Surface Water Hydrology
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Lecture – 56
Risk Analysis to Determine Return Period

In today's lecture will learn about the risk analysis to determine the return period.

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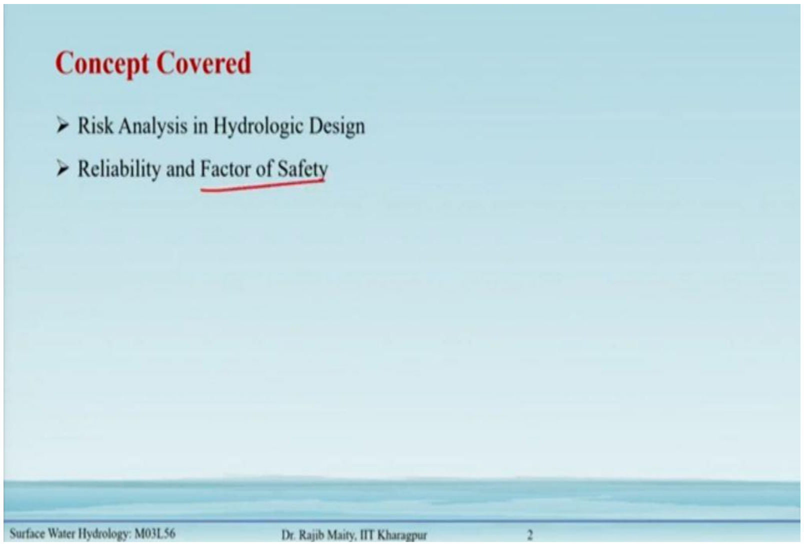

This concept cover risk analysis in hydrologic design this will discuss, and reliability and factor of safety these two things are also important in this design perspective that we will discuss.

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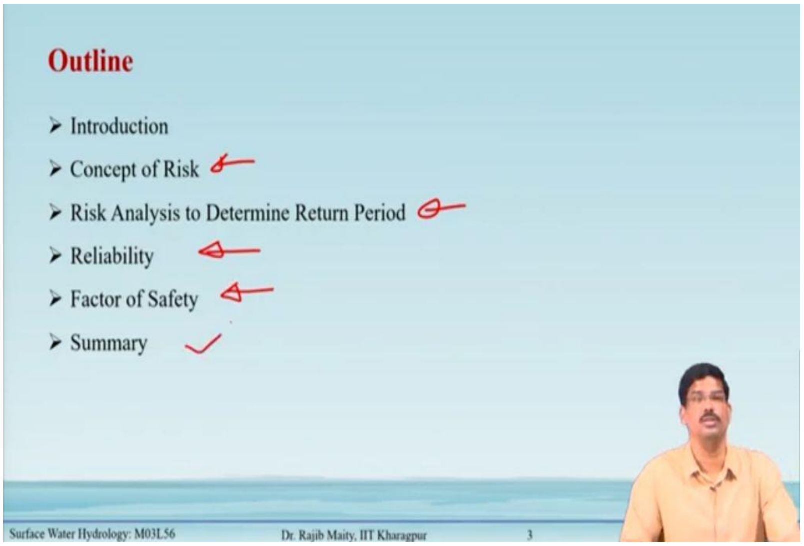

The outline of the lecture goes like this. The first is a basic introduction, the concept of risk, and the risk analysis to determine the return period is under the main focus. We will also put some discussion on this reliability and factor of safety before going to the summary of this lecture.

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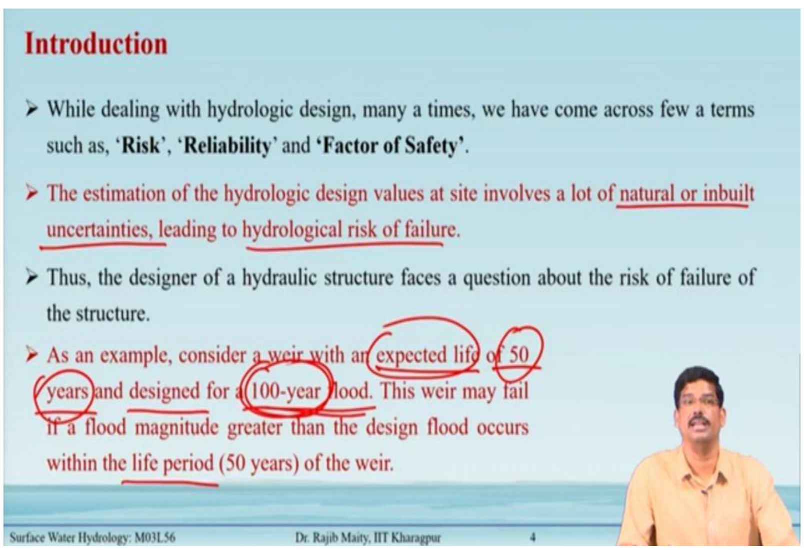

Introduction

While dealing with hydrologic design, many times, we have come across a few terms such as, 'Risk', 'Reliability', and 'Factor of Safety. The estimation of the hydrologic design values at a site involves a lot of natural and inbuilt uncertainties are there.

Thus, the designer of the hydraulic structure faced a question about the risk of failure of the structure and whether we can quantify that. As an example, say if we say that a weir with an expected life of 50 years, this is the one thing that is expected life that we talked about and designed for a 100-year flood. So, this 100 years is the return period that we utilize as a frequency concept in the previous week we discussed it. So, one thing is 50 years which is the design life of the structure, and the other thing is the from the frequency point of view of the hydrologic event.

Now, the weir may fail if the flood magnitude greater than the design flood occurs within the life of the structure itself, that is within the 50 years itself. So, the 100 years flood means it is the frequency of the return period is 100 years, as we traced in the previous week also, it is not that it will occur only once in 100 years or every 100 years, not like that is in a statistical sense.

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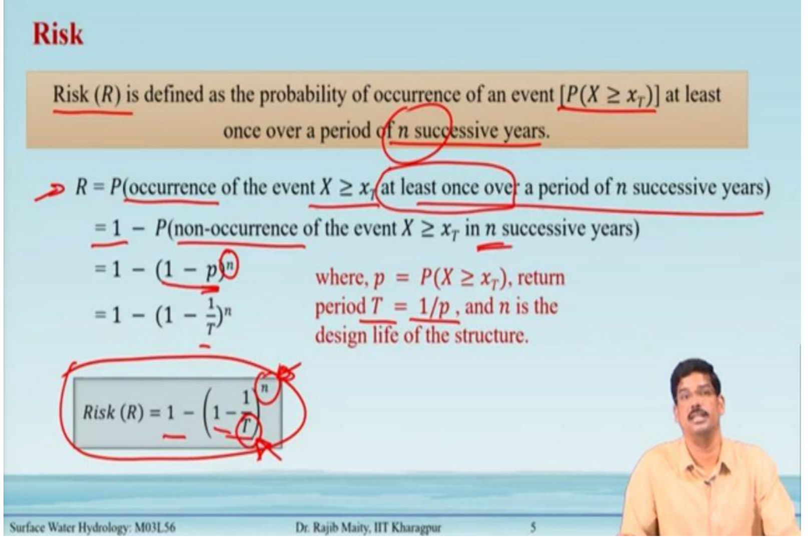

Risk

Risk (R) is defined as the probability of occurrence of an event [$P(X \geq xT)$] at least once over a period of n successive years.

R = P(occurrence of the event $X \geq xT$ at least once over a period of n successive years)

= $1 - P$(non-occurrence of the event $X \geq xT$ in n successive years)

$= 1 - (1 - p)n$

$= 1 - (1 - \frac{1}{T})n$

where, $p = P(X \geq xT)$, return period $T = 1/p$, and n is the design life of the structure.

$$Risk\ (R) = 1 - \left(1 - \frac{1}{T}\right)^{n}$$

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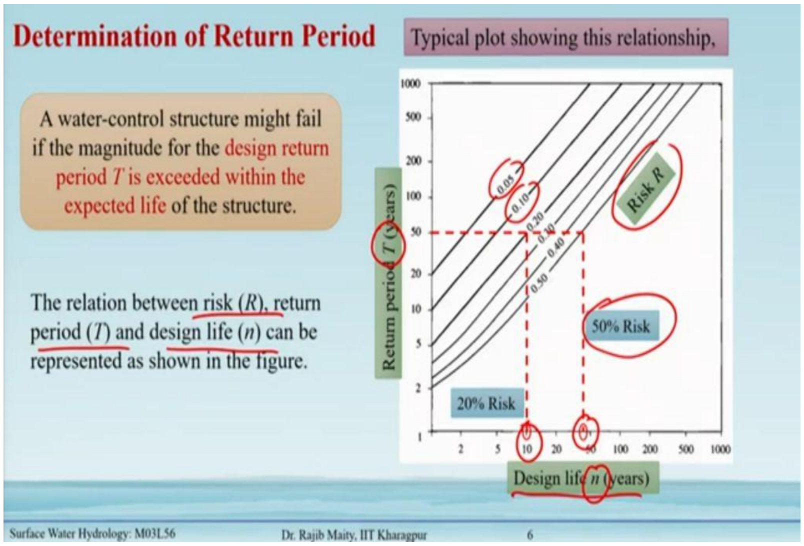

Determination of Return Period

A water-control structure might fail if the magnitude for the design return period T is exceeded within the expected life of the structure. The relation between risk (R), return period (T), and design life (n) can be represented as shown in figure 1.

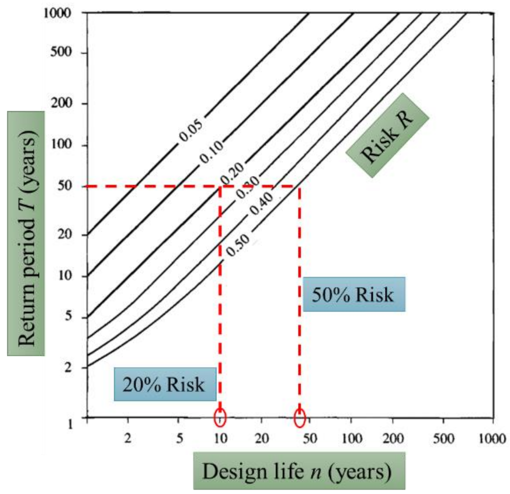

Figure 1 shows the relation between risk (R), return period (T), and design life (n)

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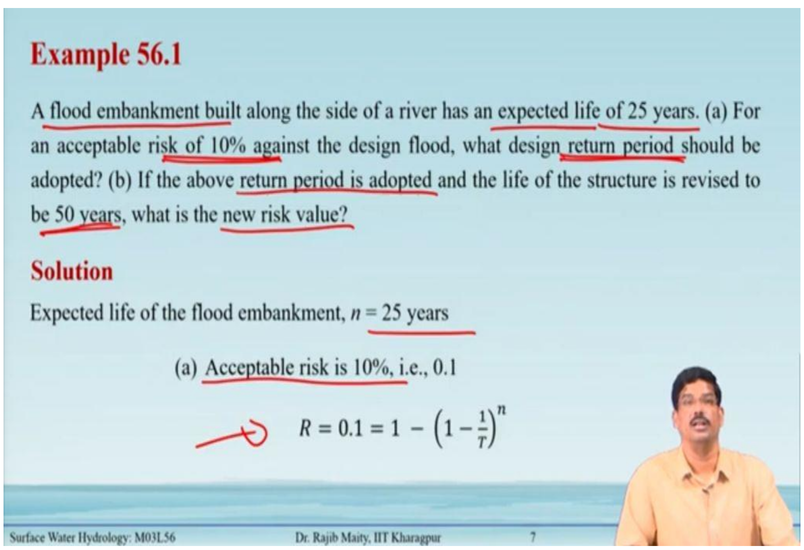

Example 56.1

A flood embankment built along the side of a river has an expected life of 25 years. (a) For an acceptable risk of 10% against the design flood, what design return period should be adopted? (b) If the above return period is adopted and the life of the structure is revised to be 50 years, what is the new risk value?

Solution

The expected life of the flood embankment, n = 25 years

(a) Acceptable risk is 10%, i.e., 0.1

$$R = 0.1 = 1 - \left(1 - \frac{1}{T}\right)^n$$

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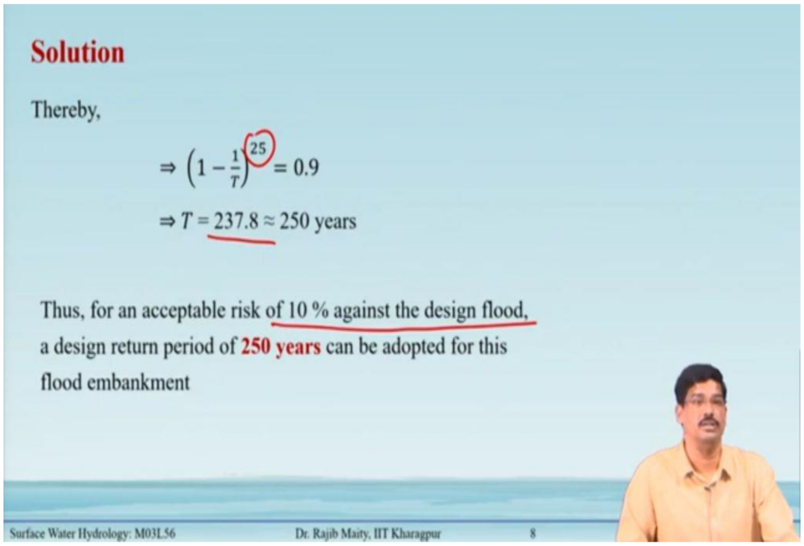

Thereby,

$$\Rightarrow \left(1 - \frac{1}{T}\right)^{25} = 0.9$$

$\Rightarrow T = 237.8 \approx 250$ years

Thus, for an acceptable risk of 10 % against the design flood, a design return period of **250 years** can be adopted for this flood embankment

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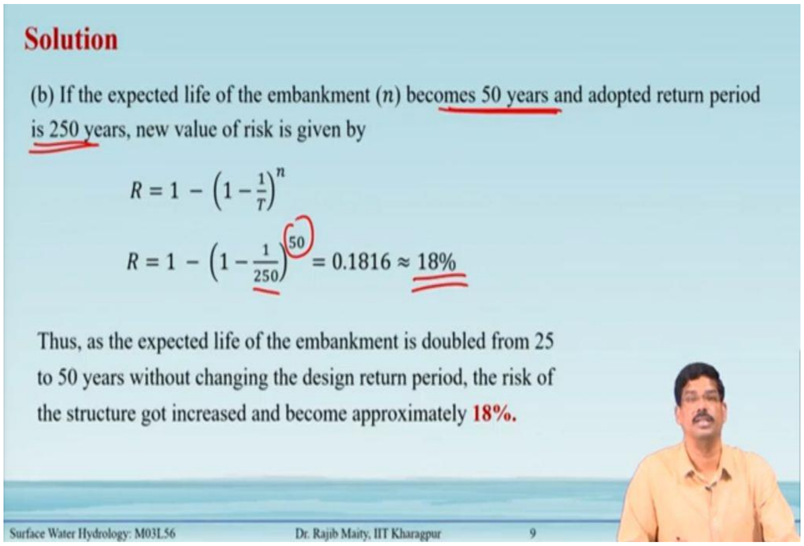

(b) If the expected life of the embankment (n) becomes 50 years and the adopted return period is 250 years, the new value of risk is given by

$$R = 1 - \left(1 - \frac{1}{T}\right)^n$$

$$R = 1 - \left(1 - \frac{1}{250}\right)^{50} = 0.1816 \approx 18\%$$

Thus, as the expected life of the embankment is doubled from 25 to 50 years without changing the design return period, the risk of the structure got increased and become approximately **18%.**

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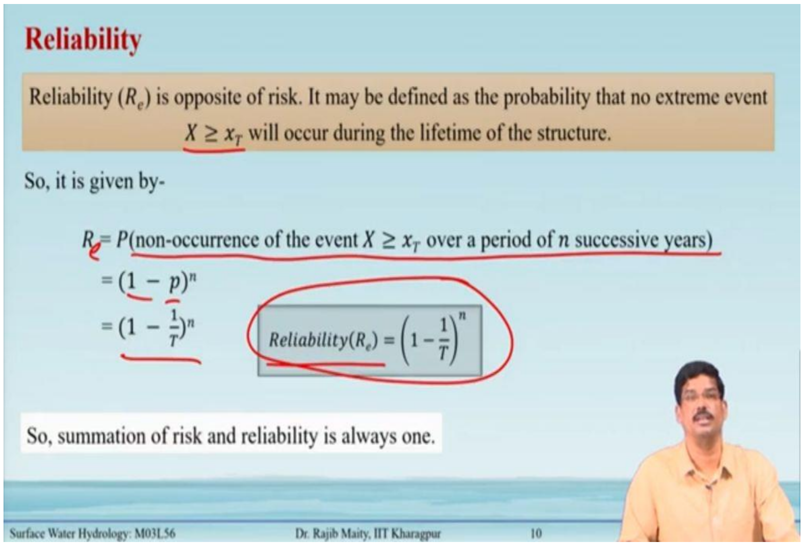

Reliability

Reliability (Re) is the opposite of risk. It may be defined as the probability that no extreme event $X \geq xT$ will occur during the lifetime of the structure.

So, it is given by-

R = P(non-occurrence of the event $X \geq xT$ over a period of n successive years)

$= (1 - p)n$

$= (1 - \frac{1}{T})n$

$$Reliability(Re) = \left(1 - \frac{1}{T}\right)^n$$

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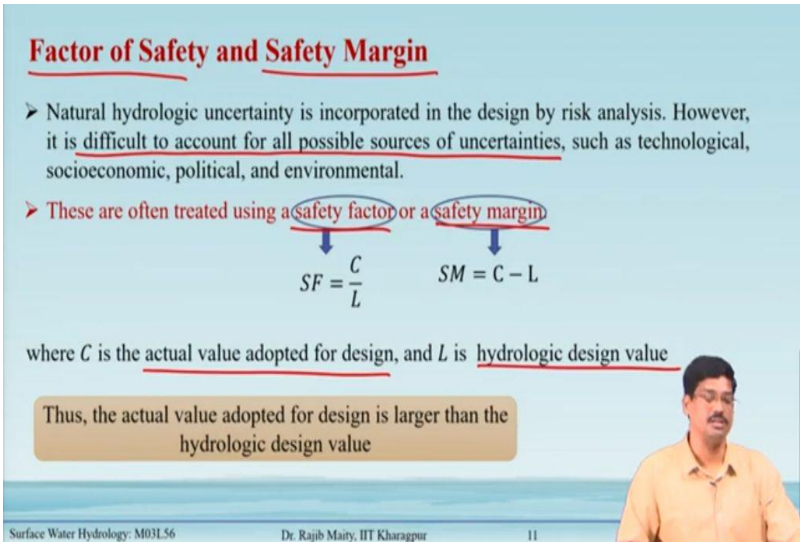

The factor of Safety and Safety Margin

Natural hydrologic uncertainty is incorporated into the design by risk analysis. However, it is difficult to account for all possible sources of uncertainties, such as technological, socioeconomic, political, and environmental.

These are often treated using a safety factor or a safety margin.

Safety Factor $(SF) = \frac{C}{L}$

Safety Margin $(SM) = \mathrm{C} - \mathrm{L}$

Where $C$the actual value is adopted for design, and L is the hydrologic design value

Thus, the actual value adopted for design is larger than the hydrologic design value

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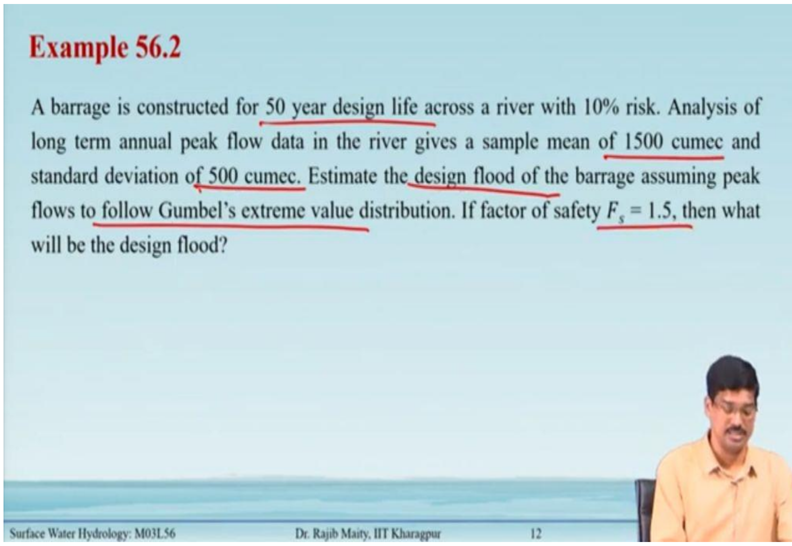

Example 56.2

A barrage is constructed for 50-year design life across a river with 10% risk. Analysis of long-term annual peak flow data in the river gives a sample mean of 1500 cumec and a standard deviation of 500 cumecs. Estimate the design flood of the barrage assuming peak flows to follow Gumbel's extreme value distribution. If the factor of safety Fs = 1.5, then what will be the design flood?

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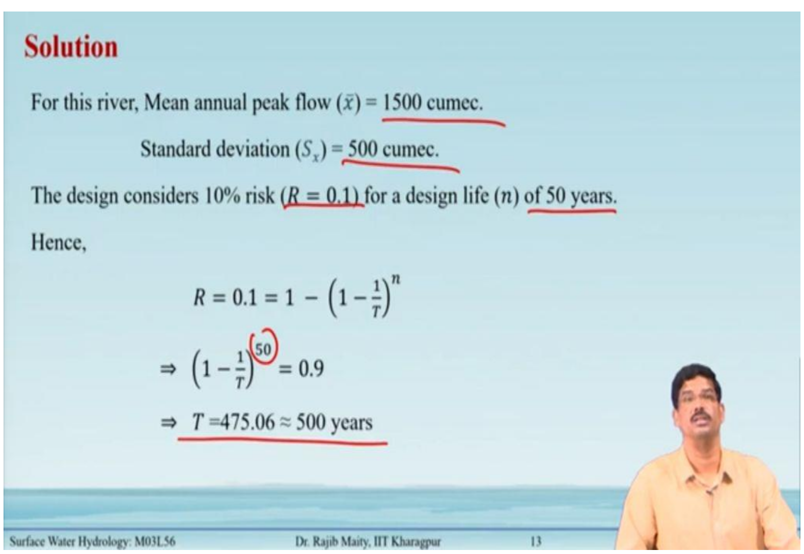

Solution

For this river, the Mean annual peak flow ($\bar{x}$) = 1500 cumec.

Standard deviation (Sx) = 500 cumec.

The design considers a 10% risk ($R = 0.1$) for a design life (n) of 50 years.

Hence,

$$R = 0.1 = 1 - \left(1 - \frac{1}{T}\right)^n$$

$$\Rightarrow \left(1 - \frac{1}{T}\right)^{50} = 0.9$$

$$\Rightarrow T = 475.06 \approx 500 \text{ years}$$

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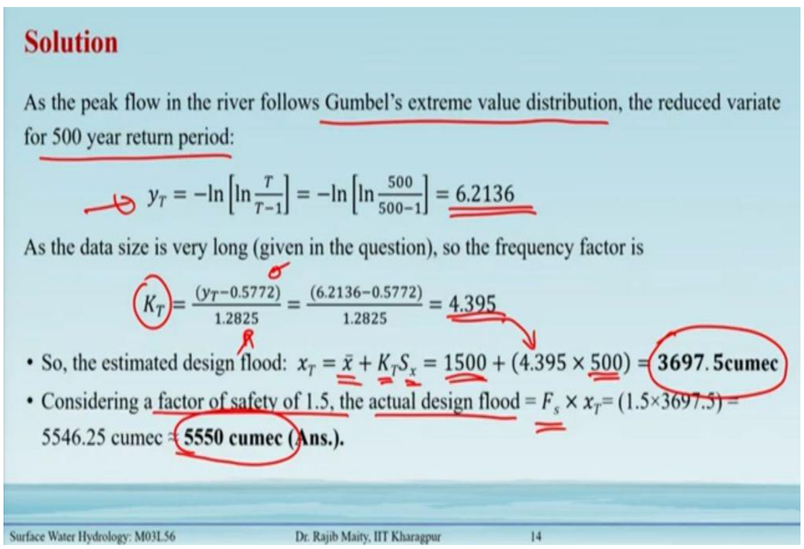

As the peak flow in the river follows Gumbel's extreme value distribution, the reduced variate for 500-year return period:

$$yT = -\ln\left[\ln\frac{T}{T-1}\right] = -\ln\left[\ln\frac{500}{500-1}\right] = 6.2136$$

As the data size is very long (given in the question), the frequency factor is

$$K_T = \frac{(y_T - 0.5772)}{1.2825} = \frac{(6.2136 - 0.5772)}{1.2825} = 4.395$$

- So, the estimated design flood: $xT = \bar{x} + KTSx = 1500 + (4.395 \times 500) = \mathbf{3697.5 cumec}$
- Considering a factor of safety of 1.5, the actual design flood = $Fs \times xT$= (1.5×3697.5) = 5546.25 cumec ≈ **5550 cumec (Ans.).**

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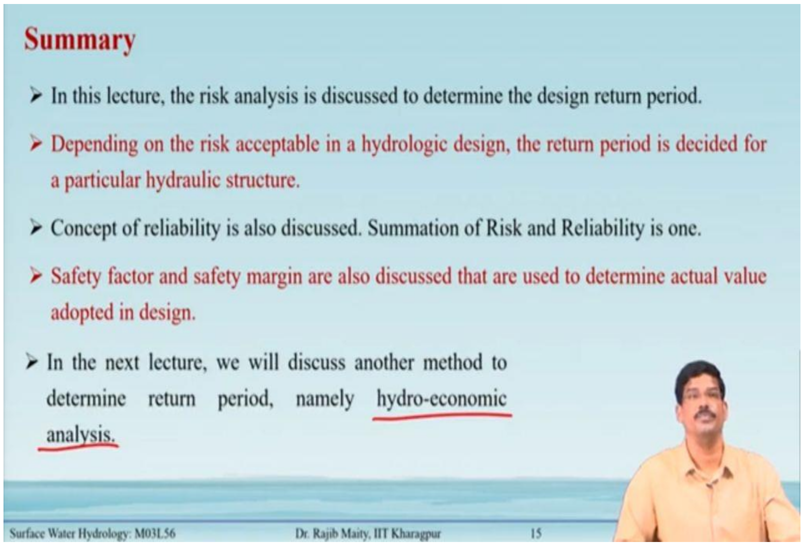

Summary

In summary, we learned the following points from this lecture:

- In this lecture, the risk analysis is discussed to determine the design return period.
- Depending on the risk acceptable in a hydrologic design, the return period is decided for a particular hydraulic structure.
- The concept of reliability is also discussed. The summation of Risk and Reliability is one.
- The safety factor and safety margin are also discussed that are used to determine the actual value adopted in design.

- In the next lecture, we will discuss another method to determine the return period, namely hydro-economic analysis.