

ATTACHMENT 1 TO APPENDIX F**Method to Calculate Baseline Phosphorus Load (Baseline), Phosphorus Reduction Requirements and Phosphorus Load Increases due to Development (P_{DEVinc})**

The methods and annual phosphorus load export rates presented in Attachments 1, 2 and 3 are for the purpose of calculating nutrient (phosphorus and nitrogen) loads from stormwater runoff from impervious or pervious cover across different land uses (e.g., commercial, industrial, residential) and nutrient reductions achieved by non-structural best management practices (BMPs) and structural stormwater control measures (SCMs). The estimates of annual phosphorus and nitrogen loads and load reductions are intended for use by the permittee to track and report nutrient reductions achieved through the implementation of BMPs and SCMs. In particular, the phosphorus load and load reductions are intended to assess compliance with applicable Phosphorus Reduction Requirements under the permit.

Permittees subject to numeric, water quality-based phosphorus load reduction requirements in Appendix F Part I.A (Charles River TMDL) and Appendix F Part I.B (Lakes and Ponds TMDLs) must calculate and report phosphorus loads and load reductions in annual reports. Lists of municipalities subject to these requirements are included in Parts 2.2.1.a and 2.2.1.b of the Permit, as well as Appendix F Parts I.A and I.B. This attachment explains how permittees calculate baseline phosphorus load, phosphorus reduction requirement (in lbs/year), and phosphorus load increase due to development.

The Baseline Phosphorus Load is the annual phosphorus load discharging in stormwater from the impervious and pervious covers and across different land uses (e.g., commercial, industrial, residential) within the area subject to numeric, water quality-based permit requirements (i.e., the Charles River Watershed or Lake and Pond TMDL Areas).

The Phosphorus Reduction Requirement represents the required reduction in annual phosphorus load in stormwater to meet the target phosphorus load for the impaired watershed. The percent phosphorus reduction for each watershed is applied to the Baseline Phosphorus Load to calculate the Phosphorus Pounds Reduction.

The Phosphorus Load Increase due to Development (P_{DEVinc}) is the increase in phosphorus load in stormwater runoff from new development. Increases in stormwater phosphorus load from development will increase the permittee's baseline phosphorus load and therefore, the phosphorus reduction requirement.

I. Methodology for Calculating Phosphorus Loads

A. Baseline Phosphorus Load

The annual composite phosphorus load export rates (PLERs) by land use category (Table F1-1) are used to calculate (or update) Baseline Phosphorus Load. The permittee shall select the land use category that most closely represents the actual use of the watershed. Institutional type uses, such as government properties, hospitals, and schools, are categorized as commercial land use category for the purpose of calculating phosphorus loads. To maintain consistency with the 2016 MA MS4 permit, the composite PLERs in Table F1-1 include consideration of directly connected impervious area (DCIA). The permittee may determine, based on site-scale mapping and investigations, that the overall DCIA for the collective area for each land use category is different than the corresponding values in Table F1-1. In this case, the permittee may submit this information to EPA in its annual report and request that EPA revise the composite PLERs for calculating the Baseline Phosphorus Load.

Table F1-1. Annual Composite Phosphorus Load Export Rates

Land Cover	Representative DCIA, %	Composite PLERs, lb/ac/yr
Commercial/Institutional	57	1.13
Industrial	67	1.27
High Density Residential	36	1.04
Medium Density Residential	16	0.49
Low Density Residential	11	0.30
Freeway	44	0.73
Open Space	8	0.26
Agriculture	0.4	0.45
Forest	0.1	0.12

The **Baseline Phosphorus Load** is calculated as follows:

- 1) Determine the total area (in acres) of the impaired watershed.
- 2) Determine the total area (in acres) of each of the applicable land use categories (in Table F1-1) within the impaired watershed.

- 3) Calculate the annual phosphorus load for each land use category by multiplying the area of land use by the corresponding land use-based composite phosphorus load export rate (in Table F1-1).
- 4) Determine the Baseline Phosphorus Load by summing annual phosphorus load for all land uses.

Baseline Phosphorus Load Example

The total area of Impaired Watershed A is 18.0 acres. There are 11.0 acres of industrial land (IND) use (e.g. access drives, buildings, and parking lots), 3.0 acres of medium-density residential (MDR), and 4.0 acres of wooded area (FOR).

Baseline Phosphorus Load = (Baseline P Load_{IND}) + (Baseline P Load_{MDR}) + (Baseline P Load_{FOR})

Using the composite PLER values for each land use from Table F1-1:

$$\begin{aligned}\text{Baseline P Load}_{\text{IND}} &= (\text{Area}_{\text{IND}}) \times (\text{PLER}_{\text{IND}}) \\ &= 11.0 \text{ acres} \times 1.27 \text{ lbs/acre/year} \\ &= 14.0 \text{ lbs P/year}\end{aligned}$$

$$\begin{aligned}\text{Baseline P Load}_{\text{MDR}} &= (\text{Area}_{\text{MDR}}) \times (\text{PLER}_{\text{MDR}}) \\ &= 3.0 \text{ acres} \times 0.49 \text{ lbs/acre/year} \\ &= 1.5 \text{ lbs P/year}\end{aligned}$$

$$\begin{aligned}\text{Baseline P Load}_{\text{FOR}} &= (\text{Area}_{\text{FOR}}) \times (\text{PLER}_{\text{FOR}}) \\ &= 4.0 \text{ acres} \times 0.12 \text{ lbs/acre/year} \\ &= 0.5 \text{ lbs P/year}\end{aligned}$$

$$\text{Baseline Phosphorus Load} = 14.0 \text{ lbs P/year} + 1.5 \text{ lbs P/year} + 0.5 \text{ lbs P/year} = \mathbf{16.0 \text{ lbs P/year}}$$

B. Phosphorus Load Reduction Requirement for Lake & Pond TMDLs

Permittees subject to Lake & Pond TMDLs must calculate the Phosphorus Load Reduction Requirement based on the percent phosphorus reduction specified in Appendix F of Table F-6 for each impaired watershed. The Phosphorus Load Reduction Requirement is calculated by multiplying the Baseline Phosphorus Reduction (from Part A, above) by the applicable Required Percent Reduction in Table F-6 of Appendix F.

Phosphorus Load Reduction Requirement Example

The applicable Required Percent Reduction for impaired Watershed A in Table F-6 is 45%.

Phosphorus Load Reduction Requirement = (Baseline P Load) x (Required Percent Reduction from Table F-6)

Phosphorus Reduction Requirement	= (Baseline P Load) x (0.45)
	= (16.0 lbs P/year) x (0.45)
	= 7.2 lbs P/year

C. Phosphorus Load Increase Due to Development for Charles River TMDL and Lake & Ponds TMDLs

The Permit carries forward numeric phosphorus reduction targets consistent with wasteload allocations (WLA) in TMDLs for the Charles River Watershed and Lakes and Ponds. These phosphorus targets are necessary to meet, or make progress towards, water quality standards based on an assessment of water quality at the time of the TMDL. The target phosphorus load reductions are based on land use, land cover, and water quality for a specific time period and do not account for changes due to new development after the time period of the water quality analysis. New development that adds impervious cover in the watershed will increase the corresponding phosphorus load in stormwater runoff from the developed site. The Permit requires permittees subject to numeric phosphorus load reduction requirements in Part 2.2.1, 2.2.2, and Appendix F of the Permit to track and report increases in phosphorus loads due to development to ensure that the phosphorus reductions achieved through implementation of BMPs and SCMs are not eclipsed by increased loads from new development.

The Phosphorus Load Increase due to Development ($P_{DEV\ INC}$) is estimated as the difference between the pre-development Baseline Phosphorus Load and the Phosphorus Load due to Development Load (P_{DEV}). The Baseline Load (i.e., “pre-development”) for the area of new development is calculated consistent with the methodology described in Part I.A, above using the composite annual PLERs in Table F1-1. The new development load is estimated using the annual PLERs for impervious and pervious areas within each land use category in Table F1-2. The permittee shall select the land use category that most closely represents the actual use of the watershed. For pervious areas, if the hydrologic soil group (HSG) is known, use the appropriate value. If the HSG is not known, assume HSG C for the phosphorus load export rate. Institutional type uses, such as government properties, hospitals, and schools, are categorized as commercial/industrial land use for the purpose of calculating phosphorus loads. Tables F1-3 and F1-4 provide a crosswalk table of land use codes between Tables F1-1 and F1-2 and the codes used by MassGIS in the 2005 and 2016 Land Use data sets.

Table F1-2: Average annual distinct P Load export rates for use in estimating P Load reduction credits the MA MS4 Permit

Phosphorus Source Category by Land Use	Land Cover	P Load Export Rate lbs/acre/year
Commercial (Com) and Industrial (Ind)	Directly connected impervious	1.78
	Pervious	See* DevPERV
Multi-Family (MFR) and High-Density Residential (HDR)	Directly connected impervious	2.32
	Pervious	See* DevPERV
Medium -Density Residential (MDR)	Directly connected impervious	1.96
	Pervious	See* DevPERV
Low Density Residential (LDR) - "Rural"	Directly connected impervious	1.52
	Pervious	See* DevPERV
Highway (HWY)	Directly connected impervious	1.34
	Pervious	See* DevPERV
Forest (For)	Directly connected impervious	1.52
	Pervious	0.13
Open Land (Open)	Directly connected impervious	1.52
	Pervious	See* DevPERV
Agriculture (Ag)	Directly connected impervious	1.52
	Pervious	0.45
*Developed Land Pervious (DevPERV)- Hydrologic Soil Group A	Pervious	0.03
*Developed Land Pervious (DevPERV)- Hydrologic Soil Group B	Pervious	0.12
*Developed Land Pervious (DevPERV) - Hydrologic Soil Group C	Pervious	0.21
*Developed Land Pervious (DevPERV) - Hydrologic Soil Group C/D	Pervious	0.29
*Developed Land Pervious (DevPERV) - Hydrologic Soil Group D	Pervious	0.37

The **Phosphorus Load Increase due to Development** ($P_{DEV\ INC}$) is calculated as follows:

- 1) Determine the total area of development (in acres) by land use category and calculate the Baseline Phosphorus Load for that area using the composite PLERs in Table F1-1 and methodology in Part I.A of Attachment 1.

- 2) Quantify the total acres of impervious and pervious area for each land use category within the total area of development.
- 3) For each land use category, calculate the phosphorus load due to development (P_{DEV}) of the impervious and pervious subarea by multiplying the subarea by the appropriate annual PLER rate provided in Table F1-2.
Note: P_{DEV} is not adjusted to account for phosphorus reductions resulting from BMPs and SCMs on new development. The reductions achieved through BMPs and SCMs is calculated using the methodology in Attachments 2 and 3 to Appendix F accounted for when calculating the annual phosphorus export rate as directed in Part I.A.4.d and I.B.3.d of Appendix F.
- 4) Determine the phosphorus load increase (P_{DEVinc}) by subtracting the Baseline Phosphorus Load (in 1, above) from the Increased Phosphorus Load due to Development (P_{DEV}) (in 3, above).

Phosphorus Load Increase Due to Development Example

New development in Watershed A (an 18-acre impaired watershed subject to a Lake & Pond TMDL from the examples above) has occurred since the permittee calculated the baseline phosphorus load and phosphorus load increase. New development of 2 acres in the area subject to permit requirements has been converted to high density residential (HDR) impervious cover. Prior to development, the land use on these 2 acres was medium density residential (MDR) (1.5 acres) and forest (FOR) (0.5 acres). The undeveloped MDR area is pervious area, HSG C soil and the undeveloped forest area is pervious, HSG B soil.

Land Use Category	Pre-Development Baseline Area (acres)	Undeveloped Baseline Area (acres)	Developed Area converted to HDR Impervious Cover (acres)
IND	11.0	No change	No change
MDR	3.0	1.5	1.5
FOR	4.0	3.5	0.5

The permittee must calculate the developed phosphorus load to account for the change in land use and land cover using the composite annual PLERs in Table F1-1 (for the undeveloped baseline area) and the annual PLERs in Table F1-2 (for the developed area). As explained above, 2 acres of the HDR land use is impervious area (IA_{HDR}), the undeveloped 1.5 acres of MDR is pervious area/HSG C (PA_{MDR}), and the undeveloped 3.5 acres of FOR is pervious (PA_{FOR}).

Land Use Category	Post-Development Area (acres)	Phosphorus Export Rate (Table F1-1)	Phosphorus Export Rate (Table F1-2)

IND	11.0	1.27	---
HDR	2.0	---	2.32
MDR	1.5	0.49	---
FOR	3.5	0.12	---

The Phosphorus Load due to Development (P_{DEV}) is calculated as the sum of phosphorus loads for the undeveloped and developed areas:

$$\begin{aligned}
 P_{DEV} &= (\text{Area}_{IND} \times \text{PLER}_{IND}) &= 11.0 \times 1.27 &= 13.97 \\
 &+ (\text{IA}_{HDR} \times \text{PLER}_{HDR}) &= 2.0 \times 2.32 &= 4.64 \\
 &+ (\text{PA}_{MDR} \times \text{PLER}_{MDR}) &= 1.5 \times 0.49 &= 0.74 \\
 &+ (\text{Area}_{FOR} \times \text{PLER}_{FOR}) &= 3.5 \times 0.12 &= 0.42 \\
 &= \mathbf{19.8 \text{ lbs P/year}}
 \end{aligned}$$

The Phosphorus Load Increase due to Development ($P_{DEV \text{ INC}}$) is calculated as:

$$\begin{aligned}
 P_{DEV \text{ inc}} &= P_{DEV} - \text{Baseline Load (from Example in Part I.A)} \\
 &= 19.8 - 16.0 \text{ lbs/year} \\
 &= \mathbf{3.8 \text{ lbs/year}}
 \end{aligned}$$

Table F1-3: Crosswalk of 2005 MassGIS land-use categories to land-use groups for P Load Calculations

2005 MassGIS Land Use Code (LU_CODE)	Description	Land Use group for calculating P Load 2024 MA MS4
1	Crop Land	Agriculture
2	Pasture (active)	Agriculture
3	Forest	Forest
4	Wetland	Forest
5	Mining	Industrial
6	Open Land includes inactive pasture	open land
7	Participation Recreation	open land
8	spectator recreation	open land
9	Water Based Recreation	open land
10	Multi-Family Residential	High Density Residential
11	High Density Residential	High Density Residential
12	Medium Density Residential	Medium Density Residential
13	Low Density Residential	Low Density Residential
14	Saltwater Wetland	Water
15	Commercial	Commercial
16	Industrial	Industrial
17	Urban Open	open land
18	Transportation	Highway
19	Waste Disposal	Industrial
20	Water	Water
23	cranberry bog	Agriculture
24	Powerline	open land
25	Saltwater Sandy Beach	open land
26	Golf Course	Agriculture
29	Marina	Commercial
31	Urban Public	Commercial
34	Cemetery	open land
35	Orchard	Forest
36	Nursery	Agriculture
37	Forested Wetland	Forest
38	Very Low Density residential	Low Density Residential
39	Junkyards	Industrial
40	Brush land/Successional	Forest

Table F1-4: Crosswalk of 2016 MassGIS land use categories to land use groups for P load calculations

2016 MassGIS Land Use Code (USEGENCODE)	Description	Land Use Group for Calculating P Load - 2024 MA MS4
0	Unknown	Open Land
2	Open land	Open Land
3	Commercial	Commercial/ Industrial
4	Industrial	Commercial/ Industrial
6	Forest	Forest
7	Agriculture	Agriculture
8	Recreation	Open Land
9	Tax exempt	Commercial/ Industrial
10	Mixed use, primarily residential	Commercial/ Industrial
11	Single Family Residential	Medium Density Residential
12	Multi-family Residential	High Density Residential
13	Residential, other	Medium Density Residential
20	Mixed use, other	Commercial/ Industrial
30	Mixed use, primarily commercial	Commercial/ Industrial
55	Right-of-way	Commercial/ Industrial
88	Water	Water