Integrating Green Infrastructure Into Stormwater Policy: Reliability, Watershed Management, and Environmental Psychology as Holistic Tools for Success

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Abstract

As cities continue to expand, the issues of flood control and urban water quality have become major modern sustainability challenges. Green infrastructure—the use of nature-based solutions to target, treat, and store stormwater at its source—has emerged as a possible solution. While green infrastructure does offer multiple benefits for urban users, its performance is also highly variable. This Article addresses a key gap in existing literature by explicitly addressing how uncertainty in environmental and anthropogenic factors affects green infrastructure performance and integration within the Clean Water Act's municipal separate storm sewer (MS4) regulatory program.

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Introduction

More than half of the global population lives in cites; consequently, the management of urban areas has been heralded as one of the most important development challenges of the twenty-first century.[1] As the size and density of urban areas increase, the growth of paved areas has led to a sharp rise in issues of degraded water quality and localized flooding.[2] Overall, the impairment of U.S. waters by urban runoff constitutes nearly five thousand square miles of estuaries, 1.4 million acres of lakes, and thirty thousand miles of rivers across the country.[3] In some watersheds, the impact of urban runoff can be even more concentrated. For example, urban runoff constitutes sixteen percent of the nitrogen entering the Chesapeake Bay watershed and is the only nitrogen source that is still increasing.[4]

To address some of these challenges, many urban areas are turning to green infrastructure, a low-cost, distributed, flexible alternative to traditional (grey) infrastructure. Green stormwater infrastructure (GSI) is the use of natural processes to filter, capture, treat, and store stormwater runoff at its source.[5] GSI includes bioretention, green roofs, and permeable pavements. These different interventions use a combination of vegetated surfaces and artificially enhanced infiltration to reduce runoff in urban areas.[6] However, the efficiency of green infrastructure benefits is highly variable and contingent upon a number of factors.[7] Not surprisingly, GSI better mitigates runoff

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1. *World's Population Increasingly Urban with More Than Half Living in Urban Areas*, United Nations (July 10, 2014), https://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html [https://perma.cc/VF4Y-RZM4].

2. The U.S. Environmental Protection Agency (EPA) reports that urban runoff is a leading source of pollutants causing water quality impairment related to human activities in ocean shoreline waters. Envtl. Prot. Agency, 1996 National Water Quality Inventory Report to Congress 64 fig.4.6, 78 fig.4.9 (1996), https://www.epa.gov/waterdata/1996-national-water-quality-inventory-report-congress [https://perma.cc/4L88-FQUT].

3. Eric Strassler, Jesse Pritts & Kristen Strellec, Envtl. Prot. Agency, Preliminary Data Summary of Urban Storm Water Best Management Practices 4-1 (1999), https://www.epa.gov/sites/production/files/2015-11/documents/urban-stormwater-bmps_preliminary-study_1999.pdf [https://perma.cc/4QQE-P2WP]. Nitrogen deposition due to auto emissions falls onto urban surfaces and then is channeled into the Chesapeake Bay through the MS4 drainage system. *Id.*

4. *Polluted Runoff*, Chesapeake Bay Foundation, https://www.cbf.org/issues/polluted-runoff/index.html [https://perma.cc/HT9P-RMB6] (last visited May 3, 2019); *Polluted Runoff: How Investing in Pollution Control Systems Improves the Chesapeake Bay Region's Ecology, Economy, and Health*, Chesapeake Bay Foundation 6 (Jan. 2014), https://www.cbf.org/document-library/cbf-reports/2014-Polluted-Runoff-Report-compressed20b2.pdf [https://perma.cc/Y6TE-2DEY].

5. *What is Green Infrastructure?*, Envtl. Prot. Agency, https://www.epa.gov/green-infrastructure/what-green-infrastructure [https://perma.cc/SRK3-Y2RE].

6. *Stormwater Management and Green Infrastructure Research*, Envtl. Prot. Agency, https://www.epa.gov/water-research/stormwater-management-and-green-infrastructure-research [https://perma.cc/C8KD-WSR2].

7. For example, the effectiveness of comparable rain gardens varies from 51 percent

from smaller storms with shorter return periods than high intensity events.[8] Moreover, green infrastructure capability scales nonlinearly with catchment size. In other words, the layout of existing stormwater networks, and the location of green infrastructure within those networks play important roles in the runoff reduction effectiveness of green infrastructure.

A game theoretic study of municipal policies governed by economic stimuli suggests that the efficiency of private green infrastructure at the catchment scale is determined by network location, with important environmental justice implications.[9] To mitigate some of these challenges, we build upon these

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to 100 percent across the contiguous United States. *See* Aaron A. Jennings, *Residential Rain Garden Performance in the Climate Zones of the Contiguous United States*, 142 J. ENVTL. ENG'G, 1 (2016). Storm size continues to be a good predictor of GSI performance at the catchment scale. *See* Jinsong Tao et al., *Quantitative Analysis of Impact of Green Stormwater Infrastructures on Combined Sewer Overflow Control and Urban Flooding Control*, 11 FRONTIERS ENVTL. SCI. & ENG'G 11, 11–12, 19 (2017). Antecedent soil moisture conditions and interstorm duration also play an important role in green infrastructure runoff reduction. *See* Eline Vanuytrecht et al., *Runoff and Vegetation Stress of Green Roofs Under Different Climate Change Scenarios*, 122 LANDSCAPE AND URB. PLAN. 68, 68–74 (2014); Nicholaus D. Vanwoert et al., *Green Roof Stormwater Retention: Effects of Roof Surface, Slope, and Media Depth*, 34 J. ENVTL. QUALITY 1036, 1036–1039, 1042–1043 (2005). Other factors that affect green infrastructure efficiency include soil texture, media depth or pavement thickness, drought stress, and vegetation type. *See* Christopher M. Chini et al., *The Green Experiment: Cities, Green Stormwater Infrastructure, and Sustainability*, 9 SUSTAINABILITY 105, 105, 106, 117 (2017); N. Dunnett & A. Nolan, *The Effect Of Substrate Depth And Supplementary Watering on the Growth of Nine Herbaceous Perennials in a Semi-Extensive Green Roof*, 643 ACTA HORTICULTURAE 305, 308 (2004); Daniele Masseroni & Alessio Cislaghi, *Green Roof Benefits for Reducing Flood Risk At the Catchment Scale*, 75 ENVTL. EARTH SCI. 1, 1–3, 5, 9 (2016); Poomima Natarajan & Allen P. Davis, *Hydrologic Performance of a Transitioned Infiltration Basin Managing Highway Runoff*, 1 J. SUSTAINABLE WATER BUILT ENV'T 1, 1, 6, 10 (2015); Thomas C. Walsh, Christine A. Pomeroy & Steven J. Burian, *Hydrologic Modeling Analysis of a Passive, Residential Rainwater Harvesting Program in an Urbanized, Semi-arid Watershed*, 508 J. HYDROLOGY 240, 240–43 (2014); Reshmina William & Ashlynn S. Stillwell, *Use of Fragility Curves to Evaluate the Performance of Green Roofs*, 3 J. SUSTAINABLE WATER BUILT ENV'T 1, 1–6 (2017). Finally, infrastructure age and maintenance play a crucial role in determining GSI efficiency. *See* G Lindsey, L Roberts & W Page, *Inspection and Maintenance of Infiltration Facilities*, 47 J. SOIL & WATER CONSERVATION 481, 481–86 (1992); L. L. Willard et al., *Does It Pay to be Mature? Evaluation of Bioretention Cell Performance Seven Years Postconstruction*, 143 J. ENVTL. ENG'G 1, 3–6 (2017).

8. *See* Jennifer K. Holman-Dodds, A. Allen Bradley & Kenneth W. Potter, *Evaluation of Hydrologic Benefits of Infiltration Based Urban Storm Water Management*, 39 J. AM. WATER RESOURCES ASS'N 205, 213 (2003); *see also* Timothy L. Carter & Todd C. Rasmussen, *Hydrologic Behavior of Vegetated Roofs*, 42 J. AM. WATER RES. ASS'N 1261, 1261–70 (2006); Allen P. Davis, *Field Performance of Bioretention: Hydrology Impacts*, 13 J. HYDROLOGIC ENG'G 90, 95 (2008); Hua-Peng Qin, Zhuo-Xi Li & Guangtao Fu, *The Effects of Low Impact Development on Urban Flooding Under Different Rainfall Characteristics*, 129 J. OF ENVTL. MGMT. 577, 577–80 (2013).

9. *See* Reshmina William, Jugal Garg & Ashlynn S. Stillwell, *A Game Theory Analysis of Green Infrastructure Stormwater Management Policies*, 53 WATER RESOURCES RES. 8003, 8015 (2017).

game theory results by applying aspects of environmental psychology within the context of green infrastructure implementation. This inclusion of environmental psychology enables us to better frame green infrastructure solutions for municipal separate storm sewer (MS4) regulatory regimes and provide a more holistic perspective for addressing watershed-scale challenges.

I. Technical Aspects of Green Stormwater Infrastructure (GSI)

Green infrastructure mitigates urban runoff by attenuating stormwater volume and reducing or delaying peak flows.[10] In many instances, the substantial reductions in runoff volume in dense urban environments achieved by combinations of GSI present a viable, cost-effective alternative to traditional grey infrastructure,[11] and in years of high rainfall could exceed grey infrastructure performance.[12]

From a pollution-prevention perspective, GSI can remove heavy metals, sediment, excess nutrients, and other contaminants commonly found in urban runoff.[13] In addition to water quality and flood mitigation benefits, GSI has other positive externalities, including mitigation of urban heat island effects and air quality improvements,[14] as well as social benefits associated with

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10. *See* Jeroen Mentens, Dirk Raes & Martin Hermy, *Green Roofs as a Tool for Solving the Rainwater Runoff Problem in the Urbanized 21st Century?*, 77 Landscape & Urb. Plan. 217, 218–19 (2006); Reshmina William & Ashlynn S. Stillwell, *Use of Fragility Curves to Evaluate the Performance of Green Roofs*, 3 Sustainable Water Built Env't 1, 2, 8 (2017).

11. *See* Heather E. Golden & Nahal Hoghooghi, *Green Infrastructure and Its Catchment-Scale Effects: An Emerging Science*, 5 Wiley interdisc. revs.: Water 1, 10–11 (2017); A. R. Martin, L. M. Ahiablame & B. A. Engel, *Modeling Low Impact Development in Two Chicago Communities*, 1 Envtl. Sci: Water Res. & Tech. 855, 855–57, 862 (2015); Hassan Tavakol-Davani et al., *Performance and Cost-Based Comparison of Green and Gray Infrastructure to Control Combined Sewer Overflows*, 2 J. Sustainable Water Built Env't 1, 1–5, 7–11 (2016).

12. William C. Lucas & David J. Sample, *Reducing Combined Sewer Overflows By Using Outlet Controls for Green Stormwater Infrastructure: Case Study in Richmond, Virginia*, 520 J. Hydrology 473, 473–74, 487 (2015).

13. *See* R. A. Brown, D. E. Line & W. F. Hunt, *LID Treatment Train: Pervious Concrete with Subsurface Storage in Series with Bioretention and Care with Seasonal High-Water Tables*, 138 J. Envtl. Eng'g 689, 690, 694 (2012); Robert A. Brown & Michael Borst, *Nutrient Infiltrate Concentrations From Three Permeable Pavement Types*, 164 J. Envtl. Mgmt. 74, 74–76 (2015); Jennifer Drake, Andrea Bradford & Tim Van Seters, *Winter Effluent Quality from Partial-Infiltration Permeable Pavement Systems*, 140 J. Envtl. Eng'g 1, 10, 12 (2014); Chi-Hsu Hsieh, Allen P. Davis & Brian A. Needelman, *Bioretention Column Studies of Phosphorus Removal from Urban Stormwater Runoff*, 79 Water Env't Res. 177, 177, 183 (2007); William F. Hunt, Allen P. Davis & Robert G. Traver, *Meeting Hydrologic and Water Quality Goals through Targeted Bioretention Design*, 138 J. Envtl. Eng'g 698, 701, 703, 705 (2012); Marie-Charlotte Leroy et al., *Performance of Vegetated Swales for Improving Road Runoff Quality in a Moderate Traffic Urban Area*, 566–567 Sci. Total Env't 113, 117 (2016).

14. *See* Jong-Jin Baik et al., *Effects of Building Roof Greening on Air Quality in Street Canyons*, 61 Atmospheric Env't 48, 48–49, 51, 55 (2012); Corrie Clark, Peter Adriaens & F. Brian Talbot, *Green Roof Valuation: A Probabilistic Economic Analysis of Environmental Benefits*, 42 Envtl. Sci & Tech. 2155, 2155, 2157, 2160 (2008); Erdem Cuce, *Thermal Regulation*

increased urban green space such as improvements in mental and physical health,[15] decreases in violent crime,[16] and environmental equity.[17]

As a result of these benefits, several medium to large cities are exploring GSI to meet Municipal Separate Storm Sewer Systems (MS4)[18] permit requirements and/or improve urban sustainability. For example, Madison, Wisconsin has committed to the installation of one thousand rain gardens throughout the city,[19] Philadelphia, Pennsylvania has adopted a twenty-five-year GSI plan to reduce annual pollution entering surface waters by eighty five percent,[20] and Chicago, Illinois has pledged fifty million dollars to the installation of an additional ten million gallons of green stormwater storage.[21]

Public perception of GSI as a risky investment persists, however, despite the benefits outlined above. A lack of data to quantify variability in GSI performance reinforces these perceptions. Soil type and condition, current land uses, vegetation type, existing soil moisture, and water table height all impact the performance of GSI.[22] Most importantly, rainfall distribution, specifically

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Impact of Green Walls: An Experimental and Numerical Investigation, 194 Applied Energy 247, 247–48 (2017); Fanhua Kong et al., *Energy Saving Potential of Fragmented Green Spaces Due to Their Temperature Regulating Ecosystem Services in the Summer*, 183 Applied Energy 1428, 1428–29, 1438 (2016); Gurdane Virk et al., *Microclimatic Effects of Green and Cool Roofs in London and Their Impacts on Energy Use for a Typical Office Building*, 88 Energy & Buildings 214, 214, 223 (2015); Reshmina William et al., *An Environmental Cost-benefit Analysis of Alternative Green Roofing Strategies*, 95 Ecological Eng'g 1, 1, 5–8 (2016).

15. *See, e.g.*, Ming Kuo, *How Might Contact with Nature Promote Human Health? Promising Mechanisms and a Possible Central Pathway*, 6 Frontiers in Psychol. 1, 1–2 (2015); Andrea Faber Taylor & Frances E. Kuo, *Children with Attention Deficits Concentrate Better After Walk in the Park*, 12 J. Attention Disorders 402, 402–04, 407 (2009).

16. *See* Kuo, *supra* note 15, at 2; Michelle C. Kondo et al., *The Impact of Green Stormwater Infrastructure Installation on Surrounding Health and Safety*, 105 Am. J. Pub. Health 114, 114, 119 (2015).

17. Mathieu Carrier et al., *Application of a Global Environmental Equity Index in Montreal: Diagnostic and Further Implications*, 106 Annals Am. Ass'n Geographers 1268, 1268–70, 1280 (2016).

18. *See* 40 C.F.R. § 122.26(b)(8) (2018) (defining MS4 as "a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains)" that are: (i) "owned or operated" by a public body; (ii) "designed or used for collecting or conveying storm water"; but (iii) are not "a combined sewer"; nor (iv) "part of a Publicly Owned Treatment Works (POTW) as defined at 40 C.F.R. 122.2").

19. *1,000 Rain Gardens*, City of Madison, https://www.cityofmadison.com/engineering/stormwater/raingardens/1000raingardens.cfm [https://perma.cc/Q8U8-JZ26].

20. *Green City, Clean Waters*, Philly Watersheds, http://www.phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan [https://perma.cc/Q48G-V7VT].

21. City of Chicago, Green Stormwater Infrastructure Strategy 32 (2014), https://www.chicago.gov/content/dam/city/progs/env/ChicagoGreenStormwaterInfrastructureStrategy.pdf [https://perma.cc/EF7N-2H7H].

22. Kyle Eckart, Zach Mcphee & Tirupati Bolisetti, *Performance and Implementation of Low Impact Development—A Review*, 607–608 Sci. Total Env't 413, 417, 427 (2017).

the prevalence of high intensity rainfall events, predicts GSI failure rates.[23] Because of this variability of GSI performance across space and time, it is important to develop and implement a risk-based evaluation of flood and water quality infrastructure to the regulatory environment of urban stormwater.[24]

At the catchment scale, green infrastructure layout makes a significant difference in runoff reduction effectiveness. The relative placement within a network is a significant contributor to its collective success; however, because investment in green infrastructure requires multiple instances of private actions for a public good, public policy mechanisms need to be developed to nudge optimal GSI placement by private actors within a watershed.

In other words, the net effect is contingent on private citizens' willingness to implement GSI on their own properties. The following Part explores some of the policy, psychological, and legal implications of this private-public integration of green infrastructure performance. We begin by evaluating the implications of green infrastructure within the current legal framework of the Clean Water Act's (CWA) MS4 regulations. To better understand these findings, we explore the implementation of green infrastructure at the private, individual scale. As previously discussed, a game theoretic study of municipal stormwater management practices suggests that not only does network layout play a key role in the effectiveness of green infrastructure policy, but that this finding has significant environmental justice implications.[25] Accordingly, we propose an alternative framework for human motivation, and suggest some practical methods to integrate a psychological model to influence and optimize green infrastructure uptake as part of the CWA's MS4 program.

II. Legal Implications for Green Stormwater Infrastructure

A. *Current Framework for Stormwater Regulations*

The aim of the CWA is to protect "the physical, chemical, and biological integrity of the nation's waters."[26] Despite this broad mandate, it took a surprisingly long time for urban stormwater, a significant source of pollution for many streams, lakes, and rivers, to come under the Act's purview. The court's ruling in *NRDC v. Costle*[27] eventually forced the EPA to include urban

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23. *See* Carter & Rasmussen, *supra* note 8, at 1267; Allen P. Davis, *Field Performance of Bioretention: Hydrology Impacts*, 13 J. Hydrologic Engineering 90, 90–91, 93 (2008); Jennifer K. Holman-Dodds, A. Allen Bradley & Kenneth W. Potter, *Evaluation of Hydrologic Benefits of Infiltration Based Urban Storm Water Management*, 39 J. Am. Water Resources Ass'n 205, 212 (2003).

24. Nell Green Nylen & Michael Kiparsky, Wheeler Institute for Water Law & Policy, Accelerating Cost-Effective Green Stormwater Infrastructure: Learning from Local Implementation 22–24 (2015), https://www.law.berkeley.edu/files/CLEE/GSI_Report_Full_2015-02-25.pdf [https://perma.cc/HCB5-RB6U].

25. *See* William et al., *supra* note 9, at 8015.

26. 33 U.S.C. § 1251(a) (2012).

27. Nat. Res. Def. Council v. Costle, 568 F.2d 1369, 1369 (D.C. Cir. 1977).

stormwater as a part of the National Pollutant Discharge Elimination System (NPDES) permitting process.[28] It took an additional ten years for Congress to pass substantial amendments to section 402 of the statute that specifies NPDES permitting requirements for storm sewer systems.[29] As a result, the first set of MS4 regulations did not come into effect until 1990.[30]

The EPA defines stormwater as all "stormwater runoff, snow melt runoff, and surface runoff and drainage," not including infiltration into pipes or street wash waters.[31] From a civil engineering perspective, urban stormwater is classified as a non-point source pollutant (i.e., water that is distributed rather than channeled).[32] Several legal interpretations concur with the hydrological approach adopted in the engineering disciplines.[33] For example, in *Ecological Rights Foundation v. Pacific Gas and Electric Company*,[34] the court found that leachate from urban utility poles containing toxic substances could not be regulated under the CWA because the discharge was not from a point source (i.e., utility poles), but rather, from stormwater.[35] Once stormwater flows into an MS4, however, the legal nature of the water is transformed into a point source. In other words, MS4 discharges are regulated under the CWA through the same permitting process that is used to regulate wastewater treatment plants and other industrial discharges.[36]

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28. *See id.* at 1373 (holding that "[the EPA] has no authority to exempt point sources [including separate storm sewers containing only storm runoff] from the NPDES program.").

29. Water Quality Act of 1987, Pub. L. No. 100–4, § 405, 101 Stat. 7, 69 (codified as amended at 33 U.S.C. § 1342(p) (Municipal and industrial stormwater discharges)). Section 402(p) exempted permits for certain storm water discharges until October 1, 1992. However, five types of storm water discharges required permits prior to the 1992 cutoff, most importantly for this Article, discharges from MS4s serving a population of 250,000 or more, discharges from MS4s serving a population between 100,000 and 250,000, and storm water discharges that contribute to a violation of water quality standards or are a significant contributor of pollutants to waters of the United States. *Id.* at 69.

30. National Pollutant Discharge Elimination System Permit Application Regulations for Storm Water Discharges, 55 Fed. Reg. 47990 (Nov. 16, 1990) (codified at 40 C.F.R. pts. 122–124).

31. 40 C.F.R. § 122.26(b)(13)–(14) (2018).

32. *See* Brik R. Zivkovich & David C. Mays, Predicting Nonpoint Stormwater Runoff Quality from Land Use, PLOS ONE (2018), https://doi.org/10.1371/journal.pone.0196782 [https://perma.cc/ET54-3XK].

33. *See* Decker, Or. State Forester v. Nw. Envtl. Def. Ctr., 568 U.S. 597, 602–603 (2013) (discussing silvicultural rule and nonpoint source discharges); Envtl. Def. Ctr., v. EPA, 344 F.3d 832 (9th Cir. 2003) (noting that diffuse runoff that is not channeled through a point source is non-point source pollution and upholding EPA rules for small municipal separate storm sewer systems); League of Wilderness Defs. v. Forsgren, 309 F.3d 1181, 1184 (9th Cir. 2002) (describing non-point source pollution); Trs. for Alaska v. EPA, 749 F.2d 549, 558 (9th Cir. 1984) (discussing non-point source pollution in the mining context and what activities would qualify as a point source).

34. Ecological Rights Found. v. Pac. Gas & Elec. Co., 713 F.3d 502 (9th Cir. 2013).

35. *Id.* at 510 (finding that utility poles are not a discernible, confined, and discrete conveyance that channel and control stormwater).

36. *See* 33 U.S.C. § 1342(p) (2012 & Water Structure Improvement Act, Pub. L. No.

The EPA regulates MS4s through NPDES permits allocated to the sewer network on a system- or jurisdiction-wide basis.[37] Permit requirements are based on ambient, state-controlled water quality standards and require controls to reduce the discharge of pollutants to the maximum extent practicable (MEP), rather than technology-based effluent limitations.[38] The EPA implemented the MS4 permitting structure in two phases: Phase I (implemented in 1990) required individual NPDES permits for MS4s serving over one hundred thousand people,[39] while Phase II (implemented in 1999) provided general permits for all MS4s not covered by Phase I.[40] While Phase I permittees are required to submit detailed information and quantitative data sampling of stormwater discharges collected during storm events, Phase II permit requirements are significantly less stringent, requiring either an individual permit application or the filing of a notice of intent to comply with a general permit.[41] Both Phase I and Phase II MS4s are required to meet six minimum control measures: i) public education and outreach, ii) public participation, iii) illicit discharge detection and elimination, iv) construction runoff control, v) postconstruction runoff control and pollution prevention, and vi) good housekeeping.[42] The final measure, good housekeeping, is intended to create protocols for municipalities to inspect whether control practices are working in the longterm, as designed. These measures are recorded and updated in a municipal stormwater management plan. As discussed below, successful longterm implementation of GSI requires a degree of preventative maintenance and inspection captured by the good housekeeping requirement.[43]

Total maximum daily loads (TMDLs) are an alternative regulatory strategy used to control MS4 discharges. TMDLs are tools designed to help plan and implement strategies for both point and non-point sources within a watershed to manage pollutant loadings.[44] Section 303(d)(1)(A) of the Clean Water

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115-436, § 3(a), 132 Stat. 5558 (Jan. 14, 2019)).

37. 33 U.S.C. § 1342(p)(3)(B)(i) (2012).

38. 33 U.S.C. § 1342(p)(3)(B)(iii).

39. National Pollutant Discharge Elimination System Permit Application Regulations for Storm Water Discharges, 55 Fed. Reg. 47,990 (Nov. 16, 1990) (codified at 40 C.F.R. pts. 122–124).

40. Regulations for the Revision of the Water Pollution Control Program Addressing Storm Water Discharges, 64 Fed. Reg. 68,722 (Dec. 8, 1999) (codified at 40 C.F.R. pts. 9, 122–24).

41. 40 C.F.R. § 122.33(b) (2018).

42. 40 C.F.R. § 122.34(b)(1)–(6).

43. 40 C.F.R. § 122.34(b)(6)(ii).

44. TMDLs provide a blueprint for federal, state, and local agents to work together to implement pollutant controls to improve water quality standards. *See* Pronsolino v. Nastri, 291 F.3d 1123, 1128-29 (9th Cir. 2002); Am. Farm Bureau Federation v. EPA, 792 F.3d 281 (3rd Cir. 2015). One of the most complex and comprehensive TMDLs created to-date is based in the Chesapeake Bay watershed in the northeastern United States. The precedent-setting Chesapeake Bay TMDL allocates loadings in a highly detailed fashion, even to the level of separating load allocations and waste load allocations for non-point and point sources,

Act requires states to identify waters within their jurisdictions that fail to meet established water quality standards. If technology-based pollution controls are insufficient to maintain the designated standards for a water body, Section 303(d)(1)(C) obligates the state to develop and submit to the EPA for approval TMDLs for the pollutants in that water body.[45] Waste load allocations to comply with TMDLs may then be assigned to MS4s on an individual point source or aggregate basis.[46]

B. *Point-Source Regulation for a Non-Point Source Pollutant*

Urban stormwater runoff, the type of pollution discharged by MS4s, is inherently difficult to control and assign responsibly given its diffuse, non-point source origin from a wide range of public and private properties.[47] The runoff is subsequently channelized into a network of pipes, often spanning vast areas, before final discharge into navigable waters. In practice, federal or state regulation is most feasible at the downstream end of the pipe rather than regulating each potential source of stormwater runoff. But, this presents yet another challenge to the MS4 operator, as the network may span thousands of miles of pipes and have multiple outflows, creating what the Ninth Circuit characterized as a "Sisyphean task" of monitoring and testing each drain for potential pollutants.[48] In light of the practical difficulty of monitoring and treating each outfall as needed, jurisdictions operating MS4 networks often attempt to meet downstream regulations by implementing upland urban land use policies that enable individual landowners to decrease the amount of contaminants being washed off their property. As noted above, network layout is an essential element of implementing land use policies involving green infrastructure.[49] Moreover, stormwater pollutant discharges are by their nature inherently uncertain.[50] Stormwater runoff volumes vary based on storm magnitude, duration, and intensity. These challenges are magnified for non-point source pollutant loadings, which are affected by other factors such as construction, traffic patterns, topology, and land use.[51]

While efforts to manage stormwater effluent at the federal level are commendable, there remain multiple challenges with the existing legal framework.

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respectively. *Id.* at 299–300. It is also unique in that it encompasses multiple states, and gives the EPA the authority to reinforce state watershed implementation plans if the states fail to meet their own benchmarks. *Id.* at 309.

45. *See* Friends of the Earth, Inc. v. EPA, 446 F.3d 140, 144 (D.C. Cir. 2006).

46. Anacostia Riverkeeper, Inc. v. Jackson, 798 F.Supp.2d 210, 249–51 (D.D.C., 2011).

47. *See* Nat. Res. Def. Council v. Cty. of L.A., 673 F.3d 880, 884–85 (9th Cir. 2011), *reversed on other grounds*, L.A. Cty. Flood Control Dist. v. Nat. Res. Def. Council, 568 U.S. 78 (2013).

48. *Id.* at 899.

49. *See* City Of Chicago, *supra* note 21 and accompanying text.

50. Nat'l Research Council, Urban Stormwater Management in the United States 28 (2009).

51. *See id.* at 29–30.

The biggest cause for confusion remains the conflation of stormwater (a non-point source pollutant) with a point source legal framework. The awkward combination of different legal paradigms is most obvious in the fact that MS4 NPDES permits are largely based on water quality standards: an area that is typically the purview of the TMDL process. Multiple EPA memoranda and other guidance documents point towards the fact that the agency expected municipal stormwater discharges to comply with existent water quality standards, particularly when a TMDL was already in place. For example, a 1991 EPA Office of General Counsel memorandum stated that permits must require MS4s to reduce stormwater pollutant discharges to the maximum extent practicable as well as comply with water quality standards.[52] More recently, EPA's TMDL stormwater policy states that stormwater permits must include permit conditions consistent with the assumptions and requirements of existing waste load allocations.[53]

In contrast to the water quality standard approach, the development of effluent standards for point source industrial users and publicly owned treatment works stemmed from reasoning that cumulative and iterative advances in technology could indirectly enable improvements in the quality of receiving water bodies.[54] Congress' intent with respect to these effluent standards was that they be uniform throughout the nation, to avoid the potential for a geographic race to the bottom, and that the condition of the receiving waters should not be taken into account in establishing technology-based effluent limitations.[55] Rather, effluent control technologies would be regulated on a progressively more stringent set of expectations over time, beginning with the implementation of "best practicable technology" in 1977 and proceeding to a "best available technology" standard by 1983.[56] While the creation of these technology-based standards has significantly improved water quality, critics also note the limits to this approach due to a lack of incentives for industry to develop better pollution control technology.[57] Equally importantly,

52. *Id.* at 78.

53. Memorandum from R.H. Wayland, Dir., Office of Wetlands, Oceans and Watersheds and J.A. Hanson, Director, Office of Wastewater Mgmt., to Water Division Directors Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs (Nov. 22, 2002), https://www.epa.gov/sites/production/files/2015-07/documents/final-wwtmdl.pdf [https://perma.cc/WHK8-P8SK].

54. *See* D. Bruce La Pierre, *Technology-Forcing and Federal Environmental Protection Statutes*, 62 Iowa L. Rev. 771, 806–26 (1977) (discussing role of technology forcing in the Clean Water Act).

55. *See* Weyerhaeuser Co. v. Costle, 590 F.2d 1011, 1042 (D.C. Cir. 1978).

56. 33 U.S.C. § 1311(b) (2012). Congress subsequently extended the 1983 deadline to July 1, 1988. Municipal Wastewater Treatment Construction Grant Amendments of 1981, Pub. L. No. 97-117, § 21(a), 95 Stat. 1631 (1981).

57. *See* Bruce A. Ackerman & Richard B. Stewart, *Reforming Environmental Law*, 37 Stan. L. Rev. 1333, 1336 (1985).

technology-based standards do not guarantee that water quality and associated health-related goals will be met, but merely that the technology will be employed.[58]

These challenges to a technology-based standard for point sources are even more pertinent to the regulation of non-point sources, such as municipal stormwater, using stormwater control measures. Within the industrial context, the entities causing the pollution can assume the responsibility for its end-of-pipe treatment. In the case of municipal stormwater, the uncertainties associated with variability in pollutant loading in time and space mean that permit holders usually lack direct control over flows from individual properties that contribute to water quality standard exceedances.[59] Many of these same issues have arisen in contexts outside of urban stormwater. For example, in 2017, the Iowa Supreme Court ruled that the Des Moines Water Works did not have standing to bring suit against upstream drainage districts for water quality impairment because the drainage districts lacked statutory authority to mandate the requisite changes in farmers' nitrate management that would have brought relief to Des Moines' strained drinking water treatment facility.[60] The key difference between the Des Moines case and the challenge facing many municipalities is that the drainage districts in Iowa only had legal authority to maintain drainage ditches and existing streams, not land use control measures that could abate nitrate pollution loads.[61] Municipalities, on the other hand, assume responsibility for all stormwater conveyance structures within their jurisdiction and, potentially, could institute some means of land use controls.[62]

Besides the public-private jurisdictional challenges that inevitably ensue from this paradigm, the point source/non-point source dichotomy leads to issues associated with monitoring and compliance. EPA's guidelines require that Phase I MS4s conduct analytic monitoring of pollutants of concern in discharges from outfalls that are thirty-six inches or greater in diameter or

58. Howard Latin, *Ideal Versus Real Regulatory Efficiency: Implementation of Uniform Standards and 'Fine-Tuning' Regulatory Reforms*, 37 Stan. L. Rev. 1267, 1305 (1985).

59. For example, the Los Angeles County Flood Control District is comprised of multiple actors. Each city within the District operates a MS4 within its respective jurisdiction. Los Angeles County itself operates its own MS4 for unincorporated areas of the county. Each of these MS4s connects to the District's infrastructure. The result is more than 500 miles of open channels and 2,800 miles of storm drains with no comprehensive map of the overall system or knowledge of the specific location and number of outfalls into the various navigable waters. *See* Nat. Res. Def. Council, Inc. v. Cty. of L.A., 725 F.3d 1194, 1197–98 (9th Cir. 2013).

60. Bd. of Water Works Tr. of the City of Des Moines v. SAC Cty. Bd. of Supervisors, 890 N.W.2d 50, 62–63 (Iowa 2017).

61. *Id.* at 65 ("The legislature has not authorized drainage districts to assess costs to redesign existing drainage systems to abate nitrates.").

62. *See* Nat. Res. Def. Council v. Cty. of L.A., 673 F.3d 880, 899 (9th Cir. 2011) (noting role as "controllers of thousands of miles of MS4 and the stormwater it conveys"); *see also* City of Abilene v. EPA, 325 F.3d 657, 664–65 (5th Cir. 2003) (noting legal authority of municipalities to implement permit conditions and land use controls).

drain more than fifty acres.[63] Few municipalities are able to comply effectively with this requirement. Stormwater discharge monitoring for all major municipal outfalls would be time-intensive and onerously expensive.[64] Moreover, because storm discharges are highly dynamic in nature,[65] it is difficult to evaluate whether an MS4 complies with existing water quality standard limits. The National Stormwater Quality Database is a broad survey of water quality samples gathered as a part of NPDES monitoring requirements for MS4s across the country. Of the one hundred MS4s participating in the database, 58 percent reported issues with monitoring.[66] The majority of these problems related to meeting sampling requirements for specific rainfall conditions or land use types.[67] Another significant problem was equipment failure: a particular challenge for automated samplers.[68]

Although the exceedance of effluent limitations technically constitutes a permit violation, permitting authorities have thus far proceeded cautiously in interpreting MS4 discharge data. In extended litigation between MS4 operations in Los Angeles County and the Natural Resources Defense Council, the seven mass pollution monitoring stations designated in the County's NPDES permit were located in channelized portions of the MS4 controlled by the Los Angeles County Flood Control District that subsequently fed into the natural channels of the Los Angeles and San Gabriel Rivers. The location of the gaging stations—within the channel rather than at specific outfalls—coupled with the sheer number of municipalities draining into the river upstream of the District's gaging stations, made it difficult to attribute pollution directly to the defendants. The discrepancies in how and where monitoring was conducted ultimately led to contradictory rulings by the trial and appellate courts.[69] In

63. *See* 40 C.F.R. § 122.26 (d)(1)(iv)(D) (2018). A major municipal separate storm sewer outfall or major outfall is a discharge from a single 36 inch diameter pipe or an equivalent pipe that drains more than 50 acres. 40 C.F.R. § 122.26(b)(5).

64. *See*, Envtl. Prot. Agency, EPA Response to Comments on: National Pollutant Discharge Elimination System (NPDES) General Permits for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems in Massachusetts 141 (2016) (discussing cumbersome and costly permit requirements), https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/rtc-2016-ma-sms4-gp.pdf [https://perma.cc/XF2Y-8A2N].

65. P. Göbel, D. Dierkes & W.G. Coldewey, *Storm Water Runoff Concentration Matrix for Urban Areas*, 91 J. of Contaminant Hydrology 26, 27–29 (2007) (describing types of pollutants and discharges based on characteristics of the land surface).

66. Nat'l Research Council, *supra* note 50, at 276.

67. *Id.* at 276–77.

68. *Id.* at 277.

69. The U.S. District Court for the Central District of California granted summary judgment in favor of the Los Angeles County defendants because sampling of the pollution was downstream of the County's outfalls rather than at the relevant discharge points themselves. Nat. Res. Def. Council, Inc. v. Cty. of L.A., No. CV 08-1467 AHM (PLA), 2010 WL 761287 (C.D. Cal. Mar. 2, 2010). The Court of Appeals subsequently reversed. Nat. Res. Def. Council v. Cty. of L.A., 673 F.3d 880 (9th Cir. 2011). The Court of Appeals decision was then reversed by the Supreme Court. L.A. Cty. Flood Control Dist. v. Nat. Res. Def. Council,

sum, it is difficult to control and allocate responsibility under a polluter pays perspective for pollution originating from urban stormwater runoff and discharged by MS4s due to the diffuse, non-point source origin from both public and private properties.

C. *A Deterministic Framework for a Stochastic Solution*

To afford municipalities more flexibility in addressing stormwater pollution, the EPA has taken the approach of allowing the use of stormwater control measures (SCMs) in creating effluent limits and guidelines. For all other NPDES permits, the CWA requires either numeric pollutant limits (i.e., water quality-based standards) or technology performance standards. The EPA typically employs water quality-based effluent limits in situations where technology-based limits are insufficient to achieve applicable water quality standards. In *Defenders of Wildlife v. Browner*,[70] the federal court upheld EPA's policy to issue stormwater permits to MS4s that use SCMs rather than numeric discharge limits.[71] The court held that the CWA does not require municipal storm sewer discharges to strictly comply with its other mandate that NPDES permits adhere to state water quality standards.[72] As a result, effluent limits often use SCMs when numeric limits are infeasible or for discharges where monitoring data is insufficient. As green infrastructure has become more popular, many SCM-based effluent limits may include larger proportions of green infrastructure to meet regulatory requirements.

However, the use of SCMs as effluent limits in NPDES permits bumps up against the CWA's explicit requirement that MS4s treat their discharges to the maximum extent practicable.[73] Maximum extent practicable, of course, is an inherently vague term left to the discretion of the EPA to define further. The statute further provides that this could include "management practices, control techniques and system, design and engineering methods" along with other provisions deemed appropriate for controlling pollutants,[74] so long as the preceding mandate to reduce pollutants to the maximum extent practicable is met.[75] Reviewing courts have applied an "extremely deferential" standard of

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Inc., 568 U.S. 78 (2013). On remand and after the filing of supplemental briefs, the Court of Appeals again reversed the District Court's grant of summary judgment and held that pollution data gathered at the downstream monitoring stations was sufficient to establish liability for NPDES permit violations as a matter of law. Nat. Res. Def. Council, Inc. v. Cty. of L.A., 725 F.3d 1194, 1196–97 (9th Cir. 2013), *cert. denied*, L.A Cty. Flood Control Dist. v. Nat. Res. Defense Council, Inc., 572 U.S. 1100 (2014).

70. Defenders of Wildlife v. Browner, 191 F.3d 1159 (9th Cir. 1999).

71. *Id.* at 1166–67.

72. *Id.* at 1165–66.

73. 33 U.S.C. § 1342(p)(3)(B)(iii) (2012); 40 C.F.R. §§ 122.26(d)(2)(iv), 122.34(a) (2018).

74. 33 U.S.C. § 1342(p)(3)(B)(iii).

75. *See* Envtl. Def. Ctr. v. EPA, 344 F.3d 832 (9th Cir. 2003) (holding that the EPA must review proposed stormwater management plans to confirm that the proposed measures in

review for whether permit requirements are arbitrary and capricious,[76] especially when reviewing factual questions involving scientific matters that fall within an area of the agency's technical expertise.[77] MS4 permit requirements and the maximum extent practicable requirements fall squarely within this standard of deference. While this flexibility is useful for municipalities in tailoring how to meet their regulatory needs for stormwater mitigation, it creates a legal headache for stormwater practitioners. While some states, such as California, have made concerted efforts to quantify maximum extent practicable standards, others retain the original flexible definition, making enforcement of water quality standards challenging, particularly for larger watersheds.[78]

From a technical standpoint, the use of SCMs to define effluent standards runs into a much larger issue: the regulation of non-point source runoff employs technologies that themselves have a high degree of performance uncertainty associated with them. Multiple studies show that effectiveness of pollutant removal—particularly of nutrients—using green infrastructure is determined by compounding factors such as soil moisture, storm magnitude, native soil type, native flora and fauna, maintenance, and network location.[79] Through this lens, other studies have quantified green infrastructure performance variability across time and space.[80] Accordingly, an understanding of green infrastructure reliability can be used to predict both the longterm impacts of clogging and

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fact reduce pollution to the maximum extent practicable, but without further defining or limiting the agency's presumed broad discretion in approving these measures).

76. *See, e.g.*, Md. Dept. of Env't v. Anacostia Riverkeeper, 134 A.3d 892, 911 (Md. 2016); City of Abilene v. EPA, 325 F.3d 657, 660–61 (5th Cir. 2003). *See also* 55 Fed. Reg. 47,990, 48,038 (Nov. 16, 1990) (noting the flexible manner of site-specific permits in the MS4 context).

77. Md. Dept. of Env't, 134 A.3d at 911 (citing Nat. Res. Def. Council v. EPA, 808 F.3d 556, 569 (2d Cir. 2015)).

78. *See* California State Water Resources Control Board, Storm Water Program, *Phase II Small MS4 General Permit Questions and Answers Document* (2004), https://www.waterboards.ca.gov/water_issues/programs/stormwater/smallms4faq.shtml [https://perma.cc/W2VH-U6F5] (illustrating an iterative approach to obtaining maximum extent practicable); *see also* Barry Fagain, *Is the Maximum Extent Practicable?*, Stormwater Tools (April 5, 2014), http://stormwatertools.com/2014/04/05/is-the-maximum-extent-practicable [https://perma.cc/H8XT-L6M5] (discussing vague nature of the standard and encouraging stormwater design professionals to focus on the maximum extent aspect of the standard to achieve the best possible outcomes for water quality); Adam Sapp, *When is "Maximum Extent" Practicable?*, Stormwater Solutions (April 25, 2012) https://www.estormwater.com/when-maximum-extent-practicable [https://perma.cc/7CUC-LKJV] (arguing for measureable standards and a defined process to meet the regulatory requirements).

79. *See* Jennifer K. Holman-Dodds, Allen Bradley & Kenneth W. Potter, *Evaluation of Hydrologic Benefits of Infiltration Based Urban Storm Water Management*, 31 J. Am. Water Resources Ass'n, 205, 214 (2003); Nicholaus D. VanWoert, et al., *Green Roof Stormwater Retention*, 34 J. of Env't Quality, 1036, 1036–37 (2005); Poornima Natarajan & Allen P. Davis, *Hydrologic Performance of a Transitioned Infiltration Basin Managing Highway Runoff*, 1 J. of Sustainable Water Built Env't, 1, 10 (2015).

80. *See* Tao et al., *supra* note 7, at 12; William & Stillwell, *supra* note 7, at 2.

the effects of interstorm duration.[81] A reliability-based framework can also be used as a design tool in regions with highly heterogeneous urban soils.[82]

Accordingly, meeting the maximum extent practicable standard by using largescale green infrastructure-based SCMs requires sophisticated reliability analyses along with a delicate exercise of public-private partnerships to prevent suboptimal placement or design of stormwater management infrastructure intended to accommodate private landowners' personal preferences. Moreover, without appropriate downstream monitoring, it is challenging to determine whether designated SCMs for MS4s are meeting the CWA's objective to restore and maintain the integrity of the nation's waters or simply fulfilling the letter of the law as specified in general NPSES permits.

D. *Watershed-Scale Approaches as a Way Forward*

While green infrastructure affords many potential opportunities to municipalities seeking to meet their legal obligations under the CWA, it does sit at an uncomfortable intersection between several different philosophies. Green infrastructure is explicitly designed to regulate a non-point source pollutant—urban stormwater—yet, its implementation is often incorporated into legal regimes intended to deal with point source pollutants such as in the MS4 context. Its performance is often highly variable, contingent on both natural and humanmade factors, including appropriate design and maintenance. Yet green SCMs are often used as deterministic standins for the numeric effluent standards demanded by most other point source pollution permits.

To ensure that green infrastructure meets its potential in helping urban environments truly embrace the lofty goals of the CWA, much work remains. Adequate maintenance of green infrastructure is a mandatory requirement of many state watershed implementation plans. Preventative and scheduled maintenance, however, often is subject to budget pressure or shifting priorities.[83] Even if financial and management commitments exist, a trained workforce may not be available to perform the required maintenance.[84] Certi-

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81. Reshmina William, Paolo Gardoni & Ashlynn S. Stillwell, *Reliability-Based Approach to Investigating Long-Term Clogging in Green Stormwater Infrastructure*, 5 J. Sustainable Water Built Env't 1, 1 (2018); Reshmina William, Paolo Gardoni & Ashlynn S. Stillwell, *Predicting Green Infrastructure Performance Under Antecedent Moisture Conditions Using SCLA*, Sustainable and Resilient Infrastructure (forthcoming 2019).

82. Jin-Ling Yang & Gan-Lin Zhang, *Formation, Characteristics and Eco-Environmental Implications of Urban Soils—A Review*, 61 Soil Sci. and Plant Nutrition 30, 38–39 (2015).

83. Nat'l Ass'n of Home Builders, A Developer's Guide to Post-construction Stormwater Regulation 27, 60 (2017), https://www.nahb.org/-/media/Sites/NAHB/research/priorities/stormwater/stormwater-developers-guide [https://perma.cc/2VQM-2FQY].

84. *See generally National Green Infrastructure Certification Program*, NGICP, https://ngicp.org/about-ngicp [https://perma.cc/NA8K-UX3U] (describing the provision of base-level skill sets for the proper construction, inspection and maintenance of green stormwater infrastructure).

fied training programs for longterm green infrastructure maintenance, such as the newly introduced National Green Infrastructure Certification Program,[85] should be a mandatory component of all MS4 NPDES permits and can help fill these knowledge gaps.

Monitoring is also an essential component of any program that seeks to include green infrastructure as a part of a holistic management strategy for stormwater. General best management practices for MS4 stormwater monitoring should be observed, including the use, appropriate calibration, and upkeep of automated sampling. Monitoring stations should also collect flow and precipitation data to avoid using overly broad regional precipitation data for large watersheds. Flow-composite data should be collected for the entire duration of a storm event to avoid bias. More importantly, longterm data collection efforts need to be made at the watershed scale to evaluate the runoff and pollutant reduction effects of green infrastructure implementation. A semipermanent network of collection stations can be used to evaluate urban runoff over concentrated time periods before, during, and after largescale implementation of green infrastructure.[86]

At a larger scale, innovative legal and management frameworks such as watershed permitting[87] could help alleviate some of the challenges associated with the non-point source/point source dichotomy. Assigning NPDES permits based on local ecology and geography rather than artificial political or institutional boundaries has several benefits. Permits would be more closely aligned with the water quality goals of TMDLs associated with the watershed. This strategy also allows for a more flexible, integrated approach to water management, and encourages participation by all stakeholders in a given region rather than piecemeal efforts by individual jurisdictions. As a result, watershed permits could encourage water quality trading markets, providing a cost-effective strategy to achieve pollution discharge goals. Such water quality trading programs already exist both at a basin scale for the Ohio River[88] and within municipalities as pioneered by Washington, DC's stormwater retention credit system.[89] Most importantly, from the perspective of this research focused on variability for green infrastructure, watershed permitting avoids the blame

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85. *See id.*

86. *See e.g.*, NAT'L RESEARCH COUNCIL, *supra* note 50, at 390–96 (discussing monitoring pre- and post-construction for low-impact development projects).

87. The EPA described watershed-based permitting as "[an approach] that emphasizes addressing all stressors within a hydrologically-defined drainage basin, rather than individual pollutant sources on a discharge-by-discharge basis." *Watershed-based Permitting*, ENVTL. PROT. AGENCY, https://www.epa.gov/npdes/watershed-based-permitting [https://perma.cc/B4EU-X6FX].

88. *EPRI and First Climate Bring Water Quality Credits to Environmental Stewardship Markets* ELECTRIC POWER RES. INST., (May 29, 2019), https://wqt.epri.com/pdf/EPRI_First-Climate_WQT_PressRelease.pdf [https://perma.cc/X5CL-WVHK].

89. *See Stormwater Retention Credit Trading Program*, DEP'T. OF ENERGY & ENV'T, https://doee.dc.gov/src [https://perma.cc/WK6Q-PVYP].

attribution squabbles often associated with urban stormwater disputes by delegating a single authority as the permit holder and, therefore, responsible for MS4 water quality within the watershed.

III. Leveraging Environmental Psychology to Understand Green Infrastructure Implementation

In the previous Part, we presented examples of watershed-scale approaches to mitigate some of the challenges of integrating green infrastructure within the framework of the CWA. However, for these largescale solutions to be effective, we must also consider how private green infrastructure can be incentivized at the individual scale. In this Part, we explore several theoretical approaches to incentivizing human behavior.

A. *Economic Self-Interest*

The classic approach to incentivizing green infrastructure is the use of an Economic Self-Interest model in which individuals systematically evaluate choices, and then act in accordance with rational self-interest.[90] This framework motivates many municipal programs that use financial incentives to encourage green behaviors.

The most common forms of green infrastructure incentives programs are direct incentives, stormwater fees and credits, and municipal regulation. Chicago's Green Roof Grant Program, which offered up to five-thousand dollars in subsidies for residents and small businesses who chose to implement green roofs on their properties, is a prime example of a direct incentives program.[91] Other cities, such as Baltimore, assess stormwater fees based on impervious building footprint, and offer fee reductions based on green infrastructure that is installed onsite.[92] Finally, some cities, including Toronto, Canada, use a stick rather than a carrot, mandating certain types of technology for new development and assessing fines for failure to follow mandates.[93]

Although Economic Self-Interest forms the basis of many municipal policies surrounding private green infrastructure implementation, there are significant challenges with using this framework. Multiple sustainability efforts that focus on underscoring the monetary effects of sustainability have failed.

90. Stefano De Dominicis, P. Wesley Schultz & Marino Bonaiuto, *Protecting the Environment for Self-Interested Reasons: Altruism Is Not the Only Pathway to Sustainability*, 8 Frontiers in Psychology 1, 2 (2017).

91. Catherine Malina, *Up on the Roof: Implementing Local Government Policies to Promote and Achieve Environmental, Social, and Economic Benefits of Green Roof Technology*, 23 Geo. Int'l Envtl. L. Rev. 437, 450 (2011) (describing Chicago's incentive program).

92. *See Reducing Your Stormwater Fee*, Balt. City Dep't. of Pub. Works, https://publicworks.baltimorecity.gov/stormwater-fee/reducing-stormwater-fee [https://perma.cc/MQN4-TP5B].

93. *See* Malina, *supra* note 91 at 455–56 (describing green roof mandates for Toronto).

McKenzie-Mohr suggests that the Economic Self-Interest approach overlooks cultural practices, social interactions, and human feelings that influence behavior of individuals, social groups, and institutions.[94] Moreover, an overuse of extrinsic monetary motivators can decrease longterm intrinsic motivation and sustainable behavior.[95]

On a broader scale, an economically based incentives program can lead to environmental justice issues. A game-theoretic analysis of municipal policies for green infrastructure implementation shows that individuals further downstream in the stormwater network should theoretically have a significant amount of bargaining power, because these individuals can control the amount of pollution (i.e., stormwater) released from the system and the corresponding compliance with MS4 permit obligations.[96] In reality, these downstream populations are often low-income and minority.[97] From a stormwater perspective, a recent study in Miami, Florida indicated that non-Hispanic blacks and Hispanics are more likely to live in neighborhoods with inland-flooding challenges that do not have water-related amenities.[98] These same populations have historically been less likely to have the political influence necessary to help formulate new laws and policies that might take advantage of their relative position in the stormwater context and exercise their bargaining power.[99] Accordingly, exclusive use of an economic self-interest model may decline in effectiveness over the long-run, as well as exacerbate environmental justice issues.

B. *Self-Determination Theory*

Given the difficulties with the Economic Self-Interest model, we turn to other potential frameworks. Self-Determination Theory creates a model

94. D. McKenzie-Mohr, *Fostering Sustainable Behavior Through Community-Based Social Marketing*, 56 J. of Soc. Issues 543, 545 (2000).

95. Marianne Promberger & Theresa M. Marteau, *When Do Financial Incentives Reduce Intrinsic Motivation? Comparing Behaviors Studied in Psychological and Economic Literatures*, 32 Health Psychol. 950, 951–52 (2013) (summarizing the psychological and economic literature regarding rewards and the undermining intrinsic motivation). Promberger and Marteau, however, conclude that with respect to rewards targeting health, specifically behaviors that involve problems of self-control, financial incentives may not have an undermining effect but rather assist individuals in selecting behaviors associated with a delayed healthier outcome. *Id.* at 955–56. From a financial sustainability perspective, financial incentives can strain government budgets resulting in program termination. *See* Malina, *supra* note 91, at 458 (describing budget constraints for green roof programs in Berlin, Germany).

96. William, Garg & Stillwell, *supra* note 9, at 8015.

97. *Id.* at 8016. Studies show that low-income populations are more likely to live in areas with more environmental pollution than higher-income populations. *See* Carrier et al., *supra* note 17, at 1281.

98. In the context of this study, the categorization of "water-related amenities" included the percentage of tracts that included seasonal homes, and proximity to public beach access. Marilyn C. Montgomery & Jayajit Chakraborty, *Assessing the Environmental Justice Consequences of Flood Risk: A Case Study in Miami, Florida*, 10 Envtl. Research Letters 1, 2 (2015).

99. *See* William, Garg & Stillwell, *supra* note 9, at 8016.

of human motivation contingent on three factors: autonomy, relatedness, and competence.[100] Autonomy is the urge to be a causal agent in one's own life. In other words, autonomy represents the need to be self-directed.[101] Relatedness is the desire to feel connected to other people. In particular, relatedness is strong between members of similar social circles.[102] Mastery or competence is the feeling of accomplishment that comes from overcoming a challenge, or perfecting a skill.[103] A good example of the power of mastery as a fundamental human drive is the ability of games to keep us engaged for long periods of time by rewarding effort with rapid, clear feedback.[104]

The flipside of autonomy is reactance—the resistance of social influence by others arising from a perceived loss or threat to individual freedom.[105] Because reactance is so prevalent in many arenas of human interaction, psychologists have meticulously studied reactance, what induces it, and how it can be avoided.[106] Certain behavior-modification approaches seem more likely to elicit reactance than others because they are perceived as more directly limiting the target audience's autonomy.[107] The most obvious of these approaches are laws and regulations, as well as direct threats.[108] However, tangible rewards can also elicit reactance in certain cases.[109] Choosing an appropriate approach to incentivize behavior-modification is thus important to limiting the negative consequences of reactance.[110] Other factors, including how a message is delivered, and who delivers it, can be equally consequential. In general, the more socially distant the messenger is from the intended audience, the more likely an approach is to induce reactance.[111] Therefore, community-created rules and

100. Richard M. Ryan & Edward L. Deci, *Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being*, 55 Am. Psychologist 68, 68 (2000).

101. *See id.* at 70.

102. *See id.* at 73.

103. *See id.* at 70.

104. *See* Isabela Granic, Adam Lobel & Rutger C.M.E. Engels, *The Benefits of Playing Video Games*, 69 Am. Psychologist 66, 71 (2014).

105. Christina Steindl et al., *Understanding Psychological Reactance*, 223 Zeitschrift fur Psychologie 205, 205 (2015).

106. *See id.* at 206 (summarizing research literature on reactance theory); *see also* Marieke L. Fransen, Edith G. Smit & Peeter W.J. Verlegh, *Strategies and Motives for Resistance to Persuasion: An Integrative Framework*, 6 Frontiers in Psychol. 1, 5 (2015).

107. *See* Fransen, Smit & Verlegh, *supra* note 106, at 5 (discussing factors affecting reactance responses).

108. *See id.; see also* S. Greybar et. al., *Psychological Reactance as a Factor Affecting Patient Compliance to Physician Advice*, 18 Cognitive Behav. Therapy 43, 44 (1989) (discussing reactance in the medical context).

109. *See* Ran Kivetz, *Promotion Reactance: The Role of Effort-Reward Congruity*, 31 J. Consumer Res. 725, 726 (2005) (noting that consumers are sensitive to rewards, especially store loyalty programs).

110. *See id.* at 727 (discussing need to allow consumers to construe their consumption behavior to match their individual tastes and preferences).

111. *See* Steindl et al., *supra* note 105, at 207 (discussing the impact of whether the

initiatives are much more likely to be followed. Another potential trigger for reactance is how invested the messenger is in the outcome: a messenger who is perceived as neutral is much less likely to elicit reactance than someone who has a vested interest.[112]

Relatedness is another key driver of human motivation.[113] One of the best examples of the power of relatedness is the impact of social norms on behavior. Social norms, in the form of positive role models, have a powerful effect on behavior.[114] A study of student water conservation indicated that student compliance in saving water in the shower jumped to 49 percent (up from 6 percent) in the presence of a positive role model.[115] After the addition of a second role model, compliance rose to 67 percent.[116]

Social norms can be divided into two different types: injunctive norms and descriptive norms.[117] Injunctive norms evaluate societal approval or disapproval for a certain behavior, while descriptive norms define typical behaviors, both positive and negative.[118] An important aspect of maximizing the effectiveness of social norms is to ensure that injunctive and descriptive norms do not accidentally cancel each other out. If negative behaviors are common, then negative descriptive norms might encourage further unsustainable behaviors.[119] Conversely, the confluence of positive injunctive and descriptive norms can be powerful: using praise as a motivator when someone is doing above average can lead to further behavioral improvements, not just for that particular person, but for their neighbors.[120] Importantly, studies also show that social norms are most likely to stick if they are presented as coming from peers and other members of similar social circles.[121] Social norms are also most likely

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threat to freedom comes from inside or outside the person's group, but also noting that the result can depend on whether the person is more of an individualist or collectivist).

112. *Id.* at 209 (noting the difference in reactance if the message is delivered by an expert versus a layperson).

113. *See* Richard M. Ryan & Cynthia L. Powelson, *Autonomy and Relatedness as Fundamental to Motivation and Education*, 60 J. EXPERIMENTAL EDUC. 49, 53 (1991) (discussing relatedness).

114. *See* Noelle M. Hurd, Marc A. Zimmerman & Yange Xue, *Negative Adult Influences and the Protective Effects of Role Models: A Study with Urban Adolescents*, 38 J. YOUTH ADOLESCENCE 777, 786 (2009) (describing various impacts of role models on behavior).

115. Elliot Aronson & Michael O'Leary, *The Relative Effectiveness of Models and Prompts on Energy Conservation: A Field Experiment in a Shower Room*, 12 J. ENVTL. SYSTEMS 219, 223 (1982–83).

116. *Id.*

117. Robert B. Cialdini, *Crafting Normative Messages to Protect the Environment*, 12 CURRENT DIRECTIONS IN PSYCHOL. SCI. 105, 105 (2003).

118. *Id.*

119. *See id.* at 105–6.

120. *See id.* at 107 (describing research in the context of public service announcement to encourage recycling).

121. *See* Noah J. Goldstein, Robert B. Cialdini & Vladas Griskevicius, *A Room with a Viewpoint: Using Social Norms to Motivate Environmental Conservation in Hotels*, 35 J. CONSUMER RES. 472, 479–80 (2008) (discussing matching of behavior to norms in one's

to create positive change when examples of the desired change are present in close proximity.[122]

C. *Applications for Self-Determination Theory to Green Infrastructure*

Leveraging the psychology of human motivation to influence community perceptions of green infrastructure can have a significant effect on the longterm integration of green infrastructure into the urban landscape. Because green infrastructure is highly visible, social norms dictate whether their presence positively or adversely affects the perceived value of a home and neighborhood.[123] Nassauer surmises that the halo effect is particularly strong with regards to green infrastructure: not only does the appearance of neighbors' yards have marked impacts on individual preferences, but examples of care and maintenance are also contagious.[124]

Creating a network of peer-to-peer neighborhood role models can provide guidance to their local communities and help create templates to show what works and what does not in the green infrastructure context. This could also include proper maintenance techniques. A role model approach relies on traditional modes of social diffusion, targeting information about green infrastructure at early adopters within host communities to ensure reasonable community uptake rather than pure financial self-motivation. Importantly, it facilitates several factors that research has identified as drivers of social diffusion: simplicity and ease of use, trialability, and observable results.[125] Peer role models can help "test drive" green infrastructure and applicable tool kits, providing communities with unique pilot sites in their own neighborhoods so that they can have better indications of final outcomes, aesthetics, and costs. In action, real-world practitioners have found this approach useful, suggesting that identifying a small group of influencers early in the planning process is key to success and can facilitate a more optimal network layout for green infrastructure.[126]

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immediate setting or with those with whom they share similar social relationships).

122. *See id.* at 479.

123. Joan Iverson Nassauer, *Care and Stewardship: From Home to Planet*, 100 LANDSCAPE & URB. PLAN. 321, 322 (2011).

124. *Id.* at 323.

125. *See* Trisha Greenhalgh et al., *Diffusion of Innovations in Service Organization: Systematic Review and Recommendations*, 82 THE MILBANK Q. 581, 596 (2004) (discussing drivers of social diffusion and innovation theory).

126. *See id.* at 601–02 (discussing peer influence and horizontal networks); *see also* Andrew J. Reese, *Developing Technical Policy with Citizens Groups*, FORESTER MEDIA (January 1, 2002), https://www.foresternetwork.com/home/article/13001517/developing-technical-policy-with-citizen-groups [https://perma.cc/CW6U-SPNT]; Robert Goo, *Green Infrastructure Done Well: Making Communities More Livable and Economically Vibrant* (September 9, 2016), https://www.jff.org/points-of-view/green-infrastructure-done-well-making-communities-more-livable-and-economically [https://perma.cc/6YP6-MZCA].

Leveraging existing institutions such as homeowner associations (HOAs) can help to more widely spread positive social norms (both descriptive and injunctive), whilst also allowing community buy-in and rule creation. This last factor is important in helping mitigate reactance, which might occur if outside authorities, such as the MS4 permit holder, were to impose such rules. For example, HOAs in Montgomery County, Maryland coordinate institutional parcel rebates as part of the RainScapes Rewards program.[127] Importantly, HOAs in this context are not being used as a top-down mandate, but rather as a coordinating mechanism to encourage bottom-up growth and broader acceptance of green infrastructure.

Indiscriminate use of green stormwater infrastructure in the MS4 context may satisfy NPDES permit requirements, but due to inherent variability and the potential for suboptimal network layout may not obtain the desired levels of reliability and pollution reduction. As top-down mandates on land use control are historically unpopular, and financial incentives following the economic self-interest model may have limited effectiveness, along with significant budget implications and environmental justice concerns, stormwater districts may find more lasting success from a different approach. An approach grounded in the theory of the self-determination model may be unfamiliar in the traditional stormwater infrastructure culture of civil engineering and regulatory compliance, but nonetheless may offer a more effective alternative in the green infrastructure context. Fitting this into the MS4 permitting realm will require innovating and relying on nontraditional methods such as peer networks and nongovernmental institutions (HOAs or neighborhood associations, for example) to improve network layout and maintenance efforts. But, doing so may nudge the pollution discharges by MS4s toward the unifying goal of maintaining and restoring the nation's waters.

Concluding Thoughts

The integration of green infrastructure into the framework of the CWA opens up numerous possibilities. Creating opportunities for cities to implement green infrastructure to meet their requirements under the CWA provides them flexibility in their approach. However, the current framing of green infrastructure within the CWA creates legal and practical challenges for practitioners. Urban stormwater, a non-point source pollutant, is currently regulated as a point source pollutant under the CWA, contributing to confusion over who is responsible for stormwater monitoring and cleanup. Moreover, the use of green stormwater control measures as a substitute for numeric effluent discharge standards assumes a deterministic view of GSI treatment when the science clearly shows that GSI performance is variable.

127. *RainScapes Rewards Rebates*, Montgomery County, MD, https://www.montgomerycountymd.gov/water/rainscapes/rebates.html [https://perma.cc/B8WL-FA3L].

While watershed approaches to monitoring and management offer opportunities to address these issues at the national and regional level, an alternative approach is needed to ensure that these approaches can be implemented at the individual level. Viewing green infrastructure through the lens of environmental psychology helps us to identify and avoid the pitfalls of regulation based purely on an economic self-interest framework. In doing so, we can instead leverage more powerful motivators of human behavior: autonomy, relatedness, and mastery. Identifying these core drivers of behavior allows the development of concrete strategies to encourage long-term individual green infrastructure implementation and maintenance.

Green infrastructure offers an exciting new approach to the challenges of urban stormwater. As the technology matures and becomes more widely implemented, policymakers need to carefully consider how GSI is being integrated—or not—into the current legal landscape. While challenges to effective green infrastructure implementation at both the national and individual parcel levels remain, potential strategies already exist to mitigate these stormwater management challenges. Watershed management, risk and reliability assessment, and environmental psychology provide an array of tools that can facilitate future integration of green infrastructure into existing policy.