Equitable Solutions for a Clean and Resilient Salish Sea

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Abstract

As urbanization continues to expand in the Puget Sound region, stormwater management has wide ranging impacts to human and ecosystem health and is therefore fundamental to creating equitable and sustainable cities. This paper brings forward dominant discourses between stormwater experts in regard to which solutions should be implemented in the Puget Sound region and what outcomes would be most beneficial to this ecosystem. We used Q-methodology to investigate differences in prioritization of stormwater solutions currently being considered in the region and considered how emergent perspectives may affect decisions for stormwater management. The purpose of study is to explore these perspectives to find which solutions lead to the most efficient and beneficial recovery of the Puget Sound ecosystem. Through centroid extraction analysis we discovered 3 discourses, each with different themes, values, and beliefs. Within our 21 participants, each shared common stormwater goals, the reduction of toxins to receiving waterways and reducing stormwater quantity. Though even with these shared end goals, our participants disagreed on the prioritization and overall outcomes of solution types. Those types being source control, green infrastructure, and gray infrastructure solutions which each lead to different co-benefits and environmental outcomes. Our findings are important to spark discussion between municipalities with differing worldviews and outcomes associated with stormwater management and to highlight multiple benefits associated with solutions and how they can be utilized in environmental justice actions.

Keywords
Stormwater Pollution, Q Methodology, Puget Sound, Green Infrastructure, Environmental Justice, Sustainability, Conservation

Introduction

Urbanization is one of the prevailing patterns across the globe (Tonne et al. 2021), with nearly 7 out of 10 people expected to inhabit cities by 2050 (World Bank,). Indeed, McDonald and Beatley (2021), suggest that we have entered is the "urban century" – a time when we must choose how we relate to and interact with cities. Urbanization can generate economic growth and vitality (Glaeser 2012); however, expansion of urban landscapes generates cascading impacts on ecosystems and human health, (e.g., Bratman et al. 2019; Bounoua et al., 2015 (e.g., Seto et al. 2011; Levin et al., 2020; Alberti 2010).

One of the most recognizable changes associated with urbanization is the removal of vegetation and replacement with impervious surfaces which increase the volume and peak flow of surface runoff (Goonetilleke et al 2005; Paule-Mercado et al., 2017). As surface runoff travels over parking lots, roads, roofs, and other imperious surfaces it picks up contaminants from residential neighborhoods, commercial and industrial areas, and roads before reaching receiving waters (Tsihrintzis & Hamdi, 1997; Barbosa et al., 2012). This stormwater runoff includes excess nutrients (Davis et al., 2009; Pitt et al., 1999), pesticides (Pitt et al., 1999; Bucheli et al., 1998), toxic metals (Davis et al., 2009; Mahbub et al., 2010), pathogens (Davis et al., 2009; Pitt et al., 1999), petroleum hydrocarbons (Davis et al., 2009; Pitt et al., 1999), and suspended solids (Davis et al., 2009; Hathaway & Hunt, 2011). These pollutants can lead to significant adverse effects downstream (Levin et al., 2020; Walsh et al., 2005). In particular, urbanized waterways suffer from 'urban syndrome'—a condition that results in low abundance and survival of sensitive aquatic and coastal species (Walsh et al 2005). In addition, stormwater can have serious consequences for human health. For example, exposure to metals in stormwater increases risk of cancer, hypertension and renal dysfunction (Ma et al. 2016)

The Puget Sound Region in Washington USA is one of the fastest growing urban areas in the U.S. With a population of 4,779,172, the Puget Sound region has increased in population size by more than 500,000 since 2010 (Trimbach et al., 2020) and is projected to increase by another 2 million in the next thirty years (PSRC, 2018). A rise in the coverage of impervious surfaces has accompanied population growth (Hepinstall-Cymerman et al., 2011), with concomitant impacts on contaminants reaching urban streams and receiving waters (Tsihrintzis & Hamdi, 1997; Barbosa et al., 2012; Gilbert & Clausen, 2006). These pollutants have had negative ecological effects in the Puget Sound. As examples: 1) Southern Resident Killer Whales (*Orcinus orca*) are exposed to high levels of contaminants including persistent organic pollutants (Mongillo et al., 2012) that cause health issues such as cancer, endocrine disruption, reproductive disruption, immunotoxicity, neurotoxicity, and neurobehavioral disruption (Mongillo et al., 2016); 2) runoff of the tire compound 6PPD-quinone from roads causes increased mortality of adult coho salmon (*Oncorhynchus kisutch*) prior to spawning (Tian et al., 2022).

Addressing stormwater is thus a pressing issue in Puget Sound (Messager et al 2021; National Research Council 2009) and beyond (Keeler et al. 2019). Even so, there are dozens of approaches to stormwater mitigation (US EPA; Prose, 2013) and thus determining what management practices to adopt is a matter of much discussion. There are three major sectors of stormwater solutions: green infrastructure, gray infrastructure, and source control: 1) Gray infrastructure for stormwater is storage structures and conveyances, most commonly made out of concrete and or metal, that are used to contain and control stormwater. (Svendsen et al., 2012; Dhakal & Chevalier, 2016); 2) Green infrastructure includes human-made structures that use soil and plants to reduce stormwater flow and/or increase filtration of toxic substances from runoff (Svendsen et al., 2012; Ahmed et al., 2018; Steele et al., 2018); and, 3) source control solutions are those that reduce stormwater flows by storage and use, reduce flow to impermeable areas, and those that place barriers between water sources and toxics and contaminates (Marsalek, 2001). Stormwater managers differ in their perspectives about the efficacy of these three classes of management actions. Some argue that gray infrastructure adequately reduces flooding but does not address other environmental problems associated with increased urbanization (Porse, 2013). Others advocate for green infrastructure because it can address stormwater issues while also providing a diversity of co-benefits (Andersson et al., 2014; Coutts & Hahn, 2015). While some managers promote source control because it is cost-effective, others note that spatial heterogeneity of sources and impacts may limit or complicate the effectiveness of source control (Marsalek, 2001).

Here, we investigate discourses on management practices for stormwater in the Puget Sound region. Our general objective was to explore perspectives held by actors engaged in stormwater issues about which actions would most effectively mitigate stormwater and contribute to the recovery of the Puget Sound ecosystem. Specifically, we used Q methodology to investigate differences in prioritization of stormwater solutions currently being considered in the region and considered how emergent perspectives may affect decisions for stormwater management.

Methods

Q Methodology

Q Methodology is a structured approach for discourse analysis that uses both qualitative and quantitative techniques to reveal dominant discourses, as well as consensus and divergent perspectives using a rank ordering activity and factor analysis (Webler et al, 2009, Zabala et al, 2018; Brown, 1980). A discourse is defined as the way an individual views, or forms conceptions of, the world (Barry & Proops, 1999), and can be elicited by discussion and the rank ordering activity. Q Methodology initially was used in psychology (Webler et al., 2009; Watts & Stenner, 2005), but has more recently been used in studies surrounding environmental and resource management issues (e.g., Nelson et al., 2022; Gruber 2011). Because W methodology aims to understand perspectives of individuals (rather than extrapolating to populations) Q studies can be successful with sample sizes between 10 and 40 subjects (e.g., Cairns, 2012; Sandbrook et al., 2013).

We used Q Methodology to investigate perspectives of stormwater managers in the Puget Sound region of Washington State, U.S.A. Specifically, we focused on perspectives of managers regarding the efficacy and priority of a diverse suite of potential solutions to stormwater pollution. In general, a Q study consists of 4 steps: 1) creation of the Q set (or the statements to be ranked); 2) ranking of the Q set (creating a “Q sort”); 3) factor analysis of Q sorts; 4) interpretation of factor analysis (Brown et al., 1999). To sort the Q Set, participants were tasked with placing the statements into predetermined semi-normal distribution along a spectrum of lower priority to higher priority (Webler et al., 2009; Watts & Stenner, 2005). Factor analysis is used on completed Q sorts to reduce dimensionality of the data and creates idealized Q sorts for each group of individuals. Idealized Q sorts disclose common viewpoints regarding stormwater solutions held by group members.

Q Set

The first step in Q Methodology is to create the list of statements or items to be sorted by the participants – the Q Set. In developing our Q set, we heeded the advice of Stephenson (1953) to be inclusive of a broad range of perspectives. To accomplish this, we hosted a workshop in partnership with The Water 100 Project (water100project.org), a collaboration between The Nature Conservancy and Puget Sound Partnership that details the 100 most impactful solutions for a clean and resilient Puget Sound. The workshop was attended by stormwater experts in stormwater infrastructure, planning, and research. Workshop attendees were employed by Tribes, city or state agencies, NGOs, and universities. The workshop took place in Winter of 2021 was conducted via Zoom due to the COVID pandemic.

To create the Q Set we integrated sentiments expressed at the workshop about stormwater solutions with language used by the Water 100 Project. Our final Q Set consisted of 29 statements; 13 statements fell into Green Infrastructure solutions, 8 statements are Gray Infrastructure, and 8 are considered Source Control (Table 1).

P Set

We recruited diverse experts as participants for our Q-sort exercise. We defined an expert as someone who is professionally involved in stormwater policy, science, or management. We used stratified chain referral (Biernack and Waldorf, 1981) to enlist subjects. We first engaged participants from the workshop, and following their participation we asked them to refer other potential experts who would be appropriate for the study. Twenty-one individuals participated in the study – a sample size within the typical range of Q studies that meaningfully captures a diversity of views (Watts and Stenner, 2005). We offered no money or exchange of goods for their participation. Each Q-sort interview averaged 42 minutes (range 14 and 61 minutes).

Q Sort

Because of the Covid 19 pandemic, we used the online platform, Q Method Software (qmethodsoftware.com) to conduct Q sorts. We guided each participant through the Q sort using Zoom video conferencing. After receiving consent from 20 of 21 participants, we recorded and transcribed zoom interviews to capture explanations and the thought process used by subjects during the exercise.

Prior to conducting the W-sort activity, we asked each participant basic demographic information and to identify as a scientist, practitioner, manager, or something else. We also asked participants to describe their area of stormwater expertise. Next, participants were given the prompt, "Consider each of the stormwater solutions identified in each of the 29 statements and rank them as low, high, and highest priority for implementation." We chose to use the language "low, high, and highest" rather than "low, medium, and high" because pilot Q sorts revealed that stormwater experts tended to prioritize solutions as low or high, and thus the use of "highest" forced individuals to identify those solutions that should receive highest priority. Experts then performed a preliminary sort where each stormwater solutions were ranked as low, high, or highest priority. This was followed by a detailed sort where subjects placed the pre-sorted statements onto a Q board where -4 represented their lowest priority and 4 represented their highest ranked solutions (Figure 1). Throughout the exercise, we prompted participants to explain their rationale for their sorting choices.

Following the completion of the activity, we asked participants to articulate the ecological or human outcomes that they considered during their sort. We also asked for anything that was especially challenging during this process.

Statistical Analysis

Once all participants completed the exercise, all 21 Q sorts were analyzed using qmethodsoftware.com (Lutfallah and Buchanan, 2019). We used Centroid Extraction (CE) factor analysis to reduce the data into factors which were then rotated using varimax rotation to associate each individual with only one factor. In Q Methodology, there is not one objectively correct number of factors to choose to extract (Watts and Stenner, 2005), instead it is determined by amount of variability explained, scree plot inspection, eigenvalue test, and the interpretability and theoretical significance of the factors (Watts and Stenner, 2005; Brown et al., 1999). Based on these criteria, three factors were best supported (see appendix 1 for details).

The factors are idealized Q sorts reflecting the dominant discourse of the group. Each statement has a z-score which represents the weighted average of the scores that similar respondents gave to the statement (Zabala et al., 2018), as well as an integer that represents where the statement was placed in the idealized Q Sorts. Each individual participant also has a factor loading indicating how closely they associated with the idealized Q sorts (Zabala et al., 2018). The analysis also identifies consensus and distinguishing statements – statements that are statistically different ($p \leq 0.05$) or similar to other perspectives. We interpreted discourses by comparing the ranking of statements among factors, overlapping distinguishing and consensus statements among the factors, and qualitative analysis of the transcribed interviews.

Results

Eighteen sorts loaded significantly onto one of three factors; three sorts did not align with any of the emergent perspectives. The three factors represent the common discourses held by the stormwater experts we interviewed, and we refer to these discourses as follows: (1) Green Action Now, (2) First Things First, and (3) Don't Forget the Urban Fringe. The discourses are described in the following sections and the distribution of statements for each idealized Q sort can be found in Figure 2. A complete list of statements with associated factor scores and consensus or distinguishing status can be found in Appendix 1.

Discourse Analysis

Factor A "Green Action Now"

The first discourse, "Green Action Now", is defined by the prioritization of green infrastructure that not only mitigates to stormwater toxicity and high flow rates, but also provides co-benefits to human health (Table 2). The eight participants in this group had a higher proportion of individuals employed by NGOs with more interdisciplinary jobs than the other groups. This group also prioritized newer stormwater solutions (e.g., smart sensors, floodable parks, and neighborhood scale stormwater facilities) that would have an immediate positive impact on stormwater metrics and human health once implemented. Participants in this discourse ranked some known contaminant removal techniques, such as street sweeping, lower than other forms of contaminant removal, such as roadside bioswales, which provide multiple benefits (see also Wolf, 2014; Hansen & Pauleit, 2014; Coutts & Hahn, 2015). This discourse also prioritized nature-based solutions that had positive effects on adjacent ecosystems such as eelgrass and stream systems rather than limiting contaminants by reducing toxics at the source. One participant summed up the prioritization of multi-benefit solutions by this group as follows:

"*I think it was multi-benefit outcomes, so one of the things my agency works on is the ecosystem recovery plan for Puget Sound which looks at habitats across all landscapes across all watersheds and looks at habitat recovery, human wellbeing, equity, and salmon recovery. So, as we do all that planning, and we are aware of the limited amount of resources there are available for restoration and recovery and protection. It's really trying to find those things that have that multi-benefit impact… something like stream restoration well that's everything, that's* *clean water, that's salmon, you know, healthy drinking water for people, that's connected habitat, so that ends up getting much higher [ranking]."*

In addition, the "Green Action Now" discourse places greater emphasis on nature-based stormwater solutions that provide benefit to humans living in urban rather than rural areas. They prioritize solutions that will green cities and enhance the delivery of ecosystem services, to city dwellers.

Factor B "First Things First"

The second discourse, "First Things First", is characterized by experts that rank solutions that address stormwater at its source and have been demonstrated to be effective (Table 3). These individuals' reason that "end of the pipe" more "green" solutions are ineffective unless toxic reduction and flood control are addressed first. More often than the other two discourses, these individuals advocated addressing stormwater issues at their root before implementing new or expensive green solutions. The attitude of this discourse was concisely expressed by one participant who said the key question to ask is "What is the most important thing you can do with the resources that you've got?"

This discourse focused on maximizing a return on investment and minimizing uncertainty in outcomes. For example, those in the "First Things First" discourse collectively ranked eelgrass restoration, wastewater treatment wetlands, and regenerative fish farming, agriculture and carbon farming low. While these solutions benefit stormwater, their impact is less direct, and the return on investment is less clear than solutions that focus on controlling sources of stormwater toxicity. Instead, this group ranked street sweeping, smart sensors, and industrial area source control as their top three solutions. This preference is highlighted by a participant who stated that we should focus on

"…known impact of actions versus researching innovative technologies. I think there's an urgency to doing this work and we ought to be doing the things that we know work…"

This participant as well as the others in this group felt that we need to act now with the solutions we know work to reduce the stormwater problem in Puget Sound. Participants expressed that they valued green space and agreed that there were benefits to those solutions, but ultimately decided that known and immediately implementable solutions are the ones that we should be focusing on first.

Factor C "Don't Forget the Urban Fringe"

Experts included in the "Don't Forget the Urban Fringe" discourse prioritized solutions with benefits that cross the urban-rural interface. Only two participants loaded onto this discourse but their views regarding the urban-rural divide were not reflected in any other discourse (Table 4). "Don't Forget the Urban Fringe" puts more emphasis on space for urban agriculture and urban soil health than "Green Action Now" and "First Things First". This group placed their focus on the relationship and connection between individuals living in urban areas and those living in rural areas. Stormwater infrastructure and solutions are more geared toward urban areas due to the higher concentrations of contaminants and impervious surfaces. While "Don't Forget the Urban Fringe" still prioritize known contaminant removal practices that are effective in urban areas, such as street sweeping which they ranked 1st, they also preferred source control methods that focused on rural areas, such has regenerative agriculture, more than the other groups. When discussing the urban-rural divide, one participant in this group said,

"…*when you talk about multiple benefits the cultural urban-rural divide is this really big scary issue that we've got nationally and for folks to start collaborating across that geography and for urban communities to understand rural communities better and vice versa and to work together and collaborate…There's this rural stormwater conversation that I think has a lot of potential to start bridging some of those cultural gaps that are tearing us apart."*

Experts in this group did not prioritize gray infrastructure as highly as the other two discourses, which four of the bottom six solutions falling tin the gray infrastructure category. Smart sensors ranked near the bottom in the "Don't Forget the Urban Fringe" discourse, while it ranked first in the other two groups. This general lack of interest in gray infrastructure reflects a desire to protect the rural-urban fringe from expanding urbanization and greater coverage of impervious surfaces. This perspective is further highlighted by the prioritization of green infrastructure by this group.

Consensus Views

In addition to identifying statements that set each factor apart, we used Q sort to identify statements that were agreed upon by each factor, called consensus statements. Out of the 29 statements, four were identified as statistical points of consensus between all three discourses because there are no statistical differences between z-scores of the statements (Table 7; appendix 3). By use of z-scores and table 7 we can better evaluate the and find trends in statements by how different the z-scores are for a statement between factors. The smaller the difference between z-scores of a statement, the more that statement is agreed upon between factors. The statements, 5, 14, 17, and 26, were consensus statements across factors with all falling in the moderate priority range. All four statements are considered green infrastructure. Statement 26 (Floodable parks and flex space) had the highest average z-score of the consensus statements (1.087) compared to statement 5 (Green roofs and walls) which had the lowest average z-score (-0.593). Overall, there was little interest in implementing gray infrastructures such as separate sewer systems and emergency backup fail safes for combined sewer overflow events and it was the lowest overall priority across all 3 discourses (overall z-score -2.5). Participants were most supportive of floodable parks and outdoor flex space (overall z-score 3.261).

Discussion

Urban vs Rural Solutions

Making the decision to prioritize one solution over another is an intricate dance of weighing pros and cons across multiple factors including cost, landscape and land availability, sources of pollution, and desired outcomes among many others. The way that experts prioritize these stormwater solutions alludes to how difficult it is to decide on what outcomes are more needed and which solutions will provide the area with those outcomes. We used Q methodology to investigate how a subset of stormwater experts in Puget Sound tackle that challenge and to explore their opinions and perspectives on how to utilize stormwater solutions to reduce the ecological impact of stormwater while simultaneously improving human wellbeing. Ultimately, this study revealed three distinct discourses surrounding the governance of stormwater solutions focused on the need for green and nature-based solutions, regulation and known effective solutions, and protecting the urban fringe and its natural habitats which provide ecosystem services to the community from urbanization.

In urban areas, space is often the limiting factor in deciding what type of stormwater infrastructure to implement (Copeland, 2014). Because of the amount of impervious surface, infiltration of surface water is often prioritized in urban areas with hopes to mitigate combined sewer overflow events (Cousins, 2017; Tackett & Mills, 2010). Whereas rural areas have more yards, pastures, and farmland with ample surface water infiltration reducing the priority of solutions focused on infiltration. There is a priority in rural areas to limit the expansion of urbanization and limit the land use changes that remove vegetative cover and add impervious surfaces (Goonetilleke et al., 2005) which results in faster peak flow rates, increased runoff volume, and degradation of receiving water bodies (Paule-Mercado et al., 2017).

The discourse around surface water runoff in rural areas differs from urban, particularly with how solutions are described. Rural areas refer to stormwater solutions as best management practices (BMPs) which are more focused on reducing the amount of pesticide and sediment runoff (Cooper et al., 2004; Zhang & Zhang, 2011). Examples of known effective BMPs are sediment ponds and pesticide use reduction (Zhang & Zhang, 2011) but there is a growing trend of innovative BMPs which use vegetative and nature-based components of contaminant and pesticide removal (Cooper et al., 2004; Zhang & Zhang, 2011) similar to the growing trend of green infrastructure in urban areas. Stormwater management goals also differ between urban and rural municipalities. Seattle's stormwater management plan focuses on source control and limiting runoff from construction sites for the benefit of receiving water (Seattle Public Utilities, 2022). On the other hand, Woodinville, WA, a suburban city outside of Seattle with more pasture and agriculture, emphasizes reducing the use of excess pesticides and fertilizer in lawn care and maintaining septic systems (Prevent Stormwater Pollution | Woodinville, WA) which are much more prevalent in rural areas.

Urban areas dominate the discourse surrounding stormwater management strategies due to increased quantity of surface runoff from impervious surfaces and larger populations compared to rural areas (Cousins, 2017; Goonetilleke et al., 2005; Walsh et al., 2005). However, there is still the need for stormwater solutions in rural areas. Priorities for stormwater management differ between urban and rural areas because of differences in land use practices (Paule-Mercado et al., 2017). There are less impervious surfaces, population density, and traffic pollution in rural areas compared to urban areas but due to more farmland there is more nutrient runoff and pesticides in stormwater that needs to be addressed (Zhang & Zhang, 2011). These differences in pollution sources require different stormwater solutions. Solutions such as street sweeping and pharmaceutical management don't have the same effect in rural areas compared to urban areas because there are less people and fewer cars contributing to vehicle pollution and improper disposal of pharmaceuticals. Stormwater solutions that are agreed upon by experts to be efficient and worthwhile to implement may not translate well to more rural areas. When discussing street sweeping, one of our interviewees said:

"*Doing it in highly urbanized areas where you're getting a lot of pollutants and pollutants are your main cause of impairments makes sense and has high value. [Doing it in] more rural agricultural areas, the value goes down depending upon the sources of pollutants and areas that are draining directly to a stream… Doing it on a country road that is surrounded by pastures, I'd really struggle to defend the value of that*."

This participant addresses a common perspective linking all three of our discourses; the specific stormwater intervention must be based around the specific outcome or goals the managers have in mind. There is no "one size fits all" solution that can be implemented in any situation to provide immediate and effective benefits to water quality. This is why making these decisions is difficult, even for stormwater experts, and why conversations like this are important.

Solution Trade Offs

There is difficulty in deciding which solution to implement, where to implement it, and for what purpose or goal in mind. This study has shown us that even stormwater experts who have been working in this field for years have difficulty choosing which solutions to prioritize. All stormwater solutions are important for different reasons and more or less efficient in different settings. Source control solutions prevent specific pollutants that have known adverse effects from entering into the environment, such as pharmaceutical management and household best practices. Additionally, we are finding new contaminants of concern that draw attention from media and research (Tian et al., 2022) potentially affecting the public's level of concern. It is important to limit the amount of contaminants with known adverse health effects from getting into the environment, but source control measures are tricky because there are many different compounds of interest stemming from different sources that affect different species. 6PPD has only been found to affect coho salmon, and while it is an important species to protect, making the decision to use the limited resources that municipalities have for stormwater for solutions that only benefit specific species is difficult to accept when those resource could be used to fund projects that provide a wider range of benefits. Stormwater entering the Puget Sound contains more than 5,000 different unique pollutants annually (Saifur & Gardner, 2021; Tian et al., 2022; Peter et al., 2018). With research and solutions targeting specific pollutants to control or remove from stormwater it can be difficult to decide on which pollutant to focus on and why.

How do managers make the decision between solutions that provide known ecological protection versus solutions that protect humans from environmental contaminant exposure and improve human well-being? In this study we found two divergent views on this question; "Green Action Now" prioritized stormwater solutions with nature-based components because they have co-benefits related to human health and environmental justice, while "First Things First" prioritized solutions that prevented contaminants with adverse ecological and human health effects from entering into the environment. There is no objectively correct answer or viewpoint because both achieve stormwater quality improvements that provide ecological and human health benefits. The ways in which solutions go about achieving these outcomes is where perspectives surrounding this decision diverge. However, we do feel that solutions that have a broader range of co-benefits and more capacity to alleviate environmental injustices by improving access to green space, improving air quality, and reducing the urban heat island effect (Copeland, 2014) should be prioritized when applicable.

One of the themes that came up throughout our interviews of stormwater experts was "known solutions" such as gray infrastructure and source control solutions vs new green infrastructure solutions. Some participants revealed that they placed higher value on solutions that produced multiple benefits. One using the stream restoration solution as an example. Of this they state

"*…we are aware of the limited amount of resources available for restoration and recovery and protection. It's really trying to find those things that have that multi-benefit impact. Something like putting roofs over the industrial area of-- certainly that does benefit multiple things but it's kind of you have to go down your logic chain a bit vs something like stream restoration well that's everything, that's clean water, that's salmon you know healthy drinking water for people, that's connected habitat so that ends up [ranking] much higher.*"

This participant felt that green infrastructure and restoration solutions would bring about the most positive change for stormwater improvement. They decided that broad ranging solutions that promoted natural systems and their ecosystem services were of higher priority than more pigeonholed solutions focusing specifically on the quality of the stormwater. They do acknowledge that while solutions like industrial area source control are necessary and important to include in stormwater management plans, it is important to look further than the immediate outcome and take into account outcomes that may be further removed from the solution. Another participant takes a different stance in favor of source control and gray infrastructure solutions stating

"Nature based treatment approaches are great, but you know, at the end of the day you need something- and these are all engineered of course- that's engineered to do the job that you need it to do."

This participant put more value on the knowledge that a solution is going to produce known and measurable results rather than risk implementing a nature-based solution that may not be as effective at doing the same thing for stormwater. This viewpoint is that of a more conservative approach to stormwater management. Many stormwater managers believe there is insufficient evidence supporting green infrastructure's efficiency and longevity in a number of climates to advocate for its implementation (Copeland, 2014). The decision here falls to how well the solution performs from a stormwater quality and quantity perspective or how well does the solution do in doing its particular job. This viewpoint neglects to include the additional non-water benefits green infrastructure solutions provide.

Multiple Benefits of Green Infrastructure Solutions

Multiple benefits are often prioritized in other fields of conservation, sustainability and land management (e.g. Stagnari et al., 2017; Feng et al., 2004; Gardali et al., 2021). Multiple Benefit Conservation is an emerging term and sector of conservation science that uses pre-decided ecological and societal goals for each project and measures success based on simultaneously reaching those goals (Gardali et al., 2021). Conservation efforts that promote and focus on multiple benefits can open up opportunities for inclusivity of a diverse set of people, values and worldviews (Gardali et al., 2021; Gould et al., 2018). If stormwater solutions can be billed as not only interventions that benefit receiving waters but multiple benefit conservation that addresses human health as an end goal, perhaps it can open up federal, state, and smaller municipalities funding opportunities. Policies that promote the funding of projects that benefit human health, or environmental justice may have larger budgets than those only promoting green infrastructure stormwater action (Copeland, 2014). If stormwater interventions and initiatives also provide substantial benefits to human health and wellbeing perhaps they can dip into budgets not typically set aside for stormwater infrastructure. Instead of focusing on stormwater as the center for the solution, what if these solutions are framed with the intent of promoting human and community wellbeing and have co-benefits to stormwater quality and quantity? This is an example of diversifying the funding and resource allocation for stormwater solutions to be implemented. Currently there is no federal funding specifically toward green infrastructure projects, typically smaller municipalities offer incentives for private landowners to implement green infrastructures (Copeland, 2014; Kirschbaum & Lowry, 2012). Our Q sort revealed that a major factor in stormwater decision making oftentimes is related to budget and financial and/or political feasibility.

Green infrastructure solutions offer a plethora of benefits to human health, community strength, and climate change mitigation (Copeland, 2014). Solutions that increase green space such as floodable parks, tree planting, and neighborhood stormwater facilities not only aid in stormwater filtration and carbon uptake, but they also aid in physical and mental human health (Mackenzie & McIntyre, 2018). Increased greening is also linked to improvements in standardized test scores, concentration in children with ADHD, hospital recovery time, and physical activity in residents (Mackenzie & McIntyre, 2018). Not only does green infrastructure implementation provide benefits to biodiversity, increased green space is also linked to lowered crime rates and an increased sense of community (Dunn, 2010). One of our participants from Green Action Now stated of the link between green space and community strength

"*I think a lot about community-based solutions and those that will also incentivize the people who live in those areas to invest in it and to help manage it just because it benefits them, so you know things like urban soil, and rainwater harvesting. Especially things that end up contributing to community gardens, you know, have that build incentive to work on it locally and support it locally.*"

The Green Action Now discourse stood apart from other groups because of its recognition of the benefits of these infrastructures and more importantly, their decision to rank them above source control and gray infrastructure solutions. Participants in other discourses may have been interested and knowledgeable about the beneficial effects of green infrastructure, but ultimately ranked them lower than Green Action Now.

Since green infrastructure and nature-based solutions increase foliage and green space, these solutions can lessen the urban heat island effect as well as increase carbon sequestration if implemented in urban spaces (Balany et al., 2020; Block, 2012; Foster et al., 2011). There is also an environmental justice component to lessening these adverse effects on communities, because most often the neighborhoods with the least green space are those with people of color and those of lower socioeconomic status (Voelkel et al, 2018; House et al., 2016). Green infrastructure solutions such as floodable parks, green walls, and tree planting could combat the urban heat island effect as well as environmental issues if placed in areas of most need. There is potential to alleviate climate injustices by use of nature-based stormwater solutions given the co-benefits to human health they provide (Choi et al., 2021; Williams et al., 2020). Access to safe greenspace in low income and non-white communities is lower than in more affluent white neighborhoods (Day, 2006; Williams et al., 2020) The implementation of specific stormwater solutions that have a multiple benefit conservation framework can simultaneously benefit stormwater, human health, and promote environmental justice by providing underrepresented low income and non-white communities with the multiple benefits associated with green stormwater infrastructures.

Since Q methodology can highlight minority perspectives within a group (Watts & Stenner, 2012), it may be useful in uplifting underrepresented voices in the stormwater realm particularly those linking solutions to human health and wellbeing. Understanding how stormwater solutions are decided upon and managed as well as outcomes related to solutions is a critical skill for decision makers, we chose participants with experience and knowledge surrounding these aspects of stormwater. Q studies such as this one are not intended to be extrapolated to a larger population due to their small sample size and non-random participant selection (Brown et al., 1999). Furthermore, the perspectives found in this study do not encompass all perspectives and worldviews of stormwater experts in the Puget Sound, however they do highlight important connections between stormwater solutions, human health and wellbeing, and environmental justice. While we limited our participant group to stormwater managers, practitioners, and scientists, next steps could include involving policy makers and elected officials who make legislative decisions regarding funding and regulation or community members who are negatively affected by poor stormwater infrastructure. Further work like this could help to inform these decision makers about tradeoffs and the multiple benefits associated with green infrastructure (Copeland, 2014; Andersson et al., 2014; Coutts & Hahn, 2015).

Categorizing stormwater solutions as multiple benefit conservation is yet to be discussed, but the inclusion of more holistic goals and outcomes for stormwater solutions is still a work in progress (Wang et al., 2016). Obstacles facing stormwater solutions can be found on all levels of implementation from designers and land managers to policy decision makers. Exposing dominant discourses within this realm can help to spark discussion based on disagreements and further define overall goals of stormwater solutions. While there are many perspectives and opinions on specific solutions, the ultimate end goal for stormwater management is shared: mitigate anthropogenic pollutants affecting receiving water quality and the associated biodiversity while simultaneously promoting human health and wellbeing in an equitable and environmentally just way.

Figures/Appendix

Table 1. Q Set Statements and Associated Solution type

	Statement	Solution Type
1	Implement neighborhood stormwater facilities -- utilizing nature-based stormwater retention and treatment systems.	Gray Infrastructure
2	Implement bluegreen roadside bio swales -- channels with gently sloped sides that often utilize wetland type plants and rocks or other elements to slow water movement to allow for stormwater infiltration and treatment.	Green Infrastructure
3	Research and implement permeable pavement -- Removing unnecessary pavement or converting impervious surfaces to porous pavement.	Gray Infrastructure

4	Implement green clean bridges -- using private land adjacent to bridges and elevated highways to treat community road pollution at a district or neighborhood scale.	Green Infrastructure
5	Implement green roofs/walls -- Green walls- free standing walls for pollution barriers treatment facility, improves infiltration, source control, grabs pollutants from air before getting to paved surfaces.	Green Infrastructure
6	Invest in and increase pipeline & outfall cleaning -- A one-time cleaning of stormwater pipes provides a safe and contained means of removing years of chemical build-up.	Source Control
7	Increase rainwater harvesting -- from rooftops or paved surfaces.	Gray Infrastructure
8	Increase street sweeping--Street sweeping vehicles can remove pollution, dust and debris that collects on streets before it enters stormwater systems or enter local waterways.	Gray Infrastructure
9	Invest in urban soil building -- restores these soils into a life-giving substrate and effective flood control urban asset, while microbes help to break down pollutants in runoff.	Green Infrastructure
10	Invest in eelgrass restoration.	Green Infrastructure
11	Invest in industrial area source control--Putting roofs over activities that have a high potential to result in polluted runoff.	Source Control
12	Increase space for urban agriculture--Urban agriculture brings the source of food closer to the demand reducing the need for transportation and help generate rich soils that can replace impervious surfaces, providing infiltration and treatment of stormwater.	Green Infrastructure
13	Research and invest in advanced brake pads/tires--Copper is used in vehicle brake pads to dissipate heat, however particles of copper in break dust poses significant health risks to aquatic life.	Source Control
14	Increase voluntary buyouts -- of repeatedly flooded properties to reduce future private property losses and injury while returning land to open space or wetland habitat.	Green Infrastructure
15	Increase/implement Wastewater treatment wetlands -- nature-based treatment approach reduces the use of chemicals and energy required for water treatment.	Green Infrastructure
16	Increase the number of Stormwater ponds -- Ponds can be optimized to empty before storm events and reduce the burden on streams, combined sewer overflows, and offer initial filtration of water.	Gray Infrastructure
17	Implement Groundwater recharge areas -- engineered filtration systems using pipes and permeable gravels to help manage high spring/winter flows and store and then augment available water during the rest of the year.	Green Infrastructure
18	Increase awareness of household best practices -- for example Hazardous Waste Community Collection Sites.	Source Control
19	Invest in Pharmaceutical management – proper disposal of household pharmaceutical products.	Source Control
20	Implement Gray infrastructure -- separating combined systems and emergency power backup and fail-safe equipment for combined sewage overflow control.	Gray Infrastructure
21	Invest in Red List free materials -- worst in class materials and chemicals that are too often used in the construction industry.	Source Control
22	Increase Stream Restoration	Green Infrastructure
23	Increase Tree planting -- filtering inorganic nutrients and shading the stream.	Green Infrastructure
24	Research and implement fish safe culverts.	Gray Infrastructure
25	Increase use of Manure control and nutrient management	Source Control
26	Research and implement Floodable parks and outdoor flex space.	Green Infrastructure
27	Implement Soft shorelines -- filter and slow runoff before reaching the ocean, help to restore natural processes in the Sound, and promote ecological exchange between terrestrial and aquatic systems.	Green Infrastructure
28	Research and implement Regenerative fish farming, agriculture, carbon farming -- Integrated multi-trophic aquaculture. Agriculture -- holistic practices that build soil health, increase biodiversity, improve watersheds, and support ecosystem services. Carbon Farming -- mimics the migratory behavior of large herbivores to build soil health and capture carbon in the soil using native grasses with deep root systems.	Source Control
29	Implement Smart sensors -- Real-time and low-cost monitoring of water characteristics enabling improved management of water flow, identification and elimination of water pollution.	Gray Infrastructure

Figure 1. Q Board Distribution

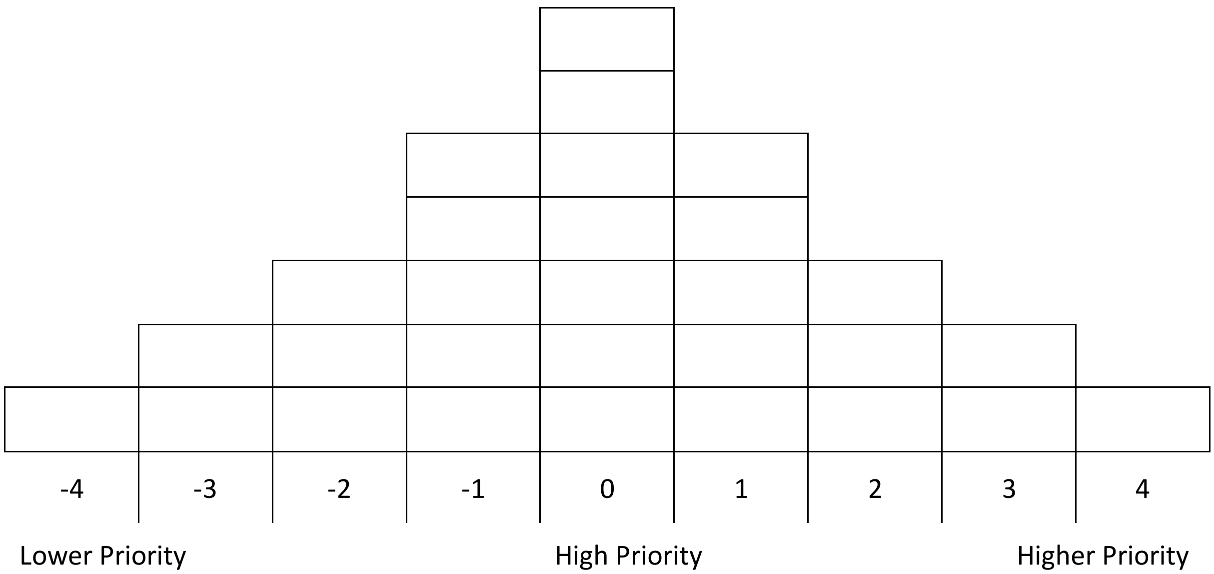
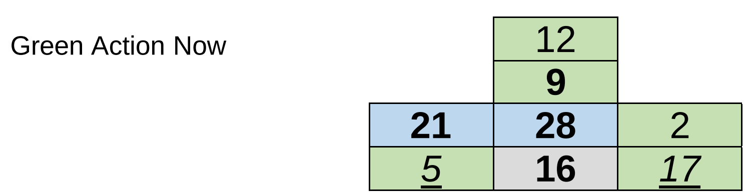


Figure 2. Distribution of statements in each discourse. Numbers in bold are distinguishing statements, numbers italicized and underlined are consensus statements. Green boxes represent green infrastructure solutions, gray boxes represent gray infrastructure solutions, and blue boxes represent source control solutions. Column 4 is the highest priority while -4 represents the lowest.



-4	-3	-2	-1	0	1	2	3	4
		18	6	11	*14*	*26*		
	8	19	20	4	10	**22**	23	
25	7	3	**13**	15	**24**	27	**1**	**29**

First Things First

-4	-3	-2	-1	0	1	2	3	4
				20				
				7				
			24	25	**21**			
			12	2	22			
		3	19	13	*14*	**6**		
	28	**9**	*5*	**18**	**1**	**16**	**11**	
10	**15**	**27**	4	*17*	*26*	23	**29**	8

Don't Forget the Urban Fringe

-4	-3	-2	-1	0	1	2	3	4
				4				
				17				
			7	**3**	**9**			
			11	**1**	22			
		18	6	19	10	13		
	20	24	2	15	*14*	27	*26*	
16	**29**	25	*5*	**23**	**12**	**28**	**21**	8

Table 2. Factor A Characteristics

Name	Loading Q Sorts	% Variance Explained	Eigenvalues	Genders	Work Sectors
Green Action Now	8	22	4.6	4 M, 4 F	Government, NGO, Private Sector
Top 3 Priorities					Z-Scores
Implement Smart Sensors					2.101
Implement Neighborhood Stormwater Facilities					1.483
Increase Tree Planting					1.472

Table 3. Factor B Characteristics

Name	Loading Q Sorts	% Variance Explained	Eigenvalues	Genders	Work Sectors
First Things First	8	13	2.7	3 M, 5 F	Government, NGO
Top 3 Priorities					Z-Scores
Increase Street Sweeping					1.583
Implement Smart Sensors					1.506
Invest in Industrial Area Source Control					1.241

Table 4. Factor C Characteristics

Name	Loading Q Sorts	% Variance Explained	Eigenvalues	Genders	Work Sectors
Don't Forget the Urban Fringe	2	9	1.8	1 M, 1 F	Government, NGO
Top 3 Priorities					Z-Scores
Increase Street Sweeping					1.901
Invest in Redlist Free Materials					1.825
Research and implement Regenerative fish farming, agriculture, carbon farming					1.216

Appendix 1. Detail Q sort Results

The following tables and figures show general factor characteristics (Table 5), support for the three-factor solution (Table 6, Fig 6), and factor scores and status of each statement (Table 7).

Table 5. General Factor Characteristics

	Average Reliability Coefficient	Loading Q Sorts	Eigenvalues	Explained Variance (%)	Composite Reliability	SE Factor Scores
Green Action Now	0.8	8	4.6	22	0.97	0.17
First Things First	0.8	8	2.7	13	0.97	0.17

Don't Forget the Urban Fringe	0.8	2	1.8	9	0.89	0.33

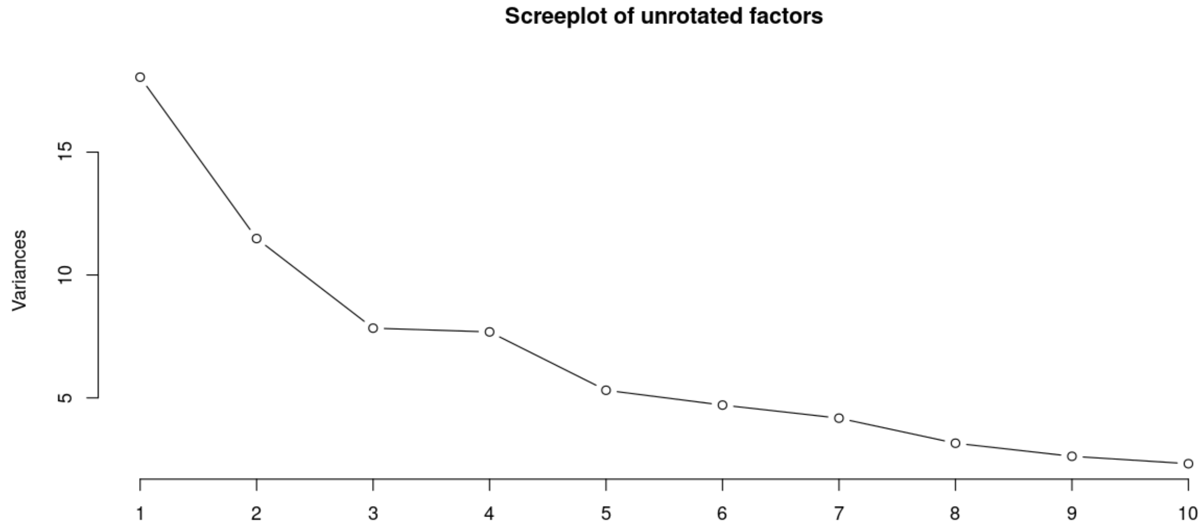
Table 6. Correlation between factor z-scores

	A	B	C
A	1	0.17	0.01
B	0.17	1	-0.13
C	0.01	-0.13	1

Table 7. Statements and associated factor scores, distinguishing or consensus status and supporting statistics. A_B represents the absolute difference between the *z*-scores for factors A and B for that statement.

		Statement Factor Scores						
	Statements	A	B	C	Distinguishing or Consensus status	A_B	A_C	B_C
1	Implement neighborhood stormwater facilities -- utilizing nature-based stormwater retention and treatment systems.	3	1	0	Distinguishes All	0.625	1.483	0.858
2	Implement bluegreen roadside bio swales -- channels with gently sloped sides that often utilize wetland type plants and rocks or other elements to slow water movement to allow for stormwater infiltration and treatment.	1	0	-1		0.294	0.914	0.62
3	Research and implement permeable pavement -- Removing unnecessary pavement or converting impervious surfaces to porous pavement.	-2	-2	0	Distinguishes C only	0.177	0.982	1.159
4	Implement green clean bridges -- using private land adjacent to bridges and elevated highways to treat community road pollution at a district or neighborhood scale.	0	-1	0		0.54	0.132	0.408
5	Implement green roofs/walls -- Green walls- free standing walls for pollution barriers treatment facility, improves infiltration, source control, grabs pollutants from air before getting to paved surfaces.	-1	-1	-1	Consensus	0.272	0.398	0.125
6	Invest in and increase pipeline & outfall cleaning -- A one-time cleaning of stormwater pipes provides a safe and contained means of removing years of chemical build-up.	-1	2	-1	Distinguishes B only	1.758	0.266	1.492
7	Increase rainwater harvesting -- from rooftops or paved surfaces.	-3	0	-1		1.077	0.5	0.577
8	Increase street sweeping--Street sweeping vehicles can remove pollution, dust and debris that collects on streets before it enters stormwater systems or enter local waterways.	-3	4	4	Distinguishes A only	2.765	3.082	0.318
9	Invest in urban soil building -- restores these soils into a life-giving substrate and effective flood control urban asset, while microbes help to break down pollutants in runoff.	0	-2	1	Distinguishes All	0.594	0.779	1.373
10	Invest in eelgrass restoration.	1	-4	1	Distinguishes B only	2.881	0.55	2.331
11	Invest in industrial area source control--Putting roofs over activities that have a high potential to result in polluted runoff.	0	3	-1	Distinguishes B only	1.247	0.469	1.716
12	Increase space for urban agriculture--Urban agriculture brings the source of food closer to the demand reducing the need for transportation and help generate rich soils that can replace impervious surfaces, providing infiltration and treatment of stormwater.	0	-1	1	Distinguishes C only	0.118	1.393	1.511
13	Research and invest in advanced brake pads/tires--Copper is used in vehicle brake pads to dissipate heat, however particles of copper in break dust poses significant health risks to aquatic life.	-1	0	2	Distinguishes A only	0.819	1.467	0.647
14	Increase voluntary buyouts -- of repeatedly flooded properties to reduce future private property losses and injury while returning land to open space or wetland habitat.	1	1	1	Consensus	0.004	0.037	0.034
15	Increase/implement Wastewater treatment wetlands -- nature-based treatment approach reduces the use of chemicals and energy required for water treatment.	0	-3	0	Distinguishes B only	1.777	0.066	1.71
16	Increase the number of Stormwater ponds -- Ponds can be optimized to empty before storm events and reduce the burden on streams, combined sewer overflows, and offer initial filtration of water.	0	2	-4	Distinguishes All	1.427	1.975	3.402
17	Implement Groundwater recharge areas -- engineered filtration systems using pipes and permeable gravels to help manage high spring/winter flows and store and then augment available water during the rest of the year.	1	0	0	Consensus	0.277	0.531	0.255
18	Increase awareness of household best practices -- for example Hazardous Waste Community Collection Sites.	-2	0	-2	Distinguishes B only	1.359	0.188	1.546
19	Invest in Pharmaceutical management â€" proper disposal of household pharmaceutical products.	-2	-1	0		0.468	1.175	0.707
20	Implement Grey infrastructure -- separating combined systems and emergency power backup and fail-safe equipment for combined sewage overflow control.	-1	0	-3	Distinguishes C only	0.45	1.062	1.512
21	Invest in Red List free materials -- worst in class materials and chemicals that are too often used in the construction industry.	-1	1	3	Distinguishes All	1.367	2.719	1.352
22	Increase Stream Restoration	2	1	1	Distinguishes A only	0.877	1.02	0.143
23	Increase Tree planting -- filtering inorganic nutrients and shading the stream.	3	2	0	Distinguishes C only	0.314	1.263	0.949
24	Research and implement fish safe culverts.	1	-1	-2	Distinguishes A only	1.631	2.01	0.379
25	Increase use of Manure control and nutrient management	-4	0	-2	Distinguishes A only	1.511	0.792	0.719
26	Research and implement Floodable parks and outdoor flex space.	2	1	3	Consensus	0.101	0.144	0.245
27	Implement Soft shorelines -- filter and slow runoff before reaching the ocean, help to restore natural processes in the Sound, and promote ecological exchange between terrestrial and aquatic systems.	2	-2	2	Distinguishes B only	2.221	0.292	1.929
28	Research and implement Regenerative fish farming, agriculture, carbon farming -- Integrated multi-trophic aquaculture. Agriculture -- holistic practices that build soil health, increase biodiversity, improve watersheds, and support ecosystem services. Carbon Farming -- mimics the migratory behavior of large herbivores to build soil health and capture carbon in the soil using native grasses with deep root systems.	0	-3	2	Distinguishes in All	1.503	1.672	3.174
29	Implement Smart sensors -- Real-time and low-cost monitoring of water characteristics enabling improved management of water flow, identification and elimination of water pollution.	4	3	-3	Distinguishes All	0.595	3.45	2.855

Figure 6.



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