# Surface Water Hydrology Professor Rajib Maity Department of Civil Engineering Indian Institute of Technology Kharagpur 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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<b>Concept Covered</b>			
<ul> <li>Risk Analysis in Hydro</li> <li>Reliability and Factor of</li> </ul>	ologic Design of Safety		
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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 a times, we have come across few a terms such as, 'Risk', 'Reliability' and 'Factor of Safety'.
The estimation of the hydrologic design values at site involves a lot of <u>natural or inbuilt</u> <u>uncertainties</u> , leading to hydrological risk of failure.
> Thus, the designer of a hydraulic structure faces a question about the risk of failure of
the structure. As an example, consider a weir with an expected life of 50 (years and designed for a 100-year lood. This weir may fail
if a flood magnitude greater than the design flood occurs
within the life period (50 years) of the weir.
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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  $[P(X \ge xT)]$  at least once over a period of *n* successive years.

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

- $= 1 P(\text{non-occurrence of the event } X \ge xT \text{ in } n \text{ successive years})$
- =1 (1 p)n
- $=1 (1 \frac{1}{T})n$

where,  $p = P(X \ge xT)$ , 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) (Refer Slide Time: 07:35)

Example 56.1	
A flood embankment built alon	ng the side of a river has an expected life of 25 years. (a) For
an acceptable risk of 10% ag	ainst the design flood, what design return period should be
be 50 years, what is the new rit	isk value?
Solution	
Expected life of the flood emba	ankment, $n = 25$ years
(a) Acceptal	ble risk is 10%, i.e., 0.1
~	$R = 0.1 = 1 - \left(1 - \frac{1}{T}\right)^n$
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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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Solution		
Thereby,		
$\Rightarrow \left(1 - \frac{1}{2}\right)$	$2^{(25)} = 0.9$	
$\Rightarrow T = 23$	$7.8 \approx 250$ years	
Thus for a secondal la	ile of 10.0% and int the desire flood	
a design return period of	250 years can be adopted for this	
flood embankment		
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Thereby,

$$\Rightarrow \left(1 - \frac{1}{T}\right)^{25} = 0.9$$
$$\Rightarrow T = 237.8 \approx 250 \text{ years}$$

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 $(R_e)$ is opposit $X \ge x$	e of risk. It may be defined as the $\frac{1}{T}$ will occur during the lifetime	e probability th of the structure	hat no extreme event
So, it is given by- $R = P(\text{non-occurrent})$ $= (1 - p)^{n}$ $= (1 - \frac{1}{T})^{n}$ So, summation of risk and	nce of the event $X \ge x_T$ over a provide $Reliability(R_e) = \left(1 - \frac{1}{T}\right)^n$ reliability is always one.	period of <i>n</i> succ	eessive years)
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# Reliability

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

So, it is given by-

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

= (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) = C - 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 (Refer Slide Time: 12:20)



# Example 56.2

A barrage is constructed for 50-year design life across a river with 10% risk. Analysis of longterm 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.

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Standard deviation (Sx) = 500 cumec.
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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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Solution		
As the peak flow in the river follo for 500 year return period:	ows Gumbel's extreme valu	e distribution, the reduced variate
$y_T = -\ln\left[\ln\frac{T}{T-1}\right]$	$= -\ln\left[\ln\frac{500}{500-1}\right] = 6.2136$	6
As the data size is very long (give $K_T = \frac{(y_T - 0.5772)}{1.2825}$ • So, the estimated design flood: • Considering a factor of safety of 5546.25 cumee = 5550 cumee	en in the question), so the fr = $\frac{(6.2136-0.5772)}{1.2825} = 4.395$ $x_T = \bar{x} + K_T S_x = 1500 +$ of 1.5, the actual design floor (Ans.).	equency factor is $(4.395 \times 500) = 3697.5$ cumec $d = F_s \times x_T = (1.5 \times 3697.5) =$
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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:  $xT = \bar{x} + KTSx = 1500 + (4.395 \times 500) = 3697.5$ cumec
- Considering a factor of safety of 1.5, the actual design flood =  $Fs \times xT = (1.5 \times 3697.5) = 5546.25$  cumec  $\approx$  **5550 cumec (Ans.).**

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Summary		
$\succ$ In this lecture, the risk analysi	is is discussed to determine th	ne design return period.
Depending on the risk accepta a particular hydraulic structure	able in a hydrologic design, t e.	the return period is decided for
Concept of reliability is also d	liscussed. Summation of Risk	and Reliability is one.
Safety factor and safety marginadopted in design.	in are also discussed that are	used to determine actual value
In the next lecture, we will determine return period, analysis.	discuss another method to namely hydro-economic	
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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.