Tool

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Decision Support for Selecting Projected Intensity-Duration-Frequency Curve Change Factors

A Guide for Stormwater Professionals

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About This Tool

This document provides step-by-step guidance for stormwater managers and planners on how to select and apply change factors, which represent the difference between historic and future precipitation projections, using the *Projected Intensity-Duration-Frequency (IDF) Curve Data Tool for the Chesapeake Bay Watershed and Virginia* (IDF Curve Tool) (Miro et al., 2021). We developed the IDF Curve Tool and this companion guidance to help stormwater professionals across the region[1] make informed, transparent decisions about how to account for future rainfall in design, planning, and policy. The IDF Curve Tool provides locally relevant, climate-adjusted change factors derived from the latest climate model datasets to estimate how rainfall intensity, duration, and frequency may shift over time and to plan accordingly.

This companion guidance helps users identify the most appropriate change factor to select within the IDF Curve Tool through a structured, risk-based decision process. Rather than prescribing a single "correct" choice, the guidance enables users to connect technical data selections to their project goals, local conditions, and tolerance for risk. The online IDF Curve Tool includes an abbreviated and interactive version of this guidance.

The guidance also provides illustrative vignettes that show how and why different choices might be made in practice and sample communications designed to help practitioners explain forecasted rainfall clearly and confidently to stakeholders, including policymakers, partners, and community members.

This project is developing a suite of practical tools to help stormwater professionals in the Chesapeake Bay watershed integrate climate change considerations into planning, design, and management:

- a Vulnerability Assessment Tool,
- this Climate Projection Decision Support Tool,
- a Resilient Best Management Practices (BMP) Design Manual, and
- modeling to produce BMP climate sensitivities.

The project team is developing these tools through a collaborative, co-production process with Chesapeake Bay Program partners. The project emphasizes usability, transparency, and stakeholder engagement, and includes training and dissemination through the Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) Program, the Chesapeake Stormwater Network, and other regional networks.

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[1] We define the region as all of the states of Virginia, Maryland, Delaware, and Washington, D.C. and the portions of West Virginia, Pennsylvania, and New York that fall within the boundaries of the Chesapeake Bay watershed.

RAND Education, Employment, and Infrastructure

This work was conducted in the Infrastructure and Justice Program of RAND Education, Employment, and Infrastructure, a division of RAND that aims to improve educational opportunity, economic prosperity, and civic life for all. For more information, visit www.rand.org/eei or email eei@rand.org.

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Decision Support for Selecting Projected Intensity-Duration-Frequency Curve Change Factors

Purpose of this Guidance

Planning for future rainfall means confronting a fundamental challenge: precipitation patterns are changing, but the magnitude and timing of those changes remain uncertain. There is no single "best" projection or most likely future—only a range of plausible outcomes, each with implications for how today's stormwater systems and decisions will perform over time. In practice, many practitioners default to "middle-of-the-road" estimates, assuming they represent the most likely trajectory, yet evidence shows these are no more probable than other futures.

Practitioners across the Mid-Atlantic have emphasized the need for credible, user-friendly guidance to help them navigate the range of projections, climate scenarios, and datasets available—particularly those the Projected Intensity-Duration-Frequency (IDF) Curve Data Tool for the Chesapeake Bay watershed and Virginia (IDF Curve Tool) provides (Miro and Romita Grocholski, 2023).

This guidance responds directly to those needs. It provides a structured, step-by-step approach for selecting and applying projected precipitation information from the IDF Curve Tool (Miro et al., 2021). It organizes decisionmaking around the concept of risk orientation, which helps users connect climate data choices to how conservative or flexible their planning, design, or policy decisions could be. It also emphasizes understanding the implications of a range of futures on a system or asset, rather than seeking a single "most likely" outcome (Adger, 2006; New et al., 2022).

We developed this guidance with and for regional practitioners. The authors both created the IDF Curve Tool and have worked closely with it since publication, supporting communities, agencies, and consultants in applying it to a variety of planning and design decisions. Lessons from this ongoing engagement, combined with extensive practitioner consultation and co-development across the Chesapeake Bay watershed and Virginia, shaped the structure, examples, and recommendations in this document (see Appendix A for more detail on our methodology and the key findings that underpin this guidance).

IDF Curve Tool

RAND, Carnegie Mellon University, and the Northeast Regional Climate Center developed the IDF Curve Tool in 2021 with support from the Chesapeake Bay Trust and Virginia agencies. The tool provides rainfall estimates for the Chesapeake Bay watershed and Virginia that account for projected changes in precipitation due to climate change. It applies climate-informed adjustments to National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation frequency estimates which results in a set of projected IDF curves for multiple storm durations and return periods under different climate scenarios. The web-based tool (https://midatlantic-idf.rcc-acis.org) allows users to view, download, and compare historical and projected rainfall data at station and county levels, with accompanying uncertainty ranges and documentation on methods and data sources.

The tool provides projected IDF curves by applying change factors to Atlas 14 IDF curves. Change factors are estimated for each return period, county, emissions scenario and future time period in the IDF Curve Tool using the following equation:

$$Change\ Factor = \frac{\text{Future IDF curve value}}{\text{Historic IDF curve value}}$$

A change factor of 1.2 for a 2-year, 24-hour storm, for example, would suggest a 20 percent increase in future precipitation. That 20 percent change factor can be multiplied by the Atlas 14 value for the same 2-year, 24-hour storm to obtain the projected value.

The range of change factors presented in the IDF Curve Tool for a given location reflects multiple sources of uncertainty inherent in projecting future precipitation. Uncertainty related to global climate models (GCMs) and the downscaling of GCM outputs is represented by the percentile spread of change factors, representing how different models and downscaling methods yield varying estimates of future rainfall intensity. Uncertainty related to future greenhouse gas emissions is captured through the inclusion of two emissions scenarios, which bracket a range of plausible futures based on different assumptions about global development and mitigation pathways. More information on the methodology is available in Miro et al. (2021).

In addition to the technical data analysis, the tool was developed in coordination with the Chesapeake Bay Program's Urban Stormwater Workgroup to ensure it met the needs of the region's engineers, planners, and stormwater program managers. It has been used to support updates to design standards, stormwater infrastructure planning, and flood risk assessments. Since its release, feedback from users emphasized the value of its clear documentation, transparency in methods, and compatibility with existing design practices.

How to Use this Document

Stormwater professionals in the Chesapeake Bay watershed and Virginia should use this guide alongside the IDF Curve Tool. It helps stormwater professionals make structured, transparent decisions about which projected change factors to use in design, planning, and policy. Rather than prescribing a single "correct" factor, the guide explains the reasoning that supports different choices, recognizing that the right choice depends on each user's context, goals, and risk orientation.

The document follows the same decision process that users typically apply when incorporating projected rainfall data into stormwater management.

The three main steps are:

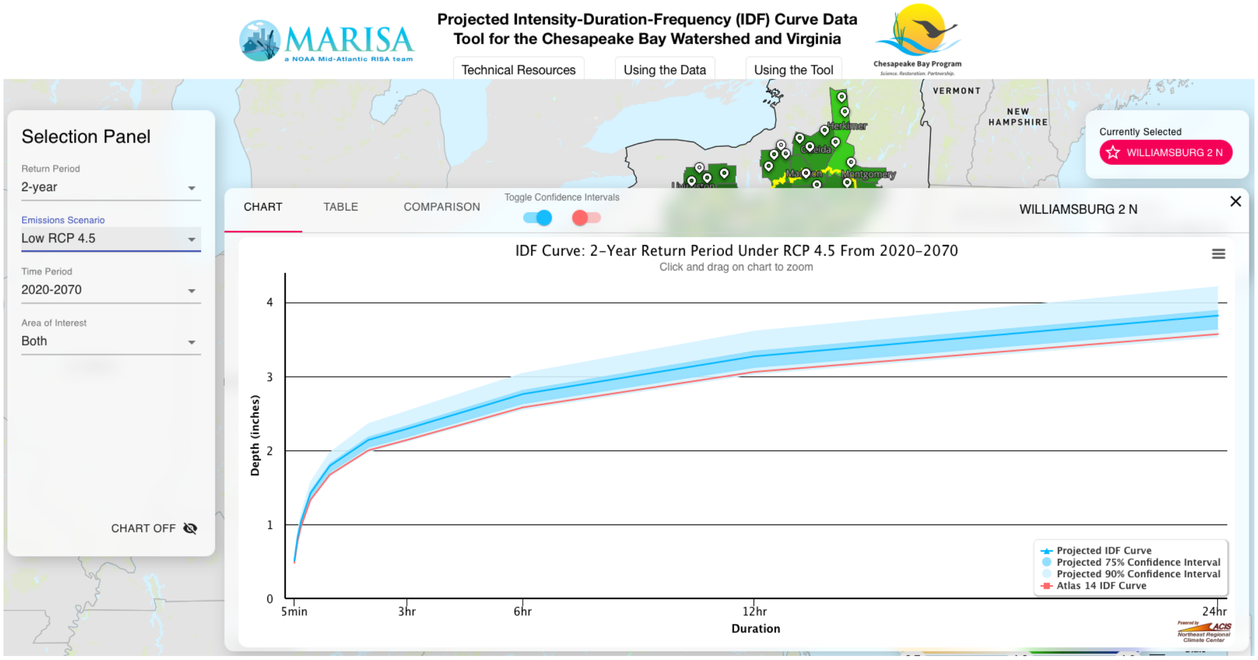
- Step 1: Determine Purpose and Context – Identify the use of the tool for (e.g., designing infrastructure, assessing vulnerability, updating policy) and clarify what outcomes matter most.
- Step 2: Select a Risk Orientation – Characterize the asset, system, or jurisdiction in terms of exposure, sensitivity, and adaptive capacity to determine how conservative or flexible the design approach should be.
- Step 3: Select a Change Factor – Use the chosen risk orientation to guide which time period, emissions scenario, and percentile should inform planning or design.

Sections that follow these steps—Communicating Your Choices and Application in a Policy Context—provide guidance for explaining the user's decisions and adapting them for regulatory or policy-related decisions.

Relationship Between This Document and the IDF Curve Tool

When used alongside the IDF Curve Tool, this document provides recommendations for each of the major choices available within the tool. Figure 1, below, shows the main interface and selection panel of the tool. The interactive map includes rainfall monitoring stations based on those in NOAA's Precipitation Frequency Data Server (NOAA, 2026). Clicking a station marker brings up a pop-up window showing projected IDF curves, associated change factors, and additional tabs to switch between Chart, Table, and Comparison views.

Figure 1. IDF Curve Tool Choices



Projected Intensity-Duration-Frequency (IDF) Curve Data Tool for the Chesapeake Bay Watershed and Virginia

Selection Panel

Return Period: 2-year

Emissions Scenario: Low RCP 4.5

Time Period: 2020-2070

Area of Interest: Both

Currently Selected: WILLIAMSBURG 2 N

IDF Curve: 2-Year Return Period Under RCP 4.5 From 2020-2070

Source: IDF Curve Tool (https://midatlantic-idf.rcc-acis.org/) as of March 2026

The table below summarizes what guidance this document provides for each choice in the IDF Curve Tool, and which selections the user must make based on project-specific or jurisdictional requirements.

Table 1. Guidance Provided for IDF Curve Tool Choices

Choices	Location in IDF Curve Tool	Guidance Provided
Provided in this Guide		
Time Period	Selection Panel	Based on asset life or planning horizon; See Steps 1-3
Emissions Scenario	Selection Panel	Based on risk orientation; See Steps 1-3
Percentile/Confidence Interval[2]	IDF curve pop-up window (Table or Chart tabs)	Based on risk orientation and resources; See Steps 1-3
User Selected		
Area of Interest	Selection Panel	Based on location of infrastructure or user jurisdiction
Station	Interactive map	Based on location of infrastructure or jurisdiction of interest
Return Period	Selection Panel	Based on policy
Duration	IDF curve pop-up window (Table, Chart or Comparison tabs)	Based on policy

The IDF Curve Tool also includes an abbreviated and interactive version of this guidance, which is accessible through the Selection Panel. This interactive guidance not only walks through the decision points for each step but also captures the inputs from each decision and provides both a summary of these decisions and the recommended change factor after the last step of the guidance. This document provides an expanded version of this step-by-step guidance, as well as information on the justification and rationale for each choice.

User Selections Required

As Table 1 shows, several selections within the IDF Curve Tool must be made by the user based on their own planning context before applying the structured decision steps in this document. We review these again in Step 3.1. Specifically, users will need to:

- Select their relevant station and/or area of interest within the Chesapeake Bay watershed or Virginia;
- Choose a design storm return period (e.g., 10-, 25-, or 100-year event) and storm duration (e.g., 15-minutes, 24-hours), as these are set by local design standards or project goals; and

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[2] Percentile and Confidence Interval are used interchangeably in the IDF Curve Tool. In this document, we refer to this choice as the Percentile.

Considering Cost and Risk Tradeoffs

This guidance does not provide direct methods for calculating or comparing the cost implications of selected change factors. However, it can serve as the foundation for those analyses. Once users identify one or more change factors using the framework in this document, they can carry out a cost or tradeoff analysis to evaluate how different change factor choices may affect design, implementation, maintenance, or retrofit costs. This type of analysis helps decisionmakers weigh risk tolerance against investment costs, clarifying the potential financial and performance implications of adopting more or less conservative design assumptions. Recent studies, federal and international guidance suggest that such analyses can compare the direct costs of adaptation investments, such as construction, operation, and maintenance, against the expected costs of inaction, including future damage, service disruptions, and emergency response expenses (Eastern Research Group, 2013; U.S. EPA, 2015; Wise and Capon, 2016; European Environment Agency, 2023).

As part of this project, the authors are developing several case studies with state and local agencies applying this guidance in practice. Each case study will include a section on cost considerations to illustrate how organizations are assessing tradeoffs between resilience and cost in real-world contexts. These case studies will be accessible from the IDF Curve Tool webpage and will be published in the fall of 2026.

Step 1: Determine Purpose and Context

Before diving into the process of this guide, it is important to pause and clearly define what the IDF Curve Tool will be used to inform. Understanding what is being done (e.g., designing infrastructure, assessing community vulnerability, or developing policy) and why (e.g., protecting public safety, prioritizing investments, or ensuring consistency across jurisdictions) provides the foundation for choosing and incorporating an appropriate change factor from the IDF Curve Tool.

Most stormwater planning and management decisions fall into one of two main contexts:

- Infrastructure-level decisions, focused on the design or planning of an individual asset or system of assets. They typically focus on performance and function. They might involve designing a new culvert, evaluating stormwater conveyance capacity, analyzing vulnerability to intense precipitation events, or developing a long-term plan.
- Policy-level decisions, focused on establishing or updating the standards or regulations that govern multiple projects or systems, such as updates to design manuals, stormwater regulations, or permit requirements. These contexts may, instead, aim to ensure consistency, predictability or fairness across projects or jurisdictions.

In prior work evaluating the IDF Curve Tool, infrastructure-level decisions—including both design and planning applications—are by far the most common use case (Miro et al., 2025). The authors have therefore scoped the main steps of this guidance for infrastructure-related design and planning. The section entitled Application in a Policy Context provides specific guidance on using this document for policy-level decisions.

For infrastructure-level decisions, the following questions can help to think through the key outcomes to achieve or support by applying change factors from the IDF Curve Tool:

- What specific performance goals matter most for this asset or system? (e.g., maintaining reliability during a 10-year storm, preventing nuisance flooding, or managing water quality treatment flows)
- How critical is the asset or system to broader operations or public safety?
- What constitutes "acceptable performance" as conditions change?
- How long will the asset be in service, and how difficult or costly would modifications be once it is built?

Next, think about available resources for planning and analysis. Later sections of this guide will consider how resources, such as staff time, technical expertise, available data, and institutional flexibility, shape the use of projected IDF curves. Taking stock early of what resources can be brought to the process will help identify which guidance steps are feasible and where simplified or phased approaches may make sense.

Step 2 will build on this context by helping define a risk orientation through the lens of exposure, sensitivity, and adaptive capacity and determine how conservative or flexible a design approach could be.

Step 2: Select a Risk Orientation

In this guidance, risk orientation describes how conservative or flexible approaches could be to selecting a change factor or an infrastructure asset(s) or system. It ranges from risk tolerant (able to accept more uncertainty) to risk averse (requiring a higher level of protection). In this guide, we use the concepts of exposure, sensitivity, and adaptive capacity to help characterize how to best incorporate a risk-based perspective.

These three elements—exposure, sensitivity, and adaptive capacity—are widely recognized as the core determinants of climate vulnerability across climate science and adaptation research. The Fifth National Climate Assessment (NCA5) characterizes vulnerability based on these three components, defining it as "the propensity or predisposition to be adversely affected by climate change," acknowledging that vulnerability arises from the interaction of exposure, sensitivity, and adaptive capacity within a system (U.S. Global Change Research Program (USGCRP), 2023). Foundational work in climate adaptation research describes vulnerability, similarly, emphasizing it as a function of a system's sensitivity to climatic stressors and its capacity to respond or adapt (Adger, 2006; Turner et al., 2003). More recent applications of this framework in infrastructure and water management demonstrate that integrating these dimensions enables planners and engineers to systematically evaluate climate vulnerability and design more resilient systems (Terando et al., 2024; New et al., 2022).

Here, we recommend assessing the vulnerability of the relevant asset(s) or system using these three components as way to select the risk orientation that could be taken in planning and design. In Step 3, we provide guidance on selecting change factors based on this risk orientation

Step 2.1: Characterize Exposure, Sensitivity and Adaptive Capacity

Table 2, below, provides definitions and guidance on how to assess each of these dimensions as low, moderate or high for the relevant asset(s) or system. Based on the context and purpose for the use of the IDF Curve Tool, use Table 2 to select a Low, Moderate, or High value for each dimension. These assessments will be used in the Risk Orientation Decision Tree below. It is important to note that these dimensions can differ across community and environmental contexts. For example, adaptive capacity may depend on local institutional resources, community preparedness, or ecological resilience, while exposure and sensitivity may vary among areas based on topography, drainage, or land use. Incorporating these contextual variations helps ensure that risk orientation reflects the diversity of conditions influencing infrastructure performance. For contexts in which a full vulnerability assessment is warranted, *A Practical Guide to Vulnerability Assessments for Stormwater Agencies* provides guidance on selecting an approach and carrying out a vulnerability assessment (Miro et al., 2025).

Table 2. Guidance on Exposure, Sensitivity and Adaptive Capacity

Dimension	Description	How to Assess	Select Level
Exposure	The degree to which an asset, site, or system is subject to flooding or other compounding hazards. Exposure reflects the location of assets and the surrounding conditions that influence how frequently or severely rainfall and runoff may affect a location (USGCRP, 2023; Turner et al., 2003). These conditions can vary across communities and environments, depending on land use, elevation, and local hydrologic or ecological characteristics.	Draw on flood history, site characteristics, and expected future changes that might increase or decrease flood hazard (e.g., new upstream development, changing land use, or sea level rise).	• Low: Located on high ground or outside flood-prone areas; no flood history. • Moderate: Some drainage concerns or occasional localized flooding events. • High: Frequent or severe flooding, limited drainage capacity, or multiple overlapping hazards (e.g., tidal or riparian influences).
Sensitivity	The extent to which an asset or system's performance changes when rainfall intensity, duration, or frequency increases. These conditions can vary across communities and environments, depending on land use, elevation, and local hydrologic or ecological characteristics (Adger, 2006).	Consider design standards, system age, and existing performance under heavy rainfall. Assess how close the system operates to its design capacity and whether past events have caused failures.	• Low: Performs reliably under a wide range of conditions or includes redundancy that limits performance loss. • Moderate: Some degradation in performance under heavier rainfall but retains function or recovers quickly. • High: Fails or floods when rainfall modestly exceeds design thresholds;

Dimension	Description	How to Assess	Select Level
			limited tolerance before capacity is exceeded.
Adaptive Capacity	The ability of a system, organization, or community to adjust, recover, or maintain function if performance declines under extreme rainfall. Adaptive capacity can depend on institutional readiness, available resources, and community or environmental contexts that influence how effectively systems can adapt or respond over time. (New et al., 2022; Adger, 2006).	Consider whether detours, backups, redundancy, or contingency plans exist. Evaluate access to funding, staffing, and institutional processes for rapid response or system modification. For new infrastructure, assess how much rainfall the system could tolerate before performance degrades.	• High: Strong redundancy, clear contingency plans, and access to resources enable continued service or rapid restoration • Moderate: Some alternatives or interim responses exist but may be limited in scope or duration • Low: Minimal redundancy or contingency capacity; few options for temporary or permanent response.

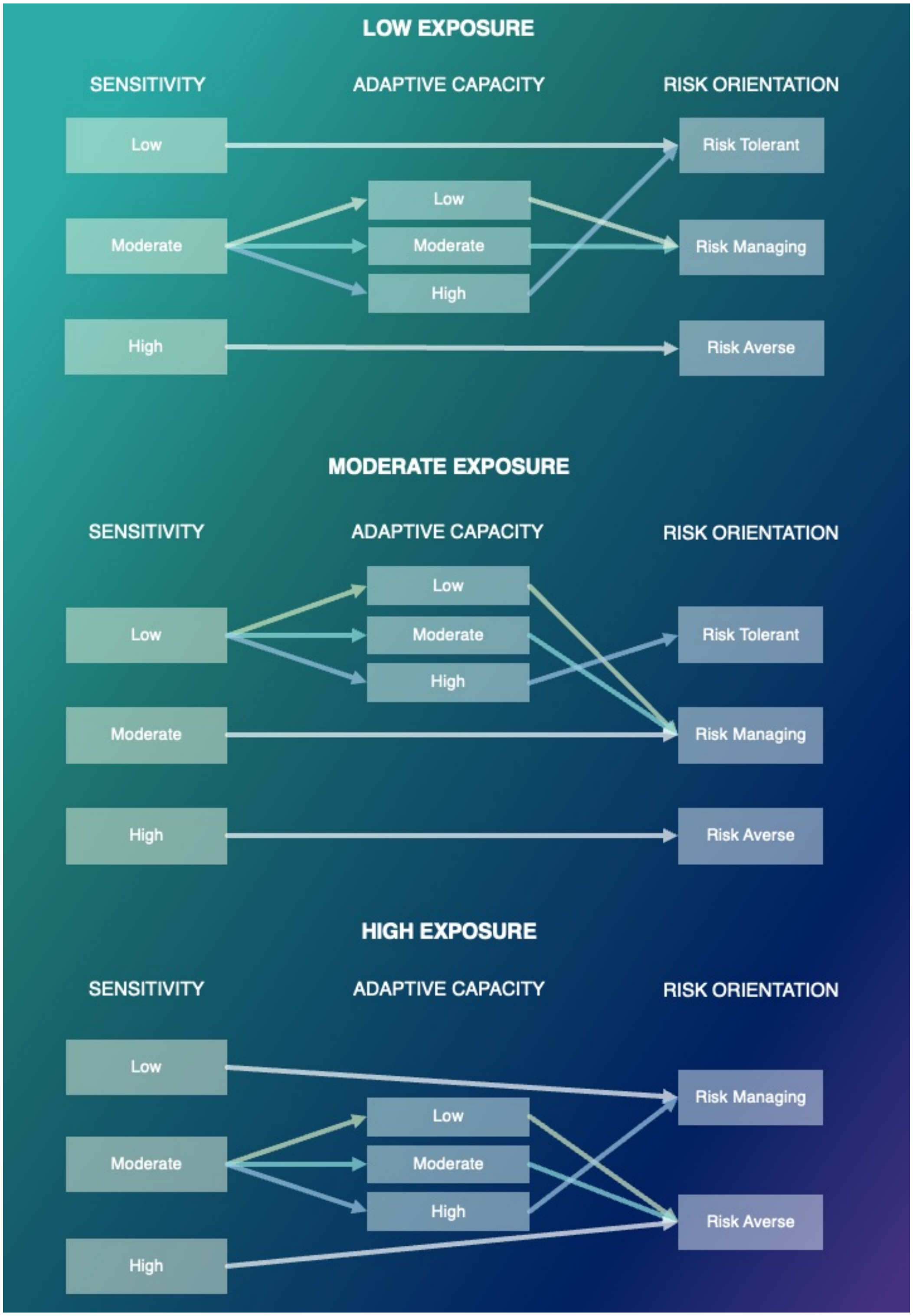
Step 2.2: Select a Risk Orientation

Use the decision tree in Figure 2 to map the assessed levels of exposure, sensitivity and adaptive capacity to determine the overall risk orientation. We define risk orientation based on the following three categories:

- Risk Tolerant: Assets or systems with low exposure, low sensitivity, and high adaptive capacity. In these cases, users can prioritize near-term performance or cost-efficiency and tolerate more uncertainty.
- Risk Managing: Contexts with mixed or moderate levels across the dimensions of vulnerability. Here, users can balance long-term protection with near-term goals.
- Risk Averse: Assets or systems with high exposure, high sensitivity, or low adaptive capacity. These cases suggest a goal of avoiding the worst-case impacts.

Begin with the asset(s) or system level of exposure, from Table 2 above. For Low exposure levels, start with the top decision tree in Figure 2, for Medium, the middle decision tree and for High, the bottom decision tree. Using the relevant decision tree in Figure 2, trace horizontally through the corresponding combinations of sensitivity and adaptive capacity to determine a risk orientation. If users are unsure of the level for exposure, sensitivity or adaptive capacity, we recommend tracing through Figure 2 multiple times to determine if differences in the level selected affects the resulting risk orientation selection. For example, a High level of sensitivity suggests a Risk Averse orientation regardless of the levels for the other two dimensions. A Low level of sensitivity could suggest a Risk Tolerant or Risk Managing orientation, depending on exposure and adaptive capacity. If users need to narrow down their selection for any dimension, we suggest returning to the How to Assess column in Table 2 to determine if additional information may help.

Figure 2. Risk Orientation Decision Tree



Step 3: Select a Change Factor

Change factors represent the ratio between projected future precipitation intensity and historical values for a given storm duration and return period. They provide a way to adjust NOAA Atlas 14 estimates to reflect climate-informed projections. The IDF Curve Tool presents a range of change factors derived from multiple climate models, downscaling methods, and emissions scenarios—each representing a plausible future rather than a probabilistic forecast.

This guide emphasizes that all futures are equally likely; GCM outputs do not provide probabilities indicating that one future is more likely than another. Instead of interpreting these projections through a likelihood lens, which can lead to under- or over-design, this guide uses a risk orientation approach. Risk orientation connects the choice of change factors to the stakes, lifespan, and flexibility of the asset or decision, helping practitioners select values that are proportionate to the potential consequences of failure.

Table 3 summarizes the selection guidance provided in this section and describes the aspects of uncertainty each choice addresses. These elements form the foundation for Step 3, where users apply their selected risk orientation to make informed decisions about which change factors to use in planning, design, or policy contexts. There are a number of user-informed selections covered in Step 3.1.

Table 3. Change Factor Selections and Sources of Uncertainty

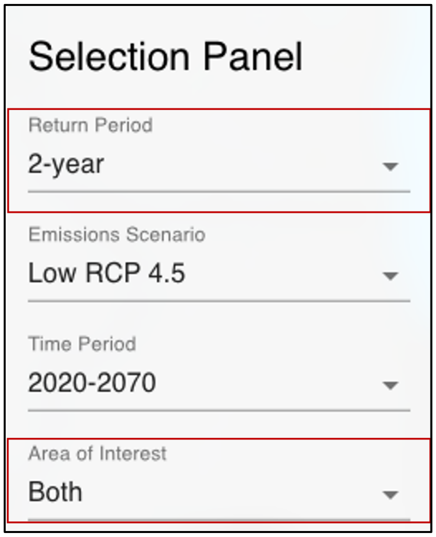
Change Factor Selections	Location in IDF Curve Tool	Aspect of Uncertainty Addressed
Time Period	Selection Panel	Represents uncertainty in timing and magnitude of projected precipitation changes; aligns projections with the asset's life or planning horizon.
Emissions Scenario	Selection Panel	Captures uncertainty in future greenhouse gas emissions and associated climate forcing; provides a range of plausible futures based on global development and mitigation pathways.
Percentile	IDF Curve pop-up window (Table or Chart tabs)	Reflects uncertainty from climate model structure and downscaling methods; the percentile spread shows how different models and downscaling approaches yield varying change factors.

Step 3.1 Make User-Informed Selections

Once users choose a risk orientation, the process of selecting a change factor can begin. To start, there are several selections that must be made based on a specific purpose and context. These were introduced in a prior section (see Table 1) and are highlighted in red in the IDF Curve Tool Selection panel in Figure 3. The first of these choices is the design storm, specifically the return period (e.g., 2-, 100-year event) and the duration (e.g., 1 hour, 24 hours).

These are often dictated by policy or specific project needs and goals. The second selection is the location (e.g., station, county) within the Chesapeake Bay watershed or Virginia, which can be selected in the Selection Panel and with location markers on the interactive map (see Figure 1). Duration options are only available once a user clicks on a location marker and the IDF Curve pop-up window is visible.

Figure 3. IDF Curve Tool Selection Panel



Selection Panel

Return Period: 2-year

Emissions Scenario: Low RCP 4.5

Time Period: 2020-2070

Area of Interest: Both

Source: IDF Curve Tool (https://midatlantic-idf.rcc-acis.org/) as of February 2026

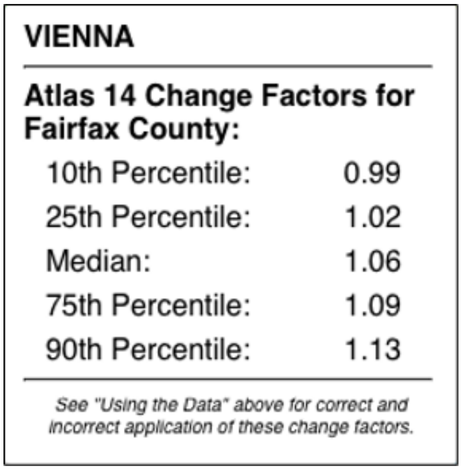
Step 3.2 Select A Time Period

We next address the selection of a time period. The IDF Curve Tool provides change factors for two future time periods 2020-2070 (mid-century) and 2050-2100 (late-century). Regardless of the selected risk orientation in Step 2, we recommend considering the anticipated or intended lifetime of the stormwater infrastructure, plans, or policy when making this choice. For projects, plans, and infrastructure expected to last for less than 30 years or so, we recommend initially using change factors associated with the mid-century (2020-2070) time period because this timeframe captures projected changes in climate within the life of the project/asset. For infrastructure, plans, or policy expected to last for more than 30 years we recommend that the 2050-2100 timeframe be used to account for long-term exposure and longer-term changes in precipitation patterns. Users select their chosen time period in the Selection Panel of the IDF Curve Tool.

Step 3.3 Select an Emissions Scenario and Percentile(s)

This brings us to the choice of a final change factor by selecting a future emissions scenario and percentile. In the IDF Curve Tool, users select the emissions scenario in the drop-down menu within the Selection Panel (Figure 3). The tool shows percentiles in the County pop-ups (see Figure 4 below) or in the IDF Curve pop-up windows. Here, the percentile information is illustrated as a blue shading representing the confidence interval on the IDF Curve Chart tab, as well as in the Table tab. The Comparison tab provides the 50th percentile change factors. Our guidance on how to make these choices is covered below.

Figure 4. Change Factor Table from IDF Curve Tool



VIENNA

Atlas 14 Change Factors for Fairfax County:

10th Percentile:	0.99
25th Percentile:	1.02
Median:	1.06
75th Percentile:	1.09
90th Percentile:	1.13

See "Using the Data" above for correct and incorrect application of these change factors.

Source: IDF Curve Tool (https://midatlantic-idf.rcc-acis.org/) as of February 2026

Step 3.3.1 Determine Resource Level(s)

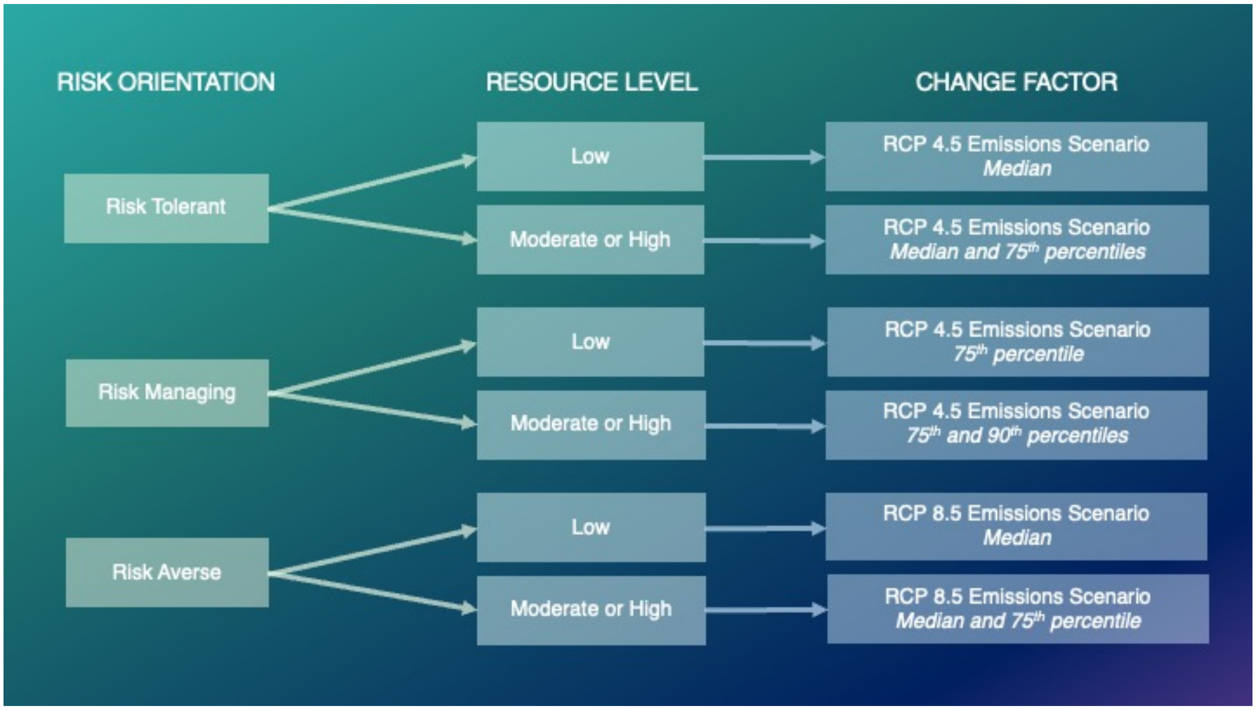
To determine whether multiple change factors should be considered, we also recommend examining the resources available for the design and/or planning process. In this case, resources constitute not just financial resources, but also how much time and number of personnel are available for the analysis, the degree of familiarity and experience relevant personnel have with climate data, and the flexibility built into the process. The resources available or needed for the infrastructure project itself are *not* considered at this stage.

We created two general categories for resource levels “Low” and “Moderate or High”. In the Low category, the agency or stormwater practitioners engaging in the process may have little to no experience working with climate data, minimal time, limited financial resources, or other constraints, or any combination thereof. In the Moderate or High category, relevant personnel may have some familiarity with future climate data up to detailed technical expertise, moderate to advanced internal capacity or ability to seek external support for the project/process, and abundant time for analysis and iteration.

Step 3.3.2 Use the Decision Tree

With the selected risk orientation from Step 2 and resource level from above, users can follow the flow chart in Figure 5 to select a recommended change factor. We provide these recommendations as starting points for selecting specific change factors based on an emissions scenario and percentile within the uncertainty bounds of the climate model outputs. Generally, in this decision tree, the choice of risk orientation is the key choice that leads to a recommended emissions scenario and resource level determines which percentile or percentiles are recommended.

Figure 5. Change Factor Decision Tree



For Risk Tolerant and Risk Managing risk orientations, we recommend using the Representative Concentration Pathway (RCP) 4.5 future emissions scenario, regardless of resource level. If users selected a Risk Averse risk orientation, we recommend using change factors from the RCP 8.5 emissions scenario. As risk orientation increases from Risk Tolerant to Risk Managing, the percentile we recommend also increases from the median to the 75th percentile.

In practice, emissions scenarios are not forecasts of what will happen but representations of a range of plausible futures based on different global development and mitigation pathways. The RCP 4.5 emissions scenario reflects a stabilization pathway in which global emissions peak mid-century and then decline, consistent with many current policy commitments and observed trends. It serves as a reasonable baseline for planning because it represents neither the most optimistic nor the most extreme case. Selecting scenarios below this level (e.g., low-emissions or aggressive mitigation pathways) would assume rapid global decarbonization that is not supported by current trajectories. For this reason, RCP 4.5 is recommended as the minimum level of consideration for most stormwater planning and design contexts, with RCP 8.5 used when a more risk-averse approach is warranted.

The recommendation to use the 75th percentile for the Risk Managing orientation, or as an upper bound consideration for Risk Tolerant, reflects the need to account for the upper range of plausible precipitation increases while still maintaining design practicality. While Atlas 14 typically relies on median estimates, future climate projections introduce additional uncertainty from model structure and downscaling methods (see the Appendix for additional discussion of the sources of uncertainty). Using the 75th percentile does not imply that higher rainfall is more likely, it simply provides a risk-informed buffer that helps practitioners design for potential increases in intensity without assuming probabilistic likelihoods. This approach aligns with the guide's emphasis on risk orientation rather than likelihood, ensuring that design decisions are proportionate to the potential consequences of under- or over-design rather than based on uncertain probabilities.

For each risk orientation, if Resource Levels are assessed to be Low, we recommend only one change factor. However, if Resource Levels are Moderate or High, we recommend considering multiple change factors. Given the amount of uncertainty associated with projected future precipitation, we recommend users incorporate multiple change factors into analytic processes whenever resources allow in order to better understand how different assumptions about future precipitation change the results. This requires additional time and resources (e.g., expertise, financial) but can help support more resilient and transparent decision-making.

Decision Guidance Vignettes

To illustrate how this decision guidance can be used, we provide two brief vignettes that describe a fictional situation and apply it to the steps described above for a low resourced and a high resourced scenario. A vignette examining a policy context is provided in the Application to a Policy Context section below.

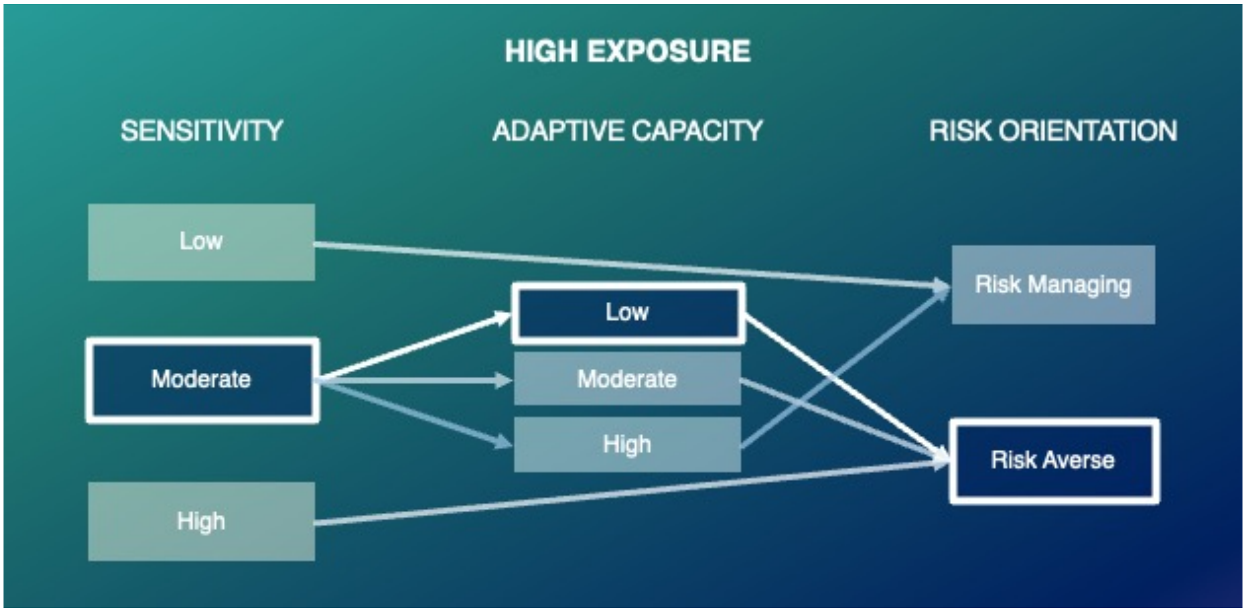
Low Resourced Vignette

A stormwater engineer working in the Delandria City Department of Public Works is writing a long-term stormwater plan. The department is relatively small and is often understaffed, so a limited amount of time and other resources can be spent on the analysis supporting this planning process. Delandria City has seen an increase in the number of heavy rainfall events over the past several years and flooding issues no longer only impact low lying areas. They are also seeing increased impacts for areas along the river that runs through downtown. The floodwaters tend to recede relatively quickly, but business have been impacted by repeated repairs, renovations, and loss of car and foot traffic due to flooded roads during these events.

Based on the history of flood events, the increasing number of the events, and concerns about how river levels will interplay with extreme precipitation in the future, the engineer decides that

Delandria City qualifies as High Exposure. Next in the flow chart, based on the impacts they are seeing to the downtown area, they decide that Delandria City has Moderate sensitivity. Finally, they select Low for their adaptive capacity given that there aren't a lot of obvious options for reducing the flooding. Following the decision tree shown in Figure 6, which has these choices highlighted in dark blue boxes with white outlines, we see that the recommended risk orientation for Delandria City is Risk Averse.

Figure 6. Vignette Risk Orientation Decision Tree



The stormwater engineer then pulls up the IDF Curve Tool to start figuring out what change factors they need to use to incorporate future precipitation into their plans. Their local stormwater manual dictates that they use a 25-year storm for long-term planning, so they select that option from the return period drop down menu. Next, given the long-term nature of the plan, they choose the late-century time period (2050-2100).

Finally, it is time to choose which change factor Delandria City will use for their planning. Using the Change Factor Decision Tree, starting with the Risk Averse risk orientation, they then select the Low resource level, which leads them to the selection of the median of the RCP 8.5 emissions scenario. These choices are highlighted in Figure 7 below.

Figure 7. Vignette Change Factor Decision Tree

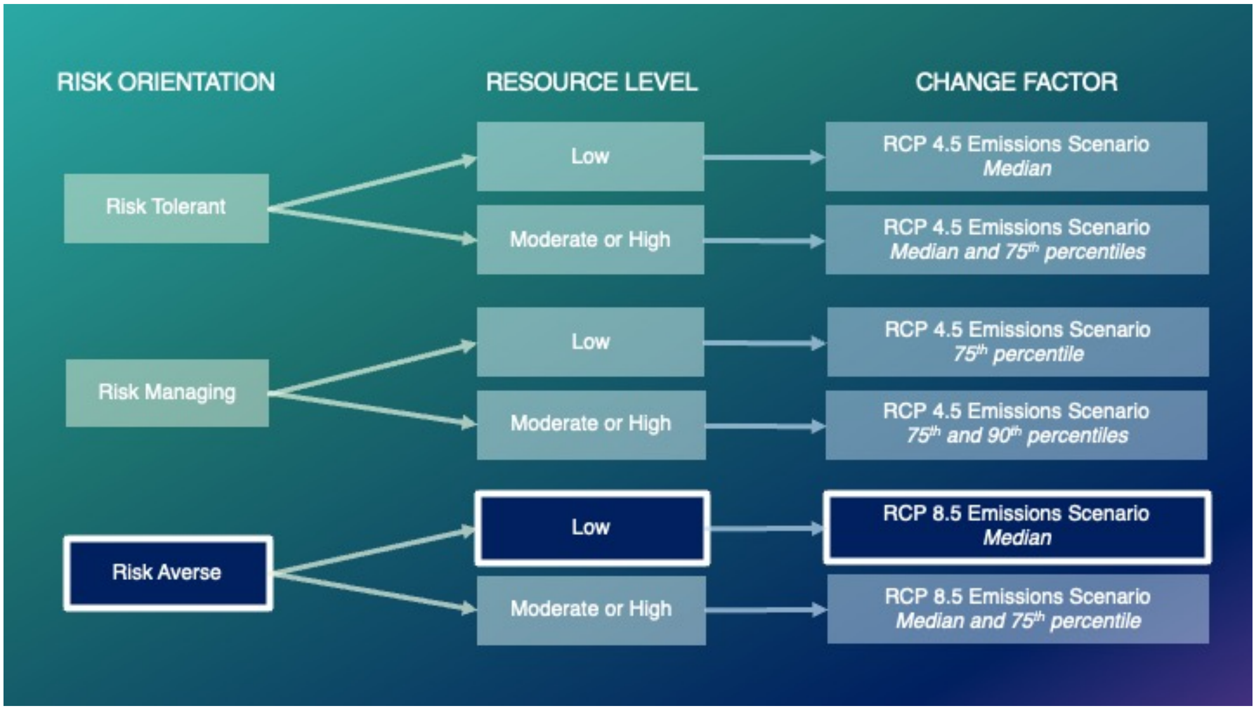
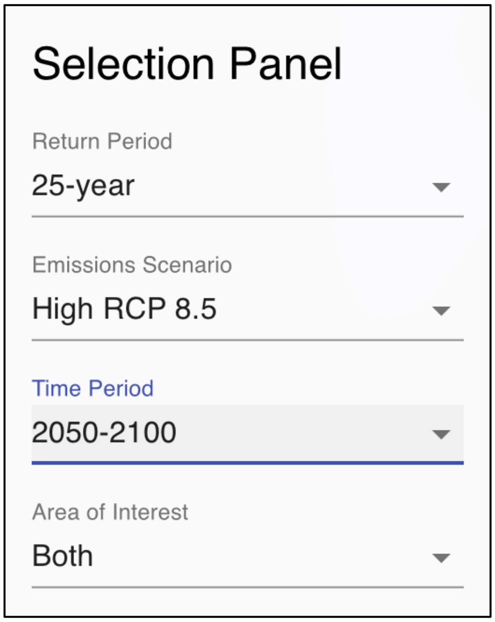


Figure 8 shows what the selection panel in the IDF Curve Tool would look like and Figure 9 shows where the median value can be found in the table view of the change factors.

Figure 8. Vignette IDF Curve Tool Selection Panel



Selection Panel

Return Period
25-year

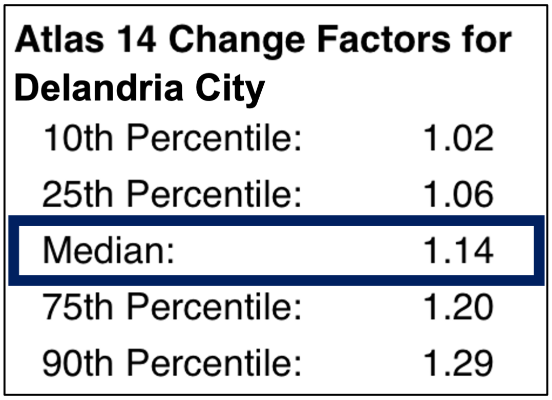
Emissions Scenario
High RCP 8.5

Time Period
2050-2100

Area of Interest
Both

Source: IDF Curve Tool (https://midatlantic-idf.rcc-acis.org/) as of February 2026

Figure 9. Vignette IDF Curve Tool Change Factor Table



Atlas 14 Change Factors for Delandria City

10th Percentile:	1.02
25th Percentile:	1.06
Median:	1.14
75th Percentile:	1.20
90th Percentile:	1.29

Source: IDF Curve Tool (https://midatlantic-idf.rcc-acis.org/) as of February 2026

High Resourced Vignette

Just as the stormwater engineer completes their initial change factor selection, they receive news that the Delandria City Department of Public Works has been awarded a substantial grant to support the integration of future climate considerations into their stormwater planning process. The new funding allows the department to hire a consulting team to develop detailed hydrologic and hydraulic models of downtown Delandria City. The stormwater engineer's task is now to provide the change factors that the consultants will use to adjust model inputs and evaluate future flood risk.

The engineer revisits the Risk Orientation Decision Tree (Figure 6) to confirm Delandria City's classification. The city remains High Exposure with Moderate Sensitivity, tracing both options through the decision tree shows that the resulting Risk Orientation remains Risk Averse. Confident in this classification, the engineer proceeds to the Change Factor Decision Tree (Figure 7).

Based on the combination of a Risk Averse orientation and a Moderate or High resource level, the recommended approach is to use two change factors—the median and 75th percentile values from RCP 8.5. In the IDF Curve Tool, these correspond to a 14 percent and 20 percent increase in future precipitation intensity relative to NOAA Atlas 14 values (Figure 9).

The engineer meets with the consultants to discuss how to apply these two change factors in the modeling process. Together, they decide to run two sets of simulations: one using the 14 percent increase (median) to represent a central estimate of future conditions, and another using the 20 percent increase (75th percentile) to explore a higher-impact but still plausible future. The resulting flood maps show that, under the 20 percent increase scenario, the number of downtown businesses affected by flooding rises substantially due to the area's topography and drainage constraints.

Based on these findings, the department decides to incorporate the 20 percent change factor into its long-term stormwater plan. This choice reflects Delandria City's Risk Averse orientation and ensures that the city's infrastructure investments are robust to a wider range of potential future precipitation intensities.

Communicating Your Choices

Through our work with stormwater professionals across the Chesapeake Bay watershed and the Mid-Atlantic region, we consistently heard that communicating how and why design and policy decisions are made using the IDF Curve Tool is just as critical as making them. Clear communication builds understanding, trust, and confidence among decisionmakers, staff, and the public, and it ensures that climate information is used transparently and effectively.

Practitioners emphasized several recurring communication needs:

- Translating technical information about future rainfall projections into plain, defensible language.
- Explaining the rationale behind selected change factors, design storms, or risk orientations.
- Navigating conversations about cost, uncertainty, and risk tolerance with policymakers and constituents.
- Providing consistent, transparent messages across agencies and teams.

To support these needs, Table 4 below summarizes sample messages for common questions relevant to technical decisions as well as broader planning and policy discussions. Depending on the intended audience, these answers can be modified to reduce technical language or further explain some concepts.

Table 4. Communicating About Future Rainfall Projections

Question	Answer
Why account for future changes in rainfall patterns?	Many localities within the Chesapeake Bay Watershed and Virginia have already experienced increases in total annual rainfall and in the frequency and intensity of extreme precipitation compared with historical averages (Fischbach et al., 2018). These trends are expected to continue in the future. Standard methods for estimating rainfall, such as NOAA's Atlas 14, are based on historical observations—largely from before 2000—and assume rainfall patterns will remain stable over time (Bonnin et al., 2004). Because these methods do not reflect rainfall changes that are already occurring or projected for the future, they can underestimate future extremes, increasing the risk of under-preparing for flood conditions and compounding impacts to people, property, and critical services.
Why do future rainfall projections produce a range of estimates, and how should that range be interpreted?	Projections of future rainfall are inherently uncertain. They depend on (1) assumptions about future greenhouse gas emissions, land use, and socioeconomic development ("scenarios"); (2) the climate models used to represent complex physical processes; and (3) the methods used to translate global climate data to local scales (Briley et al., 2021). Precipitation is also naturally variable and thus uncertain even in the absence of methodology considerations. As a result, projections represent a range of plausible futures rather than a single forecast. Because no single projection is "most likely," best practice is to evaluate decisions across multiple projections and to select assumptions appropriate to the stakes of the decision, using more cautious approaches where consequences are high or difficult to reverse (OSTP, 2023). Decision support guidance, such as in this

Question	Answer
	document, can help practitioners think through how to select projections for a given purpose.
How do decisions about change factors affect the cost of projects?	Planning for more severe future rainfall conditions can involve higher initial costs for planning, design, zoning, insurance, and construction, but can avoid the often-greater costs of inaction or under-preparation. When rainfall exceeds what systems are designed to handle, impacts can include damage to property, business disruption, and expensive emergency responses. A risk-based perspective helps weigh these potential cost and other consequences against the cost of taking action. In practice, this means asking not only "How much does this cost?" but also "How costly in both monetary and non-monetary terms would failure to prepare be—and how much risk are we willing to accept?"
How can a risk-based approach be applied in practice?	Because decisions differ in their stakes and flexibility, different projections are appropriate for different levels of risk. More cautious assumptions and more rigorous stress testing are warranted in higher-risk contexts—where exposure and sensitivity to compounding stressors is high or the ability of communities or systems to respond is limited (Intergovernmental Panel on Climate Change [IPCC], 2022; Terando et al., 2024). Using risk as a guide helps select projections and change factors that are proportionate to the decision's importance and time horizon.

Table 5 below provides sample language that tool users can adapt when describing the rationale behind their change factor selections. Each example aligns with one of the risk orientations defined in this guidance and includes a suggested base change factor, an optional additional change factor for testing or comparison, and narrative text that explains the reasoning in plain, defensible terms. These examples can be used in staff reports, design documentation, public presentations, or policy discussions to convey how climate data choices reflect local context, risk tolerance, and planning goals.

Table 5. Sample Communication Materials by Risk Orientation

Risk Orientation	Base Change Factor	Additional Change Factor	Description of Rationale
Risk Tolerant	Median (50th percentile) RCP 4.5 emissions scenario	75th percentile, RCP 4.5 emissions scenario	We selected the median change factor from the RCP 4.5 emissions scenario, because it represents a "best-case" planning assumption suitable where assets or systems have low vulnerability. This is appropriate because we expect our system to perform adequately under future rainfall due to low exposure, low sensitivity, and high capacity to adjust operations, maintenance, or infrastructure if rainfall exceeds this estimate *If used:* We have also considered a second change factor 75th percentile from the RCP 4.5 emissions scenario to help us test these assumptions on a slightly more risk averse scenario.
Risk Managing	75th percentile RCP 4.5 emissions scenario	90th percentile, RCP 4.5 emissions scenario	We selected the 75th percentile change factor from the RCP 4.5 emissions scenario, because it represents a balanced approach that accounts for severe but plausible future rainfall conditions while avoiding reliance on the most extreme assumptions.

Risk Orientation	Base Change Factor	Additional Change Factor	Description of Rationale
			This is appropriate where there is moderate vulnerability to extreme rainfall. *If used:* We have also considered a second change factor, the 90th percentile from the RCP 4.5 emissions scenario, to examine potential impacts under a more risk averse set of assumptions.
Risk Averse	Median (50th percentile), RCP 8.5 emissions scenario	75th percentile, RCP 8.5 emissions scenario	We selected the 50th percentile from the RCP 8.5 emissions scenario because it reflects planning for extreme but plausible future conditions. This assumption is appropriate for systems with high exposure and sensitivity to extreme rainfall and limited adaptive capacity. Under these conditions, a more conservative projection helps support reliable system performance and reflects limited flexibility to accommodate future increases in rainfall. *If used:* We have also considered a second change factor, the 75th percentile from the RCP 8.5 emissions scenario, to explore potential cost or performance trade-offs under a slightly less conservative assumption.

Application to a Policy Context

We wrote the above steps to specifically support infrastructure-level decisions; however, users can easily modify this guidance modified to support policy-level decisions that are focused on updating or creating stormwater regulations and standards (e.g., design manuals, permit requirements). There are some particular ways in which policy decisions may differ from the infrastructure-focused ones discussed above. In Table 6, we illustrate how each of the steps can be adjusted to be more easily applicable and relevant to policy decisions.

Table 6. Decision Guidance for a Policy Context

Step	Interpretation for Policy Context
Step 1: Determine Purpose and Context	Further consider the options available in terms of the overall policy approach, particularly, whether to take a uniform or tiered approach. There are pros and cons to each approach. With a uniform approach, a single standard is applied across all areas and asset types. This is simple to understand and follow, consistent, and easier to enforce. However, if is not consistent across all areas, a uniform standard may lead to over-design in low-risk areas and under-design in higher risk areas. With a tiered approach, establish a baseline requirement and a higher threshold(s) for areas with increased risk. This approach better matches with local variations in risk but can be more complex to write and implement.
Step 2: Select a Risk Orientation	This step needs little adjustment for the uniform approach aside from considering a larger area or number and type of assets in the assessment of exposure, sensitivity, and adaptive capacity. The same is true of the consideration of resource levels across the area for which policy is being written/applied. If a tiered approach is chosen, this step should consider the levels of exposure, sensitivity, and adaptive capacity that should correspond with each of the intended policy thresholds and choose risk orientations accordingly. Leveraging

Step	Interpretation for Policy Context
	a vulnerability assessment or hazard mitigation plan would be useful in this case.[3] Then, determine which risk orientation applies to each threshold.
Step 3: Select a Change Factor	Again, this step needs little adjustment if users take a uniform approach and simply are considering a broader area or set of assets in their thinking. For a tiered approach, repeat these considerations for each chosen risk threshold and ultimately decide how many change factors and thresholds may be reasonable to include in the policy.

Policy Vignette

We provide a brief vignette below to further illustrate how this guidance can be applied to a policy context.

The Portham Beach Regional Commission is beginning a major update to its stormwater design standards. The Portham Beach Regional Commission represents a region whose economy has expanded rapidly due to the success and growth of its port. This expansion has led to extensive new development—both commercial and residential—across the area. However, risk is not distributed evenly. Low-lying, historically disinvested neighborhoods experience frequent flooding from heavy rainfall and even sunny-day high-tide events. Regional planners are increasingly concerned that continued growth and rising impervious surface coverage will exacerbate flooding and strain existing drainage systems.

Step 1: Determine Purpose and Context

Recognizing that risk varies substantially across the region, the planning team decides to take a tiered approach to updating its stormwater regulations. The new policy will establish a baseline standard applicable region-wide and higher design thresholds for areas with greater flood risk. This approach allows the region to maintain consistency while tailoring requirements to local conditions. The team notes that a uniform standard would be simpler to administer but could lead to over-design in low-risk areas and under-design in high-risk ones. The tiered approach better aligns with Portham Beach's diverse topography and development patterns.

Step 2: Select a Risk Orientation

Using the Risk Orientation Decision Tree (Figure 6), the planners identify a baseline risk orientation of Risk Managing for the region as a whole. For areas with extensive impervious surface, frequent flooding, and a high concentration of housing and businesses, they assign a Risk Averse orientation, while areas with lower exposure and better drainage capacity are classified as Risk Tolerant. To make this assessment more systematic, the team develops a metric

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[3] The authors have previously written practical guidance for conducting vulnerability assessments that may be a helpful reference. Miro, Michelle E., Krista Romita Grocholski, Nihar Chhatiawala, David Wood, and Michele Berry, *A Practical Guide to Vulnerability Assessments for Stormwater Agencies: Approaches, Applications, and Best Practices,* RAND Corporation, TL-A4308-1, 2025.

that combines historical flood frequency, impervious surface percentage, and presence of homes and businesses as a proxy for flood risk. Each metric is normalized on a scale of 0 to 1 and then summed together, with higher numbers indicating higher risk. Using a GIS analysis, they map these components of risk across the area and define thresholds for each risk orientation— areas with a metric greater than two are considered Risk Averse, between one and two Risk Managing, and below one as Risk Tolerant. This method provides a transparent, data-driven basis for differentiating policy requirements.

Step 3: Select a Change Factor

Next, the Portham Beach Regional Commission planners turn to the Change Factor Decision Tree (Figure 7) to determine which change factors should inform the design standards for each tier. For the Risk Managing baseline, they select the RCP 4.5 emissions scenario and the median percentile, representing a balanced approach suitable for most areas. For Risk Averse zones, they choose the Very High emissions scenario and the 75th percentile, providing a more conservative adjustment to account for higher exposure and lower adaptive capacity. For Risk Tolerant areas, they retain RCP 4.5 at the median percentile to avoid unnecessary over-design.

The team then works with technical staff to translate these change factors into design guidance. For example, based on the IDF Curve Tool, the Risk Managing baseline corresponds to an 11 percent increase in precipitation intensity relative to Atlas 14 values, while the Risk Averse tier corresponds to a 17 percent increase. These values are incorporated into the Portham Beach Regional Commission's updated design manual, which specifies that drainage infrastructure in high-risk zones must be sized using the higher change factor.

By applying the decision trees to a policy context, the Portham Beach Regional Commission developed a tiered, risk-informed regulatory framework that aligns design standards with local conditions and future climate projections. This approach ensures that new development across the region is resilient to increasing precipitation and flooding while maintaining clarity and consistency in enforcement.

Appendix A. Methodology and Background

This appendix presents a summary of and findings from a literature and document review, a practitioner survey, interviews, and a participatory workshop conducted with stormwater practitioners. The purpose of this effort was to identify and synthesize best practices, practical challenges, and real-world examples of incorporating climate considerations into stormwater planning and design. These findings served as inputs and background for the guidance and recommendations presented in the preceding sections of this document.

Interviews

We conducted 10 semi-structured interviews with individuals and groups of stormwater managers, engineers, and consultants working in county-level governments across Maryland, Washington, D.C. and Virginia. Interviews were guided by a set of open-ended questions designed to understand how practitioners are, or are considering, incorporating projected future rainfall conditions into stormwater engineering, planning, and policy and the barriers they face in doing so. Interviewees asked about planned and existing or in-progress use cases for the IDF Curve Tool, their perceived benefits, challenges, and suggestions for improving the tool and enabling its use as well as broader questions about climate-informed decision-making, particularly how practitioners approach to navigating uncertainty and choosing between future climate scenarios. Insights from these interviews are documented in Miro & Romita Grocholski, 2023 and informed much of this work.

Survey

We also drew on an online survey conducted by the MARISA team in the spring of 2025 to gather information on who uses MARISA tools, how they are used in practice, and perceived strengths and limitations (Miro et al., 2025). Respondents were asked to describe use cases, rate the usefulness of different tool features, and identify any additional data or resources that would better support climate-informed planning, design, and decision-making. For this document, we focused on a subset of 16 survey respondents who reported using the IDF Curve Tool out of 25 total respondents who reported using any MARISA tools. These 16 respondents represented a mixture of stormwater professionals from state and local governments, consulting firms, universities, and non-profit organizations.

Literature and Document Review

The literature and document review examined peer-reviewed academic literature, policy and guidance documents, and applied planning and technical reports related to the use of climate projections in stormwater planning and infrastructure design. This included municipal, regional, and state stormwater design manuals, climate-resilient design guidelines (e.g., Climate Ready DC: Climate-Resilient Design Guidelines, Advancing Stormwater Resiliency in Maryland (A-StoRM), and state hazard mitigation plans. These materials were used to identify how projections of future precipitation have been incorporated into planning and design decisions, including the selection of future emissions scenarios and time horizons.

Additionally, this review included guidance and synthesis reports addressing best practices for interpreting climate projections, characterizing and communicating uncertainty, and supporting decision-making under uncertainty. These sources included federal and interagency guidance such as the National Institute of Standards and Technology report on Incorporating Climate Projections into Infrastructure Planning and Design (Burgos et al., 2024), White House Office of Science and Technology Policy guidance on selecting climate information for risk and impact assessments (OSTP, 2023), and national and international assessments such as the Fifth National Climate Assessment (USGCRP, 2023) and the IPCC Sixth Assessment Report (IPCC, 2022). Finally, we drew of peer-reviewed literature on risk analysis, climate adaptation, and decision-making under uncertainty to inform the characterization of uncertainty in climate projections, conceptual framings of risk, and the use of robust approaches. These sources were synthesized and provide the empirical and conceptual foundation for the guidance and recommendations presented in this tool.

Participatory Workshop Session

After developing an initial draft of this decision guidance, which was informed by the previously described interviews, survey, and literature review, our team facilitated a participatory workshop session to test the guidance with practitioners and gather user feedback. The 75-minute session, held at the 2025 Bay-wide Stormwater Partners Retreat, hosted by the Chesapeake Stormwater Network, included more than 40 stormwater professionals from across the watershed. The session used a series of scenario-based, interactive activities designed to understand how stormwater practitioners would approach the selection of future climate scenarios, time periods, and percentiles within an uncertainty band to choose a single change factor from the IDF Curve Tool in practice and to assess the usability of the draft guidance under realistic planning and design conditions. This approach allowed us to document existing heuristics and reasoning, examine how decision-making changed with the introduction of structured decision guidance, and gather direct feedback on what worked, what did not, and what needs remained unmet.

Participants worked in small groups and completed worksheets that walked them through two short decision vignettes: one without decision guidance and one with guidance. Groups were randomly assigned to one of four worksheet versions covering either engineering design or planning and vulnerability assessment contexts, with vignette order varied to reduce ordering effects. All worksheets followed a consistent structure, prompting groups to select a time period, future emissions scenario, and percentile and ultimate IDF curve change factor, while documenting their reasoning and reflecting on decision difficulty and on the clarity and usefulness of the draft decision guidance.

Sensitivity Analysis

To better understand how different sources of uncertainty influence change factor values, we conducted a sensitivity analysis using the full 2021 change factor dataset underlying the IDF Curve Tool. The analysis examined how change factors vary across three key dimensions: i) emissions scenario (RCP 4.5 vs. RCP 8.5), ii) time period (mid-century [2020–2070] vs. late-century [2050–2100]), and iii) percentile within the model ensemble (10th, 25th, 50th, 75th, and 90th).

Using R, we fit linear models for each return period (2-, 5-, 10-, 25-, 50-, and 100-year events) to quantify the relative effect of each factor on the resulting change factor values. The table below summarizes the average change in change factor values associated with shifting from the baseline case (RCP 4.5, 50th percentile, mid-century) to each alternative condition. The results of this analysis are shown in Table A.1.

Table A.1 Sensitivity Analysis Results

Storm Type	Effect of Changing to RCP 8.5 emissions scenario	Effect of Changing to 2050-2100	Effect of Moving to 10th Percentile	Effect of Moving to 25th Percentile	Effect of Moving to 75th Percentile	Effect of Moving to 90th Percentile
2-yr	0.038	0.060	-0.088	-0.047	0.049	0.099
5-yr	0.040	0.060	-0.106	-0.057	0.059	0.121
10-yr	0.044	0.058	-0.122	-0.066	0.069	0.140
25-yr	0.051	0.054	-0.150	-0.080	0.088	0.179
50-yr	0.063	0.052	-0.178	-0.093	0.109	0.222
100-yr	0.081	0.039	-0.208	-0.112	0.130	0.273
Average	0.053	0.054	-0.142	-0.076	0.084	0.172

Overall, the analysis indicates that percentile selection has the largest influence on change factors. Moving from the 50th to the 75th percentile increases change factor values by roughly 8 percent, while moving to the 90th percentile increases it by 17 percent on average. Emissions scenario and time period have smaller but comparable effects, each contributing about a 5 percent increase on average when shifting from the baseline to alternative options. The influence of all factors tends to grow with storm magnitude, suggesting that uncertainty is greater for rarer, more extreme events.

These findings reinforce the importance of explicitly considering percentile selection when using the IDF Curve Tool. While emissions scenario and time period choices affect results, the percentile within the model ensemble often drives the largest variation in projected change factors.

Summary of Findings

How Projected IDF Curves Are Being Used in Practice

Drawing on stakeholder interviews, survey responses, a review of national guidance on incorporating climate projections, and case examples from the Mid-Atlantic (Table A.1), this section summarizes how projected IDF curve data are currently being used in practice and how this informed the preceding guidance.

Across interviews and survey responses, practitioners described incorporating projected rainfall data into drainage manuals, public facilities design manuals, stormwater design guidelines, and nuisance flooding guidance to standardize practice and account for increasingly extreme precipitation conditions. Our document review identified multiple examples of how jurisdictions have operationalized projections in regulatory standards. Several agencies have embedded projected rainfall data into design standards through uniform future adjustments applied across projects, such as in the Virginia Beach and Pittsburgh examples summarized in Table A.1 (City of Virginia Beach Department of Public Works, 2022; City of Pittsburgh Department of Public Works, 2022). These approaches emphasize consistency, predictability, and administrative simplicity by reducing the need for project-by-project scenario selection. Our literature review also revealed cases where the regulatory guidance adopts a more risk-based approach that varies scenario selection or design assumptions based on features of the decision context, such as the Washington, D.C. example in Table A.1 (District of Columbia Department of Energy & Environment, 2024).

Projected IDF curve data may also be applied in broader policy contexts, such as land-use planning, zoning, and building regulation, where decisions shape long-term exposure to flood risk. While our document review did not identify Mid-Atlantic examples that explicitly incorporate projected IDF curves for pluvial flooding in zoning ordinances or building codes, national assessments and infrastructure guidance indicate that these policy domains are increasingly recognized as appropriate venues for integrating forward-looking climate information. The Fifth National Climate Assessment emphasizes growing expectations that state and local governments incorporate best available climate science into land-use and regulatory decisions (USGCRP, 2023). Norfolk, Virginia's Vision 2100 provides an illustrative example of how climate projections can be incorporated into land-use and regulatory frameworks to mitigate flood risks, though this example focuses on projected sea level rise rather than projected rainfall (City of Norfolk Department of Economic Development, 2016).

Projected IDF curve data are also applied at the site or project scale to inform the design and evaluation of individual stormwater assets. Several respondents described incorporating change factors from projected IDF curves directly into hydrologic analyses for asset sizing, noting that they "added a projection factor based on the IDF tool to [their] hydrologic analysis for stormwater and drainage infrastructure sizing." Others described site-specific applications, such as local parks, stream restoration projects, and retention and detention basins, where projected rainfall estimates were used to evaluate future inundation and ensure designs remain functional under projected flow conditions. Others described potential uses of projected IDF curve data at the design and construction stage, particularly as a tool to support conversations with decision-makers about appropriate storm size selection and to explain the risk-reduction benefits of designs that exceed minimum code requirements.

A third identified application of projected IDF curve data is in planning and vulnerability assessment. Practitioners described using projected rainfall information in stormwater master planning, climate adaptation plans, watershed assessments, and hazard mitigation efforts to evaluate how flood risk may change over time and across locations. In these settings, projected IDF curves are used to support prioritization and strategic planning rather than to set prescriptive design requirements. As one respondent explained, projected rainfall data can help "figure out what areas in the jurisdiction we need to upgrade, at a prioritization level." Examples identified in our review include Virginia's Hazard Mitigation Plan, which is summarized in Table A.2 (Commonwealth of Virginia Office of Emergency Management, 2023). Practitioners similarly reported using projected IDF curves to develop future-looking pluvial flood models, update watershed master plans by evaluating uniform precipitation increases, and support communication with decision-makers and stakeholders about long-term resilience challenges, including demonstrating how risks may evolve under different future conditions.

Understanding the major use cases for the application of future projected precipitation information helped inform the structure and focus of our guidance primarily on infrastructure and planning, while also highlighting the need for guidance for applying this information to a policy context. Additionally, observing that some jurisdictions apply uniform future adjustments while others adopt risk-based approaches that vary assumptions when applying projected IDF curve information to policy context informed our guidance on selecting a policy approach.

Table A.2. Mid-Atlantic Examples of Projected IDF Curves' Application in Practice

Reference	Jurisdiction	How Projected Rainfall is Incorporated
City of Virginia Beach Public Works Design Standards Manual (2022)	Virginia Beach, VA	Prescribes a uniform 20% increase to Atlas 14 rainfall depths to account for projected increases over the next ~30 years. The manual states that updated rainfall depths are intended *"to address the need for more accurate design rainfall data and to consider projected increases in rainfall frequency depths,"* while retaining standard design storms and methods.
City of Pittsburgh Stormwater Design Manual (2022)	Pittsburgh, PA	Requires use of both present-day and future rainfall estimates. Adopts change factors to Atlas 14 intensities (e.g., 1.15 for 10-year storms; 1.23 for 100-year storms) and a future 95th-percentile 24-hour rainfall depth for long-term resilience, with provisions to update values as new data become available.
Climate Change Projections & Scenario Update, District of Columbia (2024)	Washington, D.C.	Provides explicit decision rules for selecting projections from the IDF Curve Tool based on project criticality and design life. The guidelines state: *"To incorporate future impacts, users should choose the mean value for either the low or high emission scenario depending on the criticality of the project."* Recommends more conservative scenarios and longer time horizons for critical or long-lived assets, and emphasizes flexibility where uncertainty is high.
Draft Maryland Stormwater Design Manual (2025)	Maryland	Incorporates county-specific, climate-adjusted IDF curves developed using the IDF Curve Tool, including multiple emissions scenarios, confidence intervals, and two planning horizons (2020–2070; 2050–2100). Develops projected design storms alongside Atlas 14 values for use in stormwater design, rather than relying solely on historical precipitation.
Advancing Stormwater Resilience in Maryland (A-StoRM) (2021)	Maryland	Uses projections from the IDF Curve Tool to motivate regulatory updates. Estimates an ~11% increase in the 1-year storm and states that the Maryland Department of Environment *"may consider regulatory changes"* including increased design storms and expanded peak-flow management requirements in flood-prone watersheds.
Virginia Hazard Mitigation Plan (2023)	Virginia	Uses median projections from the IDF Curve Tool under RCP 4.5 and RCP 8.5 emissions scenarios to assess future flood risk. Identifies regions with the largest projected departures from current IDF curves and links increased rainfall intensity to heightened risks of flooding, erosion, and dam failure, informing mitigation priorities.

Best Practices for Managing Uncertainty in Climate Projections

Drawing on national and international policy guidance and peer-reviewed literature, this section synthesizes established insights from climate science, decision science, and environmental management that informed the theoretical foundation of the guidance presented in this tool, clarifying why uncertainty arises and how it can be handled constructively in planning, infrastructure, and policy contexts. Climate projections are inherently uncertain for several reasons (Knutti & Sedláček, 2013; IPCC, 2021). First, climate models are driven by scenarios, which represent sets of assumptions about future conditions such as greenhouse gas emissions, land use, and socioeconomic development and are uncertain because they depend on future human decisions (Briley et al., 2021). Second, the climate system is highly complex and cannot be fully represented in models. Consequently, climate models differ in the simplifying assumptions they use to represent key physical processes—such as cloud formation, ocean circulation, and land–atmosphere interactions—as well as in the observational data that constrain them. Third, most climate models operate at global or coarse spatial scales. To produce information relevant for regional or local applications, their outputs must be downscaled using statistical or physical techniques, which add local detail but also introduce additional assumptions and uncertainty. Finally, the climate system exhibits natural variability, meaning that some fluctuations occur even in the absence of long-term climate change.

For these reasons, decisions that use climate projections are best understood as taking place under deep uncertainty, where no single climate model or future pathway can be identified as most likely, probabilities cannot be reliably assigned, and reasonable disagreement exists about how to value different climate risks (Walker et al., 2013; Lempert et al., 2003). Rather than yielding one most likely future, climate projections therefore describe multiple plausible representations of future conditions—reflecting different models, assumptions, and pathways—without a clear or agreed-upon way to rank them by likelihood (Kwakkel et al., 2010; IPCC, 2021). Effective use of climate projections therefore requires approaches that explicitly account for deep uncertainty, rather than seeking a single best estimate (Walker, Haasnoot, & Kwakkel, 2013).

A widely recognized best practice for applying climate projections is to evaluate decisions across multiple climate scenarios and consider the range of projections within each scenario, in order to account for plausible future emissions pathways and uncertainty across climate models, rather than relying on a single future estimate (White House Office of Science and Technology Policy (OSTP), 2023; Terando et al., 2024). This best practice is grounded in a substantial body of peer-reviewed decision-science literature showing that effective decision-making under deep uncertainty relies on identifying strategies that perform reasonably well across a range of plausible futures, rather than optimizing for a single expected outcome (Lempert, 2003; Lempert & Collins, 2007; Weaver et al., 2013). Building on these insights, our guidance recommends examining multiple futures whenever feasible.

Decision contexts vary substantially in their tolerance for risk, reversibility, planning horizons, and available resources, and these differences should shape how climate projections are selected and applied. Although evaluating decisions across multiple plausible futures is widely recognized as best practice, practical constraints—such as limited time, budget, data availability, or modeling capacity—often limit the ability to explore a full range of scenarios in applied settings (OSTP, 2023; Terando et al., 2024). When constraints prevent the use of multiple projections, guidance commonly recommends selecting higher-end projections, particularly for large investments, high-stakes, long-lived, or irreversible decisions, as a way to reduce the likelihood of failure or regret (OSTP, 2023; Terando et al., 2024). However, other guidance emphasizes aligning projection choices with the risk orientation of the decision itself, rather than defaulting to a uniformly conservative approach. This background helped to inform the structure of our change factor selection decision tree.

In the context of climate-related hazards, risk is commonly defined as the potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with those systems (IPCC, 2022). Climate-related risks emerge from dynamic interactions among climate hazards, exposure, and vulnerability (IPCC, 2022). Exposure refers to the presence of people, livelihoods, species or ecosystems, environmental functions and services, infrastructure, or economic, social, and cultural assets in places that could be adversely affected. Vulnerability is defined as the propensity to be adversely affected and comprises both sensitivity (susceptibility to harm) and adaptive capacity (the ability to cope with and adapt to impacts) (Adger, 2006).

This framework is particularly useful for identifying where risks may arise and for comparing relative levels of risk across places or systems. When the focus shifts from assessing risk to making planning and design decisions, effective risk management also requires explicit attention to how adverse consequences are evaluated and prioritized within a given context (Purdy, 2010). Accordingly, guidance on incorporating climate projections into engineering and infrastructure design recommends considering the societal value and criticality of assets when determining whether higher-end climate projections (e.g., under the RCP 8.5 emissions scenario) are appropriate for planning and design (OSTP, 2023; Terando et al., 2024).

These insights directly inform how risk is defined and assessed in our guidance. Drawing from the IPCC risk framework, we retain the concepts of exposure, sensitivity, and adaptive capacity as central determinants of climate-related risk and the key components of our risk orientation decision tree.

Abbreviations

A-StoRM	Advancing Stormwater Resiliency in Maryland
BMP	Best Management Practice
CMIP	Coupled Model Intercomparison Project
EPA	Environmental Protection Agency
GCMs	Global Climate Models
IDF	Intensity-Duration-Frequency
IPCC	Intergovernmental Panel on Climate Change
MARISA	Mid-Atlantic Regional Integrated Sciences and Assessments
NCA5	Fifth National Climate Assessment
NOAA	National Oceanic and Atmospheric Administration
OSTP	Office of Science and Technology Policy
RCP	Representative Concentration Pathway
SSP	Shared Socioeconomic Pathway
USGCRP	U.S. Global Change Research Program

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