Appendix A – Stormwater Regulation

As noted in Chapter 1 - Introduction, this Manual has no regulatory authority but rather provides guidance to address the various regulations (federal, state and local) regarding post-construction stormwater management. This appendix provides a summary of the various stormwater management programs in Connecticut with regulatory authority. The table below summarizes the applicable regulations, provides an overview of the program, and defines the party responsible for implementation ("End User").

Federal/ State/ Local	Program	Program Overview	End User
Federal	Clean Water Act (CWA) Section 303 Water Quality Standards and Implementation Plans	Under Section 303 of the CWA, states are required to adopt surface water quality standards, subject to review and approval by the U.S. EPA, and identify surface waters that do not meet these water quality standards following the installation of minimum required pollution control technology for point sources discharging to surface water bodies. These impaired water bodies must be ranked by the states and a Total Maximum Daily Load (TMDL) must be established for the pollutant(s) that exceed the water quality standards. A TMDL both specifies a maximum amount of pollutant that the surface water body can receive and allocates that amount, or load, among point and nonpoint sources, including stormwater discharges.	Federal and State
Federal	CWA Section 319 – Nonpoint Source Management Program	CWA Section 319 addresses the need for federal guidance and assistance to state and local programs for controlling nonpoint sources of pollution, including stormwater runoff. Under Section 319, states, territories and Indian Tribes receive federal grant money to support various activities that address nonpoint source pollution control. These activities include technical and direct financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the effectiveness of specific nonpoint source implementation projects.	Federal and State
Federal	CWA Section 401 – Water Quality Certification	Section 401 of the CWA requires applicants for a federal license or permit to obtain a certification or waiver from the state water pollution control agency (EPA, states and authorized tribes) for any activity which may result in a	Federal and State

Federal/ State/ Local	Program	Program Overview	End User
		discharge into navigable waters of the state or tribal lands, including wetlands, watercourses, and natural and man-made ponds. This waiver certifies that the discharge will comply with the applicable provisions of the CWA and Connecticut's Water Quality Standards. Examples of federal licenses and permits for which water quality certification is required include U.S. Army Corps of Engineers Section 404 dredge and fill permits, Coast Guard bridge permits, and Federal Energy Regulatory Commission permits for hydropower and gas transmission facilities.	
Federal	Section 402 – National Pollutant Discharge Elimination System (NPDES)	The NPDES program was established under Section 402 of the CWA and specifically targets point source discharges by industries, municipalities, and other facilities that discharge directly into surface waters. Stormwater discharges are addressed under the NPDES Stormwater Program. The NPDES permitting program is administered in Connecticut by DEEP through a series of permits noted below in this table.	Federal and State
Federal	Coastal Zone Act Reauthorization Amendments	Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990 (16 U.S.C. §1455b) is designed to address the problem of nonpoint source pollution in coastal waters. Under Section 6217, states and territories with approved Coastal Zone Management Programs, including Connecticut, are required to develop Coastal Nonpoint Source Pollution Control Programs or face funding sanctions in both their coastal programs and their nonpoint programs established under Section 319 of the Clean Water Act.	Federal and State

Federal/ State/ Local	Program	Program Overview	End User
		The program must describe how the state or territory will implement management measures to reduce or eliminate nonpoint source pollution, including stormwater runoff, to coastal waters. These management measures must conform to those described in the U.S. EPA publication Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.	
State	Connecticut Industrial Stormwater Permit	The General Permit for the Discharge of Stormwater Associated with Industrial Activity ("Industrial Stormwater General Permit") regulates industrial facilities with point source discharges that are engaged in specific activities listed in the permit. To register for this program, these facilities must submit a registration form, and implement a Pollution Prevention Plan (PPP). The PPP must include information about the site, an inventory of exposed materials, a summary of potential pollutants, a description of and schedule for implementation of storm water control methods, storm water monitoring, and site inspection.	State and Permittees
State	Construction Stormwater General Permit	The General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities ("Construction Stormwater General Permit") requires developers and builders to implement a Stormwater Pollution Control Plan to prevent the movement of sediments off construction sites into nearby water bodies and to address the impacts of stormwater discharges from a project after construction is complete.	State and Permittee

Federal/ State/ Local	Program	Program Overview	End User
State	General Permit for the Discharge of Stormwater Associated with Commercial Activity	The General Permit for the Discharge of Stormwater Associated with Commercial Activity ("Commercial General Permit"), found only in Connecticut, requires operators of large paved commercial sites such as malls, movie theaters, and supermarkets to undertake actions such as parking lot sweeping and catch basin cleaning to keep stormwater clean before it reaches water bodies.	State and Permittee
State	General Permit for the Discharge of Stormwater from Small Municipal Separate Storm Sewer Systems	The General Permit for the Discharge of Stormwater from Small Municipal Separate Storm Sewer Systems ("MS4 General Permit") requires each municipality to take steps to keep the stormwater entering its storm sewer systems clean before entering water bodies. One important element of this permit is the requirement that towns implement public education programs to make residents aware that stormwater pollutants emanate from many of their everyday living activities, and to inform them of steps they can take to reduce pollutants in stormwater runoff.	
State	Connecticut Coastal Zone Management Plan	Per the requirements of the federal CZARA (noted above) Connecticut and other coastal zone states are required to have a Coastal Zone Management Plan and an assessment of that plan ever five years after the adoption of said plan. The plans and the assessments there after are required to review nine key elements, one of which is Cumulative and Secondary Impacts, this is where stormwater is assessed and considered.	

Federal/ State/ Local	Program	Program Overview	End User
		Additionally, Connecticut management plan includes the Water Quality Certification and Coastal Permit Program, noted below, these permits and water quality certifications are required to consider stormwater impacts. Connecticut's latest assessment can be found here: https://coast.noaa.gov/czm/enhancement/	
State	Coastal Individual Permits[93]	The DEEP's Land and Water Resources Division (LWRD) regulates all activities conducted in tidal wetlands and in tidal, coastal, or navigable waters in Connecticut under the Structures, Dredging and Fill statutes, Connecticut General Statutes (CGS) Sections 22a-359 - 22a-363h, inclusive, and the Tidal Wetlands statutes, CGS Sections 22a-28 - 22a-35, inclusive. The major objectives of the permit program are to avoid or minimize navigational conflicts, encroachments into the state's public trust area, and adverse impacts on coastal resources and uses, consistent with Connecticut's Coastal Management Act (CCMA), CGS Sections 22a-90 - 22a-112, inclusive. Certain activities require an "individual" permit specific to the proposed work. These activities typically include new construction and other work for which a detailed review of potential	Permittee, State and Army Corp of Engineers

[93] In 2012, the jurisdiction of the coastal zone was modified from the high tide line to a "coastal jurisdiction line" it is anticipated this line will continue to be revised with the updated information regarding sea level rise. See the details of this zone here: https://portal.ct.gov/DEEP/Coastal-Resources/Coastal-Permitting/Coastal-Jurisdiction-Line-Fact-Sheet

Federal/ State/ Local	Program	Program Overview	End User
		environmental impacts is needed. Many of the applications require a Stormwater Management Plan.	
State	Coastal General Permits[13]	General permits are issued to authorize certain minor activities. Because the environmental impacts of those activities are understood, detailed permit reviews are generally not required. There are three kinds of coastal general permits: Minor Coastal Structures, Coastal Maintenance, and Coastal Storm Response. The following structures and activities may be eligible for authorization through a general permit: • Small residential docks having no navigational or environmental impacts • Boat moorings • Osprey nesting platforms and perch poles • Residential flood hazard mitigation • Buoys and markers for navigation and certain recreational activities • Swim floats • Pump-out facilities at marinas • Coastal remedial activities May require a Stormwater Management Plan.	State and Permittee
State	Coastal Certificate of Permissions	The DEEP's Land and Water Resources Division (LWRD) regulates all activities conducted in tidal wetlands and in tidal, coastal, or navigable waters in Connecticut under the Structures, Dredging and Fill statutes, Connecticut General Statutes (CGS) Sections 22a-359 - 22a-363h,	State and Permittee

Federal/ State/ Local	Program	Program Overview	End User
		inclusive, and the Tidal Wetlands statutes, CGS Sections 22a-28 - 22a-35, inclusive. The major objectives of the permit program are to avoid or minimize navigational conflicts, encroachments into the state's public trust area, and adverse impacts on coastal resources and uses, consistent with Connecticut's Coastal Management Act (CCMA), CGS Sections 22a-90 - 22a-112, inclusive. Minor activities related to previously authorized work may be eligible for a Certificate of Permission (COP). These activities include maintenance dredging and substantial maintenance of existing structures. In some cases, maintenance of unauthorized activities that were completed prior to specific dates may also be eligible for a COP. In addition, certain environmentally beneficial activities, such as the removal of derelict structures and restoration of degraded tidal wetlands, may be approved through the COP process. COPs are issued within 45 days, or within 90 days if additional information is requested by LWRD to complete its review. COP applications can be completed and submitted through our on-line portal, ezFile. May require a Stormwater Management Plan.	
State	Flood Control Management Certification	Any state agency proposing an activity within or affecting a floodplain or that impacts natural or man-made storm drainage facilities must submit a flood management certification. Such activities include, without limitation: a) any structure, obstruction or encroachment proposed for emplacement within the floodplain area; b) any proposal for site development	State

Federal/ State/ Local	Program	Program Overview	End User
		which increases peak runoff rates; c) any grant or loan which affects land use, land use planning or the disposal of state properties in floodplains; or d) any program regulating flood flows within the floodplain. (For more information see: Sections 25-68h-1 through 25-68h-3 of the Regulations of Connecticut State Agencies (RCSA))	
State	Section 401 Water Quality Certification	Under Section 401 of the CWA, States must administer and regulate any applicant for a federal license or permit who seeks to conduct an activity that may result in any discharge into the navigable waters, including all wetlands, watercourses, and natural and man-made ponds. Such persons must obtain certification from DEEP that the discharge is consistent with the federal Clean Water Act and the Connecticut Water Quality Standards. Any conditions contained in a water quality certification become conditions of the federal permit or license. In making a decision on a request for 401 Water Quality Certification, DEEP must consider the effects of proposed discharges on ground and surface water quality and existing and designated uses of waters of the state.	State, Army Corp of Engineers and Permittees
State	Water Diversion Permits	The Water Diversion Program regulates activities that cause, allow or result in the withdrawal from, or the alteration, modification or diminution of, the instantaneous flow of the waters of the state through individual and general permits. The Water Diversion Policy Act is codified in Section 22a-365 through 22a-379 of the Connecticut General Statutes as well as Sections 22a-372-1, 22a-377(b)-1 and 22a-377(c)-1	State and Permittees

Federal/ State/ Local	Program	Program Overview	End User
		to 22a-377(c)-2 of the Regulations of Connecticut State Agencies. You must apply for a permit if, among other things, you propose to: • withdraw groundwater or surface water in excess of 50,000 gallons of per day; • collect and discharge runoff, including storm water drainage, from a watershed area greater than 100 acres; • transfer water from one public water supply distribution system or service area to another where the combined maximum withdrawal from any source supplying interconnection exceeds fifty thousand (50,000) gallons during any twenty-four hour period; • expand a registered public water supply service beyond a service area as identified (1) within registration documents, (2) in a water supply plan submitted prior to October 1, 2016, or (3) beyond an exclusive service area identified on the Department of Public Health's 2016 Public Water Supply Management Area maps; • relocate, retain, detain, bypass, channelize, pipe, culvert, ditch, drain, fill, excavate, dredge, dam, impound, dike, or enlarge waters of the state with a contributing watershed area greater than 100 acres; • transfer water from one water supply distribution system to another in excess of 50,000 gallons per day; • or modify a registered diversion.	

Federal/ State/ Local	Program	Program Overview	End User
State	Dam Safety Program	The mission of the DEEP Dam Safety Regulatory Program is to ensure the safety of dams to protect life, property, and the environment by ensuring that all dams are designed, constructed, operated, and maintained safely and effectively. Dam Safety Statutes & Regulations. The Dam Safety Statutes were last substantially revised by Public Act 2013-197, which authorized changes regarding Emergency Action Plans (EAPs) and inspection requirements: • Dam owners in the State of Connecticut are now responsible for hiring a consultant to conduct regular dam inspections. • The owners of high hazard (Class C) and significant hazard (Class B) dams must file an EAP every two years. The Dam safety program manages two kinds of permits individual permits and general permits for releases, construction, repairs or other modifications to dams (including stormwater impoundments). This program also requires a 401 certification and thereby, stormwater impacts may need to be considered.	State, Dam Owners and Permittees
State	Standards for Public Drinking Water	Regulations of Connecticut State Agencies 19-13-B102 provide the authority and requirements for the protection of public drinking water. This includes the protection of sources from stormwater, the delineation of protected areas, and when necessary treatment of water supplies when contaminated from stormwater events.	State (DPH)

Federal/ State/ Local	Program	Program Overview	End User
State	Connecticut Nonpoint Source Program	As noted above the federal Clean Water Act §319 establishes a national program to control nonpoint sources (NPS) of water pollution. The U.S. Environmental Protection Agency defines NPS pollution as that which is "caused by diffuse sources that are not regulated as point sources and are normally associated with precipitation and runoff from the land or percolation." To help address NPS pollution, §319(h) authorizes the EPA to award grants to states and tribes with EPA-approved NPS management programs.	State and Grantees
State and Local	Aquifer Protection Area Program	Connecticut's Aquifer Protection Area Program protects major public water supply wells in sand and gravel aquifers to ensure a plentiful supply of public drinking water for present and future generations. Aquifer Protection Areas (sometimes referred to as "wellhead protection areas") are being designated around the state's 127 active well fields in 80 Towns in sand and gravel aquifers that serve more than 1000 people. Land use regulations will be established in those areas to minimize the potential for contamination of the well field. The regulations restrict development of certain new land use activities that use, store, handle or dispose of hazardous materials and requires existing regulated land uses to register and follow best management practices. The Aquifer Protection Area Program responsibilities are shared by the state DEEP, the municipalities and the water companies.	State and Municipalities

Federal/ State/ Local	Program	Program Overview	End User
		The municipal aquifer protection manual includes consideration of stormwater management plans.	
Local	Inland Wetlands and Watercourse Act	The Act creates a land-use regulatory process which considers the environmental impacts of proposed development activities. A person proposing to conduct an activity that will likely impact or affect an inland wetland or watercourse must first obtain a permit from the municipal inland wetlands agency. In the case of a state agency activity, or when an activity is conducted on state land, a permit is required from the Department of Energy and Environmental Protection (DEEP). Assisted by the State, Connecticut's 169 municipalities apply and enforce the law through a local Wetlands Agency.	State, Local and Permittees
Local	Municipal Zoning and Planning	Post construction stormwater controls must be considered for many projects to be approved by the local municipal zoning and planning commissions. Considerations for impacts on receiving waters are an important element of the commissions' reviews.	Local

Appendix B – Structural Stormwater BMP Maintenance Inspection Checklist

Included in this Appendix:

- Standard checklist that can be used during maintenance inspections of most types of structural stormwater Best Management Practices (BMPs). Not all system components will be applicable to every BMP. For proprietary stormwater BMPs, use inspection checklists provided by the system manufacturer.
- An additional blank page is provided for non-standard system components not shown on the standard inspection checklist.
- Complete a separate inspection checklist for each stormwater BMP at a given site and provide a site plan or sketch showing the locations of each stormwater BMP.
- Additional inspection and maintenance resources.

INSPECTION CHECKLIST

DATE/ TIME: ______________________

INSPECTOR: ______________________

TYPE OF BMP: ____

WEATHER DURING INSPECTION: ____________________________

____

LOCATION: ____

TYPE OF INSPECTION (check if applicable):

Storm Event ☐ Complaint Response ☐ Routine ☐

AS IS BUILT PLANS AVAILABLE: Yes ☐ No ☐

PRECIPITATION AMOUNT IN 24 HR PRIOR TO INSPECTION: _______

INLET	APPLICABLE: Yes ☐ No ☐
Circle or note applicable element(s): level spreader, inlet curb cut opening, inlet structure, piped flow entrance, flow diversion structure _________________________	Guidance on what to look for: -Accumulated debris/ sediment at the inlet and within the structure (if applicable) -Structural damage or erosion
CONDITION: Satisfactory ☐	Unsatisfactory ☐

RECOMMENDED MAINTANENCE

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DATE FOR FOLLOW UP

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PRETREATMENT

APPLICABLE: Yes ☐ No ☐

Circle or note applicable element(s):
sediment forebay, pretreatment vegetated filter strip, deep sump pump catch basin, oil grit separator, proprietary treatment device

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Guidance on what to look for:
-Accumulated debris/ sediment
-Structural damage or erosion

CONDITION: Satisfactory ☐ Unsatisfactory ☐

RECOMMENDED MAINTANENCE

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DATE FOR FOLLOW UP

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BASIN CELL

APPLICABLE: Yes ☐ No ☐

Circle or note applicable element(s):
infiltration trench, infiltration basin, bioretention, sand filter, subsurface gravel wetland

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Guidance on what to look for:
-Accumulated debris
-Damage (e.g. erosion/ animal burrowing)
-Overgrown/ dead vegetation
-Standing water
-Condition of wetland vegetation

CONDITION: Satisfactory ☐ Unsatisfactory ☐

RECOMMENDED MAINTANENCE

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DATE FOR FOLLOW UP

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FILTER BED

APPLICABLE: Yes ☐ No ☐

Circle or note applicable element(s):
bioretention, sand filter, tree filter, dry water quality swale, permeable pavement

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Guidance on what to look for:
- Accumulated debris/ sediment
-Overgrown/ dead vegetation and weeds
-Standing water above filter bed
-Erosion/ rutting in upgradient areas
-Cracks or damage to permeable pavement

CONDITION: Satisfactory ☐ Unsatisfactory ☐

RECOMMENDED MAINTANENCE

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SUBSURFACE RESERVOIR/ OBSERVATION WELL

APPLICABLE: Yes ☐ No ☐

Circle or note applicable element(s):
infiltration trench, underground infiltration system, dry well, bioretention, tree filter, dry water quality swale, subsurface gravel wetland*

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Guidance on what to look for:
-Standing water in the

*if underdrain present

CONDITION: Satisfactory ☐ Unsatisfactory ☐

RECOMMENDED MAINTANENCE

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DATE FOR FOLLOW UP

Berm/ Weir

APPLICABLE: Yes ☐ No ☐

Circle or note applicable element(s):
stormwater ponds, stormwater wetlands including subsurface gravel wetland, water quality swales

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Guidance on what to look for:
-Debris sediment buildup
-Damage (e.g. erosion, cracks, spalling, seepage/ weeps, failure, animal burrows)

CONDITION: Satisfactory ☐ Unsatisfactory ☐

RECOMMENDED MAINTANENCE

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DATE FOR FOLLOW UP

Outlet

APPLICABLE: Yes ☐ No ☐

Circle or note applicable element(s):
outlet curb cut openings, raised overflow structures or risers, outflow weirs, outlet pipes/ culverts, stone riprap apron, stone riprap stilling basin or plunge pool

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Guidance on what to look for:
-Accumulated debris/ sediment at the outlet and within the structure (if applicable)
-Structural damage or erosion

CONDITION: Satisfactory ☐ Unsatisfactory ☐

RECOMMENDED MAINTANENCE

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DATE FOR FOLLOW UP

Maintenance Access APPLICABLE: Yes ☐ No ☐

All BMPs are appliable
Guidance on what to look for:
-Access to pretreatment and all parts of BMP that require routine maintenance or sediment removal
-Structural damage or erosion access road
-Overgrown/ dead vegetation preventing or impeding access by maintenance personnel or equipment

CONDITION: Satisfactory ☐ Unsatisfactory ☐

RECOMMENDED MAINTANENCE

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DATE FOR FOLLOW UP

Other:____

Note applicable element(s):
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CONDITION: Satisfactory ☐ Unsatisfactory ☐

RECOMMENDED MAINTANENCE

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DATE FOR FOLLOW UP

Inspection and Maintenance Resources

Bioretention

https://stormwater.pca.state.mn.us/index.php?title=Operation_and_maintenance_of_bioretention_and_other_stormwater_infiltration_practices

https://www.epa.gov/sites/default/files/2016-11/documents/final_gi_maintenance_508.pdf

Detention Basin

https://s3.amazonaws.com/bethtwpassets/Bethelehem+SWM+Guideline.pdf

http://water.rutgers.edu/Projects/GreenInfrastructureChampions/Talks_2020/8_Handouts/8_DetentionBasinMaintenanceGuidelines.pdf

Dry Well

https://www.cbf.org/document-library/presentation-webinar-materials/CBF_Dry_Well_011614.pdf

https://www.youtube.com/watch?v=bflb0R-cYfs

Grass Swale

https://www.aacounty.org/departments/public-works/wprp/bmp_maintenance/Archive/Grass%20Swale%20Maintenance-2.pdf

https://stormwater.pca.state.mn.us/index.php?title=Operation_and_maintenance_of_dry_swale_(grass_swale)

https://www.cbf.org/document-library/cbf-guides-fact-sheets/CBF_Vegetated-Swale_01161476fc.pdf

https://www.epa.gov/sites/default/files/2016-11/documents/final_gi_maintenance_508.pdf

Infiltration Trench

https://www.cbf.org/document-library/presentation-webinar-materials/CBF_Infiltration_Trench_011614.pdf

https://stormwater.pca.state.mn.us/index.php?title=Operation_and_maintenance_of_Infiltration_trench&redirect=no

Permeable Pavement

https://askhrgreen.org/wp-content/uploads/2015/04/PermeablePavement.pdf

https://www.montgomerycountymd.gov/DEP/Resources/Files/PostersPamphlets/Porous-Pavement-Maintenance.pdf

https//stormwater.pca.state.mn.us/index.php/Operation_and_maintenance_of_permeable_pavement

https://www.perviouspavement.org/downloads/pervious_maintenance_operations_guide.pdf

https://www.cbf.org/document-library/cbf-guides-fact-sheets/CBF_Pervious-Pavement_0116142c76.pdf

Rain Barrel

https://montgomerycountymd.gov/DEP/Resources/Files/PostersPamphlets/Rain-Barrels.pdf

https://www.cbf.org/document-library/cbf-guides-fact-sheets/CBF_Rainbarrels_011614e420.pdf

Sand Filter

https://stormwater.pca.state.mn.us/index.php/Operation_and_maintenance_of_filtration

Stormwater Pond

https://www.cbf.org/document-library/cbf-guides-fact-sheets/CBF_Pervious-Pavement_0116142c76.pdf

Stormwater Wetland

https://stormwater.pca.state.mn.us/index.php?title=Operation_and_maintenance_(O%26M)_of_stormwater_treatment_wetland_practices

https://www.cbf.org/document-library/cbf-guides-fact-sheets/CBF_Pervious-Pavement_0116142c76.pdf

https://www.fayettevillenc.gov/home/showdocument?id=8085

Tree Box Filter/Tree Trench

https://stormwater.pca.state.mn.us/index.php?title=Operation_and_maintenance_(O%26M)_of_tree_trenches_and_tree_boxes

https://megamanual.geosyntec.com/npsmanual/treeboxfilters.aspx

https://archives.lib.state.ma.us/bitstream/handle/2452/803682/on1103924280-task_3_deliverables.pdf?sequence=5&isAllowed=y

https://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/UNHSC%20Biofilter%20Maintenance%20Guidance%20and%20Checklist%201-11_0.pdf

Appendix C – BMP Performance Curves and Static Storage Volume Calculation Methods

Sources of EPA Region 1 Stormwater BMP Performance Curves

The BMP Performance Curves are included in a variety of MS4 Stormwater General Permits and tools developed by EPA Region 1 and/or state agencies in New England.

- New England Stormwater Retrofit Manual
- EPA MS4 General Permit for Massachusetts (Appendix F, Attachment 3)
- EPA MS4 General Permit for New Hampshire (Appendix F, Attachment 3)
- EPA Best Management Practice Accounting and Tracking Tool (BATT)
- Rhode Island Department of Transportation (RIDOT) Stormwater Control Plan Calculator
- University of New Hampshire Stormwater Center BMP Performance Fact Sheets
- EPA BMP Performance Curves for Fecal Indicator Bacteria
- EPA Technical Information for Use and Application of Performance Curves for Indicator Bacteria

BMP Performance Curve Category[1]	Stormwater BMP Type Connecticut Stormwater Quality Manual	Static Storage Volume Equation[2]
Infiltration Trench	**Infiltration Trench** Static Storage Volume = ponding water storage volume and void space volume of stone	$V = (A * D_{ponding}) + (L * W * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) A = average area between maximum ponding depth and the trench surface (square feet) $D_{ponding}$ = maximum ponding depth (feet) L = length (feet) W = width (feet) D_{stone} = depth of stone (feet) n_{stone} = porosity of stone (use default value of 0.4). Other porosity values may be used as determined from testing of the proposed materials.
	Dry Well **Infiltrating Catch Basin** **Underground Infiltration System (Chambers)** Static Storage Volume = water storage volume of storage structures and void space volume of stone underlying and surrounding the storage structures	• Static storage volume equations vary based on type of system. • Refer to manufacturer's design guidance for calculating static storage volume for manufactured infiltration chambers and similar subsurface storage units. • When calculating the stone storage capacity, subtract the storage volume of the chambers from the calculated storage volume of the stone layer before multiplying by stone porosity.
	Permeable Pavement (no underdrain) Static Storage Volume = void space volume of choker course (stone), filter course (sand), and stone reservoir	$V = L * W * (D_{stone} * n_{stone} + D_{sand} * n_{sand})$ V = static storage volume (cubic feet) L = length (feet) W = width (feet) D_{stone} = depth of stone courses (feet) D_{sand} = depth of sand filter course (feet) n_{stone} = porosity of stone courses (use default value of 0.4) n_{sand} = porosity of sand filter course (use default value of 0.3)

BMP Performance Curve Category[1]	Stormwater BMP Type Connecticut Stormwater Quality Manual	Static Storage Volume Equation[2]
Infiltration Trench (continued)	**Tree Filter (no underdrain)** Static Storage Volume = ponding water storage volume and void space volume of soil filter media and gravel/stone layers (pea gravel and stone reservoir) if stone reservoir is used. If stone reservoir is not included, exclude pea gravel and stone from the static storage volume calculation.	The following equation for bioretention systems may be used. Refer to manufacturer's design guidance for manufactured tree filters for additional guidance. $V = (L * W * D_{ponding}) + (L * W * D_{soil} * n_{soil}) + (L * W * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) L = length of bioretention system (feet) W = average width of bioretention system between maximum ponding depth and the bottom of the system (feet) $D_{ponding}$ = maximum ponding depth (feet) D_{soil} = depth of bioretention soil layer (feet) D_{stone} = depth of underdrain gravel and/or stone reservoir layer(s) between bottom of the bioretention soil layer and native soil (feet) n_{soil} = porosity of bioretention soil (use default value of 0.3) n_{stone} = porosity of gravel/stone (use default value of 0.4)
Infiltration Basin	**Infiltration Basin** Static Storage Volume = ponding water storage volume	$V = A * D_{ponding}$ V = static storage volume (cubic feet) A = average area between maximum ponding depth and the basin bottom (square feet) $D_{ponding}$ = maximum ponding depth (feet)

BMP Performance Curve Category[1]	Stormwater BMP Type Connecticut Stormwater Quality Manual	Static Storage Volume Equation[2]
Infiltration Basin (continued)	**Dry Water Quality Swale (no underdrain)** Static Storage Volume = water storage volume of swale and void space volume of soil filter media and gravel/stone layers (pea gravel and stone reservoir) if stone reservoir is used. If stone reservoir is not included, exclude pea gravel and stone from the static storage volume calculation.	$V = (L * W * D_{ponding}) + (L * W * D_{soil} * n_{soil}) + (L * W * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) L = length of swale (feet) W = average width of swale between maximum ponding depth and the bottom of the swale (feet) $D_{ponding}$ = maximum ponding depth (feet) D_{soil} = depth of bioretention soil layer (feet) D_{stone} = depth of underdrain stone/gravel layer (feet) n_{soil} = porosity of bioretention soil (use default value of 0.3) n_{stone} = porosity of gravel/stone (use default value of 0.4)
	Bioretention (no underdrain) Static Storage Volume = ponding water storage volume and void space volume of soil filter media and gravel/stone layers (pea gravel and stone reservoir) if stone reservoir is used. If stone reservoir is not included, exclude pea gravel and stone from the static storage volume calculation.	$V = (L * W * D_{ponding}) + (L * W * D_{soil} * n_{soil}) + (L * W * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) L = length of bioretention system (feet) W = average width of bioretention system between maximum ponding depth and the bottom of the system (feet) $D_{ponding}$ = maximum ponding depth (feet) D_{soil} = depth of bioretention soil layer (feet) D_{stone} = depth of underdrain gravel and/or stone reservoir layer(s) between bottom of the bioretention soil layer and native soil (feet) n_{soil} = porosity of bioretention soil (use default value of 0.3) n_{stone} = porosity of gravel/stone (use default value of 0.4)

BMP Performance Curve Category[1]	Stormwater BMP Type Connecticut Stormwater Quality Manual	Static Storage Volume Equation[2]
Biofiltration	**Bioretention (with underdrain)** **Tree Filter (with underdrain)** Static Storage Volume = Ponding water storage volume and void space volume of soil filter media and stone/gravel layers (pea gravel and stone reservoir)	$V = (L * W * D_{ponding}) + (L * W * D_{soil} * n_{soil}) + (L * W * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) L = length of bioretention system (feet) W = average width of bioretention system between maximum ponding depth and the bottom of the system (feet) $D_{ponding}$ = maximum ponding depth (feet) D_{soil} = depth of bioretention soil layer (feet) D_{stone} = depth of underdrain gravel and/or stone reservoir layer(s) between bottom of the bioretention soil layer and native soil (feet) n_{soil} = porosity of bioretention soil (use default value of 0.3) n_{stone} = porosity of gravel/stone (use default value of 0.4) The above equation for bioretention systems may be used for tree filters. Refer to manufacturer's design guidance for manufactured tree filters for additional guidance.
	Surface Sand Filter (with underdrain) Static Storage Volume = ponding volume and void space volume of sand and gravel/stone layers	$V = (A * D_{ponding}) + (A_{bed} * D_{sand} * n_{sand}) + (A_{bed} * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) A = average area between maximum ponding depth and the filter bed surface (square feet) A_{bed} = surface area of filter bed (square feet) $D_{ponding}$ = maximum ponding depth above filter bed (feet) D_{sand} = depth of sand layer (feet) D_{stone} = depth of underdrain stone layer (feet) n_{sand} = porosity of sand (use default value of 0.3) n_{stone} = porosity of stone (use default value of 0.4)

BMP Performance Curve Category[1]	Stormwater BMP Type Connecticut Stormwater Quality Manual	Static Storage Volume Equation[2]
Biofiltration (continued)	**Dry Water Quality Swale (with underdrain)** Static Storage Volume = Water storage volume of swale and void space volume of soil filter media and gravel/stone layers (pea gravel and stone reservoir)	$V = (L * W * D_{ponding}) + (L * W * D_{soil} * n_{soil}) + (L * W * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) L = length of swale (feet) W = average width of swale between maximum ponding depth and the bottom of the swale (feet) $D_{ponding}$ = maximum ponding depth (feet) D_{soil} = depth of bioretention soil layer (feet) D_{stone} = depth of underdrain stone/gravel layer (feet) n_{soil} = porosity of bioretention soil (use default value of 0.3) n_{stone} = porosity of gravel/stone (use default value of 0.4)
Gravel Wetland	**Subsurface Gravel Wetland** **Shallow Wetland** Static Storage Volume = pretreatment volume plus volume of ponding and volume of void space in subsurface gravel/stone bed	$V = (A_{pretreatment} * D_{pretreatment}) + (A_{wetland} * D_{ponding}) + (A_{ISR} * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) $A_{pretreatment}$ = pretreatment surface area (square feet) $A_{wetland}$ = surface area of wetland (square feet) $A_{Internal\ Storage\ Reservoir}$ = surface area of internal storage reservoir (square feet) $D_{pretreatment}$ = maximum ponding depth in pretreatment area (feet) $D_{ponding}$ = maximum ponding depth above wetland floor (feet) D_{stone} = depth of gravel/stone bed (feet) n_{stone} = porosity of gravel/stone (use default value of 0.4)

BMP Performance Curve Category[1]	Stormwater BMP Type Connecticut Stormwater Quality Manual	Static Storage Volume Equation[2]
Porous Pavement	**Permeable Pavement (with underdrain)** Static Storage Volume = void space volume of choker course (stone), filter course (sand), and stone reservoir	$V = L * W * (D_{stone} * n_{stone} + D_{sand} * n_{sand})$ V = static storage volume (cubic feet) L = length (feet) W = width (feet) D_{stone} = depth of stone courses (feet) D_{sand} = depth of sand filter course (feet) n_{stone} = porosity of stone courses (use default value of 0.4) n_{sand} = porosity of sand filter course (use default value of 0.3)
Wet Pond	**Wet Pond** **Micropool Extended Detention Pond** **Wet Extended Detention Pond** **Multiple Pond System** **Wet Water Quality Swale** Static Storage Volume = permanent pool volume prior to high flow bypass (excludes pretreatment volume)	$V = A_{pond} * D_{pond}$ V = static storage volume (cubic feet) A = average area between maximum ponding depth and bottom of pond (square feet) $D_{ponding}$ = maximum ponding depth (feet) Static storage volume can also be calculated based on microtopography (proposed contours) and the elevation of the high flow bypass or overflow.
Dry Pond	**Dry Extended Detention Basin** **Extended Detention Shallow Wetland** **Pond/Wetland System** Static Storage Volume = ponding volume prior to high flow bypass (excludes pretreatment volume)	$V = A_{pond} * D_{pond}$ V = static storage volume (cubic feet) A = average area between maximum ponding depth and bottom of pond (square feet) $D_{ponding}$ = maximum ponding depth (feet) Static storage volume can also be calculated based on microtopography (proposed contours) and the elevation of the high flow bypass or overflow.

BMP Performance Curve Category[1]	Stormwater BMP Type Connecticut Stormwater Quality Manual	Static Storage Volume Equation[2]
Impervious Cover Disconnection	**Impervious Area Disconnection** **Vegetated Filter Strip** **Vegetated Buffer** **Qualifying Pervious Area (QPA)**	Use of BMP performance curves is based on the ratio of impervious area to pervious area instead of static storage volume.

[1] BMP categories and nomenclature used with EPA Region 1 BMP Performance Curves and EPA Region 1 MS4 Stormwater General Permits.

[2] Static Storage Volume is also commonly referred to as "Design Storage Volume (DSV)" in the context of the EPA Region 1 BMP Performance Curves and EPA Region 1 MS4 Stormwater General Permits. Other porosity values may be used for subsurface aggregate layers (bioretention soil, sand, pea gravel, stone, etc.) in lieu of those recommended in the table above as determined from testing of the proposed materials.

Appendix D – Water Quality Flow Calculation Method

The Water Quality Flow (WQF) is the peak rate of discharge associated with the water quality storm or Water Quality Volume (WQV). This section describes the recommended method for calculating the WQF when designing flow diversion structures for off-line stormwater Best Management Practices (BMPs). The WQF is also used for the design of stormwater BMPs that are sized based on flow rate rather than volume, including grass channels and proprietary stormwater BMPs such as hydrodynamic separators, catch basins inserts, and media filters.

The WQF should be calculated using the design WQV and a modified Runoff Curve Number for small storm events. This method is used to estimate peak discharges for small storm events based on the approach described in Claytor and Schueler (1996).[94] This method is more appropriate than: 1) the traditional Natural Resources Conservation Service (NRCS) Curve Number methods, which are valuable for estimating peak discharge rates for storms greater than 2 inches but can significantly underestimate runoff from small storm events, and 2) the Rational Formula, which should only be used with reliable intensity, duration, and frequency (IDF) tables or curves for the storm and region of interest (Claytor and Schueler, 1996).

The design WQV (either 100% or 50% of the WQV depending on the applicable retention/treatment requirement, as described in Chapter 4), converted to watershed inches, should be substituted for the runoff depth (Q) in the NRCS TR-55 Graphical Peak Discharge Method.

1. Compute the NRCS Runoff Curve Number (CN) using the following equation, or graphically using Figure 2-1 from TR-55 (USDA, 1986)[95] (see Figure 1 below):

$$CN = \frac{1000}{\left[10 + 5P + 10Q - 10 * (Q^2 + 1.25 * Q * P)^{1/2}\right]}$$

where:

CN = Runoff Curve Number

[94] Claytor, R. and T. Schueler. 1996. Design of Stormwater Filtering Systems. Center for Watershed Protection. Ellicott City, MD.

[95] Soil Conservation Service. 1986. Urban Hydrology for Small Watersheds. USDA Soil Conservation Service Technical Release No. 55. Washington, D.C.

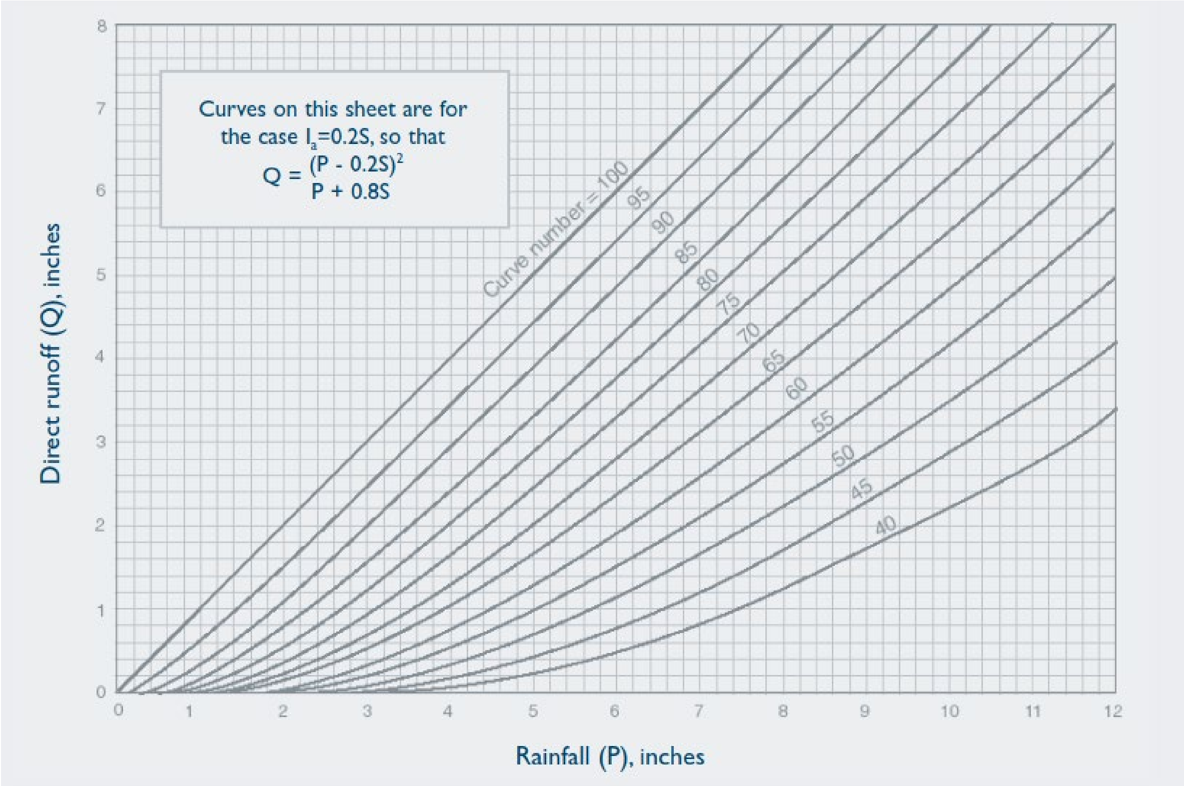
P = Design precipitation, inches (1.3 inches[96] for 100% of the WQV and 0.65 inches for 50% of the WQV)
Q = Runoff depth (in watershed inches)

$$Q = \frac{WQV\ (cubic\ feet)}{Drainage\ Area\ (acres)} * \frac{12\ inches}{foot} * \frac{acre}{43{,}560\ square\ feet}$$

where:

WQV = design Water Quality Volume (100% or 50% of the WQV)

Figure 1. Graphical Solution of Runoff Equation



Source: Figure 2-1 from TR55 (USDA, 1986).

Once the modified CN is calculated, either follow Steps 2 and 3 below or use a stormwater hydrologic/hydraulic model (e.g., HydroCAD or similar software) to calculate peak discharge (WQF). **This modified CN must be used when using a stormwater hydrologic/hydraulic model or analysis method to calculate the WQF.**

[96] Per NOAA Atlas 14, Upon the release of the next generations of this product the most recent value should be used.

2. Compute the time of concentration (t_c) based on the methods described in Chapter 3 of TR-55. A minimum value of 0.167 hours (10 minutes) should be used. For sheet flow, the flow path should not be longer than 100 feet.

3. Using the computed *CN*, t_c, and drainage area (*A*) in acres, compute the peak discharge for the design water quality storm (i.e., WQF) as follows, which is based on the procedures described in Chapter 4 of TR-55:

   - Read initial abstraction (I_a) from Table 4-1 in Chapter 4 of TR-55 (see Figure 2 below); compute I_a/P (P = 1.3 inches for 100% of the WQV and 0.65 inches for 50% of the WQV).

Figure 2. Initial Abstraction (I_a) Values for Runoff Curve Numbers

Curve number	I_a (in)	Curve number	I_a (in)	Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	55	1.636	70	0.857	85	0.353
41	2.878	56	1.571	71	0.817	86	0.326
42	2.762	57	1.509	72	0.778	87	0.299
43	2.651	58	1.448	73	0.740	88	0.273
44	2.545	59	1.390	74	0.703	89	0.247
45	2.444	60	1.333	75	0.667	90	0.222
46	2.348	61	1.279	76	0.632	91	0.198
47	2.255	62	1.226	77	0.597	92	0.174
48	2.167	63	1.175	78	0.564	93	0.151
49	2.082	64	1.125	79	0.532	94	0.128
50	2.000	65	1.077	80	0.500	95	0.105
51	1.922	66	1.030	81	0.469	96	0.083
52	1.846	67	0.985	82	0.439	97	0.062
53	1.774	68	0.941	83	0.410	98	0.041
54	1.704	69	0.899	84	0.381		

Source: Table 4-1 in Chapter 4 of TR-55 (USDA, 1986).

   - Read the unit peak discharge (q_u) from Exhibit 4-III in Chapter 4 of TR-55 (see Figure 3 below) for the appropriate t_c.

Note: NRCS has not developed unit peak discharge curves for the NOAA Atlas 14 rainfall distributions, including the NOAA_D rainfall distribution, which has replaced the NRCS Type III distribution for use in Connecticut for peak flow rate calculations (see Chapter 4 of this Manual). The NRCS Type III rainfall distribution may be used for calculating the WQF using the TR-55 Graphical Peak Discharge method. The NOAA_D rainfall distribution is slightly less intense than the NRCS Type III distribution, so the resulting peak discharge will be conservative. The NOAA_D rainfall distribution should be used for calculating peak flow rates associated with stormwater quantity control design storms (2-year, 10-year, and 100-year, 24-hour events) described in Chapter 4.

   - Substituting the design WQV, converted to watershed inches, for runoff depth (*Q*), compute the WQF from the following equation:

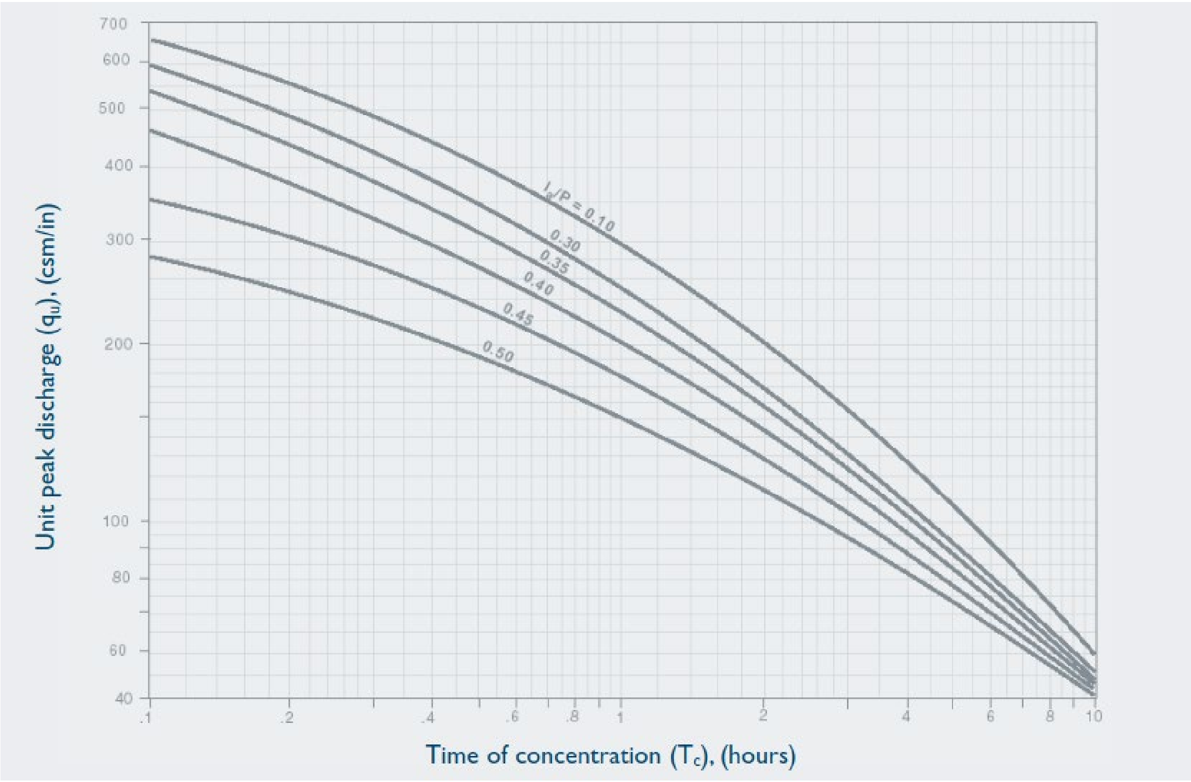
$$WQF = (q_u)(A)(Q)$$

where:

WQF = Water Quality Flow (cubic feet per second, cfs)
q_u = unit peak discharge (cfs, per square mile, per inch of runoff, csm/in)
A = drainage area (square miles)
Q = runoff depth (in watershed inches)

$$Q = \frac{WQV\ (cubic\ feet)}{Drainage\ Area\ (acres)} * \frac{12\ inches}{foot} * \frac{acre}{43{,}560\ square\ feet}$$

Figure 3. Unit Peak Discharge for NRCS Type III Rainfall Distribution



Source: Exhibit 4-III in Chapter 4 of TR-55 (USDA, 1986).

Appendix E – Stormwater Management Plan Checklist

Stormwater Management Plan Checklist

Title of Plan Reviewed: ____

Reviewer Name: ________________________ Review Date: ____________________

Completeness Summary

Section	Completed?	Notes
Report		
Summary of Compliance		
Design Calculations		
Design Drawings		
Soil Erosion & Sediment Control Plan		
Operations & Maintenance Plan		
Other Supporting Documents		

Detailed Checklist by Section

Report: General & Summary Information

Section		Completed?	Notes
General	Applicant Name		
	Applicant Address		
	Applicant Contact Information		
	Site Location Address/Information		
	Site Location Map		
	Current Use and Zoning of Property		
	Proposed Use of Project		
Summary	Project Description and Purpose		
	Project Schedule (Include phasing if applicable)		
	Applicable Permits and Approvals		
	Applicable Regulation Requirements		

Report: Existing Conditions

	Section	Completed?	Notes
Existing Conditions	Site area, ground cover, vegetation, existing development features (roads, buildings, utilities, septic systems, etc.)		
	Site topography (2-foot contours based on aerial or field survey), slopes, drainage patterns, drainage systems, drainage areas, and stormwater discharge locations		
	Existing impervious area and DCIA		
	On-site and adjacent waterbody information ➢ Water quality classifications Water quality impairments and Total Maximum Daily Loads		
	Site soils as identified by USDA NRCS mapping or soil scientist ➢ Soil types Hydrologic Soil Groups		
	Soil evaluation results ➢ Initial screening information ○ Test pits and soil borings results (i.e., USDA soil textural class, depth to bedrock, depth to seasonal high groundwater, and Significant subsurface or geologic features) Field infiltration (if applicable)		
	Other site constraints (i.e., site contamination)		
	On-site and off-site critical resources[97] ➢ Inland wetlands and watercourses, tidal wetlands, and associated regulatory setbacks ➢ Streams ➢ Lakes/ponds ➢ Vernal pools ➢ Coastal waters (Connecticut Coastal Jurisdiction Line) ➢ Coldwater streams ➢ Drinking water supply areas ➢ Tree canopy ➢ Steep slopes (≥25%) Conservation easement areas		
	Locations of 100-year floodplain, floodway, and flood elevations from current FEMA mapping		
	Land uses and development adjacent to the site		

[97] Watershed scale map with the site boundaries identified and these attributes identified is preferable.

Report: Proposed Conditions

	Section	Completed?	Notes
Proposed Conditions	Type of project or activity (new development, redevelopment, linear project, retrofit)		
	Proposed ground cover, vegetation, development features (roads, buildings, utilities, septic systems, etc.)		
	Proposed drainage area boundaries and design points		
	Proposed activities classified as Land Uses with Higher Potential Pollutant Loads (LUHPPLs)		
	Proposed impervious area and DCIA		
	Proposed area of land disturbance		
	Coastal Jurisdiction Line (CJL) for properties fronting coastal, tidal, or navigable waters		

Report: Applicable Stormwater Management Standards

	Section	Completed?	Notes
Stormwater Management Standard	Standard 1 – Runoff Volume and Pollutant Reduction ➢ LID Site Planning and Design ➢ Stormwater Retention and Treatment		
	Standard 2 – Stormwater Runoff Quantity Control ➢ Design Storm Rainfall Depth and Distribution ➢ Peak Runoff Attenuation ➢ Conveyance Protection ➢ Emergency Outlet Sizing		

Report: Proposed LID Site Planning

	Section	Completed?	Notes
Proposed LID Strategies	Avoided Impacts ➢ Minimizing Soil Compaction ➢ Minimizing Site Disturbance ➢ Protecting Sensitive Natural Areas ➢ Preserving Vegetated Buffers ➢ Avoiding Disturbance of Steep Slopes ➢ Siting on Permeable and Erodible Soils ➢ Protecting Natural Flow Pathways ➢ Conservation and Compact Development		
	Reduced Impacts ➢ Reducing Impervious Surfaces (Roads, Cul-de-sacs, Sidewalks, Driveways, Buildings, Parking Lots) ➢ Preserving Pre-development Time of Concentration ➢ Use of Low Maintenance Landscaping		
	Managed Impacts at the Source ➢ Disconnecting Impervious Surfaces - Impervious Area (Simple) Disconnection ➢ Conversion of Impervious Areas to Pervious Areas ➢ Source Controls		

Report: Proposed Structural Stormwater BMPs

	Section	Completed?	Notes
Proposed Stormwater BMPs	Description of proposed structural stormwater BMPs and why they were selected ➢ Location, size, types by drainage area/design point ➢ Design criteria		

Summary of Compliance: Standard 1

<table>
<tr><th colspan="2">Section</th><th>Completed ?</th><th>Notes</th></tr>
<tr><td rowspan="2">Standard 1 - Runoff Volume and Pollutant Reductions</td><td>LID Site Planning and Design
➢ LID Site Planning and Design Opportunities and Constraints Plan
➢ Completed LID Site Planning and Design Checklist
➢ Total LID Site Planning and Design credits and DCIA reduction</td><td></td><td></td></tr>
<tr><td>Stormwater Retention and Treatment
➢ Impervious area and Directly Connected Impervious Area (DCIA)
➢ Retention and Treatment Required
o Water Quality Volume and Water Quality Flow
o Required Retention Volume
➢ Retention and Treatment Provided including Maximum Extent Achievable Documentation
o Explanation of site limitations
o Description of the stormwater retention practices implemented
o Explanation of why this constitutes the Maximum Extent Achievable
o Alternate retention volume
o Description of measures used to provide additional stormwater treatment without retention
o Use of EPA stormwater BMP performance curves to demonstrate compliance with required average annual pollutant load reductions</td><td></td><td></td></tr>
</table>

Summary of Compliance: Standard 2

	Section	Completed?	Notes
Standard 2 - Stormwater Runoff Quantity Control	Design Storm Rainfall Depth and Distribution		
	Comparison of pre- and post-development ➢ Runoff volume and peak flow rate ○ 2-year, 10-year, and 100-year, 24-hour storms		
	Downstream Analysis: Comparison of pre- and post-development 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		
	Conveyance Protection		
	Emergency Outlet Sizing		

Design Calculations: Standard 1

	Section	Completed?	Notes
Standard 1 - Runoff Volume and Pollutant Reduction	LID Site Planning and Design Credit Calculations		
	Impervious Area and Directly Connected Impervious Area (DCIA)		
	Water Quality Volume, Water Quality Flow, and Required Retention Volume		
	Structural Stormwater BMP Sizing Calculations ➢ Static and dynamic sizing methods (infiltration systems) ➢ Drain time and groundwater mounding analysis (infiltration systems) ➢ Required versus provided design volumes Pollutant specific load reductions (BMP performance curves) where Standard 1 cannot be met by retention alone		

Design Calculations: Standard 2

	Section	Completed?	Notes
Standard 2 - Stormwater Runoff Quantity Control	Stormwater Runoff Calculations for Pre-Development and Post-Development (with and without stormwater BMPs) Conditions ➢ Design storm depth and duration, recurrence interval, and rainfall distribution ➢ Runoff volume and peak flow rate (2-year, 10-year, and 100-year, 24-hour storms) ➢ Runoff Curve Number ➢ Time of Concentration (and associated flow paths)		
	Routing analysis for proposed stormwater BMPs including drainage routing diagram		
	Conveyance protection (including flow velocity calculations and outlet protection sizing) and emergency outlet sizing calculations		
	Downstream analysis hydrograph routing calculations		
	Storm drain system conveyance calculations		

Design Drawings: Existing Conditions

Section		Completed?	Notes
Existing (Pre-Development) Conditions Plan	Location of existing man-made features on or adjacent to the site, such as roads, buildings, driveways, parking areas, other impervious surfaces, drainage systems, utilities, easements, septic systems, etc.		
	Surveyed locations of property boundaries and easements		
	Drainage systems and sanitary sewers should include rim and invert elevations of all structures and sizes and connectivity of all pipes		
	Vegetative communities on the site, including locations of tree canopy		
	Site topography (2-foot contours based on aerial or field survey), slopes, drainage patterns, conveyances systems (swales, storm drains, etc.), drainage area boundaries, flow paths, times of concentration		
	Locations of existing stormwater discharges		
	Areas of steep (25% or greater) slopes		
	Perennial and intermittent streams		
	Inland wetlands and watercourses (and associated regulatory setbacks) as defined by a soil scientist in the field and flags located by a licensed land surveyor		
	Locations of vernal pools		
	Locations of 100-year floodplain, floodway, and flood elevations from current FEMA mapping		
	Locations of soil types as identified by USDA NRCS mapping or soil scientist, test pit and soil boring locations, and field infiltration testing locations		
	Areas of site contamination		
	Location, size, type of existing structural stormwater BMPs and conveyance systems		
	Limits of developable area based on site development constraints		
	Coastal Jurisdiction Line (CJL) for properties fronting coastal, tidal, or navigable waters		

Design Drawings: Proposed Conditions

	Section	Completed?	Notes
Proposed (Post-Development) Conditions Plan	Location of proposed man-made features on or adjacent to the site such as roads, buildings, driveways, parking areas, other impervious surfaces, drainage systems, utilities, easements, septic systems, etc.		
	Surveyed locations of property boundaries and easements		
	Drainage systems and sanitary sewers should include rim and invert elevations of all structures and sizes and connectivity of all pipes		
	Vegetative communities on the site, including proposed limits of clearing and disturbance		
	Site topography (2-foot contours based on aerial or field survey), slopes, drainage patterns, conveyances systems (swales, storm drains, etc.), drainage area boundaries, flow paths, times of concentration		
	Locations of proposed stormwater discharges/design points		
	Perennial and intermittent streams		
	Inland wetlands and watercourses (and associated regulatory setbacks) as defined by a soil scientist in the field and flags located by a licensed land surveyor		
	Locations of vernal pools		
	Locations of 100-year floodplain, floodway, and flood elevations from current FEMA mapping		
	Locations and results of on-site soil evaluation (test pits/soil borings and field infiltration testing)		
	Areas of site contamination		
	Development envelope and areas of site preserved in natural condition		
	Location, size, type of proposed structural stormwater BMPs and conveyance systems. Structural BMPs should have rim, invert, and contour elevations and pipe sizes and construction material.		
	Locations of soil erosion and sedimentation controls		
	Locations of non-structural source controls		
	LID Site Planning and Design Opportunities and Constraints Plan		
	Structural Stormwater BMP Design Details and Notes		
	Coastal Jurisdiction Line (CJL) for properties fronting coastal, tidal, or navigable waters		

Other Plans

	Section	Completed?	Notes
Soil Erosion & Sediment Control Plan	See the Soil Erosion and Sediment Control Guidelines https://portal.ct.gov/DEEP/Water/Soil-Erosion-and-Sediment-Control-Guidelines/Guidelines-for-Soil-Erosion-and-Sediment-Control		
Operation & Maintenance Plan	Detailed inspection and maintenance requirements/tasks		
	Inspection and maintenance schedules		
	Parties legally responsible for maintenance (name, address, and telephone number)		
	Provisions for financing of operation and maintenance activities		
	As-built plans of completed structures		
	Letter of compliance from the designer		
	Post-construction documentation to demonstrate compliance with maintenance activities		
	Other considerations if needed		

Other Supporting Documents

Section		Completed?	Notes
Other Supporting Documents	Completed Stormwater Management Plan Checklist		
	LID Site Planning and Design Checklist (Chapter 5 – Low Impact Development Site Planning and Design Strategies)		
	NRCS Soils Mapping		
	Soil Evaluation Documentation (Test Pits/Soil Borings and Field Infiltration Testing Results)		
	DCIA Tracking Worksheet required by the reviewing authority to satisfy MS4 Permit requirements		
	Groundwater impacts for proposed infiltration structures		
	Reports on wetlands and other surface waters (including available information such as Maximum Contaminant Levels [MCLs], Total Maximum Daily Loads [TMDLs], 303(d) or 305(b) impaired waters listings, etc.)		
	Water quality impacts to receiving waters		
	Water quality impacts to receiving waters		
	Impacts on biological populations/ecological communities including fish, wildlife (vertebrates and invertebrates), and vegetation		
	Flood study/calculations		
	Other permits and approvals issued for the project		

Appendix F – Planting Guide

Summary

This appendix provides an overview of planting considerations for structural stormwater Best Management Practices (BMPs), with the goal of selecting plants that are well-suited for a specific design and site. This planting guide provides information on incorporating native plantings that are well-adapted to site conditions and plants that are most tolerant to site limitations. The guidance also includes several examples of planting pallets to meet aesthetic and functional goals.

Maintenance and Care Considerations

As with any element of a stormwater BMP, plantings require maintenance and care. This care can be simplified with careful consideration of planting needs. The following key concepts can help ensure success, reduce maintenance needs, and create an aesthetically pleasing stormwater BMP:

- **Planting schedule.** Newly established trees will be stressed when planting in high heat and low water conditions, while many perennials will be stressed by a late frost.
- **Planting methods.** There are some simple tricks of the trade to help plantings become more self-sufficient. For example, coercing some tree roots to grow deeper into soils by setting up a system for deep watering rather than surface watering.
- **Intercropping.** While the term intercropping primarily applies to large-scale agriculture, the principles can be applied to any garden or landscaping. Planting nitrogen fixers can reduce fertilization needs or improve poor soil, and planting ground covers can reduce erosion, weeding and watering needs, and more.
- **Planting Tolerance.** Each plant has an ability or limited ability to handle various chemicals, moisture, and temperature extremes. The simplest way to address this is to implement native plants well-conditioned to the site conditions.

Each of these concepts is described in greater detail in the sections below, including additional resources to find further information. In addition to being strategic with site design to minimize maintenance, there are also methods to make maintenance of plantings easier. The table below outlines routine maintenance needs and some considerations to make maintenance easier.

Maintenance Consideration	Frequency	Level of Expertise Required	Other Tips
Watering	Initial planting may need more frequent watering (i.e., weekly or every other week).	None	➢ Training roots to grow deep with underground watering can make your planting less dependent on your efforts. ➢ Mulching and setting drip lines beneath (avoiding top watering) can help reduce waste to evapotranspiration and make each watering more efficient. ➢ Timing planting during shoulder seasons where rain is more likely to occur can reduce watering needs. ➢ Companion planting with ground cover can help reduce evaporation much like mulching.
Weeding & Trash Removal	Trash removal is location dependent. Weeding typically will need to be monthly but can be strategically reduced see column to right.	Minimal knowledge of weeds versus desirable plantings.	➢ Some traditional weeds can be beneficial neighbors, consider allowing those that do provide benefits to your planting to sustain and only eliminate those that may be damaging to your site, such as an invasive like bittersweet. ➢ Mulching and ground cover can reduce the need to frequently weed and water
Fertilization	Annual	Some gardening knowledge. Fertilizer should only be used in quantities necessary for specific plantings.	➢ Timing with optimal weather conditions can limit run off and root burn. ➢ Companion planting can reduce fertilization needs, see the plant list below.
Structure Stabilization	Annual /Additional as needed per storm frequency	Some knowledge in landscape design (or engineering if design is complex)	➢ Cover crops can help stabilize sloping sides and reduce maintenance needs.
Soil Health	Project start and as needed (if needed).	Minimal knowledge needed if test is sent to a lab.[98]	

[98] Connecticut Agriculture Experiment Station offers free soil testing to Connecticut residents.

Safety Consideration

Before beginning construction of any kind, one must assure the safety of those involved in site construction as well as long-term maintenance of the site including stormwater management measures. Consider access for maintenance – what are the risks at the site and can they be mitigated? Consider what may lay below ground at the site. Anyone using power or mechanized equipment who disturbs the earth on or below the surface must call the clearinghouse for a location request. You must call for a locate request at least two full working days but not more than 30 days before any excavation starts excluding holidays & weekends). There are two ways to access this free service:

1. File an online e-ticket at https://www.cbyd.com/
2. Call 811

Planting Selection

When selecting plants, the primary considerations are the local environmental factors and the intended function of the site. When considering these factors, also account for the conditions that the proposed stormwater BMP will create as well as the natural landscape around the site. Below is a list of essentials and potential site considerations:

- **USDA Plant Hardiness Zone.** This is the standard by which landscapers, gardeners, and homeowners can determine which plants will survive at a given location.

- **Frequency of flooding,** whether creating an intentionally planted wet area like a stormwater pond/wetland or evaluating the natural tendency for the site to flood. Not all plants will tolerate flooding; as such, consider the flooding characteristics of the site in addition to the hydrologic conditions that are needed for a specific type of stormwater BMP.

- **Soil Health.** Soil health plays an important role in planting success. If at all possible, limiting the disturbance of the top organic layer is optimal. When this is not possible, there are many plants that can tolerate differing levels of soil quality.

- **Site stabilization.** Consider the effectiveness for the proposed plantings to provide site stabilization. Cover crops and plants with deeper root structure can often function and survive better than many other species.

- **Salinity.** Considering salt tolerance of plant species can mean the difference between a self-sustaining landscape and costly replantings in many sites near roads and sidewalks or coastal sites.

- **Pollutants of concern.** Many plant species are particularly adapted to filtration of particular pollutants and have even been utilized at contaminated sites for these qualities. Knowing the specific potential pollutants of a site will help select plants for optimal pollutant removal. EPA's Phytoremediation Guide provides a helpful consolidation of phytoremediation resources.

- **Sun Exposure.** Different plant species have differing needs for sunlight. Consider the sun exposure of the site and if the site is to include trees or shrubs that will introduce shading.

In addition to considering site environmental conditions, plant diversity is key to successful functioning and reduced maintenance. A monoculture is far more susceptible to disease and pests and can be more costly in the long run. Plant diversity can provide additional benefits by ensuring a healthier pollinator population, better site stabilization, and less maintenance and fertilization (see the section below on planting companions intercropping for further information). It is also important to avoid introducing invasive species and, where possible, restricting plant selection to native species to help retain diverse, productive landscaping.

As noted above, when developing planting plans choosing plants that can tolerate and thrive in similar or complementary conditions (i.e., shade tolerant plants that will survive beneath shade of tree, or sets of wet tolerant plants for sites like stormwater ponds/wetlands) is necessary for success of the design. There is a plethora of plant databases that provide detailed plant needs, planting instructions, and native status. This authors of this Manual have reviewed and recommend the following to obtain reliable up-to-date information:

- https://plants.usda.gov/
- https://plantdatabase.uconn.edu/
- https://can-plant.ca/ecommerce/woody-plants
- https://plants.ces.ncsu.edu/plants
- https://www.arborday.org/trees/treeguide
- https://www.fs.usda.gov/treesearch/
- https://www.conncoll.edu/the-arboretum/ecological-landscaping/
- https://wetland-plants.sec.usace.army.mil/nwpl_static/v34/home/home.html
- https://www.ct-botanical-society.org/gardening-with-natives/

The additional resources below provide further information for function-specific design and specific maintenance guidance.

- https://nemo.uconn.edu/raingardens/
- https://ct.audubon.org/conservation/plant-native-species
- https://portal.ct.gov/DEEP/Invasive-Species/Invasive-Species
- https://cipwg.uconn.edu/
- https://www.pollinator.org/guides
- https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5368392.pdf
- https://www.conncoll.edu/the-arboretum/ecological-landscaping/
- https://www.wildflower.org/plants/index.php
- https://www.pca.state.mn.us/sites/default/files/pfsd-section2.pdf
- http://www.newmoonnursery.com/plan

- https://cipwg.uconn.edu/wp-content/uploads/sites/244/2013/12/CTCoastal_planting.pdf

Intercropping & Planting Companions

As noted above, the term “intercropping” is typically used in the context of large-scale agriculture, but intercropping principles can be applied to any garden or functional landscaping including stormwater BMPs. “Planting companions” is a more popular term with landscaping and small scale-gardening and can be incredibly useful but can also lead to a variety of unconfirmed sources and information that may be too experimental for the purposes of users of this Manual. Therefore, the focus of this section highlights how intercropping can be beneficial to landscaping/gardening and for stormwater BMPs. As noted by Oliver Duchene et al.:

> *“Intercropping is a powerful way to promote a more diversified plant community in the field, thereby enabling complementary and facilitative relationships.”* [99]

Enabling the complementary and facilitative relationships can aid in reducing costs, maintenance needs, increase survivorship of plantings, increase biodiversity, and more. This co-beneficial partnership of plants, while a modern application to commercial farming and government guidance, is far from new knowledge that can be credited to First Nations all around the America’s but even right those right here in the Northeast.[100, 101] As such, these practices are not only beneficial financially and sustainably, but also culturally. Some of the key benefits of intercropping with regards to stormwater control are:

- **Attracting Pollinators.** Providing pollinator pathways through landscaping can be aesthetic and provide the additional support needed to assure success of pollinator populations. Even simple actions like allowing for dandelions, clovers and other species commonly found in New England Lawns can be beneficial for pollinators.[102, 103]

- **Deterring or Distracting Pests.** Introducing plants that are either attractive to pests to keep them from your preferred plants or plants that will naturally deter pests can be an

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[99] Duchene, Olivier, Vian, Jean-François, and Celette, Florian. legume for agroecological cropping systems: Complementarity and facilitation processes and the importance of soil microorganisms. A review. Agriculture, Ecosystem and Environment. 240,149-616 (2017) https://doi.org/10.1016/j.agee.2017.02.019

[100] Kimmerer,R.W. Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants. Milkweed Editions October 2013.

[101] Kimmerer, R. W Native Knowledge for Native Ecosystems. Journal of Forestry. 98(8):4-9 (2000)

[102] Gathof, A.K., Grossmann, A.J., Herrmann, J. *et al*. Who can pass the urban filter? A multi-taxon approach to disentangle pollinator trait–environmental relationships. *Oecologia* 199, 165–179 (2022). https://doi.org/10.1007/s00442-022-05174-z

[103] https://www.pollinator-pathway.org/about

effective and cost reducing approach. Common Yarrow is a good example, as it will attract insects that are predators to aphids[104, 105] and deter other pests such as mosquitoes.[106]

- **Reducing Watering Needs.** The physical structure of some plants' growing habits can be beneficial. Ground covers can reduce evapotranspiration and runoff and increase infiltration into the soil surrounding other plantings. By reducing the water loss, scheduled waterings can be significantly reduced if not even eliminated in many cases. Several studies have noted reduced water stress and even instances of negating the impacts of arid conditions when utilizing ground cover crops interplanted among the desired plantings.[107, 108, 109]

- **Reducing Fertilization Needs.** Nitrogen is necessary for plant growth but is often applied in such a way that is causes water quality problems. Including plants that are efficient nitrogen fixers can greatly reduce the need for synthetic or fossil-based fertilizer. One study found that this practice, if applied to the world's grain legumes, could reduce the global (for all uses) requirements for fossil-based fertilizers by 26%.[110] Many plants, grasses

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[104] Torsten Meiners, Elisabeth Obermaier, Hide and seek on two spatial scales – vegetation structure effects herbivore oviposition and egg parasitism, *Basic and Applied Ecology*, Volume 5, Issue 1, 2004, Pages 87-94, https://doi.org/10.1078/1439-1791-00182

[105] N. J. Bostanian ,H. Goulet,J. O'Hara,L. Masner &G. Racette Intercropping with Towards Insecticide Free Apple Orchards: Flowering Plants to Attract Beneficial Arthropods. *Bioscience Control and Technology*. Volume 14: Issue 1, 2003, Pages 25-37 https://doi.org/10.1080/09583150310001606570

[106] Jaenson TG, Pålsson K, Borg-Karlson AK. Evaluation of extracts and oils of mosquito (Diptera: Culicidae) repellent plants from Sweden and Guinea-Bissau. *J Med Entomol.*;43(1), Pages 113-9. 2003 https://doi.org/10.1093/jmedent/43.1.113

[107]Nelson, William C. D., Hoffmann, Munir P., Vadez, Vincent, Rötter, Reimund P., Koch, Marian and Whitbread, Anthony M. Can intercropping be an adaptation to drought? A model-based analysis for pearl millet–cowpea. *Journal of Agronomy and Crop Science.* 00, Pages 1-18, 2021 https://onlinelibrary.wiley.com/doi/epdf/10.1111/jac.12552

[108] Baker, Sophie, "Intercropping for Water Conservation: Environmental and Economic Implications of a Sustainable Farming Practice in California's Central Valley" (2020). Scripps Senior Theses. 1583. https://scholarship.claremont.edu/scripps_theses/1583

[109] Nyawade, S.O., Karanja, N.N., Gachene, C.K.K. *et al.* Intercropping Optimizes Soil Temperature and Increases Crop Water Productivity and Radiation Use Efficiency of Rainfed Potato. *Am. J. Potato Res.* 96, 457–471 (2019). https://doi.org/10.1007/s12230-019-09737-4

[110] Jensen, E.S., Carlsson, G. & Hauggaard-Nielsen, H. Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. Agron. Sustain. Dev. 40, 5 (2020). https://doi.org/10.1007/s13593-020-0607-x

and trees have associative relationships with nitrogen fixing bacteria, like clover, switch grass and grey alder, that can provide beneficial nitrogen inputs into the soils.[111, 112]

- **Increasing Biodiversity.** Biodiversity is not only increased by directly diversifying the plant species, but also increases the biodiversity of soil microbes and pest predators in certain conditions.[113, 114]

Planting Palette Examples

Utilizing these principles outlined in this appendix, four planting palette guides are provided in this section for vegetated stormwater BMPs. Designers should use these planting palette guides as determined appropriate and applicable for a given site. These palettes are not exhaustive and are only provided here as examples.

The planting palette guides are guided checklists intended to meet a variety of site needs, including low-maintenance and, where needed, salt-tolerant vegetation. The examples provided in these palette guides are limited to native plants, which are preferred wherever practicable. If non-native species are used, careful and thorough research is required to ensure that invasive species are not introduced. These palettes also include pollinators to support biodiversity and improve the ecosystem by cleaning air, purifying water and soil, and preventing erosion. Note that these palettes are provided as a starting point; it is the ultimate responsibility of the designer to select vegetation that is suited for the project location. Additional and more specific planting palettes that may be useful can be found in the RIDOT Linear Stormwater Manual.

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[111] Roley SS, Duncan DS, Liang D, Garoutte A, Jackson RD, Tiedje JM, Robertson GP. Associative nitrogen fixation (ANF) in switchgrass (Panicum virgatum) across a nitrogen input gradient. PLoS One. 13(6), (2018) https://doi.org/10.1371/journal.pone.0197320

[112] Nancy A. Eckardt and David D. Biesboer. Ecological aspects of nitrogen fixation (acetylene reduction) associated with plants of a Minnesota wetland community. Canadian Journal of Botany. 66(7): 1359-1363. https://doi.org/10.1139/b88-190

[113] Viviana Alarcón-Segura, Ingo Grass, Gunnar Breustedt, Marko Rohlfs, Teja Tscharntke. Strip intercropping of wheat and oilseed rape enhances biodiversity and biological pest control in a conventionally managed farm scenario. Journal of Applied Ecology. 59 (6) pages 1513-1523. https://doi.org/10.1111/1365-2664.14161

[114] Lian T, Mu Y, Jin J, Ma Q, Cheng Y, Cai Z, Nian H. Impact of intercropping on the coupling between soil microbial community structure, activity, and nutrient-use efficiencies. PeerJ. 8 (7) (2019). https://doi.org/10.7717/peerj.6412

Figure A-1. Planting Palette Example A

Location Suitability	Legend
	Sunny; Partly Shaded; Directly Adjacent to Roadways; Wet Areas

BMP Suitability	Dry Water Quality Swale	Dry Extended Detention Basin	Stormwater Pond	Bioretention	Infiltration Trench	Infiltration Basin	Filter Strip

Plant Photo	Name	Attributes	Notes
	*Ceanothus americanus,* New Jersey Tea	• Nitrogen fixing • Can grow nutritionally poor soils • Beneficial for pollinators & wildlife • Quick to establish • Salt tolerant • Deep roots provide good erosion control • Drought tolerant • Best for upland zone • Prefers well drained soils	Spacing 4-5 Feet
	*Lobielia cardinalis,* Cardinal Flower	• Prefers Wet to Moist Soil • Best for Wet meadow, Emergent or Submergent Zones • Somewhat tolerant of salt and urban pollution	Spacing 18- 24 inches
	*Juncus tenuis,* Path Rush	• Drought and flooding tolerant • Tolerant of compacted soils • Moderately tolerant of salt • Nitrogen fixing • Good for nesting birds • Good cover crop to reduce weeding needs • Deer Resistant	Spacing 12 inches
	*Asclepias tuberosa,* Butterfly Weed	• Beneficial for pollinators • Drought tolerant • Best for upland zone • Moderate salt tolerance • Deer resistant • Best to seed in fall	Spacing 18-24 inches
	*Coreopsis tinctoria Nutt,* Golden Tickseed	• Beneficial for Pollinators • Flooding tolerant prefers moist soil • Best for wet meadow and emergent zones • Moderate salt tolerance	Sow at least 2 lb of pure live seed per acre

Figure A-2. Planting Palette Example B

Location Suitability

Legend

Sunny | Partly Shaded | Directly Adjacent to Roadways | Wet Areas

BMP Suitability

Stormwater Pond | Bioretention | Infiltration Trench | Infiltration Basin | Filter Strip

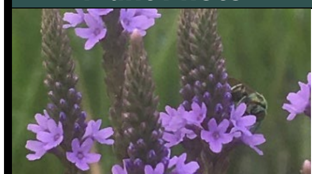
Plant Photo	Name	Attributes	Notes
	*Verbena hastata,* Swamp Verbena	• Livestock will not eat • Beneficial for pollinators • Quick to establish • Prefers wet to moist soil • Best for wet meadow, emergent or submergent zones • Moderate salt tolerance • Nitrogen fixing	Spacing 12-24 inches
	*Eupatorium maculatum,* Spotted Joe Pye Weed	• Prefers wet to moist soil • Best for wet meadow, emergent or submergent zones • Prefers sandy soils but will grow in non-sandy wetlands • Beneficial for pollinators • Drought tolerant • Fibrous roots can make it ideal for erosion control	Spacing: 4-5 feet on center
	*Iris versicolor,* Harlequin Blueflag	• Preference for acidic soils • Good filter of excess nutrients • Deer resistant • In wet soils will thrive without fertilizer • Wet to moist soils • Best for wet meadow, emergent or submergent zones • Roots can be good erosion control	Spacing 2-3 Feet
	*Carex stricta,* Tussock Sedge	• Drought tolerant for short periods • Prefers standing water or moist soils • Deer resistant • Nitrogen Fixing • Best for wet meadow, emergent or submergent zones • Good filter for water clarity	Spacing 1-3 Feet
	*Caltha palustris,* Marsh Marigold	• Beneficial for pollinators • Flooding tolerant, prefers moist soil • Best for wet meadow and emergent zones • Deer resistant • High salt tolerance • Alkaline tolerant • Beneficial for wood ducks • Good ground cover	Spacing 12 inches

Figure A-3. Planting Palette Example C

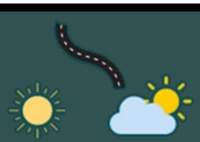
Location Suitability		**Legend** Sunny, Partly Shaded, Directly Adjacent to Roadways, Wet Areas	
BMP Suitability	Bioretention	Dry Extended Detention Basin	
Plant Photo	**Name**	**Attributes**	**Notes**
	*Cercis canadensis L.* Eastern Redbud	• Provides flowers in early spring • Tolerates a wide range of pH but will grow best in alkaline soils • Grows deep tap root in first few years if conditions are conducive • Rounded vase shape provides good summer shade • Known to be wind and ice tolerant • Not salt tolerant • Drought tolerant	Spacing 20-30 Feet
	*Phlox divaricata L.* Wild Blue Phlox	• Beneficial for pollinators • Good ground cover • Tolerant of wide range of soil types and pH • Shade tolerant, good for beneath trees • Drought tolerant • Deer resistant	Spacing 12 inches
	*Phlox subulata,* Moss Phlox	• Beneficial for Pollinators • Drought tolerant • Deer resistant • Prefers sun • Tolerant of nutrient poor soils • Moderately salt tolerant • Mildly alkaline tolerant • Good ground cover	Spacing 12-24 inches

Photo Sources:
Palette A (Top-Bottom): EPA.GOV via wikicommons, Judy Gallagher, CC BY 2.0 via Wikimedia Commons, Stefan.lefnaer, CC BY-SA 4.0 via wiki commons https://www.conservect.org/product/crccd-butterfly-weed/, https://www.fs.fed.us/wildflowers/plant-of-the-week/coreopsis_tinctoria.shtml
Palette B (Top – Bottom): HLWolfe, CC BY-SA 4.0 via Wikimedia Commons, Joshua Mayer CC BY-SA 2.0 Wikimedia Commons , Government of Quebec via Wikimedia Commons , gmayfield10, CC BY-SA 2.0 , via Wikimedia Commons, Eppu, CC BY 4.0 via Wiki Commons
Palette C (Top-Bottom): Wil540 art, CC BY-SA 4.0 via Wikimedia Commons, Cbaile19, via Wikimedia Commons , Agnieszka Kwiecień, Nova, CC BY-SA 4.0, via Wikimedia Commons

Appendix G – Climate Change Considerations

Overview and Purpose

Climate change (i.e., increasing precipitation and temperature and sea level rise) and its implications for stormwater management design and implementation were important considerations during the revision of this Manual for the following reasons:

- Previous guidance regarding design storm precipitation (e.g., 10-, 25-, and 100-year storms) is no longer relevant due to the shift in climate and precipitation that has been observed since the development of the original Connecticut Stormwater Quality Manual.
- Increasing trends in precipitation also include observed and projected increases in average precipitation amounts, which has implications for smaller, more frequent storms including the water quality storm.
- Rising sea levels have begun and are projected to continue to result in rising groundwater levels in coastal areas of Connecticut and elsewhere along the eastern coast of the United States.[115, 116] Rising groundwater has implications for stormwater infiltration and treatment practices along Connecticut's coast.
- The design life of many stormwater BMPs and related stormwater infrastructure is intended to be well over 20 years. Over this period, it is possible the design limits could be exceeded as a result of changing precipitation conditions, thereby reducing the effectiveness of the stormwater BMP or resulting in failure of the stormwater infrastructure.

This Manual incorporates various climate change and resilience considerations for stormwater management design and implementation:

- Preserving pre-development site hydrology using LID site planning and design strategies and structural stormwater BMPs
- Updated design storm precipitation for stormwater quantity and quality control

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[115] Jasechko, S., Perrone, D., Seybold, H. et al. Groundwater level observations in 250,000 coastal US wells reveal scope of potential seawater intrusion. Nat Commun 11, 3229 (2020). https://doi.org/10.1038/s41467-020-17038-2

[116] Bjerklie, D.M., Mullaney, J.R., Stone, J.R., Skinner, B.J., and Ramlow, M.A., 2012, Preliminary investigation of the effects of sea-level rise on groundwater levels in New Haven, Connecticut: U.S. Geological Survey Open-File Report 2012–1025, 46 p., at http://pubs.usgs.gov/of/2012/1025/.

- Sea level rise and other considerations for stormwater BMP siting and design in coastal areas
- Design considerations for mitigating the potential negative impacts of climate change on stream temperatures and nutrient loads.

This appendix provides additional details regarding climate change and stormwater impacts in Connecticut, including the basis for the selected approach to incorporating updated design storm precipitation and other climate change considerations into this Manual.

Evaluating Design Storm Approaches

Approach

During the development of this Manual, the Workgroup evaluated various approaches to updating design storm precipitation in Connecticut by considering: 1) observed changes in precipitation since the release of the original Connecticut Stormwater Quality Manual in 2004, and 2) potential future changes in precipitation, both for projects designed today and at some point in the future, over the design life of the stormwater infrastructure.

The Workgroup evaluated design storm approaches in stormwater manuals of other states within the region. The Workgroup reviewed these approaches both in terms of current design storm precipitation and consideration of future precipitation and climate change (see Table G-1). It is also important to note that while the current versions of the other state stormwater manuals did not explicitly include consideration of climate change and future precipitation, several states had related guidance on resilient infrastructure design accounting for future climate change (e.g., Resilient MA Action Team guidance documents including Climate Resilience Design Standards and Guidelines Tool, and New Jersey Climate Resiliency Strategy) and several states (Massachusetts and New Hampshire) were in the process of updating their manuals and/or design storm precipitation to account for ongoing and future climate change effects. Furthermore, many states were considering creating a more concrete connection between stormwater management and climate change and actively researching potential avenues to do so. The activities of the Governor’s Council on Climate Change and associated policy recommendations, as well as research and precipitation projections developed by the Connecticut Institute for Resilience and Climate Adaptation (CIRCA), were also reviewed to inform the design storm approach for Connecticut and the revised Manual. Based on the stated goals of the Manual update and the Workgroup’s review, it was clear that Connecticut’s revision of this Manual needed to consider both observed and potential future changes in precipitation as a result of climate change.

Table G-1. Design Storm Precipitation Approaches of State Stormwater Management Programs in the Northeast U.S.

State	Stormwater Quantity Control Design Storm		Water Quality Design Storm and Water Quality Volume
	Consideration for Observed Increase in Design Storm Precipitation Due to Climate Change?	Consideration for Future Increase in Design Storm Precipitation Due to Climate Change?	
Connecticut	No (TP-40)	No	Initial 1 inch of rainfall over contributing drainage area, runoff coefficient approach to calculate runoff
Massachusetts	No (TP-40) Proposed NOAA Atlas 14+ in updated guidance	Yes Proposed NOAA Atlas 14+ in updated guidance	Initial 1 inch of runoff from contributing impervious area
Rhode Island	Yes (NRCC)	No	Same as Massachusetts
New Hampshire	Yes (NRCC)	Updated design storms for climate change is a stated goal of the ongoing manual update	Same as Connecticut
Vermont	Yes (NOAA Atlas 14)	No	Same as Connecticut
Maine	Yes (NRCC)	No	Initial 1 inch of runoff from impervious area plus 0.4 inch of runoff from pervious area
New York	Yes (NRCC)	No	Initial 1 to 1.5 inches of rainfall over contributing drainage area, runoff coefficient approach to calculate runoff
New Jersey	Yes (NOAA Atlas 14)	No	1.25-inch, 2-hour rainfall, rainfall runoff modeling to calculate runoff

TP-40: National Weather Service Technical Paper 40 (out of print, last updated for Connecticut in 1977)

NRCC: Extreme Precipitation in New York and New England, Northeast Regional Climate Center

NOAA Atlas 14: 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

NOAA Atlas 14+: 90% of the upper limit of the 90th percentile confidence interval (NOAA Atlas 14)

Options Evaluated

Stormwater Quantity Control Design Storm

As described above, the Workgroup evaluated several alternative approaches for updating the stormwater quantity control design storm precipitation (24-hour design storm depths) in the revised Manual (Table G-2).

The first three options in Table G-2 utilize NOAA Atlas 14 values (median, 90% of the upper limit of the 90% confidence interval, or the upper limit of the 90% confidence interval), which are readily available from the NOAA Atlas 14 Precipitation Frequency Data Server web tool. NOAA14+ and NOAA14++ reflect the upper range of current extreme precipitation.

The fourth option in Table G-2 is similar to the approach used by Massachusetts in the RMAT Climate Resilient Design Standards and Guidelines Tool in which downscaled GCM precipitation estimates are used to estimate statewide or regional percent increases to the NOAA Atlas 14 median values. To help evaluate this alternative approach for Connecticut, the Connecticut Institute for Resilience & Climate Adaptation (CIRCA) provided downscaled estimates of 24-hour maximum precipitation for Hartford, New London, Bridgeport, and a statewide ensemble average. Downscaled precipitation estimates were provided for baseline (1970-1999) conditions and mid-century (2040-2069) and late century (2070-2099) future planning horizons, as well as for four different return periods (10-yr, 20-yr, 50-yr, and 100-yr). The estimates were derived using the Multivariate Adaptive Constructed Analogs (MACA) climate downscaling method as described in the Connecticut Physical Climate Science Assessment Report (PCSAR).[117] The NOAA Atlas 14 median values were then multiplied by the ratio of future to baseline statewide average downscaled precipitation estimates to derive estimated future 10-year and 100-year 24-hour rainfall depths. This "NOAA14 Future Downscaled" method accounts for anticipated future increases in precipitation associated with climate change projections, using the relative change in downscaled precipitation as the basis for increasing the NOAA Atlas 14 precipitation frequency estimates.

In addition to 24-hour rainfall depths, the rainfall distribution – how rain falls during a storm event – is also important in calculating the peak flow rates of stormwater runoff. Precipitation events typically begin with a lighter intensity, followed by a period of higher-intensity rainfall, and then gently tapering off. The USDA NRCS developed synthetic rainfall distributions from historical records from the different regions of the country based on the assumption that the rain distribution is bell-shaped. The NRCS rainfall distributions were grouped into four types according to the applicable regions. Type III distributions historically have been used in Connecticut, where tropical storms produce large 24-hour rainfall events.

[117] Connecticut Physical Climate Science Assessment Report (PCSAR), Observed trends and projections of temperature and precipitation, August 2019, Connecticut Institute for Resilience and Climate Adaptation and University of Connecticut Atmospheric Sciences Group.

Table G-2. Alternative Approaches Considered for Updating Stormwater Quantity Control Design Storm Precipitation

<table>
<tr><th>Alternative</th><th>Description</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>NOAA Atlas 14</td><td>NOAA Atlas 14 (median values)</td><td>• Reflects observed increases in precipitation to date (e.g., 2014)
• Easy to use - values reported directly from Atlas 14 website
• Values already adopted in CT DEEP Stormwater General Permits and by CTDOT</td><td>• Does not account for anticipated future increases in precipitation associated with climate change projections</td></tr>
<tr><td>NOAA Atlas 14+</td><td>90% of the upper limit of the 90th percentile confidence interval</td><td rowspan="2">• Reflects upper range of current expected storms
• Generally consistent with anticipated future increases in precipitation associated with climate change projections
• Provides greater resilience for infrastructure than NOAA Atlas 14 median values
• Larger stormwater controls better able to accommodate runoff from larger storms, less localized urban flooding
• Easy to use - 90th percentile confidence interval values reported from Atlas 14 website</td><td rowspan="2">• Results in larger, more expensive stormwater quantity controls such as stormwater basins or subsurface storage (peak flow attenuation)</td></tr>
<tr><td>NOAA Atlas 14++</td><td>Upper limit of the 90th percentile confidence interval</td></tr>
<tr><td>NOAA Atlas 14, Future Downscaled</td><td>NOAA Atlas 14 median values multiplied by the ratio of future to baseline downscaled GCM precipitation estimates developed by CIRCA for mid-century and late-century planning horizons</td><td>• Accounts for anticipated future increases in precipitation associated with climate change projections
• Provides greater resilience for infrastructure than NOAA Atlas 14 median values
• Larger stormwater controls better able to accommodate runoff from larger storms, less localized urban flooding
• Increase in NOAA Atlas 14 values tied to CT-specific future precipitation estimates</td><td>• Results in larger, more expensive stormwater quantity controls such as stormwater basins or subsurface storage (peak flow attenuation)
• Requires periodic update of downscaled precipitation estimates by CIRCA</td></tr>
</table>

In 2015, the Northeast Regional Climate Center (NRCC) developed updated NRCS rainfall distributions for the Northeast states, including Connecticut. These NRCC rainfall distributions were then replaced in 2018 for use in the NRCS WinTR-55 computer program in CT, as NRCS derived four new regional rainfall distributions (Types N10 A, B, C, and D) from the NOAA data to cover the NOAA Atlas 14, Volume 10 study area, which supersede all previous distributions. Connecticut NRCS recommends the use of the Type N10_D regional rainfall distribution to represent the entire state of Connecticut in WinTR-55. This or site-specific rainfall distributions can be used with the NOAA Atlas 14 estimates of 24-hour precipitation depths. The NRCS Type N10_D rainfall distribution is also recommended for use with other common rainfall runoff and stormwater design programs such as HydroCAD.

Water Quality Design Storm

In Connecticut, the water quality design storm is defined by 1 inch of rainfall over a 24-hour period. The 1-inch rainfall depth was selected as the event whose precipitation total is greater than or equal to 90 percent of all 24-hour storms on an average annual basis. During development of the original Connecticut Stormwater Quality Manual in 2004, rainfall data from the Northeast U.S. indicated that the 90th percentile 24-hour rainfall event was equal to approximately 1 inch. Several of the states in the northeast, including Connecticut, adopted the 1-inch rainfall event in their stormwater manuals.

The volume of runoff generated by the 1-inch rainfall is defined as the Water Quality Volume (WQV) in the 2004 manual, and by reference in the Soil Erosion and Sediment Control Guidelines and the CT DEEP Stormwater General Permits. Conceptually, the WQV is the volume of stormwater runoff from any given storm that should be captured and treated to remove a majority of stormwater pollutants on an average annual basis. The equation used to calculate the WQV uses a volumetric runoff coefficient as a function of impervious area, a rainfall depth of 1 inch, and the drainage area to the specified design point.

The WQV and 90th percentile rainfall concepts were originally developed to treat the majority of 24-hours storms and the associated average annual pollutant load in stormwater runoff. In 2009, EPA released technical guidance on implementing stormwater management requirements for certain federal projects, emphasizing the use of green infrastructure (GI) and low impact development (LID) to preserve pre-development hydrology as closely as possible.[118] The 2009 EPA guidance proposed the use of green infrastructure and LID practices that manage rainfall on-site, and prevent the off-site discharge of runoff from events less than or equal to the 95th percentile rainfall event to the maximum extent technically feasible. According to the EPA guidance, the 95th percentile storm event appears to best represent the volume that is fully infiltrated in a natural condition and thus should be managed on-site to restore and maintain pre-development hydrology for duration, rate and volume of stormwater flows.

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[118] USEPA. Section 438 Technical Guidance December 2009. Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act. EPA 841-B-09-001. December 2009. www.epa.gov/owow/nps/lid/section438

Retaining runoff from all storms up to and including the 95th percentile storm event (i.e., retention standard) serves to maintain or restore pre-development hydrology with respect to the volume, flow rate, duration and temperature of the runoff for most sites, in addition to providing treatment or pollutant removal. The volume reduction benefits provided by this retention standard result in greater overall pollutant load reduction, since pollutant loads are the product of pollutant concentration and runoff volume.

In 2018, the Northwest Conservation District, working with the Northwest Hills Council of Government through a CIRCA Matching Grant, developed a model Low Impact Development design manual to address stormwater management and the impacts climate change. The Morris, CT manual, a model for other small communities in the state, adopted a locally-applicable 95th percentile rainfall (1.3 inches) as the water quality design storm.

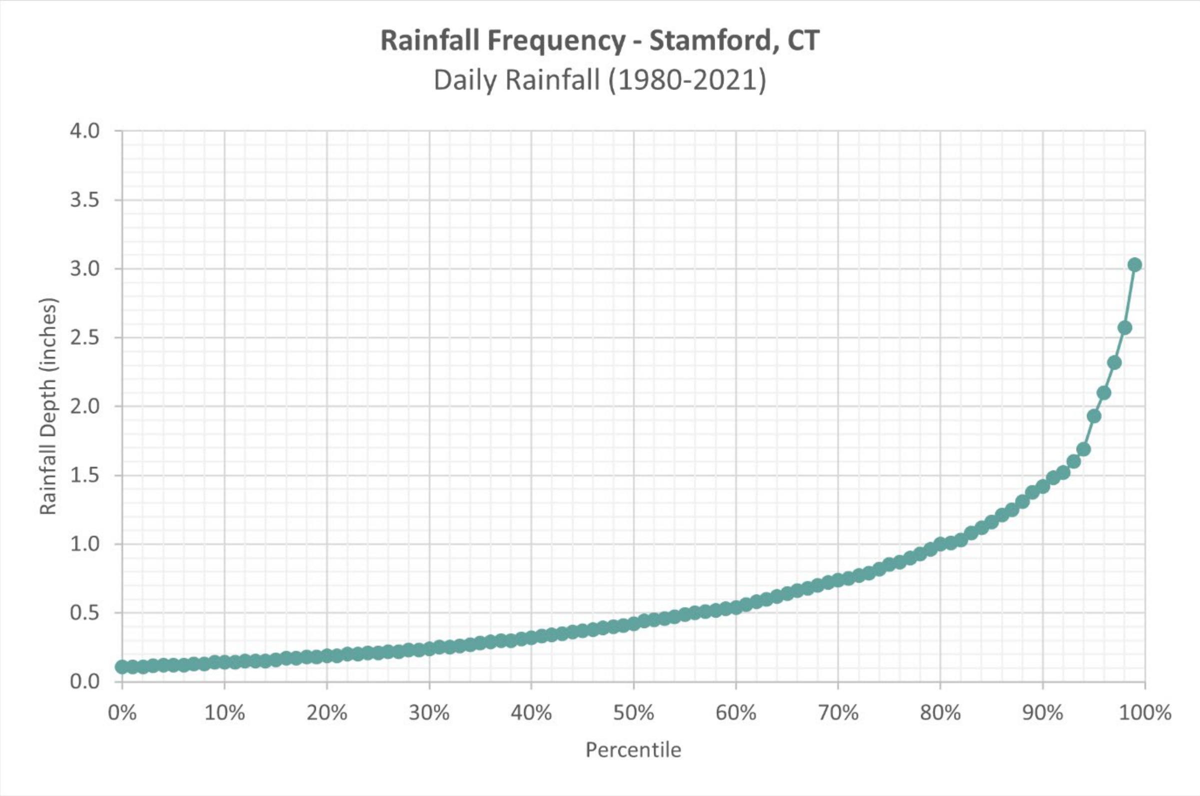
The Workgroup evaluated two options for updating the water quality design storm and associated Water Quality Volume in the revised Manual. The two options, including advantages and disadvantages of each, are summarized in Table G-3.

Table G-3. Alternative Approaches Considered for Updating Water Quality Design Storm Precipitation

Alternative	Description	Advantages	Disadvantages
Updated 90th Percentile 24-hour Rainfall	Update the 90th percentile 24-hour rainfall based on the latest CT rainfall data (at least a 30-year period)	• Reflects current Connecticut rainfall amounts • Better preserves pre-development hydrology (runoff duration, rate, volume, and temperature and groundwater recharge) as the basis for the retention standard in the CT DEEP Stormwater General Permits and this Manual	• Stormwater management cost increases noted as a potential concern
95th Percentile 24-hour Rainfall	Switch to the 95th percentile 24-hour rainfall	• Closer alignment with EPA Guidance • Even more effective in preserving pre-development hydrology	• Would be even more costly and, in some cases, difficult to achieve for constrained sites

The 90th and 95th percentile rainfall events were estimated for three Connecticut locations with long-term daily rainfall records – Hartford, Groton, and Stamford – using daily precipitation observations over an approximately 40-year period of record (1980-2021) and the procedure cited in the 2009 EPA guidance. Small rainfall events (0.1 inch or less and snowfall events that do not immediately melt) were removed from the data sets since these events do not typically cause runoff and could potentially cause bias in the estimates. Figure G-1 shows a cumulative frequency distribution of daily rainfall for one of the three locations analyzed (Stamford).

Figure G-1. Cumulative Frequency Distribution of Daily Rainfall for Stamford, CT (1980-2021)



The 90th percentile rainfall amounts vary from 1.25 to 1.42 inches, with an average of approximately 1.3 inches for the three locations analyzed. This is consistent with the 90th percentile rainfall amounts for New York State (1.0-1.5 inches) estimated by NYSDEC in 2013, as well as 90th percentile rainfall estimates for Boston, MA for the period 1948-2004 (approximately 1.3 inches).[119] The 95th percentile rainfall amounts are generally 30% to 35% higher than the 90th percentile amounts for the Connecticut locations evaluated.

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[119] Stormwater Best Management Practices (BMP) Performance Analysis. Revised Document: March 2010 (Original Document: December 2008). Prepared for United States Environmental Protection Agency - Region 1 by Tetra Tech, Inc.

Conclusions

Stormwater Quantity Control Design Storm

The revised Manual replaces the TP-40 24-hour rainfall depths with the NOAA Atlas 14 (and subsequent generations of NOAA precipitation-frequency products[120]) precipitation frequency estimates, at a minimum, for consistency with the CT DEEP Construction Stormwater General Permit and CTDOT design practice. While consideration was given to the use of larger design storm depths to account for observed and projected future increases in precipitation, such as the upper range of current expected storms (e.g., NOAA14+ or NOAA14++) or future climate projections, the Workgroup was concerned that adopting such an approach could be cost-prohibitive and potentially result in site designs with over-engineered stormwater controls rather than greater emphasis on use of non-structural LID site planning and design techniques. CT DEEP will continue to consider new climate resources and tools to inform future updates of design storm precipitation, including adoption of future generations of NOAA precipitation-frequency products, which are expected to reflect increasing trends in observed and future precipitation over time.

Water Quality Design Storm

The revised Manual replaces the 1.0-inch water quality storm with the updated 90th percentile rainfall depth of 1.3 inches to: 1) reflect current Connecticut rainfall amounts, and 2) better preserve pre-development hydrology (runoff duration, rate, volume, and temperature and groundwater recharge) as the basis for the retention standard (using the same WQV calculation method as used in the original manual) in the CT DEEP Stormwater General Permits and this Manual. This revision was deemed to be consistent with more recent rainfall data for Connecticut without being overly burdensome in meeting the stormwater retention and treatment standard for most sites.

Additional Climate Considerations

Ongoing and future projected climate changes will continue to impact stormwater management in Connecticut, as well as related environmental, infrastructure, and community resources, in the following ways:

- More frequent and intense storms can increase stormwater runoff, which can cause more frequent and extreme flooding events and can exacerbate existing, or introduce new, pollution problems. Overwhelmed stormwater management systems can lead to backups that cause localized flooding or lead to greater runoff of contaminants such as trash, nutrients, sediment, and bacteria into local waterways.

[120] As of the writing of this manual, NOAA was developing the "next generation" precipitation-frequency product that is expected to replace NOAA Atlas 14. The new product (NOAA Atlas 15) is anticipated to update current Atlas 14 precipitation frequency estimates based on historical data and reflect the increasing trend in observed precipitation, as well as account for future precipitation information.

- More frequent and intense downpours can also challenge cities with combined stormwater and wastewater drainage systems. These systems can be overwhelmed by large amounts of rainfall or snowmelt and lead to more combined sewer overflows (CSOs) into waterways. An increase in CSOs can reduce water quality and make meeting water quality standards more difficult.

- Increased stormwater runoff and transport of pollutant loads to waterbodies can diminish water quality and threaten drinking water sources. Projected increases in the number of days of precipitation over 1 inch, as well as the total amount of precipitation falling in the heaviest 1% of rainfall events are important factors in determining future pollutant loads to waterbodies.

- Warming air and water temperatures combined with increased precipitation and stormwater pollutant loads will increase the potential for harmful algal blooms, loss of high-quality headwater streams and cold-water habitat, further degradation of impaired waters, and negative impacts on recreational use of waters.

- More frequent, intense, and longer-lasting periods of drought, combined with new land development, can exacerbate loss of groundwater recharge, reducing streamflow and affecting water quality, stream ecology, recreational use of waters, and drinking water supplies.

- Sea level rise and increased frequency and intensity of coastal storms has implications for stormwater management systems along the Connecticut coast and tidally influenced areas. According to projections by the Connecticut Institute for Resilience & Climate Adaptation (CIRCA), sea level rise is expected to increase water levels in Long Island Sound by up to 20 inches by 2050 and to continue increasing after that. Continued rising sea levels will result in more regular coastal flooding, increased water depths will result in greater potential for wave and storm surge propagation further inland during storms, and groundwater elevations will rise in areas that are directly influenced by coastal

Summary of Climate Change & Its Impacts in Connecticut

- By 2050, average temperatures are expected to increase about 5°F, with increases thereafter dependent on emissions choices now.
- Average precipitation is expected to increase about 8% (4 inches/year).
- Indices of hot weather, summer drought, and extreme precipitation are expected to increase.
- Sea level is expected to rise by up to 20 inches by 2050 and continue increasing after that.
- Small changes in mean sea level have a big impact on the frequency of flooding.
- Areas that experience flooding every few years now should expect flooding multiple times a year by 2050.

Source: Connecticut Institute for Resilience & Climate Adaptation (CIRCA) Fact Sheets

Temperature and Precipitation

Sea Level Rise

waters. Stormwater management systems in these areas are vulnerable to rising sea levels and, backwatering and submerging of outfalls, rising groundwater and reduced infiltration, storm surge inundation of facilities, and additional wind, sand, and salt exposure.