

Example: nonstationarity and the 100-year flood

2026-09-28

We cover this at the board in class. For supplementary notes, read Honeycutt et al. (2023) Appendix B, pp. 77-83.

What a 1-percent flood means once its probability changes from year to year.

- When the hazard is changing, “the 100-year flood” has three reasonable meanings: the level today, the highest level over the planning period, and one level with the same chance of being flooded at least once over that period.
- If the years are independent, the chance of at least one flood in n years is one minus the product of the chances of no flood in each year.
- A risk that changes every year can be reported as the single unchanging yearly chance that gives the same risk over the period.

$$P_n = 1 - \prod_{i=1}^n (1 - p_i)$$

$$p_{\text{equiv}} = 1 - (1 - P_n)^{1/n}$$

Three definitions of the 1-percent flood

Suppose the flow with a 1-percent annual chance at a river site is rising, and a floodplain map made this year will be used for the next 30 years. There are three reasonable levels to put on that map:

1. The 1-percent level as it is today.
2. The highest 1-percent level at any point in the 30 years.
3. A single level chosen so that, over the 30 years, it has the same chance of being flooded at least once as the rising hazard does.

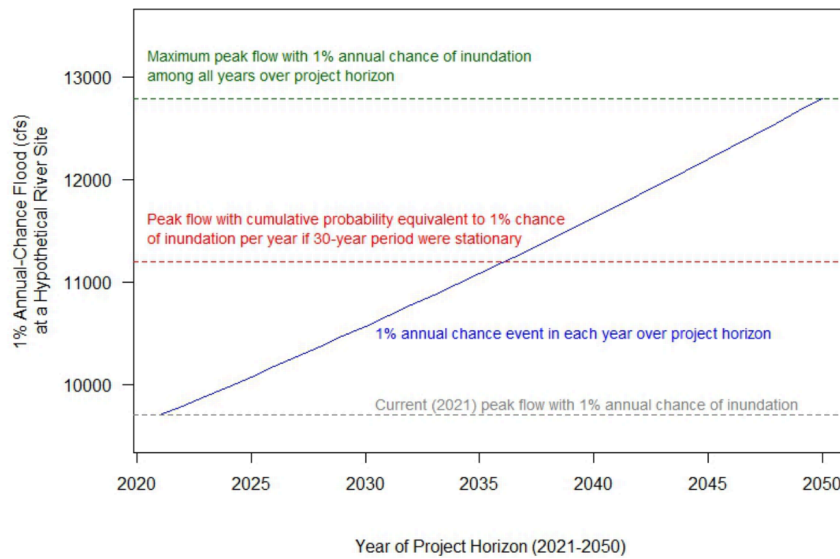


Figure 13. Three possible definitions for the 1-percent AEP flood (green, red, gray) when flood hazards are changing over time (blue) at a hypothetical river site.

Figure 1: The 1-percent flow rising over a 30-year horizon (blue), with the three levels: today's (gray), the highest over the horizon (green), and the one with the same 30-year risk (red) (Honeycutt et al., 2023, Fig. 13, p. 78).

💡 Ask

Which of the three should the map show?

Each one is right for some purpose. The first is correct on the day the map is published and too low every year after that. The second is never too low, and it is too high in every year except the last. The third gets the chance of at least one flood over the 30 years right, and it matches the 1-percent level in only one year.

! Leave up

The three levels.

Risk over a design life, stationary

In week 1 we treated each year as a flip of a bent coin that comes up heads, a flood, with probability p . With independent flips and the same coin every year, the chance of no flood in n years is the chance of n tails in a row, so the chance of at least one flood is

$$P_n = 1 - (1 - p)^n$$

i Say

This is the mortgage number from week 1. A house on the 1-percent line has a 26.0% chance of flooding at least once over a 30-year mortgage.

Risk over a design life, changing

Now the coin is bent a little further each year, so year i has its own chance p_i . The flips are still independent, so the chance of no flood is still a product, now of 30 different factors:

$$P_n = 1 - \prod_{i=1}^n (1 - p_i)$$

At Grand Isle, Louisiana, sea level rise makes a 6.9-foot water level more likely every year: a 1.0% chance in the first year, rising to 3.22% in the thirtieth (Honeycutt et al., 2023, p. 81). Over those 30 years, P_{30} is 43.18%.

i Say

Grand Isle starts at the same 1-percent chance as the mortgage. If nothing changed, the chance of at least one flood would be 26.0%; with the rise it is 43.18%. The years are still independent once we know the sea level in each one: this is the conditional independence from the start of class, with sea level as the covariate.

The stationary equivalent

We can ask which unchanging coin would give the same 30-year risk. Set the stationary formula equal to P_{30} and solve for the constant chance, p_{equiv} :

$$1 - (1 - p_{\text{equiv}})^{30} = P_{30}$$

$$p_{\text{equiv}} = 1 - (1 - P_{30})^{1/30}$$

For Grand Isle, p_{equiv} is 1.87%.

i Say

The report suggests saying it to the public this way: your risk over this period is “the same as if the chances were an unchanging 1.87 percent per year” (Honeycutt et al., 2023, p. 82). That is the third level on the first board.

The level in the Brays paper

In the paper you are reading for Wednesday, every nonstationary flood estimate for Brays Bayou comes from the fitted distribution for 2024, the last year of the record (Smith et al., 2026, pp. 7-8).

💡 Ask

Which of the three levels is that?

The first, the level today. The authors' reason is that dam and levee safety are judged against present-day conditions.

Bibliography

Honeycutt, M., Marcy, D., Kinsman, N., Clark, E., Mason, R., Hecht, J., et al. (2023). *Federal Flood Risk Management Standard Climate-Informed Science Approach (CISA) State of the Science Report*. Retrieved from <https://www.whitehouse.gov/wp-content/uploads/2023/03/Federal-Flood-Risk-Management-Standard-Climate-Informed-Science-Approach-CISA-State-of-the-Science-Report.pdf>

Smith, C. H., Skahill, B., & Margo, D. A. (2026). Nonstationary Flood Frequency Analysis for Urban Watersheds Using Open-Source Bayesian Software: Contrasting Case Studies from Texas. *Water*, 18(5), 636. <https://doi.org/10.3390/w18050636>