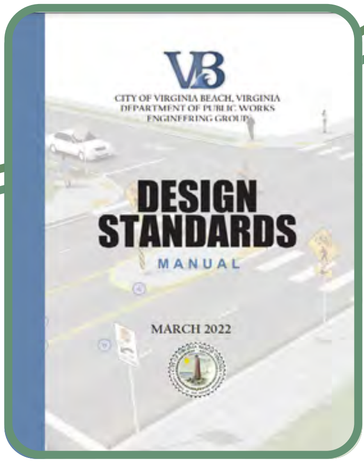
Scaling and Application of Climate Projections to Stormwater and Wastewater Resilience Planning

City of Virginia Beach, Department of Public Works

Developing Future Precipitation Projections and Design Standards



Summary

The City of Virginia Beach commissioned a study to assess changes in historical and future extreme precipitation in response to heavy flooding events. The study, which received a third-party review, resulted in updates to the Department of Public Works Design Standards Manual (2020), including new requirements and design parameters for stormwater management. The effort also included an assessment of sea level rise and the potential for combined flooding impacts from extreme precipitation and storm surge events.

The Backstory

In 2016, Virginia Beach experienced a series of three large storm systems (tropical storms and hurricanes) back-to-back that brought 33 inches of rain in a 6-week period. The heavy flooding resulted in increased interest in considering the influence of climate change on extreme precipitation.

The Challenge

The best available precipitation information in 2016 was NOAA Atlas 14, which is baselined to the year 2000 and does not consider future climate change. A review of two long-record rain gauges showed that the NOAA Atlas 14 10-year rainfall event is about 7 to 10% below local observational data, and it was not representative of the extreme precipitation during the 2016 hurricane season.

Project Timeline
2014-2020

Project Area/ Geographic Scale
City of Virginia Beach

Study Focus
Extreme Participation,
Sea Level Rise, combined flooding (rainfall/surge correlation)

Lead Agency
Department of Public Works

Target Audience
City of Virginia Beach, Developers, Residents

Type of Data Used
NA-CRODEX regional climate models (CMIP5)

Types of Precipitation Inputs Used
Historical rain gauge data

The Approach

In 2015 the City began an initiative called Sea Level Wise to evaluate sea level rise and flood risks. In response to the 2016 flood events, this was extended to include analyses of historical and future extreme precipitation projections. The observational trend showed an increase of 3 to 7% per decade for the 10-year event, and future projections suggested potential increases of 7% for RCP4.5 and 24-27% for RCP8.5 by 2060 (relative to the year 2000). Using a combination of the historical trends and future projections, the city recommended the use of a 20% increase in extreme precipitation by the year 2060, assuming a 40-year lifecycle for infrastructure projects.

The analysis was reviewed and verified externally by the Virginia Department of Transportation and the Transportation Research Council. The dual verification provided confidence in the analysis, and Public Works submitted their recommendations to the City Council for approval. The City Council unanimously approved the use of the future precipitation estimates in June 2020, resulting in an update to the Design Standards Manual which applies to both public and private projects.

The Outcome

The Design Standards Manual updates included design standard changes to address future precipitation estimates, recurrent flooding, and sea level rise risks. The updates also required using this information in the City's Storm Water Management Model (SWMM). The city is continuously updating their SWMM master model to better represent the stormwater system, and these updates, combined with the future precipitation updates, have allowed the city to be proactive in their efforts to reduce flood risks.

Practical Applications

Projects are designed using the revised design guidelines. The Design Storms and Hydrologic Methods requires that designers must increase the NOAA Atlas 14 design storm rainfall depths by 20% and must use dynamic modeling (SWMM) to analyze the pre- and post-development conditions, except for areas less than 20,000 sq. feet.

The City of Virginia Beach uses the updated design storms in the Master Drainage Model (MDM) which includes the Primary Stormwater Management System (PSMS) for the majority of the City. This model allows the city to identify the areas of greatest risk and prioritize projects to reduce the flood risks.

Street flooding in Virginia Beach. (Photo Courtesy from Virginia Beach Fire Department.)

Project Data and Methods

Time Horizons / Climate Scenarios Used	All rain gauges within a 60-mile radius were used. Ensemble approach used regional climate models within the NA-CRODEX archive, using medium emissions (RCP4.5) and high emissions (RCP8.5) scenarios. Applied bias correction to allow for direct comparison between projected precipitation-frequency curves and NOAA Atlas 14 guidance for easy interpretation. All simulations were conducted using variable resolution (11- and 44-km). The findings from the historical trends and both future condition scenarios were blended to account for uncertainty.
Updates to model runs with the latest IPCC GCM data?	Consistently updating SWMM models as data becomes available (typically every 3 months).
Objective for Using Future Precipitation Projections	Reduce stormwater flood risks, including flooding exacerbated by sea level rise and rising groundwater. Accurately describe and prepare for increasing extreme precipitation events.
Application	Department of Public Works Design Standards Manual

Lessons Learned

1. Confirm and identify the question at hand
It is important to confirm the questions to be answered and the desired outcomes (e.g., updates to design standards) from the outset to help streamline the process and gain agreement across multiple parties.

2. Use best available science and data
The city relied on multiple rain gauges, used the best available data, and clearly documented their analysis approach and results. This allowed two independent third parties (Virginia Department of Transportation and the Transportation Research Council) to review and validate the methods and findings. This provides confidence in the process.

3. Do not wait, get started
These studies and the corresponding updates to existing design standards can require multiple years for planning, analysis, and implementation. The most difficult step is getting started. Waiting for the "most up-to-date" data impedes advancements.

4. Rely on regional efforts
The City of Virginia Beach benefited from a series of "green light" situations that eased the entire process (from analysis, to adoption, to implementation). There was sufficient budget, political support, and staff capacity to move this effort forward. However, the city recognizes that this is not always the case. Under alternative circumstances, the city could have waited for a regional effort to be completed to inform similar updates.