Technical Evaluation of Relative Risk Measures,
Including Reexamination of Pros and Cons

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Background

The Commission directed the staff in SRM-SECY-12-0081, "Risk-Informed Regulatory Framework for New Reactors" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12296A158), to give additional consideration to the use of relative risk metrics or other options that would provide a more risk-informed approach to the determination of the significance of inspection findings for new reactors. Specifically, the Commission directed the staff to perform a technical evaluation of the use of relative risk measures, including a reexamination of the pros and cons listed in the staff's 2009 white paper.

As shown in Figure 1, the current significance determination process (SDP) of the Reactor Oversight Process (ROP) has quantitative thresholds for CDF at 10^{-6}/year, 10^{-5}/year, and 10^{-4}/year, for the green-white, white-yellow, and yellow-red thresholds respectively. Also, the current SDP has quantitative thresholds for LERF at 10^{-7}/year, 10^{-6}/year, and 10^{-5}/year, for the green-white, white-yellow, and yellow-red thresholds, respectively. These thresholds are independent of the baseline CDF of the plants which they are being applied, and each threshold denotes an increase in safety significance of a finding.

Relative Risk Approach

At the public meeting on March 25, 2013, the staff presented the relative risk approach as proposed by the Advisory Committee on Reactor Safeguards (ACRS) (Figure 2). Also, the staff presented a slightly different relative risk approach with change in core damage frequency (ΔCDF) on the y-axis (Figure 3) instead of fractional change in CDF on the y-axis which the ACRS proposed. These two graphs have the same finding thresholds, but portray the information differently (i.e., ΔCDF vs. fractional change in CDF). The staff used ΔCDF instead of fractional change in CDF because ΔCDF is more commonly used by the staff and is consistent with RG 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis." The change from fractional change in CDF to ΔCDF is not a substantive change, but one that the staff believed would be useful in discussions moving forward with the technical evaluation of the relative risk approach.

The purely relative risk approach uses the total baseline CDF (x-axis) and the ΔCDF (y-axis) for a plant to determine the significance of an inspection finding using the sloped lines shown on the graph (Figure 3). The concept behind this approach is that the lower the baseline CDF of a plant, the lower the ΔCDF value, or larger fractional change, necessary for increased significance of a finding. Conversely, the higher the baseline CDF of a plant, the higher ΔCDF value, or smaller fractional change, necessary for increased significance of a finding. Therefore, the significance of a finding would be relative to the baseline CDF value, instead of the current approach of absolute thresholds which do not change given a particular plant's baseline CDF.

Results of Applying Purely Relative Risk Approach

The staff conducted a series of tabletop exercises in 2011 in response to SRM-SECY-10-0121, "Modifying the Risk-Informed Regulatory Guidance for New Reactors" (ADAMS Accession No. ML102230076). As part of those tabletops, the staff looked at the application of the ROP to new reactors. The ROP tabletops tested various scenarios that are or will be relevant to the licensing basis for new reactors to confirm the adequacy of the current ROP risk-informed processes for regulatory decisionmaking or to identify areas for improvement. For each scenario, the staff applied similar situations to the new reactor designs, filling in any gaps with realistic hypothetical situations and reasonable assumptions, and then compared the risk values and resulting regulatory responses from the new reactor scenarios to those derived from the current fleet.

The staff presented the results of its technical evaluation at the public meeting on March 25, 2013. The staff took the same cases from the 2011 tabletop and applied the relative risk approach with and without including seismic estimates to determine the significance of potential findings. The cases in 2011 were evaluated using the existing ROP thresholds. The results of applying relative risk with and without including seismic estimates are shown in Table 1 and are compared to the existing SDP for the same scenario. It should be noted that the cases that were chosen for the new reactors from the 2011 tabletop assume long exposure times and common cause failure (CCF) of multiple trains of equipment.

The results in Table 1 show that applying the relative risk approach with and without including seismic estimates will increase the significance of, and therefore the regulatory response to, findings compared to the existing approach. Applying relative thresholds (without including seismic estimates) to the 19 cases from 2011, 13 of the findings moved up one color (i.e., green to white, white to yellow, or yellow to red). This is an increase in the significance of the finding and represents an increase in regulatory response accordingly. When applying relative thresholds including seismic estimates to the 19 cases from 2011, only six of the findings moved up one color. A very approximate range of seismic CDFs, from 3E-7/year to 3E-6/year, was applied to the baseline CDFs based on estimates using the low and high seismic hazard curves with a high confidence low probability value of 0.5 g. It should be noted that three of the 19 cases had a significance of red already based on the current SDP, so no increase was possible. Baseline CDFs for new reactors that included seismic estimates were examined because new reactors' baseline CDFs will include internal and external events (e.g., seismic, flooding, and fires), and it is believed that the CDF values for new reactors will be dominated by external events, particularly seismic events. Increasing the baseline CDF values for the new reactors by the estimated seismic CDF resulted in an expected decrease in the significance of some scenario findings. This is a result of the concept behind the relative risk approach that the higher the baseline CDF of a plant, the higher the ΔCDF value necessary for increased significance of a finding.

Other Options Considered

The staff considered other options than the proposed relative risk approach, such as the hybrid thresholds approach and the staircase thresholds approach. Both of these alternative approaches are discussed below:

Staircase Thresholds Approach

At the public meeting on March 25, 2013, the staff presented the staircase thresholds approach (Figure 4). The staircase thresholds approach uses a step function with the total baseline CDF (x-axis) and the ΔCDF (y-axis) for a plant to determine the significance of an inspection finding using the staircase lines on the graph. A staircase function is a concept that simplifies the selection of thresholds by not having to use an algorithm, like the relative approach, to calculate the threshold as a function of baseline CDF.

The staircase thresholds approach has very acute cliff effects that have very negative implications. It is possible that a licensee could calculate total baseline CDF just to the right of the cliff and lessen the chance of non-green findings by increasing the thresholds. Therefore, the staff does not view this approach as a viable option.

Hybrid Thresholds Approach

At the public meeting on March 25, 2013, the staff presented the hybrid thresholds approach (Figure 5). The hybrid thresholds approach uses the total baseline CDF (x-axis) and the ΔCDF (y-axis) for a plant to determine the significance of an inspection finding using the lines on the graph. This approach combines the relative risk thresholds with the existing thresholds, with the transition happening at a baseline CDF of 10^{-6}/year on the x-axis. The staff's idea behind this hybrid approach, and selecting the transition point at 10^{-6}/year, was that it would enable the application of a relative approach to the new reactors and the operating reactors would continue with the existing approach. The relative portion (CDF < 10^{-6}/year) of the hybrid thresholds approach is identical to the same portion of the relative risk approach shown in Figure 3, with baseline CDF on the x-axis and ΔCDF on the y-axis.

Industry representatives discussed with the staff pros and cons of the hybrid approach at the public meeting on April 15, 2013. In summary, many of the industries' "problems with establishing alternate risk metrics and/or thresholds" from the 2009 NEI white paper would not arise if the <u>total</u> baseline CDFs were used and the transition point was established at or near 10^{-6}/year. Industry expects the total baseline CDF values for new reactors, which include internal and external events, to exceed 10^{-6}/year and therefore will retain the same color band thresholds as that of the existing fleet. Therefore, this approach would yield the same result as using the existing ROP thresholds.

Whether or not new reactor designs will have total baseline CDF values greater than or less than 10^{-6}/year is debatable. However, if not now, eventually a design will likely have a CDF value below 10^{-6}/year and the same concerns identified by NEI in 2009 will apply. Therefore, the staff views this approach as a short-term solution. If the new reactors' total baseline CDF values are greater than 10^{-6}/year there would be no benefit to implementing the hybrid thresholds approach, because it would yield the same results as the existing approach given that the thresholds would be identical. Accordingly, the staff does not view this approach as a viable option.

Reexamination of the Pros and Cons

The staff developed a white paper (ADAMS Accession No. ML090160004) in 2009 that identified the issues posed by the lower risk estimates for new reactor designs in risk-informed applications and potential options for implementation. The staff specifically addressed the pros and cons of converting to a relative risk approach for the ROP thresholds and RG 1.174. The Nuclear Energy Institute (NEI) developed an additional white paper in 2009 (ADAMS Accession No. ML090900674) to discuss these issues and recommended no change to the current risk metrics.

The staff reexamined the pros and cons from both the staff and NEI white papers. An additional advantage, or pro, of the relative risk approach as presented in the ACRS letter, dated April 26, 2012 (ADAMS Accession No. ML12107A199) is that it maintains the enhanced level of overall plant safety, supports improved decisions for increased regulatory oversight, and provides substantially increased operational flexibility, compared to current reactors. The example that was used by the ACRS, based on the ACRS conceptual thresholds (Figure 2), was that a plant with a baseline CDF of 10^{-4}/year would trigger a White finding with a CDF increase of 1 percent (i.e., an absolute CDF increase of 10^{-6}/year). However, a plant with a baseline CDF of 10^{-8}/year would trigger a White finding with a CDF increase of a factor of 10 (i.e., an absolute CDF increase of 10^{-7}/year). The ACRS states that this would preserve the Commission's stated expectation to maintain the enhanced safety margins for new reactors, while providing greater operational flexibility than current reactors. The staff understands the ACRS's recommendation, and an approach involving relative risk was previously considered, but was not pursued because the Commission did not approve the development of lower numerical thresholds for new reactors (in SRM-SECY-10-0121) in which the ACRS recommendation would effectively result. Further, the industry does not agree that the relative risk approach proposed by the ACRS provides substantially increased operational flexibility, but rather, views the relative risk approach as decreasing operational flexibility for plants with lower CDF values.

An additional pro for the use of a relative risk approach is that a single methodology could be adapted for all operating and new reactors. Both internal and external stakeholders noted at the public meetings that the ROP should be consistent for operating and new reactors. If a change to the ROP was made for new reactors, it was the consensus by all participants at the public meetings that it would likely impact the operating reactors. If not, there would be a double standard for operating and new reactors. Industry was not in favor of the relative risk approach and used the analogy that it would be like having two different speed limits for new and old cars, with newer cars having a slower speed limit.

The pros and cons of a relative risk approach for new reactors, including a reexamination of those noted in the staff's and NEI's white papers from 2009, were discussed during the public meetings. Some of the more significant impediments, or cons, to a relative risk approach for new reactors that were discussed included:

- concerns with implementation depending on how baseline CDF is defined

- difficulty articulating the potential differences in regulatory approach for operating and new reactors
    - If applied only to new reactors, operating and new reactors would have different SDP finding thresholds
- potential to overly infringe on the operational flexibility afforded the safer and more robust new reactor designs
- complexity in developing, documenting, and implementing a relative risk approach
- potential to inadvertently focus licensee and staff attention on relatively insignificant issues as far as overall plant safety is concerned
- If applied to operating reactors in addition to new reactors then the NRC would need to develop and use a broader scope PRA that addresses internal and external hazards for all plants. Licensees are likely to also want to develop their own plant-specific broad-scope PRAs to use in discussions with the NRC regarding SDP evaluations and outcomes.
    - resource-intensive for both NRC and the licensees to develop accurate, plant-specific broad-scope PRA models

The use of the relative risk approach depends on the total baseline CDF. Before implementing such an approach, a definition of total baseline CDF would be necessary. Total baseline CDF for new reactors is commonly referred to as all contributions from internal events and external events during all plant operating modes. However, alternate definitions of the baseline CDF metric may be needed for specific risk-informed applications. For example, the overall risk for some new reactors may be dominated by external events which are relatively insensitive to changes in the availability or configuration of specific SSCs. Because risk-informed decisions under the ROP are concerned primarily with the significance of operational events, equipment failures, and abnormal plant alignments, it could be more appropriate to focus those ROP applications on changes in the CDF from internal hazards.

Applying the relative risk approach to new reactors, but not operating reactors would create a double standard. Having two sets of SDP thresholds, one for new reactors and one for operating reactors, would create public perception issues as pointed out in NEI's 2009 white paper. The double standard would bring into question the thresholds for operating reactors and why those values are safe enough for the public and the environment when the newer reactors, which are supposed to have enhanced safety margins, are held to more restrictive thresholds. Also, a site with both a new reactor and one or more already operating reactors (e.g., Vogtle and V.C. Summer) would have different SDP thresholds for potential findings at various units on the same site. This would not provide a consistent regulatory response within the existing ROP framework.

At the public meeting it was mentioned that the potential exists to overly infringe on the operational flexibility afforded the safer and more robust new reactor designs with a relative risk approach. Participants stated that if the Commission directed the staff to pursue a relative risk approach, the details would be important to ensure a balance between enhanced safety and increased operational flexibility.

Developing, documenting, and implementing a relative risk approach would be complex and potentially difficult. The details would need to be developed with input from internal and external stakeholders, which could be contentious. After the details were decided, documentation would need to be revised or created to explain the relative risk approach. Implementing a relative risk approach would be time and resource intensive, seemingly more intensive than the integrated risk-informed approach using qualitative measures for a similar outcome.

Participants at the public meeting discussed the potential to inadvertently focus licensee and NRC staff attention on relatively insignificant issues as far as safety is concerned if the approach selected were mostly risk-based instead of risk-informed. The concern was that if the Commission directed the staff to adopt relative risk thresholds that more focus would be given to a finding at a plant with a lower baseline CDF value. For example, a plant with a baseline CDF of 10^{-8}/year would have a greater than green finding if the ΔCDF was greater than 10^{-7}/year. However, the current SDP threshold is at 10^{-6}/year for a greater than green finding, so essentially more attention, by both licensees and NRC staff, would be spent on 10^{-7}/year finding, for a plant that was designed to be safer, than a 10^{-6}/year finding at an operating reactor. It was noted that this would be a step in the wrong direction as far as improving focus on safety-significant issues through the use of PRA.

There is no regulatory requirement for operating reactor licensees to develop or use a broad-scope PRA. If the Commission decided on the relative risk approach, then the NRC would need to develop broad-scope PRA models for every plant. This would be necessary in order to establish a baseline CDF value and to evaluate the significance of each finding. Licensees are likely to also want to develop their own plant-specific broad-scope PRAs to use in discussions with the NRC regarding SDP evaluations and outcomes. Implementing the relative risk approach and developing the broad-scope PRA models would be resource intensive for both the industry and the NRC.

The relative risk approach may potentially have merit, but the cons of the relative risk approach appear to outweigh its pros. Therefore, the staff does not view this approach as a viable option.

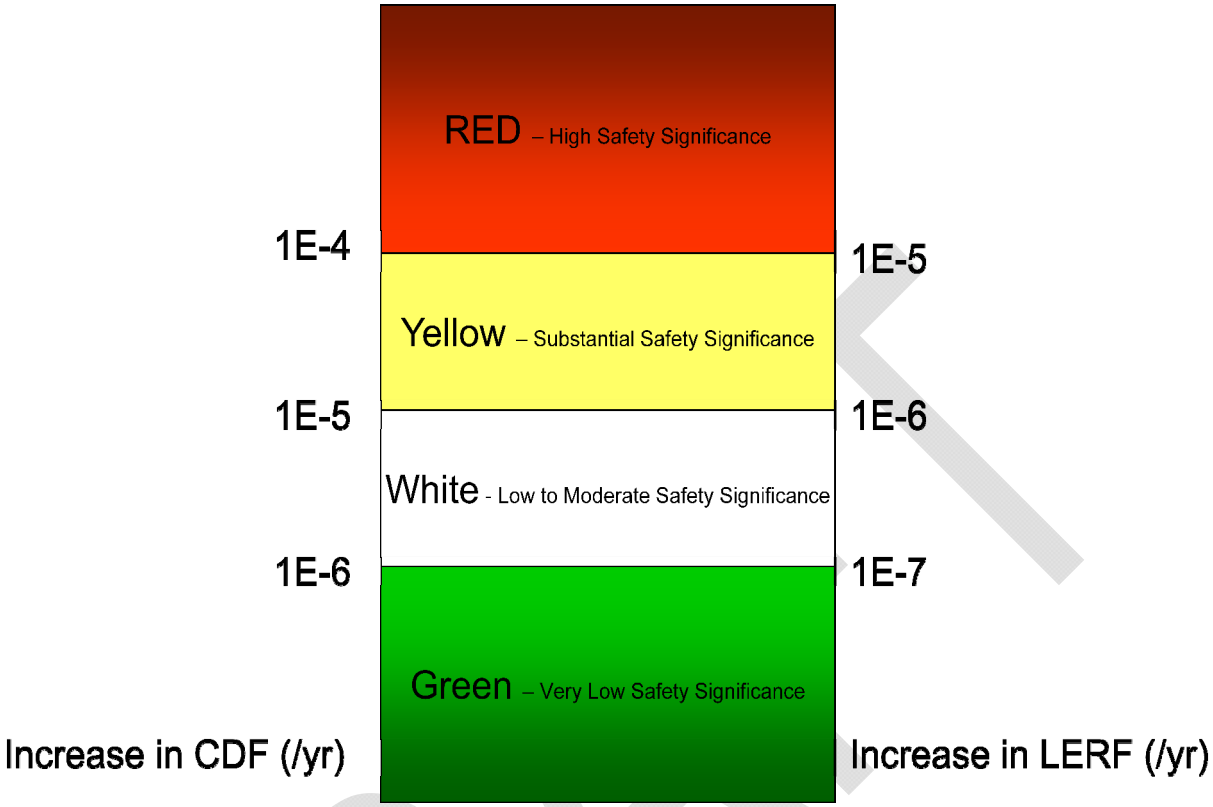

Figure 1: Quantitative Thresholds for the Significance of Findings for the Current SDP

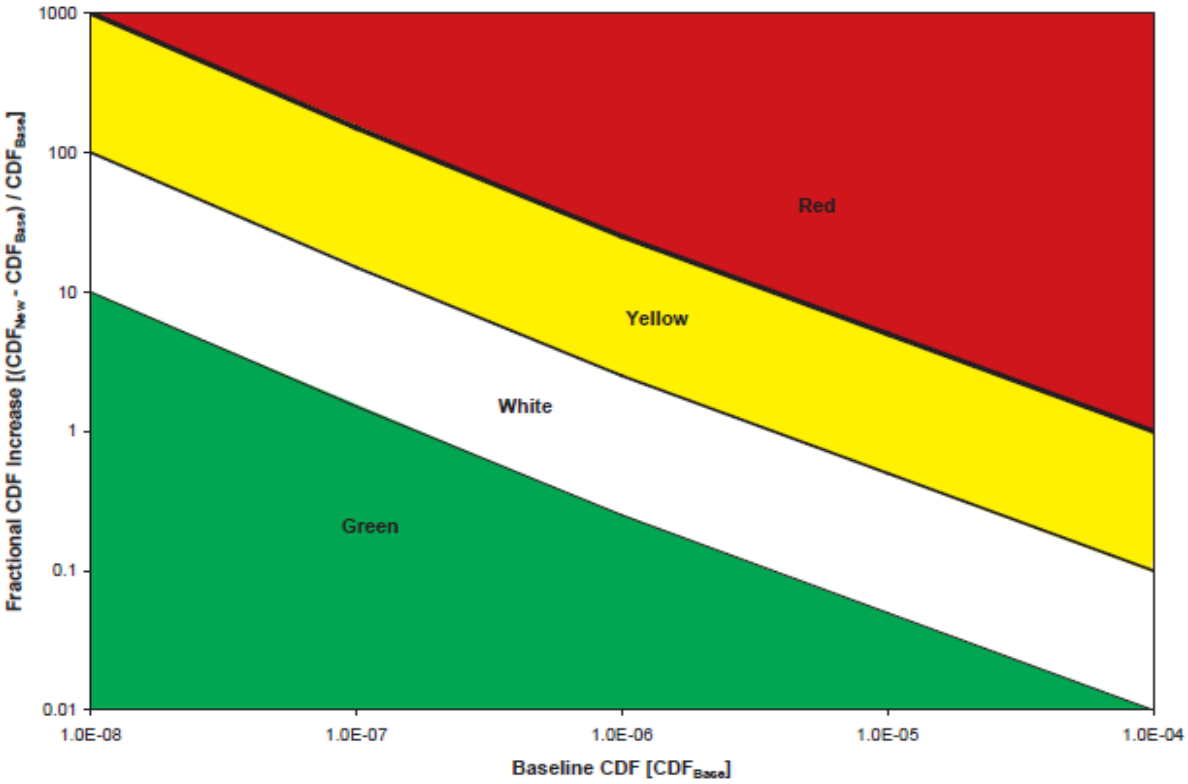

Figure 2: Relative Risk Approach - ACRS

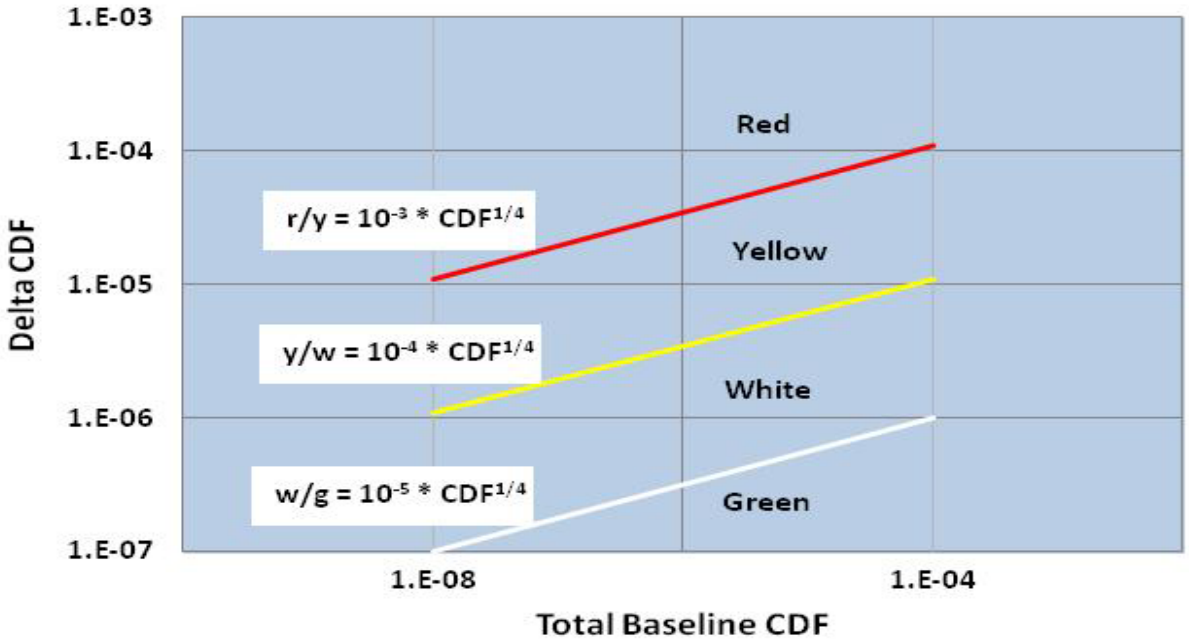

Figure 3: Relative Risk Approach - Staff

Table 1: Application of Relative Risk with and without Seismic Estimates to the 2011 Tabletop Cases

Design	Example	Exposure Period	ΔCDF (/yr)	Model	2011 Tabletop Outcome	Applying Purely Relative Threshold	Applying Relative Threshold w/Seismic
ABWR	HPCF pump fails	23 days	1.4E-8	SPAR			
		1 year	2.2E-7				
	Both HPCF fail due to common cause	23 days	4.8E-8	SPAR			
		1 year	7.7E-7				
US-APWR	One TDEFW pump fails	1year	2.2E-5	SPAR			
		1year	3.4E-6	PRA importances (internal events)			
		1year	3.4E-6	MHI PRA (internal fire and flooding)			
	Both TDEFW pumps fail due to common-cause	1year	4.4E-4	SPAR			
		1year	3.4E-5	PRA importances (internal events)			
		1year	8.8E-6	MHI PRA (internal fire and flooding)			
ABWR	RCIC pump unavailable	1 year	4.1E-7	SPAR			
	RCIC pump and both HPCF pumps unavailable	1 year	1.6E-6	SPAR			
US-APWR	One MDEFW pump and one TDEFW pump unavailable due to lost suction source	1 year	1.3E-4	SPAR			
		1 year	7.7E-5	MHI PRA (internal fire and flooding)			
U.S. EPR	One train of EFW unavailable due to lost suction source	1 year	7.7E-7	Areva PRA			
AP1000	PXS-V121A fails to remain open due to disk-stem separation	295 days	9E-5	SPAR			
		1 year	1.1E-4	SPAR			
US-APWR	RV head corrosion (increase medium and large LOCA frequencies)	1 year	1.4E-7	SPAR			
AP1000		1 year	1.2E-6	SPAR			

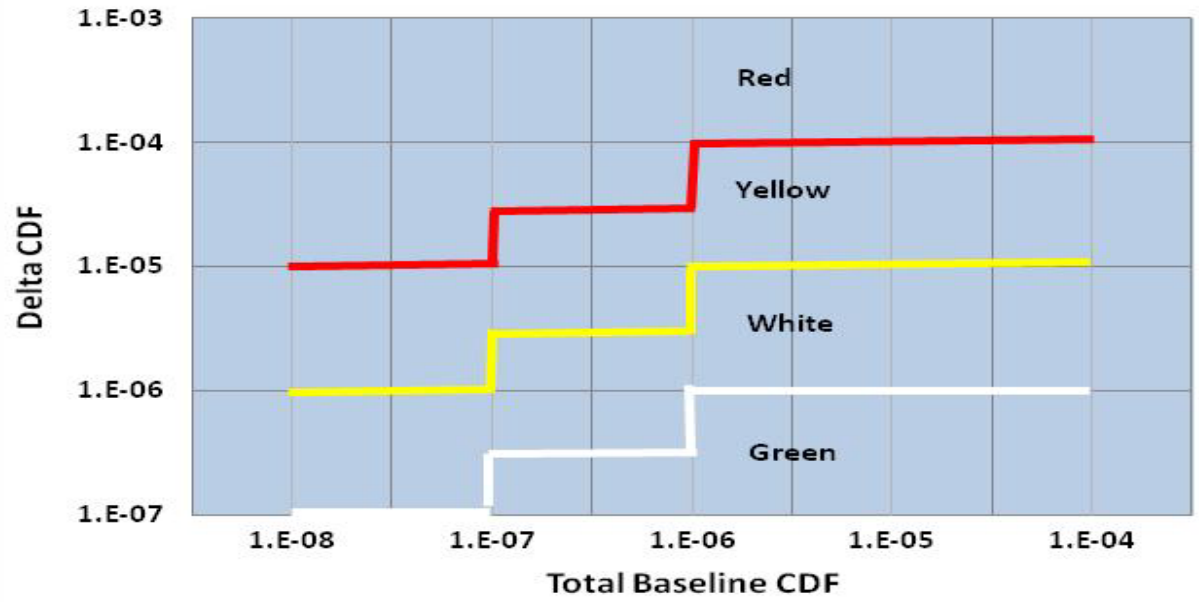

Figure 4: Staircase Thresholds Approach

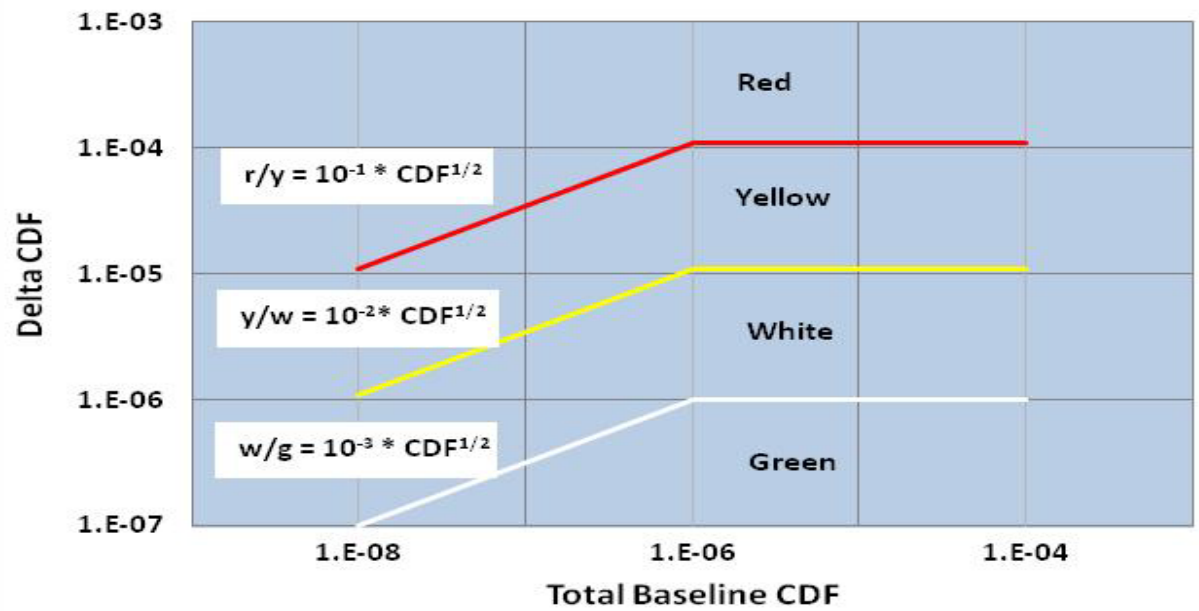

Figure 5: Hybrid Thresholds Approach