A. Evaluation of Retrofit Opportunities and Areas for Structural BMP Installation

MOTT MACDONALD

Town of Ludlow Year 5 Massachusetts Small MS4 General Permit

Evaluation of Retrofit Opportunities and Areas for Structural BMP Installation

September 2023

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Town of Ludlow Year 5 Massachusetts Small MS4 General Permit

Evaluation of Retrofit Opportunities and Areas for Structural BMP Installation

September 2023

Issue and revision record

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A	9/18/2023	Alexandra Wagner	Suzanne Newman	Suzanne Newman	Draft
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Contents

Tables

1 Introduction

This memorandum identifies a list of planned structural stormwater best management practices (BMPs) and a plan and schedule for their implementation in accordance with the US Environmental Protection Agency's (EPA's) 2016 Massachusetts Small MS4 General Permit and its appendices.

1.1 Regulatory Context

The Town of Ludlow ("the Town") is subject to the requirements of the US Environmental Protection Agency's (EPA's) 2016 Massachusetts Small MS4 General Permit ("MS4 permit"). The MS4 permit took effect on July 1, 2018 and was subsequently modified on December 7, 2020. The Town's runoff drains to the Chicopee River, which is a tributary to the Connecticut River that ultimately flows into Long Island Sound. Therefore, the Town is located in the watershed of Long Island Sound and is subject to its approved TMDL for nitrogen as identified in Appendix F section B.I of the MS4 permit.

As part of the MS4 permit year 5 requirements, the Town must evaluate all properties previously identified as presenting retrofit opportunities or areas for structural BMP installation either as part of the MS4 permit section 2.3.6.d.ii. or as identified by the Nitrogen Source Identification Report developed by the Town in 2022 as part of the year 4 MS4 permit requirements. According to Appendix F, the evaluation shall include:

1. The next planned infrastructure, resurfacing, or redevelopment activity planned for the property (if applicable) or planned retrofit date;
2. The estimated cost of redevelopment or retrofit BMPs; and
3. The engineering and regulatory feasibility of redevelopment or retrofit BMPs.

MS4 permit section 2.3.6.d.ii also outlines factors for consideration in determining the potential for modifying or retrofitting properties, as well as factors for determining the priority ranking of potential properties. These factors, shown in **Table 1** and **Table 2**, shall be considered as part of the evaluation of properties identified for structural BMPs.

Finally, MS4 permit Appendix F requires that the Town provide a listing of planned structural BMPs and a plan and schedule for implementation as part of the year 5 annual report. This appendix also requires that a structural BMP targeting a catchment with high nitrogen load potential be installed within six years of the permit effective date.

Table 1. Factors to Determine Property Potential for Modifying/Retrofitting with BMPs

Access for maintenance purposes
Subsurface geology
Depth to water table
Proximity to aquifers and subsurface infrastructure including sanitary sewers and septic systems
Opportunities for public use and education

Table 2. Factors to Determine Priority Ranking of Properties to be Modified/Retrofitted with BMPs

Schedules for planned capital improvements to storm and sanitary sewers infrastructure
Schedules for planned pavement projects
Current storm sewer level of service
Control of discharges to water quality limited waters, first or second order streams, public swimming beaches, drinking water supply sources, and shellfish growing areas

1.2 Nitrogen Source Identification Report

A Nitrogen Source Identification Report was created as part of the MS4 permit's year 4 requirements. Details from this report have been referenced in this section.

The Nitrogen Source Identification Report identified the five catchments with the highest estimated nitrogen loading in the Town's permitted MS4 area. These five catchments and their estimated nitrogen loading appear in **Table 3**.

Table 3. Catchments with the Five Highest Estimated Nitrogen Loadings

Catchment Identifier	Estimated N Load (Lbs./Yr.)
LUDLOW-CHW04	1246.39
LUDLOW-TCA01	943.34
LUDLOW-MCP03	508.86
LUDLOW-CHW11	403.93
LUDLOW-MCP01	359.30

The Nitrogen Source Identification Report also identified six high-priority parcels to be considered for development of stormwater control measures, as noted below in **Table 4**. These six properties have been evaluated per the key factors listed in **Table 1** and **Table 2** above to provide a list of planned structural BMPs. Where properties listed below have been removed from consideration, additional properties have been added to the evaluation as necessary to maintain a minimum of five potential sites to be retrofitted with BMPs per part 2.3.6.d.ii. of the permit.

Table 4: High-Priority Parcels to be Considered for Development of Stormwater Control Measures for Nitrogen Loading

Address	Property Description	Parloc_ID[1]	Nitrogen BMP Score
499 Center Street	Island Pond Cemetery	M_119015_880832	90/95
508 East Street	East Street Elementary School	M_120074_879463	90/95
53 Chestnut Street	Senior Center	M_118800_879103	90/95
167 Howard Street	Whitney Park	M_119212_879727	89/95
488 Chapin Street	Town Hall	M_120319_880450	88.75/95
486 Chapin Street	Veterans Park Elementary School	M_120435_880642	N/A
All Rights-Of-Way in Priority Catchments	N/A	N/A	All

[1]Parloc_ID is a parcel identification number used to differentiate properties and included in the GIS shapefile's attribute table.

1.3 Reprioritization of Previously Identified Parcels

As noted in Section 1.2, there were six sites identified by the Nitrogen Source Identification Report as high priority parcels to be considered for stormwater control measures. However, two of these properties have been deprioritized or removed from evaluation entirely:

1. 508 East Street: The property at 508 East Street has been removed from this round of property evaluations. Although this site may be considered for BMP installation in the future, there are multiple drawbacks and unknowns that make the East Street Elementary School a less desirable property for retrofit than those identified in Section 2 of this report. These drawbacks have been listed below:
    a. This site is on the edge of CHW06, and the roof drainage may be routed to an outfall not included in the regulated area of the Town.
    b. A BMP placed in the grassed area north of the entrance to the elementary school may be able to manage roadway drainage area from East Street and Yale Street. However, the available drainage area would be small.
    c. Placement of a BMP in this location is likely to negatively impact the existing trees in front of the school.
2. 53 Chestnut Street: The property at 53 Chestnut Street has been removed from evaluation for future BMPs. The property previously housed the Ludlow Senior Center. However, the Senior Center has been relocated to another property. Although this parcel is currently still owned by the Town, the future of the property is unknown. Per

coordination with the Town, installation of a BMP at 53 Chestnut Street is not recommended at this time.

Given that these two parcels have been removed from the original high-priority parcels list identified by the Nitrogen Source Identification Report, additional properties were identified and evaluated as part of Section 2.

Note, the Nitrogen Source Identification Report also identified all rights-of-way in priority catchments as parcels to be considered for BMPs. In this evaluation, Town-owned properties outside of the right-of-way were prioritized. If in the future the Town needs to identify additional properties for retrofit, BMPs placed in the right-of-way of priority catchments should be considered.

2 Planned Structural BMPs

2.1 Siting Factors

Five properties were identified for planned structural BMPs in accordance with the factors identified in **Table 1** and **Table 2** in Section 1.1. A summary of the applicable factors for the five sites below can be found in **Appendix A**.

In general, each of the proposed sites is easily accessible for maintenance and does not have planned capital improvements to storm and sanitary sewer infrastructure, planned pavement projects, or known storm sewer level of service concerns. A few of the proposed properties have sanitary and/or storm sewer infrastructure through the parcel. However, these sites are expected to have ample space for placement of a BMP despite this infrastructure. It is anticipated that the existing infrastructure can be assessed and avoided during future due diligence and design phases.

According to the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey, the soil texture at each site is anticipated to be loamy sand or sandy loam, and the hydrologic soil group is anticipated to be A or C. Therefore, the subsurface geology appears to be suitable for structural BMP installation at each of these sites. However, the depth to the water table is unknown for the five sites listed below. It is expected that geotechnical investigation will be performed as part of the design process for each of these BMP sites to further investigate subsurface geology and the depth to the water table.

Additionally, multiple of the proposed properties for structural BMPs provide opportunities for public use and education. Three of the properties target control of discharge to the Chicopee River, which is impaired by fecal coliform and Escherichia Coli (E. Coli), and one of the properties targets control of discharge to a second order stream.

2.2 Methodology

As part of the evaluation of the planned structural BMPs, a desktop analysis was performed and supplemented by site visits and coordination with the Town. Approximate drainage areas were estimated using Town GIS data of the existing storm sewer infrastructure, aerial imagery, and 1-foot contours extracted from Massachusetts Bureau of Geographic Information (MassGIS) Lidar Digital Elevation Model (DEM)[1] as shown in the maps in **Appendix B**. Note, the estimated drainage areas include only impervious roadway drainage area. During future design phases, impervious area to each BMP should be revisited and refined. A BMP type has been recommended for each site depending upon the aforementioned existing conditions and the use of the parcel. Additional BMP types may be considered during future design phases when more detailed site information is available.

Estimated costs for construction and design were calculated for each of the planned structural BMPs using the “Methodology for developing cost estimates for Opti-Tool” memorandum

[1] MassGIS (Bureau of Geographic Information). (n.d.). Retrieved from https://www.mass.gov/orgs/massgis-bureau-of-geographic-information

published by the EPA in 2016.[2] This memorandum has been included in **Appendix C**. Based on the approach outlined in this document, estimated costs were calculated according to Equation 1 below.

Equation 1:

$$\textit{Estimated Cost} = \textit{Storage Volume of BMP } (ft^3) * \textit{Cost Estimate for BMP } \left(\frac{\$}{ft^3}\right) * \textit{Adjustment Factor}$$

The storage volume of each BMP has been calculated as 1.0 inch of runoff multiplied by the total impervious area treated, which is similar to the typical requirement outlined by the Massachusetts Stormwater Handbook Volume 2 Chapter 2 for required water quality volume.[3] Per the Massachusetts Stormwater Handbook Volume 1 Chapter 1, 1.0 inch of runoff was used rather than 0.5 inches to be conservative in sizing the system and given that the estimated drainage area is from roadways with a high potential pollutant load.[4]

The Opti-tool memorandum provides the cost per cubic foot for each BMP type in 2016 dollars. These costs were converted to 2023 dollars using the Engineering News-Record Construction Cost Index History.[5] Given that the construction of the proposed BMPs is scheduled for years into the future, the estimated present costs were then adjusted for an assumed inflation rate according to the scheduled construction of the BMP. According to an investigation performed by CBRE in 2022, forecasted construction costs are expected to stabilize within historical averages in 2023 and 2024, (between 2% and 4%).[6] To be conservative, an annual cost increase of 3.5% was assumed for this evaluation. Finally, a general 40% contingency was applied to this estimated cost due to the early stage of this planning study and possibility for significant cost fluctuations once designs are initiated.

The cost adjustment factor shown in **Equation 1**: and used in these estimated costs is meant to reflect the cost implications due to site location. The Opti-tool memorandum provides example cost adjustment factors dependent upon the extent to which an area is already developed and notes that these cost adjustment factors can be adjusted as needed. For this evaluation, a cost adjustment factor of 2.0 was used given that the proposed BMP locations are all in developed areas.

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[2] Karen Mateleska, EPA Region-I. (2016, February 20). *Methodology for developing cost estimates for Opti-Tool.* Retrieved from https://www3.epa.gov/region1/npdes/stormwater/tools/green-infrastructure-stormwater-bmp-cost-estimation.pdf

[3] *Massachusetts Stormwater Handbook Volume 2 Chapter 2: Structural BMP Specifications for the Massachusetts Stormwater Handbook.* (n.d.). Retrieved from https://www.mass.gov/doc/massachusetts-stormwater-handbook-vol-2-ch-2-stormwater-best-management-practices/download

[4] *Massachusetts Stormwater Handbook Volume 1 Chapter 1: Overview of Massachusetts Stormwater Standards.* (n.d.). Retrieved from https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.mass.gov%2Fdoc%2Fmassachusetts-stormwater-handbook-vol-1-ch-1-stormwater-management-standards%2Fdownload&wdOrigin=BROWSELINK

[5] *Construction Cost Index History - As of August 2023.* (2023, August). Retrieved from Engineering News-Record: https://www.enr.com/economics/historical_indices/construction_cost_index_history

[6] CRBE. (2022, July 6). *2022 U.S. Construction Cost Trends.* Retrieved from https://www.cbre.com/insights/books/2022-us-construction-cost-trends#:~:text=CBRE%E2%80%99s%20new%20Construction%20Cost%20Index%20forecasts%20a%2014.1%25,2023%20and%202024%2C%20on%20par%20with%20historical%20averages.

Costs were also estimated for the operations and maintenance (O&M) of the proposed structural BMPs. The Massachusetts Stormwater Handbook outlines recommended maintenance activity and frequency for various BMPs.[7] Using these recommendations, yearly maintenance hours were estimated for each BMP type. Cost per maintenance hour was estimated assuming an average hourly rate for two workers[8] plus a cost for required equipment. Estimated costs for O&M of the planned BMPs in each calendar year were calculated assuming that O&M begins in the same year that the BMP is planned to be installed. Finally, these estimated costs were adjusted for future prices using a 3.5% inflation rate. This inflation rate assumes that increases to labor rates, which make up the majority of the estimated O&M costs, will mimic increases to the construction inflation rates discussed above.

2.3 Identified Sites

Using the methods outlined in Section 2.2, the following planned structural BMPs and estimated costs were identified, as outlined in **Table 5**. **Table 6** provides the estimated O&M costs for the planned structural BMPs in future prices. A summary of the estimated cost calculations is provided in **Appendix D**. Note, the planned construction years assume that each BMP would be designed and installed consecutively. It is anticipated that the Town will need to secure external funding to implement the planned structural BMPs. Therefore, the timeline for each of these BMPs is dependent upon securing external funding for design and construction.

Table 5: Planned Structural BMPs

Property Address	Property Name	BMP Type	Planned Construction Year	Estimated Construction Cost (Construction Year)[1]
486 Chapin Street	Veterans Park Elementary School	On-Site Impervious Area Reduction	2023	N/A
24 Center Street	Hubbard Memorial Library	Bioretention Area	2027	$206,000
167 Howard Street	Whitney Park	Bioretention Area	2030	$146,000
211 Highland Avenue	John F. Thompson Memorial Swimming Pool	Infiltration Trench	2033	$68,000
499 Center Street	Island Pond Cemetery	Bioretention Area	2036	$83,000

[1] Costs adjusted to estimated construction year prices, as detailed in Section 2.2.

[7] *Massachusetts Stormwater Handbook Volume 2 Chapter 2: Structural BMP Specifications for the Massachusetts Stormwater Handbook.* (n.d.). Retrieved from https://www.mass.gov/doc/massachusetts-stormwater-handbook-vol-2-ch-2-stormwater-best-management-practices/download

[8] *Public works Department Salary in Massachusetts*. (n.d.). Retrieved from ZipRecruiter: https://www.ziprecruiter.com/Salaries/Public-Works-Department-Salary--in-Massachusetts

Table 6: Estimated O&M Costs for Planned BMPs

Year	Estimated Cost (Specified Year)
2024	$0
2025	$0
2026	$0
2027	$4,800
2028	$5,000
2029	$5,100
2030	$10,600
2031	$10,900
2032	$11,300
2033	$19,700
2034	$20,400
2035	$21,100
2036	$28,300

Note, the proposed on-site impervious area reduction project at 486 Chapin Street was already planned and approved by the town. Therefore, an estimated cost has not been provided as the Town does not need to plan further for this BMP. Furthermore, the O&M costs associated with maintaining the proposed pervious area are expected to be minimal and have not been estimated. This project is to be completed during the MS4 permit year 6 and will convert an estimated 3 acres of impervious area to pervious area. Although 486 Chapin Street does not fall within a high loading catchment area, the reduction to impervious area at this site is significant and will be completed within six years of the permit effective date.

2.4 Regulatory Barriers

As noted in the Local Impervious Requirements Assessment and Green Infrastructure Report created by the Town as a part of the MS4 permit Year 4 permit requirements, there are some potential hindrances to green infrastructure implementation in the existing Town of Ludlow Subdivision Rules and Regulations. Most notably, the report determined that the Town of

Ludlow Subdivision Rules and Regulations Section IV. E requirement for curbing the entire gutter line with bituminous concrete berm restricts curb cuts, at-grade inlets, and no-curb inflows. The need for any of these inflow types will not be known until each of the BMPs is designed.

3 Appendices

A. Factors to Determine Property Potential and Priority Ranking

Appendix A: Factors to Determine Property Potential and Priority Ranking

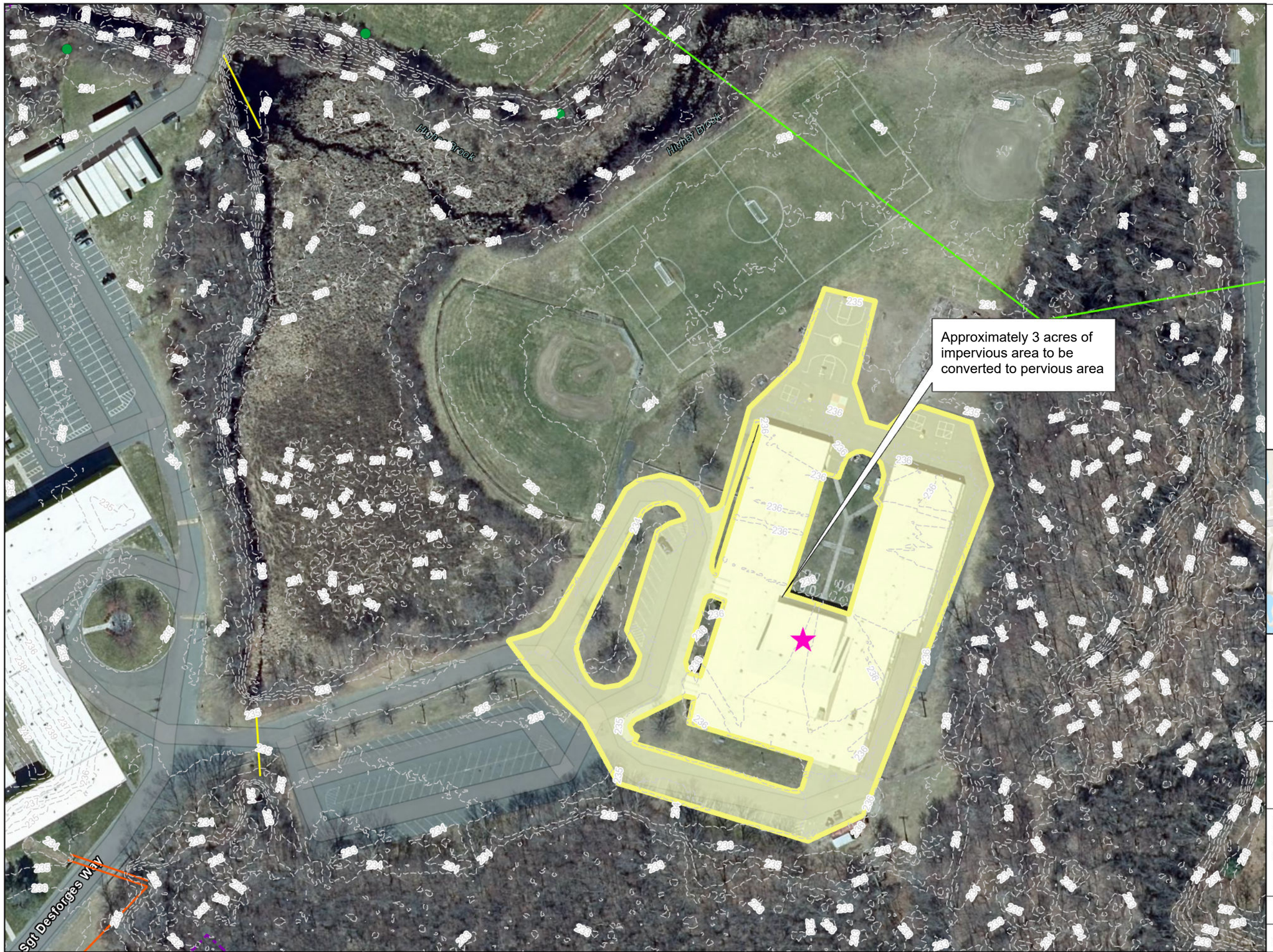
			Factors to Determine Property Potential for Modifying/Retrofitting with BMPs					
Property Address[1]	**Property Name**	**Catchment Area**	**Access for maintenance purposes**	**Subsurface Geology[2]**		**Depth to water table**	**Proximity to aquifers and subsurface infrastructure including sanitary sewers and septic systems**	**Opportunities for public use and education**
				Hydrologic Soil Group	**Soil Texture**			
24 Center Street	Hubbard Memorial Library	CHW04	Site is accessible for maintenance	A	Loamy sand	Unknown. To be evaluated during design	GIS data depicts a sanitary sewer through the property. BMP design will need to account for this infrastructure.	Parcel houses a library near the town center. Opportunity for public use and education through the library.
167 Howard Street	Whitney Park	TCA01		Null/A	Urban land/Sandy loam		GIS data depicts a storm sewer and a sanitary sewer through the athletic field at 167 Howard Street. BMP design will need to account for this infrastructure.	Ludlow Recreation Department is on this property, providing an opportunity for public use and education.
211 Highland Avenue	John F. Thompson Memorial Swimming Pool	TCA01		C	Sandy loam		Storm sewer runs along Highland Street. BMP design will need to account for this infrastructure.	Close to Ludlow Recreate Department, which may provide opportunity for public use and education.
499 Center Street	Island Pond Cemetery	HGB16		A	Sandy loam		No known subsurface infrastructure near proposed BMP location.	Location is adjacent to the entrance of a cemetery off of a major roadway.

[1] 486 Chapin Street - Veterans Park Elementary School has not been evaluated according these factors given that this project is already underway.
[2] Hydrologic soil group and soil texture analyzed using the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey.

			Factors to Determine Priority Ranking of Properties to be Modified/Retrofitted with BMPs			
Property Address[1]	**Property Name**	**Catchment Area**	**Schedules for planned capital improvements to storm and sanitary sewer infrastructure**	**Schedules for planned pavement projects**	**Current storm sewer level of service**	**Control of discharges to water quality limited waters, first or second order streams, public swimming beaches, drinking water supply sources, and shellfish growing areas**
24 Center Street	Hubbard Memorial Library	CHW04	No known planned capital improvements to storm and sanitary sewer infrastructure.	No known planned pavement projects.	No known storm sewer level of service concerns	Parcel and proposed drainage area are within CHW04 catchment. The CHW04 outfall discharges to the Chicopee River, which is impaired by fecal coliform and Escherichia Coli (E. Coli).
167 Howard Street	Whitney Park	TCA01				Parcel and proposed drainage area are within TCA01 catchment area, which discharges to the Chicopee
211 Highland Avenue	John F. Thompson Memorial Swimming Pool	TCA01				Parcel and proposed drainage area are within TCA01 catchment area, which discharges to the Chicopee River. Impairment noted above.
499 Center Street	Island Pond Cemetery	HGB16				HGB16 discharges to a second order stream.

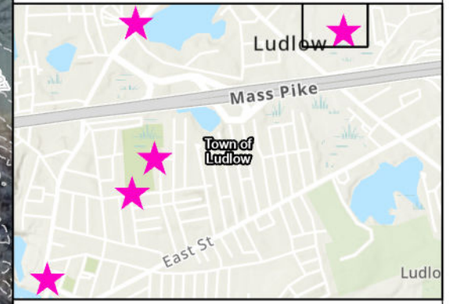
[1] 486 Chapin Street - Veterans Park Elementary School has not been evaluated according these factors given that this project is already underway.

B. Maps of Identified Sites



Legend

- Potential BMP Location
- Potential Drainage Area
- Town-owned Parcel
- Catchment with Outfall ID
- 1-ft Contour
- # House Number
- Sanitary Sewer
- Drain Pipe
- Culvert
- Pump Station
- End Wall
- Catch Basin
- Drain Manhole
- Sanitary Manhole



N

0 50 100 200 Ft

1 inch = 100 feet

MOTT MACDONALD

Ludlow BMP Locations
486 Chapin Street
September 2023

Drawn	GIS Checked	Checked	Approved
EGD		ASW	SJN
Scale	Status	Revision	Security
1 in = 100 ft			

Potential Drainage Area: 26,600 sf

Potential Drainage Area: 11,200 sf

CHW04

Winsor St

Park Ter

Park Pl

Center St

Chestnut St

Chestnut Pl

Library Park

East St

Legend

- Potential BMP Location
- Potential Drainage Area
- Town-Owned Parcel
- Catchment with Outfall ID
- 1-ft Contour
- # House Number
- Sanitary Sewer
- Drain Pipe
- Culvert
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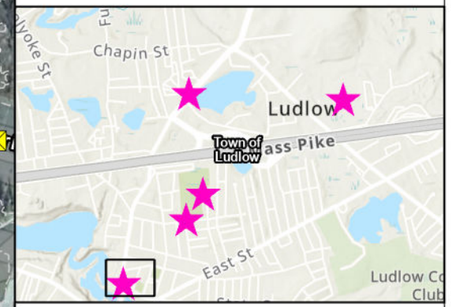
- Drain Manhole
- Sanitary Manhole



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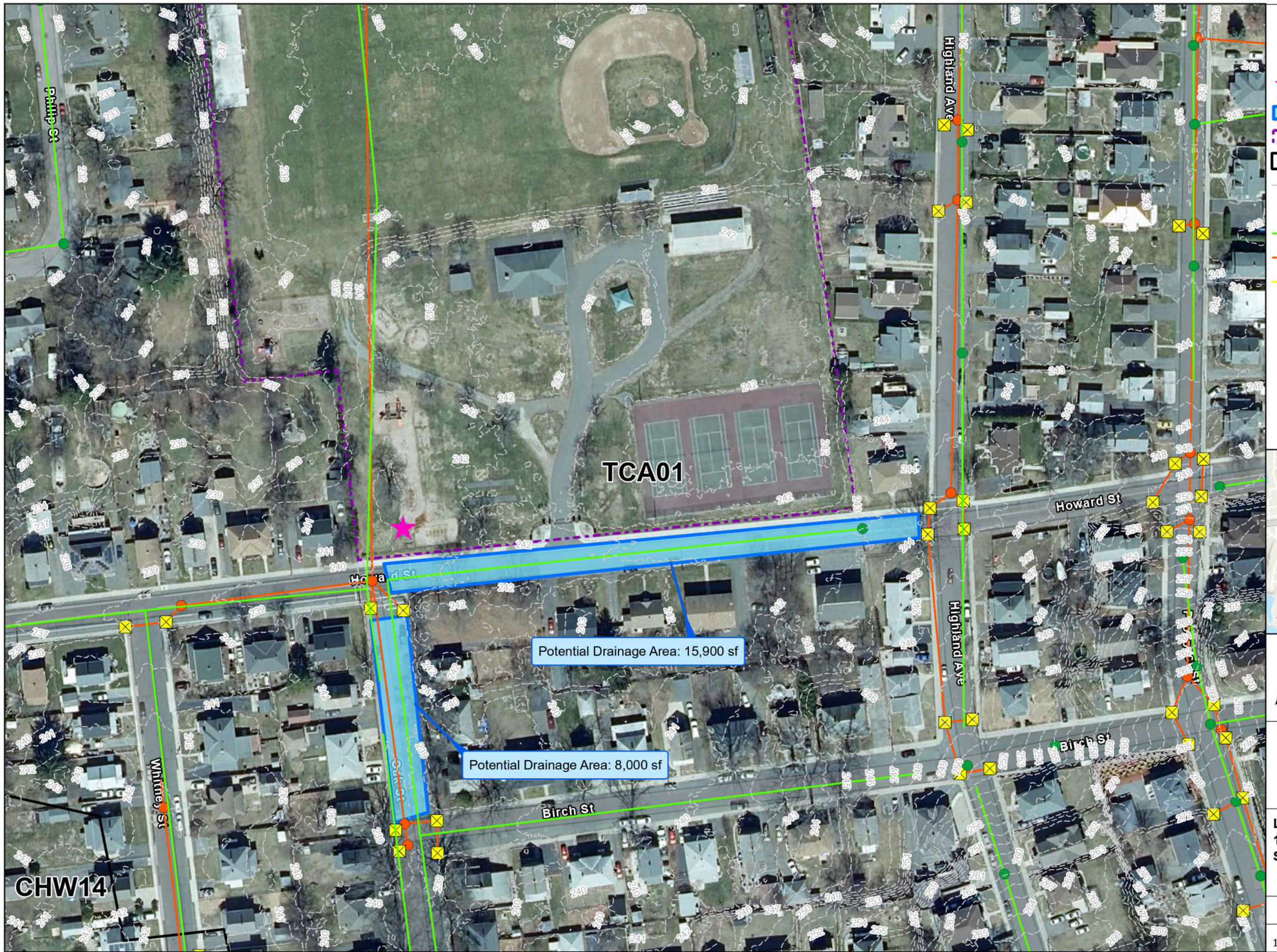
1 inch = 100 feet

MOTT MACDONALD

Ludlow BMP Locations
24 Center St
September 2023

Drawn	GIS Checked	Checked	Approved
EGD		ASW	SJN
Scale	Status	Revision	Security
1 in = 100 ft			



Legend

- Potential BMP Location
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- Town-Owned Parcel
- Catchment with Outfall ID
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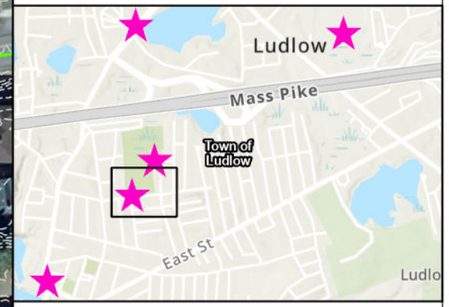

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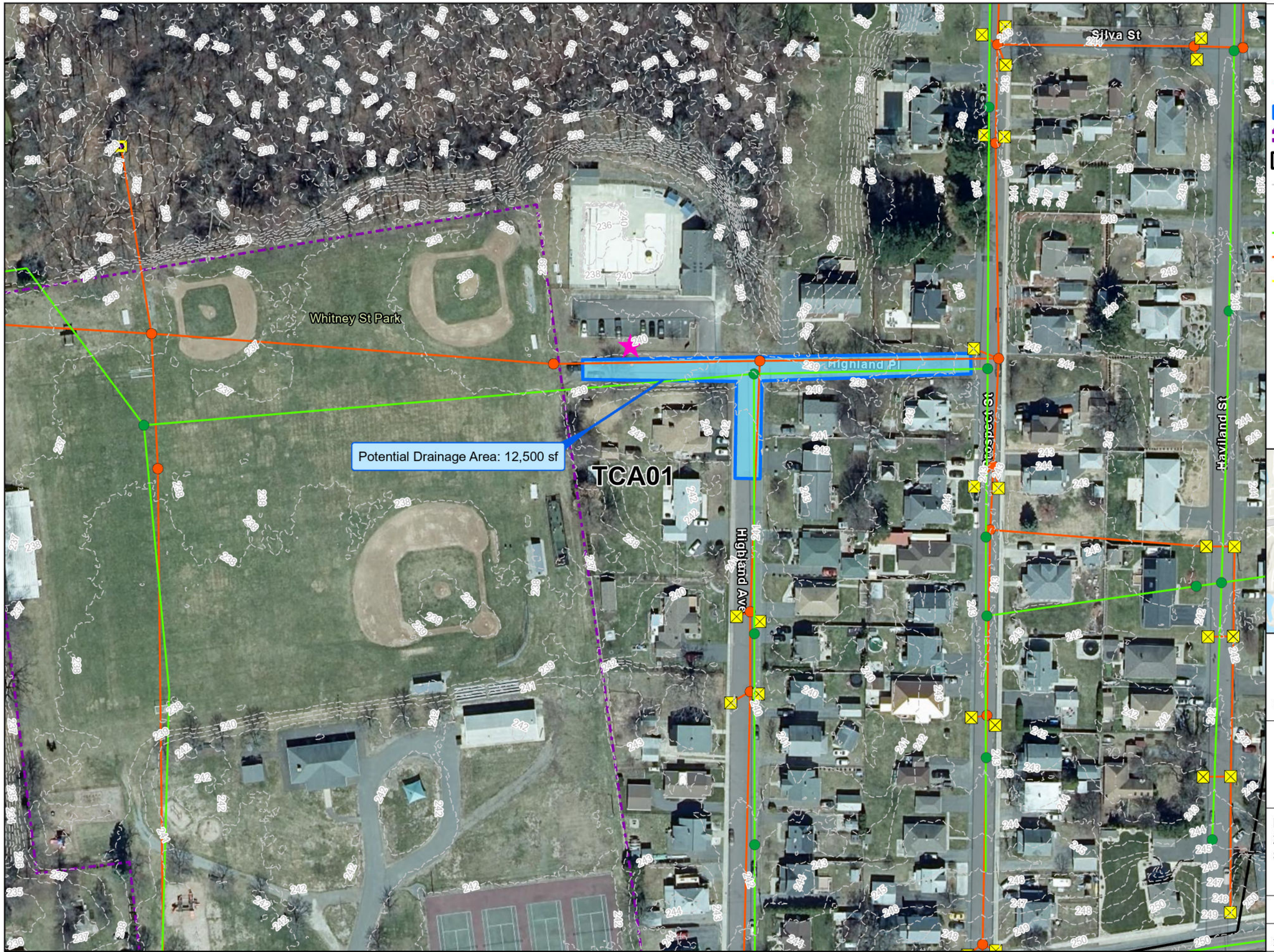
1 inch = 100 feet

MOTT MACDONALD

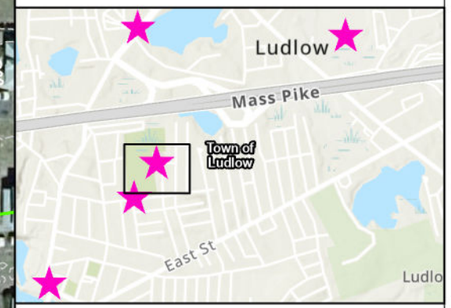
Ludlow BMP Locations
167 Howard Street
September 2023

Drawn	GIS Checked	Checked	Approved
EGD		ASW	SJN
Scale	Status	Revision	Security
1 in = 100 ft			



Legend

- Potential BMP Location
- Potential Drainage Area
- Town-Owned Parcel
- Catchment with Outfall ID
- 1-ft Contour
- # House Number
- Sanitary Sewer
- Drain Pipe
- Culvert
- Pump Station
- End Wall
- Catch Basin
- Drain Manhole
- Sanitary Manhole



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1 inch = 100 feet

MOTT MACDONALD

Ludlow BMP Locations
211 Highland Avenue
September 2023

Drawn	GIS Checked	Checked	Approved
EGD		ASW	SJN
Scale	Status	Revision	Security
1 in = 100 ft			

Legend

- Potential BMP Location
- Potential Drainage Area
- Town-Owned Parcel
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- Drain Pipe
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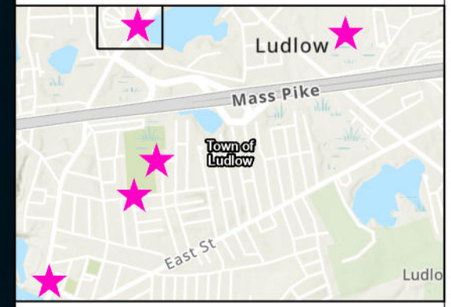

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1 inch = 100 feet

MOTT MACDONALD

Ludlow BMP Locations
499 Center Street
September 2023

Drawn	GIS Checked	Checked	Approved
EGD		ASW	SJN
Scale	Status	Revision	Security
1 in = 100 ft			

C. Memorandum: Methodology for developing cost estimates for Opti-Tool

MEMORANDUM

DATE: February 20, 2016

TO: Opti-Tool TAC

FROM: Karen Mateleska, EPA Region- I

SUBJECT: **Methodology for developing cost estimates for Opti-Tool**

Introduction

EPA – Region I offered to provide TetraTech with BMP cost information for the New England Stormwater Management Optimization Tool (Opti-Tool). The goal was to include the latest available information that would accurately reflect capital costs for select BMPs installed in the New England region. This document describes the approach used to determine these values.

The unit cost estimates originally developed as part of a 2010 study were used as the basis/starting-point for the cost estimates for the Opti-Tool. This study, entitled *Stormwater Management Plan for Spruce Pond Brook Subwatershed,* was produced by the Charles River Watershed Association (CRWA). The full report can be viewed at: http://www.crwa.org/hs-fs/hub/311892/file-636820515-pdf/Our_Work_/Blue_Cities_Initiative/Scientific_and_Technical/CRWA_Franklin_Plan.pdf. This subwatershed in the Town of Franklin (in eastern Massachusetts) was selected, in part, because it represented one of the many communities in the watershed that would be required to reduce nutrient (phosphorus) loads in stormwater runoff as part of EPA's Phase II MS4 General Stormwater Permit and a TMDL for Nutrients in the Upper/Middle Charles River. The cost estimates developed in the study can predominantly be attributed to CRWA and both Rich Claytor and Nigel Pickering of Horsley Witten Group (CRWA *et al.* 2010). The development of these costs was based on a literature review of BMP cost information and Claytor's extensive experience working in this field with Massachusetts communities. These values were originally reported in Appendix B of the aforementioned CRWA document. Those cost estimates have also been used in additional stormwater studies supported by EPA – Region I, including the *Sustainable Stormwater Funding Evaluation for the Upper Charles River Communities of Bellingham, Franklin, and Milford, MA (*2011). (That report can be viewed at: http://www.epa.gov/region1/npdes/charlesriver/pdfs/20110930-SWUtilityReport.pdf)

Before simply relying on the CRWA cost estimates, additional research was conducted of publicly available (online) resources to determine if more recent BMP cost information for the New England region was available. These resources included:

- EPA's LID webpage: http://water.epa.gov/polwaste/green/
- EPA's 2013 Article: *Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs: http://water.epa.gov/polwaste/green/upload/lid-gi-programs_report_8-6-13_combined.pdf*

- New England Environmental Finance Center: http://efc.muskie.usm.maine.edu/
- UNC Environmental Finance Center's *Catalog of Finance Publications on Green Infrastructure Approaches to Stormwater Management* (This spreadsheet provides a catalog of 46 publications related on green infrastructure for stormwater management that have finance relevance; Several of the sources from the catalog were reviewed for this document) : http://www.efc.sog.unc.edu/reslib/item/catalog-green-infrastructure-and-stormwater-finance-publications
- Houle, *et al. Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management*: http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/Houle_JEE_July-2013.pdf
- University of New Hampshire Stormwater Center's *Forging the Link: Linking the Economic Benefits of LID and Community Decisions: http://www.unh.edu/unhsc/forging-link-topics*
- Center for Neighborhood Technology's *Green Values Stormwater Tool Box: http://greenvalues.cnt.org/* which included the Green Values Calculator: http://greenvalues.cnt.org/national/calculator.php
- Water Environment Research Foundation (WERF): User's Guide to the BMP and LID Whole Life Cost Models, Version 2.0: www.werf.org/bmpcost
- Low Impact Development Center: http://www.lowimpactdevelopment.org/
- ECONorthwest's *The Economics of Low-Impact Development: A Literature Review:* http://www.econw.com/our-work/publications/the-economics-of-low-impact-development-a-literature-review/
- Drexel University's Low Impact Development Rapid Assessment (LIDRA Model) http://www.lidratool.org/home/publications.aspx

A review of these resources did highlight the multitude of variables that can impact the cost of installing LID BMPs and the variety of cost analysis methods that can be used when assessing the cost effectiveness of various LID storm water controls. For example, many of the resources emphasized that costs tend to be site specific. Costs often differ significantly among different geographical locations, depending upon labor and material expenses and the constraints of a particular site. Unfortunately, most of the aforementioned resources highlighted projects outside of the New England region (with the exception of the articles by Houle of the UNHSC and New England Environmental Finance Center.)

EPA's recent (2013) report entitled *Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs* listed the 7 different types of economic analyses that were represented by the 13 case studies highlighted in the report. These ranged from the simplest form of economic analysis (i.e., the capital cost assessment) to more robust forms, including the life cycle cost assessment. Whole life-cycle costs would provide a more accurate estimate of the cost of installing, operating, maintaining, and replacing a project (i.e., BMP) throughout its expected lifetime. However this type of analysis requires solid estimates for capital, land purchase, O&M, and other related costs.

Ideally, the goal was to include a more advanced economic analysis (i.e. – life cycle costs) in the Opti-Tool while still maintaining some level of simplicity for the end user. However, such a robust economic analysis does not currently appear possible because the literary search for more recent BMP cost estimates, reflective of New England states, was largely unsuccessful. However, the search was not

entirely fruitless. Jamie Houle of the UNHSC did provide extremely valuable information on capital and maintenance costs for various BMPs that have been tested at the UNHSC. Cost estimates for a particular BMP available from *both* the CRWA study and UNHSC were discussed among Mark Voorhees of EPA, Jamie Houle of UNHSC, and Karen Mateleska of EPA, and a best professional judgment decision was made.

The recommendation at this time is to use a combination of the CRWA cost estimates **and** UNHSC costs estimates as the basis for the Opti-Tool BMP cost estimates, and to use a modified capital cost assessment (which includes a fixed percentage for Design and Contingency Costs) as well as a separate field for maintenance hours (from the UNHSC). The details supporting this approach are described below.

Overview of Scope and Approach

According to a draft memo, dated 6/20/14 from Tetra Tech to EPA Region I, the current SUSTAIN BMP Cost function has seven major individual components, using a formula that would likely be useful in a more detailed design mode. For purposes of simplicity, EPA Region I is proposing the following cost function formula for the tool's "planning" mode:

General Cost Function Formula = Storage Volume of BMP* (ft^3) X Cost Estimate for BMP ($/$ft^3$)

X Adjustment Factor

* Storage Volume of BMP is more accurately defined as (Design) Physical Storage Capacity of BMP; See Section A below for more details

Initially, the intention was to include the preliminary Operations and Maintenance (O&M) costs in the general formula (page 3) by simply multiplying the formula results by our Preliminary O & M costs. However, such an approach would only include **one year's worth** of operations and maintenance, which could have been misleading because it would not have reflected the true life cycle cost of the BMP (i.e., assume life cycle of 20 years). However, simply including the 20 year life cycle cost (O&M cost *20) in the above formula would have greatly increased the cost value and perhaps have created misconceptions about BMP use and affordability.

Therefore, the subcommittee decided to include the anticipated operation and maintenance **hours** required for each BMP per year instead. This parameter was included as a completely separate field in the Opti-Tool. The rationale was that Opti-Tool users need to understand that operation and maintenance impact the overall cost-effectiveness of BMPs and should be considered when selecting a BMP. Including O&M hours (instead of costs) as a separate field, would still highlight this important consideration for stormwater managers.

A. Storage Volume and Proposed Cost Estimate Values

As highlighted above, the general cost function formula used in the Opti-Tool consists of 3 factors: the BMP storage volume, the proposed BMP storage volume cost estimate, and the adjustment factor. The first two factors will be covered together in this memo because they are so closely linked. Table 1 below summarizes the proposed BMP cost estimates for the Opti-Tool.

Table 1: Proposed BMP Cost Estimates for Opti-Tool

BMP (From Opti-Tool)	Cost ($/ft^3) [1]	Cost ($/ft^3) – 2016 dollars[6]
Bioretention (Includes rain garden)	13.37 [2,4]	15.46
Dry Pond or detention basin	5.88 [2,4]	6.80
Enhanced Bioretention (aka-Bio-filtration Practice)	13.5 [2,3]	15.61
Infiltration Basin (or other Surface Infiltration Practice)	5.4 [2,3]	6.24
Infiltration Trench	10.8 [2,3]	12.49
Porous Pavement - Porous Asphalt Pavement	4.60 [2,4]	5.32
Porous Pavement - Pervious Concrete	15.63 [2,4]	18.07
Sand Filter	15.51 [2,4]	17.94
Gravel Wetland System (aka-subsurface gravel wetland)	7.59 [2,4]	8.78
Wet Pond or wet detention basin	5.88 [2,4]	6.80
Subsurface Infiltration/Detention System (aka-Infiltration Chamber)	54.54[5]	67.85

[1] Footnote: Includes 35% add on for design engineering and contingencies

[2] Costs in 2010 dollars

[3] From CRWA Cost Estimates

[4] From UNHSC Cost Estimates; Most of original costs were from 2004 and converted to 2010 dollars using U.S. Department of Labor (USDOL). (2012). Bureau of Labor Statistics consumer price index inflation calculator. http://www.bls.gov/data/inflation_calculator.htm

[5] From Cost Estimate of MA TT Rizzo Project (2008 Dollars)

[6] 2010 costs were converted to 2016 values to adjust for inflation. The ENR Cost Index Method was used for this conversion.

Table 1 includes all of the BMPs that are included in the Opti-Tool. The unit costs represent the dollar amount ($) per cubic foot of storage volume (ft^3), where the storage volume reflects the (design) physical static storage capacity that the relevant BMP can hold. This volume includes the volume of ponding water *and* the volume of water retained in the porous media or subbase materials if applicable. (This storage volume does *not* represent the *treated* volume of stormwater, which may be significantly higher than the physical storage volume of a BMP particularly for systems that are sized dynamically or

by a water quality flow rate as opposed to a water quality volume.) This unit cost per storage volume captured by a BMP differs from other (perhaps more traditional) methods that can be used. By choosing to use the unit cost per storage volume instead of volume of water treated, we are trying to eliminate confusion over what the actual dimensions of the BMP will be for the costs being estimated. Additionally, this use of the unit cost per storage volume is consistent with the approach used in developing the BMP performance curves (used in the Opti-Tool) where the x-axis is the actual **physical storage capacity** to hold water. Lastly, expressing the unit costs in this manner will benefit users who are simply interested in using the unit costs (outside of the Opti-Tool) by eliminating the step of modeling hydrology and routing the water through the BMP, which can yield widely varying results depending on modeling approach and supporting assumptions. Attachment A describes the method used in calculating the design storage volume for each of the selected BMPs.

Also, each unit cost per storage value represents the capital cost of construction/installation of the BMP and includes a 35% design/engineering/contingency (D & E) cost. This 35% fixed percentage of the total construction cost follows a general "rule of thumb," often used by consulting firms. Based upon a conversation between Mark Voorhees and Jamie Houle (two members of the Opti-Tool cost subcommittee), a decision was made to include this D&E cost. The values in Table 1 do *not* include the cost of purchasing any land, nor does it include any O&M costs (which is discussed in more detail in a subsequent section). Therefore, each unit cost in Table 1 that was based on the CRWA's 2010 values was calculated by multiplying the relevant BMP cost by 1.35.

Since the CRWA study did not include cost estimates for porous pavement or sand filters, which are BMPs included in the Opti-Tool, relevant data was obtained from Jamie Houle of the University of New Hampshire Stormwater Center (UNHSC). He also provided additional cost estimates (as denoted by Footnote 4 in Table 1) for some of the other BMPs included in the tool. UNHSC can provide valuable data because they have been directly involved with the engineering, design and construction of numerous LID controls, as well as evaluating multiple stormwater treatment systems over multiple years at their primary field research facility in Durham, N.H. Since they could provide cost information for both porous asphalt pavement and pervious concrete, separately, the general category of porous pavement was divided into the aforementioned two sub-categories.

It should be noted that the costs used for the Opti-tool *assume linearity*, which will both allow for *and* incentivize the scaling to smaller-sized systems. For example, EPA has estimated that *smaller* capacity designs for BMPs, rather than large-sized BMPs, can increase both the technical and economic feasibility of installing controls, particularly for retrofits. The assumption of linearity was made for the following reasons: 1) Limited data currently exists on the cost of small capacity systems. Until a larger pool of cost data becomes available which will allow for the development of a non-linear cost curve, the current method is the best available alternative; 2) As the installation of smaller systems becomes more wide-spread, it is likely that economies of scale will develop and cost savings will occur. For example, if one entity is contracted to install multiple small systems at once, materials can be bought in bulk and the installation process can become more efficient and less expensive; 3) An undersized system built to treat a large area can be a very cost effective approach. As an example, there should not be a significant cost difference between a 1-inch system treating 1 acre and a 1/10-inch-system that treats 10 acres, since the absolute capacity of the system is the same in both cases. This topic of linearity will be revisited in the future when more data is available.

Since UNHSC typically calculates the capital costs per cubic foot (ft^3) *treated*, using WQv, Jamie Houle converted the costs to represent the capital costs per BMP storage volume (ft^3). This was necessary so the capital cost data would be consistent with the method used in the Opti-Tool. Also, all of the costs were converted to 2010, and ultimately 2015, dollars. As with the CRWA costs, the UNHSC capital costs were already adjusted to include the 35% design/engineering/contingency (D & E) cost. Details of all of these calculations, and any other assumptions made, are presented in Attachment B.

When developing cost estimates, another topic for consideration was whether or not to address the issue of inflation. CRWA's BMP cost estimates were based on capital costs from 2010. As previously stated, UNHSW's cost estimates have also already been converted to constant 2010 dollars using consumer price index inflation rates [U.S. Department of Labor (USDOL) 2014].[1] Therefore, there was the option of converting all of these 2010 costs to 2016 costs, using the U.S. Department of Labor's consumer price index inflation calculator. However, another suggestion was made to use the ENR Cost Index method to adjust for inflation instead because it more closely tracks construction work. At least one New England state (i.e., Vermont) also uses the ENR Cost Index method, so this could provide some consistency, as well. Therefore, the decision was made to ultimately convert all of the costs to 2016 values using the ENR Cost Index method. These values are reflected in Table 1.

To use the index, one calculates the quotient of the current index number (based on the month and year of *current* date) divided by the index number from a given date (e.g., June of 2010). Since the month was not known for the 2010 costs, the month of June was used as an estimate. This assumption was used because it falls mid-way between the construction season and would likely provide a reasonable estimate. Once the quotient was calculated, it was multiplied by the construction cost (found in the middle column in Table 1, above) to provide the 2016 construction cost value

B. Cost Adjustment Factor

Since the cost of installing a BMP will vary depending on the specific site location, the TAC subcommittee believed it was important for the Opti-Tool to include a scalable cost adjustment factor. The proposed cost estimates for the Opti-Tool (in Table 1) are all based on a Cost Adjustment Factor of 1. However, each Opti-Tool user has the option to choose and enter into the tool a cost adjustment factor that is appropriate for their site. This will adjust the storage volume cost function in the Opti-Tool.

For example, the CRWA report included the cost factors summarized in Table 2.

[1] Reference: U.S. Department of Labor (USDOL). (2014). Bureau of Labor Statistics consumer price index inflation calculator." ⟨http://www.bls.gov/data/inflation_calculator.htm⟩(Sep. 12, 2014)

Table 2: Example of Cost Adjustment Factors

BMP Type	**EXAMPLE** Cost Adjustment Factor
New BMP in undeveloped area	1
New BMP in partially developed area	1.5
New BMP in developed area	2
Difficult installation in highly urban settings	3

(Source: Table 4 of Appendix B of CRWA's Spruce Pond Brook Subwatershed Project for Town of Franklin)

The assumption made was that it would cost more to install a new BMP in a developed area (with more site constraints) than it would cost to install the same BMP in a previously undeveloped area. So in the above example, the cost adjustment factor would be 2 for installing a BMP in a previously developed area versus a cost adjustment factor of 1 for installing a BMP in an undeveloped area.

It should be noted that Table 2 (above) provides just *one example* of adjustment factors. The factor should be flexible enough so that another location (or Opti-Tool user) can adjust it, as needed. For example, the Charles River Watershed (in eastern Massachusetts) used an adjustment factor of 2 for installing a BMP in a developed area, while the State of Vermont uses an adjustment factor of 1.4 to estimate the cost of installing a BMP for existing development.

C. Maintenance (O&M) Costs

Originally, one goal was to include Operation and Maintenance (O&M) costs as part of the cost estimates for the Opti-Tool. These O&M costs would help to provide a more realistic reflection of the long-term expenses of structural storm water controls, which is obviously critical in the practical, real-world implementation of BMPs. However, it is difficult to obtain accurate maintenance costs and they will be highly variable depending on the size, location and equipment needed to perform long-term O&M.

This point was highlighted by a key finding in EPA's recent (2013) publication, *Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs.* The report indicated that only a small percentage of the entities that implement LID and GI approach for stormwater management conduct economic analyses due to the "uncertainties surrounding costs, operation and maintenance (O&M) requirements, budgetary constraints, and difficulties associated with quantifying the benefits provided by LID/GI" and the need "to obtain better estimates of the O&M costs associated with different types of LID/GI projects" was a key finding of the report.

As previously mentioned, one article entitled, *Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management* (Houle *et al. 2013)*, did contain relevant information for BMP costs in the New England region. During initial discussions between EPA Region I (Mark Voorhees) and UNHSC (Jamie Houle), there was concern that not enough data existed on O&M costs to propose accurate values for each of the BMPs included in the Opti-Tool. There was also

the concern that the O&M costs were not scaleable. For example, initial O&M costs for each BMP were based on the cost of operation and maintenance per year per acre of IC treated. Scaled differences such as the annual O&M costs for treating 0.5 acres of IC or 2 acres of IC have **not** been evaluated and may or may **not** result in a simple linear relationship. Yet the Opti-Tool costs subcommittee also realized the importance of including some maintenance parameter in order to *initiate* the conversation on the importance of accounting for O&M to maintain the functionality of the BMPs. Therefore Table 3, below, presents these annual maintenance costs (in $) for select BMPs, as well as the annual maintenance hours. Although the O&M costs have been presented in this memo, only the O&M **hours** will be included (as a separate field) in the Opti-Tool.

Table 3: Maintenance Costs ($) and Hours per year for select BMPs – From UNHSC

BMP	Maintenance Cost ($) per year	Annual Maintenance Hours
Bioretention	$1,890.00	20.7
Chamber System	Not Assessed	Not Assessed
Detention Pond	$2,380.00	24.0
Gravel Wetland	$2,138.33	21.7
Porous Asphalt	$1,080.00	6.0
Pervious Concrete	$1,080.00	6.0
Retention Pond	$3,060.00	28.0
Sand Filter	$2,807.50	28.5

*Note: initial costs based on cost of maintenance per year per acre of IC treated

Annual maintenance strategies were evaluated by directly quantifying hours spent categorizing maintenance activities, and assessing difficulty of those activities. To better illustrate costs and anticipate maintenance burdens, activities were characterized into distinct categories and a standard cost structure was applied. This unit conversion can easily be adapted according to local conditions, current economic climate, and regional cost variations which is why we decided to go with maintenance **hours** as those were directly measured and should remain constant. These maintenance activity categories allow more accurate cost predictions and provide insight into the appropriate assignment of maintenance responsibilities.

Annual maintenance costs were normalized to 2012 dollars and calculated for all SCMs by both dollars and personnel hours per acre of IC treated per system per year. It is important to note that inflation was not considered in life cycle maintenance cost projections.

D. Cost Estimate Calculations

Appendix D: Cost Estimate Calculations

Estimated Costs of Planned Structural BMPs

Property Address	Property Name	BMP Type	Approximate Drainage Area (SF)	Assumed Depth of Runoff (in)[1]	Approximate Required Storage Volume (CF)[2]	Storage Volume Cost per Opti-Tool[3] (2016)	Adjustment Factor[3]	Estimated Cost (2016)	Estimated Cost (2023)[4]	Planned Construction Year	Estimated Cost (Construction Year)[5]	Applied Contingency	Estimated Cost (Construction Year)[5]
486 Chapin Street	Veterans Park Elementary School	On Site Impervious Area Reduction	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2023	N/A	N/A	N/A
24 Center Street	Hubbard Memorial Library	Bioretention Area	37,800	1.0	3,150	$15	2.0	$97,000	$128,000	2027	$147,000	40%	$206,000
167 Howard Street	Whitney Park	Bioretention Area	23,900	1.0	1,992	$15	2.0	$62,000	$82,000	2030	$104,000	40%	$146,000
211 Highland Avenue	John F. Thompson Memorial Swimming Pool	Infiltration Trench	12,500	1.0	1,042	$12	2.0	$26,000	$34,000	2033	$48,000	40%	$68,000
499 Center Street	Island Pond Cemetery	Bioretention Area	11,400	1.0	950	$15	2.0	$29,000	$38,000	2036	$59,000	40%	$83,000

[1] Assumed 1.0 inch depth of runoff per Massachusetts Stormwater Handbook Volume 1 Chapter 1 to be conservative in sizing the system and given that the estimated drainage area is from roadways with a high potential pollutant load. (*Massachusetts Stormwater Handbook Volume 1 Chapter 1: Overview of Massachusetts Stormwater Standards* . (n.d.). Retrieved from https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.mass.gov%2Fdoc%2Fmassachusetts-stormwater-handbook-vol-1-ch-1-stormwater-management-standards%2Fdownload&wdOrigin=BROWSELINK)

[2] Storage volume calculated as runoff depth multiplied by the total impervious area treated, similarly to the required water quality volume outlined in the Massachusetts Stormwater Handbook Volume 2 Chapter 2. (*Massachusetts Stormwater Handbook Volume 2 Chapter 2: Structural BMP Specifications for the Massachusetts Stormwater Handbook*. (n.d.). Retrieved from https://www.mass.gov/doc/massachusetts-stormwater-handbook-vol-2-ch-2-stormwater-best-management-practices/download)

[3] Karen Mateleska, EPA Region-I. (2016, February 20). *Methodology for developing cost estimates for Opti-Tool* . Retrieved from https://www3.epa.gov/region1/npdes/stormwater/tools/green-infrastructure-stormwater-bmp-cost-estimation.pdf

[4] Costs converted to 2023 dollars using the Engineering News-Record Construction Cost Index History (*Engineering News-Record Construction Cost Index History - As of August 2023*. (2023, August). Retrieved from Engineering News-Record: https://www.enr.com/economics/historical_indices/construction_cost_index_history)

[5] Costs adjusted to future year prices assuming 3.5% annual construction cost increase per 2022 CBRE study of forecasted construciton costs. (CRBE. (2022, July 6). *2022 U.S. Construction Cost Trends* . Retrieved from https://www.cbre.com/insights/books/2022-us-construction-cost-trends#:~:text=CBRE%E2%80%99s%20new%20Construction%20Cost%20Index%20forecasts%20a%2014.1%25,2023%20and%202024%2C%20on%20par%20with%20historical%20averages.)

Estimated O&M Costs for Planned Structural BMP Types

BMP Type	Number of Maintenance Hours per Year[1]	Yearly O&M Cost
Bioretention Area	35	$4,200
Infiltration Trench	48	$5,700

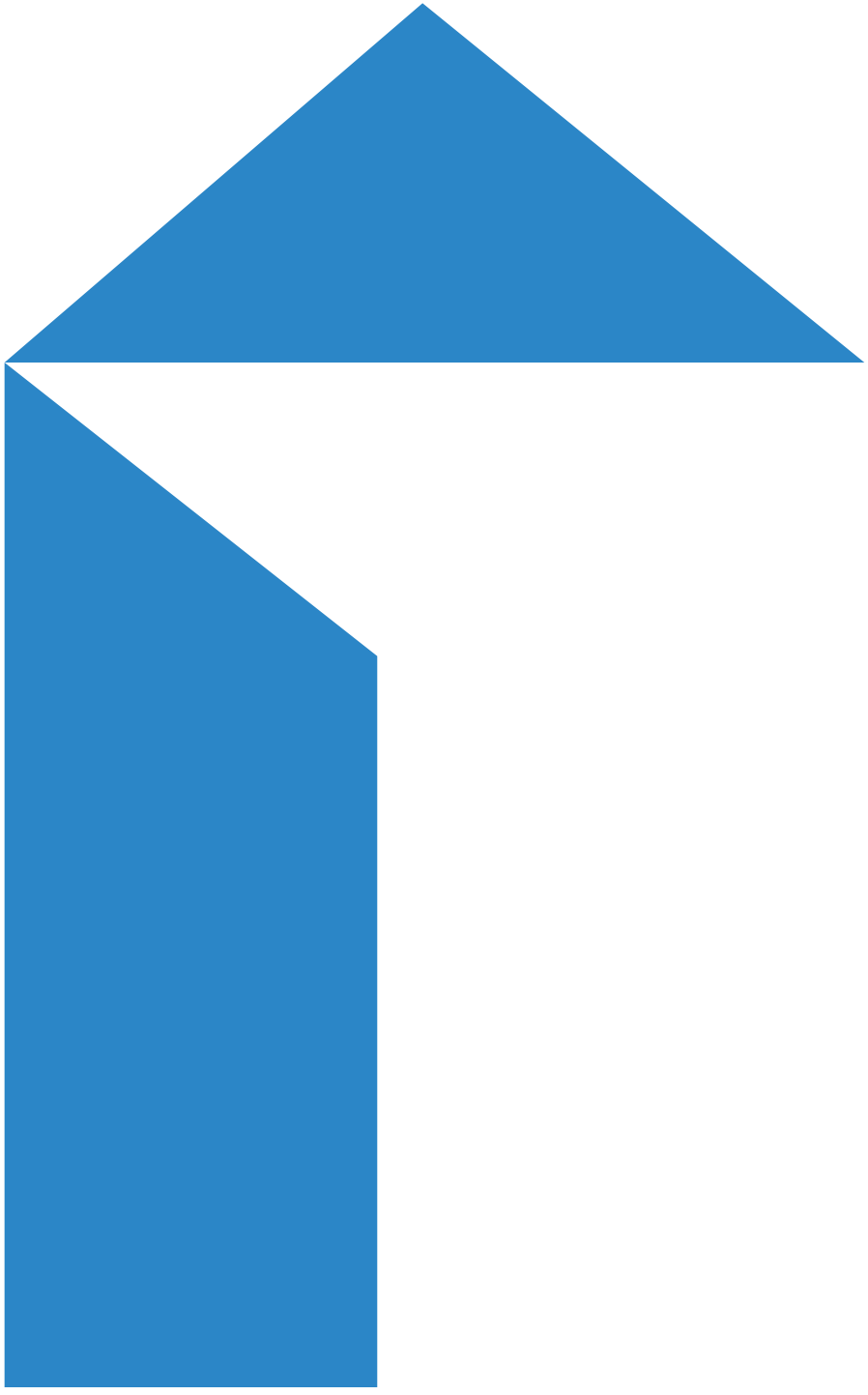
[1] Number of maintenance hours per year estimated based on recommended maintenance for each BMP Type outlined in the Massachusetts Stormwater Handbook. (*Massachusetts Stormwater Handbook Volume 2 Chapter 2: Structural BMP Specifications for the Massachusetts Stormwater Handbook.* (n.d.). Retrieved from https://www.mass.gov/doc/massachusetts-stormwater-handbook-vol-2-ch-2-stormwater-best-management-practices/download)

Estimated O&M Costs by Year

Year	Bioretention Areas Built as of Specified Year[1]	Infiltration Trenches Built as of Specified Year[1]	Estimated O&M Costs for Planned BMPs (Specified Year)[2]
2024	0	0	$0
2025	0	0	$0
2026	0	0	$0
2027	1	0	$4,800
2028	1	0	$5,000
2029	1	0	$5,100
2030	2	0	$10,600
2031	2	0	$10,900
2032	2	0	$11,300
2033	2	1	$19,700
2034	2	1	$20,400
2035	2	1	$21,100
2036	3	1	$28,300

[1] Assumes that O&M begins in the same year as the planned structural BMP installation.

[2] Costs adjusted to future year prices assuming 3.5% annual construction cost increase per 2022 CBRE study of forecasted construciton costs. (CRBE. (2022, July 6). *2022 U.S. Construction Cost Trends*. Retrieved from https://www.cbre.com/insights/books/2022-us-construction-cost-trends#:~:text=CBRE%E2%80%99s%20new%20Construction%20Cost%20Index%20forecasts%20a%2014.1%25,2023%20and%202024%2C%20on%20par%20with%20historical%20averages.)



B. Structural BMP Tracking and Estimated Nitrogen Removal

Town of Ludlow BMP Tracking

Revised: September 2023

BMP ID or Description	Location	BMP Type from Plans	Functional BMP Type to Match Model	Total Drainage Area (Ac)	Impervious Drainage Area (Ac)	Estimated Storage Volume (cf)	Estimated Nitrogen Removal (lb/yr)
BMP-CHE03-01	End of Isabel Lane before Chicopee River	Detention Basin	Dry Pond/Detention Basin	2.17	0.86	717	4.0
BMP-CHW05-01	Riverside Drive, inside manhole just upstream of CHW05 outfall	Hydrodynamic Separator	Proprietary	9.32	7.13	N/A	0.0
BMP-CHW11-01	North of Riverside Drive	Rain Garden	Bioretention	5.12	3.54	16,000	30.0
BMP-CHW11-02	North of Riverside Drive	Rain Garden	Bioretention	1.03	0.87	5,375	8.1
BMP-CHW11-03	Riverside Drive, inside of manhole upstream of CHW11 outfall and to the east	Hydrodynamic Separator	Proprietary	6.13	4.42	N/A	0.0
BMP-CHW11-04	Riverside Drive, inside of manhole upstream of CHW11 outfall and to the west	Hydrodynamic Separator	Proprietary	0.73	0.45	N/A	0.0
BMP-CHW11-05	North of Riverside Drive and South of the Healthsouth Rehabilitation Hospital	Infiltration Basin	Infiltration Basin (or practice)	3.70	2.51	41,740	26.1
BMP-CHW11-06	North of Riverside Drive and West of the Healthsouth Rehabilitation Hospital	Bioretention	Bioretention	1.06	0.64	633	3.0
BMP-CHW11-07	North of Riverside Drive and West of the Healthsouth Rehabilitation Hospital	Bioretention	Bioretention	1.54	0.69	787	3.5
BMP-CHW11-08	North of Riverside Drive and East of the Healthsouth Rehabilitation Hospital	Bioretention	Bioretention	2.95	0.57	1,344	4.1
BMP-CHW11-09	North of Riverside Drive and South of the Healthsouth Rehabilitation Hospital	Bioretention	Bioretention	0.48	0.42	1,134	3.0
BMP-CHW11-10	North of Riverside Drive and South of the Healthsouth Rehabilitation Hospital	Bioretention	Bioretention	0.64	0.36	1,187	2.8
BMP-CHW11-11	North of Riverside Drive and South of the Healthsouth Rehabilitation Hospital	Bioretention	Bioretention	0.24	0.13	543	1.1
BMP-CHW12-01	North of Riverside Drive	Infiltration Trench	Infiltration Trench	0.79	0.41	3,300	4.1
BMP-CHW12-02	North of Riverside Drive	Rain Garden	Bioretention	0.86	0.48	2,468	4.2
BMP-CHW12-03	Riverside Drive, inside 2nd manhole upstream of CHW12 outfall	Hydrodynamic Separator	Proprietary	2.33	1.47	N/A	0.0
BMP-HGB10-01	At the Cul-de-sac of Harris Lane and discharges into harris pond	Detention Basin	Dry Pond/Detention Basin	17.86	7.15	25,954	58.6
BMP-MBT09-01	End of Irla Drive (second Cul de sac)	Underground Infiltration Chamber	Infiltration Basin (or practice)	1.01	0.39	1,410	3.2

Town of Ludlow BMP Tracking

Revised: September 2023

BMP ID or Description	Location	BMP Type from Plans	Functional BMP Type to Match Model	Total Drainage Area (Ac)	Impervious Drainage Area (Ac)	Estimated Storage Volume (cf)	Estimated Nitrogen Removal (lb/yr)
BMP-MCP01-01	BMPs Connected halfway up King Street	Leaching Galley	Infiltration Trench	2.02	0.84	509	3.3
BMP-MCP01-02	BMPs Connected halfway up King Street	Leaching Galley	Infiltration Trench				
BMP-MCP01-03	BMPs Connected halfway up King Street	Leaching Galley	Infiltration Trench				
BMP-MCP01-04	Connected at the end of King St	Leaching Galley	Infiltration Trench	0.70	0.61	339	2.0
BMP-MCP01-05	Connected at the end of King St	Leaching Galley	Infiltration Trench				
BMP-MCP03-01	At the end of Bowles Avenue	Leaching basin	Infiltration Trench	2.44	0.59	1,553	4.4
BMP-MCP03-02	At the end of Bowles Avenue	Leaching Basin	Infiltration Trench				
BMP-TCH01-01	Between Parker Ln and Miller St	Detention Basin	Dry Pond/Detention Basin	12.00	3.94	14,300	40.2
BMP-TCH01-02	Parker Lane	Detention Basin	Dry Pond/Detention Basin	11.15	1.97	7,139	22.1
BMP-TCS02-01	Northwood Circle first drainage pipe	Detention Basin	Dry Pond/Detention Basin	5.58	2.03	5,793	17.0
BMP-WHA01-01	Allison Lane	Wet Pond	Wet Pond	13.00	2.25	36,694	18.5
BMP-XXX-01	Applewood Drive	Gravel Wetland	Gravel Wetland	1.32	0.75	3,300	3.7
BMP-XXX-02	Applewood Drive	Infiltration Trench	Infiltration Trench	0.44	0.20	420	1.4
BMP-XXX-03	Applewood Drive	Infiltration Trench	Infiltration Trench	0.30	0.13	420	1.0
BMP-XXX-04	Applewood Drive	Infiltration Trench	Infiltration Trench	0.58	0.23	420	1.4
BMP-XXX-05	Applewood Drive	Infiltration Trench	Infiltration Trench	0.31	0.14	420	1.1
BMP-XXX-06	Autumn Ridge Road	Infiltration Basin	Infiltration Basin (or practice)	15.96	1.93	6,992	24.9
BMP-XXX-07	Intersection of Autumn Ridge Rd and Turning Leaf Rd	Infiltration Basin	Infiltration Basin (or practice)	15.65	1.93	6,992	27.2
BMP-XXX-08	At end of Avelino Way at court	Wet Pond	Wet Pond	8.22	1.64	5,968	9.8
BMP-XXX-09	At intersection of avelino and Alden st	Infiltration Trench	Infiltration Basin (or practice)	0.81	0.16	904	1.8
BMP-XXX-10	At intersection of avelino and Alden st	Infiltration Trench	Infiltration Basin (or practice)	0.81	0.16	904	1.8
BMP-XXX-11	End of Brook Hollow Drive	Dry Well	Infiltration Trench	4.57	1.23	267	3.0
BMP-XXX-12	Intersection of Brook Hollow and Church St	Dry Well	Infiltration Trench	0.29	0.16	107	0.6
BMP-XXX-13	Intersection of Brook Hollow and Church St	Dry Well	Infiltration Trench	2.88	0.71	68	1.7
BMP-XXX-14	Intersection of Colonial Dr. and Munsing St.	Dry well	Infiltration Trench	0.19	0.06	170	0.5
BMP-XXX-15	Intersection of Colonial Dr. and Munsing St.	Dry Well	Infiltration Trench	0.26	0.15	170	0.8
BMP-XXX-16	Lower basin--Closer to Cady Street between Daisy and Focosi	Wet Pond	Wet Pond	9.22	2.09	7,575	10.1
BMP-XXX-17	Upper basin--at intersection of daisy and focosi	Wet Pond	Wet Pond	3.82	0.89	3,225	4.3
BMP-XXX-18	Daisy Lane	Detention Basin	Dry Pond/Detention Basin	2.59	0.75	2,707	6.1

Town of Ludlow BMP Tracking

Revised: September 2023

BMP ID or Description	Location	BMP Type from Plans	Functional BMP Type to Match Model	Total Drainage Area (Ac)	Impervious Drainage Area (Ac)	Estimated Storage Volume (cf)	Estimated Nitrogen Removal (lb/yr)
BMP-XXX-19	Deer Hill Circle	Detention Basin	Dry Pond/Detention Basin	2.92	0.88	18,700	11.3
BMP-XXX-20	Jerad Dr btwn lot 1 and 2	Detention Basin	Dry Pond/Detention Basin	4.70	0.95	3,452	9.8
BMP-XXX-21	Jerad Dr btwn lot 4 and 5	Detention Basin	Dry Pond/Detention Basin	2.95	1.04	3,768	9.4
BMP-XXX-22	West of Jerad Drive Bend	Detention Basin	Dry Pond/Detention Basin	6.58	2.29	8,322	20.9
BMP-XXX-23	Between Emma way and Mariana lane	Wet Pond	Wet Pond	7.36	2.13	7,728	11.8
BMP-XXX-24	Dinis Ave	Detention Basin	Dry Pond/Detention Basin	5.66	1.95	7,090	18.3
BMP-XXX-25	Pinewood Circle	Detention Basin	Infiltration Basin (or practice)	12.39	4.17	50,901	49.7
BMP-XXX-26	Rosewood Dr. larger basin	Infiltration Basin	Infiltration Basin (or practice)	14.43	2.29	59,833	33.6
BMP-XXX-27	Rosewood Dr. smaller basin	Infiltration Basin	Infiltration Basin (or practice)	12.69	1.37	34,763	21.8
BMP-XXX-28	At Sportsman Rd and Service Area Access Rd	Detention Basin	Dry Pond/Detention Basin	1.56	0.82	2,964	6.6
BMP-XXX-29	Near Baird Middle School	Detention Basin	Dry Pond/Detention Basin	4.42	2.58	2,291	11.3
BMP-XXX-30	At Spring Meadow Dr and Sunbriar Ln	Detention Basin	Dry Pond/Detention Basin	6.81	2.45	17,500	26.1
BMP-XXX-31	Watson Lane	Detention Basin	Dry Pond/Detention Basin	10.09	2.89	10,476	27.4
BMP-XXX-32	North of Wedgewood Drive	Detention Basin	Dry Pond/Detention Basin	9.23	2.77	35,925	31.9
BMP-XXX-33	Westover Road near the air force base	Wet Pond	Wet Pond	4.63	0.00	246,586	0.7
BMP-XXX-34	Woodside Road	Detention Basin	Dry Pond/Detention Basin	2.23	0.93	15,300	9.8
BMP-XXX-35	Woodland Circle 1B	Detention Basin	Dry Pond/Detention Basin	4.03	1.55	5,623	14.6
BMP-XXX-36	Woodland Circle 2C	Detention Basin	Dry Pond/Detention Basin	6.44	2.27	8,226	21.4
BMP-XXX-37	Woodland Circle 2D	Detention Basin	Dry Pond/Detention Basin	9.93	2.44	8,845	25.3
BMP-XXX-38	Woodland Circle 2A	Detention Basin	Dry Pond/Detention Basin	4.31	1.47	5,329	13.4
BMP-XXX-39	DPW Yard	Dry Well	Infiltration Trench	0.41	0.37	170	1.1
BMP-XXX-40	DPW Yard	Dry Well	Infiltration Trench	0.43	0.42	170	1.0
			Totals:	**307.2**	**96.0**		**742**

C. Lake Phosphorus Control Plan – Minechoag Pond

MOTT MACDONALD

Town of Ludlow Year 5 Massachusetts Small MS4 General Permit

Lake Phosphorus Control Plan (LPCP) - Minechoag Pond

September 2023

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Town of Ludlow Year 5 Massachusetts Small MS4 General Permit

Lake Phosphorus Control Plan (LPCP) - Minechoag Pond

September 2023

Based on a document originally prepared by Kleinfelder for Charles River Watershed Association (CRWA) and MassDEP in June 2021. Updated June 2022, with additional information and feedback from MassDEP.

Issue and revision record

Revision	Date	Originator	Checker	Approver	Description
A	9/15/2023	Alexandra Wagner	Suzanne Newman	Suzanne Newman	Draft
B	9/22/2023	Alexandra Wagner	Suzanne Newman	Suzanne Newman	Revised Draft

Document reference: 507108568 |

Information class: Standard

Contents

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Appendices

LAKE PHOSPHORUS CONTROL PLAN (LPCP)

1 LPCP

The 2016 National Pollutant Discharge Elimination System General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4) in Massachusetts ("MS4 Permit" or "the Permit") took effect on July 1, 2018. The Permit was subsequently modified on December 7, 2020. The MS4 Permit conditions the operation, regulation, and management of MS4s in subject Massachusetts municipalities. Terms and conditions include requirements across six Minimum Control Measures (also referred to as Maximum Extent Practicable or MEP provisions), and water quality-based effluent limitations (WQBEL), including requirements for waterbodies with approved Total Maximum Daily Loads (TMDLs) and other water quality-limited waters.

There are thirteen approved TMDLs covering 78 lakes and ponds located in the Commonwealth of Massachusetts. As an element of the Permit's WQBEL provisions, communities that discharge to one or more of the waterbodies included in the TMDLs are obligated to address phosphorus impairments through the development and implementation of a Lake Phosphorus Control Plan (LPCP). Appendix F of the MS4 Permit describes specific requirements of the LPCP, implementation of which is anticipated to achieve the TMDL-established targeted phosphorus reductions over a 15-year timeframe. LPCP implementation includes structural and non-structural best management practices (BMPs) executed through programs, projects, and policies. The LPCP must be fully implemented within 15 years of the Permit effective date (i.e., by June 30, 2033), as illustrated in **Table 1-1**. The targeted phosphorus reductions are broken out into interim mandatory milestones, culminating in achievement of the allowable TMDL phosphorus loads for each municipality at the end of the 15-year schedule.

Table 1-1: General LPCP Implementation Timeline for Lake and Pond Communities

Timeframe	Deadline (End of Fiscal Year)	Phosphorus Reduction Requirement (% of Total)
0-8 years	2026	20%
5-10 years	2028	40%
10-13 years	2031	70%
13-15 years	2033	100%

1.1 OVERVIEW OF LPCP MILESTONES

This document represents the LPCP and outlines all the major milestones as required by the Permit Appendix F. The LPCP must mitigate the phosphorus load reduction requirement within these 15 years, with an interim milestone of achieving the first 20% of phosphorus load reduction by Year 8 (i.e., by June 30, 2026), 40% by Year 10 (i.e., by June 30, 2028), and 70%

by Year 13 (i.e., by June 30, 2031). The detailed components of the LPCP are outlined in **Table 1-2**.

Table 1-2: LPCP Component Deadlines

Permit Year #	Year-End (June 30th)	LPCP Component(s) Due
Year 1	2019	None
Year 2	2020	Legal Analysis
Year 3	2021	Funding Source Assessment
Year 4	2022	LPCP Scope; calculate Baseline Phosphorus, Allowable Phosphorus Load, and Phosphorus Reduction Requirement
Year 5	2023	Descriptions of the following items: - Nonstructural controls - Structural controls - O&M program for structural controls - Implementation schedule - Cost and Funding Source Assessment - Written LPCP
Year 6	2024	Full implementation of nonstructural controls Performance Evaluation
Year 7	2025	Performance Evaluation
Year 8	2026	Performance Evaluation Implementation of structural controls to achieve 20% of target phosphorus reduction
Year 9	2027	Performance Evaluation
Year 10	2028	Update written LPCP Performance Evaluation Implementation of structural controls to achieve 40% of target phosphorus reduction
Year 11	2029	Performance Evaluation
Year 12	2030	Performance Evaluation
Year 13	2031	Performance Evaluation Implementation of structural controls to achieve 70% of target phosphorus reduction
Year 14	2032	Performance Evaluation
Year 15	2033	Performance Evaluation Implementation of structural controls to achieve 100% of target phosphorus reduction

The Town of Ludlow ("the Town") acknowledges that to meet the phosphorus reduction deadlines set forth in the MS4 Permit, significant preparation is required. In order to plan, design, and construct structural controls to meet the Year 8, Year 10, Year 13, and Year 15 reduction deadlines, there is significant work to be completed during the initial years of LPCP implementation. Some controls that rely on local bylaw or regulatory updates, or engaging landowners directly through incentives, may take even longer to implement. This is taken into account in the implementation schedule.

1.2 LAKE/POND WATERSHED DESCRIPTION

The Town of Ludlow discharges to Minechoag Pond, which is subject to an approved Lake and Phosphorus TMDL and is subject to the requirements of Appendix F, Part II.1 of the Permit. See

Appendix A for an Environmental Protection Agency (EPA) map of the Waterbody Assessment and TMDL Status for Ludlow.

1.3 LPCP LOAD REDUCTION TARGETS

Permit Requirement: *The permittee shall indicate the area in which the permittee plans to implement the LPCP, this area is known as the "LPCP Area". The permittee must choose one of the following: 1) to implement its LPCP in the entire area within its jurisdiction discharging to the impaired waterbody (for a municipality this would be the municipal boundary) or 2) to implement its LPCP in only the urbanized area portion of its jurisdiction discharging to the impaired waterbody. If the permittee chooses to implement the LPCP in its entire jurisdiction discharging to the impaired waterbody, the permittee may demonstrate compliance with the Phosphorus Reduction Requirement and Allowable Phosphorus Load requirements applicable to it through structural and non-structural controls on discharges that occur both inside and outside the urbanized area.*

1.3.1 LPCP Area

Ludlow has the option to implement its LPCP either within the entirety of the community that falls within each lake or pond watershed, or just the MS4-regulated area of our community within each lake or pond watershed.

Given that the entire watershed area of Minechoag Pond is in the urbanized MS4 regulated area, Ludlow plans to implement the LPCP on the entire watershed area and will therefore calculate the Baseline Phosphorus Load within the corresponding watershed. The Reduction Requirement Percentage will be applied to this Baseline Load.

1.3.2 Baseline Phosphorus Load, Allowable Phosphorus Load, and Stormwater Phosphorus Reduction Requirement

Ludlow has calculated the Baseline Phosphorus Load in conformance with Attachment 1 to Appendix F. As outlined in the "Town of Ludlow Year 4 Massachusetts Small MS4 General Permit Phosphorous Report – Minechoag Pond," estimates of the baseline phosphorus load were created using the 2016 Land Cover/Land Use data set and the town's catchment delineations for the four outfalls that drain to Minechoag Pond. The land use identified by the "USEGENNAME" attribute in the 2016 Land Cover/Land Use data set was matched to a phosphorus load export rate based on the values in Table 1-2 in Attachment 1 to Appendix F of the Permit.

This Baseline Load represents the estimated annual phosphorus loading based on land use types, and it does not include any existing structural or non-structural BMPs already implemented. No known development has occurred within the watershed over the previous reporting period or since the 2016 land cover data set was produced. Therefore, no phosphorus load increases have been added to the baseload calculated as part of the Year 4 permit requirements.

Once the Baseline Load was calculated, the Required Percent Reduction of 48%, as identified in Table F-7 of Appendix F of the Permit, was used to determine the Stormwater Phosphorus Load Reduction Requirement, Allowable Phosphorus Load, and each of the interim milestones that must be met through this LPCP. These values are summarized in **Table 1-3**.

Table 1-3: LPCP Timeline of Reduction Requirements for Minechoag Pond

Condition	Load Value (lbs./yr.)
Baseline P-Load	*100.47*
Allowable P-Load	*52.25*
Stormwater P-Load Reduction Requirement	*48.22*
Year 8 Milestone: 20% of Reduction	*9.64*
Year 10 Milestone: 40% of Reduction	*19.29*
Year 13 Milestone: 70% of Reduction	*33.75*
Year 15 Milestone: 100% of Reduction	*48.22*

To reduce phosphorus loads to Minechoag Pond, Ludlow is planning on implementing a series of structural and non-structural BMPs, updating regulatory mechanisms as necessary to aid with achieving these goals, evaluating funding mechanisms and costs, and developing its O&M and recordkeeping programs to support the continued compliance and functionality of all installed BMPs.

1.4 LEGAL ANALYSIS

Permit Requirement: *The permittee shall develop and implement an analysis that identifies existing regulatory mechanisms available to the MS4 such as by-laws and ordinances and describes any changes to these regulatory mechanisms that may be necessary to effectively implement the LPCP. This may include the creation or amendment of financial and regulatory authorities. The permittee shall adopt necessary regulatory changes by the end of the permit term.*

Appendix F of the MS4 Permit requires Ludlow to develop and implement an analysis that identifies existing regulatory mechanisms available to the MS4 such as bylaws and ordinances and describes any changes to regulatory mechanisms that may be necessary to effectively implement the entire LPCP (the “Legal Analysis”). This may include the creation or amendment of financial and regulatory authorities.

A regulatory analysis was completed as part of the Year 2 LPCP requirements, which has been attached as Appendix B to this report. A further analysis was completed in the Permit Year 4, as required in the Permit, Part 2.3.6 b and c, to evaluate potential hindrances to low impact development and green infrastructure practices imposed by local and state regulations. Although some recommendations were made in this report, the hindrances identified are not expected to impact the controls planned as part of this phosphorus control plan. The Local Impervious Requirements Assessment and Green Infrastructure Report is attached as Appendix C.

1.5 FUNDING SOURCE ASSESSMENT

Permit Requirement: *The permittee shall estimate the cost for implementing its LPCP and describe known and anticipated funding mechanisms. The permittee shall describe the steps it will take to implement its funding plan. This may include but is not limited to conceptual development, outreach to affected parties, and development of legal authorities.*

Appendix F of the MS4 Permit requires Ludlow to describe known and anticipated funding mechanisms (e.g., general funding, enterprise funding, stormwater utilities) that will be used to fund LPCP implementation (the “Funding Source Assessment”). Ludlow completed an LPCP

Funding Source Assessment as part of the Year 3 Permit requirements, which has been attached as Appendix D.

1.6 NON-STRUCTURAL CONTROLS

Permit Requirement: *The permittee shall describe the non-structural stormwater control measures to be implemented to support the achievement of the milestones in Table F-7. The description of non-structural controls shall include the planned measures, the areas where the measures will be implemented, and the annual phosphorus reductions that are expected to result from their implementation. Annual phosphorus reduction from non-structural BMPs shall be calculated consistent with Attachment 2 to Appendix F [of the MS4 Permit]. The permittee shall update the description of planned non-structural controls as needed to support the achievement of the milestones in Table F-7 [of Appendix F of the MS4 Permit], including an update in the updated written LPCP 10 years after the permit effective date.*

Ludlow's approach for non-structural BMP implementation for LPCP compliance is detailed in this section.

1.6.1 Current Non-Structural BMPs

Ludlow has already implemented non-structural BMPs including street sweeping and catch basin cleaning as a part of their Municipal Stormwater Infrastructure Operation and Maintenance Plan, which will be expanded upon as part of the planned non-structural BMPs. The current non-structural BMPs do not qualify for phosphorus reduction credit under the frequency requirements outlined in the MS4 Permit Appendix F Attachment 2. Planned non-structural BMP credits have been calculated in section 1.6.2 below.

1.6.2 Planned Non-Structural BMPs

Ludlow is planning on making the following changes to the non-structure controls starting in permit Year 6 as funding and manpower allows. The associated phosphorus reductions are presented in **Table 1-4.**

- Street Sweeping: All streets within the Minechoag Pond watershed are planned to be swept with a mechanical broom sweeper monthly nine out of twelve months of the year.
- CB Cleaning: All catch basins within the Minechoag Pond watershed are planned to be cleaned semi-annually.
- Organic Waste and Leaf Litter Collection Program: All impervious roadways within the Minechoag Pond watershed are planned to be maintained according to an enhanced organic waste and leaf litter collection program. Attachment 2 to Appendix F of the Permit outlines the following requirements for this leaf litter collection program:
  - Gather and remove all landscaping wastes, organic debris, and leaf litter at least once per week during the period of September 1 to December 1 of each year. The gathering and removal should occur immediately following any landscaping activities in the Watershed and at additional times when necessary to achieve a weekly cleaning frequency.
  - Ensure that the disposal of these materials will not contribute pollutants to any surface water discharges.
  - Note, Attachment 2 to Appendix F also outlines that the permittee may use an enhanced sweeping program with weekly frequency as part of earning this credit provided that the sweeping is effective at removing leaf litter and organic materials. Therefore, it is anticipated that the Town will sweep weekly between September 1 to December 1 as part of the plan to meet this requirement.

Table 1-4: Planned Non-Structural Control Summary

Planned Non-Structural BMP	Average Annual Acres Managed	Average Estimated Annual P-Reduction (lbs./yr.)	Anticipated Implementation Level (frequency, sweeper type, year-round)
Street Sweeping	23.1	0.70	Monthly sweeping, mechanical broom, 9/12 months per year
CB Cleaning	23.1	0.62	Semi-annual
Organic Waste and Leaf Litter Collection Program	23.1	1.55	Weekly during the period of September 1 to December 1 each year
Total Estimated Phosphorus Credit from Planned Non-Structural Controls		2.87	

See Appendix E for more details on the non-structural control calculations.

1.7 STRUCTURAL CONTROLS

Permit Requirement: *The permittee shall develop a priority ranking of areas and infrastructure within the municipality for potential implementation of phosphorus control practices. The ranking shall be developed through the use of available screening and monitoring results collected during the permit term either by the permittee or another entity and the mapping required pursuant to part 2.3.4.6 of the Permit. The permittee shall also include in this prioritization a detailed assessment of site suitability for potential phosphorus control measures based on soil types and other factors. The permittee shall coordinate this activity with the requirements of part 2.3.6.8.b of the Permit. A description and the result of this priority ranking shall be included in the LPCP. The permittee shall describe the structural stormwater control measures necessary to support achievement of the milestones in Table F-7 [of Appendix F of the MS4 Permit]. The description of structural controls shall include the planned measures, the areas where the measures will be implemented, and the annual phosphorus reductions in units of mass/yr. that are expected to result from their implementation. Structural measures to be implemented by a third party may be included in the LPCP. Annual phosphorus reduction from structural BMPs shall be calculated consistent with Attachment 3 to Appendix F [of the MS4 Permit]. The permittee shall update the description of planned structural controls as needed to support the achievement of the milestones in Table F-7 [of Appendix F of the MS4 Permit], including an update in the updated written LPCP 10 years after the permit effective date.*

Our community plans to employ structural BMPs to detain, treat, and better manage runoff from well-defined areas of impervious surface, such as roads, parking lots, or rooftops. Semi-structural BMPs are more passive stormwater management approaches that can still produce excellent water quality benefits such as rainwater harvesting, impervious area disconnection, conversion of impervious area to pervious, and enhancement of pervious areas. For the purposes of this document, the term “structural controls” refers to both structural and semi-structural BMPs.

Structural BMPs historically have been incorporated into Ludlow via stormwater compliance for private development projects. As part of this LPCP, Ludlow has investigated methods by which structural BMPs can be implemented outside of private development projects in an effort to reduce phosphorus loads to Minechoag Pond. However, due to the land use distribution in the watershed, Ludlow is severely limited in the number and type of structural BMPs that can be implemented on Town property.

The Minechoag Pond watershed is largely made up of residential use, with approximately 62% of the watershed classified as residential, (multi-family and high-density residential or low density residential.) The next largest land-use type in the watershed is forest, accounting for approximately 13% of the watershed. This is followed by highway land-use at 12% of the watershed.[1] The majority of the forest land use area is classified as wetlands, as identified by the National Wetlands Inventory Wetlands Mapper.[2]

The breakdown of existing land use in the Minechoag Pond watershed creates significant barriers to the reduction of phosphorous loading using structural BMPs. Given that the majority of the watershed is already developed or unlikely to be developed due to wetlands, there is little opportunity to harness development-required stormwater control methods for phosphorus reduction. Additionally, Ludlow does not own any properties in the area that would be suitable for retrofit or BMP installation. Therefore, the most feasible location to install structural BMPs for phosphorus reduction will be within the right-of-way.

The following sections describe the assessment, performance, and implementation of current structural BMPs (those that were built prior to development of this LPCP) and proposed structural BMPs (those that were newly identified for LPCP compliance).

1.7.1 Current Structural BMPs

The Town already employs regulatory mechanisms to implement structural BMPs. As a result of these regulations, there are multiple constructed structural BMPs in the Minechoag Pond watershed. The associated phosphorus reduction from these constructed BMPs is outlined in **Table 1-5** and further detailed in Appendix F. Phosphorus load calculations were performed following the equations and requirements in Attachment 3 to Appendix F of the Permit.

Table 1-5: Summary of Current Structural Controls

Name of Lake/Pond Watershed in which BMP is Located	BMP ID(s)	Current Functional Structural BMP Type	Number of BMPs	Total Acres Managed	Average Estimated Annual P-Reduction (lbs./yr.)
MCP01	BMP-MCP01-01 BMP-MCP01-02 BMP-MCP01-03	Infiltration Trenches in Series	3	2.02	0.59
MCP01	BMP-MCP01-04 BMP-MCP01-05	Infiltration Trenches in Series	2	0.70	0.38
MCP03	BMP-MCP03-01 BMP-MCP03-02	Infiltration Trenches	2	2.72	1.12
		Total Estimated Phosphorus Credit from Current Structural BMPs			2.09

Existing Structural BMPs have contributed to an estimated annual load reduction of 2.09 lbs/yr. The Town has inspected and conducted appropriate maintenance of these existing BMPs in the past six months as part of their annual maintenance.

[1] Calculated using 2016 Land Cover/Land Use Mass GIS data set (https://www.mass.gov/info-details/massgis-data-2016-land-coverland-use) and Town of Ludlow GIS files.

[2] *National wetlands Inventory Surface Waters and Wetlands. (n.d.). Retrieved from https://fwsprimary.wim.usgs.gov/wetlands/apps/wetlands-mapper/*

1.7.2 Planned Structural BMPs

As noted above, the Town does not own any properties in the watershed that provide opportunities for structural BMPs. Therefore, Ludlow is limited to installation of structural BMPs in the right-of-way, where the Town can construct and maintain BMPs without acquiring property. Within the right-of-way, leaching catch basins were chosen as a preferred BMP type due to their potential for higher levels of phosphorus removal and their potential for compact or linear designs which can fit within the right-of-way.

Ludlow has considered multiple factors in developing a priority ranking for placement of leaching catch basins:

- Per the Phosphorous Report which the Town prepared for Minechoag Pond as part of the Year 4 Permit requirements, the majority of the phosphorus load is associated with catchment area MCP03, followed by MCP01, and finally MCP02. Therefore, proposed structural BMPs have been prioritized accordingly as feasible and with consideration to other prioritization factors.
- Using the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey, the watershed was analyzed by hydrologic soil group and soil texture. Structural BMPs have been prioritized based on soil type and the potential for higher infiltration rates according to soil properties and hydrologic soil group.
- Subsurface geology, depth to water table, and proximity to subsurface infrastructure are unknown at this time. These factors should be further investigated during future BMP design phases.
- The proposed structural BMPs fall within the Town right-of-way, providing sufficient maintenance access to all of the proposed leaching catch basins.
- There are no known capital plans at this time for facilities, utilities including sewer and drainage work, or roadway paving that would affect the priority ranking of leaching catch basins.
- There are no known level of service issues with the current storm sewer that would affect the priority ranking.

A high-level BMP suitability assessment was conducted using ArcGIS to identify potential locations where an existing catch basin can be supplemented by a leaching catch to mitigate phosphorus loading. The average phosphorus reduction credit per leaching catch basin was calculated using the following methods:

- The proposed leaching catch basins have been modeled as infiltration trenches, assuming infiltration will be feasible, according to Appendix F Attachment 3.
- It is assumed that each leaching catch basin would be sized to manage 1” of runoff from the contributing impervious area.
- As noted above, the USDA NRCS Web Soil Survey was used to determine hydrologic soil group and soil texture. The proposed leaching catch basin locations are located within HSG A and B areas, with either loamy sand or sandy loam soil textures.
- The assumed design infiltration rate for loamy sand and sandy loam are 2.41 inches/hour and 1.02 inches/hour, respectively.[3] The corresponding infiltration trench table from the

[3] Massachusetts Stormwater Handbook Volume 3 Chapter 1: Documenting Compliance with the Massachusetts Stormwater Management Standards. (n.d.). Retrieved from https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.mass.gov%2Fdoc%2Fmassachusetts-stormwater-handbook-vol-3-ch-1-documenting-compliance%2Fdownload&wdOrigin=BROWSELINK

MS4 permit Appendix F Attachment 3 has been used to identify the cumulative phosphorus load reduction.

- Per Table 3-10 for a runoff depth of 1" and infiltration rate of 2.41 inches/hour, the cumulative phosphorus load reduction is 98%.
- Per Table 3-9 for a runoff depth of 1" and infiltration rate of 1.02 inches/hour, the cumulative phosphorus load reduction is 96%.

– Given that these planned leaching catch basins are planned to be placed on Town roadways, the drainage area to each of these leaching catch basins has been assumed to include only the impervious highway land use.

The Town has identified 58 potential locations for planned leaching catch basin installation spread across ten roadways within the watershed. **Table 1-6** summarizes the total phosphorus reduction anticipated from the proposed leaching catch basins; **Table 1-7** provides the recommended prioritization of the ten streets with planned leaching catch basins from highest to lowest priority based on the factors listed above. Appendix G includes a Supporting Map for Planned Structural BMP Prioritization depicting ranking factors. Implementation of these planned leaching catch basins will be dependent upon funding and manpower to design, construct, and maintain the structures. Additionally, feasibility of the planned leaching catch basins will be dependent upon existing subsurface infrastructure (i.e. utilities) which may preclude placement of the planned leaching catch basins as planned.

Table 1-6: Planned Structural Control Summary

Average Drainage Area (acres)	Phosphorus Load Export Rate (lbs/acre/year)	Phosphorus Reduction Rate[1]	Average Phosphorus Reduction per Leaching Catch Basin	Number of Leaching Catch Basins to be Installed	Total Phosphorus Reduction Anticipated (lbs/year)
0.090	1.34	96%-98%	0.117	58	6.78

[1]The specific Phosphorus Reduction Rate applied to each planned control varies based on hydrologic soil group and soil texture and fell within this range.

Table 1-7: Street Ranking Summary from Highest to Lowest Priority

1	Chapin Street (South of East Street)
2	Chapin Street (North of East Street)
3	East Street (West of Chapin Street)
4	East Street (East of Chapin Street)
5	Laroche Street
6	Armand Street
7	Karen Drive
8	King Street
9	Amherst Street
10	C. Abair Street

1.8 SUMMARY OF PLANNED CONTROLS

As outlined in Sections 1.6 and 1.7, the Town has planned considerable non-structural and structural controls to reduce phosphorus loading to Minechoag Pond. Unfortunately, the Town faces significant barriers in reaching the phosphorus load reductions outlined in the Permit.

As noted in the Structural Controls section of the LPCP, the existing land use distribution of the Minechoag Pond watershed is heavily residential and privately owned. Approximately 61% of the total phosphorus load to the pond is attributable to residential areas, while only 31% of the total load is from the roadways.[4] Additionally, the Town does not own any properties outside of the right-of-way that would allow for the construction of Town-owned structural BMP installation in the Minechoag Pond watershed. Therefore, the Town is limited to installation of structural BMPs within the right-of-way, i.e. in the roadways. Given that only 31% of the phosphorus load to Minechoag Pond is derived from the roadways, even if the Town were able to entirely remove the phosphorus loads from roadways, this would only result in approximately a 31lb P/year reduction. Including the planned non-structural controls and the current structural BMPs that together provide approximately a 5 lb. P/year reduction, it is not feasible to achieve the 48.22 lb. P/year reduction goal outlined by the Permit without finding ways to remove phosphorus from private properties within the watershed, which the Town has limited methods of doing.

Furthermore, most of the developable area within the watershed is already developed. The majority of the existing undeveloped forested land is classified as wetlands. The remaining areas designated as open land largely fall between existing homes and roadways, and therefore do not lend themselves to future development either. Therefore, the Town does not expect significant amounts of phosphorus reduction credit from structural controls built during future developments.

The Town also considered the semi-structural measure of impervious area disconnection through storage. According to preliminary calculations, even if the Town were to provide a rain barrel for every property in the watershed, the resulting phosphorus reduction would be approximately 2 lbs/year. This additional reduction, plus the planned structural controls, and 100% management of the roadway phosphorus would only result in approximately a 38 lb. P/year reduction.

In addition to the non-structural, semi-structural, and structural controls investigated, the Town also considered an untraditional in-lake treatment option using a phosphorus reducing product. However, this option requires the application of a chemical to the pond and treats the symptom rather than the source of the phosphorus load problem. Given that the amount of phosphorus reduction from this method depends upon the depth of the pond as well as other factors, it would be difficult to quantify the amount of the product required and the corresponding phosphorus reduction anticipated in advance of the product application. Given these drawbacks, the Town has not included an in-lake treatment option in this LPCP, but is something that can be explored, if necessary, in later phases of the LPCP implementation.

Ultimately the Town faces significant barriers in achieving the required 48.22 lbs P/year reduction given all of these aforementioned constraints. Nonetheless, the Town has planned for a significant phosphorus reduction and will continue to seek to reduce phosphorus loading to Minechoag Pond as much as feasible and to seek future methods as funding allows to encourage private property owners to implement phosphorus reduction BMPs.

[4] Calculated using 2016 Land Cover/Land Use Mass GIS data set (https://www.mass.gov/info-details/massgis-data-2016-land-coverland-use) and Town of Ludlow GIS files.

1.9 DESCRIPTION OF OPERATION AND MAINTENANCE (O&M) PROGRAM FOR ALL PLANNED AND EXISTING STRUCTURAL BMPS

Permit Requirement: *The permittee shall establish an Operation and Maintenance Program for all structural BMPs being claimed for phosphorus reduction credit. This includes BMPs implemented to date as well as BMPs to be implemented. The Operation and Maintenance Program shall become part of the LPCP and include: (1) inspection and maintenance schedule for each BMP according to BMP design or manufacturer specification and (2) program or department responsible for BMP maintenance.*

As part of this LPCP, the Town is proposing to install a significant number of leaching catch basins to supplement the existing stormwater infrastructure in the right-of-way of the Minechoag Pond watershed as available funding and manpower allows. Additionally, the current structural BMPs described in Section 1.7.1 include multiple leaching basins that require regular maintenance. Although the Town does not have any manufacturer specifications regarding the maintenance of these existing BMPs, it has been assumed that they must be maintained per typical leaching catch basin requirements. According to the Massachusetts Stormwater Handbook Volume 2 Chapter 2[5], the required maintenance for a leaching catch basin includes the following:

- Inspect annually or more frequently as needed.
- Remove sediment when the basin is 50% filled.
- Rehabilitate the basin if it fails due to clogging.

These requirements are included in the catch basin cleaning that the Town undertakes on existing drainage infrastructure as per MS4 Permit MCM 6 (BMP 5 within the Town's Stormwater Management Plan (SWMP)), Catch Basin Cleaning Program. Furthermore, the planned non-structural controls set out in Section 1.6.2 includes semi-annual catch basin cleaning. Appendix F of the Town's SWMP includes Standard Operating Procedure (SOP) 3: Catch Basin Inspection and Cleaning, which outlines the methods by which catch basins should be maintained. This SOP shall apply to the operations and maintenance of the proposed leaching catch basins and has been included in this report as Appendix H for reference.

The Ludlow Department of Public Works will be responsible for the operation and maintenance of the proposed and existing leaching basins. The DPW plans to continue its internal trainings for maintenance of catch basins as currently implemented.

1.10 LPCP IMPLEMENTATION SCHEDULE

Permit Requirement: *An initial schedule for implementing the BMPs, including, as appropriate: funding, training, purchasing, construction, inspections, monitoring, O&M and other assessment and evaluation components of implementation. Implementation of planned BMPs must begin upon completion of the LPCP, and all non-structural BMPs shall be fully implemented within six years of the permit effective date. Where planned structural BMP retrofits or major drainage infrastructure projects are expected to take additional time to construct, the permittee shall within four years of the effective date of the permit have a schedule for completion of construction consistent with the reduction requirements in Table F-7. The permittee shall complete the implementation of its LPCP as soon as possible or at a minimum in accordance*

[5] Massachusetts Stormwater Handbook Volume 2 Chapter 2: Structural BMP Specifications for the Massachusetts Stormwater Handbook. (n.d.). Retrieved from https://www.mass.gov/doc/massachusetts-stormwater-handbook-vol-2-ch-2-stormwater-best-management-practices/download

with the milestones set forth in Table F-7. The implementation schedule shall be updated as needed to support the achievement of the milestones in Table F-7, including an update in the updated written LPCP 10 years after the permit effective date.

Ludlow has prepared an implementation schedule of the planned non-structural and structural controls. This schedule is attached as Appendix I. Note, implementation of the planned control methods may be dependent upon securing funding for these methods. As noted in Section 1.8, it is not feasible for the Town to reach the phosphorus reduction goals outlined in the Permit without significant contributions from BMPS constructed on privately-owned land within the watershed. The attached schedule outlines implementation of the proposed non-structural and structural methods planned given the constraints in the Minechoag Pond watershed. Given that the proposed structural control methods include installation of over 50 leaching catch basins, implementation of these BMPs has been spread over the remaining permit term and will be dependent upon available funding and manpower. The proposed schedule seeks to mirror the milestones outlined in Section 1.3 while providing time for the programming and design of the first group of proposed structures.

1.11 ESTIMATED COST FOR IMPLEMENTING THE LPCP

Permit Requirement: *The permittee shall estimate the cost for implementing its LPCP and describe known and anticipated funding mechanisms. The permittee shall describe the steps it will take to implement its funding plan. This may include but is not limited to conceptual development, outreach to affected parties, and development of legal authorities.*

Ludlow has developed an estimated cost to implement the non-structural and structural methods planned as part of this LPCP. **Table 1-8** below summarizes this cost estimate, which is shown in more detail in Appendix J, and includes costs which were inflated to reflect estimated costs during the planned year of construction.

The following methods and assumptions were used to calculate these estimated costs:

- Base costs for non-structural controls were estimated based on available estimates of costs associated with each particular practice and scaled based on the frequency of each planned practice per Section 1.6.2.
    - Costs for the organic waste and leaf litter collection program include estimated costs for weekly street sweeping assuming that weekly sweeping with a mechanical broom sweeper will generally meet the requirements of this non-structural control.
    - The estimated cost per catch basin cleaned includes an estimated cost for disposal of material to a landfill that is permitted by MassDEP to accept solid waste as required by SOP 3: Catch Basin Inspection and Cleaning.
- Base costs for structural controls were estimated based on vendor quotes and past itemized bid costs.
    - Leaching catch basin costs were estimated based on approximate volume required to manage 1” of impervious runoff for estimated average drainage area to each leaching catch basin, as assumed in Section 1.7.2.
- O&M costs for the planned structural controls were estimated assuming semi-annual maintenance of each leaching catch basin. These estimated O&M costs assume the same cost to maintain a leaching catch basin as the cost estimated as part of the non-structural controls to maintain an existing catch basin, since the procedures are similar. Additionally, these estimated costs assume that O&M begins in the same year as the planned structural BMP installation.

- Assumed a 3.5% annual construction cost inflation rate for the cost of planned structural controls to be implemented over the permit term. This annual inflation rate was chosen given an investigation performed by CBRE in 2022 that forecasted construction costs stabilizing within historical averages in 2023 and 2024, (between 2% and 4%).[6] To be conservative, an annual construction cost increase of 3.5% was assumed for this LPCP.
- Assumed 3.5% annual increase to the costs of the non-structural controls to be implemented over the permit term. This assumes that increases to labor rates, which make up the majority of the assumed non-structural costs, will mimic increases to construction inflation rates.
- Added engineering and design contingency to planned structural controls costs.
- Added general contingency to planned structural controls costs due to early stage of planning study and possibility for significant cost fluctuations once designs are initiated.

Table 1-8: Estimated Costs for Planned Non-Structural and Structural Controls

Planned Construction Year	Number of Leaching Catch Basins Planned	Estimated Cost for Structural Controls (Construction Year)[1]	Estimated Cost for Non-Structural Controls (Construction Year)	Total Estimated Cost for Planned Control Methods (Construction Year)
2024	0	-	$68,400	$68,400
2025	0	-	$70,800	$70,800
2026	10	$228,300	$73,300	$301,600
2027	0	$4,500	$75,900	$80,400
2028	16	$395,900	$78,500	$474,400
2029	0	$12,400	$81,300	$93,700
2030	0	$12,900	$84,100	$97,000
2031	16	$447,100	$87,000	$534,100
2032	0	$22,300	$90,100	$112,400
2033	16	$487,700	$93,200	$580,900

[1]Includes estimated O&M costs.

1.12 PERFORMANCE EVALUATIONS

Permit Requirement: *The permittee shall evaluate the effectiveness of the LPCP by tracking the phosphorus reductions achieved through implementation of structural and non-structural BMPs and tracking increases in phosphorus loading from the LPCP Area beginning six years after the effective date of the permit. Phosphorus reductions shall be calculated consistent with Attachment 2 (non-structural BMP performance), Attachment 3 (structural BMP performance) and Attachment 1 (reductions through land use change), to Appendix F [of the MS4 Permit] for*

[6] CRBE. (2022, July 6). 2022 U.S. Construction Cost Trends. Retrieved from https://www.cbre.com/insights/books/2022-us-construction-cost-trends#:~:text=CBRE%E2%80%99s%20new%20Construction%20Cost%20Index%20forecasts%20a%2014.1%25,2023%20and%202024%2C%20on%20par%20with%20historical%20averages.

all BMPs implemented to date. Phosphorus load increases resulting from development shall be calculated consistent with Attachment 1 to Appendix F. Phosphorus loading increases and reductions in units of mass/yr. shall be added or subtracted from the calculated Baseline Phosphorus Load to estimate the yearly phosphorus export rate from the LPCP Area in mass/yr. The permittee shall also include all information required in part II.2 of [Appendix F of the MS4 Permit] in each performance evaluation.

Ludlow will provide performance evaluations as required by the Permit. A sample performance evaluation sheet has been attached as Appendix K for reference.

1.13 PUBLIC COMMENT

Permit Requirement: *The permittee shall make the LPCP available to the public for public comment during LPCP development. EPA encourages the permittee to post the LPCP online to facilitate public involvement.*

Ludlow will make the LPCP available to the public on their website as an appendix of the SWMP. The public therefore has the opportunity to comment on or ask questions about the LPCP at any time.

2 DOCUMENTATION AND REPORTING

2.1 TRACKING AND ACCOUNTING

As noted in Section 1.13, the LPCP shall be added as an appendix of the SWMP. The most current information for annual updates to Ludlow's LPCP progress can be found in the following appendices:

- For non-structural controls: Appendix E
- For structural controls: Appendix F
- For the operations and maintenance program: Appendix H

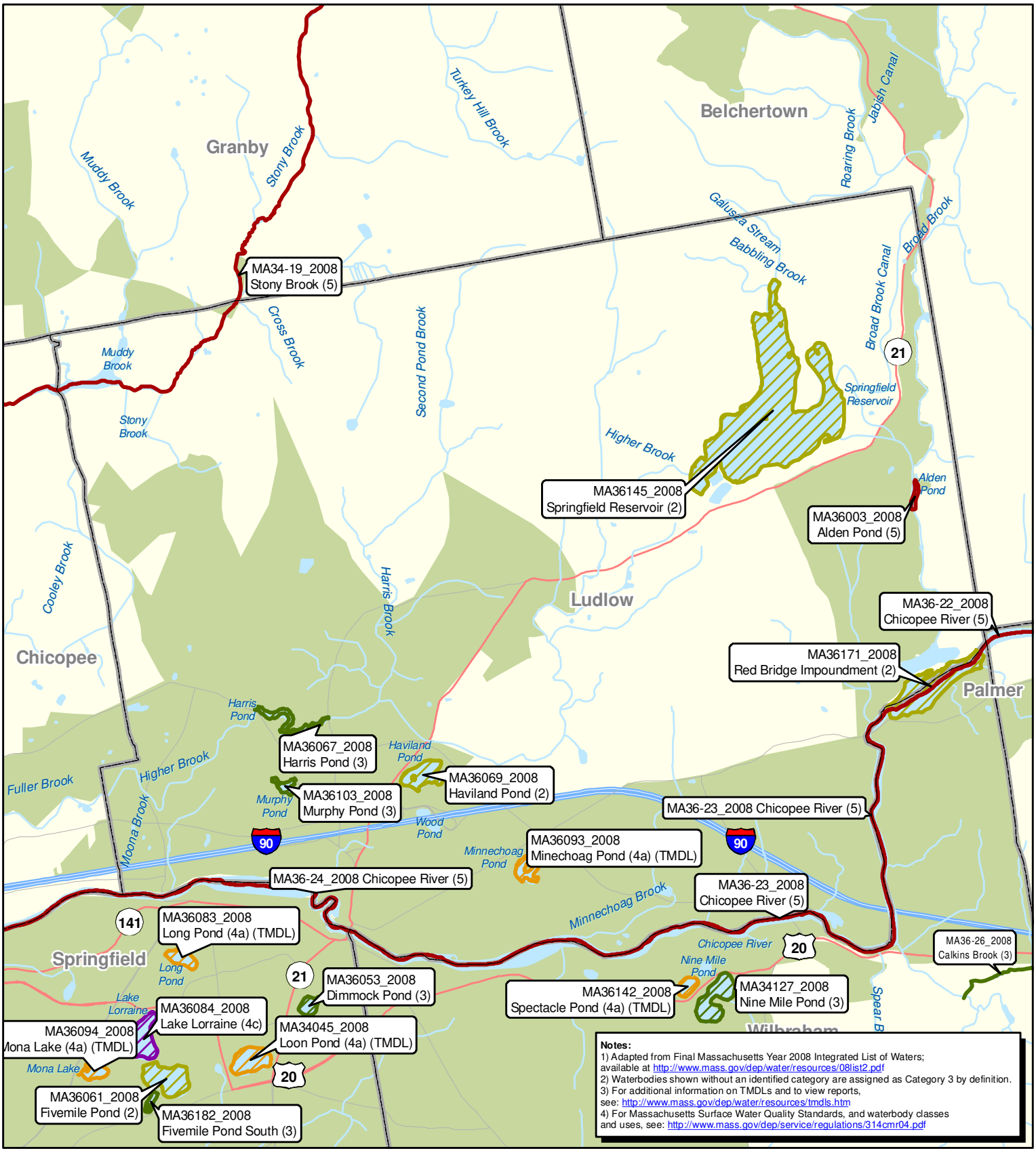
Annual progress updates on the LPCP and Performance Evaluations shall be included in the Annual Report for Years 6-15. Each annual report starting in Permit Year 5 shall also include the following:

- All non-structural controls implemented in the reporting year and associated phosphorus reduction.
- All structural controls implemented during the reporting year, locations, associated phosphorus reduction, and date of latest maintenance and inspections.
- Phosphorus load increases due to development.
- Estimated yearly phosphorus export rate, subtracting reductions.
- Recognition that all structural BMPs are being inspected and maintained according to O&M program.
- Recognition that all municipally owned and maintained turf grass areas are being managed in accordance with Massachusetts Regulation 331 CMR 31 pertaining to proper use of fertilizers on turf grasses.

Appendices

Appendix A. Waterbody Assessment and TMDL Status for Ludlow

A. Waterbody Assessment and TMDL Status for Ludlow



Notes:
1) Adapted from Final Massachusetts Year 2008 Integrated List of Waters; available at http://www.mass.gov/dep/water/resources/08list2.pdf
2) Waterbodies shown without an identified category are assigned as Category 3 by definition.
3) For additional information on TMDLs and to view reports, see: http://www.mass.gov/dep/water/resources/tmdls.htm
4) For Massachusetts Surface Water Quality Standards, and waterbody classes and uses, see: http://www.mass.gov/dep/service/regulations/314cmr04.pdf

Waterbody Assessment and TMDL Status
Ludlow, MA

N

0 0.5 Miles

EPA

Map produced by EPA Region I GIS Center
Map Tracker ID 6678, February 25, 2010
Data Sources: TeleAtlas, Census Bureau, USGS, MassDEP

Waterbody Label

State ID,
Waterbody Name (Category)
(TMDL(s) approved for this waterbody)

See companion table for a listing of pollutants, non-pollutants, and TMDLs for each waterbody

Assessment of Waterbody Segment

- **Category 2:** Attaining some uses; other uses not assessed
- **Category 3:** Insufficient information to make assessments for any use.
- **Category 4a:** TMDL is completed and approved for one or more pollutants
- **Category 4c:** Impairment not caused by a pollutant.
- **Category 5:** Impaired or threatened for one or more uses and requiring a TMDL.

- Waterbodies
- Swamp/Marsh
- MS4 Urbanized Areas (2000 Census)
- Municipal Boundaries

Appendix B.
LPCP Regulatory Analysis

B. LPCP Regulatory Analysis

MOTT MACDONALD

Memorandum

Subject	**Task 8 Lake Phosphorus Control Plan Regulatory Analysis**
To	James Goodreau
From	Suzanne Ciavola and David Goncalves
Our reference	507395991-003
Office	West Springfield
Date	September 15, 2020

Mr. Goodreau,

Mott MacDonald is assisting the Town of Ludlow (the Town) with some of the requirements for Year 2 of the 2016 Massachusetts MS4 Permit (MS4 Permit). As part of this assistance, Mott MacDonald is helping to identify existing regulatory mechanisms and describe changes which may be necessary to implement the lake phosphorus control plan (LPCP).

Section II.1.i of Appendix F to the MS4 Permit outlines the LPCP elements which will be required over 15 years after the permit effective date. Mott MacDonald reviewed these elements and timeline as well as the Town bylaws (including the zoning bylaws) published online. After reviewing these documents, we are not recommending any changes to the bylaws at this time due to the nascent status of the LPCP and already established stormwater requirements incorporated into the Town's Zoning bylaws. As part of the Town's MS4 Permit, the Town will be required to complete additional LPCP milestones throughout the next three years (through Permit Year 5) which will result in a funding source assessment (Permit Year 3), LPCP scope (Permit Year 4), and completed LPCP (Permit Year 5). We recommend that as part of the Permit Year 3 funding assessment and in future LPCP milestones that the Town reassess whether a legal analysis needs to be completed, specifically if the Town plans on generating funds dedicated to completing the LPCP phosphorus reduction required as part of the MS4 permit. Finally, please note that in completing this task, Mott MacDonald is providing recommendations based on engineering judgement, and recommends that the Town coordinate with legal counsel regarding future legal analysis as required.

Sincerely,

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Appendix C.
Ludlow Street Design Parking Lot and GI Assessment Memo 2022

C. Ludlow Street Design Parking Lot and GI Assessment Memo 2022

MOTT MACDONALD

Memorandum

Subject	**Local Impervious Requirements Assessment and Green Infrastructure Report**
To	James Goodreau
From	Suzanne Newman, P.E.
Our reference	2022 MS4 Permit Support, 507106794
Date	September 28, 2022

1 Background

The Town of Ludlow (The Town) is a permittee and required to address the requirements of the United States Environmental Protection Agency's (USEPA's) 2016 National Pollutant Discharge Elimination System (NPDES) General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4 permit) in Massachusetts, hereafter referred to as the 2016 Massachusetts MS4 Permit. This permit includes a requirement for permittees to develop a Stormwater Management Plan (SWMP). As a part of the SWMP, the Town of Ludlow is required to assess the current street design and parking lot guidelines and other local requirements that affect the creation of impervious cover. This assessment was conducted to determine whether changes can be made to support low impact development (LID) and if so, include recommendations and a schedule for when these changes are to be implemented and reported on in future MS4 permit annual reports.

The Town of Ludlow is also required to assess existing local regulations to determine the feasibility of making specific green infrastructure (GI) practices allowable when appropriate site conditions exist. These practices include green roofs, infiltration practices, and water harvesting devices. This report assesses existing local regulations to determine the feasibility of making these GI practices allowable and includes recommendations to remove hindrances as well as a schedule for implementing the recommendations.

2 Methodology

As part of both required assessments, various local and state-wide regulations and bylaws were reviewed. The rules and regulations stipulated within these documents were reviewed to see whether they created potential or definite obstacles to the implementation of low impact design and/or green infrastructure. The documents reviewed are listed below in **Table 1**.

Table 1. Local regulations/documents Included in Assessment

Document No.	Document
1	Town of Ludlow Subdivision Rules and Regulations Effective May 24, 2012
2	Town of Ludlow General Bylaws Amended May 10, 2021
3	Town of Ludlow Zoning Bylaws Amended October 4, 2021
4	Town of Ludlow Conservation Commission Bylaws (Downloaded from Town website on July 26, 2022)
5	Town of Ludlow Department of Public Works Regulations for Construction within the Public Way Revised October 2012
6	Massachusetts Amendments to the International Building Code 2015 780 CMR, Ninth Edition, Effective October 20, 2017
7	Massachusetts Uniform State Plumbing Code 248 CMR. Mass. Register #1442 April 30, 2021

To streamline the process of reviewing the bylaws, Mott MacDonald used a worksheet created by the Pioneer Valley Planning Commission (PVPC) in February 2022, titled “Assessment of Street Design and Parking Lot Guidelines and Feasibility of Allowing Green Infrastructure”. This worksheet served as a template and guide for locating specific instances within local rules and regulations which may hinder low impact design or green infrastructure implementation. This worksheet documents specific considerations and notes taken as part of this assessment and is attached as **Appendix A**. Based on this worksheet, as well as input from the Town, recommendations were identified and included below in Sections 3 and 4.

3 Local Impervious Requirements Assessment

According to section 2.3.6.b of the MS4 permit, the permittee shall assess current local guidelines and regulations related to street and parking lot design that affect the creation of impervious cover. Local bylaws, rules, and regulations were reviewed accordingly and assessed for any hindrances to low impact design related to the design of parking lots and streets.

3.1 Street Design and Parking Lot Guidelines

There are several possible hindrances within local regulations to low impact design, which were identified and are listed below in **Table 1**.

Table 2. Key Findings in Assessment for Local Requirements Affecting the Creation of Impervious Cover

Design Parameter	Document	Section	Explanation/Recommendations
Porous and Pervious Pavements	Town of Ludlow Subdivision Rules and Regulations	IV. G. & IV. H.	The noted two sections within the Town of Ludlow Subdivision Rules and Regulations specify the use of MassDOT Standard Specification, Division II, Section 701 for sidewalks and driveways, respectively. This specification describes the use of concrete for the building material, which is impermeable. It is recommended that this language be revised to include and allow for the use of permeable concrete or permeable pavers under the appropriate circumstances (typically low-volume areas).
Curb Construction	Town of Ludlow Subdivision Rules and Regulations	IV. E.	According to this section within the Town of Ludlow Subdivision Rules and Regulations, “All ways shall have their entire gutter lines curbed with bituminous concrete berm”, which restricts the use of curb cuts, at-grade inlets, and no-curb inflows, which are commonly used for green stormwater management practices. It is recommended that this language be updated to allow common green infrastructure inflow practices which may require a gap in curbing.
Parking Pavement	Town of Ludlow General Bylaws	15.A.4.4	According to this section within the Town of Ludlow General Bylaws, “Surface: Shall have a uniform, paved, or hard packed smooth surface”. This language may encourage the use of impermeable surface materials. It is recommended that this language be revised to include and/or encourage the use of permeable concrete or permeable pavers where appropriate.

Design Parameter	Document	Section	Explanation/Recommendations
Number of Parking Spaces	Town of Ludlow Zoning Bylaws	5.5.8.1 & 6.4.2.a	The number of spaces across various categories within the document called *Assessing Street and Parking Design Standards to Reduce Excess Impervious Cover in New Hampshire and Massachusetts*[1] are generally less than the number of spaces stipulated in the Town of Ludlow Zoning Bylaws. The minimum number of spaces specified within the Town of Ludlow Zoning bylaws for various categories can be decreased, which would result in less impervious area for a given lot. This could lead to a reduction in impervious area within the Town.

4 Green Infrastructure (GI) Report

According to section 2.3.6 c. of the MS4 permit, the permittee shall assess the feasibility of making the following practices allowable when appropriate site conditions exist:

1. Green Roofs
2. Infiltration practices such as rain gardens, curb extensions, planter gardens, porous and pervious pavements, and other designs to manage stormwater using landscaping and structured or augmented soils.
3. Water harvesting devices such as rain barrels and cisterns, and the use of stormwater for non-potable uses

As noted previously, several local bylaws, rules, and regulations were reviewed to evaluate possible obstacles to the implementation of such green infrastructure.

4.1 Green Roofs

There were no identified restrictions to building green roofs found within the Ludlow bylaws and rules and regulations.

4.2 Infiltration Practices

Infiltration practices such as rain gardens, curb extensions, planter gardens, porous and pervious pavements, and other designs to manage stormwater using landscaping are restricted in some instances within the bylaws of subdivisions.

Table 3 shows instances where restrictions were identified and recommendations on how to remove these restrictions.

[1] US EPA. (2011, April). *Assessing Street and Parking Design Standards to Reduce Excess Impervious Cover in New Hampshire and Massachusetts.* https://www3.epa.gov/region1/npdes/stormwater/assets/pdfs/ImperviousAssessment.pdf

Table 3. Key Findings in Assessment for Local Requirements Affecting the Implantation of Green Infrastructure

Infiltration Practice	Hindrance (Y/N/?)	Document	Section	Explanation/Recommendations
Rain Gardens	N	N/A	N/A	None
Curb Extensions	N	N/A	N/A	None
Planter Gardens	N	N/A	N/A	None
Porous and Pervious Pavements	Y	Town of Ludlow Subdivision Rules and Regulations	IV. G. & IV. H.	The noted two sections within the Town of Ludlow Subdivision Rules and Regulations specify the use of MassDOT Standard Specification, Division II, Section 701 for sidewalks and driveways, respectively. This specification describes the use of concrete for the building material, which is impermeable. It is recommended that this language be revised to include and allow for the use of permeable concrete or permeable pavers under the appropriate circumstances (typically low-volume areas).
Other Design(s):				
Curb Construction	Y	Town of Ludlow Subdivision Rules and Regulations	IV. E.	According to this section within the Town of Ludlow Subdivision Rules and Regulations, “All ways shall have their entire gutter lines curbed with bituminous concrete berm”, which restricts the use of curb cuts, at-grade inlets, and no-curb inflows, which are commonly used for green stormwater management practices. It is recommended that this language be updated to allow common green infrastructure inflow practices which may require a gap in curbing.
Miscellaneous	N	Town of Ludlow Subdivision Rules and Regulations	III.E	It is recommended that language be added which required developers to install standard signage indicating that waters drain directly to a waterbody when installing a stormwater inlet. This is not a hindrance to green infrastructure, but this recommendation is intended to discourage illicit discharges to the storm sewers.

4.3 Water Harvesting Devices

There were no noted restrictions on water harvesting devices found in the reviewed bylaws and rules.

5 Proposed Schedule

Table 4 below includes a schedule for the Town to address the recommendations summarized in **Table 2** and **Table 3**. This schedule is laid out to allow the Town time to discuss each recommendation and implement these accordingly over the active MS4 permit period.

Table 4. Schedule for Implementation of Recommendations

Item	Document	Schedule
Include porous and pervious pavements as materials for sidewalks and driveway aprons	Town of Ludlow Subdivision Rules and Regulations	June 30, 2024
Allow for new roadway development without curb construction	Town of Ludlow Subdivision Rules and Regulations	June 30, 2024
Require developers to add signage when installing inlets	Town of Ludlow Subdivision Rules and Regulations	June 30, 2024
Include porous and pervious pavements as materials for parking lots	Town of Ludlow General Bylaws	June 30, 2026
Reduce the minimum number of parking spaces amongst various categories	Town of Ludlow Zoning Bylaws	June 30, 2028

6 Conclusions

A number of local regulations and requirements were reviewed and potential hindrances to low impact design and green infrastructure implementation were identified. The PVPC document called “Assessment of Street Design and Parking Lot Guidelines and Feasibility of Allowing Green Infrastructure” was used to document and tabulate many aspects of the local regulations where potential barriers to LID and GI were expected. The final 5 (five) recommended changes to these regulations as well as their schedule for implementation are summarized above in **Section 5**. Please note that each recommendation is a suggestion for further assessment of whether these changes can be implemented. This determination should include relevant agencies and stakeholders (such as local planning board and local transportation board) to evaluate whether recommendations can be implemented. These recommendations are also broadly stated and the final language included in any regulatory documents should be worded to consider specific circumstances and include consideration for public safety and or planning/engineering concerns.

In addition to the formal recommendations above, another action which the Town should consider is creating incentives which would promote LID and GI practices. A specific example would be how a number of communities in the Unites States use their zoning codes to encourage the use of green roofs. Portland, Oregon,

has a provision within its zoning bylaws stating that: “for each square foot of rooftop garden area, a bonus of one square foot of additional floor area is earned.”[2] Another example is Chicago, Illinois, which has a fee structure in place that lowers the building permit fee by $0.05 for every square foot of green roof provided.[2] The Town of Ludlow should consider adding incentives for LID and GI practices within their bylaws, similar to these examples.

Appendix

Appendix A – Detailed Documentation of Assessments included as part of the Pioneer Valley Planning Commission’s “Assessment of Street Design and Parking Lot Guidelines and Feasibility of Allowing Green Infrastructure”

[2] Pioneer Valley Planning Commission. *Understanding Green Roof Incentives*. https://www.pvpc.org/sites/default/files/files/PVPC-Green%20Roof%20Model%20Incentives.pdf

Appendix A

INTRODUCTION

STREET DESIGN AND PARKING LOT GUIDELINES AND INFRASTRUCTURE

ASSESSMENT OF FEASIBILITY OF ALLOWING GREEN

NPDES MS4 Community: Ludlow, MA

Pioneer Valley Planning Commission, February 2022

Introduction

The United States Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems in Massachusetts (MS4) (with modifications effective on January 6, 2021) requires the development of two local assessments within four (4) years of the effective date of the permit as follows:

2016 Massachusetts Small MS4 General Permit, Section 2.3.6.b: Assessment of Street Design and Parking Lot Guidelines

Within four (4) years of the effective date of this permit, the permittee shall develop a report assessing current street design and parking lot guidelines and other local requirements that affect the creation of impervious cover. This assessment shall be used to provide information to allow the permittee to determine if changes to design standards for streets and parking lots can be made to support low impact design options. If the assessment indicates that changes can be made, the assessment shall include recommendations and proposed schedules to incorporate policies and standards into relevant documents and procedures to minimize impervious cover attributable to parking areas and street designs. The permittee shall implement all recommendations, in accordance with the schedules, contained in the assessment. The local planning board and local transportation board should be involved in this assessment. This assessment shall be part of the SWMP. The permittee shall report in each annual report on the status of this assessment including any planned or completed changes to local regulations and guidelines.

2016 Massachusetts Small MS4 General Permit, Section 2.3.6.c: Assessment of Feasibility of Allowing Green Infrastructure

Within four (4) years from the effective date of the permit, the permittee shall develop a report assessing existing local regulations to determine the feasibility of making, at a minimum, the following practices allowable when appropriate site conditions exist: i. Green roofs; ii. Infiltration practices such as rain gardens, curb extensions, planter gardens, porous and pervious pavements, and other designs to manage stormwater using landscaping and structured or augmented soils; and iii. Water harvesting devices such as rain barrels and cisterns, and the use of stormwater for non-potable uses. The assessment should indicate if the practices are allowed in the MS4 jurisdiction and under what circumstances are they allowed. If the practices are not allowed, the permittee shall determine what hinders the use of these practices, what changes in local regulations may be made to make them allowable, and provide a schedule for implementation of recommendations. The permittee shall implement all recommendations, in accordance with the schedules, contained in the assessment. The permittee shall report in each annual report on its findings and progress towards making the practices allowable.

Compliance Recommendation: Pre-Application Meeting with Developers

Requiring project applicants to participate in a pre-application meeting with local officials can be one of the most important and cost-effective strategies to limiting impervious cover and ensuring best stormwater management approaches. For this pre-application meeting, an applicant can be asked to take some first steps in thinking about the site through a Low Impact Development lens that involves analysis of site resources, soils, and a sketch plan informed by those considerations. (See link below to PVPC checklist for developer use in preparing for this meeting). The pre-application meeting then enables a preliminary conversation about the site, stormwater management and erosion control considerations, and concept plan prior to investing in extensive professional design efforts. This pre-application meeting can be included as part of stormwater management permitting and site plan review in zoning if there are smaller projects (under 1 acre) that a municipality wishes to include.

https://thinkblueconnecticutriver.org/wp-content/uploads/2020/12/10.-LID-Checklist-for-Preapplication-Meeting-PVPC-Model.docx

Benefits of Impervious Cover Reduction and Use of Green Infrastructure

While the MS4 permit requirements are aimed at water quality improvements, impervious cover and encouraging green infrastructure stormwater management can also reduce localized flooding, improve groundwater recharge, enhance neighborhood aesthetics, and reduce summer heat. Please refer to the resources provided below for additional information.

A Word About Stormwater Management in Drinking Water Supply Protection Areas

For drinking water supply protection areas--particularly recharge areas for public water supplies, but also where there is reliance on private wells for supply--it is important to carefully consider the impervious surfaces from which stormwater flows will be managed. For example, flows from non-metal rooftops could be managed to infiltrate directly into soils. The likelihood of contamination in such flows is typically low and thus the likelihood of eventual harm to groundwater sources for drinking is also low. A parking or loading area, however, is very different. In such circumstances, best practice would be to ensure that the perimeter area is curbed so that flows go through a pretreatment device prior to infiltration. The pretreatment facility should also include an emergency shutoff valve that can be activated in case of a spill to keep contaminated flows contained within the parking area and from reaching the infiltration facility. Note that the current 2008 MassDEP Stormwater Handbook does not allow for the location of any stormwater bmps in Zone 1 areas, unless necessary to manage stormwater from essential drinking water facilities.

How to Use This Checklist

This checklist can be used as a method of documenting review of existing local code for requirements that affect the creation of impervious cover and feasibility of allowing green infrastructure and it contains some notes and recommendations for potential policy and language changes. This checklist could also serve as the submission to EPA once code review assessment has been completed with additions in the column headings, "changes recommended" and "proposed schedule to incorporate changes." Best practice for review of code and potential revisions occurs through conversations with relevant boards and departments, such as the Planning Board, Public Works, Conservation Commission, Board of Health, and Fire Department.

Relevant Local Documents / Code to Review

Assuming that local stormwater bylaw/ordinance and regulations have been updated to comply with new pre and post construction MS4 permit standards, including promoting a Low Impact Development approach and advancing green infrastructure stormwater management, other key places within municipal code for review are as follows:

Subdivision Rules & Regulations	Wetland Protection Bylaws / Rules & Regulations	Local Building Codes
Zoning Bylaws	Board of Health Bylaws / Rules & Regulations	Local Plumbing Codes
General Bylaws		

Citations / Resources

Author	Title	Web Link
American Planning Association - Massachusetts Chapter and Homebuilders Association of Massachusetts	Sustainable Neighborhood Road Design: A Guidebook for Massachusetts Cities and Towns	https://www.apa-ma.org/wp-content/uploads/2018/12/NRB_Guidebook_2011.pdf
Casey Trees and Davey Tree Expert Co.	National Tree Benefit Calculator	http://www.treebenefits.com/calculator/
Center for Watershed Protection	The Code & Ordinance Work sheet: A Tool for Evaluating the Development Rules in Your Community	https://owl.cwp.org/mdocs-posts/better-site-design-code-and-ordinance-cow-worksheet-2017-update/
Commonwealth of Massachusetts, Executive Office of Energy and Environmental Affairs	Smart Growth / Smart Energy Toolkit: Smart Parking Model Bylaw	https://www.mass.gov/files/documents/2017/11/03/Smart%20Parking.pdf
Massachusetts Association of Conservation Commissions	MACC Wetlands Buffer Zone Guide Book	https://www.readingma.gov/conservation-division/files/macc-wetlands-buffer-zone-guidebook
Metropolitan Area Planning Council	Massachusetts Low Impact Development Toolkit: Low Impact Development - Do Your Local Codes Allow It? A Checklist for Regulatory Review	https://www.mapc.org/resource-library/do-your-local-codes-allow-lid/
Metropolitan Area Planning Council	Low Impact Development Toolkit	https://www.mapc.org/resource-library/low-impact-development-toolkit/
Metropolitan Area Planning Council	Once is Not Enough: Guide to Water Reuse in Massachusetts	http://www.mapc.org/wp-content/uploads/2017/11/3-1-Once-is-Not-Enough-Guide-to-Water-Reuse-10-05.pdf
Minnesota Pollution Control Agency	Overview for Stormwater and Rainwater Harvest and Use/Reuse	https://stormwater.pca.state.mn.us/index.php/Overview_for_stormwater_and_rainwater_harvest_and_use/reuse
Pioneer Valley Planning Commission	Low Impact Development Checklist	https://thinkblueconnecticutriver.org/wp-content/uploads/2020/12/10.-LID-Checklist-for-Preapplication-Meeting-PVPC-Model.docx
Pioneer Valley Planning Commission	Green Infrastructure Fact Sheets	http://www.pvpc.org/content/green-infrastructure-toolkit
Pioneer Valley Planning Commission	Pioneer Valley Sustainability Toolkit	http://www.pvpc.org/plans/pioneer-valley-sustainability-toolkit
U.S. Environmental Protection Agency	Water Quality Scorecard: Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scales	https://www.epa.gov/sites/default/files/2014-04/documents/water-quality-scorecard.pdf
U.S. Environmental Protection Agency	Assessing Street and Parking Design Standards to Reduce Excess Impervious Cover in New Hampshire and Massachusetts	https://www3.epa.gov/region1/npdes/stormwater/assets/pdfs/ImperviousAssessment.pdf
U.S. Environmental Protection Agency	General Permits for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems in Massachusetts Authorization to Discharge under the National Polluntant Discharge Elimination System (with modifications effective January 6, 2021)	https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/final-2016-ma-sms4-gp-mod.pdf
U.S. Environmental Protection Agency	Overcoming Barriers to Green Infrastructure	https://www.epa.gov/green-infrastructure/overcoming-barriers-green-infrastructure
U.S. Environmental Protection Agency	Incorporating Low Impact Development into Municipal Stormwater Programs	https://www3.epa.gov/region1/npdes/stormwater/assets/pdfs/IncorporatingLID.pdf
U.S. Environmental Protection Agency	Encouraging Low Impact Development: Incentives Can Encourage Adoption of LID Practices in Your Community	https://www.epa.gov/sites/default/files/2015-09/documents/bbfs7encouraging.pdf
U.S. Environmental Protection Agency	Soak Up the Rain Outreach Tools	https://www.epa.gov/soakuptherain/soak-rain-outreach-tools
U.S. Forest Service	The Sustainable Urban Forest Guide: A Step-by-Step Approach	https://urbanforestrysouth.org/resources/library/ttresources/the-sustainable-urban-forest-guide-a-step-by-step-approach/at_download/file

Acronyms/Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Trips
BMP	Best Management Practice
EPA	Environmental Protection Agency
LID	Low Impact Development
LUHPPL	Land Uses with Higher Potential Pollutant Loading
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
ROW	Right of Way

SUBDIVISION REGULATIONS

ASSESSMENT OF STREET DESIGN AND PARKING LOT GUIDELINES AND FEASIBILITY OF ALLOWING GREEN INFRASTRUCTURE

Pioneer Valley Planning Commission, February 2022
(Edited by Mott MacDonald, September 2022)

NPDES MS4 Community: Ludlow, MA

Within Subdivision Regulations, standards for the following are critical for consideration: right of ways; utilities; roadway widths and lengths; cul-de-sacs; curbs; sidewalks; and bus waiting areas.

Street Standards in Subdivision Regulations

Right of Ways

Y/N	Checklist Item	Location in code and any standards	Example Language/*Notes (shown in italics)*	Change(s) recommended	Proposed schedule to incorporate changes
N	Is the minimum right of way width less than 45 feet for a residential street? (For 500 ADT, between 33 and 36 feet?)	50 ft - Section III.A.2.a of Subdivision Rules and Regulations - Town of Ludlow, MA	*See table from Sustainable Neighborhood Road Design Guidebook for MA provided in this workbook at Tab 5 - Reference Tables and Figures.* *Good design has not so much to do with the width of the right of way itself, but considerations of context and what makes for efficient and effective use of the right of way. What makes sense for the elements of a right of way on a busy suburban road will likely not make sense for a low volume rural road.*	None- although the current ROW width is wider than what is listed in the table on Tab 5, the Town uses this width not just for impervious roadway, but for underground utilities and pedestrian paths. Reducing this value is not expected to reduce impervious cover.	N/A
N	Are street cross sections provided to show how elements of a right of way might vary given different contexts?	page 101.1 of the Standard Construction Details	*Such drawings can provide a clear understanding about objectives and efficient and effective use of the right of way area in different contexts, bringing together "complete streets" considerations of accommodating different modes of transportation with "green streets" objectives of reducing impervious surface and improving stormwater management.*	N/A	N/A
N	Do the regulations limit clearing and grubbing within the right-of-way to the minimum necessary?	N/A	Developers are encouraged to limit clearing within the right-of-way to the minimum necessary to construct the roadway, drainage, sidewalk, and utilities, and to maintain site lines. Under this approach, it is not required to clear and grub the entire right-of-way.	N/A	N/A
Y	Are street trees required for new streets?	"Shade trees shall be on both sides of subdivision streets in the right-of-way or within ten feet of the right-of-way" - (Section III.K.(a) of Subdivision Rules and Regulations - Town of Ludlow, MA)	*In addition to requiring the planting of street trees, it is a good idea to specify that the tree belt can be designed for stormwater management. Tree belts may include bioretention areas or other vegetated stormwater systems. Bioretention areas should utilize noninvasive species (not on any Massachusetts invasive plant list) that can tolerate cycles of drought and inundation.*	N/A	N/A

Utilities

Y/N	Checklist Item	Location in code and any standards	Example Language/*Notes (shown in italics)*	Change(s) recommended	Proposed schedule to incorporate changes
Y	Does the code allow utilities to be placed under the paved section of the ROW?	"All lines and/or wires used for the transmission of electricity and/or intelligence shall be placed underground within the subdivision" - Section III.E.4.a. of Subdivision Rules and Regulations - Town of Ludlow, MA; there are no restrictions for utilities being placed under the paved section of the ROW.	Utilities (electric, telephone, cable TV, fiber optic, and all other conduits) may be located under the roadway or immediately adjacent to the roadway so as to optimize use of the right of way area for swales and other stormwater management facilities, sidewalks, and street trees.	N/A	N/A
Y	Does the code allow utilities to be placed immediately adjacent to the paved section of the ROW?	There are no restrictions for utilities being placed immediately adjacent to the paved section of the ROW.	*Often there is concern that such placement of utilities under the road will result in traffic delays and additional costs to utility companies. In the Rhode Island LID Site Planning and Design Guidance for Communities, however, authors from the Horsley Witten Group note that the reality is, "The amount of pavement needed to be removed during such operations can be decreased through better diagnostic tests and trenchless technologies for utility construction and repair." If the idea of putting utilities under the road edge is too great a concern for Departments of Public Works, then the next best strategy is to place utilities directly abutting roadway pavement, within 1 to 2 feet*	N/A	N/A

Roadway Widths and Lengths					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
N	Is paved roadway width between 18 and 22 feet in low density residential developments with no bicycle lanes present? Low density residential neighborhoods are those with less than 400 average daily trips according to AASHTO, 2001.	"The minimum width and alignment or roadway pavement within the right-of-way shall be shown on the Standard Construction Details" - Section III.A.2.b of Subdivision Rules and Regulations - Town of Ludlow, MA; this does not give a guideline for the street width.	*Refer to table from Sustainable Neighborhood Road Design Guidebook for MA provided in this workbook at Tab 5 - Reference Tables and Figures.* *Many existing standards are based on universal application of guidelines for highways or very large-scale subdivisions planned more than 50 years ago. Revised standards should involve the minimum required pavement width and derive from careful considerations with public works and emergency response officials of traffic volume, on-street parking (where required), and passage of emergency vehicles and school buses.*	N/A	N/A
N	At higher densities, are parking lanes allowed to also serve as traffic lanes (i.e., queuing streets)?	N/A		N/A	N/A
N	Are narrower pavement widths allowed on road sections were there are no houses, buildings, intersections, or on-street parking spaces?	N/A	*Revise local street standards to consider design speed, street type, and traffic volume on arterial and residential roads to allow for more compact roadways and intersections.* *If not currently permitted, allow for curb extensions such as pinchpoints, gateways, and chicanes to narrow roadways and utilize street space for pervious pavement or bioretention.*	N/A	N/A
N	Are reductions in frontage distances allowable where appropriate (i.e. open space developments, around cul-de-sacs, and along outside sideline of curved streets) to increase number of homes per unit length and to minimize street length?	N/A	Reduce street length in residential neighborhoods to minimize overall impervious cover creation and land disturbance.	N/A	N/A
N	Are developers encouraged to explore alternative street layouts to increase the number of homes per unit length and minimize the length of the roadway?	N/A	Exploration of alternative street layouts to increase the number of homes per unit length and minimize the length of the roadway is encouraged.	N/A	N/A
N	Can permeable paving be used for residential roads, shoulders, and parking lanes?	there are references to specifications that specify that pavement for roads be of bituminous concrete make-up - Section III. I. 4. of Subdivision Rules and Regulations - Town of Ludlow, MA	Where appropriate, use of permeable paving is allowed for road shoulders/parking lanes in residential neighborhoods and for sidewalks as compatible with Americans with Disabilities Act and Massachusetts Architectural Advisory Board design standards. *This approach could involve combining a traditional asphalt surface for the travel lanes and an adjacent porous surface for the shoulder/parking lanes or bike lane area. Snow and ice management for the roadway must avoid sand so as to avoid clogging of the porous shoulder area.*	None-the Town does not want to allow permeable paving on roadways due to maintenance and longevity concerns.	N/A
N	Do alignments specify: Streets ought to be located in order to protect important natural features, avoiding low areas and steep slopes in particular?	N/A	Streets shall be located and designed to minimize: 1. disturbance of the site's natural features and environmentally sensitive areas, including low areas and steep slopes, native vegetation, and trees with a trunk diameter measured at 4.5' DBH (Diameter at Breast Height), breast height of 8 inches or more; 2. cut and fill, thereby reducing disturbance of native soils; 3. unnecessary contouring of the site to preserve natural topography. *Another possible consideration here (though unrelated to MS4 permit)* : Street lay out along east-west or north-south axes is encouraged. This allows building siting to take advantages of passive solar heat gain and accommodate future solar electric installations on south-facing roofs.	N/A	N/A

Cul-de-Sacs					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
N	Are dead ends discouraged by the regulations? (e.g. by encouraging or requiring connected streets or one-way loop streets)?	Dead-end streets are limited to 1,000 feet - Section III.A.4.b. of Subdivision Rules and Regulations - Town of Ludlow, MA	A connected road network is of great importance to functioning and efficient road network, reducing response time for public safety officials. Dead-end streets are discouraged. An applicant should make every effort to avoid the creation of dead-end streets and should connect proposed subdivisions to existing dead end streets wherever reasonable and practicable. An applicant may demonstrate that a dead end street is appropriate when they can demonstrate that a future connection to an existing street is not possible or practicable, or when the surrounding property will never need a street connection because of extremely sensitive or permanently protected natural resources	N/A	N/A
Y	Are landscaped/bioretention islands allowed in the center of cul-de-sacs?	Landscaped islands are allowed - Section III.A.4.b. of Subdivision Rules and Regulations - Town of Ludlow, MA	All dead-end streets with turnaround islands may be planted with trees and/or other vegetation or left with natural tree growth in lieu of paving the entire area of the island. The maintenance of the inner circle shall be the responsibility of developers, their successors and assigns, or a homeowners' association.	N/A	N/A
N	If curbing for cul-de-sacs is required, is it allowed to be perforated or notched to enable the flow of stormwater into the island area?	Curbing is not discussed in Section III.A.4.b. of Subdivision Rules and Regulations - Town of Ludlow, MA.	Where soils are conducive to infiltration (Natural Resource Conservation Service hydrologic soils group A or B), the center island may serve as a stormwater bioretention area with notched or perforated curbing to allow for entry of storm flows. Invisible curbing, where granite curbing forms an at-grade edge with the asphalt, may also be permitted in this situation.	N/A	N/A
Y	Is minimum required radius for a cul-de-sac set for LID purposes?	35 feet - Section III.A.4.b. of Subdivision Rules and Regulations - Town of Ludlow, MA.	*Sustainable Neighborhood Road Design recommends 50-foot outside radius with vegetated center island.* *Massachusetts Fire Code 527 CMR requires 20-foot drive lanes and minimum inside turning radius of 25 feet.*	N/A	N/A
N	Are alternative turnarounds such as hammerhead allowed on short streets in low density residential developments?	N/A	*Hammerheads use less pavement overall than cul-de-sacs. Example below is per Sustainable Neighborhood Road Design:* *A hammerhead turnaround having a thirty (30) foot minimum curb radii; forty-five (45) foot minimum center lane radii, a head adequate for three point turn maximum, and a (length to accommodate local firefighting vehicle).*	N/A	N/A
Sidewalks					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
Y	In lower density residential contexts, are sidewalks allowed on just one side of a street? (As opposed to always required on both sides of residential streets.)	Sidewalks are required on one side of the street - Section III.F.1. of Subdivision Rules and Regulations - Town of Ludlow, MA.	*For low density neighborhoods, consider allowing sidewalks on just one side of street.* *See table from Sustainable Neighborhood Road Design Guidebook for MA provided in this workbook at Tab 5 - Reference Tables and Figures.*	N/A	N/A
N	Is permeable paving allowed for sidewalks?	N/A	If the site permits infiltration, sidewalks may be constructed of permeable paving materials. If using permeable materials, the developer must work in consultation with the Department of Public Works and an engineer with experience in this field, and materials must be evaluated at regular intervals as they age. Pervious asphalt should be based on specifications such as those found in the University of New Hampshire Stormwater Center Design Specifications for Porous Asphalt Pavements and Infiltration Beds. Sidewalks or pedestrian areas may also be constructed to direct stormwater runoff to a swale or other BMP. Permeable pavements provide increased traction when wet because water does not pool, and the need for sal and plowing is reduced during winter due to low/no black ice development. Compared to traditional paving methods, long-term maintenance costs may be lower in cold climates since permeable pavements resist cracking and buckling in freeze-thaw conditions. Nevertheless, permeable paving requires regular maintenance including: annual inspection of paver blocks for deterioration; periodic replacement of void material (gravel, etc.) if part of the facility; and annual industrial vacuuming of pavements to unclog sand and debris that have accumulated on the surface over time.	Provide the option for a different specification for permeable paving materials	June 30, 2024
N	Are alternative pedestrian network layouts allowed (rather than placement in ROW)?	N/A	For certain developments, it may be more sensible for pedestrian circulation to make use of common areas rather than street right of ways.		
N	Is sidewalk width standard set for LID purposes?	Sidewalks are required to be a minimum of 5 ft - Section III.F.1. of Subdivision Rules and Regulations - Town of Ludlow, MA.	*LID standard = 4 feet or less*	None-The wider width is a requirement the Town would like to keep to maintain safe widths for ADA accessibility.	N/A
N	Where curb and gutter streets are required for stormwater drainage, are sidewalks allowed to be disconnected from the stormwater drainage system?	N/A	Grading of impervious sidewalk surfaces should be done so as to direct stormwater runoff to bioretention areas or other such facilities to eliminate or keep flow out of the municipal storm drain system.		

Bus waiting areas					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
N	Do bus waiting areas require use of permeable paving unless infeasible?	N/A	*Permeable paving must be used for bus waiting areas in locations where soils are indicated to be in Natural Resource Conservation Service hydrologic soils group A or B.*		
Curbs					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
N	Do street standards allow for LID stormwater management approaches (i.e. swales or other such BMPs instead of curb and gutter)? Or are curbs and gutters REQUIRED improvements?	"All ways shall have their entire gutter lines curbed with bituminous concrete berm..." - Section IV.E.1. of Subdivision Rules and Regulations - Town of Ludlow, MA.	*In low or medium density developments where topography, soils, and slope permit, allow conveyance and treatment of stormwater runoff in the street right-of-way via vegetated open channels that incorporate runoff reduction practices such as dry swales, bioretention, biofilters, or vegetated swales, rather than requiring the use of curb and gutter stormwater conveyances.*	See example note in column D	June 30, 2024
N	Where curbs are necessary/required, are perforated curbs that allow runoff into swales or other stormwater BMPs allowed?	N/A	*Where curbing is needed, think about specifying granite curbing as a way to help keep roads narrow overall. (With asphalt curbing it is hard to plow to the curb since material can be easily damaged. The tendency is to account for this extra width needed in winter months.* *If pursuing LID design standards, curbs should either be eliminated or, when deemed necessary to protect the roadway edge, they should be interrupted or invisible. Interrupted curbs are curbs with gaps that allow stormwater to move from the street through to a stormwater management facility, such as planters, swales, rain gardens, or tree filter boxes. Invisible curbs are buried along the street edge so as to allow stormwater to flow over into a stormwater management facility. All LID curb options should be implemented in connection with stormwater management facilities. In shared streets, curbs should either be eliminated or be invisible.*	N/A	N/A
N	Does the town have criteria for design of roadside swales?	There is generally no criteria for the design of roadside swales, however, there is some language describing instances where they shall be used: "The Department of Public Works shall give preference to the use of swales in place of the traditional use of curbs and gutters based on a case by case review of stormwater management plans." - 7.2 F. 8.B.4. of Zoning Bylaws - Town of Ludlow, MA	*Refer to the design standards presented in the Massachusetts Stormwater Management Handbook: Volume Two.* *Potential design considerations / limitations:* *- Depending on land use and soil type, each grassed swale can treat a relatively small drainage area of a few acres. Large areas should be divided and treated using multiple swales.* *- Swales are impractical both in areas with steep slopes and with very low slopes.* *- Soil compaction can reduce infiltration capacity.* *- Pre-treatment practices may be required in areas with higher potential pollutant loading.*	N/A	N/A
N	Where curb and gutter systems are installed, are inlets / drains required to have a notice regarding discharge to receiving waters?	N/A	*Could require that developers install standard signage indicating that waters drain to _____ River, etc.*	Recommend including example language in Column D in Subdivision Rules and Regulations (Section III.F)	June 30, 2024
Ensuring Soil Permeability					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
			<u>Important note</u> : These suggested standards on ensuring soil permeability might serve better under standards required for a stormwater management permit/and or under the zoning bylaw/ordinance - site plan review for projects that do not trigger stormwater permit requirements. They are included here to underscore the importance of soils in performance of infiltration facilities, but also in ensuring that runoff curve numbers used in calculations remain as accurate as possible post construction.	N/A	N/A
N	Is it clear that topsoil removal from the site should not diminish the infiltration characteristics of the site?	N/A	Applicants must describe how their project will minimize and limit topsoil removal from the site.	N/A	N/A
N	Is it clear that any new soils brought on site should not diminish the infiltration characteristics of the site?	N/A	Applicants must describe how they will ensure that any new fill or soils brought to the site will not diminish the infiltration characteristics of the site.	N/A	N/A
N	Is there any mention of avoiding compaction of soils by construction vehicles and restoring permeability of soils for infiltration if compacted?	N/A	Ensure that all work is planned and executed so as to avoid compaction of topsoil and subsoils, including such best practices as reducing the number of trips required over area of disturbance, laying down soil protective mats for trafficked areas, and avoiding work after rain or snowmelt that soaks soils. For construction equipment, best practices should include using vehicles with low axle loads, reduced tire pressures, and use of flotation tires, doubles, radial tires, and/or large-diameter tires. For areas where such practices are not possible and soils are to be compacted by heavy equipment, subsurface restoration must occur prior to final landscaping activities .	N/A	N/A

Green Infrastructure Feasibility					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
	Are the following practices allowable when appropriate site				
Y	Green roofs	No code or standard limits the implementation of a green roof	*Green roofs are particularly appropriate for structures with a wide roof area, and typically are installed on flat or low angle rooftops. Design and maintenance considerations are described in more detail in PVPC's Green Infrastructure Fact Sheet on "Green Roofs." See:*	N/A	N/A
			http://www.pvpc.org/content/green-infrastructure-individual-fact-sheets		
N	Infiltration practices such as rain gardens, curb extensions, planter gardens, porous and pervious pavements, and other designs to manage stormwater using landscaping and structured or augmented soils	Impervious pavement is the guideline here for roadway pavement, sidewalk pavement, and driveway pavement - Sections IV. F., IV. G., and IV. H. of Subdivision Rules and Regulations - Town of Ludlow, MA.	*Rain gardens, also referred to as bioretention areas, use soil, plants and microbes to treat stormwater before it is infiltrated or discharged, and function effectively on small sites or on large sites divided into multiple small drainages. Common applications include parking lot islands, median strips, and traffic islands. Limitations, design considerations, and maintenance requirements are described in more detail in PVPC's Green Infrastructure Fact Sheets on "Bioretention Areas," Green Streets," and "Tree Box Filters." See:*	Add pervious pavement standards	June 30, 2024
			http://www.pvpc.org/content/green-infrastructure-individual-fact-sheets		
			Porous/pervious paving is appropriate for pedestrian-only areas and for low- to medium-volume, low-speed areas such as overflow parking areas, residential driveways, alleys, and parking stalls. If the underlying soils have a permeability of less than 0.3" per hour, use of an underdrain will be required. Permeable paving is not ideal for high traffic/high speed areas because it generally has lower load-bearing capacity than conventional pavement. Design and maintenance requirements are described in more detail in PVPC's Green Infrastructure Fact Sheet on "Porous Asphalt." See:		
			http://www.pvpc.org/content/green-infrastructure-individual-fact-sheets		
			Encourage both preservation of existing stands of trees and mature trees on site as well as plans that incorporate trees into stormwater management practices. This can be done through specific requirements and through a system of credits. Calculating stormwater benefits of certain species based on size can be done through the National Tree Benefit Calculator. See calculator at:		
			http://www.treebenefits.com/calculator/		
			Allow for bioretention areas or other vegetated stormwater facilities within treebelt areas and to count toward other required landscaping features, including site, parking or perimeter screening. This creates areas that function on several levels, including aesthetics and stormwater management.		
Y	Water harvesting devices such as rain barrels and cisterns, and the use of stormwater for non-potable uses	No code or standard that limits the implementation of rain harvesting devices in the state of Massachusetts	*Cisterns and rain barrels are used to store rooftop runoff for later use for landscaping and other non-potable uses such as car washing. Water stored in cisterns is even used in some cases for toilet flushing and/or irrigation of planters within buildings. Cisterns and rain barrels can be used in most commercial and residential properties where rooftop runoff is directed to a gutter and downspout. Design and maintenance requirements are described in more detail in PVPC's Green Infrastructure Fact Sheet on "Rain Water Harvesting." See:*	N/A	N/A
			http://www.pvpc.org/content/green-infrastructure-individual-fact-sheets		
	If no, please describe impediments: _____				
N	If yes, are there developer incentives for utilizing green infrastructure practices?	There are generally no incentives or credits explained in the town bylaws	*The use of green infrastructure practices can be encouraged by offering incentives such as stormwater utility fee discounts or credits, waived or reduced permit fees, recognition programs for successful green infrastructure sites, and/or exemptions from portions of the local stormwater permitting requirements. For additional ideas on types of incentives and implementation, please refer to the EPA's Encouraging Low Impact Development Fact Sheet:*	N/A	N/A
			https://www.epa.gov/sites/default/files/2015-09/documents/bbfs7encouraging.pdf		

Development Policies in Subdivision Regulations					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
N	Does the preliminary plan processes promote an LID approach?	N/A	*At the outset, encourage developers to undertake a Low Impact Development (LID) approach in their projects by requiring an LID plan for preliminary subdivision applications. The City/Town could help by providing a developer with a standard site analysis checklist that will help during the early stages of the project to maximize design and functionality of LID strategies and stormwater management practices. As part of this analysis and reporting, the applicant could identify proposed LID strategies and stormwater BMPs. Use of PVPC checklist could be part of this early review. See:* https://thinkblueconnecticutriver.org/wp-content/uploads/2020/12/10.-LID-Checklist-for-Preapplication-Meeting-PVPC-Model.docx	N/A	N/A
			Important note : It is best to include this early review element as part of stormwater management permit requirements for larger projects and site plan review requirements for smaller projects, but good to reinforce that process in Subdivision Regulations.		
			Under Preliminary Plan/General: To the fullest extent reasonable and practicable, all subdivisions shall be designed and constructed to incorporate the most recent LID and stormwater management design standards, best practices, policies and design elements. *To include in Preliminary Plan Contents (some of these elements go beyond the PVPC LID checklist, but are worthwhile considerations for this stage of subdivision review):* *Location and limits of soil types consistent with the soils classification maps prepared by the Natural Resources Conservation Service.* *Areas where the depth of natural soil to bedrock is four (4) feet or less.* *The extent of any Interim Wellhead Protection Areas and Recharge Areas.* *Delineation of slopes of twenty-five percent (25%) or greater.* *Areas delineated as "BioMap Core Habitat" or "Supporting Natural Landscape" on the Massachusetts BioMap Project developed by the Massachusetts Natural Heritage & Endangered Species Program.*		
Y	Is the definitive plan process coordinated with the stormwater management and erosion and sediment control permit process requirements?	Section III. E. 1 - Subdivision Rules & Regulations - Town of Ludlow, MA	*Define a process that combines submissions for stormwater management permits with Definitive Plans to avoid duplication.* *Possibly state:* An Application for a Stormwater Management and Erosion and Sediment Control Permit, in accordance with Section ___ of the _____ , along with all required plans and supporting information and documentation, must be included as part of the submission for a Definitive Subdivision Plan. No work shall commence on the construction of a Definitive Subdivision Plan until a Stormwater Management and Erosion and Sediment Control Permit has been approved and issued.	N/A	N/A
N	Is there a section within the subdivision regulations that addresses drainage?	N/A	*Consider removing specific stormwater management language from subdivision regulations and referring out to standards in the stormwater management ordinance/bylaw and regulations is recommended. It is best not to describe requirements in subdivision regulations to avoid conflict and inconsistencies as standards are updated from time to time.*	N/A	N/A
N	Do the site development standards explicitly permit LID stormwater management approaches?	According to Subdivision Rules and Regulations - Town of Ludlow, MA, LID may be hindered.	*Review any additional standards carefully to ensure they enable LID stormwater management approaches and do not present barriers to such development strategies.*	This recommendation's intent is being carried out as part of analysis in Year 4 permit work.	N/A

ZONING BYLAW/ORDINANCE

ASSESSMENT OF STREET DESIGN AND PARKING LOT GUIDELINES AND FEASIBILITY OF ALLOWING GREEN INFRASTRUCTURE

Pioneer Valley Planning Commission, February 2022
(Edited by Mott MacDonald, September 2022)

NPDES MS4 Community: Ludlow, MA

Within Zoning, the following elements are critical considerations: parking ratios; parking lots and driveways (stall sizes, travel lanes, landscaping, etc.); dimensions and density; and landscaping.

Parking Ratios

Y/N	Checklist Item	Location in code and any standards	Example Language/*Notes (shown in italics)*	Change(s) recommended	Proposed schedule to incorporate changes
N	Are parking maximums used in any instances (to prevent too much parking)?		*Consider the following: 1. Establishing both minimum and maximum parking ratios to provide adequate parking while reducing excess impervious coverage. Parking reductions could be allowed for factors such as: mixed land uses, access to alternative transportation, demographics, and utilization of Transportation Demand Management (TDM) Programs including subsidized mass transit and parking cash out programs. Flexibility is a key component to providing adequate but not excessive parking.* *2. Requiring a Special Permit for an increase in maximum parking allowance. Some onsite parking requirements could be met off-site particularly in redevelopment sites and compact mixed use centers.* *For useful language on parking, see the MA Smart Parking Model Bylaw at:* https://www.mass.gov/files/documents/2017/11/03/Smart%20Parking.pdf	N/A	N/A
Y	Does zoning require more than 3 **off street parking spaces** per 1,000 sq. ft. of gross floor area for office uses?	3.33 spaces per 1,000 sq. ft. - 5.5.8.1 of Zoning Bylaws - Town of Ludlow, MA	*For recommended parking requirements per 1,000 sq ft of Gross Floor Space, see table provided in this workbook at Tab 5 - Reference Tables and Figures.*	Reduce the number of parking spaces per 1,000 sq ft. of gross floor area for office uses.	June 30, 2028
Y	Does zoning require more than 4.5 off street parking spaces per 1,000 sq. ft. of gross floor area for shopping centers?	5 spaces per 1,000 sq. ft. - 5.5.8.1 of Zoning Bylaw - Town of Ludlow, MA		Reduce the number of parking spaces per 1,000 sq ft. of gross floor area for shopping centers.	June 30, 2028
N	Does zoning **vary parking requirement by zone** to reflect places where more trips are on foot or by transit?	N/A		N/A	N/A
N	Does zoning have reduced off-street parking requirements for its downtown zoning district?	N/A		N/A	N/A
N	Does zoning have lower parking requirements for properties near transit stops?	N/A		N/A	N/A
N	Does zoning allow reduced parking requirements for properties within walking distance to multiple services?	N/A		N/A	N/A
N	Does zoning have lower parking requirements for properties in the more densely developed residential districts?	N/A		N/A	N/A
N	Does zoning allow **alternative measures** such as custom parking demand calculations, transportation demand management or in-lieu payments to reduce required parking?	N/A		N/A	N/A
N	Does zoning have provisions allowing for **shared parking** to reduce parking requirements?	N/A	*Refer to the Smart Parking Model Bylaw for bylaw language around three strategies for shared parking: opportunities to share parking between competing and non-competing uses on the same site, locating parking off-site on other privately owned lots or public parking facilities, and/or for using a "fee-in-lieu" approach. See:*	N/A	N/A
N	Are shared parking provisions by right?	N/A	https://www.mass.gov/files/documents/2017/11/03/Smart%20Parking.pdf	N/A	N/A
N	Does the municipality provide model shared parking arrangements for private use?	N/A	*See model for shared parking here:*	N/A	N/A
N	Does zoning require more than 2 **off-street parking spaces per residential** unit?	6.4.2.a of Zoning Bylaw - Town of Ludlow, MA	https://www.gardinermaine.com/sites/g/files/vyhlif611/f/news/appendix_d_sampleparkingagreement_0.pdf	N/A	N/A
Y	Does zoning require 2 off-street parking spaces per residential unit?	6.4.2.a of Zoning Bylaw - Town of Ludlow, MA		N/A	N/A
N	Does zoning require less than 2 off-street parking spaces per residential unit?	6.4.2.a of Zoning Bylaw - Town of Ludlow, MA		N/A	N/A
N	Does zoning require more than 1 off-street parking space for an accessory dwelling unit?	N/A		N/A	N/A
Y	Does zoning have lower parking requirements for smaller residential units?	Efficiency units and units with one bedroom - 6.4.2.a of Zoning Bylaw - Town of Ludlow, MA		N/A	N/A

Parking Lots and Driveways					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
Y	Is requirement for standard parking lot stall consistent with LID purposes?	6.4.6 A of Zoning Bylaws - Town of Ludlow, MA	*LID Standard = 9 feet or less by 18 feet or less*	N/A	N/A
N	Is requirement for drive lane width consistent with LID purposes?	The minimum width and alignment or roadway pavement within the right-of-way shall be shown on the Standard Construction Details in Section III.A.2.b of Subdivision Rules and Regulations - Town of Ludlow, MA; this does not give a guideline for the street width.	*LID Standard = 9 feet wide for one lane / 18 feet wide for two lanes*	N/A	N/A
N	For larger parking lots, are there provisions requiring compact car spaces?	N/A		N/A	N/A
N	If yes, are at least 30% of parking spaces required to have smaller dimensions for compact cars?	N/A		N/A	N/A
Y	Is there a minimum percentage of a parking lot required to be landscaped?	N/A		N/A	N/A
N	Do **landscaping** requirements for parking areas allow for vegetated areas with bioretention functions?	Table 3 of Zoning Bylaws - Town of Ludlow, MA	If landscaped islands are located in an area with existing soils classified in the NRCS hydrologic soil groups A/B, such that the existing soils are suitable for infiltration stormwater runoff, the internal landscape areas may/shall be installed at a lower grade than the parking lot pavement, and curbing shall allow drainage from the pavement to enter and percolate through the landscaped areas while simultaneously protecting the landscape materials.	N/A	N/A
N	Do landscaping requirements for parking areas encourage vegetated areas with bioretention functions?	Bioretention areas are not encouraged in the Zoning Bylaws		N/A	N/A
N	Is the use of **pervious surfacing materials** allowed for parking stalls, spillover parking areas, shoulders, etc.?	Allowance of pervious surfacing materials is not written in the Zoning Bylaws or Subdivision Rules and Regulations	Pervious materials such as porous asphalt or concrete, porous pavers, and reinforced grass blocks may be allowed in lower volume stalls or overflow parking areas. Note that snow storage should not coincide with these areas as plow piles may include sand, which will clog pervious pavement and prevent infiltration.	Allow pervious surfacing materials to be used for parking stalls, spillover parking areas, shoulders, etc, in general bylaws.	June 30, 2026
N	Is the use of pervious surfacing materials encouraged for parking stalls, spillover parking areas, shoulders, etc.?	Encouragement of pervious surfacing materials is not written in the Zoning Bylaws or Subdivision Rules and Regulations			
N	Are pervious materials for **single family driveways** (porous pavers, paving stones, pervious asphalt or concrete), and/or use of two-track design for residential driveways allowed?	Allowance of such pervious materials is not written in the Zoning Bylaws or Subdivision Rules and Regulations		N/A	N/A
Y	Does zoning allow for **common or shared driveways**?	Planned business development - Section 4.3.4 of Zoning Bylaws - Town of Ludlow, MA	*Example from Hadley – through special permit: The Planning Board may issue a special permit permitting a common driveway (a single curb cut and driveway providing vehicular egress/access to more than one lot) when, in its judgment, such action is in the public interest and not inconsistent with the intent of this Zoning Bylaw, provided:* *5.7.1. Said common driveway shall not service more than three residential lots. In the case of commercial/retail and industrial/manufacturing uses in Business and Industrial zoned Districts a common driveway may serve more than three lots, but the total shall be set by the Planning Board in the issuance of their special permit.* *5.7.2. Said common driveway shall provide the only vehicular egress/access to the lots being serviced by it, and this shall be so stated in the deeds to the subject lots.* *5.7.3. Said common driveway shall not be eligible for maintenance by the Town or for acceptance by Town Meeting as a street, and this also shall be so stated in the deeds to the subject lots.* *5.7.4. The grade, length and location of the common driveway shall be of suitable construction, in the opinion of the Planning Board, for the access and turnaround of the number and types of vehicles, including moving vans, ambulances, fire and police, which will be utilizing such driveway.* *5.7.5. For common driveways servicing commercial/retail and industrial/manufacturing uses in Business and Industrial zoned Districts, the design and construction standards of said common driveway shall be set by the Planning Board in the issuance of their special permit.* *5.7.6. Common driveways servicing residential properties shall comply with all of the following:* *5.7.6.1 Shall have a length of no more than 500 feet; and* *5.7.6.2. Shall have a width of at least 15 feet; and* *5.7.6.3. Shall have passing turnouts providing a total width of at least 20 feet along a distance of at least 25 feet, spaced with no more than 300 feet between turnouts, and with the first such passing turnout being located at the driveway connection to the street; and* *5.7.7. All common driveways must:* *5.7.7.1. Meet the prior approval of the Highway Division and the Fire Department; and* *5.7.7.2. Conform to all other driveway requirements of the Zoning Bylaw.* *5.7.8. Where applicable, easements and easement plans must be submitted with the special permit application*	N/A	N/A
N	If yes, are they allowed by right?	N/A		N/A	N/A

Dimensions and Density					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
Y	Are there any special districts or flexible design opportunities that enable clustering of buildings and greater protection of open space areas on a site?	Industrial and business districts allow for smaller frontage (50') compared to Residential and Agricultural - Table 2 of Zoning Bylaws - Town of Ludlow	*Open Space Residential Development (OSRD), Open Space Design (OSD), Conservation Development and Natural Resource Protection Zoning (NRPZ) are the current zoning models for what was previously called cluster or flexible development. These models reverse the typical subdivision planning process by utilizing LID site design strategies for conserving natural hydrologic functions and reducing impervious surfaces for preventing runoff, and integrating green infrastructure as a fundamental design element. Resulting development plans typically retain native vegetation and natural areas, and structure site layout to greatly reduce street infrastructure. It has been noted that the open space set aside should be based on resource values, not by formula such as X% of the development.*	N/A	N/A
N	Is this type of development allowed by right?	N/A	*Permit such development as a "by right" form of development, where no special permit is required.*	N/A	N/A
N	Are the submittal or review requirements for such developments greater than for conventional development?	N/A		N/A	N/A
N	Are there any other regulations that allow for reductions in dimensional requirements to increase flexibility in building placement?	N/A	*Allow flexible site design criteria such as reduced setbacks and smaller lot sizes.* *Reductions in frontages would allow for reduced road length/paved area, perhaps where appropriate such as in open space residential developments, at the outside sideline of curbed streets, and around cul-de-sacs.*	N/A	N/A
N	Is the use of bioretention and other stormwater practices allowed in setback areas?	Explicit allowance of pervious surfacing materials is not written in the Zoning Bylaws or Subdivision Rules and Regulations; Explicit hindrance is also not written.	*Explicitly allow bioretention areas, rain gardens, filter strips, swales, and constructed wetlands within required setback areas for front, rear, and side yards based on site-specific conditions such as soils, depth to groundwater table and slope.*	N/A	N/A
			In a mixed-use district, setbacks should include enough space for a substantial vegetated buffer adjacent to the residential use as screening that can also serve as stormwater green infrastructure.	N/A	N/A

Landscaping					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
N	Is the use of bioretention and other stormwater practices allowed within landscaped areas for parking lots (versus requirement for curb and gutter management of stormwater)?	Explicit allowance of pervious surfacing materials is not written in the Zoning Bylaws or Subdivision Rules and Regulations; Explicit hindrance is also not written.	Edging and curbing in parking lots can be notched or perforated to allow stormwater flows into infiltration and bioretention areas. For larger parking lots, parking rows may be separated with planting strips that function to manage stormwater. Shade tree requirements in planting strips should also take into consideration stormwater treatment. Note that shade in parking lots will also help to reduce the "heat island" effect.	N/A	N/A
N	Does language on screening and buffers indicate that these areas could be used for stormwater management?	N/A	Depending on site-specific conditions such as soils, depth to groundwater table and slope, buffer and landscaped areas may include bioretention areas and other green infrastructure stormwater management facilities.	N/A	N/A
N	Is the use of bioretention and other stormwater practices explicitly allowed within landscaped areas?	N/A		N/A	N/A
			Consider also including design standards for landscaping and screening that encourage the use of green stormwater management infrastructure facilities. In the same way that architectural design standards serve a town, design standards for landscaping can support placemaking within neighborhoods and across a community.		
			<u>Important note</u> : Suggested standards on ensuring soil permeability below serve best under standards required for a stormwater management permit/and, but they may also be appropriate under zoning bylaw/ordinance - site plan review for projects that do not trigger stormwater permit requirements. They are included here to underscore the importance of soils in performance of infiltration facilities, but also in ensuring that curve runoff numbers used in calculations remain as accurate as possible post construction.		
N	Is it clear that topsoil removal from the site should not diminish the infiltration characteristics of the site?	N/A	Applicants must describe how their project will minimize and limit topsoil removal from the site.	N/A	N/A
N	Is it clear that any new soils brought on site should not diminish the infiltration characteristics of the site?	N/A		N/A	N/A
N	Is there any mention of avoiding compaction of soils by construction vehicles and restoring permeability of soils for infiltration if compacted?	N/A	Ensure that all work is planned and executed so as to avoid compaction of topsoil and subsoils, including such best practices as reducing the number of trips required over area of disturbance, laying down soil protective mats for trafficked areas, and avoiding work after rain or snowmelt that soaks soils. For construction equipment, best practices should include using vehicles with low axle loads, reduced tire pressures, and use of flotation tires, doubles, radial tires, and/or large-diameter tires. For areas where such practices are not possible and soils are to be compacted by heavy equipment, subsurface restoration must occur prior to final landscaping activities.	N/A	N/A

Development Policies in Zoning Regulations					
Y/N	**Checklist Item**	**Location in code and any standards**	**Example Language/*Notes (shown in italics)***	**Change(s) recommended**	**Proposed schedule to incorporate changes**
Y	Are standards and requirements within the zoning code consistent with the Stormwater Management Bylaw/Ordinance and Regulations?	Section 7.2 - Zoning Bylaws - Town of Ludlow, MA	*A best practice for eliminating conflicting standards is to reference the local stormwater bylaw or regulation within needed sections of the zoning code for appropriate drainage standards, thereby keeping all drainage standards and specifications in one section of the local code. All zoning standards for drainage should be consistent with the purpose and standards identified in any local stormwater management bylaw, regulation or policy to provide a seamless process for promoting LID site planning. Conserving the natural hydrologic function of a site, reducing impervious surfaces and preventing runoff are key principles in ensuring post development peak flows do not exceed predevelopment peak flows. Green infrastructure facilities should be explicitly encouraged for treatment, attenuation, and infiltration of stormwater at decentralized locations around a site to capture stormwater at its source.*	N/A	N/A
N	Does the site plan approval process promote and enable an LID approach?	N/A	*Critical to effective implementation of green infrastructure facilities is the site inventory and analysis process which should occur before any design work. Existing site conditions may offer opportunities to minimize impacts as well as the costs of stormwater management and can be identified through careful site analysis. Local zoning and permitting can promote a thoughtful process by defining the planning process and providing standards for green infrastructure, especially for smaller projects that do not trigger review for a stormwater management permit.*	N/A	N/A
	What elements count toward meeting open space requirements? (indicate all that apply)		*Consider allowing applicants to count green infrastructure stormwater management facilities as open space, especially if their project goes above and beyond requirements for stormwater management.*	N/A	N/A
N	Bioretention areas	N/A		N/A	N/A
N	Constructed wetlands	N/A		N/A	N/A
N	Green roofs	N/A		N/A	N/A
	Other: _____			N/A	N/A

OTHER CONSIDERATIONS

ASSESSMENT OF STREET DESIGN AND PARKING LOT GUIDELINES AND FEASIBILITY OF ALLOWING GREEN INFRASTRUCTURE

Pioneer Valley Planning Commission, February 2022
(Edited by Mott MacDonald, September 2022)

NPDES MS4 Community: Ludlow, MA

Y/N	Checklist Item	Location in code and any standards	Example Language/*Notes (shown in italics)*	Change(s) recommended	Proposed schedule to incorporate changes
Board of Health Bylaw and Regulations					
N	Do regulations exceed Title 5 requirements, requiring oversized septic systems or larger setback distances?		*Regulations should not require additional setbacks or classify stormwater structures so as to increase minimum setback distances (e.g. some towns require dry wells and bioretention areas to meet the same setbacks as a septic system).*	N/A	N/A
Y	Do regulations allow the use of stormwater for non-potable uses?	There were no regulations found that would suggest that stormwater could not be used for non-potable use.	*The type of and quantity of pollution in stormwater depends on the composition of the surfaces over which stormwater runoff flows and the activities within the drainage area that generate pollution. The water quality requirements of common beneficial uses of stormwater and the level of treatment needed for various types of harvested stormwater to meet these requirements are summarized in the Minnesota Stormwater Manual's Water Harvesting and Use System Matrix:*	N/A	N/A
			https://stormwater.pca.state.mn.us/index.php?title=Water_harvesting_and_use_system_matrix		
Wetlands Bylaw and Regulations					
N	Do regulations increase the required buffer above beyond what is required by the Wetlands Protection Act and/or establish more protective standards for buffer zones?	Section 2. Jurisdiction - Ludlow Conservation Commission Bylaws	*Increased wetland buffer zones improve sediment filtration and nutrient removal from stormwater, and decrease potential flooding by providing additional opportunities for stormwater infiltration. However, the Wetlands Protection Act does not include performance standards for the buffer zone, and not all resource areas are afforded a buffer zone under the definitions of the Wetlands Protection Act. Through local wetlands bylaws and/or regulations, municipalities can claim jurisdiction over the 100-foot Buffer Zone (or larger areas) as a Resource Area in and of itself; expand the definition of Buffer Zone to include buffer zones to resource areas not currently included in the Wetlands Protection Act; and/or extend the 200-foot Riverfront Area to intermittent streams, brooks, and ponds.* *Additional information regarding the science behind the importance of buffer zones and bylaw/ordinance considerations can be found in the MACC Wetland's Buffer Zone Guidebook (link provided below), which includes a standard Burden of Proof statement that can apply to Buffer Zones if such areas are defined as within the local Conservation Commission's area of jurisdiction:* *The applicant for a permit shall have the burden of proving by a preponderance of the credible evidence that the work proposed in the permit application will not have unacceptable significant or cumulative effect upon he resource area values (i.e., ecosystem services and functions) protected by this bylaw. Failure to provide adequate evidence to the Conservation Commission supporting this burden shall be sufficient cause for the Commission to deny a permit or grant a permit with conditions.*	N/A	N/A
			https://www.readingma.gov/conservation-division/files/macc-wetlands-buffer-zone-guidebook		
Municipal Policies and Programs					
N	Does the municipality have a plan for water efficiency that includes reuse?		*MAPC's Guide to Water Reuse in Massachusetts includes limitations, benefits, and design considerations for different types of water reuse systems. See:*	N/A	N/A
			http://www.mapc.org/wp-content/uploads/2017/11/3-1-Once-is-Not-Enough-Guide-to-Water-Reuse-10-05.pdf		
Y	Does the municipality have a program to address stormwater runoff and/or LID?	Section III.E.1. of Subdivision Rules and Regulations - Town of Ludlow, MA		N/A	N/A
N	Does the municipality provide information brochures / manual for homeowners describing rainwater harvesting and stormwater management techniques?	N/A	*PVPC's Green Infrastructure fact sheets include a guide to Rainwater Harvesting:*	N/A	N/A
			http://www.pvpc.org/sites/default/files/files/PVPC-Rain%20Water%20Harvesting.pdf		

N	Does the municipality have policies that promote complete streets or LID considerations within capital improvement plans or in ranking road construction projects?	N/A		N/A	N/A
	Do municipal policies require new street trees as part of road reconstruction projects?	Section III.K.(a). of Subdivision Rules and Regulations - Town of Ludlow, MA	*Trees are effective in capturing and promoting absorbtion of stormwater. For more information, see the US Forest Service Report, entitled The Sustainable Urban Forest Guide: A Step-by-Step Approach at:*	N/A	N/A
Y	Do capital improvement plans include tree planting as part of project budgets?	Subdivisions require two trees per lot along roads	https://urbanforestrysouth.org/resources/library/ttresources/the-sustainable-urban-forest-guide-a-step-by-step-approach/at_download/file	N/A	N/A
N	Has there been any review of emergency services policies or building and fire regulations to ensure that they allow LID techniques?	N/A		N/A	N/A
Local Building / Plumbing Codes					
Y	Do local building codes allow the use of permeable paving, narrow driveways, green roofs or other LID techniques?	There were no regulations found that would suggest that these listed things are disallowed.		N/A	N/A
N	Do local building codes allow the use of harvested rainwater for interior non-potable uses?	N/A		N/A	N/A
N	Do local plumbing codes allow the use of harvested rainwater for interior non-potable uses such as toilet flushing?	N/A		N/A	N/A

ASSESSMENT OF STREET DESIGN AND PARKING LOT GUIDELINES AND FEASIBILITY OF ALLOWING GREEN INFRASTRUCTURE

Pioneer Valley Planning Commission, February 2022

Example of Parking Requirements per 1,000 sq ft of Gross Floor Space from *Assessing Street and Parking Design Standards to Reduce Excess Impervious Cover in New Hampshire and Massachusetts*

Land Use	Maximum	Minimum
Bank	3	2
Large Scale Retail	4	2
General Office Building	4	2
Medical Building	8	2
Nursing Home	3	2
Restaurants	10	6
Shopping Centers	4	3
Bed and Breakfast	1.2 spaces per guest room or suite	1 space per guest room or suite
Personal Services	3	2
Churches and Places of Worship	1 space per 3 seats in the service portion of the building	1 space per 5 seats in the service portion of the building
Museums and Libraries	2	1
Public and Private Educational Institutions	1 space per 3 seats in the classroom	1 space per 5 seats in the classroom

General Parameters for Residential Road Design from *Sustainable Neighborhood Road Design: A Guidebook for Massachusetts Cities and Towns*

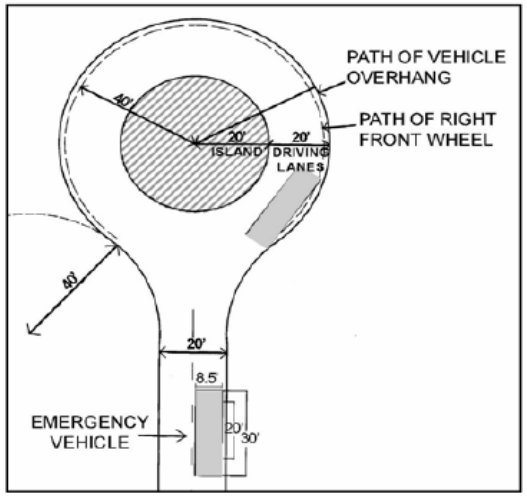
Parameter	Single Use Residential Wide	Single Use Residential Medium	Single Use Residential Narrow	Single Use Residential Alley
Traveled Way				
Typical ADT	4,999 < 1,500	1,499 < 400	399 < 0	100 < 0
Design Speed	25 - 30 mph	20 mph	20 mph	15 mph
Operating Speed	20 - 25 mph	20 mph	15 - 20 mph	15 - 20 mph
Number of Through Lanes	2	2	2	1
Lane Width	10 - 12 feet	10 - 12 feet	10 feet	9 - 10 feet
Shoulder	2 feet	2 feet	2 feet	2 feet
Bike Lanes	Shared road or 6 feet wide	Shared road	Shared road	Shared road
Utility Easement Width	--	--	10 feet	10 feet
Range of ROW Width	40 - 50 feet	36 - 40 feet	33 - 36 feet	20 feet

ASSESSMENT OF STREET DESIGN AND PARKING LOT GUIDELINES AND FEASIBILITY OF ALLOWING GREEN INFRASTRUCTURE

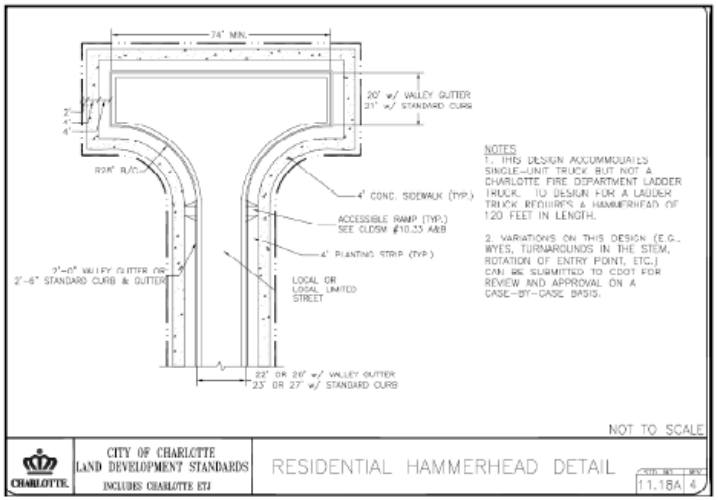
Pioneer Valley Planning Commission, February 2022

Parameter	Single Use Residential Wide	Single Use Residential Medium	Single Use Residential Narrow	Single Use Residential Alley
Roadside				
Desirable Roadside Width (pedestrian, swale, and planting strip)	5.5 - 12 feet	5.5 - 10 feet	5.5 feet	None
Grass Plot / Planting Strip	0 - 6 feet	0 - 6 feet	0 - 6 feet	None
Minimum Sidewalk Width	4 feet; one side OK	4 feet / shared road	Shared road	Shared road
Street Lighting	At intersections and pedestrian-scale lighting at residential driveways	At intersections and pedestrian-scale lighting at residential driveways	At intersections and pedestrian-scale lighting at residential driveways	At intersection with road
Intersections				
Traffic Control	Stop signs, 4-way yield	4-way yield	4-way yield	Yield exiting alley
Curb Radii	15 - 25 feet	15 - 25 feet	15 - 20 feet	15 feet

Example of Cul-de-Sac Designs and Dimensions, from *Sustainable Neighborhood Road Design: A Guidebook for Massachusetts Cities and Towns*



a. Cul-de-sac with vegetated island



b. Hammerhead turnaround design

Appendix D.
LPCP Funding Source Assessment

D. LPCP Funding Source Assessment

MOTT MACDONALD

Memorandum

Subject	**Lake Phosphorus Control Plan Funding Source Assessment**
To	James Goodreau
From	Billy Krukowski, P.E. Suzanne Newman, P.E.
Our reference	2021 MS4 Permit Support, 507395991-005
Date	9/28/2021

Complying with federal permits can be a challenge for small towns in addition to maintaining existing infrastructure. The costs associated with permit requirements can drain limited operating funds needed for staff to provide basic services. Future phases of the Town's MS4 permit will require capital investment in the development and funding of a Lake Phosphorus Control Plan (LPCP) for Minechoag Pond.

1 Background

The United States Environmental Protection Agency (EPA) National Pollution Discharge Elimination System (NPDES) General Permit for Stormwater Discharges from Small Municipal Separated Storm Sewer Systems (MS4) establishes requirements which regulated cities and towns must comply with to discharge stormwater to "Waters of the United States", as defined by the Clean Water Act (CWA). The Town of Ludlow is permitted under the 2016 Massachusetts (MA) MS4 permit which includes water quality standards where there are EPA-approved or established Total Maximum Daily Loads (TMDLs) for a given nutrient or pollutant. Ludlow is required to comply with Appendix F part A.II of the MA MS4 Permit due to a Lake and Pond Phosphorus TMDL for Minechoag Pond and Appendix F part B.I of the Permit due to a Nitrogen TMDL for Long Island Sound. This funding source assessment is required as part of the Town's Permit Year 3 requirements to describe potential funding mechanisms to meet the required phosphorus reductions as part of the LPCP. Nitrogen reduction requirements may be addressed in part by the efforts included in the LPCP but are not directly considered as part of this funding assessment.

Key components, task objectives, and due dates for the LPCP are included in the MA MS4 Permit Appendix F and summarized below in **Table 1**.

Table 1. LCPC Summary and Schedule (adapted from 2016 MA MS4 permit, Appendix F, Part A. II)

Item #	LPCP Component	Description	Years After Permit Date*
1	Legal Analysis	The permittee shall develop and implement an analysis that identifies existing regulatory mechanisms available to the MS4 such as by-laws and ordinances and describes any changes to these regulatory mechanisms that may be necessary to effectively implement the LPCP. This may include the creation or amendment of financial and regulatory authorities. The permittee shall adopt necessary regulatory changes by the end of the permit term	2

Item #	LPCP Component	Description	Years After Permit Date*
2	Funding source assessment	---	3
3	Define LPCP Scope (LPCP Area)	The permittee shall indicate the area in which the permittee plans to implement the LPCP, this area is known as the "LPCP Area"	4
4	Calculate Baseline Loads & Reduction Requirements	Permittees shall calculate their numerical Allowable Phosphorus Load and Phosphorus Reduction Requirement in mass/yr. by first estimating their Baseline Phosphorus Load in mass/yr. from its LPCP Area consistent with the methodology in Attachment 1 to Appendix F, the baseline shall only be estimated using land use phosphorus export coefficients in Attachment 1 to Appendix F and not account for phosphorus reductions resulting from implemented structural BMPs completed to date.	4
5	Description of Structural and Non-Structural BMP's	The permittee shall describe the non-structural stormwater control measures to be implemented to support the achievement of the milestones in this table. The permittee shall develop a priority ranking of areas and infrastructure within the municipality for potential implementation of phosphorus control practices.	5
6	Description of O&M Program	The permittee shall establish an Operation and Maintenance Program for all structural BMPs being claimed for phosphorus reduction credit.	5
7	Implementation schedule	An initial schedule for implementing the BMPs, including, as appropriate: funding, training, purchasing, construction, inspections, monitoring, O&M and other assessment, and evaluation components of implementation	5
8	Cost and funding source assessment	The permittee shall estimate the cost for implementing its LPCP and describe known and anticipated funding mechanisms.	5
9	Complete Written LPCP	The permittee must complete the written LPCP 4 years after permitting effective date.	5
10	Full implementation of nonstructural controls	Implement any nonstructural controls used to reduce phosphorus loads	6
11	Performance Evaluation	Evaluate the performance of nonstructural BMPs.	6/7
12	Performance Evaluation and Full implementation of all structural BMPs	Evaluate the performance of nonstructural BMPs and implement all structural BMP's	8
13	Performance Evaluation	Evaluate both structural and structural BMP performance	9
14	Performance Evaluation, Revised LPCP, Full implementation of all structural BMPs	Evaluate both structural and structural BMP performance, revise LPCP as needed.	10
15	Performance Evaluation	Evaluate both structural and structural BMP performance	11/12
16	Performance Evaluation, Revised LPCP, Full implementation of all structural BMPs	Evaluate both structural and structural BMP performance, revise LPCP as needed.	13
17	Performance Evaluation	Evaluate both structural and structural BMP performance	14
18	Performance Evaluation, Revised LPCP, Full implementation of all structural BMPs	Evaluate both structural and structural BMP performance, revise LPCP as needed.	15

In their 2021 phosphorus report, the Pioneer Valley Planning Commission (PVPC) calculated baseline phosphorus loads and required reduction rates for the three MS4-regulated catchments within Ludlow which contribute to Minechoag Pond. The PVPC has estimated that Ludlow must reduce phosphorus by a total of 48.22 pounds per acre per year based on the overall 48% phosphorus reduction required in the 2016 MA MS4 permit for the Town. Multiplying the reduction rate by the total catchment acres results in a total of 9,314 lbs./year of phosphorus to be removed. More details of this analysis are shown in **Table 2.**

Table 2. Summary of Ludlow's Phosphorus Reduction Requirements Determined by the PVPC

Catchment Identifier	Baseline Phosphorus Loading Rate lbs./ac/yr.	Required Phosphorus Reduction Rate lbs./ac/yr.	Catchment Acres	Impervious Acres	DCIA Acres
MCP03	51.55	**24.74**	96.16	28.41	4.94
MCP01	33.45	**16.06**	72.96	18.50	3.33
MCP02	15.47	**7.42**	24.04	9.43	3.04
Totals	**100.47**	**48.22**	**193.16**	**56.34**	**11.31**

Available funding sources and options are introduced within this funding source assessment report to meet the Year 3 permit requirements. Also included, as part of this assessment, is an estimate of phosphorus reduction requirements and a high-level order-of-magnitude cost assessment so that the Town would understand the general order of magnitude of the efforts required to comply with the Permit. Note that the required phosphorus reductions and costs are not required as part of the Year 3 efforts and will need to be refined in more detail as required by subsequent permit year terms. Mott MacDonald is also providing introductory information on all funding sources. Once the Town reviews these sources and decides to pursue any of these options, it is recommended that the Town further evaluate the chosen funding source to determine whether it is appropriate for the Town and what additional steps need to be taken.

2 Funding Sources

Mott MacDonald has identified potential funding sources for the LPCP program. One funding source category, grants, includes a number of funding sources which were identified to potentially reduce the Town's required direct cost of program implementation; however, these sources are competitive and may be limited and should therefore not be relied upon solely to support this program. The following funding sources have been identified and are explained in more detail within this section:

1. Taxes
2. Fees
3. Grants
4. State loans programs
5. Partnerships

2.1 Taxes

Many communities fund stormwater management through taxes (usually property taxes) paid into their general funds. Municipalities typically determine the funding amount for the stormwater management program during their annual budgeting process and there are a few strategies the Town can pursue to increase funding.

Surplus funds from town budgets are often returned to a general fund at the end of the fiscal year. Use of these funds are approved by annual town meeting or special town meeting. The Town can consider allocating a set portion of these funds to a stormwater capital account. This will provide some level of funding for stormwater assets and MS4 permit compliance which may minimize the impact to the current year's operating budget. It should be noted that while funds would be moved to a stormwater fund, existing use of free cash will be impacted.

Additionally, if Town revenues are not sufficient to fund the LPCP, the Town can consider increasing revenue by raising the levy limit or funding capital project through debt exclusions. Debt exclusions are used to fund specific capital projects and the increased taxes for the debt exclusion are removed once the loan is paid off. Debt exclusions are not subject to the levy limit. Alternatively, a tax override increasing the levy limit can permanently increase town revenue to fund, capital projects, increased operating costs, or secure funds for loan repayment.

2.2 Fees

2.2.1 Stormwater Enterprise Fund

As more towns and cities in Massachusetts experience increased costs related to stormwater compliance, the creation of a stormwater utility and associated enterprise fund has often been used as a solution and effective means to fund aspects of the MS4 permit, including LPCP costs. Creating a stormwater enterprise fund can generate a stable and adequate revenue stream to fund stormwater projects and distribute costs equitably. Over 1,700 towns in the United States (21 in Massachusetts) have created stormwater enterprise funds to address regulatory stormwater requirements and make stormwater improvements.

Enterprise funds are dedicated accounts used for a specific purpose, such as sanitary sewers, for example. The revenue for an enterprise fund is normally generated by fees related to the fund's purpose. The creation of a stormwater utility and charging utility fees for stormwater operations, maintenance, capital improvements, planning, permitting, and compliance is authorized by Massachusetts General Law Chapter 83, Section 16[1] and Chapter 40 Section 1A[2].

The Town of Ludlow currently includes stormwater operation and maintenance as part of the department of public work's (DPW's) annual budget. As the MS4 permit is executed, new work and capital projects not previously included in DPW budget will be required to be executed. This new work comes with a significant cost and the Town may not be able to be cover these future costs with available budgets.

Enterprise funds have been established by a number of towns and cities close to Ludlow, including East Longmeadow, Longmeadow, Northampton, Westfield, and Chicopee. Other towns and cities in Massachusetts that have established enterprise funds include Chelmsford, Braintree, Milton, Ashland, Millis, Reading, Westford, Shrewsbury, Bellingham, Pepperell, and Fall River. MassDEP recognizes enterprise funds as a reliable resource for financing stormwater management activities. Enterprise funds in Massachusetts have primarily utilized three distinct funding structures: flat fee, residential equivalent unit, and impervious surface area tiers. Flat fees distribute charges evenly across all property owners. Residential equivalent unit establishes a base charge for the standard residential lot and include additional charges for land area greater than the average lot. Finally, a charge based on impervious surface area has also been used. For any of these methods, the Town can consider offering a reduction in costs or a fee credit for removing impervious surfaces and/or implementing stormwater BMPs.

2.2.2 Developer Fees

Communities often charge land developers for site plan reviews and inspections and use those fees to support their conservation and/or stormwater programs. Additional fees for the creation of impervious areas and increases in pollutants of concern (phosphorus & nitrogen) can be considered to offset some of the costs of implementing the MS4 requirements including the LPCP.

[1] General Law - Part I, Title XIV, Chapter 83, Section 16 (malegislature.gov)

[2] General Law - Part I, Title VII, Chapter 40, Section 1A (malegislature.gov)

2.2.3 Special Assessments

If a stormwater construction project benefits only a portion of a municipality, it can be funded by fees assessed only to those properties within that area. This is called a special assessment district. Areas within the permitted MS4 area or within catchments draining to a waterbody subject to a TMDL or pollutant reductions could be considered a “special assessment district” and fees added to projects within these areas.

2.2.4 One-time Fees and Other Local Program Fees

New customers connecting to a public water main or sanitary sewer system are generally charged a one-time fee, commonly referred to as a connection fee or tie-in charge. In this way, new customers buy into the existing infrastructure or the infrastructure expansion necessary to serve them. Municipalities can also develop stormwater system development charges or fees tied to the area of the customer’s property. New construction and renovations could be considered for a one-time Stormwater Fee. The fee could provide the Town a source of revenue for MS4 compliance to mitigate any possible stormwater violations or illicit discharges. Additionally, since stormwater programs may relate to the missions and/or services of allied departments, it may be reasonable to adjust or share fees charged by other local programs for program work in shared areas.

2.3 Grants Funds

Many State agencies related to environmental, transportation, emergency management, and community development offer grants that can be used to help fund stormwater structures included in their projects and programs. In addition to state agencies, non-profit organizations offer support for environmental causes that align with MS4 requirements. Below are descriptions of some of the grants which may be available to the Town to help fund projects that meet MS4 requirements. Please note that the majority of the grants discussed below are not funding sources which can be pursued as direct funding for the LPCP or MS4 requirements. These grants encourage green infrastructure solutions which can result in phosphorus or other nutrient/pollutant reductions and thus aid in meeting phosphorus reduction requirements.

2.3.1 Community Development Block Grant (CDBG)

The Community Development Fund (CDF) awards grants to communities throughout the Commonwealth of Massachusetts. This program helps eligible cities and towns to meet a broad range of community development needs in housing, infrastructure, revitalization, economic development, and public social services. It supports CDBG-eligible activities and encourages applicants to develop coordinated, integrated, and creative solutions to local problems. Municipalities with a population of under 50,000 that do not receive CDBG funds directly from the federal Department of Housing and Urban Development (HUD) are eligible for CDBG funding.

Community Development Block Grants are competitive grants that can be used to fund road and drainage improvements as well as many other community development projects. These grants do not require a cost share; although, matching funds do increase application scores. Mott MacDonald staff has experience working with Pioneer Valley Planning Commission (PVPC) to develop CBDG projects in other towns in Massachusetts. These projects focused on infrastructure improvements and incorporated green infrastructure and stormwater best management practices (BMPs) to meet future MS4 Permit obligations.

2.3.2 Complete Streets

The MassDOT Complete Streets Funding Program provides technical assistance and construction funding to eligible municipalities. The Complete Streets Program does not fund drainage- or stormwater-specific projects. Eligible projects include intersection redesign, street reconfiguration, traffic calming, pedestrian crossing modifications, pedestrian and bike network connections, and environmental & streetscapes improvements. Using complete streets funds for

traffic calming, street reconfiguration, and environmental & streetscape improvements can include stormwater BMPs that remove phosphorus if incorporated into the design.

Eligible municipalities must pass a Complete Streets Policy and develop a prioritization plan. The Town of Ludlow is not a part of the Complete Streets program and would need to take steps to become a participating town to capitalize on available grant opportunities. Phase I and II grants are non-competitive; Phase III grants for construction are competitive.

Please note that the Complete Street Program strives to award 33% of grant funding to communities that have a median house income equal to or less than the statewide average. The Town of Ludlow (according to US Census Data) has a median income of $73,460, while the State median income is $81,215, and thus, it is expected that special consideration will be given to Ludlow in accordance with Mass DOT policies and award considerations.

2.3.3 Municipal Vulnerability Preparedness Action Grant (MVP)

The Municipal Vulnerability Preparedness grant program (MVP) provides support for cities and towns in Massachusetts to begin the process of planning for climate change resiliency and implementing priority projects. The state awards communities with funding to complete vulnerability assessments and develop action-oriented resiliency plans. Communities who complete the MVP program become certified as an MVP community and are eligible for MVP Action Grant funding and other opportunities. Like the Complete Streets program, the MVP program can address environmental issues, if vulnerability is found in those areas. Flooding from impervious surfaces and impacts from heat islands are common causes for vulnerability in the MVP program. Flooding can be addressed with stormwater BMPs such as infiltration basins and trenches, which can also provide phosphorus reduction credits. Heat islands can be reduced by creating green streets and green parking lots which will often include stormwater BMPs such as infiltration trenches, basins, bio-filtration swales, and dry ponds; all of which are eligible for phosphorus reduction credits.

2.3.4 MS4 Municipal Assistance Grant Program

The Municipal Assistance Grant Program offers no direct assistance to individual municipalities. Eligible applicants are groups of two or more municipalities, or MPO's acting on behalf of two or more municipalities. While no direct funding would be provided to the Town of Ludlow, if the Town works with the PVPC, the area MPO, this program could provide support for the LPCP requirements through PVPC funding.

2.4 State Loan Programs – CWSRF

The Massachusetts Clean Water State Revolving Fund (CWSRF) is intended to provide a low-cost financing method that communities can take advantage of to make sure they are meeting water-quality standards. Each June the Division of Municipal Services (DMS) posts solicitations for proposals for financial assistance the following year. Applications (project evaluation forms) are due by August. If a project is selected and added to the intended use plan (IUP), final applications and construction plans are due in October of the same IUP year. CWSRF grants can include engineering design and construction management costs. Loans are typically made with a low interest rate and some communities or projects may be eligible for zero percent interest. The current program allows for zero interest loans for nutrient management projects.

Applicants must secure local borrowing authorization for the cost of the project by June 30 of the IUP year. Applicants must complete and submit a loan application with buildable plans and specifications, by Oct 15 of the same year. Once a proposal is approved by the DMS, the applicant has 6 months to initiate construction.

2.5 Partnering with Municipal Planning Organizations (MPOs)

While direct financial support may not be provided, MPOs provide services to develop reports and studies as well as assist in securing funding for municipalities. Ludlow has worked with the Pioneer Valley Planning Commission (PVPC) to complete some components required by the permit, including requirements related to the LPCP.

MPOs are required to develop a Transportation Improvement Program (TIP). TIP projects are multimodal project aligned with Complete Streets priorities. Green infrastructure improvements, which can achieve high levels of nutrient reduction credits (both nitrogen and phosphorus), are allowable costs for TIP funding. Note that TIP funds do not cover the costs for design and that Towns that receive TIP funds are required to provide a shovel-ready project. Chapter 90 road funds, which are distributed annually to the Town, can be considered as a funding source for the design costs.

3 Assessing Program Cost

The cost of implementing the LPCP, as mentioned previously, will require a more detailed assessment of the Town's preferred methods to reduce phosphorus as required by the MS4 permit and a detailed understanding of the Town's approach to meeting their reduction goals. Costs can change significantly depending on the types of and size of BMPs proposed. To assist the Town in understanding the magnitude of funding which will be required for the LPCP and therefore better understand which funding sources best suites them, Mott MacDonald is providing a planning-level order-of-magnitude range of costs to meet the required phosphorus reductions. The provided costs rely upon broad assumptions which should be refined during later phases of the LPCP implementation. Depending on future decisions and conditions, these costs can change drastically and therefore these cost ranges are not meant to provide an accurate estimate.

3.1 Estimating Structural BMP Costs

Using the information from the 2016 MS4 Permit, information received from the Town, and the Phosphorus Report provided by the Pioneer Valley Planning Commission (PVPC) in 2021, and publicly available cost information, Mott MacDonald has included rough order-of-magnitude costs for structural BMPs associated with the LPCP. Mott MacDonald reviewed EPA publication # 820-F-15-096, "A Compilation of Cost Data Associated with Impacts and Control of Nutrient Pollution". This document was used to generate a range of costs associated with constructing structural BMP's needed to meet permit objectives. Costs have been adjusted based on ENR construction cost index. **Table** 3 provides three different costs to construct structural BMPs which will reduce phosphorus as required by the permit. These costs are based on EPA reported costs for structural BMPs and assuming each type of BMP is solely used to address the 9,314 lbs. of phosphorus reduction required, as estimated by the PVPC. This is included to provide the Town with a general assessment of the required level of funding needed and to demonstrate how the costs can range significantly depending on how the Town decides to address the phosphorus removal requirement.

Table 3. Structural BMP Costs (adapted from EPA publication # 820-F-15-096, May 2015)

BMP Type	Unit Cost	Adjusted Cost[1]	Total Cost[2]
Bio-Swale	$ 308 / lb. removed	$ 390 / lb. removed	$ 3,600,000
Infiltration Trench	$ 1,300 / m^3	$ 1,646 /m^3 (76.5 /ft^3)	Req. field testing to size
Media Filtration	$ 1,060 / lb. removed	$ 1,343 / lb. removed	$ 12,500,000
Infiltration Basin	$ 494 / lb. removed	$ 626 / lb. removed	$ 4,600,000

1 – Cost adjusted based on ENR yearly construction cost index for 2021.
2 – Total costs for construction only, no design, permitting or construction management included.

4 Summary

The Town of Ludlow has limited options for funding the LPCP. As previously identified, competitive grants identified are not guaranteed and therefore, should not be relied upon as a significant funding source. Grants do present an opportunity for the Town to fund green infrastructure projects and stormwater BMPs to reduce nutrient pollution, revitalize areas, and create a positive impact on the local ecosystem.

Low interest loans and municipal bond sales present a promising option for financing capital costs over multiple years. Should the Town consider new loans to fund capital projects funding repayment of these loans will need to be addressed. Town Meeting approval is likely required to increase the levy limit or pass a debt exclusion sufficient to repay anticipated capital costs. Note that loan and bonds cannot be used to cover increasing operating costs associated with permit compliance.

Taxes can be raised on a short-term basis (debt exclusion) or can be permanently increased (override) to fund the stormwater requirements. A combination of these two methods can be used. Alternatively, each year, surplus funds are returned to the general fund in the form of “free cash”, these funds, or a portion thereof, can be directed into a stormwater account. Reliance upon free cash is not recommended because the value fluctuates annually, and free cash is often used to fund small value projects and necessary capital purchases such as vehicles.

Finally, a stormwater utility and associated enterprise fund can be created to cover all aspects of stormwater operations (i.e., capital, and operating costs). A stormwater utility operates in the same manner as a sanitary sewer utility, with the authority to set rates with the board/commission. This funding mechanism allows the Town to properly fund stormwater operations, plan for future costs, and borrow funds without impacting the Towns finical resources.

Mott MacDonald recommends the Town complete the EPA provided, “Cost Estimation Spreadsheet for Medium/Suburban Communities (https://www.epa.gov/npdes-permits/stormwater-tools-new-england#ms4cei) or independently estimate the operating costs to be incurred by the Town due to the MS4 program and consider existing operational compliance gaps. The estimates generated should be compared to department budgets to determine if these cost obligations can be included in future budgets, or if a onetime override to cover these costs is needed. It is not recommended to decrease existing services to meet these obligations since other essential services would likely suffer if the town attempted to meet MS4 obligations with existing staff and budgets. Additionally, Mott MacDonald recommends the Town consider the magnitude of the funded required to reach compliance with TMDL’s in Minechoag Pond and other requirements not included in this assessment (related to the Chicopee River (E. Coli) and Long Island Sound Nitrogen TMDL) when considering how to proceed with funding requirements. Mott MacDonald is available to discuss these options with the Town and offers our continued support with executing the Massachusetts MS4 General Permit.

Appendix E.
Supporting Calculations for Non-Structural Controls

E. Supporting Calculations for Non-Structural Controls

Supporting Calculations for Non-Structural Controls

			Street Sweeping			Catch Basin Cleaning		Organic Waste and Leaf Litter Collection Program	
Catchment Area	Impervious Area (acres)[1]	P Load Export Rate (lbs P/acre/year)[2]	Phosphorus Reduction Factor[3]	Annual Frequency of Sweeping[3]	Phosphorus Credit (lbs P/year)	Phosphorus Reduction Factor[4]	Phosphorus Credit (lbs P/year)	Nutrient Reduction Factor[5]	Phosphorus Credit (lbs P/year)
MCP01	8.0	1.34	0.03	0.75	0.24	0.02	0.22	0.05	0.54
MCP02	4.6	1.34	0.03	0.75	0.14	0.02	0.12	0.05	0.31
MCP03	10.5	1.34	0.03	0.75	0.32	0.02	0.28	0.05	0.70
MCP04	0.0	1.34	0.03	0.75	0.00	0.02	0.00	0.05	0.00
				Total Street Sweeping Credit (lbs P /year)	0.70	Total Catch Basin Cleaning Credit (lbs P /year)	0.62	Total Organic Waste and Leaf Litter Collection Program Credit (lbs P /year)	1.55

[1] Calculated using 2016 Land Cover/Land Use Mass GIS data set (https://www.mass.gov/info-details/massgis-data-2016-land-coverland-use) and Town of Ludlow GIS files. Note, for the Catch Basin Cleaning credit, the impervious drainage area to the catch basins has been assumed to be the impervious roadway area only.

[2] Assuming "Highway" for Phosphorus Source Category by Land Use for all roadway areas to be swept. P Load Export Rate was determined using Table 2-1 in MS4 Permit Attachment 2 to Appendix F.

[3] Phosphorus Reduction Factor identified using Table 2-4 in MS4 Permit Attachment 2 to Appendix F, assuming monthly sweeping with a mechanical broom.

[4] Assuming sweeping is infeasible during the winter months, sweeping has been planned for 9 out of 12 months of the year.

[5] Phosphorus Reduction Factor identified using Table 2-5 in MS4 Permit Attachment 2 to Appendix F, assuming semi-annual catch basin cleaning.

[6] Per MS4 Permit Attachment 2 to Appendix F, assuming a 5% nutrient reduction factor for organic waste and leaf litter collection program in the watershed.

Appendix F.
Supporting Calculations for Current Structural Controls

F. Supporting Calculations for Current Structural Controls

Supporting Calculations for Current Structural Controls

BMP ID or Description	Location	BMP Type from Plans	Functional BMP Type to Match Model	Total Drainage Area (acres)	Impervious Drainage Area (acres)	Estimated Storage Volume (cf)	Runoff Depth Captured for Use in %-P Reduction (in.)	Phosphorus Load (lb. P/year)[1]	Assumed Infiltration Rate (in./hr.)	BMP Phosphorus Reduction Rate (%)[4]	Estimated Phosphorus Removal (lb. P/yr.)
BMP-MCP01-01	East side of King Street across from 93 King Street	Leaching Galley	Infiltration Trench	2.02	0.84	509	0.17	1.40	1.02[2]	42%	0.59
BMP-MCP01-02	East side of King Street across from 93 King Street	Leaching Galley	Infiltration Trench								
BMP-MCP01-03	East side of King Street across from 93 King Street	Leaching Galley	Infiltration Trench								
BMP-MCP01-04	In front of 148 King Street	Leaching Galley	Infiltration Trench	0.70	0.61	339	0.15	0.97	1.02[2]	39%	0.38
BMP-MCP01-05	In front of 148 King Street	Leaching Galley	Infiltration Trench								
BMP-MCP03-01	Within island in center of cul-de-sac at south end of Bowles Avenue	Leaching Basin	Infiltration Trench	2.44	0.59	1,553	0.68	1.13	8.27[3]	99%	1.12
BMP-MCP03-02	Within island in center of cul-de-sac at south	Leaching Basin	Infiltration Trench								

[1] Calculated using 2016 Land Cover/Use MassGIS Data Set and P Export Rate from Table 3-1 in MS4 Permit Attachment 3 to Appendix F.

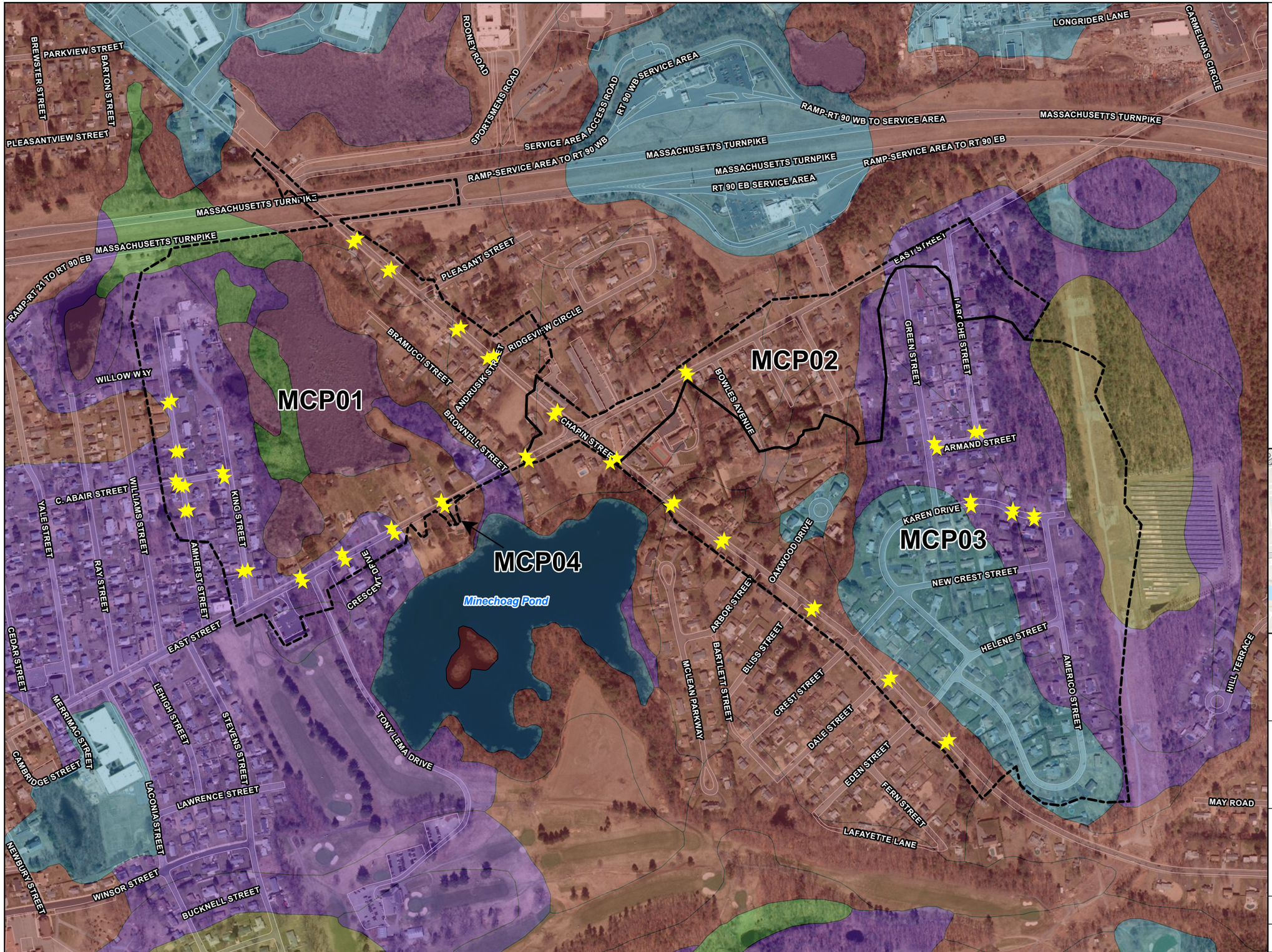
[2] Assumed sandy loam soil type per USDA NRCS Web Soil Survey (https://websoilsurvey.nrcs.usda.gov/app/). Therefore, assumed design infiltration rate 1.02 in./hr. per "Massachusetts Stormwater Handbook Volume 3 Chapter 1: Documenting Compliance with the Massachusetts Stormwater Management Standards," (https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.mass.gov%2Fdoc%2Fmassachusetts-stormwater-handbook-vol-3-ch-1-documenting-compliance%2Fdownload&wdOrigin=BROWSELINK)

[3] The "Extension of Bowles St. Hydrology & Drainage Calculations" report provides conductivity calculations that indicate high soil conductivity and classifies the soil as "sand" for the Bowles Avenue leaching basins. Therefore, assumed an 8.27"/hr. infiltration rate per "Massachusetts Stormwater Handbook Volume 3 Chapter 1: Documenting Compliance with the Massachusetts Stormwater Management Standards," (https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.mass.gov%2Fdoc%2Fmassachusetts-stormwater-handbook-vol-3-ch-1-documenting-compliance%2Fdownload&wdOrigin=BROWSELINK)

[4] Phosphorus reduction rate identified using Infiltration Trench BMP Performance Curves from MS4 Permit Attachment 3 to Appendix F.

Appendix G.
Supporting Map for Planned Structural BMP Prioritization

G. Supporting Map for Planned Structural BMP Prioritization

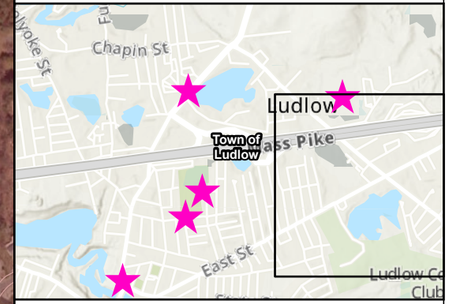


Legend

- Planned Leaching Catch Basin
- Minechoag Pond Watershed

Hydrologic Soil Group (USDA NRCS)

- N/A
- A
- A/D
- B
- B/D
- C
- C/D
- D



N

0 250 500 1,000 Ft

1 inch = 500 feet

MOTT MACDONALD

Appendix G: Supporting Map for Planned Structural BMP Prioritization
September 2023

Drawn	GIS Checked	Checked	Approved
EGD		ASW	SJN
Scale	Status	Revision	Security
1 in = 500 ft			

Appendix H. Standard Operating Procedure 3: Catch Basin Inspection and Cleaning

H. Standard Operating Procedure 3: Catch Basin Inspection and Cleaning

SOP 3: CATCH BASIN INSPECTION AND CLEANING

Introduction

Catch basins help minimize flooding and protect water quality by removing trash, sediment, decaying debris, and other solids from stormwater runoff. These materials are retained in a sump below the invert of the outlet pipe. Catch basin cleaning reduces foul odors, prevents clogs in the storm drain system, and reduces the loading of suspended solids, nutrients, and bacteria to receiving waters.

During regular cleaning and inspection procedures, data can be gathered related to the condition of the physical basin structure and its frame and grate and the quality of stormwater conveyed by the structure. Observations such as the following can indicate sources of pollution within the storm drain system:

- Oil sheen
- Discoloration
- Trash and debris

Both bacteria and petroleum can create a sheen on the water surface. The source of the sheen can be differentiated by disturbing it, such as with a pole. A sheen caused by a oil will remain intact and move in a swirl pattern; a sheen caused by bacteria will separate and appear "blocky". Bacterial sheen is not a pollutant but should be noted.

Observations such as the following can indicate a potential connection of a sanitary sewer to the storm drain system, which is an illicit discharge.

- Indications of sanitary sewage, including fecal matter or sewage odors
- Foaming, such as from detergent
- Optical enhancers, fluorescent dye added to laundry detergent

Each catch basin should be cleaned and inspected at least annually. Frequency should be increased to twice a year if credit is to be taken for a stormwater best management practice (such as catch basin cleaning or a structural management practice). Additionally, frequency may be increased if required by another applicable O&M manual. Catch basins in high-use areas may require more frequent cleaning. Performing street sweeping on an appropriate schedule will reduce the amount of sediment, debris, and organic matter entering the catch basins, which will in turn reduce the frequency with which structures need to be cleaned.

Cleaning Procedure

Catch basin inspection cleaning procedures should address both the grate opening and the basin's sump. Document any and all observations about the condition of the catch basin structure and water quality on the Catch Basin Inspection Form (attached).

Catch basin inspection and cleaning procedures include the following:

1. Work upstream to downstream.
2. Clean sediment and trash off grate.
3. Visually inspect the outside of the grate.
4. Visually inspect the inside of the catch basin to determine cleaning needs.
5. Inspect catch basin for structural integrity.
6. Determine the most appropriate equipment and method for cleaning each catch basin.
    a. Manually use a shovel to remove accumulated sediments, or
    b. Use a bucket loader to remove accumulated sediments, or
    c. Use a high pressure washer to clean any remaining material out of catch basin while capturing the slurry with a vacuum.
    d. If necessary, after the catch basin is clean, use the rodder of the vacuum truck to clean downstream pipe and pull back sediment that might have entered downstream pipe.
7. If contamination is suspected, chemical analysis will be required to determine if the materials comply with the Massachusetts DEP Hazardous Waste Regulations, 310 CMR 30.000 (https://www.mass.gov/doc/310-cmr-30-hazardous-waste/download). Chemical analysis required will depend on suspected contaminants. Note the identification number of the catch basin on the sample label, and note sample collection on the Catch Basin Inspection Form.
8. Properly dispose of collected sediments. See following section for guidance.
9. If fluids collected during catch basin cleaning are not being handled and disposed of by a third party, dispose of these fluids to a sanitary sewer system, with permission of the system operator.
10. If illicit discharges are observed or suspected, notify the appropriate Department (see "SOP 10: Addressing Illicit Discharges").
11. At the end of each day, document location and number of catch basins cleaned, amount of waste collected, and disposal method for all screenings.
12. Report additional maintenance or repair needs to the appropriate Department.

Disposal of Screenings

Catch basin cleanings from storm water-only drainage systems may be disposed at any landfill that is permitted by MassDEP to accept solid waste. MassDEP does not routinely require stormwater-only catch basin cleanings to be tested before disposal, unless there is evidence that they have been contaminated by a spill or some other means.

Screenings may need to be placed in a drying bed to allow water to evaporate before proper disposal. In this case, ensure that the screenings are managed to prevent pollution.

Attachments

1. Catch Basin Inspection Form

Related Standard Operating Procedures

1. SOP 10, Addressing Illicit Discharges
2. SOP 13, Water Quality Screening in the Field

Job No.: _____ **Town:** _____

Inspector: _____ **Date:** _____

CATCH BASIN INSPECTION FORM

Catch Basin I.D.	_____	**Final Discharge from Structure?** Yes ☐ No ☐ **If Yes, Discharge to Outfall No:**_____	
Catch Basin Label:	**Stencil** ☐ **Ground Inset** ☐ **Sign** ☐ **None** ☐ **Other**_____		
Basin Material:	Concrete ☐ Corrugated metal ☐ Stone ☐ Brick ☐ Other: _____ ☐	**Catch Basin Condition:**	Good ☐ Poor ☐ Fair ☐ Crumbling ☐
Pipe Material:	Concrete ☐ HDPE ☐ PVC ☐ Clay Tile ☐ Other:_____	**Pipe Measurements:**	Inlet Dia. (in): d= ____ Outlet Dia. (in): D= ____

Required Maintenance/ Problems (check all that apply):

- ☐ Tree Work Required
- ☐ New Grate is Required
- ☐ Pipe is Blocked
- ☐ Frame Maintenance is Required
- ☐ Remove Accumulated Sediment
- ☐ Pipe Maintenance is Required
- ☐ Basin Undermined or Bypassed
- ☐ Cannot Remove Cover
- ☐ Ditch Work
- ☐ Corrosion at Structure
- ☐ Erosion Around Structure
- ☐ Remove Trash & Debris
- ☐ Need Cement Around Grate

Other: _____

Catch Basin Grate Type :	**Sediment Buildup Depth :**	**Description of Flow:**	**Street Name/ Structure Location:**
Bar: ☐ Cascade: ☐ Other:_____ Properly Aligned: Yes ☐ No ☐	0-6 (in): _____ 6-12(in): _____ 12-18 (in): _____ 18-24 (in): _____ 24 + (in): _____	Heavy ☐ Moderate ☐ Slight ☐ Trickling ☐	

***If the outlet is submerged check yes and indicate approximate height of water above the outlet invert.** h above invert (in):___ Yes ☐ No ☐

☐ **Flow**

☐ **Standing Water**

(check one or both)

Observations:

Color:

Odor:

Weather Conditions : Dry > 24 hours ☐ Wet ☐

Sample of Screenings Collected for Analysis? Yes ☐ No ☐

Comments:

Circle those present:

Foam	Oil Sheen
Sanitary Waste	Bacterial Sheen
Orange Staining	Floatables
Excessive sediment	Pet Waste
Other:_____	Optical Enhancers

Daily Catch Basin Inspection Log
Town of Ludlow, Massachusetts

Date	Inspector	Weather Conditions	Number of Catch Basins Inspected/Cleaned	Amount of Material Removed	Catch Basins More than 50% Full	Corrective Action Taken/Recommended if More than 50% Full

Appendix I.
LPCP Implementation Schedule

I. LPCP Implementation Schedule

LPCP Implementation Schedule - Planned Control Methods

<table>
<tr><th>BMP Category</th><th>BMP Type</th><th>Permit Year (PY) 6
Fiscal Year (FY) 2024</th><th>Permit Year (PY) 7
Fiscal Year (FY) 2025</th><th>Permit Year (PY) 8
Fiscal Year (FY) 2026</th><th>Permit Year (PY) 9
Fiscal Year (FY) 2027</th><th>Permit Year (PY) 10
Fiscal Year (FY) 2028</th><th>Permit Year (PY) 11
Fiscal Year (FY) 2029</th><th>Permit Year (PY) 12
Fiscal Year (FY) 2030</th><th>Permit Year (PY) 13
Fiscal Year (FY) 2031</th><th>Permit Year (PY) 14
Fiscal Year (FY) 2032</th><th>Permit Year (PY) 15
Fiscal Year (FY) 2033</th></tr>
<tr><td rowspan="3">Nonstructural BMPs</td><td>Catch Basin Cleaning</td><td rowspan="3">To be fully implemented by Permit Year 6</td><td colspan="9" rowspan="3">To be implemented yearly throughout the Permit term</td></tr>
<tr><td>Enhanced Sweeping Program</td></tr>
<tr><td>Organic Waste and Leaf Litter Collection Program</td></tr>
<tr><td rowspan="4">Structural BMPs</td><td rowspan="4">58 Leaching Catch Basins</td><td colspan="2" rowspan="4"></td><td colspan="9">10 Leaching Catch Basins</td></tr>
<tr><td colspan="8">16 Leaching Catch Basins</td></tr>
<tr><td colspan="6">16 Leaching Catch Basins</td></tr>
<tr><td colspan="5">16 Leaching Catch Basins</td></tr>
</table>

Appendix J.
Supporting Calculations for Estimated Costs

J. Supporting Calculations for Estimated Costs

Supporting Calculations for Estimated Costs

Non-Structural Controls

Street Sweeping and Organic Waste and Leaf Litter Collection Program

	Value
Miles of Roadway in Minechoag Watershed	9
Assumed Cost per Curb Mile Swept ($)	$50
Number of Times Swept per Year[1]	18
Total Sweeping Costs per Year[2]	$8,100

[1] Assuming sweeping once per month for 6 out of 12 months and once per week between September 1 and December 1 for planned street sweeping and organic waste and leaf litter collection

[2] Estimated costs are in 2023 dollars.

Catch Basin Cleaning

	Value
Number of Existing Catch Basins	148
Assumed Cost to Clean a Catch Basin	$194
Number of Times Cleaned per Year[1]	2
Total Catch Basin Cleaning Costs per Year for Existing Catch Basins[2]	$58,000

[1] Assuming that all existing catch basins in the Minechoag Pond watershed will be cleaned semi-annually per proposed non-structural controls.

[2] Estimated costs are in 2023 dollars.

Structural Controls - Leaching Catch Basins

Estimated Material and Construction Cost per Leaching Catch Basin[1,2]				
Item	**Estimated Unit Cost**	**Unit**	**Estimated Quantity**	**Cost**
Stone	$104	CY	25	$2,600
Excavation	$79	CY	28	$2,200
Catch Basin	$1,800	Each	1	$1,800
Pavement	$162	SY	25	$4,100
			Total per Leaching Catch Basin	$10,700
			Engineering & Design Contingency (35%)	$14,400
			General Contingency (40%)	$20,200

[1] Leaching catch basin costs estimated based on approximate volume required to manage 1" of impervious runoff for estimated average drainage area to each leaching catch basin.

[2] Estimated costs are in 2023 dollars.

Estimated Costs for Planned Non-Structural and Structural Controls

Estimated Costs of Planned Control Methods per Implementation Schedule						
Planned Construction Year	**Number of Leaching Catch Basins Planned**	**Estimated Cost for Structural Controls (2023)[1,2,3]**	**Estimated Cost for Structual Controls (Construction Year)[4]**	**Estimated Cost for Non-Structural Controls (2023)[1]**	**Estimated Cost for Non-Structual Controls (Construction Year)[4,5]**	**Total Estimated Cost for Planned Control Methods (Construction Year)[4,5]**
2024	0	-	-	$66,100	$68,400	$68,400
2025	0	-	-	$66,100	$70,800	$70,800
2026	10	$205,888	$228,300	$66,100	$73,300	$301,600
2027	0	$3,888	$4,500	$66,100	$75,900	$80,400
2028	16	$333,308	$395,900	$66,100	$78,500	$474,400
2029	0	$10,108	$12,400	$66,100	$81,300	$93,700
2030	0	$10,108	$12,900	$66,100	$84,100	$97,000
2031	16	$339,528	$447,100	$66,100	$87,000	$534,100
2032	0	$16,328	$22,300	$66,100	$90,100	$112,400
2033	16	$345,748	$487,700	$66,100	$93,200	$580,900

[1] Costs are in 2023 dollars.

[2] Structural control costs have been depicted during the construction year of the planned leaching basins given that construction represents the majority of the structural control costs. However, engineering and planning costs incurred to design the planned leaching basins will be spread between the construction years.

[3] Includes estimated costs for semi-annual cleaning of the planned leaching catch basins as of the specifed year. Assumes the same cost to clean a leaching catch basin as the cost estimated as part of the non-structural controls to clean an existing catch basin. Additionally, assumes that O&M begins in the same year as the planned structural BMP installation.

[4] Assumes construction cost inflation rate of 3.5%. CRBE. (2022, July 6). 2022 U.S. Construction Cost Trends. Retrieved from https://www.cbre.com/insights/books/2022-us-construction-cost-trends#:~:text=CBRE%E2%80%99s%20new%20Construction%20Cost%20Index%20forecasts%20a%2014.1%25,2023%20and%202024%2C%20on%20par%20with%20historical%20averages.

[5] Assumes increases to labor rates, which make up the majority of the assumed non-structural costs, will mimic increases to construction inflation rates.

Appendix K. Performance Evaluation Example

K. Performance Evaluation Example

Performance Evaluation for Year XX

Ludlow has completed the required Performance Evaluation that assesses our LPCP progress for Minechoag Pond through Year XX. Documentation of the Land Development Impacts and Phosphorus Credits for this effort is included in ##LOCATION##.

A summary of Ludlow's performance through Year XX is included in the table below.

Table 1. Year XX Performance Evaluation Summary

Parameter	Value (lbs/yr)
Baseline Load	
Allowable Load	
Calculations to Update to Current Conditions	
Changes in P-Load Since Baseline	
Current Phosphorus Load = Baseline +/- Impacts	
Updated Phosphorus Reduction Required to Meet Allowable Load (Allowable Load)	
Year 8 Milestone (lbs/yr)	
Year 10 Milestone (lbs/yr)	
Year 13 Milestone (lbs/yr)	
Year 15 Milestone (lbs/yr)	
Phosphorus Credits for Year XX	
Total Reduction from Non-Structural BMPs	
Total Reduction from Structural BMPs	
Evaluation	
Remaining Phosphorus Reduction Requirement (Updated Phosphorus Reduction Requirement to Meet Allowable Load – Total Reductions)	

Based on this year's evaluation, Ludlow has successfully reduced phosphorus by ##AMOUNT## lbs/yr.

D. Catchment Investigations Completed During Permit Reporting Period

MOTT MACDONALD

Memorandum

Subject	**CHE02 Catchment Investigation Technical Memorandum**
To	James Goodreau
From	Suzanne Newman, P.E.
Our reference	2022 MS4 Permit Support, 507106794
Date	September 28, 2022

1 Background

The 2016 National Pollution Discharge Elimination System (NPDES) General Permit for Stormwater Discharges from Small Separate Storm Sewer Systems (MS4) in Massachusetts requires catchment investigations as part of an Illicit Discharge Detection and Elimination (IDDE) Program. The procedures for this investigation are detailed in the Town of Ludlow's IDDE Plan. Mott MacDonald has completed the catchment investigation for outfall CHE02, the results of which are summarized below. This Memorandum is intended to document how the investigation was completed per the requirements of the permit, specifically Section 2.3.4.8.c.iii, which states: "All data collected as part of the dry and wet weather catchment investigations shall be recorded and reported in each annual report".

2 Catchment Description

Catchment Area CHE02 is located in the southeastern section of the Town of Ludlow, Massachusetts, as shown on the map provided in **Appendix A**. The area is bounded, in general, by the intersection of Miller Street and driveway to the Eversource Liquified Natural Gas (LNG) Plant to the north, and the middle of the Green-Towne Bridge to the south; The east and west boundaries of the area align with the width of Miller Street between the north and south boundaries.

The infrastructure of CHE02 consists of stormwater lines that run from east to west across Miller Street to the outfall located west of Miller Street. The catch basins along the bridge collect stormwater that drains to the bridge drain under the road surface which ties into the catch basin on the west side of Miller Street.

There are no junction manholes within the CHE02 catchment area.

3 Catchment Investigation

Mott MacDonald utilized the catchment investigation procedures developed in the Town of Ludlow Illicit Discharge Detection and Elimination (IDDE) Plan. Prior to conducting field investigations, historic maps and plans were reviewed and System Vulnerability Factors (SVFs) were identified. Mott MacDonald then monitored weather forecasts for potential dry weather days on which the investigations could be conducted.

- On August 5th, 2022, Mott MacDonald and the Town of Ludlow commenced an investigation of the CHE02 Catchment Area, with personnel looking into catch basins along the bridge's end and determining the path of underground stormwater infrastructure. Mott MacDonald personnel did not observe any flow during dry weather inspections, and thus did not see evidence of an illicit connection.

3.1 Maps, Plans and Other Data Sources

Mott MacDonald reviewed the plans titled "Site Plan – Proposed Road Layout". According to this plan, a catch basin and an outfall exist along the western side of Miller Street, just north of the bridge Green-Towne Bridge.

Table 1 summarizes the historic plans which were reviewed for this exercise.

Table 1. Supplemental Historic Plans

TOWN PLAN IDENTIFIERS	STREETS	PLAN NAME	PLAN TYPE	PLAN DATE
Drawer 08 Plan 16B	Miller Street	Site Plan - Proposed Road Layout	Proposed Road Layout	N/A

3.2 System Vulnerability Factors (SVF)

No system vulnerabilities were identified for this catchment. Additionally, as noted in **Appendix B**, the bridge drainage infrastructure is estimated to be over 40 years old, which is not a SVF, but is a consideration for assessing the overall system state. This infrastructure's age was estimated based on the appearance of and assumed age of the plans.

4 Catchment Investigation Results

Mott MacDonald has completed the dry weather catchment investigation of the CHE02 Catchment Area.

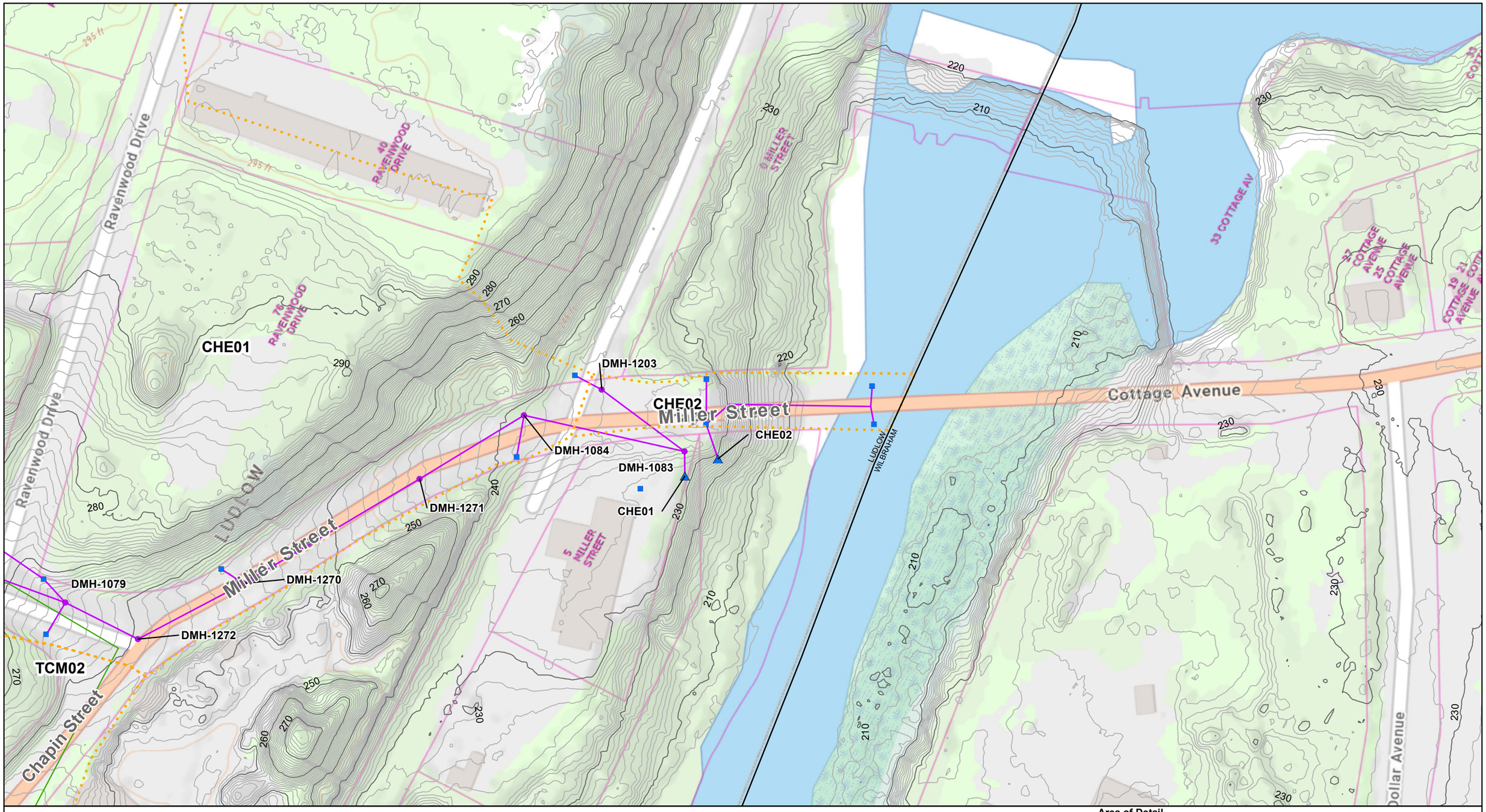
Dry Weather Sampling: No samples taken as no flow was observed in the catch basins.

Conclusion:

The dry weather catchment investigation for CHE02 is complete. No illicit discharges were identified. Wet weather sampling is not required as no System Vulnerability Factors (SVFs) were identified.

Appendix A

Catchment Area Map



Storm Drain Manhole
- In-Service
- Abandoned

Storm Drain Pipe
- In-Service
- Abandoned

- Discharge Outfall
- Catch Basin
- Sanitary Manhole
- Sanitary Pipe

- 10-ft Contour
- 1-ft Contour
- Catchment Area
- Town Boundary

Catchment Area - CHE02

Department of Public Works

Town of Ludlow, Massachussets

Area of Detail

0 75 Feet

MOTT MACDONALD

Document Path: C:\GIS\Ludlow\0_Master_GIS\Ludlow_Catchment_Investigation_MapBook.mxd

Appendix B

System Vulnerability Factors

Outfall Catchment System Vulnerability Factor (SVF) Inventory
Town of Ludlow, Massachusetts
Revision Date: September 28, 2022

		Presence/Absence Evaluation Criteria for SVFs								Additional Considerations Not Included in SVFs			
Outfall ID	Receiving Water	1 History of SSOs	2 Common or Twin Invert Manholes	3 Common Trench Construction	4 Storm/Sanitary Crossings (Sanitary Above)	5 Sanitary Lines with Underdrains	6 Inadequate Sanitary Level of Service	7 Areas Formerly Served by Combined Sewers	8 Sanitary Infrastructure Defects	1 SSO Potential in Event of System Failures	2 Sanitary and Storm Drain Infrastructure >40 years Old	3 Septic with Poor Soils or Water Table Separation	4 History of BOH Actions Addressing Septic Failure
CHE02	MA36-23	No	No	No	No	No	No	No	No	No	Yes	No	No

Presence/Absence Evaluation Criteria for SVFs:

1. *History of SSOs, including, but not limited to, those resulting from wet weather, high water table, or fat/oil/grease blockages*
2. *Common or twin-invert manholes serving storm and sanitary sewer alignments*
3. *Common trench construction serving both storm and sanitary sewer alignments*
4. *Crossings of storm and sanitary sewer alignments where the sanitary system is shallower than the storm drain system*
5. *Sanitary sewer alignments known or suspected to have been constructed with an underdrain system*
6. *Inadequate sanitary sewer level of service (LOS) resulting in regular surcharging, customer back-ups, or frequent customer complaints*
7. *Areas formerly served by combined sewer systems*
8. *Sanitary sewer infrastructure defects such as leaking service laterals, cracked, broken, or offset sanitary infrastructure, directly piped connections between storm drain and sanitary sewer infrastructure, or other vulnerability factors identified through Inflow/Infiltration Analyses, Sanitary Sewer Evaluation Surveys, or other infrastructure investigations*

Additional Considerations Not Included in SVFs:

1. *Sewer pump/lift stations, siphons, or known sanitary sewer restrictions where power/equipment failures or blockages could readily result in SSOs*
2. *Any sanitary sewer and storm drain infrastructure greater than 40 years old*
3. *Widespread code-required septic system upgrades required at property transfers (indicative of inadequate soils, water table separation, or other physical constraints of the area rather that poor owner maintenance)*
4. *History of multiple Board of Health actions addressing widespread septic system failures (indicative of inadequate soils, water table separation, or other physical constraints of the area rather that poor owner maintenance)*

MOTT MACDONALD

Memorandum

Subject	**CHW05 Catchment Investigation Technical Memorandum**
To	James Goodreau
From	Suzanne Newman, P.E.
Our reference	2022 MS4 Permit Support, 507106794
Date	March 7, 2023

1 Background

The 2016 National Pollution Discharge Elimination System (NPDES) General Permit for Stormwater Discharges from Small Separate Storm Sewer Systems (MS4) in Massachusetts requires catchment investigations as part of an Illicit Discharge Detection and Elimination (IDDE) Program. The procedures for this investigation are detailed in the Town of Ludlow's IDDE Plan. Mott MacDonald has completed the catchment investigation for outfall CHW05, the results of which are summarized below. This Memorandum is intended to document how the investigation was completed per the requirements of the permit, specifically Section 2.3.4.8.c.iii, which states: "All data collected as part of the dry and wet weather catchment investigations shall be recorded and reported in each annual report".

2 Catchment Description

Catchment area CHW05 is located in the southwestern section of the Town of Ludlow, Massachusetts, as shown on the map provided in **Appendix A**. The area is located within the Riverside Drive area that was recently developed.

A drain trunk line within the CHW05 Catchment runs along Riverside Drive, with two branches meeting at DMH-1276. From this manhole, the stormwater exits at an outfall at the Chicopee River.

Key junction manholes investigated in the CHW14 Catchment include:

- **DMH-1275**, which directs stormwater collected along the northern section of Riverside Drive and the parking lot west of Riverside Drive to the trunk line running south along Riverside Drive.
- **DMH-1276**, which directs stormwater collected from the northerly and southerly branches of Riverside Drive stormwater infrastructure and directs it to the outfall at the Chicopee River.
- **DMH-1281**, which is the easternmost manhole in the catchment area and collects stormwater from two catch basins and diverts it west along the main trunkline along Riverside Drive.

3 Catchment Investigation

Mott MacDonald utilized the catchment investigation procedures developed in the Town of Ludlow Illicit Discharge Detection and Elimination (IDDE) Plan. Prior to conducting field investigations, historic maps and plans were reviewed and System Vulnerability Factors (SVFs) were identified. Mott MacDonald then monitored weather forecasts for potential dry weather days on which the investigations could be conducted.

3.1 Maps, Plans and Other Data Sources

Mott MacDonald reviewed as-built plans and design plans for the 2020 Riverside Drive Project. These plans show the stormwater infrastructure installed throughout the CHW05 catchment area. GIS data was reviewed and compared to the historic plans, and Mott MacDonald has updated the GIS data to reflect both the plans and field observations where applicable.

Table 1 summarizes the historic plans which were reviewed for this task.

Table 1. Supplemental Historic Plans

PLAN NUMBER	STREETS	PLAN NAME	PLAN TYPE	PLAN DATE
C-9 through C-12	Riverside Drive	Town of Ludlow, Massachusetts Riverside Drive Infrastructure Improvements (Note, they are stamped with "As-Built, Ludlow Construction Co. Inc., 19 Carmilina's Circle, Ludlow, MA 01056)	As-Built	9/30/2020 (no date shown for as-built stamp)
C-1 through C-24	Riverside Drive	Town of Ludlow, Massachusetts, Riverside Drive Infrastructure Improvements	Design	9/30/2020
Report and Appendices A through K (350 PDF pages total)	Riverside Drive	Town of Ludlow, Application for Definitive Approval, Stormwater Management Report	Stormwater Report	June 2020

3.2 Manhole Inspection Methodology

Mott MacDonald, with the assistance of the Ludlow DPW, performed dry weather inspections at three (3) manholes in the CHW05 Catchment Area (DMH-1275, DMH-1276, and DMH-1281, shown in **Appendix A**). Manhole inspections followed the steps identified in the Town of Ludlow Illicit Discharge Detection and Elimination (IDDE) Plan for dry weather inspections. Manholes were opened to check for signs of illicit flows and to confirm connection locations and sources. Signs of illicit flows include olfactory

evidence (odors such as sewage smell, mustiness, rotten eggs / sulfur, ammonia, and/or petroleum) and visual evidence (floatable matter, pet waste, oily sheen, sanitary waste, algae, and/or foams). No flow was observed at any of the manholes inspected, and therefore no samples were taken. Additionally, no olfactory or visual evidence of illicit flows were present in any of the manholes inspected, and therefore the area was not flagged for further upstream investigation.

3.3 System Vulnerability Factors (SVF)

No system vulnerabilities were identified for this catchment.

3.4 Key Junction Manholes and Piping

Three (3) manholes in the CHW05 Catchment Area were opened and investigated in accordance with the Town of Ludlow Illicit Discharge Detection and Elimination (IDDE) Plan. A manhole inspection form was completed for each inspected manhole, included in **Appendix C**. Attributes of the key junction manholes investigated are listed below (DMH identifications correspond to map labels as found in **Appendix A**):

- **DMH-1275** (approximately 250 feet south of the intersection of State Street and Sewall Street)
  - Inlet: from upstream DMH-1274 on Riverside Drive, flowing south
  - Outlet: to downstream DMH-1276 on Riverside Drive, flowing southeast
- **DMH-1276** (approximately 320 feet south of the intersection of State Street and Sewall Street)
  - Inlets: from upstream DMH-1275 on Riverside Drive, flowing southeast, and upstream DMH-1277 on Riverside Drive, flowing northwest.
  - Outlet: to outfall at CHW05 the Chicopee River.
- **DMH-1281** (Eastern end of catchment area on Riverside Drive)
  - Inlets: from two catch basins.
  - Outlet: to downstream DMH-1280 on Riverside Drive, flowing west.

As a result of this investigation, the CHW05 Catchment Area limits were delineated as presented in **Appendix A**. Overall updates to the Town GIS system were made based on the above information.

4 Catchment Investigation Results

Mott MacDonald has completed the dry weather catchment investigation of the CHW05 Catchment Area.

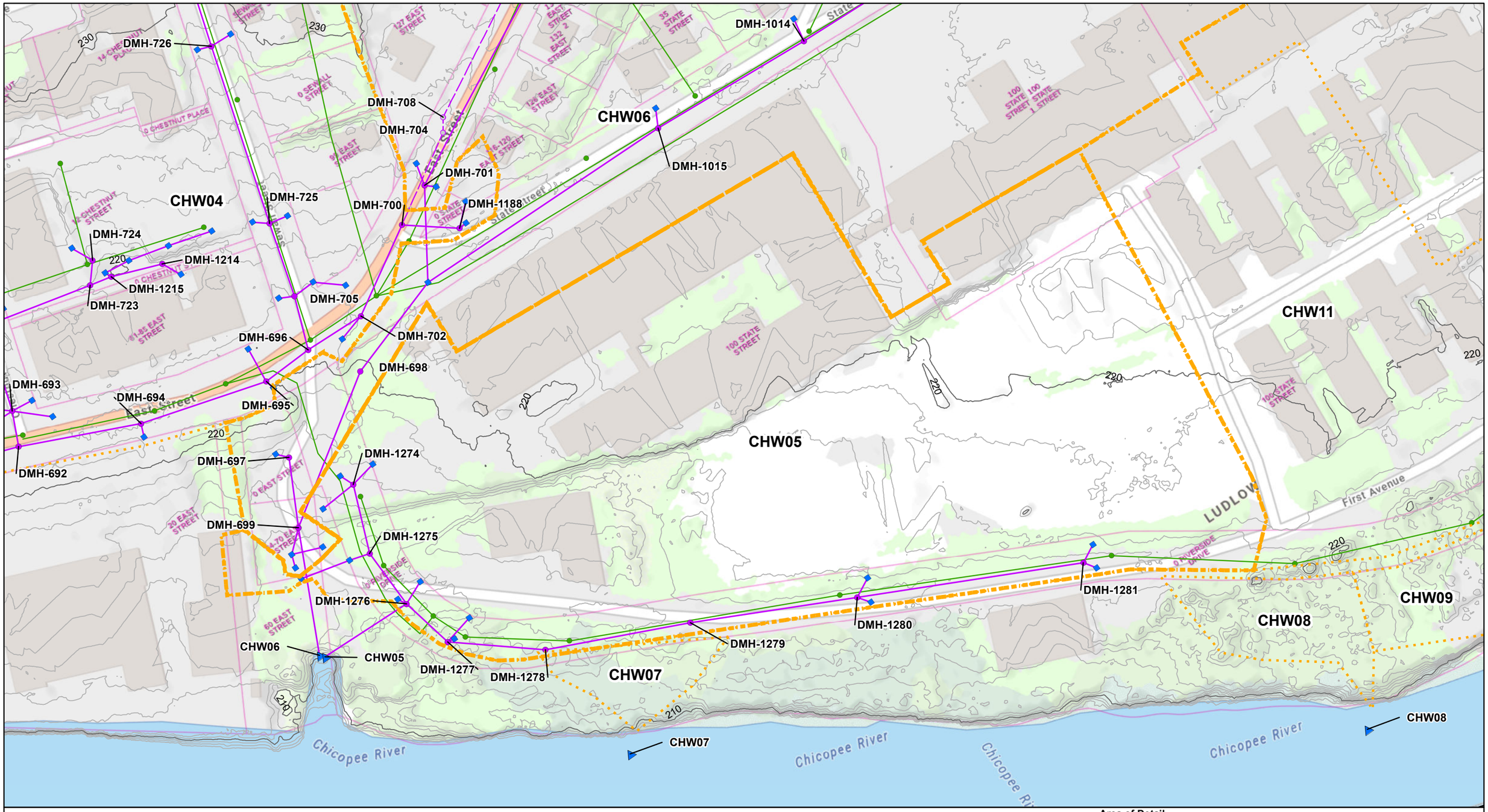
Dry Weather Sampling: No samples taken as no flow was observed in the catch basins.

Conclusion:

The dry weather catchment investigation for CHE05 is complete. No illicit discharges were identified. Wet weather sampling is not required as no System Vulnerability Factors (SVFs) were identified.

Appendix A

Catchment Area Map



Storm Drain Manhole
- In-Service
- Abandoned

Storm Drain Pipe
- In-Service
- Abandoned

- Discharge Outfall
- Catch Basin
- Sanitary Manhole
- Sanitary Pipe

- 10-ft Contour
- 1-ft Contour
- Catchment Area
- Town Boundary

Catchment Area - CHW05

Department of Public Works

Town of Ludlow, Massachussets

Area of Detail

0 100 Feet

MOTT MACDONALD

Document Path: G:\W_WW\Ludlow_MA_DPW_GIS_Central_Repository\MXD\Ludlow_Catchment_Investigation_MapBook.mxd

Appendix B

System Vulnerability Factors

Outfall Catchment System Vulnerability Factor (SVF) Inventory
Town of Ludlow, Massachusetts
Revision Date: January 23, 2023

		Presence/Absence Evaluation Criteria for SVFs								Additional Considerations Not Included as SVFs			
Outfall ID	Receiving Water	1 History of SSOs	2 Common or Twin Invert Manholes	3 Common Trench Construction	4 Storm/Sanitary Crossings (Sanitary Above)	5 Sanitary Lines with Underdrains	6 Inadequate Sanitary Level of Service	7 Areas Formerly Served by Combined Sewers	8 Sanitary Infrastructure Defects	1 SSO Potential in Event of System Failures	2 Sanitary and Storm Drain Infrastructure >40 years Old	3 Septic with Poor Soils or Water Table Separation	4 History of BOH Actions Addressing Septic Failure
CHW05	MA36-24	No	No	No	No	No	No	No	No	No	No	No	No

Presence/Absence Evaluation Criteria for SVFs:

1. *History of SSOs, including, but not limited to, those resulting from wet weather, high water table, or fat/oil/grease blockages*
2. *Common or twin-invert manholes serving storm and sanitary sewer alignments*
3. *Common trench construction serving both storm and sanitary sewer alignments*
4. *Crossings of storm and sanitary sewer alignments where the sanitary system is shallower than the storm drain system*
5. *Sanitary sewer alignments known or suspected to have been constructed with an underdrain system*
6. *Inadequate sanitary sewer level of service (LOS) resulting in regular surcharging, customer back-ups, or frequent customer complaints*
7. *Areas formerly served by combined sewer systems*
8. *Sanitary sewer infrastructure defects such as leaking service laterals, cracked, broken, or offset sanitary infrastructure, directly piped connections between storm drain and sanitary sewer infrastructure, or other vulnerability factors identified through Inflow/Infiltration Analyses, Sanitary Sewer Evaluation Surveys, or other infrastructure investigations*

Additional Considerations Not Included as SVFs:

1. *Sewer pump/lift stations, siphons, or known sanitary sewer restrictions where power/equipment failures or blockages could readily result in SSOs*
2. *Any sanitary sewer and storm drain infrastructure greater than 40 years old*
3. *Widespread code-required septic system upgrades required at property transfers (indicative of inadequate soils, water table separation, or other physical constraints of the area rather that poor owner maintenance)*
4. *History of multiple Board of Health actions addressing widespread septic system failures (indicative of inadequate soils, water table separation, or other physical constraints of the area rather that poor owner maintenance)*

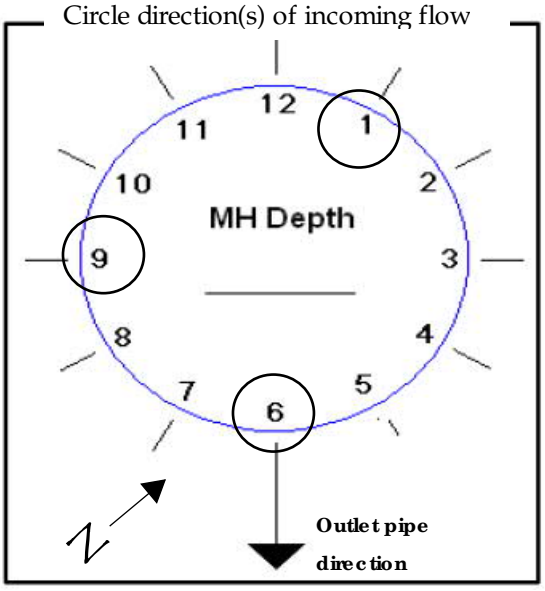
Appendix C

Manhole Inspection Forms

Manhole Inspection Form

Catchment ID CHW05	**Date/ Time** 10 Jan 2023 9:00 AM
Structure ID DMH-1275	**Last Rain Date/ Amount** 6 Jan 2023: 0.25 in.
Location Description Riverside Drive	
Inspector Wiktor Tomkiewicz , William Cruikshank	

Circle direction(s) of incoming flow



Clock Position (1-12) Pipe Material (Concrete, HDPE, PVC, Ductile Iron, CMP)	Pipe Diameter (in.)	Invert Elevation (ft)	Upgradient Structure/ Source (MH ID, CB, Priv, Unk)	Flow (Damp, Trickle, Moderate, High)
(6) HDPE	18	5' down from rim	MH	Damp
(1) HDPE	18	4.5' down from rim	MH	Damp
(9) HDPE	12	5.1' down from rim	CB	Damp

Cover Conditions: Diameter of clear opening (in.) 24 ☐ Buried ☐ Cannot Inspect ☐ Cannot Locate

Evidence of Flow: ☐ Yes ☒ No **If Yes, Description of Flow:** ☐ Damp ☐ Trickle ☒ Moderate ☐ High

Visual Evidence of Illicit Discharge (select all that apply)

Visual Inspection: ☒ None ☐ Floatables ☐ Pet Waste ☐ Oily Sheen ☐ Sanitary Waste ☐ Algae ☐ Foam

Olfactory Evidence of Illicit Discharge (select all that apply)

Olfactory Inspection: ☒ None ☐ Sewage Smell ☐ Musty ☐ Rotten Eggs ☐ Ammonia ☐ Petroleum

Samples Taken and Sampling Results

Chlorine NA	Surfactants NA	Ammonia NA	

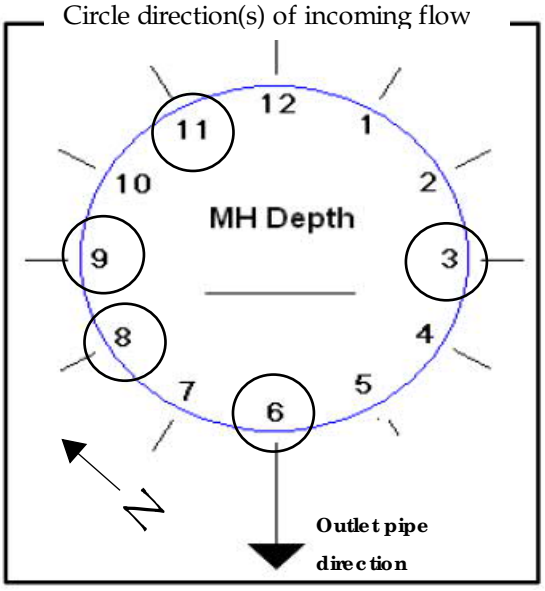
COMMENTS:

Further investigation needed? ☐ Yes ☒ No

Manhole Inspection Form

Catchment ID CHW05	**Date/ Time** 10 Jan 2023 8:50 AM
Structure ID DMH-1276	**Last Rain Date/ Amount** 6 Jan 2023: 0.25 in.
Location Description Riverside Drive	
Inspector Wiktor Tomkiewicz , William Cruikshank	

Circle direction(s) of incoming flow



Clock Position (1-12) Pipe Material (Concrete, HDPE, PVC, Ductile Iron, CMP)	Pipe Diameter (in.)	Invert Elevation (ft)	Upgradient Structure/ Source (MH ID, CB, Priv, Unk)	Flow (Damp, Trickle, Moderate, High)
(3)		7.41' down from rim	MH	Damp
(6)			Outfall	Damp
(8)			CB	Damp
(9)			MH	Damp
(11)			CB	Damp

Cover Conditions: Diameter of clear opening (in.) 24 ☐ Buried ☐ Cannot Inspect ☐ Cannot Locate

Evidence of Flow: ☐ Yes ☒ No **If Yes, Description of Flow:** ☐ Damp ☐ Trickle ☒ Moderate ☐ High

Visual Evidence of Illicit Discharge (select all that apply)

Visual Inspection: ☒ None ☐ Floatables ☐ Pet Waste ☐ Oily Sheen ☐ Sanitary Waste ☐ Algae ☐ Foam

Olfactory Evidence of Illicit Discharge (select all that apply)

Olfactory Inspection: ☒ None ☐ Sewage Smell ☐ Musty ☐ Rotten Eggs ☐ Ammonia ☐ Petroleum

Samples Taken and Sampling Results

Chlorine NA	Surfactants NA	Ammonia NA	

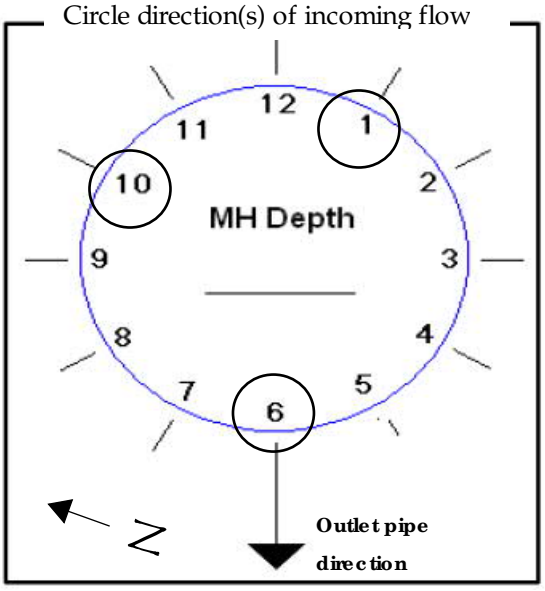
COMMENTS:

Further investigation needed? ☐ Yes ☒ No

Manhole Inspection Form

Catchment ID CHW05	**Date/ Time** 10 Jan 2023 9:10 AM
Structure ID DMH-1281	**Last Rain Date/ Amount** 6 Jan 2023: 0.25 in.
Location Description Riverside Drive	
Inspector Wiktor Tomkiewicz , William Cruikshank	

Circle direction(s) of incoming flow



Clock Position (1-12) Pipe Material (Concrete, HDPE, PVC, Ductile Iron, CMP)	Pipe Diameter (in.)	Invert Elevation (ft)	Upgradient Structure/ Source (MH ID, CB, Priv, Unk)	Flow (Damp, Trickle, Moderate, High)
(1) HDPE	12	4.2' down from rim	CB	Damp
(6) HDPE	18	4.7' down from rim	MH	Damp
(10) HDPE	12	3.3' down from rim	CB	Damp

Cover Conditions: Diameter of clear opening (in.) 24 ☐ Buried ☐ Cannot Inspect ☐ Cannot Locate

Evidence of Flow: ☐ Yes ☒ No **If Yes, Description of Flow:** ☐ Damp ☐ Trickle ☒ Moderate ☐ High

Visual Evidence of Illicit Discharge (select all that apply)

Visual Inspection: ☒ None ☐ Floatables ☐ Pet Waste ☐ Oily Sheen ☐ Sanitary Waste ☐ Algae ☐ Foam

Olfactory Evidence of Illicit Discharge (select all that apply)

Olfactory Inspection: ☒ None ☐ Sewage Smell ☐ Musty ☐ Rotten Eggs ☐ Ammonia ☐ Petroleum

Samples Taken and Sampling Results

Chlorine NA	Surfactants NA	Ammonia NA	

COMMENTS:

Further investigation needed? ☐ Yes ☒ No

E. SSO Inventory (from Town of Ludlow IDDE)

Table 3: SSO Inventory
Town of Ludlow, Massachusetts
Revision Date: September 28, 2023

SSO Location[1]	Discharge Statement[2]	Date[3]	Time Start[3]	Time End[3]	Estimated Volume[4]	Description[5]	Mitigation Completed[6]	Mitigation Planned[7]
21 Park Terrace	Discharge to catch basin into Chicopee River	12/11/2018	3:30 PM	4:00 PM	50 gallons	Sewer System Blockage	Jetted the sewer line to clear blockage. Area disinfected as well.	N/A
44 Center Street	Discharge to catch basin into Chicopee River	1/21/2020	12:30 PM	12:35 PM	100 gallons	Sewer System Blockage	Jetted the sewer line to clear blockage.	N/A

[1] *Location (approximate street crossing/address and receiving water, if any)*

[2] *A clear statement of whether the discharge entered a surface water directly or entered the MS4*

[3] *Date(s) and time(s) of each known SSO occurrence (i.e., beginning and end of any known discharge)*

[4] *Estimated volume(s) of the occurrence*

[5] *Description of the occurrence indicating known or suspected cause(s)*

[6] *Mitigation and corrective measures completed with dates implemented*

[7] *Mitigation and corrective measures planned with implementation schedules*

F. Outfall Inventory and Priority Ranking

Infrastructure and Investigation Information							Catchment Composition						Receiving Water			Ranking Output	
Outfall ID	Stream Segment	Known/ Suspected Problem and/ or Complaints?	Past Sewer Conversion or CSO in Catchment?	Culverts Longer Than Street Crossing In Catchment?	Previous Screening Results Indicate Likely Sewer Input? [1]	Infrastructure Score	Catchment Area	Weighted Business Loading Score [2]	Weighted Residential Housing Age Score [3]	Sewer Pipe Density Score	Septic System Density Score [4]	Catchment Score	Discharging to Area of Concern to Public Health? [5]	Stormwater Related Impairments	Receiving Water Score	Outfall Score for Catchment Investigation	Priority Rank
Information Source		*Town of Ludlow Staff*	*Town of Ludlow Staff, GIS Maps*	*Town of Ludlow Staff, GIS and Storm Sewer Maps*	*Outfall inspections and sample results*	-	*GIS*	*Town of Ludlow Staff, Parcel IDs/ GIS*	*Town of Ludlow Parcel Maps*	*GIS Mapping*	*GIS Mapping*	-	*GIS Maps*	*Impaired Waters List*	-	-	-
Scoring Criteria		*0 or 1 (if 1 automatically problem)*	*0 or 1*	*0 or 1*	*0 or 1 (if 1 automatically problem)*	*0 to 100*	*acres*	*0 to 1*	*0 to 1*	*0 to 1*	*0 to 1*	*0 to 100*	*0, 1, 2, or 3 (if >0 automatically high)*	*0 or 1 (0= Long Island Sound Impairment, 1= Other Impairments, 2 = Fecal Coliform & E. Coli Impairment; if>1 automatically high)*	*0 to 100*	*0 to 100 (weighted average of the three scores)*	*Problem, High, or Low*
CHE01	MA36-23	0	0	0	0	0	23.81	*0.67*	*1.00*	0.12	0.04	46	0	0	0	15.2	LOW
CHE02	MA36-23	0	0	0	0	0	0.27	*0.00*	*0.00*	0.00	0.00	0	0	0	0	0.0	LOW
CHE03	MA36-23	0	0	0	0	0	2.17	*0.33*	*0.33*	0.00	0.14	20	0	0	0	6.7	LOW
CHW01	MA36-24	0	0	0	0	0	10.41	*0.33*	*1.00*	0.44	0.00	44	0	2	50	31.4	HIGH
CHW02	MA36-24	0	0	0	0	0	43.05	*0.33*	*0.67*	0.22	0.00	30	0	2	50	26.8	HIGH
CHW03	MA36-24	0	0	0	0	0	8.13	*0.00*	*0.67*	0.28	0.00	24	0	2	50	24.6	HIGH
CHW04	MA36-24	1	1	0	0	50	32.61	*1.00*	*0.67*	0.41	0.00	52	1	2	75	59.0	PROBLEM
CHW05	MA36-24	0	0	0	0	0	8.79	*0.00*	*0.67*	0.27	0.00	23	1	2	75	32.8	HIGH
CHW06	MA36-24	1	1	0	0	50	94.63	*1.00*	*1.00*	0.45	0.00	61	1	2	75	62.1	PROBLEM
CHW07	MA36-24	0	0	0	0	0	0.25	*0.00*	*0.67*	0.00	0.00	17	1	2	75	30.6	HIGH
CHW08	MA36-24	0	0	0	0	0	0.42	*0.00*	*0.67*	0.00	0.00	17	1	2	75	30.6	HIGH
CHW09	MA36-24	0	0	0	0	0	0.37	*0.00*	*0.67*	0.00	0.00	17	1	2	75	30.6	HIGH
CHW10	MA36-24	0	0	0	0	0	6.06	*0.00*	*0.67*	0.07	0.00	18	1	2	75	31.2	HIGH
CHW11	MA36-24	0	1	0	0	25	75.86	*0.33*	*1.00*	0.32	0.00	41	1	2	75	47.1	HIGH
CHW12	MA36-24	0	0	0	0	0	5.20	*0.00*	*0.67*	0.36	0.00	26	1	2	75	33.6	HIGH
CHW13	MA36-24	0	0	0	0	0	21.36	*0.00*	*1.00*	0.30	0.00	32	1	2	75	35.8	HIGH
CHW14	MA36-24	1	1	0	0	50	51.98	*1.00*	*1.00*	0.62	0.00	66	0	2	50	55.2	PROBLEM
CHW15	MA36-24	0	0	0	0	0	6.64	*0.00*	*0.67*	0.03	0.00	17	1	2	75	30.8	HIGH
HGB01	MA36-42	0	0	0	0	0	22.40	*0.00*	*0.67*	0.42	0.00	27	0	0	0	9.0	LOW
HGB02	MA36-42	0	0	0	0	0	7.25	*1.00*	*0.67*	0.44	0.00	53	0	0	0	17.6	LOW
HGB03	MA36-42	0	0	0	0	0	5.52	*0.33*	*1.00*	0.04	0.05	36	0	0	0	11.9	LOW
HGB04	MA36-42	0	0	0	0	0	7.58	*0.00*	*0.67*	0.51	0.00	29	0	0	0	9.8	LOW
HGB05	MA36-42	0	0	0	0	0	0.87	*0.00*	*0.67*	0.00	0.35	25	0	0	0	8.5	LOW
HGB06	MA36-42	0	0	0	0	0	4.22	*0.00*	*1.00*	0.10	0.47	39	0	0	0	13.0	LOW
HGB07	MA36-42	0	0	0	0	0	57.21	*0.33*	*1.00*	0.17	0.02	38	0	0	0	12.7	LOW
HGB08	MA36-42	0	0	0	0	0	2.12	*0.00*	*0.67*	0.00	1.00	42	0	0	0	13.9	LOW
HGB09	MA36-42	0	0	0	0	0	14.07	*0.00*	*0.67*	0.37	0.00	26	0	0	0	8.6	LOW
HGB10	MA36-42	0	0	0	0	0	17.86	*0.33*	*1.00*	0.13	0.09	39	1	0	25	21.3	HIGH
HGB11	MA36-42	0	0	0	0	0	1.19	*0.00*	*0.67*	0.35	0.00	26	0	0	0	8.5	LOW
HGB12	MA36-42	0	0	0	0	0	10.78	*0.00*	*1.00*	0.43	0.00	36	1	0	25	20.2	HIGH
HGB13	MA36-42	0	0	0	0	0	9.46	*0.67*	*0.67*	0.50	0.00	46	0	0	0	15.3	LOW
HGB14	MA36-42	0	0	0	0	0	2.15	*0.00*	*0.67*	0.50	0.00	29	0	0	0	9.7	LOW
HGB15	MA36-42	0	0	0	0	0	8.00	*0.00*	*0.67*	0.36	0.00	26	0	0	0	8.6	LOW

Infrastructure and Investigation Information							Catchment Composition						Receiving Water			Ranking Output	
Outfall ID	Stream Segment	Known/ Suspected Problem and/ or Complaints?	Past Sewer Conversion or CSO in Catchment?	Culverts Longer Than Street Crossing In Catchment?	Previous Screening Results Indicate Likely Sewer Input? [1]	Infrastructure Score	Catchment Area	Weighted Business Loading Score [2]	Weighted Residential Housing Age Score [3]	Sewer Pipe Density Score	Septic System Density Score [4]	Catchment Score	Discharging to Area of Concern to Public Health? [5]	Stormwater Related Impairments	Receiving Water Score	Outfall Score for Catchment Investigation	Priority Rank
HGB16	MA36-42	0	0	0	0	0	34.36	*1.00*	*1.00*	0.22	0.00	55	1	0	25	26.8	HIGH
HGB17	MA36-42	0	0	0	0	0	1.52	*0.33*	*0.67*	0.37	0.30	42	0	0	0	13.9	LOW
HGB18	MA36-42	0	0	0	0	0	0.40	*0.00*	*0.00*	0.60	0.00	15	0	0	0	5.0	LOW
HGB19	MA36-42	0	0	0	0	0	0.75	*0.00*	*0.00*	0.15	0.00	4	0	0	0	1.2	LOW
HGB20	MA36-42	0	0	0	0	0	27.55	*0.00*	*0.67*	0.33	0.00	25	1	0	25	16.6	HIGH
HGB21	MA36-42	0	0	0	0	0	2.70	*0.00*	*0.00*	0.00	0.00	0	1	0	25	8.3	HIGH
HRB01	N/A	0	0	0	0	0	11.37	*0.67*	*1.00*	0.00	0.12	45	0	0	0	14.9	LOW
HRB02	N/A	0	0	0	0	0	6.84	*0.00*	*0.67*	0.00	0.07	18	0	0	0	6.1	LOW
HRB03	N/A	0	0	0	0	0	36.67	*0.00*	*1.00*	0.00	0.10	27	0	0	0	9.2	LOW
HVP01	N/A	0	0	0	0	0	1.20	*0.33*	*0.67*	0.66	0.00	41	1	0	25	22.1	HIGH
MBT01	MA36-24	0	0	0	0	0	12.49	*0.33*	*0.67*	0.18	0.00	30	0	2	50	26.5	HIGH
MBT02	MA36-24	0	0	0	0	0	4.15	*0.00*	*0.33*	0.40	0.00	18	0	2	50	22.8	HIGH
MBT03	MA36-24	0	0	0	0	0	48.51	*1.00*	*1.00*	0.14	0.00	54	0	2	50	34.5	HIGH
MBT04	MA36-24	0	0	0	0	0	20.91	*0.00*	*1.00*	0.19	0.00	30	0	2	50	26.6	HIGH
MBT05	MA36-24	0	0	0	0	0	1.66	*0.00*	*0.33*	0.74	0.00	27	0	2	50	25.6	HIGH
MBT06	MA36-24	0	0	0	0	0	16.81	*0.33*	*1.00*	0.39	0.00	43	0	2	50	31.0	HIGH
MBT07	MA36-24	0	0	0	0	0	5.67	*0.00*	*1.00*	0.75	0.00	44	0	2	50	31.3	HIGH
MBT08	MA36-24	0	0	0	0	0	69.34	*0.33*	*0.67*	0.18	0.00	29	1	2	75	34.8	HIGH
MBT09	MA36-24	0	0	0	0	0	2.80	*0.00*	*0.33*	0.18	0.00	13	0	2	50	20.9	HIGH
MCP01	N/A	0	1	0	0	25	74.74	*0.33*	*1.00*	0.18	0.01	38	1	1	50	37.7	HIGH
MCP02	N/A	0	0	0	0	0	24.78	*1.00*	*1.00*	0.40	0.00	60	0	1	25	28.3	LOW
MCP03	N/A	0	0	0	0	0	95.69	*1.00*	*1.00*	0.00	0.00	50	0	1	25	25.0	LOW
MCP04	N/A	0	0	0	0	0	0.12	*0.00*	*0.67*	0.00	0.00	17	0	1	25	13.9	LOW
MPP01	N/A	0	1	0	0	25	26.42	*0.33*	*1.00*	0.17	0.19	42	0	0	0	22.5	LOW
MPP02	N/A	0	0	0	0	0	5.36	*0.00*	*0.67*	0.24	0.11	25	0	0	0	8.5	LOW
TBR01	N/A	0	0	0	0	0	13.99	*0.00*	*0.67*	0.00	0.00	17	0	0	0	5.6	LOW
TCA01	MA36-24	1	0	0	0	25	126.38	*1.00*	*1.00*	0.00	0.00	50	1	2	75	50.0	PROBLEM
TCD01	MA36-23	0	0	0	0	0	7.05	*0.00*	*0.67*	0.00	0.19	21	0	0	0	7.2	LOW
TCE01	MA36-23	0	0	0	0	0	47.67	*0.00*	*1.00*	0.00	0.07	27	0	0	0	8.9	LOW
TCH01	MA36-23	0	0	0	0	0	29.30	*0.00*	*1.00*	0.15	0.08	31	0	0	0	10.3	LOW
TCH02	MA36-23	0	0	0	0	0	2.32	*0.00*	*0.00*	0.00	0.00	0	0	0	0	0.0	LOW
TCH03	MA36-23	0	0	0	0	0	4.76	*0.00*	*0.00*	0.00	0.22	6	0	0	0	1.9	LOW
TCH04	MA36-23	0	0	0	0	0	26.64	*0.00*	*0.67*	0.00	0.22	22	0	0	0	7.4	LOW
TCM01	MA36-23	0	0	0	0	0	1.26	*0.00*	*1.00*	0.32	0.00	33	0	0	0	11.0	LOW
TCM02	MA36-23	0	0	0	0	0	20.54	*1.00*	*0.33*	0.19	0.00	38	0	0	0	12.7	LOW
TCO01	MA36-23	0	0	0	0	0	1.15	*0.00*	*0.00*	0.00	0.00	0	0	0	0	0.0	LOW
TCO02	MA36-23	0	0	0	0	0	2.92	*0.33*	*0.67*	0.00	0.26	31	0	0	0	10.5	LOW
TCO03	MA36-23	0	0	0	0	0	8.02	*0.33*	*0.67*	0.00	0.09	27	0	0	0	9.1	LOW
TCS01	MA36-23	0	0	0	0	0	3.81	*0.00*	*0.33*	0.00	0.44	19	0	0	0	6.4	LOW
TCS02	MA36-23	0	0	0	0	0	5.58	*0.33*	*0.33*	0.00	0.30	24	0	0	0	8.0	LOW
TCS03	MA36-23	0	0	0	0	0	2.62	*0.33*	*0.33*	0.00	0.17	21	0	0	0	7.0	LOW
TCT01	MA36-24	0	0	0	0	0	18.32	*0.00*	*0.00*	0.10	0.03	3	0	2	50	17.8	HIGH
TCT02	MA36-24	0	0	0	0	0	1.45	*0.00*	*0.67*	1.00	0.00	42	0	2	50	30.6	HIGH
THB01	MA36-42	0	0	0	0	0	4.04	*0.00*	*0.67*	0.00	0.64	33	0	0	0	10.9	LOW
THB02	MA36-42	0	0	0	0	0	8.33	*0.00*	*0.67*	0.00	0.16	21	0	0	0	6.9	LOW

Infrastructure and Investigation Information							Catchment Composition						Receiving Water			Ranking Output	
Outfall ID	Stream Segment	Known/ Suspected Problem and/or Complaints?	Past Sewer Conversion or CSO in Catchment?	Culverts Longer Than Street Crossing In Catchment?	Previous Screening Results Indicate Likely Sewer Input? [1]	Infrastructure Score	Catchment Area	Weighted Business Loading Score [2]	Weighted Residential Housing Age Score [3]	Sewer Pipe Density Score	Septic System Density Score [4]	Catchment Score	Discharging to Area of Concern to Public Health? [5]	Stormwater Related Impairments	Receiving Water Score	Outfall Score for Catchment Investigation	Priority Rank
THK01	N/A	0	0	0	0	0	96.19	*0.00*	*0.67*	0.06	0.00	18	0	0	0	6.0	LOW
THK02	N/A	0	0	0	0	0	16.99	*0.33*	*1.00*	0.02	0.00	34	0	0	0	11.2	LOW
THK03	N/A	0	0	0	0	0	4.86	*0.67*	*0.67*	0.14	0.00	37	0	0	0	12.3	LOW
THK04	N/A	0	0	0	0	0	1.84	*0.00*	*0.67*	0.25	0.00	23	0	0	0	7.7	LOW
THK05	N/A	0	0	0	0	0	2.43	*0.33*	*0.67*	0.48	0.00	37	0	0	0	12.3	LOW
THK06	N/A	0	0	0	0	0	2.31	*0.00*	*0.33*	0.56	0.26	29	0	0	0	9.6	LOW
THK07	N/A	0	0	0	0	0	2.64	*0.00*	*0.67*	0.39	0.00	26	0	0	0	8.8	LOW
THL01	MA36-42	0	0	0	0	0	1.75	*0.00*	*1.00*	0.00	0.26	31	0	0	0	10.5	LOW
THR01	MA36-42	0	0	0	0	0	1.18	*0.00*	*0.00*	0.00	0.26	6	0	0	0	2.1	LOW
WHA01	MA36-42	0	0	0	0	0	5.41	*0.00*	*0.33*	0.00	0.62	24	0	0	0	7.9	LOW
WHB01	MA36-42	0	0	0	0	0	9.27	*0.33*	*0.67*	0.42	0.00	35	0	0	0	11.8	LOW

Notes:

[1] Town of Ludlow has not conducted any recent outfall screenings. Screening results indicate likely sewer input if any of the following are true:

- Olfactory or visual evidence of sewage,
- Ammonia ≥ 0.5 mg/L, surfactants ≥ 0.25 mg/L, and bacteria levels greater than the water quality criteria applicable to the receiving water, or
- Ammonia ≥ 0.5 mg/L, surfactants ≥ 0.25 mg/L, and detectable levels of chlorine

[2] The weighted business loading scores are based on the presence of high and medium loading businesses within each catchment. High loading businesses were given twice the weighting of the medium loading businesses.
Medium Loading businesses were defined as: auto repair facilites/automotive vehicles or supplies sales and service, automobile parking lots or garages, bus transportation facilites and related properties, campgrounds/RV parks, car dealers, car washes, food stores and wholesale beverage/supermarkets, small retail and services stores, eating and drinking establishments, gasoline stations/fuel service areas, marinas, nurseries and garden centers, oil change shops, restaurants, chemical products, food processing, rubber and plastics, colleges and universities, airports, rental car lots, US postal service trucking companies and distribution centers.

High Loading businesses were defined as: heavy construction equipment rental and leasing, building and heavy construction (for land disturbing activites), buildings for manufacturing operations, apparel and other fabrics, auto recyclers and scrap yards, boat building and repair, chemical products, food processing, garbage truck washout activities, leather tanners, paper and wood products, petroleum storage and refining/gas production plants, tanks holding fuel and oil for retail distribution, natural or manufactured gas storage, textile mills, transportation equipment, landfills and hazardous waste material disposal, maintenance depots, streets and highways construction, metal production, planting and engraving operations, ports, railroads, petroleum bulk stations or terminals, research and development facilites; and facilites providing business material, hardware, farm equipment, heating, hardware, plumbing, lumber supplies and equipment.

[3] The weighted residential housing age scores are based on the presence of houses which are older than 40 years and houses which are between 20 and 40 years of age. Houses older than 40 years were given twice the weighting of the houses which are between 20 and 40 years of age.

[4] The septic system density scores are based on a scale of 0 to 1, where the catchment with the highest number of septic systems per acre will be given a score of 1, and all other catchments are scored proportionally to the catchment with the highest septic system density.

[5] Outfalls/interconnections that discharge to or in the vicinity of any of the following areas: public beaches, recreational areas, drinking water supplies, or shellfish beds

G. Outfall Catchment System Vulnerability Factor Inventory

Table 9: Outfall Catchment System Vulnerability Factor (SVF) Inventory
Town of Ludlow, Massachusetts
Revision Date: September 28, 2023

		Presence/Absence Evaluation Criteria for SVFs								Additional Considerations Not Included as SVFs			
Outfall ID	Receiving Water	1 History of SSOs	2 Common or Twin Invert Manholes	3 Common Trench Construction	4 Storm/Sanitary Crossings (Sanitary Above)	5 Sanitary Lines with Underdrains	6 Inadequate Sanitary Level of Service	7 Areas Formerly Served by Combined Sewers	8 Sanitary Infrastructure Defects	1 SSO Potential in Event of System Failures	2 Sanitary and Storm Drain Infrastructure >40 years Old	3 Septic with Poor Soils or Water Table Separation	4 History of BOH Actions Addressing Septic Failure
CHE01	MA36-23	No	No	No	No	No	No	No	No	No	Yes	No	No
CHE02	MA36-23	No	No	No	No	No	No	No	No	No	Yes	No	No
CHW04	MA36-24	Yes	No	No	No	No	No	Yes	No	No	No	No	No
CHW05	MA36-24	No	No	No	No	No	No	No	No	No	No	No	No
CHW11	MA36-24	No	No	No	No	No	No	Yes	No	No	Yes	No	No
CHW12	MA36-24	No	No	No	No	No	No	No	No	No	No	No	No
CHW14	MA36-24	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No

Presence/Absence Evaluation Criteria for SVFs:

1. *History of SSOs, including, but not limited to, those resulting from wet weather, high water table, or fat/oil/grease blockages*
2. *Common or twin-invert manholes serving storm and sanitary sewer alignments*
3. *Common trench construction serving both storm and sanitary sewer alignments*
4. *Crossings of storm and sanitary sewer alignments where the sanitary system is shallower than the storm drain system*
5. *Sanitary sewer alignments known or suspected to have been constructed with an underdrain system*
6. *Inadequate sanitary sewer level of service (LOS) resulting in regular surcharging, customer back-ups, or frequent customer complaints*
7. *Areas formerly served by combined sewer systems*
8. *Sanitary sewer infrastructure defects such as leaking service laterals, cracked, broken, or offset sanitary infrastructure, directly piped connections between storm drain and sanitary sewer infrastructure, or other vulnerability factors identified through Inflow/Infiltration Analyses, Sanitary Sewer Evaluation Surveys, or other infrastructure investigations*

Additional Considerations Not Included as SVFs:

1. *Sewer pump/lift stations, siphons, or known sanitary sewer restrictions where power/equipment failures or blockages could readily result in SSOs*
2. *Any sanitary sewer and storm drain infrastructure greater than 40 years old*
3. *Widespread code-required septic system upgrades required at property transfers (indicative of inadequate soils, water table separation, or other physical constraints of the area rather that poor owner maintenance)*
4. *History of multiple Board of Health actions addressing widespread septic system failures (indicative of inadequate soils, water table separation, or other physical constraints of the area rather that poor owner maintenance)*

H. Dry Weather Screening Log

Outfall ID	Receiving Water	Date of most Recent Inspection	Pipe or swale?	Dimensions	Shape	Material	Spatial Location (lat/long w/in 30ft accuracy)	Physical Condition	Flow?	Indicators of Potential Non-Stormwater Discharges? (Y/N)	If yes, what indicators?
CHW12	Chicopee River (MA36-24)	8/18/2021	Pipe	12"	Round	Plastic	lat 42.1538 long -72.4687	Good	Dry	No	N/A
CHE02	Chicopee River (MA36-23)	1/30/2020	Pipe	12"	Round	Clay Tile	lat42.1573 long-72.4240	Good	Dry	No	N/A
MBT06	Minechoag Brook Tributary to Chicopee River (MA36-24)	1/30/2020	Pipe	24"	Round	Concrete	lat42.1587 long-72.4400	Good	Trickling	No	N/A
MBT07	Minechoag Brook Tributary to Chicopee River (MA36-24)	1/30/2020	Pipe	60"	Round	Concrete	lat42.1587 long-72.4400	Good	Moderate	No	N/A
MBT08	Minechoag Brook Tributary to Chicopee River (MA36-24)	1/30/2020	Pipe	24"	Round	Corrugated Metal	lat42.1593 long-72.4396	Fair	Dry	No	N/A
TCE01	Tributary to Chicopee River (MA36-23) (Near Elizabeth Dr.)	1/30/2020	Pipe	36"	Round	Concrete	lat42.1638 long-72.4201	Good	Trickling	No	N/A
TCH04	Tributary to Chicopee River (MA36-23) (Starting near Deer Hill Circle)	1/30/2020	Pipe	30"	Round	Concrete	lat42.1662 long-72.4307	Good	Trickling	No	N/A
TCM01	Tributary to Chicopee River (MA36-23) (Miller St. to Chapin Street)	1/30/2020	Pipe	12"	Round	Concrete	lat42.1583 long-72.4301	Good	Dry	No	N/A
TCM02	Tributary to Chicopee River (MA36-23) (Miller St. to Chapin Street)	1/30/2020	Pipe	18"	Round	Concrete	lat42.1583 long-72.4301	Good	Trickling	No	N/A
CHW10	Chicopee River (MA36-24)	1/24/2020	Pipe	24"	Round	Concrete	lat42.1542 long-72.4757	Good	Trickling	No	N/A
CHW08	Chicopee River (MA36-24)	1/14/2020	Pipe	24"	Round	Concrete	lat42.1539 long-72.4786	Good	Dry	No	N/A
CHW01	Chicopee River (MA36-24)	1/10/2020	Pipe	15"	Round	Concrete	lat42.1624 long-72.5004	Good	Dry	No	N/A
CHW04	Chicopee River (MA36-24)	1/10/2020	Pipe	42"	Round	Corrugated Metal	lat42.1580 long-72.4861	Fair	Dry	No	N/A
CHW06	Chicopee River (MA36-24)	1/10/2020	Pipe	60"	Round	Concrete	lat42.1558 long-72.4819	Good	Submerged	No	N/A
CHW11	Chicopee River (MA36-24)	1/10/2020	Pipe	42"	Round	Concrete	lat42.1541 long-72.4734	Good	Dry	No	N/A
CHW03	Chicopee River (MA36-24)	1/8/2020	Pipe	18"	Round	Concrete	lat42.1629 long-72.4875	Good	Dry	No	N/A
TCA01	Tributary to Chicopee River (MA36-24) (Near Davis St.)	1/8/2020	Pipe	48"	Round	Concrete	lat42.1639 long-72.4866	Good	Moderate	No	N/A
MCP02	Minechoag Pond	8/22/2023	Pipe	30"	Round	Plastic	lat42.1650 long-72.4599	Good	Submerged	No	N/A
MCP04	Minechoag Pond	8/22/2023	Pipe	8"	Round	Corrugated Metal	lat42.1649 long-72.4599	Poor	Dry	No	N/A

Outfall ID	Receiving Water	Date of most Recent Inspection	Pipe or swale?	Dimensions	Shape	Material	Spatial Location (lat/long w/in 30ft accuracy)	Physical Condition	Flow?	Indicators of Potential Non-Stormwater Discharges? (Y/N)	If yes, what indicators?
MCP01	Minechoag Pond	8/22/2023	Pipe	30"	Round	Corrugated Metal	lat42.1651 long-72.4600	Poor	Trickling	No	N/A
MCP03	Minechoag Pond	8/22/2023	N/A	N/A	N/A	N/A	lat42.1645 long-72.4565	Crumbling	N/A	No	N/A
CHW13	Chicopee River (MA36-24)	8/22/2023	Pipe	36"	Round	Concrete	lat42.1596 long-72.4540	Good	Dry	No	N/A