Soil and Water Conservation Engineering

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Lecture – 12
Contour Bunds

Welcome, friends. Welcome, back to NPTEL online certification course on Soil and Water Conservation Engineering. I am Professor Rajendra Singh of Agriculture and Food in Department IIT, Kharagpur. We are in week number – 3. Today, we are going through lecture number – 12 and the topic is Contour Bunds.

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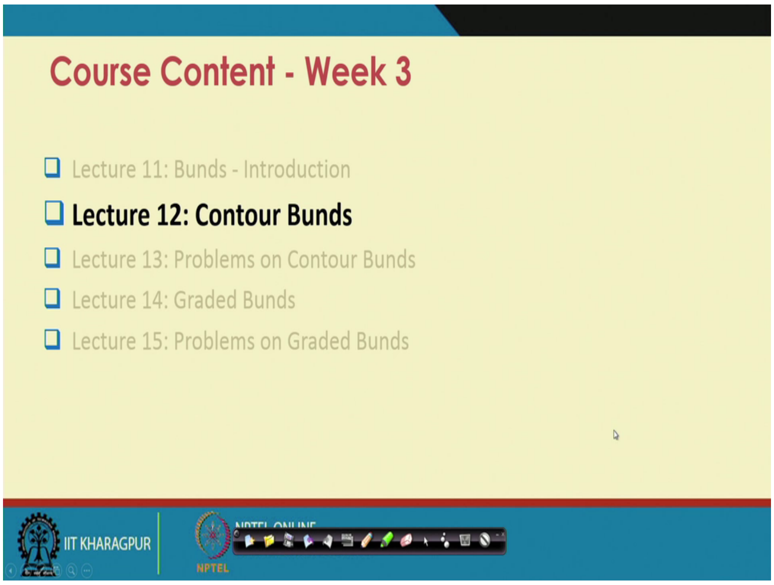

Just to give you an idea about the course content of this week, in previous lecture that is a lecture 11 we introduced bunds, in today’s lecture we will see through the concepts of contour bunds, some of the design concepts as well. And then in following lecture, lecture number – 13 we will utilize those concepts which we learn today for handling or tackling problems, dealing with the design of contour bunds and in lecture number – 14 we will go through graded bunds and lecture number – 15, then we will utilize the concepts learned in lecture number – 14 for designing graded bunds. So, let us go through today’s lecture.

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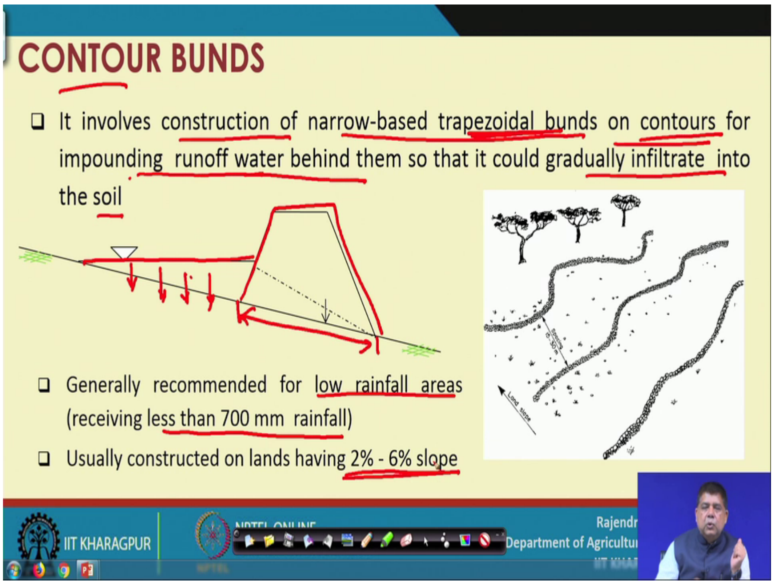

Now, we just gave you a brief idea in the previous lecture alsothe contour bunds involves construction of narrow-based trapezoidal bunds on contours, for impounding runoff water behind them so, that it could gradually infiltrate into this soil. So, that simply means that they are trapezoidal, they are having trapezoidal cross section which is as you can see here, they are typically trapezoidal cross section and narrow-based; narrow based means the base width is as narrow as possible from this stability point of view of course, it has to be.

Because, as we in the previous class we saw one of the drawbacks of their contour bunds or bunding is that results in the loss of cultivable land and as you can see that if this cross section is built here, and here and here and if the base width deal too much then; that means, which will result in a higher amount of loss of cultivable land so, that is why we always see that the base width of this is the base width the base width of the contour bunds are as narrow as possible.

They are always constructed on contours and that is why named contour bund. Contour bund, the name comes because they are bunds constructed on contours. So, contour bund that is how the name comes and their primary function is impounding runoff water behind them. So, primary function is storage of water. So, because of the construction whatever rainfall occurs that get is stored here and obviously, because it is standing there for longer period of time so, more and more of infiltration could take place besides checking erosion and flow of water.

Contour bunds are generally recommended like any other typically in bund case also we saw, that they are recommended for low rainfall areas which receive less than 700 millimetre of rainfall annually. So, any place where the annual rainfall is there is a 700 mm of rainfall, we can go for contour bunds and they are usually constructed on lands having 2 to 6 percent slope. We saw in the previous lecture there was a adaptability table which said that the slant slope should always be limited to 8 percent. So, it can never be constructed for slant slope having 8 more than 8 percent slope and usually usual recommendation is 2 to 6 percent of land slope.

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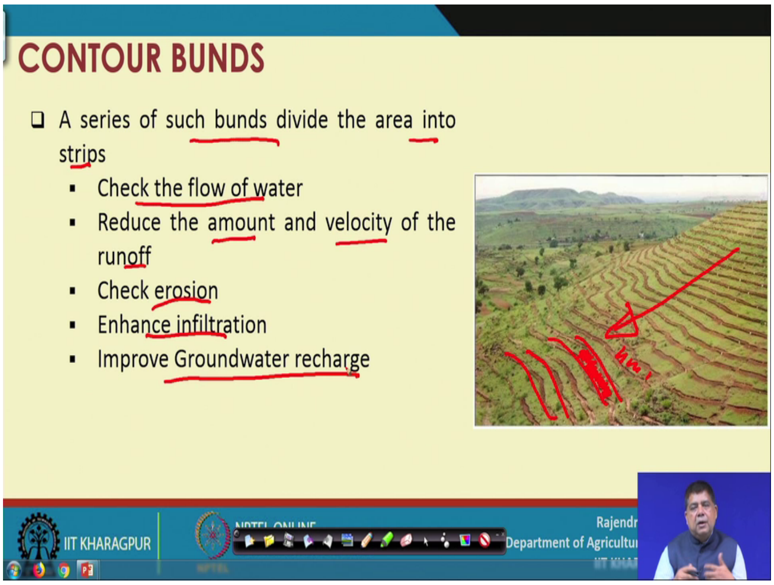

Now, some of the functions or advantages, a series of such bunds divide the area into strips. So, as you can see here because they are constructed on contours so, obviously, what is happening that entire land is getting divided into a narrow strips and obviously it checks the flow of water. So, as we have already seen that whatever rainfall will occur in between the area occupied by two bunds that is stored there so, and obviously, that is not allowed to flow.

So obviously, the total flow or total amount of water which otherwise would have available would have been flown out of the area that is not there in this case because they are constructed in this direction which shows that the land slope is in this direction. So, if these strips would not have been there much larger amount of flow would have reached this point, but in this case because of these strips narrow strips which are where water get restored the total amount of water which is available or flows that flows out is much less and of course, the velocity of the runoff is also checked because we are storing water in between these structures.

And, obviously, once amount of water is not allowed to flow, velocity is not there so, obviously the erosion is not there because if over land flow is not there the sheet erosion process will not take place. Transportation of eroded material will not take place, so that either is how it checks erosion. And as far enhancement of infiltration is concerned, because water is standing for longer period of time in between two bund structures. So, that means, more opportunity time is available for water to infiltrate and; that means, the total infiltration will be much larger and in effect it will result in groundwater recharge. So, ground water will be recharged in wherever contour bunds are constructed.

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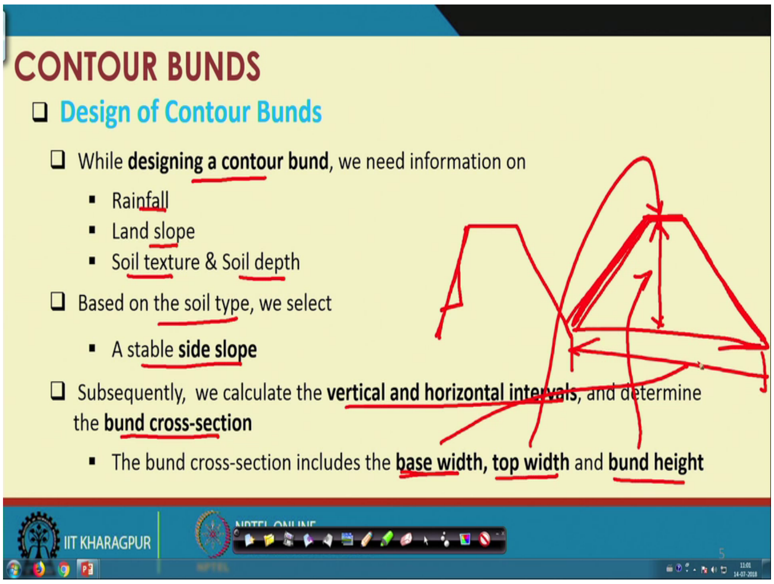

Now, coming to design of contour bunds: basically, while designing contour bund we need information on rainfall that is because we wish to know how much water needs to be stored or what is the maximum amount of water that is available for storing in between the bunds.

Then the land slope that basically it governs adaptability of course, that ways we know that it should be less than 8 percent and normally between 2 to 6 percent and some of the design components also are governed by land slope and of course, the type of soil the soil texture and soil depth, because it also is related to adaptability.

Now, based on the soil type once we know the soil type a stable side slope, side slope means this is typically this is the cross section we have seen. So, this is this is referred as side slope the slope of the sides that is referred to side slope. So, we have to decide based on the soil type, we decide a stable soil slope, because the stability is a factor here. So, if a if the soil is very sandy then obviously we have to have a very I mean if it is a clay soil then we can have a steep slope otherwise, if it is a sandy soil then the slope has to be flat. So, the step from the stability point of view the soil types helps us in deciding the side slope.

Subsequently, we calculate the vertical and horizontal intervals which basically govern the spacing between the consecutive structures. And then also we calculate the bund cross section and when we say bund cross section this involves base width, top width and bund height. So, if we consider this is a this is a typical cross section then obviously this is nothing, but the bund height, this one is top width and the base width is this to this which we have already considered earlier this is base width.So, basically when we say construction the cross section we have to decide on the height, the top width and the base width and of course, the spacings has to be decided.

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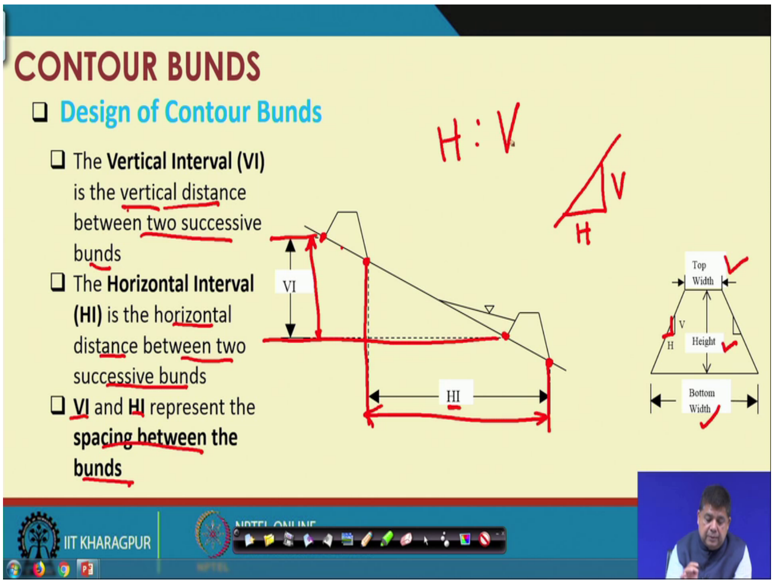

Now, the we use two terms vertical interval and horizontal interval, which define the spacing between the bunds basically. So, what are these? So, the vertical interval is the vertical distance between two successive bunds. So, if we take two successive lines of bunds and then we take any corresponding points in the two successive bunds, it could be the upstream toe, it could be downstream toe, it could be center whatever corresponding point you check.

So, if you take the upstream toe here the same upstream toe has to be taken here. So, if we take two corresponding points and then we find out the vertical distance the measure the vertical distance between these two, these two corresponding points that is referred to as vertical interval or the vertical spacing between two consecutive bunds. So, this is vertical interval.

Then, horizontal interval is the name itself suggest, basically it is the horizontal distance between two successive bunds. So, in this case also we can take any corresponding points. So, if you say for example, if you consider the downstream toe, then for both bunds we have to consider downstream tow and if we draw the vertical lines here and then measure the horizontal distance between these two points that that is referred to as horizontal interval. And in this case we had to draw the horizontal lines and then measure the vertical distance.

So, horizontal line from two corresponding points whether the vertical distance that is vertical interval and vertical lines and measure the horizontal distance between two corresponding points that gives us the horizontal interval and of course, VI and HI represent the spacing between the bunds. And, the cross section already we have seen that when we say cross section involves height, bottom width and top width. So, these are the various design criteria this is the side slope H is to V typical, whenever we say a side slope we always represent H is to V. So, the typical convention of representing side slope is H is to V horizontal is to vertical. So, we will see little detail of this little further.

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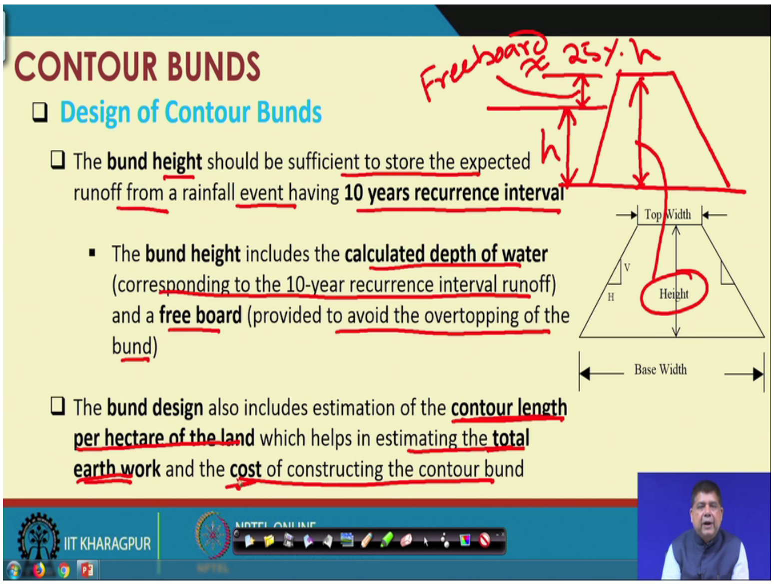

Now, about the bund height, if continuing design the bund height should be sufficient to store the expected runoff from a rainfall event having 10 years recurrence interval. So, that means, for designing these structures the capacity is decided based on the rainfall event having 10 years recurrence interval; that means, the rainfall event which is likely to occur once in 10 years. So, that is how they the capacity of these structures are designed decided.

So, the bund height includes the calculated depth of water corresponding to 10 year recurrence interval runoff and a free board provided to avoid the over topping of bund. So, obviously, when we say if this is the bund cross section, say for example. So, once we know how much water to be stored. So, first we will calculate that so, this could be let us say we call it h which is the depth of water and then this is the theoretical depth which we calculate first and, then in order to avoid overtopping we provide some kind of a safeties, that is referred to it free board. And typically this free board is taken in approximately 25 percent of h so, this h plus 25 percent of h that gives us the complete height of the height which is here height of the bund.

The bund design also includes estimation of contour length per hectare of land which helps in estimating the total earth work required and the cost of constructing the contour bund. So, obviously, once we have the cross section with us, when we know how many the vertical or horizontal interval, then we can also find out in a hectare of area what will be the total contour length and that will tell us knowing the cross section of the contour length total length, we can find out what will be the total earth work required if you want to go for construction. So, if you know the unit cost of earth work, we can calculate the total cost of earth work.

And of course, that will help us in finding out the total cost of course, remember when we said the total economics is calculated, then not only the cost of earth work, but the cost of land which is lost due to construction bund is also considered. But, as far as only the construction or implementing these measures are concerned then obviously, we are more focused on cost of constructing these contour bunds.

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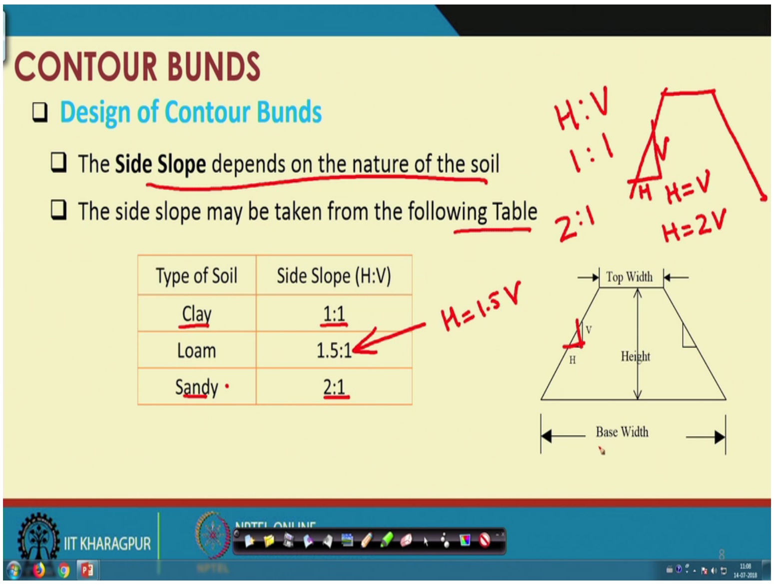

Then the side slope which we considered earlier it comes into picture. The side slope depends on the nature of the soil, as I already mentioned the stability of the dam or structure basically is governed by the side slopes. And may be taken from the following table as I already mentioned if it is clay, then we can have much steep slope, if it is a sandy then we have to have flat slope and when we say 1 is to 1 or 2 is to 1 as you already mentioned that we always use the convention H is to V that is horizontal is to vertical.

So, if we say 1 is to 1 that is one horizontal to one vertical; that means, horizontal is equal to vertical. So, if we say that 1 is to 1 means H and V so, H is equal to V. But, in case of sandy soil when we say it is 2 is to 1 that means, horizontal will be twice of V.

So, H V we will H will be 2 times of V or in this case in the loam soil it H will be 1.5 times of V. So, that means, H will be much bigger, so that means, which will be much flatter structure and that means, base width will be much larger.

So, if it is a sandy soil then we have to have a very flat slope and that means, in that case the base width will be larger, if it is a clay then we can go for a steep slope and then base width will be much smaller.

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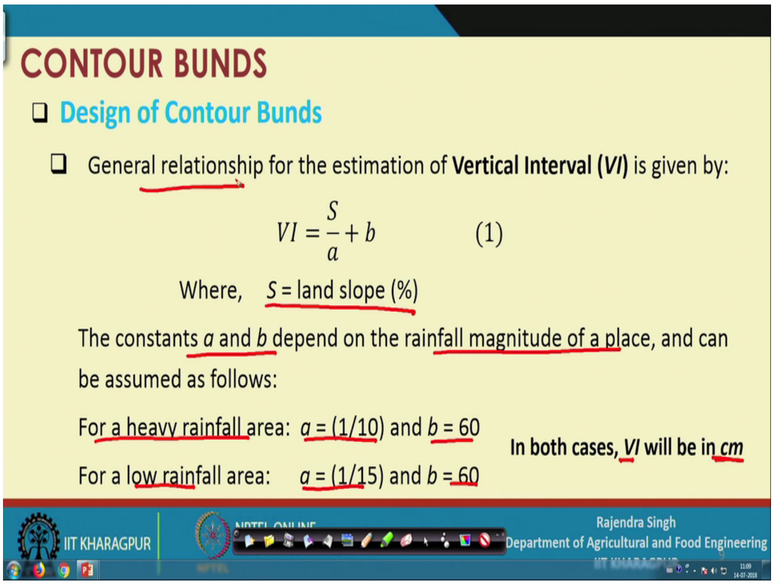

Then, for calculating the vertical interval, we have several formulae available this is the general relation if it is given, which is VI equals to S by a plus b, where S is the land slope in percent so, VI is represented as a function of S here. And the constants a and b in this general relationship they represent the rainfall magnitude of a place and they can be assumed as follows.

That is, for heavy rainfall areas a is given as 1 by 10 and b is 60 and for lower rainfall areas a is 1 by 15 and b is 60 in both cases VI will be in centimetres remember, because this empirical equation and because these constant values are already given in empirical form. So, obviously, we have to always remember the units. So, S has to be in percent and the resultant VI will be calculated in centimeters, if we use these values of a and b for heavy or low rainfall areas while using the general relationship so, that we have to remember.

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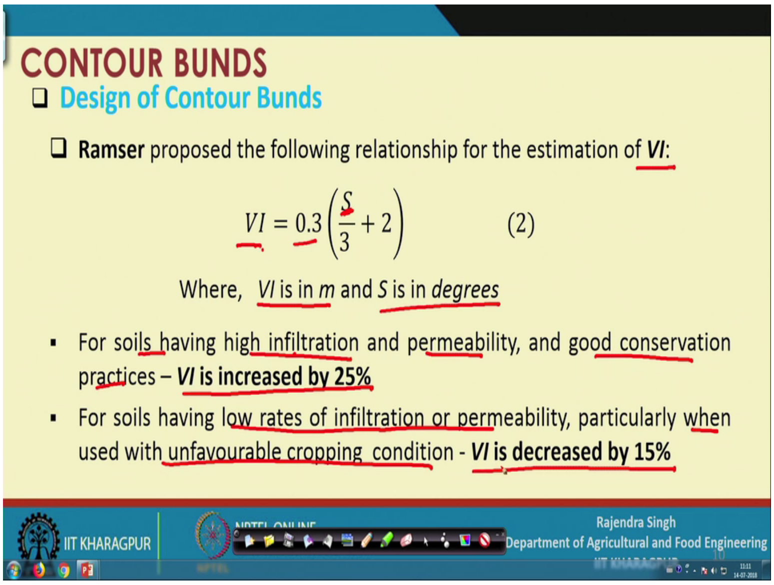

As I said there are alternates available so, one of the formula which is I will given by Ramser that is also used for estimating VI and in this case VI is given as 0.3 S by 3 plus 2 there it was in terms of a and b, here there are fixed values already given, but the change is that VI is in meters and S is in degrees. So, you have to remember VI is in meters, S in degrees and here what happens that as you can see that VI is only taken as a function of land slope here.

So, again in this case for soils having in order to account for the soil characteristics that is, the soils having high infiltration and permeability. And in order to take care of conservation practices or cover condition and good conservation practice VI is increased by 25 percent. So, considering only the slope we first calculate VI and depending upon the rainfall infiltration characteristics the soil characteristics and also the conservation practices VI is increased by 25 percent.

But, when the soil have low rate of infiltration or permeability and when the unfavourable cropping conditions are used, then VI is decreased by 15 percent. So, in Ramser formula one you have to remember, that first you use equation to calculate VI and then knowing the soil and crop cover conditions we have to either increase or decrease VI depending upon the conditions which are available.

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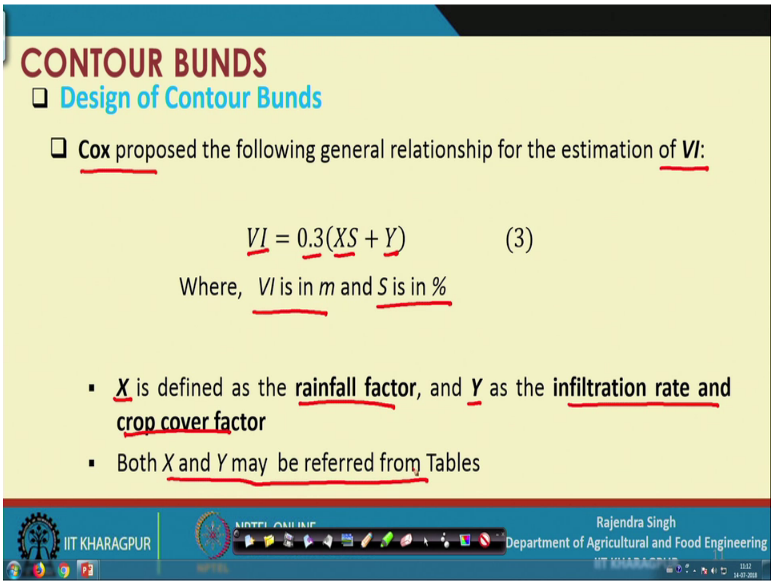

Then, the other alternate is Cox formula which is probably the most popularly used formula for calculating the vertical interval, where VI is given as 0.3 XS plus Y, where VI is in meters and S is in percent so, very convenient to use. And, X is defined as rainfall factor and Y is infiltration rate in crop factor. So, here also X and Y they take care of rainfall and soil and cover conditions and both X and Y can be taken from standard tables are available.

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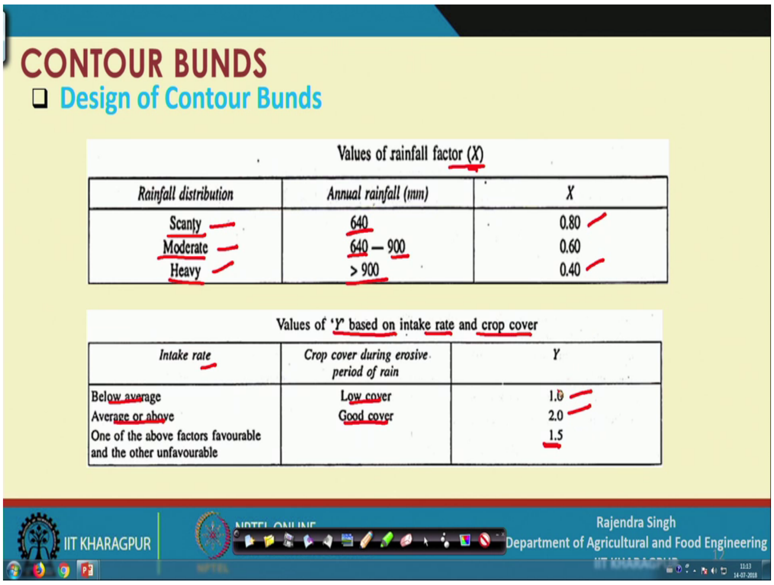

So, just we can see the tables here that these are the values. So, values of rainfall factor X depending upon the rainfall that is whether it is scanty moderate or heavy; that means, the magnitude are also given that is rainfall inward rainfall, if it is less than 640 or around 640 it is referred to as scanty. In between 640 and 900 it is moderate, greater than 900 is heavy the values of X vary from a 0.8 to 0.4. But, remember typically we limit the rainfall to 700 millimeters while designing the bunds, but in odd cases it may maybe also designed for heavy rainfall areas.

Then, similarly values of Y which are based on integrated crop cover, then integrate is below average and cover condition is low, then the value of Y is 1. If the integrate is above or average or above and cover condition is good the value is 2 and one of the average factors favourable and the other unfavourable; that means, the if it is below average, but good cover or average or above, but low cover then we take a value of 1.5.

So, depending upon the rainfall conditions and based on the soil and cover conditions, we can take X and value from X and Y value from here and then we can use the Cox formula for calculating the vertical interval and as I said that this is one of the quite popular formulas which are used.

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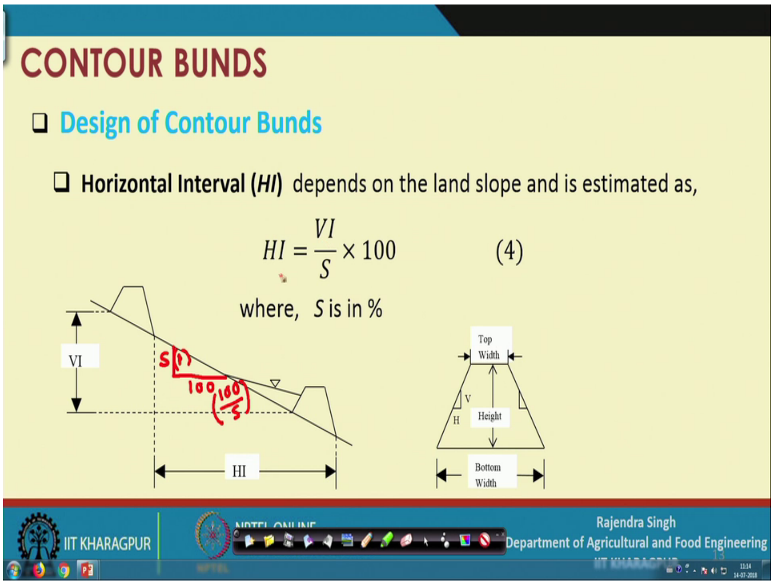

Then, comes a design of the horizontal interval. Horizontal interval basically depends on the land slope and estimated by this relationship. So, basically when we say S percent sothat means, the land slope is this is S percent and that simply means S meter over 100 meter, basically it means that is S percent means S meter suppose unit is metre so, S over 100 meter or S units over 100 units, that simply means what? That if it is 1 unit then it will be 100 by S if it is 1 then it is 100 by S.

So, that is why when it is VI, then if it is VI then this becomes 100 S times VI. So, from this very simple relationship itselfso, you do not have to remember basically HI equal to VI by S into 100. Knowing this relationship we can always find out what is the relationship between HI and VI. So, V HI once VI is known HI V can be calculated very easily using this relationship.

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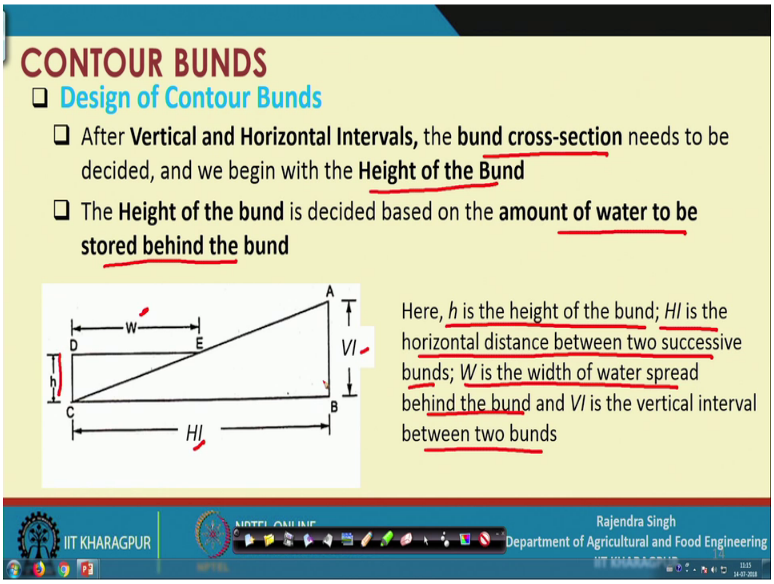

Then comes once the vertical and horizontal intervals are estimated then comes the bund cross section and obviously, we start with the height of the bund. And, the height of the bund is decided based on the amount of water that is to be stored behind the dam; that means, we have to know how much rainfall will occur and how much water that needs to be stored behind the dam.

And, for that the we just we are considering this definition sketch, that h is the height of the bund that is this is H is the height of the bund, HI is the horizontal distance between two successive bunds that is here, W is the width of water is spread behind the bund this is the W here and VI is the vertical interval between two bunds. So, obviously, this is always the diagram which will be built, because in between two bunds this will be how the condition will be. So, this is the definition sketch if it consider then obviously, we can take this little further.

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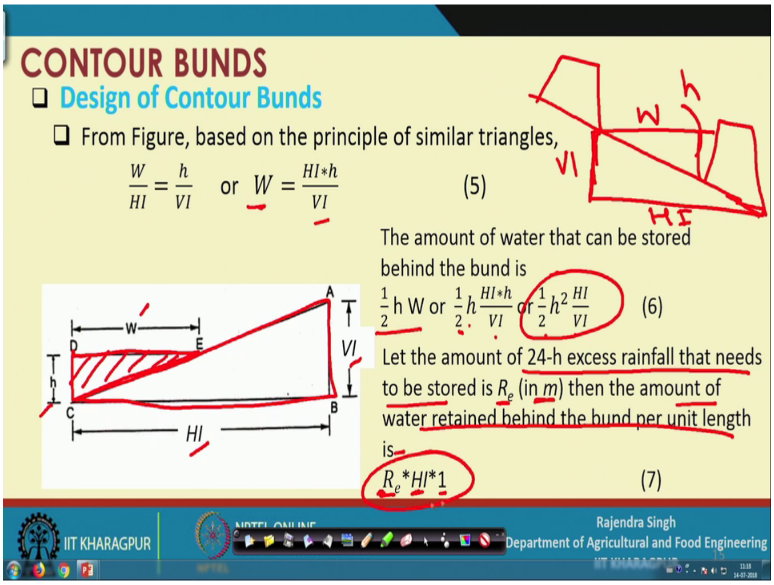

So, based on this figure we have two triangles, one is triangle this is one triangle, triangle CDE and the other larger triangle is ABC. So, from figure based on a principle of similar triangles that is basic geometry W by HI is equal to h by VI that is the principle of similar tingles and from here W is can be said as HI times h is equal to VI.

And, the amount of water that can be stored behind the dam that is basically the area of this triangle. So, behind the bund per unit length that is the total volume of water if you talk about then obviously, that is R e times HI because basically if what we are saying is that we have here and we have another section another bund here. So, this is the water we are retaining.

So, if we consider this figure here and so, obviously, from this point itself this is this is basically we are talking about this two triangles here, this is one triangle larger triangle and this is smaller triangle. So, this we are saying is h this is W, this is VI, this is HI, that is same thing we are talking about. And that simply means the total volume of water that can be stored is the total rainfall that is occurring in between this, this HI so, that is the total horizontal interval which is available for storing the water and so, that that is R e times HI into 1, 1 is perpendicular to the board. So, this is the total volume of water that can be that needs to be stored.

So, we have two things one is that volume of water that can be stored or the total water that can be amount of water that can be stored, volume we are not saying because it is a unit length, we are talking about and this is the total water that needs to be stored. So, that means, this and this has to be equal.

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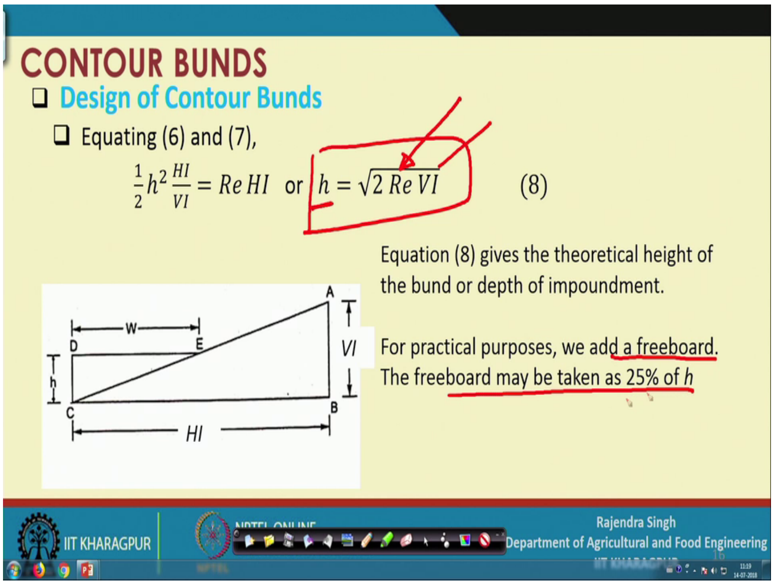

And, if we equate these then from equation 6 and 7 half h square HI VI is equal to R e HI or h is equal to 2 square root of 2 R e VI. So, V I is the vertical interval, R is the amount of excess rainfall over 24 hours. So, if we know these two then based on that we can calculate the height of the bund and also this is only the theoretical h. And, we already considered, that in order to avoid overtopping we also add a freeboard and this free board may be taken as 25 percent of S the total height of the bund will be h plus 0.25 h in order to that is the total height of the bund which we can calculate.

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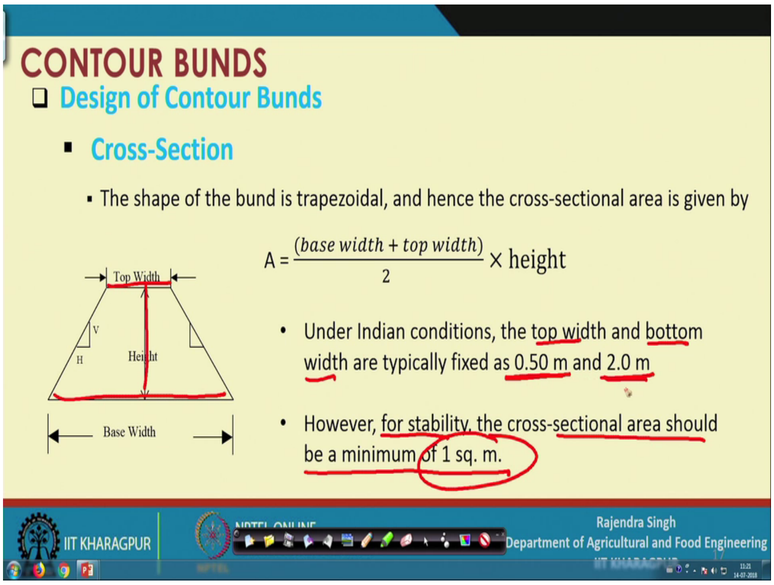

And, then once the height of the bund is calculated then obviously, we will have the cross section and the cross section is very simple it is a trapezoidal section. So, the total area is half base width plus top width into height. So, the sum of this and this divided by 2 times height that is the total area. So, under Indian conditions, the top width and the bottom width are typically fixed is are recommended as 0.5 meters and 2 meters. So, one can always calculate these values, but suppose you want to use the thumb rules, then the top width could be taken as 0.5 meters and the bottom width could be taken as 2 meters.

But in any case for stability purposes, the cross-sectional area of the bunds should be minimum 1 square meter so, this is a this is a catch. So, if you want to use this 0.5 meters and 2 meters, then your height is should be such that the total cross sectional area is more than 1 square meter. So, this is what we have to remember.So, height once we have calculated the height we can also calculate the top width and the bottom base width, but at the same time we can also use the typically recommended values for Indian conditions for developing the cross section.

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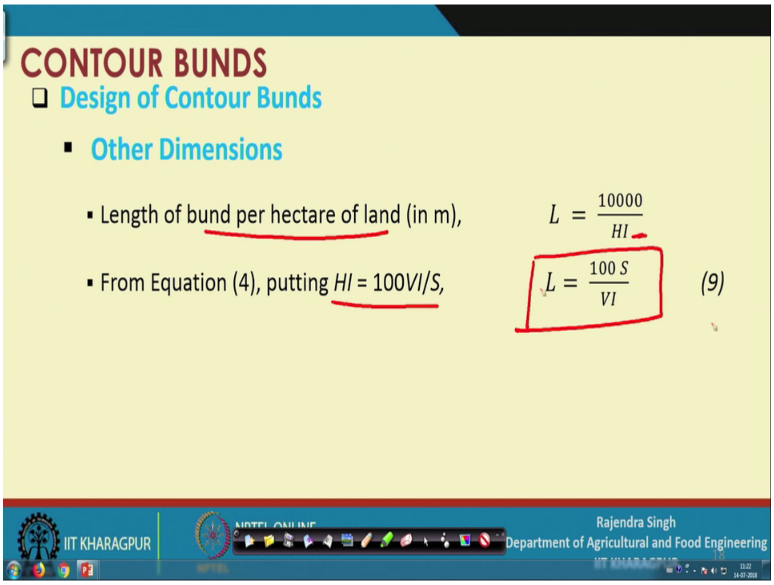

Now, coming to design of contour bunds continuing with there are certain other dimensions also which we need to calculate and that is length of bund per hectare of land. So, once we have calculated the horizontal interval and we know per unit area means 1 hectare of land had 10000 square meters. So, length of will be total length will be 10000 square meters divide divided by a horizontal interval in meters that will give us the total length.

And, we also know the relationship between HI and VI and so, by putting that HI equals 100 VI into S then this equation we will be able to get L equals to 100 S by VI. So, once we have calculated VI S is already known. So, length of the bund per hectare of land is also can also be estimated using equation number – 9.

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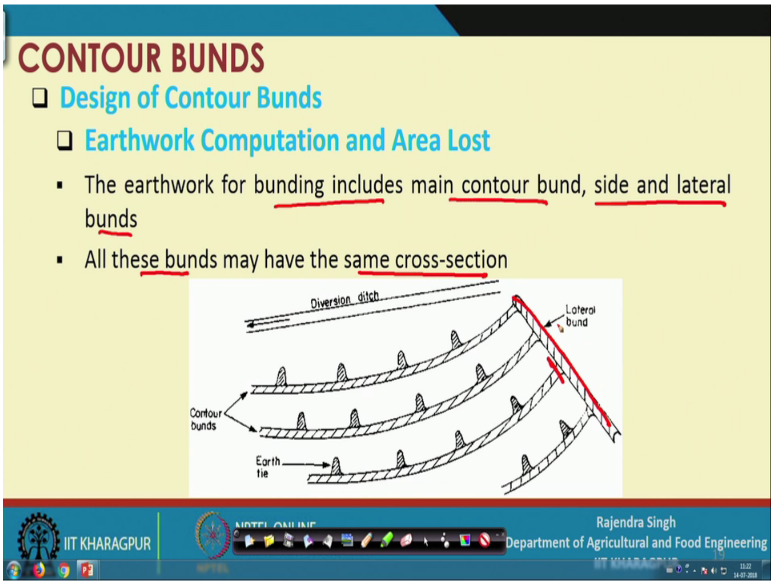

Then, coming to earthwork computation and area lost the earthwork for bunding includes main contour bund and side and lateral bunds. We have already seen side and lateral bunds, these are the lateral bunds and the side bund could be just limited on either side. So, depending upon the condition there could be side bund, there could be lateral bunds.

And, all these bunds are assumed for ease of calculation may have the same cross section. So, that is assumption that the main bund here and then the side and lateral bunds, they will have the same cross section. That is a basic assumption could they could differ also.

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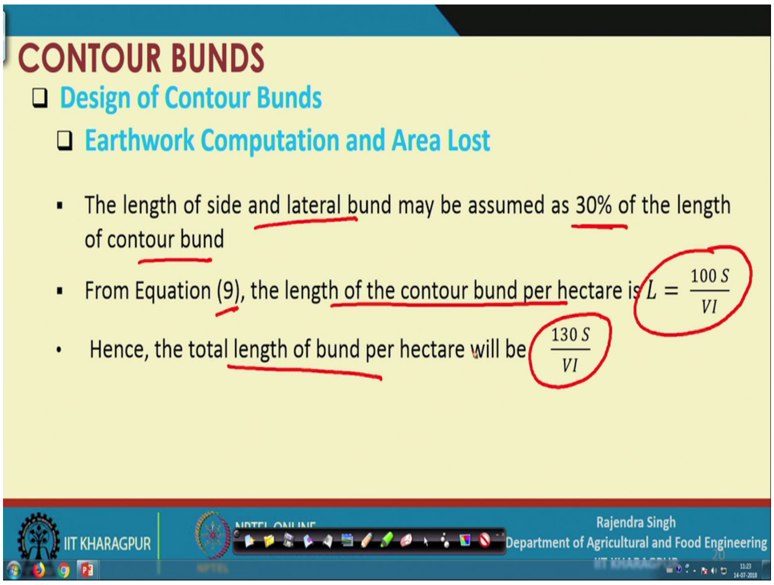

So, earthwork computation in area lost basically: the length of side and lateral bund they are typically assumed as 30 percent of the length of the contour bund. So, from equation – 9 the length of contour bund per hectare is L equals to 100 S by VI. So, the total length of bund will be 30 percent aided that is 130 S by VI. So, that will be the total length of bund per hectare including the lateral and side bunds.

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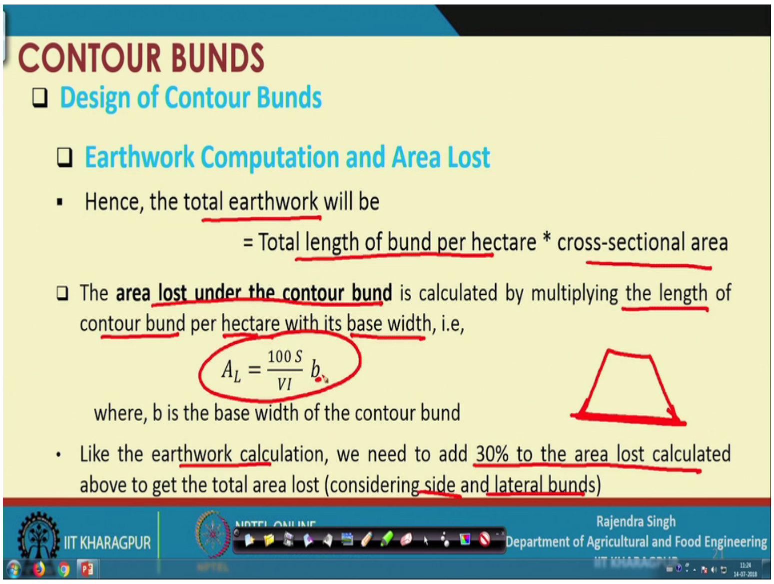

And, if you take into account the total earthwork that will be require will be the total length of the bund per hectare into cross-sectional area, that isfor each bund we have already calculated the cross-sectional area. So, total length times cross sectional area will give us the total earthwork.

And, the area lost per under the contour bund can be calculated by multiplying the length of the contour bund per hectare with it is base width, because that is the base width if we consider anywhere this is the area which we are basically losing on the ground actual field. So, this base width is taken into consideration. So, the total area lost per hectare will be 100 S by VI which is the total length of the contours times the base width of the contour bund.

And, like in the earthwork calculation here also we need to add 30 percent of the area lost due to side and lateral bunds. So, total area lost will be 130 S by VI into b like in the case of earthwork.

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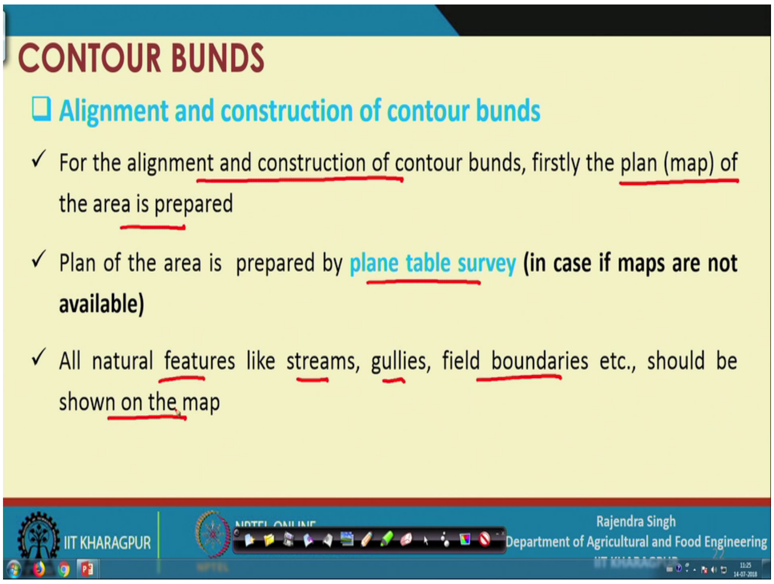

So, to once we have decided various cross-sections, when we know the cost of work earth then lastly it comes to alignment and construction of a contour bund. So, for alignment and construction of contour bunds we first need the plan or a map of the area. So, that may map may be readily available with us, or we can go for plain table survey if the map is not available.

And, today's time we can also use digital elevation maps or RGI software for creating the maps. So, and on the map of course, all natural features like streams, gullies, field boundaries they have to be shown so, the complete map is first either it has to be available or this has to be created for alignment and construction of contour bunds.

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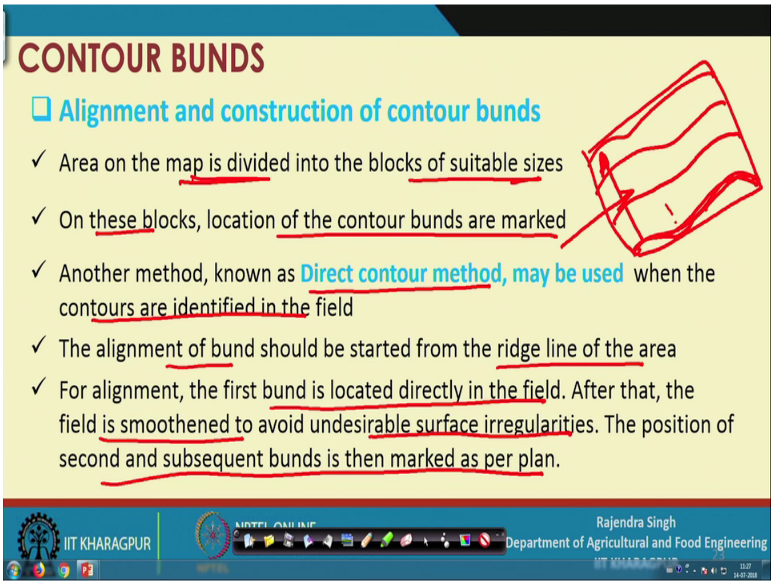

And, once the map is the area then we divide the area of a total area of the map into blocks of suitable sizes, that is for ease of management from management point of view and then on these blocks location of contour bunds are marked. So, basically we require contour we have to generate the contours, or we can always have the contours lines are if already contours are already identified, if we have a contour map with us, then we can straight away use the direct contour method for locating the contour bunds because they are always they will always follow the contours.

And, the alignment of bund should be start from the ridge line of the area, that is the from the top and the first bund is located directly in the field after that the field is smoothened to avoid undesirable surface irregularities. And, the position of second and subsequent bund is then marked as per plan. So, we know horizontal interval vertical interval. So, what we do is that first mark if this is the total this is the true area and let us says that this is the slope and that means, we have to construct our bund in this direction and so, if our contour is marked here.

So, obviously, when we say these line; that means, we have to start construction from this side and then we do some kind of a smoothing on this entire area and, then once smooth land is smoothen then knowing the location of this knowing the horizontal interval whatever interval, we can decide on and also the contour line we know what should be the location of the second line, third line and so on. So, this is how the contours can be located and built in the field.

So, in this lecture we have seen what are contour bunds, what are their functions how to decide the horizontal vertical interval, how to calculate how to calculate the cross section especially the height of the bund by using the principle of a similar triangles. And then what will be the total length of contour per hectare, what will be total area lost because of the contouring and how to align them, we have seen that and then in the next lecture we will take up certain problems, where we will see how to apply these principles which we have learnt today for designing the contour bunds.

Thank you very much.