious that; or, you can also draw, means, from many situations, you can see that, E 1 minus E 2 is equal to; for the, based on the various assumptions given, it is nothing but, the hump height del z; I will explain it again.

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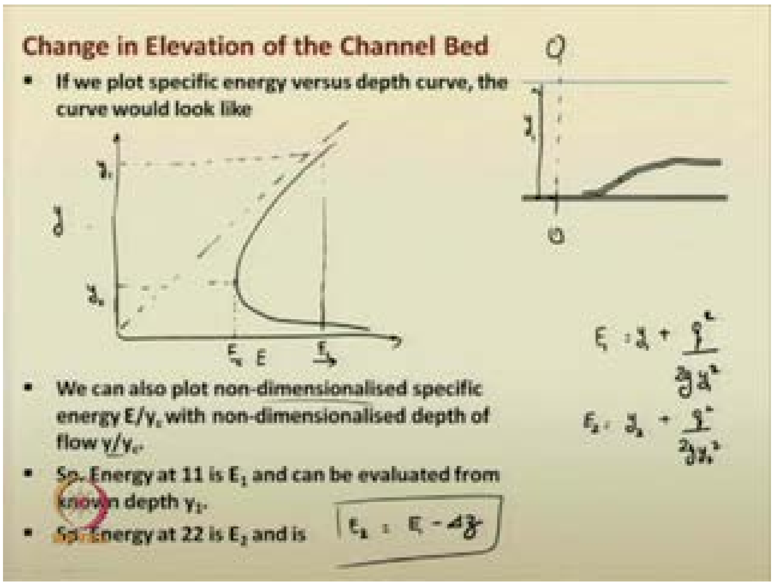

Just go through this thing. If I, if I draw specific energy versus depth of flow curve; so, these things we have done it in our module one also. So, this is a 45 degree line, where both the specific energy and depth of flow are same. So, you recall that. You know that the specific energy versus depth of flow curve looks something of this nature, and you also know that the location of the minimum specific energy E c, that is the critical energy and the corresponding depth is the critical depth.

So, therefore, suppose if we have a subcritical flow, it will be somewhere here, upstairs; and, the upstream section, the curve, depth of flow y 1, this is the depth of flow y 1; corresponding energy E 1, fine. We can also plot non-dimensionlized specific energy E by y c with non dimensional depth y by y c. We have seen some non dimensional curves of similar nature for various things and all.

So, this specific energy at section 1 1; this is section 1 1. So, E, it is E 1; E 1 is based on the depth of flow. E 1 is equal to y 1 plus q square by, 2 g y 1 square. So, you can see that E 1 is function of y 1 only. Similarly, E 2 is also a function of y 2; y 2 plus q square by 2 g y 2 square. But, y 2 is unknown to you; you do not know the, what is the value of y 2. So, though, those can be now interrelated; means, you can use the continuity equation for determining the relationship between y 1 and y 2. And, subsequently, you will see that specific energy at section 2 2 is E 2, and E 2 is nothing but, equal to E 1 minus del z, based on the conservation of energy rho and all, you will see that, because we are neglecting all the other types of energy loses. So, you will get the following form, ok.

So, once you understand this thing, you can use the same specific energy versus depth of flow curve; from that you can infer, what is the depth of flow at the upstream condition? Again, let us go back into the detail.

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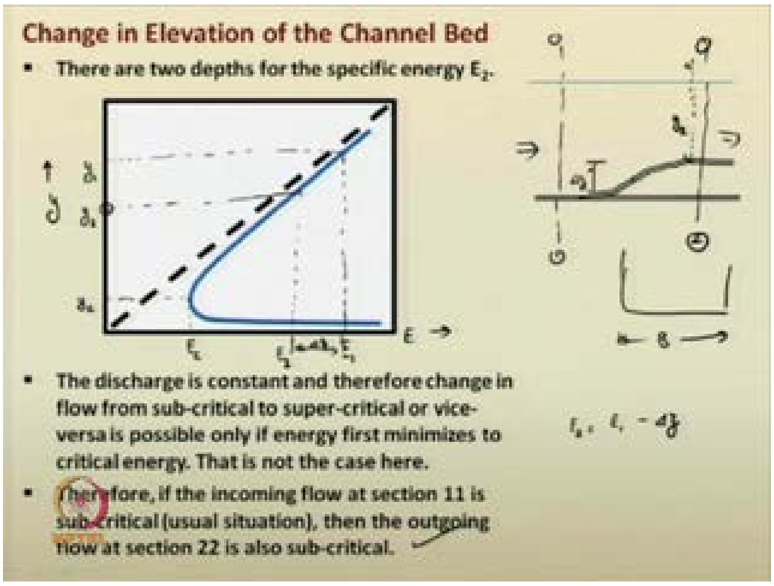

I have just drawn it here. So, this is specific energy, this is depth of flow, like this. So, if you look into this curve, you have the minimum specific energy E c here; corresponding depth, critical depth of flow y c for the given channel section; say, if this is the rectangular channel given to you of width B; you can just see the previous case also, here the width is same at the upstream as well as the downstream section, the width is same. So, only the depth of flow is getting changed. So, based on those thing, now if you plot that; say, at the upstream section, at the upstream section for E 1 and the corresponding depth y 1, if y 1 was the subcritical flow occurring; if, let us assume that the flow is subcritical at the upstream section and the corresponding specific energy is E 1.

So, the specific energy now, at the downstream section, section 2 2, this can be given by, as mentioned earlier, E 2 is equal to E 1 minus del z; del z is a known value to you. So, I will be just deducting del z from here, from here a quantity del z is deducted. I will just observe what is the corresponding specific energy? I will, from this thing you will see that there are 2 depths- one supercritical depth and one subcritical depth. From this curve you get, for the same specific energy E 2, 2 depths- one super critical depth and one subcritical depth and one subcritical depth. You have to appropriately select, which is the depth of flow.

So, as the discharge is constant in the channel; means, as the discharge from this section to this section, both are means same and if the flow is subcritical in the upstream section, it can become supercritical flow, only when it encounters a section in between section 1 1 and section 2 2, where the flow is critical. So, that situation has not yet arised here. We have, all though we have elevated the depth; means, elevated the bed, bed, we have not mentioned that; in between section 1 1 and section 2 2, the flow has been changed to critical section, critical conditions and all.

So, definitely in the normal practice the, due to the raise in bed level, there will be change in the flow pattern; but, you know that the specific energy at section 2 2 is less than specific energy at section 1 1, so you, say, by a magnitude del z. So, you spot from this particular diagram, for the corresponding E 2, what is the subcritical flow y 2; that is being selected. So, from here, you will just see, what is y 2?

So, this y 2 can be above this water surface, it can be above, or it can be below, or it can be same, that we do not know. Based on the exact numerical value and all, you have to identify it. So, you will be selecting the corresponding subcritical depth y 2. So, that is the way how you determine the downstream flow depth conditions. If the incoming flow at section 1 1 is subcritical, that is a usual situation, then the outgoing flow at section 2 2 is also subcritical. So, this you need to keep in mind. You cannot take a supercritical flow depth, all of a sudden in this situation. So, that becomes a rapid change in the flow profile. That is not the thing, we are suggesting here.

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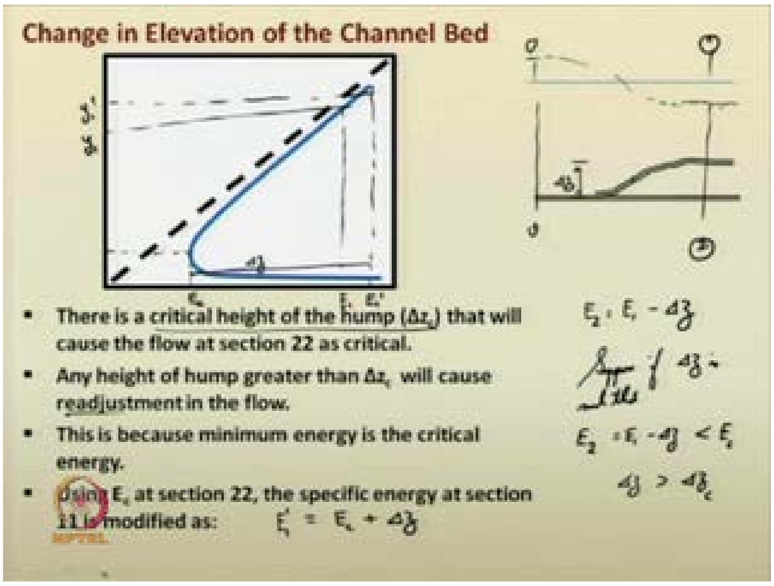

So, again, with the same thing del z, this is section 1 1, section 2 2. So, you know that E 2 is equal to E 1 minus del z, that is the energy; specific energy at section 2, 2 2 is nothing but, E 1 minus del z. What happens? That is, there is a critical height of the… So, in this case, you know this is the location where the specific energy in that particular rectangular channel will be minimum. You already have E 1 here. So, suppose, if del z is such that E 2 becomes, E 2 is less than the minimum energy or the specific energy at that section. What happens? So, your theory definitely tells that energy at the upstream cannot fall below the critical energy. So, E c you need to maintain it, as it is.

So, the flow at the upstream, sorry, downstream section that is at section 2 2, it becomes critical. So, the critical energy will be there; from that, you need to take into account del z, such a way that the specific energy at upstream section gets modified. So, the critical depth will be followed here; then it will change the upstream conditions. So, you will see the corresponding depth, y 1 dash; this was the actual depth y 1. So, y 1 dash, it will just change, the depth of flow will just change. So, if the critical height of the hump del c that will cause the flow at section 2 2 is encountered; or, if your del z is greater than del z c, then you have to re-adjust the flow.

So, any height of hump greater than del z will cause readjustment of the flow, this because you have to change the energy at upstream section. So, this section, means using E c, you will get such a way that E 1 dash is nothing but, equal to E c plus, whichever height of the jump is being given; that way you need to modify the specific energy at section 1 1; that is the procedure. So, if you modify the specific energy at section 1 1, that implies that the depth of the flow at the upstream section is modified. So, that is how the flow gets readjusted when it encounters a hump whose height is greater than the critical height of the hump.

So, you can also suggest, this is the critical height for the, for the given discharge; this is, this height del z c is the critical height of the hump; if the hump height is greater than critical height, definitely the depth of flow at the upstream section will increase for the subcritical condition. If you are analyzing supercritical flow, both at the upstream section and downstream section, the entire process gets reversed. So, you will see that; the depth of flow at the upstream section will further reduce and such a, such are the things.

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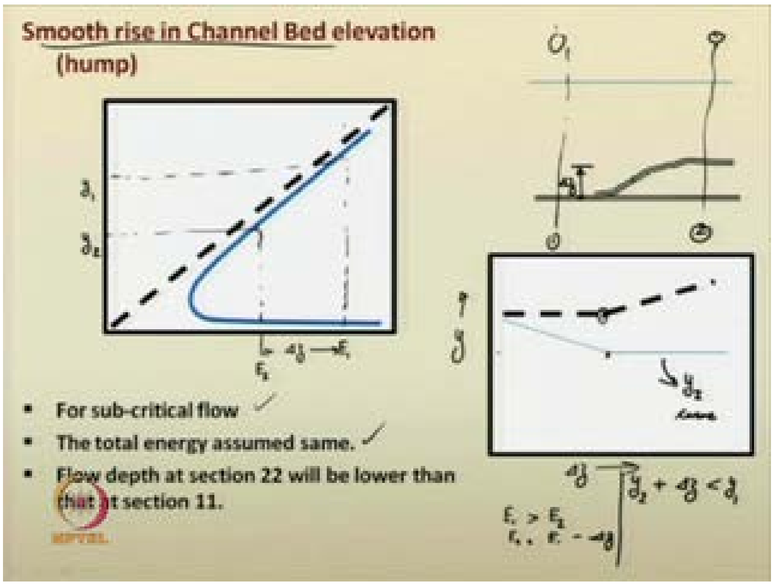

So, I can just plot it. For the smooth raise in the channel bed elevation; as this is the subcritical flow, we are assuming the total energy at section 1 1 and section 2 2, they are same; that is the reason, why we are able to directly use the hump height in the energy calculation, right. So, as the total energy are same, flow depth at section 2 2 will be lower than that at section 1 1. How?

That is, you are seeing here, E 1 is greater than E 2, because E 2 is equal to E 1 minus del z. So, for smooth raise in channel bed conditions, this is the E 1, corresponding depth is y 1, fine. Then, let this be the hump height. So, this becomes E 2, the corresponding depth is y 2. So, you can see that between the depths, y 1 and y 2, the energy of the flow, specific energy of the flow is decreasing from E 1 to E 2. So, mostly for those situations in the upstream conditions, sorry, in the downstream condition at section 2 2, y 2 is naturally less than y 1. But, you will see that y 2 plus del z is mostly less than y 1, you will see this thing also. According to the nature of the curve given here, y 2 plus del z is less than y 1 in most of the condition. Therefore, the downstream curve, this is y 2 curve, it will decrease, it will reach a critical depth value; this is the critical depth value; say, this is depth y, and this is the, you can say, channel profile means.

So, as the del z height increases, as the del z height increases, you will see there will be decrease in the depth of flow at the downstream section or section 2 2, then it reaches the critical depth, that critical depth will be maintained as such. Similarly, the upstream flow depth if you compare, the upstream flow depth will remain same; even though if you increase the hump height, it will reach at the, till the critical level, then the upstream depth slowly increases. This is the depth of flow verses the hump height profile, if you observe for sub critical conditions and all.

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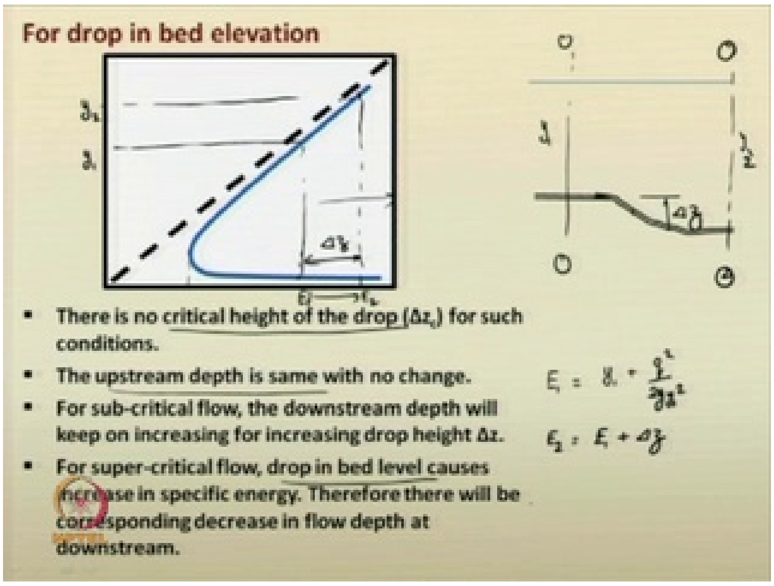

Similar analysis can be done for channel drop in the bed elevation also. See, here again, if we are taking 2 sections- 1 1 in the upstream, 2 2 in the downstream, in the bed of the channel it is getting decreased by an amount del z. So, here, this is, height of water is y 1; here, height of water is y 2. How will you analyze? The same theory will be used here. You know that E 1, E 1 is equal to y 1 plus q square by 2 g y 1 square. And, in this case, E 2 is equal to E 1 plus del z; based on the conservation of energy principle, you will get E 2 is equal to E 1 plus del z. Then, you will see that E 2 is greater than E 1.

So, if this was the E 1 condition; say E 1, corresponding depth y 1, then you have to increase it; you will get the corresponding depth of flow y 2. So, for E 2. So, this is the magnitude del z, or height of the or drop, sorry, drop elevation, del z. So, in this situation there are no critical height of the drop; means, there is no such situation; you can give the height of the drop by any magnitude, because it is going in this particular direction. So, there is no minimum specific energy is coming into the picture there. The energy is only increasing, if you increase the height of the drop. So, that way, there is no such critical condition arising here. You will also see that the upstream depth will remain same, with no particular change in the flow profiles and all.

For subcritical flow, the downstream depth will keep on increasing. You know that for subcritical flow, the downstream depth will just keep on increasing as you increase the drop height. For super critical flow, the drop in bed level causes increase in the specific energy. So, if there is drop in bed level, definitely it causes increase in the specific energy as it is evident here.

So, what happens? If there is increase in specific energy, for supercritical flow, the depth of flow gets reduced, or it reduces for super critical flow, right. So, that, from this figures, it is quite evident; that you can use those intuitions theories and all, to analyze them. So, there will be corresponding decrease in flow depth at downstream. That you need to keep in mind, for depth of, means, when you use for elevation as well as drop in bed and all.

Next, we will discuss on change in width of the channel, that is expansion or contraction that may occur. This is also a particular type of channel transition. So, the flow of the water in such transitions, it gets changed; means, the pattern of the flow gets changed.

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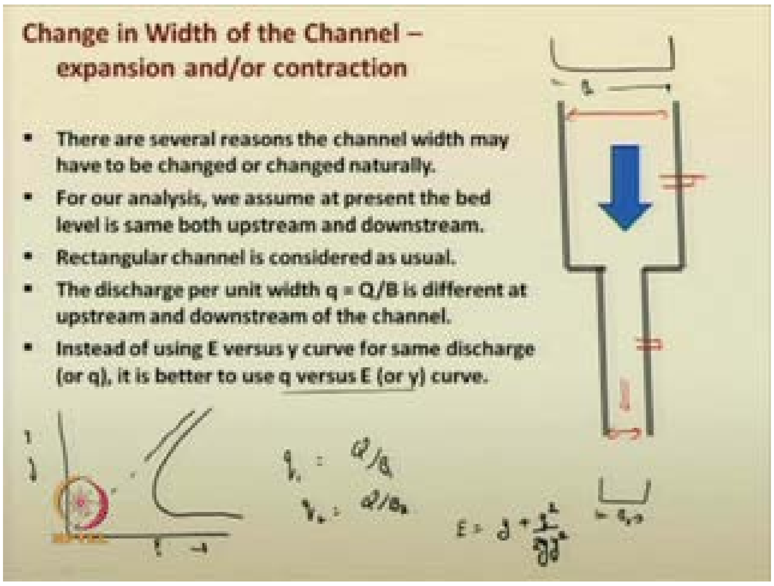

Here, just I had given a brief top view, where the channel; flow from a wider channel is occurring, flow from a wider channel is occurring and it is getting constricted within a narrow channel. So, flow is entering through a wider channel, but it is going out through a narrow channel. So, all of a sudden, there is a constriction occurring in the rectangular channel. So, how the flow is getting affected? So, these things also one need to study.

So, there are several reasons, why the channel width have to be changed, or it is changed naturally. So, we, when we take these things into aspects, how the analysis is being carried out now? So, for our analysis, let us assume that the bed level is same both upstream section as well as the downstream section, the bed elevation is same. Let us, again we are considering rectangular channel, here also rectangular channel, here also rectangular section, so, we considering rectangular channel.

You know the quantity q is equal to Q by B. So, here if the width of the channel is B 1, and here if the width of the channel is B 2, so you have q 1 is equal to discharge Q by B 1, q 2 is equal to Q by B 2. Recall our specific energy versus depth curve; so, we had such a curve, specific energy verses depth curve. So, if you recall them, the width of the channel in the earlier problem, whichever, or earlier cases whichever we have discussed, the width of the channel is not getting changed.

So, you have E is equal to y plus small q square by 2 g y square, for an rectangular channel you have E in the following form. Now, what happens if the width of the channel, it is getting changed? Definitely Q is getting changed. So, the specific energy at the upstream location and the specific energy at the downstream location, they are now different. So, you cannot use the same specific energy curve, because the conditions are getting changed there, right. So, you have different specific energy criteria at upstream location and downstream location.

So, how will you analyze them? Now, instead of using specific energy versus depth of flow curve for the same discharge, it is better to use another curve that is the discharge per unit width small q versus specific energy curve. One can easily built such type of curve also.

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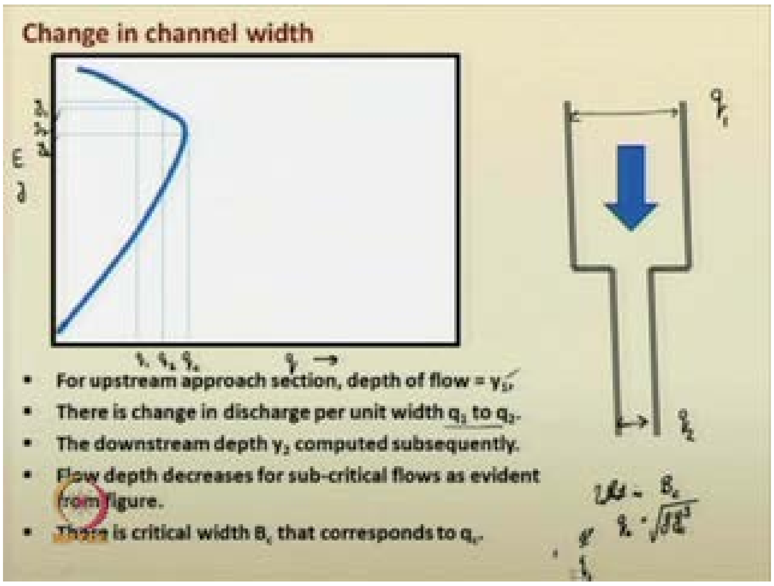

So, this particular curve looks like this. So, if I give on the x axis, the specific, that is the discharge per unit width q, and if I give on the y axis both E as well as y, whichever be, then you can easily plot them. So, for a given condition, for a given condition, energy for a given; we can say, for a given specific energy, you have been provided depth of flow; say, this is, here the width is B, so the discharge per unit width at this section is q 1, at this section it is q 2, right. So, for this particular; from this curve, you will see specific discharge q versus depth of flow.

Now, at this, for this discharge per unit width q 1 at the upstream section, let us assume that this is q 1 and the corresponding depth of flow is y 1, let us assume that; that you can easily infer, from this particular diagram you can easily infer. This case, so there is a change in the discharge per unit width from q 1 to q 2. So, if the specific quantity, if this discharge per unit width if it gets changed, q 2 is naturally higher than q 1. So, the corresponding depth of flow is y 2, let us assume that for this situation. If you further decrease the width of the channel, it will further increase the discharge per unit width quantity small q, right.

So, how long it will go? As we have, as you see from this particular curve, there is a maximum value for those rectangular channels; there is a maximum value q c, where the depth of flow will be critical, right. What is that q c? That is, the flow will be in critical conditions. That is, so, what can you infer from this particular diagram? Actually, we have done it in our module one courses and all, any discharge that will be the maximum; or, for a given rectangular channel, the discharge will be having maximum conditions when it is flowing in critical state, like we have studied that.

Or, for any quantity, the discharge will be maximum when it is, when the channel is allowing that discharge to be in critical condition, all right. That, that, and in a similar way, we have studied them. So, you, you can see that; any quantity q, here the maximum discharge per unit width occurs when it is in critical condition for the channels, for the rectangular channels; this is, from this particular curve it is quite obvious. So, you cannot have a discharge beyond the critical conditions, in that channel, right. So, you cannot have more than that quantity. So, this is the maximum possible, and the corresponding depth is that much.

So, if you have any width, any constriction the width of the rectangular channel, in such a way that it extends beyond q c, then what you have to do is that, you have to again readjust the flow pattern in the upstream condition, fine. So, that is, there is a change in discharge from q 1 to q 2. So, the downstream depth v 2, y 2, you can compute it from this particular curve; the flow depth decreases for subcritical flow as, as is evident from the figure.

This is the critical direct, this is the flow pattern. So, from here, you will see that for subcritical flow conditions, the depth of flow in the downstream section decreases. There is a critical width B c that corresponds to q c. From this q c one can evaluate what is B c, right. Because, if q c is known, q c for rectangular cross section, we have already seen that in, we have already derived those things; this is nothing but, acceleration due to gravity g into y c cube, right. So, based on these things also you can infer B c. So, B c is nothing but, q by q c, like this you can suggest the thing.

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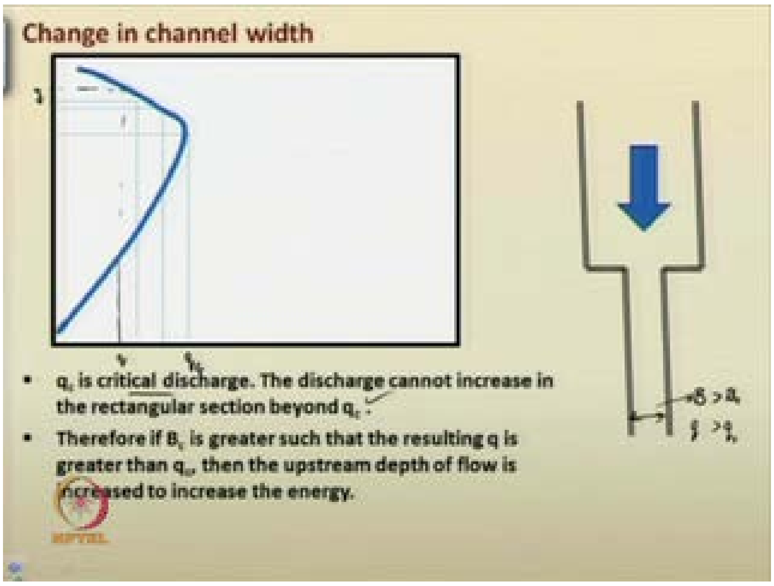

So, q c will become the critical discharge in such situations. The discharge cannot increase in the rectangular section beyond the q c value, so q c. Therefore, if B c is greater than, greater, such that the resulting q is greater than q c, if your B, if the B, constricted width B, if it is greater than B c, so that the q becomes greater than q c; that is not theoretically possible. What happens is, the upstream depth of flow is increased to increase the energy.

So, if you increase the upstream depth, what happens? So, I just increase the upstream depth, the energy gets, so q gets reduced; upstream depth is further increased, like that the energy is also increased, all right. Here, the E is also there. So, that way the flow is being compensated. So, similarly, you can analyze for width, change in the channel width also.

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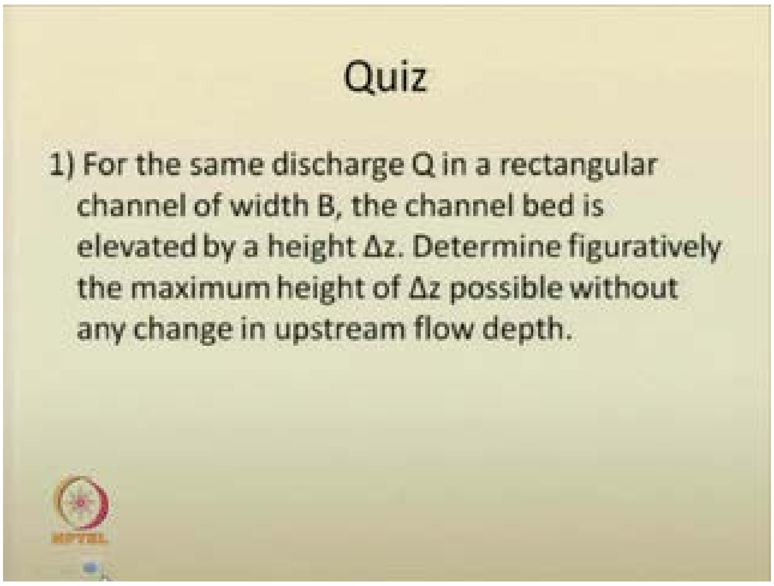

Let us do some, 2 quiz problems quickly. The first question for today's lecture is: For the same discharge Q in a rectangular channel of width B, the channel bed is elevated by a height del z. Determine figuratively the maximum height of del z possible without any change in the upstream flow depth. You have to solve it using figure; you have to explain it through figure.

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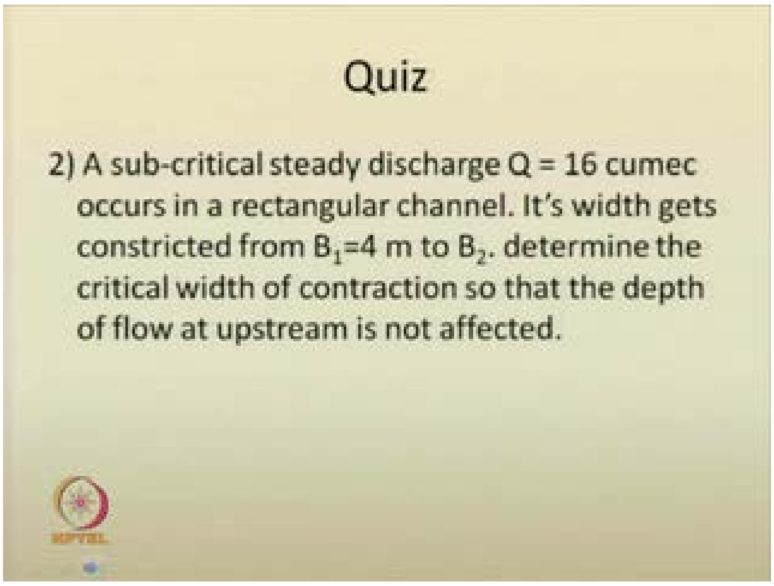

The next question, it is a numerical problem, which is quite easier; although you have not done but, it is easier for you to solve it. A subcritical steady discharge Q having 16 cumec in that rectangular channel, occurs in a rectangular channel. It is width gets constricted from 4 meters to a particular value. Determine the critical width of the contraction so that the depth of flow at upstream is not affected. Your upstream depth should not get affected; what is the critical flow that is possible? That is, that is the maximum constriction in width possible; so, that the upstream flow is also not affected.

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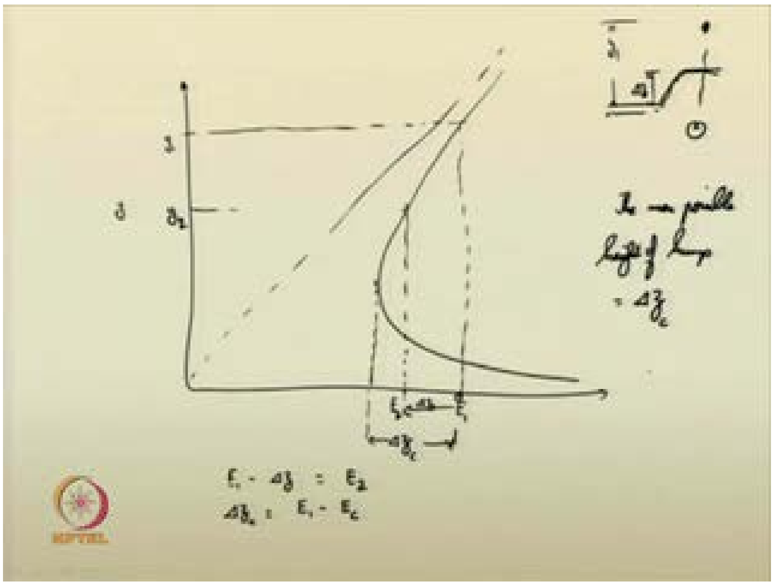

So, the solution for the first question of today is, you can just draw a specific energy versus depth curve, the angle of 45 degree curve where depth of flow and specific energy are same. You are just drawing a specific energy versus depth curve like this. So, for the given channel, rectangular channel section; say, like this, the bed elevation it is increasing; here the depth of flow is y 1. So, for the y 1 value, you just evaluate what is the specific energy? You just find, what is the hump elevation del z at E 1. You minus del z; that is E 1 minus del z, whatever value is there; you will get corresponding value somewhere here; that will be the specific energy at the upstream section 2 2. So, this is given as E 2, and the corresponding depth of flow is y 2.

If the maximum possible height of hump is equal to del z c, let us suggest del z c; such that from E 1, from E 1 upto the critical condition, what is this value? This is your maximum elevation of hump possible, del z c. To, del z c is nothing but, E 1 minus E c; E c it is quite clear means how to evaluate E c for the rectangular channels. There is, means, you know that the critical conditions are not at all dependent on the geometry of the problem for critical rectangular channels and all, you have already derived those things. So, E c you can evaluate it; E 1 minus E c will give you the maximum height of the hump in which the upstream conditions are not affected.

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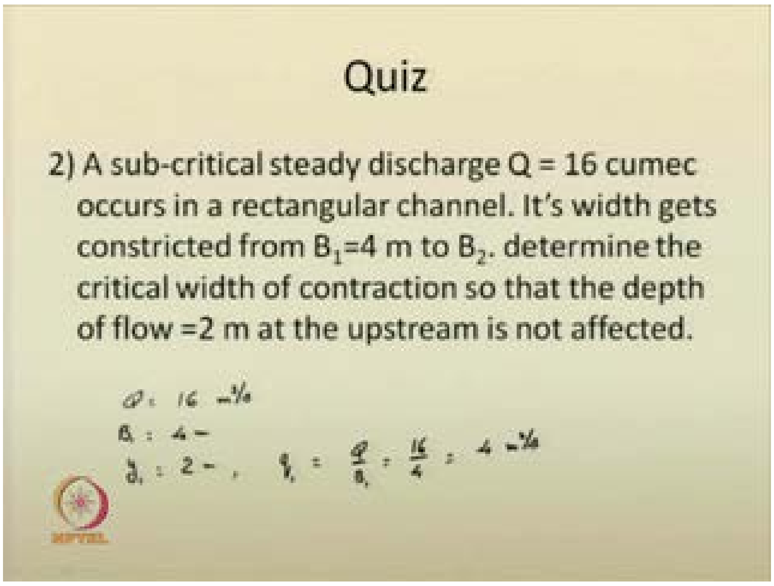

The solution for the next problem; we have asked you a subcritical study discharge Q; that is Q is equal to 16 cumec per second. So, the width gets reduced from 4 meter. You have been asked, determine the critical width of contraction so that the depth of flow at upstream is not affected. B 1 is equal to 4 meter, it is given. So, depth of flow at the upstream section, it is 2 meters. So, you have discharge per unit width, Q by B 1 is equal to 16, so 4 meter square per second, this particular quantity you have.

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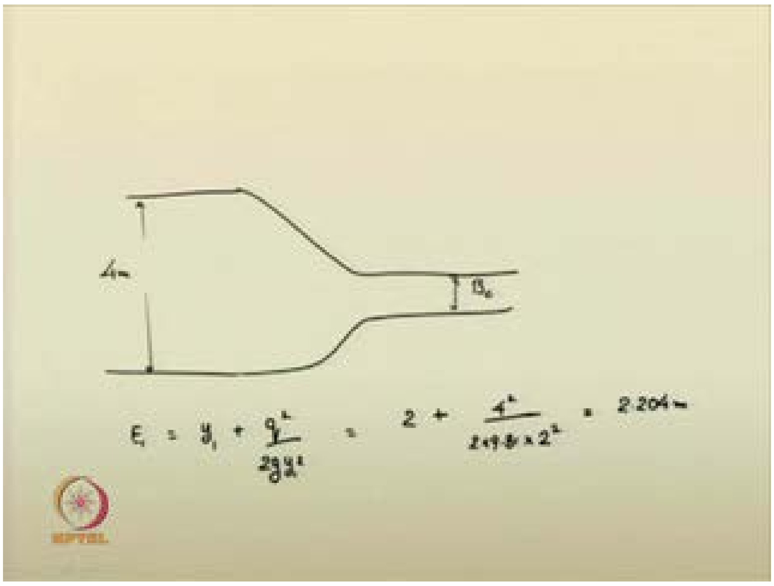

Now, you can evaluate at the; say, if the channel is getting restricted; so, here the channel width is 4 meter; this is the critical width, we do not know, what is that value B c. So, you have E 1 is equal to, at the upstream section, y 1 plus q square by 2 g y 1 square. So, I can write this as, 2 plus 4 square by twice 9.81 into y 1 is 2 square, so you just calculate it; it will come to be around 2.204 meter.

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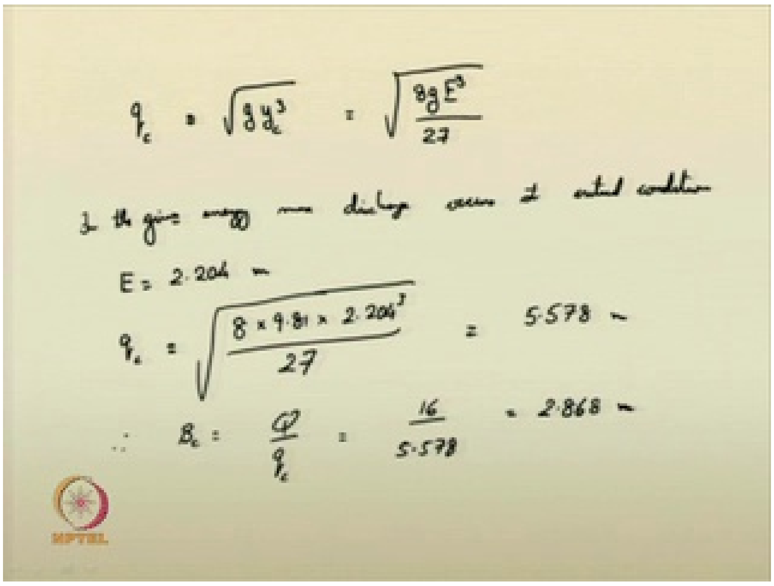

Based on this quantity, we have suggested that the critical, the given energy, given depth or given discharge per unit width, it will be having; that means, it will be having critical conditions at q c, right. So, q c, we have already suggested that this is nothing but, equal to g root of g y c cube; or if energy is given, this is nothing but for rectangular channel 8 g E cube by 27. These, from these things, it can be easily found it out. So, for the given, for the given energy, maximum discharge occurs at critical conditions. If that energy is critical, then you have maximum discharge; so, q c. So, you have E is equal to 2.204 meter.

So, for this specific energy, to be in having maximum discharge, you have to see that, that energy is in critical condition. So, you, adopting the same thing, q c; we will see that q c is nothing but equal to 8 into 9.81 into whole cube by 27 it, evaluate it; it will come to be around 5.578 meter. So, what is B c then? B c is nothing but discharge, original discharge by q c. So, it is 16 by 5.578. So, this comes to be around 2.868 meter. So, the maximum constriction, or the width can be constricted upto 2.86 meters, it cannot constrict it beyond that if we are constricting beyond this, the elevation of the water gets increased.

Thank you.