Drainage Design: Truly Understand What 'Year Event' Really Means

An Online Continuing Education Course for Engineers

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Drainage Design: Truly Understanding What 'Year Event' Really Means

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Overview

Hydrologic analysis and results are statistically based. The term 'year event' is the common way to express the hydrologic magnitude of precipitation and runoff quantities, but it does not tell the entire story. What does it really mean?

Discussing drainage and flood issues with the general public and policymakers sometimes needs more than thinking just in terms of 'year event'. Its brevity in expression does not illustrate important considerations. One such is that the 100-year event has only a 63% chance of happening in 100 consecutive years yet can occur more than once in a single year.

Three other primary expressions are 'probability', 'service level', and 'expected occurrence'. There is a direct relationship between these terms and 'year event'. All are important to understand and doing so can help an engineer better grasp situations and relate the impact of their work to others. This course relates the four terms with discussion, formulas, and examples.

Terms

Probability of an N-year event flood event being equaled or exceeded in any year

$P = 1 / N$
P is probability (expressed as a ratio, not a percentage)
N is year event

Year Event of a flood with a P probability being equaled or exceeded in any year

$N = 1 / P$
N is year event
P is probability

Service Level is the probability of an N-year event flood event not being equaled or exceeded in any year

$S = 1 - 1 / N = 1 - P$
S is Service Level
N is year event
P is probability

Expected Occurrence of an N-year event flood event being equaled or exceeded at least once in X consecutive years

$E = 1 - (1 - 1 / N)^X = 1 - (1 - P)^X$
N is year event
P is probability
X is the number of consecutive years

Storms Used in Statistical Analysis

The only storms used in a hydrologic statistical analysis are the maximum values in each year (largest storm only). Below is a table of rainfall amounts for the three largest storms in each of ten consecutive years.

Table 1 – Recorded Rainfall Amounts

Year and Storm	Rainfall (inches)	Year and Storm	Rainfall (inches)
1991 – Largest Storm	**4.8**	1996 – Largest Storm	**4.2**
1991 – 2nd Largest Storm	**3.7**	1996 – 2nd Largest Storm	1.6
1991 – 3rd Largest Storm	**3.3**	1996 – 3rd Largest Storm	0.9
1992 – Largest Storm	**3.5**	1997 – Largest Storm	0.8
1992 – 2nd Largest Storm	**3.1**	1997 – 2nd Largest Storm	0.7
1992 – 3rd Largest Storm	2.4	1997 – 3rd Largest Storm	0.6
1993 – Largest Storm	2.2	1998 – Largest Storm	1.4
1993 – 2nd Largest Storm	2.0	1998 – 2nd Largest Storm	1.2
1993 – 3rd Largest Storm	1.6	1998 – 3rd Largest Storm	0.8
1994 – Largest Storm	1.7	1999 – Largest Storm	1.9
1994 – 2nd Largest Storm	1.5	1999 – 2nd Largest Storm	1.5
1994 – 3rd Largest Storm	1.4	1999 – 3rd Largest Storm	1.4
1995 – Largest Storm	**4.5**	2000 – Largest Storm	**2.7**
1995 – 2nd Largest Storm	**4.0**	2000 – 2nd Largest Storm	**2.6**
1995 – 3rd Largest Storm	0.9	2000 – 3rd Largest Storm	2.3

Shown in bold are the ten largest values regardless of year. Note that some years have more than one of these ten largest values while other years have none. No matter when they occur, the ten largest storms are not the ones used in a statistical analysis. Again, only the largest value in each year is used.

Recall from each term's definition the phrase 'being equaled or exceeded in any year'. This is the key why only the largest value in each year is used. Hydrologic analysis deals with the more rare occurrences, ones not at frequencies such as daily, weekly or monthly, but ones that occur less frequently than annually. Including more than one rainstorm per year overemphasizes years with multiple large storms. Each year must be represented with the same statistical weight as every other year.

Statistical Analysis

Using the statistical analysis method Log Pearson Type III, the ten years of data in Table 1 produce the following results. In this case, the rainfall amount is being used to define the flood probability, year event, and service level. Runoff flow rate, not rainfall amount, is often the better parameter to perform statistical analysis, as rainfall amount does not always directly correlate to runoff flow rate. In this discussion rainfall amount is used.

Table 2 – Statistical Analysis of Rainfall Amounts

Probability of Being Equaled or Exceeded	Year Event	Service Level	Rainfall (inches)
0.01 (1%)	100	0.99 (99%)	8.54
0.02 (2%)	50	0.98 (98%)	7.46
0.05 (5%)	20	0.95 (95%)	6.06
0.10 (10%)	10	0.90 (90%)	5.01
0.20 (20%)	5	0.80 (80%)	3.96
0.50 (50%)	2	0.50 (50%)	2.46

Explanation of this statistical analysis method requires detailed discussion that is not part of the scope of this document. For more information, refer to: *Guidelines For Determining Flood Flow Frequency, Bulletin #17B, U.S. Department of the Interior, Geological Survey, Office of Water Data Collection, March 1982.*

Discussion

Using Table 2 results, the probability of 3.96 inches of rain being equaled or exceeded in any year is 0.20 to 1 or there is a 20% chance of that occurring in any given year. That is also expressed as the 5-year event (1 / 0.20). The year event implies to many that this should only occur once every five years. Considering ten years of records were used to compute Table 2, one could infer that only two rainfalls should have equaled or exceeded 3.96 inches. Review of Table 1 shows that this value was exceeded four times including twice in one year (1995). This illustrates how 'year event' as a term to express magnitude or rarity can easily portray an inaccurate perception.

Now look at it from the perspective of the term service level. The 5-year event, 20% probability of occurring, also means that whatever is designed should be adequate for all storms in 80% of the years. Table 1 shows that during seven years the rainfall does not equal 3.96 inches, thus the actual service level in those ten years was 70%, a much closer perception of accuracy.

These terms are obviously directly related mathematically, thus there is no actual difference amongst them, the importance is the message they convey to the general public and policymakers.

In terms of year event, non-technical people will have the perception that your designs are inadequate as they 'failed' four times in ten years while the 5-year event gives the impression only two 'failures' should have occurred in ten consecutive years.

In terms of probability, 20% of the years there should have been failures while it occurred in 30% of the years.

In terms of service level, 80% of the years there should have been no failures while that success occurred in 70% of the years.

When speaking in terms of probability and service level, it is crucial to always state they are in terms of years, not storms. Example: 'This design should adequately convey flows for 80% of the years and it is possible in any given year it will not adequately convey flow more than once in that year.'

Service level is an optimistic approach as it focuses on success rather than failure. When communicating to the general public and policymakers, it can be effective to communicate that a drainage facility will be successful 80% of the years rather than merely being only the 5-year event or susceptible to failure 20% of the years. For higher standards, such as the 20-year event, that is a service level for 95% of the years.

Expected occurrence is the probability that a specific probable flood or rainfall will be equaled or exceeded at least once in a certain number of consecutive years.

The expected occurrence of the 10-year event occurring at least once in 10 consecutive years is 65%. The rainfall amounts in Table 1 show that the 10-year event in Table 2, 5.01 inches, did not occur in those ten consecutive years, a reasonable expectation at a 35% probability.

The expected occurrence of the 5-year event occurring at least once in 10 consecutive years is 89%. The rainfall amounts in Table 1 show that the 5-year event in Table 2, 3.96 inches, did occur at least once in those ten consecutive years, a reasonable expectation at an 89% probability.

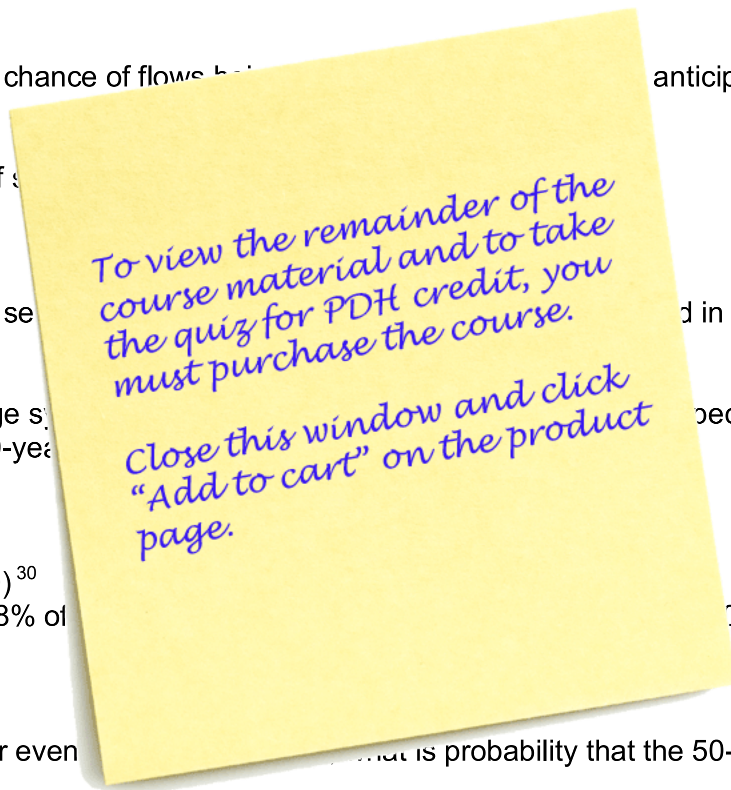
Examples

The following examples use the hypothetical values in Tables 1 and 2.

Example 1

1a) A City uses the 10-year event as its design standard storm drainage facilities sizing. What is the probability that the drainage system will receive flows equal to or greater than those anticipated in the design?

N = 10
P = 1 / N
P = 1 / 10
P = 0.10 or 10% chance of flows [...] anticipated in any year



1b) What level of [...]

S = 1 – P
S = 1 – 0.10
S = 0.90 or 90% se[...] in any year

1c) If the drainage s[...]pectation that flows will equal or exceed the 10-yea[...]
X = 30

E = 1 - (1 - P) ^{X}
E = 1 – (1 – 0.10) ^{30}
E = 0.958 or 95.8% o[...] consecutive years

Example 2

2a) If the 50-year even[...] is probability that the 50-year event will occur this year?

N = 50
P = 1 / N
P = 1 / 50
P = 0.02 or 2% of occurring this year, as each year is an independent event.

2b) What is the expected occurrence that the 50-year event will occur this year or next year?

X = 2
E = 1 - (1 - P) ^{X}
E = 1 – (1 – 0.02) ^{2}
E = 0.0396 or 3.96% of the 50-year event being equaled or exceeded in two consecutive years