Natural Hazards
Prof. Javed N Malik
Department of Earth Sciences
Indian Institute of Technology Kanpur

Lecture – 07
Introduction to Natural Hazards (Seismic Zonation of India & Landslide)

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Taking it all in Slide —
How the Trans-Alaska Pipeline Survived a Big One

Compiled by Heather Friesen

The Nov. 3, 2002, magnitude-7.9 central Alaska earthquake was one of the largest recorded earthquakes in our nation's history. The epicenter of the temblor was located near Denali National Park, approximately 75 miles south of Fairbanks and 176 miles north of Anchorage. It caused countless landslides and road closures, but minimal structural damage, and amazingly, few injuries and no deaths.

In contrast, the 1906 magnitude-7.9 earthquake and subsequent fires took 3,000 lives and caused $524 million in property losses. The remote location of the magnitude-7.9 Denali Fault earthquake played a role in ensuring that the earthquake was not more devastating. However, advanced seismic monitoring, long-term research and a commitment to hazard preparedness and mitigation also played a key role. The science done before the Denali Fault earthquake aided in the successful performance of the Alaska pipeline, and the science done after the Denali Fault earthquake revealed more about large quakes that will help save lives and property during future temblors, especially in populated areas.

USGS seismologists and geologists serving on a federal task force were instrumental to ensuring that the Trans-Alaska Pipeline was designed and built to withstand the effects of a magnitude-8.0 earthquake with up to 20 feet of movement at the pipeline. The USGS design guidance proved to be on target. In 2002, the Denali Fault ruptured beneath the pipeline, resulting in an 18-foot horizontal offset. The resilience of the pipeline is a testament to the importance of science in hazard mitigation and decision making.

More than 30 years ago, Trans-Alaska Pipeline System (TAPS), formed by seven oil companies, confirmed the existence of a great deal of oil on the North Slope. In February 1969, TAPS announced plans to build a 48-inch-diameter, 800-mile pipeline to carry crude oil from Prudhoe Bay to Valdez. Issues pertaining to the safety of the design emerged. Would the heat in the oil melt the pervasive, thick, permafrost layer and cause damaging spills? Would the pipeline be able to withstand a large earthquake in the nation's most seismically active state?

Designed to withstand a magnitude-8 earthquake with up to 20 feet of movement, the Trans-Alaska Pipeline is supported by rails on which it can slide freely during an earthquake.

Walter Hickel, then U.S. Secretary of the Interior (1969-70), was alerted about the proposed pipeline and immediately appointed Bill Pecora, then USGS director (1965-71), to chair a technical advisory board. Pecora appointed the Menlo Park working group, made up mostly of USGS scientists, to advise the board.

USGS created several scientific documents to be used in planning the pipeline location and construction. Documents included an estimate of potential earthquake shaking levels and a report on thermal effects of a heated pipeline in permafrost that described how the pipe would float, twist and break.

In 1971, Pecora brought the Menlo Park group to Washington and thanked them for telling the oil companies 'what they can't do,' but now he wanted them to tell the companies 'what they can do.' Pecora locked the door of the conference room and told the group that he would not let them out until they had finished the analysis of the question "To bury or not to bury?" So the group put together the necessary stipulations on the pipeline construction. Among other things, the stipulations required that the pipeline system be designed to prevent oil leakage from the effects of a magnitude-8.0 earthquake on the Denali Fault.

In April 1974, construction of a 400-mile, all-weather road from the Yukon River to Prudhoe Bay was started. Pipeline and storage tank construction at Valdez began in 1975. Large segments of the Trans-Alaska Pipeline were elevated above ground to keep the permafrost from melting, and about half of the 800-mile pipeline was buried. A special fault design was adopted for crossing the Denali Fault Zone. Here the pipeline is supported by rails on which it can slide freely in the event of fault offset. In mid-1977, the first tanker shipped Alaska north slope oil from Valdez.

More than 14 billion barrels (nearly 550 billion gallons) have moved through the pipeline since startup in 1977. After the 2002 quake, the pipeline continued to carry 1 million barrels of oil each day, though it was temporarily shut down for inspection. With the pipeline intact, an important source of revenue for the state of Alaska was preserved. Moreover, as Alaskans know all too well, the consequences to the environment, should the pipeline have failed, would have been catastrophic.

"Good science made the difference between an emergency and a tragedy," said P. Patrick Leahy, USGS. "It's an example of how partnerships between the USGS, the Federal Emergency Management Agency, universities, state and local officials, and business leaders and the community enable us to apply our scientific knowledge. We know we can't stop the Earth from changing, but we can work together making public safety our primary goal."

The 2002 Denali earthquake is the largest seismic event ever recorded on the Denali Fault system — one of the longest continental faults in the world. The earthquake was similar to the magnitude-7.9 1906 earthquake, which ruptured the San Andreas Fault in Northern California. Both fault systems exhibit strike-slip movement, where blocks of continental crust slip horizontally past each other.

"Studying the 2002 Denali Fault earthquake is an opportunity to understand the consequences of a very large earthquake to better prepare for the time when one will occur in a much more densely populated area," said USGS scientist Peter Haeussler.

The Denali Fault earthquake was very directional. It ruptured rapidly over a long distance, focusing the earthquake energy in the direction of the earthquake

Welcome back, so yesterday we were talking about the example from US on the Denali Faults. So, this is one of the biggest example which I told in the last lecture also that the geologist and the Paleo seismologist they took after detail study and then how they saved the pipeline.

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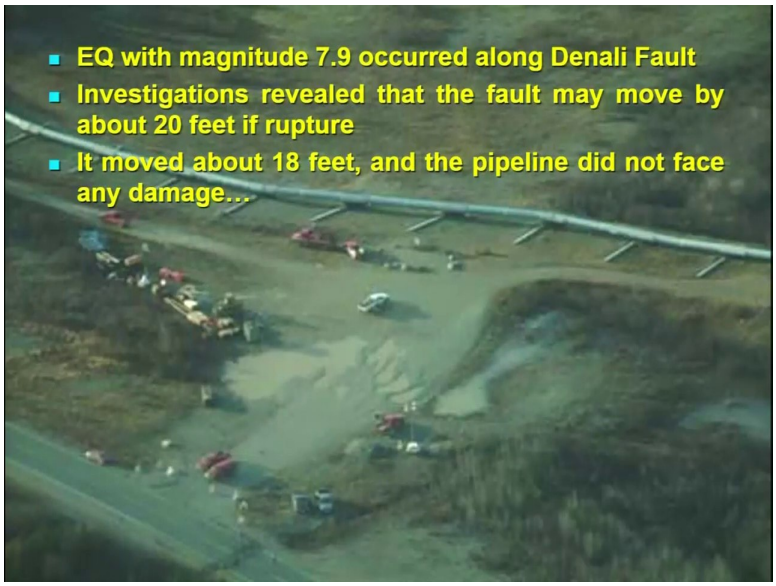

So, this is this is the way how one can minimize the hazard. So, this earthquake was in 2002 belong a Denali Fault and then fault this close to the plate boundary between Pacific and North American plate. So, investigation revealed that the fault may move by about 20 feet and when the earthquake occurred it moved by 18 feet and the pipeline did not face any problems or damage related to that.

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So, this is the after the earthquake photograph was taken, where you can see clearly the exact form of the pipeline which was because of the fault moment and of course also due

to the ground shaking. So, the pipe was made flexible the material was differently used and to withstand the, at the moment as well as ground shaking.

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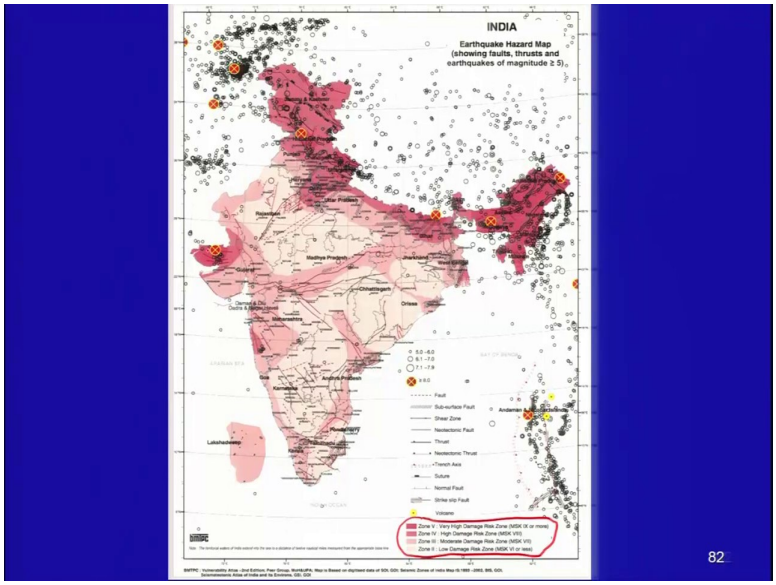

So, as I discussed in one of the slide that in India if you take we have like 4 zones which are been like zone 5 to zone 2, where zone 2 is low damage risk zone and then we are having 3 moderate damage risk zone, then 4 high damages risk zone and very high damage risk zone.

So, this zonation I would say it is an macro zonation, so as we discussed in one of the previous slides that India if we take as an whole in terms of the earthquake hazard; this is what we have the macro zonation on a very large regional scale. The India has been divided into 4 zones we will try to put in very like high resolution or blown up image when we are putting up the slides and all that on line. But if you look at the colour variation is very clear, now the colour variation the darker colour which I am pointing out here is zone 5. So, you can see this over here that is the Northeast and that when then we were moving along this play area in the Northern part Northwest part this whole region is the Himalayan belt and apart from the Himalayan belt in the in the Southern side or the Western side we are having the Kutch and some locations around the Andaman and Nicobar area. So, this all are in zone 5 and we have in total 4 zones zone 5 to zone 2 zone 5 is very high damaged zone and then zone 4 is high damaged zone with slightly lighter colour than what you are having the reddish colour here.

So, lighter colour is over here where I am putting the pointer this all are in zone 4 and then coming to the zone 3, zone 3 is probably this is this is zone 3 actually this is zone 3 which we are putting here right now. Zone 4 is slightly close to the front, but if you look at the red the colour combination the reddish one is over here and then slightly red lighter red is partly somewhere sink here that is in the Indo Gangetic plain and then comes down to zone 3 which is moderate damaged zone. So, this slightly more lighter colour here is all zone 3.

But one thing which I feel is that still we do not have the very good data from this region that is in Narmada zone area which partly falls in Gujarat and then goes in Madhya Pradesh we do not have the good data in terms of the historical earthquakes. But this zone will also be considered or either it will fall in 4 or 5 if we have we get more data on that. So, we can keep improving the zonation map if you are having more data available with us or we incorporate that data or generate that data considering or doing more research in this region along the fault lines.

So, this is one very important problem which it runs here which is termed as Narmada zone fault or normal zone lineament. So, along this there was an earthquake of 1996 or so there was an Jabalpur earthquake in this, but that that can I am not very sure about that here. But yes of course, there was an moderate earthquake in this region and that is definitely a matter of concern for us, that whether this zone is capable of triggering the large magnitude earthquakes in near future or not. Other than that if we come down to this place again we have the 2 zone with the similar light colours, we are having darker colour here and then slightly light here and then lighter become here. So then that this is what we have the zone 5 then, zone 3, zone 4 and zone 3 and zone 2.

So, you have like the variation which goes this side and why this is in zone 5 because, there is there is an historical earthquakes which you have been recorded from this region in 1668 other was in big earthquake and then there was an 1819 there was an big earthquake 1956 there was large magnitude earthquake, of course but not as large as what we experienced in 2001 (Refer Time: 06:42) Earthquake.

So, we have an next the record of couple of large magnitude earthquakes from this region which were more than 7 7.5 more than 7.5 in this region, hence we have this Kutch region is in zone 5 and then comes down to zone 4 which lies in the alluvial plain area

similar to what we see here in the Indo Gangetic plain like Bihar pay Bihar area then some part of Uttar Pradesh Punjab and all that they falls in zone 4 close to the Himalayan range and further if you move here we see again they are there in the alluvial plain and all that these are in zone 3 and then lighter yellow or whitish yellow area all is in zone 2.

So, earlier they we were having so on one which was which was been removed, so as an when we keep on incorporating more data or in we are improving our database then we keep on improving our hazard map also.

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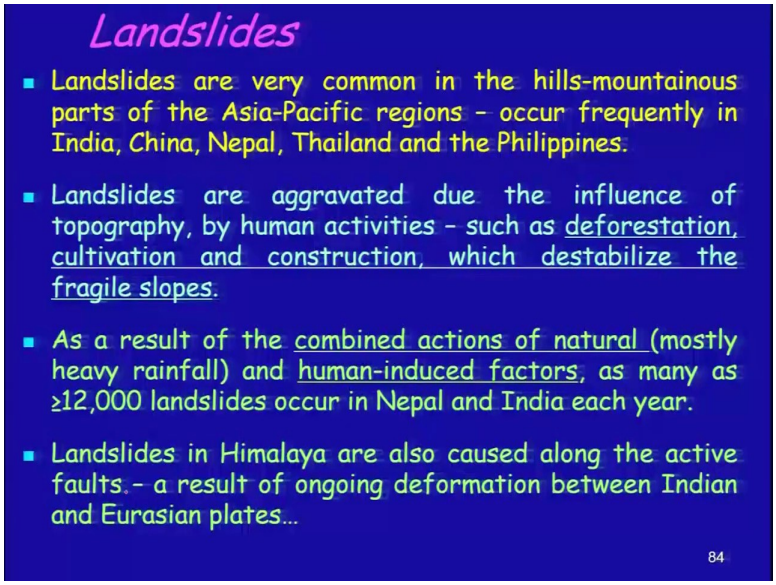

Now, coming to the another part that is landslides or we can say mass waste wasting, this is also important but again as I as I was talking about that every hazard has it is own specific geographic location. You cannot expect all type of hazard at all points it is it is difficult because of the sight conditions and of course the feasibility or we can say the that whether the side is ideal to trigger that type of eventually.

So, landslides are very common in mostly the hilly areas and we know that the hilly tracks been during the monsoon and all that will definitely face or we can say we frequent landslides and the areas in Asia pacific region mostly frequent landslides are experienced in India China Nepal Thailand and Philippine. So, these are in the areas where we are having the hilly tracks, so we will have more landslides in that particular area.

Nevertheless during like seismic shaking we experienced and we recorded a landslip even along the slope or the area where which was having a slope of hardly 2 degrees. So, that is also one important point which we should take into consideration that land slip can also occur even if the land is having or the area is having a gentle slope up to 2 degrees also. So, landslides are aggravated due to the influence of topography by human activity.

Now, topography as we were talking about we will we would say that we if we are having slope and then this area is likely to have the slip if other conditions are fulfilled, like it we have heavy rainfall you are having weak zones or weak material lying sitting on the on the slope that that are prone to the landslides and when the landslide would occur because, if the sediments are losing their shear strength or the capability of holding it they themselves on the on the slope. Another is the deforestation we keep on talking about deforestation. We also learn this at the school level that deforestation is not good but definitely they if you if you keep exposing the slope.

So, if you are having the slope full of trees and then vegetation that what we will say then definitely this will help us in holding the soil over the slope. But if you remove this then you are what you are doing is you are exposing the slope directly to the erosion or you are subjecting the slope material to erosion which will result into the percolation of the water as well as the loss in shear strength of the material. Human interference is deforestation and construction also. So a human interference for example will be like you cut this area for the construction of road, then you are exposing this part further you or you do you put more load on the on the slope that also will result into the destabilization of the fragile surfaces. So, overloading by putting more of more construction material or dumping more material on the slope can also be the region for triggering the landslide.

Now, as a result of the combined action of natural mostly heavy rain and human induced factor as many as greater than 12000 landslides occur in India and Nepal per year. Now this is just based on the your rainfall. But if suppose there is an earthquake in this region because, this both the both regions in the Himalayan side are prone to earthquakes also and if there is an earthquake then also the landslide will be triggered.

So, landslide can be triggered in 2 fold either it is because of the earthquakes or because of the heavy rain and now recently as I mention in the last month only there was a

landslide which was been triggered by volcanic eruption in Indonesia. So, landslides in Himalayas are also caused along active fault this is what I was talking about, the active faults when we are talking we say that they are going they are capable of triggering the earthquake or they are the places where we will have the surface displacement will result, then this is this is because of the ongoing deformation between Indian and Eurasian plates.

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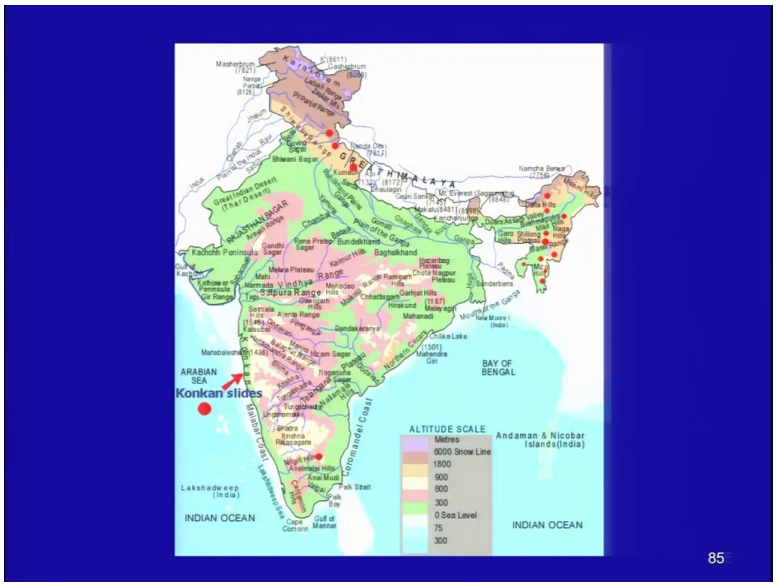

So, these are the locations which are been shown which are the areas in India which are prone to landslides mostly in the hilly tracks. So, we have a Northeast lot of landslides are been triggered this has been left out, but therefore there is a part of the Himalayan organic belt. So, we have landslides and Nepal and in this region also and partly we see along the Konkan slide. So, you will find a lot of news during monsoon at this area is experiencing more landslide. So this is because of the lithology the rock type in that area as well as because of the heavy rain. So, prominent areas of landslide in India map showing landslide affected states.

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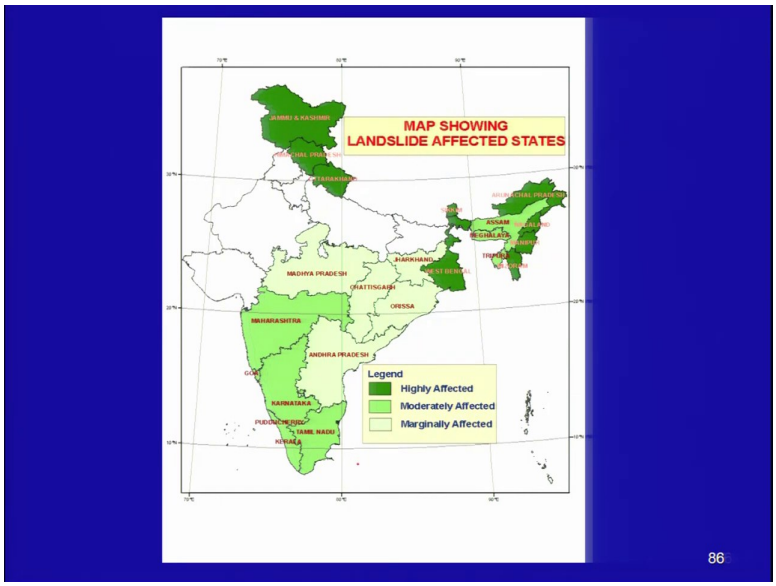

So, darker green colour is highly affected and lighter one is moderately affected and lightest is marginally affected.

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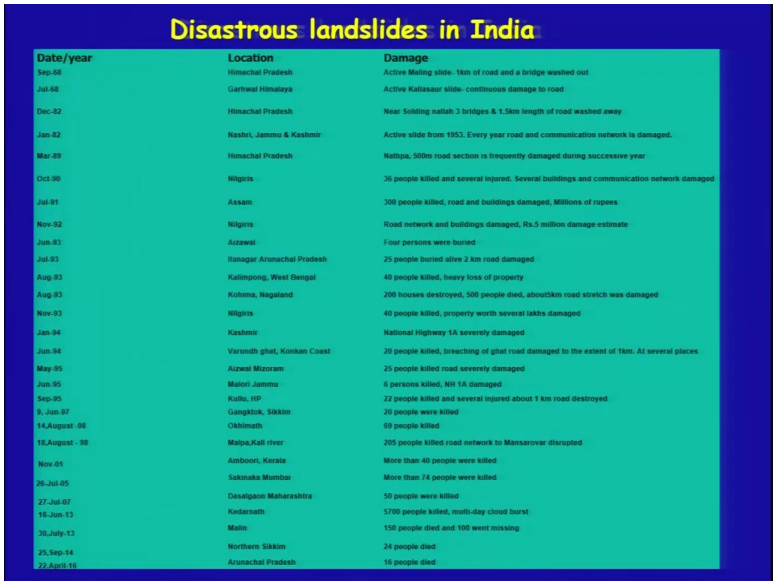

These are couple of events landslide events which we have been experienced since 1968 to see 2016 in India.

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Landslide in Nepal because of heavy rain.

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Pune landslide in 2014 again it was subjected to heavy rains and in Bihar also as well as in Nepal in 2015 or 2014.

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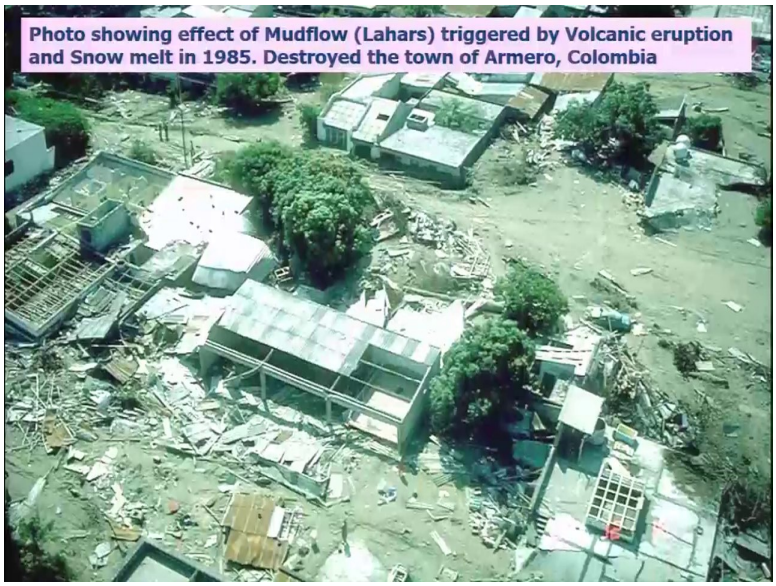

This picture is bit interesting it shows the effect of the material which move down during a landslide or mass movement and if you just carefully look at this half of this house is been covered in debris. So, lot of course or material will be transported during landslide and one example is from here the boulder huge boulder which was been transported or moved and also the material which has been seen here comparatively fine and then this one but these are all (Refer Time: 16:08) material. This is an example of a mud flow which is termed as Lahar triggered by volcanic eruption.

So, in previous lecture I one of the lecture I was talking about the Lahar flow, so Lahar flow is an typical mud flow which is been triggered if you are having any snow or cap volcanic cones. So, when it when the lava is poured out on the area then the snow covered will melt and will result into the Lahar flow or the mud flow which is termed as Lahar flow. So, this occurred in 1985 which destroyed the town of Armero and Colombia, so this is termed as a Lahar flow. So, this you can keep in mind that wherever we are having the volcano capped by snow will result in to the Lahar flow when there is an eruption.

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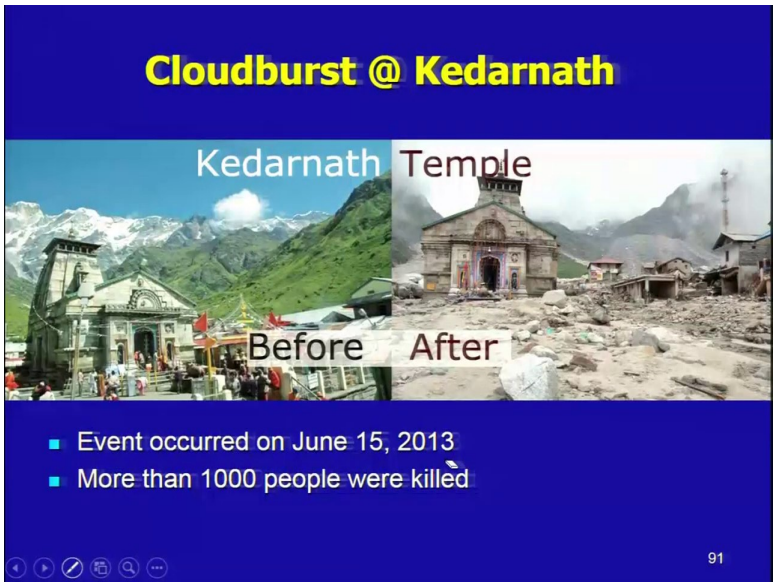

Now, coming to the next has a part of the landslide is the Kedarnath event which occurred in 2013 and this 2 photographs which shows that how devastating it was the temple remain intact, either you consider that was because of the met or religious effect. Of course there may be, but let us not get into that but yes the temple did not face any issues during the landslide or the debris flow again you can look at the size of Clast here. It is a huge and one of the photograph which is not shown here, but we saw that in public domain had a very large boulder which came and stopped behind this tower of the temple which was responsible for saving this time.

But surrounding the houses and shops and everything was been completely destroyed. So, this happened on June 15 and June is the months or is this the month during one of the month during the season were was the monsoon season. The heavy rains was one of the reason, but it was the cloud burst or southern pouring of the and the water and more than 1000 people were killed in this event.

Now, the geologists or the Sedimentologist what they identified later on that similar type of debris deposits were preserved in sedimentary sections which clearly suggest that in past also this area experienced similar type of events. So, you can go into the past through the signatures which are available either at the surface on the surface in form of some records in sediments and try to reconstruct the history. So, this was been done but

this was done after the event and people have been talking about the scientific group has been talking about that they were similar type of events in the past also.

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This move in this picture is here which shows that lot of big boulders which came and stopped behind this tower and was responsible for saving the whole structure, but rest of the area was completely in mess. So, damage was severe because of sudden pouring of huge amount of water due to cloud burst and which triggered in turn the debris flow.

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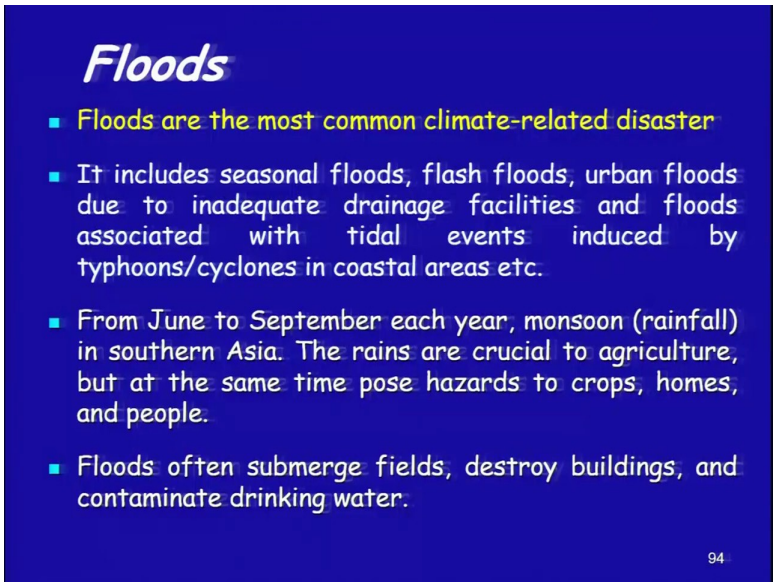

Coming to Floods, floods are the most common climate related disaster it includes seasonal flooding flash floods, urban floods. Now urban floods are mainly because of the inadequate drainage facility and floods associated with tidal events which are induced by typhoon cyclones in the coastal areas. So, inadequate facility of what the question is that inadequate of our facilities of what the inadequate facilities of drainage we are talking about, the drainage which is responsible to remove the excess water as fast as possible from that particular area.

So, we can say the storm sewer or the natural sewer lines are choked one is one maybe that may be one of the reason, that it does not allow the flood water to flow through as quickly as possible or we have come in between in terms of the urbanization we have come on the way of the drainage which existed in the past. So, we have somehow blocked the flow paths of that, but those particular streams and came up with constructions or we are not having the good plan for draining out the water as fast as possible.

Now, from June to September each year monsoon in Southern Asia is experienced, the rains are crucial for agriculture but at the same time poses hard to crop homes and people floods often submerged fields destroy buildings and contaminate drinking water. So, when there is no rain we cry but when there is excess rain we again cry. So, these are the problems which are associated with heavy precipitation in any particular area if we are having inadequate drainage facility.

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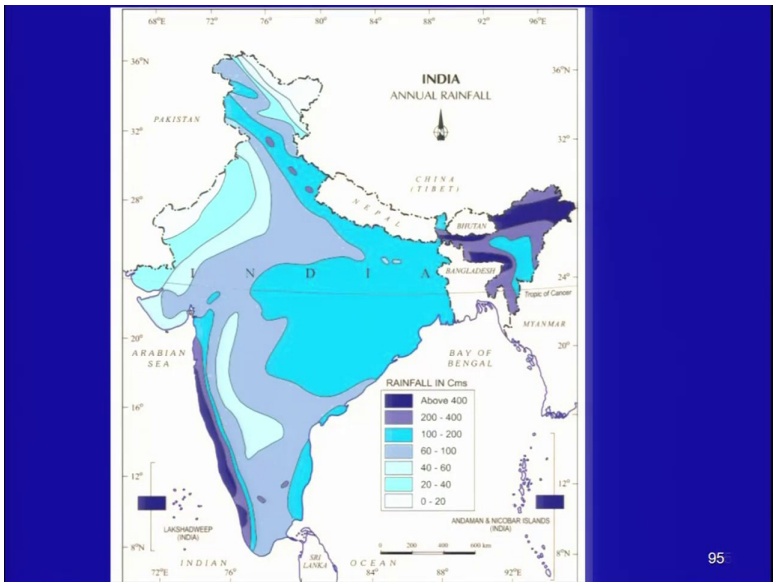

Now, this just to show you that what is the scenario around the Indian part, we have the areas which are receiving very heavy rain like amount of rainfall about above 400 centimetre which are shown by dark blue colour and then 200 to 400 by lighter one and then fluorescent blue 100 to 200 centimetre a very huge area of India. Then comes down to even 0 to 20 which is of course, in the area along the third region this is third desert to Rajasthan area.

So, one can easily make out that the areas which are having very high rainfall or which are going to experience very high rainfall during monsoon will be prone to flooding, but it may be other way around. The areas which are having like in this region where one of the area is Delhi which always experience flooding the metros areas like Bombay which always experience flooding and many such metro cities are experiencing flooding. Even with slight higher rainfall or in that particular period all are because of the inadequate drainage facility which is available there.

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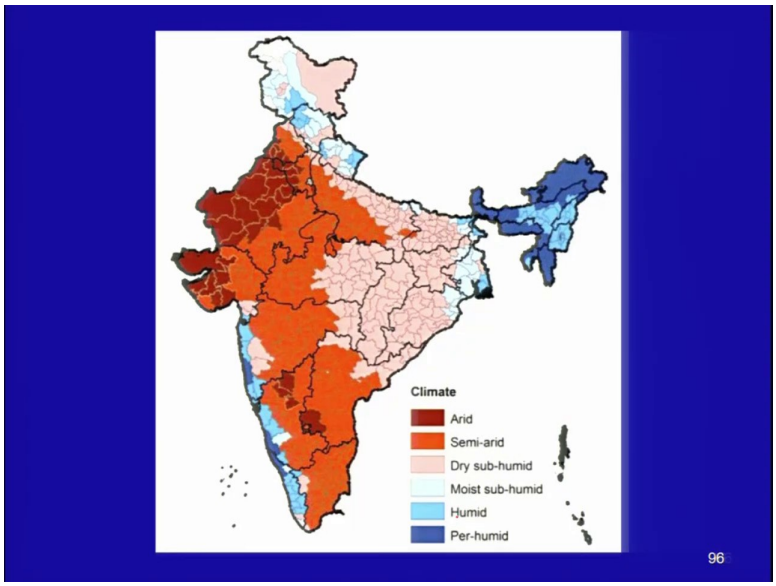

Now, based on the rainfall and other atmospheric parameters the areas have been divided into arid semi arid dry, of course the arid area is the area which has which is likely to have or receive a very less rainfall as compared to the other area and then the area which you we were talking about heavy rains and the annual rainfall is very high are marked by the blue here and it termed as pre humid area and then, we are having a little bit higher than there like less than that it is humid and moist areas.

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Now, in India regions like Bihar Uttar Pradesh Gujarat Maharashtra are facing flooding problems every year. Now in addition to that since last couple of years if you look at like a Rajasthan and Kutch region, Rajasthan and Kutch region of are here. So, Kutch region is in arid which receives less rainfall and then we are having the Rajasthan again it is an arid or semi arid area which receives less rainfall they are also experiencing flooding. Now most of the floods which we have been experienced in Kutch and that is an area of Gujarat and Rajasthan where because, of the heavy rain or sudden pouring out of the water in a very short period.

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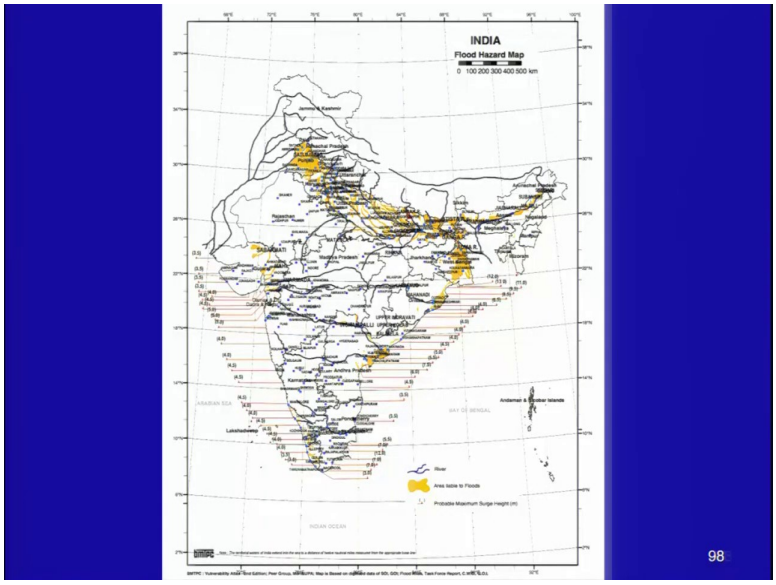

So, the coastal areas are also having their own issues. So again the this is these are the maps which I was showing in the previous slides also most of the maps are from a BMTPC. This shows other records of that what will be the wave heights and because of the either during the high wave and then what will be the flooding conditions which may experience. So, these are the recorded wave heights along this area which had been given here in numbers.

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Now, this is a very good example from Gujarat, there was and the flooding experienced in Surat. So, what I will do is build an very interesting story and need more time, so we will continue in the next lecture and discuss more about the man made or human induce flood in this part of India, that is a Western India Gujarat the city name is Surat.

Thank you so much.