The integrated and comprehensive approach to risk management utilized by Reclamation is consistent with the concepts outlined in the 2015 Federal Guidelines [4] and in the dam safety risk management guidance documents of other Federal agencies. For example, the U.S. Army Corps of Engineers references four *tolerable risk guidelines* [17], the first two of which are analogous to Reclamation's visual guidelines (see below), and the second two of which cover the routine activities (discussed in this section) performed by Reclamation outside of the immediate RIDM context.

3. Risk portrayal chart

Figure 3.1 shows the updated version of the risk portrayal chart, which is used to compare risk estimates to the threshold values for increasing justification to reduce or better understand risks (also referred to as the "visual guidelines" in order to distinguish them from the PPG as a whole). The primary difference compared to the 2011 version is that the overlapping AFP and ALL segments have been dropped in favor of a single piecewise-linear guideline. In the decade since the 2011 PPG revision, the redundant segments have been a frequent source of confusion and have made it difficult for both internal and external audiences to differentiate between the operative guideline segments and the non-controlling segments. The intent of the update is to make it clear that there is only one meaningful threshold value of risk in any area of the chart. The chart is "tri-axial" in the sense that any point on the chart can be interpreted as having either an AFP and a life loss coordinate (as in the case of individual PFM risk estimates) or an AFP and an ALL coordinate (as in the case of the total risk estimates). Appendix D contains more detailed information on how risk estimates are plotted on the chart.

Another change from the 2011 version of the risk portrayal chart is that the vertical dashed line segment in the lower right corner has been eliminated. Previously, this line represented the left edge of the so-called "low probability high consequence box," wherein the ALARP concept was considered to specifically apply. The change is consistent with the current view that the applicability of the ALARP concept should not be limited to only one area of the risk portrayal chart, and that the concept should apply regardless of plotting position.

The updated Reclamation risk portrayal chart appears slightly different than the charts used by other Federal agencies with dam safety oversight responsibility. However, Reclamation continues to use the same basic visual guideline risk thresholds as the other Federal agencies and continues to strive for a level of protection consistent with that of the other agencies. As noted in the 2015 Federal Guidelines, "Federal agencies may establish their own standards to best accomplish their unique missions" [4], and the first step in updating the PPG was in fact evaluating whether the threshold visual guideline values were still consistent with Reclamation's mission and organizational objectives. In attempting to answer this question, Reclamation sought to develop an explanation that could convince a person without any background in decision science. The interpretation of the guidelines presented below is not intended to replace the 2011 rationale but to supplement it by providing a simple explanation of why the guideline values continue to be reasonable. For alternative explanations, refer to the 2011 PPG rationale document [2] or to the rationale used by other agencies [17].

Figure 3.2 shows the visual guidelines in terms of three segments, including a horizontal component plotted along an AFP contour of 1E-4 (Segment 1), a diagonal component plotted along an ALL contour of 1E-3 (Segment 2), and a second horizontal component plotted along an AFP contour of 1E-6 (Segment 3). Of these three components, Segment 1, analogous to the "individual risk" guidelines of other agencies [17], is significant in that it represents the basic level of protection provided to residents of the downstream area (regardless of how sparsely or densely populated the area is). In order for the 1E-4 value selected for Segment 1 to be viewed as reasonable, the continuing operation of a Reclamation facility whose total estimated risk plots close to the visual guideline would need to result in only a very small change in the risk exposure of the typical downstream resident. The idea that the use of a Segment 1 AFP threshold of 1E-4 is a step toward achieving this objective can be explained in terms of the average annual reference risk for U.S. residents.

The term "average annual reference risk" is defined as the average probability (prior probability) that a randomly selected individual will lose their life in a given year. It considers all possible causes of death and all demographic categories. Although the expression "background risk of death" is more common, it has become associated with a specific type of demographic breakout and is being avoided here to lessen the potential for confusion with respect to the rationale given in the 2011 document [2]. The average annual reference risk can be estimated as the number of deaths in a given year divided by the size of the population. As of this writing, the most recent published data is from 2019, when a total of 2,854,838 deaths were registered among U.S. residents [18]. In that same year, the U.S. population was reported as 328,329,523 [19], suggesting an average annual reference risk of about 0.009. This value is 90 times (nearly two orders of magnitude) greater than the 1E-4 Segment 1 threshold value, suggesting that for the average person, residing downstream of a Reclamation dam plotting near or below guidelines would result in a comparatively minor increase in risk exposure.

Segment 2 is analogous to the "societal risk" guidelines used by other agencies [17] and has previously been explained in terms of the idea that society may be willing to accept some level of risk in exchange for public benefits. However, it may be easier to explain in terms of individual risk. Whereas Segment 1 establishes the basic standard of care, Segment 2 reinforces it by requiring that the threshold AFP further decreases with increasing potential life loss. That the slope of this line is -1 (as opposed to some other value) or that it intersects Segment 1 at a life loss value of 10 (as opposed to some other number of fatalities) is less important than the idea that dams whose failure has the potential to result in mass casualties are generally being held to a higher standard. Thus, for example, when a failure has the potential to result in 100 fatalities, the threshold AFP value "at guidelines" becomes 1E-5, 10 times lower than the 1E-4 Segment 1 threshold value and approximately 3 orders of magnitude lower than the average annual reference risk.

For facilities with an elevated risk of failure (AFP), understanding the risks with reasonable levels of uncertainty or developing risk reduction alternatives can be fairly straightforward in terms of design options and impactful in terms of risk reduction. However, this is not necessarily the case when the baseline AFP is relatively low. Segment 3 can be explained in terms of the idea that there exists a point of diminishing returns beyond which expenditures to further understand or reduce the risk associated with a particular facility become economically unfeasible. For a dam whose total AFP

estimate is close to the 1E-6 Segment 3 threshold value, the estimated risk of failure would be 2 orders of magnitude lower than the basic guideline value of 1E-4 and 9000 times (nearly 4 orders of magnitude) lower than the average annual reference risk. In contrast, there are numerous Reclamation facilities whose total AFP lies somewhere in the 1E-4 to 1E-6 range. Absent this "truncation" of the diagonal guideline segment, facilities with an estimated AFP lower than one in a million would be competing for funding against those with a much higher risk of failure (and more straightforward risk reduction options). As mentioned above, ALARP is now considered to apply anywhere on the risk portrayal chart (as in Figure 3.3), which provides an alternative means of addressing concerns associated with these scenarios. Any facility whose failure (e.g., by virtue of its geographical location) has the potential to result in extreme life loss still merits scrutiny beyond the basic risk considerations, and as shown in Figure 3.4, there is increasing justification to take practicable (ALARP-based) actions toward the right side of the chart.

In summary, the visual guidelines used by Reclamation continue to strike a reasonable balance between the objectives of not imposing excessive risks on the downstream public and minimizing the likelihood of a mass casualty event, and Reclamation's responsibility as a Federal bureau to exercise judiciousness in the expenditure of public monies while providing Congressionally mandated benefits. The approximately two order of magnitude difference between Segment 1 (the basic standard of care) and the average annual reference risk not only sets up the rationale for the remaining two segments but also ensures that the guidelines need not be interpreted rigidly to remain meaningful (e.g., a risk estimate plotting slightly above Segment 1 would still imply a relatively small increase in risk exposure). That said, it should be stressed that the numbers generated in a risk analysis are not exact, and risk estimates plotting slightly above guidelines are in many cases indistinguishable from those plotting slightly below. Taken outside of their proper context, the visual guidelines are merely lines on a drawing; it is only through the lens of the broader dam safety case that they become indispensable tools for supporting a decision.

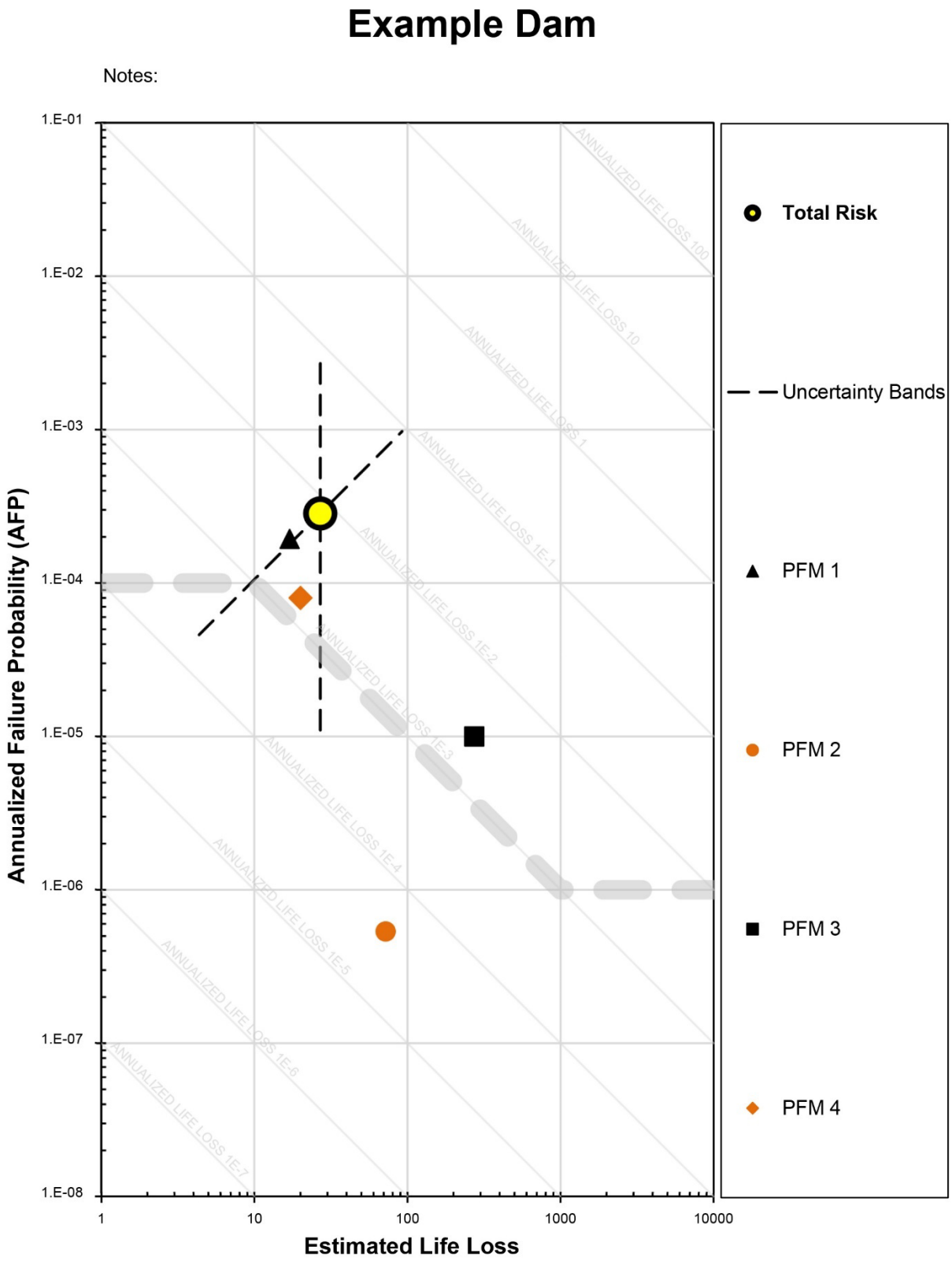

Figure 3.1. Updated Reclamation risk portrayal chart.

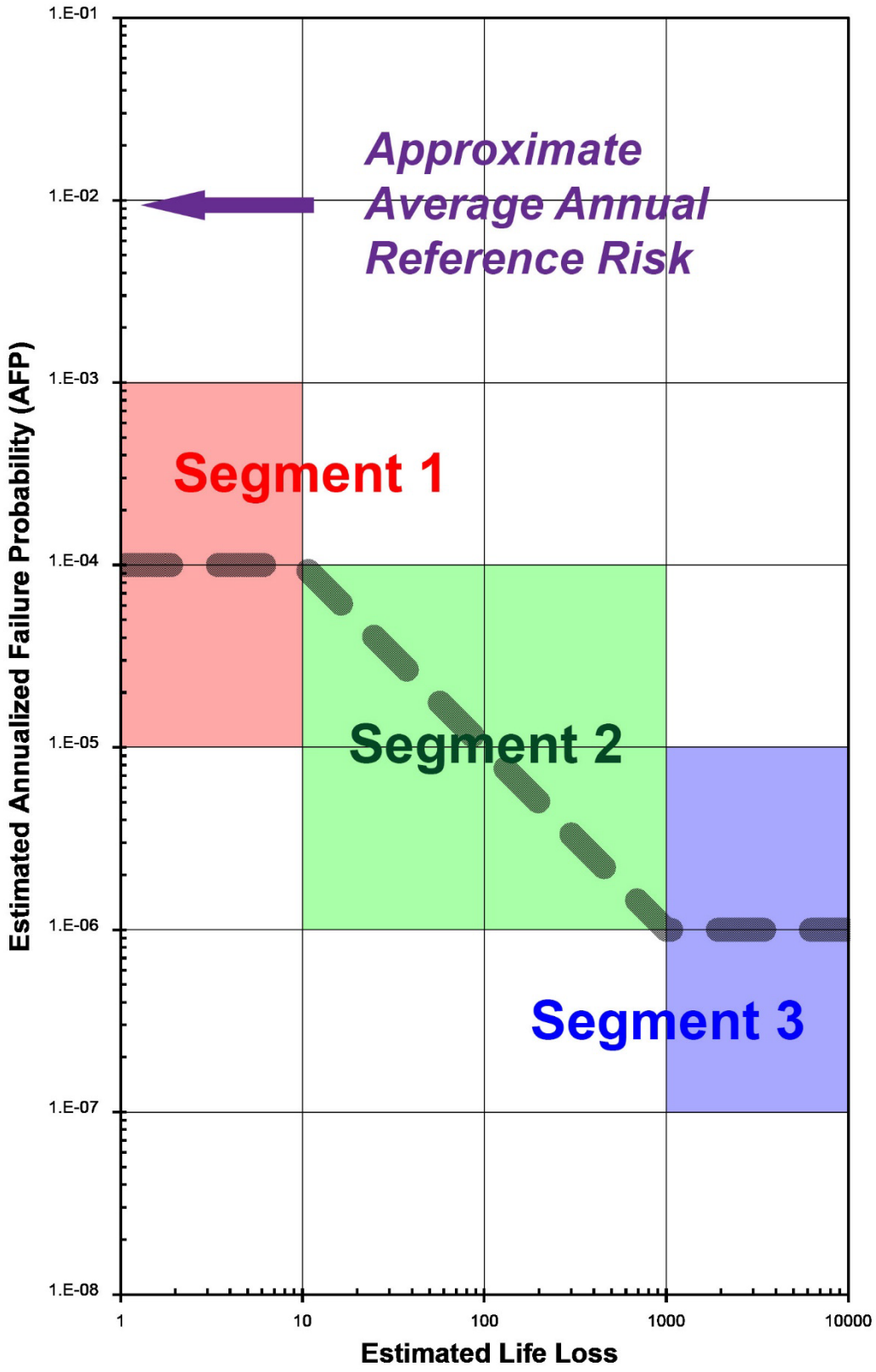

Figure 3.2. The visual guideline can be thought of as one feature consisting of three segments.

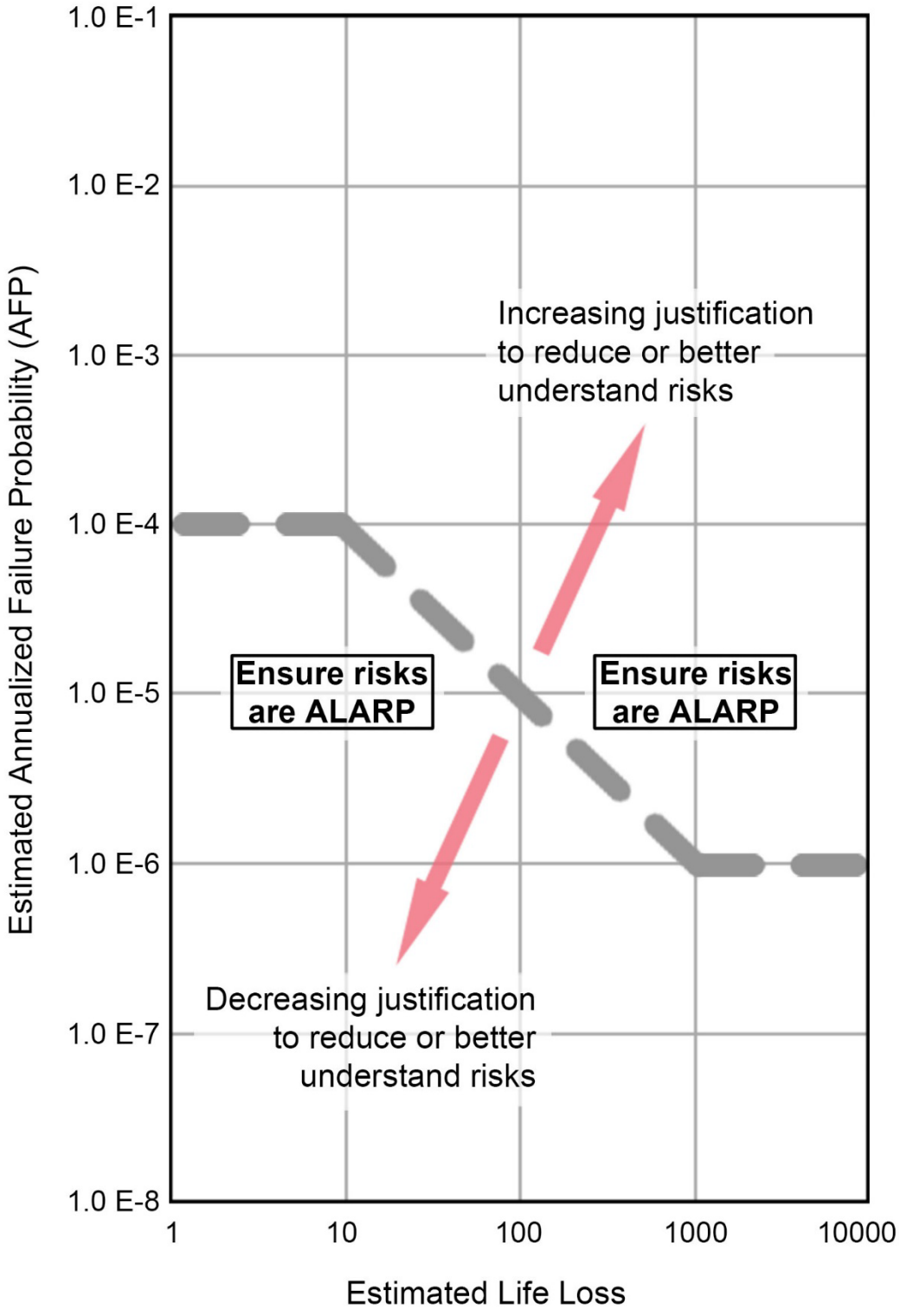

Figure 3.3. Annotated Reclamation risk portrayal chart. Justification to reduce or better understand risks would generally be considered to increase above the visual guideline and decrease below it. The ALARP concept is considered to apply everywhere on the chart.

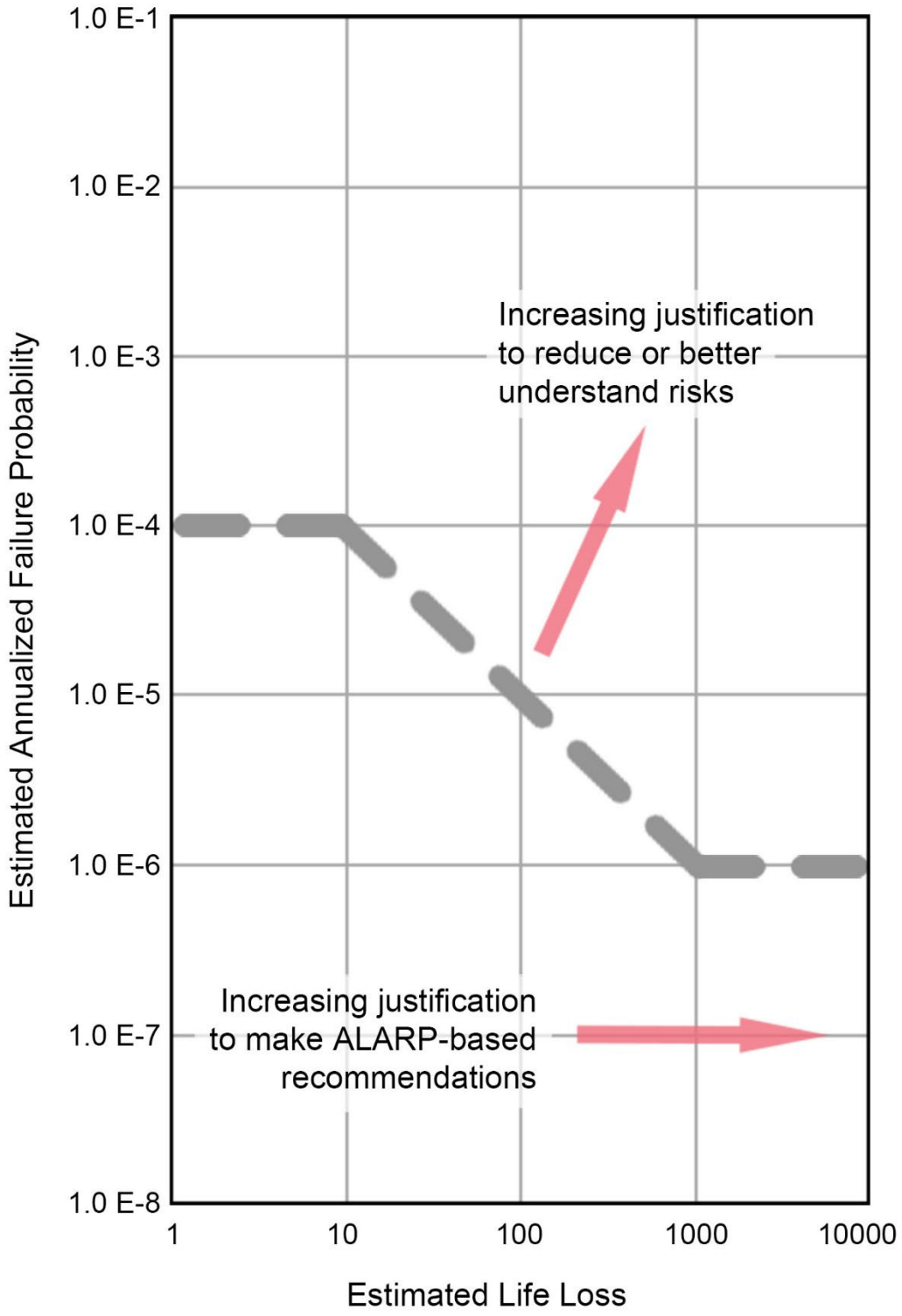

Figure 3.4. The expectation that ALARP-based actions be identified and recommended would effectively increase with increasing potential life loss.