



Diffusing responsibility, decentralizing infrastructure: hydrosocial relationships within the shifting stormwater management paradigm

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A paradigm shift process has begun in stormwater governance and management in the United States, away from centralized infrastructure and toward more decentralized practices. This transition is prompted by heightened climate change, increased urbanization, and an intense call for change in regulatory measures. Within this shift, two key and related developments have arisen: (1) the implementation of small-scale, green infrastructure, and (2) the increasing involvement of individuals and communities in managing stormwater. Despite a perceived need for this paradigm shift by most experts, there continues to be slow progress toward achieving decentralization due to changes involving redefining who is responsible for managing stormwater and how and where stormwater management is being managed. Through semi-structured interviews and Q-methodology within two urban watersheds in Maryland and Washington DC, we assess perspectives on the evolving stormwater paradigm among residents and stormwater professionals, such as nonprofit organizations, funders, policy makers and researchers. We evaluated differences in stakeholder perspectives related to who is responsible for management, the best ways to do it, and the future of stormwater management. We identified three hydrosocial relationships that stakeholders have with stormwater: Market Decentralists, Anti-Market Decentralists, and Technocratic Opportunists. Across these hydrosocial relationships, we demonstrate that there is agreement for decentralizing stormwater management through infrastructural changes and involvement of residents and communities. Nevertheless, substantial differences remain as to how stormwater is viewed, the role and responsibilities of residents, and the most effective policies to engage with residents and communities. We highlight how these differences represent significant hurdles toward implementing decentralized infrastructure and involving residents and communities in managing stormwater. Using these insights, we discuss the potential for alignment and cooperation among these diverging hydrosocial relationships and continuing the shift toward decentralized stormwater management.

Keywords: stormwater; hydrosocial; water governance; decentralization; Q-methodology

1. Introduction

Stormwater management is currently undergoing a paradigm shift, especially within urban areas (Brown, Keath, and Wong 2009; Cousins 2018; Dhakal and Chevalier 2016). This shift has been driven by increasing concerns surrounding the public and environmental

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health issues caused by stormwater, more frequent severe storm events, and an overall increase in urbanization across the USA (Roy *et al.* 2008; Wilfong and Pavao-Zuckerman 2020; Wong, Rogers, and Brown 2020). To address these growing concerns, stormwater governments have begun rethinking how and where stormwater is managed, as well as who partakes in, and is responsible for, stormwater management (Patra *et al.* 2021). Two important developments underpin these evolving changes – the implementation of more decentralized infrastructure and the practice of recruiting residents and communities to manage stormwater from privately-owned property.

Historically in the USA, stormwater management and governance has been highly top-down and technocratic where planning and decision-making was conducted entirely by scientists, engineers, and policymakers (Finewood 2016; Karvonen 2011; Trowsdale, Boyle, and Baker 2020). State and local governments have used gray infrastructure, characterized by centralized conveyance systems that temporarily detain or slow the flow of stormwater prior to treatment at large-scale treatment plants (Dhakal and Chevalier 2017; Eger, Chandler, and Driscoll 2017; Frantzeskaki 2019). This technocratic, centralized management style primarily aimed to protect public and environmental health from the potential adverse effects posed by uncontrolled stormwater runoff. Overall, centralized stormwater management infrastructure has improved stormwater management throughout the USA, reducing the hazardous impacts of stormwater flooding and pollution in cities (Ehlers 2009).

Over the past few decades, however, significant concerns have been raised surrounding the ability of these centralized systems to continue to protect public and environment health (Barrett 2005; Dhakal and Chevalier 2016). Across the USA, centralized stormwater management systems, which were built upwards of seventy years ago, are frequently overwhelmed during storm events due to higher proportions of impervious surfaces and more intense precipitation dynamics within urbanized areas (Brown, Keath, and Wong 2009; Ehlers 2009; Loperfido *et al.* 2014). These infrastructural failures and impacts on public and environmental health have prompted increased concerns about improving and rethinking stormwater management and governance in urban areas (Cettner *et al.* 2014; Gandy 2004).

In response, beginning in the early 2000s, a shift away from the established centralized infrastructural systems and toward a more decentralized approach began. This decentralization is twofold: a decentralization of infrastructure and decentralization of management. This shift was accompanied by stricter stormwater regulations at the federal, state, and local levels building on the Clean Water Act (CWA) and National Pollutant Discharge Elimination System (NPDES) (Ehlers 2009). These stricter regulations require the management of stormwater on-site at new developments, increasing the use of more decentralized, green infrastructure (GI) across the landscape. In the United States, GI has primarily been utilized for stormwater management and is characterized by small-scale practices that mimic natural processes such as infiltration and evapotranspiration (Jefferson *et al.* 2017; McIntyre *et al.* 2016; Meerow and Newell 2017). More broadly, GI has been introduced alongside Nature-Based Solutions (NBS) which pushes for a transition toward building infrastructure that re-introduces ecosystem services to the urbanized landscapes (Frantzeskaki 2019; Kabisch *et al.* 2017; Matsler *et al.* 2021). These NBS and GI approaches promote more stakeholder engagement in planning and decision-making; for stormwater management this tends to entail a decentralization of infrastructure across the landscape and smaller-scale infrastructural practice (Pahl-Wostl *et al.* 2010; Schuetze and Chelleri 2013).

Despite these stricter regulations and the push toward decentralization, there continues to be slow progress toward these endpoints (Cousins 2018; Dhakal and Chevalier 2016; Roy *et al.* 2008). One major issue inhibiting progress (Eckart, McPhee, and Bolisetti 2017; Finewood, Matsler, and Zivkovich 2019; Jefferson *et al.* 2017), especially in highly urbanized areas, has been coined the “private vs. public dilemma” (Dhakal and Chevalier 2016; Lemos and Agrawal 2006; Trowsdale, Boyle, and Baker 2020). This issue in stormwater management, created by the CWA, is characterized by the inability of governments to directly regulate stormwater emanating from private property. Despite this, the responsibility for the management of this stormwater is still placed onto state and local governments, rather than the local landowner (unless new development occurs on the privately-owned land). In urbanized areas, public spaces and new developments, where state and local governments have authority to implement stormwater infrastructure, are a small portion of the total area producing stormwater (Dunn 2010; Karvonen 2011). Coupled with this disparity in land ownership, private lands are broken up into countless parcels with separate and distinct owners, making management on private property even more complex and difficult. As a result, these enhanced stormwater regulations remain insufficient to create noticeable changes in how and where stormwater is managed in urbanized watersheds.

Many stormwater professionals actively acknowledge that meeting stormwater regulatory requirements is highly reliant on residents’ participation on privately-owned land; however, this represents a significantly large undertaking due to the large amount and diverse set of private property owners within urban and suburban areas (Green *et al.* 2012; Meerow and Newell 2017). To begin to overcome this “private vs. public dilemma,” state and local governments are actively engaging with residents and communities to promote their involvement in the management of stormwater. State and local governments have begun implementing outreach programs to educate residents and communities about stormwater management (Chesapeake Bay Foundation 2020; Montgomery County Department of Environmental Protection 2021). In addition, local governments have begun enacting a stormwater utility fee and rebate system to engage residents and communities with stormwater management (The Watershed Protection and Restoration Act – HB 987 A Stormwater Management Utility to Clean Water 2015). The stormwater utility fee is a charge added to a water bill that is calculated by the size and percentage of impervious surfaces on a given property. This fee is used to fund stormwater infrastructure improvements throughout cities and to provide a financial incentive for property owners to mitigate the stormwater emanating from their properties (Stormwater Fee Background 2021; The Watershed Protection and Restoration Act – HB 987 A Stormwater Management Utility to Clean Water 2015). Property owners can implement stormwater best management practices on their properties to receive a rebate against these stormwater utilities fees.

1.1. Research questions

Despite these programs, most urban and suburban residents continue to have little knowledge of where, how, and who manages stormwater due to the decades of centralized, underground, and top-down management and infrastructure (Baptiste 2014; Green *et al.* 2012; Trowsdale, Boyle, and Baker 2020; Turner *et al.* 2015). As a result, there continue to be many questions and concerns among residents and communities about their roles, responsibilities, and duties toward managing stormwater (Giacalone *et al.*

2010; Keeley *et al.* 2013; Langemeyer *et al.* 2016; Maeda *et al.* 2018; Turner *et al.* 2015). Additionally, most stormwater professionals and government officials acknowledge that individual involvement on private property through the implementation of household-scale best management practices is necessary, but there are questions about the most effective and equitable policies and techniques to recruit and enlist their involvement. Throughout this study, we attempt to address the following research questions:

1. What are the roles, responsibilities, and duties of individuals toward managing stormwater?
2. What are the most effective and equitable policies and techniques that state and local governments can use to increase individuals' involvement in stormwater management?

These questions and concerns within this evolving paradigm continue to severely limit progress toward decentralizing stormwater management and the involvement of residents in managing stormwater (Cousins 2018; Dhakal and Chevalier 2017; Roy *et al.* 2008).

1.2. Theoretical framework

To address these questions, we use the hydrosocial cycle theoretical framework to explore various perceptions across stormwater professionals and urban residents concerning the shifting decentralization of stormwater management. The hydrosocial cycle promotes the assessment of water management and governance as socio-natural, where specific social relationships produce specific kinds of “water” (Budds, Linton, and McDonnell 2014; Linton and Budds 2014; Schmidt 2014). Through these socio-natural processes, the framework promotes increased attention and consideration to the role of power relationships in shaping and defining “water” (Bakker 2012; Gandy 2004; Heynen, Kaika, and Swyngedouw 2006; Swyngedouw, Kaika, and Castro 2002). The hydrosocial cycle emphasizes that water and society are inherently related, where each provides meaning and context to one another (Linton and Budds 2014). Within the cycle, water-society relationships are shaped and constructed that convey how water's production, meaning, value, and context is the product of the co-evolution of water and society (Budds 2008; Cantor 2021; Radonic 2019a). These co-evolutionary processes produce distinct hydrosocial relationships and can highlight how specific economic, social, cultural, and political dynamics shape, define, and reinforce these relationships (Hommes *et al.* 2019; Meehan and Moore 2014).

Within research on hydrosocial relationships, a major focus is subject formation or subjectivity. Subjectivity has been described as the way in which individuals reflexively understand themselves (Ekers and Loftus 2008; Radonic 2019a). Subjectivity represents a distinct hydrosocial relationship and tends to be shaped by political, social, and cultural factors, and the materiality of water. Subjectivities between individuals and water are influenced by dominant discourses and institutions (Wong and Sharp 2009). Importantly, water, technology, and infrastructure co-evolve, producing distinct relationships between individuals and water, typically resulting in inequities in water access, quality, and health (Anand 2019; Schnitzler 2021). Within this evolving paradigm shift in stormwater management, we seek to use Q-methodology (REFS) within

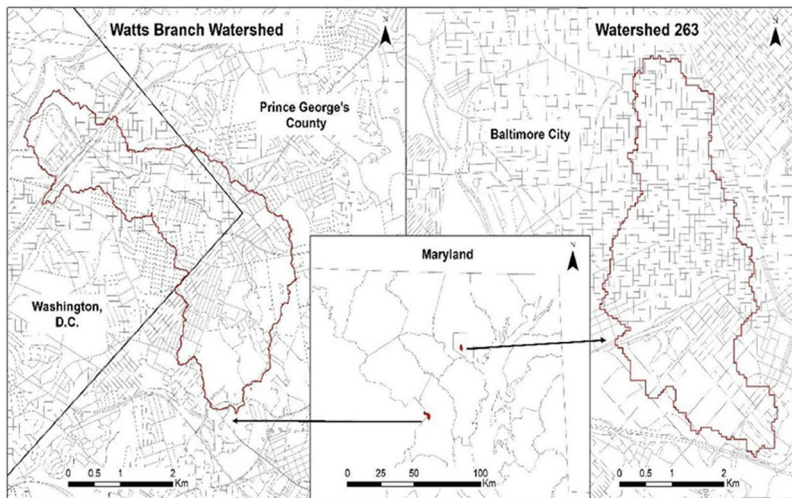


Figure 1. Map depicting the geographical location of each of the two study watersheds. Watershed 263 located on the southeastern side of Baltimore City and Watts Branch watershed located on the northeastern side of Washington DC, straddling Washington DC and Prince George's County in Maryland. The red line outlines the watershed boundaries for each watershed (Patra *et al.* 2021).

the hydrosocial cycle framework to explore the subjectivities and hydrosocial relationships between stakeholders and stormwater.

2. Study location and methodology

2.1. Study watersheds

Our research focused on two Mid-Atlantic urban watersheds: Watts Branch watershed and Watershed 263 (Figure 1). Watershed 263 resides within Baltimore City, Maryland and Watts Branch watershed crosses between Prince George's County, Maryland and Washington, District of Columbia (DC) (Patra *et al.* 2021). These two watersheds were chosen through community-based participatory planning alongside local nonprofit organizations, government organizations, and University of Maryland Extension (UME), to represent socioeconomically and physiochemically diverse watersheds, likely to exhibit varying hydrosocial relationships (Patra *et al.* 2021). Watts Branch watershed and Watershed 263 differ in socio-economic and physical characteristics, but both contain predominantly African American populations (Appendix, Table A1 [online [supplementary material](#)]) (Patra *et al.* 2021). Watershed 263 is significantly more urbanized compared to Watts Branch watershed, as measured by higher population density and impervious surface coverage. Additionally, Watershed 263 has lower median household incomes, education attainment, and a higher proportion of vacancy parcels as compared to Watts Branch.

Both Watershed 263 and Watts Branch watershed primarily utilize centralized, gray infrastructural systems to manage stormwater by conveying and transporting stormwater to wastewater treatment plants using complex systems of underground pipes and storage. Watershed 263 has a separated sewer system, meaning that household wastewater and stormwater pipes are separated from one another, while Watts

Branch watershed uses a combined system where stormwater and wastewater are transported together in the same pipes. In both watersheds, these centralized systems are frequently being overwhelmed during storm events due to a host of synergistic factors, including increasing urbanization and more frequent high intensity storms. As a result, incidences of flooding, stormwater pollution, and combined sewer overflows (when combined sewer systems overflow during a storm event leaking raw sewage into nearby waterways prior to treatment) have increased significantly over the past decade in these watersheds and other urbanized areas throughout the Mid-Atlantic. Both watersheds represent typical urbanized watersheds in the Mid-Atlantic region and the issues surrounding stormwater management within these urbanized areas.

Within both watersheds the two-fold transition toward more decentralized infrastructure and decentralized management of stormwater is underway. Local and state governments are increasingly implementing decentralized GI to manage stormwater and increasing community engagement efforts, including educating, empowering, and recruiting residents to partake in managing stormwater on their properties (Nature in the City: Sustainability Report 2019). Due to this ongoing shift in stormwater management, these two urban watersheds provide an excellent platform to investigate the evolving hydrosocial relationships between stormwater professionals, residents, and stormwater.

2.2. Study methodology

Q-methodology is a semi-quantitative approach to determine stakeholders' subjective understandings of a particular topic by testing statistical interrelationships between different interview statements across stakeholders (Brown 1996). By identifying and characterizing hydrosocial relationships using Q-methodology, we aim to highlight the potential drivers (political, economic, social, and cultural) that influence differences across the various relationships. We then aim to provide recommendations toward remedying divergent perspectives to facilitate the decentralization of stormwater management and to ensure more sustainable, resilient, and equitable outcomes across all stakeholders. Finally, we use this research to demonstrate the effectiveness of hydrosocial to situate and understand varying perspectives within environmental governance and management, more broadly.

Here, we used Q-methodology to group responses across two key stakeholder groups, stormwater professionals and residents, on their perceptions about the decentralization of stormwater governance and management. Q-methodology is a way to determine a person-subjective understanding of a particular topic (Brown 1996). The method is increasingly being used by social scientists interested in evaluating stakeholders' understanding of environmental issues (Barry and Proops 1999; Neff 2011; Robbins and Krueger 2000; Sneegas *et al.* 2021). Rather than measure responses to variables between people (i.e. how many people agree with a statement or set of statements), a Q analysis is meant to examine the interrelation of many different statements across individual stakeholders. This approach allows for a coherent "discourse" or set of beliefs about a particular topic, to emerge (Brown 1996; Webler, Danielson, and Tuler 2009). Researchers can then gauge which actors tend to align with particular discourses (Brannstrom 2011; Lansing 2013; Robbins and Krueger 2000). We use Q-methodology to assess potential differences and similarities in the hydrosocial relationships across stormwater professionals and residents, specifically toward the role of

residents in stormwater management and how individual involvement should be mediated through specific policies or techniques.

The Q-methodology research in this study was conducted in four main phases. Phase one consisted of forty-two semi-structured interviews with (22) stormwater professionals (government officials, university researchers, stormwater experts with non-profit organizations, funding agency officials, policy makers, and environmental activists) and (20) residents, both groups split evenly across watersheds. Respondents were chosen through purposive sampling, working alongside a Community Advisory Board comprising residents and stormwater professionals from local nonprofit organizations, government organizations, and the University of Maryland Extension working within these watersheds (Patra *et al.* 2021). Residents who had prior engagement with GI adoption through the local organizations were selected. These interviews employed six open-ended questions to understand the perceptions of stormwater management and governance of stakeholders from these watersheds (Appendix, Table A2 [online [supplementary material](#)]). These semi-structured interviews were conducted between March and November 2019 and lasted between 45 and 90 min each. Otter.ai was used to transcribe each interview and all identifying information was removed to maintain confidentiality (Liang 2021). A thematic analysis of these interviews was published by Patra *et al.* (2021), and more details can be found there.

The second phase of the research was a content analysis to extract concourse statements from within each interview using MAXQDA (MAXQDA 2021 [No. 2021]. [2021]). Each of the forty-two interview transcripts was read thoroughly and potential concourse statements were extracted that specifically provided a respondent's perspectives on stormwater management in these watersheds, specifically focusing on our two research questions: What are the roles, responsibilities, and duties of individuals toward managing stormwater? What are the most effective and equitable policies and techniques that state and local governments can use to increase individuals' involvement in stormwater management? The content analysis produced a list of approximately 750 statements across all respondents that reflected the range of perspectives for each of the questions. We organized these quoted statements based on the research question they respectively answered and the broader perspective they provided on each question. From these groupings, we developed a concourse of nineteen paraphrased statements that effectively covered the range of perspectives expressed throughout the interviews amongst all respondents (Appendix, Table A3 [online [supplementary material](#)]).

The third phase consisted of a Q-sort survey whereby respondents ranked concourse statements from strongly disagree to strongly agree on a quasi-normal distribution ranking system (Appendix, Figure A1 [online [supplementary material](#)]). A total of twenty participants completed the Q-sort survey, consisting of fourteen stormwater professionals and six residents. Due to the ongoing COVID-19 pandemic, the Q-sort process was conducted entirely online, using QMethod software, during November and December 2021 (Lutfallah and Buchanan 2019). Through the software, respondents were asked initial survey questions to help identify their watershed affiliation and resident or professional status (Appendix, Table A4 [online [supplementary material](#)]). The respondents were then presented with the Q-sort survey itself, where they were asked to rank the concourse statements (Appendix, Table A3 [online [supplementary material](#)]) on the quasi-normal distribution ranking system (Appendix, Figure A1 [online [supplementary material](#)]). After completing the Q-sort survey, respondents were asked

optional follow-up questions that could be used to better understand how and why each respondent ranked the concourse statements (Appendix, Table A4 [online [supplementary material](#)]). All participants were contacted via email and were from the pool of forty-two interviewees from Phase two and twenty other participants identified from interviews during Phase one (Patra *et al.* 2021). The response rate was 32.25%; however, smaller, purposefully chosen survey populations typically provide a sufficiently diverse range of perspectives in Q-methodology (Neff 2011; Robbins and Krueger 2000; Webler, Danielson, and Tuler 2009). Importantly, Q-methodology is more focused on identifying the groups or clusters in perspectives than the prevalence of the perspectives in the broader population.

The fourth and final phase of the research involved a correlation and factor analysis of the resultant Q-sorts. These analyses were conducted within the online QMethod software (Lutfallah and Buchanan 2019). The correlation and factor analysis mathematically works by creating “new variables” or factors that group together consistent rankings of statements. Pearson correlation and Principal Component Analysis (PCA) were conducted producing eight distinct factors. It is typical in Q-methodology for any factor with an eigenvalue greater than one to be kept for analysis if those factors represent a socially significant perspective and/or account for significant variance among the Q-sorts (Barry and Proops 1999; Brown 1996; Webler, Danielson, and Tuler 2009). Of the eight factors in our PCA analysis, three were kept for varimax rotation due to their higher eigenvalues (>2) and a substantial percentage of explained variance within the Q-sorts ($>10\%$). These three factors represented distinct and significant perspectives that identify and explain significant hydrosocial relationships present within the changing stormwater management and governance paradigm in these two urbanized watersheds.

3. Results

Three factors emerged from the factor analysis that portray significant thoughts, perceptions, and knowledge of stormwater governance and management within these two watersheds. The summarized statistics for the factor analysis are shown in Appendix, Table A5 (online [supplementary material](#)). Importantly, stormwater professionals and residents were identified within each of the three factors with the distribution of respondents for each factor shown in Appendix, Table A6 (online [supplementary material](#)). Two respondents (one Watts Branch watershed resident and one Watts Branch watershed professional) were not assigned a factor due to their high correlation with multiple factors and inability to distinguish an appropriate single factor. The factor analysis produces an “idealized” sort where statistically significant statement rankings represent important divergent views and perspectives across each factor. These idealized sorts for each factor and factor rank for each statement are shown in Table 1. We defined each of the three factors as (1) Market Decentralists, (2) Anti-Market Decentralists, and (3) Technocratic Opportunists. Each of these factors represent “descriptive archetypes” and perspectives on stormwater management and governance. These archetypes correspond to distinct hydrosocial relationships that arise due to varying influence of social, economic, cultural, and political factors on how these archetypes know, interact with, and view stormwater governance and management.

Across all the three factors, certain concourse statements were mostly agreed with or disagreed with, regardless of their assigned factor (Appendix, Figure A2 [online

Table 1. Identified factors and idealized rankings for each concourse statement for each factor produced through factor analysis and Q-methodology.

#		Factor 1 rank	Factor 2 rank	Factor 3 rank
1	Stormwater is an important resource in urban environments.	0*	1*	2*
2	Stormwater is a hazard to public and environmental health.	3	3	-1*
3	Stormwater is most effectively managed through large-scale centralized projects that capture and treat stormwater.	-2	-3	-2
4	Stormwater is most effectively managed through small-scale, decentralized green infrastructure.	1	0	1
5	The government should be solely responsible to manage stormwater.	-3	-1*	-3
6	All property owners should be responsible for the stormwater emanating from their property.	1	-2*	0
7	Local landowners lack the knowledge to effectively participate in stormwater management planning.	0	0	0
8	All stormwater planning and management decisions should be made with direct and continuous input from local landowners.	1*	1*	2*
9	Stormwater fees are necessary to ensure that cities and local governments have the funding required to effectively manage stormwater.	1*	-1	0
10	Stormwater fees have a negative connotation due to the inequity in who pays, how much each landowner pays, and how the revenues from the fees are utilized.	-2*	1	0
11	The stormwater fees, and rebates system promotes the implementation of stormwater management practices on private land.	2*	-1	-2
12	Stormwater fee and rebate systems are unjust and inequitable due to the inability for lower income landowners to either pay the fee or implement practices to receive rebates.	-1*	2	1
13	The future of stormwater management must be driven by technological innovations and scientific research.	0	0	3*
14	The future of stormwater management must contain a mixture of centralized and decentralized infrastructure.	2	2	1
15	The future of stormwater management must be decentralized and use small-scale infrastructural practices.	0	1	-1*
16	The best way to improve stormwater management is through updating existing large-scale, centralized infrastructure.	-1	-2*	-1
17	The best way to improve stormwater management is through adoption of small-scale, decentralized practices.	-1	0	0
18	The best way to improve stormwater management is through increased regulations and market-based approaches.	-1	-1	-1
19	The best way to improve stormwater management is through education and outreach.	0	0	1

Each of these factors: (1) Market Decentralists, (2) Anti-Market Decentralists, and (3) Technocratic Opportunists represent distinct perspectives and hydrosocial relationships between stormwater management and governance across residents and stormwater professionals. Values in bold and with * are distinguishing statements that are statistically significant at $p < 0.05$.

[supplementary material](#)]). Statements were identified where greater than half of the respondents had a shared ranking of the statement. For example, concourse statement one had thirteen respondents agree (ranked +1, +2, or +3) with the statement, while only two respondents disagree (ranked -1, -2, or -3) – demonstrating agreement with this statement broadly across all respondents. Additionally, concourse statements 2 and 14 were regularly agreed with, while statements 3, 5, and 16 were consistently disagreed with. Using a similar approach, statement rankings were compared across stormwater professionals and residents (Appendix, Figure A3 [[online supplementary material](#)]). Key differences arose surrounding statements 9, 12, and 17 that portray potential divergent perspectives between stormwater professionals and residents. These two figures portray convergences in hydrosocial relationships, demonstrating shared perspectives on stormwater management and governance. These areas of convergence are important to further situate and explain differences between the identified factors. While these areas of convergence are important, investigating the differences across respondent groups and using factor analysis highlights the distinct hydrosocial relationships arising within the shifting stormwater management paradigm.

3.1. Factor 1 – market decentralists

The market decentralists group was composed of eight respondents, seven stormwater professionals from both Watts Branch watershed and Watershed 263, and one resident from Watershed 263. Market decentralists, along with the other two factors, identify closely with the need to shift stormwater management infrastructure away from large-scale centralized infrastructure and toward smaller-scale, decentralized management practices. This perspective believes that decentralization also involves shifting the sole responsibility of managing stormwater away from the government and onto private landowners and communities. Uniquely, this group considers market-based approaches, like the stormwater fee and rebate systems, to be an effective mechanism to shift responsibility onto residents and communities while promoting the implementation of more decentralized, small-scale management practices across the landscape. For this factor, market-based approaches are important for state and local governments to raise funds dedicated to improving stormwater management and provide residents and communities with the financial incentive to partake in the management of stormwater on private properties.

Market decentralists strongly view stormwater as a hazard for public and environmental health. One Watts Branch watershed stormwater professional, assigned to the market decentralists' factor, conveyed this viewpoint during the post Q-sort survey response, explaining which concourse statement they most agreed with:

Stormwater is a hazard to public health and environmental health. I don't think there is any way you can dispute or argue with this statement.

This perspective believes that the primary goal of stormwater management is to protect society and the environment from the adverse effects of stormwater. Within this group, the responsibility to protect the health and safety of society and environment is not entirely that of the local governments, but also of all private landowners. Market decentralists place the most responsibility onto private landowners compared to

other factors, but suggest that market-based approaches and financial incentives are the best way to impart this responsibility onto all landowners.

For this perspective, state and local governments have the specific expertise and knowledge needed to make decisions on how and where to manage stormwater, but direct input from local landowners is necessary and important. Market-based approaches allow and promote state and local governments to use their expertise and knowledge to maintain control over decision-making and planning for managing stormwater. Collectively, market decentralists can be described as residents who view stormwater as a hazard that must be dealt with by the government, communities, and residents, alike. Market decentralists recognize that individual involvement and decentralization of management practices is necessary and suggest that market approaches, such as the stormwater fee and rebate system, can be a successful mechanism to begin this process.

3.2. Factor 2 – anti-market decentralists

This factor group contained two stormwater professionals, both from Watershed 263, and three residents, two from Watts Branch watershed and one from Watershed 263. As with the other two factors, anti-market decentralists describe the importance of decentralizing stormwater management through the implementation of smaller-scale management practices. During the post Q-sort survey, one stormwater professional from Watershed 263, describes the pitfalls of large-scale centralized systems:

Large-scale centralized solutions, they can't handle the loads. [Stormwater flows] often overwhelms the system (especially combined sewer/stormwater systems) causing sanitary overflows that are potentially more harmful than stormwater effects alone. No centralized system is large enough to handle it

This factor takes the perspective that decentralization is needed and the responsibility to support this shift in stormwater infrastructure lies primarily with state and local governments. Anti-market decentralists keep most of the responsibility on the government, while acknowledging that residents and communities should play a role. Notably, anti-market decentralists do not believe all property owners should be responsible for managing stormwater on their own property. Particularly, this group also strongly opposes market-based approaches, like the stormwater fee and rebate system, to involve private landowners in managing stormwater. Anti-market decentralists universally agree with the statement that a stormwater fee and rebate system is inherently unjust and inequitable, especially for lower-income residents and communities. During the post Q-sort survey, one anti-market decentralist, a resident from Watts Branch watershed, explained this perspective by stating that:

[Placing responsibility onto all landowners promotes] unfairness to low-income landowners. There should be a greater sense of equity across the board.

Like Market Decentralists, this factor perceives stormwater as a hazard for public and environmental health, ranking this statement the highest in the idealized factor sort. Anti-market decentralists perceive managing stormwater as one of the responsibilities of state and local governments to ensure protection of the public and environment

against the hazard of stormwater. This perspective identifies implementing new, decentralized management practices alongside the existing centralized infrastructure as the best way forward to improve stormwater management toward protecting society and the environment. Crucially, while anti-market decentralists agree that governments should not be solely responsible, the current market-based mechanisms to recruit communities and residents to manage stormwater on private properties is inefficient, unsuccessful, and inequitable. Anti-market decentralists seek to begin programs that work with and alongside residents and communities to connect them with the benefits and risks of implementing small-scale stormwater management practices on their properties – a more equitable and integrated approach than market-based techniques, such as the stormwater fee and rebate system.

3.3. Factor 3 – technocratic opportunists

The technocratic opportunist factor contained one resident from Watts Branch watershed and four stormwater professionals from Watershed 263. Technocratic opportunists align with the other two factors, suggesting that the decentralization of stormwater management is necessary – specifically, using more decentralized infrastructure and the involvement of communities and residents in the stormwater management paradigm. In contrast with the other two factors, technocratic opportunists suggest that this decentralization needs to be structured around, and driven by, technological innovations and scientific research. During the post Q-sort survey, one stormwater professional from Watershed 263 typified this perspective by stating that they most agreed with the statement that:

Technology and research are needed to better manage stormwater and increase the implementation of GSI [green stormwater infrastructure].

Technocratic opportunists identify that better infrastructure and technology is needed to treat stormwater, especially smaller-scale decentralized technologies. This factor acknowledges that the government, and stormwater experts therein, typically have more technical knowledge and expertise needed to implement and utilize these infrastructures. Despite this, technocratic opportunists highly agree that stormwater planning, and management decision-making must be made with direct and continuous input from local landowners. Along with this collaborative process, this group acknowledges that the government alone cannot manage stormwater effectively, especially in urban areas, and suggests that residents and communities should play a role in managing stormwater.

Most uniquely, technocratic opportunists regard and perceive stormwater as a potential “resource” rather than a “hazard,” as compared to the other two factors. This factor suggests that stormwater is an under-harnessed and underutilized opportunity and potential resource in urban areas. One stormwater professional and technocratic opportunist from Watershed 263 exemplified this perspective by stating during the post Q-sort survey that:

Stormwater is not necessarily dangerous to people and the environment. [If] harnessed/captured it can be beneficial for such things as irrigation and alternative energy production.

Technocratic opportunists identify that a reform of how stormwater is managed and governed is necessary to view stormwater as a “resource” rather than a “hazard.” By doing so, stormwater has the potential to become a valuable resource that can supply numerous benefits in urban areas, such as irrigation and alternative energy production. This factor represents a unique way of managing stormwater compared to the other two factors.

4. Discussion

These three identified factors represent distinct hydrosocial relationships between stakeholders and stormwater. Across these factors, there are converging views and perspectives that highlight the growing support for decentralizing stormwater management. Despite these similarities, substantial differences remain between perspectives on the best way forward toward this overarching goal of decentralization. Table 2 conveys a summary of key perspectives across each identified factor and highlights where these hydrosocial relationships converge and diverge in perspectives. Additionally, there appear to be areas of divergent perspectives between stormwater professionals and residents that are valuable to identify as significant hurdles that are slowing the decentralization of stormwater management, more broadly.

4.1. Convergent perspectives toward decentralization

Across all respondent groups and identified factors, there were two critical perspectives on the evolving stormwater management paradigm that were shared universally: the need to transition away from large-scale centralized infrastructure and the view that the government should not be burdened with the sole responsibility for stormwater management. Both views are at the root of the continuing push toward decentralizing stormwater management and are key areas of convergence across these hydrosocial relationships.

These convergences amongst the hydrosocial relationships show that these perspectives are commonly shaped by the political power dynamics that remain from decades of top-down, expert-based management (Bakker 2012, 2005; Gandy 2004; Heynen, Kaika, and Swyngedouw 2006; Swyngedouw, Kaika, and Castro 2002). State and local governments are harnessing their position as “experts” to promote decentralization that will both benefit public and environmental health, but also their political and economic bottom-line. We acknowledge that decentralizing infrastructure and diffusing responsibility will benefit stormwater management, more broadly; but it also portrays the continued political influence and power that state and local governments have on how, who, and where stormwater is managed. While these identified hydrosocial relationships are uniformly influenced by these dynamics, significant differences arise when investigating how these factors view the policies and techniques utilized to promote this decentralization.

4.2. Divergent perspectives on achieving decentralization

These areas, where hydrosocial relationships diverge, provide an important view into the varying perspectives on the shifting stormwater management paradigm. Across these three identified hydrosocial relationships and respondent groups, three primary

Table 2. Summary of key perspectives across six important topic areas for each identified factor, which represent distinct hydrosocial relationships, toward the current evolving paradigm in stormwater management.

Factor	Infrastructure for management	Responsibility to manage stormwater	Perception of stormwater	Policies to engage with individuals	Role of individuals	Future of stormwater management
	Convergences		Divergences			
1 Market Decentralists	Decentralize – need for more small- scale practices	Diffusion – government not solely responsible	Hazard – to public and environmental health	Fee and rebate system	Responsible for stormwater on/ from property	Mixture of centralized and decentralized practices
2 Anti-Market Decentralists	Decentralize – need for more small- scale practices	Diffusion – government not solely responsible	Hazard – to public and environmental health	Collaborative programs and policies	No responsibility	Mixture of centralized and decentralized practices
3 Technocratic Opportunists	Decentralize – need for more small- scale practices	Diffusion – government not solely responsible	Resource – for utilization in urban environments	Educational outreach programs	Responsible for participation in planning	Technological innovation drive changes

Areas of convergence and divergence are highlighted to show similarities and differences across each hydrosocial relationship.

differences arose that have substantial effects on overall transition toward decentralization: (1) how stormwater is viewed and defined, (2) the role and responsibilities of residents in managing stormwater, and (3) the most effective policies to engage with residents and communities.

4.2.1. *Hazard or resource*

Stormwater, including both rainwater and run-off associated with rainwater, has effectively been managed and defined as a “hazard,” “pollutant,” and “liability” throughout the top-down, centralized management paradigm (Brown, Keath, and Wong 2009; Cousins 2017; Wong, Rogers, and Brown 2020). In response to the growing transition toward decentralized management, many scholars have suggested that redefining stormwater, both rainwater and runoff, as a “resource” will benefit stormwater management (Cousins 2018; Karvonen 2011; Radonic 2018; Wilfong and Pavao-Zuckerman 2020). This transition in how stormwater is conceptualized and defined is still actively contested across stakeholders.

We argue that this transition toward redefining stormwater is primarily affected by political, social, and economic drivers (Cousins 2018; Dhakal and Chevalier 2017; Roy *et al.* 2008). For stormwater professionals: regulations, existing centralized infrastructure, and the political necessity to protect the public from flooding reinforces stormwater as a “hazard.” In contrast, stormwater professionals tend to have highly technical knowledge that could influence their ability to envision infrastructure and practices that utilize stormwater as a “resource” – this could be influencing the perspectives of the technocratic opportunists, who were predominantly stormwater professionals from Watershed 263. For residents, whether stormwater is viewed as a hazard or resource is impacted by economic standing. Lower-income communities are more likely to be negatively impacted by stormwater issues and, as a result, view stormwater as a hazard. Oppositely, residents in higher-income neighborhoods and communities, protected against flooding and pollution issues, can take advantage of stormwater as a resource (Baker *et al.* 2019; Berland *et al.* 2015; Chan and Hopkins 2017; Kong, Yin, and Nakagoshi 2007; Schwarz *et al.* 2015). We highlight these potential influences to demonstrate that, while redefining and managing stormwater as a resource is an ideal goal, multiple divergent hydrosocial perspectives remain that limit this transition.

4.2.2. *Role and responsibility of residents and communities*

Despite active outreach efforts and policies, our research suggests that there continues to be a lack of agreement and tension surrounding the role and responsibilities of residents and communities within stormwater management. The diffusion of responsibility for managing stormwater is being prompted by political drivers which seek to shape the social and cultural perspectives on stormwater and stormwater management, reminiscent of other forms of environmental citizenship (Gearey, Church, and Ravenscroft 2019; Sarmiento, Landström, and Whatmore 2019). Despite these political influences, the involvement of residents in stormwater management remains mostly a novel approach due to decades of top-down, centralized infrastructure and management and a lack of political and legal authority to mandate residents to manage stormwater emanating from their properties. As a result, the involvement, responsibility, and role of residents remains highly contentious. This is highlighted by the anti-market

decentralists' perspective, which importantly, is the factor which contains the highest number of resident respondents. This suggests that while political influences have been successful in educating residents about stormwater, the social and cultural transition toward universal responsibility is still debated and contested. We convey these discrepancies to suggest that political, social, and cultural factors are influencing and driving these factors separately and differently, creating distinct hydrosocial relationships between people and stormwater. Consequently, the overall diffusion on responsibility of managing stormwater remains primarily on state and local governments and the role that residents and communities can and will play in stormwater management continues to be questioned.

4.2.3. Policies to engage residents and communities

The final area of distinguishable differences between the factors was their perception of the most effective policies to engage with residents and communities for stormwater management. The perception of these policies was the most recognized difference between the factors and conveys how influential these policies are in shaping and defining the hydrosocial relationships between people and stormwater. Our research demonstrates that the current policies and outreach utilized by state and local governments to engage residents and communities will continue to limit the overall involvement of the public, especially private property owners.

We argue that stormwater fees and rebate systems can produce uneven benefits throughout cities as higher income communities can implement more stormwater BMPs on their properties (benefitting from the increased stormwater management and auxiliary ecosystem services); while, lower-income communities primarily pay the stormwater utility fee, rarely become involved in managing stormwater, and continue to rely on government interventions that are often insufficient to protect against stormwater (Baker *et al.* 2019; Berland *et al.* 2015; Chan and Hopkins 2017; Kong, Yin, and Nakagoshi 2007; Schwarz *et al.* 2015). Collectively, these policies driving individual and community involvement with stormwater management are highly impactful on shaping the hydrosocial relationships between people and stormwater. As a result, current and future policies must focus on influencing sociocultural aspects of these relationships and continued economic approaches must consider equity and justice concerns to ensure that the benefits of these policies are felt equally across all stakeholders.

5. Conclusions

This research and the use of Q-methodology and the hydrosocial framework has allowed for some important insights into the social, cultural, political, and economic factors influencing and shaping stormwater-society relationships within the shifting stormwater management paradigm. Our research indicates that there is acknowledgement and acceptance that this transition toward decentralization is necessary and essential. Across the identified hydrosocial relationships, there were converging perspectives on the need for the implementation of additional, decentralized GI and the involvement of residents and communities in the management of stormwater. Despite this broad-scale agreement, there are areas where stakeholders' perspectives diverge. These differences across hydrosocial relationships convey areas where changes are needed to

promote alignment and cooperation between the currently divergent perspectives. We argue that, until these areas of conflict and tension are ameliorated, there will continue to be overall slow progress toward an overall decentralization of stormwater governance and management. We briefly highlight two recommendations that can help to begin marrying the divergent hydrosocial relationships: (1) valuing stormwater and (2) promoting more collaborative involvement of residents and communities within planning and decision-making for stormwater management.

The process and transition through which stormwater is valued can help progress stormwater away from being conceptualized as a “hazard” and more toward a “resource.” The current types of infrastructure built and legal structures in place regulating stormwater hinder progress toward valuing stormwater as a “resource” in urbanized areas (Cousins 2018; Wilfong and Pavao-Zuckerman 2020). The implementation of decentralized, GI that manage and treat stormwater on-site allow for the harvesting and beneficial utilization of stormwater, especially at the household, residential scale (Keeley *et al.* 2013; Radonic 2019b). Additionally, GI can provide multitudes of auxiliary benefits, or ecosystem services, (urban heat mitigation, access to green space, air pollution abatement, etc.) that when effectively valued can push stormwater management infrastructure to be viewed as an important resource in urban areas, rather than a liability or necessity (Mittman and Kloss 2014; O'Neill and Spash 2000). Along with decentralized GI, updating the legal and regulatory framework for stormwater, will be important in this transition toward stormwater as a “resource.” This will be a significant undertaking, as decades of legal structuring and resulting infrastructure has been built to manage stormwater as a “hazard.” There have been a few examples of reworking water rights around stormwater or rainwater; however, successful examples required years of concerted legislative efforts and this overall reconceptualization of stormwater as a “resource” will require a complete overhaul of existing regulations (Cousins 2018; Radonic 2019a). We argue that this research demonstrates that the existing legal framework for managing stormwater promotes these divergent hydrosocial relationships and continued slow progress toward decentralization.

The current policies and techniques through which residents and communities are becoming engaged with stormwater management must be re-evaluated and adjusted. The current policies and programs promote divergent perspectives on how individuals and communities should be involved in stormwater management. As a result, the needed decentralization and participation of individuals in managing stormwater remains actively disputed. To overcome this, there must be more collaborative, participatory programs and policies through which residents and communities can discuss their views and needs within stormwater management to ensure that the process is not entirely technocratic and allows for more bottom-up approaches. This change will allow individuals to participate in defining their roles, responsibilities, and rights within stormwater management and begin to decide the outcomes and goals of their involvement. These policies cannot be a “one size fits all” solution and must be more diverse and adaptable for the various stakeholders involved. We argue that until the involvement of individuals and communities is designed to primarily serve the localized interests, the involvement of those outside the government and partnered NGOs in stormwater management will remain insufficient to progress toward broad decentralization.

In conclusion, this research has demonstrated that significant changes are needed within the shifting stormwater management paradigm, to overcome the differences among the emergent hydrosocial relationships between stakeholders and stormwater.

While this research conveyed a few of the hydrosocial relationships and perspectives prevalent within stormwater management, there are likely others, including amongst residents, with little to no knowledge of stormwater management. Despite this, our research highlights that the need for this decentralization is agreed upon across stakeholders, but the techniques and policies to achieve this transition is not. The process toward decentralizing stormwater management will remain inadequate to protect public and environmental health in the face of these divergent hydrosocial relationships, unless substantial regulatory and policy changes are supported and enacted.

More broadly, this research demonstrates the effectiveness of the hydrosocial cycle framework and Q-methodology to help identify the drivers behind obstacles facing transitions within water governance and management. Additionally, this research highlights that as decentralization of water governance and management occurs, attention to how different stakeholders are affected, burdened, and/or benefited must occur to ensure equitable and sustainable outcomes (Chelleri, Schuetze, and Salvati 2015; Herrfahrdt-Pähle *et al.* 2020; Massoud, Tarhini, and Nasr 2009; Pahl-Wostl *et al.* 2010). Overall, the inherent and growing linkages between water, technology and infrastructure must be at the forefront of water research to progress toward more sustainable, resilient, and equitable water futures.

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Supplementary material

Supplemental data for this article can be accessed [here](#).

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