Green Infrastructure: A Means for Community Agency

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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 in the United States of America (U.S.) is not designed for long-term environmental or human success. Rather, it results in a pervasive cycle of construction and repair, leading to continuous degradation of the water sources which provide water for the processes civilization relies upon, most notably the sustenance of life. This conventional infrastructure is called "grey" infrastructure because the components of the system are made of nonliving, man-made materials, such as concrete, asphalt, or plastic. Grey infrastructure includes a collection system, usually curbs and gutters, which then conveys stormwater runoff, or rainfall that flows over the ground, through a network of pipes to a local waterbody. The goal of these systems is to transport stormwater away as quickly as possible (Brears, 2018). However, this goal has become an issue as municipalities continue to grow and develop, as there is less "away" for stormwater to go which does not interfere with inhabitants' quality of living. Additionally, the waterbodies demarcated as the final destination for stormwater have eroded or become polluted. This occurs because grey infrastructure does not treat conveyed stormwater or reduce its volume, leading to an accumulation of polluted water, especially as development continues and more impervious surfaces cover the landscape (Dhakal & Chevalier, 2017).

To counteract the unsustainability of grey infrastructure, "green" infrastructure has arisen. Green infrastructure (GI) mimics nature by capturing stormwater and allowing rain to infiltrate where it falls. Thus, the goal of GI, converse to grey infrastructure, is to reduce and treat stormwater at its source (U.S. Environmental Protection Agency (EPA), 2015). These practices often incorporate living materials, like vegetation and soil, and common examples include rain gardens, green roofs, trees, and permeable pavement. GI technologies are easily scaled to fit site constraints and aesthetic requirements, resulting in systems which are functional amenities. Furthermore, GI has become increasingly popular recently due to the ability for these practices to provide various environmental, social, and economic benefits. These benefits further the sustainability of GI and include improved air quality, increased wildlife habitat, enhanced community livability, reduced energy demand, and many others (Elkington, 1994; EPA, 2015). These benefits primarily stem from the integration of nature, as well as the drawing of people to these areas and the interactions which come from this behavior, such as environmental learning and stronger social ties.

Therefore, GI has the potential to both remedy municipalities' stormwater infrastructure and initiate positive social and economic change in host communities. However, the strategies which enable this transition are not well-established, and because it is impractical to commence projects in every community, equity of implementation becomes an important challenge. Generally, each municipality faces a similar set of obstacles. The first obstacle faced is altering the perspectives of those in charge of the decision-making process, such as government officials and civil engineers. The second obstacle is the planning and organization of such a transition. The third and final obstacle is receiving community acceptance and ensuring proper long-term operation and maintenance. This paper addresses these obstacles by determining actions municipalities and their associated communities can take within the context of green infrastructure to democratize the decision-making process and increase equity of implementation.

Actor Network Theory: Interdependence of Humans and Non-Humans

To understand the power dynamics involved in green infrastructure implementation, it is necessary to recognize green infrastructure as a sociotechnical system, meaning it is composed of technology, humans, and the interaction between the two. To analyze the workings of this system, a framework is needed which accounts for this sociotechnical reality. Actor-network theory (ANT), as posited by Bruno Latour, suits this role, particularly because green infrastructure is already readily understood as a network (Latour, 1992; Lennon, 2015). Rather than claiming that technology is formed through negotiations between people and institutions, or that technology determines the relationships between people and institutions, ANT asserts that people and technological artifacts, considered nonhumans, are both actors that affect each other through their relationships. These human-nonhuman relationships result in a network which shapes the behavior of the included actors. Further, this network is constantly shifting and evolving due to the erasure of old actors and enrolling of new ones. However, one key notion of ANT is that an actor can only act, or gain agency, if in combination with other actors because the other actors and relationships provide the power to do so. For example, it would not be possible for schools to educate students during the COVID-19 pandemic if students, teachers, or administration did not have access to computers and the internet. Thus, because of this relational dependence, the primary uses of ANT are to determine how networks form, trace the associations involved, understand how those associations shift, and assess the stability, or instability, of the resulting network.

Especially important to the application of ANT is the terminology put forth which describes the interactions between humans and nonhumans. In these networks, humans are responsible for delegation of specific actions to nonhumans. In turn, nonhumans are responsible for prescription of actions back onto humans. If some humans are unable to complete these prescribed actions, then the nonhuman discriminates against this group due to the adoption of assumptions of the humans which designed them. In this way, humans can “act a distance” through nonhumans (Latour, 1992). In sum, the relationship between the actions of humans and nonhumans can be understood by recognizing their program of action, or the goal of the actor's action. If the resulting discrimination of a nonhuman is not cohesive with the program of action of the human, the system must be redesigned.

To make sense of these terms, consider an example. An architect is hired to design a new apartment building. The architect delegates the action of transporting humans from the ground to the apartments with a staircase. The staircase prescribes that inhabitants are able to climb up and down the stairs. This staircase thus discriminates against handicapped or elderly persons who are unable to complete the prescribed action because the architect assumed the inhabitants were able-bodied. Analyzing this situation, the architect's program of action is to make the apartments accessible for inhabitants, but the staircase only makes the apartments accessible for able-bodied inhabitants. Therefore, a redesign is required because the nonhuman staircase does not completely fulfill the human architect's program of action.

When applying ANT to a system, it is necessary to first determine the human and nonhuman actors and distinguish their level of agency. To determine a basis for agency, Latour proposes that one should ask two questions of each actor: Does its existence make a difference for another actor's action? And is there a way to detect if this difference occurs? If both answers are yes, then the actor has agency, whether or not it is human or nonhuman (Sayes, 2014). Additionally, by asking these questions, relationships and the actions which mediate them can be traced, which is fundamental to understanding the power dynamics of the system. Essentially, the perspective supplied by ANT requires nonhumans to be considered in the social context of a chain of events (Latour, 2005; Sayes, 2014). In other words, an action occurs in part because of how nonhumans function, thus illustrating the need for their inclusion in the network which underlies a system and governs its success.

Proposed Green Infrastructure Actor Network

Infrastructure mediates human relations by connecting and disconnecting people and flows, thus providing a material reflection of race and socioeconomic class tension (Guerrero, 2018). Green infrastructure is no exception to this observation, but those responsible for GI planning and implementation often obscure its sociotechnical nature through black-boxed bureaucratic processes where decisions are guided by normative ideologies, such as technical/social dualism (Finewood et al., 2019). More specifically, GI is perceived as complex and apolitical, something which can only be controlled by civil engineers and other qualified “experts,” who traditionally consider social issues as not being in their purview. Due to these realities, the social impact of GI is neglected. Nevertheless, there are consequences, one of the most detrimental being “green gentrification,” where the installment of GI facilities significantly improves neighborhood appeal, resulting in increased property values that displace low-income and minority residents (Hart et al 2019). Moreover, the success of GI heavily relies upon community stewardship and feedback concerning installed facilities. Without proper maintenance and funding for upkeep, multi-million-dollar designs will fail in practice. Therefore, communities play a major role in GI networks, and their exclusion only intensifies the second and third obstacles faced by municipalities, which are planning and community acceptance of GI. This dilemma opens the door for communities to assert their importance and pursue initiatives which can accomplish two key tasks: provide increased negotiating power for communities and actualize GI’s full potential. To determine the pathways which would offer such success, exploration of the existing actor-network is required.

GI systems at the municipal level encompass two interacting subnetworks. The first is the social network built of government officials, engineering and architecture consultants, researchers, environmental non-profits, property owners, and tenants. Today, the general public is also an important addition to this network, as the internet connects actors to a national audience. The second is the material network constructed of GI technologies which collectively provide the methods to manage stormwater effectively in a given watershed, as well as the built environment and pre-existing grey infrastructure, which both constrain and determine where stormwater management is most needed. Together, the actors involved have an overarching program of action, which is best summarized as the equitable transition of grey infrastructure to GI to actualize environmental, economic, and social benefits. Figure 1 illustrates both of these networks and the connections which exist between actors. Equivalent shading represents a similar level of agency.

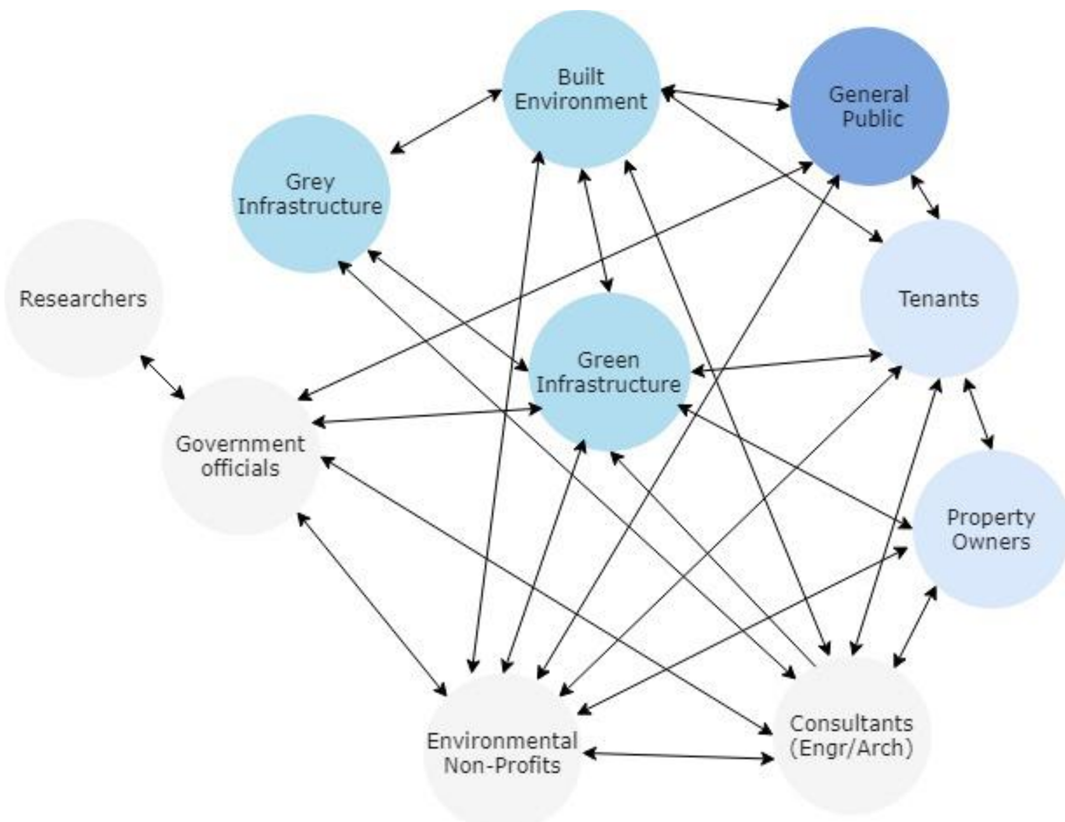

Figure 1. Green infrastructure actor network, composed of social and material subnetworks.

Primarily, alignment between these networks is facilitated by those who have the most agency, which are the conventional decision-makers (CDMs), meaning government officials and engineering and architecture consultants directly responsible for GI implementation. The civil engineers and architects craft GI designs, delegating the tasks of reducing pollutant loading and stormwater quantity to a variety of technologies distributed throughout the region. These designs operate under policy documents, which act as intermediaries that bring key actors into association, including government officials, civil engineers, architects, and researchers. Additionally, community members, including property owners and tenants, are enrolled into the social network through these policies, as public hearings and community engagement must be conducted by those responsible for GI projects to meet formal or informal requirements. Additionally, alignment of the subnetworks occurs when GI designs are constructed, as GI technologies have associated prescriptions and discriminations which affect the surrounding community. The foremost prescription of GI onto the community is maintenance of these technologies. However, if the community lacks the funding or resources, as is often the case for disadvantaged communities, these technologies discriminate against the members of that community. Unfortunately, the subsequent underperformance is prone to misinterpretation and results in unfair treatment of those communities and skepticism of GI technologies.

To resolve the frustration experienced by these actors, engineering and architecture consultants can clarify prescriptions of GI through increased communication with the host community and local government. However, to resolve the discrimination experienced due to variance of available community resources, CDMs must pursue action to reform GI. Therefore, guiding policies for GI must change to better represent communities. The problem thus becomes the determination of strategies to spur democratized decision-making. One theoretical solution is community activism, which enrolls the last actor, the general public. Broadcasting experienced issues and frustration reveals how existing policies may inadvertently act wrongly towards communities, and the general public has the capacity to persuade CDMs through augmented advocacy on behalf of the community. There may also exist other pathways for success, but the connection between communities and CDMs must be realized to fulfill the collective program of action.

Research Design and Methods

The potential of community activism is promising in theory, but the primary result of democratizing decision-making and secondary result of increasing equitability and efficiency of GI requires actions to be taken and correctly navigated by and on behalf of communities. To determine what these specific actions are, the following question is proposed: what actors and actions are necessary for the incorporation of communities in GI planning and policy?

This question was answered through conducting eight semi-structured interviews (Finewood et al., 2019; Thorne et al., 2018) with representatives from groups of human actors that are involved with communities through GI, which include engineering and architecture consultants, government officials, environmental non-profit personnel, and academic researchers. Interviewee candidates were collected by leveraging existing personal networks and verifying experience with GI community involvement. After initially contacting six actors who met these characteristics, a snowball approach was employed to expand the candidate list. Associated groups of selected actors are shown in Table 1.

Table 1. Interviews were conducted with eight green infrastructure actors.

Green Infrastructure Actors	
Associated Actor Group	**Number of Interviewees**
Consulting Firm (Engr/Arch)	3
Government	3
Academic Institution	1
Environmental Non-Profit	1
Total	8

Interviews were transcribed and analyzed to understand limitations of the proposed GI network, actor responsibilities, common difficulties, and transferrable strategies for increasing community agency. Conveyed perceptions were supported by prior literature, policy documents, and published media concerning the discussed initiatives, projects, or policy outcomes. The geographical scope in which these actors exist was largely limited to the Mid-Atlantic region of the U.S. The four-component model of procedural justice, which speaks to the fairness of who is included in decision-making and to what extent, was adapted and employed to guide the evaluation of outcomes (Maiese & Burgess, 2020). The four components assessed include formal decision-making, formal quality of treatment, informal decision-making, and informal quality of treatment (Tyler & Blader, 2000; Tyler & Blader, 2003). In this manner, the fairness of the resultant outcomes will be analyzed and used to identify valuable strategies for actor uptake.

Results

Expectedly, the proposed GI actor network underestimated the number and importance of select human and nonhuman actors revealed during interviews. Nonhuman actors were mentioned just as many times as human actors, displaying the reality of interconnectedness between human and nonhuman subnetworks. Concerning human actors, most were discussed favorably, and the community, general public, and government were perceived to have significant influence upon GI implementation. Specifically, the government was identified as having the most responsibility for these implementation efforts. Common difficulties cited by interviewees included the general public's unfamiliarity with green infrastructure and stormwater management systems, the lack of property available to install GI, the unintended consequences of existing policy systems, and the required maintenance. Projects and initiatives found to raise the degree of procedural justice were parks, educational and workforce training programs, and outreach initiatives. Importantly, these forms of projects and initiatives operate on underlying principles which make explicit the connection of human to nonhuman and focus upon building existing social infrastructure of communities, and they also work jointly to combat the noted difficulties associated with GI by increasing awareness and resources, such as labor for maintenance or property for GI opportunities.

Restructured green infrastructure actor network

Before determining the actions that enhance community agency in GI, the proposed GI actor network was updated to reflect the actors mentioned by interviewees (see Figure 2). Nonhuman and human actor groups are distinguished by their associated color. Humans are shaded in various colors to represent the associations with each actor group. Nonhumans are monochromatic to reflect no specific association, as this study primarily focuses upon understanding roles of human actors. Links between actor groups are not drawn for the sake of legibility, but Table 1 illustrates the average number of mentions which the interviewees discussed all human and nonhuman actors through color, where a darker shade represents a larger number of mentions by the interviewee. Notable differences between the theoretical and the actual actor networks include the combination of tenants and property owners into the category of community, the replacement of built environment with general infrastructure, the replacement of researchers with academic institutions, and the addition of developers, contractors, water, policy and regulations, living organisms, digital infrastructure, and physical items.

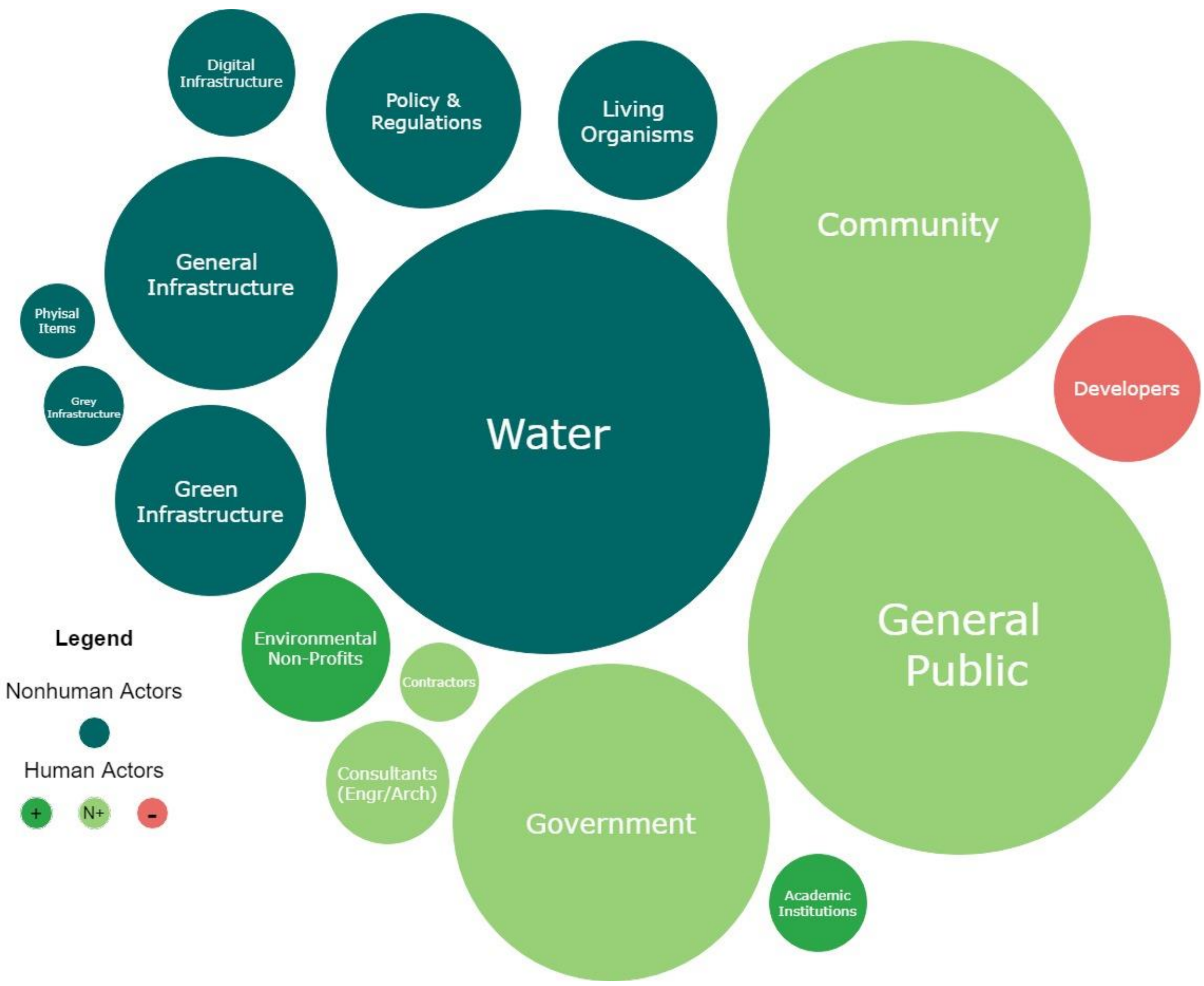

Figure 2. The theoretical green infrastructure network is restructured above. The color of human actor groups denotes their average association, such as positive, weakly positive, or negative. Size of each actor group is representative of total mentions in interview responses.

Table 1. The average number of mentions of each actor per interviewee actor group were calculated and shaded to illustrate the importance of human and nonhuman actors.

Links	**CM**	**GOV**	**ENP**	**PUB**	**CO**	**CN**	**D**	**ACD**	**GLI**	**GYI**	**DI**	**PI**	**LO**	**GI**	**W**	**P&R**
CN	28	25	9	24	1		9	7	10	1	6	3	5	8	18	8
GOV	16		7	27	7	4	11	6	21	8	9	4	16	20	59	20
ACD	21	6	11	42	0	4	0		7	0	10	0	4	4	5	7
ENP	19	10		27	1	3	4	0	9	1	4	3	8	2	2	4

Table 2. Meanings for abbreviations used in Table 1 are listed.

Abbreviation	**Meaning**
CN	Consultants
GOV	Government
ACD	Academic Institutions
ENP	Environmental Non-Profits
CM	Community
PUB	Public
CT	Contractors
D	Developers
GLI	General Infrastructure
GYI	Grey Infrastructure
DI	Digital Infrastructure
PI	Physical Items
LO	Living Organisms
GI	Green Infrastructure
W	Water
P&R	Policy & Regulations

The community and general public are perceived as significant actors by engineering and architectural consultants, government officials, academic researchers, and environmental non-profit personnel. This is highly beneficial for increasing community agency, as many of the human actors already recognize community influence within the process of GI implementation. Further, the interviewees perceived the community and general public favorably, meaning that communication pathways between CDMs and the community exist and that negotiations between communities and CDMs may not have to overcome previous or existing friction between actors.

Additionally, a larger number of nonhuman actors were considered by interviewee actor groups in the context of GI implementation, including general infrastructure, digital infrastructure, living organisms, policy and regulations, and water itself. These nonhuman actor groups are further broken down in Figure 3 to reveal specific actors within each. Throughout interviews, many GI difficulties experienced by CDMs revolved around limitations of these nonhuman actors. These difficulties will be expanded upon in the section concerning common themes exhibited during interviews.

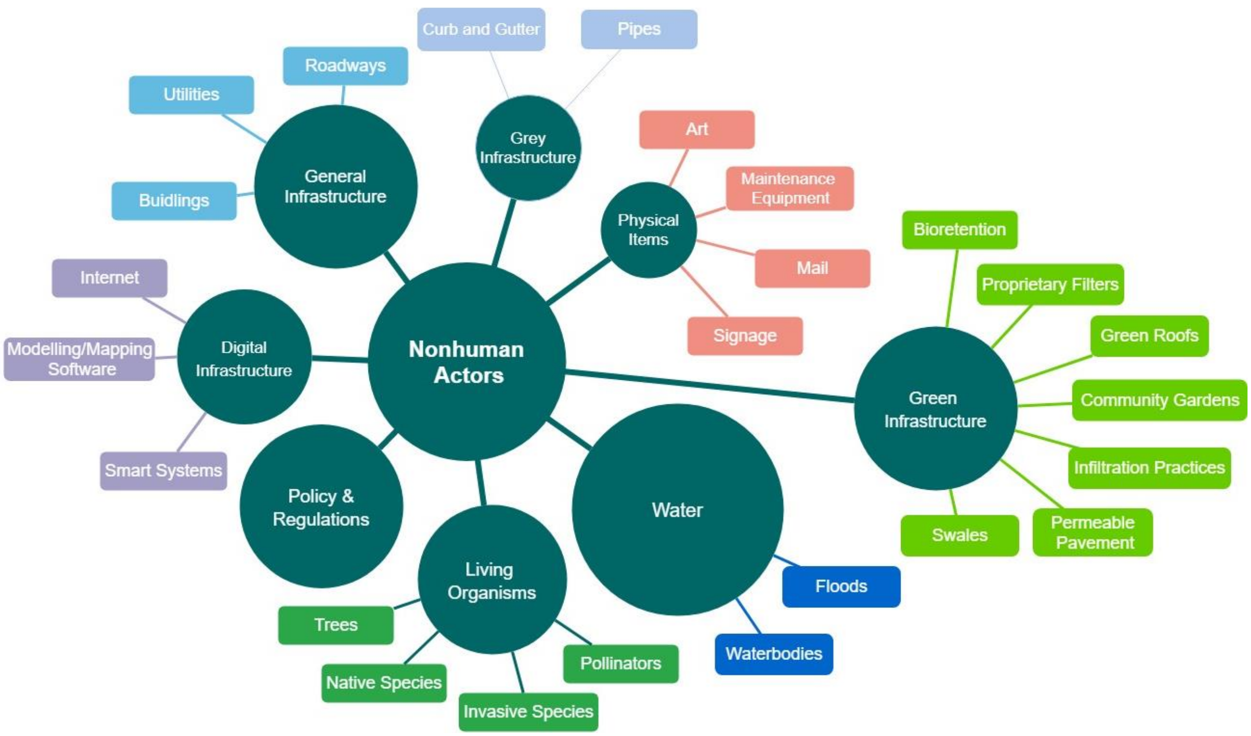

Figure 3. Nonhuman actor groups are composed of various nonhuman actors.

Responsibilities of human actors

Once these human and nonhuman actors were identified, perceived responsibilities of each human actor group were derived from interviewee responses. Each inferred responsibility and associated actor were counted and organized to determine collective expectations for the human actor groups. The actor group considered the most accountable for tasks associated with GI planning and implementation was the government, including federal, state, and local levels. Environmental non-profits, the community, and engineering and architectural consultants were also considered to be key groups in facilitating wider implementation of GI. Figure 4 displays the percentage of all identified responsibilities.

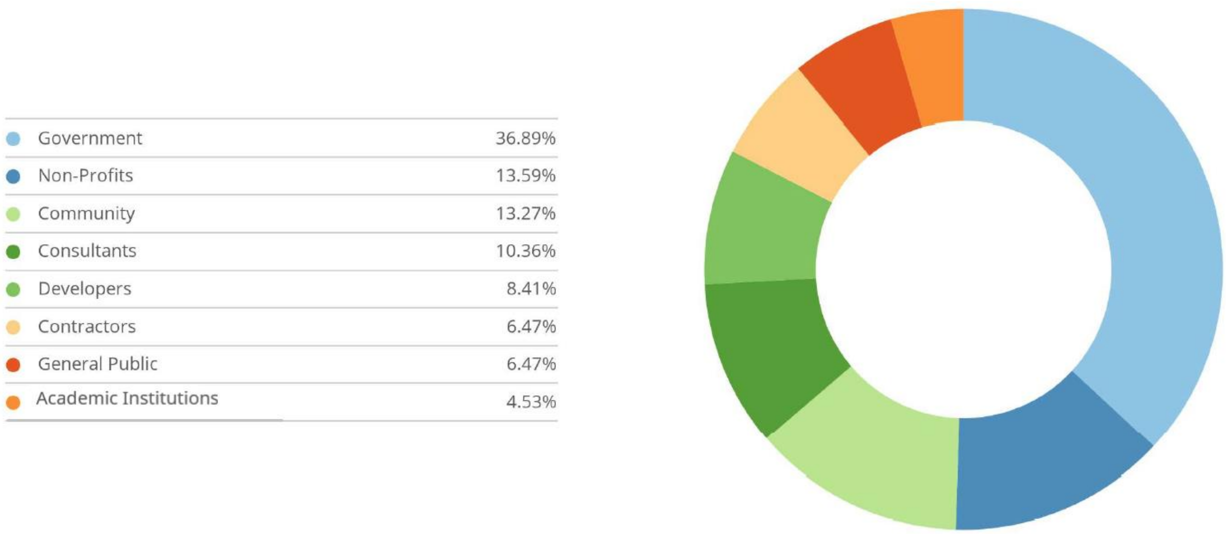

Figure 4. Percentage of GI-related responsibilities for human actor groups was found using the total responsibility count.

In addition to determining responsibilities for each human actor group, the number of interviewees who mentioned a specific responsibility was counted (see Appendix A). To understand common conceptions of responsibilities, Table 3 recounts responsibilities mentioned in at least half of the interviews. Oftentimes, conveyed responsibilities of human actor groups relied upon the completion of a corresponding responsibility of another human actor group. For instance, the local government is expected to inspect and maintain green infrastructure, but when municipalities are responsible for thousands of facilities, it is necessary to prioritize the maintenance schedule, which is done through communities providing feedback on the state of these facilities. Another example involving communities and governments is that communities are expected to use grants, but, first, governments are expected to provide grants and remove any barriers to entry for disadvantaged communities. Other examples can be determined from Table 3, and important dynamics between groups were further conceptualized through tracing common threads among interview responses.

Table 3. Common responsibilities for identified human actor groups were assumed to be those mentioned in at least half of interviews.

Human Actor Group	Responsibilities (Number of Interviews Mentioned In)
Government	Inspect and maintain green infrastructure (7)
	Secure funding for stormwater management (7)
	Recognize need for innovation (6)
	Develop regulations and adjust previous regulations (6)
	Provide grants for communities (6)
	Conduct community outreach (6)
	Recognize need for department/agency collaboration (6)
	Remove barriers to entry for grants and community engagement (5)
	Set high standard for community engagement (5)
	Identify opportunities and challenges for stormwater management (5)
	Meet federal and state permit requirements (MS4/TMDL) (5)
	Develop climate resiliency goals and plans (5)
	Listen and react to community complaints (4)
	Translate technical concepts for public understanding (4)
	Determine cost-efficiency of green infrastructure projects (4)
	Understand effects of watershed on stormwater (4)
Environmental Non-Profits	Provide visibility through awards and certifications (5)
	Conduct community outreach (5)
	Convince community of green infrastructure's role (5)
	Recognize intersection of climate resiliency, environmental justice, and green infrastructure (4)
Community	Provide feedback on design, maintenance, and operation of green infrastructure (7)
	Recognize benefit of balancing priorities (6)
	Form and engage in civic organizations (6)
	Use grants (6)
	Build internal capacity (5)
	Consider effects of climate change (5)
	Provide local expertise to government/consultants/non-profits (5)
	Educate oneself if provided means to do so (4)
Consultants (Engr/Arch)	Seek and listen to community feedback (5)
	Design green infrastructure (5)
	Recommend innovative strategies to client (4)
Developers*	Initiate innovative green infrastructure approaches (3)
	Satisfy stormwater management requirements (3)
	Develop drainage design for site based on larger context (3)
General Public*	Participate in green infrastructure workforce training (3)
	Understand concept of green infrastructure (3)
	Pay taxes/stormwater utility (3)
	Broadcast environmental justice concerns (3)
Contractors	Build green infrastructure (4)
	Maintain green infrastructure (4)
	Provide workforce training for green infrastructure (4)
Academic Institutions*	Partner with government and non-profits to perform outreach (3)
	Maintain owned green infrastructure to set standard (3)

*Human actor groups with no responsibilities found common in at least half of the interviews. Responsibilities mentioned in at least three of the eight interviews are shown instead.

Common difficulties of green infrastructure

Following actor and responsibility identification, common themes regarding implementation of GI were ascertained to characterize relationships between human and nonhuman actors and recognize specific difficulties which actors must overcome to increase community agency in decision-making. These themes were referenced in at least five of the eight interviews. The first major obstacle consistently conveyed by interviewees was that the concept of "green infrastructure" is in itself difficult to grasp. Due to the invisibility or hidden nature of most stormwater management, the existence and decreasing efficiency of grey infrastructure is not acknowledged by the general public and thus most communities, so the need for green infrastructure is not established. Moreover, GI's intended function can be ambiguous. Green infrastructure performs a variety of stormwater management functions and offers many co-benefits, so definitions or explanations may be confusing without a full understanding or demonstration of the technology. This idea is best exemplified by the following quote from an officer of an environmental non-profit:

> Green infrastructure, LIDs, and stuff like that are totally an inside story for people who are understand about those issues, and nobody else really cares.

Another obstacle is compounded by the invisibility of stormwater infrastructure and is related to the obduracy of identified nonhuman actors, specifically general infrastructure, or the buildings, roadways, utilities, and other urban artifacts which compose a municipality, as well as the debate around privatization of property (Hommels, 2005; Goodman & Loveman, 1991). Due to the fixed nature of these components of the built environment and the increasing amount of privatized land that encompasses these components, governments lack the ability to fix disintegrating grey infrastructure or install GI practices. One local government official noted:

> The next step is knowing when not to put in a conveyance system and instead use green infrastructure, and we face that challenge in these neighborhoods. What limits us is that we don't have easements to put infrastructure in. All we have are small, narrow easements on our existing pipes, which basically consists of ditches.

The difficulty experienced in accessing and retrofitting private property drives local governments to implement large, universal stormwater solutions rather than small, integrated systems, which is much of what GI encompasses.

Further, the existing stormwater crediting system used by the state and local governments for granting stormwater management permits deprioritizes smaller, more context-dependent options by awarding more credit to larger alternatives and by allowing developers to purchase nutrient credits, or "quantifiable and certified units of improvement to the environment," from nutrient credit banks, which are lands designated for protection in the local sub-watershed (Natural Resources Conservation Service, 2015, p. 1). This is best stated by another local government official:

> It seems like in the last 10 years, we've sort of been swinging in the opposite direction, away from green infrastructure, away from low impact developments, towards things like maximizing the utility of your site so you can do as little onsite as possible in order to meet the rules.

Therefore, the actor groups that are ultimately responsible for GI, which are governments and engineering and architecture consultants, are dissuaded from implementing GI practices that are more context-dependent and would necessarily require input of local expertise from community members for success. Due to the decreased need for community input, community engagement by governments and developers tends to be cursory, creating a power disparity between these groups and the community, as noted by an engineering consultant reflecting on past experience working in the local government:

> It wasn't really assumed that anybody was interested in it. It was a technocratic machine that just cranked stuff out. If it was a development project, there would be some kind of perfunctory engagement, either put something on the website or maybe have a meeting.

This power disparity is especially emphasized in disadvantaged communities due to systemic barriers to entry. If a government, developer, or any other external organization approaches a community for engagement purposes, only those who have the time and education to understand the process and technology will participate.

The last, most emphasized difficulty with GI is the required maintenance. Since GI facilities require increased frequency of maintenance and specialized skills and equipment, property owners and local governments experience backlash from communities due to untended facilities. These maintenance requirements are increasingly problematized when context-dependent practices are employed, as they often require extensive knowledge of the installed plants and the desired function of the facility. One engineering consultant stated:

> People in local governments that have to maintain it are starting to get a little bit sour on it because, especially with vegetated communities, it takes a lot of maintenance. It takes specialized skills to maintain, particularly if there's invasive species that come in and get overgrown and the neighborhood starts complaining. Sometimes it's not that fun to be on that side of things. Frankly, that has to be figured out as a stormwater community if it's going to survive.

Community-based solutions for green infrastructure difficulties

Through understanding common difficulties experienced with GI, solutions which aid and employ the community as a central actor group can be formulated and employed to promote democratized decision-making and improve equitability of GI. During interviews, the discussed GI projects and initiatives completed by actors were assessed with regards to the community through formal decision-making (F-DM), formal quality of treatment (F-QT), informal decision-making (IF-DM), and informal quality of treatment (IF-QT). F-DM was represented by necessary community engagement procedures, F-QT was represented by allowance for community input opportunities, IF-DM was represented by level of community agency, and IF-QT was represented by the level to which equity was addressed in community engagement. Table 4 depicts results of these assessments. Additionally, the projects and initiatives were critiqued in terms of their effects on community engagement procedures after completion. The most successful types of GI projects or initiatives for enhancing procedural justice were found to be parks, educational/workforce training opportunities, and outreach initiatives. Unlike projects designing best management practices (BMPs), which are GI facilities constructed using statewide standards, these endeavors were usually expected to meet intensive guidelines for community engagement and frequently resulted in the organization or increased activity of community members.

Table 4. Analysis of discussed GI initiatives and projects using four-component model of procedural justice.

Human Actor Group	Type of GI Project /Initiative	Degree of: [During Project/Initiative] Community Engagement (F-DM)	Community Input Opportunities (F-QT)	Community Agency (IF-DM)	Equity in Community Engagement (IF-QT)	[After Project/Initiative] Improved Community Engagement (F-DM)
Private Firm	Park	1	1	1	0	Yes
Private Firm	BMP	1	1	1	0	No
Private Firm	Educational /Training Program	3	3	3	3	Yes
Government	BMP	1	1	1	0	No
Government	BMP	2	1	2	0	No
Government	Outreach	3	3	1	3	Yes
Academic Institution	Educational Program	3	3	3	3	Yes
Environmental Non-Profit	Park	3	2	1	2	Yes

Note. The degree to which these components were scored varies from 0-3, where 0 is equivalent to not required or no effort, and 3 is equivalent to inclusive or high effort.

Although types of projects or initiatives may vary depending on the determined needs of a municipality, the underlying principles of these efforts can be summarized to comprehend transferrable strategies. One of these underlying principles is the conception that green infrastructure efforts should entail approaches which directly connect human and nonhuman actor groups. By doing so, community members can actively participate in GI development, and through visual demonstrations, they are provided the means to learn and overcome the foremost obstacle of understanding green infrastructure. The enlightening power of demonstration was often cited and used by interviewees to facilitate this understanding. In fact, seven out of eight interviewees reflected on the utility of site walks and demonstration projects. A second key principle is the recognition that actor groups external to communities, including governments, consultants, and non-profits, should identify and engage existing social infrastructure within a community to determine the community's priorities and enable base-building. One engineering consultant framed it this way:

> Because really at the end of the day…we want to make sure that we're not stomping on what they have more concerns about. Who are we to say what they prioritize in that community?

Central to the utilization of any transferrable strategies is the need for them to be mutually beneficial to all involved actor groups. Thus, before and during conversations with the community, shared interests must be established to ensure collective, cohesive action and prevent detrimental outcomes. One such example is placing an emphasis upon existing communities and subsequently working to provide GI resources while keeping property prices low to prevent green gentrification. Opportunely, there has been an emergence of groups which recognize the intersectionality of issues like social justice, environmental degradation, and climate change because, according to half of the interviewees, the general public opinion in the U.S. has shifted to perceive coexistence with the environment as the pathway necessary for sustained human progress. Therefore, external groups may find that more community organizations have shared interests that can be activated for pursuing GI projects and initiatives.

Reflecting on these principles, perceived responsibilities, and the discussed actions taken by interviewees to accomplish GI efforts which resulted in increased democratization of decision-making, the necessary actors and actions for success in this area can be proposed. Table 5 displays these recommendations, and Appendix B provides an example infographic which can be shared amongst actors to promote awareness. Listed actors include governments, environmental non-profits, engineering and architecture consultants, the general public, communities, academic institutions, and contractors. Many of these actors, especially environmental non-profits, academic institutions, and consultants, have shared actions, meaning there are actions which can be completed by any of the actors listed. Ideally, each of those listed actors would individually pursue these shared actions.

Table 5. Actors and actions recommended for increasing community agency through GI efforts.

Actor(s)	**Action**
Government	Develop effective regulations for green infrastructure solutions that encourage innovation, allow for flexibility within standards, and further protect local waterbodies Provide grants for communities that emphasize community engagement and incorporate GI Recognize and remove barriers to entry for disadvantaged communities by critically analyzing requirements for grants and addressing communication disparities
Environmental Non-Profits	Increase visibility of GI through awards and certifications
Consultants (Engr/Arch)	Stay aware of advancements in GI technology and recommend innovative solutions to clients Design GI to simplify and clarify maintenance requirements
General Public	Broadcast and discuss environmental concerns or related issues Understand role of stormwater management and need for GI Vote for policies that enhance climate resiliency, equity, and/or grants for green infrastructure
Community	Provide feedback on design, maintenance, and operation of green infrastructure Form and engage in civic organizations Provide local expertise to government/consultant/non-profit Support GI projects through letters and word-of-mouth Participate in GI workforce training and/or educational opportunities concerning GI
Environmental Non-Profits, Consultants (Engr/Arch)	Help communities use grants and write grant proposals
Government, Environmental Non-Profits, Consultants (Engr/Arch)	Identify and engage existing social infrastructure of communities without overriding community priorities Provide adequate food, childcare, and other services necessary for engagement
Environmental Non-Profits, Academic Institutions	Develop programs and partnerships to educate youth about GI (tree planting programs, community volunteering, outdoor classrooms)
Environmental Non-Profits, Academic Institutions, Contractors	Create and offer educational or workforce training programs relating to the GI industry (design, maintenance, or building procedures for GI) Provide GI work opportunities for certified individuals

Discussion

The collective findings and proposed set of actors and actions largely agree with existing literature concerning green infrastructure as a concept and green infrastructure as a method for community wealth building and restorative governance. One of the most significant barriers for implementation is the ambiguity of the term "green infrastructure." Its meaning depends upon both the context and the communicator (Monteiro, Ferreira, & Antunes, 2020), which is emphasized by half of the interviewees noting confusion or multiple definitions when asked to define green infrastructure. However, all responses coincided with the definition of green infrastructure as "an interconnected network of natural areas and open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife" (Benedict & McMahon, 2006, p. 1). Therefore, it appears that the best understanding of green infrastructure is gleaned through maintaining a broad, encompassing description that is not tied to specific planning practices or terminology, such as the term "BMP," which was noted earlier.

Secondly, strategies for enhancing the equity of green infrastructure gathered from these interviews and prior literature commonly refer to approaches which focus upon community wealth building and restorative governance (American Planning Association, 2017; Cole, McPhearson, Herzog, & Russ, 2017; Grabowski 2020). Community wealth building can be thought of as a framework which aims to foster a place-based system wherein democratized decision-making results in inclusive, equitable outcomes (Bozuwa, 2019), and restorative governance can generally be understood as "doing things *with* people rather than *to* or *for* them" (Wachtel, 2016). Each of these theories underly the proposed actions and are ultimately required for municipalities aiming for resiliency, as trust between community members and all actors must be established to withstand uncertainty. Important identified pathways concluded from these sources, such as assisting with community grant proposals or developing educational and workforce training programs, revolve around early engagement of the community by external actor groups, like local governments, environmental non-profits, and engineering and architectural consulting firms. This early engagement fosters the conception of these organizations as reliable anchor institutions which can be trusted to include the community in decision-making and demotivate inequitable outcomes, such as green gentrification. However, for these actor groups to initiate these actions, responsibility must be acknowledged. As proven by the results of interviews, there is a common notion that the government is heavily responsible for the implementation of a green infrastructure plan. Therefore, actor groups must recognize that: (1) there will never be enough public funding or internal capacity for governments to singlehandedly solve issues related to green infrastructure and (2) successful green infrastructure outcomes for a collective future rely upon mutual support and shared resources (Benedict & McMahon, 2006; Bozuwa, 2019).

The main assumption which remains to be confirmed is the idea that once these external actors begin action, a positive feedback loop will be produced that will continually increase the viability and visibility of GI. This loop would theoretically begin with the removal of barriers to entry and the continued engagement of communities in GI implementation, which would increase a community's general knowledge and commitment to GI initiatives. Increased community awareness would then aid in combatting the local government's limitation of only having access to public easements, as this study shows that public and private lands must both be employed to form a resilient GI network. Further, educational and workforce opportunities would decrease the magnitude of maintenance barriers, as communities could volunteer or acquire employment through environmental non-profits and contractors to aid in maintenance of GI facilities.

Additionally, communication lines required for acquiring local expertise to design effective context-dependent GI facilities would be established and reinforced through commitment to communities. In this fashion, each of the common difficulties discussed by interviewees, which were invisibility of stormwater infrastructure, lack of available land for GI, required local expertise for context-dependent GI, and lack of resources for maintenance, would be diminished by initiating increased community engagement.

A significant limitation to this study is the lack of an interviewed community member or activist. Without this connection, it was not possible to incorporate direct insight into community organizations or community-led projects. Consequently, the proposed actions for communities and other actors may not be comprehensive enough to provide guidance for overcoming each of the three key obstacles municipalities face when implementing GI. Moreover, a lack of community input means that no community reactions to any existing or attempted educational or workforce training programs could be accurately gauged. Community perceptions of these programs are vital for their uptake and relative usefulness for communities and for GI. One aspect leading to this gap is the lack of community connections exhibited by personal networks. Other limitations include the difficulty of overcoming the intrinsic complexity of identifying actors and characterizing relations between actors when using ANT, as well as the difficulty of determining informal decision-making and informal quality of treatment without having firsthand experience with the community engagement described by interviewees. Although one of the advantages of ANT is its appreciation of the fluidity of reality, comprehensive documentation of a GI actor network requires significantly more time and data. Also, the four-component model of procedural justice employed here methodically addresses key components for fulfillment of procedural justice, but, without firsthand knowledge and involvement with community engagement procedures, these informal measures had to be estimated using the context and knowledge provided by a given interviewee. Therefore, the degree of equity in informal decision-making and informal quality of treatment are likely overestimates.

I plan on leveraging the information stemming from this research to direct my future conduct with communities, environmental non-profits, governments, and developers. Important lessons learned from interviews consisted of appreciating the existing social infrastructure of communities, actively developing my personal connections to communities in and out of work, directing projects to reflect community priorities as much as possible in expected project outcomes, and participating in and promoting initiatives which promote equity and environmental justice.

Conclusion

Climate resiliency may be central to the nation's current agenda, but the realization of a sustainable and equitable path forward within municipalities requires the recognition of interconnectedness of all humans and of humans with nonhumans, as well as expansive subsequent action operating on this principle (Biden, 2021). Notably, this recognition will also require the confrontation of systemic issues produced by current power dynamics, such as irresponsible development patterns, prioritization of universal solutions over context-dependent solutions, and displacement of disadvantaged communities. This process of recognition and confrontation can be aided by technologies such as green infrastructure, as green infrastructure operates on the principle of connectivity and distribution of influence, meaning that if it is to be successfully employed, conventional decision-makers, such as government officials and engineering and architecture consultants, must engage and enlist the help of communities. Through using community wealth building approaches, people and place can connect through green infrastructure to democratize decision-making and ensure equity of outcomes.

Future work needed to understand mechanisms for shifting power to communities in the realm of green infrastructure includes the collection of community input, observation and recording of challenges faced during completion of proposed actions, acknowledgement of green infrastructure policy challenges and solutions, and exploration of other successful actions not proposed in this study. However, if this technology is employed without recognizing the interconnectedness of humans and nonhumans or the importance of community involvement, the benefits provided by alternative means for human development, such as GI, will never be realized. The significance of green infrastructure is just as much its technical function as it is its ability to enhance the quality of living for its host community. Therefore, as one interviewee stated:

> The way we're going to be most successful in pushing ourselves towards different ways to think about the urban world is to identify many benefits instead of just one. We must learn to see things through a prism, instead of through a singular return on monetary investment.

To become resilient and persevere through future difficulties, networks of trust must be built by pursuing a course of action that values all actors, and that course will require a critical assessment of potential costs and benefits, where notions of cost and benefit do not revolve around short-term profit and instead value the continuation of people and their place, Earth.

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Appendix A. Complete List of Identified Human Actor Group Responsibilities

Organization	Responsibilities (# Interviews Mentioned In)
Government	Inspect and maintain green infrastructure (7)
	Secure funding for stormwater management (7)
	Recognize need for innovation (6)
	Develop regulations and adjust previous regulations (6)
	Provide grants for communities (6)
	Conduct community outreach (6)
	Recognize need for department/agency collaboration (6)
	Remove barriers to entry for grants and community engagement (5)
	Set high standard for community engagement (5)
	Identify opportunities and challenges for stormwater management (5)
	Meet federal and state permit requirements (MS4/TMDL) (5)
	Develop climate resiliency goals and plans (5)
	Listen and react to community complaints (4)
	Translate technical concepts for public understanding (4)
	Determine cost-efficiency of green infrastructure projects (4)
	Understand effects of watershed on stormwater (4)
	Take chances (3)
	Co-invest in innovative projects (3)
	Incorporate flexibility into standards (3)
	Acquire easements for green infrastructure (3)
	Hire consultants to design green infrastructure (3)
	Hire contractors to build and maintain green infrastructure (3)
	Improve efficiency of internal processes (3)
	Adopt standards created by non-profits (3)
	Encourage demonstration projects (3)
	Provide tours of demonstration projects (3)
	Create and support green job initiatives (3)
	Communicate with developers and consultants to promote long-term planning (2)
	Convince internal contacts of green infrastructure's role (2)
	Promote consideration of stormwater management in initial stages of projects (2)
	Require educational signage (2)
	Approve permits (2)
	Use social media to connect with community (2)
	Model and monitor water quality (2)
	Simplify green infrastructure design and maintenance (2)
	Actively prevent community displacement (2)
	Provide community engagement information collected at initial project stages
	Require community engagement metrics reflective of equity
	Apply for grants on behalf of community
	Partner with non-profits to provide workforce training
	Provide volunteering opportunities to community
	Limit use of nutrient credits by developers
	Adopt grey infrastructure on private property
Environmental Non-Profits	Provide visibility through awards and certifications (5)
	Conduct community outreach (5)
	Convince community of green infrastructure's role (5)
	Recognize intersection of climate resiliency, environmental justice, and green infrastructure (4)
	Address inequities in access (internet/parks) (3)
	Develop workshops to disseminate stormwater management strategies (3)
	Partner with schools/academia to construct demonstration projects (outdoor classrooms) (3)
	Acquire good community reputation (3)
	Recognize detriment of saviorism (3)

	Maintain relationships with community (3) Help communities use grants and write grant proposals (2) Follow community engagement requirements (2) Provide workforce training for green infrastructure (2) Offer workforce training certification (2) Build upon existing social infrastructure (2) Aid government by conducting watershed studies (2) Perform tree planting initiatives (2) Remove barriers to entry for community engagement (2) Set standards for stormwater management Understand available green infrastructure data Use social media to connect with community
Community	Provide feedback on design, maintenance, and operation of green infrastructure (7) Recognize benefit of balancing priorities (6) Form and engage in civic organizations (6) Use grants (6) Build and create internal capacity (5) Consider effects of climate change (5) Provide local expertise to government/consultant/non-profit (5) Educate oneself if provided means to do so (4) Support projects through letters and word-of-mouth (2) Maintain green infrastructure (2) Understand inequities in community
Consultants (Engr/Arch)	Seek and listen to community feedback (5) Design green infrastructure (5) Recommend innovative strategies to client (4) Have technical knowledge for green infrastructure design (3) Research social infrastructure of community (3) Understand community desires (3) Conduct public outreach (3) Collaborate with other disciplines (2) Remain aware of advancements in stormwater management (2) Convince government agencies (2) Provide educational materials (2) [Architects] provide creativity [Engineers] provide practical lens Aid in developing regulations Perform site walks with interested parties Address maintenance concerns in design Develop water quality reports for developers Improvise green infrastructure design if standards are not applicable Translate technical concepts for public understanding Consider long-term cost-efficiency of green infrastructure design Develop climate resiliency plans
Developers	Initiate innovative green infrastructure approaches (3) Satisfy stormwater management requirements (3) Develop drainage design for site based on larger context (3) Maintain green infrastructure (2) Respond to community concerns (2) Recognize existence of non-monetary benefits of designs (2) Generate profit (2) Apply for awards Provide funding Attain permits Take risks Set high standard for community engagement

	Maximize cost-efficiency of design in long-term and short-term
General Public	Participate in green infrastructure workforce training (3) Understand concept of green infrastructure (3) Pay taxes/stormwater utility (3) Broadcast environmental justice concerns (3) Understand role of stormwater management (2) Vote for policies that enhance climate resiliency and/or grants for green infrastructure (2) Broadcast government initiatives (2) Learn "soft skills" (communication) Critique government regulations Maintain properties
Contractors	Build green infrastructure (4) Maintain green infrastructure (4) Provide workforce training for green infrastructure (4) Move utilities (3) Clear project sites (2) Provide community with construction expectations Perform third party inspections Recognize cost-efficiency in collaboration efforts
Academic Institutions	Partner with government and non-profits to perform outreach (3) Maintain green infrastructure to set standard (3) Provide volunteering opportunities for community (2) Allocate funding for green infrastructure upkeep (2) Educate youth about stormwater management (2) Offer workforce training certification Partner with non-profits to provide green infrastructure training Hire consultants to design green infrastructure

Appendix B. Infographic for Community-Based Actions

Attached.

COMMUNITY-BASED ACTIONS

FOR GREEN INFRASTRUCTURE

GOVERNMENT

- Develop effective regulations for green infrastructure solutions that encourage innovation, allow for flexibility within standards, and further protect local waterbodies
- Provide grants for communities that emphasize community engagement and incorporate green infrastructure
- Recognize and remove barriers to entry for disadvantaged communities by critically analyzing requirements for grants and addressing communication disparities

ENVIRONMENTAL NON-PROFIT

- Increase visibility of GI through awards and certifications

ENGINEERING / ARCHITECTURE FIRM

- Stay aware of advancements in green infrastructure technology and recommend innovative solutions to clients
- Design green infrastructure to simplify and clarify maintenance requirements

COMMUNITY

- Provide feedback on design, maintenance, and operation of green infrastructure
- Form and engage in civic organizations
- Provide local expertise to government/consultant/non-profit
- Support green infrastructure projects through letters and word-of-mouth
- Participate in green infrastructure workforce training and/or educational opportunities

GENERAL PUBLIC

- Broadcast and discuss environmental concerns or related issues
- Understand role of stormwater management and need for green infrastructure
- Vote for policies that enhance climate resiliency, equity, and/or grants for green infrastructure

SHARED ACTIONS

ENVIRONMENTAL NON-PROFITS + ENGR/ARCH FIRMS

- Help communities use grants and write grant proposals

ENVIRONMENTAL NON-PROFITS, ENGR/ARCH FIRMS, + GOVERNMENT

- Identify and engage existing social infrastructure of communities without overriding community priorities
- Provide adequate food, childcare, and other services necessary for engagement

ENVIRONMENTAL NON-PROFITS, ACADEMIC INSTITUTIONS, + CONTRACTORS

- Create and offer educational or workforce training programs relating to the green infrastructure industry (design, maintenance, or building procedures)
- Provide work opportunities for certified individuals