

Design Note No. 16 \*

Subject: Probability of Occurrence for Certain Design Events

In view of the interest in emergency spillway and stable earth channel designs, engineers might reflect upon the interplay between the chance of occurrence of any given event, the project life of a structure, and the total number of structures for which SCS has some responsibility.

The probability that a given event, Y, will be equaled or exceeded in a specified number of years, n, is:

$$P = 1 - [1 - (1/Y)]^n \quad \text{Eq. 1}$$

Equation 1 can be solved for n as:

$$n = \ln [1 - P] / \ln [1 - (1/Y)] \quad \text{Eq. 2}$$

The event, Y, is defined to be the reciprocal of the chance a particular event will be equaled or exceeded in any one year. It is sometimes referred to as a 25 year storm, 100 year storm, emergency spillway storm, etc. The specified number of years is the number of times a structure or group of independent structures are exposed to the event. The project life of a structure can be one example of the specified number of years. The attached tables show solutions of equations 1 and 2 for certain design events, project life, and probability of occurrence.

The following situations illustrate the actual risks involved with typical engineering structures.

SITUATION 1: A channel is to be constructed with a project life of 25 years and a ten year design storm.

Question: What is the probability that a 10 year event will occur or be exceeded during its project life?

Answer: Y = 10 yr. & n = 25 yr.

$$P = 1 - [1 - (1/10)]^{25} = 0.9282 = 92.82\%$$

Conclusion: Channel stability problems can be expected especially if not properly designed.

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SITUATION 2: A dam has been built with a project life of 100 years.

Question: What is the probability that a 100 year event will occur or be exceeded during its project life?

Answer:  $Y = 100$  yr. &  $n = 100$  yr.

$$P = 1 - [1 - (1/100)]^{100} = 63.40\%$$

Conclusion: Emergency spillway flows can be expected for most of our retarding structures sometime during their useful lifetime.

SITUATION 3: Same as Situation 2 with an emergency spillway storm which has a return period greater than 500 years.

Question: What is the probability that an emergency spillway storm event will be equaled or exceeded?

Answer:  $Y \geq 500$  yr. &  $n = 100$  yr.

$$P \leq 1 - [1 - 1/500]^{100} = 18.14\%$$

Conclusion: The emergency spillway storm has a good chance of occurring at any one of our retarding structures.

SITUATION 4: Assume ten widely separated dams are located so as to be hydrologically independent with conditions as in Situation 3 above.

Question: Same as Situation 2 with an emergency spillway storm which has a return period greater than 500 years.

Answer:  $Y \geq 500$  yr. &  $n = 10 * 100 = 1000$  yr.

$$P \leq 1 - [1 - 1/500]^{1000} = 86.49\%$$

Conclusion: Emergency spillway storms are likely to be equaled or exceeded sometime, somewhere in our watershed projects.

SITUATION 5: Same as Situation 4.

Question: What would be the period of years in which the Situation 4 event would likely as not occur?

Answer:  $P = 50\%$  &  $Y \geq 500$  yr.

$$n \leq \ln[1 - 0.50]/\ln[1 - 1/500] = 346$$

$$T \geq 346/10 = 35 \text{ yr.}$$

Conclusion: Emergency spillway storms are likely to be equaled or exceeded sometime, somewhere in our watershed projects during your career. In fact, all of the above situations can (and probably will) happen during your career.

TABLE NO. 1

Yr. Y	Probability of Occurrence, P - %						
	n=1 yr.	10	25	50	100	500	1,000
5	20.00	89.26	99.62	100.00	100.00	100.00	100.00
10	10.00	65.13	92.82	99.48	99.997	100.00	100.00
25	4.00	33.52	63.96	87.01	98.31	100.00	100.00
50	2.00	18.29	39.65	63.58	86.74	99.996	100.00
100	1.00	9.56	22.22	39.50	63.40	99.34	99.996
500	0.20	1.98	4.88	9.53	18.14	63.25	86.49
1,000	0.10	1.00	2.47	4.88	9.52	39.36	63.23
10,000	0.01	0.10	0.25	0.50	1.00	4.88	9.52
100,000	0.001	0.01	0.02	0.05	0.10	0.50	1.00

TABLE NO. 2

Yr. Y	Number of Opportunities, n - yr.				
	P = 10%	25	50	75	99
5	0 <sup>+</sup>	1	3	6	21
10	1	3	7	13	44
25	3	7	17	34	113
50	5	14	34	69	228
100	10	29	69	138	458
500	53	144	346	692	2,300
1,000	105	288	693	1,386	4,603
10,000	1,054	2,877	6,931	13,862	46,049
100,000	10,536	28,768	69,315	138,629	460,517

P - Probability of an event, Y, being equaled or exceeded at least once in n years.

n - Number of opportunities for an event to be equaled or exceeded; n may be the project life for a single structure or may be equivalent to the sum of the project lives for a group of independent structures.

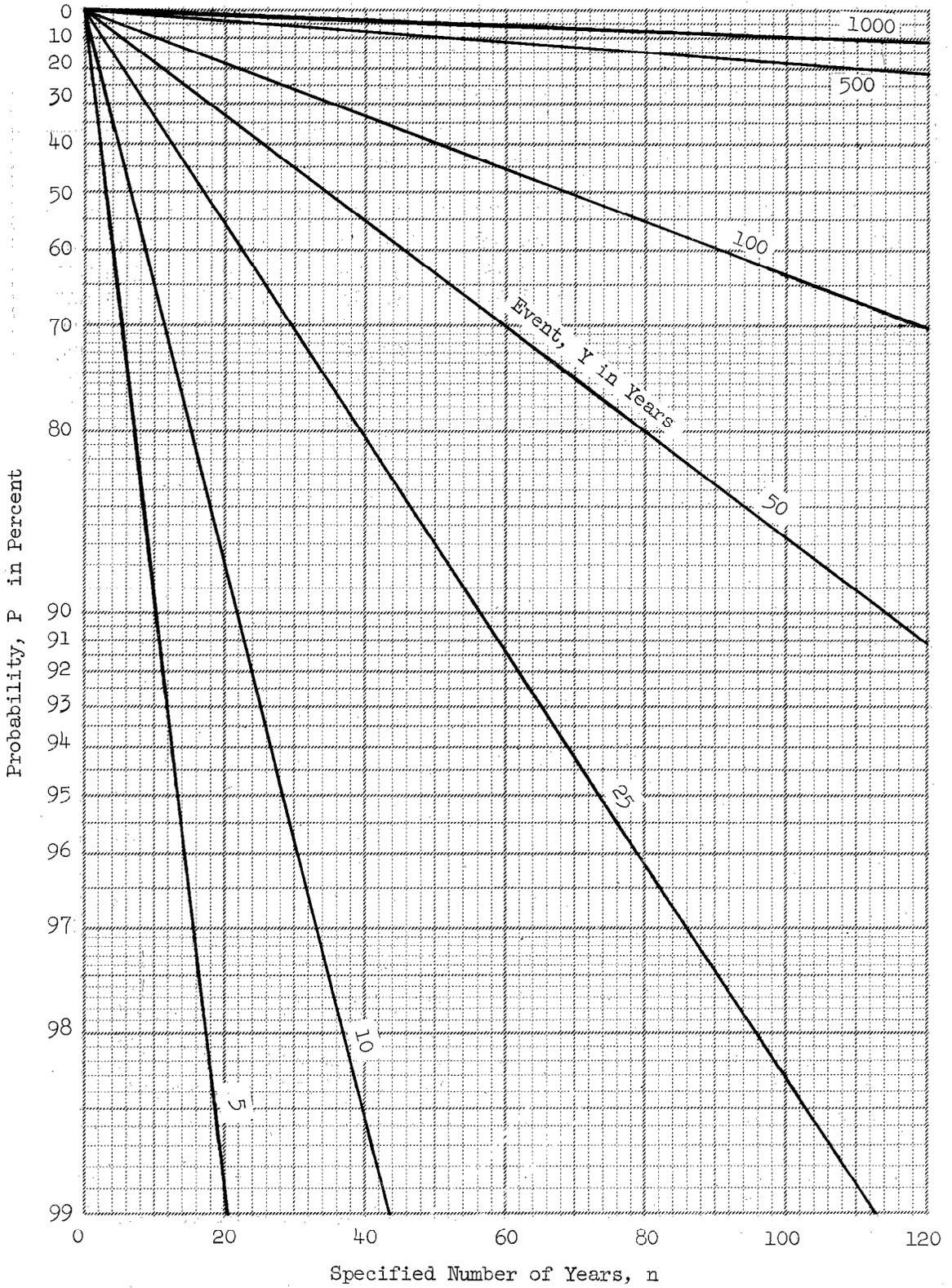


Figure 1 - Probability of Occurrence for Certain Design Events