Standard 2 – Stormwater Runoff Quantity Control

The objective of Standard 2 (Stormwater Runoff Quantity Control) is to maintain pre-development peak runoff rates and manage the volume and timing of runoff to prevent downstream flooding, channel erosion, and other adverse impacts resulting from development. The associated performance criteria address relatively frequent events that cause channel erosion and larger events that result in bankfull and overbank flooding. The stormwater runoff quantity control standard also addresses the design of stormwater conveyance systems associated with stormwater BMPs to safely manage flows during larger storms. Figure 4- 3 illustrates schematically the major elements of Standard 2.

Figure 4- 3 Stormwater Runoff Quantity Control (Standard 2) Elements

Peak Runoff Attenuation for Site Development\ Redevelopment

2,10,100-yr, 24-hr Storms

Control the 2-yr post development peak flow rate to 50% of predevelopment rate.

Control the 10-yr post development peak flow rate to pre-development rate.

Potentially Control the 100-year post development peak flow rate to pre-development rate, as required by review authority.

Conveyance Protection

10-yr, 24-hr Storm

For on-line structural stormwater BMPs, design the conveyance system leading to, from, and through the stormwater BMPs based on the 10-yr or larger storm event.

Design conveyance system based on peak flow rate of the largest storm for which peak runoff attenuation is provided (i.e., 10-yr storm or larger up to 100-year storm).

Emergency Outlet Sizing

100-yr, 24-hr Storm

For on-line stormwater quantity control BMPs, size the emergency outlet of stormwater quantity control structures to safely pass the post-development peak flow rate from the 100-year storm event or larger storm (at the discretion of the review authority) in a controlled manner without eroding the outlet and downstream drainage systems.

Note: The storms for peak runoff attenuation control should be verified with the appropriate review authority. The examples provided above represent the storms storm events most often required by municipalities. However, some review authorities may have different requirements. In addition, please note that CT DEEP's Construction Stormwater General Permit only requires peak run off attenuation evaluation and control only for large-scale solar project with regards to the 2, 25, 50 and 100-year 24-hour storms.

The Standard 2 stormwater quantity control criteria should be met at each individual discharge point along the boundary of the development site or internal to the site (i.e., design point) such as abutting properties, roadways, wetlands and watercourses, and receiving storm drainage systems.

Linear projects have alternative standards and may take an alternative approach to address constraints that are different than those that affect traditional parcel development projects. These alternative linear project standards can be found in the CTDOT drainage manual, the

CTDOT MS4 General Permit, the General Construction Permit and in the supporting materials that CTDOT has developed.

Stormwater Quantity Control Design Storms

Stormwater quantity controls are designed to manage peak rates of runoff from storm events of various sizes, which are also called "design storms." Stormwater quantity control design storms are defined in terms of rainfall depth and duration, recurrence interval (i.e., the likelihood or probability of the occurrence of a certain size storm event), and rainfall distribution (i.e., how rain falls during a storm event).

Updated Stormwater Quantity Control Design Storm Rainfall

NOAA Atlas 14 (and subsequent generations of NOAA precipitation-frequency products) replaces Technical Paper No. 40 (TP-40) as the definitive source of design rainfall in Connecticut. The version of NOAA Atlas 14 for the northeastern United States, including Connecticut, was released in 2015 and revised in 2019. NOAA Atlas 14 contains precipitation frequency estimates for selected durations and frequencies with associated lower and upper bounds of the 90% confidence interval (5% lower and 95% upper confidence limits). NOAA Atlas 14 is a significant improvement over the TP-40 precipitation estimates since it includes more observation locations, more sophisticated statistical analysis methods, a much longer period of record, and more recent precipitation data, thereby accounting for observed increases in extreme precipitation as the climate has become warmer and wetter. NOAA Atlas 14 has also been adopted by CT DEEP as the source of design storm precipitation in the Construction Stormwater General Permit and in the CTDOT Transportation MS4 Permit. CTDOT has incorporated the use of NOAA Atlas 14 precipitation frequency estimates in the CTDOT Drainage Manual. The NOAA Atlas 14 results are published online through the Precipitation Frequency Data Server.

Stormwater runoff quantity control design storms in Connecticut should be based on:

- **Rainfall Depth and Duration:** 24-hour precipitation depth with a specified recurrence interval as defined by the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 (or latest generation of this product at the time of the site planning) precipitation frequency estimates,[49] or equivalent regional or state rainfall probability information developed from NOAA Atlas 14. Designs should be based on, at a minimum, the 50th percentile (median) NOAA Atlas 14 precipitation depth, which is the primary value reported by the online Precipitation Frequency Data Server (PFDS). The review authority

[49] NOAA Atlas 14 Volume 10 Version 3, Precipitation-Frequency Atlas of the United States, Northeastern States. NOAA, National Weather Service, 2015, revised 2019. https://www.weather.gov/media/owp/oh/hdsc/docs/Atlas14_Volume10.pdf

may require at their discretion the use of greater 24-hour precipitation depths such as the upper bound of the 90% confidence interval (also reported by the PFDS) to account for larger and more intense observed storm events.

- NOAA Atlas 14 (or latest generation of this product at the time of the site planning) precipitation frequency estimates should be selected for the project site based on the site address, latitude/longitude coordinates, or by clicking on the approximate center of the site.

- "Precipitation depth" and "Partial duration" time series type should be selected from the dropdown menus.

- Select precipitation depths from the storm duration row labeled "24-hour" (see Figure 4- 4).

- County-wide average 24-hour precipitation depths derived from NOAA Atlas 14 (or latest generation of this product at the time of the site planning) may also be used, provided that the county-wide average values are representative of the project site and the values are based on the latest version of NOAA Atlas 14. Such values have been incorporated as standard options in hydrologic analysis software such as HydroCAD. However, site-specific precipitation estimates obtained from the NOAA Atlas 14 Precipitation Frequency Data Server are preferred.

- **Rainfall Distribution:** Natural Resources Conservation Service (NRCS) Type D regional rainfall distribution, which is derived from the NOAA Atlas 14 rainfall data (referred to as "NOAA_D" rainfall distribution). Other equivalent regional rainfall distributions specifically developed for use in Connecticut, or a site-specific rainfall distribution based on NOAA Atlas 14 data, may be used for design purposes at the discretion of the review authority.[50]

[50] USDA Natural Resources Conservation Service. 2018. Connecticut Instruction 210-397 – Using NOAA Atlas 14, Volume 10 Extreme Precipitation Data with WinTR-55 in Connecticut, January 24, 2018. file:///F:/P2020/0636/A11/Background%20Documents/Climate%20Change%20and%20Precipitation/Win%20TR-20%20Rainfall%20Distributions/CT_INSTRUCTION_210-397-WinTR-55_NOAA.pdf

Updated Rainfall Distribution

The NOAA_D rainfall distribution replaces the NRCS Type III regional distribution, which has historically been used in Connecticut and other Atlantic coastal areas, as well as the Northeast Regional Climate Center (NRCC) regional rainfall distributions developed in 2015. In 2018, Connecticut NRCS began recommending the use of the NOAA_D regional rainfall distribution throughout Connecticut. The NRCS NOAA_D rainfall distribution is available as a standard rainfall distribution in hydrologic analysis software such as WinTR-55. In HydroCAD, the NRCC_D distribution is available as a pre-defined rainfall distribution for Connecticut, while NOAA_D is not. NOAA_D may be created as a user-defined rainfall distribution in HydroCAD. The NOAA_D rainfall distribution is available online in text format.

Figure 4- 4 24-hour Design Storm Rainfall Depths from NOAA Atlas 14 Precipitation Frequency Data Server

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION

NOAA Atlas 14, Volume 10, Version 3

PF tabular | PF graphical | Supplementary information | Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.332 (0.259-0.415)	0.405 (0.315-0.506)	0.523 (0.406-0.656)	0.621 (0.479-0.784)	0.756 (0.565-1.00)	0.858 (0.629-1.16)	0.965 (0.686-1.36)	1.08 (0.730-1.57)	1.25 (0.813-1.88)	1.39 (0.881-2.13)
10-min	0.471 (0.367-0.588)	0.573 (0.447-0.717)	0.740 (0.574-0.929)	0.879 (0.679-1.11)	1.07 (0.800-1.42)	1.22 (0.890-1.65)	1.37 (0.971-1.93)	1.54 (1.03-2.22)	1.78 (1.15-2.67)	1.97 (1.25-3.02)
15-min	0.554 (0.432-0.692)	0.675 (0.525-0.843)	0.872 (0.677-1.09)	1.04 (0.800-1.31)	1.26 (0.942-1.67)	1.43 (1.05-1.94)	1.61 (1.14-2.26)	1.81 (1.22-2.61)	2.09 (1.35-3.13)	2.32 (1.47-3.56)
30-min	0.761 (0.593-0.950)	0.922 (0.718-1.15)	1.19 (0.921-1.49)	1.41 (1.09-1.78)	1.71 (1.27-2.26)	1.93 (1.42-2.62)	2.17 (1.54-3.06)	2.44 (1.64-3.52)	2.82 (1.83-4.23)	3.14 (1.99-4.81)
60-min	0.968 (0.755-1.21)	1.17 (0.912-1.46)	1.50 (1.17-1.88)	1.78 (1.37-2.24)	2.15 (1.61-2.85)	2.44 (1.79-3.30)	2.74 (1.95-3.86)	3.07 (2.07-4.44)	3.56 (2.30-5.33)	3.95 (2.50-6.06)
2-hr	1.28 (1.00-1.59)	1.53 (1.20-1.90)	1.95 (1.52-2.42)	2.29 (1.78-2.87)	2.76 (2.08-3.64)	3.11 (2.30-4.20)	3.49 (2.51-4.92)	3.93 (2.66-5.65)	4.59 (2.99-6.85)	5.15 (3.27-7.84)
3-hr	1.49 (1.18-1.84)	1.78 (1.40-2.20)	2.25 (1.77-2.80)	2.65 (2.07-3.31)	3.19 (2.42-4.19)	3.60 (2.67-4.84)	4.03 (2.92-5.67)	4.55 (3.09-6.51)	5.34 (3.48-7.93)	6.01 (3.82-9.11)
6-hr	1.89 (1.50-2.31)	2.26 (1.80-2.77)	2.87 (2.28-3.54)	3.38 (2.67-4.19)	4.09 (3.12-5.33)	4.60 (3.45-6.17)	5.17 (3.77-7.24)	5.85 (3.98-8.32)	6.89 (4.51-10.2)	7.79 (4.97-11.7)
12-hr	2.32 (1.86-2.82)	2.81 (2.25-3.42)	3.61 (2.89-4.41)	4.27 (3.40-5.26)	5.19 (3.99-6.73)	5.87 (4.42-7.81)	6.60 (4.84-9.19)	7.49 (5.13-10.6)	8.86 (5.81-13.0)	10.0 (6.42-15.0)
24-hr	2.72 (2.21-3.28)	3.35 (2.71-4.05)	4.38 (3.53-5.32)	5.23 (4.20-6.39)	6.41 (4.98-8.28)	7.28 (5.54-9.65)	8.23 (6.09-11.4)	9.41 (6.46-13.2)	11.3 (7.41-16.4)	12.9 (8.25-19.1)

While precipitation frequency estimates published in NOAA Atlas 14 reflect observed increases in extreme precipitation over the last several decades, NOAA Atlas 14 does not account for anticipated future increases in extreme precipitation due to projected climate change. The NOAA Atlas 14 analysis methods assume stationarity in both the historical data used in making the estimates and in future conditions. This assumption may not be appropriate under changing (i.e., non-stationary) climatic conditions. NOAA is working with several research universities to develop precipitation frequency estimates that account for non-stationary climate assumptions and factor in climate projections; however, that product was not available as of the revision date of this Manual and is therefore not specifically addressed in this Manual. To account for the best science, including current and projected future rainfall, this Manual recommends the inclusion of the most recent generation of NOAA Atlas precipitation frequency products at the time of the site planning.

Peak Runoff Attenuation for Site Development and Redevelopment

Select and design stormwater BMPs (structural or non-structural measures) in accordance with the appropriate permits and the guidance contained in this Manual to control stormwater runoff quantity impacts, including flooding and erosive flows. The peak runoff attenuation criterion is intended to address increases in peak flow rates associated with a range of design storms, including events that result in bankfull flow conditions (typically the 2-year storm, which controls the form of the stream channel) and larger storms that cause overbank flooding.

- Through hydrologic and hydraulic analysis, calculate pre-development and post-development peak flow rates for the 2-year, 10-year, and potentially the 100-year 24-hour storms for each point at which stormwater discharges from a site (i.e., design point).

The following criteria should be met for each design point using structural stormwater BMPs:

- Control the 2-year, 24-hour post-development peak flow rate to 50% of the 2-year, 24-hour pre-development peak flow rate.
- Control the 10-year, 24-hour post-development peak flow rate to the 10-year, 24-hour pre-development peak flow rate.

The following criteria may be required at the discretion of the review authority:

- Potentially control the 100-year, 24-hour post-development peak flow rate to the 100-year, 24-hour pre-development peak flow rate.
- Demonstrate that any increase in volume or change in timing of stormwater runoff (for any design storm event) will not result in adverse effects such as increased flooding downstream of the site or at other off-site locations. Delaying the release of stormwater using detention/storage BMPs to attenuate peak flow rates, combined with upstream peak discharge (i.e., coincident peak flows), can also result in increases in peak flows at critical downstream locations such as road culverts and areas prone to flooding and is most pronounced for detention structures in the middle to lower third of a watershed.

The review authority may waive compliance with one or more of the peak runoff attenuation requirements under the following circumstances:

- Peak runoff attenuation may be waived for the 2-year, 24-hour storm event for sites having less than 1 acre of DCIA because the size of the orifice or weir required for extended detention becomes too small (approximately 1 inch in diameter) to effectively operate without clogging.
- Peak runoff attenuation may be waived for the 2-year, 10-year, and 100-year 24-hour storm events for sites that discharge stormwater directly into a large river (fourth order or greater), lake, or tidal waters where the development area is less than 5 percent of the watershed area upstream of the development site. If the stormwater runoff from a site will flow over or past another property, or discharge to a storm sewer or other conveyance, before reaching any of the above waterbodies, the project proponent should demonstrate compliance with the peak runoff attenuation performance criterion.
- When a downstream analysis indicates that peak discharge control would not be beneficial or would exacerbate peak flows in downstream areas through coincident peak flows.

The review authority, at its discretion, may require the project proponent to evaluate pre- and post-development peak runoff rates and provide peak runoff attenuation for other design storms including more intense, shorter-duration storms to reflect potential changes in rainfall characteristics due to climate change or other factors.

Stormwater Retention and Adjusted Runoff Curve Number

Retention or infiltration of the water quality design storm to meet the runoff volume and pollutant reduction requirements of Standard 1 may also reduce the peak rate of runoff for stormwater runoff quantity control design storms. A reduced NRCS runoff curve number (CN) may be used in peak flow rate calculations when stormwater is retained on-site through infiltration or reuse, either using impervious area (simple) disconnection (see Chapter 5 - Low Impact Development Site Planning and Design Strategies) or a stormwater infiltration system designed to fully infiltrate the Required Retention Volume (100% or 50% of the site's WQV).

For impervious area disconnection, the disconnected impervious area should be assigned a CN corresponding to the type of vegetation used for the qualifying pervious area (e.g., grass/lawn, brush or forest) in fair condition.

For stormwater infiltration systems, an adjusted CN for the area draining to the infiltration system should be determined for each design storm using the following method:

- Calculate the volume of stormwater retained by the infiltration system (see Chapter 10 - General Design Guidance for Stormwater Infiltration Systems and BMP-specific design guidance in Chapter 13).

- Calculate the stormwater runoff volume for the water quality storm and the 2-, 10-, and 100-year, 24-hour storms as described in this chapter.
- Subtract the volume of stormwater retained by the infiltration system from the stormwater runoff volume for the various storm events. The result is the runoff volume that will be discharged from the infiltration system during each storm event.
- Convert the volume of stormwater discharged from the infiltration system to an equivalent discharge depth (in inches) by dividing the volume discharged by the area draining to the infiltration system.
- Using the calculated discharge depth described above and the precipitation for each design storm event, calculate the adjusted CN values using the equation or graphical solution (Figure 2-1 from TR-55) presented in Appendix D of this Manual (i.e., Graphical Peak Discharge Method).

Once the adjusted CN values are determined, also calculate the time of concentration and either follow the remaining steps in the Graphical Peak Discharge Method in Appendix D or use a stormwater hydrologic/hydraulic routing model based on the NRCS Curve Number method (e.g., HydroCAD or similar software) to calculate peak discharge rates for each design storm event.

Downstream Analysis for Site Development and Redevelopment

A downstream hydrologic and hydraulic analysis may be required, at the discretion of the review authority, to demonstrate that increased volume or change in timing of stormwater runoff (for any design storm event) will not increase flooding downstream of the site or at other off-site locations. A downstream analysis may also be required when existing conditions are already causing known drainage or flooding conditions or existing channel erosion at or downstream of the project site or at other off-site locations.

The downstream analysis should include the following elements:

- Routing calculations should proceed downstream to a confluence point where the site drainage area represents 10 percent of the total drainage area above the point (i.e., the "10 percent rule").
- Calculation of peak flows, velocities, and hydraulic effects at critical downstream locations (stream confluences, culverts, other channel constrictions, and flood-prone areas) to the confluence point where the 10 percent rule applies.
- The analysis should use an appropriate hydrograph routing method, such as routing employed by TR-20, to route the pre- and post-development runoff hydrographs from the project site to the downstream critical locations.

- The analysis should include the analysis of impacts of existing land uses and projected land uses assuming full development under existing zoning and land use ordinances in the drainage area.

- A downstream analysis is not required if a project proponent can demonstrate through hydrologic and hydraulic analysis that, for stormwater leaving the site, the post-development runoff hydrograph does not exceed the pre-development hydrograph at any point in time for the same design storm event. This typically requires on-site retention/infiltration of stormwater to maintain or reduce pre-development runoff volumes and peak flow rates.

If flow rates and velocities at critical downstream locations increase by less than 5% from the pre-developed condition, and no existing structures are adversely impacted including exceedance of freeboard clearances and allowable flow velocities, then no additional analysis is necessary. Otherwise, the project proponent should redesign the stormwater quantity controls on the site and/or propose corrective actions to the impacted downstream areas.

Conveyance Protection

For structural stormwater BMPs designed in an "on-line" configuration, design the conveyance system leading to, from, and through structural stormwater BMPs based on the 10-year, 24-hour. At a minimum. On-line stormwater BMPs should be designed based on the peak flow rate of the largest storm for which peak runoff attenuation is provided (i.e., 10-yr, 24-hour storm event or larger up to the 100-year, 24-hour storm). This criterion is designed to prevent erosive flows within internal and external conveyance systems associated with stormwater BMPs such as channels, ditches, berms, overflow channels, and outfalls.

The review authority may also require the use of larger magnitude design storms for conveyance systems associated with stormwater BMPs, including stormwater drainage systems upstream or downstream of the BMPs. Such drainage systems should be designed in accordance with the Connecticut Department of Transportation Drainage Manual as well as applicable local and state design and permitting requirements.

Off-line stormwater BMPs (i.e., designed to manage and convey peak flows up to the water quality storm and bypass higher flows) should be designed with a bypass or overflow for flows larger than the water quality storm.

Emergency Outlet Sizing

Size the emergency outlet of stormwater quantity control BMPs to safely pass the post-development peak flow from the 100-year, 24-hour storm event (or larger storm events at the discretion of the review authority) in a controlled manner without eroding the outlet and downstream drainage systems. Emergency outlets constructed in natural ground are generally preferable to constructed embankments. This requirement is only applicable to stormwater management facilities that are designed in an "on-line" configuration and for the purpose of providing stormwater quantity control.