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COGNITIVE AND PERCEPTUAL BARRIERS TO GREEN INFRASTRUCTURE: LOCAL DECISION-MAKING IN RHODE ISLAND

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COGNITIVE AND PERCEPTUAL BARRIERS TO GREEN INFRASTRUCTURE: LOCAL DECISION-MAKING IN RHODE ISLAND

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ABSTRACT

Green infrastructure uses natural and nature-based systems and practices to infiltrate and treat stormwater runoff at its source, lessening the burden and reliance on "gray" piped stormwater networks. Existing academic and governmental literature reports that local decision-makers face complicated cognitive and perceptual barriers that exacerbate other hindrances to green infrastructure implementation. These barriers are understudied at the local level in general, as well as in Rhode Island ("RI") municipalities in particular. This study employs a literature review, semi-structured interviews with RI municipal officials, and thematic coding to describe the cognitive and perceptual barriers inhibiting wider green infrastructure implementation. Of the twenty-nine municipalities targeted for interviews, responses from fourteen communities, ranging from rural to urban, were collected. For cognitive barriers, the analysis suggests that, although local officials have high awareness of and access to general information related to green infrastructure, many specific informational needs (i.e., site design, monitoring, cost-estimates) remain unmet. Analysis also shows that local officials have difficulty communicating green infrastructure's co-benefits (i.e., transportation, recreation, aesthetics, etc.), despite strong understanding of these benefits. For perceptual barriers, the analysis suggests that how officials perceive external barriers like funding and maintenance may give rise to feelings of ambivalence towards implementation. Further, the analysis finds that framing green infrastructure as a product, rather than a process, limits its efficiency, thereby perpetuating feelings of ambivalence among local officials. This study serves as a starting point for this topic in RI and recommends practical strategies for improved communication and wider green infrastructure implementation.

ACKNOWLEDGEMENTS

To thank everyone that has been involved in this research, either directly or indirectly, might require more pages than the manuscript itself. Yet, first and foremost, I thank my family, friends, and loved ones—for their constant willingness to test-drive my ideas, for their understanding while I disappeared into these 21,000+ words of text, and for their absolute belief that I would successfully complete this project, this program, and anything else I set out to. I owe a tremendous thanks to Professor Richard Burroughs for serving as an excellent major professor and for always being there to provide thoughtful guidance and, most importantly, a good laugh. To my entire committee—Professors Ley, Lacasse, and Boving—thank you for bringing your expertise and insights to the table. I'm also grateful for the whole Marine Affairs Department, friends and professors alike, for giving me such a terrific graduate experience. To the entire Throwe Environmental team, thank you for your boundless support, the opportunities to grow in this field, and the chance to make real differences in the communities we work in. And finally, I thank all of the interviewees who took the time to chat with me about green infrastructure. It was a pleasure to hear about your experiences, and I commend you for the excellent work you do and credit you for so much of it that happens behind the scenes.

Completing a master's program, let alone doing so virtually in the midst of a global pandemic, is no easy feat. And so, I couldn't be prouder of this document. The piece of work that follows is a reflection of my personal and educational journey, and one that I am deeply proud of.

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ABBREVIATION/ ACRONYMN	MEANING
BMP	Best management practice
CWA	Clean Water Act
GI	Green infrastructure
GMO	Genetically modified organism
GSI	Green stormwater infrastructure
IQ1-10	Interview Questions 1-10
ISA	Impermeable surface area
LID	Low-impact development
MCM	Minimum control measure
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NPS Pollution	Non-point source pollution
RI	The State of Rhode Island
RICRMC	Rhode Island Coastal Resources Management Council
RIDEM	Rhode Island Department of Environmental Management
RIPDES	Rhode Island Pollutant Discharge Elimination System
RISDISM	RI Stormwater Design and Installation Standards Manual
RQ1-4	Research Questions 1-4
SNEP	The Southeast New England Program
STB	Save The Bay
STS	Science and technology studies
SWMP	Stormwater management program
URI	The University of Rhode Island
USEPA	Environmental Protection Agency
WQ	Water quality

I. INTRODUCTION

Green infrastructure ("GI"), as defined by the United States federal government in Section 502 of the Clean Water Act ("CWA"), is the range of nature-based or nature-mimicking technologies and practices used to manage stormwater runoff.[1] In many cases, green infrastructure can be used as an alternative to traditional hardened or piped infrastructure (hereinafter referred to as "gray infrastructure"); in some cases, green and gray infrastructure can be used in conjunction for a hybrid approach to stormwater management.[2] There are many advantages to using green infrastructure in lieu of gray infrastructure, as the nature-based practice treats stormwater runoff at its source rather than transporting it through a piped drainage network for storage, and eventual treatment and discharge.[3,4] Beyond green infrastructure's stormwater management properties, the introduction of green technologies and green spaces can also provide numerous additional benefits—from flood mitigation and climate resilience, to recreation improvements and property value increases.[5] These benefits that exist outside of stormwater management are widely referred to as secondary, or sometimes tertiary, "co-benefits."[6] With an array of direct and indirect benefits related to stormwater management and other issue areas, the United States Environmental Protection Agency

[1] USEPA, "What is Green Infrastructure?" USEPA (December 4, 2019). https://www.epa.gov/green-infrastructure/what-green-infrastructure.

[2] *Ibid.*

[3] *Ibid.*

[4] USEPA, "Benefits of Green Infrastructure," USEPA, May 28, 2020, https://www.epa.gov/green-infrastructure/benefits-green-infrastructure.

[5] *Ibid.*

[6] Amanda Phillips de Lucas, personal communication, December 15, 2020.

("USEPA") encourages the use of green infrastructure as a "cost-effective, resilient approach to managing wet weather impacts that provides many community benefits."[7]

NPDES and RIPDES Stormwater Programs

It is important to recognize USEPA's promotion of green infrastructure as a stormwater management alternative, as USEPA is the federal agency responsible for overseeing the National Pollutant Discharge Elimination System ("NPDES") Stormwater Program.[8, 9] In short, Phase II of the NPDES Stormwater Program requires municipal governments to obtain permits to regulate stormwater discharges from municipal separate storm sewer systems ("MS4s") located within federally designated urbanized areas.[10] Additionally, the NPDES Stormwater Program requires these municipalities to develop stormwater management programs ("SWMPs") to manage their discharges.[11, 12] As part of these SWMPs, municipalities are required to comply with six minimum control measures ("MCMs"): (1) public education and outreach, (2) public participation/involvement, (3) illicit discharge detection and elimination, (4) construction site runoff control, (5) post-construction runoff control, and (6) pollution prevention/good

[7] USEPA, "What is Green Infrastructure?" USEPA (2019). https://www.epa.gov/green-infrastructure/what-green-infrastructure.

[8] USEPA, "National Pollutant Discharge Elimination System: About NPDES," USEPA, (November 29, 2016), https://www.epa.gov/npdes/about-npdes.

[9] Several other program areas also fall within the NPDES program, including those requiring permits for stormwater discharges from construction activities and industrial activities. While these permits may be tangentially related to the Stormwater Program, they are not within the scope of this study.

[10] RIDEM, Office of Water Resources. "General Permit Rhode Island Pollutant Discharge Elimination System," *RIDEM*, (2008), http://www.dem.ri.gov/pubs/regs/regs/water/ms4final.pdf.

[11] USEPA, "NPDES: NPDES Stormwater Program," *USEPA*, March 20, 2020, https://www.epa.gov/npdes/npdes-stormwater-program.

[12] USEPA, "NPDES: Stormwater Discharges from Municipal Sources." *USEPA*, April 16, 2020, https://www.epa.gov/npdes/stormwater-discharges-municipal-sources.

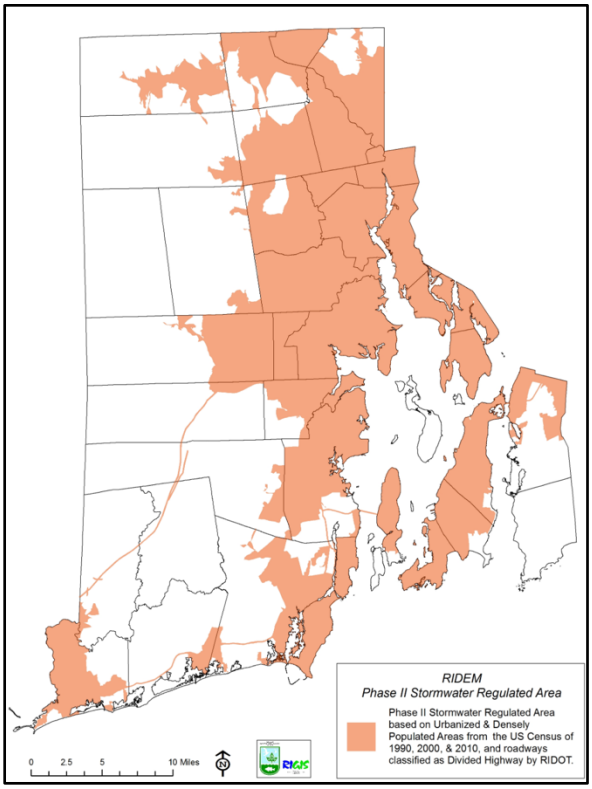

Figure I-I: Map of NPDES Phase II Stormwater Program Regulated Area in Rhode Island (Source: RIDEM, 2010)

housekeeping.[13] USEPA designates stormwater management permitting authority to the State of Rhode Island ("RI") through the Rhode Island Department of Environmental Management's ("RIDEM") Rhode Island Pollutant Discharge Elimination System ("RIPDES") program.[14] Current RIPDES requirements mandate that MS4 Stormwater Coordinators[15] submit annual reports detailing progress towards compliance with pollution standards.[16] Whereas USEPA serves as the federal regulating body that manages the NPDES Stormwater Program and oversees compliance with MS4 permitting requirements, and whereas "[USEPA] strongly encourages the use of green infrastructure approaches to manage wet weather. . . [and supports] integrating green infrastructure into [NPDES] permits," USEPA's directions on green infrastructure implementation have direct implications for state governmental bodies (i.e., RIDEM) that

[13] USEPA, Office of Water, "Stormwater Phase II Final Rule," *USEPA* (2005), https://www3.epa.gov/npdes/pubs/fact2-0.pdf.

[14] All but three Rhode Island municipalities (the Towns of Foster, Little Compton, and New Shoreham) fall within the NPDES Phase II Stormwater Regulated Area (***see Fig. I-I***) (Source: RIDEM, http://www.dem.ri.gov/programs/water/permits/ripdes/stormwater/ms4s-program.php).

[15] RIDEM, "List of Managers," *RIDEM*, accessed November 2020. http://www.dem.ri.gov/ri-stormwater-solutions/stormwater-managers/coordinator-list.php.

[16] RIDEM, "RIPDES MS4s," *RIDEM*, accessed March 26, 2021, http://www.dem.ri.gov/programs/water/permits/ripdes/stormwater/ms4s-program.php.

are responsible for direct oversight of MS4 programs, as well as for the local decision-makers ensuring compliance with these programs.

Local Implications and Justification of Research

According to USEPA, local governments "are in the best position to promote sustainable stormwater management, [i.e., green infrastructure,] on a larger scale. [However,] they also face some of the most complex challenges."[17] Municipal officials that play decision-making roles in SWMPs face several obstacles to green infrastructure implementation. In many cases, these obstacles might be empirical and/or objective—obstacles such as irregular funding or poor hydrogeological conditions for a given green infrastructure best management practice ("BMP"), for example.[18]

Also prominent, though, are complex and cross-cutting cognitive and perceptual barriers that exacerbate other barriers to implementation and impede local decision-making processes.[19, 20, 21] These cognitive barriers imply challenges with information accessibility and processing, as well as the cognitive framing of a concept—green infrastructure in this case.[22] Perceptual barriers include, but are not limited to, those that

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[17] "Overcoming Barriers to Green Infrastructure." USEPA, May 13, 2019, https://www.epa.gov/green-infrastructure/overcoming-barriers-green-infrastructure.

[18] Nell Nylen and Michael Kiparsky. "Accelerating Cost-Effective Green Stormwater Infrastructure" *CLEE, U.C. Berkeley School of Law*: (2015), 1.

[19] Krishna Dhakal and Liz Chevalier. "Managing urban stormwater for urban sustainability," *Journal of Environmental Management,* 203 (2017): 171-180.

[20] Nell Nylen and Michael Kiparsky. "Accelerating Cost-Effective Green Stormwater Infrastructure" *CLEE, U.C. Berkeley School of Law*: (2015), 1.

[21] Nylen and Kiparsky, "Accelerating Cost-Effective" 4.

[22] Reijo Savolainen, "Cognitive barriers to information seeking," *Journal of Information Science*, 41, 5: (2015), 613-623. https://journals.sagepub.com/doi/abs/10.1177/0165551515587850#:~:text=The%20study%20resulted%20in%20a,to%20deal%20with%20information%20overload.

inhibit understanding, predetermine attitudes, and precondition notions of usefulness.[23, 24] While certainly not the only obstacles to local green infrastructure implementation, these intangible cognitive and perceptual barriers are understudied and are often identified as cross-cutting exacerbators to other barriers.[25] The lack of knowledge and information gap in existing research establish this topic as being worthy of study.

Peer-reviewed academic literature and guidance produced by government agencies have generally explored cognitive and perceptual barriers as related to green infrastructure decision-making.[26] Additionally, some advocacy groups and practitioners in Rhode Island have abstractly identified on-the-ground examples of these barriers in the state.[27, 28, 29, 30] Yet, there is a gap in existing research that directly investigates these barriers and suggests potential remedies. This study aims to address that gap by exploring and describing the cognitive and perceptual barriers at the local level of decision-making,

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[23] Fanny Carlet, "Understanding attitudes toward adoption of green infrastructure," *ScienceDirect*, 51 (2015): 65-76.

[24] Dana Kochnower et al, "Factors influencing local decisions," *Ocean and Coastal Management*, (2015) 279-282.

[25] Dhakal and Chevalier, "Managing urban stormwater," 180.

[26] *Ibid.*

[27] Thomas Ardito and Teresa Crean, "Climate Adaptation for Coastal Communities," Presentation, 2017 Land and Water Conservation Summit from RILWP, Kingston, RI, March 11, 2017. https://landandwaterpartnership.org/documents/Summit2017/2A-Helping-Municipalities-with-Climate-Change.pdf

[28] Johnathan Berard and Amelia Rose, "Promoting Green Infrastructure," Presentation, 2017 Land and Water Conservation Summit from RILWP, Kingston, RI, March 11, 2017. https://landandwaterpartnership.org/documents/Summit2017/1D-Promoting-Green-Infrastructure.pdf.

[29] Brian Byrnes and Steven Ricci, "Designing 'Maintainable' Green Infrastructure," Presentation, 2018 Land and Water Conservation Summit from RILWP, Kingston, RI, March 10, 2018. https://landandwaterpartnership.org/documents/Summit2018/2A_GI_Maintenance.pdf

[30] Andrew Silvia, "~~Five~~ Seven Strategies to Improve," Presentation, 2019 Land and Water Conservation Summit from RILWP, Kingston, RI, March 9, 2019. https://landandwaterpartnership.org/documents/Summit2019/2C-StrategiestoImproveYourMunicipalStormwater.pdf.

and by offering solutions that could foster wider implementation—and in turn, wider understanding—of green infrastructure in Rhode Island.

II. BACKGROUND

Green Infrastructure

As communities have urbanized, impermeable gray infrastructure (paved parking lots, cement sidewalks, rooftops, etc.) has increasingly replaced nature's permeable surfaces. Consequentially, stormwater that was once absorbed into the earth now persists as runoff that collects and carries automotive, agricultural, and industrial pollutants into nearby waterways.[31] Whereas traditional urban planning practices have employed gray infrastructure (defined by USEPA as "single-purpose . . . conventional piped drainage and water treatment systems"[32]) to capture and move stormwater away from cities to protect against flooding, green infrastructure addresses the stormwater challenge in a more proactive and co-beneficial way. Rather than transporting, treating, and/or disposing of stormwater miles from its origin point, green infrastructure leverages the natural hydrologic cycle by absorbing and infiltrating stormwater at the source. Common BMPs listed by USEPA include permeable pavements, rain gardens, bioretention cells (bioswales), infiltration trenches, green roofs, green parking areas, rain barrels, and urban tree canopies.[33] Some green infrastructure practices, such as residential rain barrels, also collect stormwater for other uses proximal to where it originates.[34]

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[31] Claudia Copeland, "Green Infrastructure and Issues," *CRS*, (2016). https://fas.org/sgp/crs/misc/R43131.pdf.

[32] USEPA, "What is Green Infrastructure?" USEPA (2019). https://www.epa.gov/green-infrastructure/what-green-infrastructure.

[33] "Stormwater Management and Green Infrastructure Research." USEPA. (February 15, 2018). https://www.epa.gov/water-research/stormwater-management-and-green-infrastructure-research#:~:text=Green%20infrastructure%20practices%20include%20permeable,disconnection%2C%20and%20urban%20tree%20canopies.

[34] Copeland, "Green Infrastructure and Issues," *CRS*, (2016).

As most green infrastructure BMPs function with abundant open space, urban landscaping, and/or innovative porous technologies, they can also produce "co-benefits" beyond stormwater management. These co-benefits can advance recreation, ecosystems, public-health, transportation, and walkability, amongst many other areas or issues within a community.[35] The City of Lancaster, PA, serves as one example of a community that actively targets green infrastructure's co-benefits in its projects. For example, Lancaster officials renovated a neighborhood basketball court with a porous play surface and an underground infiltration bed. In addition to the 700,000 gallons of annual stormwater runoff that the project manages, the community also experiences recreational co-benefits from having improved facilities, as well as neighborhood quality of life co-benefits from the noise absorption properties that the porous court offers.[36] Across Lancaster, similar green infrastructure projects serve multiple purposes. Green sidewalks also enhance walkability, create an aesthetic unity to downtown, and increase public safety; large cisterns double as public art pieces and foster community engagement; and rain gardens and porous alleyways draw in commercial and residential investments and increase property values.[37] In short, green infrastructure can produce several co-benefits depending on how it is approached and in within a community.

The vast selection of green infrastructure BMPs is not "one size fits all." Instead, technical research shows that BMPs are best implemented on a community-by-

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[35] USEPA, "What is Green Infrastructure?" USEPA (2019). https://www.epa.gov/green-infrastructure/what-green-infrastructure.

[36] City of Lancaster. "Parks." *Save It! Lancaster*, (accessed April 19, 2021). http://www.saveitlancaster.com/local-projects/parks/#pagejump3.

[37] Kyle Gray, "S1 | E1: Green Infrastructure," Presented by the SNEP Network, *The Leadership Exchange Podcast* (podcast). September 22, 2020, https://anchor.fm/snep-leadership-exchange/episodes/S1--E1-Green-Infrastructure-ft--Lancaster-City-and-Provincetown-ejr6f2.

community basis, so as to best suit local physical conditions (i.e., hydrogeology), as well as local maintenance capacities and priorities.[38] For example, whereas one densely populated downtown community may benefit greatest from permeable pavement on narrow pedestrian walkways, another more spacious community may find bioswales that collect runoff from large impermeable parking lots or broader land conservation initiatives to be more appropriate. Similarly, there is no preset and/or uniform amount of rainfall that green infrastructure will absorb; absorption is based on BMP type(s), as well as overall impermeability within a system. In short, "the more permeable (or absorbent) the surface, the less runoff there will be" (***see Fig. II-I***).[39, 40] Integrated design processes characterized by interdepartmental cooperation, stakeholder engagement, attention to detail, and an informed understanding of costs and benefits lead to more successful projects.[41, 42] As implementation continues nationwide, even more technical information will become available, allowing for more informed and successful adoption.[43]

[38] Nylen and Kiparsky, "Accelerating Cost-Effective" 7.

[39] Denchak, Melissa. "Green Infrastructure: How to Manage Water in a Sustainable Way." Natural Resources Defense Council. (March 4, 2019). https://www.nrdc.org/stories/green-infrastructure-how-manage-water-sustainable-way.

[40] "Rhode Island Stormwater Design and Installation Standards Manual." RIDEM and RICRMC: (December 2015). http://www.dem.ri.gov/pubs/regs/regs/water/swmanual.pdf

[41] Pam Rubinoff et al., "Green Infrastructure for the Coast," *URI CRC and RISG*, 10, https://www.crc.uri.edu/download/1.-GRIP-booklet_Final.pdf.

[42] Dhakal and Chevalier, "Managing urban stormwater," 172-180.

[43] *Ibid,* 180.

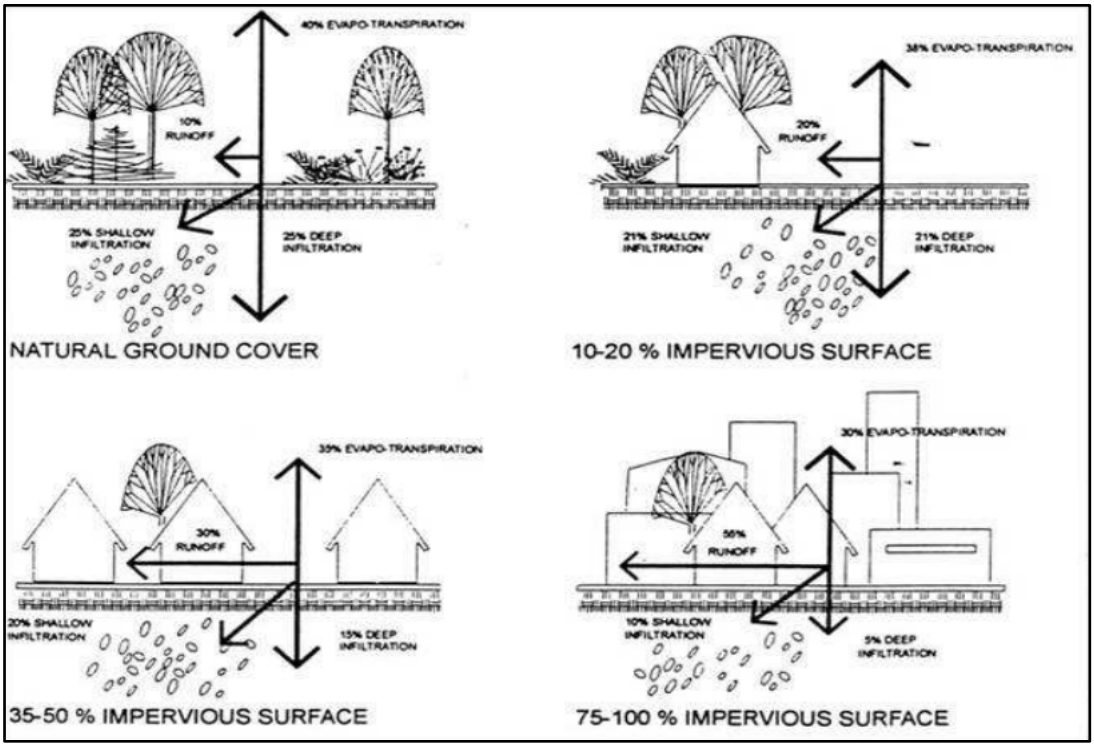

Figure II-I: Water Balance at Varying Stages of Development (Source: RISDISM, 2015)

Regulatory Drivers in Rhode Island

Despite the frameworks established by the NPDES and RIPDES Stormwater Programs, as well as existing state legislation enabling the creation of stormwater utility management districts, standard practice for municipalities in Rhode Island has not been to respond proactively to federal or state regulatory requirements.[44, 45] Instead, several

[44] "RI Stormwater Management and Utility District Act," P.L. 2002, Ch. 329, § 1, Sec. 45-61. State of Rhode Island General Assembly. (2002). http://webserver.rilin.state.ri.us/PublicLaws/law02/law02329.htm.

[45] Stormwater utilities exist as "stable, adequate, flexible, and equitable" options to finance municipal and/or regional stormwater management programs (UNB Steering Committee, 2015). In practice, stormwater utilities function similarly to other public utilities, such as wastewater. Most stormwater utility programs charge a service fee (typically based on ISA) that is proportionate to the cost of pollution abatement. For example, Lancaster City, PA charges a quarterly fee of approx. $4-$19 for residential property owners and average of $237 for commercial property owners (Save it! Lancaster, 2020). Integration of green infrastructure BMPs on private property to manage runoff at the source can serve as a method of providing "credits" against service fees. Enabling legislation (RIGL Ch. 45-61, 2002) for stormwater utility districts in the State of Rhode Island was passed in 2002. However, despite several feasibility studies on and initiatives in support of stormwater utility districts, no such district or utility has been established in the state (UNB Steering Committee, 2015; Middletown, RI, accessed on 3/25/21).

Rhode Island communities have relied on (and have been forced into) legal consent decree settlements to drive policy change. Both the Cities of Providence and Newport are examples of Rhode Island municipalities relying on consent decrees, as the failure of both towns to comply with state and federal law led to legal action being taken against the cities and to eventual settlements.[46, 47] Whereas a proactive approach to stormwater management certainly requires initial municipal investment, and whereas municipal stormwater utility fees are often perceived by municipal officials and the public as a politically undesirable tax, the reliance on consent decrees allows for delayed action with little repercussion. Under these conditions the settlements that have emerged out of consent decrees have become a sort of perverse incentive.

While consent decrees effectively allow municipalities to put off addressing stormwater management, Rhode Island state law also has characteristics that similarly fail to adequately encourage green infrastructure as a BMP for stormwater management. State law requires the, "the use of [low impact-design techniques, or green infrastructure,] as the primary method of stormwater control to the maximum extent practicable."[48] However, this legal requirement is not adequately enforceable, as the mandate to include green infrastructure in stormwater design "to the maximum extent practicable" is not strict in its language[49]. Furthermore, the regulation allows for the waiver of green

[46] US DOJ, "The City of Newport, R.I., Will Upgrade Facilities," (August 11, 2011), https://www.justice.gov/opa/pr/city-newport-ri-will-upgrade-facilities-and-pay-fine-settle-clean-water-violations.

[47] ecoRI News Staff, "Providence Forced to Invest," ecoRI News, (March 9, 2017), https://www.ecori.org/pollution-contamination/2017/3/9/providence-commits-to-investment-in-citys-stormwater-infrastructure.

[48] "Rhode Island Stormwater Design and Installation Standards Manual." RIDEM and RICRMC: (December 2015). http://www.dem.ri.gov/pubs/regs/regs/water/swmanual.pdf

[49] According to the RISDISM, "For all references to 'maximum extent practicable' in this manual, an applicant must demonstrate the following: (1) all reasonable efforts have been made to meet the standard

infrastructure inclusion requirements if developers provide proof that there is no appropriate or practical way of including green infrastructure in the design, regardless of the proof's robustness.[50] Despite regulations for stormwater management and green infrastructure inclusion, state and federal policies have yet to sufficiently persuade municipalities in Rhode Island to proactively address these issues.

Barriers to Green Infrastructure Implementation

Despite the expanding pool of guidance for green infrastructure, "there are many barriers—both perceived and real—to widespread, timely, efficient, and effective implementation."[51, 52] There is limited, though growing, academic and gray literature available that studies the specific barriers to green infrastructure implementation and adoption. This literature generally identifies similar themes, including social, political, institutional, financial, technical, and legal, as well as perceptual and cognitive barriers, "most of which stem from personal perception and existing socio-institutional setups."[53, 54] While this study takes no position in declaring any particular barrier(s) as more

in accordance with current local, state, and federal regulations, (2) a complete evaluation of all possible management measures has been performed, and (3) if full compliance cannot be achieved, the highest practicable level of management is being implemented." (RIDEM and RICRMC, 2015).

[50] "RISDISM," RIDEM and RICRMC, (2015), www.dem.ri.gov/pubs/regs/regs/water/swmanual15.pdf

[51] Nylen and Kiparsky, "Accelerating Cost-Effective" 7.

[52] Carlet, "Understanding attitudes toward adoption," 66.

[53] Dhakal and Chevalier, "Managing urban stormwater," 172.

[54] Though termed differently across different studies, most research has identified similar and/or related barriers inhibiting GI implementation. Carlet (2015) cites barriers that are social, political, and economic. Roy et al. (2008) cite financial, technical, institutional, regulatory, and cognitive barriers. Dhakal and Chevalier (2017) find policy, governance, resource, and cognitive barriers. The Clean Water Alliance of America (2015) identifies informational, technical, institutional, social, political, and financial barriers. O'Donnell et al. (2017) and Matthews et al. (2015) characterize barriers as socio-political, biophysical, or both. The URI Coastal Resources Center and RI Sea Grant (2018) find technical and physical, financial, legal and regulatory, and community and institutional barriers.

inhibitive than others, it recognizes the lack of research into and the cross-cutting nature of perceptual and cognitive barriers as warranting further study.

Information scientist Reijo Savolainen (2015) defines cognitive barriers as those that put limitations on information and information seeking, including, "unwillingness to see one's needs as information needs, inability to articulate one's information needs, unawareness of information sources, low self-efficacy, poor search skills and inability to deal with information overload."[55] Perceptual barriers, however, have not been as clearly defined in the existing literature. For example, Carlet (2015) and Kochnower et al. (2015) find that perceptions can influence understanding of, attitudes towards, and the consideration given to green infrastructure; however, the authors do not provide succinct definitions of perceptual barriers.[56, 57] Therefore, this study employs a flexible operating definition of perceptual barriers as those that impede how individuals think about, understand, and weigh the importance of green infrastructure. Some examples of perceptual barriers include lack of understanding, perceived usefulness, negative attitudes, and framing.[58, 59] In essence, both cognitive and perceptual barriers increase uncertainty. This uncertainty can cause individuals to tend to favor familiar approaches and perceive deviation from the status quo as particularly risky, thus decreasing the

[55] Savolainen, "Cognitive barriers to information seeking," JIS, (2015), 613-623. https://journals.sagepub.com/doi/abs/10.1177/0165551515587850#:~:text=The%20study%20resulted%20in%20a,to%20deal%20with%20information%20overload.

[56] Carlet, "Understanding attitudes toward adoption," 65-76.

[57] Kochnower et al, "Factors influencing local decisions," *Ocean and Coastal Management*, (2015) 279-282.

[58] Dhakal and Chevalier, "Managing urban stormwater," 172.

[59] Nylen and Kiparsky, "Accelerating Cost-Effective" 1.

likelihood of adoption of innovative technologies.[60, 61, 62] Dhakal and Chevalier (2017) report that, "enhancing the knowledge . . . and awareness [of green infrastructure], and the resulting removal of cognitive barriers, can develop social acceptance. If social acceptance is high, formulating other pro-GI policies and programs at any level becomes easier."[63]

Green Infrastructure at the Local Level of Decision-Making

While there is literature that studies the barriers to green infrastructure implementation, "little if any scholarly work has investigated the adoption of [green infrastructure] in municipalities across the US or the attitudes of local planners, engineers, and other local government staff members involved in making decisions about stormwater management."[64, 65] Local decision-makers with deep understandings of community dynamics and governmental systems have the potential to serve as policy champions for green infrastructure, and in turn further its implementation. Carlet (2015) notes, "while stormwater managers and other officials [may] lack the authority to unilaterally adopt and implement green infrastructure, they do have the ability to educate citizens and political leaders about [its] value . . . They thus could become change catalysts."[66] In other words, while local decision-makers' understanding alone may not

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[60] *Ibid.*

[61] Carlet, "Understanding attitudes toward adoption," 66.

[62] Joshua Olorunkiya et al., "Risk: A fundamental barrier," *Journal of Sustainable* Development, 5:9 (2012), 36, http://www.ccsenet.org/journal/index.php/jsd/article/view/17974.

[63] Dhakal and Chevalier, "Managing urban stormwater," 180.

[64] Carlet, "Understanding attitudes toward adoption," 66.

[65] Dhakal and Chevalier, "Managing urban stormwater," 172.

[66] Carlet, "Understanding attitudes toward adoption," 66.

lead directly to green infrastructure implementation, it does have the potential to foster even broader community understanding and action.

III. METHODOLOGY

Research Questions

This study enumerated four research questions ("RQ1-4") to explore the cognitive and perceptual barriers to local green infrastructure decision-making and to guide the processes of data collection and analysis. These research questions are as follows:

RQ1) How do local decision-makers in Rhode Island perceive different technologies (i.e. gray, green, or hybrid) for stormwater management?

RQ2) What are some of the cognitive barriers to greater green infrastructure implementation at the local level in Rhode Island?

RQ3) What are some of the perceptual barriers to greater green infrastructure implementation at the local level in Rhode Island?

RQ4) ***What are some strategies that could lead to greater green infrastructure implementation at the local level in Rhode Island?***

The above research questions sought to explore local decision-makers' perceptions, some of the cognitive and perceptual decision-making barriers as related to local green infrastructure implementation, and potential strategies for wider and more appropriate implementation across Rhode Island.

Research Design

This study employed a flexible research design with a qualitative approach to data collection and analysis. As such, the various steps of this study were loosely prescriptive, consisted of two different methods of data collection, and allowed for the presentation of

conflicting realities.[67] The approach taken for this study is similar to those of related studies, including Keeley et al (2013), Kochnower et al (2015), and O'Donnell et al (2017).[68, 69, 70] This study consisted of three stages, with some overlap between stages. Stage One consisted of data collection through a literature review of existing green infrastructure case studies. Stage Two was the central component of this study and it consisted of semi-structured participant interviews with Rhode Island municipal officials with a decision-making role related to stormwater management and green infrastructure. Stage Three of this study consisted of data analysis through thematic coding. This research was best suited to follow the structure identified by Robson (2011) in not explicitly positing hypotheses. Whereas quantitative research traditionally takes the approach of stating testable hypotheses to make broadly generalizable predictions about data, qualitative research often takes a more open-ended and flexible approach that seeks answers to research questions without predicting potential outcomes through hypotheses.[71]

Literature Review

The literature review of green infrastructure case studies served two key purposes in this study. Firstly, and most fundamentally, the literature review functioned to aggregate information from green infrastructure case studies statewide, regionally, and

[67] Robson, *Real World Research*, 130-135.

[68] Melissa Keeley et al, "Perspectives on the Use of Green Infrastructure," *Environmental Management*, (2013) 5-7.

[69] Kochnower et al, "Factors influencing local decisions," *Ocean and Coastal Management*, (2015) 279-282.

[70] E. C. O'Donnell et al, "Recognising barriers to implementation of Blue-Green infrastructure," *Urban Water Journal*, (2017), 965-966.

[71] Robson, *Real World Research*, 69.

nationally. This aggregated data served to provide important background information (i.e., key successes and challenges, implementation strategies, focal benefits, and project highlights) that was used to conceptually frame different models for implementing green infrastructure in municipal stormwater management programs. The findings from Stage One were also used to directly refine the Stage Two interview guide. Secondly, the literature review provided a sampling of external information to help inform this study's recommendations in accordance with RQ4. Whereas the communities examined in Stage One have largely served as national models for successful green infrastructure implementation, extracting components, or "lessons learned," from these case studies allowed me to explore potential strategies for implementation across Rhode Island.

Google served as the primary search engine for the literature review, with some case studies coming directly from USEPA's green infrastructure webpages. I used several keywords to return case studies that could strengthen my interview guide and serve as examples for potential recommendations. Searches focused on several of the following keywords/combinations thereof: *green infrastructure, green stormwater infrastructure, stormwater management, stormwater utility, green infrastructure BMPs, innovative stormwater management, green infrastructure case studies, natural infrastructure, Rhode Island, New England, projects, successes, challenges, barriers, co-benefits.*

As a range of green infrastructure BMPs comprise the larger field, the literature review focused predominantly on case studies that employed BMPs that are hydrogeologically appropriate and feasible for implementation in most Rhode Island communities. With this in mind, the following communities were selected as case studies in Stage One: the Cities of Cleveland, OH; Lancaster City, PA; Philadelphia, PA;

Case Study Community	Stormwater Utility/Fee	Public Engagement	Regulatory Drivers	Economic Revitalization	WQ Drivers	Leveraging Co-benefits	Long-term GI Commitment	P3s	Multiple BMPs
Cleveland, OH	x	x	x	x					x
Provincetown, MA		x			x	x			
Lancaster City, PA	x	x	x	x	x	x	x	x	x
Philadelphia, PA		x	x		x		x	x	x
GRIP					x				x
Providence, RI		x	x			x		x	
Aquidneck Isl. (RI)					x	x		x	
Bristol, RI					x	x			x

Table III-III: Key Components of Literature Review Case Studies

Providence, RI; and the Towns of Bristol, RI and Provincetown, MA. The literature review also studied the Rhode Island Coastal Green and Resilient Infrastructure Project (GRIP), which included the Cities of Warwick, RI and Newport, RI and the Town of North Kingstown, RI, as well as a project on greater Aquidneck Island (RI) that included the City of Newport.

After completion of Stage One, the findings from the literature review were used to refine the Interview Guide (***see Appendix A***) that was used to structure participant interviews in Stage Two. Many of the common components of the selected case studies were interwoven in the interview guide to prompt interviewees on these considerations (***see Table III-I***). Such components include public engagement, regulatory and water quality drivers, leveraging co-benefits, and multiple BMPs. Key components are also considered through RQ4 and in the final recommendations section of this manuscript as possible strategies for wider green infrastructure implementation in Rhode Island.

Participant Interviews

Due to the complications presented by the global COVID-19 pandemic, all components of this research were conducted virtually. Selected participants were contacted predominantly by email using a script and an attached document overviewing the study; follow-up emails and phone calls were used as necessary. Prior to the

interview, participants were required to complete an online consent form confirming their voluntarily participation and consent for audio recording. Audio recordings were captured via ZOOM and were used for data analysis in Stage Three of this study. Participants were offered the opportunity to receive a copy of their interview's audio recording, though all participants declined this opportunity. Recordings were not shared with anyone outside of the thesis committee.

Interviews took place via ZOOM and generally spanned between forty-five minutes and one hour. Interviews were semi-structured, and loosely followed a standardized interview guide (***see Appendix A),*** which allowed for flexibility in questioning and for conversations to flow naturally.[72] The semi-structured approach also allowed me to refine the interview guide as needed throughout Stage Two. The style of interview questions, which were predominantly open ended, also remained flexible, so as to provide as few restrictions as possible on participant answers. Questions pertained to topics including participants' experiences, attitudes, information sources, perceptions, greatest needs as related to green infrastructure and stormwater management. I screen-shared a checklist of green infrastructure BMPs—which I developed for the purposes of this study and in consultation with the thesis committee—with participants to gauge their familiarity and experiences with specific green infrastructure practices (***see Appendix B***). The Rhode Island Stormwater Design and Installation Standards Manual ("RISDISM")[73] was the primary information source used to populate this checklist.

Study Population and Sampling

[72] Robson, *Real World Research*, 285.

[73] "RISDISM," RIDEM and RICRMC, (2015), www.dem.ri.gov/pubs/regs/regs/water/swmanual15.pdf

Purposive and snowball sampling, two approaches common to flexible and qualitative research resign, were used in seeking interview participants.[74] As a study focused on exploring and describing some of the barriers to local green infrastructure implementation, purposive and snowball sampling allowed me to conduct interviews until the point of saturation.[75]

The determination of the study population followed the guidelines established by Carlet (2015). As such, the population consisted of "local planners, engineers, and other local government staff members involved in making decisions about stormwater management."[76] In this study, this population, referred to hereinafter as "local decision-makers," was limited to the municipal level of government, so as to fit within the scope of this research. In Rhode Island, municipal management structures vary by city and town; therefore, strict limitations based on job titles would potentially exclude several key individuals. With this in mind, the State of Rhode Island's aggregated "List of [Stormwater] Managers" was used to identify the municipal official(s) in each Rhode Island city and town that is/are most likely to oversee stormwater decision-making.[77]

I grouped Rhode Island's thirty-eight cities and towns[78] into three categories based on water quality ("WQ") as determined by impervious surface area ("ISA"), or the

[74] Robson, *Real World Research*, 275.

[75] *Ibid*, 148.

[76] Carlet, "Understanding attitudes toward adoption," 66.

[77] RIDEM, "List of Managers," *RIDEM*, accessed November 2020. http://www.dem.ri.gov/ri-stormwater-solutions/stormwater-managers/coordinator-list.php.

[78] The research team regrets that the Town of New Shoreham, Rhode Island (more commonly known as "Block Island") was excluded from this study due to lack of regularly available data. Zhou and Wang (2007) note that field data suggests that New Shoreham has approx. 10% ISA, suggesting that this study's findings regarding other communities with approx. 10% ISA (those in the "protected" classification) may also be applicable to the Town of New Shoreham.

percentage of impermeable surface within a total area. Widely cited studies by Flinker (2010) and Zhou and Wang (2007) were aggregated to categorize Rhode Island municipalities as "protected" (i.e., ≤10% ISA), "impacted" (i.e., 10–25% ISA), or "degraded" (i.e., ≥25% ISA), and this classification is hereinafter referred to as the "ISA/WQ Designation".[79, 80] Prospective interviewees were purposively selected and contacted in an attempt to achieve a normal distribution of interviewed communities across these three ISA/WQ Designation categories. Secondary sampling consideration was also given to geographical distribution of communities across Rhode Island (i.e., West Bay vs. East Bay/Islands[81], coastal vs. inland). Throughout the participant interviews, I used snowball sampling to prompt interviewees to share any recommended potential contacts for further interviews.

Recruiting and Participation

Recruiting for Stage Two took place between November 2020 and January 2021. Recruiting consisted of multiple phases of outreach via email and phone calls as necessary. Most targeted communities received one initial outreach email, as well as two follow-up emails and one phone call. Of the thirty-eight Rhode Island cities and towns within the study population, twenty-nine were targeted for interviews (***see Table III-II***) using the primary and secondary criteria explained in the previous section (***see Study***

[79] Peter Flinker, "The Need to Reduce Impervious Cover," *RIDEM Sustainable Watersheds Office*, (May 2010) 1-20.

[80] Yuyu Zhou and Y. Q. Wang, "An Assessment of Impervious Surface Areas in Rhode Island." *Northeastern Naturalist*, 14, 4: (2007), 643-650.

[81] The term "West Bay" refers to those mainland communities on the western side of Rhode Island's Narragansett Bay. Likewise, the term "East Bay" refers to those mainland communities on the eastern side of the Bay. While the communities on Conanicut (the Town of Jamestown, RI) and Aquidneck Islands (the City of Newport, RI and the Towns of Middletown and Portsmouth, RI) technically are situated in the middle of the Bay, they are commonly grouped with East Bay communities, and are thus included in category "East Bay/Islands".

Participant Interview Response Results — Grouped by ISA/Water Quality Designation

PROTECTED DESIGNATION				IMPACTED DESIGNATION				DEGRADED DESIGNATION			
City/Town Name	Targeted for Interview?	Response?	Interviewed?	City/Town Name	Targeted for Interview?	Response?	Interviewed?	City/Town Name	Targeted for Interview?	Response?	Interviewed?
South Kingstown	Yes	Yes	Yes	North Kingstown	Yes	Yes	Yes	Pawtucket	Yes	Yes	Yes
Coventry	Yes	Yes	Yes	Barrington	Yes	Yes	Yes	Newport	Yes	Yes	Yes
Smithfield	Yes	Yes	Yes	Johnston	Yes	Yes	Yes	Central Falls	Yes	Yes	Yes
Jamestown	Yes	Yes	Yes	Warren	Yes	Yes	Yes	Woonsocket	Yes	Yes	Yes
Burrillville	Yes	Yes	Declined	Middletown	Yes	Yes	Yes	North Providence	Yes	No	-
Exeter	Yes	No	-	Bristol	Yes	Yes	Yes	West Warwick	Yes	No	-
Glocester	Yes	No	-	East Greenwich	Yes	Yes	Declined	Providence	No	-	-
Scituate	Yes	No	-	Westerly	Yes	No	-				
West Greenwich	Yes	No	-	Narragansett	Yes	No	-				
Hopkinton	Yes	No	-	Cumberland	Yes	No	-				
Little Compton	Yes	No	-	Warwick	Yes	-	-				
Charlestown	Yes	No	-	East Providence	No	-	-				
Tiverton	No	-	-	Cranston	No	-	-				
North Smithfield	No	-	-	Lincoln	No	-	-				
Richmond	No	-	-	Portsmouth	No	-	-				
Foster	No	-	-								

Table III-IV: Participant Interviews Response Results — Grouped by Impervious Surface Area (ISA)/Water Quality Designation

Population and Sampling). Of the twenty-nine targeted communities, potential interviewees from sixteen cities and towns responded to recruitment materials, resulting in a response rate of 55.17% of targeted communities. Decision-makers from fourteen communities consented to participate, with decision-makers from two communities declining to participate; this resulted in an interview rate of 48.28% of targeted communities. In total, fourteen of Rhode Island's cities and towns, or 36.84%, were represented by local decision-makers in this study's participant interviews.

Communities Represented in Interviews

The fourteen Rhode Island municipalities represented in Stage Two were the Cities of Central Falls, Newport, Pawtucket, and Woonsocket and the Towns of Barrington, Bristol, Coventry, Jamestown, Johnston, Middletown, North Kingstown, Smithfield, South Kingstown, and Warren (***see Figure III-I***). Of these fourteen communities, four were within the "Protected" ISA/WQ Designation, six were within the "Impacted" Designation, and another four were within the "Degraded" Designation. Thus, a normal distribution of interviewees across these Designations was achieved (***see Figures III-IIabc***).

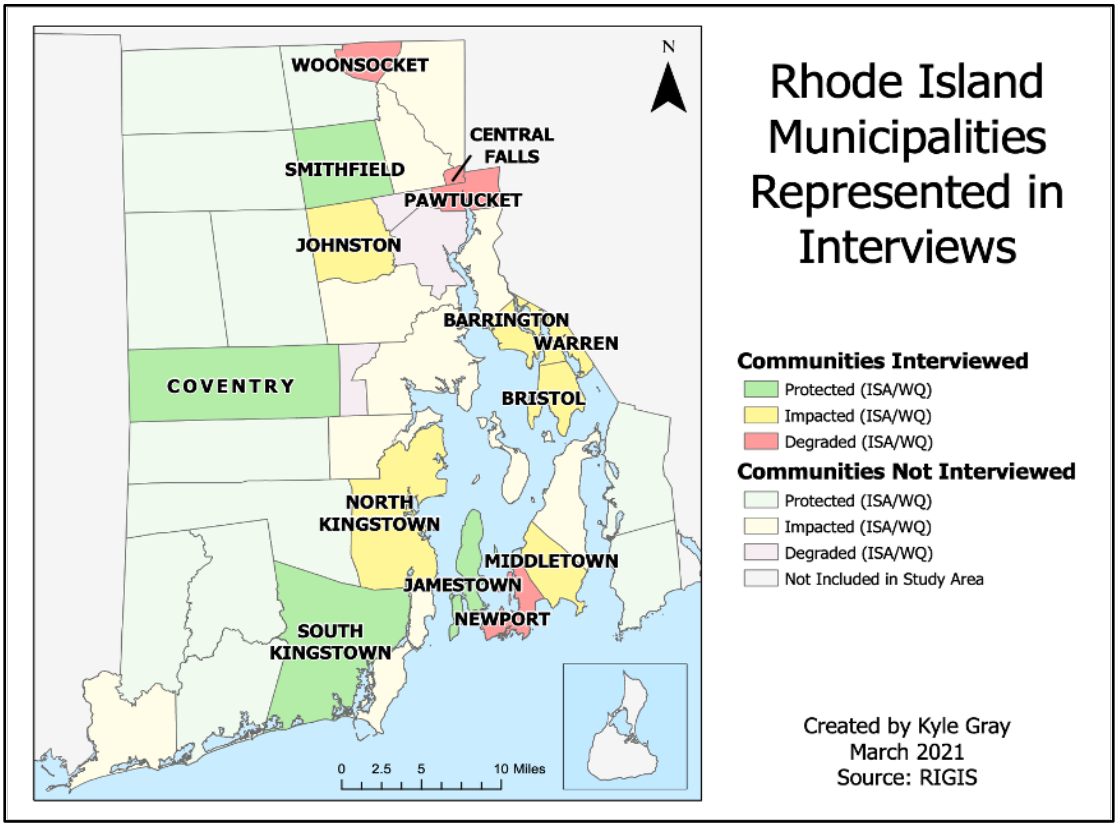

Figure III-I: Map of Rhode Island Municipalities Represented in Participant Interviews

Of the fourteen municipalities represented, nine (64.28%) were coastal and five (35.71%) were inland. This distribution favors coastal communities, as twenty (52.63%) of Rhode Island's thirty-eight cities and towns are coastal, while eighteen (47.37%) are inland. Of the fourteen communities represented in the participant interviews, eight (57.14%) were located on the West Bay and six (42.86%) were located on the East Bay/Islands. This distribution favors East Bay/Islands communities, which, in reality, comprise only 26.32% of Rhode Island's cities and towns, as compared to the West Bay's 73.67%. Thus, the findings of this study are more representative of coastal and East Bay/Islands communities (***see Figures III-IIabc***).

Confidentiality of Interviews

The population of participants interviewed for this project was comprised of employees of local government, and thus ethical and political considerations were taken in order to ensure confidentiality. All participants completed an online consent form. In doing so, participants confirmed that (1) they read and understood the consent agreement, (2) they were given unrestricted opportunities to ask questions, (3) they voluntarily consented to participate and understood that they could withdraw their participation at any time, (4) they were over eighteen years of age, and (5) they consented to audio recording and retained the right to request a copy of this recording. Participants were emailed a link to the online consent form multiple times during recruitment. Most participants read and completed the online consent form independently prior to their interview. I assisted some participants in completing the online consent form via ZOOM screensharing. Access to audio recordings was only granted to the thesis committee, as well as the participant being interviewed upon their request. Interviews were not shared outside of the committee or the interviewee. Participant's responses remained

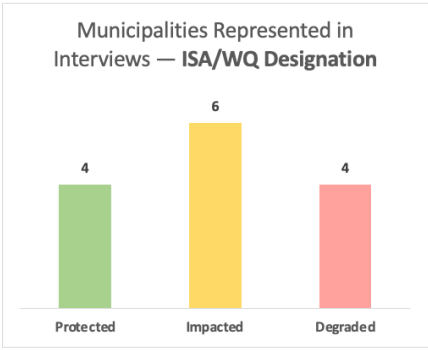

Figure III-IIa: *Interviews by ISA/WQ Designation*

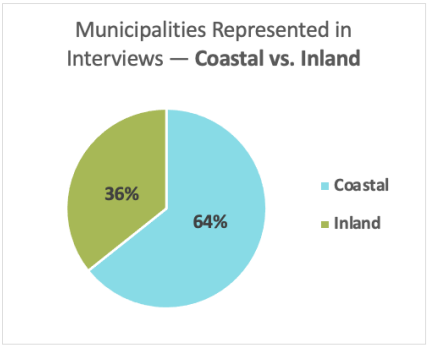

Figure III-IIb: *Interviews by Geography (Coastal vs. Inland)*

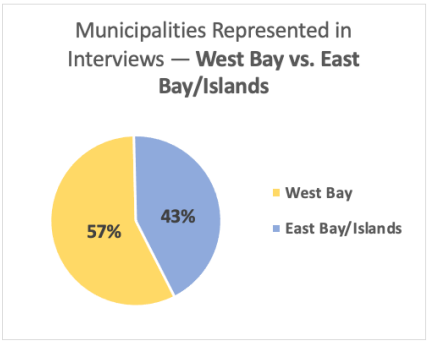

Figure III-IIc: *Interviews by Geography (West Bay vs. East Bay/Islands)*

Figures III-IIabc: Municipalities Represented in Participant Interviews

confidential and were securely stored on across password-protected devices and cloud storage platforms.

Interview Participants

Sixteen participants represented fourteen communities during the participant interviews of Stage Two. While the aforementioned confidentiality considerations prohibit ascribing characteristics to specific interviewees, they do not prevent the examination of the group as a whole. Many of the interviewees hold multiple positions and/or have a range of responsibilities in their capacities in municipal government. To that end, **Figure III-III** shows the different job roles of the interviewees. Planners and engineers were the two specific professions most represented in the interviews, which was fairly unsurprising given the fact that stormwater management often falls within these professionals' purview.[82] However, **Figure III-III** is also indicative of the variability of municipal government structures in Rhode Island, as an equal percentage of interviewees held a role that falls in the category of "Other," which consisted of resilience, wastewater/solid waste, environmental, and other specialists.

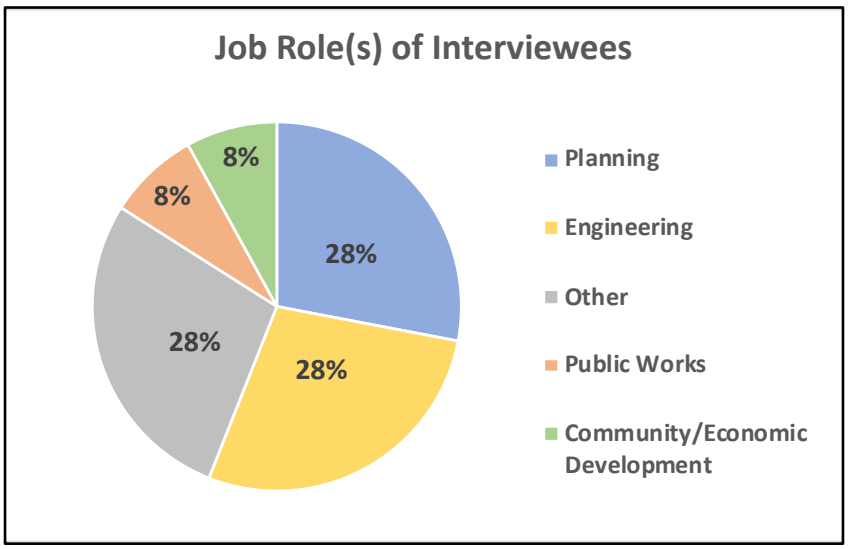

Figure III-III: Job Role(s) of Participant Interviewees

[82] Carlet, "Understanding attitudes toward adoption," 66.

Data Collection Challenges

Perhaps the greatest challenge to this study was navigating the research processes amidst the ongoing COVID-19 pandemic. Given the nature of the global pandemic, this study's participant interviews were entirely virtual. As a result, the research team and the interview participants faced unique data collection challenges that otherwise might not have impacted this research. Such challenges included weak and intermittent internet connectivity, audiovisual quality issues, "ZOOM fatigue," and scheduling challenges.[83] Municipally, COVID-19 has caused significant damage to local resources, straining budgets and complicating staffing. In many cases, green infrastructure, stormwater management, and other environmental concerns have fallen to the wayside as communities address pressing public health and economic needs. In short, the constantly evolving and wide-reaching nature of the COVID-19 pandemic has complicated advanced planning and disrupted timelines at several different points. While this research, of course, shares challenges felt by countless during this pandemic and pales in comparison to the much more serious and life-altering challenges faced by far too many, it is still important to note the genuine impacts of COVID-19 on this study.

Data Analysis

Stage Three of research consisted of qualitative data analysis of participant interview data using thematic coding. ATLAS.ti 9 Mac (hereinafter referred to as "ATLAS.ti") was the software platform used for Stage Three.[84] This research generally followed the step-by-step approach to coding (***see Appendix C for Thematic Coding***

[83] Paulina Firozi and Allyson Chiu, "Four reasons you're tired of Zoom calls," *Washington Post*, (2021), https://www.washingtonpost.com/lifestyle/2021/03/03/stanford-zoom-fatigue/.

[84] https://atlasti.com/product/mac-os-edition/.

Codebook) as prescribed by Robson (2011). Data was transcribed, then reviewed and initially coded, followed by phases of identifying and exploring themes, and ending with construction and interpretation of thematic networks.[85] I manually transcribed approximately half of the interview audio recordings. Due to time constraints, the remaining interview audio recordings were transcribed automatically using Temi.com[86], a free and secure online transcription platform. I compared all manual and automatic transcriptions to the original audio recordings to confirm accuracy and correct any transcription issues. Following this review, transcripts were upload into ATLAS.ti and grouped by ISA/WQ Designation, geographic location (coastal vs. inland and West Bay vs. East Bay/Islands), and interviewee job role(s).

As interview transcripts were uploaded into ATLAS.ti, I conducted an initial round of thematic coding on each transcript (***see Appendix C***). This initial round of coding was partially inductive (i.e., allowing codes to emerge naturally from the data), while some prescriptive codes were also drawn out of this study's research proposal and existing literature. After initially coding all interview transcripts, I reviewed the coded content for consistency. I compared codes to the research proposal and literature review and refined, grouped, split, and merged them as necessary. As coding progressed, I tracked notes using the "memo" function of ATLAS.ti. These memos captured points of interest and potential themes that began to materialize from the data. I then used these memos, as well as the initial research questions and interview guide questions to group and organize the analyzed content and to begin developing a thematic framework. At this

[85] Robson, *Real World Research*, 476.

[86] https://www.temi.com

point, several themes emerged with various related sub-themes and codes. Codes and other content were then reorganized and logically ordered in ATLAS.ti to reflect this framework of themes, and another round of content review was conducted to strengthen the themes and fill in any gaps. Additional review of codes and transcripts was conducted as needed to address any remaining gaps in the data analysis. The findings and interpretations from the data analysis stage are presented in the following Results and Discussion section.

IV. RESULTS AND DISCUSSION

Concept Map

Keeping with the overall focus of this study, these results and the discussion thereof are structured around cognitive and perceptual barriers. Within the existing literature on these barriers, conceptual frameworks are popular tools to help visualize the relationships between barriers and their various components. For example, Carlet (2015) constructs a conceptual model that "illustrates the role of attitudes in green infrastructure acceptance."[87] This study's concept map (***see Figure IV-I***), developed using the themed framework from the data analysis stage, contains four hierarchal layers, with each layer impacting or being impacted by those preceding or following it. The first layer, "Green

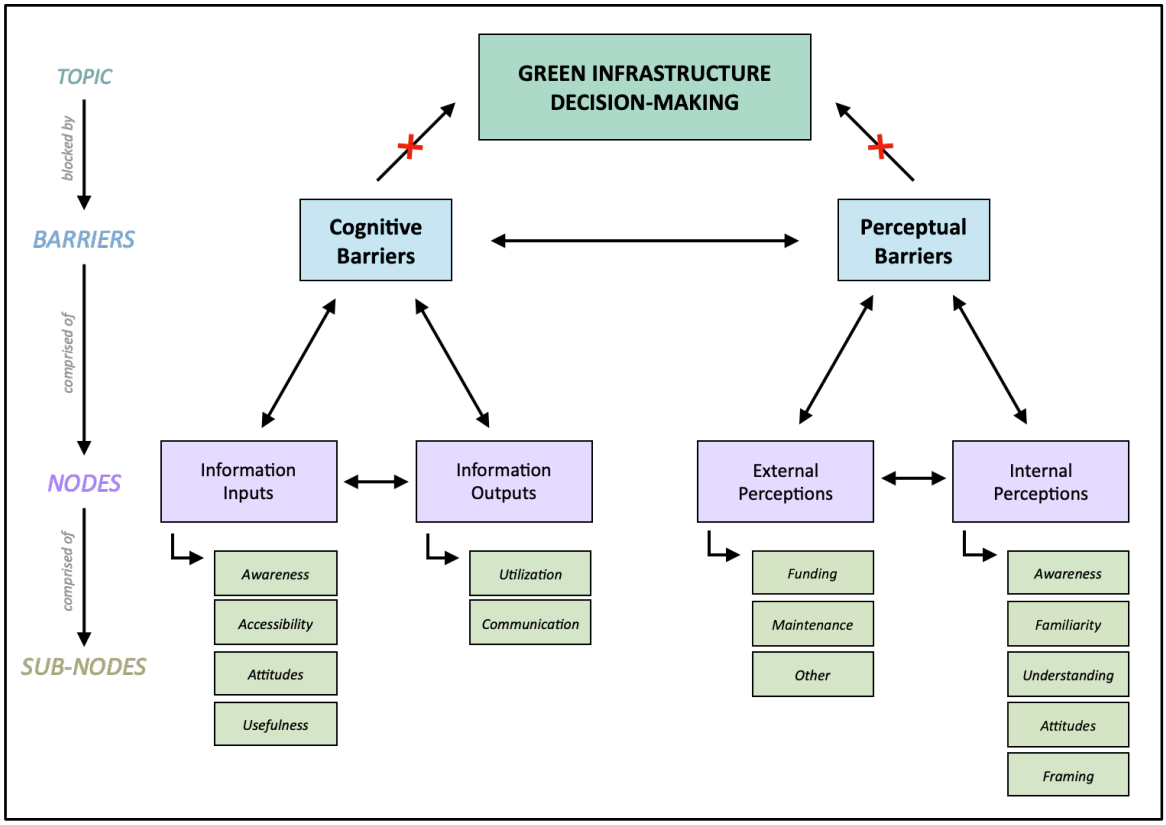

Figure IV-I: Results Concept Map

[87] Carlet, "Understanding attitudes toward adoption," 67.

Infrastructure Decision-Making," is the topic within which this research operates. Inhibiting progress on this topic are this study's two obstacles of focus: cognitive and perceptual barriers. Comprising each of these barriers are their respective nodes—cognitive barriers are divided into information inputs and outputs, while perceptual barriers are divided into external and internal perceptions. Finally, each of these nodes compiles multiple components, or sub-nodes. While countless potential nodes and sub-nodes could fit within each barrier, this study focuses on those that were most prominently represented in participant interviews. The exploration and discussion of this study's results is structured to better understand the various components of this concept map.

Cognitive Barriers

Information is the central consideration in this research's study and discussion of cognitive barriers. This study employs a working definition of cognitive barriers that is rooted in how decision-makers receive, weigh, interpret, and access information about green infrastructure. Prior research suggests that less than favorable interactions with green infrastructure information can bias decision-makers in favor of the status quo and make green infrastructure implementation less successful.[88, 89, 90] To this end, this study gives significant consideration to both the information inputs and outputs that comprise cognitive barriers.

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[88] Savolainen, "Cognitive barriers to information seeking," JIS, (2015), 613-623. https://journals.sagepub.com/doi/abs/10.1177/0165551515587850#:~:text=The%20study%20resulted%20in%20a,to%20deal%20with%20information%20overload.

[89] Kochnower et al, "Factors influencing local decisions," *Ocean and Coastal Management*, (2015) 285.

[90] Joshua Olorunkiya et al.. "Risk: A fundamental barrier," 27-41.

(1.0) Information Inputs

This research divides cognitive barriers into two nodes: information inputs and outputs. Information inputs, here, refer to the green infrastructure information that decision-makers are consuming. To that end, the following sections explore how effectively this information consumption is carried out. This node and its sub-nodes were guided primarily by Interview Question 6 ("IQ6") and its follow-up questions. These Interview Questions ("IQs") prompted interviewees to discuss their means of accessing information about green infrastructure, their experiences navigating that information, and their opinions about its completeness and usefulness.

(1.1) Awareness and Accessibility of Information

Respondents reported high levels of awareness and accessibility of general green infrastructure information. Nearly all participants were well aware of a variety of statewide and regional information sources. Respondents cited, *"state agencies or quasi-agencies, like the [Southeast New England Program ("SNEP")], through the RIPDES program . . . also from [the Rhode Island Flood Mitigation Association],"* *"[the Rhode Island Coastal Resources Management Council ("RICRMC")], [the University of Rhode Island ("URI")], the Coastal Institute, [Save The Bay ("STB")], [The Nature Conservancy], the state [of RI]. . . statewide planning, [the Rhode Island Emergency Management Agency],"* *"a great program . . . out of [the University of New Hampshire] Stormwater Center,"* *"Groundwork RI, the [Rhode Island Green Infrastructure Coalition] . . . [RI] Audubon Society,"* and *"the [Providence Stormwater Innovation Center] they have at Roger Williams Park"* as especially useful providers. One noted,*"[Many programs] have quite a few seminar and webinars. . . They're super easy*

to navigate. And they're really good about being careful of our time," while another shared, *"There's just a tremendous, tremendous amount out there. There's resources all over."* However, some responses indicated awareness and accessibility issues with specific information needs, such as monitoring and design. Interviewees shared the following comments:

> *"The gaps, I guess, are in the information. You can't always get all the information you need to do a final design without taking test pits and having engineers out there doing the work."*
>
> *"We don't actually have sensors in place to say that certain contaminants have been removed or anything like that."*
>
> *"I mean, I know that there's certain groups that are huge proponents on [green infrastructure], but I don't know that . . . I've never seen anything that focuses on how residents would view this stuff."*
>
> *"I don't know if there's been any studies that . . . identify the added cost of doing something. . . you know, taking out your traditional drainage and putting something else."*

These quotations indicate that, while there was a broad awareness and accessibility of general information, there still exist awareness and accessibility barriers related to specific information needs.

Savolainen (2015) finds that accessibility challenges can be partially characterized by "insufficient knowledge of information sources . . . [and] lack of procedural knowledge about how to conduct the information-seeking process."[91] With multiple interviewees expressing uncertainty regarding how to fill their specific information needs, the analysis of participant interviews suggests that these awareness and accessibility challenges have the potential to "[limit] the selection of potentially useful sources of information . . . [and result] in unsophisticated search strategies [and]

[91] Savolainen, "Cognitive barriers to information seeking," JIS, (2015), 620.

partial failure of the information-seeking process."[92] In short, despite high levels of access to general green infrastructure information, the lack of awareness and accessibility of information sources to fill specific information needs seems to be hindering decision-makers pursuit of wider green infrastructure implementation.

(1.2) Attitudes towards Information

In this study, most interviewees had a favorable view of the general information available on green infrastructure topics, especially the information provided by the several statewide and regional groups identified in the previous subsection. One respondent noted, *"I think [those groups] make it user-friendly for the municipalities. The instructors that they bring in for that type of information . . . they bring in their experts . . . I think it's all gone really well."* In fact, attitudes towards green infrastructure information that has been available since the beginning of the COVID-19 pandemic has been especially well received. Interviewees shared, *"Available information lately has been quite good." "I feel like when they do have a seminar or webinar, they try and keep it concise to an hour or two, and it's good,"* and *"There's a lot of stuff online, which is much more helpful than going to meetings. . . It's easier for us not to have to travel up to Providence, to go to stuff . . . So I've been able to do a lot more of the training."*

However, while attitudes towards green infrastructure may not hinder implementation, Barr and Gilg report that they are also unlikely to spur much action on their own. The authors write, "'information alone does not lead to behaviour change or close the so-called 'attitude–behaviour gap . . . substantial behavioural changes are unlikely to result from policies and campaigns that continue to present behavioural

[92] *Ibid.*

change as a consequence of increased awareness of ecological problems.'"[93] Therefore, while interviewees reported positive attitudes towards green infrastructure implementation, this information favorability is unlikely to serve as a substantial or meaningful factor towards broader implementation on its own.

(1.3) Usefulness of Information

This study considers usefulness in the same manner as Carlet (2015). Whereas Carlet defines usefulness as the extent to which one believes something will support a certain outcome, this study considers usefulness of information as the extent to which respondents believe green infrastructure information will help further the pursuit of broader implementation.[94] While this study did not employ a specific IQ to elicit responses on usefulness, some respondents' opinions on usefulness still emerged from the interviews. To this end, those respondents that did comment on usefulness had mixed opinions about the usefulness of green infrastructure information. . One respondent said, *"[Additional information] would tend to complicate things for us."* Another participant spoke about the usefulness of a specific information source—the RISDISM produced by RIDEM and RICRMC.[95] The respondent shared their experience:

> *A lot of the principles and practices that are identified in that Manual, it's kind of 'pie in the sky' stuff. It's good for new development and these cute little donut shops that have their small little parking lots and they can spill into these garden filters and bioretention areas, but on a municipal level when you have hundreds of these all across the town that you have to maintain, you can't maintain a little bioretention area. . . So that [Manual], although I reference it, it doesn't really do a lot for me. . . It's relevant and everybody has to refer to it when they do land development*

[93] Stewart Barr and Andrew W. Gilg. "A conceptual framework for understanding and analyzing attitudes (2007). *Geografiska Annaler: Series B, Human Geography*, 89:4, 361-379, https://www.tandfonline.com/doi/pdf/10.1111/j.1468-0467.2007.00266.x?needAccess=true.

[94] Carlet, "Understanding attitudes toward adoption," 67.

[95] "RISDISM," RIDEM and RICRMC, (2015), www.dem.ri.gov/pubs/regs/regs/water/swmanual15.pdf

> *projects. . . I'm familiar with how to design all those things, but they just don't work. Not on a municipal scale. . . [So,] the stuff that's in the Design Manual, it can stay in the Design Manual.*

On the other hand, some participants shared instances where green infrastructure information was useful. One participant said, *"We're currently working on a potential program with the American Forestry Organization. They're developing a tool that basically shows tree cover parcel-by-parcel. . . That's something that was never really available before. . . I think the opportunities that we have, because this information is available, is way better than it used to be,"* while another shared, *"With the input from RICRMC and STB and these types of organizations, that really helps identify opportunities that honestly, I might not have thought [of] ten years ago,"* and a third noted, *"I rely a lot on RIDEM for what they want to see . . . I'm submitting for my MS4 . . . they're sort of the approving agency. So I look to them for guidance on what needs to happen."*

The lack of a specific IQ to gauge participant's views on information usefulness is a shortcoming of this study. While some examples of usefulness still emerged from participant interviews, these responses were scattered throughout the dialogue and thus not as connected to a central idea. A dedicated IQ on usefulness would have allowed for more insightful comparison across interview responses. Nonetheless, the comments on information's usefulness in this study were mixed. This suggests that available information on green infrastructure, despite generally favorable reports of awareness, accessibility, and attitudes, is not universally useful in working towards the end goal of broader implementation.

(2.0) Information Outputs

Whereas information inputs consider the cognitive barriers related to decision-makers' consumption of green infrastructure information, information outputs consider the barriers related to decision-makers' conveyance and use of that information. In other words, the information outputs node considers decision-makers' abilities to employ green infrastructure information in pursuit of more widespread implementation. To that end, the following sub-nodes explore interviewee's capacities and experiences utilizing and communicating information related to green infrastructure and its various BMPs.

(2.1) Utilization of Information

Whereas this study considers usefulness to be how theoretically utile a piece of information is in working towards an end goal, it considers utilization to be the actual use of that information in practice. While decision-makers reported favorability, good accessibility, and general awareness of green infrastructure information, these concepts do not imply actual utilization. As previous referenced, one decision-maker found the RISDISM to be less useful than intended. However, this individual did report ongoing utilization of and reference to the RISDISM, despite their negative experiences with it. In describing their use of existing green infrastructure information in practice, another interviewee shared that their utilization of information was driven by current needs:

> *If someone mentions green [infrastructure] . . . if there's a chance we could do something green, then we'll start looking around to see what there is. It is a need response. If . . . there appears to be a need, then I'll start the research. . . I do get all my professional journals and magazines . . . but I may just store that away as a knowledge point for future examination. . . I'm not looking for anything at this point.*

Despite a reported range of information sources to use, some decision-makers reported a reliance on intuition and experience as much as, or even more than,

information. One interviewee explained, *"A lot of stuff you learn is in the field itself . . . so I think it's kind of almost on-the-job as well, kind of a learning experience,"* while another shared, *"There's no handbook on how to do all this stuff. It's just experience over time that tells you what to do, when to do, and how to do it, and do it so you don't make mistakes. . . you just kind of have to figure things out [and] surround yourself with good people and tools to help you do the job."* Actual utilization of information seemed to vary across communities, and for varying reasons. While this study does not expressly link a certain level of information utilization to overall green infrastructure implementation, variance in use of information could affect how green infrastructure is pursued in different communities.[96]

(2.2) Communication about Green Infrastructure

An interesting communication dichotomy emerged from the interviews that serves as a cognitive barrier hindering decision-makers' information outputs. In short, several decision-makers reported challenges making the public and/or town leadership aware of green infrastructure's multiple benefits, despite also self-reporting strong awareness of what multiple interviewees called "obvious benefits." Respondents tended to cite these "obvious benefits" at various times throughout the course of the interviews. These included *"the benefits in the environment and the water quality, the benefits of [public education] . . . improved circulation and better safety and maybe easier parking," "[aesthetics] . . . added landscape [features]. . . more[of a] natural feeling," "climate change [benefits]," "resiliency,"* and *"attractive streetscapes . . . air quality . . . [and] recreation."*

[96] Savolainen, "Cognitive barriers to information seeking," JIS, (2015), 620.

However, when I used IQ7 to purposely elicit responses about any clear benefits or drawbacks, multiple participants had difficulties articulating these benefits and/or responded primarily about drawbacks. For example, several unique respondents made the following statements:

> *"Well, I mean, I feel like the benefits are obvious. . . One of the hard parts though, is trying to show this."*
>
> *"Well, the benefits are, I guess, maybe obvious to those of us that are familiar with it. The bigger issue . . . is where it gets a little bit tricky."*
>
> *"Obviously I see the benefits with the green infrastructure. . . the problem that I'm coming up on is cost"*
>
> *"I think we know in the back of our head the benefit . . . But it's something that I haven't really thought about. . . I'm not necessarily saying 'Oh, we're gonna clean up the [river] because of this'. . . it isn't something that happens in the mind. I know it's good, we're doing it, we're moving forward."*
>
> *"I definitely see the good in it. I guess my biggest worry about it is that a lot of the times the systems aren't being maintained the way they should be."*

These responses indicate that, despite having displayed their understanding of green infrastructure's multiple potential benefits, participants faced difficulties communicating benefits when asked to do so. Additionally, this could also indicate that participants' perceptions of drawbacks override their perceptions of benefits, potentially resulting in a net neutral or unfavorable attitude towards green infrastructure.

Despite previous statements about green infrastructure's obvious selling points, several spoke about a difficulty communicating or "selling" these benefits to individuals with political capital, a task that several respondents felt to be incumbent upon them. One respondent exemplified this sentiment: *"It's just getting those other players to the table to understand these things is . . . is really difficult."* Other's comments supported this statement: *"There's not a mindset, I would say, across the board . . . That's a tough*

challenge, and some way we have to make people understand . . . I just don't know how to do that yet," and *"You almost always have to actually sit down with at least certain people and explain . . . what the benefits are . . . I'm not just dealing with residents; I also have to convince other departments. And politically, you know, what some of these benefits are without them necessarily seeing the benefits for themselves.*" These comments highlight further breakdowns as related to officials' abilities to effectively communicate in support of green infrastructure—breakdowns that seem to be impacting support for implementation.

The above quotations demonstrate outward communication of information as a cognitive barrier that decision-makers themselves have suggested is hindering broader green infrastructure understanding and support for implementation. The implications of such complications have been documented in existing literature. Chaffin et al (2016) report, "Until GI's performance and value can be easily be [sic] communicated and measured it will be difficult to find a place for GI within traditional community land use planning,"[97] Qiao et al. (2018) build on this assertion, noting that "[actors' ability] to communicate and measure green infrastructure performance . . . is necessary in order to change actors' attitudes."[98] The communication challenges that interviewees identified in themselves, despite having self-reported clear understandings of green infrastructure information, pose a significant barrier to broader implementation. As decision-makers,

[97] Brian Chaffin et al., "A tale of two rain gardens," *Journal of Environmental Management*, 183 (2016) 438. https://www.sciencedirect.com/science/article/pii/S0301479716303644?casa_token=BNUT8U8vKtEAAAAA:Sv_C2UsWDEVXj-eMbUpqPuxeADJ6GGK-8rYJ6g7j1cIHfVTFlskwIFLTL1_3CND0UqqcJHnD4w.

[98] Qiao, Xiu-Juan, et al., "Challenges to implementing urban sustainable stormwater management," *Journal of Cleaner Production,* 196 (2018): 943-952. https://doi.org/10.1016/j.jclepro.2018.06.049.

this study's interviewees have influential roles in pursuing green infrastructure as a municipal practice, as well as in "selling" green infrastructure to municipal leadership and the public. As Chaffin et al. (2016) and Qiao et al. (2018) note, these challenges communicating green infrastructure information make policy advocacy more difficult and can hinder broader implementation.

One possible explanation for this communication breakdown could be what participants perceived to be the difficulties showcasing visual benefits. Several participants explain that their job of "selling" green infrastructure is made harder when there are not clear visual examples to which they can point. One official explained this challenge, while also sharing an experience where the visibility of benefits was especially useful in garnering public support:

> *"One of the hard parts, though, is trying to show [the benefits]. It's a lot more difficult. . . People see the infrastructure that we're building but there's very little that shows them how it is actually making their life better. . . Half of it's [i.e., green infrastructure] underground so you're never gonna see it . . . I luckily was in a project . . . several years ago, that went from 'Hey, we can't even . . . wade in this river,' to 'Hey, we send our kids down there swimming every day,' which was great. But that's not typical."*

This idea of visualizing benefits can be directly linked to this study's literature review, as case study communities that were able to showcase green infrastructure projects often reported successful implementation experiences. For example, the introduction of porous asphalt along a main right of way in Provincetown, MA was rooted in community engagement.[99] Municipal officials and regional consultants engaged private business and

[99] SNEP Network. "Webinar 1: Incorporating Green Infrastructure," (2020). https://snepnetwork.org/2020/10/08/webinar-1-incorporating-green-infrastructure-for-stormwater-and-other-co-benefits/.

homeowners on an individual level, giving the public a clear example of, as well as a personal stake in, the project's outcome. At its finish, the porous asphalt project (along with supplemental community aesthetic and private façade improvements) was publicly visible and community support was highly favorable.[100] This example serves to underscore the opportunities for successful implementation that projects with a visible component can provide—a strategy that will be further explored in the recommendations section of this study.

Perceptual Barriers

Along with cognitive barriers, the perceptual barriers to green infrastructure implementation function as a key focus of this research study. Whereas this study's exploration of cognitive barriers considered information as its main component, the following exploration of perceptual barriers primarily considers decision-makers experiences with and conceptions about green infrastructure. While existing literature offers mixed definitions, this study considers perceptual barriers as those that negatively precondition how decision-makers feel, understand, and perceive green infrastructure. During participant interviews, multiple IQs were targeted to elicit responses related to these perceptual barriers. To that end, the exploration of those responses, and their organization into nodes (external and internal perceptions) and sub-nodes, follow in the coming sections.

(3.0) External Perceptions

This study follows the guidance set by Savolainen (2015) in considering external perceptions to be those that exist outside of decision-makers. In other words, these

[100] *Ibid.*

barriers are not reflective of the decision-makers themselves, but rather reflective of the external conditions that those decision-makers live within and identify to be inhibiting green infrastructure implementation.[101] For example, several decision-makers identified funding and maintenance to be significant barriers to broader green infrastructure implementation. While interviewees may have their own biases or preconceptions (i.e., internal perceptions) about funding or maintenance, the very fact that they identified them as barriers (i.e., external perceptions) positions them as worthy of study.

(3.1) Funding Perceptions

IQ10 asked participants their greatest overall need as related to stormwater management and green infrastructure implementation, and a general need for funding was the most widely cited necessity overall (***see Figure IV-II***). Interviewees tended to frame funding as an obvious and somewhat universally felt overarching barrier. This framing is well represented by the following participant quotations:

> *"I mean, you know, it's always a question of money."*
> *"Of course money is always a problem. Budgeting, always a problem."*
> *"I hate to sound like a broken record, but [the biggest need] is money."*
> *"You know what I'm gonna say…money, right?"*

Many interviewees expanded on these expressions of need, also adding that money serves as the mechanism by which other needs (i.e., additional staff, project designs and pilots studies, new equipment, acquisition of land for conservation) are procured.

USEPA publicly notes that "the construction, operation and maintenance of [an MS4] can involve significant expense, especially when [NPDES requirements], flooding

[101] Savolainen, "Cognitive barriers to information seeking," JIS, (2015), 613.

concerns, water quality issues . . . and population growth are factored in."[102] In the majority of interviewed communities, stormwater management is funded out of municipal general funds. To that end, federal and state grant funding is often pursued for specific project expenses. In some cases, interviewees found grant funding to be a favorable experience: *"We've been able to leverage a lot of grant funding in the last decade for some really interesting projects that have really had some great benefits."* However, others found grant requirements difficult to navigate. One interviewee shared, "*I think the town is . . . hesitant to go after grants that are strictly water quality related. Just because a lot of the grants now have a lot of requirements associated with them. . . Sometimes it's not even the grant submission. It's the requirements to finalize the grant and get the supporting documents together to get refunded for the grant."* Another explained, *"We had some grants through RIDEM to help with some urban forestry to replant some trees. The problem has been manpower and getting that to be a success. We've actually, due to the timelines, actually lost the grant funding for those."* While grant funding has the

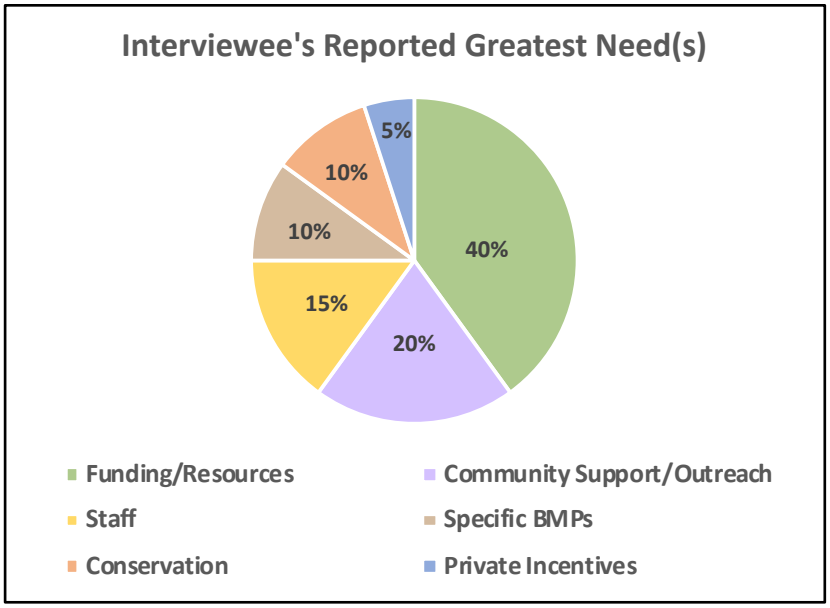

Figure IV-II: Interviewees' Reported Greatest SWM/GI Needs

[102] USEPA, Region III, "Funding Stormwater Programs," *USEPA*. (2008). https://www.epa.gov/sites/production/files/2015-10/documents/region3_factsheet_funding_0.pdf.

potential to mitigate the challenges related to general funding for stormwater management, several interviewees reported obstructive complications in navigating grant requirements.

With municipalities regularly funding a variety of town expenses via the general fund, allocations for stormwater management can easily fall to the wayside.[103] In some instances, interviewees commented on this generally: *"It's a battle right now with budgets and trying to get things funded."* In others, respondents cited school departments[104] as specific competing interests: *"It's tough to get the schools to play ball sometimes. . .even though they get 65-70% of the municipal budget."* Interestingly though, one community found particular success in working with local schools:

> *We did one [project] around an elementary school . . . that turned out fantastic. . . And the students are out there playing with the vegetables and flowers and yet they're in the middle of this bioretention area that's full of native wetland vegetation.*

Funding holds a dominant position in the larger conversation about green infrastructure barriers. Qiao et al. (2018) report, "The funding problem is a crucial influencing factor, and has been ranked highest in list of impediments to implementation of [sustainable stormwater management] on watershed scale."[105] In fact several other studies—Roy et al. (2008), Chaffin et al. (2016), Dhakal and Chevalier (2016), Keeley et al. (2013), and others—also find funding and financial challenges to be amongst the more glaring barriers to green infrastructure implementation. While a deep dive into funding as

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[103] USEPA, Region III, "Funding Stormwater Programs," *USEPA*. (2008). https://www.epa.gov/sites/production/files/2015-10/documents/region3_factsheet_funding_0.pdf.

[104] Stephen Beale, "What RI School Districts Spend," GoLocalProv, https://www.golocalprov.com/news/school-district-spending.

[105] Qiao et al., "Challenges to implementing urban sustainable stormwater management," 948.

a barrier to green infrastructure is not feasible within the scope of this study, this research does recognize the impactful role funding plays in the green infrastructure field. As related to this study, funding serves a frequently identified external barrier that seems to precondition decision-makers' feeling about green infrastructure, which could have implications for its successful implementation.

(3.2) Maintenance Perceptions

Another topic that dominated interview conversations was maintenance. As green infrastructure is typically a shift away from hardened gray infrastructure, maintenance needs and requirements will inevitably change.[106] Some participants noted that different maintenance does not necessarily imply *more* maintenance; one said, *"I don't think it requires more [maintenance], I think that they look like they're still working even if you don't maintain them. And so, I think they're kind of ignored."* However, most tended to frame maintenance of green infrastructure as an additional burden. Another respondent said, *"It's a whole different thought process, because now we're gonna have these [BMPs that] we're periodically gonna have to go and service and clean the silt and everything out of. And we're gonna have to do it more regularly than we did the old-fashioned catch basin. So it's a little more labor intensive."*

Nearly all interview participants classified green infrastructure maintenance as particularly time- and/or labor-intensive. A participant reflected on the accumulating challenges of maintenance: *"[Green infrastructure BMPs] are great, they look fantastic when they're done. All the grass is beautiful, all the rip-rap looks nice. You go back a*

[106] USEPA, "Operations and Maintenance," USEPA, (February 2018). https://www.epa.gov/G3/operation-and-maintenance-considerations-green-infrastructure.

year later and it's all full of leaves and its overgrown and there's tons of sand . . . They need to be cleaned, they need to be maintained. They need to weed-whacked in order to keep them from clogging and whatnot." In some cases, maintenance led to an aversion to certain BMPs. One respondent said, *"Rain gardens, planter boxes? Nah, we don't do too much of those, they're too time consuming,"* while another reported, *"When you include pervious streets and parking areas and sidewalks, it's very difficult for a municipality on the maintenance end because we operate so closely to our budget that any additional work . . . is time consuming."*

Decision-makers also saw the intricacy of green infrastructure maintenance to pose challenges to crew and equipment capacities. One participant noted, *"A lot of designs that come in from private projects are these nice little, cute little, quaint little things that are really difficult to maintain. I'm glad that the municipality doesn't have to maintain private projects because . . . they're just too small."* In many communities, decision-makers reported that they did not have a dedicated maintenance crew to care for and upkeep their town's stormwater and green infrastructure portfolio. In several cases, resulting maintenance has been haphazard, damaging to the integrity of the BMP, and/or forgotten. For example, one respondent shared a frustrating experience:

> *[A BMP] that is maintenance intensive is difficult for public works. Our guys are really good at mowing things. So, we had a rain garden, which was planted with shrubs and perennials and the neighborhood liked, it looked good. [We] spoke to them about cleaning it out because it . . . got some weedy brushy stuff in there and they "took care of it." They just came in there . . . they mowed everything down. The neighborhood was very upset.*

Another participant's reflection seemed to echo this sentiment: *"If I had a crew of 2-3 guys with a truck and that were dedicated . . . a fair portion of their time to going around,*

looking at these facilities, making sure that they're clean, making sure that they're functioning, understanding how they work. That's the key, you don't just send a couple of new guys out there with a shovel and they start digging everything up." This issue is further complicated by equipment challenges. Whereas certain green infrastructure BMPs require *"smaller equipment that isn't gonna destroy what [the town] just built,"* respondents reminded that *"municipal equipment isn't little, tiny lawn mowers. It's big wide equipment that is heavy and it takes up a lot of room because it's industrial equipment."* With already limited capacity, challenges related to proper equipment and staff education and awareness seem to complicate care for green infrastructure BMPs.

Interviewees also reported issues related to maintenance oversight within municipal government. Most communities did not report that they keep standardized BMP records within their city or town. One interviewee explained how this can be problematic: *"You need a committee or a group of people that keeps it going and remembers where everything is. We do great work here, but . . . there are always new projects coming in, new permits coming in, you're busy and . . . things kind of fall by the wayside."* One interviewee cited enforcement of maintenance on private lands as a particular concern and explained how the community is aiming to address this problem: *"We're not doing any follow-up on those [private BMPs]. So it's definitely an area we're trying to improve. We're trying to start a database of at least, where we know they're supposed to be and trying to follow-up on them from time-to-time. But, we're trying to work out the process of how that would be done."* Another municipality has found demonstrable success in keeping a BMP inventory:

> *Participant 1: I actually have a binder by street of all of the BMPs that go in for single family houses and commercial . . . And actually there's a*

> *binder for land development projects that are large. And this is something that [Participant 2] checks on. He literally goes out in the field and checks on them after they've been built for the last couple, the last 10 years.*
> *Participant 2: I do a lot of inspections annually and some more if necessary. But, we try to get out and look at everything at least once a year.*

As with funding, the topic of maintenance barriers permeates literature throughout the green infrastructure field. Chaffin et al. (2018) report, "maintenance issues detract would-be adopters," while Dhakal and Chevalier (2017) find, "Due to the fear of improper maintenance and attitudes to avoid perceived burden, land-owners hesitate to take maintenance responsibility and are encouraged to oppose the installation of GI on their land."[107, 108] While this study does not have the capacity to thoroughly investigate maintenance in particular, it does find maintenance, like funding, to drive internal perceptual barriers. Viewed as especially burdensome, interviewees reported that maintenance exacerbated already challenging capacity, oversight, and resource issues. Based on the existing literature and interview responses, this research finds that these external perceptions likely precondition decision-makers' perceptions of green BMPs, thus impacting their likelihood to pursue broader implementation where appropriate.

(3.3) Other External Perceptions

While funding and maintenance emerged as the two most notable external perceptions, they were certainly not the only two brought forth by participants. Interviewees also cited external hydrogeological constraints as inhibitive of wider green infrastructure implementation. One respondent framed this as a regional challenge, saying, *"Some parts of the country that have better soil conditions than we have [in*

[107] Chaffin et al., "A tale of two rain gardens," 432.

[108] Dhakal and Chevalier, "Managing urban stormwater," 176.

Rhode Island]—better draining soils or lower water table—certainly have an easier time using all green infrastructure." Physical challenges also seemed to emerge in more densely developed communities: *" I think, given the city's low soil permeability and its narrow rights of way and topography, there's limited opportunity for truly effective green stormwater infrastructure in terms of water quantity. . . I think because of the topography and the soil permeability and the intense development patterns and the pre-stormwater infrastructure development."*

Nearly every interviewee shared that town capacity issues were a challenge they regularly navigate. This is especially reflected in the multiple "hats" many participants said that they wear within the town. In some instances, participants had positive or neutral attitudes about their multiple roles: *"I always say we're like the Swiss Army Knife of government because we wear many hats,"* and *"[I wear] two hats right now, which is interesting. Most people in the city end up wearing more than one hat anyways. At the bottom of everyone's job description says 'as duties assigned,' hahaha."* In other instances, these multiple roles were viewed less favorably: *"There's just never a shortage of work. There's a shortage of people, there's a shortage of money. There's just never, ever a shortage of problems to fix. . . I also run the municipal wastewater division. So, as you can imagine, that right there is a full time job in itself and that's just 40% of my time because I just—too many other things to do."* It is important to understand the combination of external perceptions (i.e., funding and maintenance, capacity and hydrogeology, and others), as these are the external barriers that participants identified to be blocking more widespread implementation. While this study does not compare the

participants' perceptions of these issues with the reality of them, it does consider how these external perceived barriers effect internal perceptions.

(4.0) Internal Perceptions

Whereas external perceptions "originate outside of an individual and are thus imposed on [them] . . . internal barriers arise from inside of an individual."[109] In other words, these perceptions are those that are internal to decision-makers themselves. These are the barriers (such as awareness, familiarity, and attitudes) that limit understanding and inhibit broader implementation. While decision-makers were easily able to identify external perceptions that block green infrastructure implementation, they were less apt to identify internal perceptions that hinder their own feelings towards green infrastructure.

(4.1) Awareness of Green Infrastructure

Dhakal and Chevalier (2017) find that "unawareness discourage[s] landowners, water resource managers, and policy-makers to use [green infrastructure]."[110] To this end, awareness was a topic of interest in this study, and one that was integrated into the development of the interview guide. While it was impractical to directly ask participants about their awareness related to green infrastructure, multiple IQs and follow-up questions aimed to elicit responses on awareness of town projects, the feelings of town leadership, and public opinion and support.

Regarding awareness of town projects, nearly all decision-makers were well aware of the green infrastructure practices in place in their community. This was indicated less by individual responses, and more by the collective wealth of responses

[109] Savolainen, "Cognitive barriers to information seeking," 613.

[110] Dhakal and Chevalier, "Managing urban stormwater," 175.

about projects, initiatives, and BMPs in each community. This awareness of town projects serves to bolster this study's robustness, implying that an appropriate population was targeted for this research.

Several decision-makers seemed to have at least some awareness of the feelings of town leadership as related to green infrastructure. These responses are best divided based on the feelings of town leadership. In several instances, interviewees were aware of leadership's favorability towards green infrastructure: *"I think the town is really lucky with the town council we have in place and the town administration we have in place. Because they're very supportive of climate change, mitigation projects, and resilience projects,"* and *"My director here [in the department], [they are] very in favor and support this work,"* as well as *"We have some people that are very 'hot to trot' on [green infrastructure], yes. And have been very supportive."* Perhaps just as frequently, interviewees shared their awareness of leadership's feelings that were unfavorable, unsupportive, or even obstructive of green infrastructure. The following quotations exemplify this:

> *"When you get to the elected officials level, [I'm] not so sure everyone gets it. I mean, I'd say I don't see a strong desire for people to kind of dig down deep in it. And again, it's not the politically sexy thing to do."*
>
> *"The mayor doesn't wanna necessarily rock the boat because [they] want the development to happen. So we don't go around talking about green infrastructure, but we try to make it happen as best we can internally."*
>
> *"The Mayor would never push anything like this."*

In addition to decision-makers' awareness of leaderships' feelings and support of green infrastructure, participant interviews also sought to capture their awareness of public support and understanding. As they were with town leadership, most decision-makers tended to be aware of public opinions. Furthermore, they also reported variance

in opinions across municipalities. In some communities, this public opinion was largely favorable of green infrastructure. One interview said, *"We've had some really great luck with some of these projects. The community loves them. They get some great PR . . . to let people know that this is an issue and that the town is doing something,"* while another shared, *"[The public is] not opposed to it necessarily. I think there's a general appreciation for this type of [stuff]. . . So, I think there's definitely community support for that,"* and a third noted, *"Pretty much any time that there has been community outreach or a chance to discuss what's being done, people seem to love it."*

In most communities though, public support was more complex and not always favorable. One interviewee shared an example that fit within the popular "Not In My Back Yard" theory[111]: *"I think that most of our residents are supportive of the idea of green infrastructure and they can appreciate the idea of treating stormwater, water quality for protection. But when it comes to putting it on their own properties, they're not too crazy about it. There's a little disconnect."* Others noted that public support at times is even plainly unfavorable: *"I would say the biggest problem we have is some of the residents that don't acknowledge that there's a climate change issue. And those are the people that give you the negative input, that seem to go on social media"* and *"You get the public complaining all the time."*

The specific content of leadership's and the public's comments and support is outside of the scope of this study; thus, this research does not consider their representativeness or their accuracy. However, these topics are considered in the context

[111] Derek Bell et al., "Re-visiting the 'social gap,'" (2013). Environmental Politics, 22:1, 115-135, https://journals.sagepub.com/doi/10.1177/0038026116675554.

of decision-makers' awareness of them. In general, decision-makers self-reported good awareness of both the town leadership's and the community's feelings towards green infrastructure. Interviewees' responses on awareness suggest that current methods of community engagement yield at least noteworthy returns, in that decision-makers are informed on some level of public support for green infrastructure initiatives. Similarly, awareness of town leadership's and/or elected officials' support suggests some level of effective communication between municipalities' hierarchal governance structures. These at least preliminary levels of awareness are indicative of existing networks of communication within the surveyed municipalities—networks that have the potential to be leveraged for more effective communication towards broader implementation.[112]

(4.2) Familiarity with Green Infrastructure

IQ1 prompted participants to indicate their familiarity with green infrastructure by self-identification using the previously mentioned checklist of BMPs. While no clear definition of familiarity was provided, participants were generally instructed to report familiarity on any practices they were acquainted with, regardless of the BMP's presence in their current municipality. Of the seventeen BMPs included on the checklist, interviewees collectively reported more familiarity than not with all seventeen (***see Figure IV-III***). Neighborhood green spaces, bioswales/vegetated swales, bioretention basins, porous/permeable pavement, and land conservation were all BMPs with unanimous reports of familiarity. Meanwhile, green streets, green walls, and urban agriculture were reported as BMPs with the greatest percentage of unfamiliarity.

[112] Dhakal and Chevalier, "Managing urban stormwater," 178.

In application to the larger context of implementation, familiarity has been found to support wider adoption of green infrastructure. Olorunkiya et al. (2012) find, "Newness of or unfamiliarity with any innovation increases the magnitude of risks and uncertainty concerns, which in turn, reduces the rate of adoption and implementation . . . [When] familiarity is enhanced, perception of risk is reduced and ultimate [low-impact development ("LID")] technology adoption decision increases among stakeholders."[113] To this end this study finds that respondents' self-reported familiarity with green infrastructure BMPs does not serve as a barrier to implementation. Moreover, this familiarity could serve as a factor towards and has the potential to be leveraged in support of broader implementation.

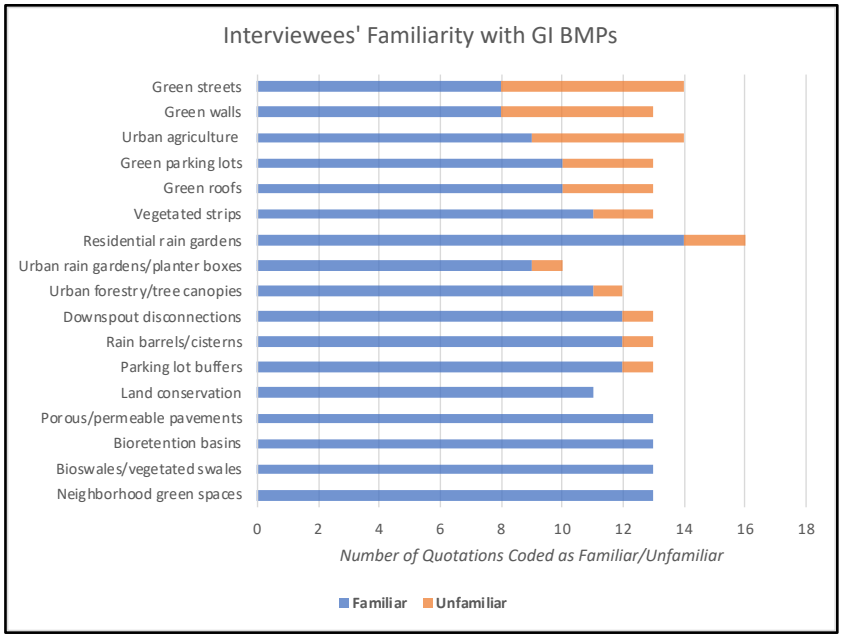

Figure IV-III: Interviewees' Familiarity with Green Infrastructure by BMP

(4.3) Understanding of Green Infrastructure

Participant interviews showed some variance in what respondents understood to be and would classify as a green infrastructure BMP. In some cases, this variance tended to mostly be attributed to acceptance—i.e., the likelihood of a respondent to see a particular BMP as green infrastructure given its appropriateness for the certain

[113] Olorunkiya et al.. "Risk: A fundamental barrier," 29.

community. For example, when asked if any of the BMPs on the green infrastructure checklist did not belong, some respondents from rural communities questioned whether BMPs that they perceived to be more appropriate for urban communities would be considered green infrastructure. [114] In a particular instance, though, one respondent demonstrated an unclear understanding of green infrastructure, asking, *"Well, by green infrastructure, what do you mean?"* When asked later in the conversation about differences in framing related to green infrastructure, this respondent followed up on this:

> *"When you said green infrastructure a number of times, I didn't realize that you were really talking about stormwater. . . And when I think of stormwater management, I think more along the lines of water quality. . . I can be wrong. I can understand maybe why my misunderstanding is wrong. But . . .when I think of green infrastructure, that's what I think of. . . There is kind of a blur there."*

Clean Water America Alliance (2011) finds that "lack of understanding and knowledge of what green infrastructure is" can be a significant and common barrier to wider implementation.[115] This participant did self-characterize their understanding as somewhat confused and unclear, posing a potential barrier to implementation. However, there is, of course, nothing to say this participant's understanding of green infrastructure is incorrect. Furthermore, this respondent's muddied understanding is not indicative of the larger

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[114] One potential explanation for the increased levels of unfamiliarity with certain BMPs seemed to be that some respondents from more rural communities perceived certain practices as more appropriate for urban communities. For example, when asked if any of the practices included on the BMP checklist did not belong, one interviewee said, *"I mean, green roofs and green streets and some of the urban type stuff, it's just not going to happen."* Similarly, when asked about their familiarity with urban forestry/tree canopies as a BMP, another respondent said, *"We're a pretty suburban community and rural, so no."*

[115] Clean Water America Alliance. "Barriers and Gateways to Green Infrastructure." Clean Water America Alliance, (September 2011). http://uswateralliance.org/sites/uswateralliance.org/files/publications/Barriers-and-Gateways-to-Green-Infrastructure.pdf.

sample. Rather, this this instance simply serves as an example of how misunderstandings about green infrastructure could hinder implementation.

(4.4) Attitudes towards Green Infrastructure

This study measured attitudes with a number of different IQs. Generally speaking, these attitudes can be characterized by ambivalence. Most interviewees had positive attitudes towards green infrastructure in a theoretical sense, but had experiences that tilted these attitudes towards ambivalence. For example, one interviewee explained, *". . . Of course we're in support of [pervious pavement]. Uh, you know, we're in support of any [green infrastructure] ideas. It's just not every idea is going to be suitable."* Another participant expressed similar feelings: *"I think the whole [green infrastructure] concept is great. I think we need to figure out how it becomes, uhm, a day-to-day operation of local government other than something special."* After speaking about specific projects, a third participant explained, *"Those are good milestones, those are good projects, those are always ones that you look forward to doing. You know, but once you do the project, the life of the project doesn't end there."* Conceptually, most interviewees held favorable views of green infrastructure. However, these attitudes mostly tended to be influenced by on-the-ground experiences, leading to less favorable attitudes.

Some interviewees' attitudes seemed to precondition them towards aversion, specifically as related to costs. As interviewees explained their experiences with funding as an inhibiting factor, several also expressed a personal aversion to projects that might accrue unexpected expenses. One respondent explained, *"It's hard to do something for less than a million bucks with water infrastructure, and [it] easily becomes tens of millions. And it's not that hard for it to become hundreds of millions."* Some respondents

conveyed their reluctance to unexpected costs even more specifically. One shared, *"Certain projects might be put off because of certain testing that's required. . . The information can be a double-edged sword. . . A lot of locations that seem like they would be good candidates, you do some environmental testing and all of a sudden it's a. . . $2,000,000 project because no one knew that there were certain chemicals or something in the soils."*

Additionally, reluctance to take on perceived cost-inefficiencies emerged in comparing green infrastructure to gray. One participant said, *"If all you're doing is laying down asphalt, it's pretty easy to . . . just lay it down with the milling machine. And when we start adding in more [green] systems, then it greatly increases the complexity and the cost and the project coordination requirements."* More specifically, another interviewee compared the cost efficiency of particular technologies, noting, *"The problem that I'm coming up on is cost. I can put a catch basin in for $1,250. If I gotta put in a storm septic unit, that's $12,000. So it reduces the amount of the tax dollars that we have available to move forward."* A third participant linked cost-efficiency to difficulties garnering public support: *"When we get money to fix something, people look at it and say 'I could fix two if I do it the normal way, but if I do green infrastructure I can only do, like two-thirds of one.' So people are very hesitant about the cost, what they view as the added cost.*"

The previous discussion of cost-inefficiencies bodes the question: when directly compared, do decision-makers perceive the costs of green infrastructure to be higher than the costs of gray? Whereas there was not a specific IQ to elicit responses on this topic, participants' responses on this issue were mixed and not structured around a central IQ. Nevertheless, some respondents did have explicit thoughts related to cost-efficiency

comparisons. One participant said, *"It's probably more expensive to maintain [green] properly, but less expensive than if you had some kind of stormwater damage that costs you more money in damages than if it was collected and treated properly."* Another participant shared, *"In the long-run, the costs [of green] are not any greater [than gray] and, if anything, it's better."* Without a preset question of provoke responses on cost-efficiency comparisons, it is difficult to conclude that these responses are representative of the larger sample. However, the collection of responses, albeit it limited, seems to indicate ambivalent feelings about cost comparisons, with disparities tending to focus on maintenance, rather than capital costs. Based on the findings of Carlet (2015), officials' ambivalent attitudes about cost-perceptions, as well their general ambivalent attitudes towards green infrastructure, could serve as a "barrier inhibiting the transition to [green infrastructure as a] sustainable stormwater management system."

(4.5) Framing of Green Infrastructure

The nexus between maintenance and funding also proved to be relevant on the topic of framing. In many interviews, participants expressed views that focused on the maintenance costs of green infrastructure, as opposed to the capital costs. Moreover, these maintenance costs were often framed as an additional expense—one that would otherwise might not exist if traditional gray alternatives were in place. Respondents shared the following comments:

> *"The pervious pavements, as we expressed, are not doing us any favors because . . . they're added costs and so maintenance heavy."*
>
> *"And once [a BMP] is done, then we have to spend time maintaining it. I think my experience has been that a lot of stuff that takes maintenance . . . People like to spend money and see something fantastic, they don't think about 'Oh, we've got to fix it, clean it, remove the sand.'. . . And we're going to have to do it more regularly than we did the old-fashioned catch basin."*

> *"Difficult is always going to be funding. GI sounds great, there's an expense to it. The design, the construction, and then there's got to be money put aside for maintenance of it. And where does that money come from?"*
>
> *"You always want to . . . make [BMPs] easy to maintain, because you have to go back later, you gotta clean these things out."*

Perhaps the most interesting framing topic to emerge from this study, though, was a dichotomy between contrasting approaches to green infrastructure. This dichotomy can be structured as product vs. process (***see Fig. IV-IV***). In many instances, green infrastructure is viewed as a product—a project for stormwater management with clear departmental and functional boundaries. In some instances though, green infrastructure is framed as a process, or an overarching approach that blurs the boundaries of BMPs and integrates green infrastructure across departments, and for multiple interconnected uses. Generally, the product-oriented approach functions reactively, choosing green BMPs when funding permits or when specific needs allow. Conversely, the process-oriented

PRODUCT FRAMING	PROCESS FRAMING
• Project-oriented approach/focus	• Policy-oriented approach/focus
• Clear departmental boundaries	• Interdepartmental collaboration
• Intended for specific function	• Intended for multiple functions
• Emphasis on one/few benefit(s)	• Leverages several co-benefits
• GI as exception to gray	• Gray as exception to GI
• Reactively seeks funding sources and opportunities within specific need(s)	• Proactively identifies funding sources and opportunities within overall needs

Figure IV-IV: Product vs. Process Framing

approach is proactive by nature—green infrastructure is pursued by default, and technical details are configured as a secondary step.

Several communities in participant interviews seemed to exemplify the product-oriented approach. One respondent said, *"It depends on what's out there. If we receive a grant for construction, we'll do that. . . So it's whatever whatever's out there, we just keep applying."* Another interviewee expressly noted that their community's approach was project-focused:

> *I don't think that it's a policy. It's not something that . . . like this project on [X] St. This was me working with the DPW Director. But, you know, he was never asked to do anything like this. The mayor would never push anything like this. When planning gets involved with this sort of project, it's mostly because of the funding. "Oh hey! There's $500,000 available, what can we do?" It's not necessarily . . . if funds weren't available, I don't think that other departments would be pushing for it. It's just a "Hey, this is money that we can get for [the municipality], we have to build this to get it, let's do it.". . . We don't sit there and say "Hey, we're doing sidewalks on this street, let's make everything green stormwater." But we look in certain situations for "these are the large areas we can do something with."*

Examples of reactive approaches can also be connected to the lack of effective regulatory drivers in Rhode Island. As aforementioned (***see Sec. II. Background***), several communities in the state have taken reactive approaches to green infrastructure, relying on federally mandated consent decrees as perverse incentives to direct policy action. Additionally, inadequately enforceable state policies fail to motivate communities to address green infrastructure above and beyond minimal requirements. This reactiveness was reflected in participant interviews, as several respondents spoke about regulatory drivers. For example, one interviewee shared, *"The first few years on [the Phase II NPDES permits]—very active. Every municipality was, because there was a lot of things that you had to accomplish. After that, it just became an annual permit . . . we meet the*

minimum standards that are on there, but typically don't exceed them," while another said, *"We're gonna do our best to control runoff and we're gonna look at—by mandate, by ordinance, we're required to do this green infrastructure,*" and a third noted, *"We don't have good regulations around pushing green infrastructure instead of gray infrastructure. And so it's been a challenge on some of our projects is we can't deny a project because it's got [gray] instead of [green].*" These quotations suggest that the current regulatory conditions in Rhode Island foster a reactive, or product-oriented, approach that fails to adequately incentivize green infrastructure beyond minimal requirements or secure the multiple benefits green infrastructure has the capacity to provide.

Meanwhile, some communities did report that they were operating within a process-oriented framework. One interviewee expressed their favorability of this approach: *"I think it's good to always . . . be aware and be thoughtful of how green infrastructure can come into play in a project and then see if that makes sense."* Another called for a conceptual shift towards process-oriented: *"I think we need to figure out how [green infrastructure] becomes a day-to-day operation of local government, other than something special. We've gotta change the mindset. So . . . when we talk about green infrastructure, it's like 'Well, of course we're doing green infrastructure because we have a whole maintenance system set up to take care of it.'"*

Davis (1995) asserts, "Framing can significantly influence how a problem is perceived and how alternative decisions are evaluated."[116] While existing literature on

[116] Joel Davis, "The Effects of Message Framing," Journalism & Mass Communication Quarterly 72, 2 (1995): 286. https://doi.org/10.1177/107769909507200203.

product vs. process framing in the green infrastructure field is still very limited, this conceptualization is emerging.[117] Within the green infrastructure field, some science and technology studies ("STS") scholars, such as Phillips de Lucas (2020) and Finewood et al. (2019), have critiqued the dominant product-oriented approach as one that underleverages and renders moot green infrastructures many co-benefits. Finewood et al. (2019) note the following:

> Green infrastructure . . . can provide diverse cobenefits (e.g., improved mental health, reduced urban heat island) . . . Despite the multifunctionality of green infrastructure, the key goal of its implementation in many cities in the United States has been to capture or slow down stormwater before it enters municipal sewer systems . . . This particular utilization reflects a discursive reforming of broadly conceived green infrastructure into a more narrowly defined green *stormwater* infrastructure (GSI) that, in practice, is mainly designed to control runoff, fitting it into existing infrastructure politics and practice while effectively deemphasizing other cobenefits."

In this study, multiple respondents that spoke about successful and/or favorable experiences with green infrastructure tended to highlight components of these experiences that aligned with the process-oriented approach. For instance, one respondent shared two examples from their community:

> *"It's been a successful approach because of collaboration. For example for the town beach [project] . . . we were able to kind of get the [Parks and Recreation] folks on board with "Hey guys, you're gonna get this beautiful new parking lot with lots of landscapes and flowers and trees and the place is gonna much more beautiful than it already is. And we're gonna get the water cleaned and it's gonna be a public education component. And the beach won't be closed as often hopefully.*

[117] Beyond the green infrastructure topic, this product vs. process framing has also been applied to other fields, ranging from genetically modified organisms ("GMOs") to English language writing. Parry and Jose (2018) conclude that a product-oriented lens places more of a "focus on what can be achieved" with a specific organism, rather than the collective "[processes] used to develop [GMOs]" in general. In the writing field, Donald Murray (2011) argues, "We teach writing as a product, focusing our critical attentions on what our students have done . . . Instead of teaching finished writing, we should teach unfinished writing, and glory in its unfinishedness. . . It is an exciting, eventful, evolving process."

> *"And then . . . we had to really get the school department on board. And the way I kind of initially sold it to them was, "Hey you're gonna get an entirely new the whole outside of your property . . . You're gonna get all new parking and driveways and beautiful landscaping." We even installed some new sidewalks for safety. But while you're digging it up it doesn't cost much to do a little bit of extra . . . safety and aesthetics."*

The collaborative, proactive, and multi-beneficial components in this example exemplify the process-oriented approach. In addition to the interviewed communities, the communities in the literature review phase that also reported especially successful/favorable experiences with green infrastructure tended to frame green infrastructure as a process. Perhaps the clearest example of this is in Lancaster City, PA, where green infrastructure has become foundational to the community. Former Lancaster City Mayor Richard Gray talks about the City's approach to green infrastructure, sharing, "Every major public works project, we would look at it and say 'How can green infrastructure fit into this?' . . . If you think that way, you don't think of green infrastructure [as] 'Let's do a green infrastructure program.' . . . Rather than think in a silo, think broader and think 'How can I incorporate green infrastructure here?'" This process-focused framing tends to be characteristic of projects that have had especially successful and favorable experiences with green infrastructure. To this end, framing also emerged as a potential strategy for broader implementation.

V. CONCLUSION AND RECOMMENDATIONS

Overview of Findings

This study sought to answer four research questions related to the cognitive and perceptual barriers inhibiting local green infrastructure decision-making and implementation in Rhode Island. RQ1 asked "***How do local decision-makers in Rhode Island perceive different technologies (i.e. gray, green, or hybrid) for stormwater management?***" This study finds that local decision-makers in Rhode Island generally perceive green infrastructure to be more burdensome than gray infrastructure, especially as related to funding and maintenance. In the context of this study, maintenance and funding emerged as primary external perceptions that tended to precondition and influence other internal perceptual barriers, such as a reluctance to take on perceived additional costs and an ambivalence towards green infrastructure as an alternative to gray. In other words, participants' external views on and experiences with maintenance and funding tended to affect their perceptions and attitudes towards green infrastructure (as indicated by RQ3).

RQ2 asked "***What are some of the cognitive barriers to greater green infrastructure implementation at the local level in Rhode Island?***" This research explored several cognitive barriers related to both information inputs and outputs. The study finds that awareness and accessibility of information related to specific needs, usefulness and utilization of information, and difficulties communicating benefits served as noteworthy cognitive barriers. Conversely, information attitudes and ISA/WQ Designation did not emerge as barriers related to implementation. Despite largely favorable reports of awareness and accessibility of general information, specific

information needs—such as design (as mentioned by one suburban community), as well as monitoring, cost estimates, and public outreach (as mentioned by two urban communities)—persisted amongst interviewees. Despite these outstanding needs, participants had generally favorable attitudes towards the field of green infrastructure information, as exemplified by one response: *"[There's] a lot of good information out there . . . it's pretty tremendous."* However, existing literature shows that attitudes towards information are not particularly meaningful proxies for implementation.[118] Moreover, participants did not find information to be unanimously useful, as many tended to place more emphasis on experiential knowledge and intuition.

Perhaps the most interesting cognitive barrier to emerge from this study, though, was the dichotomous relationship between strong self-reported understandings of green infrastructure information and difficulties communicating the practice's benefits. During interviews, decision-makers spoke to several of green infrastructure's co-benefits, such as *"[environmental]. . . water quality, [public education] . . . circulation . . . safety [and] parking."* However, they also reported difficulty conveying these advantages to municipal leaders and the public. One possible explanation for this communication breakdown is respondents' perception that green infrastructure benefits can, quite literally, be difficult to see. One official commented, *"I think [the taxpayers] tend to be visual learners, and [green infrastructure] is not something that you could easily visually put out there for them."* Respondents found that communications challenges made their jobs "selling" green infrastructure as a stormwater management alternative more difficult.

[118] Barr and Gilg, "A conceptual framework for understanding and analyzing attitudes," 361-379.

Perceptual barriers were examined through RQ3, which asked "***What are some of the perceptual barriers to greater green infrastructure implementation at the local level in Rhode Island?***" While this study considered awareness of town projects and town leadership and community support, familiarity with green BMPs, and general understanding of green infrastructure, these did not reveal themselves to be barriers. Additionally, ISA/WQ Designation did not emerge as a determining factor related to perceptual obstacles. Rather, this study found ambivalent attitudes towards green infrastructure, an aversion to undertake perceived additional costs, and various framings (i.e., maintenance as additional cost, product vs. process) to be key perceptual barriers to broader green infrastructure implementation. Abstractly, most participants had favorable opinions of green infrastructure—one shared, *"[green infrastructure] looks good on paper."* However, participants' theoretical favorability tended to give way to experiences that tilted their attitudes towards ambivalence. For example, one respondent commented, *"I think we're embracing [green infrastructure], but we're also weary of . . . some of the heavy lift that it can present."* This experiential ambivalence tended to make participants averse to undertake what they perceived to be the additional costs and inefficiencies of green infrastructure, especially as related to maintenance.

To that end, funding and maintenance, along with other challenges (e.g., town capacity and hydrogeology) emerged as especially impactful external barriers that condition officials' internal perceptions about green infrastructure. These findings align with existing research from Chaffin et al (2016) and Dhakal and Chevalier (2017), all of whom find that external barriers—most prominently funding and maintenance—decrease

overall likelihood to support broader implementation.[119] Finally, this study aimed to produce forward-looking guidance by asking RQ4: "***What are some strategies that could lead to greater green infrastructure implementation at the local level in Rhode Island?***" The findings related to RQ4 are presented throughout the following recommendation section.

Recommendations for Further Study

While this study considered a wide range of subtopics within the larger green infrastructure discussion, there were inevitable areas that remained outside of the purview of this research. Perhaps most fundamentally, this research was limited to municipal stormwater decision-makers in Rhode Island. While municipal governments play an undeniable role in stormwater management, stormwater governance also includes state, regional, and federal bodies. Meanwhile, non-profit and private institutions are also key actors. Therefore, this study recommends further research into the topics presented here, but at other levels of government and across other sectors. Similarly, an exploration of the several other stakeholders (i.e., elected officials, the public, non-governmental actors, etc.) could prove especially useful.

While some topics were intentionally excluded from this study for the sake of manageability, there were also topics that unexpectedly emerged from this research that warrant further examination. One such topic is the relationship between municipal decision-makers and the development community. Several interviewees commented on their interactions with the development community. These interactions ranged in

[119] Chaffin et al., "A tale of two rain gardens," 432.

[119] Dhakal and Chevalier, "Managing urban stormwater," 176.

favorability, from favorable/neutral to unfavorable. Whereas one respondent shared, *"We don't design [private] developments . . . it's up to [engineering] companies to come in with those designs already done. If, how much GI they want to do, what are they gonna do with their stormwater. . . We hope they bring in newer thoughts of what they can do with that. And if they do, that's great,"* another noted, *"Maybe a battle is the wrong word. But it becomes a little more contentious with an applicant who's got an existing developed site. . . It's a little bit of an educational process to get them to understand the importance of retrofitting their drainage system."* As most of the surveyed decision-makers reported that they are involved (pursuant to the NPDES MS4 MCMs) with oversight of private compliance, along with oversight of municipal BMPs, further studies that consider the relationships with the development community would greatly advance this topic.

Another topic of interest that emerged late in this study and that warrants additional interest is the idea of communicating green infrastructure's multiple benefits (as identified by interviewees to include aesthetics, recreation, transportation, resiliency, etc.). Despite mostly strong understandings of these benefits, several interviewees reported challenges in conveying them to various audiences. To this end, this study recommends further research on particularly effective methods of conveying green infrastructure information to non-scientific audiences, specifically as done by municipal officials. Whereas the municipal leaders interviewed in this study are, at least partly, responsible for the NPDES MS4 MCM related to public education, providing them with

the tools necessary to more effectively communicate with the public has the potential to lead to broader and more efficient implementation.[120]

Recommended Best Practices and Strategies for Implementation

Beyond further academic research, there also exist several practical steps that can be taken to foster more efficient and effective implementation in Rhode Island. This study recommends leveraging the strong informational networks maintained by existing regional and statewide organizations. (e.g. etc.). Whereas respondents reported well-rounded general understandings of and familiarity with green infrastructure, information providers should target future workshops and trainings sessions to connect with officials on specific informational needs. In other words, information providers should diversify their offerings to better address and service different proficiency levels and needs. For example, providers might offer regularly occurring workgroups between communities to share lessons learned about monitoring best practices, train officials on effective communication of green infrastructure topics to various audiences, or offer feedback on design proposals. With such strong and favorable information providers on green infrastructure and stormwater management topics in the region, it is crucial to leverage existing connections to make information sources more efficient and effective.

This study also recommends using pilot projects to provide local decision-makers, as well as the communities in which they operate, with positive experiences related to green infrastructure. Pilot projects offer opportunities to strengthen understanding and work through difficult funding, maintenance, and other challenges commonly associated

[120] SNEP Network. "Webinar 1: Incorporating Green Infrastructure," (2020). https://snepnetwork.org/2020/10/08/webinar-1-incorporating-green-infrastructure-for-stormwater-and-other-co-benefits/.

with green infrastructure.[121, 122] Pilots can initiate a gradual shift towards more community-wide green infrastructure integration, also providing maintenance crews with time to become acquainted with and trained in green infrastructure maintenance through a "earn-by-doing" approach.[123] This study recommends pilot projects as a multi-beneficial way to directly address and counteract several of the cognitive and perceptual barriers identified here.

The concept of framing green infrastructure as a product versus as a process was prominent in interviews. In the former framing, green infrastructure is typically conceptualized as stand-alone projects that are reactively intended to address specific environmental stressors (i.e., a single bioretention basin to address localized flooding). In the latter framing, green infrastructure is conceptualized as a community process that integrates various departments and leverages multiple co-benefits (i.e., a citywide and interdepartmental green infrastructure program). A product-oriented framing of green infrastructure limits its benefits to just those that are primary to a specific project and fails to leverage opportunities for multiple other benefits.[124] Several communities that have found particular success with green infrastructure practices have done so by

[121] *Ibid.*

[122] URI Coastal Resources Center. "Coastal Green and Resilient Infrastructure Project (GRIP)." *URI*. Accessed on April 20, 2021. https://www.crc.uri.edu/projects_page/gi-coastal-ri/.

[123] *Ibid.*

[124] Phillips de Lucas, Amanda. "Gifting a White Elephant, In the Form of Green Infrastructure." The Nature of Cities, (August 18, 2020). https://www.thenatureofcities.com/2020/08/18/gifting-a-white-elephant-in-the-form-of-green-infrastructure/.

leveraging their multiple benefits and by making green infrastructure "a part of [their] DNA."[125, 126]

This study embraces the findings of Finewood et al. (2019) and Phillips de Lucas (2020) and recommends that, collectively, practitioners in the green infrastructure field should seize the "opportunity to reframe the conversation [around green infrastructure]" as one that emphasizes process and comprehensiveness.[127] This can be done by internally and externally rethinking how we frame green infrastructure. Rather than pursuing green infrastructure only where necessary, required, or conventional, officials should leverage the range of potential benefits and tie the stormwater management capacities of green infrastructure to other issue areas, such as transportation, recreation, public health, beautification, and walkability.[128] In other words, rather than framing green infrastructure as a primarily stormwater management practice with several secondary "co-benefits," we should consider it a community infrastructure practices with multiple benefits—amongst them stormwater—that can be tailored to fit a diverse range of needs.[129] This flexible, process-oriented approach is more than a theoretical re-framing. Rather, it is a practical model that has proven effective in communities across the United States, including in

[125] Gray, "S1 | E1: Green Infrastructure," Presented by the SNEP Network, *The Leadership Exchange Podcast* (podcast). September 22, 2020, https://anchor.fm/snep-leadership-exchange/episodes/S1--E1-Green-Infrastructure-ft--Lancaster-City-and-Provincetown-ejr6f2.

[126] SNEP Network. "Webinar 1: Incorporating Green Infrastructure for Stormwater and Other Co-Benefits." SNEP Network. (October 8, 2020). https://snepnetwork.org/2020/10/08/webinar-1-incorporating-green-infrastructure-for-stormwater-and-other-co-benefits/.

[127] Finewood, Michael, Marissa Matsler, and Joshua Zivkovich. "Green Infrastructure and the Hidden Politics of Urban Stormwater Governance in a Postindustrial City." Annals of the Americans Association of Geographers, (2019), 109:3, 909-925.

[128] Gray, "S1 | E1: Green Infrastructure," Presented by the SNEP Network, *The Leadership Exchange Podcast* (podcast). September 22, 2020, https://anchor.fm/snep-leadership-exchange/episodes/S1--E1-Green-Infrastructure-ft--Lancaster-City-and-Provincetown-ejr6f2.

[129] Phillips de Lucas, personal communication, 2020.

communities (i.e., Provincetown, MA; Lancaster City, PA; and Bristol, RI) from this study's literature review and participant interviews. For example, former Lancaster Mayor Gray explained the City's approach:

> "We made a general rule that any project done by Public Works would be reviewed for green infrastructure. And it didn't mean you'd spend a fortune on it. . . For example, if you're gonna do new sidewalks, do infiltration in the sidewalks. If you're gonna do a new park, make sure there's green infrastructure in the park and make sure that people relate the park to green infrastructure. . . It was a question of 'How do you improve the infrastructure and, as you improve the infrastructure, how do you include green infrastructure, no matter how large or how small, in those improvements?'"[130]

This study recommends that Rhode Island municipalities (re)structure their approach to green infrastructure in a way that fosters interdepartmental collaboration, proactivity, and emphasis of multiple benefits, so as to leverage the operational efficiencies that have characterized successful implementation in communities like Lancaster City and others.

Conclusion

As communities across Rhode Island continue to manage their stormwater runoff within the guidelines and requirements established by USEPA, green infrastructure will continue to serve as a sustainable alternative to traditional piped infrastructure networks. The cross-cutting cognitive and perceptual barriers identified by this study complicate green infrastructure implementation at the municipal level in Rhode Island. These barriers precondition decision-makers' feelings towards green infrastructure, limit their awareness and accessibility of information related to specific needs, and influence how they frame and communicate green infrastructure. Future research should build on this

[130] SNEP Network. "Webinar 1: Incorporating Green Infrastructure for Stormwater and Other Co-Benefits." SNEP Network. (October 8, 2020). https://snepnetwork.org/2020/10/08/webinar-1-incorporating-green-infrastructure-for-stormwater-and-other-co-benefits/.

study's findings in order continue investigating these cognitive and perceptual barriers within the different facets of the green infrastructure realm. With favorable levels of awareness, understanding, familiarity, as well as strong networks of communication, this study's serves as a starting point to foster broader and more efficient green infrastructure implementation in Rhode Island.

VI. **APPENDIX A:** Participant Interview Guide

The formatting for the Interview Guide questions is sampled in red below:

1. **< QUESTION>** [RQ#(s) that question is primarily intended to address] *(other notes)*
    - <Possible follow-up questions>
    - <Possible prompts for further explanation and/or clarification if needed>

1. **Which types of green infrastructure are you familiar with?** [RQ2, RQ3] *(screen share Appendix B: Green Infrastructure Checklist)*
2. **Does your town currently incorporate green infrastructure into its SWM plans?** [RQ1]
    - *What is the green infrastructure implementation process like?*
3. **How would you characterize your town's current use of green infrastructure/SWM approach?** [RQ1]
    - *Do other decision-makers understand green infrastructure? How? If not, why?*
4. **Does your town approach green infrastructure/SWM interdepartmentally? If so, what does that process look like?**
5. **What have your experiences with green infrastructure been like?** [RQ1, RQ3]
    - *Does your town have completed green infrastructure projects? Do they work? What types of BMPs have been installed?*
    - *How does your town regulate surface water in new developments?*

6. **How much information do you seek out on green infrastructure, and from where?** [RQ2]
    - *How easily navigable is the information you've encountered on GI?*
    - *What information do you wish you had? Do you think that information exists, and if so who has it?*
7. **What are your views on/opinions about green infrastructure for SWM?** [RQ1, RQ3]
    - *Benefits/disadvantages?*
    - *In comparison to gray? As a hybrid?*
    - *What aspects of GI are particularly easy/difficult? (maintenance, financing, installation, outreach, etc.)*
8. **Do you think others feel the same about green infrastructure as you do?** [RQ1, RQ3]
    - *Peers, colleagues, public, elected officials?*
9. **Thinking about previous green infrastructure projects that the town has been involved in, what were some factors for or barriers to success?** [RQ2, RQ3, RQ4]
    - *What could have been done differently to make less successful projects easier/more likely to accomplish?*
10. **What would be most helpful to you to achieve wider green infrastructure implementation in the future?** [RQ4]
    - **If they do not support wider GI implementation, ask: what would make for <u>better</u> GI implementation?*

- *What are the barriers to GI implementation in the future?*
- *How would you like GI to look in your town in 10-20 years?*

11. Do you see any difference between "green infrastructure, or GI" and "green stormwater infrastructure, or GSI"?

12. Additional comments? [Concl.]

13. Who else do you recommend I should talk to? [Concl.]

	RQ1: How do local decision-makers in Rhode Island perceive different technologies (i.e. gray, green, or hybrid) for stormwater management?	**RQ2:** What are some of the cognitive barriers to greater green infrastructure implementation at the local level in Rhode Island?	**RQ3:** What are some of the perceptual barriers to greater green infrastructure implementation at the local level in Rhode Island?	**RQ4:** What are some strategies that could lead to greater green infrastructure implementation at the local level in Rhode Island?
IQ1: Which types of green infrastructure are you familiar with?		x	x	
IQ2: Does your town currently incorporate green infrastructure into its SWM plans?	x			
IQ3: How would you characterize your town's current use of green infrastructure/SWM approach?	x			
IQ4: Does your town approach green infrastructure/SWM interdepartmentally? If so, what does that process look like?	x		x	x
IQ5: What have your experiences with green infrastructure been like?	x		x	
IQ6: How much information do you seek out on green infrastructure, and from where?		x		
IQ7: What are your views on/opinions about green infrastructure for SWM?	x		x	
IQ8: Do you think others feel the same about green infrastructure as you do?	x		x	
IQ9: Thinking about previous green infrastructure projects that the town has been involved in, what were some factors for or barriers to success?		x	x	x
IQ10: What would be most helpful to you to achieve wider green infrastructure implementation in the future?				x
IQ11: Do you see any difference between "green infrastructure" and "green stormwater infrastructure"?	x	x	x	

VII. APPENDIX B: Green Infrastructure Checklist

Green Stormwater Infrastructure (GSI) BMPs Interviewee Checklist *(3-5min)*

Instructions: Please identify the following GSI best management practices (BMPs) with which you are familiar. In the event that there are other BMPs with which you are familiar, but are not listed, please include those BMPs in "other".

Residential rain gardens

Neighborhood green spaces

Parking lot buffers

Bioswales/vegetated swales

Bioretention basins

Green roofs

Green walls

Vegetated strips

Porous/permeable pavements

Urban forestry/tree canopies

Rain barrels/cisterns

Downspout disconnections

Urban rain gardens/planter boxes

Green streets

Green parking lots

Land conservation *(wetlands, riparian areas, etc.)*

Urban agriculture

Anything missing from this list?:

_____

Anything that shouldn't be on this list?:

_____

VIII. APPENDIX C: Thematic Coding Codebook

GROUP/ THEME	SUBGROUP/ SUBTHEME	CODE	DESCRIPTIONS
Info Inputs		Information Un/awareness	Reported awareness or lack thereof related to GI information sources and content
		Information In/accessibility	Reported difficulty/ease accessing GI information sources/content
		Information Attitudes	Attitudes related to experiences with GI information
		Information Un/usefulness	Reported usefulness or lack thereof related to GI information sources and content
		Information Utilization	Reported utilization or lack thereof related to GI information sources and content
Info Outputs		Intuition/experience vs. information	Weighing one's own intuition/experiences as more important/utile than GI information sources
		Difficulty communicating benefits/information	Challenges articulating GI benefits/information to others
		Need to "sell" GI to others	Necessity of convincing others to support GI
		Obviousness of benefits	Perceiving benefits as plainly obvious to oneself
		Co-benefits	General feelings/thoughts about secondary/co-benefits of Gi
External perceptions	Funding	Grant challenges	Difficulties accessing, applying for, managing grants
		Means of funding	Town approach to funding GI projects
		Funding as influencing factor	Challenges related to funding as a barrier that influences other barriers
	Maintenance	General maintenance challenges	General difficulties related to maintenance of GI BMPs
		Positive maintenance experiences	Favorable experiences with maintenance of GI BMPs
		Maintenance crew challenges	Difficulties with lack of dedicated crews, crew experience, crew education as related to GI maintenance
		Maintenance equipment challenges	Difficulties with lack of proper equipment, equipment expenses, equipment requirements as related to GI maintenance
		Maintenance enforcement/oversight challenges	Difficulties ensuring municipal and private GI BMPs are maintenance as needed
		Perceived intricacy/intensity of GI maintenance	Viewing GI maintenance as more detailed and labor-intensive than gray maintenance
	Other	Capacity challenges	External issues related to town size, staff capacity, multiple job roles, lack of dedicated GI/SW staff, etc.
		Physical/hydrogeological challenges	External issues related to physical, hydrogeological, engineering, etc. GI challenges
		Development community challenges	Difficulties working with private land re/developers
		Other challenges	Misc. external perceptual challenges

Internal Perceptions	Awareness	Un/awareness of town GI projects	Reported awareness or lack thereof related to GI projects within municipality
		Un/awareness of other communities GI work	Reported awareness or lack thereof related to other communities' approach to, challenges with, experiences with GI
		Un/awareness of GI regulations	Reported awareness or lack thereof related to federal, state, or local GI regulations
		Un/awareness of leaders' feelings	Reported awareness or lack thereof related to municipal leaderships' feelings about GI
		Un/awareness of public's feelings	Reported awareness or lack thereof related to public's feelings about GI
	Familiarity/BMPs	Familiarity with BMP- YES	Reported familiarity with GI
		Familiarity with BMP- NO	Reported lack of familiarity with GI
		BMP- Bioretention Basins	Mention of BMP (usually alongside BMP checklist)
		BMP- Bioswales/Vegetated Swales	Mention of BMP (usually alongside BMP checklist)
		BMP- Downspout Disconnections	Mention of BMP (usually alongside BMP checklist)
		BMP- Green Parking Lots	Mention of BMP (usually alongside BMP checklist)
		BMP- Green Roofs	Mention of BMP (usually alongside BMP checklist)
		BMP- Green Streets	Mention of BMP (usually alongside BMP checklist)
		BMP- Green Walls	Mention of BMP (usually alongside BMP checklist)
		BMP- Land Conservation	Mention of BMP (usually alongside BMP checklist)
		BMP- Neighborhood Green Spaces	Mention of BMP (usually alongside BMP checklist)
		BMP- Parking Lot Buffers	Mention of BMP (usually alongside BMP checklist)
		BMP- Porous/Permeable Pavement	Mention of BMP (usually alongside BMP checklist)
		BMP- Rain Barrels/Cisterns	Mention of BMP (usually alongside BMP checklist)
		BMP- Residential Rain Gardens	Mention of BMP (usually alongside BMP checklist)
		BMP- Urban Agriculture	Mention of BMP (usually alongside BMP checklist)
		BMP- Urban Forestry/Tree Canopies	Mention of BMP (usually alongside BMP checklist)
		BMP- Urban Rain Gardens/Planter Boxes	Mention of BMP (usually alongside BMP checklist)
		BMP- Vegetated Strips	Mention of BMP (usually alongside BMP checklist)
		BMP- Other	Mention of other BMPs (usually alongside BMP checklist)
	Internal Perceptions/ Framing	Lack of/understanding about GI	Reported understanding/lack thereof of GI as SWM practice
		Attitude towards GI	General feelings about GI
		Perceived GI vs. gray cost-efficiency	Perceptions about GI's cost-efficiency as compared to gray's
		GI maintenance cost perceptions	Perceptions about GI's maintenance costs as compared to gray's
		Framing as product vs. process	Viewing GI with a product- or process-oriented lens
		Town Approach to GI	Views about municipality's town wide approach to GI
		GI vs. GSI Framing	Differences between "green infrastructure" or "green stormwater infrastructure" framing

Components of GI		Aesthetics	Visual/beautification component of GI
		Recreation	Recreational component of GI
		Environmental/Climate	Environmental, ecosystem, climate, habitat, or wildlife components of GI
		Transportation/Parking	Transportation, parking, walkability, or rights of way components of GI
		WQ/ISA	Water quality, impermeable surface, pollution mitigation, or related components of GI
		Flooding/Water Quantity	Water quantity, flooding, inundation mitigation components of GI
		Education	Public, childhood, municipal education components of GI
		Public (all)	Public support, understanding, awareness components related to GI
Drivers, Factors, Barriers, and Benefits		Driver	Components of/factors related to GI that serve to primarily push a project towards implementation
		Barrier	Components of/factors related to GI that serve to hinder a project's movement towards implementation
		Factor	Components of GI that influence it's support/implementation
		Benefit	Positive outputs/outcomes of GI
Sentiments/ Attitudes		Negative/Unfavorable	General negative or unfavorable attitudes or sentiments
		Neutral/Ambivalent	General neutral or ambivalent attitudes or sentiments
		Positive/Favorable	General positive or favorable attitudes or sentiments
Misc. Codes		Natural of challenges	Reported characteristics of challenges (i.e., intrinsic, evolving, etc..)
		Disconnections across town government	Reported disconnections between officials, superiors, town leadership
		Generational favorability of GI	Perceptions about GI as more popular with younger generations
		Views on creativity/innovation	Feelings about "out-of-the-box" approaches to GI
		Perceived development of GI field	Views of GI that characterize it as still nascent, emerging, well-developed, etc.
		Partnership	Views about collaboration/partnering between departments, sectors, communities, regions, etc.

IX. BIBLIOGRAPHY

"About: Providence Stormwater Innovation Center." *Providence Stormwater Innovation Center.* Accessed on October 2, 2020. https://www.stormwaterinnovation.org/about.

Ardito, Thomas and Teresa Crean. "Climate Adaptation for Coastal Communities: Helping Municipalities with Climate Change Adaptation and Mitigation." Presentation at 2017 Land and Water Conservation Summit, Kingston, RI. *Rhode Island Land and Water Partnership*. March 11, 2017. https://landandwaterpartnership.org/documents/Summit2017/2A-Helping-Municipalities-with-Climate-Change.pdf.

Barr, Stewart and Andrew W. Gilg. "A conceptual framework for understanding and analyzing attitudes towards environmental behaviour." *Geografiska Annaler: Series B, Human Geography* 89, no. 4, (2007): 361-379, https://www.tandfonline.com/doi/pdf/10.1111/j.1468-0467.2007.00266.x?needAccess=true.

Beale, Stephen. "What RI School Districts Spend on Kids vs. Admin Costs." GoLocalProv, September 5, 2013. https://www.golocalprov.com/news/school-district-spending.

Bell, Derek, Tim Gray, Claire Haggett and Joanne Swaffield. "Re-visiting the 'social gap': public opinion and relations of power in the local politics of wind energy." *Environmental Politics*, 22, no. 1 (2013): 115-135, https://journals.sagepub.com/doi/10.1177/0038026116675554.

Berard, Johnathan and Amelia Rose. "Promoting Green Infrastructure Stormwater Solutions." Presentation at 2017 Land and Water Conservation Summit, Kingston, RI. *Rhode Island Land and Water Partnership*. March 11, 2017. https://landandwaterpartnership.org/documents/Summit2017/1D-Promoting-Green-Infrastructure.pdf.

"Bristol Town Beach Stormwater Outfall Retrofit." *Pare Corporation*. Accessed on October 3, 2020. http://www.parecorp.com/portfolio/water-wastewater/bristol-town-beach-stormwater-outfall-retrofit.

Byrnes, Brian and Steven Ricci. "Designing 'Maintainable' Green Infrastructure." Presentation at 2018 Land and Water Conservation Summit, Kingston, RI. *Rhode Island Land and Water Partnership*. March 10, 2018.

https://landandwaterpartnership.org/documents/Summit2018/2A_GI_Maintenance.pdf

Carlet, Fanny. "Understanding attitudes toward adoption of green infrastructure: A case study of US municipal officials." *ScienceDirect*, 51 (2015): 65-76.

Chaffin, Brian, William Shuster, Ahjond Garmestani, Brooki Furio, Sandra Albro, Mary Gardiner, MaLisa Spring, and Olivia Odom Green. "A tale of two rain gardens: Barriers and bridges to adaptive management of urban stormwater in Cleveland, Ohio." *Journal of Environmental Management*, 183 (2016): 431-441. https://www.sciencedirect.com/science/article/pii/S0301479716303644?casa_token=BNUT8U8vKtEAAAAA:Sv_C2UsWDEVXj-eMbUpqPuxeADJ6GGK-8rYJ6g7j1cIHfVTFlskwIFLTL1_3CND0UqqcJHnD4w.

Middletown Public Works Department. "Stormwater Utilities in Rhode Island." *The City of Middletown, Rhode Island.* Accessed on March 25, 2021. https://publicworks.middletownri.com/stormwater-fund-study/what-is-a-stormwater-utilityenterprise-fund/stormwater-utilities-in-rhode-island/.

Clean Water America Alliance, Staff. "Barriers and Gateways to Green Infrastructure." *Clean Water America Alliance*, September 2011. http://uswateralliance.org/sites/uswateralliance.org/files/publications/Barriers-and-Gateways-to-Green-Infrastructure.pdf.

"Coastal Green and Resilient Infrastructure Project (GRIP)." *Coastal Resources Center*. Accessed on September 24, 2020. https://www.crc.uri.edu/projects_page/gi-coastal-ri/.

Copeland, Claudia. "Green Infrastructure and Issues in Managing Urban Stormwater." *Congressional Research Service* 7-5700, (May 2, 2016). https://fas.org/sgp/crs/misc/R43131.pdf.

Damanpour, Fariborz and Marguerite Schneider. "Phases of the Adoption of Innovation in Organizations: Effects of Environment, Organization and Top Managers." *British Journal of Management*, 17 (2006): 215-236. https://doi.org/10.1111/j.1467-8551.2006.00498.x.

Davis, Joel J. "The Effects of Message Framing on Response to Environmental Communications." *Journalism & Mass Communication Quarterly* 72, no. 2 (June 1995): 285–99. https://doi.org/10.1177/107769909507200203.

Denchak, Melissa. "Green Infrastructure: How to Manage Water in a Sustainable Way." *Natural Resources Defense* Council, March 4, 2019. https://www.nrdc.org/stories/green-infrastructure-how-manage-water-sustainable-way.

Dhakal, Krishna, and Liz Chevalier. "Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application." *Journal of Environmental Management,* 203 (2017): 171-181.

ecoRI News, Staff. "Providence Forced to Invest in Stormwater System." *ecoRI News*, March 9, 2017. https://www.ecori.org/pollution-contamination/2017/3/9/providence-commits-to-investment-in-citys-stormwater-infrastructure.

Espinoza, Ambar. "Runoff Still Threatens Water on Aquidneck Island." *The Public's Radio*, July 22, 2015. https://thepublicsradio.org/post/runoff-still-threatens-water-aquidneck-island.

Feifel, Kirsten. "Project Clean Lake: Updating Cleveland's Sewer Systems to Reduce Stormwater Overflows." *Climate Adaptations Knowledge Exchange*, April 23, 2013. https://www.cakex.org/case-studies/project-clean-lake-updating-cleveland's-sewer-systems-reduce-stormwater-overflows.

Finewood, Michael, Marissa Matsler, and Joshua Zivkovich. "Green Infrastructure and the Hidden Politics of Urban Stormwater Governance in a Postindustrial City." *Annals of the Americans Association of Geographers*, 109, no. 3 (2019): 909-925. https://doi.org/10.1080/24694452.2018.1507813.

Flinker, Peter. "The Need to Reduce Impervious Cover to Prevent Flooding and Protect Water Quality." Produced by *Dobson Associates, Ltd*, May 2010. 1-20. http://www.dem.ri.gov/programs/bpoladm/suswshed/pdfs/imperv.pdf.

Flynn, Carli, and Cliff Davidson. "Adapting the social-ecological system framework for urban stormwater management: the case of green infrastructure adoption." *Ecology and Society,* 21, 4 (2016): 19. https://www.researchgate.net/publication/306013177_Adapting_the_social-ecological_system_framework_for_urban_stormwater_management_The_case_of_green_infrastructure_adoption.

Firozi, Paulina and Allyson Chiu. “Four reasons you’re tired of Zoom calls — and what to do about it.” *The Washington Post*, March 3, 2021. https://www.washingtonpost.com/lifestyle/2021/03/03/stanford-zoom-fatigue/.

Gray, Kyle. “Philadelphia/EPA Green Infrastructure Partnership Case Study.” Research Case Study, prepared for Throwe Environmental, LLC, April 2020.

Gray, Kyle. “S1 | E1: Green Infrastructure (ft. Lancaster City and Provincetown).” Presented by the Southeast New England Program Network. *The Leadership Exchange Podcast.* September 22, 2020. Podcast, MP3 audio, 59:56. https://anchor.fm/snep-leadership-exchange/episodes/S1--E1-Green-Infrastructure-ft--Lancaster-City-and-Provincetown-ejr6f2.

“Green Infrastructure Projects in Rhode Island.” *Rhode Island Green Infrastructure Coalition.* Accessed on October 2, 2020. http://www.greeninfrastructureri.org/projects.php

Jordaan, Sarah, and Carla Stevens. “Barriers along the path.” *Alternatives Journal*, 33, 4 (2007): 20. https://www.jstor.org/stable/45033299.

Keeley, Melissa, Althea Koburger, David Dolowitz, Dale Medearis, Darla Nickel, William Shuster. “Perspectives on the Use of Green Infrastructure for Stormwater Management in Cleveland and Milwaukee.” *Environmental Management,* (2013) 1-17. https://www.researchgate.net/publication/236276673_Perspectives_on_the_Use_of_Green_Infrastructure_for_Stormwater_Management_in_Cleveland_and_Milwaukee.

Kochnower, Dana, Sheila M.W. Reddy, Reinhard E. Flick. “Factors influencing local decisions to use habitats to protect coastal communities from hazards.” *Ocean and Coastal Management*, 116 (2015): 277-290. https://www.researchgate.net/publication/282742289_Factors_influencing_local_decisions_to_use_habitats_to_protect_coastal_communities_from_hazards.

Matthews, Tony, Alex Lo, and Jason Byrne. “Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners.” *Landscape and Urban Planning*, 138 (2015): 155-163. https://doi.org/10.1016/j.landurbplan.2015.02.010.

Morley, David. "Planning for Equity in Parks with Green Infrastructure." *American Planning Association,* 2017. https://www.nrpa.org/siteassets/gupc-briefing-paper-planning-equity-parks.pdf

Murray, Donald. "Teach Writing as a Process Not Product." In *Cross-Talk in Comp Theory: A Reader*, edited by Victor Villanueva and Kristin Arola, 3-6. National Council of Teachers of English, 2011. https://mwover.files.wordpress.com/2018/05/murray-teach-writing-as-a-process-not-product.pdf.

"Newport-Aquidneck." *Rhode Island Green Infrastructure Coalition*. Accessed on October 2, 2020. http://www.greeninfrastructureri.org/newport.html.

Niemczynowicz, Janusz. "Urban hydrology and water management – present and future challenges." *Urban Water*, 1 (1999): 1-14. https://doi.org/10.1016/S1462-0758(99)00009-6.

Nylen, Nell G, and Michael Kiparsky. "Accelerating Cost-Effective Green Stormwater Infrastructure: Learning from Local Implementation." *Center for Law, Energy, & the Environment, University of California at Berkeley School of Law*, 2015. https://www.law.berkeley.edu/files/CLEE/GSI_Report_Full_2015-02-25.pdf.

O'Donnell, E. C., J. E. Lamond, and C. R. Thorne. "Recognising barriers to implementation of Blue-Green infrastructure: a Newcastle case study." *Urban Water Journal*, 14, no. 9 (2017): 964-971. https://www.tandfonline.com/doi/full/10.1080/1573062X.2017.1279190?scroll=top&needAccess=true,

Olorunkiya, Joshua, Elizabeth Fassman, and Suzanne Wilkinson. "Risk: A fundamental barrier to implementation of low impact design infrastructure for urban stormwater control." *Journal of Sustainable Development*, 5, no. 9 (2012): 27-41. http://www.ccsenet.org/journal/index.php/jsd/article/view/17974.

Parry, Geraint and Sarah Jose. "Separate product from process: framing the debate that surrounds the potential uptake of new breeding technologies." *Physiologia Planatarum*, 164, no. 4 (2018): 372-377. http://orca.cf.ac.uk/108259/1/PARRY_JOSE_Review_Final_180118.pdf.

Phillips de Lucas, Amanda. "Gifting a White Elephant, In the Form of Green Infrastructure." The Nature of Cities, August 18, 2020. https://www.thenatureofcities.com/2020/08/18/gifting-a-white-elephant-in-the-form-of-green-infrastructure/.

Phillips de Lucas, Amanda. Personal communication. December 15, 2020.

"Prestigious grant awarded to lift up voices of Newport's North End residents and grow green infrastructure relationships." What's Up Newp, May 20, 2020. https://whatsupnewp.com/2020/05/prestigious-grant-awarded-to-lift-up-voices-of-newports-north-end-residents-and-grow-green-infrastructure-relationships/.

"Project: Rain Barrell Fest." *Rhode Island Green Infrastructure Coalition*. Accessed on October 2, 2020. http://www.greeninfrastructureri.org/project_details.php?id=88.

Qiao, Xiu-Juan, Anders Kristofferson, and Thomas Randrup. "Challenges to implementing urban sustainable stormwater management from a governance perspective: A literature review." *Journal of Cleaner Production,* 196 (2018): 943-952. https://doi.org/10.1016/j.jclepro.2018.06.049.

Reese, Andrew, Robert Chandler, and Sheila Dormody. "Paying for Stormwater – The Benefits of a Utility." *United States Environmental Protection Agency, Office of Wastewater Management.* (August 13, 2015). https://www.epa.gov/sites/production/files/2015-12/documents/sw_utility_-_combined_slides_-_aug_13_2015.pdf.

Reid, Matthew. "How much waste is in that water you're swimming in?" South Coast Today, August 17, 2019. https://www.southcoasttoday.com/news/20190817/how-much-waste-is-in-that-water-youre-swimming-in.

Rhode Island Department of Environmental Management. "List of Managers." *Rhode Island Department of Environmental Management*, updated January 2021. Accessed November 2020. http://www.dem.ri.gov/ri-stormwater-solutions/stormwater-managers/coordinator-list.php.

Rhode Island Department of Environmental Management, Office of Water Resources. "General Permit Rhode Island Pollutant Discharge Elimination System Storm Water Discharge from Small Municipal Separate Storm Sewer Systems and from Industrial Activity at Eligible Facilities Operated by Regulated Small MS4s." *Rhode Island Department of Environmental Management*. (December 19, 2008). http://www.dem.ri.gov/pubs/regs/regs/water/ms4final.pdf.

Rhode Island Department of Environmental Management. "RIPDES Stormwater Municipal Separate Storm Sewer Systems (MS4s)." Rhode Island Department of Environmental Management, Accessed on March 26, 2021. http://www.dem.ri.gov/programs/water/permits/ripdes/stormwater/ms4s-program.php

"Rhode Island Stormwater Design and Installation Standards Manual." *Rhode Island Department of Environmental Management and Rhode Island Coastal Resources Management Council*. (December 2010). http://www.dem.ri.gov/pubs/regs/regs/water/swmanual.pdf

"Rhode Island Stormwater Management and Utility District Act of 2002," P.L. 2002, Ch. 329, § 1, Sec. 45-61. State of Rhode Island General Assembly. (2002). http://webserver.rilin.state.ri.us/PublicLaws/law02/law02329.htm.

Robson, Colin. *Real World Research*. Chichester: John Wiley & Sons Ltd., 2011.

Roseen, Robert, Richard Waldo, Jessica Janney, and Sandra Tripp. "Provincetown Porous Asphalt Keeps Beaches Open." *National Asphalt Pavement Association*, 19, 5 (September/October 2014): 18-24. https://mdasphalt.org/wp-content/uploads/2015/08/Porous-in-Provincetown-MAA_small.pdf.

Roy, Allison, Seth Wenger, Tim Fletcher, Christopher Walsh, Anthony Ladson, William Shuster, Hale Thurston, and Rebekah Brown. "Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management: Lessons from Australia and the United States." *Environmental Management,* 42 (2008): 344-359. https://www.researchgate.net/publication/5406845_Impediments_and_Solutions_to_Sustainable_Watershed-Scale_Urban_Stormwater_Management_Lessons_From_Australia_and_the_United_States#fullTextFileContent.

Rubinoff, Pam, Kevin Proft, Shannon Brawley, Sallie Sirhal, and Catherine Weaver. "Green Infrastructure for the Coast: A Primer for Local Decision Making." *University of Rhode Island Coastal Resources Center and Rhode Island Sea Grant*. Accessed March 26, 2021. https://www.crc.uri.edu/download/1.-GRIP-booklet_Final.pdf.

Savolainen, Reijo. "Cognitive barriers to information seeking: A conceptual analysis." *Journal of Information Science*, 41, no. 5 (2015): 613-623. https://journals.sagepub.com/doi/abs/10.1177/0165551515587850#:~:text=The%

20study%20resulted%20in%20a,to%20deal%20with%20information%20overload.

Silvia, Andrew. "~~Five~~ Seven Strategies to Improve Your Community's Stormwater Program." Presentation, 2019 Land and Water Conservation Summit, Kingston, RI. *Rhode Island Land and Water Partnership*, March 9, 2019. https://landandwaterpartnership.org/documents/Summit2019/2C-StrategiestoImproveYourMunicipalStormwater.pdf.

Southeast New England Program Network. "Webinar 1: Incorporating Green Infrastructure for Stormwater and Other Co-Benefits." Southeast New England Program Network. October 8, 2020. Video, 1:00:45. https://snepnetwork.org/2020/10/08/webinar-1-incorporating-green-infrastructure-for-stormwater-and-other-co-benefits/.

Stead Sellers, Frances. "A green solution to an aging stormwater system." The *Washington Post,* (April 9, 2020). https://www.washingtonpost.com/climate-solutions/2020/04/09/philadelphia-sewage-climate-change/?arc404=true

Providence Department of Sustainability. "Stormwater Management." *The City of Providence, Rhode Island.* Accessed on October 2, 2020. https://www.providenceri.gov/sustainability/stormwater-management/

"The Benefits of Green Infrastructure: Bristol Town Beach Tree Planting." *Rhode Island Stormwater Solutions.* Accessed October 3, 2020. https://web.uri.edu/riss/files/Bristol-Tree-Fact-Sheet.pdf

"The Benefits of Green Infrastructure: Gravel Wet Vegetated Treatment Systems." *Rhode Island Stormwater Solutions.* Accessed October 3, 2020. http://www.dem.ri.gov/ri-stormwater-solutions/documents/Bristol-GWVTS-Fact-Sheet.pdf

The City of Lancaster. "Parks." *Save It! Lancaster*, (accessed April 19, 2021). http://www.saveitlancaster.com/local-projects/parks/#pagejump3.

The City of Lancaster. "Save It!" *Save It! Lancaster*, (accessed September 6, 2020). http://saveitlancaster.com/Resources/StormwaterFee/

The City of Lancaster. "Stormwater Fee & Credits." *Save It! Lancaster*, (accessed September 6, 2020). http://saveitlancaster.com/Resources/StormwaterFee/

United States Department of Justice. "The City of Newport, R.I., Will Upgrade Facilities and Pay Fine to Settle Clean Water Violations." (August 11, 2011). https://www.justice.gov/opa/pr/city-newport-ri-will-upgrade-facilities-and-pay-fine-settle-clean-water-violations.

United States Environmental Protection Agency. "Benefits of Green Infrastructure." *United States Environmental Protection Agency*. (May 28, 2020). https://www.epa.gov/green-infrastructure/benefits-green-infrastructure.

United States Environmental Protection Agency. "National Pollutant Discharge Elimination System: About NPDES." *United States Environmental Protection Agency*: (November 29, 2016). https://www.epa.gov/npdes/about-npdes

United States Environmental Protection Agency. "National Pollutant Discharge Elimination System: NPDES Stormwater Program." *United States Environmental Protection Agency*: (March 20, 2020). https://www.epa.gov/npdes/npdes-stormwater-program

United States Environmental Protection Agency. "National Pollutant Discharge Elimination System: Stormwater Discharges from Municipal Sources." *United States Environmental Protection Agency*: (April 16, 2020). https://www.epa.gov/npdes/stormwater-discharges-municipal-sources.

United States Environmental Protection Agency. "Operations and Maintenance Considerations for Green Infrastructure." *United States Environmental Protection Agency.* (February 26, 2018). https://www.epa.gov/G3/operation-and-maintenance-considerations-green-infrastructure.

United States Environmental Protection Agency. "Overcoming Barriers to Green Infrastructure." *United States Environmental Protection Agency*: (May 13, 2019). https://www.epa.gov/green-infrastructure/overcoming-barriers-green-infrastructure.

United States Environmental Protection Agency. "The Economic Benefits of Green Infrastructure: A Case Study of Lancaster, PA." *United States Environmental Protection Agency*, (February 2014). https://www.epa.gov/sites/production/files/2015-10/documents/cnt-lancaster-report-508.pdf

United States Environmental Protection Agency. "What is Green Infrastructure?" *United States Environmental Protection Agency:* (December 4, 2019). https://www.epa.gov/green-infrastructure/what-green-infrastructure.

United Stated Environmental Protection Agency, Office of Research and Development. "Healthy Benefits of Green Infrastructure in Communities." *United States Environmental Protection Agency,* August 2017). https://www.epa.gov/sites/production/files/2017-11/documents/greeninfrastructure_healthy_communities_factsheet.pdf.

United States Environmental Protection Agency, Office of Water. "Implementing Low Impact Development Practices at Bristol Town Beach Keeps the Beach Open and Improves Offshore Shellfishing Waters." *United States Environmental Protection Agency,* (August 2015). https://www.epa.gov/sites/production/files/2020-07/documents/ri_bristol-508.pdf.

United States Environmental Protection Agency, Office of Water. "Porous Pavement Improves Provincetown Harbor Beaches." *United States Environmental Protection Agency*, (December 2016). https://www.epa.gov/sites/production/files/2016-12/documents/ma_provincetown_508.pdf

United States Environmental Protection Agency, Office of Water. "Stormwater Management and Green Infrastructure Research." *United States Environmental Protection Agency,* December 31, 2020. https://www.epa.gov/water-research/stormwater-management-and-green-infrastructure-research#:~:text=Green%20infrastructure%20practices%20include%20permeable,disconnection%2C%20and%20urban%20tree%20canopies.

United States Environmental Protection Agency, Office of Water. "Stormwater Phase II Final Rule: Small MS4 Stormwater Program Overview." *United States Environmental Protection Agency*, (December 2005). https://www3.epa.gov/npdes/pubs/fact2-0.pdf.

United States Environmental Protection Agency, Region III. "Funding Stormwater Programs." *United States Environmental Protection Agency*. (January 2008). https://www.epa.gov/sites/production/files/2015-10/documents/region3_factsheet_funding_0.pdf.

University of Rhode Island Coastal Resources Center. "Coastal Green and Resilient Infrastructure Project (GRIP)." *University of Rhode Island*. Accessed on April 20, 2021. https://www.crc.uri.edu/projects_page/gi-coastal-ri/.

Upper Narragansett Bay Steering Committee. "Study Purpose." *Upper Narragansett Bay Regional Stormwater Management District*. (2015; accessed March 25, 2021). https://www.unbstormwater.org/about.html.

Weissman, Gideon. "With resources, communities can make beaches safe." *Frontier Group*, (August 21, 2020). https://frontiergroup.org/blogs/blog/fg/resources-communities-can-make-beaches-safe.

Zhou, Yuyu and Y. Q. Wang. "An Assessment of Impervious Surface Areas in Rhode Island." *Northeastern Naturalist*, 14, no. 4 (2007): 643-650. https://www.jstor.org/stable/25177072.