Engineering Geology
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Lecture - 36
Geologic Hazards - Landslide Hazards - Zoning and Mitigation

Hello everyone and welcome back. We are going to continue our discussion on geologic hazards related to landslide in this lesson. So, in this lesson, we are going to talk about landslide hazard zoning and we are going to look at a few mitigation strategies typically used to address landslide hazards.

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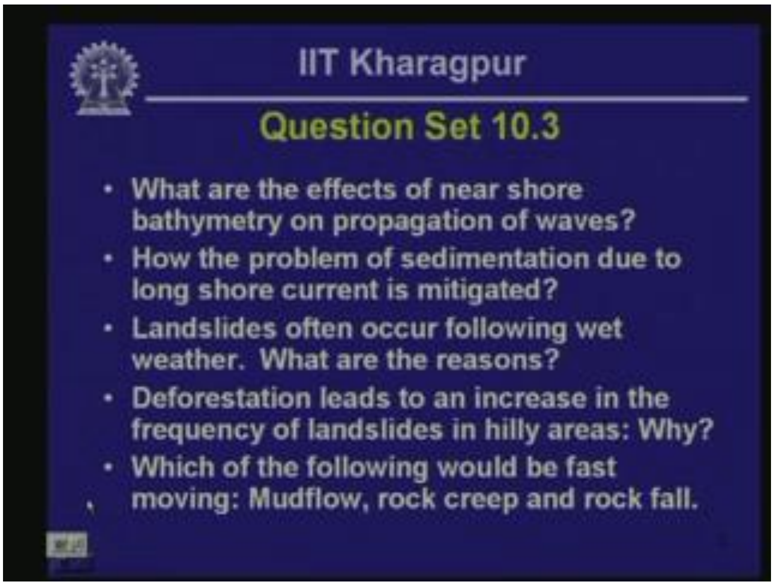

But before we go ahead with today’s subject matter, let us look back at the question set of the previous lesson. And these are the questions. The first one that I asked was what are the effects of near shore bathymetry on propagation of waves. As I discussed in the previous lessons, if we have got a protrusion of a land form jutting into the water and the bathymetry also reflects that kind of onshore or sub area topography, then that area is going to be affected by refraction and focusing of the wave energy. Let me draw a sketch to elaborate or to jog your memory about what I mean by this thing.

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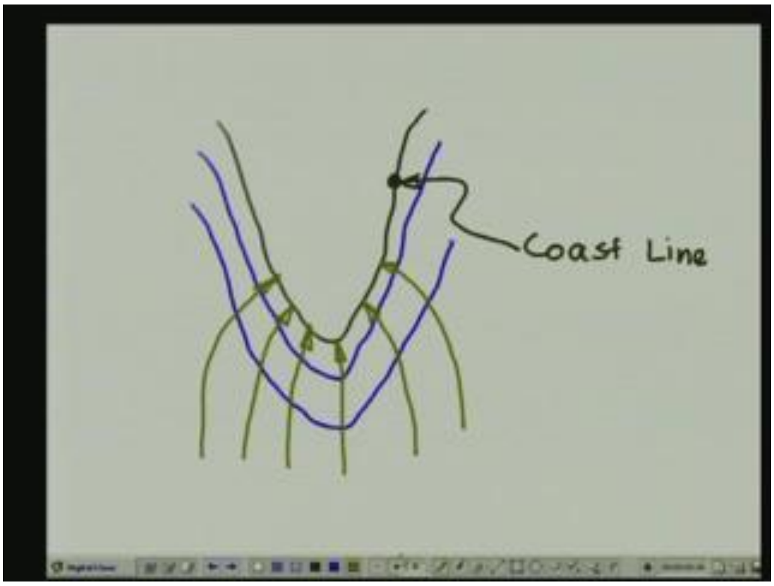

So, let us say we have got a land surface that is protruding into the sea, and the bathymetry contour near shore is also reflective of that kind of land form. So, this one here is our coastline; this is the coastline. So, in this particular case, the wave energy is going to refract, and it is going to get focused towards the portion of the coastline that is protruding into the sea in this manner. And this bending or refraction as you recall is because of slowing down of the shallow water wave depending on water depth. So, that is one of the things that you could have.

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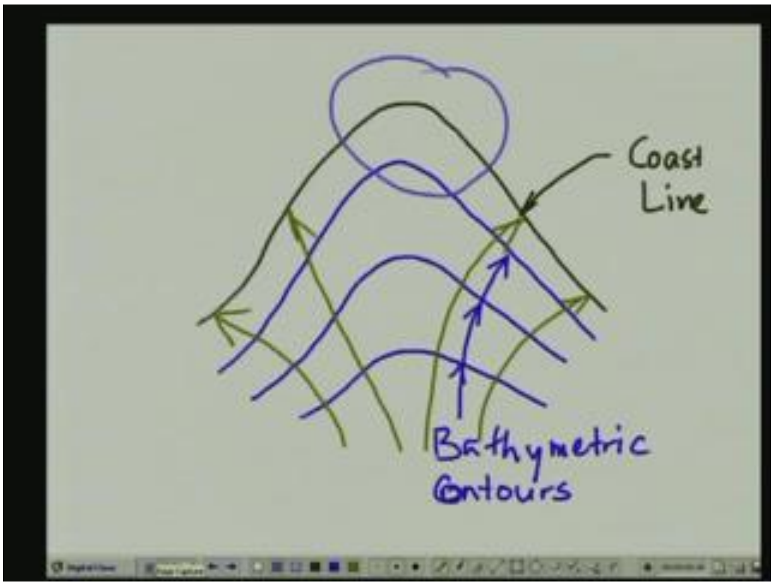

And you can have an opposite effect in areas where the coastline geometry is of this type and the near shore bathymetry is bathymetry contours are of this shape. So, these are the bathymetry contours like in the previous sketch. So, they are the bathymetric contours. And as earlier, this one here is the coastline. So, in this case, the waves are going to be refracted away from the bay, and the bay basically it is going to form a low energy environment with very little wave attack near in this particular area; in this area you are going to have very little wave attack.

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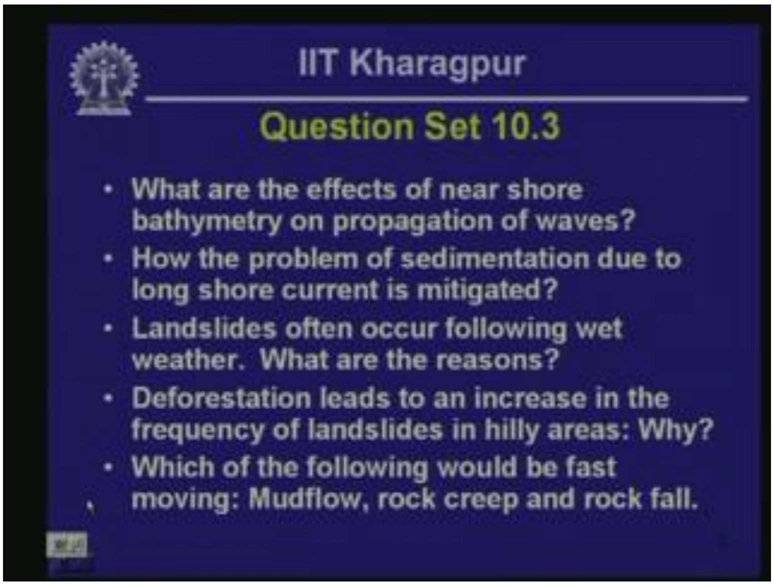

So, these two sketches basically illustrate how the near shore bathymetry affects wave propagation. Second question what I asked was how the problem of sedimentation due to long shore current is mitigated.

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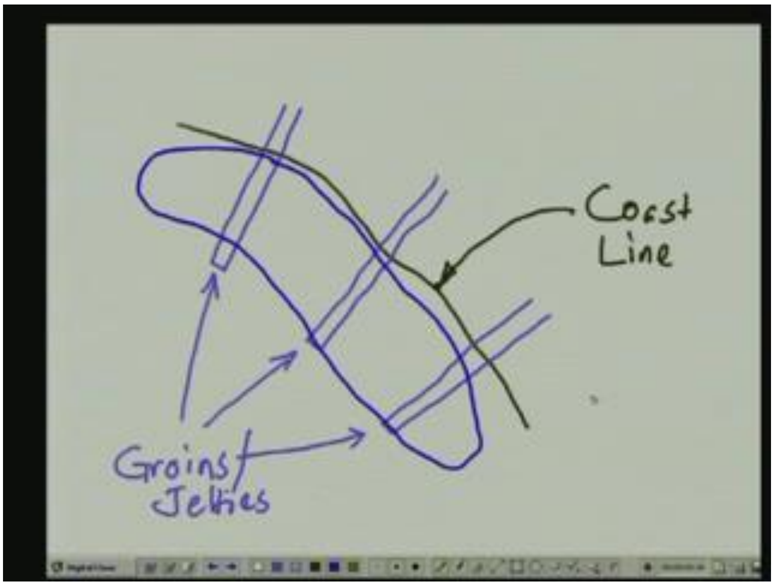

Two of the measures that I discussed if you recall are the groins and jetties. So, basically what they are? If you look at the coast line that is affected by near shore transport where you want to actually limit the near shore erosion and sedimentation; so what you are going to have? You are going to have groins or jetties constructed in this manner. So, they are basically vertical narrow structures which are going to discourage the movement of long shore current in the immediate vicinity of the coastline.

So, this is the coastline here that I am drawing same kind of color coding that I was using in the previous sketches. So, this is the coast line, and here again you are looking at the plane just like the other two sketches that I used in the previous question to answer the previous question. And these features here are groins or jetties, and by having these in this area, the long shore current and sedimentation and deposition are greatly mitigated. So, that is the measure that we discussed in the previous lesson.

Third question that I asked was these landslides often occur following wet weather, what are the reasons? Following wet weather, typically two things happen. One is water table concept to near this slope phase, and that actually may lead to egress or day lighting of the seepage near the bottom of the slope, and this may cause erosion. So, erosional instability is likely to cause landslide; that is one of the aspects.

Then the second thing that happens because of rising of water table, the effective stress within the near surface soil layers, they are going to greatly reduce as a result their frictional strength if the soils are frictional, then the frictional strength is going to be greatly reduced as well. So, that also is going to lead to frequent shallow slump pits. So, these are basically two causes which actually lead to landslides because of wet weather, okay.

Then the fourth question that I gave was this. Deforestation leads to an increase in the frequency of landslides in hilly areas and I asked why. Basically what happens? Because of deforestation, two things are happening; let us say let us look at a section of a slope.

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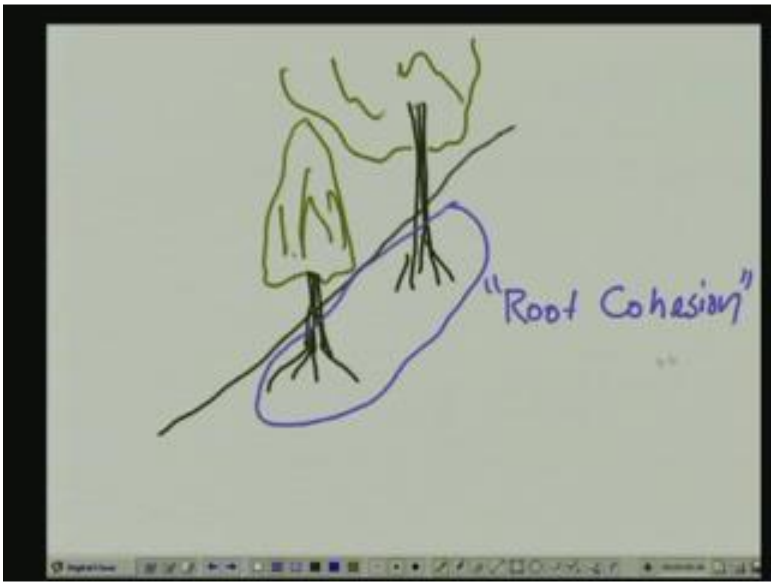

Let us say you have got a slope of this type and you have tree cover. And the roots of these trees as they actually penetrate the near surface soils, you could have other trees as well; you could have several other trees in the area. And because of deforestation, the binding power of the roots which actually impart some shear strength within the soils where the root is penetrating. So, the shear strength because of the binding power of the roots is going to greatly reduce. As a result, this thing is approximated; the shear strength because of the binding power of the roots is given the term root cohesion.

So, this component of shear strength is going to be eliminated if there is deforestation, and as a result, the soil is going to have less actual shear strength. So, that could trigger landslides because of the immediate effect of the deforestation process. Fifth question that I asked was which of the following would be fast moving. Mudflow, rock creep and rock fall.

So, this among the three mud flow rock creep and rock fall, both mud flow and rock fall, they are going to be fast moving instabilities or the velocity associated with the movement of unstable mass is going to be quite large. On the other hand, rock creep is typically a slow moving process, okay. So, that takes care of the question set of the previous lesson.

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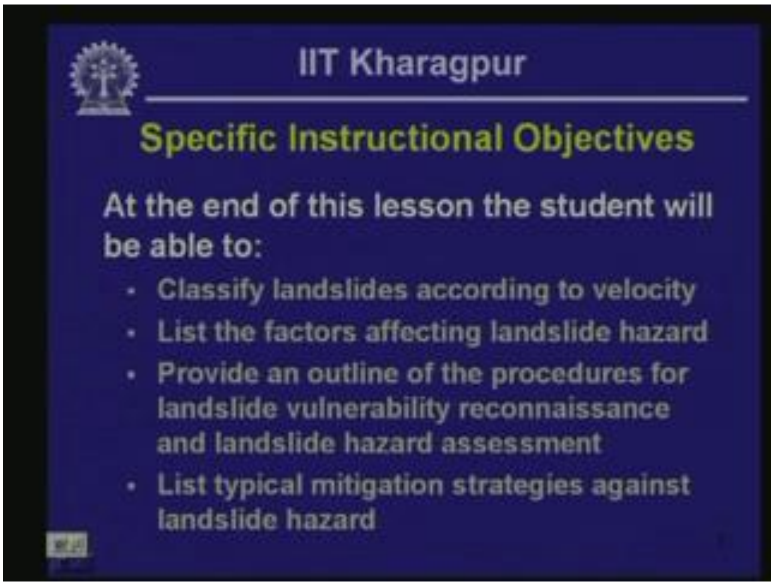

Now we move on with the subject matter of this particular lesson. The objectives of this lesson are as follows. Ah at the end of this lesson, we would like to be able to classify landslides according to the velocity of the unstable mass. Then we would like to be able to list the factors affecting landslide hazard. We would be able to provide an outline of the procedures for landslides vulnerability reconnaissance and landslide hazard assessment. And we would like to be able to list typically mitigation strategies against landslide hazard.

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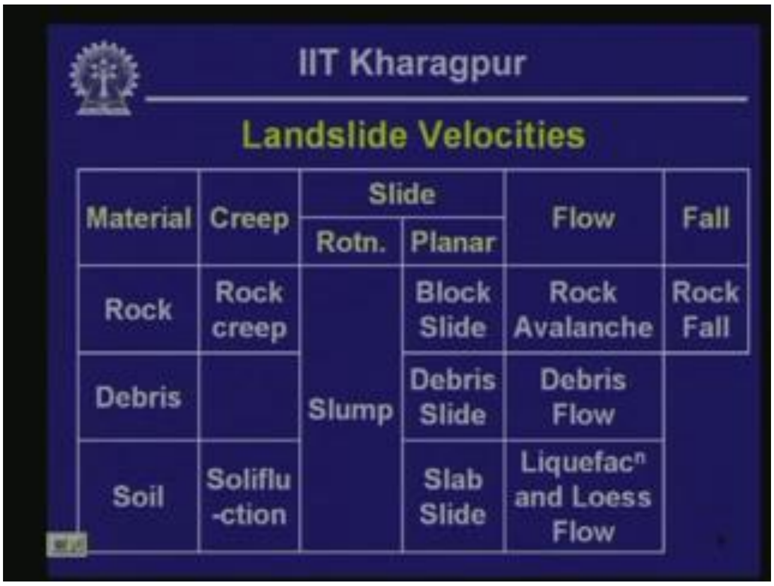

Material	Creep	Slide		Flow	Fall
		Rotn.	Planar		
Rock	Rock creep	Slump	Block Slide	Rock Avalanche	Rock Fall
Debris			Debris Slide	Debris Flow	
Soil	Soliflu -ction		Slab Slide	Liquefac^n and Loess Flow	

So, with this in mind, we first look at the landslide velocities. Some of these things were discussed already in the previous lesson. I just wanted to formalize the subject a little bit, and we consider this table here which you should have a look. We have got landslide; it could actually affect three different types of materials rock, debris and soil. Rock is actually going to encompass all such materials which are classified as hard rock or soft rock or weathered rock.

Debris on the other hand is composed both of rock fragments which could be as large as boulders and fine grained material soils which is essentially soil. Now soil on the other hand, it is on the other end of the spectrum in terms of grain size comprised of relatively fine grained materials. So, at one end of the material spectrum, we have got rock and that actually includes rock, hard rock as well as weathered rock.

Then on the other end of the spectrum we have got soil, and in between we have got both soils. The potentially unstable mass is going to be comprised of both soil size grains as well as there could be blocks of rock which is as huge as boulders and that is given the name debris. Now the first phenomenon that we looked at in the previous lesson was creep, and we can have in this respect rock creep or another process that I discussed previously involving wetting of soils as a result of melting of surface snow that is called solifluction. And because of that wetting the soil tends to creep down slope at the end of every snow melt season.

Then the third column; in the third column, it has got two parts. You could have rotational slide or planar slide. The rotational slides are slumped together for all rock debris and soil, different classes of material; they are lumped together with the name given slump. Planar slides typically through rock masses are a block slide. Through debris it is going to be debris slide, and through soils you could have slab slide. We discussed the characteristics of these things in the last lesson briefly.

And then we could have flow, and flow if it affects rock mass, then it is typically called rock avalanche. If flow affects debris, then we are going to call that debris flow. And if flow affects soil, then there could be several different phenomenon processes associated with that. You could have liquefaction flow failure or you could have lowest flow; anything of that type, or you could have mud flow for that matter. And then finally, the other end of this particular table, you have got fall where you typically can have rock fall affecting masses or weather or jointed rock.

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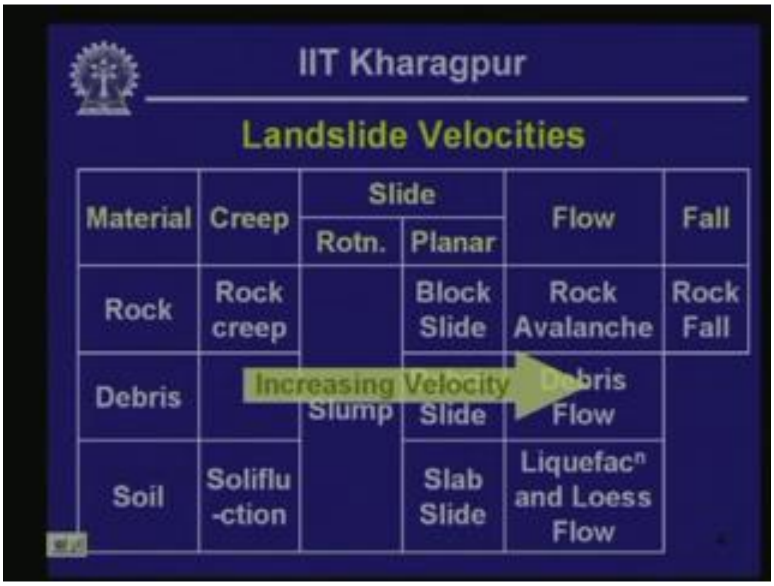

Now let us look at the velocity; let us look at the velocity. If you go from the left to the right of this particular table, what you are going to see is typically an increase in velocity of the unstable mass. So, when you are having creep movement, then the velocity is quite low. On the other hand, when you have got different types of flow or rock fall, then the flow could be quite high indeed. Then if we consider the run out distance or the distance which is affected by unstable mass or the distance to which the unstable mass is likely to travel, then the run out distance actually increases as we go from left again to the right of this particular table.

So, the run out is going to be much larger in case of liquefaction and loess flow or mud flow liquefaction flow or mud flow or loess flow. On the other hand, when you are talking about rock creep, creep movement, then the distance which is going to be travelled by unstable mass is going to be quite small. Rock creep is going to affect areas which are typically in less than a meter in horizontal distance we are talking about, whereas, mud flow for example, or liquefaction flow slide could affect several kilometers down slope from the location where the flow was originally triggered.

So, basically what you see here is two things depending on what type of land slide you are looking at the speed with which the land slide is going to move is going to be widely different as well as the run out distance to which the potentially unstable mass is going to move; that is also going to vary over a very wide margin.

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And as a consequence of what we discussed in preceding slide, the typical impacts of different classes of landslides also could vary by a wide margin. Now you could imagine very easily that if the landslide is relatively slow moving, then the impact of the landslide is going to be only on the property within the vicinity of the area affected by landslide. So, that could damage houses or other structures that are within the unstable mass constructed within the potentially unstable mass or a highway for that matter constructed across the mass through which the landslide is going or moving.

Here you can have direct or indirect economic loss. Direct economic loss is the loss that arises because of the damage caused to the property directly as a result of landslide; indirect economic loss accrues when, for instance, a slow moving landslide causes a temporary shutdown of a highway. And as a result, movement of traffic is impeded in that particular zone. So, those are indirect loss because of slow moving landslide, whereas direct losses because of slow moving landslides is the direct damage that is caused to the properties constructed within the properties or infrastructure constructed within the potentially unstable mass.

Fast moving landslides such as different types of flow are translational slides or rock fall. This could cause property damage or infrastructure damage as well as loss of life; the velocity for instance of a mud flow could be as large as 100 kilometers per hour. So, if you are within an area through which a mud slide is in progress, then you are totally trapped in that area, and many lives are lost because of that. It also is going to cause, it is going to damage the structures or infrastructural facility, the facilities that are constructed across the path of such flow slide.

So, you have got the likelihood of property damage as well as loss of life in this particular case. Likelihood of loss of life is quite limited in the case of slow moving landslides or slow moving slope instabilities. Here once again you could have direct and indirect economic loss like what we discussed in case of slow moving landslides.

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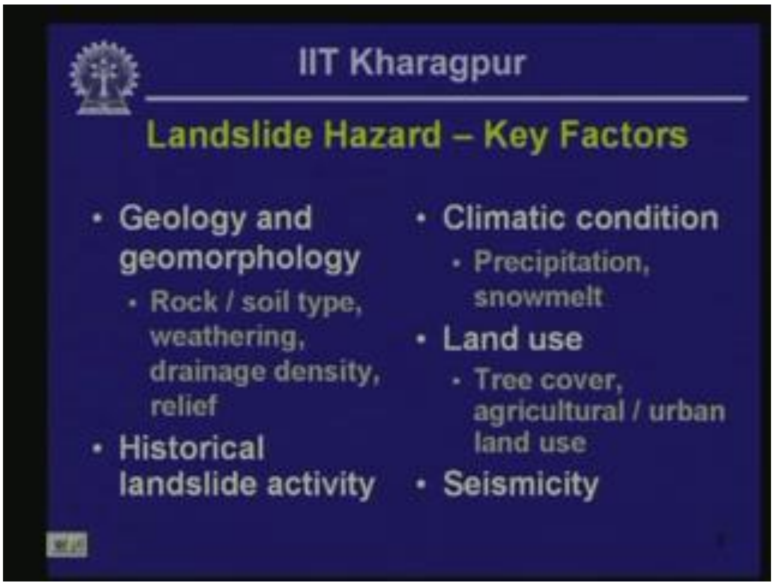

Now what we have to look at is what are the key factors that affect landslide hazards. We have got several main points listed here in this particular slide that has got remarkable influence on landslide hazard in a particular area. The first one being geology and geomorphology of a given area. Here we are looking at rock or soil type underlying the slope that we are considering, weathering of that particular rock or soil material, drainage density that is crisscrossing across the area we are considering in our landslide hazard assessment, and relief; that means how steep is the country side where we are trying to assess the landslide hazard.

Second point that is of importance is historical landslide activity. So, areas where you have got frequent occurrence of landslide in recorded history that area is likely to continue as area prone to landslide hazard. Then you have got climatic condition, hilly areas receiving a lot of precipitation is going to be more likely to be affected by landslide hazard than areas which are relatively dry; although, even in dry areas there could be, in fact, in relatively dry climatic condition also, you can have flash rainfall of great intensity that in turn is going to lead to the triggering of landslide in that particular area.

So, climatic condition in a particular area is it has got a very large influence on landslide hazard in that particular area. Land use is another factor that you need to include in landslide hazard assessment. What we are looking at here is the density of tree cover in a given area, then whether you have got agricultural or urban land use in the area. And for that matter, in fact, whether or not you are near a road cut that also is going to be going to have a remarkable influence on the landslide activity in a particular area.

For instance, in many areas in the Himalayas, landslide occurrence is greatly affected by whether or not, there is a highway passing through that particular area, because in many instances, what happens? During the construction of the highway, the slopes locally are steepened; hill slopes are steepened locally, and those hill slopes are often prone to landslide hazards. So, depending on whether or not you are near the highway is going to also influence whether you are going to be affected by future landslides.

And then finally, what we need to consider whether the area is in an earthquake, whether the area has got a lot of seismic activity or there are frequent earthquakes in the area. If you have got frequent earthquakes in the area, then also the frequency of landslide is going to be far greater than areas which are not affected by earthquakes, okay. So, these are all the key considerations when we are going to look at the landslide hazard of a particular region.

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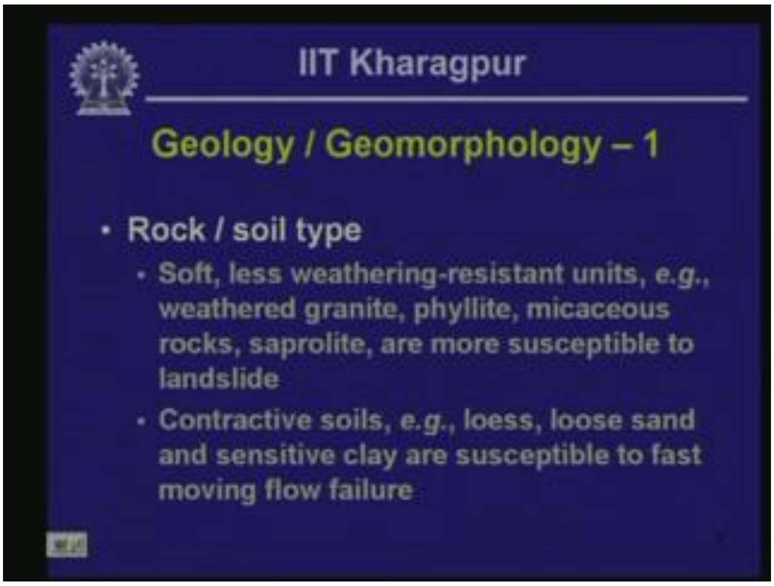

A little bit more details about those individual components or individual points that we summarized in the previous slide. First, we considered geology and geomorphology in a given area. Prime consideration in this particular case is rock and soil type underlying the slope underlying the area for which we are trying to assess the landslide hazard. If the soil type is soft soil or rock type is soft, less weathering resistant such as weathered granite, phyllite, micaceous rock, saprolite, then we are likely to have more frequent occurrences of landslide; that is the first point.

The second thing also you have to watch out for is whether you have got any contractive soil or soils or rock units that are particularly prone to landslides such as contractive soils, such as loess, windblown silt, loose sand or sensitive clays. These soil units if you have got if you encounter in a particular area, then those areas are likely to be more vulnerable in terms of landslide hazard.

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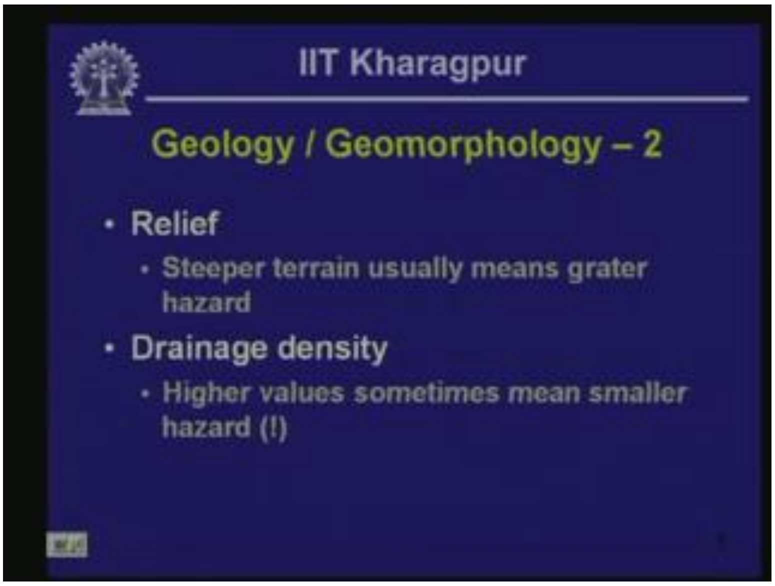

Relief of a particular area, how steep is the slope in a given area is also going to affect landslide hazard. Steeper the slope, greater usually will be the landslide hazard. That is, of course, I mean there is I should have a rejoinder here at this particular point is, because steeper terrain could also mean that the soil or rock unit underlying that particular slope is stronger and more resistant to weathering. And that also in some cases could mean that you are going to have less frequent landslides in steeper terrain, because steeper terrain itself could be an artifact of strong or sound rock or soil mass.

So, what you need to look at actually in this particular case is that one point cannot be considered in isolation from other points. And there is a very significant interplay of these individual factors that affect landslide hazard. Then finally, we have got drainage density in this context. In many places what you see is this; if you have higher drainage density; that means if you have got higher lengths of drainage channels per unit square kilometer of the area for which you are trying to assess landslide hazard.

So, for instance, if you have got more number of kilometers of drainage channels in a given area per square kilometer, then that particular area is typically in many cases that has actually is it is more stable against the occurrence of landslides. And you could argue that the point that I am trying to make here is counterintuitive, and the explanation of this thing is as follows. If you have got a greater drainage density; that means a greater amount of runoff is exceeding that particular area as surface runoff and very little is getting into the material underlying the slopes in that particular area.

And because we have seen from the previous discussion that when the slopes become wet or when water percolates into the slope, then the water table rises and that all erosional activity increases near the bottom of the slope. And in situations where lot of water is carried away as surface runoff, such percolation cannot take place. So, landslide occurrence is often sometimes actually reduced in areas where you have got a greater drainage density than a similar site where the drainage density is far less.

But again, you have to consider the interplay of other aspects here because let us say let us consider vegetation cover or forest cover on a particular area. If you have got a larger forest cover, then the drainage density is also going to decrease, but because of the presence of the forest cover, you have got a less likelihood of landslide because the penetration of roots of those trees that constitute the forest is going to impart root cohesion within the near surface soils. So, you have to consider really each of these individual points in conjunction with all other points that we have already considered or we are going to consider in the next little bit.

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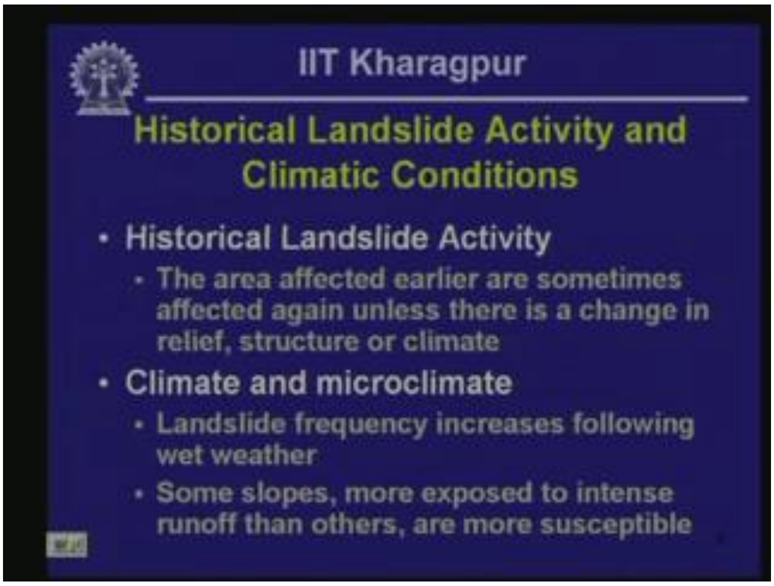

Second point that we looked at a little bit earlier was historical landslide activity in a particular area and climatic condition. And as I mentioned before, the key consideration with respect to historical landslide activity in a given area is this. An area affected in recent times by landslides is likely to be affected again unless there is a remarkable change in the slope geometry as a result of the ongoing landslide activity. So, if you have got an area where frequent landslide is taking place, then you can say that you have got a greater likelihood of occurrence of landslide in near future as well.

Then the second aspect here is climate and microclimate. The second term is of interest here is because many of the landslides activities affect hilly areas and hilly areas very small units of area are affected; they have got their own microclimate. So, they have got their own rainfall intensity; they have got their own snow cover or snow melt pattern, which may be quite different from areas which could be only a few kilometers away from the area that that we consider, okay.

So, what you have to look at here in this particular respect is both climate and microclimate of the area, and the key considerations here are as follows. Landslide frequency increases following wet weather which we have already seen, and we have also looked at the reasons why landslide frequency would increase following wet weather. And then some slopes are more exposed to intense runoff than others, and these slopes could be more susceptible to landslide.

Like for example, because of microclimate, the amount of rainfall or amount of snow cover that is going to precipitate on a particular hill slope is going to vary by a very wide margin depending on which area you are considering. And this variation could be quite remarkable in the sense that if you are away from the site that you just consider only a few hundred meters or a few kilometers, then the amount of rainfall that is received in the other area in the second side is quite different or the rainfall pattern or the precipitation pattern is quite a bit different from that associated with the first site that we considered. So, you have to really look at very small area units in hilly areas in terms of micro climate in order to assess the landslide likelihood in that particular area because of the variation in terms of the prevailing microclimate.

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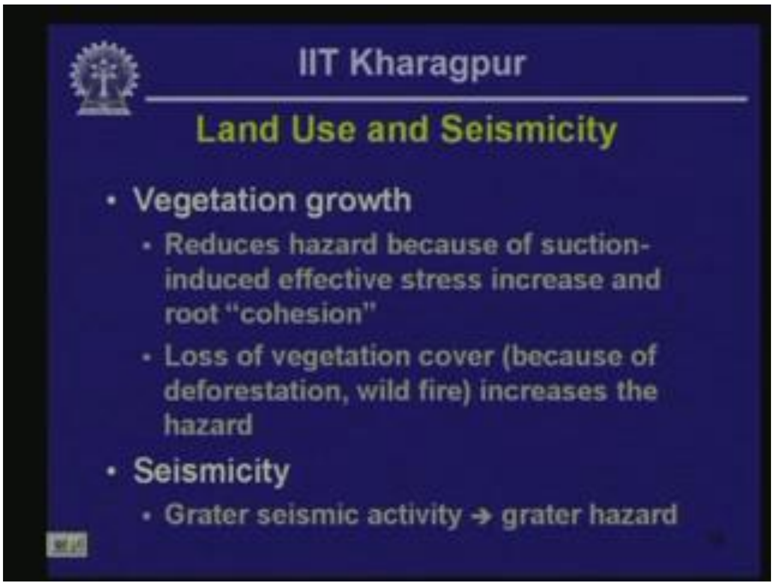

The third factor here the third consideration here is land use and seismicity. And we looked at some of these things already. It is just a mere repetition of some of the discussion that we had earlier. Vegetation growth, for example, it has got very remarkable influence on landslide likelihood in a given area. It reduces landslide hazard because it induces suction as well as see when tree wants to extract water from the soil surface, then it actually induces suction. And suction is nothing but negative pore water pressure, and as you know from the discussion that we had on effective stress, because of suction, the effective stress is going to increase.

And because of the increase in effective stress, we are going to get an increase in the shear strength within frictional material. And this particular aspect is also supplemented by root cohesion that we have already looked at. So, what happens because of loss of vegetation cover because of deforestation man made deforestation or because of natural wildfire? If you lose a substantial proportion of vegetation in a given area, that increases the likelihood of landslide hazard. And then we have got seismicity greater seismic activity or greater frequency; if the frequency of earthquakes in an area is larger, then you got greater landslide hazard as well.

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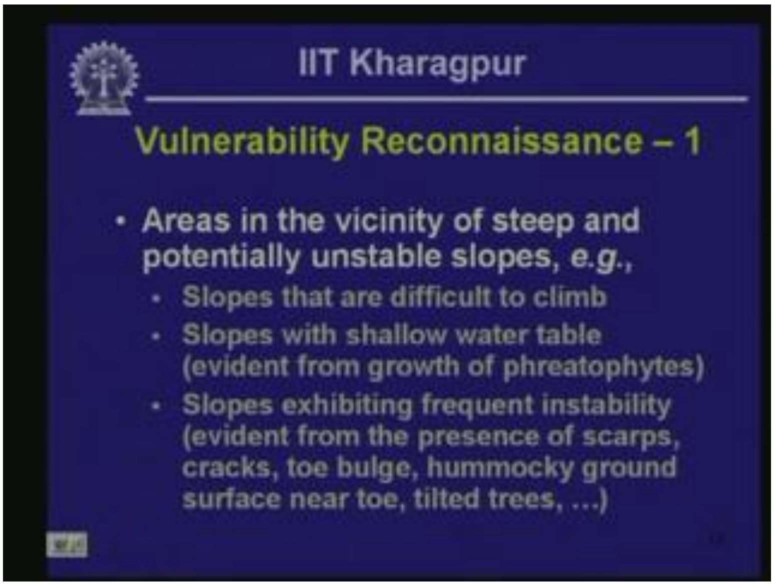

Now we look at a simple procedure simple technique for assessing landslide vulnerability in a given area. What are the considerations when you are setting up reconnaissance program in a given area for assessing landslide vulnerability? Now areas, of course, all these things are quite intuitive really. So, areas in the vicinity of steep and potentially unstable slopes are going to be more vulnerable to landslides. And these areas include slopes that are difficult to climb. This is just rule of thumb; if you find a slope difficult to climb, you can consider that type of slope as a slope where you might get landslide activities.

Then slopes with shallow water table where water table is near the surface of the slope near the slope phase, and this is evident from growth of water loving plants. The technical term for this thing is phreatophytes. There are several different plants that like to grow near the place where water is abandoned, and they grow near the places where ground water actually exits a slope phase in many instances. So, their presence actually indicates the locations of potential landslide instability in that case.

Then thirdly, slopes exhibiting frequent instability and that are evident from the presence of scarps, cracks, toe bulge, and undulating or hummocky ground surface near the toe, tilted trees, tilted electric poles and so on and so forth. We looked at this list of such anecdotic evidence of potential slope instability earlier as well. So, if we have got slopes that have got these characteristics, then those slopes are vulnerable to landslides and areas in the vicinity of such slopes are likely to be affected by landslides.

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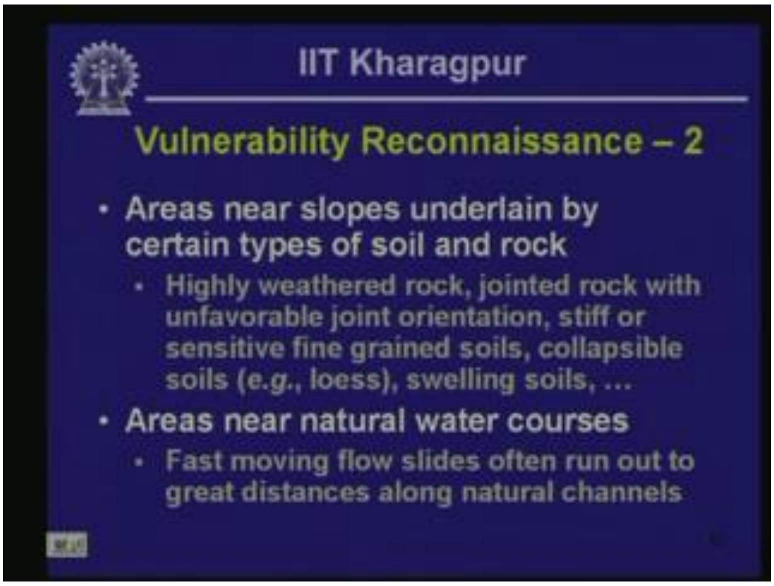

Then areas near the slopes underlain by certain types of soil and rock; you just look at the bed rock geology or near surface geology map, soils map or bed rock geology map, and then if you see occurrence or presence of certain types of rock and soil. A list of which we already looked at, and that is again indicated here in this particular slide. If we have got highly weathered or jointed rock with unfavorable joint orientation, stiff or sensitive fine grained soils, collapsible soils, swelling soils or any such soils you have got in a particular area, then those areas are likely to be more vulnerable to landslides.

Areas near natural water courses are vulnerable to fast moving flow slides if you expect one such flow slide to occur in the upstream area of that particular region, because flow slides run out as I mentioned to great distances, several kilometers down slope from the location where the flow slides are originally triggered.

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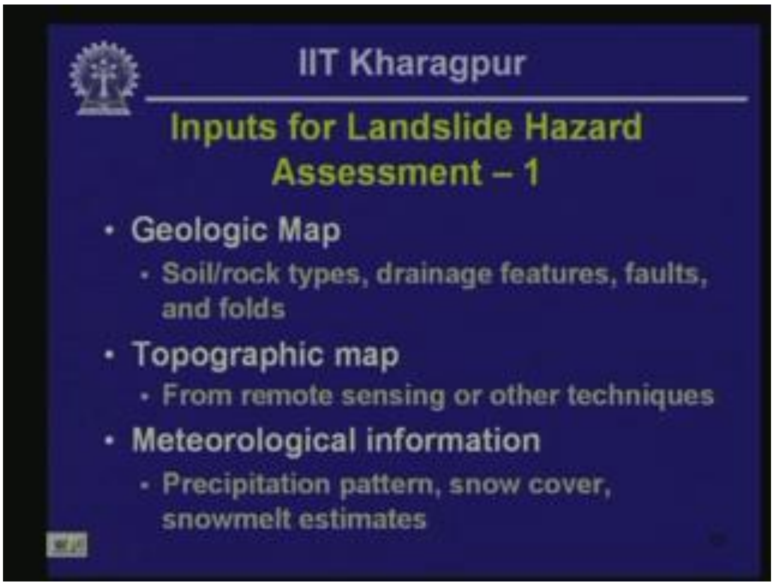

Okay, now we are in a position to formalize the notion of landslide hazard assessment; what are the inputs for landslide hazard assessment. We looked at these things earlier as well, but let us formalize what we learnt so far. We have to look at the geologic map of a given area in order to get a feel for what kind of soil or rock type is underlying a given area. We have to look at the drainage features of the given area, presence of falls and folds, and whether the faults and folds that we find on a given geologic map are seismogenic or they themselves are sources of earthquakes or not.

Then we have look at topographic map. Topographic map is going to tell us whether a particular area is underlain by very steep topography; if we have got steep areas, then typically frequency of landslide is also going to be more. Topographic map is easily obtained from remote sensing tools such as satellite imagery or other terrestrial remote sensing tools such as aerial photogrammetry or LIDAR or IFSAR which we have already discussed earlier in this course.

Then we have to look up the meteorological features of a given area. We have to look at precipitation pattern of a given area, and here again I want you to realize that in hilly area, the precipitation pattern could be, in fact, varying quite a bit from place to place even when the distance between these sites are relatively small. And often what happens? All these areas are not instrumented so that you cannot have site specific meteorological information from all these sites which could have widely different meteorological characteristics. We also need to look at the snow covered and snow melt estimates from a given area in this respect.

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Then we have to get the landslide inventory of a particular area. We have to look at the location and frequency of past landslides within the area, then we have to consider the land use map. We have to look at in this respect the forest cover in a given area or whether a hill slope is open for residential or commercial developments; whether there are any highways or railroads constructed across the hill slope. And there are other information necessary such as remote sensing images showing location of groundwater springs or and regional seismicity. So, these are the inputs that you need to consider for landslide hazard assessment.

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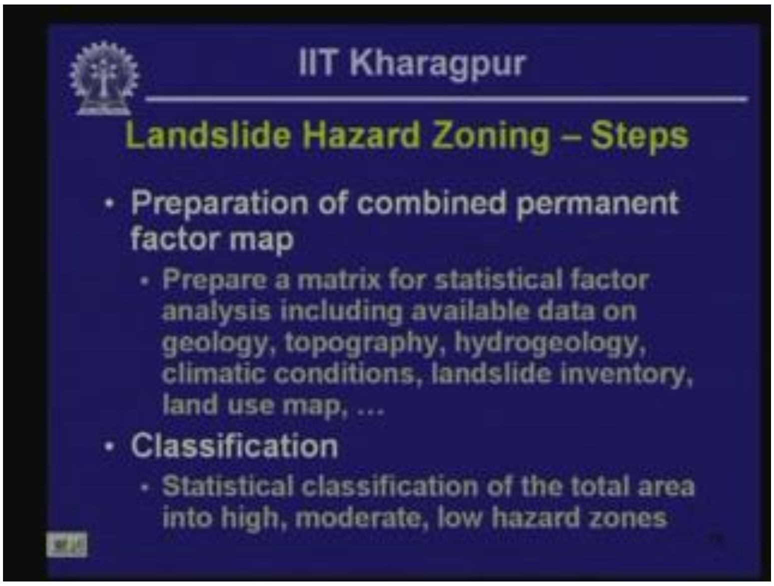

Now we are in a position actually to briefly discuss the landslide hazard zoning that is typically done by an engineering geologist. What are the steps involved in this particular assignment? So, what you need to do first is to prepare a combined permanent factor map. What is done here is to prepare a matrix for statistical factor analysis which looks at all the individual factors that are responsible for the landslide activity in a given area. We are going to look at an example, and that is going to clarify this particular issue a little bit more.

But let me list here that what you need to look at would include all the factors that we have already discussed namely geology, topography, hydrogeology, climatic conditions, landslide inventory, land use map seismicity and so on and so forth. Then we have to classify based on the information based on the statistical factor analysis, we have to classify the given area into high moderate and low hazard zones.

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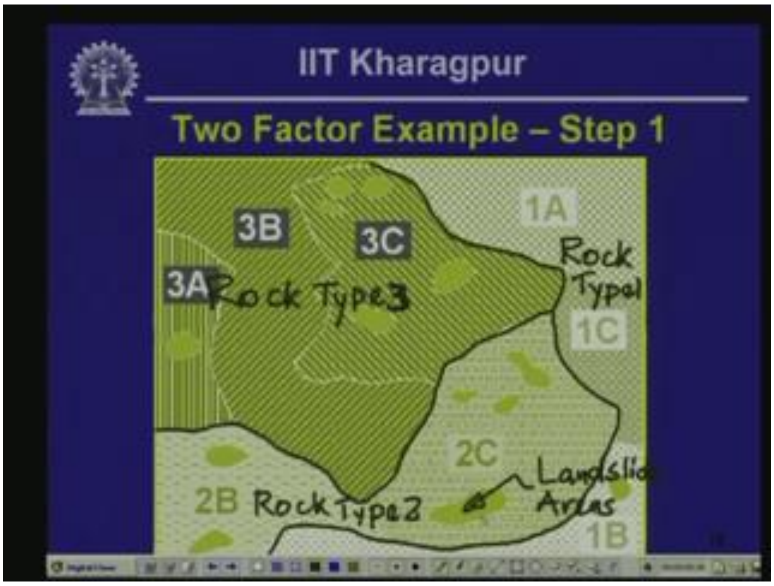

Let us consider an example. Let us say you are considering a particular area underlain by three different types of rocks. The first type of rock is indicated by the orange shading, and this is the outline of the area underlain by rock type one. So, this thing this area here is rock type three I am calling it here. So, let us maintain the same nomenclature. So, this is rock type three. Then the area along the right margin of this particular map and most of the bottom margin of the map, we have got rock type one, and in the middle, you have got rock type two.

Then we classify the areas underlain by these individual rock units by the average relief in a given area. So, for example, in this particular case, what you have got? You have got A is it has got the least amount of relief; that means the area it has got a flattest relief or the slopes in the area underlain by three A is the gentlest, most gentle slope; three B is steeper, and three C is steeper still.

Similarly, one A is the flattest area underlain by rock type one and one C on the other hand is the area that is the steepest among the areas underlain by rock type one and similarly for rock type two. Then on this map, we have to superpose the areas where we observe historical landslide activity, and these areas could be in the form of areas where landslide scarps are visible. And areas which are underlain by landslide deposits such as deposits that get generated, because of landslides such as debris flow, slope failure deposits basically.

And those are indicated by these solid shaded areas. So, these are landslide deposits landslide areas. And what you have to do? In this particular case in order to simplify our life, I just considered here a two-factor example. And here what I am considering just the effect of rock type and the effect of steepness of a given area on the landslide hazard. In addition to it, if you have got other factor such as rainfall or hydro geological factors, then you have to include those factors on top of the factors that I am considering here, okay. So, then what we do out of the data presented on these on a map like this and after we superpose the area that are affected by recent landslide activities.

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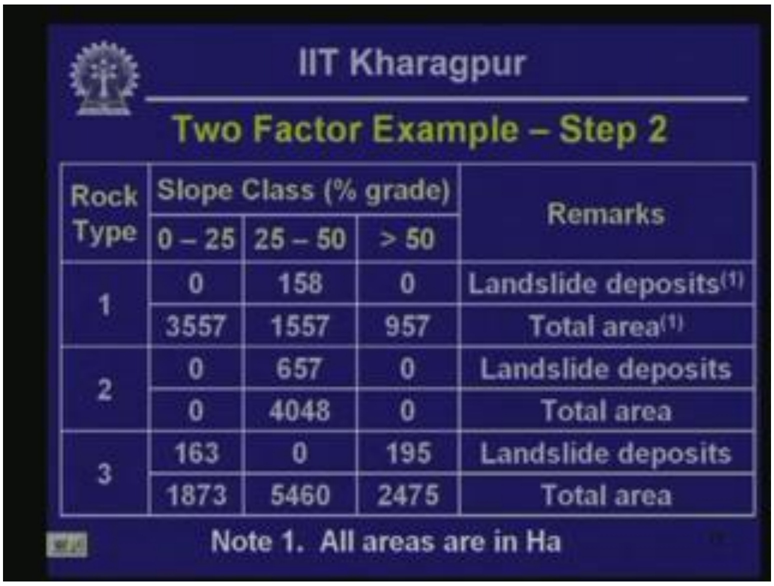
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Two Factor Example – Step 2

Rock Type	Slope Class (% grade)			Remarks
	0 – 25	25 – 50	> 50	
1	0	158	0	Landslide deposits[1]
	3557	1557	957	Total area[1]
2	0	657	0	Landslide deposits
	0	4048	0	Total area
3	163	0	195	Landslide deposits
	1873	5460	2475	Total area

Note 1. All areas are in Ha

Then we prepare a matrix such as that presented here. For example, here we have got three different rock types and three different slope classes as we have seen earlier. For instance, if we consider rock type one, for slope class 0 to 25 percent; by 25 percent what I mean is that if you move horizontally by 100 meters, then the vertical drop is going to be 25 percent. So, a slope which is between 0 to 25 percent grade underlain by rock type one, there you have got 0 hectare of land mass affected by landslide out of 3557 hectare of land underlain by rock type one which is categorized in slope class 0 to 25 and so on and so forth.

You have to complete this matrix for all the different rock types and all the different slope classes, and then you have to construct you have to express the proportion of area in a given category that is covered by landslide deposits as a ratio of the area underlain by landslide deposits to the total area which is within that particular category. For example, for rock type two for slope class 25 to 50, you are going to have a proportion of 657 divided by 4048 as the number. And then you have to classify these proportions by some statistical means in order to get the areas that are classified to be of high moderate or low landslide hazards, and the steps here are given on this particular slide.

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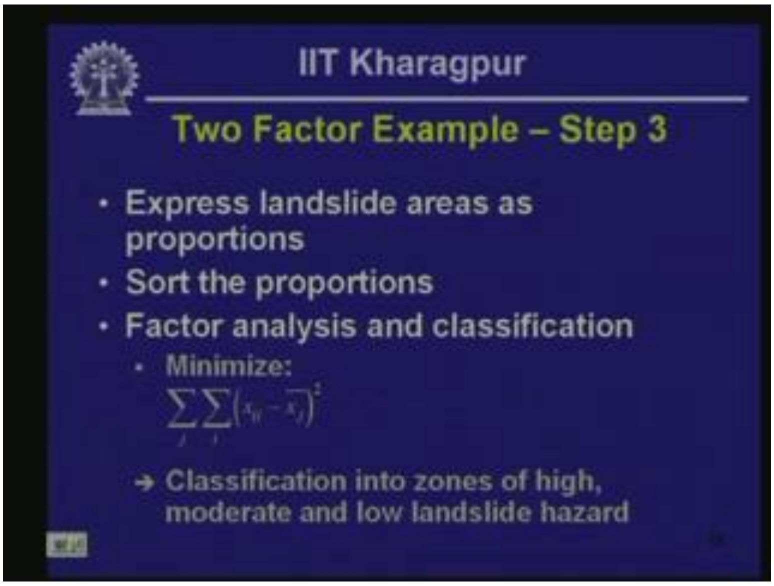

So, here near the bottom you can see a double summation and x ij x subscript ij in this particular case represents the individual observations or all those individual proportions that we got from the matrix of tables that we had before. And x j bar represents the mean for a given type of rock and then you are going to minimize basically the double summation which is shown in that particular equation there.

And by minimizing actually by adjusting the bins in which you classify the proportions that are considered highly hazardous from those that are considered moderately hazardous; by adjusting the interclass boundaries, you want to minimize the double summation that is observed in the previous equation there. So, this is basically the factor analysis that you are going to perform for a given area, and that gives you areas sub classified as zones of high moderate and low landslide hazards.

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Mitigation strategies include avoidance. So, if we have got an area which is characterized by large likelihood of landslide or highly hazardous with respect to landslide hazard. You avoid that area for any development or construction. Avoidance could be ensured by having requirement for having carrying property insurance and taxation for developing an area and land use restrictions. Then there many jurisdictions affect grading ordinance which restrict possibilities of alteration of slopes or performing excavation near a particular slope. Then you can also have stabilization measures or structural measures such as flattening of slopes, reinforcing of slopes, and installing a forest cover in an area to avoid possible landslide instabilities.

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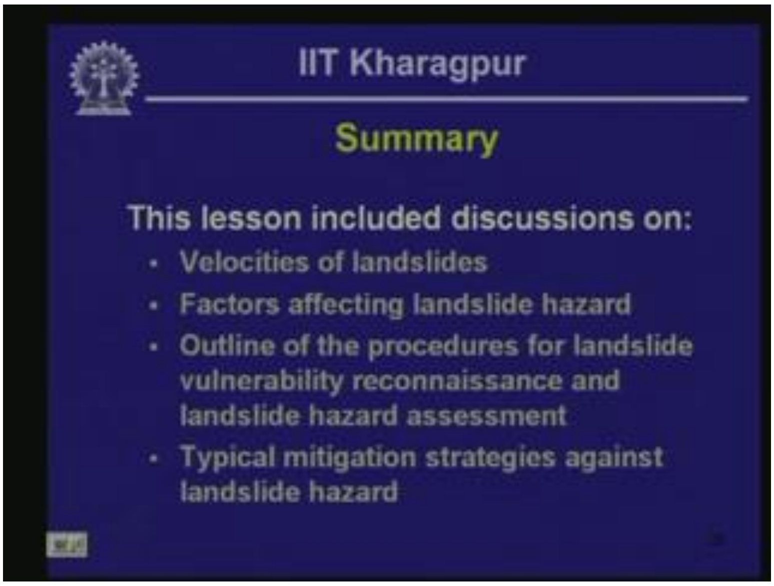

Okay, that brings us pretty much to the end of this particular lesson. So, what we learnt in this lesson are the following. We looked at velocities of different classes of landslides. We looked at factors affecting landslide hazards. We gave a very brief outline of the procedures for landslide vulnerability, reconnaissance and landslide hazard assessment. And we then looked at typical mitigation strategies against landslide hazard.

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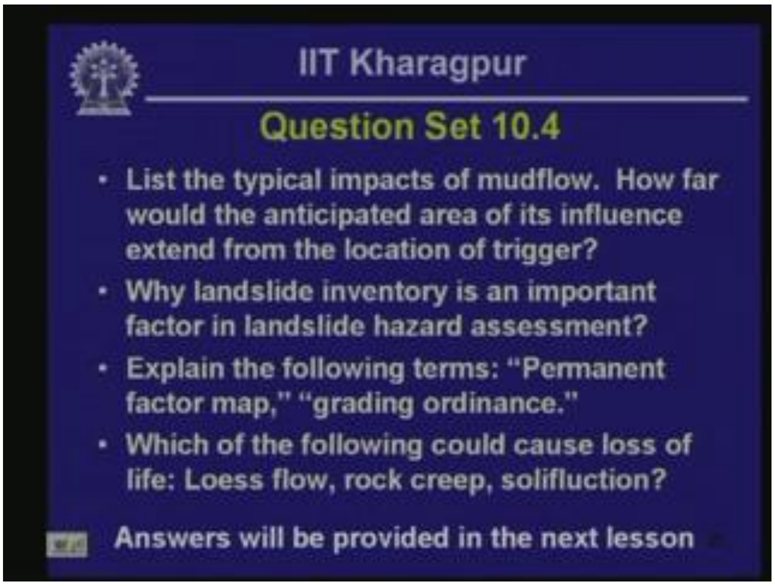

So, we wrap up this particular lesson with a question set. The first one being list the typical impacts of mudflow, how far would the anticipated area of its influence extend from the location of trigger. Second question, why landslide inventory is an important factor in landslide hazard assessment; third one, explain the following terms, permanent factor map and grading ordinance. And finally, which of the following could cause loss of life, loess flow, rock creep and solifluction, okay. So, try to answer these questions at your leisure, and I am going to provide you with my solutions when we meet with the next lesson; so until then bye for now.

Thank you.