Engineering Hydrology
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Module: 2 Lecture 20
Presentation of Rainfall Data

Hello all, welcome back, we have been discussing about precipitation, after that we have seen the different ways of measurement of rainfall. So, rain gauges are used for the measurement of rainfall, we have seen the types, different types such as recording and non-recording types. So, in India majority of the rain gauges which we are using is the recording type, earlier days we were using non-recording types, now we are using the recording type of rain gauges.

So, once we get the data from the rain gauges, how can it be presented, because we have to make use of these data for our hydrological analysis. So, flood related studies, drought related studies all these requires the precipitation data especially the rainfall data. So here we are discussing about the rainfall data. So, let us see how it can be presented in this lecture.

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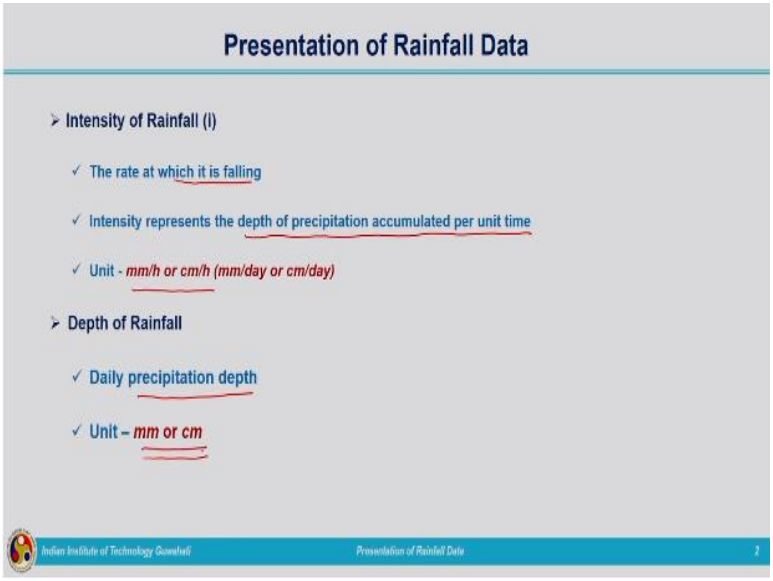

So, first way is by means of intensity of rainfall, we commonly use the term intensity of rainfall, sometimes we will be using the term rainfall depth, so these are different ways of representing rainfall. Let us see one by one. Intensity of the rainfall is the rate at which it is falling, that is we are getting the rainfall that is collected in the rain gauge and that will be automatically giving us the reading in the case of recording type of rain gauges.

So, certain amount of rainfall is recorded at an interval of time, so the rate at which the rainfall is occurring that is termed as the intensity of rainfall. So definitely the unit of this intensity of rainfall will be in terms of millimeters per hour or centimeters per hour that is this much of depth of rainfall has occurred within this much duration of time.

It can be in millimeters per hour or it can be in millimeters per day depending on the time duration we are considering or in centimeters per hour or centimeters per day or monthly ways will be representing that will be in centimeters per month. So, the intensity represents the rate of precipitation accumulated per unit time. How much is the rainfall which has occurred for a particular duration of time that is what is termed as intensity of rainfall.

Now, coming to depth of rainfall. Depth of rainfall we will be getting that is the this much of depth of rainfall has occurred at a particular point, that is rain gauges will be giving us the point measurement of rainfall. So, the depth of rainfall is the daily precipitation depth. How much is the rainfall which has happened at a particular location, so that is the daily precipitation depth and the unit of depth of rainfall is the unit of length, it can be in millimeters or in centimeters.

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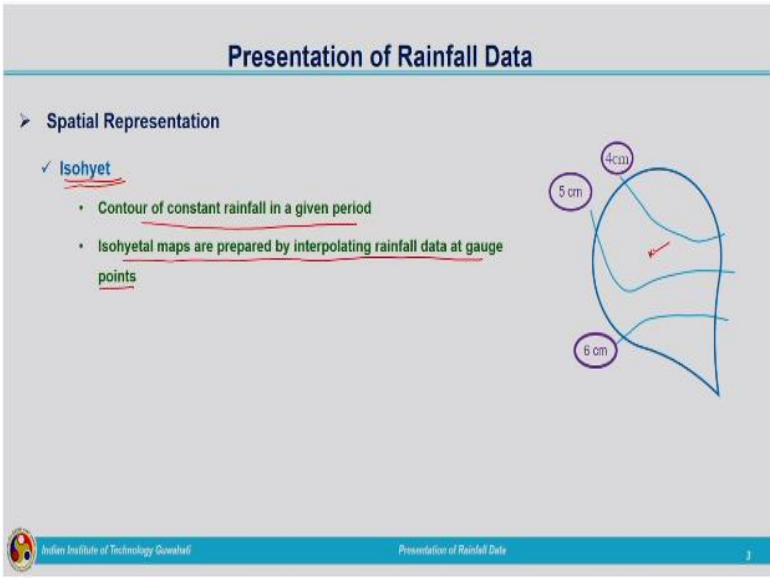

Now, when we talk about rainfall, spatial variability is also there, temporal variability is also there, that is you take a large area at different, different locations we will be having different rainfall values. At one particular location you will be experiencing rainfall, at the same time some other location would not be having rainfall, so much of variability is there for rainfall when we are talking in terms of spatially and also temporally. So, spatially how can we represent rainfall at a particular time, how the rainfall intensity is varying at different, different locations. So spatial representation can be done by means of isohyets.

What is meant by this isohyet? These are contours which are having the equal amount of rainfall, points which are having equal amount of rainfall is connected by means of contour lines, those contours are termed as isohyets. Isohyets are the contours of constant rainfall in a given period. So, based on the contours which are developed we can develop the Isohyetal map for the entire area. So, these Isohyetal maps will be giving us idea about the spatial variability of rainfall at a particular period of time.

So, Isohyetal maps how can we prepare? Isohyetal maps are prepared by interpolating the rainfall data at the gauge points. Spatially if we consider we will be having so many numbers of rain gauges, so from these rain gauges whatever rainfall data we are obtaining

that we will be analyzing, from that we can make out which are the locations having the same rainfall, those locations will be connected by means of contour lines representing the equal rainfall depth.

So, consider let this be a catchment, in that points which are having the equal rainfall depth are connected by means of lines, that is what is termed as the isohyet. So that way different isohyets will be representing different depth of rainfall. So, if this is 4-centimeter rainfall, it can be of 5 centimeters rainfall, this can be of 6 centimeters rainfall these values depend on the rainfall which has occurred in that particular catchment.

So, if we want to get the rainfall at this particular location, that is coming between the isohyets of 4 centimeter and 5 centimeters, so we can find out the average of these values 5 plus 4 divided by 2 for getting the value corresponding to this particular point. So, averaging of the rainfall value corresponding to two isohyets will be taken for getting the spatial distribution of rainfall within these two isohyets.

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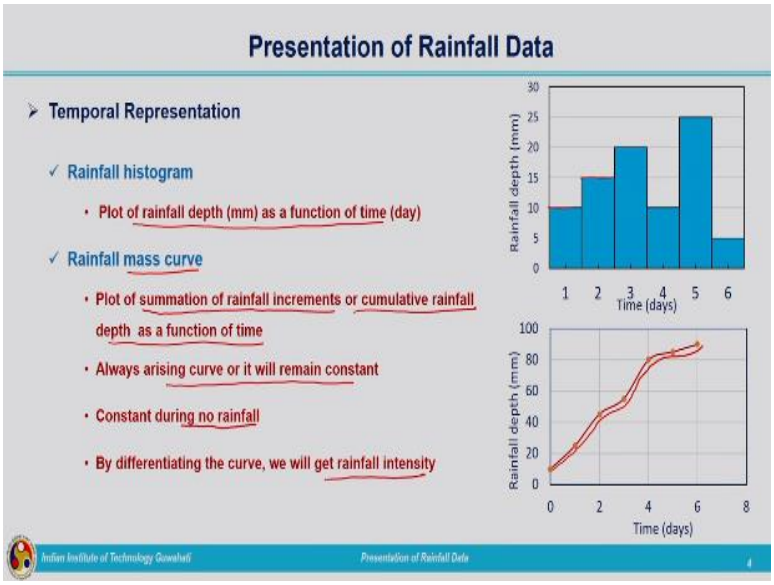

Now, coming to temporal representation when we talk about temporal representation, first commonly used representation is by means of rainfall histogram. So, in this what we are doing whatever rainfall depth we obtain from the rain gauge that will be plotted

against the time, it is plotted as a bar chart so that is termed as the rainfall histogram. So, this is the plot of rainfall depth as a function of time, along the y axis we will be plotting the rainfall depth and along the x axis we will be plotting the time.

So, rainfall depth can be in millimeters or centimeters, so this is a plot which is rainfall depth versus time, so it will be looking like this, this is a very simple plot, bar diagram with rainfall depth versus time. So, every day 24 hours how much rainfall is obtained, first day we are having 10 millimeters of rainfall, second day we are having 15 millimeters of rainfall that will be represented by using bar diagram, that is the rainfall histogram.

Second way of representing the rainfall is by means of rainfall mass curve. Rainfall mass curve is representing the cumulative rainfall, that is for 24 hours we are getting the rainfall, rain gauges will be recording the rainfall data for first 15 minutes that is in a cumulative way it will be marking. So that will be plotted, that is cumulative rainfall plotted against the time that is the rainfall mass curve, that is the plot of summation of rainfall increments or cumulative rainfall depth as a function of time. So, cumulative rainfall curve will be always a rising curve, that is it is increasing, in case for a certain period there is no rainfall then it will be a flat curve it would not be decreasing anyway it will be a flat one or increasing curve.

So, rainfall mass curve will be looking like this. Here I have considered 8 days time and the rainfall value you can see it is increasing only. In this way it is increasing as time increases rainfall depth is also increasing because it is the cumulative value, first day how much is there, second day how much is there, everything will be added up to eight day if we are checking it is giving all the entire eight days how much is the rainfall occurred that value we will be getting by making use of mass curve. And it is always a rising curve or sometimes it will be a constant, constant during no rainfall, never be a decreasing curve. And if we are differentiating this particular curve we will get the rainfall intensity.

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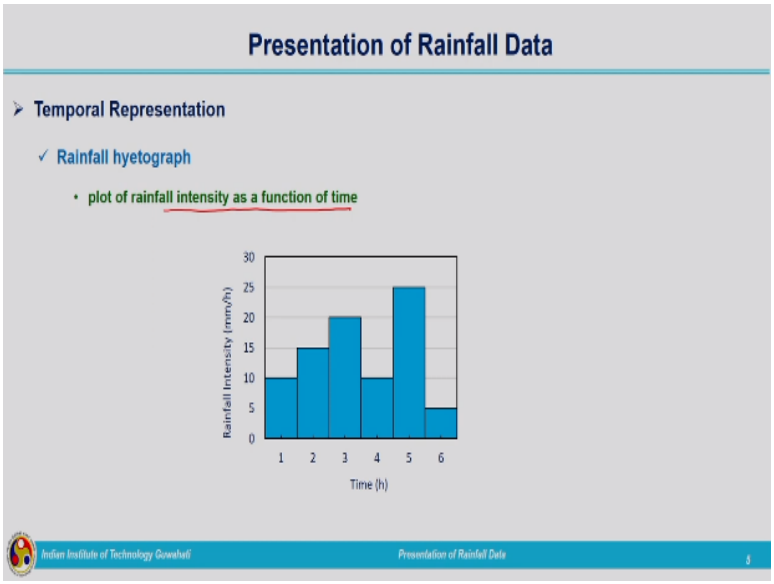

Now, another way of representing temporal representation is by making use of hyetograph, rainfall hyetograph. This is a very commonly used representation. Rainfall hyetograph is the plot of rainfall intensity as a function of time. What is intensity you already know, that is the depth of rainfall per certain duration of time. So, this plot is rainfall intensity along the y axis and time along the x axis we are plotting, this is the rainfall hyetograph.

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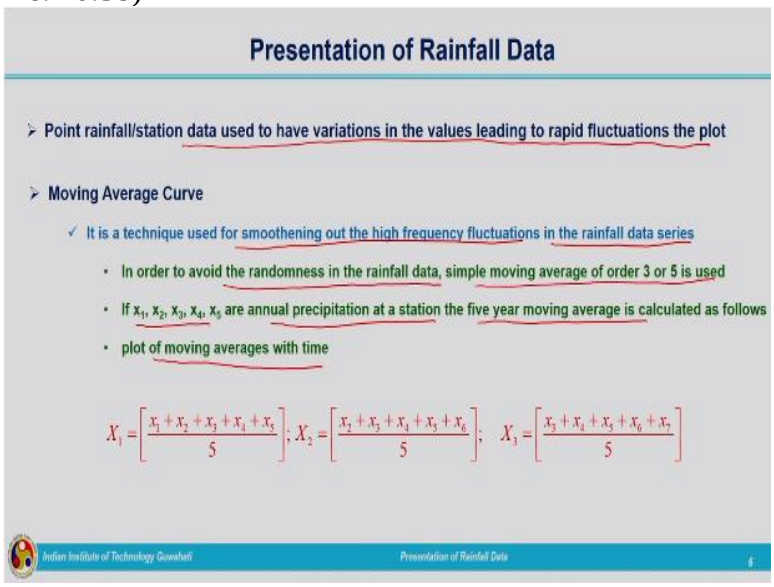

Now, we should understand, we have seen different ways of representing the point rainfall, point rainfall means at a particular location we are having the rain gauge, rain gauge is giving us the rainfall data that is plotted. So, this rain gauge data is not giving us the spatial representation, it is only giving us the temporal representation of the rainfall data.

So from the point rainfall data, different locations which are having the same or equal depth of rainfall will be marked by means of a line that is the contours which is having the equal rainfall depth is termed as the isohyet. Different isohyets can be utilized for producing the Isohyetal maps that will be giving us the spatial representation and temporal representation we have seen it will be different for different rain gauges. So, one particular temporal representation, hyetograph or mass curve or the histogram will be representing the rainfall which is collected from a particular rain gauge, so this is a point rainfall representation or the station representation.

So, this point rainfall or station data used to have variations in the values leading to rapid fluctuations in the plot. What does it mean? That is rainfall value if you see sometimes there will not be any rainfall and during a rainy day itself there will be a lot of fluctuations taking place in the data, sometimes heavy rainfall will be occurring, sometimes it will be continuously raining, so much of fluctuations will be there in the rainfall data.

So, when we are looking the station data because of this fluctuation it is very difficult to understand whether it is following a certain trend or whether it is changing in the accurate way that is if the there is any pattern in the rainfall data. So, for understanding there is any trend or not from the station data it is very difficult to understand or sometimes for some hydrologic analysis we may need to smoothen out these fluctuations, these fluctuations are of no interest to us, so we may have to smoothen out this curve by doing certain techniques.

How can it be done? So, it can be done by means of a statistical technique termed as Moving Average Curve. So, what is moving average, what we are doing in this? In this what we are doing, for smoothening out the high frequency fluctuations which are

presenting the rainfall data we will be doing certain averaging, as the name suggests moving average. So, averages are calculated from the rainfall data, so this is a technique for smoothing out the high frequency fluctuations which are present in the rainfall data.

So, in order to avoid the randomness in the rainfall data, simple moving average of order 3 or 5 is used. Commonly used moving averages are 3 data points considered average taken, 5 data points considered average taken, how it is done we will see but this is utilized for in order to avoid the random fluctuations. You can imagine a rainy day, that day morning it may be heavily raining and afternoon no rain and evening again rain started, so these type of peaks or fluctuations can be smoothened out by means of these moving averages.

So, this we will be commonly doing for the annual rainfall data series when we are doing the studies related to drought related studies and hydrological studies which need rainfall data, sometimes we are not giving much importance to the fluctuation, we need to have the smooth curve. In such cases will be making use of this moving average technique.

If we are having 50 years of data, annual data if we are representing 50 data points will be there. So how can we calculate the moving average? For example, we can consider x_1 to x_5 these are annual precipitation at a station. Then the 5-year moving average can be calculated like this, that is how we will be calculating average of these 5 values will be calculated, after that we will plot the moving averages with time. Averages which are calculated from the five data points x_1 to x_5, x_2 to x_6, x_3 to x_7 these averages calculated this will be plotted against time.

How these moving averages can be calculated? X_1 can be calculated from the first 5 data points, first 5 annual series data points

$$X_1 = \left[\frac{x_1 + x_2 + x_3 + x_4 + x_5}{5} \right]$$

In the similar way second data point in corresponding to the moving average will be X_2 will be the

$$X_2 = \left[\frac{x_2 + x_3 + x_4 + x_5 + x_6}{5} \right]$$

and corresponding to third data point it will be x_3 to x_7 divided by 5, summation of 5 terms will be taken as

$$X_3 = \left[\frac{x_3 + x_4 + x_5 + x_6 + x_7}{5} \right]$$

and the average will be found out and these X_1, X_2, X_3 up to X_n will be plotted to get the moving average curve. This curve will be a smoothened curve which will not be showing the fluctuations present in the individual data points. So, that will be clear when we solve some numerical example. So, these are the different ways of representation of rainfall data.

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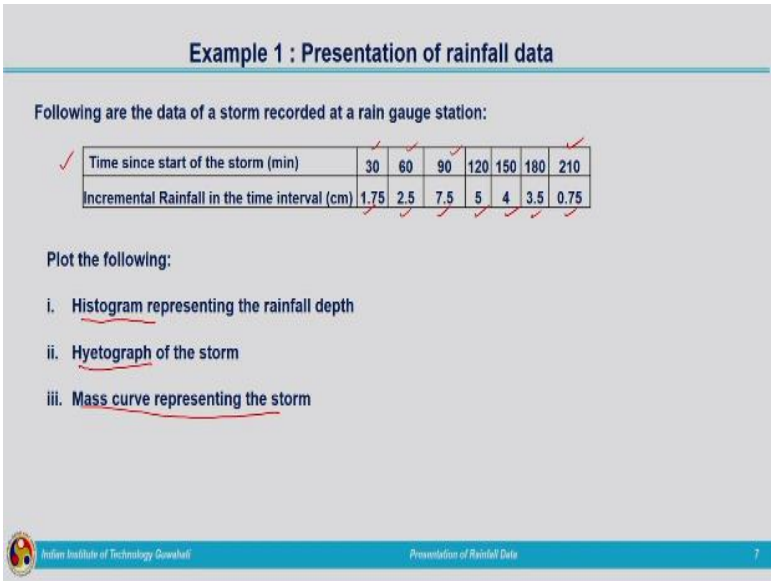

Now, let us solve some numerical examples related to the representation of rainfall data. First example is related to presentation of rainfall data. Let me read out the question, following are the data from the storm recorded at a rain gate station, data is given to us that is the table containing time and incremental rainfall depth. Time since the start of the storm and incremental rainfall in the time intervals given in centimeter. What we need to

calculate, we need to plot the following: histogram representing the rainfall depth, hyetograph and mass curve representing the storm.

The rainfall details at a particular rain gauge is given to us, we have to plot three graphs: histogram, hyetograph and also mass curve. Rainfall data is given to us, time is given in minutes and you should be careful what kind of data is given, it is the incremental rainfall data, for each time interval how much is the rainfall which has occurred that is given to us in this particular table. So, when time if we are looking at this is 30 minutes, 60 minutes, 90 min up to 210 minutes. At 30-minute intervals within that increment how much is the rainfall occurred that is given in the table.

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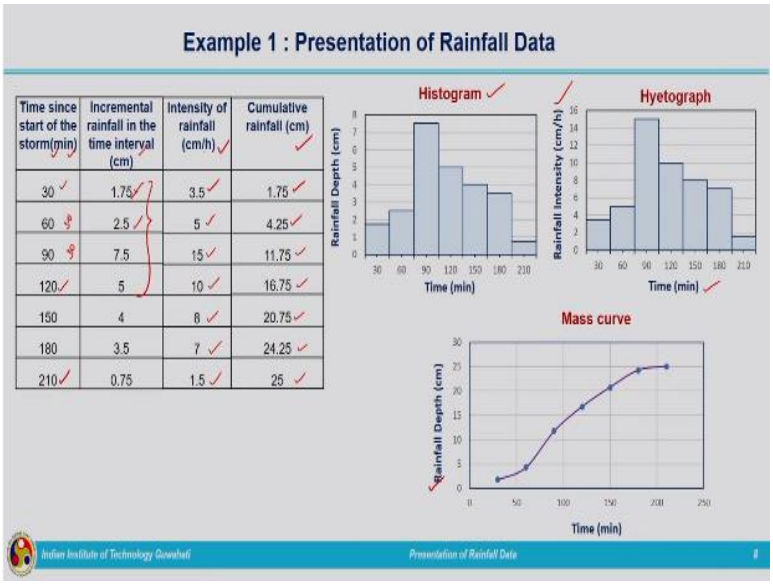

So, now let us start solving the question. So, time since the start of the storm is given, this is the question given to us, incremental rainfall in that particular time interval in centimeters also given to us. First what we will do, this will be plotting that is the rainfall depth versus time, that will be giving us the histogram, rainfall histogram. So, rainfall depth given data, that is for each increment how much is the rainfall depth, that is plotted rainfall depth versus time is plotted to get the histogram.

Now, what we need to do, we need to plot the hyetograph, what is hyetograph? Hyetograph is the plot which is plotted against rainfall intensity versus time. So, we need to calculate the rainfall intensity first before plotting the rainfall hyetograph. So, intensity how can we calculate, how much is the depth of rainfall divided by the incremental time. So, intensity of rainfall is given by 1.75 divided by 30 minutes, that is represented in centimeters per hour, so 30 minutes has to be converted to corresponding hours 30 divided by 60, that is 0.5 hours. So, 1.75 divided by 0.5 will be 3.5.

Now, coming to second interval, what is time, 30 minutes, 60 minutes time interval is again 30 minutes. So, you should be careful about the time, this is again interval is 30 minutes, time interval is 30 in all the cases, so you will be dividing the rainfall depth by that particular incremental time. So that way you will get the rainfall intensity

corresponding to each and every increment. This intensity will be plotted against the time that is the hyetograph. Rainfall intensity in centimeters per hour and time in minutes is plotted, so that is up to you, it can be in rainfall intensity centimeters per minute, it can be plotted against minute, so that is depending on our requirement will be plotting. So, intensity versus time is the hyetograph.

Now, third one is asked to plot the mass curve. How can we plot? Mass curve is the curve representing the cumulative rainfall depth versus time. So, we need to calculate the cumulative rainfall, so each and every incremental rainfall should be added up to get the cumulative rainfall up to that particular time.

So, first let us make the tabular column for that for plotting the mass curve that is initially for the 30 minutes it is 1.75 only. Now, coming to 60 minutes it is inclusive of the initial 30 minutes rainfall and also that incremental rainfall, it is the sum of 1.75 and 2.5 that will be coming to be 4.25 centimeter. In that way cumulative rainfall value will be calculated until we reach 210 minutes.

So, 120 minutes, for 120 minutes up to 120 minutes what is the rainfall occurred. All these 1.75, 2.5, 7.5 and 5. All these rainfall depths will be added together to get the cumulative rainfall at the time of 120 minutes. That way we can calculate the cumulative rainfall depth corresponding to each time. This cumulative rainfall in centimeter will be plotted against time that is our mass curve.

So, mass curve is the cumulative rainfall depth not the simply rainfall depth, it is the cumulative rainfall depth versus time. So, you can see from the figure it is a rising curve, mass curve is a rising curve. In case there is no rainfall for a particular increment then in that case it will be taking a horizontal that is it will be constant, there will not be any rise taking place it can never be a decreasing curve. So, these are the three ways of representation, temporal representation histogram, hyetograph and mass curve.

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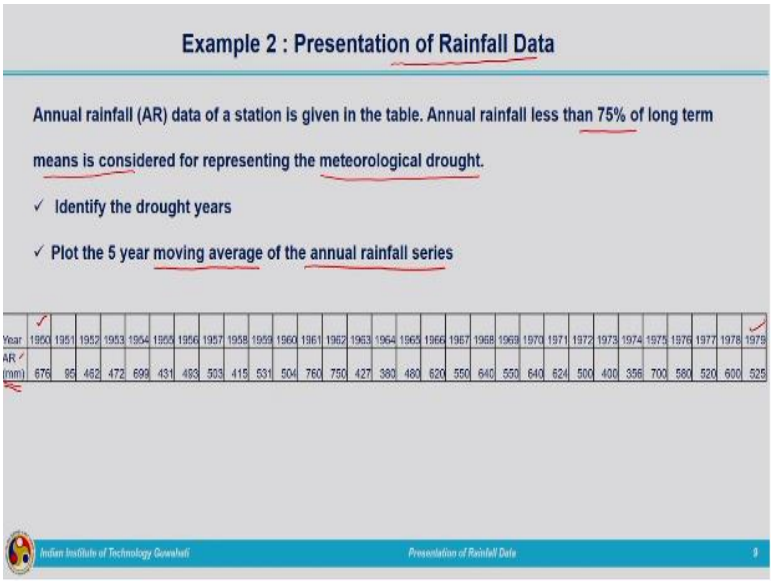

So, second example is on presentation of the data by means of moving average technique. Question is annual rainfall data of station is given in the table, annual rainfall less than 75% of long-term means is considered for representing meteorological drought. Identify the drought years, plot the 5-year moving average of the annual rainfall series.

So, what we need to do, we need to identify the drought year, condition is given to us, annual mean we will be calculating, out of that if the rainfall in a particular year is less than 75% of annual average rainfall then that particular year will be representing a drought year, that is meteorological drought year. Meteorological drought means the drought is due to less rainfall which has happened in that particular year.

So, this is the data series, you can see starting from 1950 to 1979, almost 30 years annual rainfall data is given to us. Annual rainfall is given in millimeters, unit of millimeters so that is given for 30 years data. So, first we need to identify the drought years and after that we need to calculate the 5-year moving average curve.

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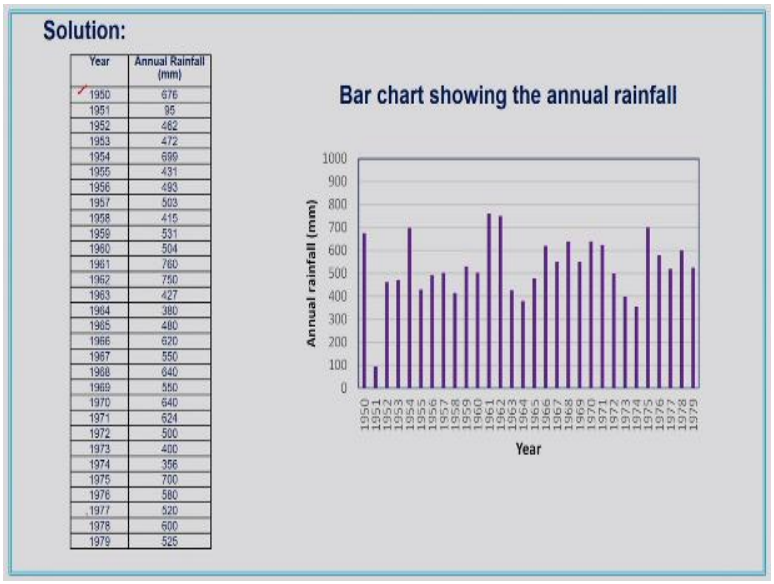

Let us start with the data first, so this is the data given to us. If it is not in the chronological order, you can order it in the chronological order and after that we will just plot the bar diagram, bar chart showing the annual rainfall. This is a simple curve, the tabular representation of the data in the schematic way, that is the data which is given as such we have plotted as a bar chart. So, annual rainfall along the y-axis and time in years along the x-axis plotted. So, this is the data in the schematic representation. Now, what we will do, we will calculate the mean of the entire series from 1950 to 1979.

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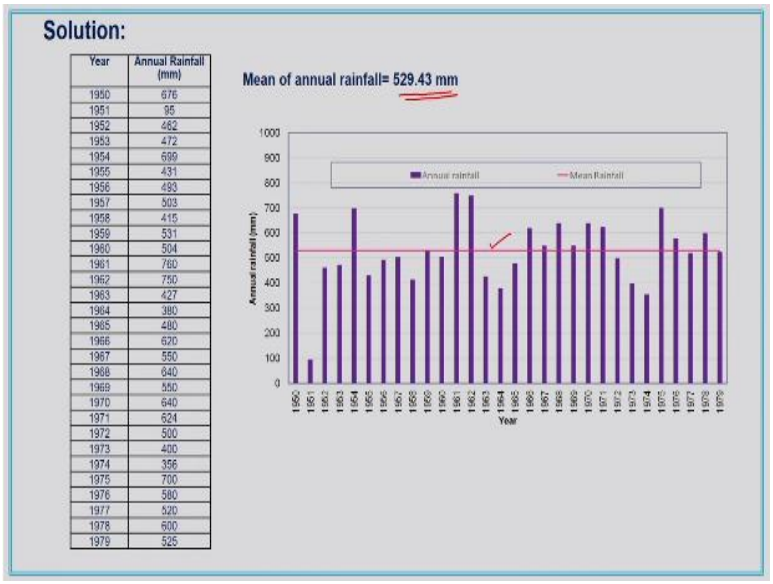

That average is calculated to be 529.43 millimeters. Just simple average we are calculating, so that can be plotted like this, we are having the bar diagram representing the rainfall for different years and after that we have plotted the mean rainfall data, mean annual rainfall data represented by a line. So, you can see here some of the years data is above the mean value. So, some years are below the mean value. Average rainfall is there, beyond that also some years they obtained the rainfall and some years were having the rainfall which is below average.

What is our question, we need to find out which are the years where there were chances of meteorological drought? So, for that condition is given 75% of the mean value needs to be calculated and the years which are experienced a rainfall, annual rainfall which is less than the 75% of the mean annual rainfall, that particular year will be considered as the year of meteorological drought.

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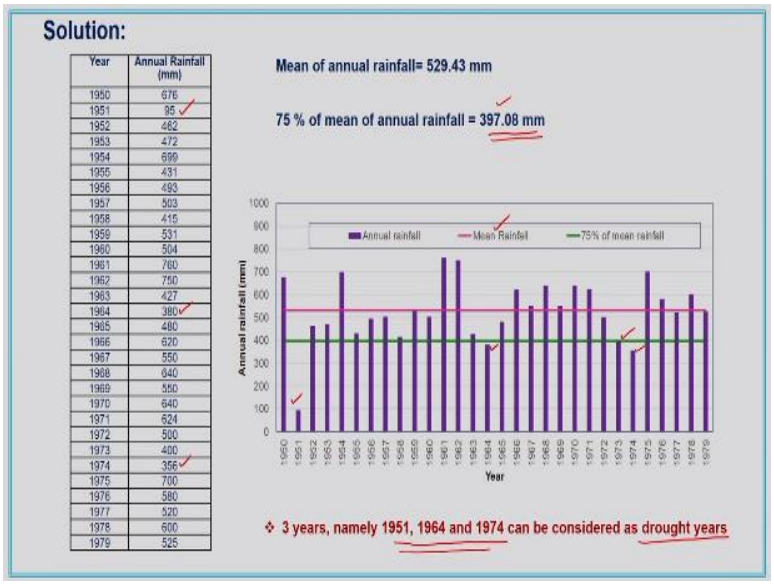

So, now let us start the 75% of this main annual rainfall. It is coming out to be 397.08 millimeters of rainfall. So, we can plot it again in the same plot, this green line is representing the 75% of the mean rainfall. Our bar chart is there, mean rainfall is plotted by means of the pink line and 75% of the mean rainfall is plotted by means of the green line. Observe the graph carefully, you can see less than 75% of main rainfall is there in the year 1951, then comes the year 1964 and 1974. 1951 you can check it is coming out to be 95 millimeters of rainfall and 1964 it is 380 less than 397 and comes 1974, 1974 we have experienced 356 millimeters of rainfall. So, these three years were experiencing the meteorological drought. Three years 1951, 64 and 74 can be considered as drought years, especially the meteorological drought because lack of rainfall has happened during these years.

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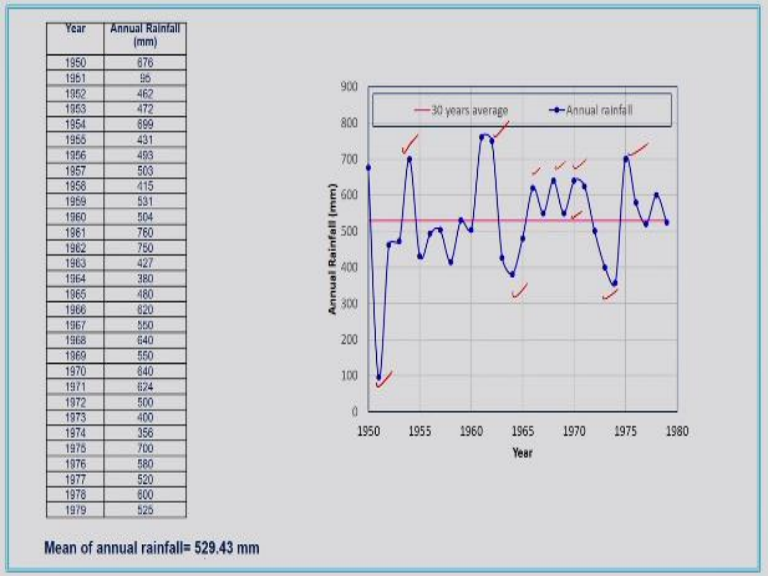

So, first part of the question is over. Now let us move on to the second part. What is the second part, moving average corresponding to 5 data points need to be there. So, mean annual rainfall is 529.43 millimeters, we know already. So, we are going to plot the moving average curve. Before that we need to know what is the need of moving average. You look at this curve, this is simply the annual rainfall is plotted as a line diagram.

So, here you can see fluctuations, so a dip in rainfall, then increase in rainfall, fluctuation is here, all these fluctuations are seen in the data point, of course, we are getting an idea that it is above the mean value or below the mean value, but we are not getting whether it is following any trend or any cyclic pattern, nothing is clear from this particular diagram, all these fluctuations are present.

So, why we are going for moving average curve? We need to smooth out this curve which are required depending on our hydrologic study. Annual average value is plotted and the actual annual rainfall is also plotted. Now, what we need to do, we need to plot the moving average curve.

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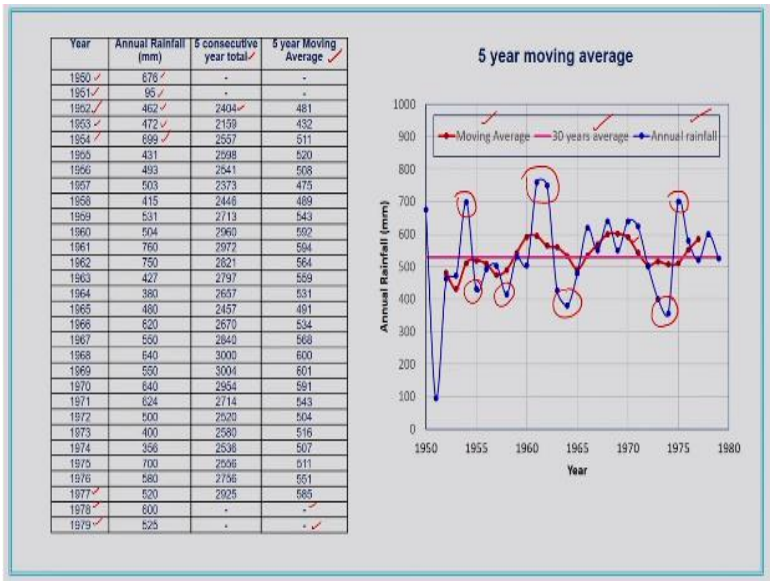

Year	Annual Rainfall (mm)	5 consecutive year total	5 year Moving Average
1950	678	-	-
1951	95	-	-
1952	462	2404	481
1953	472	2159	432
1954	699	2557	511
1955	431	2598	520
1956	493	2541	508
1957	503	2373	475
1958	415	2446	489
1959	531	2713	543
1960	504	2960	592
1961	760	2972	594
1962	750	2821	564
1963	427	2797	559
1964	380	2657	531
1965	480	2457	491
1966	620	2670	534
1967	550	2840	568
1968	640	3000	600
1969	550	3004	601
1970	640	2954	591
1971	624	2714	543
1972	500	2520	504
1973	400	2580	516
1974	356	2536	507
1975	700	2596	511
1976	580	2756	551
1977	520	2925	585
1978	600	-	-
1979	525	-	-

For that we need to calculate the moving average first. So first we will be calculating the 5 consecutive year total. So here it is asked to calculate the 5-term moving average. So, 5 consecutive years total, 1, 2, 3, 4, 5 we have calculated and where do we place that particular value. We got the sum of these 5 years data to be 2404, that will be placing at the middle, 5 data points will be placing at the third data point, that is 1950, 51, 52, 53, 54, 1, 2, 3, 4, 5 so we are placing the data corresponding to the year 1952.

If we are considering 3 terms we are calculating the moving average corresponding to 3 terms, then we will be placing at the middle term is the second term, so we will be placing the sum at the second term. So, here it is corresponding to 5 consecutive years, so it is placed at the third year corresponding to third value. Now, this is the total. Next, we need to calculate the average value. So, what we will be doing? We will be dividing the 5 consecutive year total by 5, so we will be getting the 5-year moving average.

So, you look at the table, at the end of the table that is corresponding to 1978 and 79 we are not having the data corresponding to moving average because for calculating the 5-year moving average we are not having the data below that, so we have to stop here at 1977. After calculating 5 year moving average we will be plotting that. So, the moving

average curve is given by this red line, we are having the annual rainfall, we are having the mean rainfall for 30 years and also moving average.

Compare the curves corresponding to annual rainfall and also moving average. You can see these fluctuations which are seen in the annual rainfall data got smoothened out in the moving average curve. See the curve, this red line is a smoothened curve which is not representing the fluctuations which are present in the actual data series. So, this smooth curve can be utilized for different hydrological studies, depending on the study which we are carrying out.

Sometimes we are interested in the fluctuations, sometimes we are interested in the smoothened curve, so depending on the study which we are conducting, we can make use of different type of representation. So, this is the way in which we can plot the moving average curve. Sometimes 5 data moving average will be asked, sometimes it will be 3 year moving average, depending on the requirement we will be calculating the moving averages and then plotting the smooth curve.

So, here we have seen the temporal representation and the spatial representation of the rainfall data which is obtained from the rain gauge and we have seen some of the numerical examples to understand these curves, that is the rainfall histogram, hyetograph and mass curve and after that we have seen the smoothened representation of the temporal representation by making use of the moving average technique.

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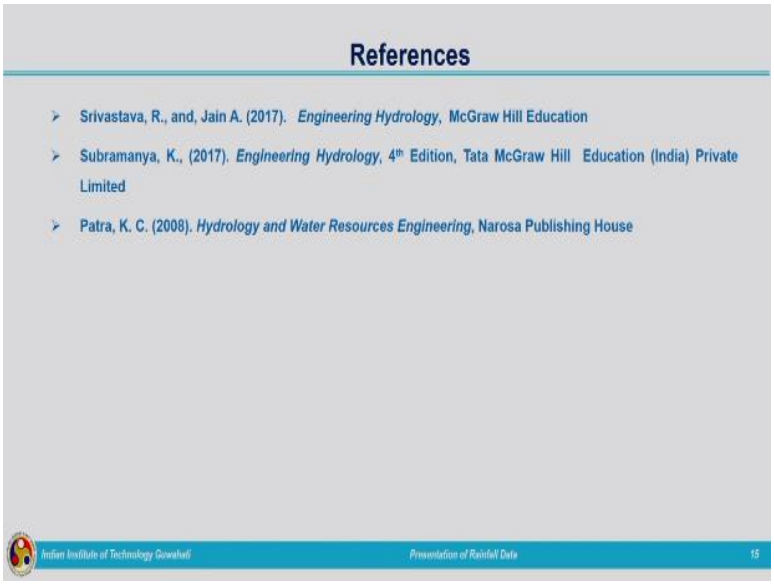

So, here I am winding up this lecture. Regarding this topic, please have a reading through this textbook. Thank you.