Geographic Information Systems
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Lecture-49
DEMs derivatives-2

Hello everyone! and welcome to the next discussion about the DEM derivatives. So, in first part, we have discussed few important derivatives of digital elevation model and before that we have also discussed the common derivatives like slope and aspect and other things. Now in this discussion, we are going to have on about the profiles or cross sections or also called longitudinal sections, elevation profiles.

So, this we are going to discuss because this is very-2 important again useful for various types of analysis like for any kind of route alignment if somebody is looking or somebody is looking for fall in the river, for rapids or somebody is you know looking how the drainage behaving in terms of topography and elevations. So, all these things can be done. It is very easy to create a longitudinal section along a straight line.

But many times, it is very difficult and challenging especially when we employee survey toposheets to create a longitudinal section or this profile along an arbitrary line. Like arbitrary line can be a road section, arbitrary line can be a section along a stream natural drainage system and maybe of our own arbitrary line. So, we will discuss those things also because in different softwares or different literature, books or others, they use different terminology.

So, I have put all four terminologies; one is topographic profile, elevation profile, cross section or longitudinal section, that means basically the same thing.

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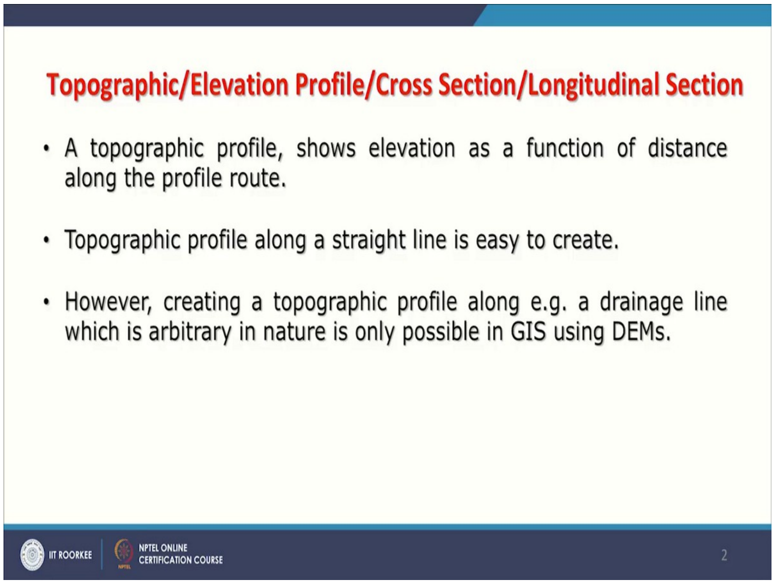

That picking the elevation values along a line and creating a 2D plot or 2D profile. So, topographic profile if we want to define basically shows elevation as a function of distance along the profile root. This profile root as i have mentioned can be a straight line which is very easy to create. But when it is an arbitrary line then it is not that easy especially with using topographic maps. As topographic profile along a straight line is easy to create however creating a topographic profile along a drainage line which is an arbitrary in nature, is only possible using GIS using DEMs. This is the point which i am re-emphasizing here.

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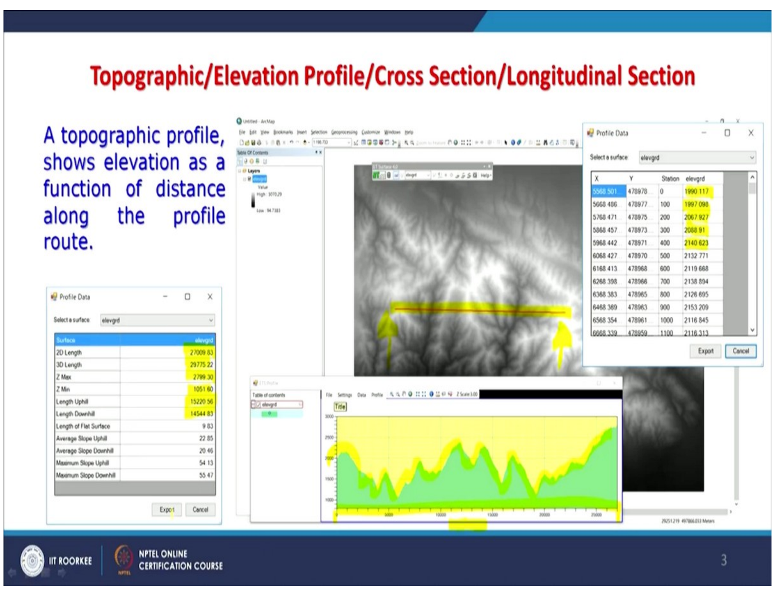

Now in this one, what you are seeing? A topographic profile along this straight line which is shown here with the red color which I have just highlighted. And when you go say in the any software, you can find out a terminology for that, a tool for that and then you can draw a cross section or a topographic profile along a straight line very easily. Not only that but you are also having for all the points which are along this straight line depending on the resolution of the cell of your digital elevation model.

These points are picked along that line and their elevation values are also picked like here which you can see and that all is plotted. So, here on x axis, you are having the distance. So, suppose my plot is starts from this direction to that; that means west to east. So, my distance 0 is here, my whatever the maximum distance is here and along with whatever the changes in elevation along that line are plotted here.

Obviously, you can get few more data sets because these are the things which are required. So, you get the 2D length and 3D length. This we have also discussed in previous lecture that the 2D length is this length which is a straight-line length. But the 3D length is this length along this profile. So, obviously the 3D length is going to be more than your 2D length. So, this point we have been already discussed in detail that whether it is an area or length, 3D length is always more than 2D length.

So, these are the two important parameters which you can drive using this tool or these facilities and of course you will get then z minimum, z maximum, length uphill, length downhill; all those parameters which might be required for construction of a road or a boundary wall or any such projects so it is then becomes. So, what basically again topographic profile shows elevations as a function of distance along the profile route which is being shown in this figure.

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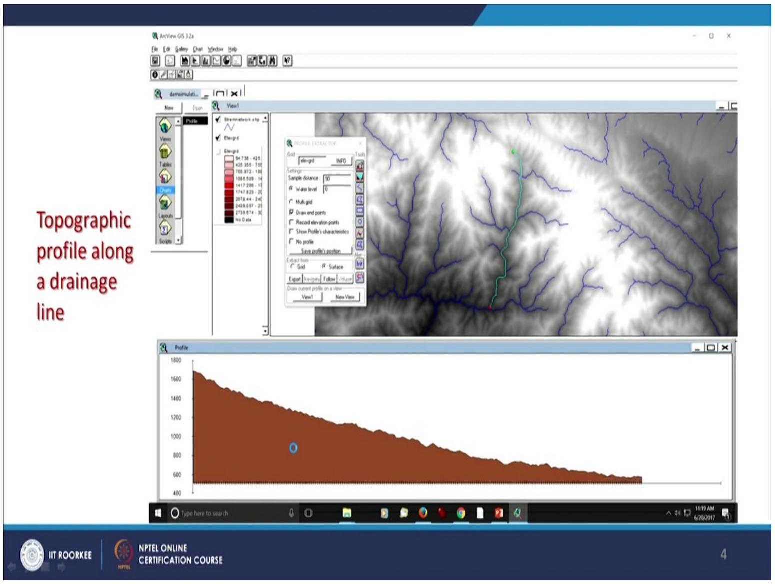

Now, when we want to have this cross section or topographic profile along an arbitrary line which is shown here also, which I will just highlight to show you more clearly. So, along this arbitrary line, then many times it is not very easy to do it even in many softwares. So, one has to search that specific tool. If it is not there then of course by using your own intelligence even by two three steps, you can achieve that thing.

Like here in the older software of ESRI; that is ArcView GIS and there along a drainage line, a cross section profile has been drawn. Starting from here, x and this is y. So, x is here and this y is here. And along an arbitrary line, you can definitely draw a profile in the similar way. But using simple toposheets, it is not possible. So, that is the biggest advantage of having GIS and digital elevation model to get the topographic section along any arbitrary line.

You know when we talk about the topographic profile along a straight line, this is what the generally geologists also use to draw geological cross sections. And they have to get first elevation values which they generally in the typical those exercises which we get these elevation values through contours and based on the contours, this topographic profile is first drawn and then using the geological contacts of different rocks, lithologies then those things are also drawn depending on their attitude and of course, the structures which are there.

But basic requirement is always to draw first topographic profile which you can do it, not only along a straight-line segment but along an arbitrary line as well.

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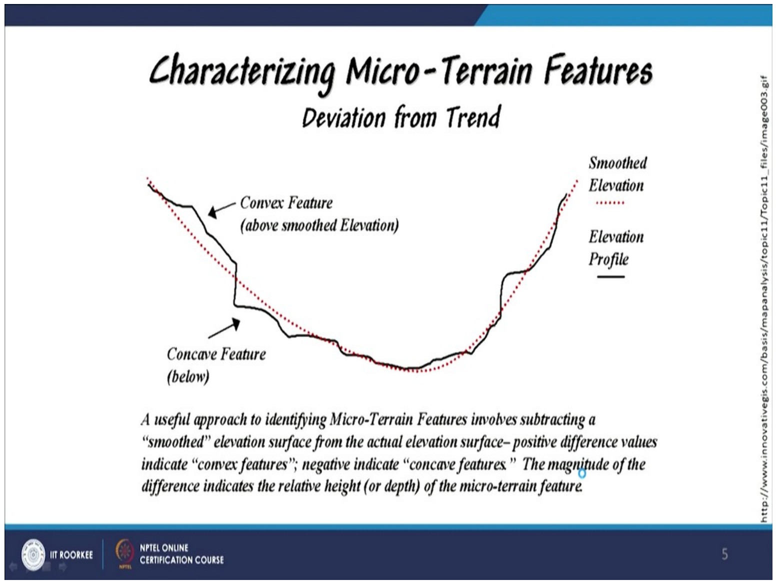

Now, once say you are having a data something like this along an arbitrary line or even a straight-line, lot of things can be then further looked into all kind of details and especially about the micro terrain features which we have also discussed in the previous lecture while discussing about the you know planimetry area and topographic area or 2D or 3D areas. So, here what we are basically seeing or those along this section or profile, what we are seeing that there are areas which are having convex features.

How this convex or concave will be decided based on the smoothened elevation line. So, anything which is above this line in terms of elevation will be considered as convex features. Anything below that you know smoothen elevation would be considered as concave feature. And then you get about the micro terrain characteristics of a terrain especially along a line; that line can be a straight line or an arbitrary line.

This information is very-2 useful for identifying micro terrain features which involves like subtracting a smoothen elevation line or you can say best fit line from the actual elevation surface. Positive differences indicate convex features and whereas the negative will indicate concave features. And of course, the magnitude of the difference indicates the relative height or depth of the micro terrain features.

So, by which we can really analyze that how along a line, the terrain is smooth or having lot of undulations. And if undulations are there, what is the magnitude of those undulations, that can also be assessed just using a smoothened elevation or best fit line.

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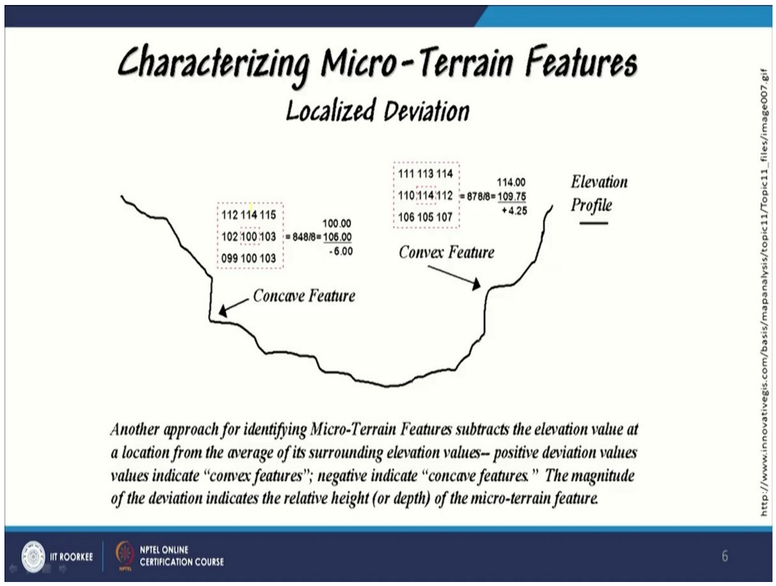

Now, if we start thinking from 2D to 3D and start you know thinking along that particular line then we can bring this 3*3 kernel. And like here, it has been done that this 3*3 kernel has been used for this area and you get this concave feature, the value -6 here. Whereas contrary to this, the convex features; here the value comes 4.25, plus how it is coming because now in the neighborhood, the search is being made and it is found that this area or this cell is having higher value than the surroundings.

Whereas in concave feature case, you know the central cell is having lower value as compared to the surroundings as you can also see in that part. So, in that way, by using this concept of 3*3 kernel or searching the neighbourhood, one can also get some values; magnitude, how much? Because this question will always be asked about how much? It is not that all the time, the analysis would be done on qualitative basis, No! Most of the time, it should be done on quantitative basis and that is possible in GIS because you are already having digital data.

So, one should always try to quantify things as accurately as possible. So, by identifying these micro terrain features using this elevation profile and other things, will give us a quantity about the convex features as well as concave features.

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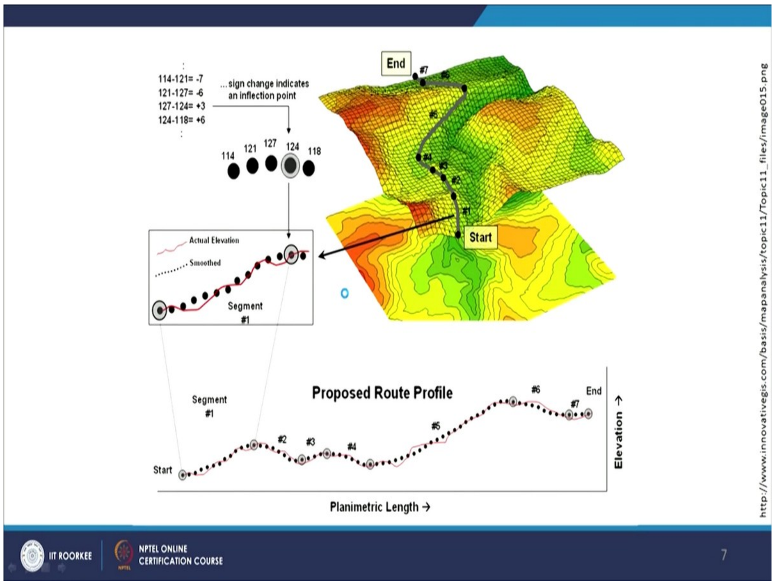

Now this is a very typical example of root alignment and root alignment along an arbitrary line. Of course, these root alignment whether it is for railway or for road or maybe for canal or maybe for power channel of hydro power project, can be many-2 things or maybe trail for human you know movement. So, for that, if we want to do that analysis that can be done. In the background, you are seeing a digital elevation model whereas that digital elevation model has been converted into 3D so that these things can be depicted very easily.

What you are seeing this blue line which is showing the proposed route alignment. Now, how this would look like while coming from higher ground to lower ground? You see this segment is like this. You can have a smoothen, you can have even sign change as an infection points and this proposed root profile along with these points is also shown.

So, you get a complete detail about that root alignment. Of course, here in a straight line, it is the planimetry length. But this is the topographic length or terrain length; the true terrain length is this one, planimetry. So, all those things can be calculated very easily.

Now here, these values will tell us that where it has to be climbed or where it has to be you know go down if it is just simple road?

But if it is decided that I want a continuous smooth road without much up and down then by looking these values, I would know that what kind of plus or minus; plus means it is convex, minus means concave. And if I want to make the road flat along this proposed line then I should know where the filling will be required and where cutting would be required. That analysis can also be done in cut and fill analysis and more accurately also there.

But here, we would know that where things are required? We will be discussing little later about cut and filling. So, topographic profiles along a straight line or along an arbitrary line are very-2 useful information for many kinds of projects. Now, what are the applications? Some of them, we have already discussed.

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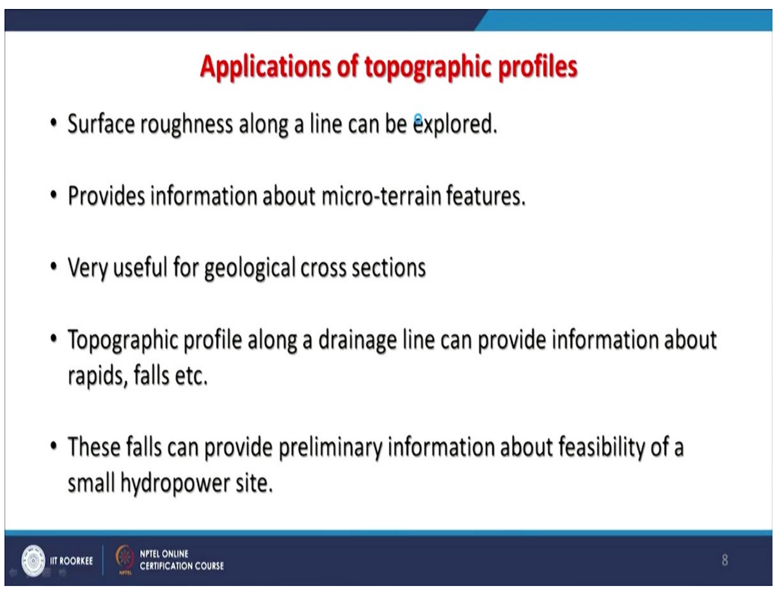

Like surface roughness along a line can be explored, that can be understood. Provides information about micro terrain features; you know how smooth the terrain is, how you know ruggedness is there? When we have to compare then we can find out which one is smoother, which one is more having up and downs. Very useful for geological cross section; this point I have already discussed that in any geological cross section, the first requirement is to have a topographic profile along a line.

Now that line can be straight or an arbitrary line. Other important point that this topographic profile along a drainage line can also provide information about rapids, falls etcetera. Not only that, they will also provide the points of deposition or erosion as well along that one. And then these falls or rapids can provide preliminary information about feasibility of a small hydropower site.

Because for a small hydropower site, many times you do not need very high head. Maybe even 5-meter, 10-meter head, a site can be developed. So, for that purpose if we get this topographic profile and find a good fall then there a site can be developed easily. So, very quick way to find out the feasibility, this tool can be used about this concept of this topographic profile. Now, as I was mentioning about this cut and fill analysis. Now, we come to related with that is the surface volume and that volume is again very much for any kind of you know road construction or making plane or in mining operations and many-2 such operations.

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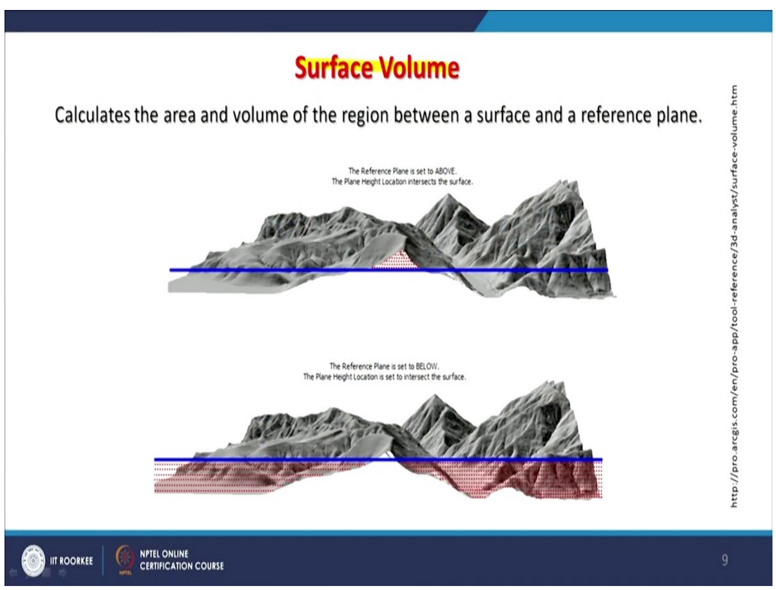

So, let us see that. What basically the surface volumes which we want to calculate which calculates the area and volume of the region between a surface and the reference plane. Like here this blue line is our reference plane and the surface is shown in shades of grey. So here, we find that this area has to be cut whereas these areas have to be filled, if I want a complete flat you know level along this line on this terrain. Similarly, if I change the position because optimization can also be done.

So, if I change the position, like here it has been raised; the height of this along this line has been raised. So, now I am having very small area to cut whereas I am having a large area to fill. So, depending on the resources, depending on the requirements of the project and if it is a particular height; suppose a runway has to be developed here then we would like to know that what is the that optimum height? If that flexibility is there what is that optimum height if we decide which will require the fill and cut in a balanced form.

That means whatever the material which will be removed from that area, can be filled nearby in order to develop a runway for aircraft landing or takeoff. So, if it is possible, the best thing is that this should be optimized in a manner that locally whatever is being cut can be used for filling and no material has to come. Minimum earth work would be required in such cases. So, employing GIS, this optimization can be achieved very easily otherwise using simple conventional method, using toposheets or other things, this will not work that means the various scenarios cannot be created there.

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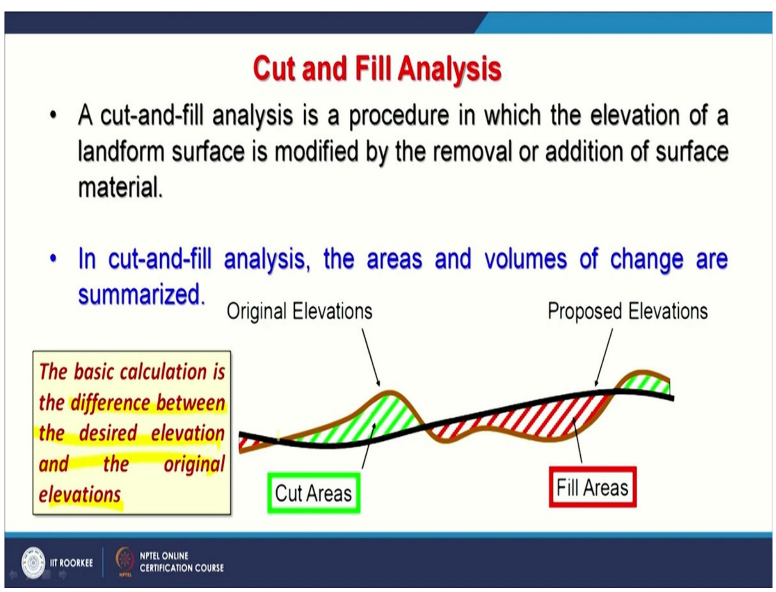

Now, part of this surface volume analysis is cut and fill analysis which I mentioned earlier, that this is a procedure in which what we basically are doing, that the elevation of a land form surface is modified by removal or addition of the surface material. So, if it has to be cut so from where it will be cut and where it will be filled, that can be decided based on this cut and fill analysis.

And in this analysis, the areas and volumes of change are summarized. So basically, we would like to know which areas will be subjected to cut and which areas would be subjected to fill, plus how much volume of the rocks or soil has to be removed and what is the volume of soil or rock has to be filled. So, as I have mentioned if optimization can be achieved then locally this problem can be solved and minimum earth work would be required and therefore less cost of the project.

And if this analysis has been done properly then many times, these projects will not fail because such estimations about cut and fill has been done very accurately then you know there are chances that project will be successful. Many civil engineering projects fails because initially they are unable to estimate the earth work required and once the project start happening on the ground then they realize oh god there is so much earth work is required, this they never estimated.

So, if that flexibility is there, that by changing the height along that line and locally the soil can be managed or rocks can be managed, that is the best solution; that is what we I am saying the optimization. So, the basic calculation in this cut and fail analysis is basically the difference between the desired elevation and the original elevation.

So, the desired elevation may be a flat part or flat terrain, you want to create flat surface and original elevation or original terrain may be having undulating like here. Though it is schematic but what it is showing that these are the green areas where the rocks or soils would be cut in order to maintain this level or surface in that area and these are the areas in which the filling will occur and again the cut will occur.

So, if cut volume and the filling volume is equal then locally things will be managed without bringing anything extra or without sending outside of this area. So, this is what is very-2 important. Now how in plan view, it will look? Because so far what we have been discussing, all this along a profile, along a cross section or in 2D.

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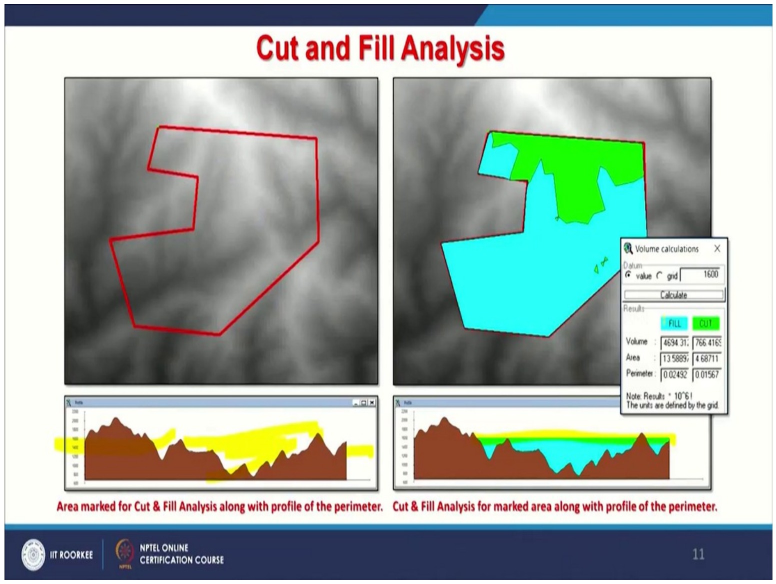

Now how it would look from the plan view if this is the area which I have decided to make as a flat for a playground or a colony or anything. Now once I have taken that area, of course it has to be in a form of polygon then immediately I would know that after deciding the level, that this is the flat I want at this height above mean sea level. So, immediately the system can calculate for us by this tool that which are the areas which will be required for filling and which are the areas which would be required for cutting or removal of the earth or rocks.

And by doing iteration, I can achieve a balance or optimization if that is choice is available. But if level is fixed or prefixed then such things cannot be done. So along this you know polygon or perimeter, I can also draw a profile. So, immediately I know that this part is very low in order to do that flat part. So definitely there, the filling would be required or elsewhere because these parts are on the edges are you know high above the required elevation therefore cutting would be required.

Now in order to have more accurate analysis from economy point of view or from success you know of the project then one should also consider whether the material which is present there is simply soil sand or hard rocks. If hard rocks are there then it should be told to the decision makers that if we go for an optimization; that means the minimum cut and minimum fill, just by adjusting the height of desired level that would be the best thing.

Because removing a hard rock is very-2 you know costly compared to just a sand or soil. So, these are the things. So, if this level has been decided then these areas which are below will be filled and the rest of the area would be cut. So, the level has to be decided by the decision makers. If flexibility is given to a GIS expert, then it is very good that one can bring lot of scenarios especially the one which is having optimized solution.

So of course, then you get all those data also that this much of fill or volume or cut is required. This much area would be involved. This is the perimeter of these two areas and the height here; it was decided that level which was decided of 1600 meters. So likewise, this cut and fill analysis can be done again.

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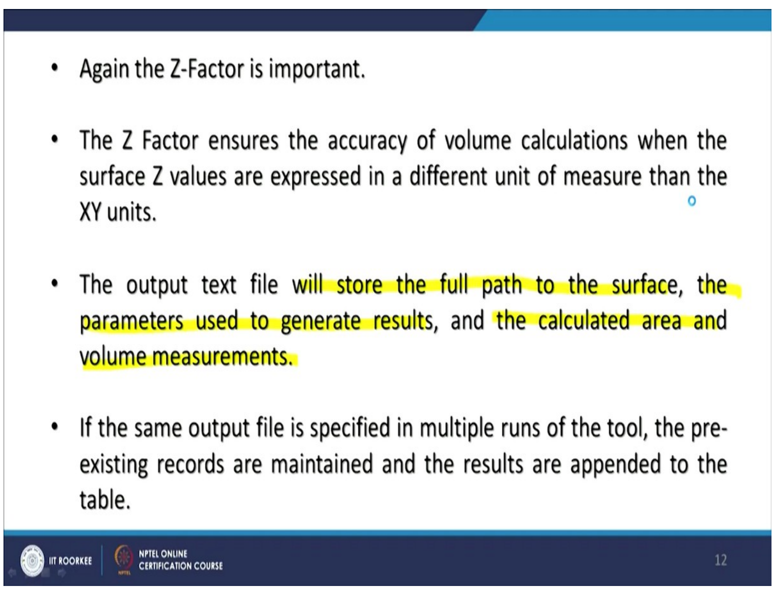

Now 2 important factors; first is the z factor. z factor has to be taken care all the time whenever is required. You know because here xy units have to be equal to z units or vice versa because the software is not intelligent enough that they can pick what is z factor? So, this has to be provided based on the you know some average longitudinal distance or some calculations. Like average for India which we have calculated is 0.0000089; that z factor.

Now this output text file will store the full path to the surface after this cut and fill analysis. The parameters used to generate results and the calculated area and volume measurements which I have already shown to you in the previous slide; here this one. Because this is what is required based on this data then the cost will be estimated. So, this data is very much required, though in the plan form it is required, in profile form it is required.

But in numbers, it is required. Numbers are required for decision makers to make appropriate decision. So, the same output is specified in multiple runs of the tool because the pre-existing records are maintained and the results are appended to the table by changing the height, by changing the desired level and just whatever the options are available.

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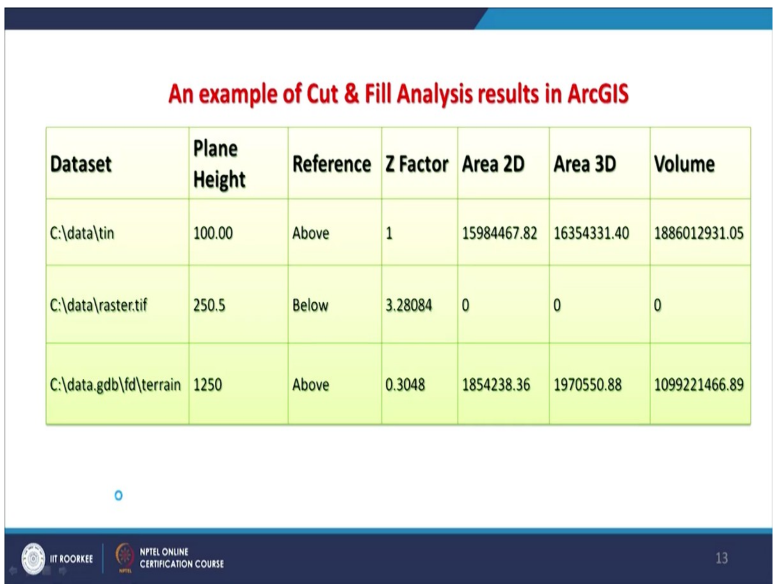

Dataset	Plane Height	Reference	Z Factor	Area 2D	Area 3D	Volume
C:\data\tin	100.00	Above	1	15984467.82	16354331.40	1886012931.05
C:\data\raster.tif	250.5	Below	3.28084	0	0	0
C:\data.gdb\fd\terrain	1250	Above	0.3048	1854238.36	1970550.88	1099221466.89

An exercise was done by me, that an example of cut and fill analysis results in ArcGIS with different z factors. Area in 2D, area in 3D, what is the volume? So, when it is done with the TIN, this is what the scenario. When it is done with the raster, this is that scenario and again with the raster with a different z factor and a reference below, above. So, depending on what kind of calculation, all types of such thing are possible because many times I will give you one example and that is Palm island of Dubai or UAE; there they reclaim the sea, that means there were only filling, no cut.

However, the cut has happened elsewhere, from where they brought the big blocks of rocks. So, definitely before starting of that project, this analysis must have been done, that is what is the subsurface profile in which this project will come. And how much of the rocks would we filled and of course from where it will come, what would be the transport cost, what do the volume of rock will required? All those things must have been estimated before the start of the project.

And this is what it should be done in almost every project where such exercise will be done or where this work will be required. Nowadays you know that all express ways or highways in India are being created which are elevated one, at many places. So, elevated means that they have to be raised; the ground has to be raised to that desired height and then they maintain a level so that along the road, you do not have to move ups and down.

So, if that calculation is required then fine. Suppose normal elevation of the ground is 200 meters whereas this elevated expressway has to be raised by you know 10 meters, then that calculation can be done for that particular width and of course that you know wage and then finally from where this will come, what is the volume required, what would be the transportation cost and of course how to make that one again you know solid or with whatever the procedures are required.

So, all these estimations can be done before even project is taken. If these things have been done properly then of course, such projects will never fail because whatever has been estimated, the real cost will be also around that figure.

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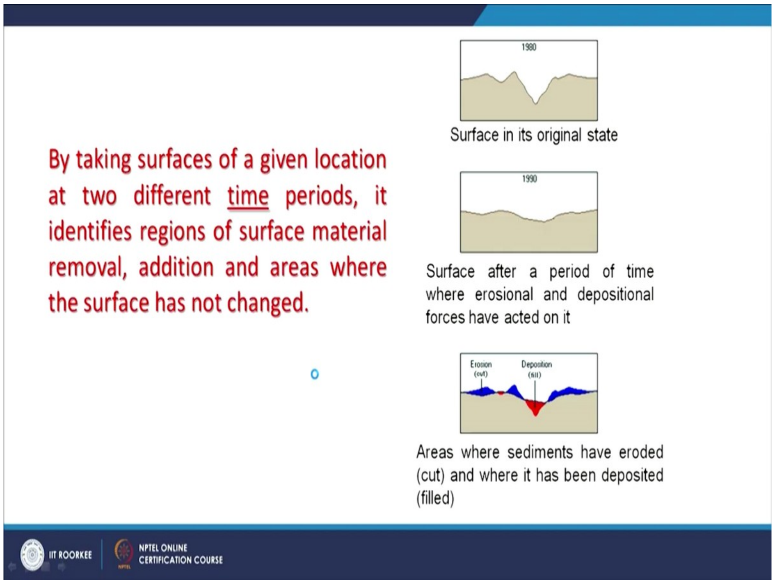

So, by taking surfaces of a given location at two different time periods, if it is possible to have two different elevation surfaces then we can also estimate few more things that is the change; how things have changed? Like here, this is the surface in its original state. This is the surface after a period of time where erosional and deposition forces have acted on and these areas of sediments have eroded where the cut is in blue color shown and where it has been deposited shown in red color.

So even if you are having age difference data. This is 10 years' time difference is here; 1980-1990 and this is what happened in 10 years, that might be along a river so that immediately you know where erosion has taken place and where deposition has taken place.

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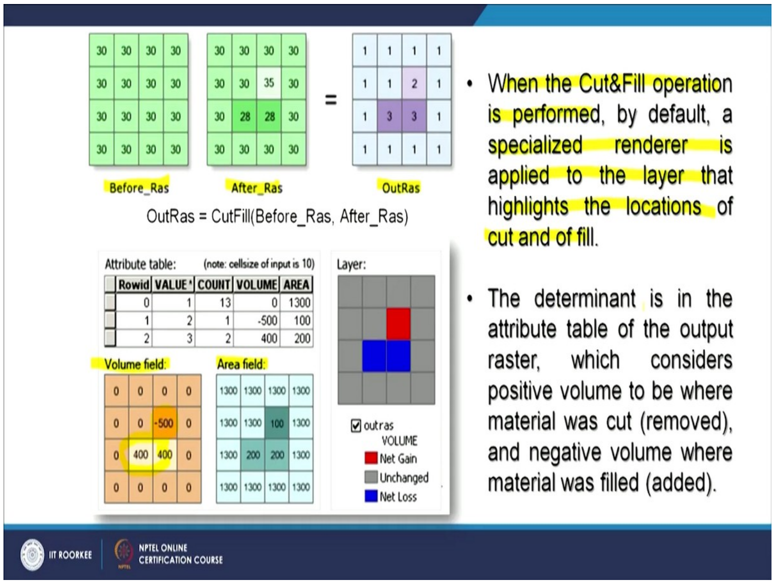

Now similarly, this cut and fill analysis like here; this is before raster, after raster. So, two inputs are there which are showing the changes and this output raster is telling how much change has occurred. So quantitatively, you know about this. So, when the cut and fill operations are performed, by default a specialized renderer is applied to the layer that highlights the location of cut and fill.

Like here in this example that if I have decided this is going to be my area or level then this is the volume field, this is the area field. So, the minus volume means it has to be removed from here and these are the areas where filling will be required. So, then you can have a proper estimate. So, this basically describes what happens at the cell level.

So, the determinant is in the attribute table which we are having here of the output which considers positive values to be where the material was cut or removed and negative values where material was filled or added.

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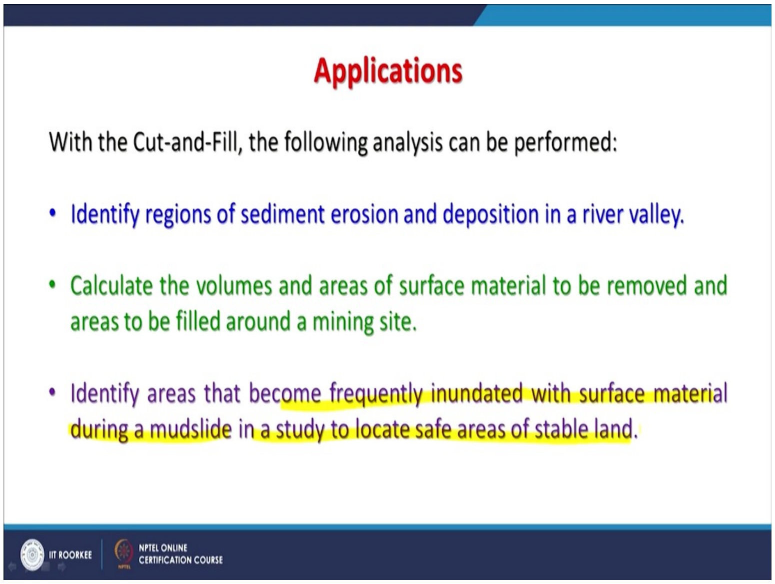

What are the applications? Some examples we have already taken. But nonetheless for completeness with the cut and fill, the following analysis can be performed: identify regions of sediment erosion and deposition in a river valley, we have seen the example. Calculate the volume and area of surface material to be removed or area to be filled along around a mining site. So, whether it is open cast mine or underground mine, cut and fill analysis still can be performed and an estimation should be done.

Same thing in case of railway line aligns, route alignment or road alignment or for a canal or a power channel, any such things. Identify areas that become frequently inundated with the surface material during the mudslide in a study locate safe areas of stable land, again cut and fill. Where water will be filled during the flood time, which are the areas which will remain safe?

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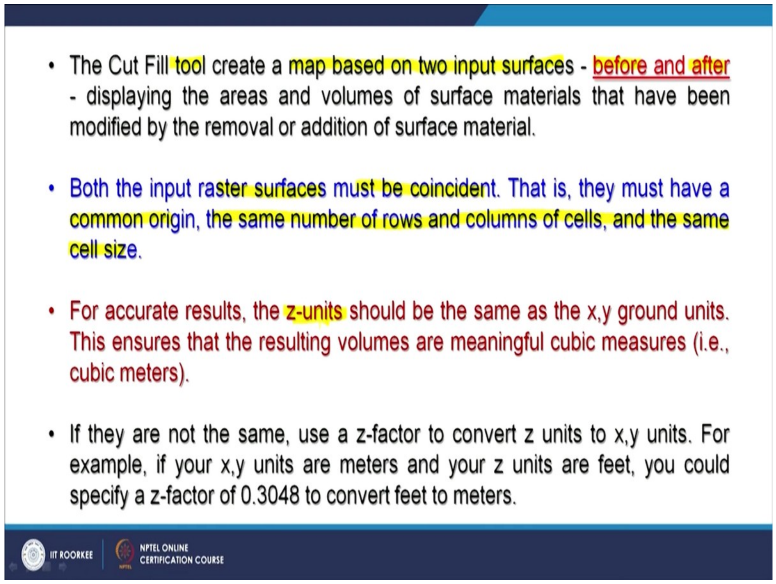

So, which can be used for you know rescuing people. So, cut and fill tool of many good softwares create a map based on two inputs surfaces; the first one is the before and after. Now, after can be a simple flat surface which is desired surface. But before is your original digital elevation model. So, both these raster surfaces must be considered; that means they should belong to the same geographic area or location. And they must have a common origin; the same number of rows and column of the cell and the same size then only cut and fill analysis can be formed which is not difficult to fulfill all these conditions.

And of course, z factors should be taken care about. And finally, about this that if they are not the same; that the z factor then it has to be converted, a value should be given and then one can achieve very good accurate results.

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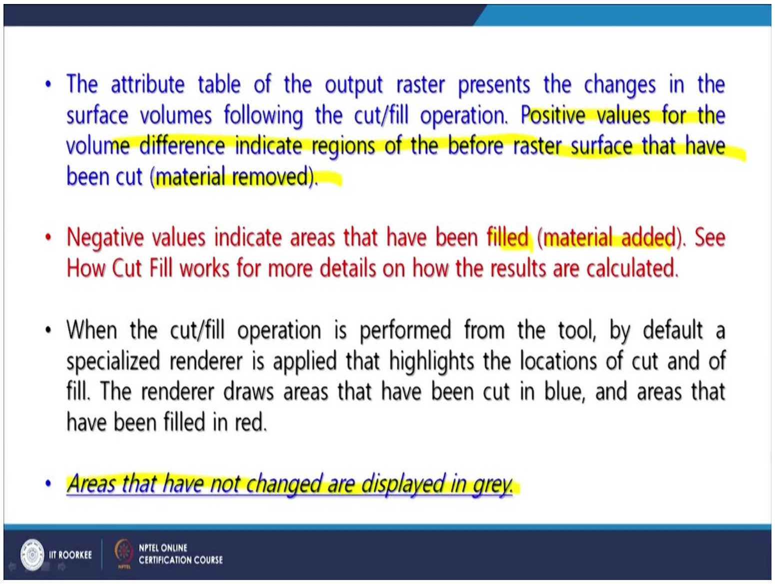

Now attribute table which we have seen in few examples, that output raster presents the changes in the surface volumes following the cut and fill operations. And these positive volumes for the volume difference indicate region before raster surface and cut that means the material removed. And negative values will indicate a reverse that is vice versa where filled material will be added. If material has to be bought in some cases, it is maybe there then the calculation can be done that how much it will cost?

So, lot of estimation even financial part can be done once you are having the area and volume calculations before this cut and fill analysis. And for finally the area that have not changed are displayed in grey which you have seen in the previous example also.

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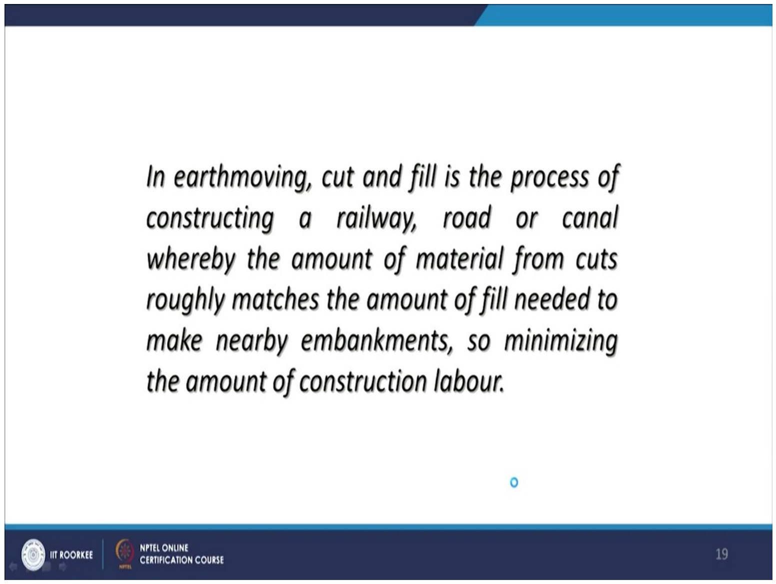

So, we are coming to end of this discussion by saying that in earth moving, cut and fill is the process of constructing railway, road, canal, power channel whereby the amount of material from cuts roughly matches the amount of fill needed to make nearby embankment. So, minimizing the amount of construction labor. That should be the target in all such civil works whether it is related to railway, road, canal or any such things so that locally it should be managed.

And if locally it can be managed, it will be very cost effective and it would not take much time either. So, with this, I end this discussion. Thank you very much.