conservation law foundation

CRWA

May 9, 2019

Deborah Szaro
Acting Regional Administrator
EPA New England Region
1 Congress Street, Suite 1100
Boston, MA 02114-2023

RE: **Petition for a Determination that Certain Commercial, Industrial, Institutional, and Multi-Family Residential Property Dischargers Contribute to Water Quality Standards Violations in the Charles River Watershed, Massachusetts, and that NPDES Permitting of Such Properties is Required**

Dear Acting Regional Administrator Szaro,

As the Regional Administrator of the EPA New England Region ("EPA Region 1"), the Conservation Law Foundation ("CLF") and Charles River Watershed Association ("CRWA") hereby petition you for a determination pursuant to 40 C.F.R. § 122.26(f)(2) that discharges of stormwater that are not currently subject to direct permitting by EPA from privately owned commercial, industrial, institutional,[1] and multi-family residential[2] real properties of one acre or greater in the Charles River Watershed ("Contributing Discharges") contribute to violations of water quality standards in the Charles River and require permits under the National Pollutant Discharge Elimination System ("NPDES").

As set forth below, the facts and the law, as developed by the United States Environmental Protection Agency ("EPA"), require that these unpermitted discharges must be

[1] For the purposes of this Petition, the "institutional" land use category encompasses properties in the MassGIS "Urban Public/Institutional" land use code that are privately owned.
[2] For the purposes of this Petition, the "large multi-family residential" land use category encompasses properties in the MassGIS "Multi-Family Residential" land use code that are privately owned and include five or more housing units.

subject to regulation under the NPDES permit program in order to restore and protect the water quality of the Charles River watershed.

I. INTRODUCTION

CLF and CRWA are nonprofit organizations that work to restore the health of New England's waterways, many of which are failing to meet basic water quality standards for public health and recreation. The CLF Clean Air and Water Program is a leader in advocating for stormwater regulation by states and EPA under the Clean Water Act to remedy severe water pollution and flooding problems throughout New England. CLF has petitioned EPA under Section 402(p)(2)(E) of the Clean Water Act, 33 U.S.C. § 1342(p)(2)(E), to require cleanup of stormwater discharges from numerous existing industrial and commercial properties in the Long Creek, Maine watershed[3], and has litigated successfully in the Vermont Supreme Court and agency tribunals to require the state's Agency of Natural Resources to extend its Clean Water Act permitting authority to existing, unregulated stormwater pollution discharges in five badly polluted watersheds surrounding Burlington, Vermont.[4]

CRWA, with many partners, has accomplished a transformational cleanup of the Charles River and continues to use science, advocacy, and the law to advocate for innovative, workable, and environmentally responsible solutions to stormwater management. CRWA was a key participant in the development of the Lower and Upper/Middle Charles Nutrient Total Maximum Daily Loads (2007, 2011) ("TMDLs") and the Massachusetts Stormwater Management Handbook. CRWA has also crafted and implemented numerous innovative demonstration projects of Low Impact Development site design and stormwater green infrastructure in Massachusetts.

Across New England, stormwater pollution has emerged as the major threat to the health of our rivers, lakes, and streams. Some of our most treasured waters—used by millions

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[3] See CLF's *Petition For a Determination that Existing, Non-De Minimis, Un-Permitted Stormwater Discharges from Impervious Surfaces into Long Creek South Portland, Maine Require a Clean Water Act Permit*, filed with Robert Varney, Administrator, EPA Region 1, March 6, 2008.
[4] *See In re Stormwater NPDES Petition*, 2006 VT 91; Judgment Order Docket No. 14-1-07 Vermont Environmental Court (Aug. 28, 2008).

for recreation, fishing, and other tourism—are suffering from toxic algae blooms and poor water quality due to nutrient-laden stormwater runoff flowing off parking lots and other paved areas. The Charles River dramatically exemplifies this pollution problem: as EPA points out in its 2012 Charles River residual designation decision,[5] a severe cyanobacteria[6] bloom in the Charles River Lower Basin required posting of public health warnings and the river could not safely support recreation in late summer and early fall of 2006. Documented reoccurrences of toxic cyanobacteria blooms occurred in the Charles River Basin in 2007, 2008, 2009, 2010, 2014,[7] 2015,[8] 2016,[9] and 2017.[10]

Cyanotoxins produced and emitted by cyanobacteria blooms have well documented negative health effects on humans. Public information from EPA cites acute health effects observed in humans and pets from oral, dermal, and inhalation/aspiration exposure to water containing cyanotoxins including abdominal pain, headache, sore throat, vomiting and nausea, dry cough, blistering around the mouth, pneumonia, fever, bloody diarrhea, tingling, burning, numbness, drowsiness, incoherent speech, salivation, and respiratory paralysis leading to death.[11] Multiple studies examining the effect on animals of exposure to the neurotoxin beta-methyl-amino-l-alanine (BMAA) produced by cyanobacteria have also indicated a potential link

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[5] Residual Designation Pursuant to Clean Water Act Region 1, EPA, https://www.epa.gov/sites/production/files/2015-03/documents/rodfinalnov12.pdf (last visited May 7, 2019) ("2012 Record of Decision").

[6] An algae-like bacteria phylum sometimes referred to as "blue-green algae".

[7] For 2007-2014 blooms, see Tamrakar, A., Clark University, "Cyanobacteria Monitoring in the Charles River Lower Basin: Water Quality Assessment and Implications for Future Practice 2006-2014" (2015), https://commons.clarku.edu/cgi/viewcontent.cgi?article=1001&context=idce_masters_papers (last visited May 7, 2019).

[8] *See, e.g.*, *Charles River bacteria levels prompt health advisory*, The Boston Globe, Aug. 13, 2015, https://www.bostonglobe.com/metro/2015/08/13/dirty-water-once-again/l5LB4ylXyICdV1UeQ3UKVP/story.html (last visited May 7, 2019).

[9] *See, e.g.*, *Health Officials Warn Of Blue-Green Algae Bloom In Charles River*, CBS Boston, Aug. 31, 2016, https://boston.cbslocal.com/2016/08/31/charles-river-blue-green-algae-bloom/ (last visited May 7, 2019).

[10] *See, e.g.*, *Stay Away From Parts Of Charles River During Bacteria Bloom, Officials Warn*, CBS Boston, Aug. 2, 2017, https://boston.cbslocal.com/2017/08/02/charles-river-cyanobacteria-bloom-algae/ (last visited May 7, 2019).

[11] *See Health and Ecological Effects, EPA*, https://www.epa.gov/nutrient-policy-data/health-and-ecological-effects (last visited May 9, 2019).

between cyanobacteria and neurodegenerative diseases like ALS.[12] Urgent action is needed to address these public health risks.

Water quality conditions in the Charles River Watershed, in Massachusetts, and around the nation demonstrate the urgent need for leadership in residual designation authority implementation to remedy water quality impairments caused in whole or in part by existing poorly controlled and uncontrolled stormwater discharges. EPA has previously provided convincing documentation of the need for residual designation authority to control stormwater discharges in the Charles River Watershed.[13] EPA has also previously identified specific categories of large unpermitted sources of stormwater runoff as among the primary contributors of stormwater discharges. EPA must act to bring these polluters into the NPDES permitting program and prevent further degradation of the Charles River.

II. FACTUAL BACKGROUND

A statement of the undisputed facts and underlying supporting documents is attached to this petition and is incorporated by reference.[14] CLF and CRWA also attach additional recent analysis of pollutant loading from stormwater by land use type in the Charles River Watershed by Waterstone Engineering.[15] We recite a summary of these facts below.

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[12] *See, e.g.*, Megan Brooke-Jones et al., Cyanobacterial Neurotoxin Beta-Methyl-Amino-l-Alanine Affects Dopaminergic Neurons in Optic Ganglia and Brain of *Daphnia magna*. 10 TOXINS 12, 527 (2018), *available at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6315693/ (last visited May 9, 2019); David A. Davis et al., Cyanobacterial neurotoxin BMAA and brain pathology in stranded dolphins. 14 PLOS ONE 3, e0213346 (2019), *available at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6426197/ (last visited May 9, 2019); Paul A. Cox et al.,. Dietary exposure to an environmental toxin triggers neurofibrillary tangles and amyloid deposits in the brain. 283 PROCEEDINGS. BIOLOGICAL SCIENCES 1823, 20152397 (2016), *available at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4795023/ (last visited May 9, 2019).

[13] *See* 2012 Record of Decision.

[14] *See* Attachment A, Statement of Undisputed Facts ("SOF").

[15] *See* Attachment B, Waterstone Engineering, TMDL Attainability Analyses for Phosphorus and Pathogens for the Charles River Watershed, Massachusetts (May 9, 2019) ("Waterstone Report").

A. The Charles River has Been Polluted by Stormwater Runoff Discharges Containing High Levels of Phosphorus that Prevent the River from Attaining and Maintaining its Designated and Existing Class B Uses.

The Charles River Watershed is highly urbanized with a high level of impervious cover, which has resulted in it losing much of its natural capacity to absorb rainfall and remove pollutants by filtering the runoff through vegetative cover and the soil matrix.[16] Specifically, the Charles River downstream of the Watertown Dam ("Lower Charles River") has a combined 66 percent commercial and industrial, and high density residential land use.[17] Recent analysis shows that impervious cover constitutes 58 percent of the high density residential land and 76 percent of the commercial and industrial land in the Lower Charles River Watershed, as well as 51 percent of the total Lower Charles River Watershed.[18] Impervious cover counts for 41 percent of high density residential land, 59 percent of commercial and industrial land, and 16 percent of the total land in the Charles River Watershed upstream of the Watertown Dam ("Upper Charles River Watershed").[19]

Throughout the watershed, stormwater runoff discharges high levels of phosphorus into the Charles River, triggering excessive algae and aquatic plant growth and low and/or highly variable dissolved oxygen levels.[20] These recurrent algal blooms, including algae-like bacteria species known to be toxic, degrade the Charles River and prevent it from attaining and maintaining its designated and existing Class B uses, including but not limited to impacting its aesthetic quality, harming aquatic life, and impairing recreational uses of the river, including boating, wind surfing, swimming, and fishing.[21] The recurrent algal blooms include toxic cyanobacteria and further impair the river from its Class B designation and present serious health risks, prompting state and local agencies to warn the public and their pets to avoid

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[16] Waterstone Report at 7.
[17] Waterstone Report at 19, Table 7. The high density residential land use category in this analysis includes the MassGIS multi-family residential land use category. *See id.* at 21, Table 8.
[18] Waterstone Report at 19, Table 7.
[19] Waterstone Report at 19, Table 6.
[20] *SOF* at ¶¶ 19-23, 30.
[21] *SOF* at ¶¶ 10, 31.

contact with the river water.[22] Scheduled public swim events have also been cancelled due to cyanobacteria.[23] During August 2006, EPA collected an algal sample in the downstream portion of the Lower Charles because of the obvious presence of a very severe cyanobacteria bloom.[24] The bloom consisted of extremely high cell counts of over one million cells/milliliters of cyanobacteria and included the organism, microcystis, which is toxic at elevated levels. The sample was analyzed by Massachusetts Department of Environmental Protection (MassDEP) and has led to further algal monitoring in the Lower Charles by the Massachusetts Department of Conservation and Recreation, MassDEP, and the Massachusetts Department of Public Health. *Id.* Toxic cyanobacteria blooms have reoccurred regularly since 2006.[25] If left without adequate controls, stormwater pollution in the Charles River will continue to degrade the water quality of the river.

B. EPA's Approved TMDLs Demonstrate that Stormwater Runoff from Unpermitted Sources Contribute to Continuing Water Quality Violations.

Based upon robust sampling and studies of the Charles River, MassDEP and EPA developed three TMDLs: one for nutrients (phosphorus) for the Lower Charles River in 2007 ("Lower Charles TMDL"), one for nutrients for the Upper/Middle Charles River in 2011 ("Upper/Middle Charles TMDL"), and one for pathogens for the entire Charles River in 2007 ("Pathogen TMDL").[26] Massachusetts maintains a "Quality System" in an EPA-approved Management Plan to ensure that the environmental data that it relies upon to identify impaired water bodies and formulate TMDLs are of known and documented quality.[27]

The TMDLs and decades of established science demonstrate that stormwater is exposed to pollutants including phosphorus and pathogens on impervious surfaces.[28] In all three TMDLs, EPA and MassDEP unequivocally determined that stormwater runoff from unpermitted

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[22] *SOF* at ¶ 31.
[23] *See, e.g.*, *Again, algae may spoil Charles swim*, The Boston Globe, Jul. 19, 2007, available at http://archive.boston.com/news/local/articles/2007/07/19/again_algae_may_spoil_charles_swim/ (last visited May 7, 2019).
[24] *SOF* at ¶¶ 14-15.
[25] *See* notes 7-10, supra.
[26] *SOF* at ¶¶ 16-17, 52.
[27] *SOF* at ¶ 18.
[28] *SOF* at ¶¶ 20-21, 36, 38, 40, 46, 54.

commercial, industrial, and high density residential (which includes multi-family residential) property dischargers of nutrient and pathogen-polluted stormwater in the Upper, Middle, and Lower Charles River are a primary cause of ongoing water quality violations in the Charles River.[29] The Lower Charles TMDL analysis determined that phosphorus loading must be reduced by 48 percent above the Watertown Dam and by 62 percent in each of the subwatersheds draining to the Lower Charles River in order for phosphorus loads to be reduced to safe levels for public health and ecosystems.[30] The Upper/Middle Charles TMDL requires a 51 percent reduction in the annual phosphorus load from stormwater.[31] Further, it requires a 65 percent reduction in phosphorus loading from all intense land uses (commercial, industrial, and high density residential sites).[32]

III. STATUTORY AND REGULATORY FRAMEWORK

A. The NPDES Program is Critical to Restoring Clean Rivers.

Congress established the Clean Water Act ("CWA") "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." 33 U.S.C. § 1251(a).[33] To achieve these objectives, the CWA prohibits the "discharge of a pollutant"[34] by "any person"[35] from any "point source"[36] into waters of the United States except when the discharge is authorized pursuant to a NPDES permit. 33 U.S.C. § 1311(a). ("Except as in compliance with … section … 1342 … of this title, the discharge of any pollutant by any person shall be unlawful.");

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[29] *SOF* at ¶¶ 24, 46, 50, 57, 60.
[30] *SOF* at ¶ 44.
[31] *SOF* at ¶ 50.
[32] *SOF* at ¶ 50.
[33] The United States Supreme Court has recognized that this objective incorporates "a broad, systematic view of the goal of maintaining and improving water quality," and that the word "integrity," as intended by Congress in the Act's statement of purpose, "refers to a condition in which the natural structure and function of ecosystems [are] maintained." *United States v. Riverside Bayview Homes, Inc.*, 474 U.S. 121, 132 (1972) (quoting H.R. Rep. No. 92-911, at 76.)
[34] In pertinent part, the Act defines the term "discharge of a pollutant" to mean "any addition of any pollutant to navigable waters from any point source." 33 U.S.C. § 1362(12)(A); 40 C.F.R. § 122.2 (stating that this definition "includes additions of pollutants into waters of the United States from: surface runoff which is collected or channeled by man.").
[35] The term "person" is defined to mean "an individual, corporation, partnership, association, State, municipality, commission, or political subdivision of a State, or any interstate body." *Id.* §1362 (5).
[36] In pertinent part, the CWA defines "point source" as "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit…from which a pollutant is or may be discharged." *Id.* § 1362(14).

33 U.S.C. § 1342(k) ("Compliance with a permit issued pursuant to this section shall be deemed compliance … [with section 1311] … of this title.").

The CWA further directs states to establish minimum water quality standards ("WQSs") sufficient to carry out the overall purpose of the Act. 33 U.S.C. § 1313; 40 C.F.R. § 131.2. These standards define a state's water quality goals by "designating the use or uses to be made of the water and by setting criteria necessary to protect those uses." 40 C.F.R. § 131.2. Massachusetts has established, and EPA Region 1 has approved, water quality standards pursuant to this requirement. M.G.L c. 21, § 27(3), (5); 14 CMR § 4.00 e*t seq*.

The CWA also requires states to identify impaired water bodies that do not meet WQSs after the implementation of technology-based controls, and to prioritize and schedule them for development of TMDLs. 33 U.S.C. § 1313(d); 40 C.F.R. § 130.7. Each TMDL is designed to reduce the pollution flowing to the water body covered by the TMDL from the entire land area that eventually drains into that water body. This area is referred to as the "watershed" for that water body. TMDLs set the maximum pollutant load that a body of water can receive while still maintaining the WQSs, and TMDLs must account for all contributing sources of pollution. 33 U.S.C § 1313(d).

The CWA and its implementing regulations require that TMDLs include: (1) the "waste load allocation" (WLA), or the portion of the pollutant load allocated to existing, or future, "point sources"; (2) the "load allocation" ("LA"), or the portion of pollutant load allocated to nonpoint sources; and (3) a "margin of safety" that takes into account any lack of knowledge concerning the relationship between pollution controls and water quality. 33 U.S.C. § 1313(d); 40 C.F.R. §§ 130.7(c)(1), 130.2(g), (h) & (i).

EPA guidance explains that "in many cases, the TMDL analysis is the trigger for determining the source(s) of pollutants" to a water body.[37] Indeed, in other guidance EPA notes the importance of determining the source(s) of pollutants to affected water bodies as part of the TMDL development process: "It is also important to understand the stormwater

[37] U.S. Envtl. Prot. Agency, *Water Quality Standards Handbook, Chapter 7: Water Quality Standards and the Water Quality-based Approach to Pollution Control*, at 6 (Jan. 2015)*, available at* https://www.epa.gov/sites/production/files/2014-10/documents/handbook-chapter7.pdf.

conveyance methods for each stormwater source in a watershed to determine whether the source is discharging to or affecting the impaired waterbody."[38]

It is well settled that "[s]torm sewers are established point sources subject to NPDES permitting requirements." *Environmental Defense Center v. U.S. Environmental Protection Agency*, 319 F.3d 398, 407 (9th Cir. 2003) (citing *NRDC v. Costle*, 568 F.2d 1369 at 1377 (D.C. Cir. 1977)). In fact, EPA expressly recognized more than a decade ago that "[f]rom a legal standpoint [] most urban runoff is discharged through conveyances such as separate storm sewers or other conveyances which are point sources under the CWA." *National Pollutant Discharge Elimination System (NPDES) Application for Storm Water Discharges*, 55 Fed. Reg. 47,990, 47,991 (Nov. 16, 1990).

NPDES permits, "while authorizing some water pollution, place important restrictions on the quality and character of that licit pollution." *Waterkeeper Alliance, Inc. v. United States E.P.A.*, 399 F.3d 486, 491 (2d Cir. 2005). Those restrictions include categorical technology-based effluent limitations that apply to all dischargers, and more stringent individualized limitations as necessary to meet minimum water quality standards. *See* 33 U.S.C. § 1311(b).

B. Congress Expressly Provided for Residual Designation of Unpermitted Stormwater Polluters Under the Clean Water Act.

In 1987, in recognition of the serious environmental problems caused by stormwater pollution and out of frustration with EPA's failure to control stormwater discharges, Congress amended the NPDES provisions for stormwater, directing EPA to phase in a comprehensive national regulatory program for stormwater discharges. 33 U.S.C. §§ 1342(p)(4), (6).[39] Though

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[38] U.S. Envtl. Prot. Agency, TMDLs to Stormwater Permits Handbook (DRAFT), § 3.3.2 (Nov. 2008), *available at* https://www.epa.gov/sites/production/files/2015-07/documents/tmdl-sw_permits11172008.pdf.

[39] Congressional dissatisfaction with the slow pace of NPDES implementation for stormwater is evident in the legislative history of the 1987 amendment, such as the following statement from Senator Durenberger during the floor debates:

> The Federal Water Pollution Control Act of 1972 required all point sources, including storm water discharges, to apply for NPDES permits within 180 days of enactment. Despite this clear directive, E.P.A. has failed to require most storm water point sources to apply for permits which would control the pollutants in their discharge. The conference bill therefore includes provisions which address industrial, municipal, and other storm water point sources. I participated in the development of this provision because I believe it is critical for the Environmental Protection Agency to begin addressing this serious environmental problem.

these amendments imposed a limited moratorium on NPDES permitting for certain discharges composed entirely of stormwater, the 1987 Congress singled out five categories of high-priority stormwater discharges for immediate and ongoing regulation through NPDES permitting. *Id.* §§1342(p)(1), (p)(2)(A)-(E). These focused primarily on well-documented and significant sources of stormwater pollution, such as runoff associated with industrial activities and large urban areas. Congress, however, also created a provision for other stormwater discharges by directing EPA to require NPDES permits for any stormwater discharge that the Administrator or the State Director determines "contribute[s] to a violation of a water quality standard or is a significant contributor of pollution to waters of the United States." 33 U.S.C. § 1342(p)(2)(E); 40 C.F.R. § 122.26(a)(1)(v).

EPA's Phase I stormwater rule, while focused on industrial polluters and urban areas, continued to recognize the need, pursuant to CWA § 402(p)(2)(E), for "immediate permitting" of stormwater discharges that contribute to violations of water quality standards. *National Pollutant Discharge Elimination System Permit Application Regulations for Storm Water Discharges*, 55 Fed. Reg. 47990, 47993 (November 16, 1990). This mandate to regulate stormwater discharges that contribute to water quality violations is commonly known as EPA's Residual Designation Authority ("RDA").

In its Phase II stormwater rule, EPA again affirmed the importance of immediately regulating stormwater discharges that contribute to water quality impairments. *See Regulations for Revision of the Water Pollution Control Program Addressing Stormwater Discharge*, 64 Fed. Reg. 68,721, 68,781 (Dec. 8, 1999), codified at 40 CFR §§ 122.26(a)(1)(v) and 122.26(a)(9)(i)(D). *See also Envt'l Def. Ctr. v. EPA*, 344 F.3d 832, 875-76 (9th Cir. 2003) (upholding inclusion of residual designation authority against industry challenge).

The Phase II rule went a step further, however, and authorized EPA to issue RDA discharge-permit determinations "on a geographic or a categorical basis within identified geographic areas such as a State or watershed." 64 Fed. Reg. 68, 736 (codified at 40 C.F.R. § 122.26(a)(9)(i)(D)). This action inherently "expanded [the agency's] authority to issue permits

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133 Cong. Rec. S752 (daily ed. Jan. 14, 1987) (emphasis added).

on a significantly broader basis, for wholesale categories of discharges in a geographic area."[40] EPA explained that this broader permitting authority would "facilitate and promote" the overarching goal of "coordinated watershed planning."[41]

Importantly, exercise of "the Agency's residual designation authority is not optional."[42] Once a discharge, or a category of discharges, is determined to be contributing to a violation of water quality standards, the operator(s) of those discharges "shall be required to obtain a [NPDES] permit." 40 C.F.R. § 122.26(a)(9)(i)(D) (emphasis added). *See also* 33 U.S.C. § 1342(p)(2)(E) (requiring NPDES permits for discharges composed entirely of stormwater that are determined to contribute to a violation of a water quality standard). As EPA has explained, and consistent with the legislative history of the 1987 Amendments to the Clean Water Act, "designation is appropriate as soon as the adverse impacts from storm water are recognized."[43]

EPA has not defined a threshold level of pollutant contribution that triggers such a finding, but the agency has acknowledged that it "would be reasonable to require permits for discharges that contribute more than *de minimis* amounts of pollutants identified as the cause of impairment to a water body."[44] This EPA analysis has been recognized as a valid interpretation of the RDA threshold by the Vermont Supreme Court.[45]

RDA determinations may be made directly at the initiative of the NPDES permitting authority, or result from the development of a wasteload allocation in a TMDL analysis. See 40 C.F.R. § 122.26(a)(9)(i)(C). Additionally, any person may petition the "Director" or "Regional Administrator" to designate a discharge or category of dischargers under RDA. 40 C.F.R.

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[40] *In re Stormwater NPDES Petition*, 2006 VT 91, ¶ 12.
[41] 64 Fed. Reg. 68, 739. *See also In re Stormwater NPDES Petition*, 2006 VT 91, ¶ 12.
[42] *In re Stormwater NPDES Petition*, 910 A.2d 824, 835 (Vt. 2006).
[43] *Letter from Tracy Mehan, III, EPA Assistant Administrator to Elizabeth McLain, Secretary, Vermont Agency of Natural Resources re: guidance on issues related to permits for discharges to impaired waters*, Sept. 16, 2003 (citing James R. Elder, Director EPA Office of Water Enforcement and Permits, *Designation of Stormwater Discharges for Immediate Permitting* at 2 (Aug. 8, 1990)) ("Mehan Letter").
[44] *See id.* at 3.
[45] *In re Stormwater NPDES Petition*, 2006 VT 91, ¶ 28, n.6.

§ 122.26(f)(2).[46] Once an RDA petition is submitted to the Director[47] or Regional Administrator, a final decision on the petition must be made within 90 days of its receipt. 40 C.F.R. § 122.26(f)(5).

IV. ANALYSIS

A. The Contributing Discharges Require a NPDES Permit Pursuant to CWA § 402(p)(2)(E) and EPA Regulations Because they Contribute to Ongoing Violations of the Water Quality Standards.

The CWA and EPA's implementing regulations require federal permits for all existing point source discharges composed entirely of stormwater that contribute to water quality standards violations. 33 U.S.C. § 1342(p)(2)(E); 40 CFR §§ 122.26(a)(1)(v), 122.26(a)(9)(i)(C) & (D). Throughout the last several decades, the Charles River has continually failed to meet its state water quality standards.[48] MassDEP and EPA have found that stormwater runoff from highly impervious land uses like commercial, industrial, institutional, and large multi-family residential is a significant contributor to these failures.[49]

In a detailed causal analysis of water quality violations in the Upper/Middle Charles, MassDEP and EPA determined that reductions in the nutrient load from the Upper/Middle Charles watershed will be needed in order to meet the target TMDL nutrient load for the Lower Charles.[50] Given the consistent, unanimous, and unequivocal nature of these findings, the Regional Administrator must determine pursuant to 33 U.S.C. § 1342(p)(2)(E) and 40 CFR §§ 122.26(a)(1)(v) that the Contributing Discharges contribute to water quality standards

[46] *See also In re Stormwater NPDES Petition*, 2006 VT 91, ¶¶ 12-14 (RDA petitions need not be made on a case-by-case basis, but may seek designation for whole classes of discharges).This petition authority is also compelled by Congress's mandate that EPA and the states provide for and encourage "public participation in the development…and enforcement of any regulation, standard, effluent limitation, plan or program" established under the Act. U.S.C. § 1251(e).
[47] The term "Director" means either the EPA Regional Administrator or the director of the state NPDES permitting authority, as the context requires. 40 C.F.R. § 122.2. Where EPA retains the authority to take certain actions even when there is an approved state program, as it does with RDA designation, 40 C.F.R. § 122.26(a)(9)(i)(C), the term Director may also mean the Regional Administrator. *Id.*
[48] *SOF* at ¶¶ 9, 19.
[49] *SOF* at ¶¶ 24-25, 46, 50-51, 57, 59-61.
[50] *SOF* at ¶ 34.

violations in the Charles River, and issue notice to all persons responsible for these that they must obtain a NPDES discharge permit. Based on recent analysis, CLF and CRWA believe that the class of Contributing Dischargers pursuant to this permit should include all commercial, industrial, institutional, and five or more unit multi-family residential real properties of one acre or greater within the Charles River Watershed.[51] Stormwater pollution from the Contributing Discharges is contributing to water quality standard violations in the Charles River, and it would be arbitrary and capricious to find otherwise.

1. Both the Upper/Middle and Lower Charles River fail to meet Massachusetts's water quality standards.

TMDL reports for both the Upper/Middle and Lower Charles River indicate that water quality standards cannot be met without significant reductions in phosphorus from stormwater runoff.[52] The Charles River Watershed's high levels of commercial, industrial, institutional, and multi-family residential land uses creates a high percentage of impervious cover, which causes contamination from polluted stormwater runoff.[53] MassDEP water quality sampling has documented that both the Upper/Middle and Lower Charles River suffer from eutrophication.[54] Eutrophication results in excessive algae and aquatic plant growth and variable dissolved oxygen levels resulting from high levels of phosphorus.[55] MassDEP monitoring identified that recurrent algal blooms include toxic cyanobacteria, which further impair the river from its Class B designation by presenting serious health risks, as a result of which state and local agencies must warn the public and their pets to avoid contact with the river water.[56]

Stormwater runoff is the overwhelming cause of eutrophication in the Charles River; there are no natural sources capable of achieving a phosphorus output this large. The Charles River has historically suffered from industrial contamination—most of which has been directly

[51] *See* Waterstone Report at 19, 21 n.16, 43. Further RDA petitions or permitting actions beyond those contemplated in this Petition may still be necessary to fully achieve the TMDL.
[52] *SOF* at ¶¶ 24, 26, 33-34, 42-45, 50.
[53] *SOF* at ¶¶ 39-40, 46, 56.
[54] *SOF* at ¶¶ 22, 29-31.
[55] *SOF* at ¶ 23.
[56] *SOF* at ¶ 31.

caused by the densely populated areas through which the river flows.[57] Elevated levels of phosphorus, low dissolved oxygen, and the presence of large algal blooms are common in urban impaired rivers and are traceable to large commercial, industrial, institutional, and multi-family residential sources.[58]

2. The Contributing Discharges contribute to the ongoing water quality standards violations in the Charles River.

The direct evidence that the Contributing Discharges are significant contributors to the ongoing water quality violations in the Charles River is definitive, as set forth in the Statement of Facts. Moreover, this direct evidence is the result of detailed studies of water quality impairments in and resulting EPA-approved TMDLs for the Charles River Watershed by MassDEP, EPA, and CRWA, all of which conclude that stormwater runoff from commercial, industrial, institutional, and multi-family residential sources is a significant contributor to the ongoing impairment of the river and its tributaries.[59]

a. The Lower Charles River TMDL

The Lower Charles TMDL determined that stormwater runoff constitutes a major source of phosphorus loading that must be controlled and/or eliminated, including from lands with higher percentages of impervious cover, *i.e.* commercial, industrial, institutional, and multi-family residential, which generate a high proportion of surface runoff.[60] Further, the Lower Charles TMDL determined that current controls for storm water runoff are inadequate to meet the TMDL's water quality goals for nutrients.[61] The data included in and supporting the TMDL "demonstrates that additional controls may well be needed on many storm water discharges."[62] To meet the TMDL in the Lower Charles, absent a major permitting program from

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[57] *SOF* at ¶ 8.
[58] *SOF* at ¶¶ 19-29.
[59] *SOF* at ¶¶ 21, 46-47, 51, 57, 59-61.
[60] *SOF* at ¶¶ 41-47.
[61] *SOF* at ¶ 48.
[62] *Id.*

EPA that requires large impervious surface landowners to contribute a proportional share of phosphorus reductions and associated innovations to collect and treat stormwater runoff before it reaches the Charles, bioretention best management practices ("BMPs") would have to be implemented on all industrial, commercial, and residential parcels larger than just 0.05 acres.[63]

b. The Upper/Middle Charles River TMDL

The Upper/Middle Charles TMDL provides a maximum phosphorus allocation for the Upper/Middle Charles River above the Watertown Dam. The Upper/Middle Charles TMDL was developed to achieve water quality standards in the Upper/Middle portions of the river and also to meet the phosphorus load allocation established in the Lower Charles TMDL.[64] To achieve these dual goals, the Upper/Middle Charles TMDL requires reductions in stormwater phosphorus loads based upon land use.[65] In order for the nutrient TMDL to be met for the Upper/Middle Charles River, absent a major permitting program from EPA that requires large impervious surface landowners to contribute a proportional share of phosphorus reductions and associated innovations to collect and treat stormwater runoff before it reaches the Charles, bioretention BMPs would have to be implemented on all industrial, commercial, and residential parcels that are larger than 0.25 acres.[66]

c. The Charles River Watershed Pathogen TMDL

The Pathogen TMDL identified stormwater as a significant contributor of pathogen pollution in the Charles River watershed.[67] The Pathogen TMDL analysis determined that stormwater discharges from land use categories including Multifamily Residential, Commercial, and Industrial "typically" contain bacteria "at levels sufficient to cause water quality

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[63] Waterstone Report at 43.
[64] *SOF* at ¶ 49.
[65] *SOF* at ¶ 50.
[66] Waterstone Report, at 43-44.
[67] *SOF* at ¶ 54.

problems."[68] Recent analysis indicates that current bioretention BMPs may not be able to achieve the full TMDL pathogen reduction requirement, but that significant reductions in pathogen loading to the Charles River would result from residual designation of stormwater discharges.[69]

MassDEP and EPA have expressly determined that the Contributing Discharges are a primary cause of water quality violations in the Charles River. Because all evidence conclusively demonstrates that the Contributing Discharges contribute to ongoing violations of applicable water quality standards for the Charles River, this petition must be granted and all persons responsible for those Contributing Discharges must be notified of their obligation to obtain NPDES permits. 33 U.S.C. § 1342(p)(2)(E); 40 CFR §§ 122.26(a)(1)(v), 122.26(a)(9)(i)(D).

B. Residual Designation Should Include, as a Class, all Existing Non-Permitted Commercial, Industrial, Institutional, and Large Multi-Family Residential Property Dischargers with one or more acres impervious surface area within the Charles River Watershed.

Since all three TMDLs were approved, the Upper/Middle and Lower segments of the Charles River continue to suffer eutrophication, excessive algae biomass and blooms (including those containing toxic cyanobacteria), and other effects of excessive phosphorus pollution.[70] To achieve the TMDL required reductions in the Upper/Middle and Lower Charles River, reductions in stormwater phosphorus loads, based upon land use, must be achieved throughout the watershed.[71] EPA regulations provide for residual designation of a category of discharges within a geographic area, such as a watershed, when it determines that discharges from that category contribute to a violation of a water quality standard. 40 C.F.R. § 122.26(a)(9)(i)(D). In the Charles River Watershed, EPA, MassDEP, and CRWA have expressly concluded that stormwater discharges from unpermitted land uses including commercial, industrial, institutional, and large multi-family residential property dischargers contribute to the non-attainment of water quality

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[68] *SOF* at ¶ 57.
[69] Waterstone Report, at 43.
[70] *SOF* at ¶ 64.
[71] *SOF* at ¶ 50.

standards in the Charles River Watershed.[72] CLF and CRWA are petitioning EPA at this time to exercise its Residual Designation Authority in order to bring currently unregulated landowners in the Contributing Discharge categories with parcels of one acre or more into the NPDES permitting program.[73]

Aside from fulfilling the CWA's statutory and regulatory mandate for immediate permitting of stormwater discharges that contribute to non-attainment of water quality standards, residual designation of the Contributing Discharges will also meet the CWA, EPA, and the Commonwealth's goal of reducing phosphorus discharges to the Charles River for public health and ecology and to restore the watershed to a healthy state.[74]

Residual designation of these impervious surfaces as a category will facilitate this process in at least two ways. First, class designation would fairly and equitably assign responsibility for non-attainment among Contributing Discharges and thereby ensure the widespread participation that will be necessary for success. Second, class designation would also provide an appropriate regulatory mechanism for implementation of future restoration plans.

Absent RDA designation, an inordinate regulatory burden for attainment of water quality standards falls only upon those stormwater dischargers (including municipal separate storm sewer systems, certain industrial activities, and construction projects) that currently fall

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[72] *SOF* at ¶¶ 24-25, 46, 50-51, 57, 59-61.

[73] As the Waterstone Report notes, private institutional land uses are virtually identical to commercial and large multi-family residential land uses. Waterstone Report at 21 n.16, 43, 45. Due to the scope of MassGIS land use categorization which groups private institutional land uses like universities and hospitals with publicly owned institutional land uses like primary and secondary schools, private institutional properties are categorized as NPDES-regulated in the Waterstone Report analysis. Waterstone Report at 21 n.16. Since private institutions cannot be considered NPDES-regulated, the Waterstone Report analysis undercounts the pollution contribution from this land use category. This is balanced by a limited overcounting of some portions of Industrial land use parcels that may be covered by the NPDES program. While the Waterstone Report considers Industrial land uses to be unregulated by the NPDES program (excluding MassGIS "Junkyard" and "Marina" parcels which are presumed to be covered by the Multi-Sector General Permit or individual NPDES permits), some portion of non-Junkyard and non-Marina industrial parcels in sectors like construction sand and gravel may be Multi-Sector General Permit jurisdictional. *See id.* However, it is certain that at least some portions of industrial sites in the Charles River watershed are not currently required to obtain NPDES permits for post-construction stormwater runoff. For this reason, CLF and CRWA are petitioning for designation of Industrial parcels or portions of parcels that are not covered by the Multi-Sector General Permit or individual NPDES permits due to their contributions to water quality impairments in the Charles River.

[74] *SOF* at ¶ 63.

under CWA jurisdiction. *See*, *e.g.*, 33 U.S.C. § 1342(p)(3)(A) (permits for stormwater discharges associated with industrial activity, including construction activities, must meet the CWA § 301(b)(1)(C) mandate to include any more stringent limitation necessary to meet water quality standards). This is not only patently unfair, but also—as indicated by the long-standing water quality violations in the Charles River—would be unlikely to result in attainment of state water quality standards. Regulation of all Contributing Discharges is therefore not only legally required, but also the most equitable, efficient, and effective means of ensuring that the Charles River meets its water quality standards.

C. Residual Designation of the Contributing Discharges Will Supplement and Enhance Existing Programs

While the sufficiency of other pollution reduction programs is not a relevant factor in a Residual Designation determination under 33 U.S.C. § 1342(p)(2)(E), it is important to note that residual designation of the Contributing Discharges would only serve to supplement and enhance the efficacy of existing NPDES permit programs affecting the Charles River watershed. In Massachusetts, the 2016 general permit for small municipal separate storm sewer systems ("MA Small MS4 Permit") refers to the Lower and Upper/Middle Charles TMDLs in requiring permittees to develop a Phosphorus Control Plan (PCP) designed to reduce the amount of phosphorus in stormwater discharges to the Charles River.[75] The MS4 permit requires permittees to develop a priority ranking of areas within the municipality for potential implementation of phosphorus control practices, and to describe the structural stormwater control measures necessary to achieve the phosphorus reduction milestones contained in the MS4 permit.[76] The description of the structural controls must include the planned measures, the areas where the measures will be implemented, and the annual phosphorus reductions in units of mass per year that are expected to result from their implementation.[77]

Crucially, however, the PCP requirements for municipalities in the Charles River Watershed remain limited by the municipalities' toolkit of bylaws and ordinances, changes to

[75] 2016 MA Small MS4 General Permit, Appendix F for the Charles River Watershed at 2 (MS4 Permit).
[76] *Id.* at 5-6.
[77] *Id.* at 6.

which may be difficult to draft and promulgate if a specific outcome is not required by state or federal law.[78] The PCP requirements do not specifically address commercial, industrial, private institutional, and large multi-family residential sources. Nor do they contain different, or any specific, obligations of new or existing properties with significant impervious surface area, beyond a requirement that permittees track and offset phosphorus load increases due to development.[79]

If EPA intends the MS4 permit program to result in a meaningful reduction in phosphorus loading to the Charles River, it must require a permitting program for significant impervious surface landowners in the commercial, industrial, institutional, and multi-family residential sectors that is designed to drive participation in, and collaboration with, MS4 communities' PCPs. A permitting program from EPA in response to this Petition can and should encourage collaboration among property owners and communities to construct regional treatment systems which create efficiencies by treating runoff from multiple sites in one system. The Town of Milford, for example, recently used Clean Water Act § 319 grant funding to construct a stormwater treatment wetland to treat runoff from a 70 acres drainage area containing multiple public and private parcels.[80] Requiring stormwater permits for individual impervious landowners within each municipality would help meet the goals of the permit program by requiring unregulated significant contributors to phosphorus pollution to take affirmative action to be part of the solution.

V. CONCLUSION

The severe degradation of the Charles River's water quality epitomizes the impact of urban stormwater discharges upon major waterways in Massachusetts. EPA has known for decades that the Contributing Discharges contribute significantly to the failure to meet water quality standards.

[78] *Id.* at 4.
[79] *Id.* at 4-5.
[80] *See* Horsley Witten Group, Constructed Stormwater Wetland in Milford, https://horsleywitten.com/stormwater-wetland/ (last visited May 9, 2019) (description of project by the project's engineering firm).

CLF and CRWA petition EPA to implement a NPDES permitting program for the Contributing Discharges. Further delay in regulating these sources is no longer defensible—legally, environmentally, or as a matter of public policy and equitable regulation.

Accordingly, this petition must be granted and EPA Region 1 must immediately develop NPDES permits for the Contributing Discharges. We look forward to your response, and to working with you to improve water quality in the Charles River and its Watershed.

Respectfully submitted this 9th day of May, 2019.

On behalf of Conservation Law Foundation and Charles River Watershed Association,

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Attachment A

Statement of Undisputed Facts

STATEMENT OF UNDISPUTED FACTS IN SUPPORT OF THE CONSERVATION LAW FOUNDATION AND CHARLES RIVER WATERSHED ASSOCIATION'S PETITION FOR A DETERMINATION THAT CERTAIN COMMERCIAL, INDUSTRIAL, INSTITUTIONAL, AND MULTI-FAMILY RESIDENTIAL PROPERTY DISCHARGERS CONTRIBUTE TO WATER QUALITY STANDARDS VIOLATIONS IN THE CHARLES RIVER WATERSHED, MASSACHUSETTS AND THAT NPDES PERMITTING OF SUCH PROPERTIES IS REQUIRED

1. The entire Charles River Watershed drains a watershed area of 308 square miles. Two hundred and sixty-eight square miles of that watershed area drain over the Watertown Dam into the Lower Charles River. The remaining 40 square miles drain directly into the Lower Charles from small tributary streams that are mostly enclosed and piped stormwater drainage systems serving the surrounding communities. *Total Maximum Daily Load for Nutrients in the Lower Charles River Basin (2007) ("Lower Charles TMDL") Executive Summary* at v.
2. The Charles River starts above Echo Lake in Hopkinton and flows about 79 miles in a northeasterly direction to the coast. The river flows through many of the surrounding Boston communities before discharging into Boston Harbor. The river drops 310 feet in its journey to the coast. The steepest elevation change is in the headwaters with the rest of the watershed being gently sloped. *Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River (2011) ("Upper/Middle Charles TMDL")* at 7-8.
3. The Charles River hydrology is impacted by 19 dams along the length of the river and by substantial natural storage in the upper and middle watershed. The Massachusetts Department of Environmental Protection ("MassDEP") has estimated that it takes three to four days for peak flows in the upper portion to reach the Lower Charles. *Final Pathogen TMDL for the Charles River Watershed (2007) ("Charles Pathogen TMDL")* at 7.
4. The Upper/Middle Charles watershed contains 5 communities in their entirety (Medway, Millis, Needham, Waltham, and Wellesley) and includes portions of 28 more (Arlington, Ashland, Bellingham, Belmont, Boston, Brookline, Dedham, Dover, Foxborough, Franklin, Holliston, Hopedale, Hopkinton, Lexington, Lincoln, Medfield, Mendon, Milford, Natick, Newton, Norfolk, Sherborn, Walpole, Watertown, Wayland, Weston, Westwood, and Wrentham). *Upper/Middle Charles Nutrient TMDL* at 1.
5. The Lower Charles is an impounded section of the Charles River that is 8.6 miles long, between the Watertown Dam and the New Charles River Dam. *Lower Charles Nutrient TMDL* at 2.

6. The Lower Charles River is in the heart of a highly urbanized area, bordered directly by the municipalities of Boston, Cambridge, Watertown, and Newton. *Lower Charles Nutrient TMDL* at 2.
7. The majority of the Lower Charles River exists downstream of the Boston University Bridge (the Basin). The Basin is 2.6 miles long and has widths varying from 300 to 2,000 feet. Its water volume accounts for approximately 90 percent of the entire water volume of the Lower Charles River. *Lower Charles Nutrient TMDL* at 2.
8. The land uses surrounding the Lower Charles River are predominantly residential (high density and multi-family). *Lower Charles Nutrient TMDL* at 8.
9. The Charles River has historically suffered from earlier industrial contamination. The major types of pollution have been excess bacteria caused by sewage contaminating the river water, and excessive amounts of nutrients entering the river. During the warm summer months, the excess nutrients cause algal blooms that can be toxic to animals and people. *About the Charles River*, EPA Region 1, https://www.epa.gov/charlesriver/about-charles-river.
10. Both the Upper/Middle and Lower segments of the Charles River are designated as a Class B water under Massachusetts' water quality standards. Class B waters are designated as capable of providing and supporting habitat for fish and other aquatic wildlife, and for primary and secondary contact recreation. *Upper/Middle Charles Nutrient TMDL* at 12.
11. In 1998, EPA New England's Regional Laboratory began an annual Core Monitoring Program to document water quality conditions and track water quality improvements in the Lower Charles River as pollution controls are implemented. EPA's Core Monitoring Program was conducted annually during July, August, and September (1998-2005) when recreational uses peak in the Lower Charles River. Samples were analyzed for nutrients, chlorophyll *a*, color, bacteria, metals, dissolved oxygen, temperature, salinity, transparency, and turbidity. *Lower Charles Nutrient TMDL* at 14.
12. Between 1998 and 2001 the USGS conducted three detailed monitoring investigations of the Lower Charles River, including (1) an examination of the extent and effects of salt water intrusion into the Lower Charles River from Boston Harbor through the New Charles River Dam, (2) a determination of the distribution and characteristics of bottom sediments, and (3) a pollutant load study that characterizes the sources and loading of several pollutants in the Lower Charles River. *Lower Charles Nutrient TMDL* at 17.

13. In the summer of 2002, EPA collected algal samples at a subset of stations to support development of the Lower Charles River TMDL. Starting in 2005, EPA's Core Monitoring Program was revised to conduct dry-weather sampling six times per year from June to October for phosphorus, chlorophyll *a*, temperature, dissolved oxygen, conductivity, transmissivity, turbidity, and bacteria. *Lower Charles Nutrient TMDL* at 14.
14. During August 2006, EPA collected a sample in the downstream portion of the Lower Charles because of the obvious presence of a very severe cyanobacteria bloom. MassDEP analyzed the sample and conducted follow-up cyanobacteria monitoring in the Lower Charles with the Massachusetts Department of Conservation and Recreation. *Lower Charles Nutrient TMDL* at 14.
15. The 2006 bloom in the Lower Charles consisted of extremely high cell counts of over one million cells per milliliter of cyanobacteria, including Microcystis, which is toxic at elevated levels. *Lower Charles Nutrient TMDL* at 34.
16. Mass DEP submitted a final TMDL to EPA for the Lower Charles River, *Total Maximum Daily Load for Nutrients in the Lower Charles River Basin, Massachusetts* ("Lower Charles TMDL") on July 6, 2007. EPA approved the Lower Charles TMDL on October 17, 2007. EPA, Region 1, *Approval of the Nutrient (Phosphorus) TMDL for the Lower Charles River* (Oct. 17, 2007).
17. Mass DEP submitted a final TMDL to EPA for the Upper/Middle Charles River, *Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River, Massachusetts* ("Upper/Middle Charles TMDL") on September 27, 2010, and a revised final report/clarification memo on June 3, 2011. On June 10, 2011, EPA approved the Upper/Middle Charles TMDL. *See* EPA, Region 1, *Notification of Approval of Upper/Middle Charles River TMDL* (Jun. 10, 2011).
18. Mass DEP maintains a "Quality System" in an EPA-approved Quality Management Plan to ensure that the environmental data that it relies upon to identify impaired water bodies and formulate TMDLs are of known and documented quality and are suitable for their intended use. *MA 2016 Integrated List of Waters* at 23.
19. The Upper/Middle Charles River outlet load at the Watertown Dam does not meet the target inlet load to the Lower Charles River at that location. *Upper/Middle Charles Nutrient TMDL* at 12.
20. Stormwater runoff includes inputs from fertilized soils and lawns; leaf litter and other vegetative debris; car wash products and some detergents; auto exhaust, fuel, and lubricants; and pet waste. *Upper/Middle Charles Nutrient TMDL* at 3.

21. Developed land uses including high-density residential, commercial, and industrial have higher loadings of phosphorus per unit area. *Upper/Middle Charles Nutrient TMDL* at 3.
22. The Upper/Middle Charles River suffers from eutrophication. *Upper/Middle Charles Nutrient TMDL* at 12.
23. Eutrophication results in excessive algae and aquatic plant growth and low and/or highly variable dissolved oxygen levels. *Upper/Middle Charles Nutrient TMDL* at 12.
24. Approximately 93% of the total annual phosphorous load to the Upper/Middle Charles River is attributed to waste water treatment facilities and stormwater discharges. *Upper/Middle Charles Nutrient TMDL* at 81.
25. Some existing stormwater drainage systems in the Upper/Middle Charles River Watershed are currently unregulated by the NPDES permit program. These systems include privately owned drainage systems serving commercial areas, small construction sites less than an acre in size, and certain industrial uses. *Upper/Middle Charles Nutrient TMDL* at 74.
26. To achieve the required reductions in the Upper/Middle and Lower Charles River, stormwater phosphorous loads must be decreased. *Upper/Middle Charles Nutrient TMDL* at 80.
27. Cultural eutrophication is the process of producing excessive plant life due to excessive pollutant inputs from human activities. *See, e.g., Upper/Middle Charles Nutrient TMDL* at 14.
28. Water quality problems common to eutrophic waters include poor aesthetic quality, low dissolved oxygen in the hypolimnion (bottom waters), and undesirable alterations to species composition and the food web (Chesapeake Bay Program 2001). *Lower Charles Nutrient TMDL* at 40.
29. Algal blooms and other water quality parameters (i.e. nutrients, water clarity, chlorophyll-*a*, and low or high dissolved oxygen) indicate the Upper/Middle Charles River is undergoing cultural eutrophication. *Upper/Middle Charles Nutrient TMDL* at 14.
30. Although many species of algae are important contributors to the base of the food web, there are species that provide poor nutrition, are inedible, or are toxic to aquatic life. *Lower Charles Nutrient TMDL* at 34.
31. These recurrent algal blooms degrade the Charles River and prevent it from attaining and maintaining its designated and existing Class B uses, including but not limited to impacting its aesthetic quality, harming aquatic life and impairing recreational use of the river, including boating, wind surfing, and swimming. *Lower Charles Nutrient TMDL* at 6.

32. The recurrent algal blooms consistently include toxic cyanobacteria. *Lower Charles Nutrient TMDL* at 6.
33. Nutrient loads from the Upper/Middle Charles contribute directly to water quality impairments in the Lower Charles. *Upper/Middle Charles Nutrient TMDL* at 14.
34. Reductions in the nutrient load from the Upper/Middle Charles Watershed will be needed in order to meet the target nutrient load for the Lower Charles. *Upper/Middle Charles Nutrient TMDL* at 11.
35. The upstream watershed represents the dominant source of phosphorus (as well as all other measured constituents) to the Lower Charles River on an annual basis, accounting for 91.4, 68, and 82 percent of the dry-weather, wet-weather, and total non-CSO phosphorus load, respectively. *See Lower Charles Nutrient TMDL* at 50.
36. Stormwater conveyed directly into the Lower Charles River from stormwater drainage systems are also a source of phosphorus pollution in the Lower Charles River. *See Lower Charles Nutrient TMDL* at 47.
37. As of 2007, there were 73 major stormwater drainage system outfalls in the Lower Charles River watershed. *Lower Charles Nutrient TMDL* at 44.
38. Areas with a high percentage of impervious cover generate more surface runoff than areas with a lower percentage, and offer less opportunity for ground cover and the soil matrix to intercept and filter pollutants from runoff. *Lower Charles Nutrient TMDL* at 100.
39. Given the level of urbanization and the extent of impervious cover, the Lower Charles River Watershed has lost much of its natural capacity to absorb rainfall and remove pollutants by filtering the runoff through vegetative cover and the soil matrix, resulting in elevated concentrations of pollutants in stormwater discharges to the Lower Charles River. *Lower Charles Nutrient TMDL* at 47.
40. Urbanized watersheds generate substantially more runoff volume than undeveloped watersheds because of the greater extent of impervious cover (and less opportunity for infiltration) in urbanized watersheds. The higher concentrations and greater volumes of stormwater runoff associated with the urban watershed result in much greater amounts of phosphorus entering the river (i.e., phosphorus loading) than would come from a naturally vegetated watershed. Also, the higher storm flows might further increase the overall stormwater pollutant load because of erosion and flooding. *Lower Charles Nutrient TMDL* at 47.

41. The Lower Charles TMDL set an aggregate waste allocation ("WLA") for each of the subwatersheds that drain into the Lower Charles and for the river above the Watertown Dam, which contributes to phosphorus loading in the Lower Charles. *See Lower Charles Nutrient TMDL* at 84-85.
42. The aggregation of sources in the WLA for the Lower Charles was based on extensive amounts of technically sound data and information that confidently define existing loads and the phosphorus reductions that are needed from the major source areas. *Lower Charles Nutrient TMDL* at 84.
43. The three aggregate WLAs for the Lower Charles are (1) contributions from the Upper/Middle Charles River above Watertown Dam; (2) non-CSO drainage areas that discharge directly to the Lower Charles River; and (3) CSO discharges. The allocations for the non-CSO drainage areas in the Lower Charles River include all sources that discharge to the major tributaries and smaller drainage systems. *Lower Charles Nutrient TMDL* at 85.
44. The Lower Charles River TMDL analysis found that phosphorus loading must be reduced by 48% upstream of the Watertown Dam and by 62% in each of the subwatersheds draining to the Lower Charles River in order for phosphorous loads to be met. *Lower Charles Nutrient TMDL* at viii, Table ES-2.
45. The Lower Charles TMDL document includes an implementation plan. *Lower Charles Nutrient TMDL* at 97.
46. The Lower Charles TMDL stated that stormwater runoff constitutes a major source of phosphorus loading that must be controlled and/or eliminated, including from lands with higher percentages of impervious cover, *i.e.* commercial, industrial, and high density residential, which generate more surface runoff than other land use types. *Lower Charles Nutrient TMDL* at 100, Table 6.2.
47. The Lower Charles TMDL analysis included multi-family residential in the "high density residential" land use category. *Lower Charles Nutrient TMDL* at 123.
48. The Lower Charles TMDL stated that current controls for stormwater runoff are inadequate to meet the TMDL's water quality goals for nutrients, and that additional controls may be needed on many stormwater discharges. *Lower Charles Nutrient TMDL* at 113-14.
49. The Upper/Middle Charles TMDL was developed to achieve water quality standards in the Upper/Middle portions of the river, and also to meet the phosphorus load allocation established in the Lower Charles TMDL. *Upper/Middle Charles Nutrient TMDL* at 11.

50. To achieve water quality standards and meet the phosphorus load allocation in the Lower Charles TMDL, the Upper/Middle Charles TMDL requires reductions in stormwater phosphorus loads based upon land use. The Upper/Middle Charles TMDL places all stormwater pollution sources in the WLA and requires a 51% reduction in annual phosphorus load from stormwater. To achieve this reduction, the TMDL sets phosphorus discharge limits for stormwater by land use category. *Upper/Middle Charles Nutrient TMDL* at 5.
51. The Upper/Middle Charles TMDL establishes a 65% reduction in phosphorus loading from all intense land uses (including commercial, industrial, and multi-family residential land uses). See *Upper/Middle Charles Nutrient TMDL* at 5, 13, 71, 75-76.
52. Due to water quality impairment from pathogens, Mass DEP developed a pathogen TMDL for the Charles River, *Final Pathogen Total Maximum Daily Load for the Charles River Watershed* (Jan. 2007) ("Charles Pathogen TMDL"). *See Charles Pathogen TMDL* at 1.
53. The Commonwealth of Massachusetts submitted the Charles River Pathogen TMDL to EPA for approval on February 9, 2007. After deliberation and consideration of the underlying record, EPA approved the Charles Pathogen TMDL on May 22, 2007. EPA, Region 1, *Approval of the Pathogen TMDL for the Charles River Watershed* (May 22, 2007).
54. The Charles Pathogen TMDL determined that stormwater runoff from overland flow directly or through stormwater drainage systems is a significant contributor of pathogen pollution to the Charles River. *See Charles Pathogen TMDL* at 39.
55. The Charles Pathogen TMDL categorized stormwater runoff in two forms: 1) point source discharges (from piped systems) and 2) nonpoint source discharges (includes sheet flow or direct runoff). *Charles Pathogen TMDL* at 68.
56. The Charles Pathogen TMDL assigned all stormwater runoff from impervious cover to the Wasteload Allocation. *Charles Pathogen TMDL* at 58.
57. The Charles Pathogen TMDL analysis determined that stormwater discharges from land use categories including multi-family residential, commercial, and industrial typically contain bacteria at levels sufficient to cause water quality problems. *Charles Pathogen TMDL* at 39.
58. The Charles Pathogen TMDL determined that the level of control for stormwater runoff in 2007 was inadequate for standards to be attained. *Charles Pathogen TMDL* at 64.
59. The Charles Pathogen TMDL analysis determined that 81.8 to 98.8 percent of pathogens from a typical stormwater event in the multi-family residential land use category would need to be reduced to meet water quality standards. *Charles Pathogen TMDL* at 40.

60. The Charles Pathogen TMDL analysis determined that 41.2 to 98.6 percent of pathogens from a typical stormwater event in the commercial land use category would need to be reduced to meet water quality standards. *Charles Pathogen TMDL* at 40.
61. The Charles Pathogen TMDL analysis determined that 97.1 percent of pathogens from a typical stormwater event in the industrial land use category would need to be reduced to meet water quality standards. *Charles Pathogen TMDL* at 40.
62. The Charles Pathogen TMDL acknowledged that some stormwater sources may not be the responsibility of the municipal government and may have to be addressed through other regulatory vehicles available to EPA including, but not limited to, EPA's exercise of its residual designation authority to require NPDES permits, depending upon the severity of the source. *Charles Pathogen TMDL* at 69.
63. EPA's goal is to reduce phosphorus discharges to the Lower Charles by 54 percent to restore the river to a healthy state. In order to meet that goal, EPA must reduce the amount of stormwater runoff entering the River. *Environmental Challenges for the Charles River*, EPA Region 1 https://www.epa.gov/charlesriver/environmental-challenges-charles-river (last visited May 7, 2019).
64. Since the three TMDLs were approved, the Upper/Middle and Lower segments of the Charles River continue to suffer eutrophication, excessive algae biomass and blooms (including those containing toxic cyanobacteria), and other effects of excessive phosphorus and pathogen pollution. *See generally Environmental Challenges for the Charles River*, EPA Region 1, https://www.epa.gov/charlesriver/environmental-challenges-charles-river#NutrientChallenges (last visited May 7, 2019).

Attachment B

Waterstone Engineering, TMDL Attainability Analyses for Phosphorus and Pathogens for the Charles River Watershed, Massachusetts

EXPERT REPORT

TMDL Attainability Analyses for Phosphorus and Pathogens for the Charles River Watershed, Massachusetts

Prepared for:
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May 9, 2019

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Table of Contents

Table of Tables

Table of Figures

Acronym	**Definition**
ASCE	AMERICAN SOCIETY OF CIVIL ENGINEERS
BMP	STORMWATER BEST MANAGEMENT PRACTICE
CFR	CODE OF FEDERAL REGULATIONS
CLF	CONSERVATION LAW FOUNDATION
CSM	CONCEPTUAL SITE MODEL
CWA	CLEAN WATER ACT
DWRE	DIPLOMATE, WATER RESOURCES ENGINEER
EPA	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
EWRI	ENVIRONMENTAL WATER RESEARCH INSTITUE
EMC	EVENT MEAN CONCENTRATION
ENT	ENTEROCOCCI
FR	FEDERAL REGISTER
FRCP	FEDERAL RULES OF CIVIL PROCEDURE
GIS	GEOGRAPHIC INFORMATION SYSTEMS
HRU	HYDROLOGIC RESPONSE UNIT
IA	IMPERVIOUS AREA
LA	LOAD ALLOCATION
LID	LOW IMPACT DEVELOPMENT
LIDAR	LIGHT DETECTION AND RANGING
MADEP	MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION
MASWM	MASSACHUSETTS STORMWATER MANUAL
MSGP	MULTI-SECTOR GENERAL PERMIT
NCDC	NATIONAL CLIMATE DATA CENTER
NOI	NOTICE OF INTENT
NRCC	NORTHEAST REGIONAL CLIMATE CENTER
NRCS	NATURAL RESOURCES CONSERVATION SERVICE
NPDES	NATIONAL POLLUTION DISCHARGE ELIMINATION PERMITS
PE	PROFESSIONAL ENGINEER
PLA	POLLUTANT LOADING ANALYSES
PLER	POLLUTANT LOAD EXPORT RATES
RDA	RESIDUAL DESIGNATION AUTHORITY
SWM	STORMWATER MANAGEMENT
SWMM	STORMWATER MANAGEMENT MODEL
SWPPP	STORMWATER POLLUTION PREVENTION PLAN
TMDL	TOTAL MAXIMUM DAILY LOAD
TP	TOTAL PHOSPHOROUS
TSS	TOTAL SUSPENDED SOLIDS
USDA	UNITED STATES DEPARTMENT OF AGRICULTURE
USGS	UNITED STATES GEOLOGICAL SURVEY
UWRCC	URBAN WATER RESOURCES RESEARCH COUNCIL
WEF	WATER ENVIRONMENT FEDERATION
WLA	WASTE LOAD ALLOCATION
WQV	WATER QUALITY VOLUME

1. Expert Opinions

This written report is prepared in compliance with the disclosure requirements set forth in the Federal Rules of Civil Procedure (FRCP) 26(a)(2)(B), subject to the right to supplement the report in accordance with FRCP 26(e). This report focuses on the TMDL attainability for phosphorus and the pathogenic fecal coliform bacteria for Upper, Middle, and Lower Charles River watersheds.

The exhibits that will be used to summarize and support the opinions expressed in this report are exhibits which appear in, are transmitted with, or referred to in this report. The exhibits may be revised to allow for presentation in a manner more suitable to the proceedings where they are used. I reserve the right to update my opinion as new information becomes available.

Disclosure items as required by FRCP 26(a)(2)(B) are listed below and can be found in the following sections:

i. A complete statement of all opinions the witness will express and the basis and reasons for them are contained within the entirety of this Report;
ii. The facts or data considered by the witness in forming them are contained or referred to within the entirety of this Report;
iii. Any exhibits that will be used to summarize or support the witness's opinions are contained or referred to within the entirety of this Report;
iv. The witness's qualifications, including a list of all publications authored in the previous 10 years (Section 1.3 and Appendix A);
v. A list of all other cases in which, during the previous 4 years, the witness testified as an expert at trial or by deposition (Section 1.3.3 and Appendix A); and
vi. A statement of the compensation to be paid for the study and testimony in the case (Section 1.3.4).

1.1. Report Objectives

Waterstone Engineering PLLC has been retained to conduct the following scope of services:

1. Conduct an analysis of pollutant loading for the Upper/Middle and Lower Charles River Watersheds;
2. Review available documentation including permits and related studies;
3. Develop a watershed model to calculate the pollutant loading of stormwater for phosphorous and pathogenic fecal coliform bacteria;
4. Calculate the load reduction potential for regulated areas considering BMP implementation;
5. Establish opinions related to TMDL attainability for phosphorous and bacteria based on BMP load reduction potential.

1.2. Summary Opinions

The following opinions are based on:

1. Review of immediately relevant permits, reports and related information by EPA and MASSDEP including the 2007 nutrient TMDL for the Lower Charles River Watershed, the 2011 nutrient TMDL for the Upper Charles River Watershed, and the 2007 pathogen TMDL for the entire Charles River Watershed.

2. Review of relevant regulatory requirements for Residual Designation Authority including the Fact Sheet for the RDA General Permit For Designated Discharges[1] and Basis for Phosphorous Reduction Requirements[2].
3. Review of land use and land cover data of the Site;
4. Development and analysis of a hydrologic and hydraulic model of the watersheds to quantify the annual average volume of discharge from the watershed, and to quantify potential pollutant loading for NPDES regulated and unregulated sources to Upper, Middle, and Lower Charles River watersheds; and
5. Development and analysis of a spreadsheet model to quantify pollutant loading by parcel size and land use, and potential BMP pollutant load reduction scenarios for TMDL attainability.

1.2.1. Phosphorus TMDL Attainability

This analysis of existing loads and a review of the Phosphorus TMDLs for the Lower and Upper Charles River watersheds determined that attainability is not possible within the current NPDES regulatory framework. The current regulated areas within the Lower Charles River watershed represent 55% (13,349 lbs. TP) of the total stormwater load (24,475 lbs. TP) within the Lower Charles River watershed, with a TMDL-mandated reduction of 60% (14,718 lbs. TP), leaving a remaining load of 5% (1,369 lbs) unregulated. The current regulated areas within the Upper Charles River watershed represent 26% (18,028 lbs. TP) of the total stormwater load (67,778 lbs. TP) within the Upper Charles River watershed, with a TMDL-mandated reduction from stormwater of 51% (34,589 lbs. TP), leaving a remaining load of 25% (16,560 lbs. TP) unregulated.

However, this analysis determined that the phosphorus TMDL can be met for the Charles River watershed by implementing bioretention BMPs (the best available technology) on currently unregulated properties.

Absent innovative approaches to off-site stormwater collection and treatment for existing impervious land cover not directly regulated under the NPDES program, this analysis finds that attainment of the phosphorus TMDL for the Lower Charles River can be met with on-site bioretention BMPs sized to capture the 1” WQV for all industrial, commercial, and residential parcels larger than 0.05 acres. Similarly, the phosphorus TMDL can be met for the Upper Charles River watershed by implementing bioretention BMPs sized to capture the 1” WQV for all industrial, commercial, and residential parcels larger than 0.25 acres.

For the purposes of this analysis, it was assumed that government-owned properties that drain to an MS4 (e.g. roads, public works yards, municipal buildings, parks, etc.) are regulated under NPDES, and residential, commercial, industrial, agricultural, and open space properties are not.[3] This analysis

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[1] EPA (2012). Fact Sheet For The General Permit For Designated Discharges In The Charles River Watershed In Milford, Bellingham And Franklin Massachusetts. RD Fact Sheet, Office of Ecosystem Protection, U.S. Environmental Protection Agency, Region I, Boston, Massachusetts.
[2] EPA (2012). Attachment 3 to Fact Sheet: Basis for Phosphorus Reduction Requirements. RD Fact Sheet Attachment 3, Office of Ecosystem Protection, U.S. Environmental Protection Agency, Region I, Boston, Massachusetts.
[3] It should be noted that due to the unique geographic characteristics of the Lower Charles watershed and MassGIS land use categorization, a significant category of properties currently unregulated by the NPDES program are characterized as regulated in this analysis. MassGIS groups large privately owned hospitals, colleges, and universities with publicly owned institutions.

assumed that EPA[4] would exercise the authority for use of residual designation to regulate residential, commercial, and industrial properties >0.05 acres in the Lower Charles River watershed and >0.25 acres in the Upper Charles River watershed.[5] A parcel-based pollutant loading analysis identified the minimum parcel area for which RDA could be applied to achieve the required load reductions.

In the Lower Charles River watershed, parcels with an area >0.05 acres encompass 86% of all residential parcels, 84% of commercial parcels, and 91% of industrial parcels, and accounts for 50% of the existing load (15,902 lbs. TP) in the Lower Charles River watershed. For comparison, a target area including parcels >1 acre encompasses just 1% of residential parcels, 6% of commercial parcels, and 24% of industrial parcels and accounts for 12% (3,762 lbs. TP) of the total phosphorus load in the Lower Charles River watershed.

In the Upper Charles River watershed, parcels with an area >0.25 acres encompass 56% of all residential parcels, 61% of commercial parcels, and 85% of industrial parcels, and accounts for 36% of the existing load (21,907 lbs. TP) in the Upper Charles River watershed. In contrast, a target area including parcels >1 acre encompasses just 8% of residential parcels, 23% of commercial parcels, and 54% of industrial parcels and accounts for 20% (12,090 lbs. TP) of the total phosphorus load in the Upper Charles River watershed.

1.2.2. Fecal Coliform TMDL Attainability

Similarly, an analysis of existing loads and a review of the Pathogen TMDL for the Charles River watersheds determined that attainability is not possible through existing NPDES permit categories within the current regulatory framework. The current regulated areas represent 25% (1.30E+16 Fecal Coliform CFUs) of the total load with a TMDL reduction required of 99% (5.16E+16 Fecal Coliform CFUs).

A tremendous 90% reduction in pollutant load could be achieved for fecal coliform in the Lower Charles River watershed, and a substantial 73% reduction in pollutant load could be achieved for fecal coliform in the Upper Charles River watershed by implementing bioretention BMPs sized to capture the 1" WQV for all industrial, commercial, and residential parcels larger than 0.05 acres. While 100% attainability of the fecal coliform TMDL does not appear to be possible under the analytical framework of this analysis, it is important to recognize that significant bacterial load reduction would still bring tremendous benefits. It is possible that bacterial reduction requirements could be achieved with an improved understanding of the system through monitoring and modeling and improvements in BMP technology.

In the Lower Charles River watershed, management of residential, commercial, and industrial parcels area >0.05 acre reduces the existing load by 90% (1.01E+16 Fecal Coliform CFUs). In contrast, a target

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[4] EPA (2012). Fact Sheet for the General Permit For Designated Discharges in the Charles River Watershed in Milford, Bellingham and Franklin Massachusetts. RD Fact Sheet, Office of Ecosystem Protection, U.S. Environmental Protection Agency, Region I, Boston, Massachusetts.

[5] EPA's historic exclusion of single family residential properties from RDA programs, including in the Draft General Permit referenced in note 4, supra, underscores the necessity of directly addressing discharge from larger impervious parcels and incentivizing off-site treatment options to address existing impervious area from small parcels that collectively amount to a significant source by class.

area of all residential, commercial, and industrial parcels >1 acre would remove 50% of the existing load (5.62E+15 Fecal Coliform CFUs).

In the Upper Charles River watershed, management of all residential, commercial, and industrial parcels reduces the existing load by 49% (1.65E+16 Fecal Coliform CFUs). In contrast, a target area of all residential, commercial, and industrial parcels >1 acre would remove 20% of the existing load (6.65E+15 Fecal Coliform CFUs).

Interestingly, in the Upper Charles River watershed a higher proportion of the pathogen load is derived from low- and medium- density residential areas (57%) as compared with phosphorus (30%) (see Table 13). This is a result of higher bacteria loads from single family residential, likely resulting from the use of fertilizer, versus multifamily residential whereas the inverse is true for phosphorous.

1.3. Qualifications and Compensation

1.3.1. Education

Dr. Roseen received a Bachelor of Arts in Environmental Science/Chemistry from Clark University in 1994. Dr. Roseen received a Master of Science in Environmental Science and Engineering from the Colorado School of Mines in 1998 and a Doctor of Philosophy (Ph.D.) in Civil and Waste Resources Engineering from the University of New Hampshire in 2002. Dr. Roseen served as the Director of the University of New Hampshire Stormwater Center from 2004 through 2012, and served as a Research Assistant Professor from 2007-2012. Dr. Roseen is a licensed Professional Engineer in the states of New Hampshire, Massachusetts, and Maine, and is a Diplomat of Water Resources Engineering ("D.WRE"), the highest professional engineering distinction in this area, through the American Academy of Water Resources Engineers.

1.3.2. Professional Experience

Dr. Roseen is the owner and principal at Waterstone Engineering, Inc. and a Water Resources Engineer in New Hampshire who offers municipal and private clients over 25 years of experience in the investigation, design, testing, and implementation of stormwater management. Dr. Roseen has many years of experience in water resources investigations and most recently, led a project team in the development of an Integrated Plan for nutrient management for stormwater and wastewater. This plan has received provisional approval by EPA and would be one of the first in the nation. Dr. Roseen is a licensed professional engineering in NH, ME, and MA. Dr. Roseen is a recognized industry leader in green infrastructure and watershed management, and the recipient of 2010 and 2016 Environmental Merit Awards by the US Environmental Protection Agency Region 1. Dr. Roseen consults nationally and locally on stormwater management and planning and directed the University of New Hampshire Stormwater Center for 10 years, and served as faculty in the Department of Civil Engineering for 5 years, and is deeply versed in the practice, policy, and planning of stormwater management. Dr. Roseen has led the technical analysis of dozens of nutrient and contaminant studies examining surface water pathways, system performance, management strategies, and system optimization.

Dr. Roseen has also served as Research Assistant Professor for five years. His areas of expertise include water resources engineering, stormwater management (including low impact development design), and porous pavements. Dr. Roseen also possesses additional expertise in water resource engineering including hydrology and hydraulics evaluations, stream restoration and enhancement alternatives, dam removal assessment, groundwater investigations, nutrient and TMDL studies, remote sensing, and GIS applications. Dr. Roseen has also taught classes on Stormwater Management and Design, Fluid Mechanics, and Hydrologic Monitoring and have lectured frequently on these subjects. He is frequently called upon as an expert on stormwater management locally, regionally, and nationally.

As a consultant, Dr. Roseen has worked for private clients engaged in site development involving project permitting, design, erosion and sediment control plans, construction management plans, construction inspections, construction inspection and reporting, water quality performance monitoring and more.

Dr. Roseen's current professional activities include participating in the Management Committee and Technical Advisory Committee for the Piscataqua Regions Estuaries Program. Dr. Roseen was the Chair of the ASCE EWRI 2016 International Low Impact Development Conference, an annual event that draws participants from around the world to discuss advances in water resources engineering. Dr. Roseen also participated as a Control Group member for the ASCE Urban Water Resources Research Council (UWRRC). Dr. Roseen has also served on the ASCE Task Committee on Guidelines for Certification of Manufactured Stormwater BMPs, EWRI Permeable Pavement Technical Committee, and the Hydrology, Hydraulics, and Water Quality Committee of the Transportation Research Board. Dr. Roseen has also been the author or co-author of over two dozen professional publications on the topics of stormwater runoff, mitigation measures, best management practices (BMPs), etc. He has also been the recipient of several awards and other honors for his work, including the 2010 Outstanding Civil Engineering Achievement Award from the New Hampshire Chapter of the American Society of Civil Engineers, and an Environmental Merit Award from the EPA. He has extensive experience working with local, state, and regional agencies and participates on a national level for USEPA Headquarters, WEF, and the White Council on Environmental Quality on urban retrofit innovations and next generation LID/GI technology and financing solutions. His resume, including a list of all publications over the past 10 years and all cases in which he has served as an expert in for the past 4 years, is provided in Appendix A: Expert Witness Resume, Publications Authored in Previous 10 years, Expert Witness Experience

1.3.3. Cases During the Previous 4 Years I have Testified as an Expert at Trial or by Deposition, or Provided Expert Witness Services

Construction General Permit (CGP), and Clean Water Act Expert Services

Dr. Roseen is currently providing expert consultation, analysis, modeling, advice, reports and testimony in regards to construction general permit compliance, erosion and sedimentation control, and monitoring. Such services include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of defendants' facilities.

Municipal Separate Storm Sewer System (MS4) Permit and Clean Water Act Expert Services

Dr. Roseen is currently providing expert consultation, analysis, modelling, advice, reports and testimony regarding stormwater discharges in regards to MS4 violations under the Clean Water Act. Such services may include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of defendants' facilities. This service is being provided for the plaintiff for two (2) cases of significant size geographically and in project scope.

Multi Sector General Permit, Stormwater Pollution Prevention Plan, and Clean Water Act Expert Services

Dr. Roseen is currently providing expert consultation, analysis, modelling, advice, reports and testimony regarding stormwater discharges in regards to MSGP under the Clean Water Act. Such services may include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of facilities. This service is being provided for the plaintiff for over ten (10) separate cases in the northeastern United States.

Expert Study and Testimony for Erosion and Sediment Control Litigation

Dr. Roseen is currently providing expert study and testimony in defense of an undisclosed Federal Client in a $25-million-dollar lawsuit from a private entity. The plaintiff alleges impacts from upstream channel erosion and sediment transport. The efforts examine urban runoff and off-site impacts to a downstream channel and subsequent erosion and sediment transport into the downstream storm sewer system.

1.3.4. Compensation

The flat rate for all work including future deposition and testimony is $140 per hour. The compensation for this effort is entirely unrelated to the outcome of this matter.

2. Introduction

2.1. Overview

Phosphorus and bacterial loads were calculated for the Charles River Watershed for the purpose of identifying if required reductions for the 2007-2011 Statewide TMDLs are attainable within the existing NPDES permit programs. The analytical methods used to determine the pollutant loads, waste load allocations, and assess BMP performance are consistent with those published by EPA[6], USGS[7] and others[8], and are generally accepted for water quality permitting purposes.

A pollutant load analysis was conducted using published contaminant concentrations and pollutant load export rates (existing[9] and derived) for specific hydrologic response units (HRUs) for respective combinations of land use, soil type, and impervious cover. This included a review of relevant federal and state permitting documents[10] for the water bodies of interest and related studies[7,8] for methods assessment and modeling of bacteria and phosphorous loads.

The pollutant load reduction potential for each watershed was assessed assuming that new development, redevelopment, or installation of stormwater best management practice (BMP) retrofits in all runoff-producing areas would provide treatment for the 1” water quality volume (WQV), the volume required to capture 1” of runoff from a given drainage area. Designing systems to capture the 1” WQV takes advantage of the ‘first flush’ principle which states that 90% of pollutants on a landscape are washed off in the first 1” of rainfall. The pollutant removal efficiency for bioretention systems from EPA (2010) were applied to each watershed to determine the upper bound for pollutant load reduction attainability.

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6 EPA (2010a)

7 Zarriello, P. J. and L. K. Barlow (2002)

8 Gamache, M., M. Heineman, et al. (2013)

9 EPA, 2016. MA Small MS4 General Permit, Appendix F

This represents a conservative assessment given that site-specific feasibility for stormwater management was not considered. It is unlikely that stormwater management (SWM) would actually be required for all impervious areas (IA). Taking this approach identifies the best-case scenario for pollutant load reduction, useful for evaluating if a given TMDL is even theoretically achievable within the current regulatory framework.

Finally, a parcel-based analysis was performed to assess how different potential RDA scenarios would impact TMDL attainability in the Upper and Lower Charles River watersheds. This analysis is not intended to imply that the purpose of any single RDA scenario should be to achieve full attainment of a given TMDL. Rather, it illustrates the inability of current NPDES permits for stormwater to meet TMDL requirements for the Charles River and provides the basis for expanded additional NPDES permitting of stormwater sources. The results of this analysis suggest that, if the best available BMP technology is applied to all residential, commercial, and industrial parcels larger than 0.05 acres in the Lower Charles River watershed, and all residential, commercial, and industrial parcels larger than 0.25 acres in the Upper Charles River watershed (including areas currently-regulated under NPDES) then the phosphorus TMDLs are attainable. However, there is no realistic scenario in which the Charles River 2007 fecal coliform TMDL is attainable with current technology, regardless of which land uses are included or excluded from an RDA process.

2.2. Study Area

The entire Charles River watershed drains a watershed area of 311 square miles. The upper region is a 264 square mile watershed area that drains over the Watertown Dam into the Lower Charles River. The remaining 47 square miles drain directly into the Lower Charles from small tributary streams that are mostly enclosed and piped stormwater drainage systems serving the surrounding communities. The Charles River starts above Echo Lake in Hopkinton and flows about 79 miles in a northeasterly direction to the coast. The river flows through many of the surrounding Boston communities, touching 23 towns and five counties, before discharging into Boston Harbor. The river drops 310 feet in its journey to the coast. The steepest elevation change is in the headwaters with the rest of the watershed being gently sloped.

The Charles River hydrology is impacted by 19 dams along the length of the river and substantial natural storage in the upper and middle watershed. MassDEP has estimated that it takes three to four days for peak flows in the upper portion to reach the Lower Charles.

Given the level of urbanization and the extent of impervious cover (e.g., streets and parking lots), the Lower Charles River's watershed has lost much of its natural capacity to absorb rainfall and remove pollutants by filtering the runoff through vegetative cover and the soil matrix. Thus, the concentrations of pollutants in stormwater discharges to the Lower Charles River have become elevated. Urbanized watersheds generate substantially more runoff volume than undeveloped watersheds because of the greater extent of impervious cover (and less opportunity for infiltration) in urbanized watersheds. The higher concentrations and the greater volumes of stormwater associated with the urban watershed results in much greater amounts of nutrients and bacteria entering the river than would come from a naturally vegetated watershed. Also, the higher storm flows further increase the overall stormwater pollutant load because of erosion and flooding (Schueler 1987).

Both the Upper/Middle and Lower Charles River are designated as a Class B water under the Massachusetts water quality standards [314 CMR 4.05(3)b]. Class B waters are designated as capable of providing and supporting habitat for fish and other aquatic wildlife, and for primary and secondary contact recreation.

2.2.1. Lower Charles River

The Lower Charles watershed is 47 square miles with an impounded section of the Charles River that is 8.6 miles long, covers approximately 675 acres. The Lower Charles River is in the heart of a highly urbanized area, bordered directly by the municipalities of Boston, Cambridge, Watertown, and Newton. The Lower Charles River is also the focal point of the Charles River Reservation, a 19,500 acre urban park that serves as a major open-space resource for the Boston metropolitan area.

2.2.2. Upper Charles River

The Upper/Middle Charles watershed is 70 miles long, covers 265 square miles in area, and ends at the Watertown Dam where it connects to the Lower Charles. The watershed contains 5 communities in their entirety (Medway, Millis, Needham, Waltham, and Wellesley) and includes portions of 28 more (Arlington, Ashland, Bellingham, Belmont, Boston, Brookline, Dedham, Dover, Foxborough, Franklin, Holliston, Hopedale, Hopkinton, Lexington, Lincoln, Medfield, Mendon, Milford, Natick, Newton, Norfolk, Sherborn, Walpole, Watertown, Wayland, Weston, Westwood, and Wrentham).

2.3. Pollutants of Concern

Between 1998 and 2001 the USGS conducted three detailed monitoring investigations of the Lower Charles River that have contributed substantially to the current understanding of water quality conditions of the Lower Charles River. These investigations include (1) an examination of the extent and effects of salt water intrusion into the Lower Charles River from Boston Harbor through the New Charles River Dam, (2) a determination of the distribution and characteristics of bottom sediments, and (3) a pollutant load study that characterized the sources and loading of several pollutants to the Lower Charles River.

During August 2006, EPA collected an algal sample in the downstream portion of the Lower Charles because of the obvious presence of a very severe bloom. The bloom consisted of extremely high cell counts of over one-million cells/milliliter of cyanobacteria and included an organism, microcystes, that is toxic at elevated levels. The sample was analyzed by MassDEP and led to follow-up algal monitoring in the Lower Charles by the Massachusetts Department of Conservation and Recreation and MassDEP.

In the Upper/Middle Charles River, stormwater runoff[11] discharges high levels of phosphorous into the Charles River, which triggers excessive algae and aquatic plant growth and low and/or highly variable dissolved oxygen levels. Approximately 93% of the total annual phosphorous load to the Upper/Middle Charles river is attributed to waste water treatment facilities and stormwater discharges.

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[11] Stormwater runoff includes inputs from fertilized soils and lawns; leaf litter and other vegetative debris; car wash products and some detergents; auto exhaust, fuel, and lubricants; and pet waste. Developed land uses including high-density residential, commercial, and industrial have higher loadings of phosphorus per unit area. *Upper/Middle Charles Nutrient TMDL* at 3.

Because of these impairments, Massachusetts developed two Nutrient TMDLs. One for the Lower Charles River ("Lower Charles TMDL") and one for the Upper/Middle Charles River ("Upper/Middle Charles TMDL"). EPA, developed both the Lower and Upper/Middle Charles TMDLs with the Massachusetts Department of Environmental Protection. EPA approved the Lower Charles TMDL on October 17, 2008. On June 10, 2011, EPA approved the Upper/Middle Charles TMDL.

Currently, stormwater drainage systems exist throughout the entirety of the Charles River watershed. These systems include privately owned drainage systems serving commercial areas, small construction sites less than an acre in size, certain industrial uses, and small municipal drainage systems. Many of these stormwater drainage systems are currently unregulated by the NPDES permit program. To achieve the required reductions in the Upper/Middle and Lower Charles River, reductions in stormwater phosphorous loads, based upon land use, must be decreased.

3. Regulatory Background

3.1. TMDL Process

As per EPA[12], a TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant.

Pollutant sources are characterized as either point sources that receive a wasteload allocation (WLA), or nonpoint sources that receive a load allocation (LA). For purposes of assigning WLAs, point sources include all sources subject to regulation under the National Pollutant Discharge Elimination System (NPDES) program, e.g. wastewater treatment facilities, some stormwater discharges and concentrated animal feeding operations (CAFOs). For purposes of assigning LAs, nonpoint sources include all remaining sources of the pollutant as well as natural background sources. TMDLs must also account for seasonal variations in water quality, and include a margin of safety (MOS) to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards.

The objective of a TMDL is to determine the loading capacity of the waterbody and to allocate that load among different pollutant sources so that the appropriate control actions can be taken and water quality standards achieved. The TMDL process is important for improving water quality because it serves as a link in the chain between water quality standards and implementation of control actions designed to attain those standards.

TMDLs are developed using a range of techniques, from simple mass balance calculations to complex water quality modeling approaches. The degree of analysis varies based on a variety of factors including the waterbody type, complexity of flow conditions and pollutant causing the impairment. All contributing sources of the pollutants (point and nonpoint sources) are identified, and they are allocated a portion of the allowable load that usually contemplates a reduction in their pollution discharge in order to help solve the problem. Natural background sources, seasonal variations and a margin of safety are all taken into account in the allocations.

It is important to note that, throughout the remainder of this document, a distinction will be made between the terms 'total maximum daily load', which will be used to refer to the numeric load target for a given pollutant, and 'TMDL', which will be used to refer to the actual document generated by EPA that defines and describes the total maximum daily load.

3.2. Existing TMDLs

There are three TMDLs for the Charles River that this analysis has drawn upon: 1) the 2007 Pathogen TMDL for the Charles River Watershed; 2) the 2007 Nutrient TMDL for the Lower Charles River Watershed; and 3) the 2011 Nutrient TMDL for the Upper/Middle Charles River Watershed. The information contained within this section represents a summary of data presented in these TMDLs.

[12] https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls

3.2.1. Phosphorus TMDLs

Phosphorus is the nutrient of concern in the Charles River that is addressed by the nutrient TMDLs due to its contribution to algal blooms in the river (phosphorus was identified as the limiting nutrient for aquatic plant growth). There are no numeric criteria for phosphorus, so numerical targets were calculated to address the excessive algal biomass. Ultimately, chlorophyll-a was used as a surrogate water quality indicator. A seasonal average of 10 ug/L and a maximum of 18.9 ug/L was chosen as acceptable targets for the Charles River.

A hydrologic water-quality model (HSPF) was created to evaluate the relationship between phosphorus loading and algal growth in both the Upper/Middle and Lower Charles River watersheds and to evaluate nutrient reduction scenarios to meet the TMDL.

The Lower Charles TMDL analysis determined that phosphorus loading must be reduced by 48% upstream of the Watertown Dam and by 62% in each of the subwatersheds draining to the Lower Charles River in order for phosphorous loads to be met. The Lower Charles TMDL determined that stormwater runoff constitutes a major source of phosphorus loading that must be controlled and/or eliminated, including from lands with higher percentages of impervious cover, *i.e.* commercial, industrial, institutional, and high density residential, which generate more surface runoff. The Lower Charles TMDL determined that current controls for stormwater runoff are inadequate to meet the TMDL's water quality goals for nutrients. The data included in and supporting the TMDL "demonstrates that additional controls may well be needed on many storm water discharges."

The target phosphorus load in the Lower Charles River Watershed was established to achieve instream water quality targets. Results of the analysis show that a 54% total reduction is required to meet water quality standards. Interestingly, the TMDL allocates none of the load to the LA, stating that there is insufficient information to distinguish the contribution from point and non-point sources. The current loads, TMDLs, and required percent reductions were broken down by subwatershed and land use type. These are shown in Tables 1 and 2, below.

Table 1 –Upper and Lower Charles River Watershed Phosphorus Loading by Land Use Type from 2007 TMDL

Land Use Category	**Existing Load**		**TMDL Load**		**Reduction**
	(kg/yr)	(lbs/yr)	(kg/yr)	(lbs/yr)	%
Commercial	3,676	8,102	1,286	2,834	65
Industrial	5,718	12,602	1,972	4,346	65
High Density Residential	10,437	23,003	3,600	7,934	65
Medium Density Residential	5,278	11,633	1,820	4,011	65
Low Density Residential	503	1,109	276	608	45
Agriculture	1,042	2,297	672	1,481	35
Forest	4,018	8,856	4,018	8,856	0
Open Land	289	637	187	412	35
POTW + CSO	9,088	20,030	4,753	10,476	48
Total	**40,050**	**88,270**	**18,565**	**40,917**	**54**

Table 2 – Lower Charles Phosphorus Loading by Subwatershed from 2007 TMDL

Source	Existing Load		TMDL Load		Reduction
	(kg/yr)	(lbs/yr)	(kg/yr)	(lbs/yr)	%
Upstream Watershed at Watertown Dam	28,925	63,751	15,109	33,300	48
CSOs	2,263	4,988	90	198	96
Stony Brook Watershed	5,123	11,291	1,950	4,298	62
Muddy River Watershed	1,549	3,414	590	1,300	62
Laundry Brook Watershed	409	901	155	342	62
Faneuil Brook Watershed	326	719	125	276	62
Other Drainage Areas	1,455	3,207	550	1,212	62
Total	40,050	88,270	18,565	40,917	54

The Upper/Middle Charles TMDL, finalized after approval of the Lower Charles TMDL, provides a maximum phosphorus allocation for the Upper/Middle Charles River above the Watertown Dam. The Upper/Middle Charles TMDL was developed to achieve water quality standards in the Upper/Middle portions of the river and also to meet the phosphorus load allocation established in the Lower Charles TMDL. To achieve these dual goals, the Upper/Middle Charles TMDL requires reductions in stormwater phosphorus loads based upon land use. The Upper/Middle Charles TMDL places all stormwater pollution sources in the WLA and requires a 51% reduction in annual phosphorus load from stormwater. To achieve this reduction, the TMDL "sets phosphorus discharge limits for stormwater by land use category." It establishes a 65% reduction in phosphorus loading from all intense land uses (commercial, industrial, institutional, and high-density residential sites).

The target phosphorus load in the Upper/Middle Charles River Watershed was established to meet two goals: 1) meeting the inlet load specified at Watertown Dam in the Lower Charles River TMDL; and 2) ensuring that phosphorus loading in the Upper/Middle watershed achieved instream water quality targets. Results from the analysis showed that an overall phosphorus load reduction of 50% would be necessary (this includes a 6% margin of safety). This was broken down to a 66% reduction from wastewater discharges (WLA) and a 51% reduction from stormwater (LA). For non-point sources, the TMDL establishes discharge limits by land use, as shown in Table 3, below.

Table 3 – Upper Charles Annual TP Loads for Current and TMDL from 2011 TMDL

Source	Current Load		Reduction (%)	TMDL Load	
	(kg/yr)	(lbs/yr)	(%)	(kg/yr)	(lbs/yr)
Low Density Res.	4,979	10,974	45	2,739	6,037
Medium Density Res.	5,505	12,133	65	1,927	4,247
High Density Res.	5,964	13,145	65	2,088	4,602
Commercial/Industrial	6,294	13,872	65	2,203	4,855
Transportation	2,167	4,776	65	759	1,673
Open/Agriculture	1,504	3,315	35	977	2,153
Forest	4,394	9,684	0	4,394	9,684
Stormwater Total (WLA)	30,808	67,901	51	15,086	33,250
Wastewater	9,611	21,183	66	3,296	7,264
Nonpoint & Background	2,801	6,173	21	2,211	4,873
Losses	-13,348	-29,419	58	-5625	-12,398
Total Allocation	**29,872**	**65,838**	**50**	**14,968**	**32,998**

3.2.2. *Pathogen TMDL*

Stormwater discharges are a major source of bacterial pollution throughout the Charles River watershed. EPA has noted that "[p]olluted stormwater runoff causes serious water quality problems, and is the next great challenge for cleaning the Charles River."[13] As such, all 35 Charles River watershed communities are regulated under EPA's municipal stormwater program.

Because of these impairments, Massachusetts developed a pathogen TMDL for the Charles River ("Charles Pathogen TMDL"). The Commonwealth of Massachusetts submitted the Charles River Pathogen TMDL to EPA for approval on February 9, 2007. After deliberation and consideration of the underlying record, EPA issued a determination approving the Charles Pathogen TMDL on May 22, 2007. The Charles Pathogen TMDL identified stormwater as a significant contributor of pathogen pollution in the Charles River watershed. Illicit sewer connections into storm drains result in direct discharges of sewage via the storm drainage system outfalls. It is estimated by EPA New England that over one million gallons per day of illicit discharges were removed in the last decade in the greater Boston area.

The Charles Pathogen TMDL assigned all stormwater runoff[14] from impervious cover to the Wasteload Allocation. The Charles Pathogen TMDL analysis determined that stormwater discharges from land use categories including Multi-family Residential, Commercial, and Industrial "typically" contain bacteria "at levels sufficient to cause water quality problems." The Charles Pathogen TMDL determined that for stormwater runoff, "the current level of control is inadequate for standards to be attained." The Charles Pathogen TMDL recommends a "basin-wide implementation approach."

The Charles River contains segments classified as Class A waterbodies and others classified as Class B waterbodies. The relevant WQS are as follows:

> Class A waterbodies – fecal coliform bacteria shall not exceed an arithmetic mean of 20 organisms per 100 mL in any representative set of samples, nor shall 10% of the samples exceed 100 organisms per 100 mL.
>
> Class B waterbodies – fecal coliform bacteria shall not exceed an arithmetic mean of 200 organisms per 100 mL in any representative set of samples, nor shall 10% of the samples exceed 400 organisms per 100 mL.

MassDEP has established daily concentration total maximum daily load targets, estimates of necessary percent reductions in loading for each priority segment of the Charles River, and also maximum daily loads based on expected streamflows. In general, their analysis suggests that fecal coliform loadings will need to be reduced by more than 90% to meet applicable standards. 20 segments of the Charles River have been found to contain indicator bacteria in excess of Massachusetts Water Quality Standards, as shown in Figure 1.

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[13] EPA Region 1, "Stormwater Pollution Tackled to Improve Water Quality in Charles River" (Nov. 17, 2008), https://archive.epa.gov/epapages/newsroom_archive/newsreleases/99312d3532cc28cf85257504005a16cc.html.

[14] Storm water runoff can be categorized in two forms; 1) point source discharges (from piped systems) and 2) nonpoint source discharges (includes sheet flow or direct runoff). *Final Pathogen TMDL for the Charles River Watershed*, at 68 (2007).

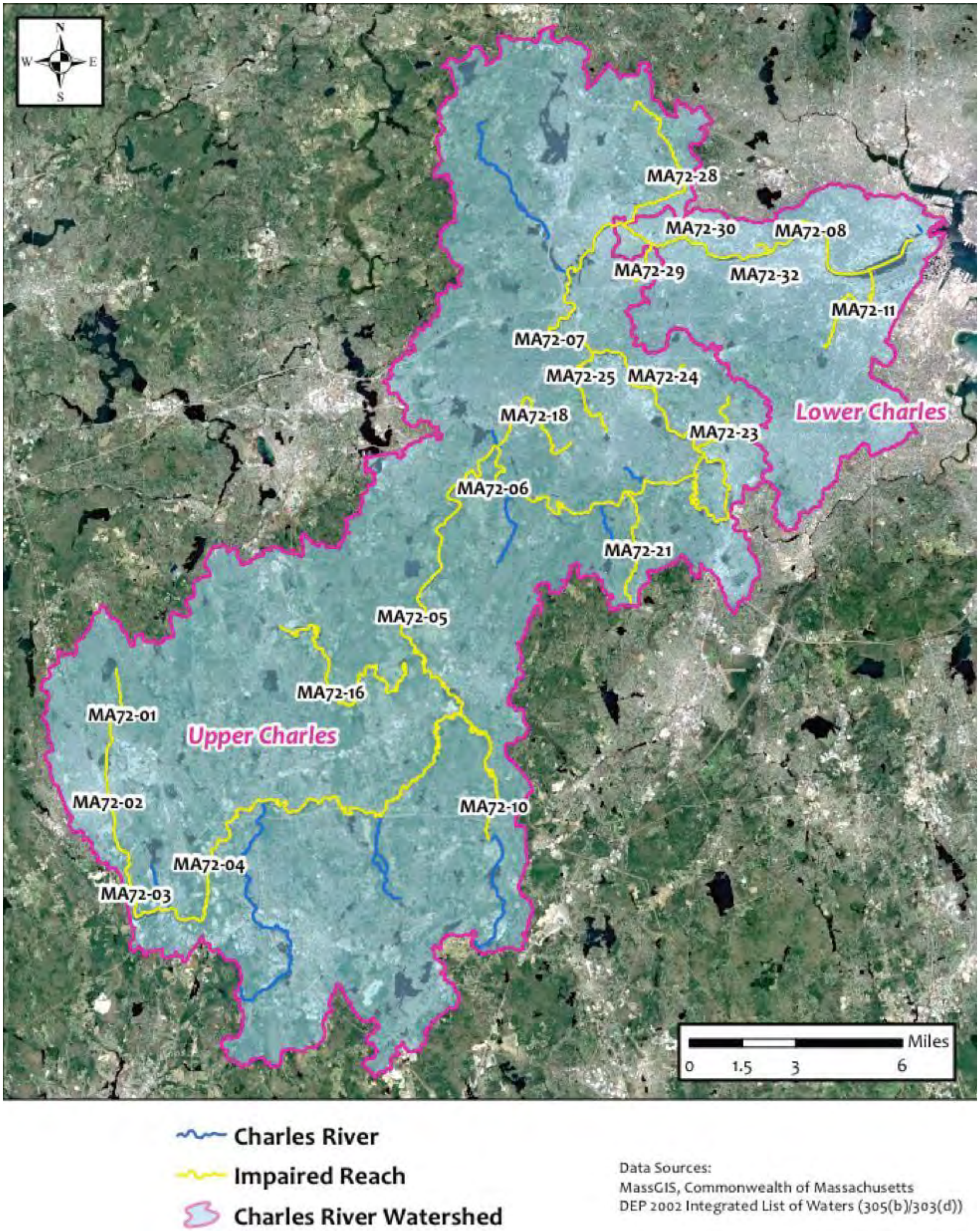

Figure 1 - Impaired Segments of the Charles River

Taking a conservative approach, MassDEP calculated required reductions to meet the 200 FC/100mL using the highest observed concentration of fecal coliform from either dry or wet weather samples. The following steps summarize their approach:

> *1. Select highest indicator bacteria (fecal coliform in this case) concentration from all current samples taken at a location or within a segment.*
>
> *2. For each station or segment, calculate the percent reduction needed to meet 200 FC/100ml (e.g., if the highest value from the samples is 2000 FC/100mL, the reduction needed at that location is: (2000-200)/2000= 90% reduction*
>
> *3. The highest percent reduction needed is the implementation target for that segment in which the samples were collected.*

The results of these calculations for each segment are given in Table 4, below.

Table 4 - Estimated Reductions to Meet WQS from 2007 TMDL

Segment	Maximum Fecal Coliform Concentration / 100mL	Estimate Required Reduction to meet Water Quality Standard (Criterion = geometric mean 200 FC/100mL)
MA72-01	No Sample Exceeded	0
MA72-02	82,000	99.8%
MA72-03	3,200	93.8%
MA72-04	5,600	96.4%
MA72-05	4,800	95.9%
MA72-10	4,700	95.7%
MA72-16	600	66.7%
MA72-06	3,100	93.5%
MA72-18	4,400	95.4%
MA72-07	17,000	98.8%
MA72-21	600	66.7%
MA72-23	7,000	97.1%
MA72-24	4,200	95.2%
MA72-25	450	55.5%
MA72-28	12,000	98.3%
MA72-29	50,000	99.6%
MA72-08	30,000	99.3%
MA72-30	44,000	99.5%
MA72-32	No Data	No Data
MA72-11	38,000	99.5%

Using average daily streamflows (50% exceedance) for each priority segment, a maximum daily load was calculated by multiplying the flow by the applicable criterion for bacteria, in this case the geometric mean. The portion of this estimated load that is attributed to stormwater is based on the ratio of pervious to impervious surfaces in the drainage area for each segment, with runoff from impervious areas assumed to be captured by a sewer system (WLA as point sources) and runoff from pervious areas assumed to reach the river untreated (LA as non-point sources). The total maximum daily load contributions from stormwater for each segment are shown in Table 5, below.

Table 5 - WLA and LA TMDL by Segment from 2007 TMDL

Segment	Drainage Area	Impervious Cover	TMDL @ Average Flow	Stormwater	
ID	Sq-mi	%	FC per Day	**WLA Load** FC per Day	**LA Load** FC per Day
MA72-01	0.26	7.5	1.44E+09	1.1E+08	1.3E+09
MA72-02	11.76	15.5	6.60E+10	1.0E+10	5.6E+10
MA72-03	10.0	14.4	5.62E+10	8.1E+09	4.8E+10
MA72-04	15.0	12.4	8.42E+10	1.0E+10	7.4E+10
MA72-05	25.0	10.4	1.40E+11	1.4E+10	1.3E+11
MA72-10	1.37	7.8	7.70E+09	6.0E+08	7.1E+09
MA72-16	2.45	9.7	1.38E+10	1.3E+09	1.2E+10
MA72-06	19.50	10.5	1.10E+11	1.1E+10	9.8E+10
MA72-18	0.81	15.3	4.58E+09	7.0E+08	3.9E+09
MA72-07	37.13	13.7	2.09E+11	2.9E+10	1.8E+11
MA72-21	0.28	10.4	1.59E+09	1.7E+08	1.4E+09
MA72-23	0.74	25.9	4.18E+09	1.1E+09	3.1E+09
MA72-24	38.38	30.1	2.16E+11	6.5E+10	1.5E+11
MA72-25	0.74	19.0	4.14E+09	7.9E+08	3.4E+09
MA72-28	2.55	22.4	1.43E+10	3.2E+09	1.1E+10
MA72-29	0.88	32.2	4.94E+09	1.6E+09	3.3E+09
MA72-08	50.44	16.3	2.83E+11	4.6E+10	2.4E+11
MA72-30	37.15	21.2	2.09E+11	4.4E+10	1.6E+11
MA72-32	0.28	48.7	1.56E+09	7.6E+08	8.0E+08
MA72-11	1.93	29.5	1.08E+10	3.2E+09	7.6E+09

3.3. Residual Designation Authority

3.3.1. Role of RDA

Under the Clean Water Act "Residual Designation Authority" (RDA) found in § 402(p)(2)(E) of the Clean Water Act, and 40 C.F.R. § 122.26(a)(9)(i)(C) and (D), EPA can require permits for new and existing stormwater discharges that contribute to a water quality violation or are a significant contributor of pollutants to waters of the United States. RDA has been used to issue NPDES permits to control unregulated discharges—including discharges from wastewater treatment facilities and MS4 communities—to include requirements for pollutant reduction consistent with the wasteload allocations of a TMDL. Within TMDLs, two major waste sources are generally defined, and allocations set: 1) a wasteload allocation (WLA), which is generally defined as the sum of the pollutant load discharged from all "discrete conveyances" contributing to the impairment, such as discharge pipes or ditches and is regulated under a NPDES permit; and 2) a load allocation (LA), which is the sum of the remaining sources such as runoff, groundwater and atmospheric deposition that are more diffuse and not subject to regulation under a NPDES permit. This division occasionally causes confusion as certain classes of stormwater are regulated under the various stormwater permits (i.e., MS4, industrial stormwater, and construction stormwater) that were previously considered non-point sources. But, because they come under a permit, they become part of the WLA; nearly identical stormwater sources in non-MS4 areas are not regulated and remain in the LA and are not typically subject to an NPDES permit.

Since 2008, EPA Region 1 has exercised RDA in watersheds in Maine and Vermont where existing programs were not adequately addressing stormwater. In these instances, RDA was used to address sources of pollution not covered under existing NPDES programs such as communities outside of the MS4 jurisdiction, and large unregulated impervious areas such as malls and shopping centers.

Stormwater management programs are being implemented in impaired streams in South Burlington, Vermont and in Long Creek and around South Portland, Maine. Those programs grew from residual designation determinations requiring stormwater controls on previously unregulated discharges and provide a third regional model for the designation and permitting of stormwater discharges to impaired waters, a significant environmental concern in New England[4]. In these cases, the TMDLs address severe water quality impairments resulting from nutrients and bacteria in stormwater. At the time of the establishment of the TMDLs, NPDES stormwater permitting addressed only discharges from Municipal Separate Storm Sewer Systems ("MS4s"), limited industrial activity sectors, and construction activities disturbing one or more acres of land. In these cases, EPA has taken the position that the existing permitting regime is not sufficiently comprehensive to achieve the necessary cuts in WLAs and that new strategies are needed to implement the TMDL. As such, EPA has expanded the scope of its stormwater permitting program in these instances by including large impervious areas primarily in commercial and industrial use to which TMDLs attribute significant pollutant loads through the use of RDA.

3.3.2. Unregulated Properties and Designated Discharge

EPA applies the designated discharge determination to cover discharges that flow directly into surface waters and its tributaries through MS4 systems or other private or public conveyance systems. Specifically, local state and federal government properties that discharge wholly into an MS4 owned and operated by the government unit need not be included. Those discharges are already being addressed by the government unit under its MS4 permit. However, a nongovernment property that discharges into an MS4 system must be counted. In the instance of EPA's proposed (but not implemented) draft RDA pilot in the Upper Charles River watershed, EPA defined "designated discharge" as those properties typically with a commercial land use designation with two or more acres of impervious surfaces located: (1) in the watershed; (2) in whole or in part in the municipalities; and (3) on a single lot or two or more contiguous lots[1]. The following impervious surfaces are not included: Any impervious surfaces associated solely with any of the following land uses:

a. Sporting and recreational camps;
b. Recreational vehicle parks and campsites;
c. Manufactured housing communities;
d. Detached single-family homes located on individual lots;
e. Stand-alone multi-family houses with four or fewer units; and
f. Any property owned by a local, state or federal government unit where the property discharges wholly into an MS4 system operated by that local, state or federal government unit that has a valid NPDES permit.

For the purposes of this study, it was assumed RDA would be applied to residential, commercial, and industrial land uses. Figure 4 illustrates areas currently covered under the NPDES jurisdiction, and areas that would need to be designated under RDA to achieve attainment.

3.4. Small MS4 General Permit Updates 2016

Aspects of this analysis are intended to be consistent to the extent possible with recent advancements in NPDES permitting by EPA. Elements of the 2016 updates to the *Massachusetts Small MS4 General Permit* include requirements for BMPs to be optimized for pollutant removal, retrofit inventory and priority ranking to reduce discharges, and Pollutant Source Identification Reporting.

4. Methods

4.1. Land Use Assessment

The Charles River runs for 79 miles before draining into the Atlantic Ocean out of Boston Harbor. The entire Charles River watershed covers 311 square miles and is commonly divided into the Upper and Lower Charles River Watersheds, with the Watertown Dam separating the two.

The Upper Charles River Watershed covers 264 square miles, 16% of which is impervious cover as shown in Figure 2. The land use breakdown for the Upper Charles River Watershed is shown in Table 1 and Figure 3.

Table 6 - Land Use / Land Cover in the Upper Charles River Watershed

Land Use	Area (acres)	% of Total Area	% Impervious
Open Land	6,278	3.7%	18%
Low Density Residential	20,305	12.0%	23%
Medium Density Residential	16,609	9.8%	28%
High Density Residential	11,285	6.7%	41%
Commercial and Industrial	12,739	7.5%	59%
Highway	2,339	1.4%	58%
Agriculture	5,241	3.1%	6%
Forest	80,932	47.9%	3%
Water	13,383	7.9%	0%
Total	**169,111**		**16%**

The Lower Charles River Watershed covers 47 square miles, 51% of which is impervious cover as shown in Figure 2. The land use breakdown for the Upper / Middle Charles River Watershed is shown in Table 2 and Figure 3.

Table 7 - Land Use / Land Cover in the Lower Charles River Watershed

Land Use	Area (acres)	% of Total Area	% Impervious
Open Land	2,940	9.9%	23%
Low Density Residential	748	2.5%	27%
Medium Density Residential	1,327	4.5%	34%
High Density Residential	12,048	40.4%	58%
Commercial and Industrial	7,619	25.6%	76%
Highway	957	3.2%	88%
Agriculture	121	0.4%	14%
Forest	2,886	9.7%	9%
Water	1,143	3.8%	3%
Total	**29,789**	**-**	**51%**

In order to perform the pollutant load analysis and waste load allocation, detailed land use data from a 2005 Massachusetts GIS dataset[15] was generalized to fit into categories for which pollutant load export rates are available. Table 8 lists the detailed land uses and resultant categorization into more generalized land uses. Figures 2 and 3 show the land use, impervious cover, and soil type distribution for the Charles River watershed. Lands classified as 'Forest' and 'Water' were excluded from pollutant load reduction calculations.

[15] https://docs.digital.mass.gov/dataset/massgis-data-land-use-2005

Table 8 - Land use category generalization

Original MassGIS Detailed Land Use	Converted to…for PLA	Converted to…for RDA
Brushland/Successional	Forest	RDA – Forest
Cemetery	Open Land	RDA – Open Space
Commercial	Commercial and Industrial	RDA – Commercial
Cranberry Bog	Agriculture	RDA – Agriculture
Cropland	Agriculture	RDA – Agriculture
Forest	Forest	RDA – Forest
Forested Wetland	Forest	Water
Golf Course	Open Land	RDA – Open Space
High Density Residential	High Density Residential	RDA – Residential
Industrial	Commercial and Industrial	RDA – Industrial
Junkyard	Commercial and Industrial	TMDL
Low Density Residential	Low Density Residential	RDA – Residential
Marina	Commercial and Industrial	TMDL
Medium Density Residential	Medium Density Residential	RDA – Residential
Mining	Commercial and Industrial	RDA – Industrial
Multi-Family Residential	High Density Residential	RDA – Residential
Non-Forested Wetland	Water	Water
Nursery	Agriculture	RDA – Agriculture
Open Land	Open Land	RDA – Open Space
Orchard	Agriculture	RDA – Agriculture
Participation Recreation	Open Land	RDA – Open Space
Pasture	Agriculture	RDA – Agriculture
Powerline/Utility	Commercial and Industrial	TMDL
Saltwater Sandy Beach	Open Land	Water
Saltwater Wetland	Water	Water
Spectator Recreation	Commercial and Industrial	RDA – Open Space
Transitional	Open Land	RDA – Open Space
Transportation	Highway	TMDL
Urban Public/Institutional[16]	Commercial and Industrial	TMDL
Very Low Density Residential	Low Density Residential	RDA – Residential
Waste Disposal	Commercial and Industrial	TMDL
Water	Water	Water
Water-Based Recreation	Water	Water

[16] For this category, MassGIS combines publicly-owned parcels with unregulated parcels sharing runoff characteristics with Multi-Family Residential and Commercial land uses, such as private educational institutions and hospitals. Based on available information about private institutional land uses, EPA should structure any RDA program so that private institutional properties are included, as EPA Region 1 did in the Draft General Permit for RDA in the Upper Charles.

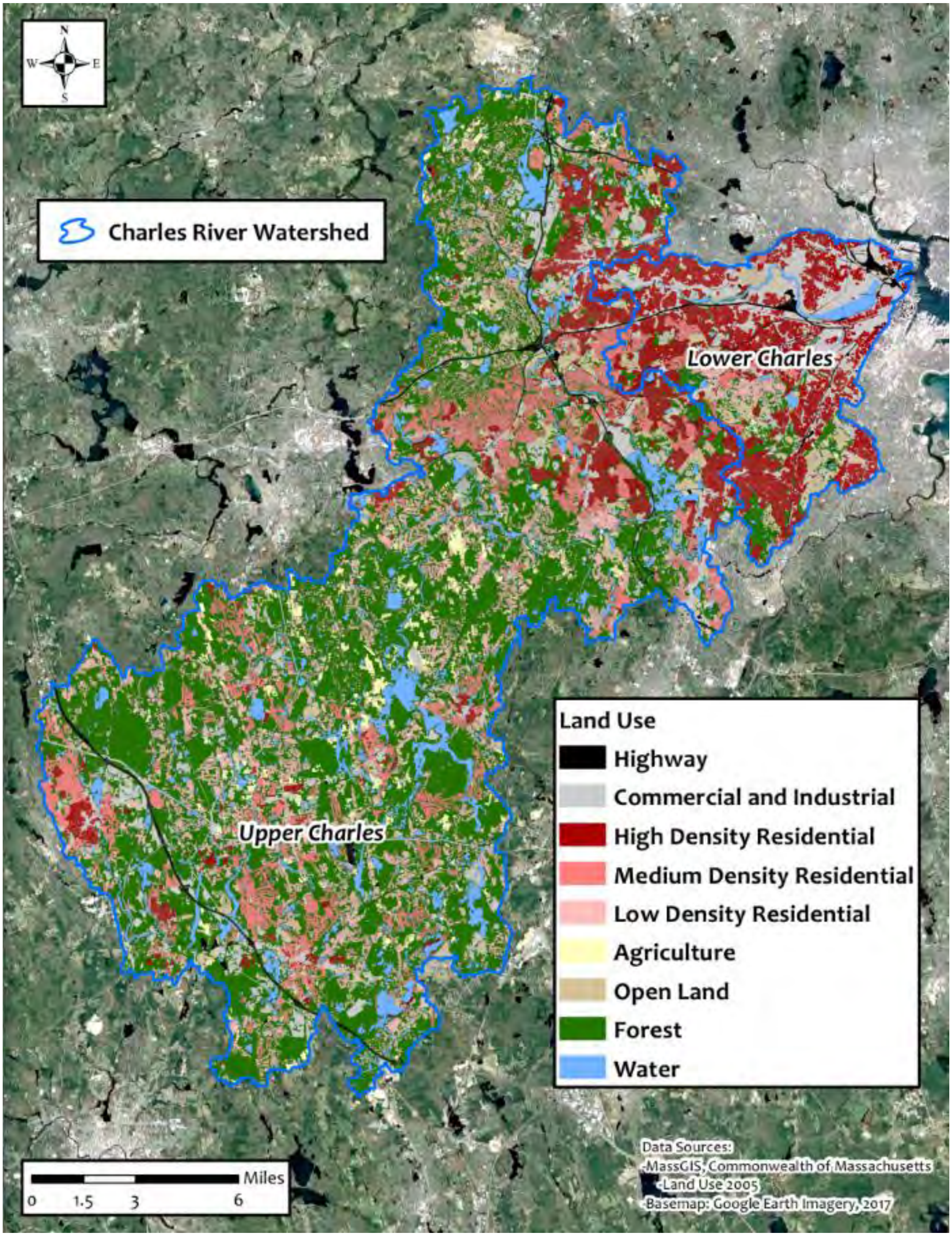

Figure 2 - Land Use in the Charles River Watershed

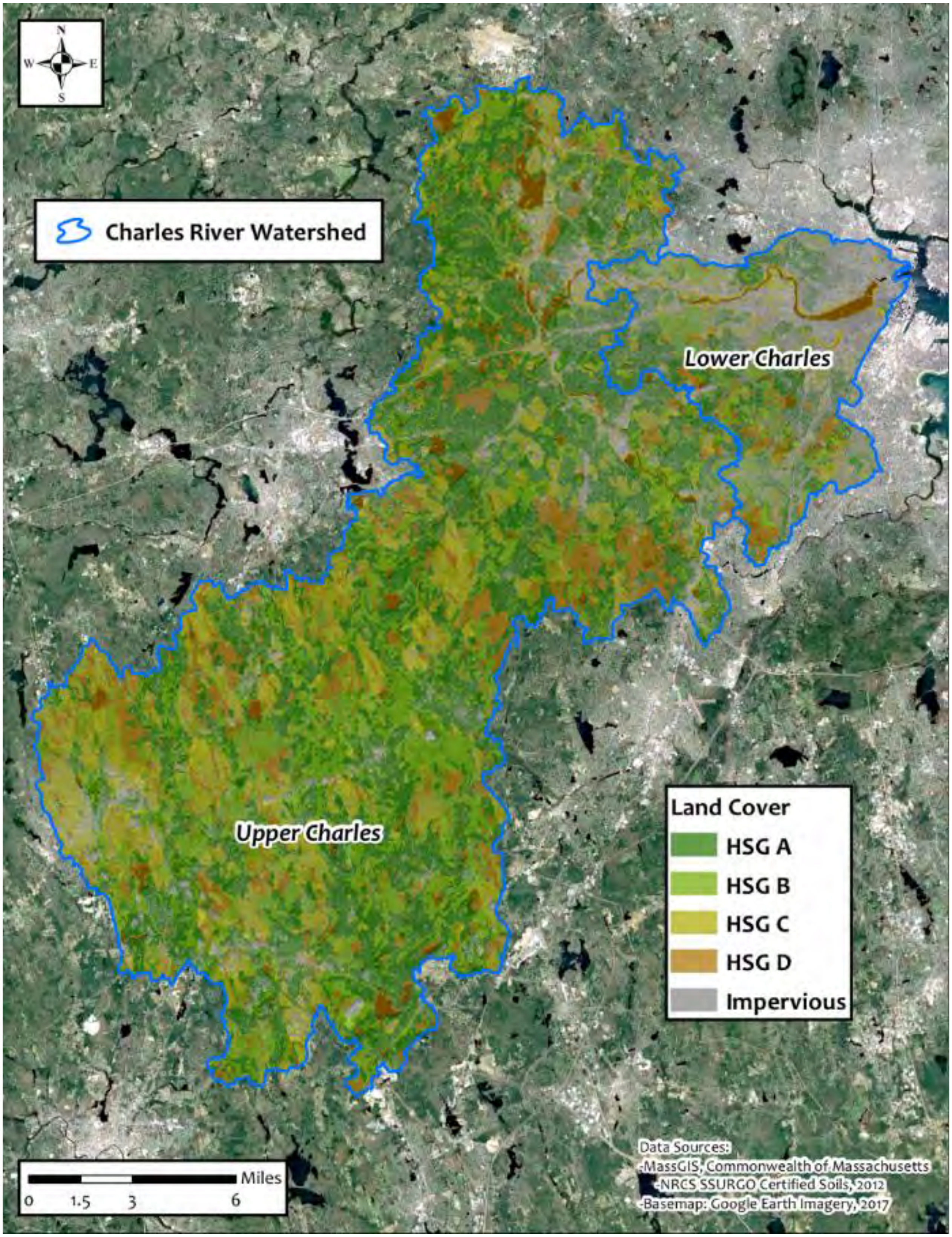

Figure 3 - Land Cover (soils and impervious) in the Charles River Watershed

4.2. Pollutant Load Analysis Modeling Approach

The volume and quality of stormwater runoff generated from each major land use within the study watershed was characterized through the use of modeling of hydrologic response units (HRUs). HRUs are idealized catchments, 1 acre in size, which represent a land use cover, one of four hydrologic soil groups (HSG) and an imperviousness condition, either 100% impervious or 100% pervious. HRUs can be used as sub-elements to represent the various combinations of land use, land cover, imperviousness, and soil type within a watershed.

Each HRU was modeled in the EPA Stormwater Management Model (SWMM)[17] as a subcatchment. Subcatchments are defined as hydrologic units of land whose topography and drainage system elements direct surface runoff to a single discharge point. SWMM calculates estimated rates at which rainfall infiltrates into the upper soil zone of a subcatchment's pervious area. Infiltration is estimated for each HRU using the Curve Number (CN) Method. The CN Method is adopted from the NRCS[18] (SCS) and assumes that the total infiltration capacity of a soil can be found from the soil's tabulated Curve Number. During a rain event this capacity is depleted as a function of the cumulative rainfall and remaining capacity. The input parameters for this method are the Curve Number and the time it takes a fully saturated soil to completely dry (used to compute the recovery of infiltration capacity during dry periods). Curve numbers were assigned to HRUs based on the soil type and impervious cover.

After the stormwater runoff volumes were determined by HRU analysis, the pollutant load analysis was conducted. This was accomplished by using event mean concentrations (EMCs), the flow weighted average concentration of a pollutant throughout a storm event. EMCs for phosphorous, nitrogen, total suspended solids, and fecal coliform bacteria were available from a variety of sources[19,20,21,22,23] for a wide range of land uses and are listed in Table 9. Pollutant load export rates (PLERs) are the mass of pollutant load that is expected to be produced by a specific land use and soil type combination for a given period of time. PLERs were developed by combining the EMCs with the computed runoff volume for each HRU and specific land use type for fecal coliform to determine colonies per acre per year for each major land use / land cover combination (Table 10). PLERs for phosphorus were developed previously using this method in prior efforts and studies and published in the recent MS4 permit.[9]

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[17] EPA (2010b)
[18] NRCS (1986)
[19] Roseen, R. et al (2015)
[20] Steuer et al (1996)
[21] Pitt, R. National Stormwater Quality Database v1.1. Summary Table.
[22] Claytor & Schueler (1996)
[23] Final Pathogen TMDL for the Charles River Watershed (2007)

Table 9 - Event Mean Concentration (EMC) values for water quality modeling[24]

<table>
<tr><th rowspan="2">Land Use Category</th><th rowspan="2">Cover Type</th><th colspan="4">Event Mean Concentration (EMC)</th></tr>
<tr><th>Total Phosphorus (mg/L)</th><th>Total Nitrogen (mg/L)</th><th>Total Suspended Solids (mg/L)</th><th>FC Bacteria (col/100mL)</th></tr>
<tr><td rowspan="3">Residential</td><td>Pervious (Lawn)</td><td>0.414 [a,f,g,l,m]</td><td rowspan="12">Buildup/ Washoff functions used for these land uses</td><td>171 [a,m]</td><td rowspan="3">37,000 Single Family; 17,000 Multi-family [n]</td></tr>
<tr><td>Roof</td><td>0.1 [a,f,g,l,m]</td><td>28 [a,l]</td></tr>
<tr><td>Other Impervious</td><td>0.81 [a,f,l,m]</td><td>178 [a]</td></tr>
<tr><td rowspan="3">Commercial, Services</td><td>Pervious</td><td>0.414 [a,f,g,l,m]</td><td>171 [a,m]</td><td rowspan="3">16,000 [n]</td></tr>
<tr><td>Roof</td><td>0.152 [a,f,g,l,m]</td><td>14 [a,l,m]</td></tr>
<tr><td>Other Impervious</td><td>0.26 [a,f,g,l,m]</td><td>64 [a,l,m]</td></tr>
<tr><td rowspan="3">Institutional, Government</td><td>Pervious</td><td>0.24 [h,k]</td><td>29.5 [h,k]</td><td rowspan="3"></td></tr>
<tr><td>Roof</td><td>0.24 [h,k]</td><td>29.5 [h,k]</td></tr>
<tr><td>Other Impervious</td><td>0.24 [h,k]</td><td>29.5 [h,k]</td></tr>
<tr><td rowspan="3">Industrial</td><td>Pervious</td><td>0.414 [a,f,g,l,m]</td><td>171 [a,m]</td><td rowspan="3">14,000 [n]</td></tr>
<tr><td>Roof</td><td>0.08 [l]</td><td>17 [l]</td></tr>
<tr><td>Other Impervious</td><td>0.65 [l]</td><td>228 [l]</td></tr>
<tr><td rowspan="5">Transportation, Communications, and Utilities</td><td>Road</td><td>0.54 [a,f,g,l,m]</td><td>1.51 [a,m]</td><td>248 [a,l]</td><td>2400 [a]</td></tr>
<tr><td>Freeway</td><td>0.36 [d,h,k,m]</td><td>2.58 [d,h,k,m]</td><td>87 [d,h,k,m]</td><td></td></tr>
<tr><td>Right-of-Way</td><td>0.54 [a,f,g,l,m]</td><td>1.51 [a,m]</td><td>248 [a,l]</td><td>2400 [a]</td></tr>
<tr><td>Utilities</td><td>0.2 [h]</td><td>1.2 [h]</td><td>20.7 [h]</td><td></td></tr>
<tr><td>Rail</td><td>0.13 [c]</td><td>1.63 [c]</td><td>97 [c]</td><td></td></tr>
<tr><td rowspan="3">Industrial and Commercial Complexes</td><td>Pervious</td><td>0.414 [a,f,g,l,m]</td><td rowspan="3">Buildup/ Washoff functions used for these land uses</td><td>171 [a,m]</td><td>4700 [a]</td></tr>
<tr><td>Roof</td><td>0.116</td><td>16</td><td>3450</td></tr>
<tr><td>Parking</td><td>0.46</td><td>146</td><td>2925</td></tr>
<tr><td>Mixed Developed Uses</td><td></td><td>0.29 [e,h,j,k,m]</td><td>2.48 [e,h,j,k,m]</td><td>103 [e,h,j,k,m]</td><td>4600 [k]</td></tr>
<tr><td>Outdoor & Other Urban and Built-up Land</td><td></td><td>0.12 [h,i,m]</td><td>1.36 [h,i,m]</td><td>27.3 [h,i,m]</td><td></td></tr>
<tr><td>Agriculture</td><td></td><td>0.53 [b,d,h,i,m]</td><td>2.85 [b,d,h,i,m]</td><td>80 [b,d,h,i,m]</td><td></td></tr>
<tr><td>Transitional</td><td></td><td>0.31 [k]</td><td>1.33 [k]</td><td>48.5 [k]</td><td>7200 [k]</td></tr>
<tr><td>Forest</td><td></td><td>0.15 [b,d,h,j,m]</td><td>1.4 [b,d,h,j,k,m]</td><td>52 [b,d,h,j,k,m]</td><td>7200 [k]</td></tr>
<tr><td>Wetlands</td><td></td><td>0.16 [d,h,m]</td><td>1.36 [d,h,m]</td><td>9.6 [d,h,m]</td><td></td></tr>
<tr><td>Barren</td><td></td><td>0.13 [c]</td><td>1.63 [c]</td><td>97 [c]</td><td></td></tr>
<tr><td colspan="6">[a] Steuer et al (1996); [b] Line, D.E. et al (2002); [c] Los Angeles County Stormwater Monitoring Report: 1998-1999; [d] Harper, H.H. (1998); [e] Guerard, P., and Weiss, W.B. (1995); [f] Bannerman et al (1992); [g] Waschbusch et al (2000) [h] CH2MHill Technical Memo. Urban Stormwater Pollutant Assessment, NC DENR 2001.; [I] Adamus and Bergman (1995); [j] Results of the Nationwide Urban Runoff Program (NURP). Volume 1 – Final Report; [k] Pitt, R. National Stormwater Quality Database v1.1. Summary Table.; [l] Claytor & Shueler (1996). Design of Stormwater Filtering Systems; [m] New Hampshire Stormwater Manual, Appendix D [n] Final Pathogen TMDL for the Charles River Watershed (2007).</td></tr>
</table>

[24] Pitt, R. National Stormwater Quality Database v1.1. Summary Table

Table 10 – Fecal Coliform Event Mean Concentrations (EMCs) and Pollutant Load Export Rates

Land Use	Land Cover	Fecal Coliform EMCs col/100mL	Average Annual Runoff L/acre	Fecal Coliform col/acre/yr
Agriculture	A	7,200	246,052	1.77E+10
	B	7,200	635,408	4.57E+10
	C	7,200	1,070,731	7.71E+10
	D	7,200	1,343,821	9.68E+10
	Impervious	7,200	4,085,541	2.94E+11
Commercial and Industrial	A	16,000	246,052	3.94E+10
	B	16,000	635,408	1.02E+11
	C	16,000	1,070,731	1.71E+11
	D	16,000	1,343,821	2.15E+11
	Impervious	16,000	4,085,541	6.54E+11
Forest	A	7,200	246,052	1.77E+10
	B	7,200	635,408	4.57E+10
	C	7,200	1,070,731	7.71E+10
	D	7,200	1,343,821	9.68E+10
	Impervious	7,200	4,085,541	2.94E+11
High Density Residential	A	17,000	246,052	4.18E+10
	B	17,000	635,408	1.08E+11
	C	17,000	1,070,731	1.82E+11
	D	17,000	1,343,821	2.28E+11
	Impervious	17,000	4,085,541	6.95E+11
Low Density Residential	A	37,000	246,052	9.10E+10
	B	37,000	635,408	2.35E+11
	C	37,000	1,070,731	3.96E+11
	D	37,000	1,343,821	4.97E+11
	Impervious	37,000	4,085,541	1.51E+12
Medium Density Residential	A	37,000	246,052	9.10E+10
	B	37,000	635,408	2.35E+11
	C	37,000	1,070,731	3.96E+11
	D	37,000	1,343,821	4.97E+11
	Impervious	37,000	4,085,541	1.51E+12
Highway	A	4,700	246,052	1.16E+10
	B	4,700	635,408	2.99E+10
	C	4,700	1,070,731	5.03E+10
	D	4,700	1,343,821	6.32E+10
	Impervious	2,400	4,085,541	9.81E+10
Open Land	A	7,200	246,052	1.77E+10
	B	7,200	635,408	4.57E+10
	C	7,200	1,070,731	7.71E+10
	D	7,200	1,343,821	9.68E+10
	Impervious	7,200	4,085,541	2.94E+11

Note: Primary EMC source, Final Pathogen TMDL for the Charles River Watershed (2007)

Table 11 - Average Annual Phosphorus Pollutant Load Export Rates9

Land Use Category	Phosphorus Load Export Rate, lbs/acre/year
Commercial and Industrial (impervious)	1.78
Multi-Family and High-Density Residential (impervious)	2.32
Medium-Density Residential (impervious)	1.96
Low-Density Residential (Rural) (impervious)	1.52
Highway (impervious)	1.34
Forest (impervious)	1.52
Open Land (impervious)	1.52
Agriculture (impervious)	1.52
Developed-Pervious, HSG A	0.03
Developed-Pervious, HSG B	0.12
Developed-Pervious, HSG C	0.21
Developed-Pervious, HSG C/D	0.29
Developed-Pervious, HSG D	0.37

4.3. Assessing TMDL Attainability

TMDLs define and allocate two major waste sources: 1) a wasteload allocation (WLA), which is generally defined as the sum of the pollutant load discharged from all "discrete conveyances" contributing to the impairment, such as discharge pipes or ditches and is regulated under a NPDES permit; and 2) a load allocation (LA), which is the sum of the remaining sources such as runoff, groundwater and atmospheric deposition that are more diffuse and not subject to regulation under a NPDES permit. This division occasionally causes confusion as certain classes of stormwater are regulated under the various stormwater permits (i.e., MS4, industrial stormwater, and construction stormwater) that were previously considered non-point sources. But, because they come under a permit, they become part of the WLA; nearly identical stormwater sources in non-MS4 areas are not regulated and remain in the LA and are not typically subject to an NPDES permit.

TMDL attainability was assessed for the Charles River watershed by applying a BMP efficiency scenario to the results of the pollutant load analysis and performing a subsequent parcel-based pollutant loading assessment. The parcel-based assessment demonstrates which land use types and size must be included in an RDA scheme in order to achieve attainment of total maximum daily loading goals.

4.3.1. BMP Potential Load Reduction

The pollutant load reduction potential for each watershed was assessed assuming that new development, redevelopment, or installation of stormwater best management practice (BMP) retrofits in all runoff-producing areas would provide treatment for the 1" water quality volume (WQV). This represents a conservative assessment given that site-specific feasibility for stormwater management was not considered. Using this approach identifies the best-case scenario for pollutant load reduction, useful for evaluating if a given TMDL is even theoretically achievable within the current regulatory framework.

A maximum BMP potential load reduction was estimated for bioretention systems with the assumption that all areas would be managed by the most effective BMP with the greatest load reduction potential regardless of site-specific feasibility. The best available BMP technology for achieving phosphorous reduction is bioretention systems. The best available BMP technology for achieving fecal coliform reductions is infiltration systems. Bioretention and infiltration system performance was based on performance curves developed by EPA (2010a). These scenarios represent the highest tier of pollutant removal.

4.3.2. Parcel-Based Analysis

As discussed in detail in 'Section 3.2.3 Role of RDA', government-owned properties that drain to an MS4 are regulated under NPDES, while residential, commercial, industrial, agricultural, and open space properties are not. However, EPA has the authority to use residual designation to permit other un-regulated sources. For this reason, a parcel-based pollutant loading analysis was performed for the Charles River watershed to determine the minimum parcel area for which RDA could be applied to achieve the required load reductions. The analysis examined the role of parcel size and land use as it relates to pollutant loading. This was done for the purpose of determining the minimum parcel size threshold needed to achieve the required load reductions and for which stormwater management would be required. This analysis can also be used to inform a determination of the "optimal" parcel size to achieve the greatest reduction practicable. Unlike the pollutant load analysis, roads were separated from each land use type and added to the 'MS4' category for the parcel-based analysis. This is described in greater detail under No. 4, Section 6.3 Assumptions and Limitations.

Figure 5 through Figure 13 illustrate the cumulative pollutant load by parcel size and land use for phosphorous and fecal coliform. Because of the different axis scales, figures 5, 7, 9, and 11 are for cumulative load for the MS4 areas and unregulated open space and forest land uses. Figures 6, 8, 10, and 12 illustrate the cumulative load for the residential, commercial, and industrial areas. This was developed by GIS analysis, correlating parcel size with pollutant loading as described in Section 3.2. This was analyzed to assess the contribution of a specific land use as a function of parcel size. This was followed by an iterative spreadsheet analysis examining BMP scenarios and a range of parcel area thresholds to determine how inclusion of different parcel sizes in various land use combinations could be implemented under RDA. EPA may prefer to iterate further using this or a similar model to determine whether more granular classification of residential land use categories yields meaningful differences in RDA threshold parcel sizes necessary to achieve significant progress toward attaining the TMDLs.

The following RDA parcel area thresholds represent different approaches based on parcel lot size that EPA could target using its residual designation authority. Each was analyzed to determine the feasibility for TMDL attainability:

1. **All Parcels:** Regulating all parcels within residential, commercial, and industrial areas, and excluding all other parcels.

2. **Parcel Areas >0.05 Acre:** Regulating all parcels larger than 0.05-acre for residential, commercial, and industrial land use types.

3. **Parcel Areas >0.25 Acre:** Regulating all parcels larger than 0.25-acre for residential, commercial, and industrial land use types.

4. **Parcel Areas >1 Acre:** Regulating all parcels larger than 1-acre for residential, commercial, and industrial land use types.

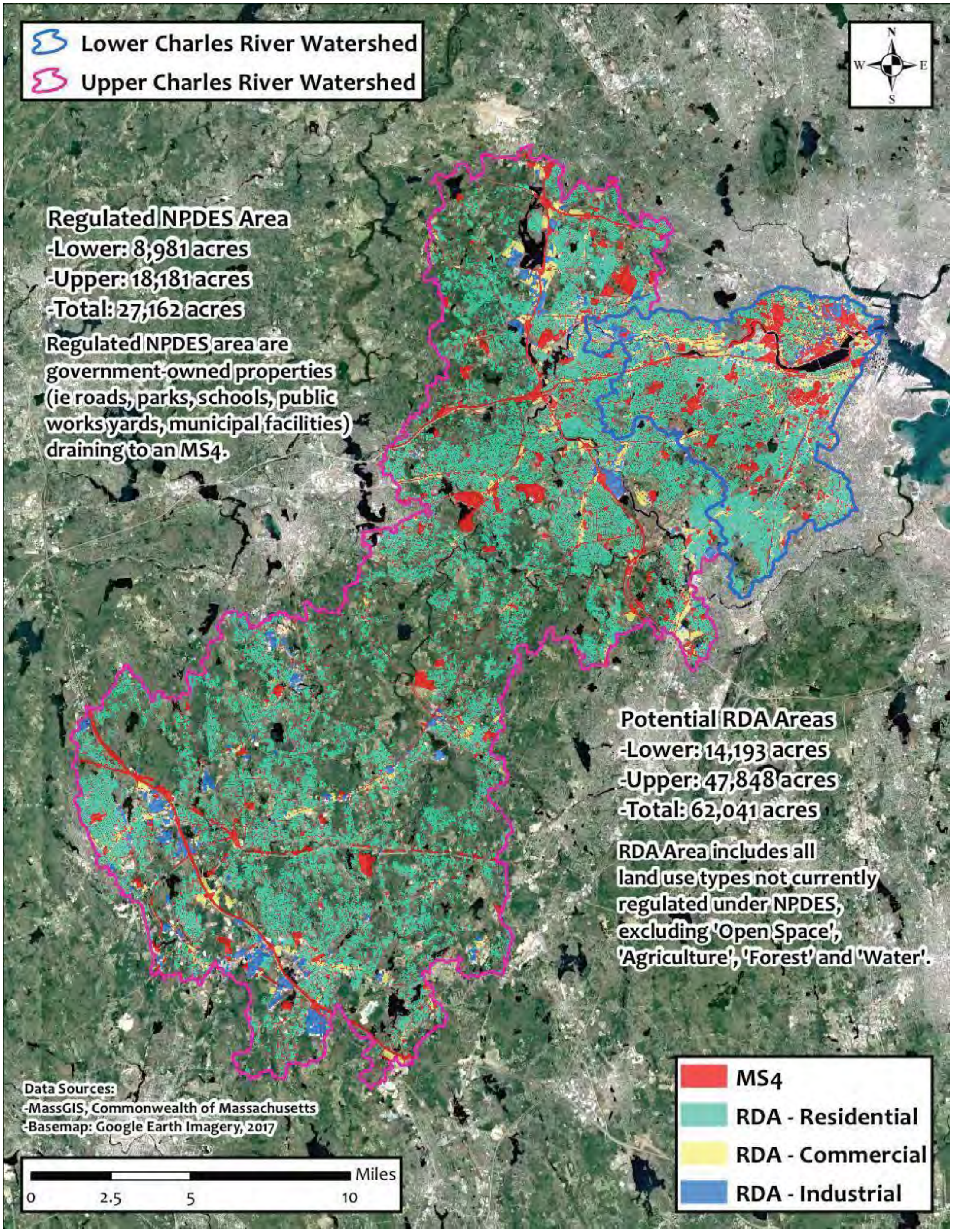

Figure 4 - Areas within the Charles River Watershed Regulated under NPDES

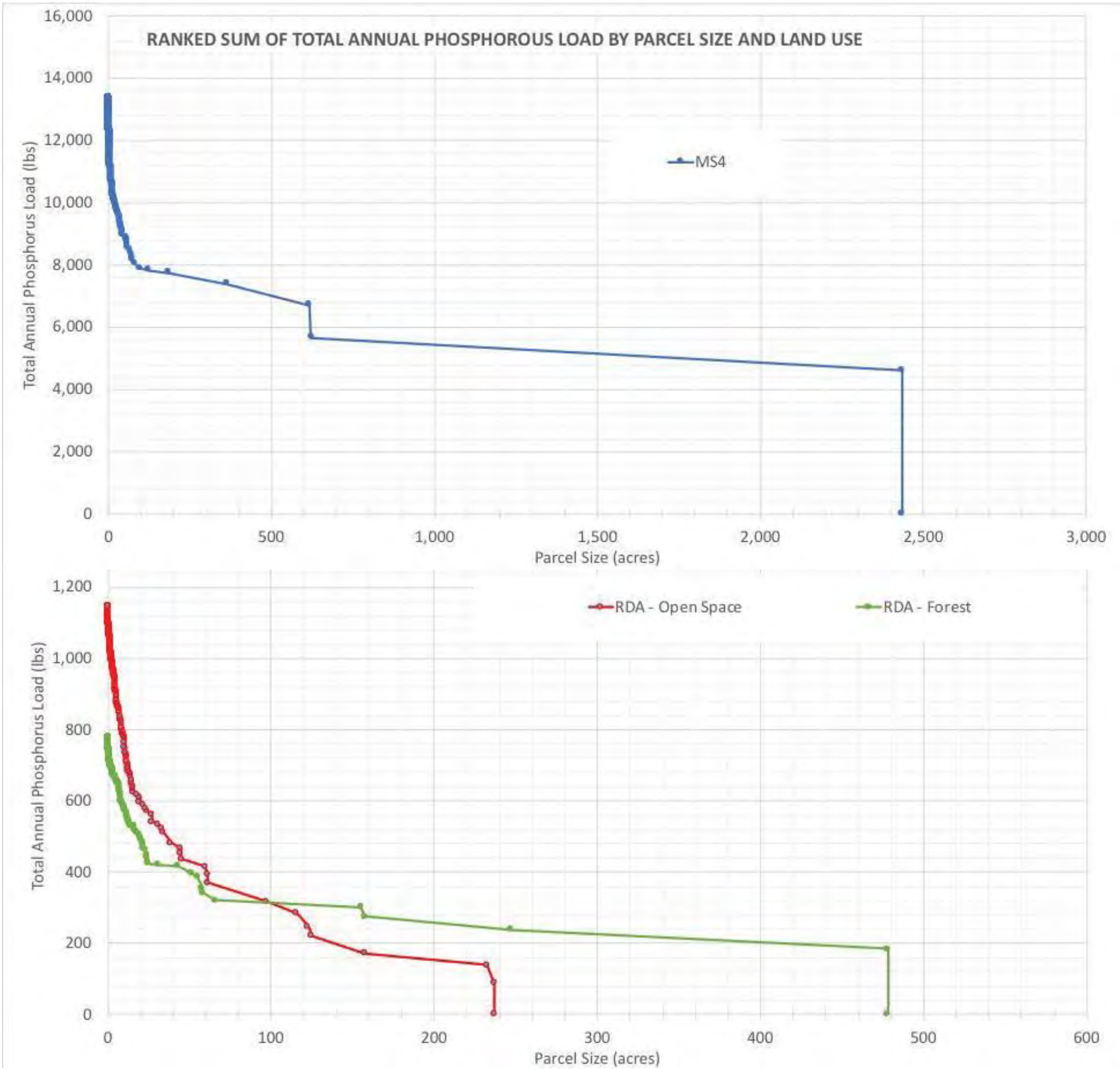

Figure 5 - Cumulative Total Annual Phosphorus Load for Lower Charles River Watershed by Parcel Size for the MS4 Areas (above), Open Space, and Forest (below)

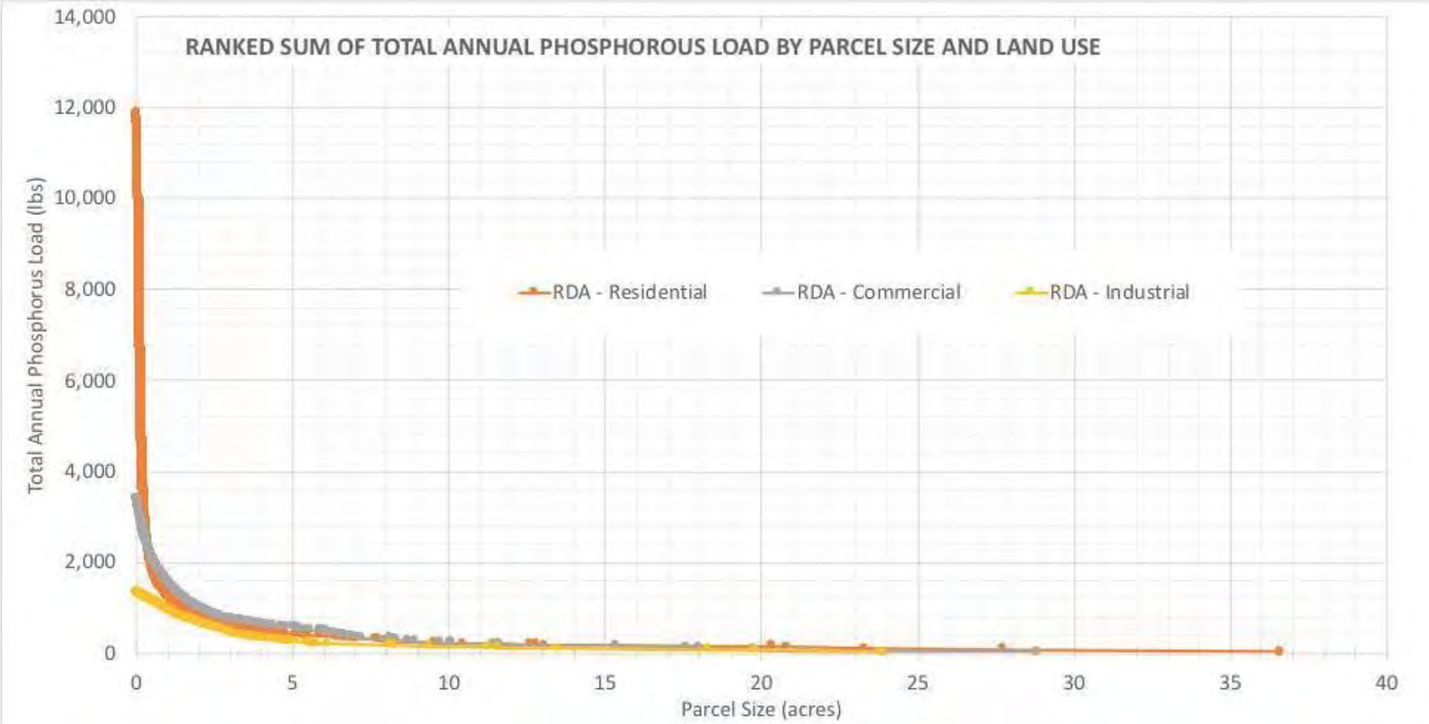

Figure 6 - Cumulative Total Annual Phosphorus Load for Lower Charles River Watershed by Parcel Size for Residential, Commercial and Industrial Land Uses

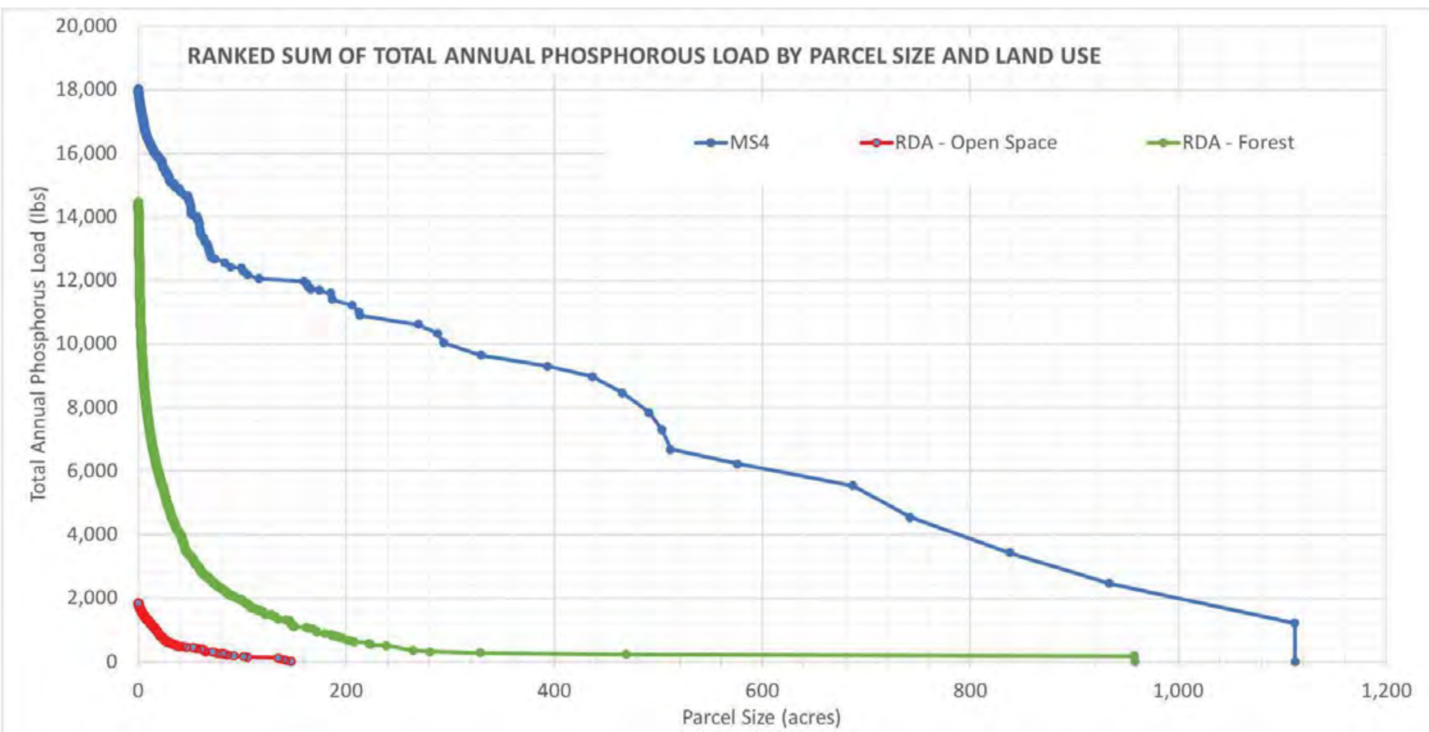

Figure 7 - Cumulative Total Annual Phosphorus Load for Upper Charles River Watershed by Parcel Size for the MS4 Areas, Open Space, and Forest

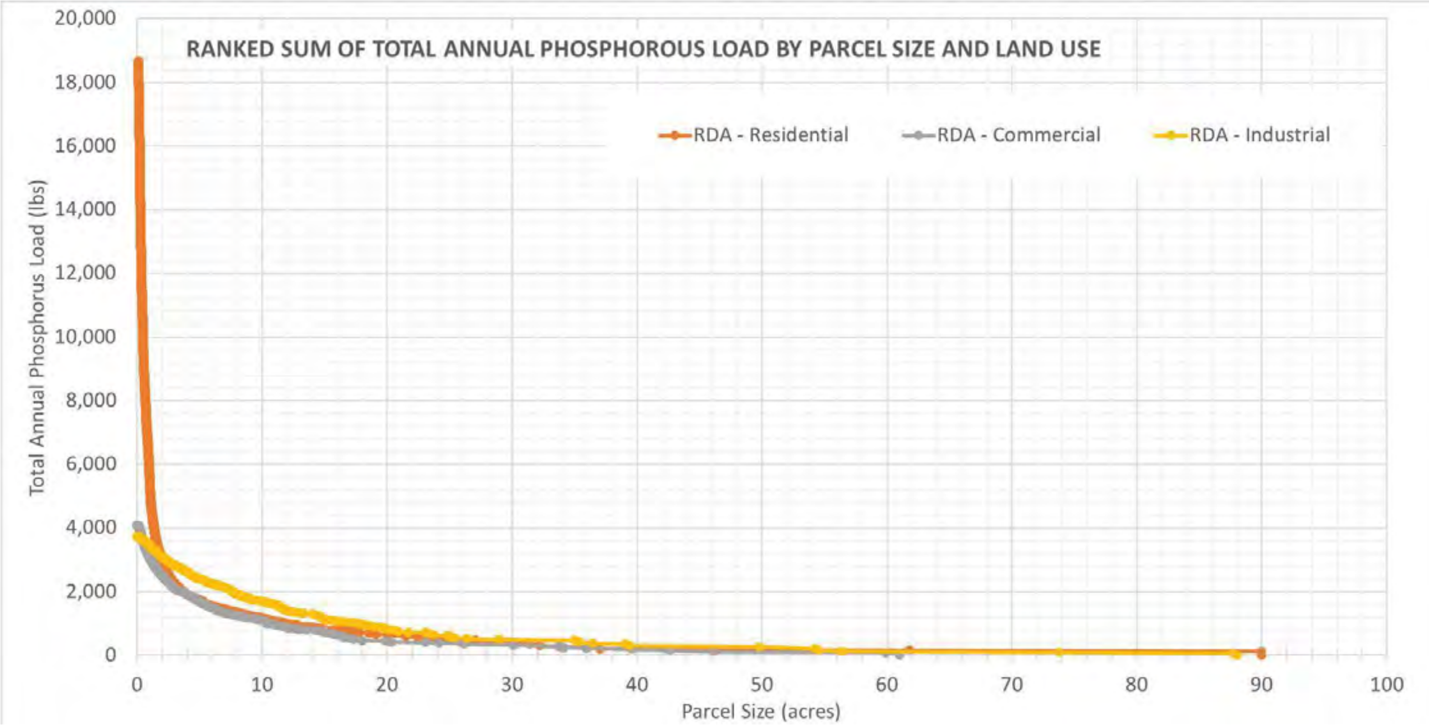

Figure 8 - Cumulative Total Annual Phosphorus Load for Upper Charles River Watershed by Parcel Size for Residential, Commercial and Industrial Land Use

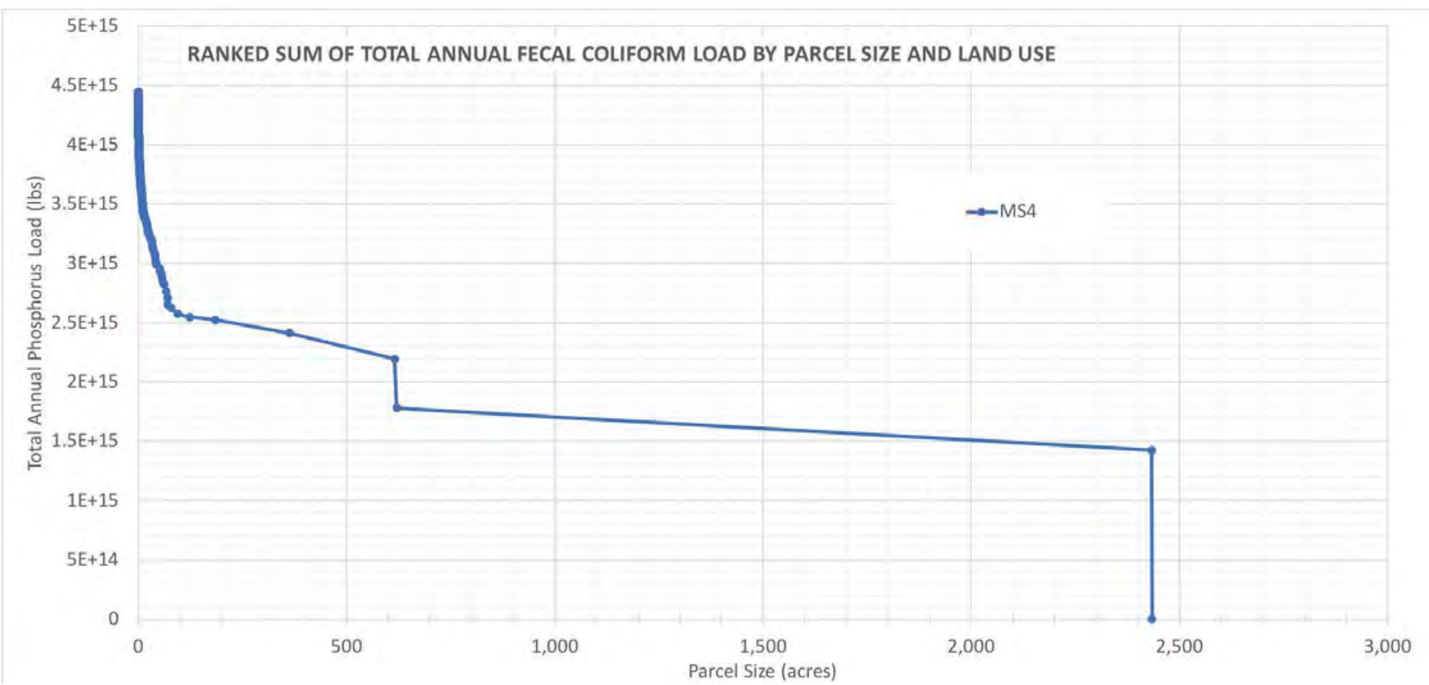

Figure 9 - Cumulative Total Annual Fecal Coliform Load for Lower Charles River Watershed by Parcel Size for the MS4 Area

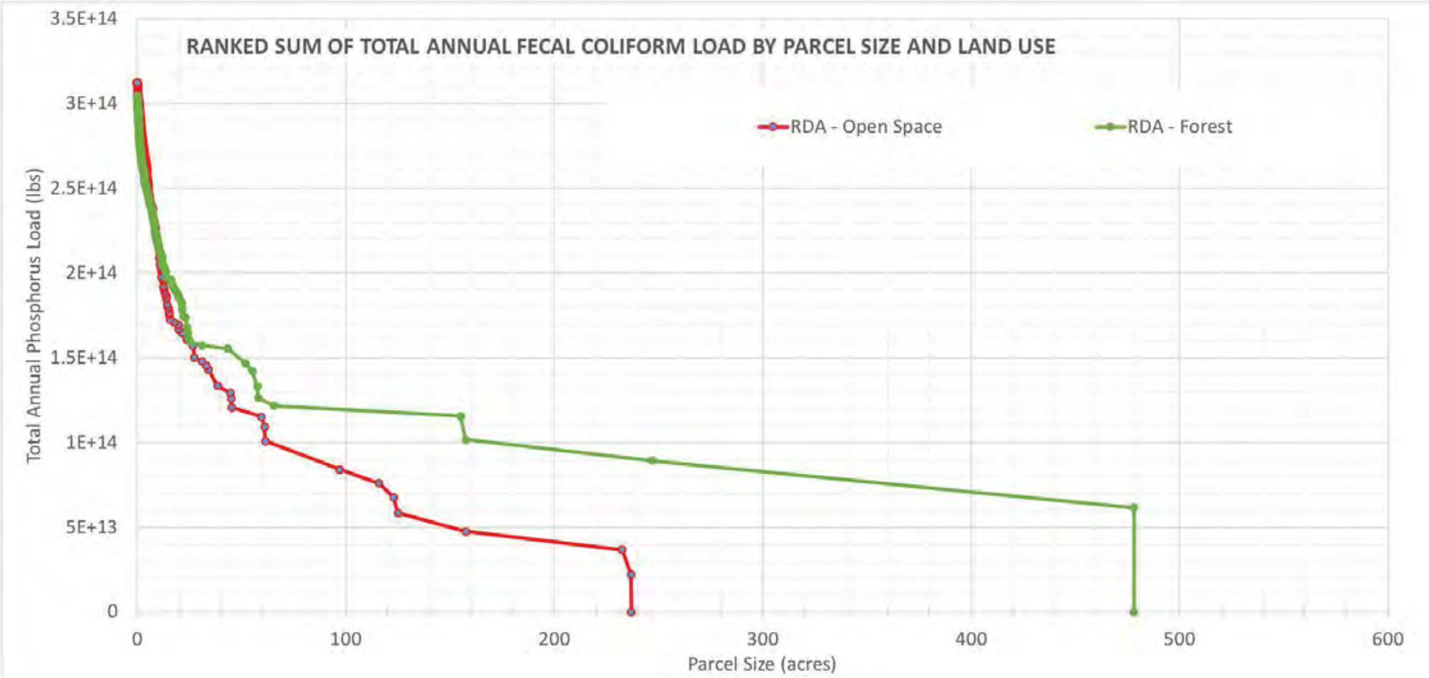

Figure 10 - Cumulative Total Annual Fecal Coliform Load for Lower Charles River Watershed by Parcel Size for Open Space, and Forest Land Uses

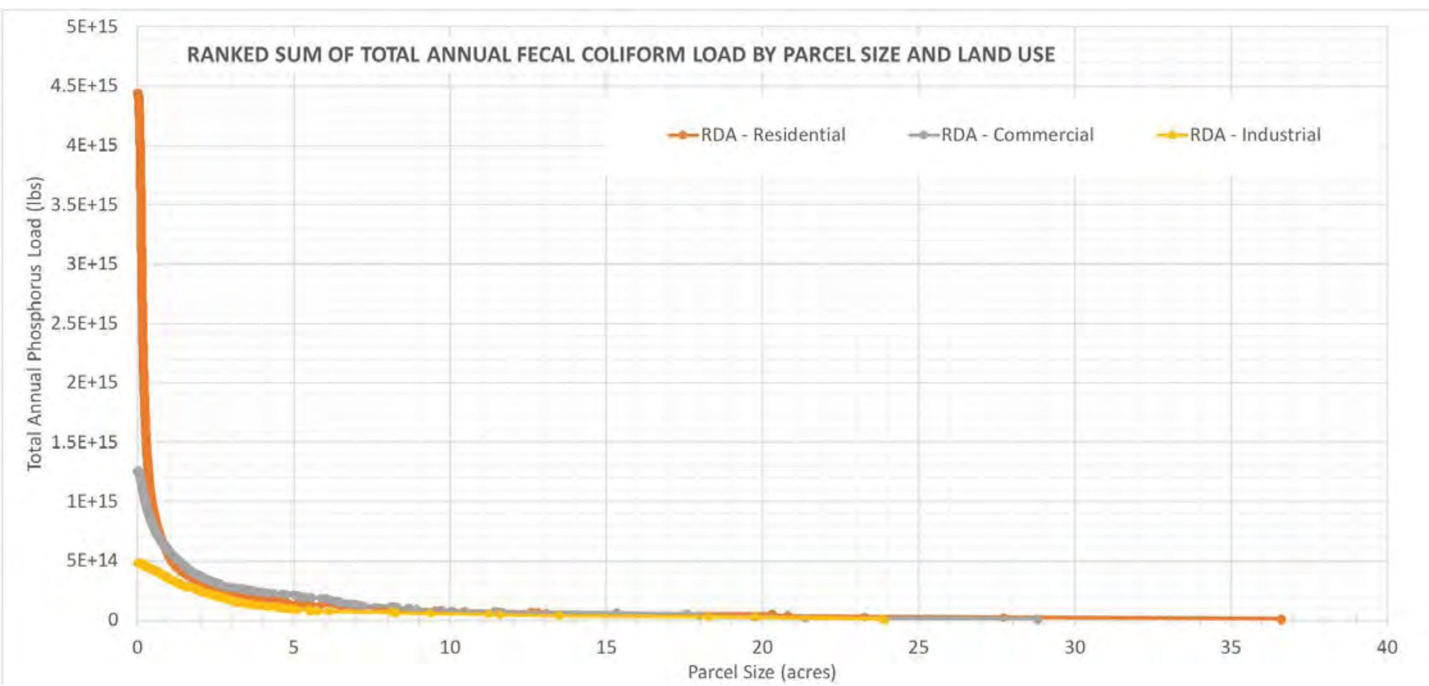

Figure 11 - Cumulative Total Annual Fecal Coliform Load for Lower Charles River Watershed by Parcel Size for Residential, Commercial and Industrial Land Uses

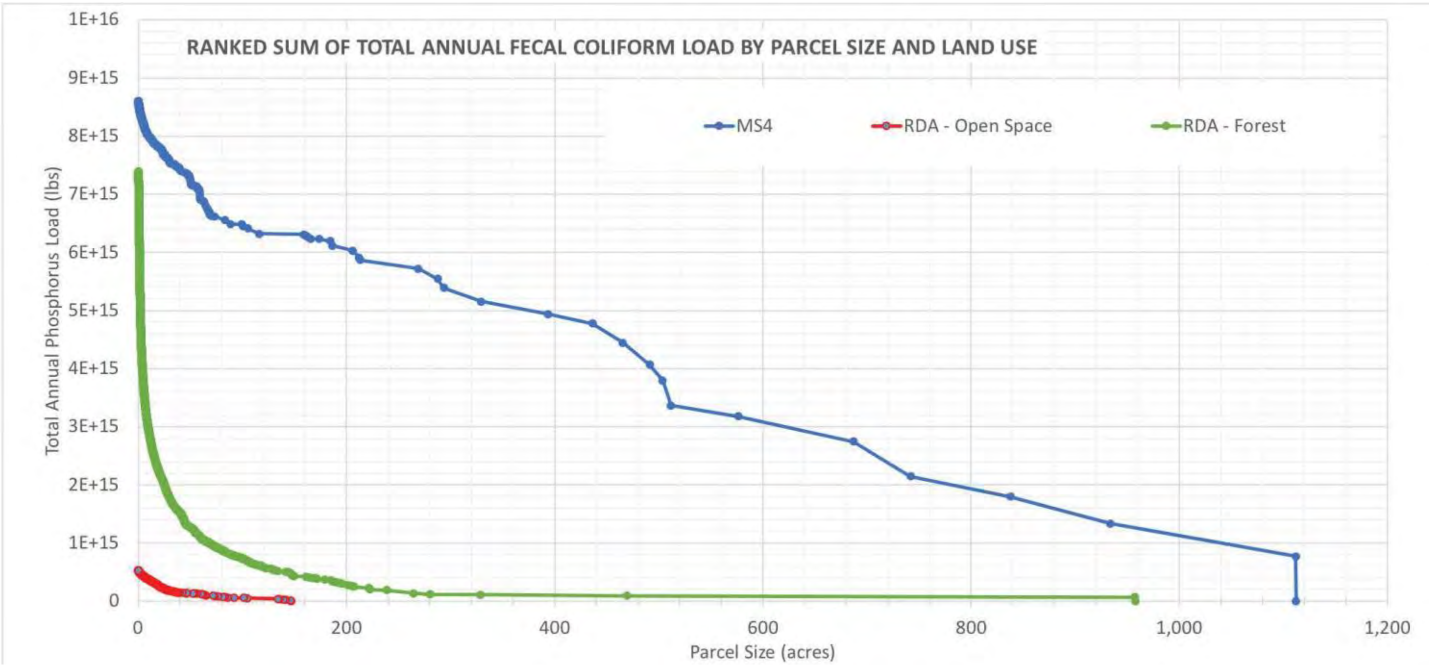

Figure 12 - Cumulative Total Annual Fecal Coliform Load for Upper Charles River Watershed by Parcel Size for MS4 Areas, Open Space, and Forest

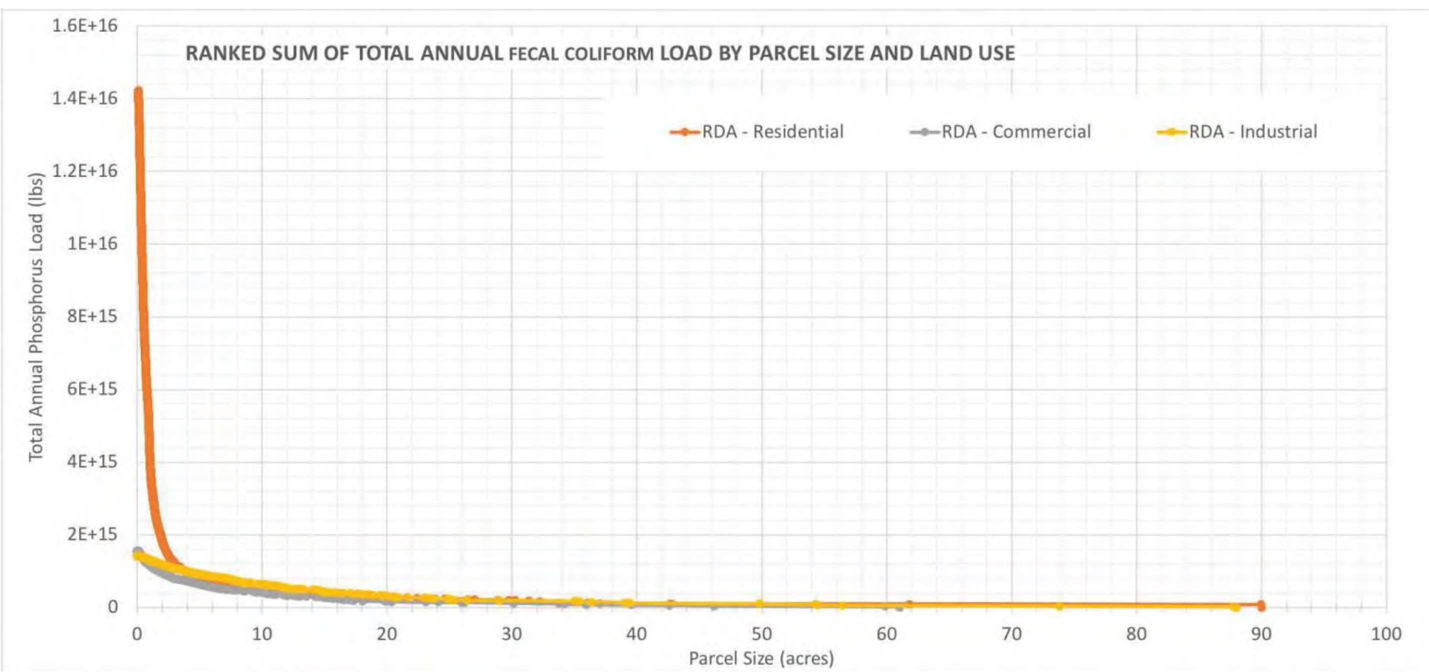

Figure 13 - Cumulative Total Annual Fecal Coliform Load for Upper Charles River Watershed by Parcel Size for Residential, Commercial and Industrial Land Uses

5. Results

5.1. Pollutant Loading Analysis

For this study, loads for phosphorus and fecal coliform were calculated by land use for the Upper and Lower Charles River watersheds. The estimated loads shown in Tables 11 and 12 are for wet weather runoff and do not include contributions from point sources such as wastewater treatment facilities, industrial discharges, illicit discharges, leaking sewers, septic systems or groundwater and atmospheric deposition.

For Tables 11 and 12, Column 1 (Land Use) lists the various land uses within each watershed area; Columns 2 and 4 (Annual Phosphorus Load (lbs), and Annual Fecal Coliform Load (CFUS)) give the total annual pollutant load from the area covered by each land use; Columns 3 and 5 (% of Total Load) give the percentage of the total pollutant load for the watershed that is derived from each land use.

Table 12 - PLA Results for Phosphorus and Fecal Coliform in the Lower Charles River Watershed

Land Use	Annual Phosphorus Load (lbs)	% of Total Load	Annual Fecal Coliform Load (CFUs)	% of Total Load
Open Land	1,349	4.2%	3.10E+14	2.8%
Low Density Residential	376	1.2%	4.28E+14	3.8%
Medium Density Residential	962	3.0%	8.39E+14	7.4%
High Density Residential	16,764	52.5%	5.35E+15	47.4%
Commercial and Industrial	10,545	33.0%	4.00E+15	35.5%
Highway	1,145	3.6%	8.72E+13	0.8%
Agriculture	72	0.2%	1.05E+13	0.1%
Forest	738	2.3%	2.48E+14	2.2%
Water	-	0.0%	0.00E+00	0.0%
Total	**31,950**	**-**	**1.13E+16**	**-**

Table 13 - PLA Results for Phosphorus and Fecal Coliform in the Upper Charles River Watershed

Land Use	Annual Phosphorus Load (lbs)	% of Total Load	Annual Fecal Coliform Load (CFUs)	% of Total Load
Open Land	2,250	3%	5.34E+14	2%
Low Density Residential	9,058	14%	1.07E+16	30%
Medium Density Residential	10,536	16%	9.64E+15	27%
High Density Residential	11,327	17%	3.78E+15	11%
Commercial and Industrial	14,079	22%	5.48E+15	16%
Highway	1,944	3%	1.64E+14	0%
Agriculture	2,683	4%	3.30E+14	1%
Forest	13,513	21%	4.64E+15	13%
Water	-	0%	0	0%
Total	**65,391**	**-**	**3.53E+16**	**-**

The pollutant loads detailed in Tables 12 and 13 are displayed graphically as heatmaps, with color intensity as a measuring of pollutant loading, in Figures 15 and 16, below.

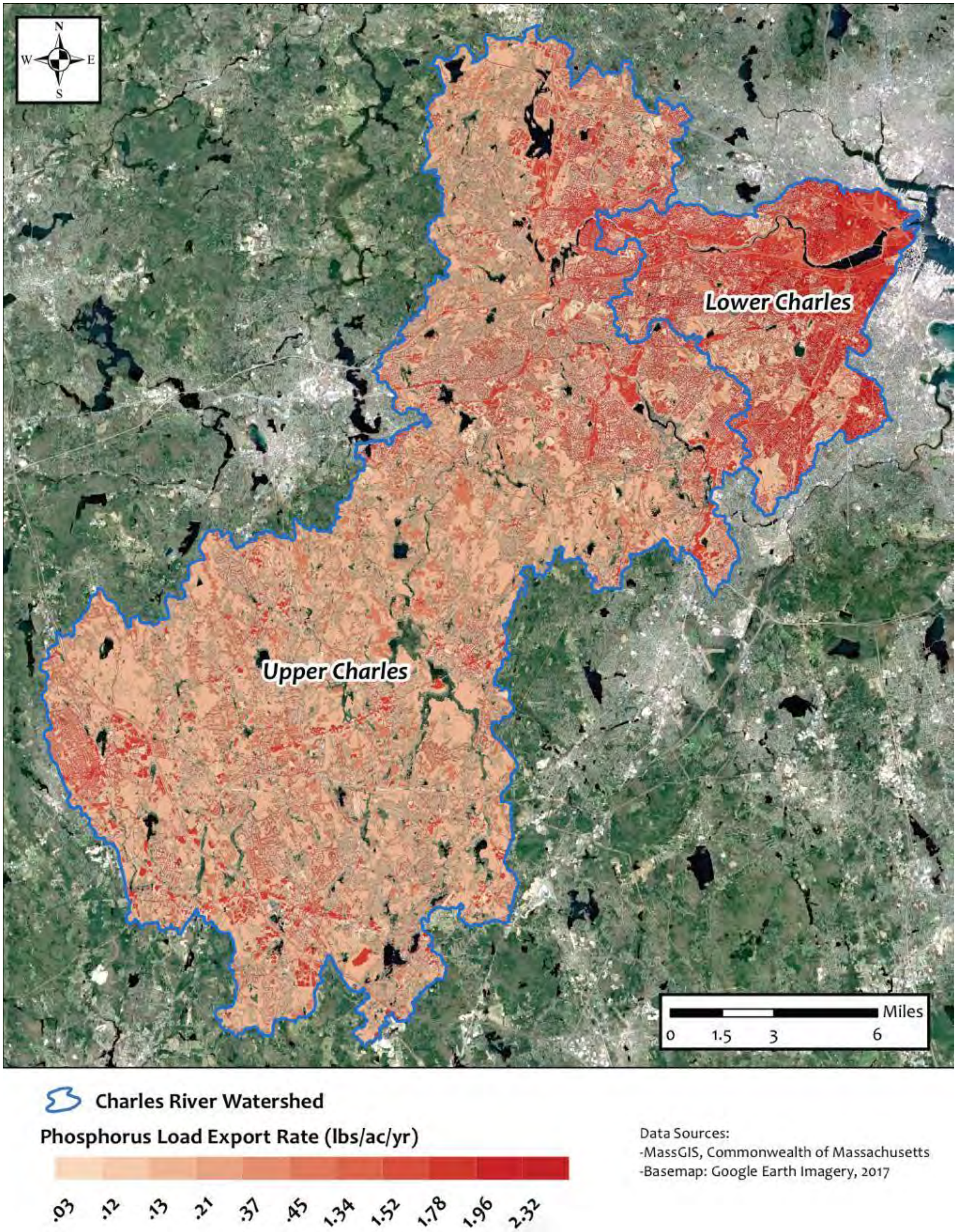

Figure 14 - Phosphorus Loading in the Charles River Watershed

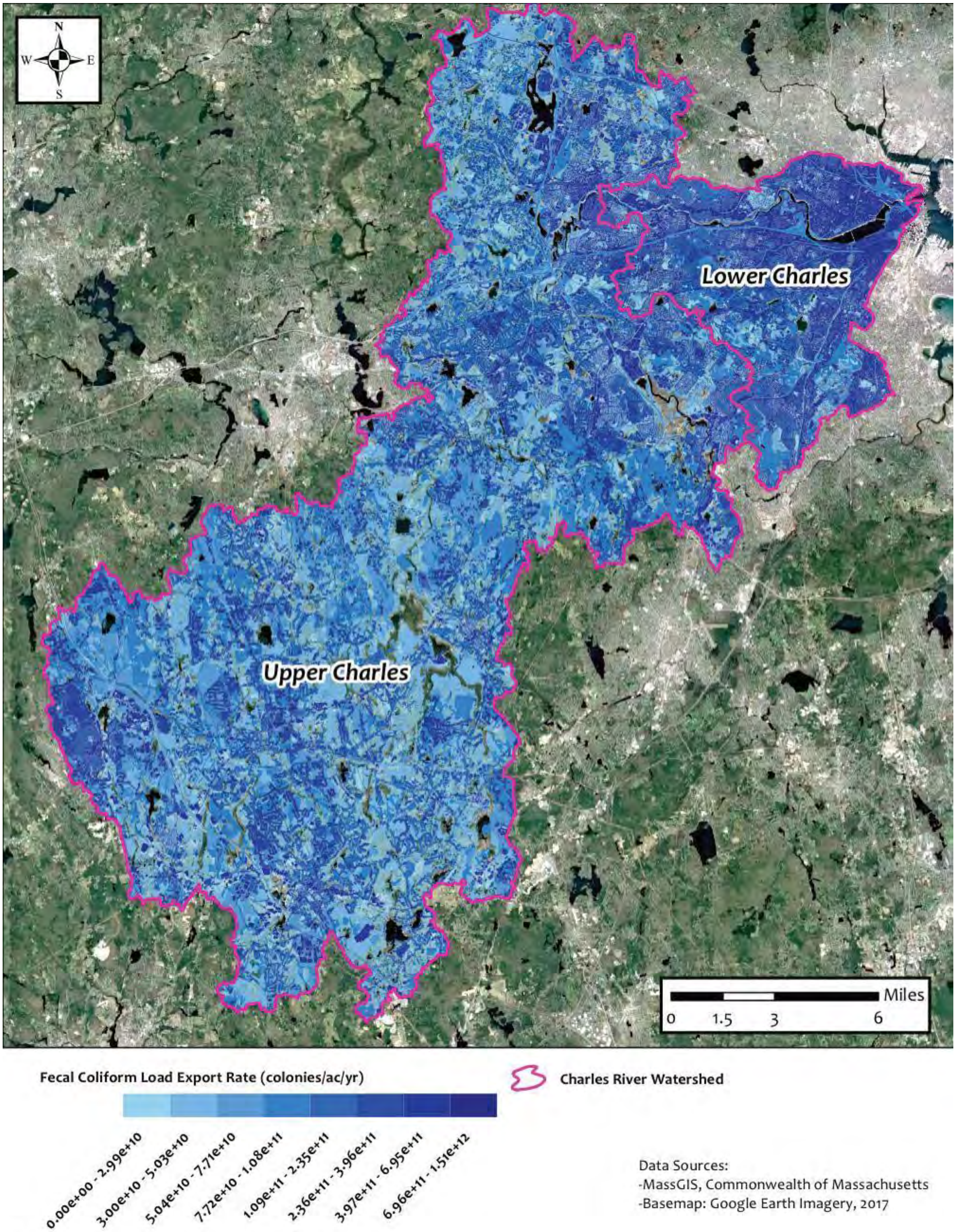

Figure 15 - Fecal Coliform Loading in the Charles River Watershed

5.2. Fecal Coliform Total Maximum Daily Load Calculations for the Charles River Watershed

Table 14 - Fecal Coliform Total Maximum Daily Load Calculations for the Charles River Watershed

Watershed	Stream Segment	Area (sq-mi)	% Impervious	Impervious Area (sq-mi)	Estimated Required Reduction*	Annual TMDL	WLA	LA	Current Load Estimate**
UPPER	MA72-01	0.3	8%	0.02	0%	5.26E+11	4.02E+10	4.85E+11	5.26E+11
UPPER	MA72-02	11.8	16%	1.82	99.8%	2.41E+13	3.65E+12	2.04E+13	1.20E+16
UPPER	MA72-03	10.0	14%	1.44	93.8%	2.05E+13	2.96E+12	1.76E+13	3.31E+14
UPPER	MA72-04	15.0	12%	1.86	96.4%	3.07E+13	3.65E+12	2.71E+13	8.54E+14
UPPER	MA72-05	25.0	10%	2.60	95.9%	5.11E+13	5.11E+12	4.60E+13	1.25E+15
UPPER	MA72-10	1.4	8%	0.11	95.7%	2.81E+12	2.19E+11	2.59E+12	6.54E+13
UPPER	MA72-16	2.5	10%	0.24	66.7%	5.04E+12	4.75E+11	4.56E+12	1.51E+13
UPPER	MA72-06	19.5	11%	2.05	93.5%	4.02E+13	4.02E+12	3.61E+13	6.18E+14
UPPER	MA72-18	0.8	15%	0.12	95.4%	1.67E+12	2.56E+11	1.42E+12	3.63E+13
UPPER	MA72-07	37.1	14%	5.09	98.8%	7.63E+13	1.06E+13	6.57E+13	6.36E+15
UPPER	MA72-21	0.3	10%	0.03	66.7%	5.80E+11	6.21E+10	5.18E+11	1.74E+12
UPPER	MA72-23	0.7	26%	0.19	97.1%	1.53E+12	4.02E+11	1.12E+12	5.26E+13
UPPER	MA72-24	38.4	30%	11.55	95.2%	7.88E+13	2.37E+13	5.51E+13	1.64E+15
UPPER	MA72-25	0.7	19%	0.14	55.5%	1.51E+12	2.88E+11	1.22E+12	3.40E+12
UPPER	MA72-28	2.6	22%	0.57	98.3%	5.22E+12	1.17E+12	4.05E+12	3.07E+14
UPPER	MA72-29	0.9	32%	0.28	99.6%	1.80E+12	5.84E+11	1.22E+12	4.51E+14
LOWER	MA72-08	50.4	16%	8.22	99.3%	1.03E+14	1.68E+13	8.65E+13	1.48E+16
LOWER	MA72-30	37.2	21%	7.88	99.5%	7.63E+13	1.61E+13	6.02E+13	1.53E+16
LOWER	MA72-32	0.3	49%	0.14	N/A	5.69E+11	2.77E+11	2.92E+11	5.69E+11
LOWER	MA72-11	1.9	30%	0.57	99.5%	3.94E+12	1.17E+12	2.77E+12	7.88E+14
TOTAL	-	-	-	-	-	**5.26E+14**	**9.15E+13**	**4.35E+14**	**5.48E+16**

*From Table 7-2 in the 2007 Charles River Fecal Coliform TMDL
**Based on estimated required reduction (from daily concentrations) and TMDL

5.3. Comparison / Combination of PLA and TMDL Results

Note that the TMDLs have all been generated using 1999 land use data, where as our analysis is based on 2005 land use data (the most recent available dataset).

5.3.1 Phosphorus Loads

Table 15 shows a comparison of the TMDL and the pollutant load analysis (PLA) for phosphorous for the Lower Charles River including the load associated with NPDES areas. For the Lower Charles River, a total phosphorous load reduction of 14,718 lbs (60%) is required for the TMDL. The regulated NPDES areas comprise 13,349 lbs (55%), an insufficient amount by 1,369 lbs. (5%) to achieve attainability. There is a discrepancy in the load calculations of 30.5%, with the PLA being larger. One factor is that the PLA study area is 16% larger than the TMDL area. The PLA area boundaries are from the 2005 land use MassGIS coverage whereas the TMDL uses a data set from 1999.

Table 15 - Lower Charles River Watershed Phosphorus TMDL and PLA Summary

	Area	**Impervious**	**Current Annual Load**	**Required Load Reduction**		**TMDL (Annual)**	**WLA**	**LA**	**MOS**
	Acres	%	lbs	%	lbs	lbs	lbs	lbs	lbs
TMDL	25,600	-	24,475	60%	14,718	9,757	7,603	-	2,154
PLA	29,789	51%	31,950	-		-	-	-	-
NPDES Areas	8,981	-	13,349	-		-	-	-	-

Table 16 shows a comparison of the TMDL and the PLA for phosphorous for the Upper Charles River. For the Upper Charles River, a total phosphorous load reduction of 34,588 lbs. (51%) is required for the TMDL. The regulated NPDES areas comprise 18,028 lbs (26%), an insufficient amount by 16,560 lbs. (25%) to achieve the TMDL load reduction.

Table 16 - Upper Charles River Watershed Phosphorus TMDL and PLA Summary

	Area	**Impervious**	**Current Annual Load**	**Required Load Reduction**		**TMDL (Annual)**	**WLA**	**LA**	**MOS**
	Acres	%	lbs	%	lbs	lbs	lbs	lbs	lbs
TMDL	171,520	-	67,778	51%	34,589	33,189	-	-	310
PLA	169,111	16%	65,391	-		-	-	-	-
NPDES Areas	18,181	-	18,028	-		-	-	-	-

5.3.2 Fecal Coliform

Table 17 shows a comparison of the fecal coliform TMDL for the entire Charles River watershed to the estimated current load calculated through the PLA and the NPDES regulated areas.

Table 17 - Charles River Watershed Fecal Coliform TMDL and PLA Summary

	Area	**Impervious**	**Current Annual Load**	**Required Load Reduction**	**TMDL (Annual)**	**WLA**	**LA**
	Acres	%	lbs	%	lbs	lbs	lbs
TMDL	164,256	18	5.48E+16	99%	5.26E+14	9.15E+13	4.35E+14
PLA	198,901	21	5.21E+16	-	-	-	-
NPDES Areas	27,162	-	1.30E+16	-	-	-	-

5.4. BMP Potential Pollutant Load Reduction

The BMP potential pollutant load reduction was determined for bioretention systems based on performance expectations by EPA (2010). Bioretention treatment was applied to a 1” WQV for all impervious areas for the entire watershed to determine an upper bound for pollutant load reduction feasibility. Performance estimates for each TMDL and watershed are summarized in Table 18 and Table 19.

Table 18 – BMP Phosphorus Load Reduction Potential for a Bioretention Sized for a 1” WQV

Watershed	**Current Annual Load (lbs)**	**BMP % Removal Efficiency for Applicable Land Uses***	**% Total Reduction**	**Potential Load Reduction (lbs)**	**New Annual Load (lbs)**	**Residual Annual Load* (lbs)**
Lower	31,950	76%	74%	23,722	8,229	(1,528)
Upper	65,391	76%	60%	39,427	25,964	(7,225)

*Note: Negative values are shown in parentheses, e.g. (1,528) is 1,528 pounds below the required load.

Table 19 – BMP Fecal Coliform Load Reduction Potential for a Bioretention Sized for a 1” WQV

Watershed	**Current Annual Load (lbs)**	**BMP % Removal Efficiency for Applicable Land Uses***	**% Total Reduction**	**Potential Load Reduction (lbs)**	**New Annual Load (lbs)**	**Residual Annual Load* (lbs)**
Lower	2.26E+15	95%	85%	1.91E+15	3.48E+14	1.64E+14
Upper	8.90E+15	95%	45%	4.05E+15	4.85E+15	4.51E+15

*BMPs applied to LU Types: Highway, Residential, Commercial / Industrial, Agricultural, and Open Land. LU Types Forest, and Water are excluded.

5.5. Parcel-Based Pollutant Loading Analysis

Parcel area thresholds (4) for which stormwater management would be required (all parcels, >0.05 acres, >0.25 acres, and >1 acre) were examined in combination with the BMP load reduction potential to determine how excluding different land use types or parcel sizes from an RDA scheme would impact TMDL attainability. Figure 5- Figure 13 demonstrate cumulative pollutant load as a function of parcel size based on land use.

For the Lower Charles River watershed, the maximum potential load reduction, by use of bioretention, is capable of achieving the phosphorus TMDL with stormwater management applied to parcels >0.05 acres. These results are summarized in Table 20, below.

Table 20 – Phosphorous TMDL Attainability by Parcel Size for the Lower Charles River by BMP Scenario; Total Maximum Daily Load is 9,757 lbs.

Unmanaged Phosphorus Load	RDA Parcel Area Threshold		
	All	>0.05 Acres	>1 Acre
BMP Scenarios	lbs.	lbs.	lbs.
100% Removal	1,925	2,569	14,709
Bioretention BMPs	9,100	9,589	18,816

*Green cells represent scenarios which achieve a given TMDL and red cells represent scenarios which do not achieve a given TMDL.

For the Upper Charles River watershed, the maximum potential load reduction, by use of bioretention, is capable of achieving the phosphorus TMDL with stormwater management applied to parcels >0.25 acres. These results are summarized in Table 21, below.

Table 21 – Phosphorous TMDL Attainability by Parcel Size for the Upper Charles River by BMP Scenario; Total Maximum Daily Load is 33,189 lbs.

Unmanaged Phosphorus Load	RDA Parcel Area Threshold		
	All	>0.25 Acres	>1 Acre
BMP Scenarios	lbs.	lbs.	lbs.
100% Removal	16,317	21,296	31,113
Bioretention BMPs	27,096	30,880	38,341

*Green cells represent scenarios which achieve a given TMDL and red cells represent scenarios which do not achieve a given TMDL.

When considering RDA scenarios, none of those assessed in this analysis were capable of meeting the TMDL for fecal coliform for either the Lower or Upper Charles River, even assuming 100% pollutant removal efficiency. These results are summarized in Table 22 and Table 23, below.

Table 22 - Fecal Coliform TMDL Attainability by Parcel Size for the Lower Charles River by BMP Scenario; Total Maximum Daily Load is 1.84E+14 CFUs

Unmanaged Fecal Coliform Load	RDA Parcel Area Threshold		
	All	>0.05 Acres	>1 Acre
BMP Scenarios	colonies	colonies	colonies
100% Removal	6.17E+14	8.19E+14	5.32E+15
Infiltration BMPs	1.15E+15	1.34E+15	5.62E+15

*Green cells represent scenarios which achieve a given TMDL and red cells represent scenarios which do not achieve a given TMDL.

Table 23 -Fecal Coliform TMDL Attainability by Parcel Size for the Upper Charles River by BMP Scenario; Total Maximum Daily Load is 3.42E+14 CFUs

Unmanaged Fecal Coliform Load	**RDA Parcel Area Threshold**		
	All	>0.25 Acres	>1 Acre
BMP Efficiency Scenarios	colonies	colonies	colonies
100% Removal	7.92E+15	1.02E+16	1.83E+16
Infiltration BMPs	9.21E+15	1.14E+16	1.90E+16

*Green cells represent scenarios which achieve a given TMDL and red cells represent scenarios which do not achieve a given TMDL.

6. Discussion and Conclusion

6.1. Assessing TMDL Attainability

The pollutant load reduction potential for each watershed was assessed assuming that new development, redevelopment, or installation of stormwater best management practice (BMP) retrofits in all runoff-producing areas would provide treatment for the 1” water quality volume (WQV). This analysis determined that the phosphorus TMDL can be met for the Lower Charles River watershed by implementing bioretention BMPs (the best available technology) sized to capture the 1” WQV for all industrial, commercial, and residential parcels larger than 0.05 acres. Similarly, the phosphorus TMDL can be met for the Upper Charles River watershed by implementing bioretention BMPs sized to capture the 1” WQV for all industrial, commercial, and residential parcels larger than 0.25 acres.

A tremendous 90% reduction in pollutant load could be achieved for fecal coliform in the Lower Charles River watershed, and a substantial 73% reduction in pollutant load could be achieved for fecal coliform in the Upper Charles River watershed (full TMDL attainability does not appear to be possible at this point in time). Achieving these fecal coliform reductions would require all residential, commercial, and industrial parcels to be managed with the best available BMP technology (infiltration systems). It is important to recognize that the significant bacterial load reduction would still bring tremendous benefits. It is possible that bacterial reduction requirements could be achieved with an improved understanding of the system through monitoring and modeling. Future studies should examine additional surface water quality investigations of sources, monitoring data, improved understanding of bacteria dynamics in relation to nutrient load reduction, and advances in technology for treatment. Bacteria concentrations and pollutant load export rates are far more varied and less well understood than more common nutrients.

With respect to phosphorous in the Lower Charles River watershed, parcels with an area >0.05 acres encompass 86% of all residential parcels, 84% of commercial parcels, and 91% of industrial parcels, and accounts for 50% of the existing load (15,902 lbs. TP) in the Lower Charles River watershed. In contrast, a target area including parcels >1 acre encompasses 1% of residential parcels, 6% of commercial parcels, and 24% of industrial parcels and accounts for 12% (3,762 lbs. TP) of the total phosphorus load in the Lower Charles River watershed. Given the disproportionate share of phosphorus loading from Multi-family residential, Commercial, and Industrial parcels, implementing current BMPs for a smaller group of larger parcels in those categories (as well as institutional parcels sharing the physical characteristics of those categories) would still represent a significant step toward meeting the Charles River TMDLs.

With respect to fecal coliform in the Lower Charles River watershed, management of all residential, commercial, and industrial parcels reduces the existing load by 90% (1.01E+16 Fecal Coliform CFUs). A target area including all residential, commercial, and industrial parcels >1 acre would remove 50% of the existing load (5.62E+15 Fecal Coliform CFUs).

With respect to phosphorous in the Upper Charles River watershed, parcels with an area >0.25 acres encompass 56% of all residential parcels, 61% of commercial parcels, and 85% of industrial parcels, and accounts for 36% of the existing load (21,907 lbs. TP) in the Upper

Charles River watershed. A target area including parcels >1 acre encompasses 8% of residential parcels, 23% of commercial parcels, and 54% of industrial parcels and accounts for 20% (12,090 lbs. TP) of the total phosphorus load in the Upper Charles River watershed.

With respect to fecal coliform in the Upper Charles River watershed, management of all residential, commercial, and industrial parcels reduces the existing load by 49% (1.65E+16 Fecal Coliform CFUs). A target area of all residential, commercial, and industrial parcels >1 acre would remove 20% of the existing load (6.65E+15 Fecal Coliform CFUs).

6.2. TMDL Implementation

The water quality volume refers to a runoff capture volume that will provide treatment of 90% of the average annual runoff, typically equivalent to 1-inch of runoff from impervious areas. The use of a WQV design criteria is intended to provide treatment for the majority of stormwater contaminants in a cost-effective manner. For example, a 1" rainfall is far smaller than even a 1-year 24-hr storm event equal of 2.6".[25] The WQV design is based in part on the first-flush phenomenon where contaminant concentrations are highest in the beginning of storm runoff and becomes progressively cleaner as the contaminant load is exhausted during the wash-off process from impervious areas. In practice, the first-flush phenomenon varies by contaminant and in some instances smaller capture depths of 0.25" can be used to capture and treat the majority of nitrogen. This is an oft used approach for sizing retrofit BMPs in existing developed areas where there may be less opportunity for stormwater management for the 1" WQV. For this reason the use of the 1" WQV is a conservative assumption for water quality treatment and TMDL attainability.

The pollutant removal efficiency for bioretention systems from EPA (2010) was applied to each watershed to determine the upper bound for pollutant load reduction attainability. This represents a conservative assessment given that site-specific feasibility for stormwater management was not considered It is unlikely that stormwater management (SWM) would be required for all impervious areas (IA). Taking this approach identified the best-case scenario for pollutant load reduction, useful for evaluating if a given TMDL is even theoretically achievable within the current regulatory framework.

The iterative spreadsheet study conducted for the parcel-based analysis is useful for determining potential RDA approaches based on parcel size. The detailed results from the parcel-based analysis are included in Appendix D. The results include a ranked-sum analysis, plotting phosphorus load against parcel size for each land use type. Each curve on the chart represents a different land use type, and each shows what percentage of the total phosphorus load for the land use type would be managed by including all parcels above a certain size in an RDA designation. For example, if all commercial parcels greater than 1 acre in size were compelled to manage 100% of their stormwater runoff under RDA, this would account for roughly 46% of the total phosphorus load contribution from commercial areas in the Lower Charles River watershed.

6.3. Assumptions and Limitations

The following assumptions and limitations were part of this analysis.

[25] A 1-yr 24-hour storm depth is equal to 2.62 inches for Lincoln, MA, Northeast Regional Climate Center, 2012.

1. It was assumed (as EPA did in the proposed Upper Charles RDA permit) that government-owned properties that drain to an MS4 are regulated under NPDES, and residential, commercial, industrial, agricultural, and open space properties are not. This analysis assumed that EPA would exercise the authority for use of residual designation to regulate industrial, commercial, and residential properties > 1 acre. A parcel-based pollutant loading analysis identified that regulation of a minimum parcel area of 1 acre by RDA could achieve the required load reductions.

2. In order to perform the parcel-based RDA scenario analysis, it was necessary to determine which land use types from the existing 2005 MassGIS dataset[15] should be included within the MS4 area. Typically, only government-owned properties are considered to be a part of the NPDES permit for an MS4. Recognizing this, the following land use types were grouped in order to determine the extent of the watershed area which had already been accounted for by NPDES: junkyard, marina, powerline/utility, transportation, urban public/institutional, waste disposal. While this categorization scheme is likely to be fairly representative of the MS4 area, it is almost certain that some areas have been included or excluded erroneously (such as churches, which are grouped with 'institutional' but are not government-owned properties). Errors like this are unavoidable without spending considerable effort manually ruling individual parcels in/out of a given land use category, but may have a small impact on the pollutant load estimates for each land use category within the parcel-based analysis. Curve numbers were assigned to HRUs based on the soil type and impervious cover. For pervious subcatchments, the land use condition was assumed to be open space in good condition: grass cover on 75% or more of the area.

3. Along the same lines, in the process of assigning a land use type to each parcel for the RDA scenario analysis, many parcels were found to be spanning multiple land use types. In these cases, whichever land use type covered the greatest amount of a parcel's area was assigned to that parcel. However, this generalization process might have led to either an over- or underestimation of pollutant load contributions from a given land use type, though it is reasonable to assume that this would balance out overall.

4. The pollutant loading analysis lumped roadways in with different land use types. Roads were separated from each land use type and added to the 'MS4' category for the parcel-based analysis. This is because the land-use data did not separate, for example, residential streets from residential property areas, so these areas were assigned a phosphorus load export rate appropriate for impervious residential areas. However, residential streets would be included in the current NPDES permit for a city, so it was important to reflect this in the RDA scenario analysis. Overall, the total phosphorus load export rate for the watershed remains virtually unchanged between the two approaches.

5. It is useful to memorialize the rationale for choosing parcel-size rather than the impervious area within a parcel as the independent variable in the parcel-based analysis. This choice was largely made with ease of implementation in mind. Impervious coverages are constantly changing in urban areas, and this could present challenges for identifying which properties are in or out of the RDA designation. Reliance on impervious area size rather than parcel size also opens the door for litigation which could challenge a property's inclusion based on use

of outdated spatial data (the most recent geospatial impervious cover dataset available for the areas is from 2005). For these reasons, it was determined that the management process would be simpler if an RDA designation was based on parcel size, a fixed value, rather than impervious area within a parcel. Tracking of impervious area would continue to be part of any such analysis.

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8. APPENDICES

Appendix A: Expert Witness Resume, Publications Authored in Previous 10 years, Expert Witness Experience

Appendix B: Literature Sources for Pollutant Load Export Rates

Appendix C: EPA SWMM Model Documentation for Bacterial HRU Analysis

Appendix D: Parcel-Based RDA Scenario Spreadsheet Tool Results

Appendix A: Expert Witness Resume, Publications Authored in Previous 10 years, Expert Witness Experience

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WATERSTONE ENGINEERING
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EDUCATION

Ph.D., Civil- Water Resources Engineering, University of New Hampshire, Durham, NH, 2002

M.S., Environmental Science and Engineering, Colorado School of Mines, Golden, CO, 1998

PROFESSIONAL EXPERIENCE

Waterstone Engineering, Owner, Stratham, NH, 2016-Present
Horsley Witten Group, Practice Leader, Newburyport, MA, 2015- 2016
Geosyntec Consultants, Inc., Associate, Acton, MA, 2012 – 2015
University of New Hampshire, Research Assistant Professor, Durham, NH, 2007 – 2012
UNH Stormwater Center, Director, Durham, New Hampshire, 2004 – 2012
University of New Hampshire, Research Project Engineer III, Durham, NH, 2001 - 2007
The Bioengineering Group, Inc., Salem, MA, 2001 - 2004

REGISTRATIONS AND CERTIFICATIONS

Registered Professional Engineer, NH No. 12215, ME No. PE15125, MA No. 333
Diplomate of Water Resources Engineering, American Academy of Water Resources Eng., No. 00556

CAREER SUMMARY

Dr. Roseen provides many years of experience in water resources investigations and most recently, led a project team in the development of an Integrated Plan for nutrient management for stormwater and wastewater. This plan has received provisional approval by EPA and would be one of the first in the nation. Rob is a recognized industry leader in green infrastructure and watershed management, and the recipient of 2010 and 2016 Environmental Merit Awards by the US Environmental Protection Agency Region 1. He consults nationally and locally on stormwater management and planning and directed the University of New Hampshire Stormwater Center for 10 years and is deeply versed in the practice, policy, and planning of stormwater management. Rob has over 20 years of experience in the investigation, design, testing, and implementation of innovative approaches to stormwater management. Rob has led the technical analysis of dozens of nutrient and contaminant studies examining surface water pathways, system performance, management strategies, and system optimization.

Dr. Roseen provides Clean Water Act expert consultation, analysis, modeling, advice, reports and testimony in regard to compliance with Construction General Permits, Municipal Separate Storm Sewer System (MS4) Permits, and Multi Sector General Permits.

He also served as Research Assistant Professor for five years. His areas of expertise include water resources engineering, stormwater management (including low impact development design), and porous pavements. He also possesses additional expertise in water resource engineering including hydrology and hydraulics evaluations, stream restoration and enhancement alternatives, dam removal assessment, groundwater investigations, nutrient and TMDL studies, remote sensing, and GIS applications.

Dr. Roseen has taught classes on Stormwater Management and Design, Fluid Mechanics, and Hydrologic Monitoring and lectures frequently on these subjects. He is frequently called upon as an expert on stormwater management locally, regionally, and nationally.

Recent activities include chairing the ASCE EWRI 2016 International Low Impact Development Conference, an annual event that draws participants from around the world to discuss advances in water resources engineering, and participating until 2017 as a Control Group member for the ASCE Urban Water Resources Research Council (UWRRC). He has also served on the ASCE Task Committee on Guidelines for Certification of Manufactured Stormwater BMPs, EWRI Permeable Pavement Technical Committee, and the Hydrology, Hydraulics, and Water Quality Committee of the Transportation Research Board. Dr. Roseen has been the author or co-author of over two dozen professional publications on the topics of stormwater runoff, mitigation measures, best management practices (BMPs), etc. He has also been the recipient of several awards and other honors for his work, including the 2010 Outstanding Civil Engineering Achievement Award from the New Hampshire Chapter of the American Society of Civil Engineers, and an Environmental Merit Award from the EPA. He has extensive experience working with local, state, and regional agencies and participates on a national level for USEPA Headquarters, WEF, and the White Council on Environmental Quality on urban retrofit innovations and next generation LID/GI technology and financing solutions.

SELECT EXPERT WITNESS EXPERIENCE

Construction General Permit (CGP), and Clean Water Act Expert Services

Dr. Roseen is currently providing expert consultation, analysis, modeling, advice, reports and testimony in regards to construction general permit compliance, erosion and sedimentation control, and monitoring. Such services include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of defendants' facilities. This service is being provided for the plaintiff for one (1) case of significant size geographically and in project scope.

Municipal Separate Storm Sewer System (MS4) Permit and Clean Water Act Expert Services

A team lead by Dr. Roseen is currently providing expert consultation, analysis, modelling, advice, reports and testimony regarding stormwater discharges in regards to MS4 violations under the Clean Water Act. Such services include sworn to written or oral expert testimony regarding such matters in Court, and site and facility inspections. This service is being provided for the plaintiff for two (2) cases of significant size geographically and in project scope.

Multi Sector General Permit (MSGP), Stormwater Pollution Prevention Plan, and Clean Water Act Expert Services

A team lead by Dr. Roseen is currently providing expert consultation, analysis, modelling, advice, reports and testimony regarding stormwater discharges in regards to MSGP under the Clean Water Act. Such services include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of defendants' facilities. This service is being provided for the plaintiff for over ten (10) separate cases in the northeastern United States.

Multi Sector General Permit (MSGP) and Clean Water Act Expert Services

A team lead by Dr. Roseen provided expert consultation, analysis, modelling, advice, reports and testimony regarding the operations of a scrap metal and automotive recycling facility in relation to Multi Sector General Permit, Safe Drinking Water Act, and National Water Quality Criteria violations of the Clean Water

Act. Such services include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of facilities. This service was provided for a single location in the northeastern United States.

Expert Study and Testimony for Erosion and Sediment Control Litigation

A team lead by Dr. Roseen is currently providing expert study and testimony in defense of an undisclosed Federal Client in a $25-million-dollar lawsuit from a private entity. The plaintiff alleges impacts from upstream channel erosion and sediment transport. The efforts examine urban runoff and off-site impacts to a downstream channel and subsequent erosion and sediment transport into the downstream storm sewer system.

Expert Testimony for HB 1295 an Act Establishing a Commission to Study Issues Relating to Stormwater, and Commission Member for NH Legislature, January 2008.

Dr. Roseen participated as a lead member of the NH Stormwater Commission, House Bill 1295. The SW commission was comprised of experts in the field and stakeholders. The Commission provided recommendations to the legislature.

Expert Testimony for HB 648 NH Flood Commission, January 2008.

Dr. Roseen has provided expert testimony to numerous commissions including the NH Legislative Flood Commission. House Bill 648 developed a comprehensive flood management plan for the state of New Hampshire that considers possible measures for minimizing flood impacts on communities and individual properties and to consider issues associated with flood abatement.

Expert Review of Stormwater Management for Proposed Mystic Woods, Groton, CT

Dr. Roseen expert testimony and review of at the request of Hawthorne Partners for the stormwater management strategy for the proposed Mystic Woods Development in Groton, CT. Review was based on the practice requirements of 2004 Connecticut Stormwater Quality Manual. Review included assessment of both quantity management through infiltration (and recharge) and detention, and water quality treatment through the use of bioretention and infiltration for rooftop runoff, and detention and treatment with subsurface gravel wetlands for roadways, parking areas and impervious surfaces runoff. Design and potential impacts were assessed for the combination of strategies incorporating treatment trains (sequential treatment strategies) as a tool for minimizing off-site impacts and changes to predevelopment hydrologic and water quality conditions.

Expert Testimony and Review of YMCA Westport/Weston Stormwater Management

Dr. Roseen provided review and expert testimony of documents presented on behalf of the proposed development. Potential impacts and impairment from the proposed stormwater management was evaluated for Poplar Plains Brook, Lee’s Pond, and the Saugatuck Estuary. Considerations included: treatment mechanisms for nitrogen removal to impaired waters, recommendations for water quality monitoring information from which to base the assessment. It appears from the limited water quality monitoring available, review of Connecticut water quality standards for Class C impaired waters, and USEPA 303D Impaired Waters requirements.

Expert Testimony on Stormwater Issues Before The Nashua Planning Board For Proposed Commercial Development, Nashua, New Hampshire, December 2005.

Dr. Roseen provided testimony and review of the stormwater treatment strategy performance for a proposed facility. In particular he examined a variety of issues of concern for the proposed activities with regards to stormwater, increased traffic counts, and estimated contaminant loading to receiving waters within the Water Supply Protection District.

Participation in National Expert Meeting by the White House Council on Environmental Quality and Environmental Protection Agency

Dr. Roseen participated in a national meeting of experts entitled “Municipal Stormwater Infrastructure: Going from Grey to Green”. This meeting purpose was to engage stakeholders in developing options and solutions that result in wider implementation of green infrastructure practices to manage municipal stormwater.

SELECT OTHER PROJECTS

Integrated Permitting for MS4 and Wastewater:

Dr. Roseen is currently leading the stormwater engineering component for a large 5 firm engineering team and an integrated planning steering committee beginning in 2016. The integrated planning effort is the first in the northeastern United States for a municipally funded effort. This project seeks to develop an integrated plan for stormwater, wastewater, and nonpoint sources for a phosphorous TMDL.

Dr. Roseen lead a team from 2013-2015 that developed the foundation for an Integrated Plan for three coastal communities in the seacoast region of New Hampshire. The goal of the plan is to help these communities meet new, more stringent wastewater and stormwater permit requirements for nutrients, improve water quality in the Squamscott River and Great Bay, and support the economic viability of the participating communities. The Plan provides the communities with the necessary information to make long-term financial commitments and planning decisions and to communicate to the public essential information that was developed jointly.

MS4 Regulatory Program Experience: Dr. Roseen lead a team from 2012-2013 with the City of Rochester, New Hampshire as part of a 3-year stormwater engineering contract to provide services to support their MS4 operations and planning. A diverse array of services were provided including nutrient management planning for stormwater and wastewater, stormwater ordinance and planning regulations development, stormwater master planning, MS4 auditing for the 2003 permit, planning and preparation for the 2013 Draft MS4 permit, assistance with developing funding mechanisms to support the municipal program, stream restoration, asset inventory and assessment for drainage infrastructure, operations and management plan preparation, and GIS database development, to name a few.

Phase III Stormwater Master Plan and GIS Updates, Framingham, Ma: Dr. Roseen was the Project Manager for the development of a stormwater master plan for select sub-basins in the Town of Framingham. This project included a field program to collect data on over 1,000 stormwater structures and associated conveyances, as well as in-depth QA/QC of field data using GIS tools, integration of field data into the Town’s geodatabase, the development of a hydraulic and hydrologic model of the stormwater system, the performance of a water quality assessment including a pollutant loading analysis, and recommendations based on the condition assessment and modeling exercises based on GIS data and modeling results to develop a Stormwater Master Plan that identifies priority projects based on schedules, capital costs, feasibility, and permitting.

Long Creek Watershed Management Team: Dr. Roseen was a recipient of an Environmental Merit Award as a participating member in the Long Creek Watershed Management Team that was awarded by the US Environmental Protection Agency Region 1 in 2010. This involved the development of the Watershed Management Plan. Rob has collaborated with the Maine Department of Environmental Protection, the Department of Transportation, and the LCWMD in the implementation, monitoring, and maintenance of LID management measures including bioretention, gravel wetlands, tree filters, and the first installation of a high-use state roadway using porous asphalt in the northeastern United States.

Water Integration for the Squamscott Exeter (WISE), (2013-2015), National Estuarine Research Reserve—Science Collaborative. Dr. Roseen was the lead author and Project Director and Principal Investigator for this two-year, $449,484 project.

UNH Stormwater Center 2004-2012. The program tested over 30 BMPs with total funding in excess of $3 million.

Community Based Planning for Climate Change in New Hampshire, National Estuarine Research Reserve—Science Collaborative. Dr. Roseen was the lead stormwater enginnering investigator for this two-year, $683,472 project.

Green Infrastructure for Sustainable Coastal Communities, National Estuarine Research Reserve—Science Collaborative. Dr. Roseen is lead author and the lead science investigator for this two-year, $589,838 project.

Great Bay Municipal Bioretention Program, *New Hampshire Department of Environmental Services*. Dr. Roseen managed this two-year, $140,000 project.

Berry Brook Watershed Restoration, *Aquatic Resource Mitigation Fund of the NHDES and US Army Corps of Engineers*. Dr. Roseen managed this two-year, $400,000 project that investigated wetland and stream restoration, buffer development, and LID retrofits.

Berry Brook Watershed Management Plan Implementation, Phase I Water Quality BMPs, *New Hampshire Department of Environmental Services.* Dr. Roseen managed this two-year, $145,000 project.

Evaluation and Optimization of the Effectiveness of Stormwater Control Measures for Nitrogen Removal, *USEPA Region 1*. Dr. Roseen managed this two-year, $190,000 project.

Assessing the Risk of 100-year Freshwater Floods in the Lamprey River Watershed of New Hampshire Resulting from Changes in Climate and Land Use, *Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET).* Dr. Roseen served as Co-Investigator for a two-year, $177,815.

SELECT PEER REVIEWED PUBLICATIONS

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PROFESSIONAL AFFILIATIONS

- Management Committee, Piscataqua Region Estuary Partnership, since 2015
- Expert Panel, Long Creek Watershed Management District, since 2014.

- USEPA Headquarters, Urban Retrofit Innovation Roundtable, Next Generation LID/GI Technology and Financing Solutions, The National Experience, Selected participant, April 2012
- Urban Water Resources Research Council, Control Group Member, American Society of Civil Engineers, 2012-2017.
- Water Quality Standards Advisory Committee, Piscataqua Region Estuary Program, since 2010
- Technical Advisory Committee, Piscataqua Region Estuary Partnership, since 2009
- American Academy of Water Resources Engineers, Member since May, 2010
- ASCE EWRI-WERF Task Committee on Guidelines for Certification of Manufactured Stormwater BMPs-Subgroup Chair, Member since 2007
- Science and Technical Advisory Committee, American Rivers, Washington, DC, since 2011
- Board of External Reviewers, Washington State Stormwater Technology Assessment Program, 2010-2014
- Board of Directors, The Low Impact Development Center, Beltsville, Maryland, 2009-2015
- Board of Directors, The NH Coastal Protection Partnership, 2008-2012

HONORS AND AWARDS

- Environmental Merit Award, as project lead for the Water Integration for Squamscott Exeter (WISE) in coastal New Hampshire, awarded by the US Environmental Protection Agency, Region 1, 2016.
- Environmental Merit Award, as participating member in the New Hampshire Climate Adaption Workgroup, awarded by the US Environmental Protection Agency, Region 1, 2015
- In 2010, received the prestigious certification as a Diplomate by the American Academy of Water Resources Engineers (D. WRE), to certify competence in water resources specialization for 1) advanced stormwater management, and 2) design and execution of experiments, data analysis, and interpretation.
- 2010 Outstanding Civil Engineering Achievement Award, New Hampshire ASCE, Project Title: State Street Utilities Replacement and Street Revitalization, Portsmouth, New Hampshire, Design Team Member and Lead for Low Impact Development
- Environmental Merit Award, as participating member in the Long Creek Watershed Management Team, awarded US Environmental Protection Agency, Region 1, 2010
- Letter of Commendation from Commissioner Burack of the New Hampshire Department of Environmental Services for School Street School Stormwater Retrofit Project, September 2010

Appendix B: Literature Sources for Pollutant Load Export Rates

Table 24 - PLER Sources

Land Use	Land Cover	Nitrogen PLER Source	Phosphorus PLER Source	Fecal Coliform EMC Source	Enterococci EMC Source
Agriculture	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Transitional	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Transitional	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Commercial and Industrial	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Developed Pervious	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Industrial and Commercial Comp.	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Forest	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Forest	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Forest	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
High Density Residential	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Developed Pervious	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Residential	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Low Density Residential	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Developed Pervious	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Residential	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Medium Density Residential	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Developed Pervious	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Residential	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Highway	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Developed Pervious	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Transportation	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Open Land	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Transitional	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Transitional	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24

Appendix C: EPA SWMM Model Documentation for Bacterial HRU Analysis

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.012)

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*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............................ CFS
Process Models:
  Rainfall/Runoff ................ YES
  RDII ................................ NO
  Snowmelt ......................... YES
  Groundwater .................... NO
  Flow Routing ................... NO
  Water Quality ................... YES
Infiltration Method ............. CURVENUMBER
Starting Date ...................... 01/01/2000 00:00:00
Ending Date ....................... 12/30/2013 23:59:00
Antecedent Dry Days ......... 0.0
Report Time Step ............... 01:00:00
Wet Time Step ................... 00:01:00
Dry Time Step .................... 00:05:00

**************************                  Volume          Depth
```

Runoff Quantity Continuity	acre-feet	inches
**************************	-------------	------------
Initial Snow Cover	0.000	0.000
Total Precipitation	282.546	678.110
Evaporation Loss	27.520	66.049
Infiltration Loss	169.563	406.951
Surface Runoff	83.767	201.041
Snow Removed	0.000	0.000
Final Snow Cover	1.690	4.056
Final Storage	0.007	0.017
Continuity Error (%)	-0.001	

**************************	Volume	Volume
Flow Routing Continuity	acre-feet	10^6 gal
**************************	-----------	------------
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	83.767	27.297
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	83.767	27.297
Flooding Loss	0.000	0.000
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	0.000	

****

Subcatchment Runoff Summary
****

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
IMP.CN98	678.11	0.00	117.99	0.00	556.45	15.11	1.68	0.821
PERV.A.CN39	678.11	0.00	34.54	605.93	33.47	0.91	0.35	0.049
PERV.B.CN61	678.11	0.00	50.28	537.15	86.51	2.35	0.64	0.128
PERV.C.CN74	678.11	0.00	60.67	467.56	145.71	3.96	0.75	0.215
PERV.D.CN80	678.11	0.00	66.77	424.11	183.07	4.97	0.77	0.270

Analysis begun on: Thu May 10 09:08:57 2018
Analysis ended on: Thu May 10 09:09:56 2018
Total elapsed time: 00:00:59

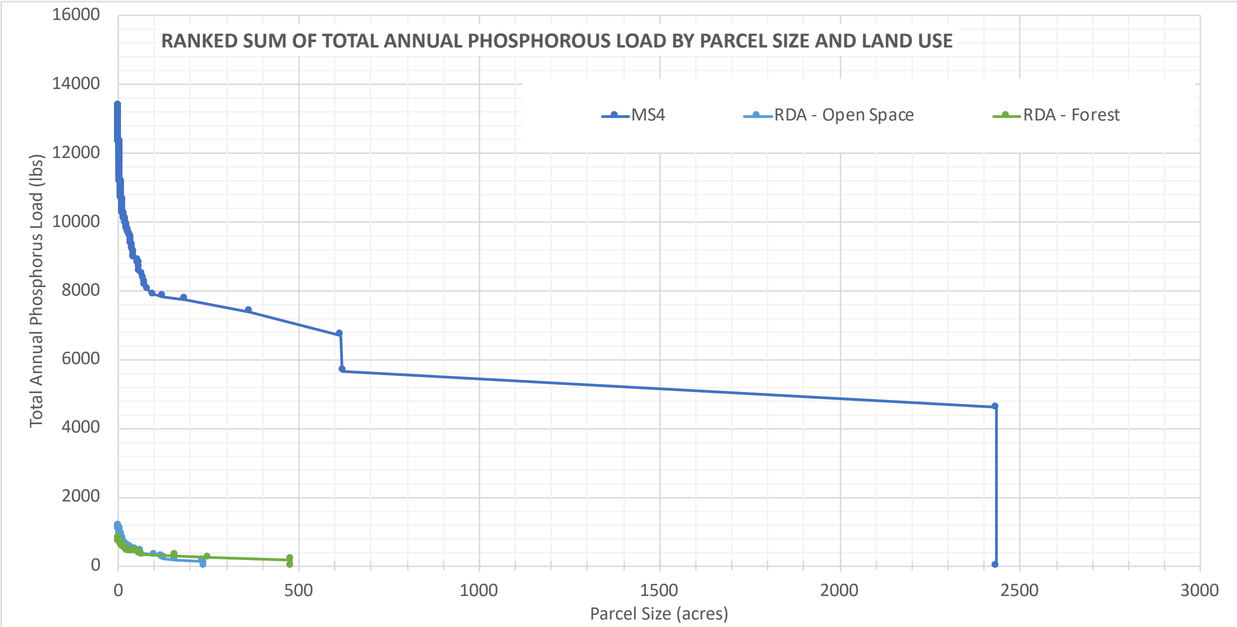
Appendix D: Parcel-Based RDA Scenario Spreadsheet Tool Results

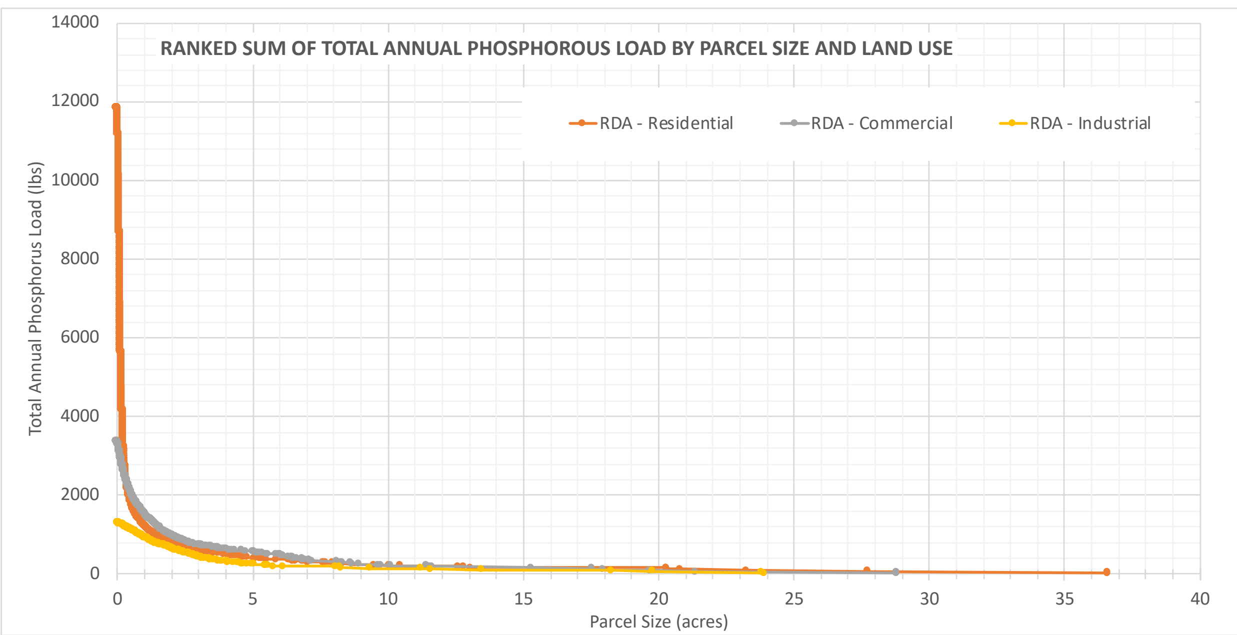
LOWER CHARLES RIVER WATERSHED PARCEL-BASED SCENARIO ANALYSIS - PHOSPHOROUS

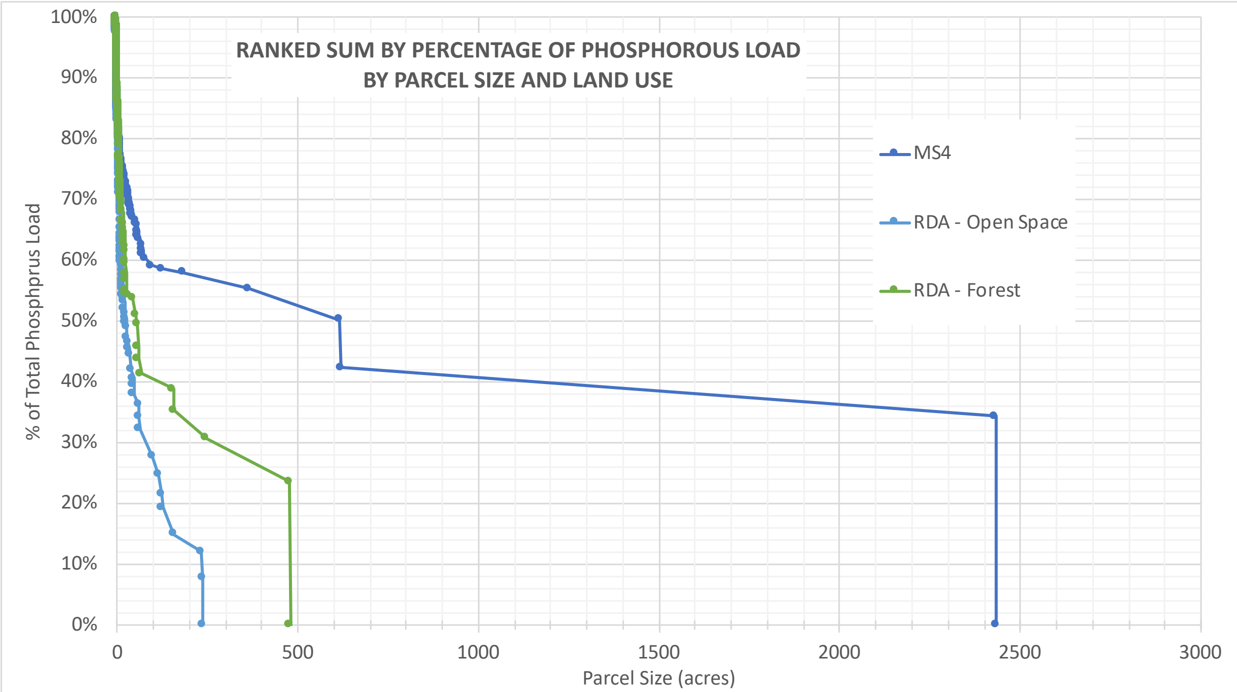
							Scenario 1: Regulating All Non-MS4 Residential, Commercial, and Industrial Parcels			
	# Parcels	Area (acres)	Total Phosphorus Load (lbs)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Bioretention BMPs; 76% Removal Efficiency	
							Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load
MS4	3842	8980.8	13349.1	0.0	3842	100%	13349.1	100%	10145.3	76%
RDA - Residential	72630	11169.7	11852.9	0.0	72630	100%	11852.9	100%	9008.2	76%
RDA - Commercial	6412	2196.6	3385.9	0.0	6412	100%	3385.9	100%	2573.3	76%
RDA - Industrial	934	826.8	1306.2	0.0	934	100%	1306.2	100%	992.7	76%
RDA - Open Space	577	2737.4	1147.5	9999.0	0	0%	0.0	0%	0.0	0%
Forest	840	2667.1	778.0	9999.0	0	0%	0.0	0%	0.0	0%
Total	**85235**	**28578.5**	**31819.6**		**83818**	**98%**	**29894.1**	94%	**22719.5**	71%
Unmanaged Load			**0.0**				**1925.4**		**9100.0**	
TMDL Requirement			9757				9757		9757	
% of TMDL			0%				80%		7%	

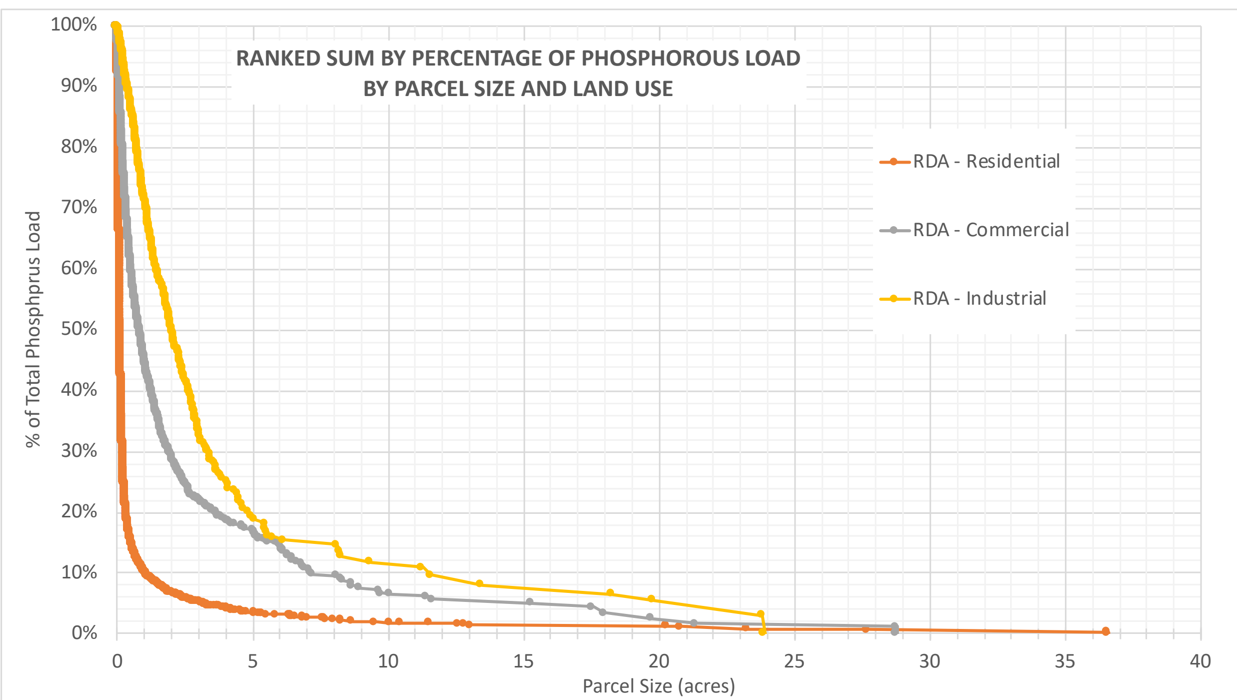
							Scenario 2: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >0.05 acres			
	# Parcels	Area (acres)	Total Phosphorus Load (lbs)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Bioretention BMPs; 76% Removal Efficiency	
							Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load
MS4	3842	8980.8	13349.1	0.0	3842	100%	13349.1	100%	10145.3	76%
RDA - Residential	72630	11169.7	11852.9	0.05	62793	86%	11268.0	95%	8563.7	72%
RDA - Commercial	6412	2196.6	3385.9	0.05	5378	84%	3332.0	98%	2532.3	75%
RDA - Industrial	934	826.8	1306.2	0.05	847	91%	1302.0	100%	989.5	76%
RDA - Open Space	577	2737.4	1147.5	9999.0	0	0%	0.0	0%	0.0	0%
Forest	840	2667.1	778.0	9999.0	0	0%	0.0	0%	0.0	0%
Total	**85235**	**28578.5**	**31819.6**		**72860**	**85%**	**29251.0**	92%	**22230.8**	70%
Unmanaged Load			**0.0**				**2568.6**		**9588.8**	
TMDL Requirement			9757				9757		9757	
% of TMDL			0%				74%		2%	

							Scenario 3: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >1 acre			
	# Parcels	Area (acres)	Total Phosphorus Load (lbs)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Bioretention BMPs; 76% Removal Efficiency	
							Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load
MS4	3842	8980.8	13349.1	0.0	3842	100%	13349.1	100%	10145.3	76%
RDA - Residential	72630	11169.7	11852.9	1.0	555	1%	1248.3	11%	948.7	8%
RDA - Commercial	6412	2196.6	3385.9	1.0	410	6%	1565.1	46%	1189.5	35%
RDA - Industrial	934	826.8	1306.2	1.0	228	24%	948.1	73%	720.6	55%
RDA - Open Space	577	2737.4	1147.5	9999.0	0	0%	0.0	0%	0.0	0%
Forest	840	2667.1	778.0	9999.0	0	0%	0.0	0%	0.0	0%
Total	**85235**	**28578.5**	**31819.6**		**5035**	**6%**	**17110.6**	54%	**13004.1**	41%
Unmanaged Load			**0.0**				**14709.0**		**18815.5**	
TMDL Requirement			9757				9757		9757	
% of TMDL			0%				-51%		-93%	


RANKED SUM OF TOTAL ANNUAL PHOSPHOROUS LOAD BY PARCEL SIZE AND LAND USE
MS4
RDA - Open Space
RDA - Forest
Total Annual Phosphorus Load (lbs)
Parcel Size (acres)
0
2000
4000
6000
8000
10000
12000
14000
16000
0
500
1000
1500
2000
2500
3000


RANKED SUM OF TOTAL ANNUAL PHOSPHOROUS LOAD BY PARCEL SIZE AND LAND USE
RDA - Residential
RDA - Commercial
RDA - Industrial
Total Annual Phosphorus Load (lbs)
Parcel Size (acres)
0
2000
4000
6000
8000
10000
12000
14000
0
5
10
15
20
25
30
35
40


RANKED SUM BY PERCENTAGE OF PHOSPHOROUS LOAD
BY PARCEL SIZE AND LAND USE
MS4
RDA - Open Space
RDA - Forest
% of Total Phosphprus Load
Parcel Size (acres)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500
1000
1500
2000
2500
3000

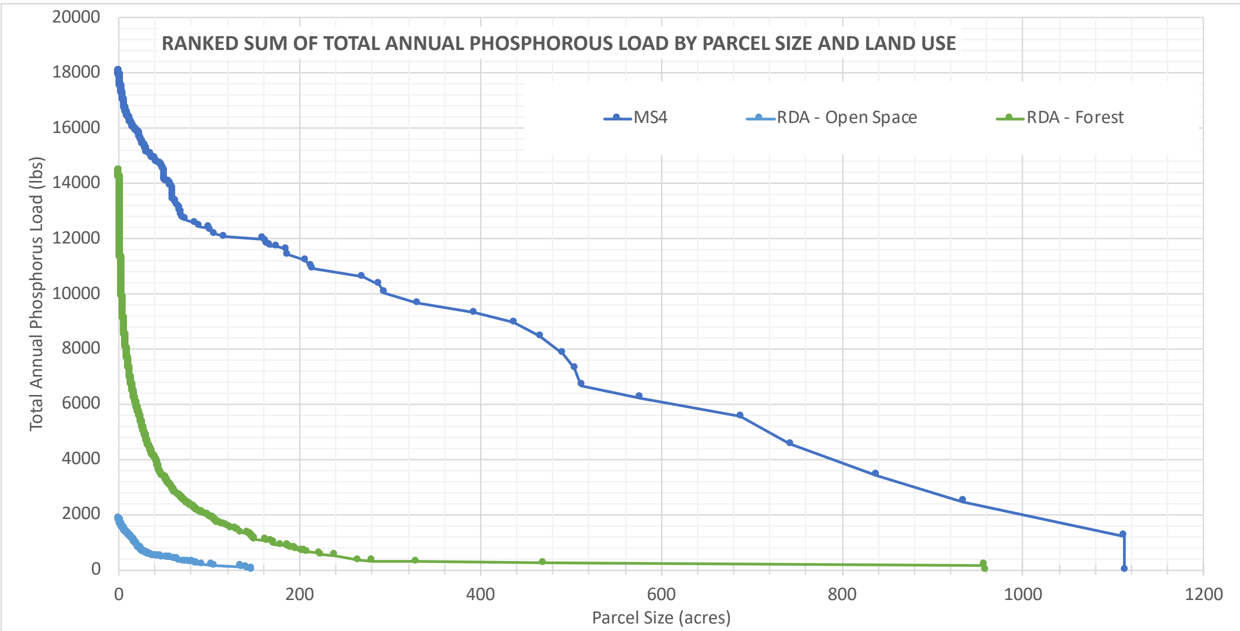

RANKED SUM BY PERCENTAGE OF PHOSPHOROUS LOAD
BY PARCEL SIZE AND LAND USE
RDA - Residential
RDA - Commercial
RDA - Industrial
% of Total Phosphprus Load
Parcel Size (acres)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
5
10
15
20
25
30
35
40

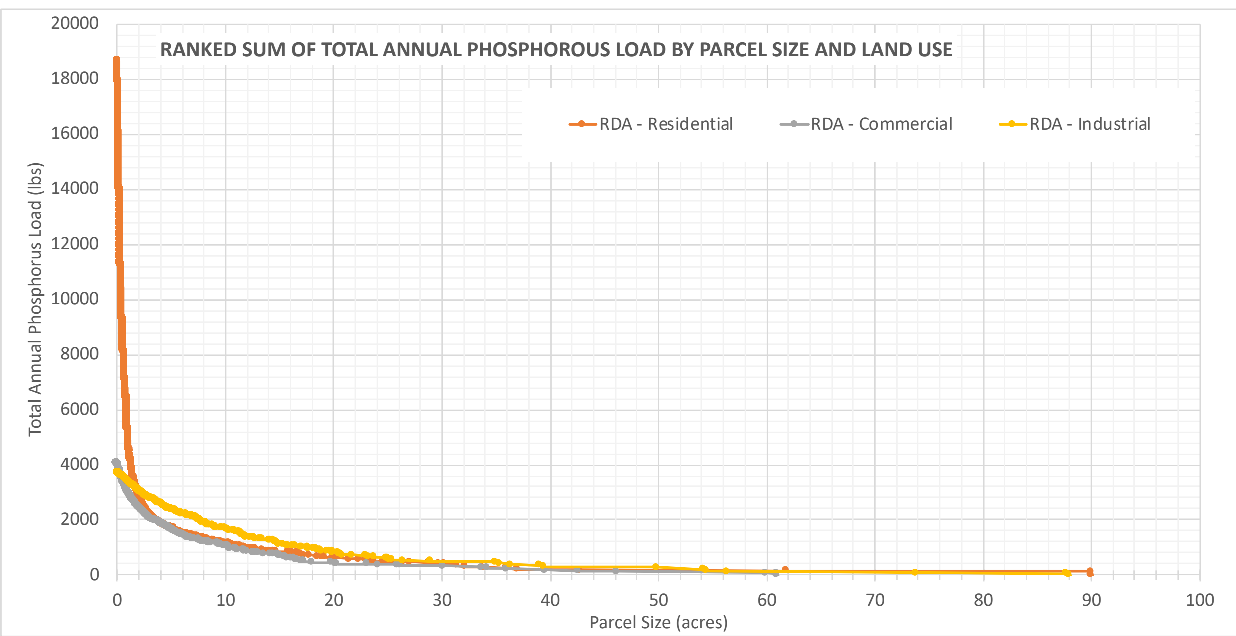
UPPER CHARLES RIVER WATERSHED PARCEL-BASED SCENARIO ANALYSIS - PHOSPHOROUS

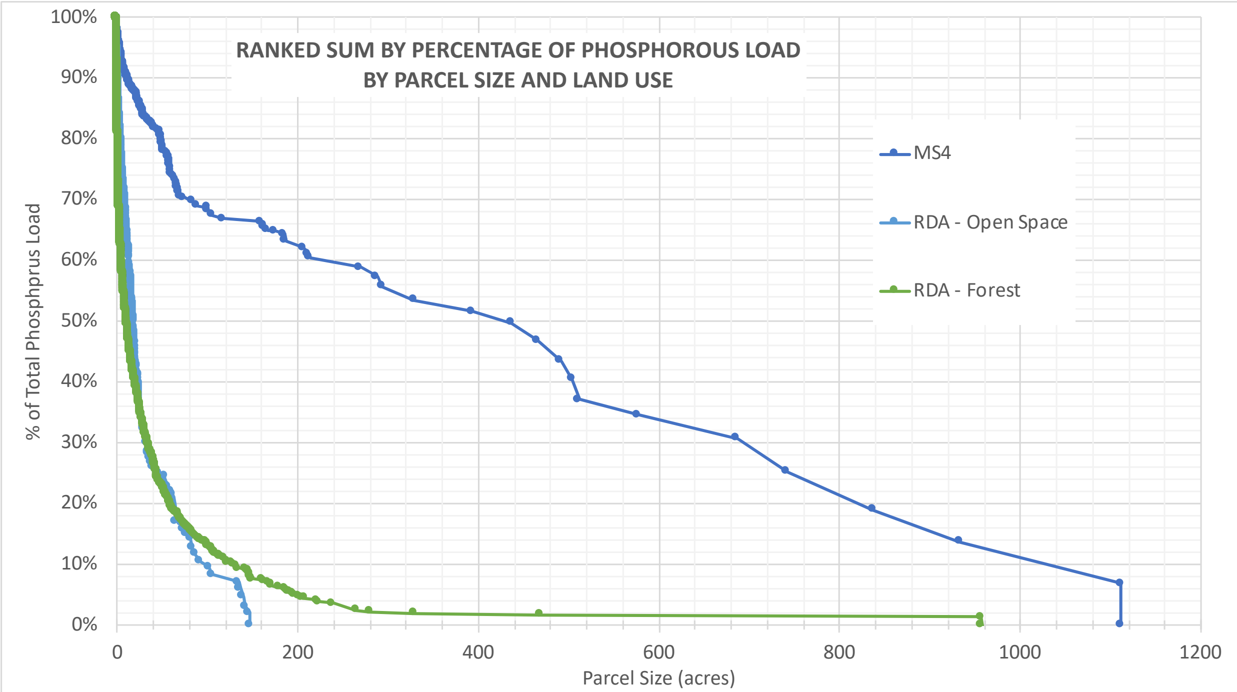
							Scenario 1: Regulating All Non-MS4 Residential, Commercial, and Industrial Parcels			
	# Parcels	Area (acres)	Total Phosphorus Load (lbs)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Bioretention BMPs; 76% Removal Efficiency	
							Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load
MS4	1698	18180.6	18028.2	0.0	1698	100%	18028.2	100%	13701.4	76%
RDA - Residential	91343	40693.2	19075.4	0.0	91343	100%	19075.4	100%	14497.3	76%
RDA - Commercial	3003	3552.3	4089.4	0.0	3003	100%	4089.4	100%	3107.9	76%
RDA - Industrial	1095	3602.7	3721.2	0.0	1095	100%	3721.2	100%	2828.1	76%
RDA - Open Space	817	5774.6	1853.0	9999.0	0	0%	0.0	0%	0.0	0%
Forest	21062	73476.4	14463.9	9999.0	0	0%	0.0	0%	0.0	0%
Total	**119018**	**145279.7**	**61231.1**		**97139**	**82%**	**44914.2**	73%	**34134.8**	56%
Unmanaged Load			**0.0**				**16316.9**		**27096.3**	
TMDL Requirement			33189				33189		33189	
% of TMDL			0%				51%		18%	

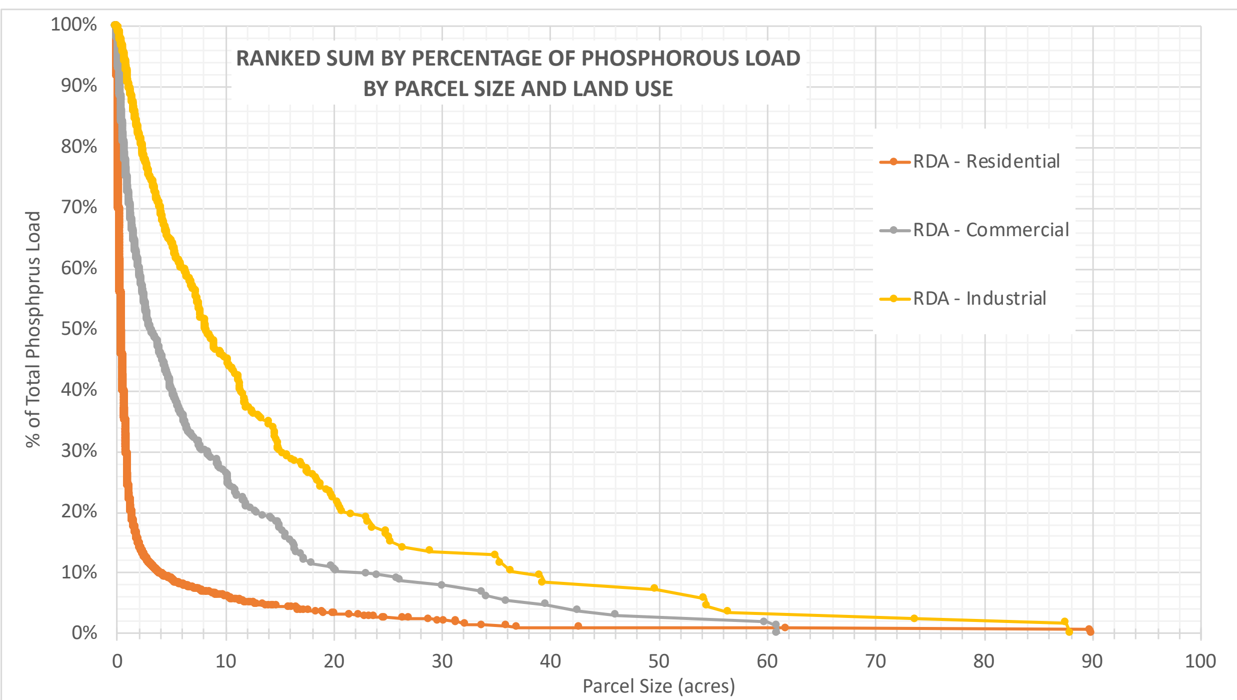
							Scenario 2: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >0.25 acres			
	# Parcels	Area (acres)	Total Phosphorus Load (lbs)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Bioretention BMPs; 76% Removal Efficiency	
							Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load
MS4	1698	18180.6	18028.2	0.0	1698	100%	18028.2	100%	13701.4	76%
RDA - Residential	91343	40693.2	19075.4	0.25	51165	56%	14363.7	75%	10916.4	57%
RDA - Commercial	3003	3552.3	4089.4	0.25	1834	61%	3853.7	94%	2928.8	72%
RDA - Industrial	1095	3602.7	3721.2	0.25	930	85%	3689.7	99%	2804.1	75%
RDA - Open Space	817	5774.6	1853.0	9999.0	0	0%	0.0	0%	0.0	0%
Forest	21062	73476.4	14463.9	9999.0	0	0%	0.0	0%	0.0	0%
Total	**119018**	**145279.7**	**61231.1**		**55627**	**47%**	**39935.3**	65%	**30350.8**	50%
Unmanaged Load			**0.0**				**21295.8**		**30880.3**	
TMDL Requirement			33189				33189		33189	
% of TMDL			0%				36%		7%	

							Scenario 3: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >1 acre			
	# Parcels	Area (acres)	Total Phosphorus Load (lbs)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Bioretention BMPs; 76% Removal Efficiency	
							Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load
MS4	1698	18180.6	18028.2	0.0	1698	100%	18028.2	100%	13701.4	76%
RDA - Residential	91343	40693.2	19075.4	1.0	7589	8%	5578.1	29%	4239.3	22%
RDA - Commercial	3003	3552.3	4089.4	1.0	692	23%	3070.1	75%	2333.3	57%
RDA - Industrial	1095	3602.7	3721.2	1.0	588	54%	3441.6	92%	2615.6	70%
RDA - Open Space	817	5774.6	1853.0	9999.0	0	0%	0.0	0%	0.0	0%
Forest	21062	73476.4	14463.9	9999.0	0	0%	0.0	0%	0.0	0%
Total	**119018**	**145279.7**	**61231.1**		**10567**	**9%**	**30118.0**	49%	**22889.7**	37%
Unmanaged Load			**0.0**				**31113.1**		**38341.4**	
TMDL Requirement			33189				33189		33189	
% of TMDL			0%				6%		-16%	


RANKED SUM OF TOTAL ANNUAL PHOSPHOROUS LOAD BY PARCEL SIZE AND LAND USE
MS4
RDA - Open Space
RDA - Forest
Total Annual Phosphorus Load (lbs)
Parcel Size (acres)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
0
200
400
600
800
1000
1200


RANKED SUM OF TOTAL ANNUAL PHOSPHOROUS LOAD BY PARCEL SIZE AND LAND USE
RDA - Residential
RDA - Commercial
RDA - Industrial
Total Annual Phosphorus Load (lbs)
Parcel Size (acres)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
0
10
20
30
40
50
60
70
80
90
100


RANKED SUM BY PERCENTAGE OF PHOSPHOROUS LOAD
BY PARCEL SIZE AND LAND USE
MS4
RDA - Open Space
RDA - Forest
% of Total Phosphprus Load
Parcel Size (acres)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
200
400
600
800
1000
1200

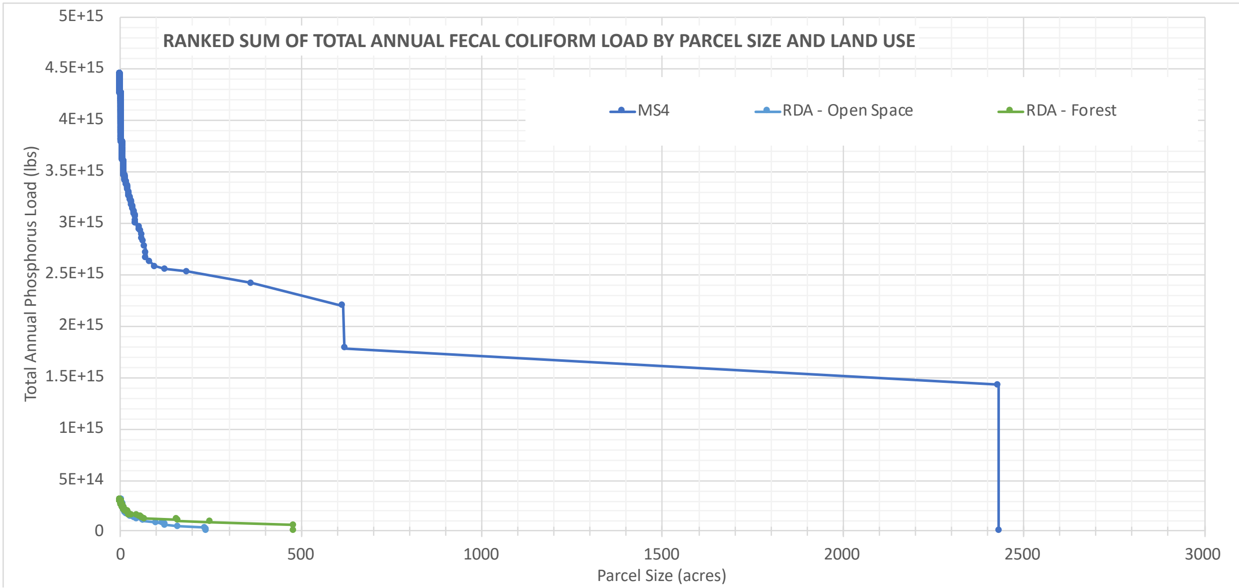

RANKED SUM BY PERCENTAGE OF PHOSPHOROUS LOAD
BY PARCEL SIZE AND LAND USE
RDA - Residential
RDA - Commercial
RDA - Industrial
% of Total Phosphprus Load
Parcel Size (acres)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
50
60
70
80
90
100

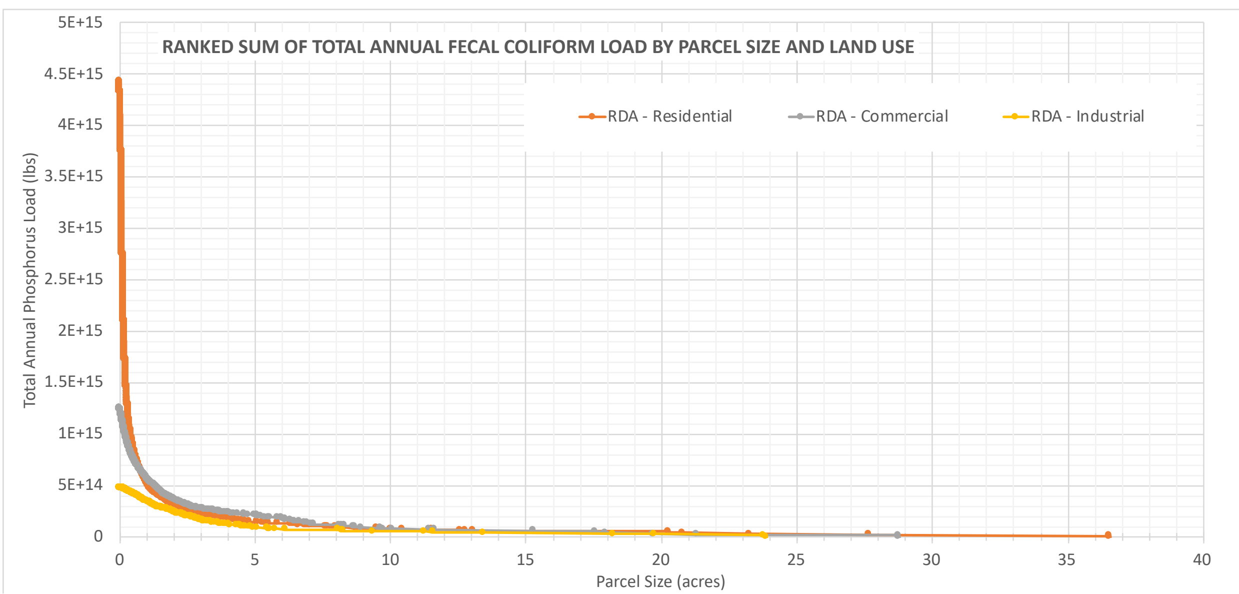
LOWER CHARLES RIVER WATERSHED PARCEL-BASED SCENARIO ANALYSIS - FECAL COLIFORM

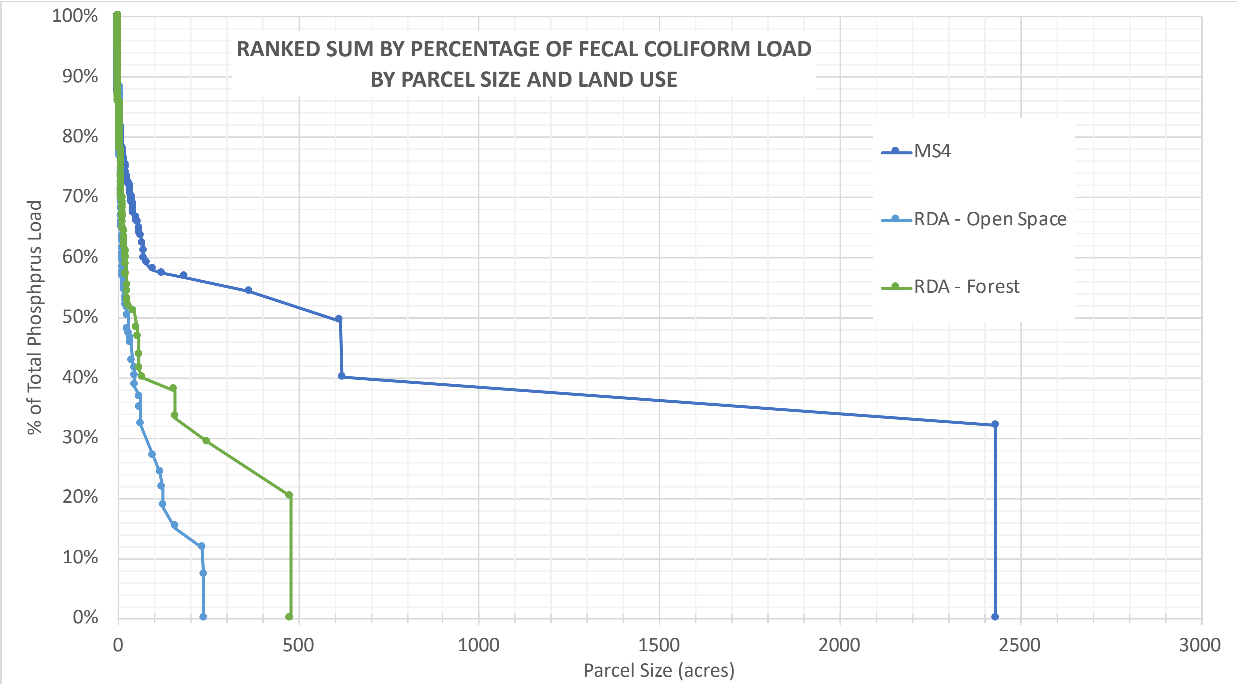
							Scenario 1: Regulating All Non-MS4 Residential, Commercial, and Industrial Parcels			
	# Parcels	Area (acres)	Total Fecal Coliform Load (colonies)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Infiltration BMPs; 95% Removal Efficiency	
							Managed Fecal Coliform Load (colonies)	% of Total Load	Managed Fecal Coliform Load (colonies)	% of Total Load
MS4	3842	8980.8	4.44E+15	0.0	3842	100%	4.44E+15	100%	4.22E+15	95%
RDA - Residential	72630	11169.7	4.44E+15	0.0	72630	100%	4.44E+15	100%	4.21E+15	95%
RDA - Commercial	6412	2196.6	1.26E+15	0.0	6412	100%	1.26E+15	100%	1.19E+15	95%
RDA - Industrial	934	826.8	4.83E+14	0.0	934	100%	4.83E+14	100%	4.59E+14	95%
RDA - Open Space	577	2737.4	3.12E+14	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Forest	840	2667.1	3.04E+14	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Total	**85235**	**28578.5**	**1.12E+16**		**83818**	**98%**	**1.06E+16**	95%	**1.01E+16**	90%
Unmanaged Load			**0.0**				**6.17E+14**		**1.15E+15**	
TMDL Requirement			1.84E+14				1.84E+14		1.84E+14	
% of TMDL			0%				-235%		-524%	

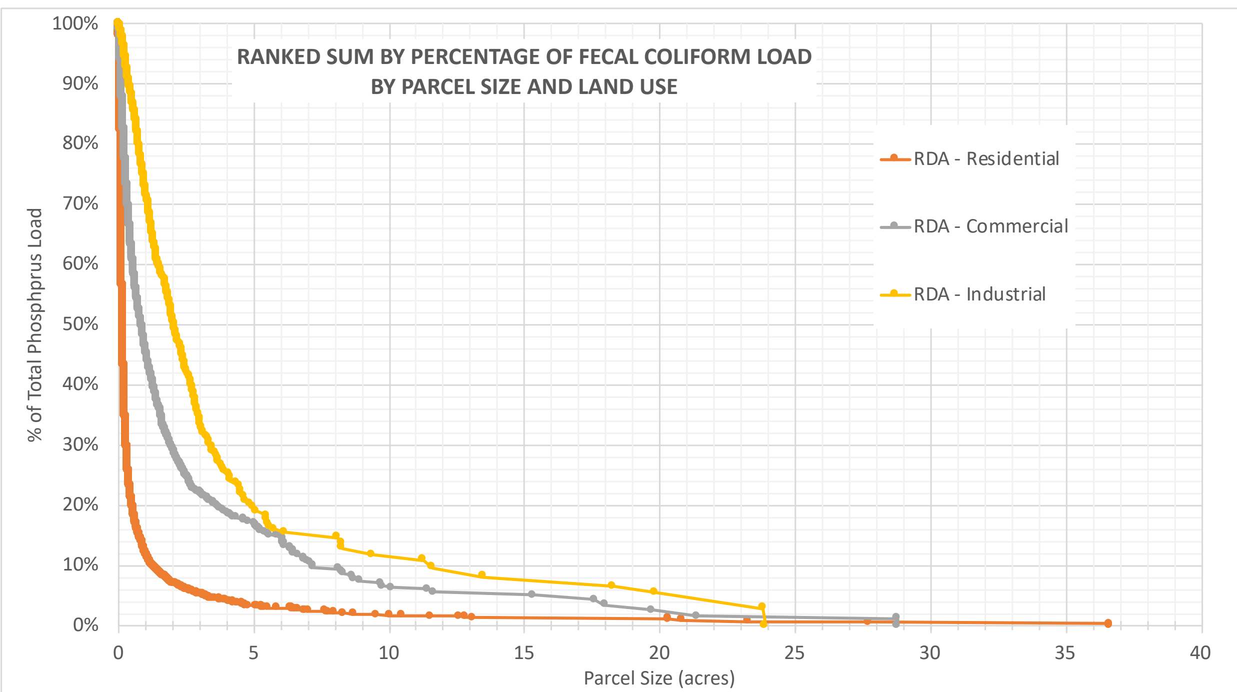
							Scenario 2: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >0.05 acres			
	# Parcels	Area (acres)	Total Fecal Coliform Load (colonies)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Infiltration BMPs; 95% Removal Efficiency	
							Managed Fecal Coliform Load (colonies)	% of Total Load	Managed Fecal Coliform Load (colonies)	% of Total Load
MS4	3842	8980.8	4.44E+15	0.0	3842	100%	4.44E+15	100%	4.22E+15	95%
RDA - Residential	72630	11169.7	4.44E+15	0.05	62793	86%	4.26E+15	96%	4.04E+15	91%
RDA - Commercial	6412	2196.6	1.26E+15	0.05	5378	84%	1.24E+15	98%	1.18E+15	94%
RDA - Industrial	934	826.8	4.83E+14	0.05	847	91%	4.82E+14	100%	4.58E+14	95%
RDA - Open Space	577	2737.4	3.12E+14	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Forest	840	2667.1	3.04E+14	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Total	**85235**	**28578.5**	**1.12E+16**		**72860**	**85%**	**1.04E+16**	93%	**9.90E+15**	88%
Unmanaged Load			**0.0**				**8.19E+14**		**1.34E+15**	
TMDL Requirement			1.84E+14				1.84E+14		1.84E+14	
% of TMDL			0%				-345%		-628%	

							Scenario 3: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >1 acre			
	# Parcels	Area (acres)	Total Fecal Coliform Load (colonies)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Infiltration BMPs; 95% Removal Efficiency	
							Managed Fecal Coliform Load (colonies)	% of Total Load	Managed Fecal Coliform Load (colonies)	% of Total Load
MS4	3842	8980.8	4.44E+15	0.0	3842	100%	4.44E+15	100%	4.22E+15	95%
RDA - Residential	72630	11169.7	4.44E+15	1.0	555	1%	5.41E+14	12%	5.14E+14	12%
RDA - Commercial	6412	2196.6	1.26E+15	1.0	410	6%	5.81E+14	46%	5.52E+14	44%
RDA - Industrial	934	826.8	4.83E+14	1.0	228	24%	3.51E+14	73%	3.33E+14	69%
RDA - Open Space	577	2737.4	3.12E+14	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Forest	840	2667.1	3.04E+14	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Total	**85235**	**28578.5**	**1.12E+16**		**5035**	**6%**	**5.92E+15**	53%	**5.62E+15**	50%
Unmanaged Load			**0.0**				**5.32E+15**		**5.62E+15**	
TMDL Requirement			1.84E+14				1.84E+14		1.84E+14	
% of TMDL			0%				-2792%		-2953%	


RANKED SUM OF TOTAL ANNUAL FECAL COLIFORM LOAD BY PARCEL SIZE AND LAND USE
MS4
RDA - Open Space
RDA - Forest
Total Annual Phosphorus Load (lbs)
5E+15
4.5E+15
4E+15
3.5E+15
3E+15
2.5E+15
2E+15
1.5E+15
1E+15
5E+14
0
0
500
1000
1500
2000
2500
3000
Parcel Size (acres)


RANKED SUM OF TOTAL ANNUAL FECAL COLIFORM LOAD BY PARCEL SIZE AND LAND USE
RDA - Residential
RDA - Commercial
RDA - Industrial
Total Annual Phosphorus Load (lbs)
5E+15
4.5E+15
4E+15
3.5E+15
3E+15
2.5E+15
2E+15
1.5E+15
1E+15
5E+14
0
0
5
10
15
20
25
30
35
40
Parcel Size (acres)


RANKED SUM BY PERCENTAGE OF FECAL COLIFORM LOAD
BY PARCEL SIZE AND LAND USE
% of Total Phosphprus Load
Parcel Size (acres)
MS4
RDA - Open Space
RDA - Forest
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500
1000
1500
2000
2500
3000

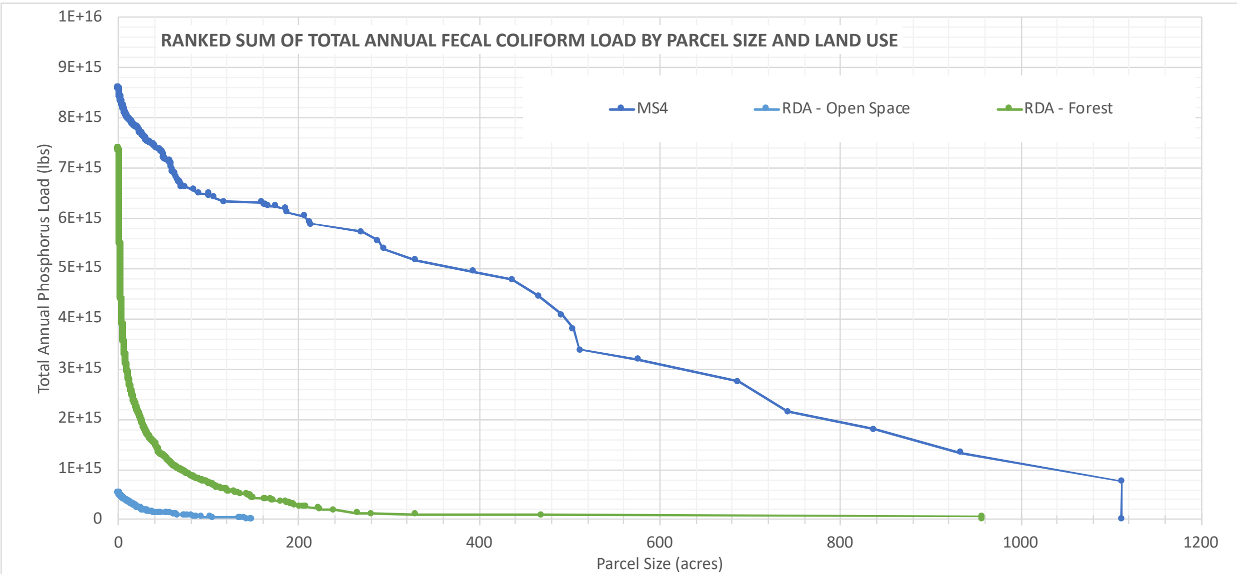

RANKED SUM BY PERCENTAGE OF FECAL COLIFORM LOAD
BY PARCEL SIZE AND LAND USE
% of Total Phosphprus Load
Parcel Size (acres)
RDA - Residential
RDA - Commercial
RDA - Industrial
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
5
10
15
20
25
30
35
40

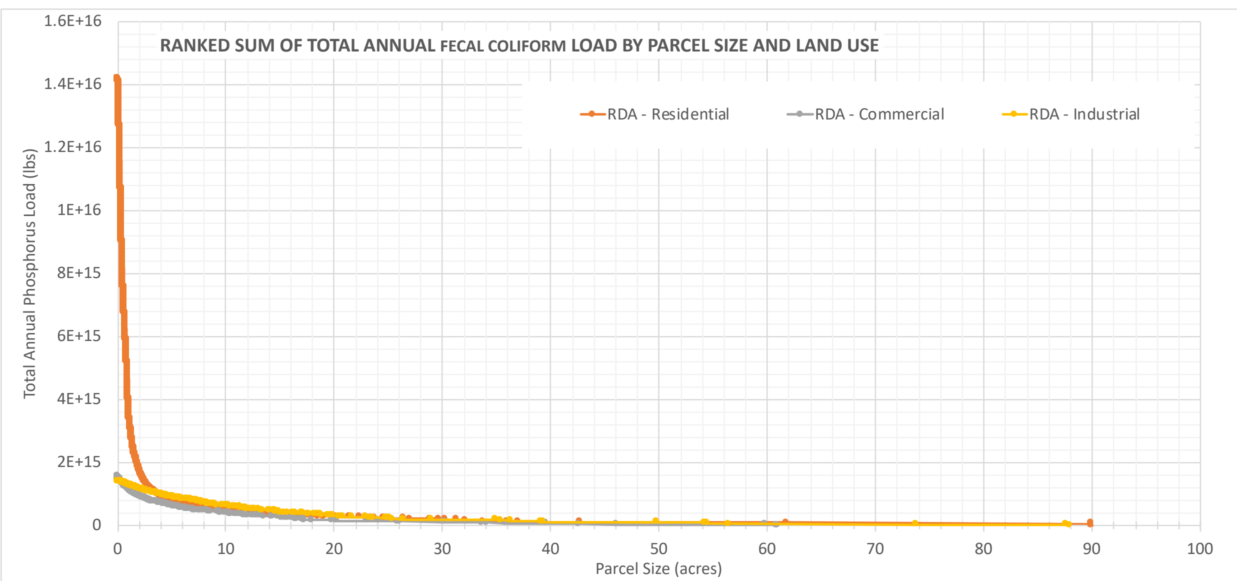
UPPER CHARLES RIVER WATERSHED PARCEL-BASED SCENARIO ANALYSIS - FECAL COLIFORM

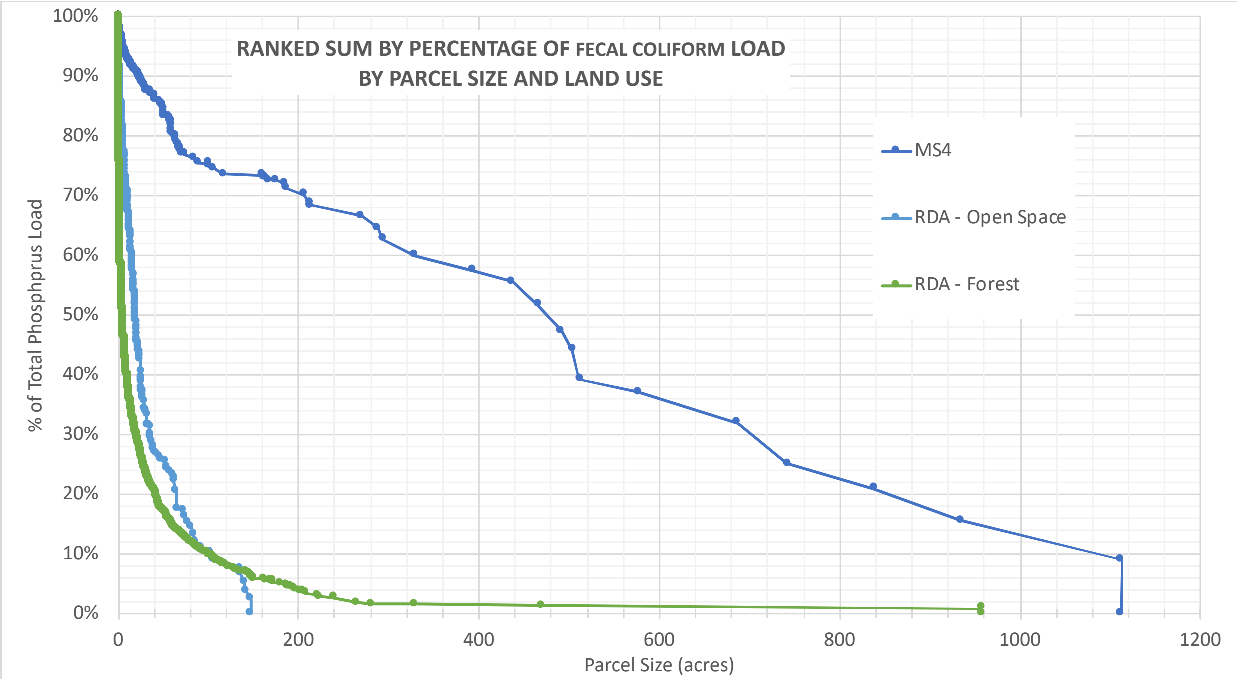
							Scenario 1: Regulating All Non-MS4 Residential, Commercial, and Industrial Parcels			
	# Parcels	Area (acres)	Total Fecal Coliform Load (colonies)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal Managed Fecal Coliform Load (colonies)	% of Total Load	Infiltration BMPs; 95% Removal Efficiency Managed Fecal Coliform Load (colonies)	% of Total Load
MS4	1698	18180.6	8.59E+15	0.0	1698	100%	8.59E+15	100%	8.16E+15	95%
RDA - Residential	91343	40693.2	1.44E+16	0.0	91343	100%	1.44E+16	100%	1.36E+16	95%
RDA - Commercial	3003	3552.3	1.56E+15	0.0	3003	100%	1.56E+15	100%	1.48E+15	95%
RDA - Industrial	1095	3602.7	1.42E+15	0.0	1095	100%	1.42E+15	100%	1.35E+15	95%
RDA - Open Space	817	5774.6	5.30E+14	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Forest	21062	73476.4	7.39E+15	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Total	**119018**	**145279.7**	**3.39E+16**		**97139**	**82%**	**2.59E+16**	77%	**2.46E+16**	73%
Unmanaged Load			**0.0**				**7.92E+15**		**9.21E+15**	
TMDL Requirement			3.42E+14				3.42E+14		3.42E+14	
% of TMDL			0%				-2215%		-2594%	

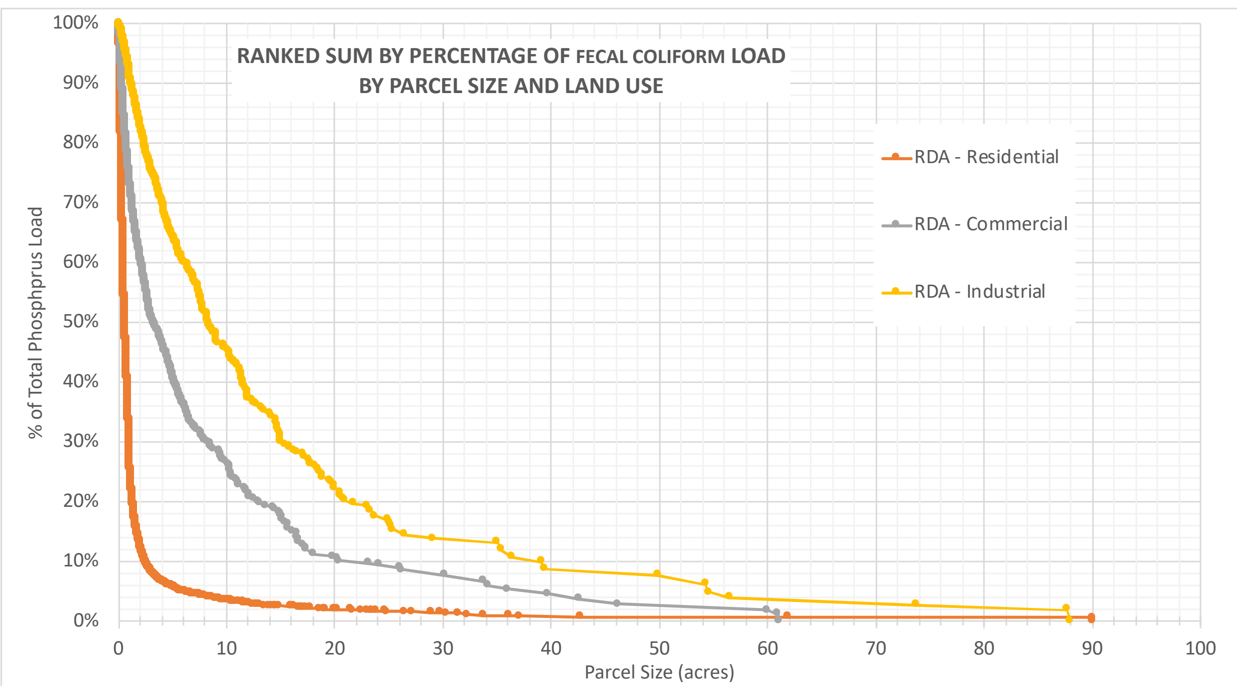
							Scenario 2: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >0.25 acres			
	# Parcels	Area (acres)	Total Fecal Coliform Load (colonies)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal Managed Fecal Coliform Load (colonies)	% of Total Load	Infiltration BMPs; 95% Removal Efficiency Managed Fecal Coliform Load (colonies)	% of Total Load
MS4	1698	18180.6	8.59E+15	0.0	1698	100%	8.59E+15	100%	8.16E+15	95%
RDA - Residential	91343	40693.2	1.44E+16	0.25	51165	56%	1.22E+16	85%	1.16E+16	81%
RDA - Commercial	3003	3552.3	1.56E+15	0.25	1834	61%	1.47E+15	94%	1.39E+15	90%
RDA - Industrial	1095	3602.7	1.42E+15	0.25	930	85%	1.41E+15	99%	1.34E+15	94%
RDA - Open Space	817	5774.6	5.30E+14	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Forest	21062	73476.4	7.39E+15	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Total	**119018**	**145279.7**	**3.39E+16**		**55627**	**47%**	**2.37E+16**	70%	**2.25E+16**	66%
Unmanaged Load			**0.0**				**1.02E+16**		**1.14E+16**	
TMDL Requirement			3.42E+14				3.42E+14		3.42E+14	
% of TMDL			0%				-2883%		-3228%	

							Scenario 3: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >1 acres			
	# Parcels	Area (acres)	Total Fecal Coliform Load (colonies)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal Managed Fecal Coliform Load (colonies)	% of Total Load	Infiltration BMPs; 95% Removal Efficiency Managed Fecal Coliform Load (colonies)	% of Total Load
MS4	1698	18180.6	8.59E+15	0.0	1698	100%	8.59E+15	100%	8.16E+15	95%
RDA - Residential	91343	40693.2	1.44E+16	1.0	7589	8%	4.51E+15	31%	4.29E+15	30%
RDA - Commercial	3003	3552.3	1.56E+15	1.0	692	23%	1.17E+15	75%	1.11E+15	71%
RDA - Industrial	1095	3602.7	1.42E+15	1.0	588	54%	1.31E+15	93%	1.25E+15	88%
RDA - Open Space	817	5774.6	5.30E+14	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Forest	21062	73476.4	7.39E+15	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Total	**119018**	**145279.7**	**3.39E+16**		**10567**	**9%**	**1.56E+16**	46%	**1.48E+16**	44%
Unmanaged Load			**0.0**				**1.83E+16**		**1.90E+16**	
TMDL Requirement			3.42E+14				3.42E+14		3.42E+14	
% of TMDL			0%				-5240%		-5467%	


RANKED SUM OF TOTAL ANNUAL FECAL COLIFORM LOAD BY PARCEL SIZE AND LAND USE
MS4
RDA - Open Space
RDA - Forest
Total Annual Phosphorus Load (lbs)
Parcel Size (acres)
1E+16
9E+15
8E+15
7E+15
6E+15
5E+15
4E+15
3E+15
2E+15
1E+15
0
0
200
400
600
800
1000
1200


RANKED SUM OF TOTAL ANNUAL FECAL COLIFORM LOAD BY PARCEL SIZE AND LAND USE
RDA - Residential
RDA - Commercial
RDA - Industrial
Total Annual Phosphorus Load (lbs)
Parcel Size (acres)
1.6E+16
1.4E+16
1.2E+16
1E+16
8E+15
6E+15
4E+15
2E+15
0
0
10
20
30
40
50
60
70
80
90
100


RANKED SUM BY PERCENTAGE OF FECAL COLIFORM LOAD
BY PARCEL SIZE AND LAND USE
% of Total Phosphprus Load
Parcel Size (acres)
MS4
RDA - Open Space
RDA - Forest
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
200
400
600
800
1000
1200


RANKED SUM BY PERCENTAGE OF FECAL COLIFORM LOAD
BY PARCEL SIZE AND LAND USE
% of Total Phosphprus Load
Parcel Size (acres)
RDA - Residential
RDA - Commercial
RDA - Industrial
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
50
60
70
80
90
100