Geographic Information Systems
Prof. A. K. Saraf
Department of Earth Sciences
Indian Institute of Technology-Roorkee

Lecture-56
Applications of DEMs in Viewshed and Flood Hazard Mapping

Hello everyone! And welcome to new discussion. Again, this is also related with applications of DEM and today in this one, we are going to discuss how we can employ DEM in Viewshed analysis and also in flood hazard mapping. This viewshed is very-2 important. In literature, you may find that they might be using some other terms like visibility analysis also and viewshed analysis also.

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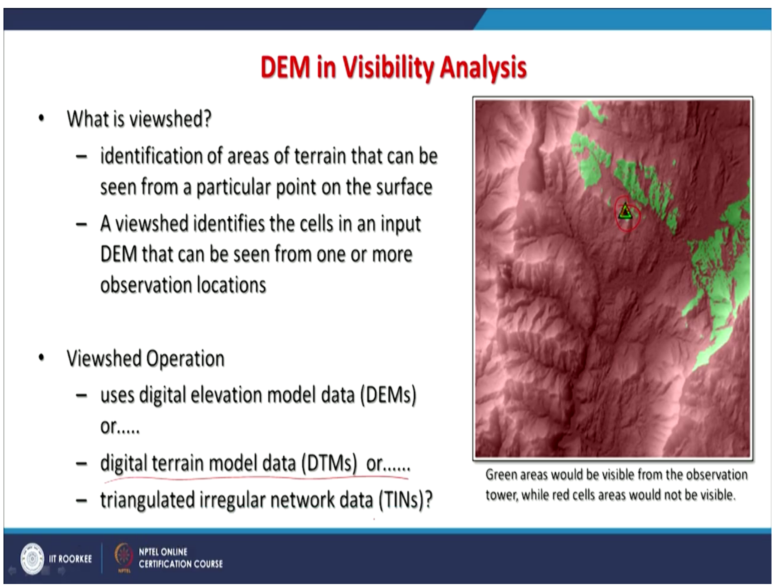

Because whenever there is a terrain involved, that means from one single point, you cannot see all parts of the terrain specially if it is undulated terrain. So that we can analysis on the GIS platform. And this is very-2 useful in various applications, especially it is becoming now very-2 this viewshed or visibility analysis for citing a mobile tower as well. So, viewshed basically is that identification of areas of terrain that can be seen from a particular point on the surface.

Because any artificial thing or human made structure has to come on the surface of the earth whether is a building tower or bridge or any other thing. So, before it really happens on the ground, can we analyze and see that what are the things would be visible from that top of a building or tower or vice-versa, that from where the tower will be visible. Because in many-2 cases, it is very important. For example, in hotel industry. You know there is always high cost for a room which is having good visibility or good view especially in hilly Terrain.

And therefore, everyone who is developing such facilities would like to know beforehand that what would be the height because height they would know, what would be the visibility or viewshed from a particular height and a window. So, all these things can be modelled before really thing happens on the ground. There are some other visibility analyses or viewshed also useful from sending missiles and other things.

But there are more impediments which are important like drags which occur, will also come in between but anyway, that is a little different. We are not going to discuss that military application part but the civilian part, we will definitely discuss. Like here if I am say standing this location and I add my height as an offset then from my height level, what are the areas which would be available or which would be visible from that location.

So, immediately from using an input digital elevation model. Obviously here in the background, a shaded relief molded is being displayed but the input required for visibility analysis is only DEM. And these green areas are telling that these are the areas from this point would be visible and remaining areas will not be visible at all. So, a viewshed basically, it identifies the cells because after all, a digital elevation model is made from cells.

Viewshed identify the cell in an input DEM that can be seen from one or more observation locations. This viewshed analysis is also important for watchtowers, especially in forest area or those who are going for photography of animals and other things. And viewshed operation basically uses a digital elevation model as input and of course the digital terrain model; DTM or whatever the best resolution is available. You can also employ TIN as well to limited extent and this analysis can be performed.

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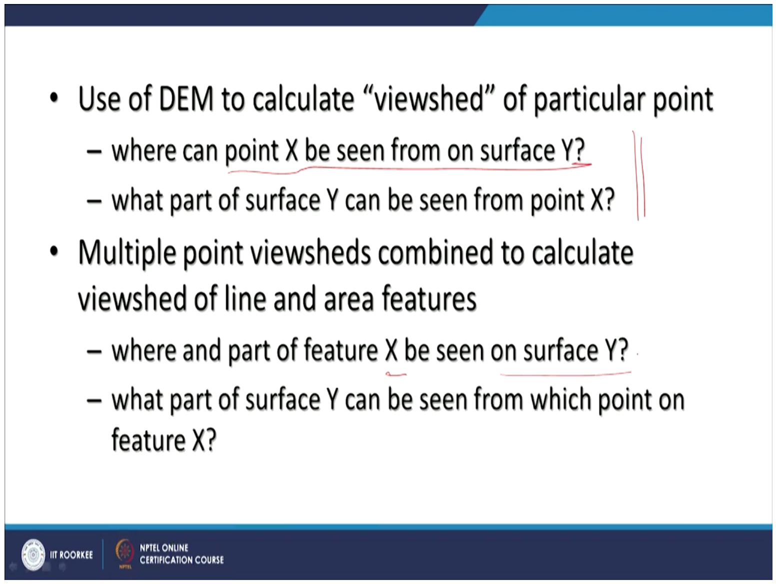

So, apart from DEM which is very much required essential, a point x to be seen on the surface of the Y. So, offset is always required but the condition here is; the interesting point if from a point X, the Y is seen then vice-versa should also true. So, keeping this thing in mind, the viewshed is done. So, if we want to have multiple point's viewshed combined to calculate viewshed of the line and area feature, that is also possible.

So when multiple is there and part of X will be seen on the surface Y and what part of surface Y can be seen from which point of feature X?

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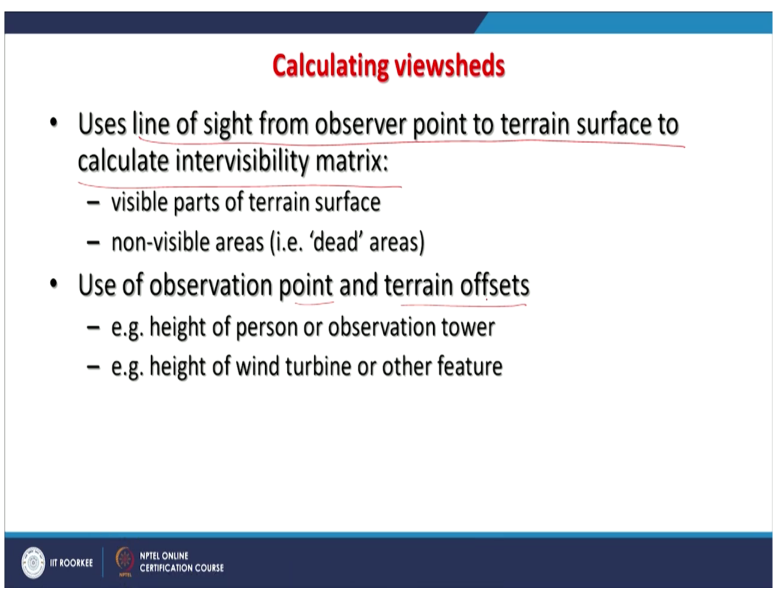

So, all this can be done. Now while doing this thing; the line of sight or viewshed analysis observation point to the terrain surface calculates intervisibility matrix. So, green areas in previous example would be visible from that point with that particular offset and other areas would not. So visible parts of terrain surface are identified, non-invisible parts or dead areas are identified and which you can use this observation point and terrain offset as well.

If there is a tower then the height of the tower has to be added. Even planning for you know power supply or these towers for taking a high-power cable because the cable will band because of its load so that can also be analyzed whether it will touch some ground or trees, or not. So, in Electrical Engineering also, the viewshed or line of site analysis can also be very-2 useful. For example, height of a person or observation tower used for that analysis. Height of the wind turbine or other features.

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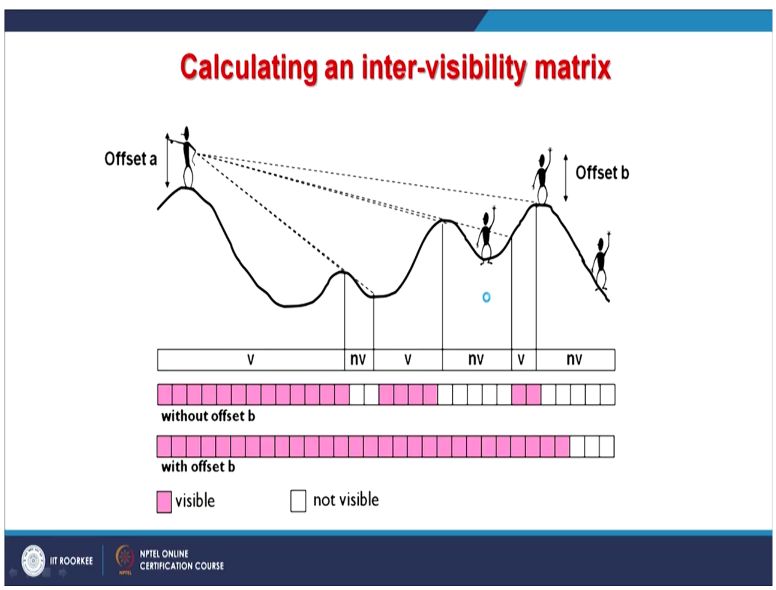

So here what you are seeing; this is offset which you have to provide. You may provide 0; that means there is no human height is added or no tower or no building. So here itself, I can use but if a person is standing that offset has to be provided and, on the target also, offset can also be provided. And if the analysis is done like in this is schematic; what we are seeing that these are the areas which are visible.

And these are the areas which are not visible from that location and offset. So, if we want to make these areas also visible then probably, we have to change the offset or location. So here, the analysis has been done that this is without offset b; this is offset b that is the target location or with offset b. So, when offset is added to the point location b, obviously the visible area has increased significantly. So, all permutations, combinations are possible.

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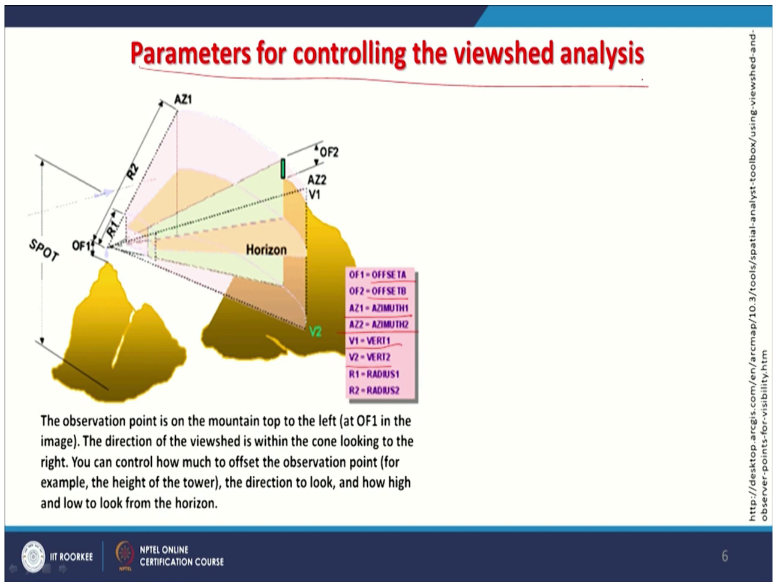

Line of sight that means along a particular direction or you can have all around. So instead of line of sight, that would call as viewshed. So here, details are given like offset 1, A, B and then direction, azimuth 1, 2 and then vertical axis and other details are there. So, depending on how the terrain is, the parameters basically controlling the viewshed analysis. So, these are important parameters which will control viewshed analysis especially in a highly rugged Terrain like Himalaya. So, it is possible to limit the region. It is not necessary that you do it for entire region all around.

You can say that only in this area, I want to do it because this happens in case of mobile towers. A mobile tower cannot transmit or receive signals from all directions, particularly they are only in one direction with certain angle. So, for that analysis can be done so that we can know that what should be the direction of mobile tower antenna so that it can cover a large population. That can be simulated and that is being done now by mobile operators.

So, observation point elevation values are required then vertical offset is required. Then horizontal and vertical scanning angle. The angle which I am seeing is also required. And then scanning distance; how much because everything will have a limit. Human eye in certain condition can see 1 kilometer, 2 kilometer, 3 kilometer but it is not infinite.

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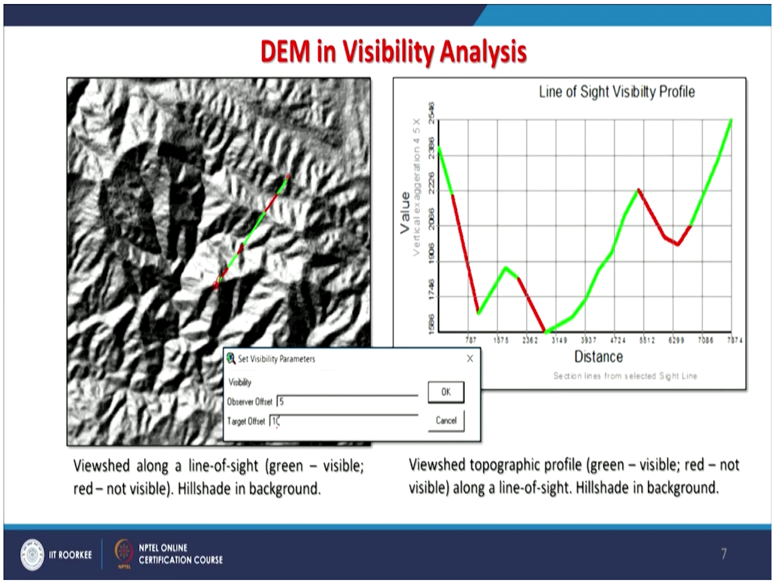

So, if I go for a line of sight like here then this there is a point and in between, what happened? So, green areas are showing that these are the areas from that point would be visible. Red areas will not be visible. You can change the offset; the offset values you can change and then re-analyze the entire thing. You can also plot an xy or a profile all along that line that will let you know in the line of sight that which are the areas would be visible and which are not. in this one.

In this one, the green one would be visible and red one will not be. So, if you change the offset from where you are looking or offset of the target, definitely all this will change.

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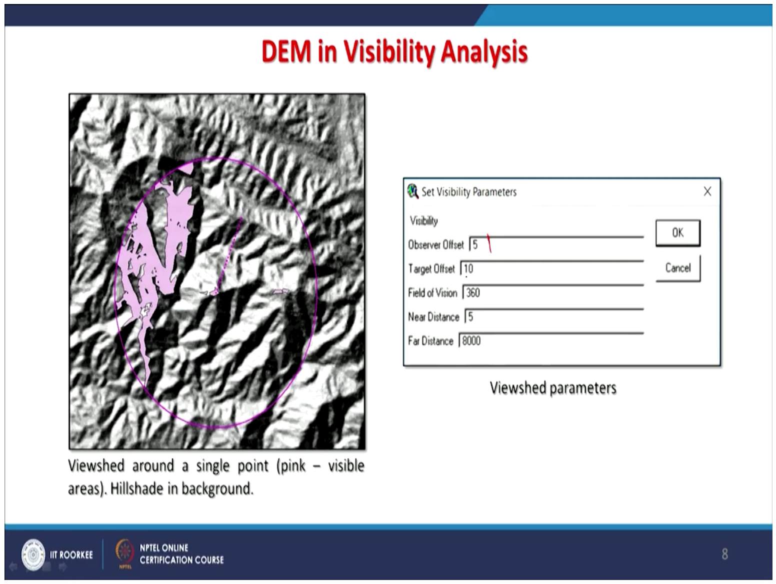

Similarly in a circular area, then it will become typical viewshed then all these areas which are showing this light pink colour would be visible otherwise they will not. You can provide the target offset. You can provide the field of vision. Rather than 360 degrees, you can have even 30 degrees in a particular direction you want. Near distance you can control and the far distance, you can control. And just when you submit all this; putting a location, you get the analysis.

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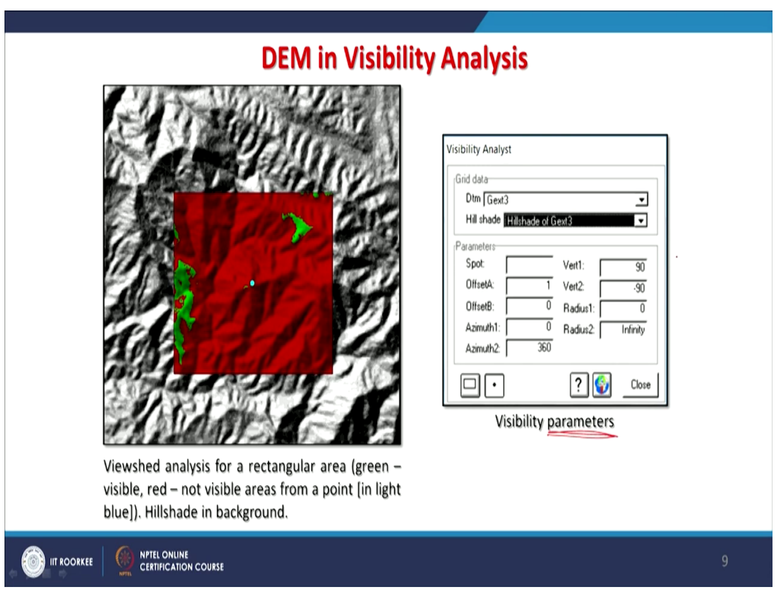

Like here instead of a circular area, I want within my area of interest. So, this is how the viewshed that these green areas from this point with that particular offset would be visible otherwise they will not. So, all these details; these visibility parameters which are mentioned here are important to get a viewshed analysis or visibility analysis for a terrain.

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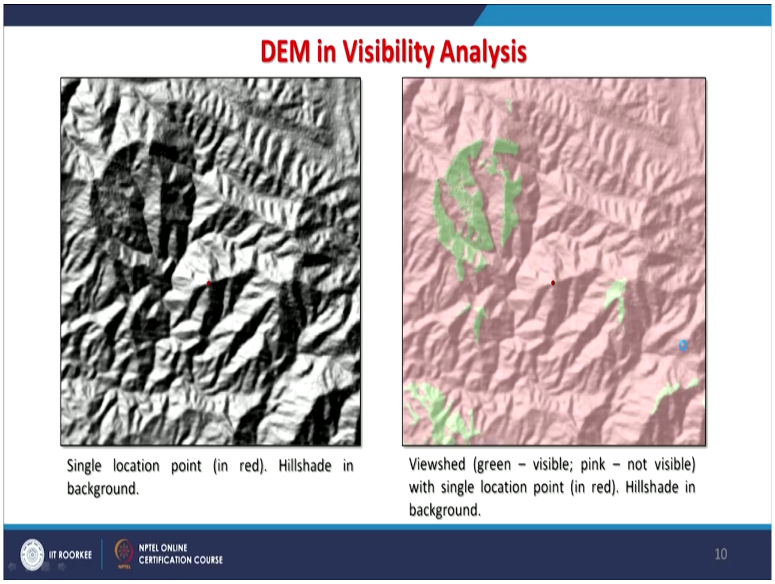

Similarly, it has been done for this. And what we do generally? Instead of putting digital elevation model in the background, a shaded relief model has been given which will give you a feeling of the Terrain and it looks much better.

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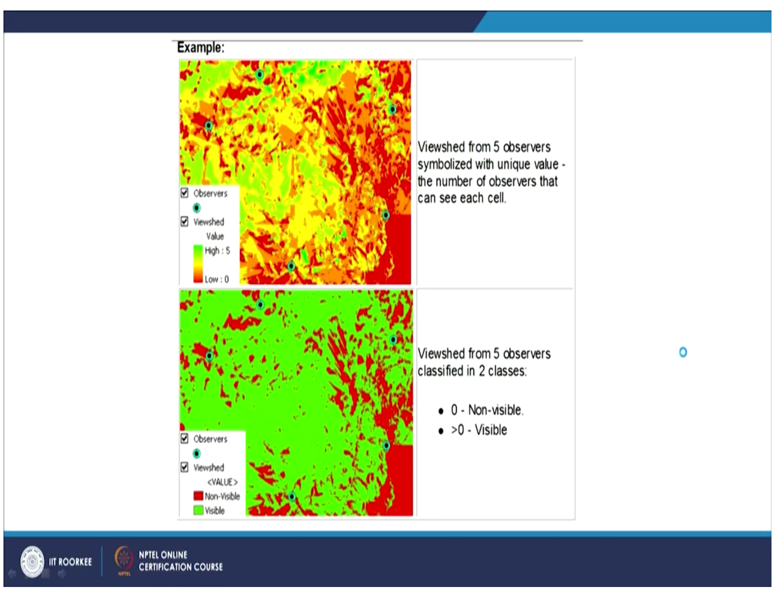

So viewshed because this is what Computer has to do or GIS software has to do it so instead of one observer, you can have multiple observers. Like here viewshed from the 5 observers. So, these 5 observers which you can see marked by circle. So, if you are having 5 observers, these are the areas which would be visible and red areas will not be visible.

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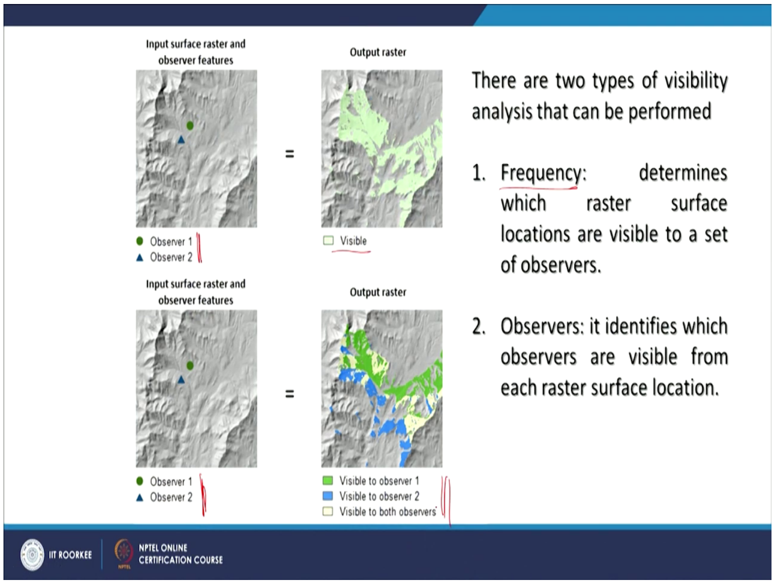

So likewise, lot of such variant analysis can be performed. Here the observer 1 and 2 are there their offsets with the visible area. And areas which are visible to observer 1, areas which are visible to 2 and visible to both observers; that kind of analysis can also be performed. So, there are two types of visibility analysis that can performed; one is the frequency which determines which raster surface locations are visible to set of observers as you can see in this example.

Or you can see that it identifies which observers are visible from each raster surface location. Now if it goes in a large distance like in case of missiles and it has to travel sometime 3000 kilometer or 1500 kilometer then the curvature of the earth and refraction will also play very important role. Not only the wind speed, directions, drag affects but other things also. So, these curvature and refraction correction can also be performed.

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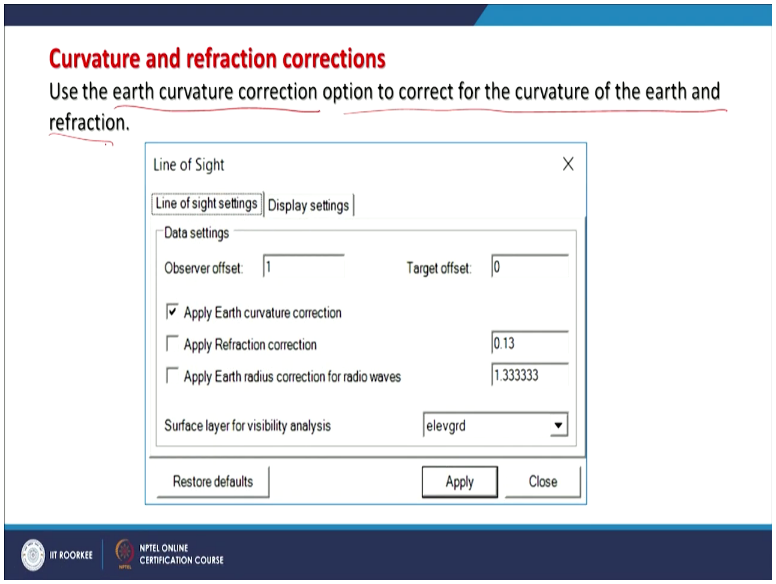

So, use of the earth curvature correction option to correct the curvature of the earth and refraction, only when the large distances are involved in viewshed on line-of-sight analysis. And this is what you can do that applied the radius correction for the radio waves. Applied refraction correction, apply curvature correction and these options you can definitely opt for and can do the analysis.

These are generally done for Line of Sight rather than a viewshed analysis but such corrections possibilities are there in good GIS softwares. But the dynamics part which is the wind direction and speed and that drag effect, it will bring to the missile may not be easily able to model that part. But the rest of the things can definitely be modelled.

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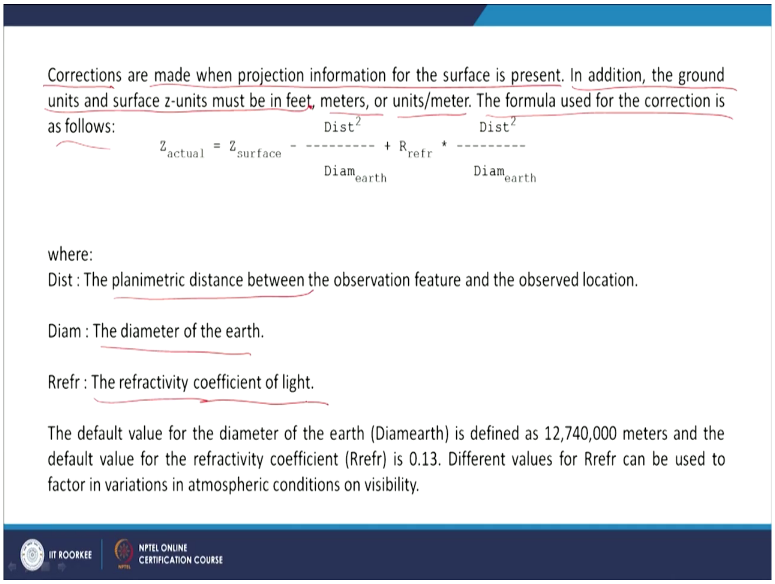

So, these corrections; refraction and curvature corrections are made when projection information of a surface is present; that is the map projection. In addition, the ground units and surface z units must be in the feet's, meters or unit/meter. The formula used for the correction is as follows.

$$\text{So, } Z_{actual} = Z_{surface} - (Dist.^2 / Diam._{earth}) + \{R_{refr} * (Dist.^2 / Diam._{earth})\}$$

So, you have here the planimetric distance and here is the diameter of the earth then refractive coefficient of the light and other values would also be required to solve this.

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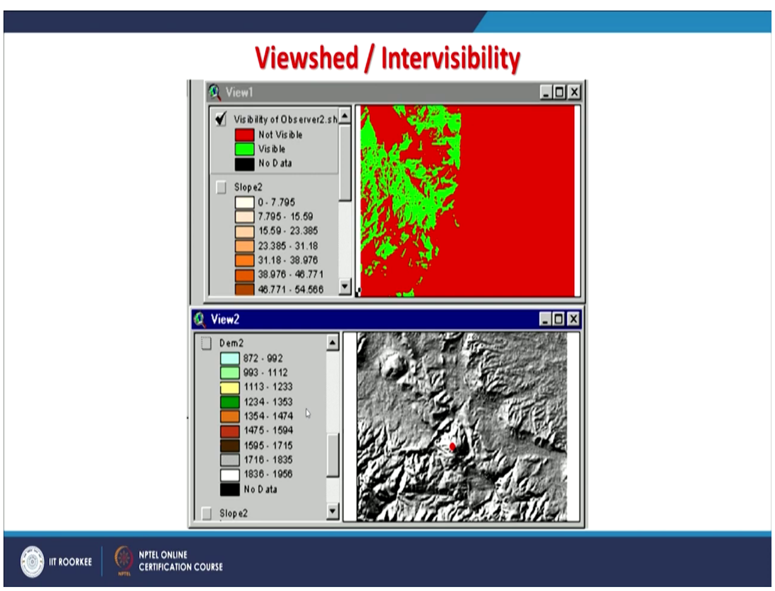

So, this Viewshed analysis has been done like here on the top one, you are saying intervisibility also and in the bottom one, you are seeing a very small area is being covered here.

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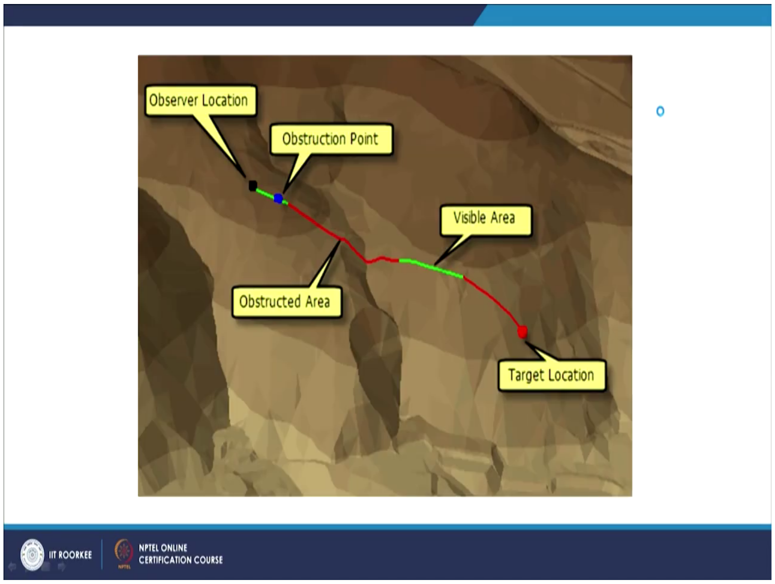

Now if I am having say road which is not a straight line but arbitrary one. There also a viewshed analysis can be done. That means viewshed is not necessarily always in a straight line but for straight line segments like it is shown here. So, this is observer location as you can see and this is target location. So, which are the areas which are completely obstructed for observer locations? And this is the obstruction point here. This is the obstructed area here and then this area would be visible. So, for defense purpose or for many other reasons, these things can be done also to that extent.

The best part here things can be done and various possibilities can also be tried and obviously things can be done very accurately and quickly. Using simple toposheets or any other technology, it is not possible to do either viewshed analysis or line of sight analyses.

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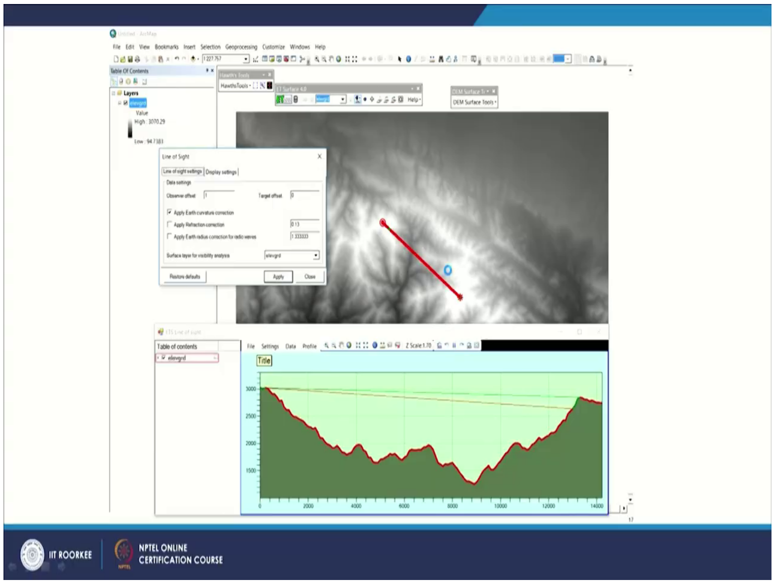

Another example here what you are seeing of ArcGIS is that there is a line and then there is a topographic profile along this line. And if I am not adding any offset then only this much area is visible. But if I add an offset then maybe large area would be visible. All this line-of-sight analysis can be done along this line so very small tiny area is green here.

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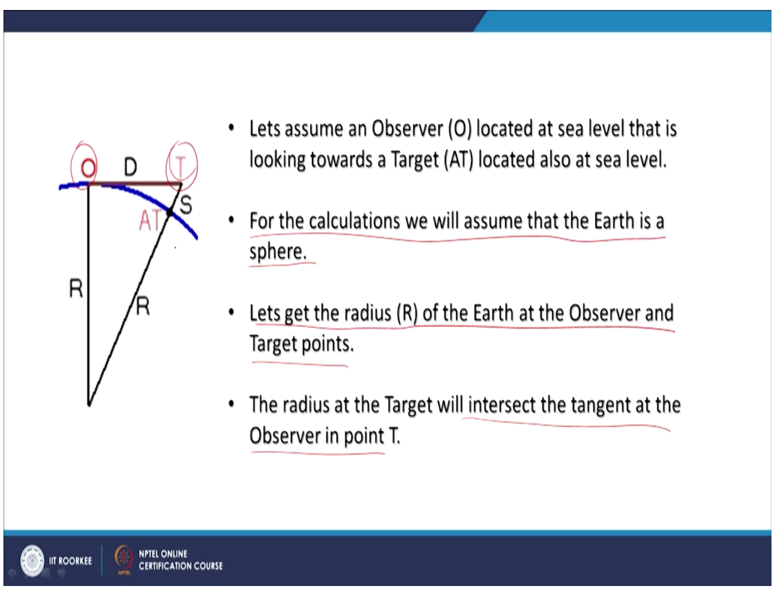

Now if we assume the observer located at sea level; that is the looking towards the target AT located also at the sea level because there this curvature for far distance will get involve and lot of other corrections would be there. For the calculations we assume that the Earth is a sphere. Taking as a sphere or a spheroid rather and let's get the radius (R) of the earth at observer and target locations. And radius at the target will intersect the tangent of the observer in point T. This shown here. So, this is observer, this is target, this is the curvature of the earth and obviously, these are the radius.

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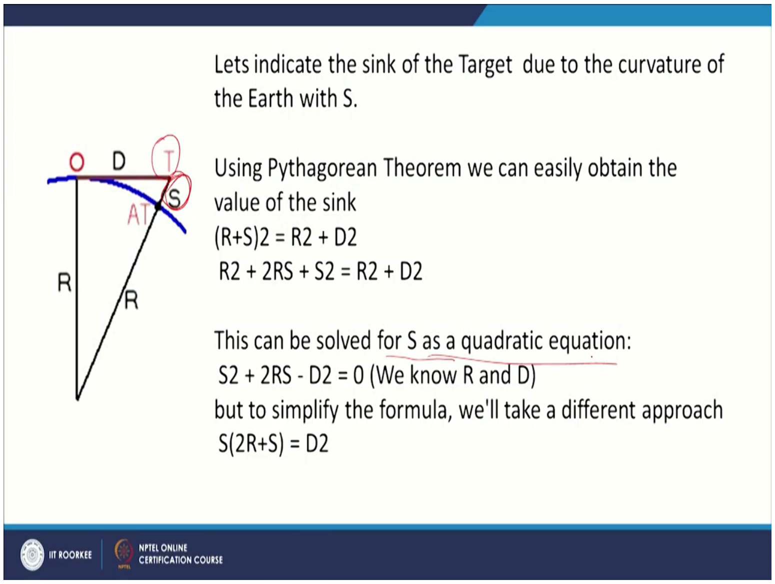

So let us indicate that the sink of target; this one, S because of due to the curvature of the earth. So, from that location, the target may not be visible though we are projecting here in a straight line. So, curvature of the earth using this Pythagorean Theorem, we can easily obtain the value of the sink that means S. So, $(R+S)^2 = R^2 + D^2$ and this can be further solved and this can be solved for S that is this part; that is sink as quadratic equation.

And we can also solve this issue like as I am just discussing. So, like when more distance is involved, there will be more sink.

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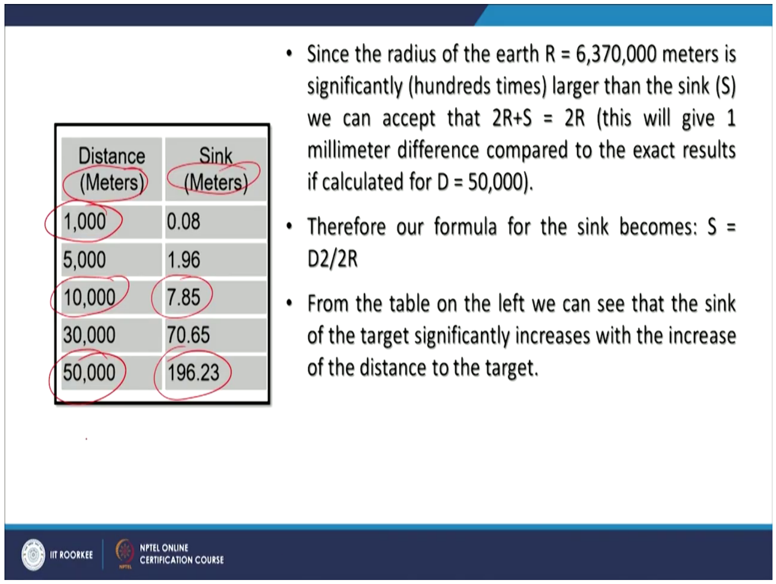

The distances are shown in meters and the sinks are shown in meters because then the curvature of the earth will play very-2 important. Why the example of sea because no other hindrances are there. Of course, the atmospherics reasons or atmospheric conditions would definitely be playing equally important role. But assuming that there is everything clear. Only thing, the curvature of the earth will play important role. For 1000 meters, this sink is just 0.08 meter but for 10000 meters; that is 10 kilometers, this sink maybe 7.85; roughly 8 meters.

And similarly for 50000 meters, this is 196 meters which is very-2 significant. Therefore, these plays very-2 important role. And as I said if large distances are involved, lot of things have to be taken care, especially the curvature of the earth and refraction.

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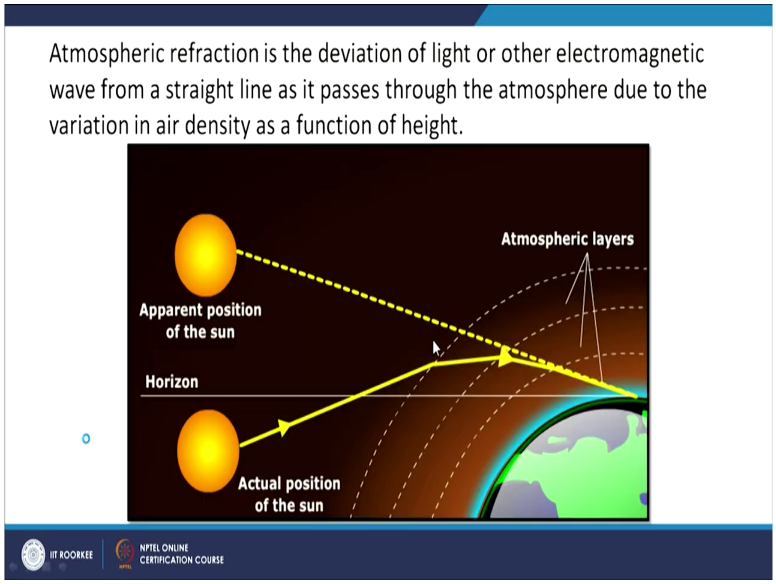

This atmospheric refraction will also change because different layers are there. So, that is basically nothing but the deviation of the light or other electromagnetic wave. We are working for visible just for Line of Sight then along the horizons, it will have a long path rather than this path.

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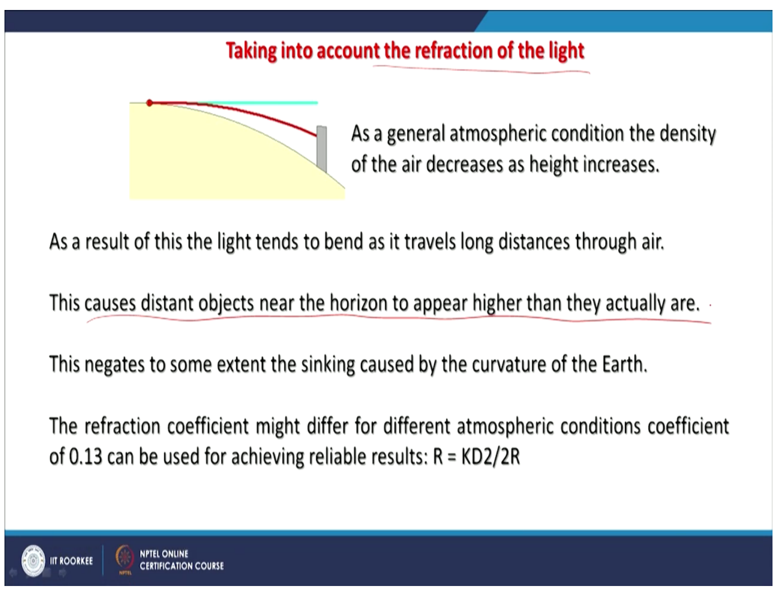

And then again complications are there so taking into account of the refraction of the light as a general atmospheric condition, the density of air at decreases as height increases. So that will also play its own role and result of this would be that the light tends to band. Like there, it was sinking because of curvature of the earth. Here not only the sink because of the curvature of the earth but light too will bend so it will add further inaccuracies in our line of sight analysis which will cause a distant object near the horizon to appear higher than they actually are. And this negates to some extent the sinking caused by the curvature of the earth. And the refraction coefficient might differ for different atmospheric conditions which are dynamic. So, this adds one more complication. So, what I am trying to say that anything which involves large distance in case of viewshed or line of site analysis, lot many other parameters have to be kept in mind.

Some are fixed like radius of the earth is fixed but like atmospheric condition, refraction is not fixed so that will have to be taken care for this. So, that is why when I mention about the missiles, I said it's a complicated.

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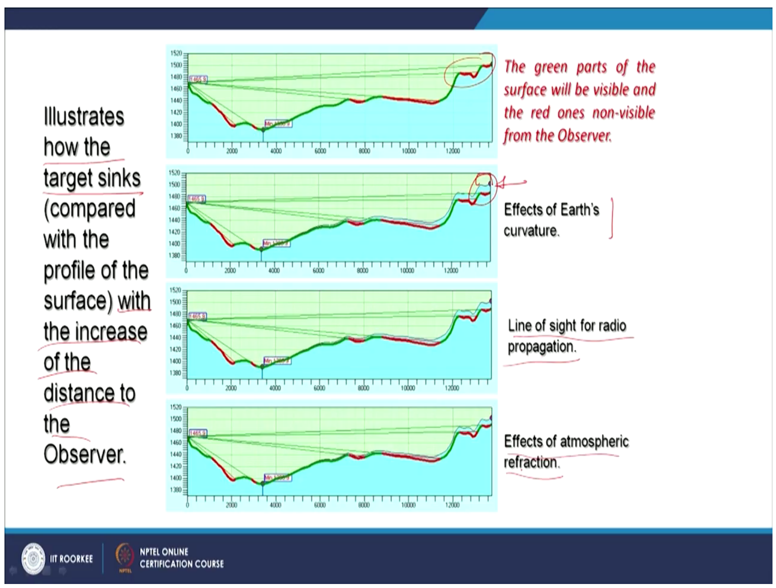

Now this also illustrates how the target sinks compared with the profile of the surface. With increase of the distance to the observer so if we change the position, this is how this will happen as you can see here that you know here, things are visible but because of these other reasons, there will be the difference here which you can see here. So, different scenarios will have different so earth. So here what you are saying curvature of the earth effects. Here you are seeing the line of sight or radio propagation and here you are seeing effects of the atmospheric refraction.

Though in your model, you may expect something like this but in real situation, these will be introduced error. These are the effects which will bring errors in your estimations. So, what are the uses? Some of the uses I have already mentioned.

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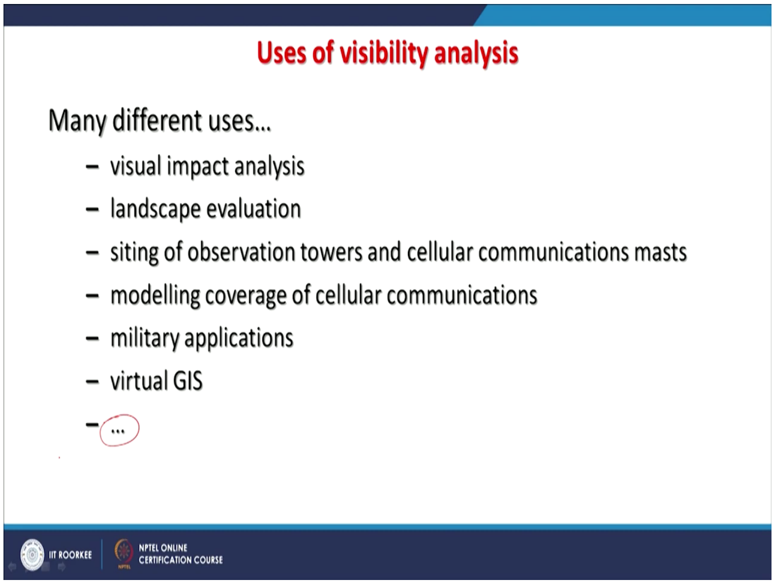

But for completeness, let us go that visual impact analysis, landscape evolution, siting of observation tower and cellular communication masts like for mobile tower, modelling coverage of cellular Communications, military applications. There are many of such applications are not in public domain and of course virtual GIS, there also play a very important role. And this list is non-exhaustive that means as more handling is possible like refraction or curvature of the earth and other parameters which may influence of a line of sight for long distances, new applications will keep coming that is why this is non-exhaustive list.

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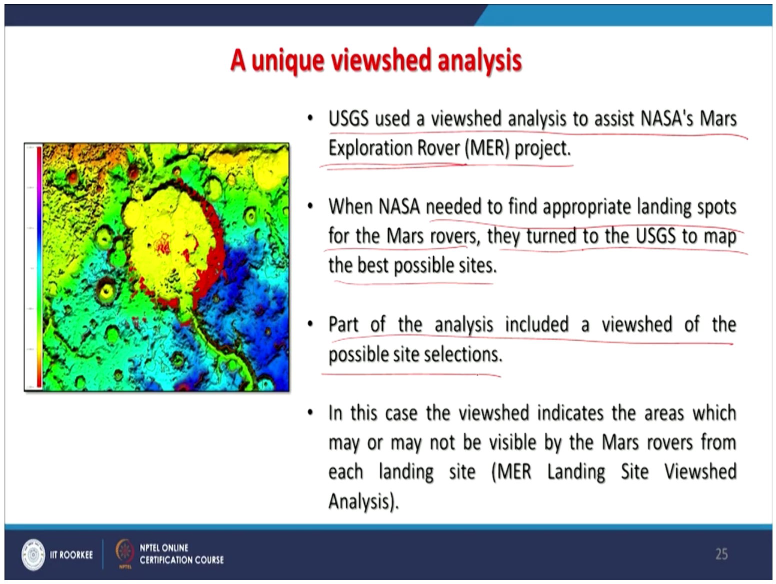

Now, it is just one example that USGS used a viewshed analysis to assist NASA's Mars exploration Rover project because the best part for Mars or the moon that the digital elevation model at very high resolution has already been developed employing satellite images. So, before anything is sent to the surface of the say Mars, things can be simulated on the ground. And this is what it has been done that the Explorer Rover or Exploration Rover (MER) project, these all viewshed analysis was done.

So, NASA needed to find the appropriate landing spot for the Mars rovers and they turned to the USGS map for the best possible sites use digital elevation model and of course satellite images. And part of the analysis included a viewshed of the possible site selection. Because you know that the surface of the Mars is treated with these impact crater so the surface of the Moon.

So, if this Rovers lands in an impact crater, the viewshed would be very limited but if carefully it lands in an area which is not part of this crater than viewshed is going to very large. So, for that purpose, they employ this viewshed analysis. And of course, they had this high-resolution digital elevation model of the area.

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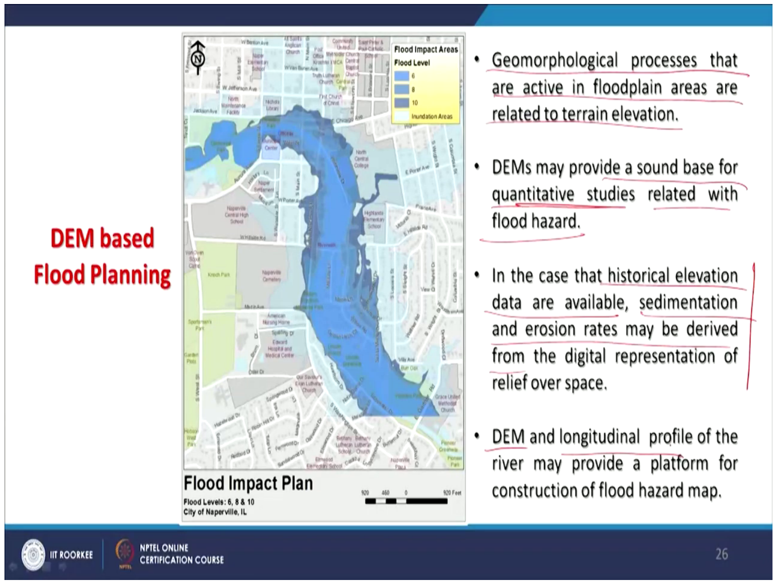

Now the second part of this discussion after this viewshed, that DEMs can also be employed and are being employed for estimating the flood. Of course, there are many other things which can also be incorporated to have a realistic picture or real estimates of flooding or flooded area. So, the geomorphological processes or geomorphological features will also be required because these processes are active in floodplain areas are related to terrain elevation.

And DEMs; of course, they are representing not only the geomorphic landforms but also, the entire elevation model of Terrain. So DEMs may provide a sound base for quantitative study related with flood hazards as shown in the left figure. So, even if it is an urban area if we are having a detailed digital elevation model, a flooding scenario can be very well predicted. So, in that case or case of historical elevation data are available.

The sedimentation and erosion rates may be derived means if we are having very old information about the Terrain and today, we would know that how much erosion and sedimentation has taken place along a river. That too is becoming now possible. Either you imply contours from a survey of India or survey toposheets, do the interpolations, create a surface or use old digital elevation model which is again based on satellite image with latest.

Even if you are having 20 years time difference, you would know that along the river or flood prone area, where sedimentation has taken place and erosion has taken place. So, that kind of analysis is also becoming possible. Further, to validate all that modelling, what you can do? You can also imply old satellite images of that time when this digital elevation model was prepared and current satellite images.

So, this DEM and longitudinal topographic profile can also be employed. And then a flood hazard map which is nothing but a predicted map of flooding in an area can be prepared. So, one DEM, various application; hundreds of applications. I will repeat satellite images and digital elevation models are store house of information. It is only our skill, our understanding, our analysis which will bring new insight in the terrain and new exploitation of these two big natural or these 2 resources which are representing natural conditions. So, with this, I end with this discussion. Thank you very much.