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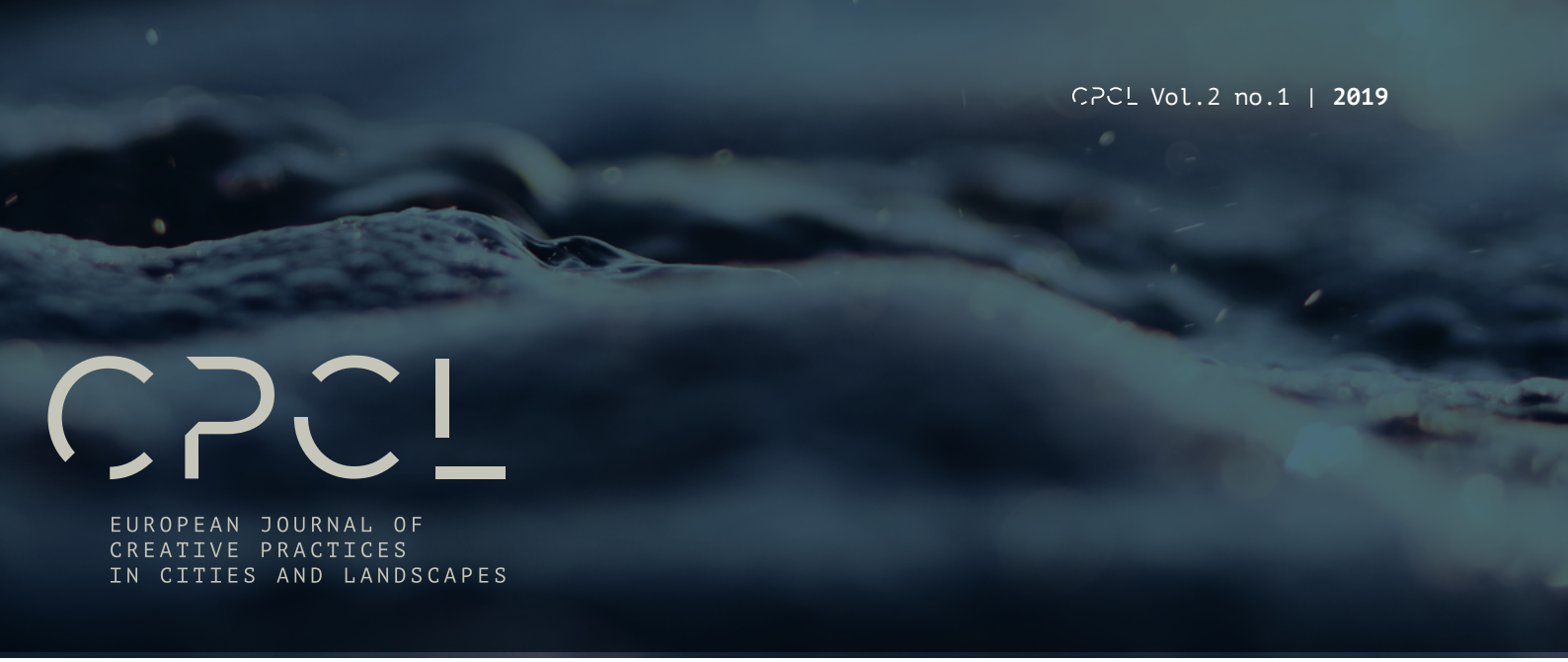

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IN CITIES AND LANDSCAPES

MAIN SECTION

Policies enabling resilience in Seattle's water services

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ABSTRACT
The combined impact of diverse transitions, such as climate change, population growth, rapid urbanization and ageing infrastructure are expected to affect the quantity, quality, accessibility and affordability of water globally. Water demand and competition for water are likely to increase. Addressing these changes and hazards requires societies to be resilient, i.e. flexible and adaptive instead of only resistant. Seattle, Washington USA, has a long history of sustainable development and adaptation to changes and hazards such as population growth, water pollution, droughts and floods. Based on a literature review and semi-structured interviews among twelve selected local water professionals, this paper a) defines development steps and policies that have led to the current situation; b) explores key policies that are important to the resilience of Seattle's water services; and c) examines challenges in and recommendations for improving resilience in the future. The results reveal the importance of specific policies and practices in enabling resilience for each water service: water supply, wastewater and stormwater. They also reveal governance levels where resilience is most powerfully implemented. The paper concludes that policies that were found to build and improve the resilience of Seattle's water services are diverse and most effective when implemented at a local level. In advancing resilience, it is important to acknowledge also informal rules, including mindsets and habits.

KEYWORDS
Water Supply; Wastewater; Stormwater; Water Services Management; Water Resilience.

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1 Introduction

The United Nations and the World Economic Forum, among others, have listed water as one of the most crucial issues in the future.[1] The availability and quality of water and water services are affected by diverse coinciding transitions, such as climate change, population growth, rapid urbanization and ageing water infrastructure. These multiple developments are expected to intensify water demand and competition for water,[2] and can threaten physical water infrastructure, such as water networks and treatment facilities, and their operation. [3]

Responding to the above-mentioned transitions, scholars have introduced the concept of resilience, which, in brief means an ability to resist, adapt to and recover from disturbances.[4] However, the majority of the existing research discusses water resilience in terms of technical aspects and there has been relatively little research on the institutional, policy, and governance aspects,[5] even though scholars and practitioners have recognized the importance of policies of water resilience.[6] Additionally, according to a search in Scopus database[7], water services – i.e. water supply, wastewater, and stormwater – have been researched less than water resources.

To help address these research gaps, we focus on the resilience of water services from the policy point of view in the case of Seattle, Washington, in the USA. We chose Seattle mainly because of (i) its long history in developing its water services management in a more sustainable direction, (ii) its location and climate, which cause a variety of challenges, and (iii) its current efforts in developing resilience. To provide the reader a sufficient backdrop for the research, the following section (1.1) presents an overview of Seattle's water services and their challenges.

Our objective for this paper is to identify the type of policies local water professionals consider important for building and enhancing resilience in water services in Seattle. In addition, we are interested in discovering not only the challenges that water professionals see as hindering water resilience, but also what could be done to avoid and to respond to those challenges. Furthermore, the study determines the governance levels at which

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1. World Economic Forum, *The Global Risks Report 2018* (Geneva: World Economic Forum, 2018), fig. I-IV, 61-62.

2. Core Writing Team, Rajendra K. Pachauri and L.A. Meyer, eds., *Climate Change 2014: Synthesis Report.* (Geneva: Intergovernmental Panel on Climate Change, 2015), 2-26.

3. World Bank, "World Bank Disaster Risk Management Hub, Tokyo: Knowledge Program, Resilient Water Supply and Sanitation Services", *World Bank* News, October 21, 2016.

4. Åsa Johannessen and Christine Wamsler, "What does resilience mean for urban water services? "*Ecology and Society* 22(1):1 (2017). Carl Folke, "Resilience (republished)," *Ecology and Society*, 21(4), 1–30 (2016).

5. Lucy Rodina, "Defining"water resilience": Debates, concepts, approaches, and gaps", *WIREs Water* 6, no. 2 (December 2018).

6. Johannessen and Wamsler, "What does resilience mean for urban water services?"

7. Scopus database, www.scopus.com.

resilience is most powerfully implemented. Our research methodology is explained in more detail in section 3.

An analysis of the development of water services management policies through a lens of resilience is useful to policy makers in Seattle. It should clarify the most fundamental elements that contribute to resilient policy design and water services management. Policy makers and water professionals can consider these elements, combined with the envisioned challenges and suggestions, in future planning.

1.1 Background – water services and their challenges in Seattle

Since at least the late-19th century, Seattleites have developed their water services as a response to various societal, institutional and environmental changes and needs. For example, in 1889, the Great Seattle Fire forced the rebuilding of the entire downtown sector, including the water infrastructure, and in 1896, the Klondike gold discovery in Canada led to the rapid growth of Seattle's population, thereby increasing water demand, and triggering massive water engineering projects in mountainous terrain.

The construction of the initial water infrastructure, which lasted for decades, has been described as "taming nature"[8]. It was more a matter of conquering nature than adapting to it, but the infrastructure forms the foundation for the more resilient and sustainable water services in Seattle today. Another part of that foundation is Seattleites' responses to some unintended consequences and environmental changes. Worsening surface water quality between the 1940s and 1960s generated water quality research, environmental awareness, and regulation. To cope with water

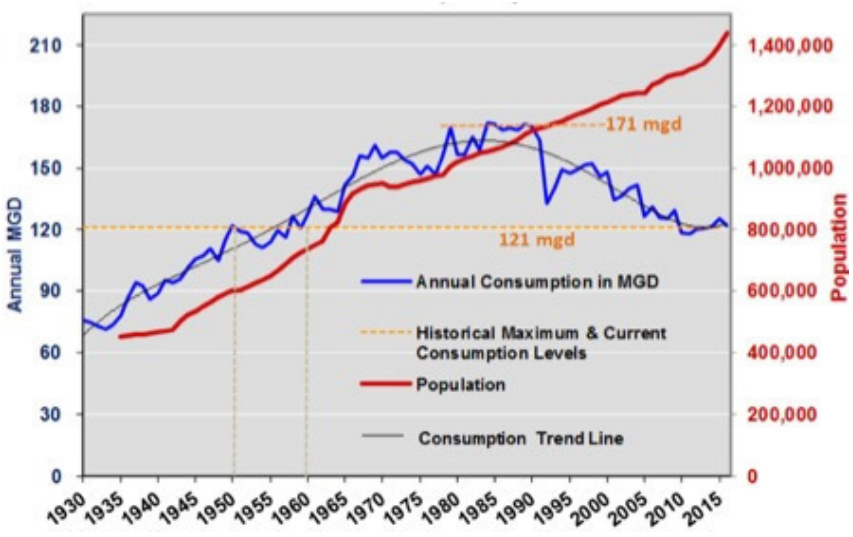

FIG. 1 Seattle region annual water demand in millions of gallons per day (MGD) and population growth 1930-2016. From Seattle Public Utilities, "Volume 1 – 2019 Water System Plan," Figure 2-3. Population Growth and Water Consumption from SPU Sources, p. 2-9.

8. Andrew Karvonen, "Metronatural™: Inventing and Reworking Urban Nature in Seattle," Progress in Planning Vol. 74, 4 (November 2010): 1-2.

scarcity during several droughts, water conservation was successfully implemented by using awareness campaigns and increased water pricing since 1980s, and thus in 2015 the water demand decreased to the level of the 1950s. [Fig. 1].

With an active citizenry and community-based politics, Seattle has been one of the leading cities in sustainability since the 1980's, and has even branded itself Metronatural™, a city in harmony with nature.[9] Our interview results in section 4.1 reveal the most fundamental development steps, creative practices, and policies that have led to the present moment. Some of these socio-economic and environmental impacts alongside selected development steps of water services are presented in Figure 2. [Fig. 2]

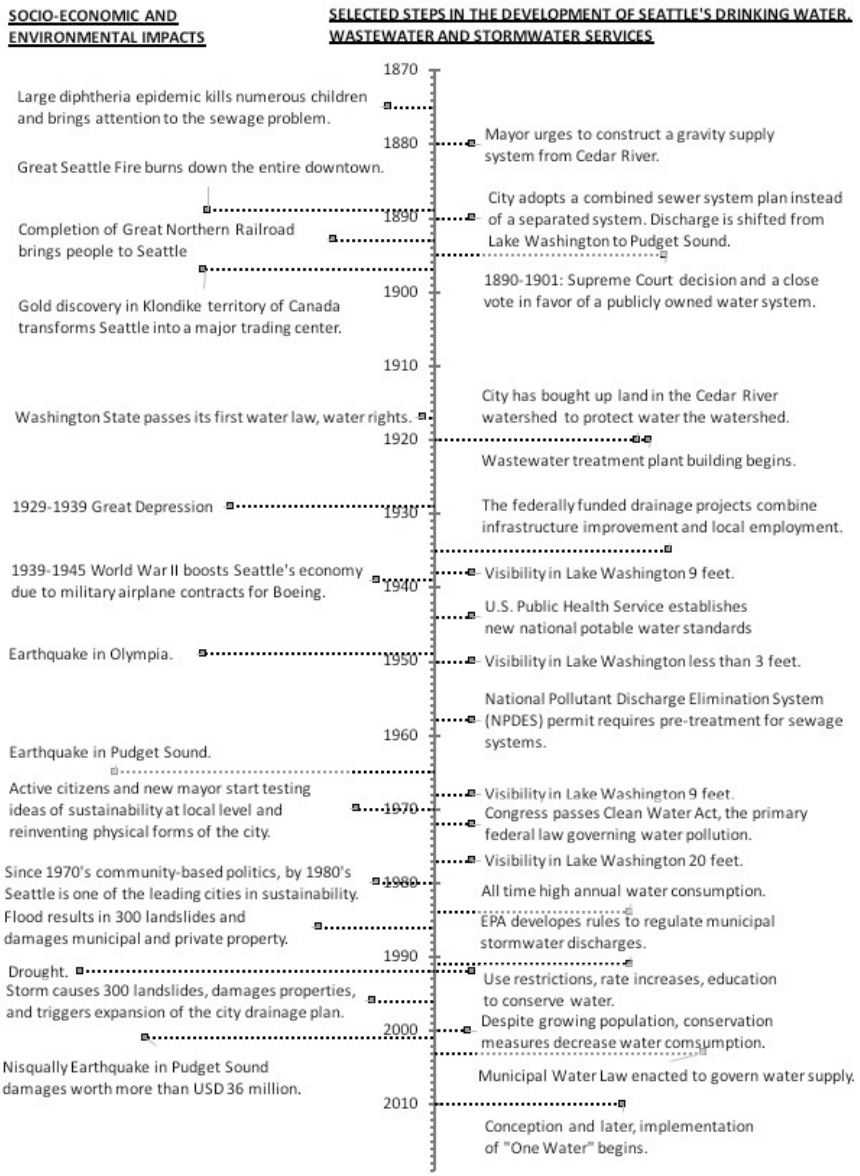

FIG. 2 Selected socio-economic and environmental impacts and development steps of Seattle's water services, 1870-2018. Compiled by the authors from Karvonen, "Metronatural™: Inventing and Reworking Urban Nature in Seattle." and Ott, "City of Seattle adopts plan to build a combined sewer system, to handle sewage and stormwater, on November 30, 1891."

9. Ibid.

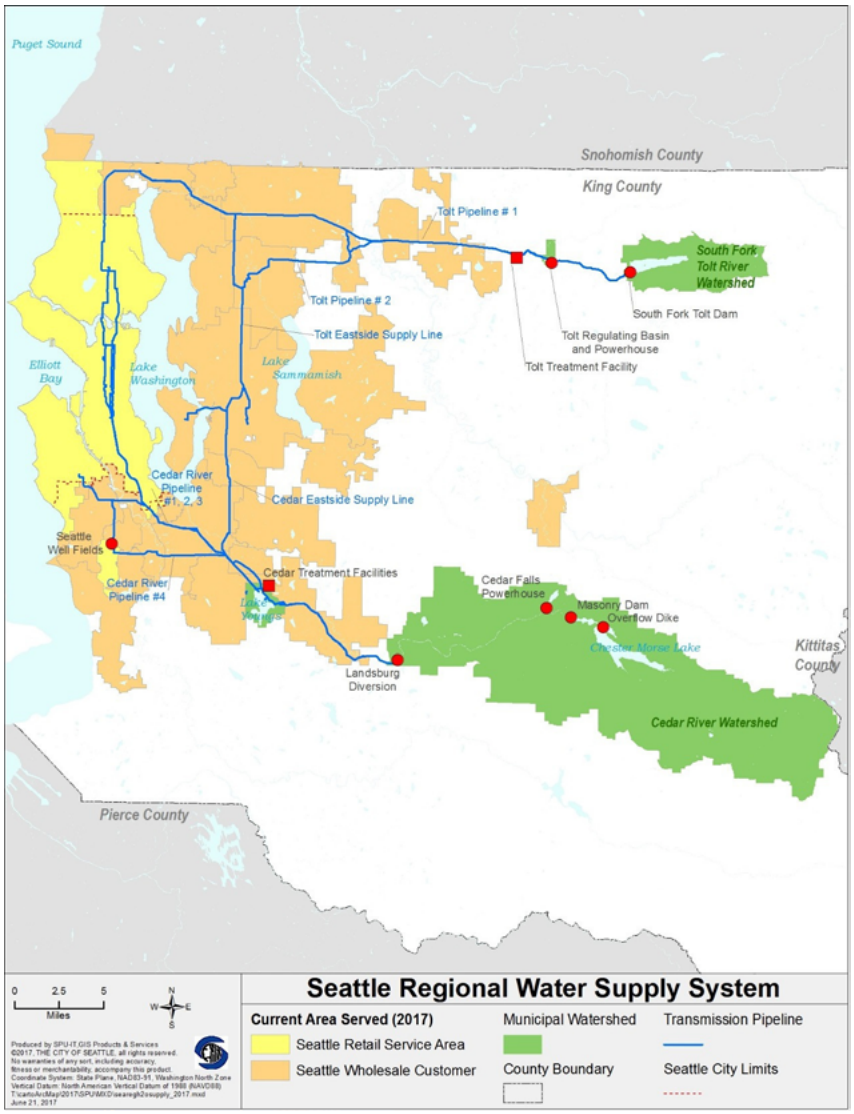

FIG. 3 Seattle regional water supply system. From Seattle Public Utilities, "Volume 1 - 2019 Water System Plan" Figure 1-1. Seattle Regional Water Supply System, p. 1-3.

The present-day water services in Seattle are managed by a city department, Seattle Public Utilities, and a county agency, King County Department of Natural Resources, Wastewater Treatment Division. Their responsibilities include providing clean drinking water, collecting and treating wastewater, and managing stormwater for 1.4 million people in the greater Seattle metropolitan region of King County and parts of southern Snohomish County.[10]

Seattle's water supply and wildlife rely mainly on two reservoirs in Cedar River and Tolt River watersheds owned by Seattle Public Utilities [Fig. 3]. Since the reservoirs depend on precipitation and snowpack and hold enough storage for approximately one water cycle year, climate change is a considerable stressor for the region. In the City of Seattle, there is one large regional wastewater treatment plant and four combined sewer

10. Seattle Public Utilities "Volume 1 – 2019 Water System Plan," 1-1.

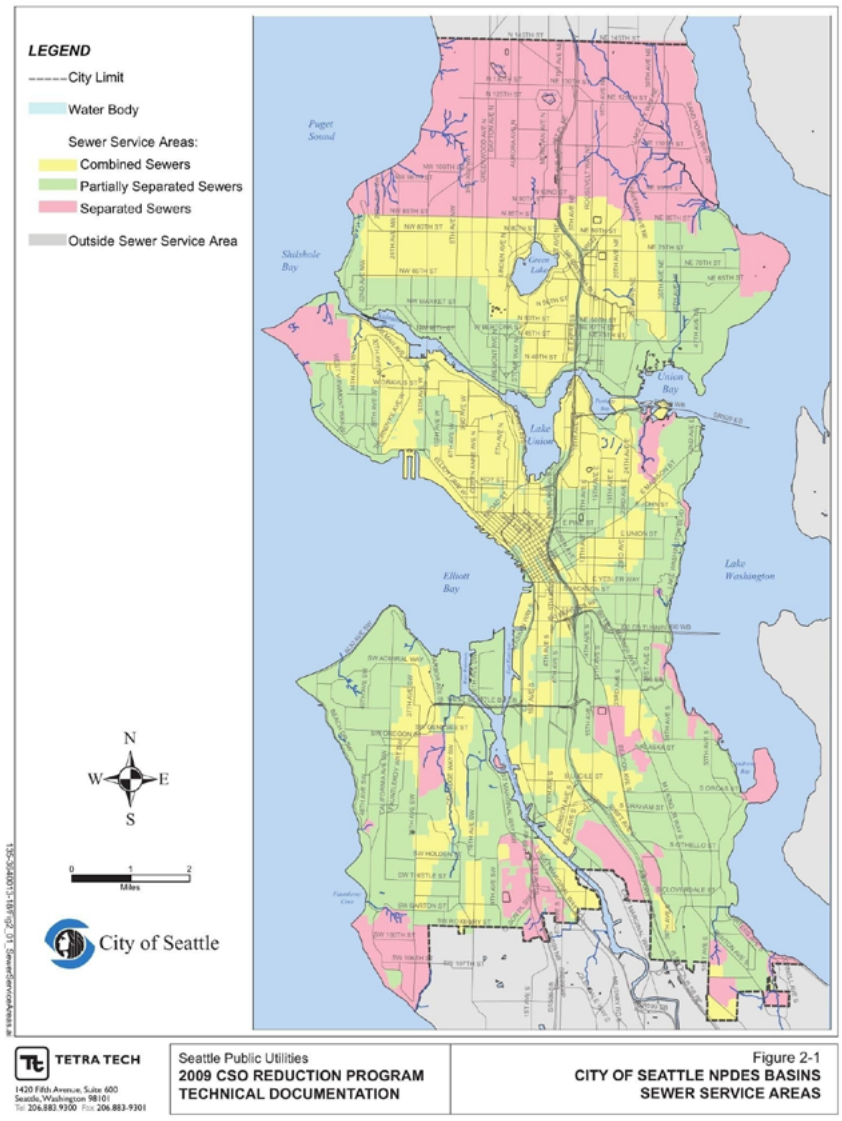

FIG. 4 Seattle sewer service areas. From Seattle Public Utilities, "Stormwater Management", map of Sewer Service Area. Accessed September 10, 2019 at http://www.seattle.gov/util/cs/groups/public/@spu/@usm/documents/webcontent/02_008214.pdf.

overflow (CSO) treatment facilities.[11] Stormwater in Seattle is conveyed partly combined with sewage and partly in separated sewer systems, but increasingly, green stormwater infrastructure is used **[Fig. 4]**.[12]

A challenge to the sewer systems are the increasing rainfall intensities, which are expected to add to urban and tidal flooding, as well as to sea level rise, resulting in, for example, increased combined sewer overflows and water quality issues in local water bodies[13]. Additionally, assessing the magnitude of the change is challenging, especially concerning

11. "King County's regional wastewater conveyance and treatment system", King County Wastewater Treatment Division, last updated December 19, 2016

12. "Stormwater Management", Seattle Public Utilities, accessed November 13, 2018 at http://www.seattle.gov/util/EnvironmentConservation/Projects/SewageOverflowPrevention/StormwaterManagement/index.htm.

13. "Adaptation: Preparing for Climate Change Impacts", Office of Sustainability & Environment, Seattle Government, accessed November 13, 2018 at https://www.seattle.gov/environment/climate-change/climate-planning/adaptation.

precipitation. Seattle's complex geography increases uncertainty and variability in future scenarios, making planning more difficult.[14]

Other great risks for Seattle are posed by earthquakes, which require seismic hazards to be addressed in infrastructure. In addition, ageing water infrastructure requires renewing, which brings the prioritization of water investments and the affordability of water into question. In 2015, the combined price of water, sewer and stormwater in Seattle was the second most expensive among the thirty major cities in the United States. Yet, compared to many European countries, water prices in the United States remain low.[15]

Along with the increasing population, the city faces pressure to densify already built-up areas. Seattle has the fastest population growth rate –18.7 percent from 2010 to 2017 – among the fifty largest US cities. [16] Additionally, Seattle's ageing and retiring workforce holds the risk of reduced numbers of professionals working in the water sector and a loss of institutional memory, knowledge, and skill.[17]

To respond to the transitions and challenges, Seattle Public Utilities aims for long-term sustainability and excellent, affordable service.[18] To achieve its goals, Seattle already has policies, plans and programs in place, for example the Seattle Public Utilities' Risk and Resiliency Assessment and Framework, which describes the efforts Seattle is planning to improve its resilience.[19]

In section 4.2, we present which current policies are the most important for resilience according to the interviewed water sector professionals. In section 4.3, we present professionals' own views on the challenges hindering resilient development as well as their suggestions on how to respond to those challenges. In the following section, we define resilience and other relevant frameworks.

2 Conceptual framework

The main conceptual framework of this paper is resilience. While there are many definitions of resilience, we chose two that ensure sufficient broadness and include consideration of temporal aspects. First, we define resilience for water services according to the United Nations Office for Disaster Risk Reduction as "the ability of a system, community or society

14. "Projected Climate Changes", Seattle Public Utilities, accessed November 13, 2018 at http://www.seattle.gov/Util/EnvironmentConservation/ClimateChangeProgram/ProjectedChanges/index.htm.

15. Sarah Frostenson, "America has a water crisis no one is talking about," *Vox* (March 2018).

16. Gene Balk, "114,000 more people: Seattle now decade's fastest-growing big city in all of U.S.", *The Seattle Times*, (May 24, 2018).

17. Seattle Public Utilities, *SPU's Risk and Resiliency Assessment and Framework, 2018 Status Report* (Seattle Public Utilities, 2018), 6.

18. "Strategic Business Plan, Update – 2018-2023", Seattle Public Utilities, accessed 13 November 2018 at http://www.seattle.gov/util/AboutUs/StrategicBusinessPlan/index.htm.

19. Seattle Public Utilities, *SPU's Risk and Resiliency Assessment and Framework, 2018 Status Report.*

exposed to hazards to resist, absorb, accommodate to and recover from the efforts of a hazard in a timely and efficient manner".[20] We borrow the second definition from Ofwat, the economic regulator of the water sector in England and Wales, which describes resilience as the ability to "anticipate trends and variability in order to maintain services for people and protect the natural environment, now and in the future".[21] These definitions were also provided for the interviewees to ensure mutual agreement about resilience.

While the definitions we selected cover different aspects of resilience, both are also vague and controversial. For example, they lack any mention of when to transition from resisting to accommodating change. Additionally, while it is important to anticipate trends, in reality it is difficult to know which scenario should guide planning. Despite the shortcomings, we still consider these definitions useful for this research.

Another important conceptual framework for this paper relates to policies, which are part of a larger framework of institutions and institutional change. According to Nobel Laureate and American economist D.C. North, "institutions are humanly devised constraints that structure political, economic and social interaction".[22] North divides institutions into informal rules, such as guidelines, norms and traditions, and formal rules, such as laws and regulations.[23] Policies consist of changes in formal institutions, but the outcomes, according to Mantzavinos, North, and Shariq, are results of changes in both formal and informal rules.[24] The institutional change does not happen at once but evolves incrementally, connecting the past with the present and the future.[25] In the next section, we introduce the methodology of this study and discuss research limitations.

3 Methods

The research methods used in this paper are a literature review, policy analysis, and semi-structured interviews. The interviews were individually conducted in 2018 with twelve selected water professionals familiar with water services and resilience in the Seattle area. These methods have been used in similar research studying long-term decisions and their

20. "Terminology," United Nations Office for Disaster Risk Reduction, UNISDR, accessed 28 February 2019 at https://www.unisdr.org/we/inform/terminology.

21. Ofwat, *Towards resilience: how we will embed resilience in our work*, (Birmingham, UK: Ofwat, 2015), 6.

22. Douglass C. North, "Institutions," The Journal of Economic Perspectives, Vol. 5, No. 1. (Winter, 1991): 97

23. Ibid.

24. C. Mantzavinos, Douglass C. North, and Syed Shariq, "Learning, Institutions, and Economic Performance," *Perspectives on Politics*, Vol. 2, No. 1. (2004): 77-79,

25. North, "Institutions," 97.

importance in water services management[26],[27] and future challenges for water services[28].

The literature review, policy analysis, and the structured part of the interviews provide an overview of the development of water services and highlight the importance of certain decisions and policies, which further understanding of different elements involved in building resilience. The open-ended interview questions allowed the interviewees to freely express their insights on the challenges in improving resilience and provide suggestions for how to overcome those challenges. Asking open-ended questions allowed us to explore informal rules, rather than only policies, which are considered formal rules.

To respond to our research questions, five interview questions were devised drawing on similar research on the importance of long-term decisions and future challenges. The first two questions concentrated on current policies: interviewees were asked about the relevance of the selected policies and asked to rank the five most fundamental current policies enabling resilience in Seattle's water services. The lists of selected policies were curated from the literature review and included only the most significant policies which enable water services and their resilience. In the third question, interviewees were asked to rank the ten most defining development steps in water services management in Seattle.

The two open-ended questions on the other hand, were intended to identify challenges in advancing resilient water services in the future and to elicit suggestions for improvement. For all five questions the interviewees were allowed to choose whether to answer questions related to water supply (eight respondents), wastewater (six respondents), and/or stormwater (eight respondents).

The results from the first three interview questions, i.e. the ranking exercises, were analyzed individually by giving each placement a set of points ranging from five or ten points for the highest-ranking policy, to one point for the lowest-ranking policy. Based on the ranking, the order of importance for the policies and development steps was revealed. Even though four interviewees ranked less than five or ten choices, and one interviewee listed more than one option as first, second and third choices, all answers were still considered in the results.

For the analysis of the last two questions, which were open-ended, we categorized all responses of both challenges and suggestions according to their content into nine broader themes: collaboration, cost, infrastructure,

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26. Tapio S. Katko, Petri S. Juuti, and Pekka E. Pietilä," Key long-term decisions and principles in water services management in Finland, 1860-2003," *Boreal Environment Research*, Vol. 11, no. 5 (2006): 389-400.

27. Petri Juuti et al.," Shared history of water supply and sanitation in Finland and Sweden, 1860-2000," *Vatten. Föreningen Vatten*. Vol. 65, no. 3 (2009): 165-175.

28. Ossi A. Heino, Annina J. Takala, and Tapio S. Katko, "Challenges to Finnish water and wastewater services in the next 20-30 years," *E-Water*, EWA (2011).

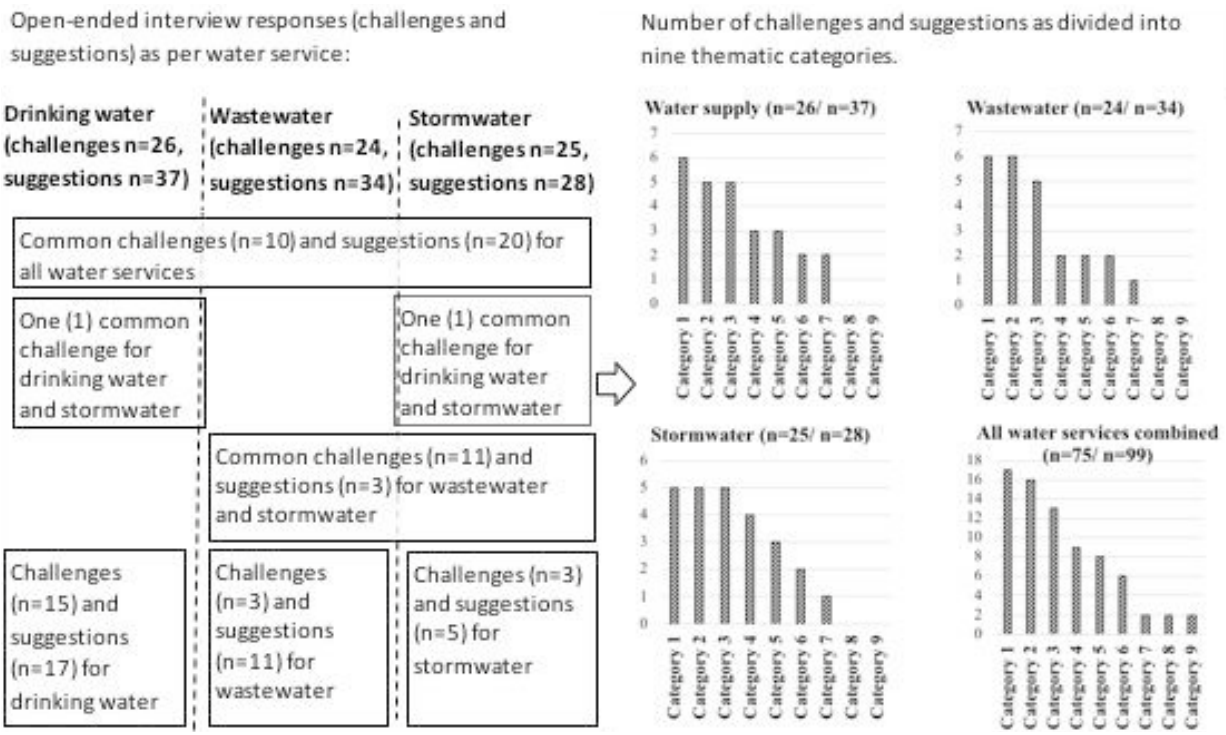

FIG.5 Schematic overview of the analysis process for open-ended questions

mindset and habits, regulation, strategy, workforce, other, and environment (only for challenges) or organizations (only for suggestions). In cases where a common challenge or suggestion was mentioned for two or for all water services, the responses were considered for both or for all water services respectively. A schematic overview of the whole analysis process for open-ended questions is illustrated in Figure 5 [Fig. 5]. All results are presented in detail in section four and discussed further in section five.

3.1 Limitations of the research

Water services management is cross-disciplinary, that is, it connects and relates to many other sectors than just water services, hence there is a vast number of related policies, many of which overlap with the other sectors. For the purpose of this study, the policy compilations used in the interviews were not intended to be comprehensive but rather as selections of the most important policies pertaining to the resilience of water services in Seattle. The selected policies included laws, rules, regulations, programs, and plans that directly related to providing water services and water quality, as well as specific policy choices such as collaborations and a decision to purchase watershed land to secure the water source. To ensure an appropriate selection, interviewees were allowed to add policies to the list.

We acknowledge that ranking the importance of policies can be subjective. Policies often create chains of dependencies where one policy requires

action, and another responds to it. Therefore, at times it can be challenging to choose whether the key policy is an important program or the law enforcing it. To address this limitation, we selected a knowledgeable and diverse group of interviewees. Based on the similarity of responses in our individually conducted interviews, we assume that the group of twelve interviewees was representative enough. In another similar research setting, the Finnish civil engineers Tapio Katko and Pekka Pietilä, and environmental historian Petri Juuti used thirteen respondents.[29] Expanding the group may result in slight changes to the ranking of the results.

4 Results

This section presents the results from the interviews. We begin with the results of ranking the importance of past development steps (section 4.1), advancing then to the importance of present policies (section 4.2). Finally, we present the future-oriented results from the open-ended questions about challenges in advancing the resilience of water services in Seattle and suggestions for improvement (section 4.3).

4.1 Past key development steps enabling resilience

This section answers the first research question about the development steps and policies that have led to the current situation. Based on respondents' choices of relevant issues found in literature and policy analysis, Figures 6-8 **[Figs. 6-8]** illustrate the importance of specific policies and practices for the development of resilient water services in Seattle. The results for each water service are discussed at the end of section 4.1 and further in section 5.

For water supply, over half of the 22 development steps that interviewees found fundamental for resilience deal with securing the water source in terms of water quality and quantity **[Fig. 6]**. Steps to securing the quantity of water include the purchase of watershed land and water conservation programs. The establishment of water testing laboratories and water treatment facilities on the other hand are important steps to ensure good water quality. Other important development steps involve development of the water infrastructure and its management. The results highlight the fundamental basics of resilient water supply: safe and available water, accessible to its users.

For wastewater, on the other hand, the two most important policies relate to the development of legislation and regulation: the National Pollutant Discharge Elimination System, NPDES, and Clean Water Act in 1972 **[Fig. 7]**. Similar to water supply, the development of the infrastructure

29. Katko, Juuti, and Pietilä, "Key long-term decisions and principles in water services management in Finland, 1860-2003."

FIG. 6 Importance of past water supply-related policies to the development of resilience in Seattle, based on respondents' choices of relevant issues found in literature and policy analysis.

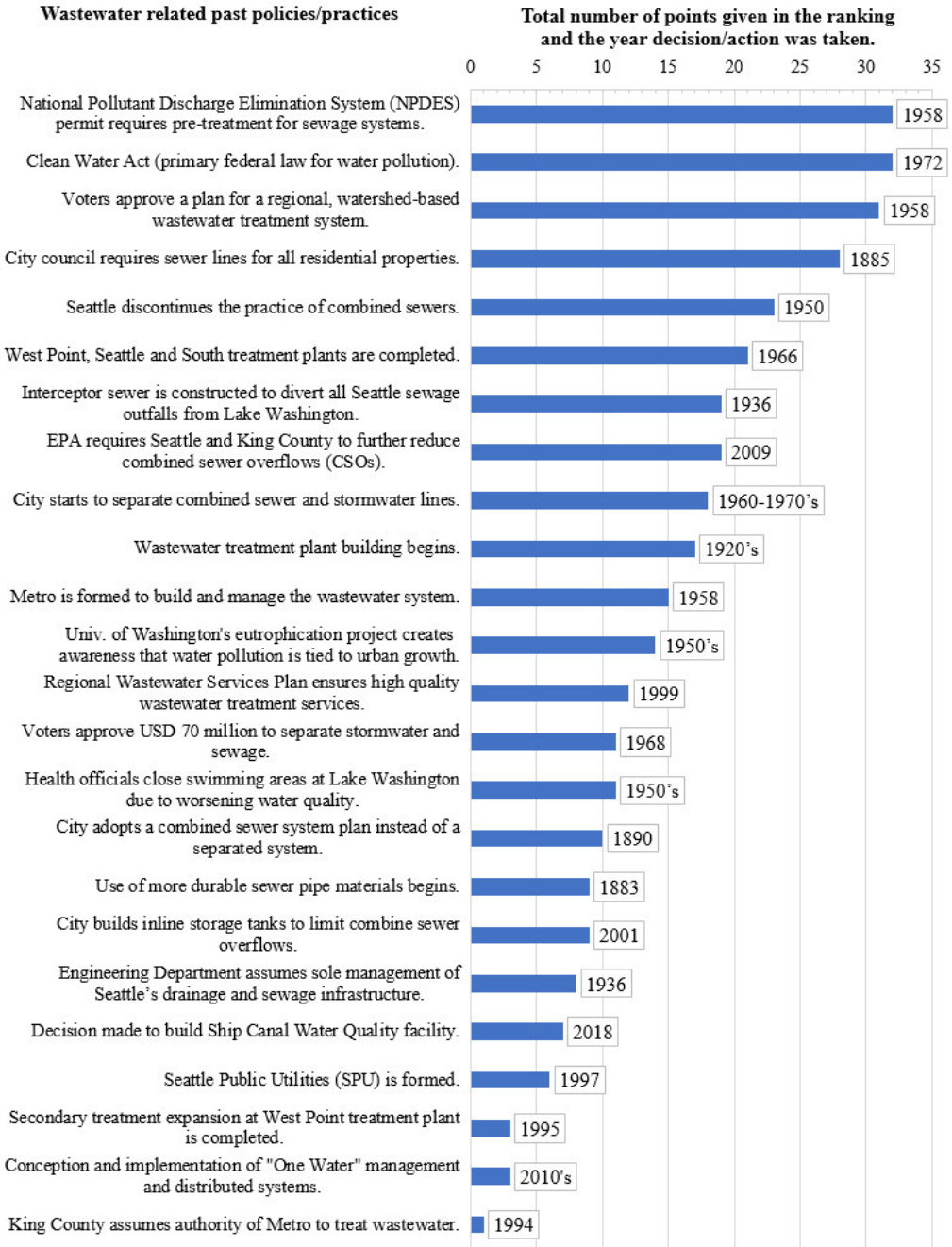

FIG. 7 Importance of past wastewater-related policies to the development of resilience in Seattle, based on respondents' choices of relevant issues found in literature and policy analysis.

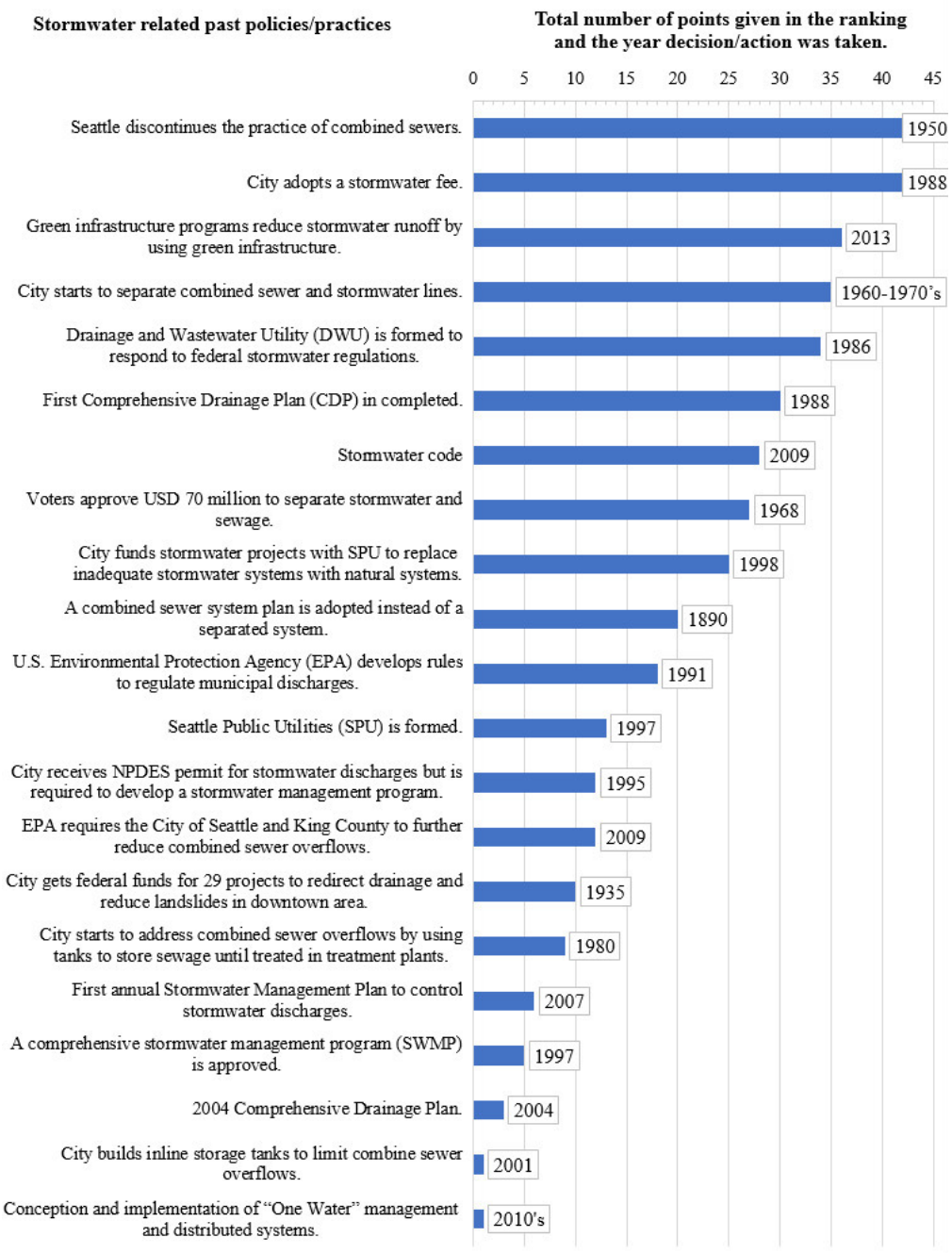

FIG. 8 Importance of past stormwater-related policies to the development of resilience in Seattle, based on respondents' choices of relevant issues found in literature and policy analysis.

and its management are also important for achieving resilience in wastewater services. Most of the 22 policies that interviewees considered fundamental for resilient wastewater services relate to improving water quality, indicating its importance not only to human health but also to the environment.

The steps interviewees found most significant for resilience in stormwater management included the decision to discontinue building combined sewer and stormwater lines, which reduced sewage overflows to the environment during heavy rains. Another was the adoption of a stormwater fee to finance stormwater management; this fee financed many of green stormwater infrastructure projects **[Fig. 8]**. Plans and programs in the ranking, such as green infrastructure and drainage plans, reflect the importance of sustainable stormwater management practices in the existing cityscape.

4.2 Importance of key current policies for resilient water services

This section answers the second research question, concerning which policies are most important for the resilience of Seattle's water services. Based on respondents' choices of relevant issues found in literature and policy analysis, Figures 9-11 **[Figs. 9-11]** illustrate current policies that are the most fundamental in enabling resilience for Seattle's water services. The order of importance provides an indication to policy makers and other officials about, for example, where to target funding, time and effort to maintain and improve resilience. The results for each water service are discussed at the end of section 4.2 and further in section 5.

For water supply, two policies stand out as most important. One is the local, periodically updated, Seattle Public Utilities' water system plans. These are plans for the regional water supply, water system, shortage response, and demand forecast for at least twenty years. The other policy is the city's historic decision to purchase watershed land to secure the quantity and quality of water supply **[Fig. 9]**. Today, that action to protect the water source results also in less need for water treatment, and thereby, in reduced cost. Other central policies highlight the importance of legislation and regulation, such as the National Safe Water Act (1972) to ensure drinking water quality, local Seattle Public Utilities Director's Rules (SPU formed in 1997) to implement legislation, state-level Tribal Rights (1855) and Washington State Law (1st in 1917 on water rights). Additionally, the ranking shows the significance of collaborations and specific programs such as Seattle Public Utilities' Capital Improvement Program (since at least 2001), which is a six-year financial planning tool to identify future capital investments and potential strategies for their funding[30].

30. "2019-2024 Proposed Capital Improvement Program", City Budget Office, last updated 24 September 2018, http://www.seattle.gov/financedepartment/1924proposedcip/default.htm.

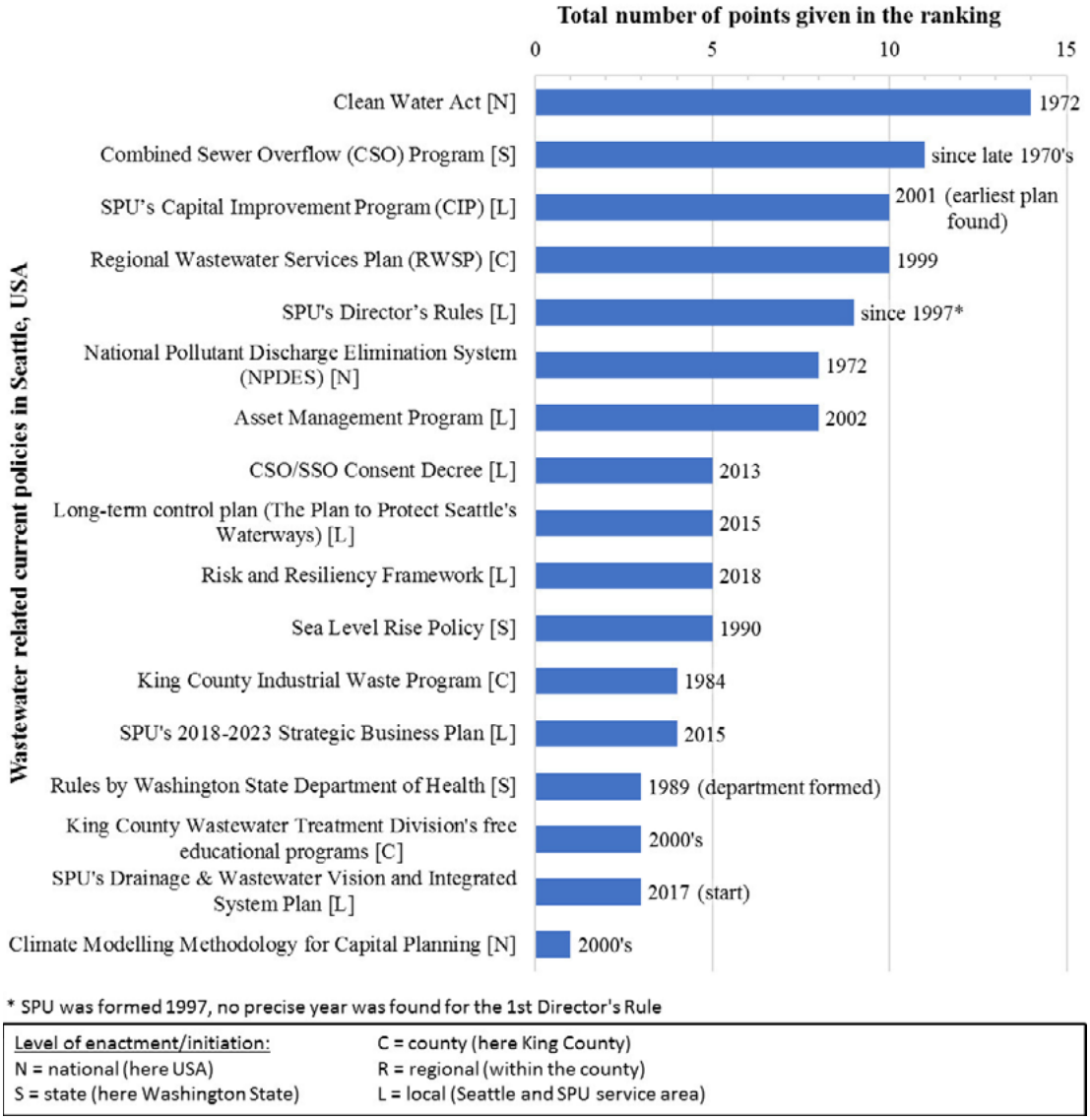

FIG. 9 Importance of current water supply-related policies to resilience in Seattle, based on respondents' choices of relevant issues found in literature and policy analysis.

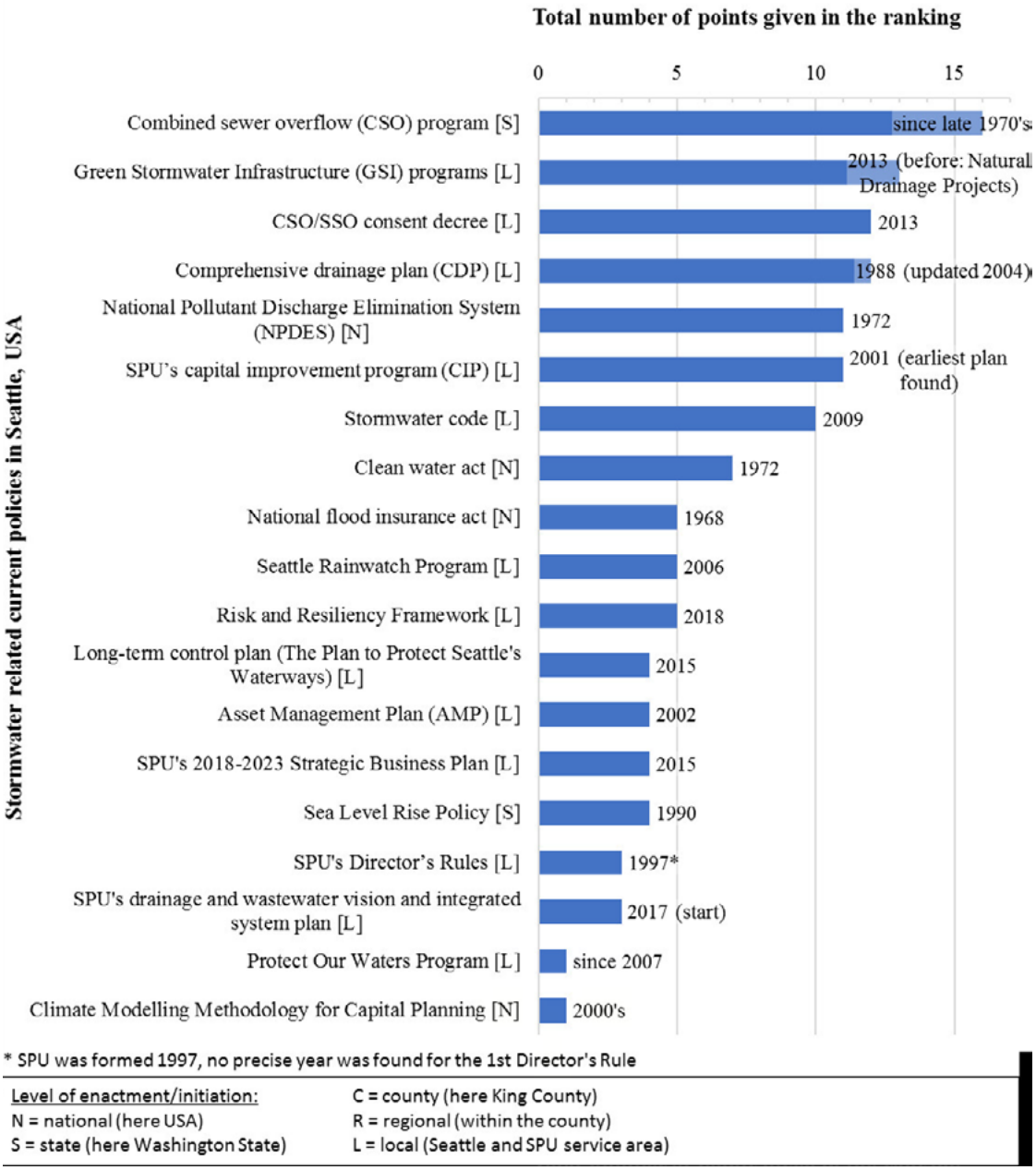

FIG. 10 Importance of current wastewater-related policies to resilience in Seattle, based on respondents' choices of relevant issues found in literature and policy analysis.

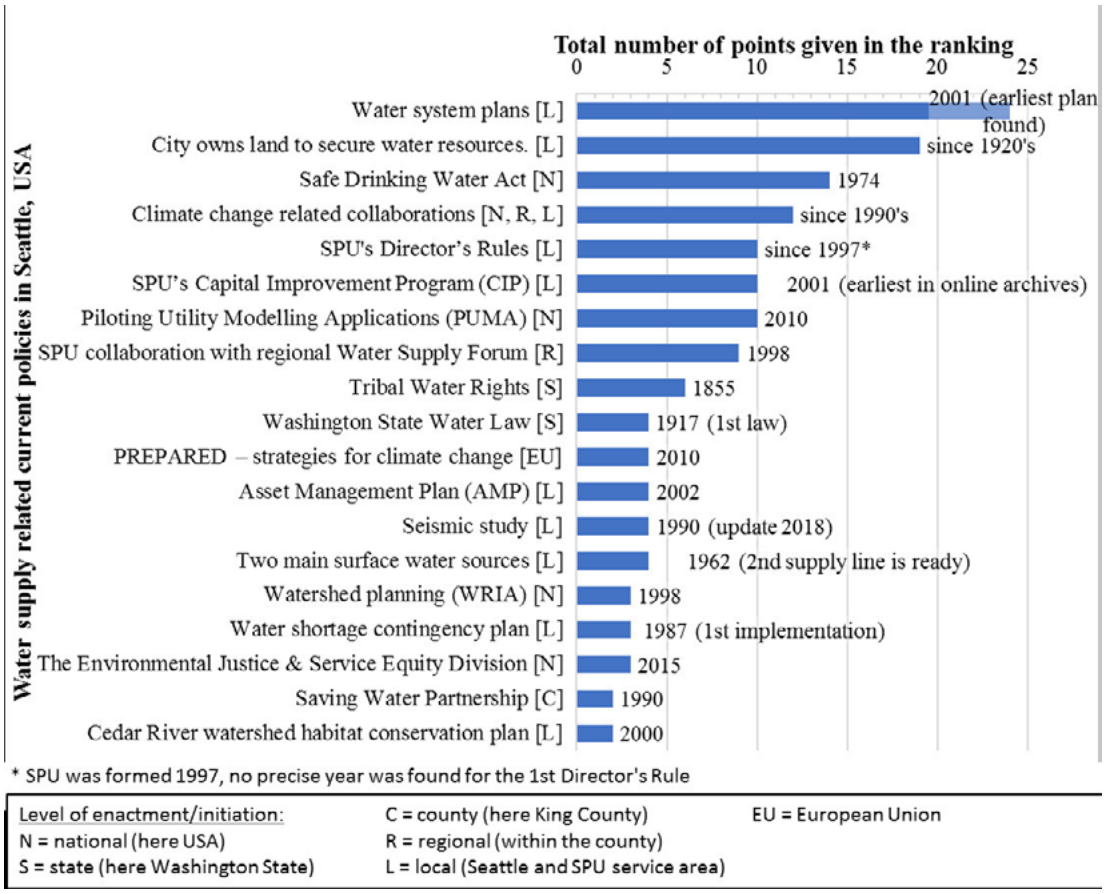

FIG. 11 Importance of current stormwater-related policies to resilience in Seattle, based on respondents' choices of relevant issues found in literature and policy analysis.

For wastewater, five of the 17 policies, which interviewees considered important to resilience involved rules and regulations, the most significant being the Clean Water Act (1972), a federal regulation [Fig. 10]. Yet, most of the highlighted policies are programs and plans such as the state-level Combined Sewer Overflow Program (in place since the late 1970's) to prevent sewage overflows, a county-level Regional Wastewater Services Plan (1999) to ensure the high quality wastewater services in the future, as well as Seattle Public Utilities' six-year financial planning tool, the Capital Improvement Program (since at least 2001) and Asset Management Plan (2002) to meet agreed customer and environmental service levels while minimizing costs of maintaining and operating the infrastructure. The number and type of plans and programs in the ranking highlight the importance of practical activities at the local level.

Interviewees considered 19 policies to be significant for the resilience of stormwater management [Fig. 11]. Similar to wastewater, interviewees highlighted several programs and plans and the Combined Sewer Overflow Program (which began in the late 1970's) ranked highest. The three most important pieces of legislation and regulations for stormwater are (i) the local Combined Sewer Overflow (CSO) / Sewage Sewer Overflow (SSO) consent decree (2013), an agreement with Seattle and the national Environmental Protection Agency, Department of Justice, and the Washington State Department of Ecology to formalize Seattle's approach to reducing

sewage overflows; (ii) the National Pollutant Discharge Elimination System (1972), which addresses water pollution by regulating point sources; and (iii) the local stormwater regulation, the Stormwater Code (2009), which aims to protects people, property, and the environment from damage caused by stormwater runoff. Noticeably, most of the plans and programs as well as the regulation deal with stormwater quality. However, urban flooding has been and is expected to be an issue in Seattle.

4.3 Improving the future resilience of Seattle's water services

This section focuses on the challenges involved in improving resilience and recommendations for improvement. Responses regarding both challenges and suggestions were divided into nine broad categories: collaboration, cost, infrastructure, mindset and habits, regulation, strategy, workforce, other, and environment (only for challenges) or organizations (only for suggestions). We begin the section with the envisioned challenges in advancing resilience followed by ideas and suggestions to avoid them.

5 Challenges in advancing resilience in Seattle

In the interviews, the respondents highlighted 75 challenges in achieving resilience for Seattle's water services. [Fig. 12].

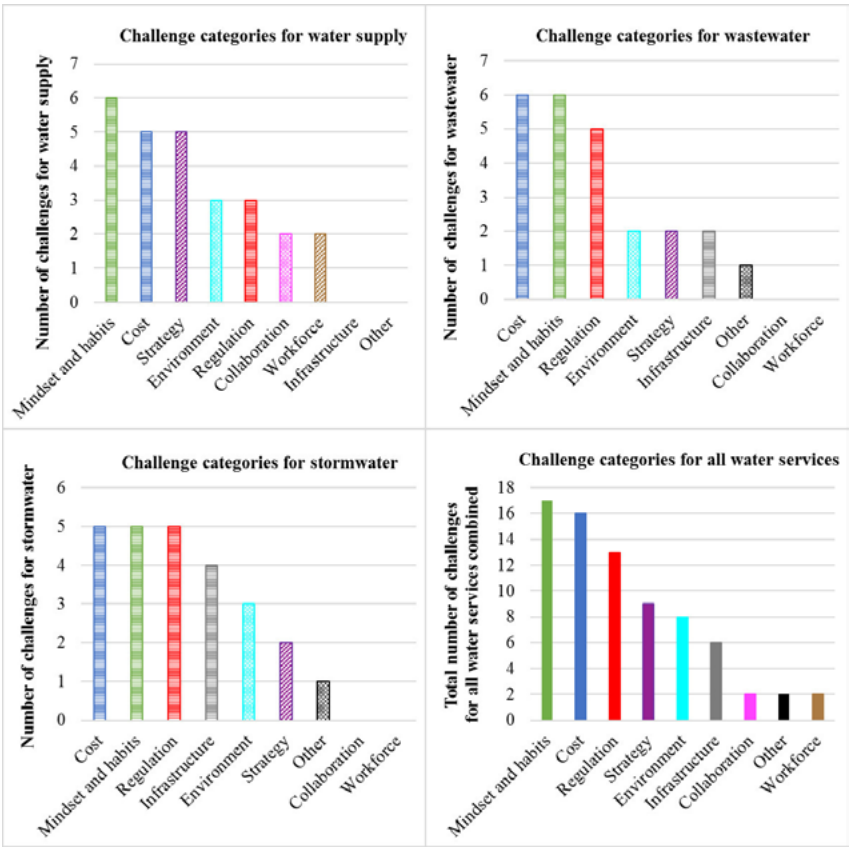

FIG. 12 Number of challenges in advancing resilience of water services in Seattle, USA based on respondents' views.

CHALLENGES	Water supply	Wastewater	Stormwater
Mindset and habits	• Dealing with public opinion about raising water rates to pay for resilience.	• Dealing with competing interests, especially between combined sewer overflows and other programs.	
Costs	• Raising water rates to pay for resilience.	• Prioritizing and directing funding. • Deciding whether capital spending should continue according to 1990's plan or challenging regulators to tackle newer problems and needs for different technologies.	• Raising taxes and getting funding.
Strategy	• Deciding on water allocation between different users. • Finding new water sources. • Balancing and prioritizing needs and requirements.		
Collaboration	• Initiating/strengthening partnerships between research and non-research communities. • Getting people to collaborate in general. • Rapidly aging and retiring workforce. • Right placement of field workforce in emergencies.		
Regulation	• Inflexible water rights.	• While broad in scope and important, the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) and associated permits over-prioritize water quality and combined sewer overflows. • Narrow and constricting regulatory instruments such as permits hamper integrated thinking and make it difficult to address affordability, resilience, and prioritization of the greatest local environmental problems.	
Infrastructure		• Combined sewers and aging infrastructure.	• Climate change adaptation: • 1. handling larger water volumes beyond upsizing systems; • 2. advancing Seattle's green infrastructure program to meet population growth.
Other		• Diversifying demographics and social issues including homelessness and its implications for the provision of water services.	

TAB. 1 Specific challenges in advancing resilience of water supply, wastewater, and stormwater services in Seattle, USA based on respondents' views.

The greatest common challenges for all water services are seen in the current *mindset and habits* of the general public, officials and professionals. These challenges include issues in understanding the impact of societal and environmental changes; a lack of holistic and long-term thinking; delays in decision-making regarding issues that are unlikely to arise in our lifetime; a mindset that concentrates only on resisting change instead of adapting to it; and a reluctance to depart from current practices, processes and ways of thinking. The second greatest challenge, *costs*, is three-fold. Interviewees reported a shortage of funding and difficulties in maintaining affordability—of water for example, and restrictions that prioritize the use and distribution of funds. In terms of *regulation*, several interviewees called for more flexibility and adaptivity. While laws and national regulations were seen as important, associated permits were considered narrow and constricting, further hampering integrated thinking and ability to address affordability, resilience, and prioritization of the greatest local environmental problems. Strategy-wise the challenge lies in choosing the right strategies to navigate uncertainty and the plethora of future scenarios. There is also a risk that, in the future, city priorities might change, resulting in less emphasis on resilience. Water service-specific challenges are described in Table 1 [Tab. 1]. The table provides detailed challenges for each water service that can be useful for future policy development.

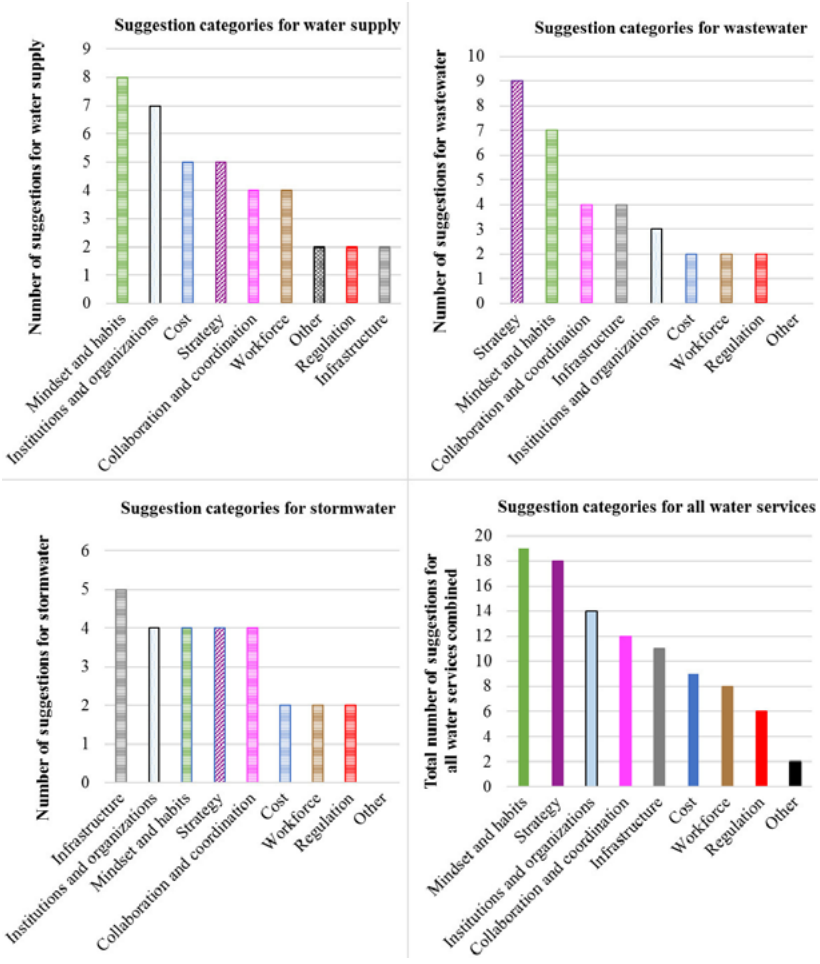

FIG. 13 Number of suggestions for advancing resilience of water services in Seattle, USA based on respondents' views.

SUGGESTIONS	Water supply	Wastewater	Stormwater
Mindset and habits	• Continue water conservation. • Continue working on demand management and people's willingness to spend money on resilience.	• Improve officials' and professionals' understanding and work on regional values, residents' issues and expectations, shifting demographics, equity and social issues, and the interconnectedness of different sectors.	• Perceive resilience as social and human capital. • Encourage acceptance to changes, rather than resisting them. • Learn to live with water.
Costs	• Consider water rate regime for climate change adaptation despite possible opposition. • Execute and plan for financial resilience. • Decide on how, where and when to use funds.		
Strategy	• Avoid overbuilding the water systems. • Plan for uncertainty.	• Improve strategies for emergencies. • Improve response strategy and recovery plans by i) enhancing understanding of interconnectedness of different sectors and actors, and ii) providing services like translation services. • Continue developing design guidelines for convenience pipelines. • Increase concentrated communication and focused outreach to certain neighborhoods. • Approach resilience in a more comprehensive manner by including ways to create resilience, starting points, and resources for action.	
Collaboration	• Improve and create connections within and outside the utility. • Explore interagency and regional collaboration to connect and find new water sources.	• Improve collaboration and coordination to prioritize the biggest combined sewer overflows. • Increase coordination between government entities, private sector and other stakeholders.	• Advance partnerships with other city agencies to better utilize the city landscape in stormwater management.
Workforce	• Respond to the aging workforce dilemma by continuing apprenticeship and internship programs and by emphasizing the benefits of the public service sector such as work-life balance. • Dedicate staff to resilience.		
Institutions and organizations	• Embed resilience as part of daily operations.		• Rethink how the utility could be more flexible and more of a catalyst for change instead of just providing services.

Institutions and organizations	• Embed resilience as part of daily operations. • Enable flexibility in changing the course of projects and programs by monitoring changes, identifying thresholds, and adapting accordingly. • Make organizational changes to better foster champions, vision, and peer networks.		
Infrastructure	• Further explore options to diversify the water source portfolio by i) interconnecting systems and water storage regionally, and ii) finding and using new sources such as groundwater and desalination.	• Continue the work on combined sewers. • Explore new pilot programs and technologies such as a real-time micro-scale wet weather monitoring program pilot from Copenhagen that allowed the drainage system to adapt automatically to changing flows. • Support installing on-site water systems and technologies during the next building boom to capture stormwater and greywater and to treat wastewater to reduce the demand in the central system.	• Use city's open space better as water storage.
Other	• Push decision making by using external pressure from partners, voters, and maintaining the Seattle brand. • Continue work on cyber security and vulnerability.		

TAB. 2 Specific suggestions for advancing resilience of water supply, wastewater, and stormwater services in Seattle, USA based on respondents' views.

6 Suggestions for advancing resilience in Seattle

The interviewees offered as many as 99 suggestions for improving the resilience of water services. Compared to the challenges section, the suggestions were more dispersed among the three water services. [Fig. 13].

In general, the on-going comprehensive work on resilience was recognized for all water services in all nine categories and interviewees thought it should be continued. In the combined ranking of interview responses for all water services, the most important category in advancing the resilience of Seattle's water services was *mindset and habits* of the general public, officials and professionals, including political will. More precisely, interviewees proposed that resilience should be perceived more as adapting instead of just resisting, and practitioners should move away from stationary, fixed practices that do not allow enough adaptation and flexibility in a changing environment. In the *strategy*-category, suggestions related to strategies, plans, research, and design guidelines. For all water services, interviewees also suggested a pre-disaster management plan, continuing the current vision plan, including social and equity factors, and

moving away from older, stationary, and change-resisting plans towards more adaptive plans.

In terms of the working culture and environment of *institutions and organizations*, resilience would be better achieved if the institutional set-up allowed more innovation, individual growth, and collaboration. Additionally, interviewees suggested organizational changes to better support the staff who have worked extensively in the field of resilience. In terms of *collaboration*, all water services were encouraged to increase it. One interview response, relating to *costs*, suggested promoting resilience by introducing a discount rate for sustainability. In terms of *workforce*, interviewees suggested recruiting talent that is aware of the past, understands the system management but is not stuck in the old procedures. In terms of *regulation*, federal and local regulation should be able to change and adapt according to changing environmental conditions. Water service-specific suggestions are summarized in Table 2 [Tab. 2]. The table provides detailed suggestions and ideas regarding how to improve resilience for each water service separately. These suggestions can be useful in future policy development.

7 Discussion

Overall, the results indicate that the important policies enabling resilient water services in Seattle are not a single type and design but a mix of laws and regulations, programs and plans, and specific policy choices that take place at all levels of governance, although mostly at the local level. Since flexibility and adaptability are part of the definition of resilience,[31] we argue that diverse policies are an essential element when responding to changing circumstances. Therefore, we suggest that for water services to be and become resilient, they need a diverse policy environment both in terms of type and design of the policies but also in terms of the governance level at which they are implemented.

While local level policy design and implementation can be restricted by its set environment (including physical location, climate and the past) and national and regional legislation [Fig. 14], we argue that local regulations, plans and programs can still significantly influence resilience due to local knowledge and understanding of the natural and social environment. Combined with sufficient authority, local policies can enable flexible and innovative policy responses. Additionally, we argue that in resilient policy design it is important to understand how current policies have been developed, because many past decisions still influence present practices.

While according to institutional theories, policies are considered formal rules and institutions, informal rules have an impact on the transforma-

31. "Terminology," United Nations Office for Disaster Risk Reduction.

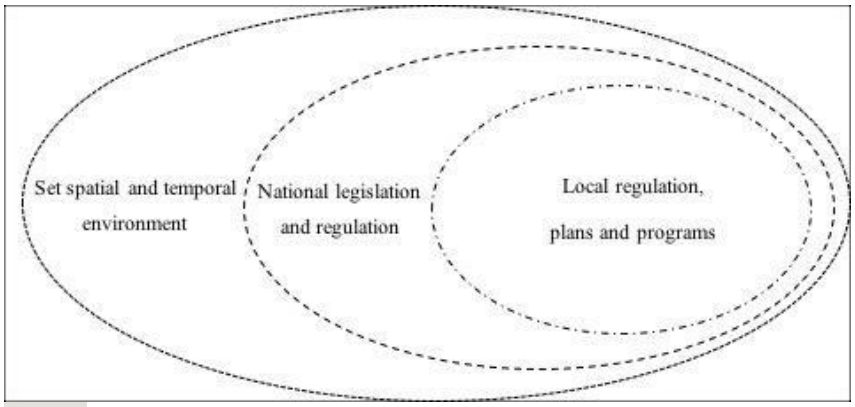

FIG. 14 Restricting spaces of resilience in water services. From United Nations Office for Disaster Risk Reduction, UNISDR. "Terminology." Accessed February 28, 2019 at https://www.unisdr.org/we/inform/terminology..

tion of formal institutions.[32] In other words, habits, norms, and traditions can influence how successful implemented policies will be. The importance of these informal rules was highlighted in the results of the open-ended interview questions. Changing people's mindsets and habits, that is, the informal rules, was seen both as the greatest challenge and best path to achieving greater resilience.

8 Conclusions and recommendations

In this study, we explored how policies have enabled resilience in Seattle's water services as well as challenges in improving resilience and ways of responding to them. Furthermore, we identified three restricting spaces or levels [Fig. 14] in implementing policies that promote resilient water services.

Based on the analysis we conclude that for resilient policy design, it is important to understand the past development steps because they are often connected to present practices. In Seattle, the most important past development steps and policies that have enabled resilience in water services relate to i) securing water quantity and quality; ii) building, operating and managing adequate infrastructure; and iii) relevant legislation and regulation. The most important current policies, on the other hand, relate more to managing and improving the existing resilience, that is, having plans and programs and managing systems which advocate resilience.

In addition to formal rules, informal rules also play a role in policy development. Based on the interviews, the greatest challenges in advancing resilience in the future involve informal rules, that is people's mindsets and habits. Other challenges included lack of funding and inflexible regulation, which can hamper integrated thinking and the ability to address, for example, the prioritization of the greatest local environmental problems. The interviews also resulted in suggestions for improving resilience, of which four main recommendations are: i) creating awareness and chang-

32. Mantzavinos, North, and Shariq, "Learning, Institutions, and Economic Performance," 77-79.

ing the general mindset (regarding the value of water and of water use and management); ii) further improving current strategies to respond to various future scenarios as well as to social and equity issues; iii) implementing concrete measures to embed resiliency into daily operations and future visions; and iv) improving holistic, cross-disciplinary collaboration and coordination.

Our findings indicate that successful policies for resilient water services are diverse in terms of their design, type, and implementation level. While actions at the local level are powerful in enabling resilience, activities and decisions or, on the contrary, inactivity, at national and global levels might impact the extent to which the local level is able to implement local policies that could enable more resilient water services. Therefore, resilience should be considered in policy-making at all levels from local to global.

The results of this study provide insights regarding the importance of certain policies to the resilience of water services. These insights should be useful to policy makers in Seattle as they clarify the most fundamental elements that contribute to resilient policy design and water services management. These elements, combined with challenges and suggestions provided in the interviews of the water sector professionals, can then be further considered in future planning. In terms of future research, repeating similar studies elsewhere would reveal whether, and to what extent, challenges in improving resilience and suggestions for improvement follow similar patterns as in Seattle.

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