Prospectus

Meadow Creek Water Management Plan
(Technical Topic)

Rethinking the Equity of Green Infrastructure
(STS Topic)

By

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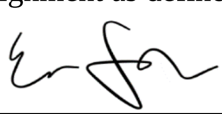
On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.



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Introduction

Conventional stormwater infrastructure within the United States of America (U.S.) does not acknowledge the value of water as a resource. Instead, this infrastructure, often denoted “grey infrastructure,” is composed of pipes, manholes, and other man-made, structural components designed to transport stormwater runoff, or rainfall that flows over the ground, away from a site as quickly as possible (Brears, 2018). Urban landscapes, characterized by impervious surfaces, transform most rainfall into stormwater runoff. Therefore, the combination of conventional stormwater infrastructure and urban landscapes results in large quantities of untreated runoff. Thus, although grey infrastructure reduces flash flooding in urban settings, receiving waterways are deteriorated by increased water quantity, which causes erosion and flooding, and decreased water quality resulting from the collected pollutants (Dhakal and Chevalier, 2017).

Since recognizing the unsustainability of traditional urbanization practices, strategies have been developed that define a new type of “green infrastructure” (US EPA, 2015). Unlike grey infrastructure that employs only structure to address water-related issues, green infrastructure applies the concepts of both structure and function by creating spaces where natural hydrological processes occur that aim to address runoff closer to the source. Common examples include rain gardens, green roofs, and grass swales. This more inclusive approach effectively restores pre-development conditions by allowing increased infiltration and treatment on-site (Kozak, Henderson, De Castro Mazarro, Rotbart, and Aradas, 2020). Unfortunately, green infrastructure implementation depends on the minimum requirements set forth by governmental mandates, which are often cost-driven and inadequately capture the holistic needs of proper stormwater management. Another impediment is the widespread ignorance of the appropriate applications, associated costs, and social co-benefits which correspond to the different strategies, such as community stewardship (Browder, Ozment, Bescos, Gartner, and Lange, 2019). Since installment of green infrastructure is guided by bare minimum requirements and overly-generalized understanding, the resulting network is often incohesive and may not benefit the local watershed as much as was anticipated. Without proper strategic planning of these practices, the affected waterbodies are weakened and continue to disintegrate, if at a marginally slower pace.

An alternative solution to waterway degradation is restoration, as restoration efforts amend waterways directly, rather than at specific points throughout the watershed like most green infrastructure. Many restoration projects involve physical reconfiguration of the channel, like adjusting waterways laterally or increasing their curvature, and often include the addition of in-stream structures, such as boulders or logs (Palmer, Hondula, and Koch, 2014). This method of restoration is better known as Natural Channel Design (NCD) and is supported by engineers. However, NCD projects are based upon an unconfirmed assumption that if a channel is adjusted to tolerate the principal flow and sediment conditions, then ecological processes will recuperate accordingly. In practice, this assumption is false, as the limiting factor for ecological function is water quality. Thus, current approaches of restoration projects arouse suspicion of long-term effectiveness and restoration of waterway health because they are based upon incorrect conclusions. In addition, restoration projects can be critiqued for addressing issues too narrow in scale. The majority of sources impacting waterways are located not in the channel, but in the watershed (Palmer, Hondula, and Koch, 2014). Therefore, these sources which endanger the watershed should be targeted to successfully restore waterways, and that is the task which green infrastructure performs. If the correct knowledge can be incorporated into stormwater infrastructure decisions, green infrastructure can heal the entirety of any given watershed, rather than treating the symptoms, and construct a new meaning for the "built" environment by blending natural and man-made systems to find an equilibrium representative of all involved actors.

Meadow Creek Water Quality Management Plan

Meadow Creek is a major waterway of Charlottesville, running through the city before connecting to the Rivanna River and ultimately to the Chesapeake Bay. It receives water from a 5,800-acre drainage area encompassing northern Charlottesville, including approximately 1,000 acres of major shopping centers along U.S. Route 29. Due to the quantity of stormwater runoff generated by the impervious area along Route 29, Meadow Creek watershed has become a concern for the City of Charlottesville. The Virginia Department of Environmental Quality (DEQ) has reported Meadow Creek on the Clean Water Act 303(d) list since 2006, which lists the state's impaired waterways (US EPA, 2015). More specifically, the level of benthic macroinvertebrates, or the organisms that live in or on the bottom sediments of a waterbody, is routinely lower than the water quality standard. This continuous violation is primarily due to the erosion of streambanks, which results in large amounts of suspended sediment in the water. To remedy Meadow Creek, the City of Charlottesville collaborated with the Rivanna Water and Sewer Authority (RWSA) and The Nature Conservancy (TNC) to conduct a stream restoration project in 2012. The goal was to stabilize the stream, improve water quality, and enhance aquatic and forest habitats. The project included implementation of NCD, installation of rock and log structures, creation of riffles and pools, improvement of the floodplain and wetlands, planting of native vegetation, and removal of invasive vegetation.

Although the restoration's effects are not fully realized, Meadow Creek requires increased effort to improve water quality and ecological integrity. In 2020, Meadow Creek was documented on the 303(d) list for violations of both benthic macroinvertebrate and bacteria levels. To alleviate the remaining issues degrading Meadow Creek, the existing stormwater infrastructure within the watershed needs to be assessed. Like many jurisdictions in the U.S., Charlottesville's residential areas and shopping centers are mostly composed of grey infrastructure (City of Charlottesville, 2020). Ideally, all stressors in the watershed would be identified and addressed, but this would require an extended timeline. Instead, the project aims to address the most prevalent issues via a multi-objective watershed analysis. These objectives are to identify stormwater hotspots, assess stream ecology, determine environmental impacts of the stream restoration, and propose an equitable water management plan to deploy green infrastructure within the watershed. The analysis will follow the basic planning cycle presented in Figure 1.

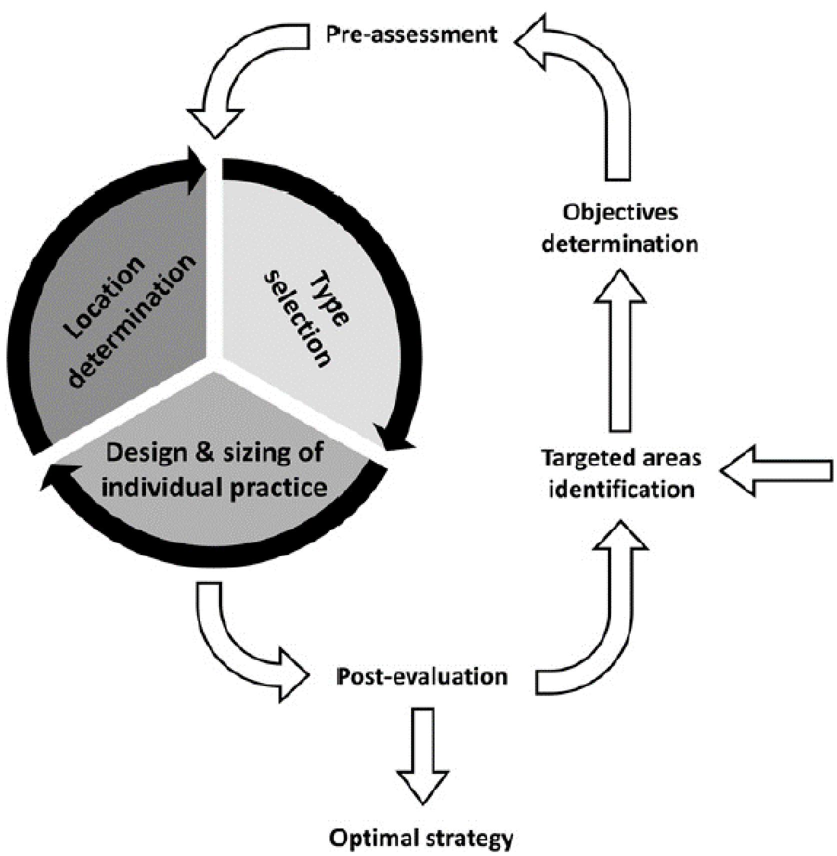

Figure 1. Strategic planning cycle (Image source: Zhang and Chui, 2018)

To accomplish these tasks, most of the project is dedicated to data collection, modeling, and analysis. To assess stream ecology and environmental impacts of the restoration, students from the team will partake in fieldwork, including grab sample retrieval, flow measurements, and downloading data from sensors at stations along Meadow Creek. The sensors include conductivity loggers, dissolved oxygen (DO) loggers, photosynthetically active radiation (PAR) smart sensors, and water level loggers, which will characterize ecosystem metabolism and energy regime. The water level loggers, when paired with the flow measurements, will create rating curves, which predict discharge based upon depth and will be used during modeling. The grab samples will be used to calibrate expected pollutant loadings from various land uses also during modeling. The modeling will be accomplished using Geographic Information System (GIS) mapping to overlay relevant layers, such as city demographics, parcel data, and areas of untreated runoff, for stormwater hotspot identification, as illustrated in Figure 2, and the EPA's Stormwater Management Model (SWMM) to simulate water quantity and quality of the Meadow Creek watershed. Next, an optimization analysis of green infrastructure options will be performed to identify the best management practices (BMPs) suited to each hotspot, which will incorporate treatment capability, social perception, potential community involvement, and associated costs of BMP alternatives. Additionally, Arc-X and SWMM-CAT will evaluate resilience of the proposed green infrastructure plan. Lastly, in an effort to deploy these BMPs, students will review available funding for selected BMP designs.

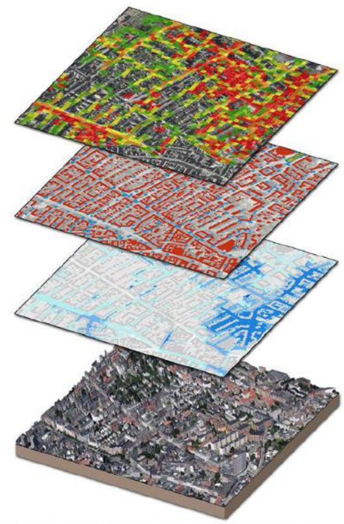

Figure 2. Hotspot identification overlays (Image source: City of Copenhagen, 2012)

An equitable green infrastructure network for Meadow Creek watershed requires the identification of design principles which are currently leading to inequitable allocation of green infrastructure. To build upon a base knowledge of stormwater management regulations, students will converse with City of Charlottesville and Albemarle County representatives, as well as civil engineers from the private sector, to illuminate drivers and obstacles for the deployment of green infrastructure in these localities. With this knowledge of the watershed, students hope that overlooked communities will have the appropriate attention brought to them. It should be noted that stakeholder interest will need to be characterized more completely when finalizing designs so community perspectives are incorporated (Brown, 2016).

Analysis of Green Infrastructure Actor Network

Green infrastructure is a sociotechnical system, meaning it is composed of technology, humans, and the interaction between the two. Thus, to determine the needed changes for equitable distribution, analysis of both the social and technical realms are required. This will be completed using actor-network theory, as described by Bruno Latour in 1992, which acknowledges that sociotechnical systems are affected by social interactions, but adds the claim that the laws of nature restrict the design of these systems. These systems are therefore made of networks that include a variety of actors which can be human, non-human, or intangible, such as the force of gravity. In these sociotechnical systems, humans delegate, or assign, specific actions to nonhumans under the constraints of the intangible, such as the use of pipes to transport water, but the nonhuman actors of these systems (the pipes) also have power because they prescribe actions back onto humans (maintenance). Some groups of people, however, may not be able to complete this prescribed action (lack of funding). Therefore, nonhuman actors can discriminate by adopting the perspectives of those who designed them. To remove these discriminatory attributes, the system must be redesigned (Latour, 1992). The following section discusses why stormwater infrastructure is one of these systems in need of rethinking.

Infrastructure mediates human relations through connecting and disconnecting people and flows, pronouncing the tensions of race and class through its design (Guerrero, 2018). Water infrastructure plays a key role in this mediation and inherits a large amount of power since the provision of water is necessary for human survival. In theory, this should result in the protection of and respect for water, but the complexity of the systems which provide it, such as sanitation and drainage, results in a lack of understanding among the public and a consideration of water as a stable resource that is dealt with in overlooked and specialized processes (Braun, 2005). The systems that deliver drinking water to the user, such as pipe networks and treatment plants, are thus veiled, hiding the aforementioned tensions which create inequities. It is then the responsibility of those who design, construct, and control water infrastructure to recognize water and water infrastructure as nonhuman actors which delegate to, and sometimes discriminate against, the communities they serve, so that inequity can be actively dealt with.

Unfortunately, those who recognize water in this network often conceptualize it as an "uncooperative commodity" (Bakker, 2004). This conception is facilitated by the consideration of water as a "flow resource," meaning it is not easily contained and external matter, like pollution and debris, can easily disperse into it. Water also takes on varying identities, depending upon if the user is upstream or downstream. For instance, water that is used as an input for a drinking supply upstream may be output downstream as wastewater, where it is more contaminated and thus more difficult to use for the same purposes as upstream. The combination of these perceptions results in making property rights and guidelines difficult to establish. Further, once they are established, water must be controlled with the required infrastructure and assigned to communities, which must be built, maintained, and updated. A failure to invest results in the decaying of infrastructure and reveals the hidden discriminations of water infrastructure, infusing disadvantaged communities with a strong mistrust in the responsible authorities. This transformation of community values becomes problematic in the case of stormwater infrastructure due to the need for replacing grey infrastructure with green infrastructure. Communities question the judgment of those approaching them with projects which aim to fix the problems of flooding and pollution because, frequently, those who propose these projects are an extension of the increasingly distrusted government. It should also be noted that the disadvantaged communities which are most likely to experience a lack of attention are often those which are located in the most pivotal locations for environmental remediation, leading to the inseparable connection which exists between social and environmental justice (Gardiner, 2020). This connection requires an investigation of the governing authority and the scientific principles that empower it, which enable the existence of discrimination.

The scientific principles that empower governing bodies require the gaining of scientific knowledge, so the actors which guide this knowledge should be considered. It has been argued that scientific knowledge is negotiated and formed by those who research, those who fund research, and those who are averse to regulation (Cozzens and Woodhouse, 1995). Interestingly, these three groups are often one and the same, as research is dependent upon the negotiating authority, which is usually the government, as it is a major provider of funding for research and public infrastructure. Consequently, it is even more critical that the policies and perceptions of governing officials must be investigated. Currently, governing officials use a separatist view of "science" and "politics" to justify actions in a turbulent political environment, but they also use increased technical language within policies to deter public understanding and thus the public's concerns and beliefs, which ignores a vital set of actors. For instance, the reframing of green infrastructure as green stormwater infrastructure is used as a mechanism of depoliticization in an attempt to avoid discussion of just infrastructure (Finewood, Matsler, and Zivkovich, 2019).

However, there is no actual division between science and politics, as it is impossible to distinguish science from policy, as is seen in the case of scientific knowledge. Further, it has not been shown that a governing body is better at making moral judgments than the public (Beitz, 1990). The rejection of public participation in policymaking and the view that scientific expertise is not affected by politics, or vice versa, leads to an undemocratic system which results in discriminatory technical policy. Therefore, a method is needed to facilitate the actor dynamics required for an equitable transition from grey to green infrastructure and connect water to the public and the public to the government. To determine this method, the following question is proposed: How can the perception of affected actors be reformed to allow equitable distribution of green infrastructure?

Research Design

This question will be answered through case studies of Portland, Oregon and Baltimore, Maryland. These two cities were selected due to the availability of prior literature, the opposing geospatial locations of these cities in the U.S., and the contrasting configurations of green infrastructure within these cities. First, secondary sources will be analyzed for each city, including review of governing stormwater management manuals, reports from their state's Department of Environmental Quality concerning water resources, prior literature describing green infrastructure of the city, and documented public outcries from non-profits and similar organizations, which will be assembled early in December. The collected data will then be descriptively assessed in two ways during winter break. First, agency reports and prior literature describing existing and proposed green infrastructure for each city will be assessed geographically to identify how spatial distribution reflects socioeconomic characteristics, if at all. Second, policy documents and documented public outcries will be assessed thematically by coding documents for references to stakeholder involvement and equity concerns. Group-centric justice, where equitable creation of infrastructure and corresponding policies are directed by needs of socioeconomic groups, will guide the evaluation of results (Young, 1990), which will occur in February. This perspective will be used because it is more comprehensive and more relevant to stormwater-related politics than distributive justice, which focuses on material aspects and, in doing so, ignores and conceals the institutional issues that pervade modern systems of injustice.

Conclusion

The study of Meadow Creek watershed and its urbanization will allow the student team to gather data and learn about the complexities and realities of the actors present in the built and natural environment, ultimately leading to the creation of a water management plan which will account for socioeconomic concerns and highlight the implementation of green infrastructure at identified stormwater hotspots. Concurrently, an assessment of the existing actor network on a broader scale will commence, leading to the discovery of the social changes that are required to provide an environment in which an equitable and sustainable transition can be made from grey to green infrastructure. The culmination of these findings will aid in the facilitation of this transition, leading humans one step closer to unity with each other and the ecosystems they inhabit.

References

Baker, A., Brenneman, E., Chang, H., McPhillips, L., & Matsler, M. (2019). Spatial analysis of landscape and sociodemographic factors associated with green stormwater infrastructure distribution in Baltimore, Maryland and Portland, Oregon. *Science of The Total Environment*, *664*, 461–473. https://doi.org/10.1016/j.scitotenv.2019.01.417

Bakker, K. (2004). *An uncooperative commodity: Privatizing water in England and Wales*. Oxford, England: Oxford University Press.

Beitz, C. R. (1990). *Political Equality: An Essay in Democratic Theory*. Princeton, NJ: Princeton University Press.

Brears, R. (2018). *From Traditional Grey Infrastructure to Blue-Green Infrastructure* (pp. 1–41). https://doi.org/10.1057/978-1-137-59258-3_1

Browder, G., Ozment, S., Bescos, I. R., Gartner, T., & Lange, G.-M. (2019). *Integrating Green and Gray: Creating Next Generation Infrastructure.* https://www.wri.org/publication/integrating-green-gray

Brown, H.J. (2016). Green infrastructure: Fostering equity. Retrieved from https://www.usgbc.org/articles/green-infrastructure-fostering-equity

City of Charlottesville. (2020). CityGreen Map. Retrieved from https://www.charlottesville.gov/699/CityGreen-Map

Cloudburst Management Plan, Copenhagen. (2012). Retrieved from https://oppla.eu/casestudy/18017

Cozzens, S. E., & Woodhouse, E. J. (1995). Science, Government, and the Politics of Knowledge. In S. Jasanoff, G. Markle, J. Peterson, & T. Pinch, *Handbook of Science and*

Technology Studies (pp. 532–553). SAGE Publications, Inc. https://doi.org/10.4135/9781412990127.n23

Finewood, M., Matsler, M., & Zivkovich, J. (2019). Green Infrastructure and the Hidden Politics of Urban Stormwater Governance in a Postindustrial City. *Annals of the American Association of Geographers*, *109*, 1–17. https://doi.org/10.1080/24694452.2018.1507813

Gardiner, B. (2020). Unequal Impact: The Deep Links Between Racism and Climate Change. Retrieved from https://e360.yale.edu/features/unequal-impact-the-deep-links-between-inequality-and-climate-change

Guerrero, T. A. (2018). Water infrastructure: A terrain for studying nonhuman agency, power relations, and socioeconomic change. *WIREs Water*, *5*(5), e1298. https://doi.org/10.1002/wat2.1298

Kozak, D., Henderson, H., De Castro Mazarro, A., Rotbart, D., & Aradas, R. (2020). Blue-Green Infrastructure (BGI) in Dense Urban Watersheds. The Case of the Medrano Stream Basin (MSB) in Buenos Aires. *Sustainability*, *12*, 2163. https://doi.org/10.3390/su12062163

Latour, B. (1992). Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts. *Shaping Technology/Building Society: Studies in Sociotechnical Change*, 225–228.

Palmer, M. A., Hondula, K. L., & Koch, B. J. (2014). Ecological Restoration of Streams and Rivers: Shifting Strategies and Shifting Goals. *Annual Review of Ecology, Evolution, and Systematics*, 45(1), 247–269. https://doi.org/10.1146/annurev-ecolsys-120213-091935

US EPA. (2015). Overview of Listing Impaired Waters under CWA Section 303(d). Retrieved from https://www.epa.gov/tmdl/overview-listing-impaired-waters-under-cwa-section-303d

US EPA. (2007*)*. Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/2008_01_02_nps_lid_costs07uments_reducingstormwatercosts-2.pdf

US EPA. (2015). What is Green Infrastructure? Retrieved from https://www.epa.gov/green-infrastructure/what-green-infrastructure

Young, I.M. (1990). *Justice and the Politics of Difference*. Princeton, NJ: Princeton University Press.

Zhang, K., & Chui, T. F. M. (2018). A comprehensive review of spatial allocation of LID-BMP-GI practices: Strategies and optimization tools. *Science of The Total Environment, 621*, 915–929. https://doi.org/10.1016/j.scitotenv.2017.11.281