Communicating the chance of a flood: The use and abuse of probability, frequency and return period

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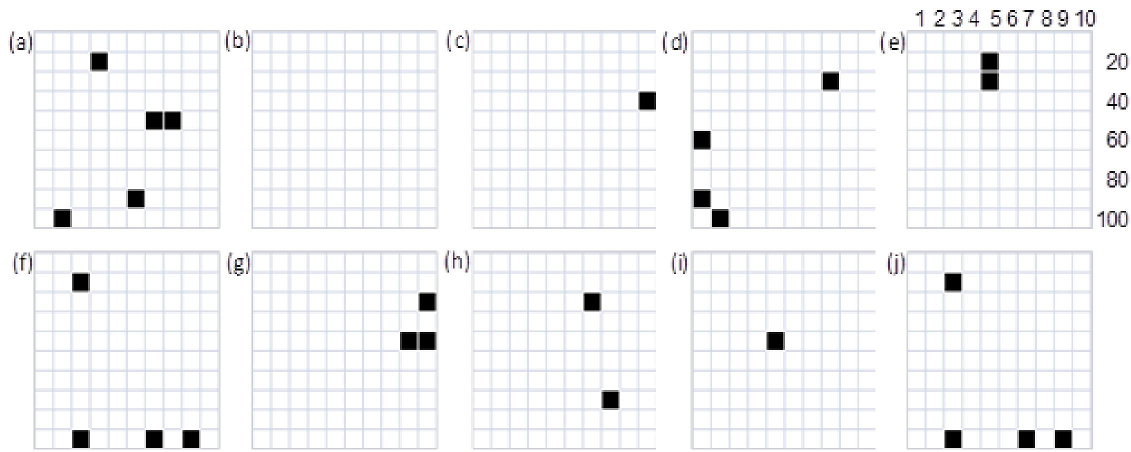
Introduction

To help understand the differences between these terms consider the probability of exceeding a defined flood that has an associated return period of one in one hundred years. The expected number of events that will exceed this value in any given 100 years is 1 (i.e. frequency), but it is easily possible that within any given 100 year period an event that exceeds this value may not occur at all, or else it may occur more than once. To illustrate this point, the following diagram represents ten different 100 year periods selected from one hundred such simulations generated using a Log-Normal distribution. Each panel (a to j) contains 100 small squares each representing a single year. The solid squares illustrate those years in which the “100 year” flood was equaled or exceeded. In one of the 100 year periods the “100 year” flood was never exceeded (panel b) and in another it was exceeded just the once (panel d). In another (panel g) the “100 year” flood was exceeded three times in the first 50 years but not again. There is even one century (panel a) in which the “100 year” flood was exceeded five times. It should be stressed that these patterns are all generated from the same distribution of annual floods: they just represent different possible outcomes that might be observed in any 100-year sequence.



(Image courtesy of Rory Nathan)

Common misconceptions by the layman

While from the perspective of a 'long term average' a flood with a return period of T years is likely to be equaled or exceeded once in T years is correct, this simple interpretation often leads to confusion and typical misinterpretations. For example:

- ***We have just had a hundred year return period event, it won't happen again for 99 years (wrong)****:* This fails to recognize return period as an expression of the 'long term average' nature of randomly distributed events.
- ***The one in a hundred year event is so unlikely we don't need to think about it (wrong)*****:** This fails to recognize that although the chance of experiencing a 1in100 year event or greater any given year may be low, as the time period of interest increases the chance of experiencing the 1in100 year event increases dramatically. For example, there is a 63% chance that a 1in100 year event or greater will be experienced in next 100 years (as determined using the so -called encounter probability).
- ***In one hundred years we will definitely see the 100 year flood (wrong)*****.** This fails to recognize the random behave of the events. To be 99% sure that a 1 in 100 year event will be observed you would have to wait for 500 years.

Common misconceptions by industry professionals

Risk managers often add to the confusion as they often fail to recognize:

- ***Frequency and probability are not the same:*** Return period typically relates to the number of times, in a given timeframe, that a particular condition is likely to be equaled or exceeded on average – i.e. in this frequentist interpretation return period is the reciprocal of the *annual exceedence frequency* but is **not** a reciprocal of the *annual probability of exceedence* – although this is a reasonable approximation for higher return period (>10 years). In this context:
    - *Probability* - defines the chance of occurrence of one event compared to the population of all events.
    - *Frequency* - defines the expected number of occurrences of a particular event

  To help understand the differences between these two terms, consider the throwing of a fair die. The probability of recording a six with one throw is 1/6. What then is the probability of recording a six with six throws? A mistake often made is to multiply the probability (1/6) by the number of trials

(6) to give an answer of one six per six throws. This answer is the expected (average) frequency and not the probability (probability of 1 implies the certainty of obtaining a six). Return period states the expected frequency of occurrence of a particular event. To calculate the probability of recording one six with six throws of the die, it is necessary to consider the total number of ways in which one six (and only one six) could be obtained, i.e.

(S=p(six)= 1/6, N=p(not a six) = 5/6)

S,N,N,N,N,N
N,S,N,N,N,N
etc

Therefore, to calculate the probability it is necessary to add the probability of each possible combination:
i.e.

(1/6*5/6*5/6*5/6*5/6*5/6) + (5/6*1/6*5/6*5/6*5/6*5/6) +….etc ~ 0.40

An analogy can be drawn between the die example given above, and the likelihood of obtaining one per hundred years return period event in a time period of 100 hundred years. The expected frequency is 1, however, a slightly more in depth calculation is required to find the probability.

- ***The chance of a flood is not the same as the chance of the driving storm event:*** Return period typically refers to the hydraulic load or rainfall event and not the response of ultimate interest - i.e. the flood. The probability of a flood occurring often considered the same as the equivalent return period of the flow; an assumption that wholly fails to capture the likely performance of the defences, temporary defences etc. The chance of harm (damage) occurring may be even less.

- ***The complication of a non-stationary climate:*** Frequency refers to the number of occurrences expected over a period of time. Within a non-stationary climate this expectation varies making frequency impossible to interpret. The definition of an Annual Exceedance Probability is less exposed to climate change and hence is a more robust term under the assumption of non-stationarity.

Are there better ways of communicating the chance of a flood?

Rather than annual probability of exceedance or return period, the change of encountering a flood over a longer time scales can provide a more meaningfully communication tool. For example, someone buying a house in the floodplain may ask:

- **What is the chance of a flood during the term of my mortgage?** Assuming a 25 year mortgage term there is a 22% chance that a 1 in 100 year return period flood many be equaled or exceeded.
- **I am planning on moving in a few years, what is the chance of a flood in the next five years?** There is a 5% chance that a 1 in 100 year return period flood many be equaled or exceeded during the next 5 years.
- **This is my forever house, what is the chance of a flood during my life time?** Assuming you live for a further 60 years there is a 45% chance that you will experience a 1 in 100 year return period flood or greater during that time.

These are all based on the so-called **encounter probability** (see below) and assume a stationary climate and catchment characteristics – both of which are poor assumptions. Increasingly the past is a poor guide to the future increasing simulation with be needed alongside statistical analysis of observation.

Supporting information: Encounter Probability explained

The encounter probability equation

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

Pe = encounter probability, T = return period in years, n = length of encounter period in years gives some surprising results; e.g. for n > 10, and for n = T,Pe ~ 0.63 or use a simple online tool….here

Acknowledgements and further information

A summary based on

Sayers et al, 2014 **'Comparison of flood hazard estimation methods for dam safety'** Published by CEATI Dam Safety Program, Canada

Sayers et al, 2002 **'Risk, Performance and Uncertainty in Flood and Coastal Defence: A review'** Published by the ICE Journal of Water Management and the supporting report Environment Agency 2002 (led by HR Wallingford).

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