MEMORANDUM

MassDEP NOAA14 PLUS – Summary of Technical Review

November 15, 2022

Background

MassDEP proposes to revise the Wetlands Protection Act (WPA) and Water Quality Certification (WQC) regulations (310 CMR 10.00 and 314 CMR 9.00, respectively) to address stormwater management. MassDEP's revisions include a proposal to update the precipitation data, currently required to ensure that construction of buildings and roads do not increase the peak stormwater runoff rate. The precipitation data that MassDEP relies upon are probabilistic storms, storms that have a 1% (100-year), 10% (10-year), 50% (2-year), and 100% (1-year) chance of occurring in any one given year. To determine those storms, MassDEP proposes to rely on a methodology referred to as "NOAA 14 PLUS."

NOAA 14 PLUS reflects the higher end of the range of storms that have already been observed. **NOAA 14 PLUS is not a projection of future extreme storms.** NOAA 14 PLUS relies directly on the 90% upper confidence intervals published in NOAA Atlas 14, Volume 10 ("NOAA 14")[1], meaning one is 90% confident that the true upper value likely falls within that range. Table 1, using Westfield MA as an example, illustrates that if one was to rely solely on the published NOAA 14 values, it would underrepresent the true upper range of variability. For example, the true upper range of variability in Westfield MA is 18.15-inches of precipitation in a day, over an 86-year period (1926-2013) and the unconstrained 100-year 24-hour storm using the Weibull[2] distribution is 22.31-inches, whereas the NOAA 14 100-year 24-hour storm is only 8.74-inches. Relying solely on the NOAA 14 fitted value, without taking into account the upper confidence published in NOAA 14, would lead to increases in the peak runoff rate. (Appendix A presents fitted values and upper and lower confidence intervals of NOAA Atlas 14, Volume 10 using Logan International Airport as an example.). MassDEP intends to use NOAA 14 PLUS in its WPA and WQC regulations which currently rely on the U.S. Weather Bureau Technical Paper 40 (TP40), published in 1961 and based only on data through 1959.

Table 1: Comparison of Precipitation Estimates for Westfield MA (in inches)

Station	ID	Highest Observed Daily Storm (inches)	100-Year 24-Hour Weibull Unconstrained (inches)	100-Year 24-Hour NOAA 14 (inches)	Upper Confidence NOAA 14 (inches)	NOAA PLUS 14 (inches)
Westfield MA	19-9191	18.15 (8/19/1955)	22.31	8.74	12.8	11.52

[1] Sanja Perica and others, 2019, NOAA Atlas 14 Precipitation-Frequency Atlas of the United States Volume 10 Version 3.0: Northeastern States, Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont

[2] Weibull, W. 1951. A statistical distribution of wide applicability. Journal of Applied Mechanics. 18: 293-297.

Technical comments provided by consultants for the MA Executive Office of Energy and Environmental Affairs' Resilient Massachusetts Action Team (RMAT) Development Team on the NOAA 14 PLUS approach indicate that it is not representative of longer-term climate change but is useful for projects with a 10-year lifespan. Subsequently, RMAT adopted NOAA 14 PLUS for its Tier 1 reviews. The tiers are based on the criticality of the assets, as defined by the RMAT Tool based on user-provided answers to a series of questions. Tier 1 represents projects that are of low and medium criticality with a lifespan of less than ten years (Figure 1).

Figure 1. Relationship Table that Informs Recommended Tier Output for Building and Infrastructure Assets

High Criticality	TIER 2	TIER 3	TIER 3
Medium Criticality	TIER 1	TIER 2	TIER 3
Low Criticality	TIER 1	TIER 2	TIER 2
	< 10 years	10 to 50 years	51 years+

All technical comments MassDEP received are summarized in this document. These include comments from the RMAT consultants as well as from municipal engineers in communities in the Mystic River Watershed. (Additional comments received on NOAA14 PLUS are included in Appendix B.)

Development of NOAA 14 PLUS

There is inherent uncertainty in precipitation analysis because it is not known to what degree a sample of storms represents the true population of storms. Each different storm (such as a 24-hour, 1% chance storm) has a probability that it will occur. Because one does not know the true probability, NOAA Atlas 14 presents 90% confidence intervals around the PDS (partial duration series)-based precipitation frequency estimates associated with each of its frequency and duration scenarios (or design storms). A

90% confidence interval means that one can be 90% confident that the true probability falls within that range.

However, the 90% confidence interval does not represent the true variability of real storms. For example, the worst daily storm in Massachusetts is 18.15-inches, recorded in Westfield MA (Station 19-9191) on August 19, 1955 (Table 1), yet NOAA 14 only provides a 100-year storm of 8.74 inches and a 90% confidence interval of 12.8-inches, based on an 86-year record. Another consideration is that NOAA 14 was developed using an assumption of Stationarity, which means that the climate is not changing. Infrastructure, such as stormwater detention basins and roadway culverts through which wetlands, streams, and rivers flow, may have design lives ranging from at least 50- to 100-years. Studies have shown that this assumption of Stationarity may significantly underestimate extreme precipitation.[3]

To account for the variability in actual storms such as the one in Westfield, and a changing climate that the NOAA 14 Stationarity method does not capture, MassDEP considered utilizing a higher confidence interval (i.e. 99% confidence interval), 90% confidence interval, and use of multipliers to lower the confidence. MassDEP utilized the Weibull probability at the Westfield weather station for these comparisons. The upper 99% confidence interval for probability exceeded many of observed storms, so was rejected as an approach. Utilizing the published NOAA 14 full 90% confidence better accounted for the variability of observed storms, but exceeded the Weibull probability of more frequent extreme storms (e.g. 2- and 10-year daily storms), so was also rejected as an approach.

MassDEP applied various multipliers to the upper confidence interval for the storms specified in the Massachusetts Wetlands Protection regulations (1-year, 2-year, 10-year, and 100-year 24-hour storms) to identify the multiplier that, when applied to the upper confidence interval, results in a precipitation estimate that is higher than the fitted estimate of NOAA Atlas 14, Volume 10 for each of these storms. As an example, applying factors less than 0.9 to precipitation estimates published in NOAA 14 Volume 10 for Boston Logan International Airport in some cases results in precipitation values that are less than the NOAA14 fitted estimate for the 1-, 2-, and 10-year storms (See Table 2). Only the 0.9 multiplier produces a higher precipitation value when multiplied by the upper confidence interval than the NOAA Atlas 14 fitted estimates for all storms specified in the WPA regulations (Table 2). Thus, the multiplier of 0.9 was selected to generate the NOAA14 PLUS precipitation estimates.

[3] Cheng and Agahakouchak 2014 show that current Intensity-Duration-Frequency (IDF) curves used in design of infrastructure can substantially underestimate precipitation extremes and may not be suitable for infrastructure design in a changing climate. Cheng and Agahakouchak 2014 show that a stationary climate assumption may lead to underestimation of extreme precipitation by as much as 60%, which increases the flood risk and failure risk in infrastructure systems. Arlberg and others 2013 indicate that although uncertainty exists in projecting future climate change that “in regions where climate change occurs a systematic adaptation effort should be undertaken to minimize the impacts on the performance of drainage systems.”

Table 2: NOAA Atlas 14 Fitted Precipitation Estimates and Precipitation Values Obtained by Multiplying the Upper Confidence Intervals by Various Factors (in inches)							
Average Recurrence Interval and Storm Duration	**NOAA 14 PDS, Boston, MA, Station # 19-0770 (inches)**	**NOAA 14 PDS upper confidence interval (inches)**	**NOAA 14 PDS upper confidence interval times 0.1 (inches)**	**NOAA 14 PDS upper confidence interval times 0.5 (inches)**	**NOAA 14 PDS upper confidence interval times 0.7 (inches)**	**NOAA 14 PDS upper confidence interval times 0.8 (inches)**	**NOAA 14 PDS upper confidence interval times 0.9 (inches)**
1-year 24-hour storm	2.53	2.99	0.30	1.50	2.09	2.39	2.69
2-year 24-hour storm	3.14	3.71	0.37	1.86	2.60	2.97	3.34
10-year 24-hour storm	4.98	5.94	0.59	2.97	4.16	4.75	5.35
100-year 24-hour storm	7.88	10.7	1.07	5.35	7.49	8.56	9.63

Note: Red highlight indicates the precipitation value is lower than the fitted estimate; green highlight indicates that value is higher.

After evaluation, MassDEP proposes to utilize a multiplier of 0.9 to the published NOAA 14 upper confidence interval. This approach is referred to as NOAA14 PLUS. This resulting NOAA14 PLUS precipitation depth is higher than the depth of fitted NOAA 14 estimate but lower than the upper confidence interval of the precipitation estimates in NOAA Atlas 14, Volume 10[4]. NOAA14 PLUS is approximately equivalent to the NOAA 14 80% upper confidence interval, meaning one is 80% confident that the true value for existing precipitation falls within this range. **NOAA14 PLUS is not a predictor of future precipitation intensity. It accounts for the upper variability of actual observed storms by relying upon the NOAA 14 published upper confidence.** The adoption of NOAA14 PLUS will help to account for the variability in actual observed storms; provide better reliability and safety for infrastructure, other development, and resource areas; and reduce future disturbance to resource areas for repair purposes.

Application of NOAA14 PLUS in the Wetlands Protection Act Regulations

MassDEP proposes to require use of NOAA14 PLUS to meet Stormwater Standard 2 (310 CMR 10.05(60[k])) which requires that post-development peak runoff rate not exceed the pre-development peak runoff rate. In addition to the interests of flood control and storm damage prevention addressed by Standard 2, hydromodifications caused by stormwater runoff may increase bank instability, increase channel widths and accelerate the lateral movement of rivers and streams. The peak runoff rate is based

[4] The NOAA 14 estimate is the "fitted" estimate which is the value that is fit to a generalized extreme value (GEV) distribution. GEV may take one of three forms, depending on the shape parameters: Gumbel, Freshet or Weibull distribution.

on design storms that have probabilities associated with them. The return period of a storm is based on a probability of occurrence and is selected based on the level of risk that is tolerable. The WPA regulations require that stormwater runoff be evaluated for the 2-year, 10-year, and 100-year 24-hour storms which have a 50%, 10%, and 1% chance of occurring over any given 24-hour period, respectively. However, over consecutive years, the probability is higher. For example, the 2-year storm has a 75% chance of occurring over any 2-year period, the 10-year storm has a 65% probability of occurring over any 10-year period, and the 100-year storm has a 63% probability of occurring over any 100-year period.[5] The probability estimates assume "Stationarity," or an unchanging climate. However, since climate is changing, there is less confidence in the probability estimates. NOAA14 PLUS is proposed to replace the TP40 in these calculations to provide Massachusetts with an approach that will better address public safety and adverse effects to the environment and reduce costs to municipalities.

In addition to the application of NOAA14 PLUS for stormwater management, NOAA14 PLUS would also be utilized to determine the extent of flood prone areas (Bordering Land Subject to Flooding) when Federal Emergency Management Agency (FEMA) flood profile data are not available. Currently, 310 CMR 10.57 requires a 7-inch storm (based on Technical Paper 40) be used to determine the extent of Bordering Land Subject to Flooding when FEMA flood profile data are not available and there is a conflict about the largest event observed or recorded. MassDEP is proposing to substitute NOAA14 PLUS for the 7-inch storm in the Bordering Land Subject to Flooding section of the Wetland regulations at 310 CMR 10.57. This approach will provide improved protection for the public by better predicting the boundaries of land likely to flood during a "100-year storm".

The high costs of water pollution, flooding, and storm damage - such as rebuilding of damaged infrastructure and homes - are currently borne by the state, municipalities, and property owners. The proposed regulations will help to offset these costs.

Technical Comments Received on NOAA14 PLUS

Technical comments were received through the following: the Resilient Massachusetts Action Team, engineers representing 10 municipalities, and the Massachusetts Climate Resilience Design Standards and Guidance – Comparative Precipitation Methodology Report Version 1.2, July 2022.

Resilient Massachusetts Action Team Development Team Review

The Massachusetts Executive Office of Energy and Environmental Affairs' (EEA) Resilient Massachusetts Action Team (RMAT) is advancing prioritized cross-agency actions from the 2018 State Hazard Mitigation and Climate Action Plan with the recent launch of the RMAT *Climate Resilience Design Standards* Tool (EEA 2021). The Tool is intended to help incorporate climate resilience into capital planning projects with physical assets owned and maintained by state agencies. It also provides guidance for state-funded projects to enhance how the Commonwealth assesses climate resilience as part of its capital planning process. The RMAT tool has three tiers. Tier 1 is the simplest of the three tiers and is recommended for

[5] This is calculated using the following relationship: $1-(1-p)^n$, where p = probability and n= number of years. Probabilities have confidence of error associated with them. For a weather station when only a shorter period of record is available, there is less confidence in the estimate. When a longer period of record is available, there is more confidence in the estimate.

assets with a useful life of less than 10 years and low and medium criticality infrastructure and buildings assets. Tiers 2 and 3 represent projects with higher criticality and longer lifespan. Although NOAA14 PLUS is not a projection of future climate change, RMAT adopted the NOAA14 PLUS precipitation values as part of the Tier 1 analysis in conjunction with projections provided by the Stochastic Weather Generator developed by researchers at Cornell University under contract to EEA. The RMAT Tier 1 was selected by the EEA to represent near-term climate change conditions through 2030. On the other hand, Tiers 2 (2070) and 3 (2090) simulate future conditions accounting for increasing future precipitation, and the resulting precipitation estimates are higher than the Tier 1 NOAA14 PLUS estimates.

During development of the RMAT *Climate Resilience Design Standards* Tool, the NOAA14 PLUS methodology was reviewed by the climate scientists from Weston & Sampson and the University of New Hampshire, comprising the RMAT Development Team. This review was conducted because the MassDEP stormwater standards and the RMAT Design Tool were being developed concurrently and would affect the same wetland resource areas and stakeholders. The review was conducted to ensure consistency in applying results. During the review, the RMAT development team gave careful consideration to the NOAA14 PLUS approach and its suitability for use in the RMAT Tool given that NOAA14 PLUS is derived from past precipitation and the RMAT tool is intended to address the impacts of climate change through climate resilience design standards.

The RMAT Development Team conducted a comparison between the NOAA14 PLUS precipitation values, which the team ultimately chose for Tier 1 (in conjunction with the Stochastic Weather Generator results for 2030), and the Tier 2 precipitation values, projected under climate change for the years 2030 and 2070, for fifteen locations in the state (Tables 2 and 3).

The RMAT Development Team concluded that for 2030, the Tier 1 and Tier 2 approaches result in comparable rainfall depths (within 10% difference) at several locations in MA for the ***smaller more frequent storms*** (2-, 5-, 10-yr storms) and the 25-year storm (EEA 2020 and Table 3). For the ***larger less frequent storms*** (100-yr storms), the Tier 2 approach results in rainfall depths that are lower (more than 10% difference) than Tier 1 in four of fifteen locations in MA (Table 4). The RMAT Development Team suggested that this could imply that Tier 2 projects at some locations could potentially use lower values compared to Tier 1.

Table 3: Precipitation Estimates for a 10-Year Recurrence Interval (inches)							
	NOAA 14	NOAA 14 90th Percentile	Tier 1 (NOAA 14+)	Tier 2 (2030)	Percent Difference Between Tier 2 and NOAA 14+ (2030)	Tier 2 (2070)	Percent Difference Between Tier 2 and NOAA 14+ (2070)
Cambridge, MA	5.2	6.3	5.7	5.9	3.5	6.3	10.6
Boston, MA	5.1[6]	6.1	5.5	5.8	4.5	6.2	11.3
Newburyport 4 NNW, MA	5.3[7]	6.5	5.9	6.0	2.3	6.5	9.5
Nantucket, MA	4.5	5.5	5.0	5.1	2.7	5.5	9.8
New Bedford, MA	5	6	5.4	5.7	4.4	6.1	11.5
Pittsfield, MA	4.6	5.8	5.2	5.2	-0.4	5.6	7.0
Worcester, MA	4.9	5.9	5.3	5.5	4.1	6.0	11.2
Westfield, MA	5.4	6.8	6.1	6.1	-0.3	6.6	7.1
Amherst, MA	4.8	5.9	5.3	5.4	2.1	5.9	9.3
Blue Hills, MA	5.3	6.4	5.8	6.0	3.8	6.5	10.9
West Otis, MA	5.2	6.5	5.9	5.9	0.4	6.3	7.8
East Wareham, MA	5	6	5.4	5.7	4.4	6.1	11.5
Plymouth-Kingston, MA	5.1	6.1	5.5	5.8	4.7	6.2	11.8
Ashburnham, MA	4.6	5.6	5.0	5.2	3.0	5.6	10.2
Lawrence, MA	4.9	6	5.4	5.5	2.5	6.0	9.7

Source: EEA 2020, All units are in inches

[6] NOAA 14 lists 4.97-inches (5.0-inches) for the 10-year 24-hour storm at Boston Logan International Airport
[7] NOAA 14 lists 5.36-inches (5.4-inches) for the 10-year 24-hour storm at Newburyport 4 NNW

Table 4. Precipitation Estimates for a 100-Year Recurrence Interval (inches)							
	NOAA 14	NOAA 14 90th Percentile	Tier 1 (NOAA 14+)	Tier 2 (2030)	Percent Difference Between Tier 2 and NOAA 14+ (2030)	Tier 2 (2070)	Percent Difference Between Tier 2 and NOAA 14+ (2070)
Cambridge, MA	8.2	11.3	10.2	9.3	-9.8	10.0	-1.7
Boston, MA	8.1[8]	11.1	10.0	9.2	-9.1	9.9	-1.1
Newburyport 4 NNW, MA	8.4[9]	11.4	10.3	9.5	-8.1	10.2	-0.1
Nantucket, MA	6.8	9.1	8.2	7.7	-6.6	8.3	1.3
New Bedford, MA	7.6	9.8	8.8	8.6	-2.7	9.3	4.9
Pittsfield, MA	7.2	10.4	9.4	8.1	-15.0	8.8	-6.6
Worcester, MA	7.6	10.5	9.5	8.6	-10.0	9.3	-1.9
Westfield, MA	8.7	12.8	11.5	9.8	-17.2	10.6	-8.5
Amherst, MA	7.7	11.1	10.0	8.7	-14.8	9.4	-6.3
Blue Hills, MA	8.4	11.5	10.4	9.5	-9.0	10.2	-1.0
West Otis, MA	8.4	12.4	11.2	9.5	-17.6	10.2	-8.9
East Wareham, MA	7.6	9.6	8.6	8.6	-0.6	9.3	6.8
Plymouth-Kingston, MA	7.6	9.8	8.8	8.6	-2.7	9.3	4.9
Ashburnham, MA	7.1	9.7	8.7	8.0	-8.8	8.7	-0.8
Lawrence, MA	7.8	10.8	9.7	8.8	-10.3	9.5	-2.1

Source: EEA 2020, all units are in inches

A comparison between the Tier 1 (NOAA 14 PLUS) precipitation methodology and the Tiers 2 and 3 methodologies was also conducted for Moakley Park in South Boston for 2070 (Table 5). The RMAT Development Team projected that for 2070, the Tier 2 approach results in design storm depths that are higher (more than 10% difference) compared to Tier 1 at several locations in MA for the ***smaller more frequent storms*** (2-, 5-, 10-yr storms) (EEA 2020, Table 3, and Table 5). For the ***larger less frequent storms*** (25-, 50-, 100-yr storms), Tier 1 and Tier 2 approaches result in comparable rainfall depths (within 10% difference) (EEA 2020 and Table 4). NOAA Atlas 14 and NOAA14 PLUS are based on historic precipitation and not on projected precipitation under climate change and the RMAT Development Team did not adopt NOAA14 PLUS as a methodology for estimating precipitation under longer-term climate change conditions (Tiers 2 and 3). According to the RMAT framework, a Tier 1 project will not be using 2070 planning horizon since Tier 1 addresses near-term climate change and the service life of a Tier 1 project is less than 10-years. Therefore, this comparison of Tiers 1 and 2 for the farther planning horizon (2070) is less relevant for RMAT.

[8] NOAA 14 lists 7.88-inches (7.9-inches) for the 100-year 24-hour storm at Boston Logan International Airport
[9] NOAA 14 lists 8.48-inches (8.5-inches) for the 100-year 24-hour storm at Newburyport 4 NNW

Table 5. RMAT Tiered Methodology to Assess 24-Hour Precipitation Storm Depth and Peak Intensity: A Comparison Across Tiers for Moakley Park, South Boston, MA				
Recurrence interval (Years)	**NOAA Atlas 14 Present Baseline (inches)**	**Tier 1 Depth (inches)**	**Tier 2 2070 Depth (inches)**	**Tier 3 2070 Depth (inches)**
2-year	3.3	3.4	4.0	3.8
5-year	4.3	4.6	5.2	5.2
10-year	5.1	5.5	6.1	6.4
25-year	6.3	7.2	7.6	8.1
50-year	7.2	8.4	8.6	9.5
100-year	8.1	9.9	10.3	11.2
200-year	9.3	11.5	12.6	13.5
500-year	11.1	14.3	15.1	17.4

Source: EEA 2020

Finally, the RMAT Development Team selected NOAA14 PLUS as the precipitation estimate for the Tier 1 methodology, in conjunction with the Cornell Stochastic Weather Generator results for 2030, for projects with a useful life of less than 10 years and low and medium criticality infrastructure and buildings assets. The *Climate Resilience Design Standards* Tool notes that these projects should incorporate Tier 2 methods where feasible, but if not, should design for today and plan for resilience reinvestment in the future. Stormwater controls permitted and constructed pursuant to the Massachusetts Wetlands Protection regulations have a service life longer than 10-years and have high criticality, so while they are not designed for future climate change, it is imperative that they are resilient to extreme events.

<u>Review by Ten Municipal Engineers (Arlington, Cambridge, Chelsea, Lexington, Medford, Melrose, Reading, Watertown, Winchester, and Woburn) in the Mystic River Watershed</u>

Ten municipal engineers in the Mystic River Watershed conducted a technical analysis of NOAA14 PLUS, comparing precipitation estimates to those under various climate change projections (Watkins et al, 2021). Figure 2 and Table 6 compare downscaled precipitation projections (in inches) with TP-40, NOAA14 and other measures of rainfall intensity. For Cambridge, the municipal engineers found that NOAA14 PLUS values are close to 2030 downscaled rainfall projections and the upper bound of the NOAA Atlas 14 90% confidence interval values are close to the 2070 downscaled rainfall projections. The engineers recommended checking these relationships in other areas as downscaled projections become available. (Currently, Statewide RMAT Tier 3 precipitation projections have not been yet completed for the Commonwealth. However, some municipalities have completed downscaled precipitation projections. Climate scientist Dr. Katharine Hayhoe, completed a downscaled model for Cambridge (https://bit.ly/39uYEpt).)

Because NOAA14 PLUS is not consistent with the higher climate change estimates for 2070, the municipal engineers concluded that NOAA14 PLUS precipitation estimates are not sufficiently high to represent conditions under climate change and strongly supported using the full NOAA14 90th percentile confidence interval, without the 0.9 multiplier. They felt that using lower rainfall estimates would result in the shift of the burden of managing stormwater from new developments onto existing taxpayers. The engineers argued that the full upper confidence interval represented longer-term climate change and NOAA14 PLUS (or 90% of the upper confidence interval) represented near-term conditions, stating, "Until statewide downscaled rainfall projections can be completed, using the upper bound of NOAA 14 90% confidence interval could be used as a proxy for 2070 rainfall projections. Using 90% of the upper bound of NOAA 14 90% confidence interval could be used as a proxy for 2030 rainfall projections."

Figure 2. Cambridge, MA rainfall data (in inches)

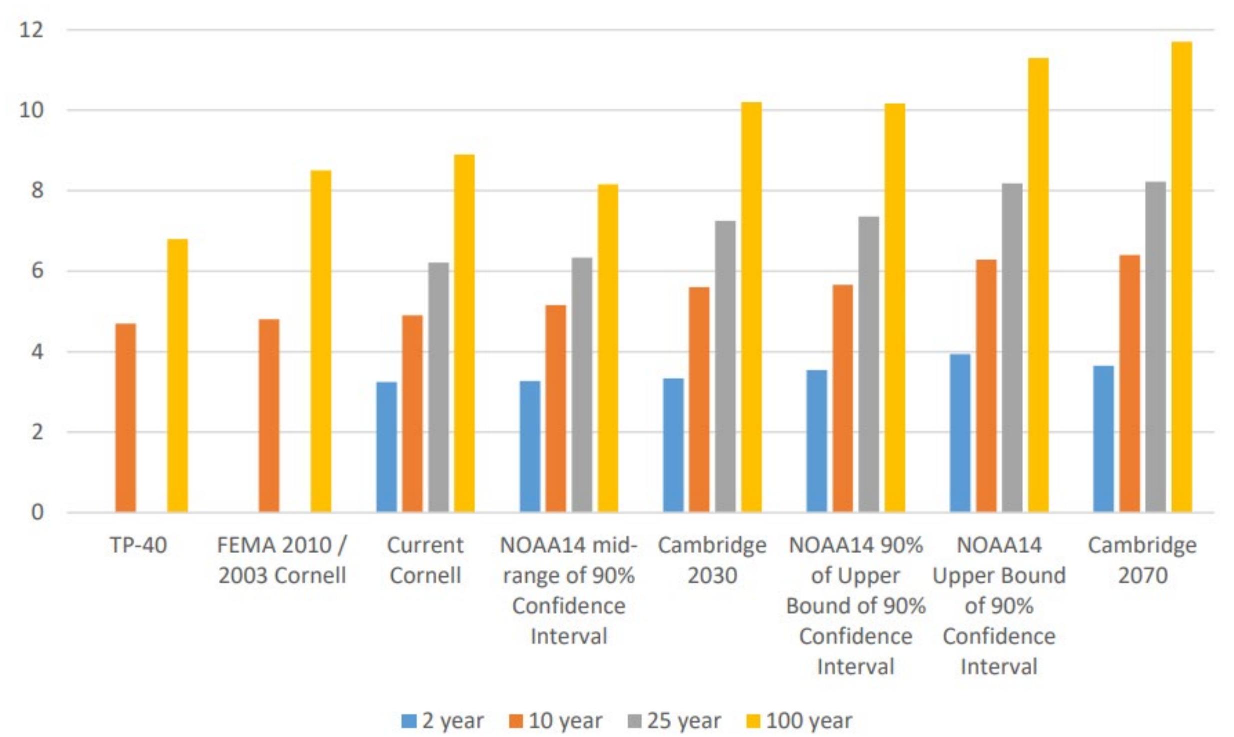

Table 6. Comparison of Various Precipitation Estimates in Cambridge (inches)

Return Period (years/24-hour storm)	TP-40	FEMA 2010/ Cornell 2003	Current Cornell	NOAA 14 ("mid-range")	NOAA 14 90th Percentile Upper Bound	Tier 1 (NOAA 14+)	Tier 3 2030 (same as Cambridge CCVA Projections)	Tier 3 2070 (same as Cambridge CCVA Projections)
2			3.25	3.27	3.94	3.55	3.34	3.65
10	4.70	4.80	4.90	5.16	6.29	5.66	5.60	6.40
25			6.21	6.34	8.18	7.36	7.25	8.22
100	6.80	8.50	8.90	8.16	11.30	10.17	10.20	11.70

Source: Watkins et al, 2021, all units are in inches

Review through the Massachusetts Climate Resilience Design Standards and Guidance – Comparative Precipitation Methodology Report Version 1.2, July 2022

As part of the EEA's Massachusetts Climate and Hydrologic Risk Project, Cornell University projected extreme precipitation depths across the northeastern United States. Version 1.2 of the Climate Resilience Design Standards Tool (the Tool) provides these extreme precipitation projections for 24-hour storms (regardless of tier).

A technical report prepared by Weston & Sampson Engineers (EEA 2022) and published with Version 1.2 of the Tool documents the comparison of methodologies used to generate projected total precipitation depth for 24-hour storms in the Climate Resilient Design Standards Tool developed by the Resilient Massachusetts Action Team (RMAT). This review compared NOAA14 PLUS current precipitation estimates with precipitation projections developed by Cornell University for EEA's Massachusetts Climate and Hydrologic Risk Project at 9 locations,[10] for the 2-year to 50-year 24-hour storms, for 2030, 2050, and 2070 (Table 7). The following conclusions were reached from this comparison:

- For 2030: NOAA14 PLUS was similar to the Cornell results.
- For 2050, the Cornell results were similar to or higher than NOAA14 PLUS.
- For 2070, the Cornell results were higher than NOAA14 PLUS.

The report encouraged users of the RMAT Tool to follow its recommendations and projected values as a basis-of-discussion for planning, early design, and evaluation of projects, and (if applicable) evaluate how the projected values estimated using the comparative recommended methodologies may impact design and performance over the useful life of the asset. Version 1.2 of the Tool provides NOAA 14 PLUS for Tier 1 assets.

[10] Amherst, Boston, Cambridge, Kingston, Newburyport, Pittsfield, Springfield, Westfield, and Worcester, Massachusetts.

Table 7. Comparison of Precipitation Projections Developed by Cornell University for EEA's Massachusetts Climate and Hydrologic Risk Project with Values Calculated Using the NOAA14 PLUS Methodology at Nine Long-Term Weather Stations

Planning Horizon	Return Period	Precipitation projections developed by Cornell University for EEA's Massachusetts Climate and Hydrologic Risk Project are:		
		similar (within ±5%) to NOAA PLUS	**higher than NOAA PLUS**	**lower than NOAA PLUS**
2030	2-yr	Cambridge, Newburyport, Kingston, Westfield, Springfield	Boston, Pittsfield, Worcester, Amherst (up to 10% higher)	No locations
	5-yr	Cambridge, Newburyport, Kingston, Amherst, Worcester, Westfield, Springfield	Boston, Pittsfield (up to 10% higher)	No locations
	10-yr, 25-yr	Boston, Cambridge, Newburyport, Kingston, Worcester, Pittsfield, Amherst, Westfield, Springfield	No locations	No locations
	50-yr	Boston, Cambridge, Newburyport, Kingston, Worcester, Pittsfield	No locations	Amherst, Westfield, Springfield (up to 10% lower)
2050	2-yr, 5-yr, 10-yr	No locations	Boston, Cambridge, Newburyport, Kingston, Worcester, Pittsfield Amherst, Westfield, Springfield (up to 15% higher)	No locations
	25-yr	Cambridge, Pittsfield, Westfield, Springfield	Boston, Newburyport, Kingston, Worcester, Amherst (up to 10% higher)	No locations
	50-yr	Boston, Cambridge, Worcester, Pittsfield, Amherst, Westfield, Springfield	Newburyport, Kingston (up to 10% higher)	No locations
2070	2-yr, 5-yr, 10-yr, 25-yr, 50-yr	No locations	Boston, Cambridge, Newburyport, Kingston, Worcester, Pittsfield Amherst, Westfield, and Springfield (up to 25% higher)	No locations

Summary

Based on the technical reviews described above, MassDEP is confident in its recommendation to address increased precipitation and associated stormwater impacts through the adoption of NOAA14 PLUS. The RMAT Development Team concluded that NOAA14 PLUS sufficiently represents present conditions over the short-term (in ten years or fewer) and recommended inclusion of NOAA14 PLUS precipitation estimates in its Tier 1 (short-term, less than 10 years) methodology. Furthermore, the RMAT Development Team and the ten municipal engineers in the Mystic River watershed concluded in separate analyses that NOAA14 PLUS produces precipitation estimates that do not represent precipitation under longer-term (2070) climate change. The review of NOAA 14 PLUS through the

Massachusetts Climate Resilience Design Standards and Guidance – Comparative Precipitation Methodology Report comparing near term (2030) and longer term (2070) projections, indicated NOAA14 Plus is similar to the short-term climate projections (2030) but that climate projections are higher over a longer term (2070). MassDEP agrees that NOAA14 PLUS does not represent projected conditions over the longer-term, however believes that its adoption will constitute a meaningful update for evaluating precipitation rates and addressing recent extreme precipitation events

References

Arnbjerg-Nielsen, K.; Olsson, P.; Olsson, J.; Beecham, S.; Pathirana, A.; Bülow Gregersen, I.; Madsen, H.; and Nguyen, V.-T.-V., 2013. Impacts of climate change on rainfall extremes and urban drainage systems: a review; Water Science and Technology; Volume 68.1, pp. 16-28. WEB: http://wst.iwaponline.com/content/ppiwawst/68/1/16.full.pdf

Cheng, Linyin; and Aghakouchak, Amir, 2014. Nonstationary Precipitation Intensity-Duration-Frequency curves for Infrastructure Design in a Changing Climate, Scientific Reports, 4:7093

Federal Emergency Management Agency, 2001. Modernizing FEMA's Flood Hazard Mapping Program: Recommendations for Using future-conditions Hydrology for the National Flood Insurance Program, 30 pages, WEB: https://www.fema.gov/media-library-data/20130726-1545-20490-3997/frm_frpt.pdf.

MA Executive Office of Energy and Environmental Affairs and MA Emergency Management Agency. 2020. RMAT Technical Assistance Project, Call with DEP to discuss feedback on RMAT methodology and on NOAA+ approach – a PowerPoint Presentation, April 21, 2020.

MA Executive Office of Energy and Environmental Affairs. 2021. Resilient Massachusetts Action Team (RMAT) Climate Resilience Design Standards & Guidelines Section 3: Climate Resilience Design Standards Overview, April 1, 2021 (https://eea-nescaum-dataservices-assets-prd.s3.amazonaws.com/cms/GUIDELINES/20210401Section3ClimateResilienceDesignStandardsOverview.pdf)

MA Executive Office of Energy and Environmental Affairs. 2022. Resilient Massachusetts Action Team (RMAT) Climate Resilience Design Standards & Guidance, Section 4: Climate Resilience Design Standards, Attachment 4-B: Comparative Precipitation Methodology Report, Version 1.2, July 2022.

National Oceanic and Atmospheric Administration, 2015 (Revised 2019). NOAA Atlas 14 Precipitation-Frequency Atlas of the United States Volume 10 Version 3.0: Northeastern States Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont.

Watkins, Kathy; Livsey, John; McGivern, Tim; Rudolph, Beth; Corey, Jay; Chouinard, Wayne; Rozycki, Alexander; Proakis Ellis, Elena; St. Louis, and Gregory; Mammolette, Louis. 2021 Letter from Ten Municipal Engineers in the Mystic River Watershed to Kathy Baskin, Assistant Commissioner, MA Department of Environmental Protection, dated June 11, 2021.

APPENDIX A

FITTED VALUES AND UPPER AND LOWER CONFIDENCE INTERVALS OF NOAA ATLAS 14, VOLUME 10 USING LOGAN INTERNATIONAL AIRPORT AS AN EXAMPLE

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1] at Logan International Airport, Boston, MA

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.296** (0.243-0.361)	**0.366** (0.300-0.446)	**0.480** (0.392-0.587)	**0.574** (0.465-0.708)	**0.704** (0.549-0.919)	**0.801** (0.610-1.07)	**0.905** (0.665-1.27)	**1.03** (0.703-1.48)	**1.22** (0.792-1.82)	**1.38** (0.870-2.10)
10-min	**0.420** (0.345-0.511)	**0.518** (0.425-0.632)	**0.679** (0.554-0.831)	**0.813** (0.659-1.00)	**0.998** (0.777-1.30)	**1.14** (0.863-1.52)	**1.28** (0.942-1.80)	**1.46** (0.994-2.09)	**1.72** (1.12-2.57)	**1.95** (1.23-2.97)
15-min	**0.494** (0.405-0.601)	**0.610** (0.500-0.743)	**0.800** (0.653-0.979)	**0.957** (0.776-1.18)	**1.17** (0.915-1.53)	**1.34** (1.01-1.79)	**1.51** (1.11-2.12)	**1.72** (1.17-2.46)	**2.03** (1.32-3.02)	**2.29** (1.45-3.50)
30-min	**0.659** (0.541-0.802)	**0.815** (0.668-0.993)	**1.07** (0.873-1.31)	**1.28** (1.04-1.58)	**1.57** (1.23-2.05)	**1.79** (1.36-2.40)	**2.02** (1.49-2.84)	**2.30** (1.57-3.30)	**2.72** (1.77-4.06)	**3.08** (1.95-4.70)
60-min	**0.824** (0.677-1.00)	**1.02** (0.836-1.24)	**1.34** (1.09-1.64)	**1.61** (1.30-1.98)	**1.97** (1.54-2.57)	**2.24** (1.71-3.00)	**2.53** (1.86-3.56)	**2.88** (1.97-4.13)	**3.42** (2.22-5.10)	**3.87** (2.45-5.91)
2-hr	**1.07** (0.882-1.29)	**1.34** (1.10-1.62)	**1.78** (1.46-2.16)	**2.14** (1.75-2.62)	**2.64** (2.08-3.43)	**3.01** (2.31-4.02)	**3.42** (2.54-4.80)	**3.92** (2.68-5.57)	**4.70** (3.07-6.94)	**5.38** (3.41-8.11)
3-hr	**1.25** (1.03-1.50)	**1.56** (1.30-1.89)	**2.08** (1.72-2.52)	**2.51** (2.06-3.06)	**3.11** (2.45-4.02)	**3.54** (2.73-4.71)	**4.02** (3.00-5.62)	**4.62** (3.17-6.52)	**5.55** (3.63-8.15)	**6.36** (4.05-9.54)
6-hr	**1.63** (1.36-1.95)	**2.03** (1.69-2.44)	**2.69** (2.23-3.24)	**3.24** (2.67-3.92)	**3.99** (3.16-5.12)	**4.54** (3.51-5.99)	**5.15** (3.85-7.12)	**5.90** (4.07-8.25)	**7.08** (4.65-10.3)	**8.10** (5.17-12.0)
12-hr	**2.10** (1.77-2.50)	**2.59** (2.18-3.09)	**3.40** (2.84-4.06)	**4.06** (3.37-4.88)	**4.98** (3.96-6.32)	**5.65** (4.39-7.37)	**6.39** (4.80-8.73)	**7.30** (5.05-10.1)	**8.69** (5.73-12.5)	**9.90** (6.34-14.5)

24-hr	**2.53** (2.14-2.99)	**3.14** (2.65-3.71)	**4.14** (3.48-4.92)	**4.97** (4.15-5.94)	**6.12** (4.91-7.72)	**6.96** (5.45-9.02)	**7.88** (5.96-10.7)	**9.04** (6.28-12.4)	**10.9** (7.17-15.4)	**12.4** (7.98-18.0)
2-day	**2.85** (2.42-3.34)	**3.62** (3.08-4.25)	**4.88(** 4.13-5.75)	**5.92** (4.97-7.02)	**7.36** (5.95-9.26)	**8.41** (6.64-10.9)	**9.58** (7.33-13.0)	**11.1** (7.74-15.1)	**13.6** (9.00-19.1)	**15.8** (10.2-22.6)
3-day	**3.12** (2.66-3.64)	**3.94** (3.37-4.61)	**5.30** (4.50-6.22)	**6.42** (5.42-7.58)	**7.97** (6.47-9.98)	**9.10** (7.21-11.7)	**10.4** (7.96-14.0)	**12.0** (8.39-16.2)	**14.7** (9.78-20.6)	**17.2** (11.1-24.4)
4-day	**3.37** (2.89-3.93)	**4.22** (3.61-4.92)	**5.62** (4.78-6.57)	**6.77** (5.73-7.97)	**8.36** (6.80-10.4)	**9.52** (7.56-12.2)	**10.8** (8.33-14.6)	**12.5** (8.76-16.8)	**15.4** (10.2-21.3)	**17.9** (11.5-25.3)
7-day	**4.07** (3.51-4.72)	**4.95** (4.26-5.74)	**6.39** (5.47-7.43)	**7.57** (6.44-8.86)	**9.21** (7.53-11.4)	**10.4** (8.30-13.2)	**11.7** (9.07-15.7)	**13.5** (9.48-18.0)	**16.4** (10.9-22.6)	**19.0** (12.3-26.7)
10-day	**4.72** (4.08-5.45)	**5.62** (4.85-6.49)	**7.09** (6.09-8.22)	**8.31** (7.08-9.68)	**9.98** (8.18-12.3)	**11.2** (8.95-14.1)	**12.6** (9.70-16.6)	**14.3** (10.1-19.0)	**17.2** (11.5-23.5)	**19.7** (12.8-27.5)
20-day	**6.60** (5.75-7.57)	**7.59** (6.59-8.70)	**9.20** (7.95-10.6)	**10.5** (9.04-12.2)	**12.4** (10.1-14.9)	**13.7** (11.0-17.0)	**15.2** (11.6-19.5)	**16.9** (12.0-22.1)	**19.4** (13.1-26.2)	**21.6** (14.0-29.7)
30-day	**8.16** (7.13-9.31)	**9.22** (8.04-10.5)	**10.9** (9.50-12.5)	**12.4** (10.7-14.3)	**14.3** (11.8-17.1)	**15.8** (12.6-19.3)	**17.4** (13.2-21.9)	**19.0** (13.5-24.6)	**21.3** (14.4-28.5)	**23.1** (15.0-31.5)
45-day	**10.1** (8.88-11.5)	**11.3** (9.86-12.8)	**13.1** (11.4-15.0)	**14.6** (12.7-16.8)	**16.8** (13.8-19.9)	**18.4** (14.7-22.2)	**20.0** (15.2-24.8)	**21.6** (15.4-27.7)	**23.6** (16.0-31.3)	**25.0** (16.3-34.0)
60-day	**11.8** (10.4-13.4)	**13.0** (11.4-14.7)	**14.9** (13.0-17.0)	**16.5** (14.3-18.9)	**18.7** (15.5-22.1)	**20.5** (16.3-24.5)	**22.2** (16.8-27.2)	**23.7** (17.0-30.3)	**25.5** (17.3-33.7)	**26.8** (17.5-36.1)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS). Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.
Please refer to NOAA Atlas 14 document for more information (https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ma).

3.14 inches = "fitted value" for the 2-yr 24-hr storm

2.65 inches = lower (10%) confidence limit; 3.71 inches = upper (90%) confidence limit

NOAA14 PLUS = NOAA published upper (90%) confidence limit * 0.9

NOAA14 PLUS = 3.71-inches * 0.9 = 3.34-inches for the 2-yr 24-hr storm

APPENDIX B

NOAA14 PLUS STAKEHOLDER COMMENTS AND MASSDEP RESPONSES

Stakeholder comments regarding the NOAA14 PLUS Method were received from the following parties:

- Massachusetts Department of Transportation (November 20, 2020)
- Massachusetts Department of Conservation and Recreation (December 2, 2020)
- NAIOP (November 23, 2020)
- Home Builders and Remodelers Association Massachusetts (April 26, 2021)
- Charles River Watershed Association (May 18, 2021)
- Ten Municipal Engineers (Arlington, Cambridge, Chelsea, Lexington, Medford, Melrose, Reading, Watertown, Winchester, and Woburn) in the Mystic River Watershed (June 11, 2021)

The discussion below presents the reviewers' major comments and concerns as well as responses from MassDEP.

Commenter: Massachusetts Department of Transportation, Highway Division
COMMENT: **"**The precipitation data used for MassDEP stormwater regulations should not conflict with the future guidelines proposed by the Resilient Massachusetts Action Team (RMAT), the team responsible for preparing the Climate Resilience Design Standards and Guidelines for the State."

RESPONSE: NOAA14 PLUS is consistent with the Resilient MA Action Team (RMAT) Climate Resilience Design Standards and Guidelines project which has developed guidance for state-funded projects to enhance how the Commonwealth assesses climate resilience as part of its capital planning process. While the RMAT is intended to address climate change, its Tier 1 methodology is presented as its the lowest level of effort to determine design criteria values and is only recommended for assets with a useful life of less than 10 years. Since the Wetlands Protection Act regulations do not require that precipitation estimates reflect climate change, MassDEP believes that the use of NOAA14 PLUS, which is based on past precipitation, and reflects more extreme precipitation, represents near-term climate change conditions and is in agreement with the RMAT Tool. MassDEP is not averse to the use of the higher Tier 2 or 3 by applicants. However NOAA14 PLUS (RMAT Tier 1) readily allows for the construction of Intensity-Duration (IDF) using localized data, to size stormwater conveyance pipes, whereas RMAT Tier 2 and 3 need additional analysis to develop sub-daily IDF curves.

COMMENT: "There is high uncertainty in the estimates of future rainfall, and data varies depending on the source and modeling approach. Instead of accepting that uncertainty and incorporating it into state regulations, it may be better to take a flexible and iterative approach to precipitation data for stormwater management design."

RESPONSE: NOAA14 PLUS recognizes the uncertainty and incorporates it into the State's Wetlands Protection regulations. NOAA14 PLUS recognizes uncertainty by using 90% of the upper confidence intervals published by NOAA. This approach provides standardization between individual projects for stormwater management and Bordering Land Subject to Flooding (BLSF) which is critical for regulatory purposes and implementation.

COMMENT: Bordering Land Subject to Flooding "typically relies on Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs) to determine its extent. These flood studies and mapping are based on historical rainfall data and stream flows and do not account for potential climate change impacts. In areas that do not have a detailed study from FEMA, hydrologic and hydraulic modeling is typically used to determine a design flood elevation. In either case, MassDEP could update the methodology for delineating BLSF in order to include climate change data. This could include using NOAA 14 + rainfall or requiring hydrologic and hydraulic modeling rather than relying on historical FEMA mapping or studies. If these changes were to occur, additional engineering costs and/or greater compensatory storage would likely be required for MassDOT projects."

RESPONSE: MassDEP agrees that climate change data could be utilized to delineate the extent of BLSF to better protect the statutory interests of flood control and storm damage prevention under climate change. Many of the FEMA Flood Insurance Studies in Massachusetts were developed using Technical Paper 40 (TP40) precipitation intensities and then-existing land-uses coupled with a rainfall-runoff model when United States Geological Survey streamflow data were not available. The approach of continuing to rely on the existing FEMA mapping, especially when it was conducted using TP40, under-represents the geographical extent of BLSF in many portions of the Commonwealth. MassDOT commented that the approach to using NOAA 14 PLUS rainfall is one method that could be utilized rather than relying on historical FEMA mapping or studies. MassDEP is proposing to rely on NOAA14 PLUS to map the geographic extent of BLSF, as was recommended by MassDOT in their comment, but only when FEMA Flood Profile Data is not available. Continuing to rely on the FEMA mapping, where Flood Profile Data exists, is prudent from a policy perspective, to ensure a unified flood boundary, rather than having different boundaries, which could cause confusion. It is MassDEP's hope that flood mapping conducted by FEMA in the future incorporates climate change, given that nationwide approximately 25% of flood insurance claims occur in locations not mapped by FEMA as flood prone (Federal Emergency Management Agency, 2021. Flood Insurance and the NFIP, https://www.fema.gov/fact-sheet/flood-insurance-and-nfip).

COMMENT: Isolated Land Subject to Flooding (ILSF) "boundaries are determined using the 100-year storm event. If MassDEP updates the calculation requirements to require the use of NOAA 14 + data, then ILSF footprints would become larger, thus reducing developable area."

RESPONSE: MassDEP agrees that that when ILSF boundaries are determined using NOAA14 PLUS, then the geographic extent of ILSF that is regulated will be larger. However, designation within ILSF does not reduce developable area. ILSF may continue to be developed under MassDEP's proposal to rely on NOAA14 PLUS for the mapping, so long as compensatory flood storage is provided.

COMMENT: "MassDOT has a vested interest in using the appropriate precipitation data for designing its infrastructure. Appropriate design will protect our public investments, reduce damage due to flooding or scour, and maintain a safe transportation network. MassDOT regularly utilizes rainfall data for design and analysis of its infrastructure including bridges, culverts, and drainage conveyance systems. Although these analyses are outside jurisdiction of the Wetland Protection Act (WPA) or Stormwater

Management Standards, the adoption of NOAA 14 + in state regulations could make this the default engineering standard for practitioners. MassDOT could be requested to use NOAA 14 + for these analyses during regulatory reviews even if it is outside the jurisdiction of the Stormwater Standards. This has the potential to add significant, and potentially unwarranted, construction costs to bridges, culverts, and drainage conveyance systems. MassDEP should review how use of NOAA 14 + may affect the design approaches for hydraulically dependent structures (e.g., bridges, culverts)."

RESPONSE: The Wetlands Protection Act regulations only regulate activities that occur in wetland resource areas and buffer zones. Proposed new bridges and culverts, when they cross river or streams, are in jurisdictional areas, and are required to be designed in such a manner so as to maintain the channel carrying capacity, comply with the Stream Crossing Standards so as to not impair aquatic organism passage, and not increase the water surface elevation of the 100-year flood. No changes to those regulations are being proposed at this time. MassDOT pointed out there are uncertainties in precipitation estimates. For peak runoff rate attenuation, MassDEP is proposing to amend the Wetlands Protection regulations to require NOAA14 PLUS be used in place of the 1961 TP40, to specifically account for the uncertainty in precipitation estimates and also to address Governor Baker's Executive Order #569 "to strengthen the resilience of our communities, prepare for the impacts of climate change, and to prepare for and mitigate damage from extreme weather events."

COMMENT: "The NOAA 14 + approach should be fully vetted through a peer review so as to be supported by the climate change community and used for the purposes of stormwater design. The peer review should be performed by entities well-versed in climate change science (e.g., academia, USGS, NOAA). A subcomponent of the peer review should include an impact analysis on use of increased precipitation depths to understand how it affects stormwater management design and other hydraulic structures (e.g., bridges, culverts, stormwater conveyance systems). The impact analysis should be completed by qualified engineers."

RESPONSE: Technical reviews were conducted by climate scientists at Weston and Sampson and the University of New Hampshire, working under contract to RMAT, and by a consortium of communities in the Mystic River watershed. Technical comments on NOAA14 PLUS are presented in the main body of this document. MassDOT commented that an impact analysis should be conducted "to understand how it affects stormwater management design and other hydraulic structures (e.g., bridges, culverts, stormwater conveyance systems). The impact analysis should be completed by qualified engineers." Comprehensive Environmental Incorporated, under contract to MassDEP, conducted an impact analysis examining three types of typical development projects that occur in wetland resource areas, including a roadway scenario. Most of MassDOT roadway projects fall under the redevelopment provisions, 310 CMR 10.05(6)(k)7., where peak runoff rate reduction is only required to the maximum extent practicable. As such, the costs to be incurred by MassDOT to implement NOAA14 PLUS for redevelopment of existing roadways is expected to be minimal. Much of the cost increase to provide peak rate reduction along roadways redeveloped is due to the difference between TP40 and NOAA 14. The roadway and other scenarios developed by CEI under contract to MassDEP were shared on December 2, 2020, with MassDOT and other members of the Advisory Committee that was convened by MassDEP to assist in developing new stormwater requirements to implement Governor Baker's Executive Order #569 and address the new Municipal Separate Storm Sewer System (MS4) permit. EPA

is planning to issue a Transportation Separate Storm Sewer System (TS4) permit to MassDOT to conditionally authorize their stormwater discharge to waters of the United States within the Commonwealth.
It is anticipated that the TS4 permit will require MassDOT to comply with the stormwater requirements similar to those in the Massachusetts Wetlands Protection regulations.

COMMENT: “MassDEP should adopt NOAA Atlas 14, and any new data that supersedes NOAA Atlas 14, as the basis to meet Standard 2 for stormwater management design, while making sure this approach will not conflict with RMAT guidelines. As the next step toward addressing climate change concerns (before respective regulatory changes), MassDEP should have a peer review performed on the NOAA14 + approach. MassDEP should also review the extent of impact that NOAA 14 + may have on other resource areas like BLSF and ILSF and design approaches for hydraulically dependent structures.”

RESPONSE: MassDEP plans to adopt NOAA14 PLUS to regulate the peak runoff rate. NOAA14 PLUS is consistent with RMAT, since it is included as the Tier 1 methodology. NOAA14 PLUS/RMAT Tier 1 results in precipitation estimates that are lower than the RMAT Tier 2 and Tier 3 precipitation estimates, which are expected to be recommended on state funded or permitted assets and projects. The RMAT design tool is expected to be used for evaluation through Environmental Impact Reports that State Agencies are required to file, when the Massachusetts Environmental Policy Act (MEPA) regulations (301 CMR 11.00) thresholds are exceeded. MassDOT may be required to prepare alternatives to address the higher precipitation intensities in RMAT Tier 2 and 3, depending on the lifespan of the infrastructure and its criticality. Financial impacts were evaluated by MassDEP through three development scenarios. Financial impacts of NOAA14 PLUS on MassDOT roadway projects are anticipated to be minimal, since compliance the majority of MassDOT roadway projects are redevelopment, where peak runoff rate attenuation requirements only apply to the maximum extent practicable.

Commenter: Massachusetts Department of Conservation and Recreation
COMMENT: “We strongly encourage MassDEP to have the NOAA14 PLUS approach peer reviewed to fully vet the approach, gain support from the climate change community and understand the impacts on other stormwater design criteria and permitting (e.g. Bordering Land Subject to Flooding and Isolated Land Subject to Flooding and vernal pool boundaries, culvert hydraulic design) before it is adopted.

RESPONSE: Technical reviews were conducted on NOAA14 PLUS by climate scientists of Weston & Sampson and the University of New Hampshire and by a consortium of municipalities in the Mystic River watershed, as described earlier in this document. NOAA14 PLUS was selected as the RMAT Tier 1 methodology for estimating precipitation under near-term climate change. NOAA14 PLUS addresses the uncertainty in current precipitation estimates and does not address future long-term precipitation under climate change. Future precipitation estimates, such as of the RMAT Tier 2 and Tier 3 methodologies are higher than Tier 1. Adopting NOAA14 PLUS will have no effect on mapping the extent of Vernal Pools, as MassDEP is proposing to rely on field mapping and not engineering computations.

Commenter: NAIOP
COMMENT: “NAIOP believes that the NOAA14 PLUS approach should be peer reviewed to fully vet the approach and demonstrate that it is supported by the climate change community for purposes of using

it for stormwater design. NAIOP asks that an outside peer reviewer assess the impact of these changes on stormwater system sizing and other related impacts."

RESPONSE: Technical reviews were conducted on NOAA14 PLUS by climate scientists of Weston & Sampson and the University of New Hampshire and by a consortium of municipalities in the Mystic River watershed, as described earlier in this document.

Commenter: Home Builders and Remodelers Association Massachusetts
COMMENT: "We concur with MassDEP in the concept of updating the precipitation rates to NOAA Atlas 14 but we do not agree with the unscientific future projections of using the Monte Carlo method, 90% confidence interval of the higher value what has been termed NOAA Atlas 14 PLUS."

RESPONSE: NOAA14 PLUS represents uncertainty in current precipitation estimates and does not represent future precipitation projects. The Resilient Massachusetts Action Team (RMAT) adopted NOAA14 PLUS precipitation estimates for near-term climate change. Precipitation estimates for RMAT Tiers 2 and 3, which represent longer-term climate change, are higher than those of NOAA14 PLUS. A Monte Carlo simulation was used to derive the 90% confidence interval of the NOAA Atlas 14, Precipitation-Frequency Atlas of the United States Volume 10 Version 3.0: Northeastern States. Using a Monte Carlo simulation is a peer-accepted method to develop confidence intervals. The NOAA14 PLUS method relies on the confidence limits published in NOAA Atlas 14 Volume 10. No Monte Carlo simulation was conducted by MassDEP.

Commenter: Charles River Watershed Association
COMMENT: "For new development projects, peak runoff calculations should use "existing" rainfall (Atlas14 or TP40) for calculating the pre-development runoff rates and should use "future" rainfall consistent with the RMAT approach for calculating the post development runoff rates. Failure to utilize that approach will underestimate the increase in future flooding over existing conditions."

RESPONSE: MassDEP is proposing the NOAA14 PLUS method be used to estimate both the pre- and post-peak discharge rate. For the post-development peak discharge rate, NOAA14 PLUS is consistent with RMAT, since NOAA14 PLUS is the precipitation estimate associated with the RMAT Tier 1 Method, the lowest of the three RMAT tiers. Using NOAA14 or TP40 to model existing conditions and then applying any of the RMAT Tiers to model proposed post-development runoff would require larger detention structures than what MassDEP is proposing. MassDEP's proposal to use NOAA14 PLUS (RMAT Tier 1) to model both existing and proposed peak runoff conditions is consistent with current modeling practices, where the peak runoff rate changes that result from land development are based solely on changes proposed to land cover (e.g. converting forest to a shopping mall). MassDEP is supportive of using the RMAT Tier 2 or Tier 3 precipitation intensities to model post development peak discharge rates. However, NOAA14 PLUS allows sub-daily Intensity-Duration-Frequency (IDF) curves (e.g. 5-minutes to 23-hours) to be constructed using localized data to size stormwater conveyances. Peak intensities are greater over shorter time periods. For instance, the NOAA14 intensity at Boston Logan International Airport (NOAA Station 19-0770) is 10.86-inches per hour over 5-minutes and 2.53-inches per hour over 60-minutes, for the 100-year storm. The RMAT Tier 2 and Tier 3 precipitation projections are based on daily intensities and need additional analysis to reflect higher sub-daily intensities.

Commenter: Ten Municipal Engineers (Arlington, Cambridge, Chelsea, Lexington, Medford, Melrose, Reading, Watertown, Winchester, and Woburn) in the Mystic River Watershed

COMMENT: Communities need to be able to use consistent, sufficiently conservative rainfall data across different regulations and project types. Five Mystic River watershed communities use a mixture of Cornell and NOAA14 data for Conservation Commission and general stormwater permits, even within the same municipality. One challenge is that, in our area of the state, mid-point NOAA14 data are higher than Cornell's estimates for smaller storms and lower for 1% storms. This problem would go away if the upper limit NOAA14 data were used. We were glad to see that the Stormwater Advisory Committee will be examining how this plays out in floodplains to ensure the same analyses are no longer using different data.

RESPONSE: By using NOAA14 PLUS throughout the state, MassDEP will be providing consistent precipitation estimates to municipalities and others.

COMMENT: MassDEP needs to develop statewide downscaled rainfall projections based on global climate models. We strongly support Mass DEP's efforts to develop statewide downscaled future projections of extreme precipitation based on global climate models. This would be the best science to use for stormwater management and modelling efforts.

Since current projects will experience future storms, municipalities need to be able to require that they be resilient to those higher rainfall projections. For example, Cambridge requires new developments to not be flooded by a 2070 10% storm and to be able to recover from a 2070 100% storm.

RESPONSE: NOAA14 PLUS is not intended to be a proxy for future precipitation projections. Separate efforts are underway through the Massachusetts Executive Office of Energy and Environmental Affairs (EEA), through its Resilient Massachusetts Action Team, to downscale precipitation projections at a resolution that can be used in design. While NOAA14 PLUS has been included as precipitation estimates for RMAT Tier 1 (near-term climate change), project proponents may choose to use the higher precipitation estimates of Tiers 2 or 3.

COMMENT: Given that TP-40 data are sixty years out of date, we are concerned that these data also would not be regularly updated. We would like to see DEP commit to updating these data every three to five years, or sooner if significantly different new consensus data become available. We would like to see a default mechanism to allow municipalities to use more conservative data for large development projects if the Stormwater Handbook data significantly diverge from the latest available standard precipitation data.

RESPONSE: The updating of precipitation estimates in New England, involving the participation of six New England states and the Federal government (NOAA), was an intensive, multi-year effort that would be difficult for MassDEP to replicate on its own. However, in a Note to Reviewers, MassDEP will ask for public comment on whether MassDEP should be updating precipitation estimates outside of this process and how this could be accomplished.

COMMENT: Finally, given concerns regarding disruption of climate science at the federal level, we would like to see the Stormwater Handbook not exclusively reference NOAA14 data. Perhaps it could also reference "the latest available standard precipitation data," whether it be updated Cornell data, downscaled global data, or other reliable sources. In this way, data delays beyond municipal control should not prevent communities from requiring that the best available data be used in enforcing regulations.

RESPONSE: MassDEP appreciates that extreme precipitation has been increasing with climate change and is predicted to continue to increase. However, to provide consistency and clarity in its regulations, MassDEP typically in specific in citing documents upon which its regulations are based.