Town of Ludlow BMP Tracking

Revised: September 2021

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-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
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

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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
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	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

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BMP-XXX-25	Pinewood Circle	Detention Basin	Infiltration Basin (or	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:	**270.3**	**71.9**		**652**

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	1.02	*0.00*	*0.67*	0.00	0.00	17	1	2	75	30.6	HIGH
CHW06	MA36-24	1	1	0	0	50	92.66	*1.00*	*1.00*	0.45	0.00	61	1	2	75	62.1	PROBLEM
CHW07	MA36-24	0	0	0	0	0	4.02	*0.00*	*0.00*	0.00	0.00	0	1	2	75	25.0	HIGH
CHW08	MA36-24	0	0	0	0	0	7.16	*0.00*	*0.00*	0.00	0.00	0	1	2	75	25.0	HIGH
CHW09	MA36-24	0	0	0	0	0	1.85	*0.00*	*0.00*	0.00	0.00	0	1	2	75	25.0	HIGH
CHW10	MA36-24	0	0	0	0	0	2.93	*0.00*	*0.00*	0.00	0.00	0	1	2	75	25.0	HIGH
CHW11	MA36-24	0	1	0	0	25	48.01	*0.33*	*1.00*	0.42	0.00	44	0	2	50	39.6	HIGH
CHW12	MA36-24	0	0	0	0	0	3.99	*0.00*	*0.00*	0.55	0.00	14	0	2	50	21.2	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
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

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
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
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	74.88	*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
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
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

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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

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?	If yes, what indicators?	Other Notes
CHE02	Chicopee River (MA36-23)	1/30/2020	Pipe	12"	Round	Clay Tile	lat42.1573 long-72.4240	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	
CHW03	Chicopee River (MA36-24)	1/8/2020	Pipe	18"	Round	Concrete	lat42.1629 long-72.4875	Good	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	
CHW08	Chicopee River (MA36-24)	1/14/2020	Pipe	24"	Round	Concrete	lat42.1539 long-72.4786	Good	Dry	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	
CHW11	Chicopee River (MA36-24)	1/10/2020	Pipe	42"	Round	Concrete	lat42.1541 long-72.4734	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	
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	
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	
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	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	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	1/30/2020	Pipe	18"	Round	Concrete	lat42.1583 long-72.4301	Good	Trickling	No	N/A	

MOTT MACDONALD

Town of Ludlow Year 4 Massachusetts Small MS4 General Permit

Phosphorous Report – Minechoag Pond

September 2022

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Town of Ludlow Year 4 Massachusetts Small MS4 General Permit

Phosphorous Report – Minechoag Pond

September 2022

Issue and revision record

Revision	Date	Originator	Checker/Editor	Approver	Description
A	July 2021	NepRWA/PVPC	PVPC	PVPC	Phosphorous Report – Minechoag Pond
B	September 2022	NepRWA/PVPC	William Cruikshank	Suzanne Newman	Updated formatting. Minor Text edits, added executive summary

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Information class: **Standard**

Contents

Executive summary

Minechoag Pond in the Town of Ludlow, MA is subject to an approved Lake and Pond Phosphorus Total Maximum Daily Load (TMDL), and therefore must meet the requirements for phosphorus reduction stated in Appendix F, part A.II of the EPA Massachusetts Small Separate Storm Sewer Systems (MS4) General Permit. The report presented below is intended to meet the requirements for 4 years after the permit effective date. These requirements are that the Lake Phosphorus Control Plan (LPCP) area must be defined, and calculations must be completed for the baseline phosphorus load, allowable phosphorus load, and phosphorus reduction requirement.

The Pioneer Valley Planning Commission (PVPC) partnered with the Neponset River Watershed Association to assist the Town of Ludlow in completing the Year 4 Lake Pond Phosphorus requirements through the Massachusetts Department of Environmental Protection's FY21 MS4 Permit Assistance Grant. As is described in more detail below, the PVPC performed an analysis using town GIS data for catchment areas, state GIS data for land cover/land use, and the USDA Soil Survey Geographic Database. The PVPC included the three catchment areas discharging to Minechoag Pond as the LPCP area. The baseline phosphorus load was calculated by applying the Phosphorus Load Export Rates from Table 1-2 of Appendix F Attachment 1 to the GIS shapefiles for land cover/land use and soil type within catchments of the defined LPCP area. PVPC's analysis was summarized in a written report, and is displayed in an ArcGIS on-line data viewer at the following location: https://tinyurl.com/MS4-NSI-PVPC.

The following report is the original report provided by PVPC with minor edits to the text and updated formatting. The numerical values determined by PVPC for as presented in Table 2 were based on the data during the time of PVPC's July 2021 analysis and have not been modified. These results have not been updated with any subsequent changes to the Town GIS which may have occurred due to subsequent catchment investigations or system updates. Changes to catchments or additional changes which may affect the results of this study should be considered and updated as part of the future MS4 Permit work.

ContentsYear 4 Lake Pond and Phosphorous Control Plan Requirements

Introduction

Several communities in the Connecticut River Watershed have Lake and Pond Phosphorus TMDL requirements associated with the EPA MS4 permit, Appendix F, Section II of Parts A and B. Through MassDEP's FY21 MS4 Permit Assistance Grant in which PVPC partnered with the Neponset River Watershed Association, PVPC assisted two communities with Year 4 requirements. This assistance tied specifically to the Lake and Pond Phosphorus Control Plan requirements.

For Spectacle Pond in Wilbraham and Minechoag Pond in Ludlow, PVPC completed the following two deliverables for Year 4:

- Defined Lake and Pond Phosphorus Control Plan Area
- Calculated baseline phosphorus load, allowable phosphorus load, and load reduction requirement

To facilitate the ongoing work associated with these TMDL requirements, PVPC created an ArcGIS on-line data viewer that can further serve Wilbraham and Ludlow. See: https://tinyurl.com/MS4-NSI-PVPC

Data Sources and Analytical Methods for Identifying Phosphorus Loading

Several existing datasets were used to complete this work. Table 2 below lists the utilized data sets and their origin.

Table 1: Data Sources

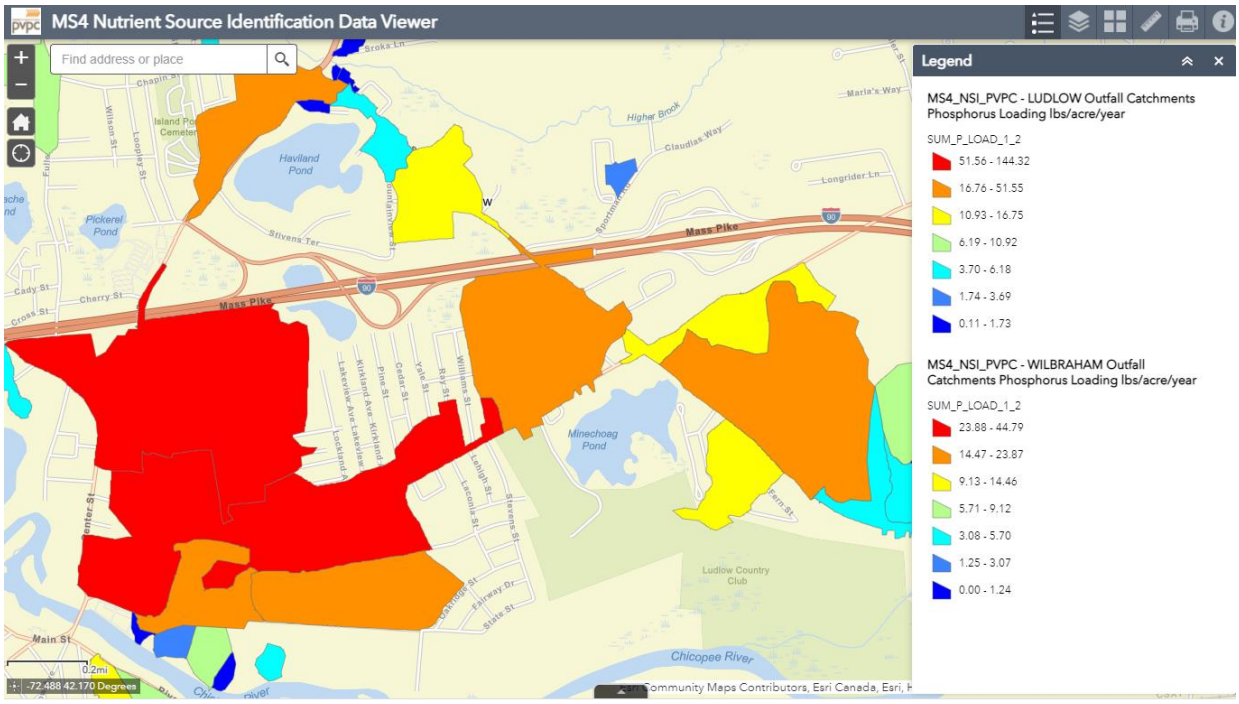
Existing Data Set	Origin	Date Published/Updated	Link
2016 Land Cover/Land Use	MassGIS	May 2019	https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use
Soil Survey Geographic (SSURGO) Database for Hampden and Hampshire Counties, Massachusetts	USDA	June 2020	Downloaded through Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). Hydrologic soil groups extracted using Soil Data Viewer Version 6.1 (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053619)
Ludlow Town Catchments	Town of Ludlow GIS Files	Current as of 2/23/21	N/A

To estimate the pollutant loads for phosphorus in each catchment, estimated pollutant loading rates for different combinations of land use type, land cover type, and soil type were applied in accordance with guidance in the EPA 2016 MS4 Permit. The individual phosphorus loads for these unique subsections were summed based on catchment, which produced an overall estimated phosphorus load.

For a more detailed description of the analytical methods used for this project, please refer to the Appendix (**Appendix A**) to this report on Methods.

Lake and Pond Phosphorous Control Plan Area

The control plan area is defined as the area discharging to Minechoag Pond and specifically the infrastructure that delivers storm flows to the Pond.



Phosphorus Loading Calculations (baseline phosphorus load, and load reduction requirement)

Using the methods described in Attachment 1 to Appendix F of the 2016 Massachusetts Small MS4 General Permit, the town's catchment delineations, and the data included in the 2016 Land Cover/Land Use data set and the SSURGO Database for Hampden and Hampshire Counties, estimates of the baseline phosphorus load and required reduction were created for each of the town's catchments.

To obtain these values, the land use (the "USEGENNAME" attribute in the 2016 Land Cover/Land Use data set) of each area 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. Calculated area, DCIA estimates, and soil hydrologic groups were then incorporated to calculate the estimated phosphorus load from each individual area. Phosphorus loads for all areas within a given catchment were then totaled to determine the estimated loading for that catchment.

Phosphorus load reductions were determined using methods described in Attachment 1 to Appendix F of the 2016 Massachusetts Small MS4 General Permit. To determine these values, calculated catchment area phosphorus loads were multiplied by 48%, the required percent reduction from Table F-6 of Appendix F.A.II. Table 2 below shows the lake and pond phosphorus control plan area catchments with the baseline phosphorus load and load reduction requirement in lbs. P/yr.

Table 2: Pond Area Catchments and Phosphorus Load and Reduction Requirements

Catchment Identifier	Baseline Phosphorus Load lbs. P/yr.	Minimum Required Phosphorus Reduction lbs. P/yr.	Maximum Allowable Phosphorus Load lbs. P/yr.	Catchment Acres	Impervious Acres	DCIA Acres	Percent Impervious Area	Percent DCIA
LUDLOW-MCP03	51.55	24.74	26.81	96.16	28.41	4.94	29.55%	5.14%
LUDLOW-MCP01	33.45	16.06	17.39	72.96	18.50	3.33	25.36%	4.57%
LUDLOW-MCP02	15.47	7.42	8.05	24.04	9.43	3.04	39.22%	12.65%
Total	100.47	48.22	52.25	193.16	56.34	11.31	29.17%	5.86%

Appendix

A. Methods

Appendix to Nutrient Source Identification Report

Methods

Methods described here are based on guidance within the EPA MS4 Permit for MA, but refined and elaborated by staff from Neponset River Watershed Association and Pioneer Valley Planning Commission in consultation with MassDEP, and EPA.

Prepared by Neponset River Watershed Association and
updated for Pioneer Valley region communities by PVPC

June 30, 2021

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Introduction

This is an appendix to the Town's/City's Nutrient Source Identification Report. This document explains the methods followed to produce the information in the report. All actions described were performed using ArcMap 10.6.1.

The analysis requires three existing shapefiles. Information on each of these required shapefiles is provided in Table 1 below.

Table 1. Shapefiles Used in Analysis

Existing Data Set	Origin	Date Published/Updated	Link
2016 Land Cover/Land Use	MassGIS	May 2019	https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use
Soil Survey Geographic (SSURGO) Database for Norfolk and Suffolk Counties, Massachusetts	USDA	June 2020	Downloaded through Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). Hydrologic soil groups extracted using Soil Data Viewer Version 6.1 (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053619)
Town/City Catchments	Town/City GIS Files	Current as of 6/10/21	N/A

Creation of Base Shapefile

First a 2016 land cover/land use crosswalk was developed to determine phosphorus loading rates, by expanding on the 2005 land use crosswalk in the MS4. This crosswalk method compares general land use to land cover and assigns a P load crosswalk value based on the predominant condition. General land use determined the crosswalk value where the predefined crosswalk category expressed an accurate depiction of land use activity, e.g. Agriculture to "Ag" or Commercial to "Com_Ind". Land cover was used to

determine the P load crosswalk value when the general land use predefined crosswalk category did not accurately depict land use activity, e.g. Tax Exempt, ROW, Open Land, Recreation, Unknown –are all better represented by using the land cover value to determine crosswalk values as opposed to the predefined land use crosswalk value of "Com_Ind".

Table 2a. MassGIS 2016 Land Use Phosphorus Load Crosswalk

COVERNAME	USEGENNAME	PLCRSS
Pervious	Agriculture	Ag
Impervious	Agriculture	Ag
Water	Agriculture	Water
Pervious	Commercial	Com_Ind
Impervious	Commercial	Com_Ind
Water	Commercial	Water
Pervious	Forest	For
Impervious	Forest	For
Water	Forest	Water
Pervious	Industrial	Com_Ind
Impervious	Industrial	Com_Ind
Water	Industrial	Water
Bare Land	Mixed use, other	Open
Cultivated	Mixed use, other	Ag
Deciduous Forest	Mixed use, other	For
Developed Open Space	Mixed use, other	Open
Evergreen Forest	Mixed use, other	For
Grassland	Mixed use, other	Open
Impervious	Mixed use, other	Open
Palustrine Aquatic Bed	Mixed use, other	For
Palustrine Emergent Wetland	Mixed use, other	For
Palustrine Forested Wetland	Mixed use, other	For
Palustrine Scrub/Shrub	Mixed use, other	For
Pasture/Hay	Mixed use, other	Ag
Scrub/Shrub	Mixed use, other	For
Water	Mixed use, other	Water
Pervious	Mixed use, primarily commercial	Com_Ind
Impervious	Mixed use, primarily commercial	Com_Ind
Water	Mixed use, primarily commercial	Water
Pervious	Mixed use, primarily residential	LDR

COVERNAME	USEGENNAME	PLCRSS
Impervious	Mixed use, primarily residential	LDR
Water	Mixed use, primarily residential	Water
Bare Land	Open land	Open
Cultivated	Open land	Ag
Deciduous Forest	Open land	For
Developed Open Space	Open land	Open
Evergreen Forest	Open land	For
Grassland	Open land	Open
Impervious	Open land	Open
Palustrine Aquatic Bed	Open land	For
Palustrine Emergent Wetland	Open land	For
Palustrine Forested Wetland	Open land	For
Palustrine Scrub/Shrub	Open land	For
Pasture/Hay	Open land	Ag
Scrub/Shrub	Open land	For
Water	Open land	Water
Bare Land	Recreation	Open
Cultivated	Recreation	Ag
Deciduous Forest	Recreation	For
Developed Open Space	Recreation	Open
Evergreen Forest	Recreation	For
Grassland	Recreation	Open
Impervious	Recreation	Open
Palustrine Aquatic Bed	Recreation	For
Palustrine Emergent Wetland	Recreation	For
Palustrine Forested Wetland	Recreation	For
Palustrine Scrub/Shrub	Recreation	For
Pasture/Hay	Recreation	Ag
Scrub/Shrub	Recreation	For
Water	Recreation	Water
Pervious	Residential - multi-family	MFR_HDR
Impervious	Residential - multi-family	MFR_HDR
Water	Residential - multi-family	Water
Pervious	Residential - other	MDR

COVERNAME	USEGENNAME	PLCRSS
Impervious	Residential - other	MDR
Water	Residential - other	Water
Pervious	Residential - single family	LDR
Impervious	Residential - single family	LDR
Water	Residential - single family	Water
Bare Land	Right-of-way	Open
Cultivated	Right-of-way	Ag
Deciduous Forest	Right-of-way	For
Developed Open Space	Right-of-way	Open
Evergreen Forest	Right-of-way	For
Grassland	Right-of-way	Open
Impervious	Right-of-way	HWY
Palustrine Aquatic Bed	Right-of-way	For
Palustrine Emergent Wetland	Right-of-way	For
Palustrine Forested Wetland	Right-of-way	For
Palustrine Scrub/Shrub	Right-of-way	For
Pasture/Hay	Right-of-way	Ag
Scrub/Shrub	Right-of-way	For
Water	Right-of-way	Water
Bare Land	Tax exempt	Open
Cultivated	Tax exempt	Ag
Deciduous Forest	Tax exempt	For
Developed Open Space	Tax exempt	Open
Evergreen Forest	Tax exempt	For
Grassland	Tax exempt	Open
Impervious	Tax exempt	HWY
Palustrine Aquatic Bed	Tax exempt	For
Palustrine Emergent Wetland	Tax exempt	For
Palustrine Forested Wetland	Tax exempt	For
Palustrine Scrub/Shrub	Tax exempt	For
Pasture/Hay	Tax exempt	Ag
Scrub/Shrub	Tax exempt	For
Water	Tax exempt	Water
Bare Land	Unknown	Open

COVERNAME	USEGENNAME	PLCRSS
Cultivated	Unknown	Ag
Deciduous Forest	Unknown	For
Developed Open Space	Unknown	For
Evergreen Forest	Unknown	For
Grassland	Unknown	Open
Impervious	Unknown	HWY
Palustrine Aquatic Bed	Unknown	For
Palustrine Emergent Wetland	Unknown	For
Palustrine Forested Wetland	Unknown	For
Palustrine Scrub/Shrub	Unknown	For
Pasture/Hay	Unknown	Ag
Scrub/Shrub	Unknown	For
Water	Unknown	Water
Bare Land	Water	Open
Cultivated	Water	Ag
Deciduous Forest	Water	For
Developed Open Space	Water	For
Evergreen Forest	Water	For
Grassland	Water	Open
Impervious	Water	Open
Palustrine Aquatic Bed	Water	For
Palustrine Emergent Wetland	Water	For
Palustrine Forested Wetland	Water	For
Palustrine Scrub/Shrub	Water	For
Pasture/Hay	Water	Ag
Scrub/Shrub	Water	Open
Water	Water	Water
COVERNAME	USEGENNAME	PLCRSS

To support the analysis, a base shapefile containing pertinent information for land cover, land use, and soil types in the area of interest was created. This was completed by performing a “intersect” operation with two input shapefiles shown in Table 1 above: the 2016 Land Cover/Land Use shapefile and a shapefile containing the SSURGO soil hydrologic groups. Each record in the shapefile represents areas with specific land cover, land use, and soil types.

Several fields were then added to the resulting "Land Use Loading Rate" (MS4_NSI_NPL_210614) shapefile to support later steps of this analysis. Table 2b below lists the added field and provides a brief description of the data that was added.

Table 2b. Summary of Fields Added to "MS4_NSI_NPL_210614" Shapefile

Added Field	Description
P Load Crosswalk	The phosphorus loading category to which a record was assigned. See Table 1-2 in Attachment 1 of Appendix F of the 2016 Massachusetts Small MS4 General Permit for a full listing of loading categories and rates.
N Load Crosswalk	The nitrogen loading category to which a record was assigned. See Table 1 in Attachment 1 of Appendix H of the 2016 Massachusetts Small MS4 General Permit for a full listing of loading categories and rates
PLER	The numerical phosphorus loading rate assigned to a record. The value originates from Table 1-2 in Attachment 1 of Appendix F of the 2016 Massachusetts Small MS4 General Permit
NLER	The numerical nitrogen loading rate assigned to a record. The value originates from Table 1 in Attachment 1 of Appendix H of the 2016 Massachusetts Small MS4 General Permit
DCIA_M	The multiplier from the applicable Sutherland equation to estimate directly connected impervious area for a record. Note that entry is <Null> for all non-impervious records. For more detailed information about how these values were assigned, see the "DCIA Calculation" section below.
DCIA_E	The exponent from the applicable Sutherland equation to estimate directly connected impervious area for a record. Note that entry is <Null> for all non-impervious records. For more detailed information about how these values were assigned, see the "DCIA Calculation" section below.

Preparation of Catchment Shapefile and Intersect with Base Shapefile

To prepare the catchment shapefile for later analysis, a field entitled either "CatchAreaAcre" was added to the attribute table. The "calculate geometry" function was used to populate this field for each record, measuring the total area of each catchment in acres.

Once the additional field was added, the "Intersect" tool was run with two input datasets: "Land use Loading Rate" (described in the last section) and the Town's/City's Catchment shapefile. The resulting shapefile was entitled "[Municipality]Catchment Segments" and is available in the files the Town/City received upon completion of this project.

This resulting shapefile limits the information contained in the broader "Land use Loading Rate" to just what specifically occurs in each of the Town's/City's catchments, allowing further catchment-level analysis of several criteria.

For the purposes of this analysis, in some cases only the portions of catchments within the Town/City boundaries were considered. For instance, if a catchment along the border of the Town/City actually extended into a neighboring jurisdiction, that portion outside of the boundary was removed during this step and any land area outside of the Town/City boundaries was not considered in the subsequent analysis. This decision was made because, even though the catchment may be mapped outside of the boundaries, the Town/City generally does not have the ability to impact properties in other jurisdictions. If the Town/City wishes to include those areas outside of Town/City in this analysis, the above steps could be repeated using the same shapefiles and steps, but without limiting the base shapefile creation by Town/City boundaries.

Summarized Analysis

New fields were added to the recently created shapefile. Table 3 below lists the new fields, the description of the data they contain, and shows the operations involved in calculating the applicable data. Further details about each calculation can be found in the individual sections below.

Table 3. New Fields Added to "[Town/CityName]Intersect" Shapefile

New Field	Description	Units	Function Used to Calculate	Calculation Method
SEG_ACRE	The area of a record.	Acres	Calculate Geometry	Calculate the area in acres.
IMPA _ACRE	The area of impervious surfaces occupied by a record.	Acres	Calculate Geometry	Query only records with "Impervious" entry for CoverName, then calculate the area in acres. After removing the query, all non-impervious records will have a "0" listed for this field.

New Field	Description	Units	Function Used to Calculate	Calculation Method
IMPA_PRCT	The amount of impervious area in a record.	Percentage of the total catchment area	Field Calculator	([IMPA_ACRE]/[Catch_Total_Acres])*100
CATCH_PRCT	The percentage of the catchment represented by a record.	Percentage of the total catchment area	Field Calculator	([SEG_ACRE]/[Catch_Total_Acres])*100
DCIA_PRCT	An estimate of directly connected impervious area represented by a record	Percentage of the total catchment area.	Field Calculator	([IMPA_PRCT]^[DCIA_E])*[DCIA_M]
DCIA_ACRE	An estimate the amount of directly connected impervious area associated with a record.	Acres	Field Calculator	([DCIA_PRCT]/100)*[Catch_Total_Acres]
P_LOAD_1_2	The estimated phosphorus load from a record	Lbs/Year	Field Calculator	[SEG_ACRE]*[PLER]
N_LOAD	The estimated nitrogen load from a record	Lbs/Year	Field Calculator	[SEG_ACRE]*[NLER]

*PercentOfCatch was only used as a “check” field and is not described further in this document.

Impervious Calculation

The "[Municipality]Catchment Segments" shapefile contains polygons of areas within each catchment with like land cover, land use, and soil type. To begin, the "[Municipality]Catchment Segments" was queried so that only polygons with an entry of "Impervious" for the "CoverName" field were shown. Then, the Calculate Geometry tool was used on those queried records to display the area of each impervious polygon in acres. These results were eventually summed for overall catchment totals of impervious area as described in the "Final Preparation of Deliverable Shapefile" section below.

To further illustrate impervious cover statistics and for use in DCIA calculation, the impervious cover in each polygon was also calculated as a percentage of each catchment. For this measurement, the Field Calculator tool was used on the "ImpPercent" field to divide the impervious area of each polygon ("ImpAreaAcre") by the total catchment size ("CatchAreaAcre", created when preparing the catchment shapefile). This figure was then multiplied by 100 to obtain a percent.

DCIA Calculation

DCIA estimates were based on the Sutherland equations within the EPA guidance document entitled "Estimating Change in Impervious Area (IA) and Directly Connected Impervious Areas (DCIA) for Massachusetts Small MS4 Permit" (Revised April 2014). Table 4 below shows the relation between various land uses in the watershed, the chosen "connectedness" category, and the associated Sutherland equation used in the DCIA estimate. Note that these estimates only occurred on polygons that contained an "Impervious" entry in the CoverName field, as DCIA only exists where impervious area exists.

Table 4. "Connectedness" Category and Sutherland DCIA Equation Assignments for All Land Uses. NOTE: DCIA and IA are both percentages.

USEGENNAME	"Connectedness" Category	Sutherland Equation
Agriculture	Mostly Disconnected	$DCIA=0.01(IA)^2$
Commercial	Average	$DCIA=0.1(IA)^{1.5}$
Forest	Mostly Disconnected	$DCIA=0.01(IA)^2$
Industrial	Average	$DCIA=0.1(IA)^{1.5}$
Mixed use, other	Average	$DCIA=0.1(IA)^{1.5}$
Mixed use, primarily commercial	Average	$DCIA=0.1(IA)^{1.5}$
Mixed use, primarily residential	Average	$DCIA=0.1(IA)^{1.5}$
Open land	Average	$DCIA=0.1(IA)^{1.5}$
Recreation	Average	$DCIA=0.1(IA)^{1.5}$

USEGENNAME	"Connectedness" Category	Sutherland Equation
Residential - multi-family	Highly Connected	$DCIA=0.4(IA)^{1.2}$
Residential - other	Average	$DCIA=0.1(IA)^{1.5}$
Residential - single family	Average	$DCIA=0.1(IA)^{1.5}$
Right-of-way	Average	$DCIA=0.1(IA)^{1.5}$
Tax exempt	Average	$DCIA=0.1(IA)^{1.5}$
Unknown	Average	$DCIA=0.1(IA)^{1.5}$
Water	Average	$DCIA=0.1(IA)^{1.5}$

In these equations, the percentage of impervious cover for a given area is used to determine the percentage of DCIA in the same area. Thus, DCIA percent was calculated in the "DCIAPercent" field using Field Calculator. In this calculation, the impervious percentage represented by the polygon ("ImpPercent") was raised to the power shown in the appropriate equation (already entered in the "DCIA_E" field when preparing the base shapefile) and multiplied by the factor shown (already entered in the "DCIA_M" field when preparing the base shapefile). Essentially, the Field Calculator equation was "DCIAPercent" = ("ImpPercent" ^ "DCIA_E") * "DCIA_M". These results were eventually summed for overall catchment totals of impervious area as described in the "Final Preparation of Deliverable Shapefile" section below.

Finally, the estimated acreage of DCIA for each polygon was calculated in the "DCIAAcre" field using Field Calculator. In this calculation, "DCIAPercent" was divided by 100 and multiplied by the overall catchment size ("CatchAreaAcr" or "CatchAreaA").

Phosphorus Load Calculation

Phosphorus loads were calculated for each record in the [Municipality]Catchment Segments shapefile by multiplying the area of each polygon ("AreaAcre") by the phosphorus loading rate assigned to the record's specific land cover/land use/soil type combination (the "PLER" field, which was entered during the creation of the base shapefile). The Field Calculator tool was used to complete this calculation in the "P_Load" field. As the name suggests, the units for the loading rates are pounds/acre/year. These results are eventually summed for overall catchment totals of impervious area as described in the "Final Preparation of Deliverable Shapefile" section below.

For reference, the phosphorus loading category into which each record is assigned is recorded in the "PLCRSS" field, which stands for Phosphorus Load Crosswalk. The entries in this field correspond to the

land uses and phosphorus load export rates shown in Table 1-2 of Attachment 1 to Appendix F of the 2016 Massachusetts Small MS4 General Permit. An abbreviated crosswalk is shown in Table 5 below.

Table 5. Crosswalk Linking Land Use and Land Cover to the Phosphorus Source Categories Shown in Table 1-2 of Attachment 1 to Appendix F of the 2016 Massachusetts Small MS4 General Permit

USEGENNAME	Phosphorus Source Category
Agriculture	Agriculture (Ag)
Commercial	Commercial/Industrial (Com-Ind)
Forest	Forest (For)
Industrial	Commercial/Industrial (Com-Ind)
Mixed use, other	Varied based on land cover
Mixed use, primarily commercial	Commercial/Industrial (Com-Ind)
Mixed use, primarily residential	Medium-Density Residential (MDR)
Open land	Open Land (Open)
Recreation	Open Land (Open)
Residential - multi-family	Multi-Family and High-Density Residential (MFR-HDR)
Residential - other	Medium-Density Residential (MDR)
Residential - single family	Medium-Density Residential (MDR)
Right-of-way	Varied based on land cover
Tax exempt	Varied based on land cover
Unknown	Varied based on land cover
Water	Varied based on land cover

Nitrogen Load Calculation

Nitrogen loads were calculated for each record in the [Municipality]Catchment Segments shapefile by multiplying the area of each polygon ("AreaAcre") by the nitrogen loading rate assigned to the record's specific land cover/land use/soil type combination (the "NLER" field, which was entered during the creation of the base shapefile). The Field Calculator tool was used to complete this calculation in the "N_Load" field. As the name suggests, the units for the loading rates are pounds/acre/year. These results are eventually summed for overall catchment totals of impervious area as described in the "Final Preparation of Deliverable Shapefile" section below.

For reference, the nitrogen loading category into which each record is assigned is recorded in the "NLCRSS" field, which stands for Nitrogen Load Crosswalk. The entries in this field correspond to the Nitrogen Source Categories and nitrogen load export rates shown in Table 1 of Attachment 1 to Appendix H of the 2016 Massachusetts Small MS4 General Permit. An abbreviated crosswalk is shown in Table 6 below. Note that this crosswalk only considers the land cover of the record (the "CoverName" field) and, where necessary, the soil type of the record (the "HSG_N" field).

Table 6. Crosswalk Linking Land Cover and Soil Type to the Nitrogen Loading Categories Shown in Table 1 of Attachment 1 to Appendix H of the 2016 Massachusetts Small MS4 General Permit

Land Cover	Soil Type	Nitrogen Source Category
Impervious	All	All Impervious Cover
Water	All	None, rate was set to 0 for records that represented surface water.
Non-Impervious, Non-Water	A	Developed Land Pervious (DevPERV)-HSG A
Non-Impervious, Non-Water	B	Developed Land Pervious (DevPERV)-HSG B
Non-Impervious, Non-Water	C	Developed Land Pervious (DevPERV)-HSG C
Non-Impervious, Non-Water	D	Developed Land Pervious (DevPERV)-HSG D
Non-Impervious, Non-Water	A/D	Developed Land Pervious (DevPERV)-HSG A
Non-Impervious, Non-Water	B/D	Developed Land Pervious (DevPERV)-HSG B
Non-Impervious, Non-Water	C/D	Developed Land Pervious (DevPERV)-HSG C/D

Final Preparation of Deliverable Shapefile

Once all calculations were made as described above, the "[Town/CityName]Intersect" shapefile was condensed using the Dissolve tool. The "Dissolve_Field" was defined as the field containing catchment identifiers and the following fields were defined as "Statistics Fields" with a "Statistic Type" of "Sum": "AreaAcre," "ImpAreaAcre," "ImpPercent," "DCIAAcre," "DCIAPercent," "P_Load," and "N_Load."

The resulting layer was named "[Municipality]_Outfall_Catchments" and was provided with all other deliverables from this project. This shapefile displays the Town's/City's catchment and contains totals of each catchment's area, impervious area, estimated DCIA, impervious percentage, estimated DCIA percentage, estimated phosphorus load, and estimated nitrogen load.

Selection of SCM/BMP Sites

Building on method described within the *Pioneer Valley 2014 Regional Green Infrastructure Plan* and through subsequent pilot projects in Springfield and Agawam, PVPC has developed a screening process approach to identify public properties that might be most appropriate for green infrastructure stormwater retrofit locations.

As part of this work, PVPC developed an on-line map/data screening tool to identify potential retrofit opportunities using ESRI's application builder (referred to as *on-line ArcGIS data viewer*). The use of this interface with these layers can help immensely in facilitating decision making. The on-line ArcGIS data viewer displays municipal, state, federal, and private properties by total score of suitability for green infrastructure retrofitting and allows the end user to further explore the values associated with the suitability score for each parcel. Input values can be viewed by either clicking on a parcel to display a "pop-up box" or by viewing the master data table at the bottom of the screen.

Screening considerations, with each their own associated score include all the elements noted in Table 7 below. Note that the outfall catchment area phosphorus or nitrogen loading rate below mean value and the outfall catchment area phosphorus or nitrogen loading rate above mean value are the latest updates to the screening tool based on the work of this project on nutrient source identification reports. These shape files were developed in ArcMap for Desktop and displayed in the on-line viewer.

For local decision making, considerations in this screening process can be further supplemented and fine-tuned based on local priorities. For some communities, localized flooding has been an important additional consideration and has been included in scoring below. PVPC has also been recommending that where possible communities add tree canopy analysis in the ranking so that investments for improved stormwater pollution control through vegetated systems might also possibly serve to cool summer temperatures in neighborhoods where there are few trees.

Table 7. GI Retrofit Screening Tool Layers and Associated Points Scoring

GIS Layers and Point System for Initial Ranking and Screening of Properties			
Italics = Use will depend on whether applies to municipality.	**Points based on whether present or not present**	**Total Possible Points**	**Total Possible Score**
General evaluation criteria - all of municipality			
A or B hydrologic soil group A/D or B/D hydrologic soil group This value is determined by average value of all soil types present in a tax parcel.	5.0 or 0 2.5 or 0	5.0	
MassGIS Drainage Areas sub-basins of waters designated as TMDL completed (Category 4a) or Impaired/Requiring a TMDL (Category 5) on the Massachusetts List of Integrated	5.0 or 0	5.0	
Environmental Justice Areas, 2010	5 .0 or 0	5.0	
Impervious area larger than 1 acre Impervious area 0.5 to 1 acre Impervious area less than 1 acre	5.0 2.5 1.0	5.0	
**Localized flooding areas MassGIS Drainage Areas sub-basins (see discussion in next section below)*	5.0 or 0	5.0	
Located within MS4 regulated area	5.0 or 0	5.0	
			30.0
Loading criteria - within MS4 regulated outfall catchment area			
Outfall Catchment area Phosphorus or Nitrogen loading rate <u>below</u> mean value	35.0 or 0	35.0	65.0
OR			
Outfall Catchment area Phosphorus or Nitrogen loading rate <u>above</u> mean value	70.0 or 0	70.0	100

Some notes on GIS layers

Hydrologic Soil Groups

Though there are thousands of soil types, soils have been grouped *according to their runoff potential* under similar storm and cover conditions.

Group A type soils, for example, "…have low runoff potential and high infiltration rates even when thoroughly wetted. They consist of deep, well to excessively drained sand or gravel and have a high rate of water transmission (greater than 0.30 in/hr)." On the other end of the spectrum are the Group D soils, which "…have high runoff potential and very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 in/hr)."[1]

The mapping layer for hydrologic soils groups provides some understanding of what the conditions may be at a site, but it is important to note that mapping is done at a scale that does not provide a fine level of detail or ensure accuracy. In developed areas the use of fill brought in from other locations may have altered the existing conditions. In heavily urbanized areas in particular, so much fill has been used that mapping provides no soils information for such areas other than to indicate "urban fill."

For the hydrologic soils group layer, see Natural Resources Conservation Service SSURGO Certified Soils data from MassGIS, November 2012, last updated December 2017.

Drainage Areas of Impaired/TMDL Status

Taken together, Total Maximum Daily Load (TMDL) status and watershed delineation is one important way of understanding where waters are impacted by human activity and which drainage areas contribute to these waters. The question here is: *Where are the biggest known water quality problems* and hence where might there be the best opportunities to improve water quality through stormwater management retrofits? A TMDL establishes the amount of a particular pollutant that a water body can receive while still meeting water quality standards.[2] The TMDL status map layer identifies those waters that do not meet applicable state water quality standards. These waters are deemed to be "impaired" by MassDEP pursuant to section 303(d) of the Clean Water Act. These include waters with approved TMDLs and those for which TMDL development has been identified as necessary, but for which a TMDL has not yet been approved. The TMDL status layers comes from MassGIS, which is derived from the *MassDEP Integrated List of Waters* (305(b)/303(d)) – *Last updated January 2018.*

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[1] Part 630 Hydrology, National Engineering Handbook, Appendix A: Hydrologic Soil Groups. United States Department of Agriculture, Natural Resources Conservation Service. January 2009.

2 http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm

Environmental Justice Area

By explicitly mapping Environmental Justice Areas, decisions about stormwater management retrofits and the associated investments can be made with greater awareness and intention in *meaningful involvement of all people and neighborhoods* regardless of race, color, national origin, or income.

Base mapping information for Environmental Justice Areas relies on four criteria from Census block groups. These criteria are as follows:

- where population is 25 percent or more minority
- where median household income is less than 65 percent of the statewide median household income
- where 75 percent or less of households have proficiency with the English language, indicating linguistic isolation
- where 25 percent or more of the population is foreign-born

Localized Flooding Areas*

Climate records for the northeastern United States indicate that the frequency of larger downpours is increasing, and this trend is expected to continue. As such, it may serve municipalities to develop a GIS map layer that identifies known flooding locations through local knowledge or insurance claim records (if obtainable). Then impervious areas located upgradient of these known flooding locations could carry a higher ranking than large impervious properties in other locations within the municipality. Localized flooding areas layer is defined by MassGIS drainage area sub-basin containing municipality identified localized flooding locations.

Impervious Areas

There is a direct correlation between the amount of impervious area—surfaces such as roofs, driveways, roads, and parking lots—and flooding and water quality in rivers, streams, and lakes receiving discharges from these areas. Removal or "disconnection" of impervious cover through retrofitting with green infrastructure stormwater management plays an important role in resolving localized flooding and water quality issues.

Additional Screening Considerations from the MS4 Permit

The Massachusetts MS4 permit in Section 2.3.6.d identifies other considerations. In determining the potential for modifying or retrofitting particular properties, the permittee shall consider factors such as:

- 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

In determining its priority ranking, the permittee shall consider factors such as:

- schedules for planned capital improvements to storm and sanitary sewer infrastructure and paving projects
- public swimming beaches
- drinking water supply sources
- shellfish growing areas

- current storm sewer level of service
- control of discharges to water quality limited waters
- first or second order streams

Other Resources

There are other more complicated tools to conduct similar ranking analyses for stormwater retrofit locations that may be useful. In particular, Opti Tool described below was designed for EPA Region 1. The second and third tools described below are not currently supported. These are listed here with the idea that there may be elements within the tools that could be of interest to municipalities looking to customize their approaches to ranking municipal properties for improved stormwater management.

- Opti Tool (Stormwater Management Optimization Tool) is a spreadsheet-based optimization tool designed for EPA, Region 1. It uses SUSTAIN (see bullet below) in the background but is more user friendly. The tool helps planners determine the best mix of BMPs to provide the greatest benefit for achieving water resource goals while balancing costs. Opti Tool provides analysis at both a planning level and implementation level. Planning Level Analysis provides maximum possible load reduction for all feasible BMP opportunities or cost-effective single solution that meets the numeric load reduction target. Implementation Level Analysis provides optimal combination of different BMP types, sizes and spatial locations or cost-effective solutions for a range of load reduction targets.
  For more information, see the following links:
  http://neiwpcc.org/nationalnpsold/documents/presentations/Voorhees_Session%205.pdf
  https://www.epa.gov/npdes-permits/stormwater-tools-new-england#pcsm

- System for Urban Stormwater Treatment and Analysis Integration Model (SUSTAIN) is a somewhat complicated decision support tool developed and piloted by EPA with the Towns of Bellingham, Franklin, and Milford that involves a cost optimization approach. The tool aggregates benefits and helps to select "best buys" or projects with the greatest environmental value per dollar. SUSTAIN was piloted in these communities because of the requirements they face in meeting federal compliance targets to reduce phosphorous inputs so that the Upper Charles River can meet Massachusetts Surface Water Quality Standards. Cost optimization analysis has involved mapping information on land use categories, unit cost information for stormwater facilities, and pollutant loading export rates for each land use category.

- For the Chesapeake Bay, the Maryland State Highway Administration, in tandem with EPA Region 3 and the U.S. Army Corps of Engineers, developed a related decision-making approach called the *Watershed Resources Registry*. The Registry is an interactive online GIS mapping tool that prioritizes areas for preservation and restoration of wetlands, riparian zones, terrestrial areas, and stormwater management control across an entire state. Driven by the Total Maximum Daily Load goals for the Chesapeake Bay, the Watershed Resources Registry identifies best opportunities to protect high quality resources, restoration of impaired resources, and improvement of stormwater management.[3] Retrofits go beyond green infrastructure stormwater management to include, urban tree plantings, stream buffer plantings, wetland restoration, stream restoration, innovative methods, and improved operations (street sweeping, inlet cleaning). The Registry scores potential restoration and preservation areas on a scale of one to five stars based on their potential benefits. Watershed Resources Registries are now available in four mid-Atlantic states, including Delaware, Maryland, Pennsylvania, and West Virginia.

Final Deliverables

On-line map/data screening tool displaying:

- Municipal, state, federal, and private properties by total score of suitability for green infrastructure retrofitting and allows the end user to further explore the values associated with the suitability score for each parcel.
- Outfall catchment areas with nitrogen and phosphorus loading rates and impervious/directly connected impervious areas.
- Outfall catchment segment areas with nitrogen and phosphorus loading rate and land use/crosswalk values.

To access the screening tool, see: https://tinyurl.com/MS4-NSI-PVPC. Along with the final report, the Town/City was provided with copies ArcGIS shapefiles that were used in or products of the analysis. Table 8 below gives a brief description of each shapefile.

Table 8. Descriptions of Shapefiles Provided as Deliverables of this Project

Shapefile Name	Description
MS4_NSI_NPL_210614	A shapefile containing polygons with like land cover, land use, soil type, and pertinent loading rates, multipliers, etc. This file will is referred to throughout this document as the "base shapefile" as it contains all the information necessary to perform the analysis.
[Municipality]_Catchment Segments	The product of an intersect operation between the base shapefile above and the Town's/City's stormwater catchment shapefile. This shapefile specifically shows only the information from the base shapefile that is pertinent to the Town's/City's catchments. Calculations for impervious area, directly connected impervious area, and pollutant loads were made within this shapefile's attribute table.
[Municipality]_Catchments	This shapefile is the final product of the analysis. It contains the following for each catchment within the Town/City: total area (acres), total impervious area (acres), percent of impervious area within the catchment, total estimated directly connected impervious area (acres), estimated percent of directly connected impervious area within the catchment, estimated phosphorus load from catchment (lbs./year), estimated nitrogen load from catchment (lbs./year)
[Municipality]_BMP_Municipal **[Municipality]_BMP_State** **[Municipality]_BMP_Federal** **[Municipality]_BMP_Private**	These shapefiles are the result of the PVPC "Green Retrofit Analysis" incorporating catchment loading data as an analysis variable.

mottmac.com

MOTT MACDONALD

Town of Ludlow Year 4 Massachusetts Small MS4 General Permit

Nitrogen Source Identification Report

September 2022

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Town of Ludlow Year 4 Massachusetts Small MS4 General Permit

Nitrogen Source Identification Report

September 2022

Issue and revision record

Revision	Date	Originator	Checker/Editor	Approver	Description
A	July 2021	NepRWA/PVPC	PVPC	PVPC	Nitrogen Source Identification Report
B	September 2022	NepRWA/PVPC	Wiktor Tomkiewicz	Suzanne Newman	Reformatted, added executive summary, updated values in Section 3 based on 2021 GIS, added property descriptions to Figure 6, and updated language in sections 5.1 and 5.2 to reflect screening results

Document reference: 507106794

Information class: Standard

Contents

Acknowledgements

This document is one among 20 Nutrient Source Identification Reports prepared by the Neponset River Watershed Association (NepRWA) and the Pioneer Valley Planning Commission (PVPC). These reports are meant to provide MS4 permitted municipalities with documents they can finalize and submit to U.S. EPA as part of their Year 4 reporting requirements.

This work is made possible through a grant from the MassDEP Municipal Assistance Program. Project staff from NepRWA and PVPC appreciate the conversation and feedback provided by MassDEP and U.S. EPA staff in working through methodology to prepare these reports. Aside from producing nutrient source identification reports for 20 communities, this project also resulted in the following: lake-pond phosphorous control plan Year 4 submission requirements for two communities; documentation of approach and methods for use by other MS4 permittees across MA in meeting these Year 4 requirements; and setting of the stage for upgrading existing stormwater infrastructure in key high pollutant loading catchments.

NepRWA and PVPC staff are grateful also to the partner communities who joined them in this pilot project. Following is a list of cities and towns that participated:

Agawam
Canton
Dedham
Foxborough
Granby
Longmeadow
Ludlow
Medfield
Milton
Northampton
Quincy
Randolph
Sharon
South Hadley
Southampton
Southwick
Stoughton
Westfield
Westwood
Wilbraham

Executive summary

This report was originally prepared by the Neponset River Watershed Association (NRWA) and the Pioneer Valley Planning Commission (PVPC) as noted in the acknowledgements above. It was reviewed, updated, and finalized by Mott MacDonald to meet the Permit Year 4 requirements of the US Environmental Protection Agency's (EPA's) 2016 Massachusetts Small MS4 General Permit (MS4 Permit) for the Town of Ludlow ("the Town").

One of the requirements of the MS4 Permit is that Massachusetts communities located in the watershed of Long Island Sound, which has an approved TMDL for nitrogen (Total Nitrogen), shall prepare a Nitrogen Source Identification Report as detailed in Appendix F of the MS4 Permit. As described below, the PVPC performed an analysis which used Town GIS data for catchment areas, state-wide GIS data for land cover/land use, and the USDA Soil Survey Geographic Database. The PVPC estimated the total nitrogen load per year for each catchment area within the Town of Ludlow MS4 by performing an analysis within GIS based on the EPA-prescribed methodology. PVPC then applied a screening method for determining high priority parcels for stormwater control measures (SCMs) based on nitrogen loading. These parcels are municipally-owned properties which were considered good candidates for the implementation of SCMs. Mott MacDonald added one property to this list based on the Town's upcoming development schedule, but otherwise did not change the priority list.

PVPC's analysis was summarized in the following written report, and is displayed in an ArcGIS on-line data viewer at the following location: https://tinyurl.com/MS4-NSI-PVPC.

This report is the original report provided by PVPC with minor updates made by Mott MacDonald to finalize this report as part of the MS4 Permit Year 4 requirements. These updates include minor text updates and updates to the overall formatting. The numerical values determined by PVPC for all catchment areas, impervious cover, and loadings were based on the data during the time of PVPC's July 2021 analysis and have not been modified. These results have not been updated with any subsequent changes to the Town GIS which may have occurred due to subsequent catchment investigations or system updates. Changes to catchments or additional changes which may affect the results of this study should be considered and updated as part of the future MS4 Permit work.

1 Introduction

1.1 Nutrients and Water Pollution

The amount of nutrients (phosphorus and nitrogen) delivered to rivers and streams increases greatly with land development and direct discharge of storm flows from certain land uses to receiving waters. In the urban environment, nitrogen and phosphorous come from a variety of sources including organic debris such as fallen leaves, animal and pet waste, lawn and agricultural fertilizers, malfunctioning sewers and septic systems, and atmospheric deposition from car exhaust, among other sources.

Some of these sources also occur in the natural environment. However, the prevalence of paved and impervious areas in the urban and suburban environment, coupled with the availability of storm drain collection systems, allows street runoff containing excess nutrient pollution to quickly move to the nearest waterbody with little or no treatment. Such flows bypass natural processes such as soil filtration and infiltration that would capture and recycle nutrients before they reach waterways in an undeveloped landscape.

As a result, nutrient-enriched stormwater runoff has become a major source of water pollution. Nutrient pollution increases undesirable plant and algae growth in waterways, which can be highly toxic to humans and wildlife and reduce oxygen levels in the water. This, in turn, impedes recreation and creates chronic challenges for aquatic life, sometimes leading to fish kills. In freshwater waterways, phosphorous is generally the primary pollutant of concern, while nitrogen becomes the primary concern once freshwater rivers flow into saltwater estuaries and bays.

1.2 Regulatory Context

Under the federal and state clean water acts, the Massachusetts Department of Environmental Protection (MassDEP) is charged with establishing water quality standards and determining whether waterways meet these designated standards. MassDEP publishes its *Massachusetts Year 2016 Integrated List of Waters*, also referred to at the 303d Impaired Waters List, identifying waters that do not meet standards. These waterways are referred to as being “impaired” or “water quality limited” based on one or more causes which may include nitrogen, phosphorous, “nutrient/eutrophication biological indicators” or in some cases turbidity or transparency. MassDEP is also charged with preparing waterbody-specific cleanup plans for nutrient pollution known as Total Maximum Daily Loads or TMDLs, though these are yet to be prepared for many impaired waterways.

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. One of the requirements of this permit is that Massachusetts communities located in the watershed of Long Island Sound -- which has an approved TMDL for nitrogen (Total Nitrogen) -- shall prepare a Nitrogen Source Identification Report as detailed in Appendix F of the permit. The Town drains entirely to the Chicopee River, which in turn joins the Connecticut River, all waters of which flow to Long Island Sound. There is one listing in Town for a water body indicated as having a completed TMDL in Category 4a and four listings for waters as impaired in Category 5 of MassDEP’s 2016 303d list. Table 1 shows the listing of these waters.

The Nitrogen Source Identification Report must be submitted with the permit year 4 annual report (year ending June 30, 2022 and report due late September 2022). Appendix F of the EPA 2016 MS4 Permit describes the following requirements for the Nitrogen Source Identification Report:

1. Calculation of total urbanized area within the permittee's jurisdiction that is within the Connecticut River Watershed, incorporating updated mapping of the MS4 and catchment delineations produced pursuant to part 2.3.4.6;
2. All screening and monitoring results pursuant to part 2.3.4.7.b., targeting the receiving water segment(s);
3. Impervious area and DCIA for the target catchment;
4. Identification, delineation, and prioritization of potential catchments with high nitrogen loading;
5. Identification of potential retrofit opportunities or opportunities for the installation of structural BMPs during redevelopment.

Figure 1: Impaired Receiving Waters

Category 4a - TMDL Completed

Water Body	Segment ID	Description	Size	Units	Impairment
Minechoag Pond	MA36093	Ludlow - EPA TMDL #3629	21.00	Acres	Nutrient/Eutrophication Biological Indicators

Category 5 - Requiring a TMDL

Water Body	Segment ID	Description	Size	Units	Impairment
Alden Pond	MA36003	Ludlow.	4.00	Acres	Nutrient/Eutrophication Biological Indicators
Chicopee River	MA36-22	Source, confluence of Ware River and Quaboag River, Palmer (through Red Bridge Impoundment formerly segment MA36171) to Red Bridge Impoundment Dam (NATID: MA00723), Wilbraham/Ludlow.	2.80	Miles	Escherichia Coli (E. Coli)
					Mercury in Fish Tissue
Chicopee River	MA36-24	Wilbraham Pumping Station (old WWTP), Wilbraham/Ludlow to Chicopee Falls Dam (NATID: MA00719), Chicopee.	8.8	Miles	Escherichia Coli (E. Coli)
					Fecal Coliform
Fuller Brook	MA36-41	From the Ludlow/Chicopee corporate boundary where the stream name changes from Higher Brook, to mouth at confluence with the Chicopee River, Chicopee.	1.9	Miles	Escherichia Coli (E. Coli)

2 Data Sources and Analytical Methods for Identifying Nitrogen Loading

Several existing datasets were used to complete this work. Table 2 below lists the utilized data sets and their origin.

Figure 2: Data Sources

Existing Data Set	Origin	Date Published/Updated	Link
2016 Land Cover/Land Use	MassGIS	May 2019	https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use
Soil Survey Geographic (SSURGO) Database for Hampden and Hampshire Counties, Massachusetts	USDA	June 2020	Downloaded through Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). Hydrologic soil groups extracted using Soil Data Viewer Version 6.1 (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053619)
Ludlow Town Catchments	Town of Ludlow GIS Files	Current as of 3/18/21	N/A

Impervious area is the portion of the Town that is paved, covered by buildings, or otherwise rendered unable to absorb water naturally due to development. Impervious area for the town was calculated using the MassGIS 2016 Land Cover/Land Use data layer which was published in 2019. This data layer maps impervious and pervious land cover by land use type based on aerial photography and other data sources. This was overlaid with the Town's data layer for outfall catchment areas (the area draining to each town-owned stormwater discharge point) to estimate total areas and total impervious area discharging to or upstream of nutrient-impaired waterways, as well as to estimate impervious area for each stormwater outfall catchment.

Directly connected impervious area (DCIA), also referred to as "effective impervious cover," is the amount of impervious area that is directly connected to the storm drain system. Most land in the Town was developed before the creation of modern requirements to capture, clean, slow, and recharge stormwater runoff using Stormwater Control Measures (SCMs). However, many new development and redevelopment projects constructed in recent years have required the installation or upgrade of SCMs, such that today some properties have no SCMs, some have SCMs that meet some modern standards, and some have SCMs that are fully compliant with modern standards.

Because site-specific information about the existence of specific SCMs is not available at the parcel level, an estimate of DCIA or effective impervious cover is used to approximate the average level of SCMs installed across the watershed. Estimating DCIA can yield a more specific pollutant loading estimate for a given area. DCIA was estimated based on land use categories following EPA guidance.

To estimate the pollutant loads for nitrogen and/or phosphorous in each catchment, estimated pollutant loading rates for different combinations of land use type, land cover type, and soil type were applied in accordance with guidance in the EPA 2016 MS4 Permit. The individual loading rates for these unique subsections were summed based on catchment, which produced an overall estimated catchment pollutant loading rate.

For a more detailed description of the analytical methods used for this project, please refer to the Methods document in **Appendix A**.

3 Total Urbanized/MS4 Regulated Area

The total area of the Town is approximately 18,135 acres, with a total of 8,220 acres located in the urbanized /MS4 regulated area. All of this MS4 regulated acreage is within the Connecticut River Watershed. The urbanized /MS4 regulated area involves 86 outfall catchment areas.

4 Impervious Area and Directly Connected Impervious Area

4.1 Within MS4 Regulated Area

Table 3 below summarizes the total impervious area (IA) and estimated Directly Connected Impervious Area (DCIA) within the Town's MS4 regulated area.

Figure 3: Summary of Impervious Area and DCIA within MS4 Regulated Area Catchments

	Acres
Total Impervious Area within MS4 Area	508
Total Estimated DCIA within MS4 Area	153

Table 4 below shows information for the 10 catchments within the MS4 regulated area with the most impervious area. The catchments are labeled using the Town's identifier for the outfall to which they drain. The table is sorted in descending order of total impervious area. A full report on impervious area and estimates of DCIA for all storm drain outfall catchments in the Town can be seen in the on-line ArcGIS data viewer at: https://tinyurl.com/MS4-NSI-PVPC

Figure 4: Total Impervious Area and DCIA for the Ten Most Impervious Catchments

Catchment Identifier	Impervious Area (Acres)	Percent Impervious	DCIA (Acres)	Percent DCIA
LUDLOW-CHW04	86.90	64.40%	28.99	21.48%
LUDLOW-TCA01	59.08	42.63%	17.62	12.72%
LUDLOW-MCP03	28.41	29.55%	4.94	5.14%
LUDLOW-CHW11	28.11	60.98%	9.96	21.60%
LUDLOW-CHW02	19.48	45.26%	4.47	10.38%
LUDLOW-MCP01	18.50	25.36%	3.33	4.57%
LUDLOW-HGB16	18.36	53.42%	8.30	24.14%
LUDLOW-CHW06	15.83	65.61%	4.52	18.73%

Catchment Identifier	Impervious Area (Acres)	Percent Impervious	DCIA (Acres)	Percent DCIA
LUDLOW-MBT08	14.04	20.25%	3.13	4.51%
LUDLOW-HGB07	11.78	20.59%	2.00	3.50%
Top 10 Catchments as % of Total	59.15%		57.03%	

5 Identification, Delineations, and Prioritization of Potential Catchments with High Nitrogen Loading

5.1 Estimated Nitrogen Loading

Using the methods described in the Appendix (**Appendix A**) to this report, estimates of nitrogen loading potential were created for each of the Town's storm drain outfall catchments.

Table 5 shows the five catchments with the highest estimated nitrogen loading in the entire MS4 area. To access full reporting, showing calculated nitrogen loading estimates for all catchments in Town, see the on-line ArcGIS data viewer at: https://tinyurl.com/MS4-NSI-PVPC

Table 5. Estimated Nitrogen Loading for Five Highest-Load Catchments in MS4 Area

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
Top 5 as a % of Total Town Load	40.59%

Note these are estimated loadings based on soil type, land use and estimated DCIA (e.g. typical level of SCMs in town). Actual loading may vary considerably from site to site depending on what SCMs are actually present, and regional studies such as the Charles River Phosphorous TMDL have indicated that the default DCIA assumptions used by EPA are somewhat optimistic, such that actual loading rates may be higher. However, these estimates provide a valuable guide to help identify those areas of the Town that should be the highest priorities for interventions to begin reducing pollutant loading.

5.2 Outfall Screening Monitoring Results

As of the writing of this report, the Town of Ludlow has completed sixteen (16) dry weather outfall screening of outfalls within the Town of Ludlow's MS4 area. For all of these outfalls, there were no indicators of potential non-stormwater discharges.

5.3 Catchment Prioritization

Since there were no indicators of potential non-stormwater discharges recorded via the outfall screenings, there is currently no data available to improve projections. This report prioritizes the catchments based solely on the nitrogen loading estimates in the order shown in Table 6 below. As more outfall screening data become available, the list of catchments should be re-examined and the "Top 5" list should be updated based on these real-world data.

6 Potential Retrofit Options

6.1 Method

Building on method described within the *Pioneer Valley 2014 Regional Green Infrastructure Plan* and through subsequent pilot projects in Springfield and Agawam, PVPC has developed a screening process approach to identify public properties that might be most appropriate for green infrastructure stormwater retrofit locations.

As part of this work, PVPC developed an on-line map/data screening tool to identify potential retrofit opportunities using ESRI's application builder (referred to as *on-line ArcGIS data viewer*). The use of this interface with these layers can help immensely in facilitating decision-making. The on-line ArcGIS data viewer displays municipal, state, federal, and private properties by total score of suitability for green infrastructure retrofitting and allows the end user to further explore the values associated with the suitability score for each parcel. Input values can be viewed by either clicking on a parcel to display a "pop-up box" or by viewing the master data table at the bottom of the screen.

Screening considerations, with each their own associated score, include:

- hydrologic soil group
- surface waters listed in Category 4a (TMDL completed) or 5 (Impaired/Requiring a TMDL) on the 2016 Massachusetts List of Integrated Waters, Environmental Justice Areas, size of impervious areas,
- location within the MS4 regulated area
- outfall catchment area phosphorus or nitrogen loading rate below mean value
- outfall catchment area phosphorus or nitrogen loading rate above mean value

The outfall catchment area bullet points above are the latest updates to the screening tool based on the work of this project on nutrient source identification reports. These shape files were developed in ArcMap for Destktop and displayed in the on-line viewer.

For local decision-making, considerations in this screening process can be further supplemented and fine-tuned based on local priorities. For some communities, localized flooding has been an important additional consideration. PVPC has also been recommending that where possible communities add tree canopy analysis in the ranking so that investments for improved stormwater pollution control through vegetated systems might also possibly serve to cool summer temperatures in neighborhoods where there are few trees.

More information on the retrofit opportunity screening tool is provided in **Appendix A** on Methodology to this report.

6.2 High Priority Parcel Based on Nitrogen Loading

PVPC mapped, evaluated, and prioritized all parcels within the MS4 regulated area for Nitrogen loading. Shapefiles were developed in ArcMap for Desktop and displayed in the on-line viewer. While Table 6 below shows the highest-priority parcels owned by the municipality, prioritization of state, federal, and private parcels are available in the on-line viewer. Additionally, Veteran's Park School (486 Chapin Street) has been added at the bottom of the list since this is a municipally-owned property with future development expected. This was not includer higher on the list because the property is not within one of the delineated catchment areas to a permitted outfall and therefore this property should be considered, but does not have a Nitrogen BMP score.

Figure 6: High-Priority Parcels to be Considered for SCM Development for Nitrogen Loading

Address	Property Description	Parloc_ID	Nitrogen BMP Score
0 CENTER STREET	Hubbard Memorial Library	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

6.3 Arc-GIS On-line Data Viewer

The on-line ArcGIS data viewer provides far greater capability in reviewing individual catchments and associated nitrogen loading data to facilitate analysis. From this tool, it is possible to generate analysis that includes the following:

- Impervious and DCIA Amounts for all Catchments, Sorted by Impervious Area
- Estimated Nitrogen Loading for All Catchments
- Ranking of Municipal-Owned Parcels for Nitrogen Removal

The results of this report provide a valuable starting point for the next phase of requirements in Appendix F of the 2016 MS4 Permit which are due by the end of permit year 5 (6/30/2023), which include:

1. Evaluate all properties identified as presenting retrofit opportunities or areas for structural BMP installation under permit part 2.3.6.d.ii. or identified in the Nitrogen Source Identification Report. The evaluation shall include:
    a. The next planned infrastructure, resurfacing or redevelopment activity planned for the property (if applicable) OR planned retrofit date;
    b. The estimated cost of redevelopment or retrofit BMPs; and
    c. The engineering and regulatory feasibility of redevelopment or retrofit BMPs.
2. Provide a listing of planned structural BMPs and a plan and schedule for implementation in the year 5 annual report.

To access the screening tool, see: https://tinyurl.com/MS4-NSI-PVPC

Appendix

A. Methods

Appendix to Nutrient Source Identification Report

Methods

Methods described here are based on guidance within the EPA MS4 Permit for MA, but refined and elaborated by staff from Neponset River Watershed Association and Pioneer Valley Planning Commission in consultation with MassDEP, and EPA.

Prepared by Neponset River Watershed Association and
updated for Pioneer Valley region communities by PVPC

June 30, 2021

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Introduction

This is an appendix to the Town's/City's Nutrient Source Identification Report. This document explains the methods followed to produce the information in the report. All actions described were performed using ArcMap 10.6.1.

The analysis requires three existing shapefiles. Information on each of these required shapefiles is provided in Table 1 below.

Table 1. Shapefiles Used in Analysis

Existing Data Set	Origin	Date Published/Updated	Link
2016 Land Cover/Land Use	MassGIS	May 2019	https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use
Soil Survey Geographic (SSURGO) Database for Norfolk and Suffolk Counties, Massachusetts	USDA	June 2020	Downloaded through Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). Hydrologic soil groups extracted using Soil Data Viewer Version 6.1 (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053619)
Town/City Catchments	Town/City GIS Files	Current as of 6/10/21	N/A

Creation of Base Shapefile

First a 2016 land cover/land use crosswalk was developed to determine phosphorus loading rates, by expanding on the 2005 land use crosswalk in the MS4. This crosswalk method compares general land use to land cover and assigns a P load crosswalk value based on the predominant condition. General land use determined the crosswalk value where the predefined crosswalk category expressed an accurate depiction of land use activity, e.g. Agriculture to "Ag" or Commercial to "Com_Ind". Land cover was used to

determine the P load crosswalk value when the general land use predefined crosswalk category did not accurately depict land use activity, e.g. Tax Exempt, ROW, Open Land, Recreation, Unknown –are all better represented by using the land cover value to determine crosswalk values as opposed to the predefined land use crosswalk value of "Com_Ind".

Table 2a. MassGIS 2016 Land Use Phosphorus Load Crosswalk

COVERNAME	USEGENNAME	PLCRSS
Pervious	Agriculture	Ag
Impervious	Agriculture	Ag
Water	Agriculture	Water
Pervious	Commercial	Com_Ind
Impervious	Commercial	Com_Ind
Water	Commercial	Water
Pervious	Forest	For
Impervious	Forest	For
Water	Forest	Water
Pervious	Industrial	Com_Ind
Impervious	Industrial	Com_Ind
Water	Industrial	Water
Bare Land	Mixed use, other	Open
Cultivated	Mixed use, other	Ag
Deciduous Forest	Mixed use, other	For
Developed Open Space	Mixed use, other	Open
Evergreen Forest	Mixed use, other	For
Grassland	Mixed use, other	Open
Impervious	Mixed use, other	Open
Palustrine Aquatic Bed	Mixed use, other	For
Palustrine Emergent Wetland	Mixed use, other	For
Palustrine Forested Wetland	Mixed use, other	For
Palustrine Scrub/Shrub	Mixed use, other	For
Pasture/Hay	Mixed use, other	Ag
Scrub/Shrub	Mixed use, other	For
Water	Mixed use, other	Water
Pervious	Mixed use, primarily commercial	Com_Ind
Impervious	Mixed use, primarily commercial	Com_Ind
Water	Mixed use, primarily commercial	Water
Pervious	Mixed use, primarily residential	LDR

COVERNAME	USEGENNAME	PLCRSS
Impervious	Mixed use, primarily residential	LDR
Water	Mixed use, primarily residential	Water
Bare Land	Open land	Open
Cultivated	Open land	Ag
Deciduous Forest	Open land	For
Developed Open Space	Open land	Open
Evergreen Forest	Open land	For
Grassland	Open land	Open
Impervious	Open land	Open
Palustrine Aquatic Bed	Open land	For
Palustrine Emergent Wetland	Open land	For
Palustrine Forested Wetland	Open land	For
Palustrine Scrub/Shrub	Open land	For
Pasture/Hay	Open land	Ag
Scrub/Shrub	Open land	For
Water	Open land	Water
Bare Land	Recreation	Open
Cultivated	Recreation	Ag
Deciduous Forest	Recreation	For
Developed Open Space	Recreation	Open
Evergreen Forest	Recreation	For
Grassland	Recreation	Open
Impervious	Recreation	Open
Palustrine Aquatic Bed	Recreation	For
Palustrine Emergent Wetland	Recreation	For
Palustrine Forested Wetland	Recreation	For
Palustrine Scrub/Shrub	Recreation	For
Pasture/Hay	Recreation	Ag
Scrub/Shrub	Recreation	For
Water	Recreation	Water
Pervious	Residential - multi-family	MFR_HDR
Impervious	Residential - multi-family	MFR_HDR
Water	Residential - multi-family	Water
Pervious	Residential - other	MDR

COVERNAME	USEGENNAME	PLCRSS
Impervious	Residential - other	MDR
Water	Residential - other	Water
Pervious	Residential - single family	LDR
Impervious	Residential - single family	LDR
Water	Residential - single family	Water
Bare Land	Right-of-way	Open
Cultivated	Right-of-way	Ag
Deciduous Forest	Right-of-way	For
Developed Open Space	Right-of-way	Open
Evergreen Forest	Right-of-way	For
Grassland	Right-of-way	Open
Impervious	Right-of-way	HWY
Palustrine Aquatic Bed	Right-of-way	For
Palustrine Emergent Wetland	Right-of-way	For
Palustrine Forested Wetland	Right-of-way	For
Palustrine Scrub/Shrub	Right-of-way	For
Pasture/Hay	Right-of-way	Ag
Scrub/Shrub	Right-of-way	For
Water	Right-of-way	Water
Bare Land	Tax exempt	Open
Cultivated	Tax exempt	Ag
Deciduous Forest	Tax exempt	For
Developed Open Space	Tax exempt	Open
Evergreen Forest	Tax exempt	For
Grassland	Tax exempt	Open
Impervious	Tax exempt	HWY
Palustrine Aquatic Bed	Tax exempt	For
Palustrine Emergent Wetland	Tax exempt	For
Palustrine Forested Wetland	Tax exempt	For
Palustrine Scrub/Shrub	Tax exempt	For
Pasture/Hay	Tax exempt	Ag
Scrub/Shrub	Tax exempt	For
Water	Tax exempt	Water
Bare Land	Unknown	Open

COVERNAME	USEGENNAME	PLCRSS
Cultivated	Unknown	Ag
Deciduous Forest	Unknown	For
Developed Open Space	Unknown	For
Evergreen Forest	Unknown	For
Grassland	Unknown	Open
Impervious	Unknown	HWY
Palustrine Aquatic Bed	Unknown	For
Palustrine Emergent Wetland	Unknown	For
Palustrine Forested Wetland	Unknown	For
Palustrine Scrub/Shrub	Unknown	For
Pasture/Hay	Unknown	Ag
Scrub/Shrub	Unknown	For
Water	Unknown	Water
Bare Land	Water	Open
Cultivated	Water	Ag
Deciduous Forest	Water	For
Developed Open Space	Water	For
Evergreen Forest	Water	For
Grassland	Water	Open
Impervious	Water	Open
Palustrine Aquatic Bed	Water	For
Palustrine Emergent Wetland	Water	For
Palustrine Forested Wetland	Water	For
Palustrine Scrub/Shrub	Water	For
Pasture/Hay	Water	Ag
Scrub/Shrub	Water	Open
Water	Water	Water
COVERNAME	USEGENNAME	PLCRSS

To support the analysis, a base shapefile containing pertinent information for land cover, land use, and soil types in the area of interest was created. This was completed by performing a “intersect” operation with two input shapefiles shown in Table 1 above: the 2016 Land Cover/Land Use shapefile and a shapefile containing the SSURGO soil hydrologic groups. Each record in the shapefile represents areas with specific land cover, land use, and soil types.

Several fields were then added to the resulting "Land Use Loading Rate" (MS4_NSI_NPL_210614) shapefile to support later steps of this analysis. Table 2b below lists the added field and provides a brief description of the data that was added.

Table 2b. Summary of Fields Added to "MS4_NSI_NPL_210614" Shapefile

Added Field	Description
P Load Crosswalk	The phosphorus loading category to which a record was assigned. See Table 1-2 in Attachment 1 of Appendix F of the 2016 Massachusetts Small MS4 General Permit for a full listing of loading categories and rates.
N Load Crosswalk	The nitrogen loading category to which a record was assigned. See Table 1 in Attachment 1 of Appendix H of the 2016 Massachusetts Small MS4 General Permit for a full listing of loading categories and rates
PLER	The numerical phosphorus loading rate assigned to a record. The value originates from Table 1-2 in Attachment 1 of Appendix F of the 2016 Massachusetts Small MS4 General Permit
NLER	The numerical nitrogen loading rate assigned to a record. The value originates from Table 1 in Attachment 1 of Appendix H of the 2016 Massachusetts Small MS4 General Permit
DCIA_M	The multiplier from the applicable Sutherland equation to estimate directly connected impervious area for a record. Note that entry is <Null> for all non-impervious records. For more detailed information about how these values were assigned, see the "DCIA Calculation" section below.
DCIA_E	The exponent from the applicable Sutherland equation to estimate directly connected impervious area for a record. Note that entry is <Null> for all non-impervious records. For more detailed information about how these values were assigned, see the "DCIA Calculation" section below.

Preparation of Catchment Shapefile and Intersect with Base Shapefile

To prepare the catchment shapefile for later analysis, a field entitled either "CatchAreaAcre" was added to the attribute table. The "calculate geometry" function was used to populate this field for each record, measuring the total area of each catchment in acres.

Once the additional field was added, the "Intersect" tool was run with two input datasets: "Land use Loading Rate" (described in the last section) and the Town's/City's Catchment shapefile. The resulting shapefile was entitled "[Municipality]Catchment Segments" and is available in the files the Town/City received upon completion of this project.

This resulting shapefile limits the information contained in the broader "Land use Loading Rate" to just what specifically occurs in each of the Town's/City's catchments, allowing further catchment-level analysis of several criteria.

For the purposes of this analysis, in some cases only the portions of catchments within the Town/City boundaries were considered. For instance, if a catchment along the border of the Town/City actually extended into a neighboring jurisdiction, that portion outside of the boundary was removed during this step and any land area outside of the Town/City boundaries was not considered in the subsequent analysis. This decision was made because, even though the catchment may be mapped outside of the boundaries, the Town/City generally does not have the ability to impact properties in other jurisdictions. If the Town/City wishes to include those areas outside of Town/City in this analysis, the above steps could be repeated using the same shapefiles and steps, but without limiting the base shapefile creation by Town/City boundaries.

Summarized Analysis

New fields were added to the recently created shapefile. Table 3 below lists the new fields, the description of the data they contain, and shows the operations involved in calculating the applicable data. Further details about each calculation can be found in the individual sections below.

Table 3. New Fields Added to "[Town/CityName]Intersect" Shapefile

New Field	Description	Units	Function Used to Calculate	Calculation Method
SEG_ACRE	The area of a record.	Acres	Calculate Geometry	Calculate the area in acres.
IMPA _ACRE	The area of impervious surfaces occupied by a record.	Acres	Calculate Geometry	Query only records with "Impervious" entry for CoverName, then calculate the area in acres. After removing the query, all non-impervious records will have a "0" listed for this field.

New Field	Description	Units	Function Used to Calculate	Calculation Method
IMPA_PRCT	The amount of impervious area in a record.	Percentage of the total catchment area	Field Calculator	([IMPA_ACRE]/[Catch_Total_Acres])*100
CATCH_PRCT	The percentage of the catchment represented by a record.	Percentage of the total catchment area	Field Calculator	([SEG_ACRE]/[Catch_Total_Acres])*100
DCIA_PRCT	An estimate of directly connected impervious area represented by a record	Percentage of the total catchment area.	Field Calculator	([IMPA_PRCT]^[DCIA_E])*[DCIA_M]
DCIA_ACRE	An estimate the amount of directly connected impervious area associated with a record.	Acres	Field Calculator	([DCIA_PRCT]/100)*[Catch_Total_Acres]
P_LOAD_1_2	The estimated phosphorus load from a record	Lbs/Year	Field Calculator	[SEG_ACRE]*[PLER]
N_LOAD	The estimated nitrogen load from a record	Lbs/Year	Field Calculator	[SEG_ACRE]*[NLER]

*PercentOfCatch was only used as a “check” field and is not described further in this document.

Impervious Calculation

The "[Municipality]Catchment Segments" shapefile contains polygons of areas within each catchment with like land cover, land use, and soil type. To begin, the "[Municipality]Catchment Segments" was queried so that only polygons with an entry of "Impervious" for the "CoverName" field were shown. Then, the Calculate Geometry tool was used on those queried records to display the area of each impervious polygon in acres. These results were eventually summed for overall catchment totals of impervious area as described in the "Final Preparation of Deliverable Shapefile" section below.

To further illustrate impervious cover statistics and for use in DCIA calculation, the impervious cover in each polygon was also calculated as a percentage of each catchment. For this measurement, the Field Calculator tool was used on the "ImpPercent" field to divide the impervious area of each polygon ("ImpAreaAcre") by the total catchment size ("CatchAreaAcre", created when preparing the catchment shapefile). This figure was then multiplied by 100 to obtain a percent.

DCIA Calculation

DCIA estimates were based on the Sutherland equations within the EPA guidance document entitled "Estimating Change in Impervious Area (IA) and Directly Connected Impervious Areas (DCIA) for Massachusetts Small MS4 Permit" (Revised April 2014). Table 4 below shows the relation between various land uses in the watershed, the chosen "connectedness" category, and the associated Sutherland equation used in the DCIA estimate. Note that these estimates only occurred on polygons that contained an "Impervious" entry in the CoverName field, as DCIA only exists where impervious area exists.

Table 4. "Connectedness" Category and Sutherland DCIA Equation Assignments for All Land Uses. NOTE: DCIA and IA are both percentages.

USEGENNAME	"Connectedness" Category	Sutherland Equation
Agriculture	Mostly Disconnected	$DCIA=0.01(IA)^2$
Commercial	Average	$DCIA=0.1(IA)^{1.5}$
Forest	Mostly Disconnected	$DCIA=0.01(IA)^2$
Industrial	Average	$DCIA=0.1(IA)^{1.5}$
Mixed use, other	Average	$DCIA=0.1(IA)^{1.5}$
Mixed use, primarily commercial	Average	$DCIA=0.1(IA)^{1.5}$
Mixed use, primarily residential	Average	$DCIA=0.1(IA)^{1.5}$
Open land	Average	$DCIA=0.1(IA)^{1.5}$
Recreation	Average	$DCIA=0.1(IA)^{1.5}$

USEGENNAME	"Connectedness" Category	Sutherland Equation
Residential - multi-family	Highly Connected	$DCIA=0.4(IA)^{1.2}$
Residential - other	Average	$DCIA=0.1(IA)^{1.5}$
Residential - single family	Average	$DCIA=0.1(IA)^{1.5}$
Right-of-way	Average	$DCIA=0.1(IA)^{1.5}$
Tax exempt	Average	$DCIA=0.1(IA)^{1.5}$
Unknown	Average	$DCIA=0.1(IA)^{1.5}$
Water	Average	$DCIA=0.1(IA)^{1.5}$

In these equations, the percentage of impervious cover for a given area is used to determine the percentage of DCIA in the same area. Thus, DCIA percent was calculated in the "DCIAPercent" field using Field Calculator. In this calculation, the impervious percentage represented by the polygon ("ImpPercent") was raised to the power shown in the appropriate equation (already entered in the "DCIA_E" field when preparing the base shapefile) and multiplied by the factor shown (already entered in the "DCIA_M" field when preparing the base shapefile). Essentially, the Field Calculator equation was "DCIAPercent" = ("ImpPercent" ^ "DCIA_E") * "DCIA_M". These results were eventually summed for overall catchment totals of impervious area as described in the "Final Preparation of Deliverable Shapefile" section below.

Finally, the estimated acreage of DCIA for each polygon was calculated in the "DCIAAcre" field using Field Calculator. In this calculation, "DCIAPercent" was divided by 100 and multiplied by the overall catchment size ("CatchAreaAcr" or "CatchAreaA").

Phosphorus Load Calculation

Phosphorus loads were calculated for each record in the [Municipality]Catchment Segments shapefile by multiplying the area of each polygon ("AreaAcre") by the phosphorus loading rate assigned to the record's specific land cover/land use/soil type combination (the "PLER" field, which was entered during the creation of the base shapefile). The Field Calculator tool was used to complete this calculation in the "P_Load" field. As the name suggests, the units for the loading rates are pounds/acre/year. These results are eventually summed for overall catchment totals of impervious area as described in the "Final Preparation of Deliverable Shapefile" section below.

For reference, the phosphorus loading category into which each record is assigned is recorded in the "PLCRSS" field, which stands for Phosphorus Load Crosswalk. The entries in this field correspond to the

land uses and phosphorus load export rates shown in Table 1-2 of Attachment 1 to Appendix F of the 2016 Massachusetts Small MS4 General Permit. An abbreviated crosswalk is shown in Table 5 below.

Table 5. Crosswalk Linking Land Use and Land Cover to the Phosphorus Source Categories Shown in Table 1-2 of Attachment 1 to Appendix F of the 2016 Massachusetts Small MS4 General Permit

USEGENNAME	Phosphorus Source Category
Agriculture	Agriculture (Ag)
Commercial	Commercial/Industrial (Com-Ind)
Forest	Forest (For)
Industrial	Commercial/Industrial (Com-Ind)
Mixed use, other	Varied based on land cover
Mixed use, primarily commercial	Commercial/Industrial (Com-Ind)
Mixed use, primarily residential	Medium-Density Residential (MDR)
Open land	Open Land (Open)
Recreation	Open Land (Open)
Residential - multi-family	Multi-Family and High-Density Residential (MFR-HDR)
Residential - other	Medium-Density Residential (MDR)
Residential - single family	Medium-Density Residential (MDR)
Right-of-way	Varied based on land cover
Tax exempt	Varied based on land cover
Unknown	Varied based on land cover
Water	Varied based on land cover

Nitrogen Load Calculation

Nitrogen loads were calculated for each record in the [Municipality]Catchment Segments shapefile by multiplying the area of each polygon ("AreaAcre") by the nitrogen loading rate assigned to the record's specific land cover/land use/soil type combination (the "NLER" field, which was entered during the creation of the base shapefile). The Field Calculator tool was used to complete this calculation in the "N_Load" field. As the name suggests, the units for the loading rates are pounds/acre/year. These results are eventually summed for overall catchment totals of impervious area as described in the "Final Preparation of Deliverable Shapefile" section below.

For reference, the nitrogen loading category into which each record is assigned is recorded in the "NLCRSS" field, which stands for Nitrogen Load Crosswalk. The entries in this field correspond to the Nitrogen Source Categories and nitrogen load export rates shown in Table 1 of Attachment 1 to Appendix H of the 2016 Massachusetts Small MS4 General Permit. An abbreviated crosswalk is shown in Table 6 below. Note that this crosswalk only considers the land cover of the record (the "CoverName" field) and, where necessary, the soil type of the record (the "HSG_N" field).

Table 6. Crosswalk Linking Land Cover and Soil Type to the Nitrogen Loading Categories Shown in Table 1 of Attachment 1 to Appendix H of the 2016 Massachusetts Small MS4 General Permit

Land Cover	Soil Type	Nitrogen Source Category
Impervious	All	All Impervious Cover
Water	All	None, rate was set to 0 for records that represented surface water.
Non-Impervious, Non-Water	A	Developed Land Pervious (DevPERV)-HSG A
Non-Impervious, Non-Water	B	Developed Land Pervious (DevPERV)-HSG B
Non-Impervious, Non-Water	C	Developed Land Pervious (DevPERV)-HSG C
Non-Impervious, Non-Water	D	Developed Land Pervious (DevPERV)-HSG D
Non-Impervious, Non-Water	A/D	Developed Land Pervious (DevPERV)-HSG A
Non-Impervious, Non-Water	B/D	Developed Land Pervious (DevPERV)-HSG B
Non-Impervious, Non-Water	C/D	Developed Land Pervious (DevPERV)-HSG C/D

Final Preparation of Deliverable Shapefile

Once all calculations were made as described above, the "[Town/CityName]Intersect" shapefile was condensed using the Dissolve tool. The "Dissolve_Field" was defined as the field containing catchment identifiers and the following fields were defined as "Statistics Fields" with a "Statistic Type" of "Sum": "AreaAcre," "ImpAreaAcre," "ImpPercent," "DCIAAcre," "DCIAPercent," "P_Load," and "N_Load."

The resulting layer was named "[Municipality]_Outfall_Catchments" and was provided with all other deliverables from this project. This shapefile displays the Town's/City's catchment and contains totals of each catchment's area, impervious area, estimated DCIA, impervious percentage, estimated DCIA percentage, estimated phosphorus load, and estimated nitrogen load.

Selection of SCM/BMP Sites

Building on method described within the *Pioneer Valley 2014 Regional Green Infrastructure Plan* and through subsequent pilot projects in Springfield and Agawam, PVPC has developed a screening process approach to identify public properties that might be most appropriate for green infrastructure stormwater retrofit locations.

As part of this work, PVPC developed an on-line map/data screening tool to identify potential retrofit opportunities using ESRI's application builder (referred to as *on-line ArcGIS data viewer*). The use of this interface with these layers can help immensely in facilitating decision making. The on-line ArcGIS data viewer displays municipal, state, federal, and private properties by total score of suitability for green infrastructure retrofitting and allows the end user to further explore the values associated with the suitability score for each parcel. Input values can be viewed by either clicking on a parcel to display a "pop-up box" or by viewing the master data table at the bottom of the screen.

Screening considerations, with each their own associated score include all the elements noted in Table 7 below. Note that the outfall catchment area phosphorus or nitrogen loading rate below mean value and the outfall catchment area phosphorus or nitrogen loading rate above mean value are the latest updates to the screening tool based on the work of this project on nutrient source identification reports. These shape files were developed in ArcMap for Desktop and displayed in the on-line viewer.

For local decision making, considerations in this screening process can be further supplemented and fine-tuned based on local priorities. For some communities, localized flooding has been an important additional consideration and has been included in scoring below. PVPC has also been recommending that where possible communities add tree canopy analysis in the ranking so that investments for improved stormwater pollution control through vegetated systems might also possibly serve to cool summer temperatures in neighborhoods where there are few trees.

Table 7. GI Retrofit Screening Tool Layers and Associated Points Scoring

GIS Layers and Point System for Initial Ranking and Screening of Properties			
Italics = Use will depend on whether applies to municipality.	**Points based on whether present or not present**	**Total Possible Points**	**Total Possible Score**
General evaluation criteria - all of municipality			
A or B hydrologic soil group A/D or B/D hydrologic soil group This value is determined by average value of all soil types present in a tax parcel.	5.0 or 0 2.5 or 0	5.0	
MassGIS Drainage Areas sub-basins of waters designated as TMDL completed (Category 4a) or Impaired/Requiring a TMDL (Category 5) on the Massachusetts List of Integrated	5.0 or 0	5.0	
Environmental Justice Areas, 2010	5 .0 or 0	5.0	
Impervious area larger than 1 acre Impervious area 0.5 to 1 acre Impervious area less than 1 acre	5.0 2.5 1.0	5.0	
**Localized flooding areas MassGIS Drainage Areas sub-basins (see discussion in next section below)*	5.0 or 0	5.0	
Located within MS4 regulated area	5.0 or 0	5.0	
			30.0
Loading criteria - within MS4 regulated outfall catchment area			
Outfall Catchment area Phosphorus or Nitrogen loading rate <u>below</u> mean value	35.0 or 0	35.0	65.0
OR			
Outfall Catchment area Phosphorus or Nitrogen loading rate <u>above</u> mean value	70.0 or 0	70.0	100

Some notes on GIS layers

Hydrologic Soil Groups

Though there are thousands of soil types, soils have been grouped *according to their runoff potential* under similar storm and cover conditions.

Group A type soils, for example, "…have low runoff potential and high infiltration rates even when thoroughly wetted. They consist of deep, well to excessively drained sand or gravel and have a high rate of water transmission (greater than 0.30 in/hr)." On the other end of the spectrum are the Group D soils, which "…have high runoff potential and very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 in/hr)."[1]

The mapping layer for hydrologic soils groups provides some understanding of what the conditions may be at a site, but it is important to note that mapping is done at a scale that does not provide a fine level of detail or ensure accuracy. In developed areas the use of fill brought in from other locations may have altered the existing conditions. In heavily urbanized areas in particular, so much fill has been used that mapping provides no soils information for such areas other than to indicate "urban fill."

For the hydrologic soils group layer, see Natural Resources Conservation Service SSURGO Certified Soils data from MassGIS, November 2012, last updated December 2017.

Drainage Areas of Impaired/TMDL Status

Taken together, Total Maximum Daily Load (TMDL) status and watershed delineation is one important way of understanding where waters are impacted by human activity and which drainage areas contribute to these waters. The question here is: *Where are the biggest known water quality problems* and hence where might there be the best opportunities to improve water quality through stormwater management retrofits? A TMDL establishes the amount of a particular pollutant that a water body can receive while still meeting water quality standards.[2] The TMDL status map layer identifies those waters that do not meet applicable state water quality standards. These waters are deemed to be "impaired" by MassDEP pursuant to section 303(d) of the Clean Water Act. These include waters with approved TMDLs and those for which TMDL development has been identified as necessary, but for which a TMDL has not yet been approved. The TMDL status layers comes from MassGIS, which is derived from the *MassDEP Integrated List of Waters* (305(b)/303(d)) – *Last updated January 2018.*

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[1] Part 630 Hydrology, National Engineering Handbook, Appendix A: Hydrologic Soil Groups. United States Department of Agriculture, Natural Resources Conservation Service. January 2009.

2 http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm

Environmental Justice Area

By explicitly mapping Environmental Justice Areas, decisions about stormwater management retrofits and the associated investments can be made with greater awareness and intention in *meaningful involvement of all people and neighborhoods* regardless of race, color, national origin, or income.

Base mapping information for Environmental Justice Areas relies on four criteria from Census block groups. These criteria are as follows:

- where population is 25 percent or more minority
- where median household income is less than 65 percent of the statewide median household income
- where 75 percent or less of households have proficiency with the English language, indicating linguistic isolation
- where 25 percent or more of the population is foreign-born

Localized Flooding Areas*

Climate records for the northeastern United States indicate that the frequency of larger downpours is increasing, and this trend is expected to continue. As such, it may serve municipalities to develop a GIS map layer that identifies known flooding locations through local knowledge or insurance claim records (if obtainable). Then impervious areas located upgradient of these known flooding locations could carry a higher ranking than large impervious properties in other locations within the municipality. Localized flooding areas layer is defined by MassGIS drainage area sub-basin containing municipality identified localized flooding locations.

Impervious Areas

There is a direct correlation between the amount of impervious area—surfaces such as roofs, driveways, roads, and parking lots—and flooding and water quality in rivers, streams, and lakes receiving discharges from these areas. Removal or "disconnection" of impervious cover through retrofitting with green infrastructure stormwater management plays an important role in resolving localized flooding and water quality issues.

Additional Screening Considerations from the MS4 Permit

The Massachusetts MS4 permit in Section 2.3.6.d identifies other considerations. In determining the potential for modifying or retrofitting particular properties, the permittee shall consider factors such as:

- 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

In determining its priority ranking, the permittee shall consider factors such as:

- schedules for planned capital improvements to storm and sanitary sewer infrastructure and paving projects
- public swimming beaches
- drinking water supply sources
- shellfish growing areas

- current storm sewer level of service
- control of discharges to water quality limited waters
- first or second order streams

Other Resources

There are other more complicated tools to conduct similar ranking analyses for stormwater retrofit locations that may be useful. In particular, Opti Tool described below was designed for EPA Region 1. The second and third tools described below are not currently supported. These are listed here with the idea that there may be elements within the tools that could be of interest to municipalities looking to customize their approaches to ranking municipal properties for improved stormwater management.

- Opti Tool (Stormwater Management Optimization Tool) is a spreadsheet-based optimization tool designed for EPA, Region 1. It uses SUSTAIN (see bullet below) in the background but is more user friendly. The tool helps planners determine the best mix of BMPs to provide the greatest benefit for achieving water resource goals while balancing costs. Opti Tool provides analysis at both a planning level and implementation level. Planning Level Analysis provides maximum possible load reduction for all feasible BMP opportunities or cost-effective single solution that meets the numeric load reduction target. Implementation Level Analysis provides optimal combination of different BMP types, sizes and spatial locations or cost-effective solutions for a range of load reduction targets.
  For more information, see the following links:
  http://neiwpcc.org/nationalnpsold/documents/presentations/Voorhees_Session%205.pdf
  https://www.epa.gov/npdes-permits/stormwater-tools-new-england#pcsm

- System for Urban Stormwater Treatment and Analysis Integration Model (SUSTAIN) is a somewhat complicated decision support tool developed and piloted by EPA with the Towns of Bellingham, Franklin, and Milford that involves a cost optimization approach. The tool aggregates benefits and helps to select "best buys" or projects with the greatest environmental value per dollar. SUSTAIN was piloted in these communities because of the requirements they face in meeting federal compliance targets to reduce phosphorous inputs so that the Upper Charles River can meet Massachusetts Surface Water Quality Standards. Cost optimization analysis has involved mapping information on land use categories, unit cost information for stormwater facilities, and pollutant loading export rates for each land use category.

- For the Chesapeake Bay, the Maryland State Highway Administration, in tandem with EPA Region 3 and the U.S. Army Corps of Engineers, developed a related decision-making approach called the *Watershed Resources Registry*. The Registry is an interactive online GIS mapping tool that prioritizes areas for preservation and restoration of wetlands, riparian zones, terrestrial areas, and stormwater management control across an entire state. Driven by the Total Maximum Daily Load goals for the Chesapeake Bay, the Watershed Resources Registry identifies best opportunities to protect high quality resources, restoration of impaired resources, and improvement of stormwater management.[3] Retrofits go beyond green infrastructure stormwater management to include, urban tree plantings, stream buffer plantings, wetland restoration, stream restoration, innovative methods, and improved operations (street sweeping, inlet cleaning). The Registry scores potential restoration and preservation areas on a scale of one to five stars based on their potential benefits. Watershed Resources Registries are now available in four mid-Atlantic states, including Delaware, Maryland, Pennsylvania, and West Virginia.

Final Deliverables

On-line map/data screening tool displaying:

- Municipal, state, federal, and private properties by total score of suitability for green infrastructure retrofitting and allows the end user to further explore the values associated with the suitability score for each parcel.
- Outfall catchment areas with nitrogen and phosphorus loading rates and impervious/directly connected impervious areas.
- Outfall catchment segment areas with nitrogen and phosphorus loading rate and land use/crosswalk values.

To access the screening tool, see: https://tinyurl.com/MS4-NSI-PVPC. Along with the final report, the Town/City was provided with copies ArcGIS shapefiles that were used in or products of the analysis. Table 8 below gives a brief description of each shapefile.

Table 8. Descriptions of Shapefiles Provided as Deliverables of this Project

Shapefile Name	Description
MS4_NSI_NPL_210614	A shapefile containing polygons with like land cover, land use, soil type, and pertinent loading rates, multipliers, etc. This file will is referred to throughout this document as the "base shapefile" as it contains all the information necessary to perform the analysis.
[Municipality]_Catchment Segments	The product of an intersect operation between the base shapefile above and the Town's/City's stormwater catchment shapefile. This shapefile specifically shows only the information from the base shapefile that is pertinent to the Town's/City's catchments. Calculations for impervious area, directly connected impervious area, and pollutant loads were made within this shapefile's attribute table.
[Municipality]_Catchments	This shapefile is the final product of the analysis. It contains the following for each catchment within the Town/City: total area (acres), total impervious area (acres), percent of impervious area within the catchment, total estimated directly connected impervious area (acres), estimated percent of directly connected impervious area within the catchment, estimated phosphorus load from catchment (lbs./year), estimated nitrogen load from catchment (lbs./year)
[Municipality]_BMP_Municipal **[Municipality]_BMP_State** **[Municipality]_BMP_Federal** **[Municipality]_BMP_Private**	These shapefiles are the result of the PVPC "Green Retrofit Analysis" incorporating catchment loading data as an analysis variable.

mottmac.com

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*

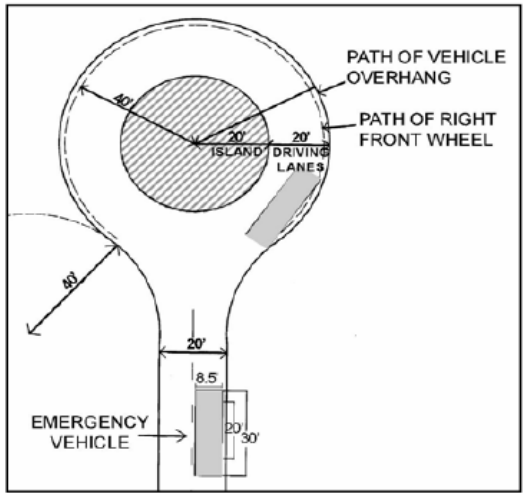
Parameter	Single Use Residential Wide	Single Use Residential Medium	Single Use Residential Narrow	Single Use Residential Alley
Traveled Way				
Typical ADT	4,999 < 1,500	1,499 < 400	399 < 0	100 < 0
Design Speed	25 - 30 mph	20 mph	20 mph	15 mph
Operating Speed	20 - 25 mph	20 mph	15 - 20 mph	15 - 20 mph
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

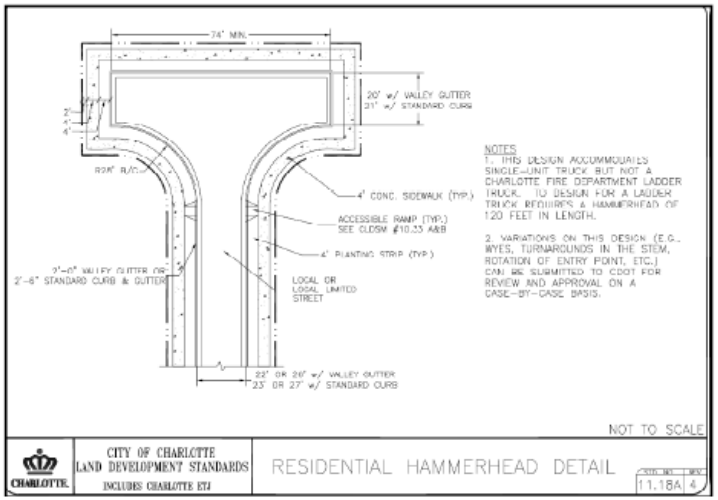
Pioneer Valley Planning Commission, February 2022

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