

FROM DISASTER TO DESIGN

How the 2021 floods changed the framing of climate adaptation in urban flood management among authorities in Wuppertal, Germany



M.Sc. Thesis by Charlotte Bürgers

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Water Systems and Global Change Group



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Master Thesis Water Systems and Global Change Group in partial fulfillment of the degree of Master of Science in Environmental Sciences at Wageningen University, the Netherlands

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11.06.2024

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ABSTRACT

From 12-15 July 2021, extreme precipitation in Western Europe, especially in Germany, caused severe flooding, resulting in hundreds of fatalities and billions of euros in damages in many cities. The disaster made the growing risk of extreme events due to climate change apparent and sparked public and political debate on climate adaptation in urban flood management. How local climate adaptation is approached depends on a variety of locally specific societal and environmental factors, and often follows the framing of the adaptation issue and desired solutions among responsible authorities. Frames of adaptation are dynamic, and the experience of extreme events has been suggested to prompt reconceptualization of the adaptation challenge. To shed light on the effect of extreme flood events on urban flood adaptation, this study investigated the impact of the July 2021 floods on framing of climate adaptation in urban flood management among responsible authorities in the affected German city Wuppertal. The study used a combination of document analysis to compare framing before to after the disaster, and expert interviews to identify a connection of observed changes with the experience of the flood disaster. The analysis revealed a definitive increase of the framed urgency and extent of needed adaptation, while the most suitable strategies, revolving around nature-based adaptation approaches, were defined well before the 2021 flood. The data suggest that the Wuppertal authority reframed the application context of the already known tools for flood adaptation to encompass all parts of the urban system. Thus, this study highlights the post-disaster window of opportunity for redeliberation about flood adaptation and emergence of new concepts, which is limited in time and must be used efficiently by professionals to advance climate adaptation after a flood. However, the study suggests that the impact of a disaster on framing in urban flood management is mediated by several variables, namely discussions on larger geographic scales, motivated individuals in the authorities and the interactions between different responsible actors.

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I like to think that I am part of an everchanging system. That any thought I am having is a result of countless conscious and subconscious interactions with the world and people around me. Thus, this is my favorite section of the thesis, because I get to point out all the different people that have given something to me and my work.

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1. INTRODUCTION

1.1 GERMAN FLOODING CATASTROPHE 2021

From 12-15 July 2021, extreme precipitation was recorded in large parts of Western Europe. Especially in Germany's West, large regions recorded over 150 mm rain within a few hours (light pink in Figure 1), which is several times the average monthly precipitation in July (Junghänel et al., 2021). The extreme rainfall caused severe floodings with hundreds of fatalities and damages of several billion € to infrastructure, including houses, bridges, roads, and train tracks (Bundesministerium des Innern für Bau und Heimat & Bundesministerium der Finanzen, 2021).

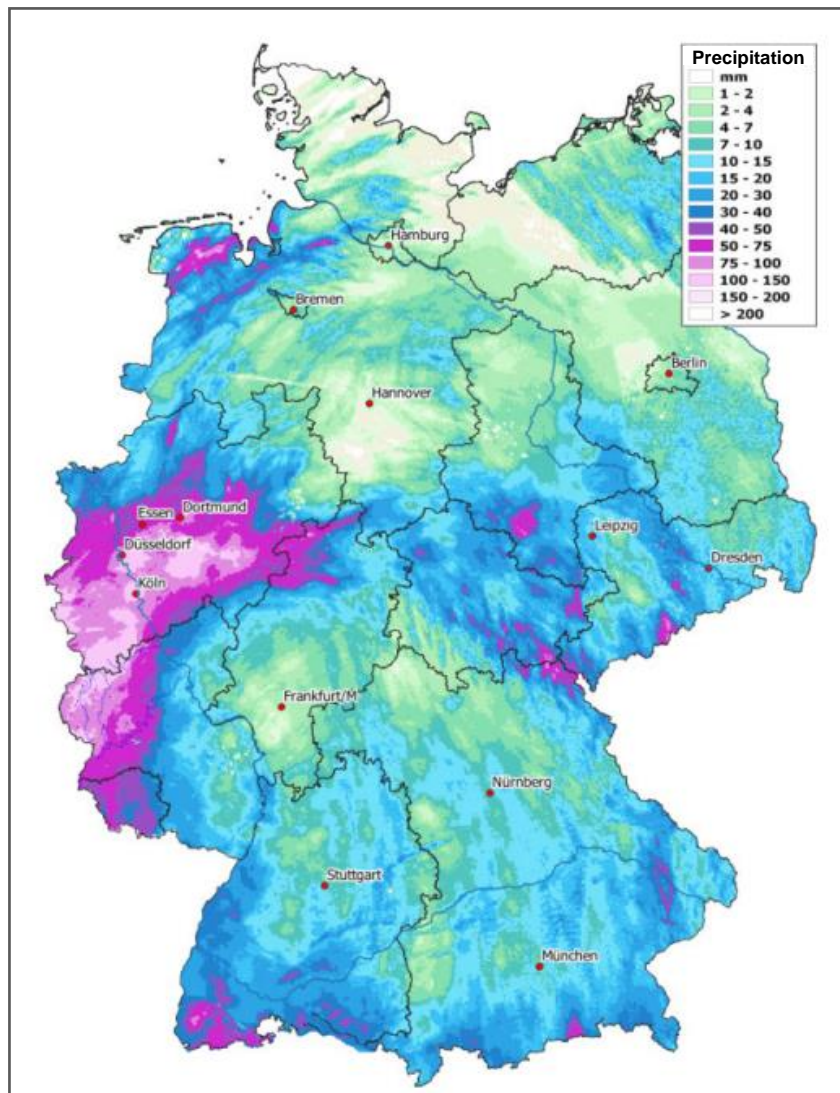


FIGURE 1: Precipitation recorded over 48 hours in Germany from July 13th to 14th 2021 (Schäfer et al., 2021). Pink indicates areas of highest precipitation, which cover a large region across the federal states North-Rhine Westphalia, Saarland and Rhineland Palatinate in western Germany.

The affected regions and state showcased a striking lack of preparation and capacity through poor authority response and exceptionally high damages to people and property (dpa-infocom, 2022; Kordes et al., 2021). This, and the fact that the disaster aligned itself with a global trend of increasing frequency and intensity of extreme weather events (EWEs) (Seneviratne et al., 2021; Wu et al., 2013) made the

need for action on all levels apparent (Kreienkamp et al., 2021). Indeed, the World Weather Attribution initiative calculated that the German flooding catastrophe of 2021 was made both more likely and more intense by global warming (Kreienkamp et al., 2021). Thus, shortly after the disaster, public and political debate was sparked about the lessons to be learned, and extensively covered in the media across the country (Fekete & Sandholz, 2021).

1.2 SPOTLIGHT ON URBAN CLIMATE ADAPTATION

While smaller villages in valleys were the most devastatingly affected, various cities also suffered significant damages by the July flood (Christensen, 2021; Decke, 2023; Hausmann, 2022; R uth, 2022; Wirtz et al., 2022). Cities are inherently vulnerable to flooding, since they concentrate population, economic activity, and densely built structures (Derkzen et al., 2017). Flood exposure is made more likely by the prevalence of impervious surfaces, which limits infiltration and water storage in soils, causing the majority of rainwater to run off the surface. This enhances surface accumulation of water during rainfalls, which can exceed the drainage capacity of the sewage system and add runoff to swelling rivers (Butler et al., 2018). Historically, human settlements were often established in proximity to streams to secure urban water needs, food production, and trade. Consequently, they are often exposed to river floods (Fang & Jawitz, 2019).

In the aftermath of the catastrophe, municipal authorities within the affected region and beyond indicated that the flood disaster was a wake-up call to the threat of climate change, expressing ambition to reflect on and adjust disaster response (dpa NRW, 2021; Hausmann, 2022; Wuppertaler Rundschau, 2022). Besides disaster response improvements, the issue was elevated to the overarching topic of climate change adaptation on a state level, emphasizing the need for more resolute action on all administrative levels (Bundesministerium des Inneren und f ur Heimat & Bundesministerium der Finanzen, 2022; Tagesschau, 2021). Numerous news reports around the country investigated the causes of the disaster, quoting experts that urged to understand the flooding not just as an expression of climate change, but also as an indication that current land use and urban design are core contributors to the issue. Discussions centered on the continuous urbanization of German ground and ensuing surface sealing, as well as channelization of rivers, that continue to create unnatural drainage conditions, thus heightening the risk of flood experience and impact. Urban stormwater management concepts such as sponge cities, water-sensitive urban design and sustainable urban drainage systems found frequent mention (Deutschlandfunk, 2021; dpa NRW, 2021; Jeschke, 2022; Nuhr, 2022; Raether, 2022; Wenzel, 2021). Adaptation to extreme precipitation events in cities became a burning topic, and experts called on affected communes to ‘build back better’ (Fekete & Sandholz, 2021).

1.3 RESEARCH OBJECTIVE AND QUESTIONS

In 2023, two years after the flooding catastrophe, the question remained whether and in which way these words and discussions in fact translated into action on climate adaptation in urban flood management. Experiences of EWEs have been suggested to place climate adaptation higher on the political

agenda, and prompt adjustments in socio-political contexts, e.g., in institutional organization and preferred adaptation strategies (Demski et al., 2017). However, assessing the effect of EWEs on climate adaptation efforts is methodologically challenging and remains understudied (Demski et al., 2017; Madsen et al., 2019). Establishing a causal link between experience of an extreme event and potentially ensuing changes in adaptation practice is inherently difficult (Demski et al., 2017), and the notorious weight of German bureaucracy in project implementation promises to further dilate adaptation time horizons in German municipalities (Wilms, 2024). Yet how adaptation is implemented and policies are designed is closely connected to the perspectives with which the adaptation issues are made sense of by policymakers (Radhakrishnan et al., 2017). Thus, studying the perspectives of climate adaptation in urban flood management among the responsible authorities has the potential to provide relevant insights into the effects of experience of an extreme precipitation event on adaptation practice. The concept of framing is a useful tool to analyze perspectives on urban climate adaptation. Frames capture how the challenge of adapting to increasing extremes is conceptualized, how the problem is understood, and which solutions are promoted (Fünfgeld & McEvoy, 2011). To date, few studies have explored the impact of EWE experiences on the framing of adaptation (Madsen et al., 2019).

Consequently, the aim of this thesis was to understand the impact of extreme precipitation and flooding events on the urgency and substance of local climate adaptation in urban flood management among responsible authorities, by assessing whether and how framing of adaptation to urban flooding has changed in affected municipalities from before to after the July 2021 floods. The study analyzed the framing of the problem of climate adaptation to urban flooding and desirable solutions before and after the event, using policy documents and expert interviews as data sources. The German city of Wuppertal served as a case study to reach the objective and answer the general research question:

How has framing of climate adaptation in urban flood management changed among urban authorities in response to the German flooding disaster of 2021?

along the following specific research questions:

SRQ 1: How was climate adaptation to extreme precipitation events in urban flood management framed in policy documents before the flooding disaster of 2021, from 2019-2021?

SRQ 2: How is climate adaptation to extreme precipitation events in urban flood management framed in policy documents after the flooding disaster in 2021, from 2021-2023?

SRQ 3: How do experts assess the impact that the 2021 flooding disaster had on the changes in urban flood management?

2. THEORETICAL FRAMEWORK

2.1 UTILIZED CONCEPTS

A consistent terminology is crucial when conducting scientific research. This chapter introduces and clearly defines the scientific concepts of *climate adaptation* and *risk, framing*, the types of *urban flooding*, and *urban flood management* to answer the research questions clearly. Additionally, this chapter presents the theoretical framework on which the framing analysis was based.

2.2 RISK TERMINOLOGY AND CLIMATE ADAPTATION

The reality of climate change has been internationally recognized for decades now. To date, the most prominent discussions in the global society revolve around climate change *mitigation*, ergo addressing the causes of climate change through reduction of greenhouse gas emissions (Leonardi, 2010). But while the world struggles to cut its emissions, climate change has arrived with far-reaching consequences for people and planet. With increasing impacts, *adaptation* to the already changing climate is growing in relevance within climate action. Climate change adaptation, or simply climate adaptation, has gained traction in international negotiations, as well as in national, regional, and local politics and practice in recent years (Dupuis & Biesbroek, 2013). While initially only focus of one subchapter, adaptation to climate change is now mainstreamed throughout the entire latest IPCC report (IPCC, 2022).

Climate mitigation and adaptation both aim to reduce the *risk* posed by climate change to people and nature, but while mitigation focuses on reducing the hazard of the issue by trying to prevent further climate change, adaptation focuses on limiting exposure and vulnerability to the hazard (Ara Begum et al., 2022). Figure 2 depicts that risk is a function of hazard, exposure, and vulnerability. The *hazard* describes the general occurrence of climate events and processes with the potential to cause harm (Ara Begum et al., 2022). However, risk only exists upon *exposure* to a hazard. Exposure is defined as the presence of assets in an area where a hazardous event may occur (Cardona et al., 2012). For example, if no people and resources are present in a floodplain, there is no disaster risk although the hazard of flooding exists. As a third determinant, vulnerability affects climate risks. *Vulnerability* consists of a variety of elements, but in essence refers to the predisposition to suffer harm upon exposure. This includes the likelihood of exposure, as well as the *sensitivity* to damage upon change in climate conditions. It further includes more social and contextual factors, such as the capacity to cope with impacts and adapt afterwards (*adaptive capacity*), which is heavily determined by variables like inequality and marginalization (Bergstrand et al., 2015). Thus, climate adaptation refers to a range of actions and activities that reduce climate risks through either decreasing exposure or reducing vulnerability.

The latest IPCC report defines adaptation as ‘the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities’, also capturing the facet of recognizing potential local benefits of a changing climate, such as more favorable temperatures for a certain crop (Ara Begum et al., 2022). In literature, distinction exists between anticipatory vs. responsive

(adaptation in anticipation or response to an impact), as well as incremental vs. transformational adaptation, although differences between the definitions is not always as clear as suggested. A longer series of incremental (step-wise) adaptation for example can in hindsight be deemed transformational, ergo have reorganized a place or social system more profoundly (Kates et al., 2012). Due to the diversity of climate impacts and contexts on a local scale, climate adaptation needs a local approach in contrast to mitigation, where international strategizing may make sense (Carter, 2011).

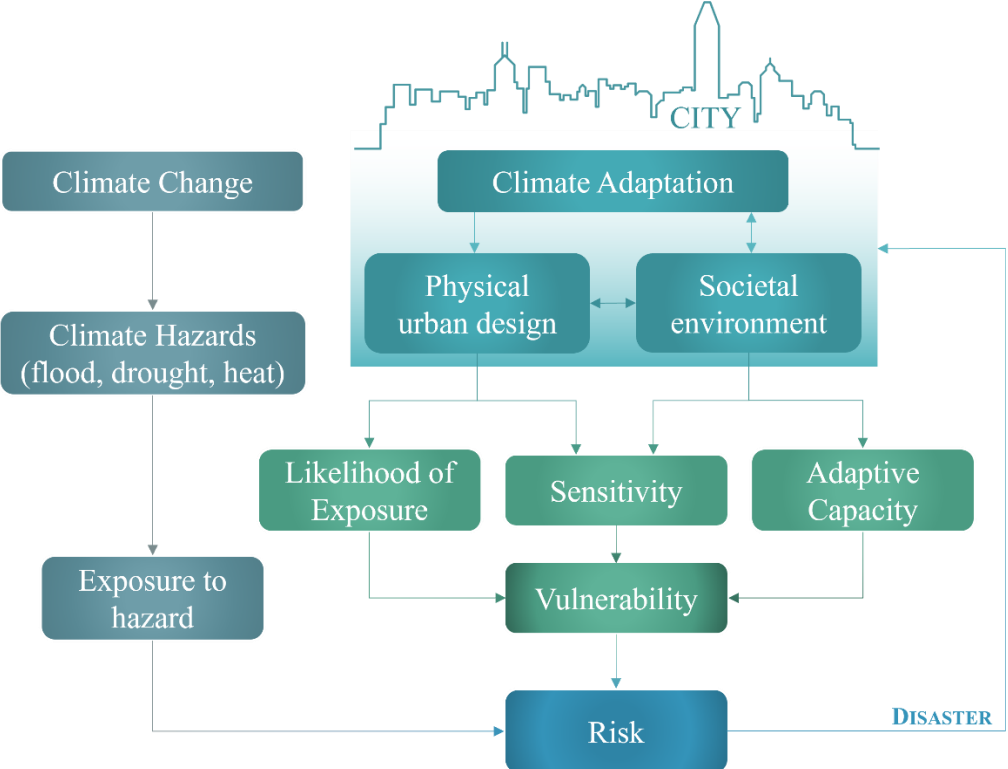


FIGURE 2: Conceptualization of local climate risk determinants and urban climate adaptation. This study focuses on the relationship of disaster with the response in the urban system. (City outline: Vecteezy.com)

2.3 URBAN FLOODS AND THEIR MANAGEMENT

Cities around the world are subjected to several types of flooding (Pedersen et al., 2012). In this study, two of the most common types are considered, namely fluvial and pluvial flooding (Figure 3). *Fluvial flooding* happens when watercourse levels rise above their banks due to accumulated high runoff in their watershed. *Pluvial flooding* generally occurs when precipitation rates are higher than infiltration and drainage rates (Miller & Hutchins, 2017; Rosenzweig et al., 2018)

As mentioned in Chapter 1.2, cities are especially vulnerable to flooding. Firstly, cities have increased exposure to fluvial flooding, as settlements are frequently found on the flood-prone banks and in the fertile floodplains of streams (Apel et al., 2016; Tingsanchali, 2012). Secondly, cities concentrate people, cultural and economic values, as well as critical infrastructure, thus exposing a large density of population and assets to floods (Butler et al., 2018; Skougaard Kaspersen et al., 2017). Lastly, land use and urban design alter natural hydrological systems in a way that heightens the flood probability in urban areas (Gimenez-Maranges et al., 2020). Often, stream courses in and around cities are restricted,

narrowed, or channeled, reducing the space for rivers and water storage space in surrounding areas (Tingsanchali, 2012). Furthermore, the high degree of impervious surfaces from buildings and traffic infrastructure in cities causes large quantities of surface runoff by preventing natural infiltration into the soil (Gimenez-Maranges et al., 2020). Peak precipitation is not attenuated by retention in soils, and thus, surface runoff peaks fast and high, causing water accumulation and stream formation on the surface (Gimenez-Maranges et al., 2020; Skougaard Kaspersen et al., 2017). Pluvial and fluvial flooding are connected, as the quick runoff from sealed surfaces can contribute to rising river levels (Apel et al., 2016; Chen et al., 2010). However, pluvial flooding and overflow of smaller streams is usually caused by much more localized precipitation events than fluvial flooding of rivers, which is usually the consequence of high precipitation throughout the larger basin. Management of these phenomena must operate at different spatial scales, as urban fluvial flooding is influenced strongly by river management in the upstream basin, not simply by runoff prevention in the city (Sørensen et al., 2016). Effective *urban flood management* thus contains *river management* within and beyond city bounds, and *urban stormwater management* throughout the fabric of the city.

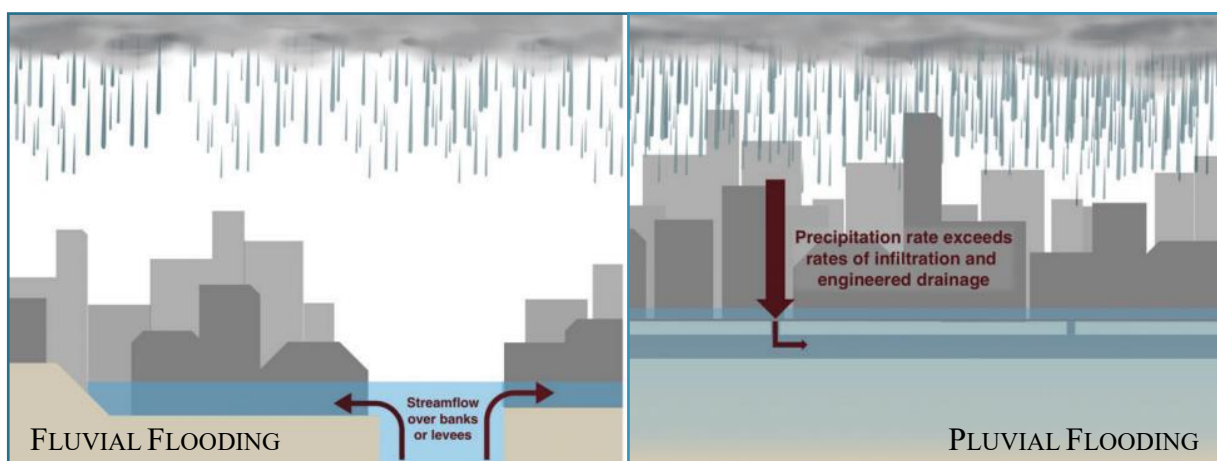


FIGURE 3: Schematic depiction of fluvial and pluvial flooding in cities, adapted after Rosenzweig et al. (2018).

Traditional urban flood management mainly focuses on responsive adaptation with dikes and dams, as well as efficient flow of stormwater into the sewage system and from there into nearby surface waters (Sørensen et al., 2016). This approach has several ecological drawbacks and rather increases risk of flooding for the urban population. Flood defenses by streams are often rigid structures that confine the watercourse, leaving little room for natural expansion during high flows and encouraging settlement in the hazard zone. Riverine health is impacted negatively by channelization and loss of banks and plains. The described ‘drainage-efficiency approach’ to stormwater management also impacts river health, by introducing large quantities of water that is often polluted or too warm for sensitive aquatic ecosystems directly into the stream (Burns et al., 2012). Additionally, urban drainage systems have a certain design limit that is easily exceeded with heavy rainfall and progressing urbanization. Design limits are based on probabilistic recurrence periods, that in Germany are calculated using the limited historical data.

With advancing climate change, these recurrence periods will become less accurate, and cities must adapt to increasing pressure from extreme precipitation (Burns et al., 2012; Pedersen et al., 2012).

Because of this, *nature-based adaptation* in urban flood management has increasingly gained traction on the operational level in recent years (Sørensen et al., 2016). The term comprises many different overlapping academic concepts, such as Sustainable Urban Drainage Systems, Water Sensitive Urban Design, or Nature-based Solutions. In river management, fluvial flood risk and environmental degradation can be addressed simultaneously by restoring natural water courses with their riparian landscapes and flood plains (Sørensen et al., 2016). In urban stormwater management, restoration of the natural hydrological functions of the soil by allowing infiltration and retention promises to deliver multiple benefits on top of reducing pressure on the conventional drainage systems (Fletcher et al., 2015; Miller & Hutchins, 2017). Nature-based stormwater management relies on spatially decentralized distribution of blue-green infrastructure, such as infiltration strips and ditches, swales, and ponds under application of a lot of urban greenery, as well as reversal of past and reduction of future surface sealing (Gimenez-Maranges et al., 2020). This greening of the urban landscape has the potential to positively impact adaptation to other climate hazards, such as heat, increase biodiversity, and improve human well-being through recreational and aesthetic value (Alves et al., 2019; Lennon et al., 2014).

At the administrative level, the challenge posed by adaptation to climate change requires a change in practice as well (Sørensen et al., 2016). Authorities in this formerly static technical discipline must embrace a more flexible approach to practice anticipatory adaptation to uncertain future climate trends and scenarios (Zhang et al., 2017). The high demand for space and acuteness of several challenges within cities require urban flood management solutions to be multi-functional and interconnected with other urban planning spheres (Sørensen et al., 2016).

2.4 FRAMING

2.4.1 FRAMING THEORY

In essence, framing theory describes that the same situation, event, process, or issue can be viewed through a variety of lenses (Chong & Druckman, 2007; Fünfgeld & McEvoy, 2011). These lenses, or frames, are cognitive structures that rest on mental heuristics, values, perceptions, and individual interest, and describe how individuals and groups conceptualize and make meaning of occurrences they experience (ElSawah et al., 2013; Kolkman et al., 2005). Several frames can exist simultaneously, be promoted throughout interactions of actors, merge, as well as change over time through learning and driving political, ecological, and contextual forces (Bell et al., 2017; ElSawah et al., 2013). The process of framing can be intentional or intuitive, and the frames can be explicitly addressed or solely implied (Fünfgeld & McEvoy, 2011). A frame does not have to be explicitly mentioned to be visible, because frames contain the interpretation of what is relevant about a phenomenon, which in turn determines how the phenomenon is interacted with and spoken about (Chong & Druckman, 2007; de Boer et al., 2010; Fünfgeld & McEvoy, 2011).

2.4.2 FRAMING OF CLIMATE ADAPTATION IN URBAN FLOOD MANAGEMENT

Climate change adaptation specifically is subject to constant framing and re-framing due to the ‘wicked’ nature of the issue (de Boer et al., 2010). The problem itself as well as appropriate solutions are widely and continuously debated (Müller & Kruse, 2021). Furthermore, the state of knowledge on climate change and the extent of experienced impacts changes continuously. This shifts the context in which adaptation issues are defined, and in which suitable strategies are designed and evaluated (Eriksen et al., 2015). Adaptation issues, such as urban floods, are therefore not simply hydro-climatic issues, to which an objective, ‘correct’ answer can be found. Rather, they are defined under influence of a variety of social and cultural factors, the political context, and environmental variables that all interact with one another (McEvoy et al., 2010). These shaping conditions are highly complex and locally specific, which means that climate adaptation can be framed in a large diversity of ways (Eriksen et al., 2015; Fünfgeld & McEvoy, 2011). To illustrate this in the urban flood adaptation context, the way decision-makers perceive and define the issue with flooding, ergo their framing of the adaptation problem, influences their responses (Dewulf, 2013; Ulibarri et al., 2023). Through framing it is decided which questions are considered relevant and the selection of answers deemed suitable by the responsible authority (Dewulf, 2013). Several frames of flood adaptation can exist at the same time, e.g. between different stakeholders or authorities that look at the issue through different lenses of experience, knowledge, and individual interest (Ulibarri et al., 2023). To exemplify, this could mean that at the same time between different stakeholders or authorities a frame of urban flooding exists that the sewers are not sufficiently dimensioned and are causing flooding, and a frame that the widely impervious urban design is causing flooding. These different views on the issue define the most suitable adaptation strategy, in this case either upscaling of the sewer pipes or unsealing of urban surfaces. Nonetheless, frames are not static in local climate adaptation, but as dynamic as the societal and natural context they are defined in (Fünfgeld & McEvoy, 2011). ‘Focusing events’, like extreme flooding events, are suggested to accelerate reframing and adaptation processes by creating windows of opportunity for deliberation about the nature and requirements of flood adaptation (Giordano et al., 2020; Madsen et al., 2019; Otto-Banaszak et al., 2011).

Different categories have been used in climate adaptation research to systematically analyze frames. Crabbé et al. (2015) adapted a framework for framing of collective action in social movements, and distinguish between diagnostic and prognostic framing of climate adaptation policy. Diagnostic framing identifies the type and origin of an issue, as well as responsible or culpable agents. Prognostic framing selects desirable solutions and approaches to solving an issue. Fünfgeld & McEvoy (2011) explore framing of local adaptation along four core questions: (1) Adaptation to what?, (2) Who or what adapts?, (3) How does adaptation occur?, and (4) What is good adaptation?. These core questions include several subquestions (Figure 4). The theoretical framework of this study integrates the first three core questions into the diagnostic and prognostic outline of climate adaptation framing by Crabbé et al. (2015). The framework incorporates subquestions that focus on the operational level, to provide insight into framing of the actual adaptation practice, not into procedures and relevant actors.

Adaptation to what?	<u>What climatic stressors exist?</u> <u>What non-climatic stressors exist?</u> <u>What local impacts are likely to result from these stressors (climatic and non-climatic, in what time frame)?</u>
Who or what adapts?	<u>What system(s) will need to adapt to climate change impacts?</u> <u>What system elements are at risk of climate change?</u> <u>What are the goals of adaptation?</u>
How does adaptation occur?	<u>What is the intended outcome of adaptation?</u> <u>What actors and organisations need to be involved in adaptation?</u> <u>What process will be followed to plan adaptation?</u> <u>What concrete adaptation measures will be taken, by whom?</u>
What is good adaptation?	<u>What can be deemed successful and efficient adaptation?</u> <u>How can the success of adaptation be measured?</u> <u>How can measures be adjusted to ensure robust adaptation outcomes?</u>

FIGURE 4: Framing questions to explore the meaning of adaptation in a local context, as described in Fünfgeld & McEvoy (2011). Subquestions that fed into my theoretical framework are underlined.

Table 1 shows this study’s theoretical framework for assessing framing in climate adaptation of urban flood management. In addition to the questions seen in Figure 4, the framework includes questions about the extent and urgency, as well as synergies of desired adaptation options with adaptation to other climate hazards, to get an idea about the broader perspective on the issue.

TABLE 1: Theoretical framework to analyze framing of climate adaptation in urban flood management, based on Crabbé et al. (2015) and Fünfgeld & McEvoy (2011).

DIAGNOSTIC	PROGNOSTIC	
Adaptation to..?	Adaptation of...?	Adaptation by...?
Cause of experienced flooding	Components in need of adaptation	Intended outcome
Climate change attribution	Extent of change needed	suitable approaches/ strategies/ interventions
Most relevant local impacts	Urgency of change needed	synergies with adaptation to other climate hazards

3. METHODOLOGY

3.1 APPROACH

Figure 5 visualizes the methodological approach of this study. Chapter 2 already explained the collation of the theoretical background and definition of most important concepts, as well as the formation of the framework for analysis. Subchapter 3.2 elaborates on data collection including the study design and selection of data sources. Subchapter 3.3 walks through the steps of the qualitative data analysis of the two data sources, and Chapter 4 and 5 show and discuss the results to answer the main research question.

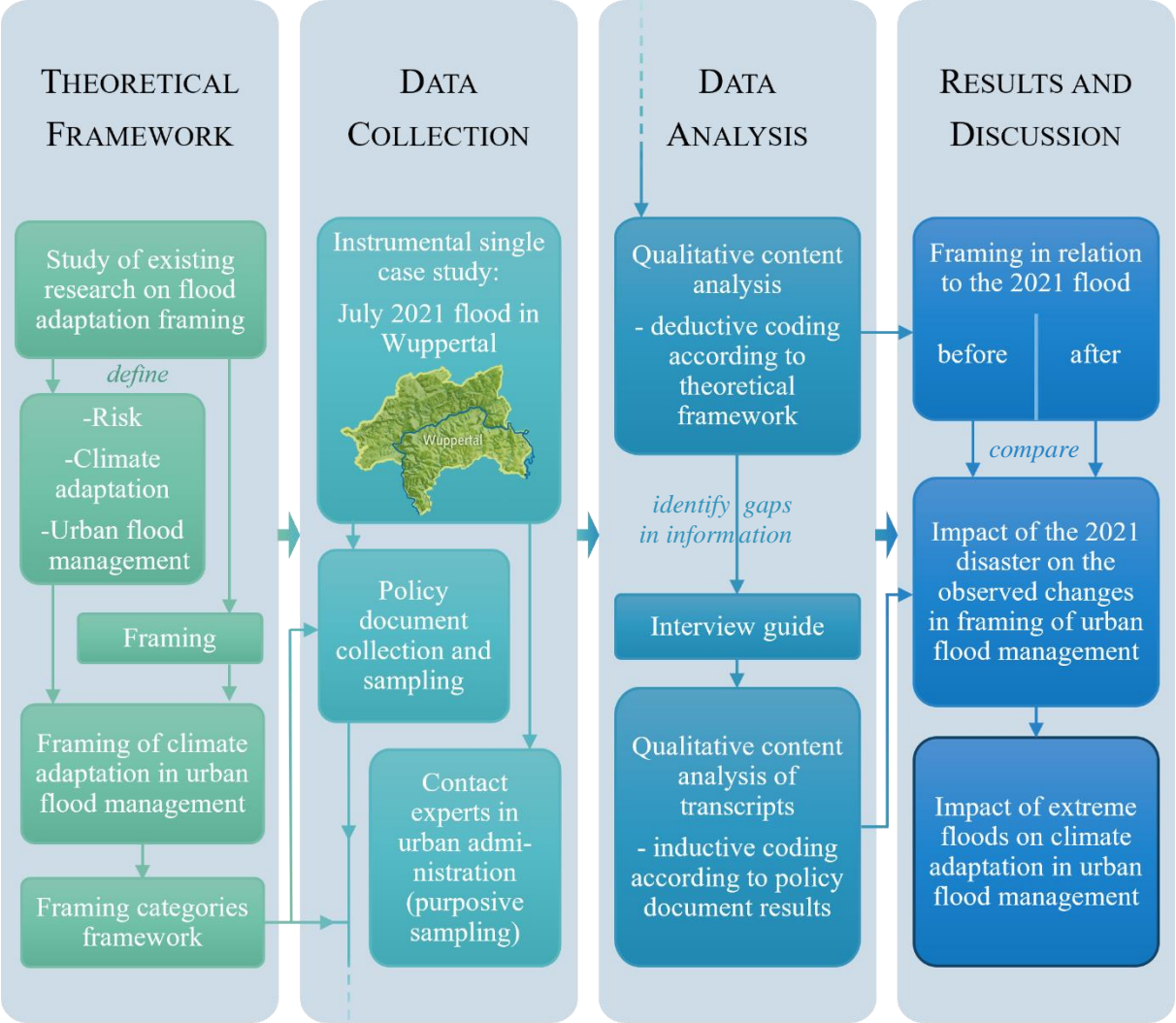


FIGURE 5: Workflow of this study from the theoretical basis to answering of the main research question.

3.2 DATA COLLECTION

3.2.1 STUDY DESIGN

3.2.1.1 INSTRUMENTAL SINGLE CASE STUDY

This study uses an instrumental single case study design. This approach is suitable for exploring a larger phenomenon by examining a specific context, when studying the phenomenon comprehensively

in all its forms is not feasible. The phenomenon, in this study urban flood adaptation response to extreme events, is generalized from the case study in awareness of the case-specific context (Cousin, 2005). The study purposively sampled a case city from the largest cities that were affected by the July 2021 flooding catastrophe in western Germany. The city of Wuppertal was chosen due to its easily accessible internet archive of policy documents that enables data collection and its strong online presentation of climate adaptation initiatives. Political processes and responses to the flooding disaster likely vary between the different affected municipalities. Therefore, the results from Wuppertal will not be applicable to other contexts yet may give an interesting insight into extreme event response in framing. This subchapter highlights the case-specific context.

3.2.1.2 WUPPERTAL’S GEOGRAPHY AND HYDROLOGY

Wuppertal is situated in hilly to mountainous terrain in the federal state of North Rhine-Westphalia (NRW) with a central valley where the Wupper River flows from east to west (Figure 6) (Information und Technik Nordrhein-Westphalen, 2023). About 800 small tributaries descend over 250 m difference in altitude within city bounds into the Wupper (Goderbauer-Marchner et al., 2015). The many creeks are often encased, piped, overbuilt, or directly connected to the stormwater sewer system before they are led into the Wupper (Michel et al., 2012). The city mostly has separate stormwater and wastewater piping, with a few mixed sewer systems in the oldest parts of the city centers (Abwasserbeseitigung in Der Stadt Wuppertal, 2023).



FIGURE 6: The mountainous city of Wuppertal in NRW in Germany’s west (Biologische Station Mittlere Wupper, 2024)

Wuppertal is prone to heavy rainfall and urban flooding due to its steep topography and status as one of Germany's rainiest cities. With about 500 streets and staircases inclining over 20%, rainfall quickly

turns streets into streams and swells creeks into torrents, blocking stormwater sewers and causing runoff issues in lower areas (Goderbauer-Marchner et al., 2015; Michel et al., 2012). In the past decade, several floods from heavy localized rainfall have caused significant material damages, particularly in low-lying areas and troughs (Nikogosian et al., 2021). The most severe event occurred in 2018, shortly before the extreme flooding of 2021 (Sprague & Prenger-Berninghoff, 2019). Flood impacts vary across the city, strongly correlated with the degree of impervious surfaces and sewage system capacity (Nikogosian et al., 2021).

3.2.1.3 URBAN FLOOD MANAGEMENT IN WUPPERTAL

The Wupper's flow is regulated by several upstream dams managed by the public corporation 'Wupperverband' (Goderbauer-Marchner et al., 2015). The largest dam, the 'Wuppertalsperre', located just upstream of Wuppertal controls extreme high and low river flows (Wupperverband, 2023). In Wuppertal, urban flood management is a joint effort between the Wupperverband, which handles fluvial flood risks from the river and the many streams, and the City of Wuppertal, responsible for pluvial flood risks and public safety (Wupperverband, 2024a). The City of Wuppertal is split into the political council and the administration, which share stormwater management responsibility by steering the strategy and implementation, respectively. In the administration, Department 3 as well as the 'Climate Coordination' office are responsible (Stadt Wuppertal, 2023). Additionally, the municipal energy company 'Wuppertaler Stadtwerke' (WSW) operates and maintains the 650 kms of pipes in the urban canal system as mandated by the semi-autonomous municipal agency 'Wasser und Abwasser Wuppertal' (WAW) (Michel et al., 2012; WSW, 2024; Wupperverband, 2024b). The WAW creates the general plan of the drainage system (all drainage objects) and ensures compliance urban wastewater legislation (WAW, 2024).

The City of Wuppertal has been active in the past to reduce the flood risk for its citizens. Grey infrastructural measures, such as designated rainwater channels and retention basins against pluvial flooding, as well as the reservoirs throughout the Wupper basin already date back several decades (Michel et al., 2012). The city received national praise for its efforts on modelling of pluvial flooding and awareness-raising among citizens in 2011 (Goderbauer-Marchner et al., 2015). The reservoirs within the basin protect Wuppertal against flooding from the Wupper up until events with a return period of 100 years. The return period is a statistical expression of likelihood calculated from a historical time series in Germany, which does not account for the changing climate, and ensuing increased likelihood of extreme events (Michel et al., 2012). The 100-year return period level of protection does not apply to the hundreds of streams throughout the city, which represent the highest fluvial risk to the city (Sprague & Prenger-Berninghoff, 2019).

3.2.1.4 THE 2021 DISASTER IN WUPPERTAL

During the 2021 disaster, Wuppertal experienced unprecedented pluvial and fluvial flooding of the Wupper and its tributary creeks after intense rainfalls in the night from the 14th to the 15th of July (see

Figure 7). The German Weather Service had warned the days leading up to the disaster that extreme rain would be reaching NRW, correcting its prognoses upwards every day, yet the 160mm of rainfall that ultimately reached Wuppertal and the entire Wupper basin within 12 hours caught authorities off guard (Slawig, 2021). By 23h on the 14th of July, the Wuppertalsperre-reservoir was full, and the flood gates were opened, unleashing a flow above the calculated fluvial flooding event of a 10,000-year return period down the narrow river course (Slawig, 2021). Aside from the river, many creeks overflowed, and streets turned into streams themselves. Failure of surveillance equipment, communication channels, and general understanding of the coming severity had the emergency services and urban population insufficiently warned (Stadt Wuppertal, 2021). Fortunately, the flooding caused no fatalities in Wuppertal, but it left high damages on buildings, as well as traffic-, energy- and communication infrastructure (Rüth, 2022). About 40 million € of damages were caused on public infrastructure alone on that day. Damages to private property from flooded houses, cellars, and business sites were substantial as well (Slawig, 2021).



Figure 7: Flooding in the district Beyenburg in Wuppertal on the 15th of July 2021 (Anna Schwartz).

3.2.2 POLICY DOCUMENTS

3.2.2.1 PURPOSE

This study used several research methods to increase the validity of the achieved results through method triangulation (Bowe, 2009). The first method is analysis of policy documents, a frequently used qualitative research method. Policy documents capture the explicit and implicit framing of the climate adaptation problem and suitable solutions by responsible authorities at a fixed point in time in the past (Fünfgeld & McEvoy, 2011; Radhakrishnan et al., 2017). Small changes within those documents can already be indicative of a pronounced change in substance (Bowe, 2009). Thus, they were a relevant

data source for assessing past developments in framing of climate adaptation in urban flood management among the urban authorities to answer SRQs 1 and 2, without the danger of and subsequent reframing.

3.2.2.2 DEFINING THE TARGET POPULATION AND SAMPLING FRAME

The target population describes the group of research units (in this case documents), that a researcher wants to analyze because they have the desired attributes (Applied Doctoral Center, 2023). The sampling frame is the part of the target population that can actually be sampled from (Taherdoost, 2016). The target population of the policy documents comprised any official document for or by the urban administration and the city council of Wuppertal that discussed or represented the latest activities and views on climate adaptation to extreme precipitation events in the city.

The sampling frame contained only documents that are publicly available on the Ratsinformationssystem (RIS; council information system), which is an archive of all meetings of (sub)municipal councils and their boards, including all agendas, input proposals, requests and briefs, as well as results of all decisions. The RIS has a search function that looks for any item in a specified timeframe that contains part of or the whole of the search terms in the title or text. The search terms ‘Hochwasser’ (flood) and its synonyms ‘Überflutung’ and ‘Überschwemmung’, ‘Klimaanpassung’ (climate adaptation), and ‘Starkregen’ (heavy rainfall), as well as ‘Regenwasser Management’ (‘stormwater management’), for the timeframe from 01.01.2019 to 25.07.2023 (starting date of data collection) yielded several hundred results. The sampling frame excluded the overlapping results from different search terms, a large share of building plans that contained sections only technical information of climate adaptation in construction, as well as false results that did not include the search terms. Ultimately, the sampling frame contained 12 documents from before the disaster and 30 documents from after (Appendix I). Chapter 4.1 shows a timeline of these documents.

3.2.2.3 SAMPLE SELECTION

The sampling of documents among the sampling frame followed the four crucial criteria for document analysis collected by Morgan (2022): authenticity, credibility, representativeness, and meaning. *Authenticity* expresses whether a document is genuine and not forged, and is granted since all documents stem from the council’s official public information system. Morgan (2022) defined *credibility* as the absence of error and distortion, stemming from inexperience or ulterior motives, such as to portray something in a favorable light. Credibility is not always easy to determine in the internal urban administration and council processes, especially on highly political topics such as climate adaptation. Framing theory itself assumes a certain level of distortion in any worded product. Nonetheless, the documents are publicly accessible and not selected by stakeholders specifically for this research. Thus, this study regarded documents that left the impression of a balanced depiction of events and progress as credible. Morgan (2022) defined *representativeness* to be “how typical a document is”, whether it is in line with content of other texts on the same matter. This study deemed documents representative of the urban authorities’ views that were approved or agreed on in the city council, or in the case of reports authored by the administration itself and received in the council. The date of the document was not when it was

authored, but when it passed through the city council without further changes. When the council did not accept or agree on a document, it was included in the timeline overview yet excluded from sampling. This study determined documents' *meaning* according to their relevance to answering the research questions both at face value and in consideration of the context that they were written in (Morgan, 2022). Documents received school grades from 1-6 according to how many of the framing dimensions of the theoretical framework (Chapter 2.4.2) they described. Sampling only occurred on documents with the grade 1 or 2 that rated positive on the other three criteria were. After this application of the criteria, six documents before and six documents after the disaster constituted the sample (see Appendix I).

3.2.3 INTERVIEWS WITH LOCAL PROFESSIONALS

3.2.3.1 PURPOSE

The second research method used in this study was interviews with professionals that work on the development, decision-making and implementation of urban flood management in Wuppertal. The interviews serve to validate the results acquired in the document analysis and answer SRQ 3. Furthermore, they capture expert's perceptions of the causes of potential changes to explore a causal link between experience of the 2021 disaster and the developments in framing of urban flood adaptation found in the document analysis.

3.2.3.2 TARGET POPULATION, SAMPLING, AND CONDUCTION OF INTERVIEWS

Potential interviewees, the target population, are in climate-adaptation, flood management, drainage, and urban planning in the responsible Department 3 of the Wuppertal administration. Sampling of interviewees was done through convenience sampling, which describes the process of choosing interviewees according to their willingness to participate in the research (Robinson, 2014). Upon contact with the project leads and heads of relevant units in Department 3, two professionals who carry responsibility in urban stormwater and fluvial flood management agreed to participate. The interviewees each answered eight main questions of the interview guide (Appendix II) within one-hour online interviews. Questions were formed beforehand according to the 'objective of the question', meaning which knowledge they were supposed to elicit to answer the research question. In line with a semi-structured approach (Owen, 2014), the interviewees also answered spontaneous questions whenever themes emerged that seemed useful to be explored further. After the written permission of the subjects, the recording and transcription function on Microsoft Teams captured the content.

3.3 DATA ANALYSIS

3.3.1 QUALITATIVE ANALYSIS OF POLICY DOCUMENTS

This study analyzed the twelve sampled policy documents with a qualitative document analysis (QDA). This is a suitable approach, as data are not directly extracted from the documents but require some level of interpretation on behalf of the researcher to derive information from text and imagery (Bowe, 2009). The method assesses the written content of a document but additionally takes 'latent content' into account, such as the context of the document (Kohlbacher, 2006). Relevant text excerpts

were coded in the Atlas.ti 23 software, through a combination of deductive and inductive coding. This describes coding of text according to already existing categories, in this case the theoretical framework of Chapter 2.4.2, and subcategories derived from the text after reading (Ho & Limpaecher, 2022). All documents were read several times before the initial codes were applied. The 600-page long document named B2 in Chapter 4.2 was read selectively according to Chapter names and expression search of the terms used in Chapter 3.2.2.2. In subsequent readings, the codes were inductively split into subcodes to create a higher granularity among the coded excerpts. Appendix III contains a list of all codes and subcodes.

3.3.2 QUALITATIVE ANALYSIS OF INTERVIEWS

The qualitative analysis of the interview transcripts used a combination of deductive and inductive coding. While part of the purpose of the interview was to understand the causes of the changes observed in the policy documents, making ‘cause’ a principal code, some themes worth coding emerged from the transcripts themselves (Ho & Limpaecher, 2022). The semi-structured interview approach created space for interesting themes to be explored that captured the professionals’ experienced changes in urban flood management conceptualization and practice. This added the code ‘barriers to change’ to the analysis (Appendix III).

4. RESULTS

4.1 TIMELINE OF FLOOD ADAPTATION DOCUMENTS

The timeline of documents that were part of the target population of policy documents by the Wuppertal authority because they discussed climate adaptation to extreme rainfall show a very slim coverage of the topic from 2019 until the disaster (Figure 8). Documents are written in low frequency and only mention flood adaptation or include it as a subtopic. Right after the July flood disaster in 2021, the frequency and depth of discussion on the topic increases visibly. Around the end of 2022, the frequency of documents that discuss flood adaptation remains high, but it becomes more of a sub-focus of policy documents or is merely mentioned.

4.2 FRAMING IN POLICY DOCUMENTS

4.2.1 BEFORE THE 2021 DISASTER

This section reports on the results of the qualitative document analysis of the six sampled policy documents from before the flooding disaster in Wuppertal in July 2021. Table 2 contains the basic information and content of the documents, as well as their indices by which they were named in the study. While Appendix IV holds a comprehensive analysis of the framing of urban flood adaptation per policy document, this Chapter synthesizes the individual results per document into one overview of the overall **diagnostic** and **prognostic** framing before the disaster.

The six before documents differ in purpose, style, length, and framing of adaptation to climate change in urban flood management. Some of the documents are designed to discuss a comprehensive solution or overarching principles in urban flood management (B2, B3, B6), while others aim at the implementation of a certain part of the strategy (B1, B4, B5). Both document types

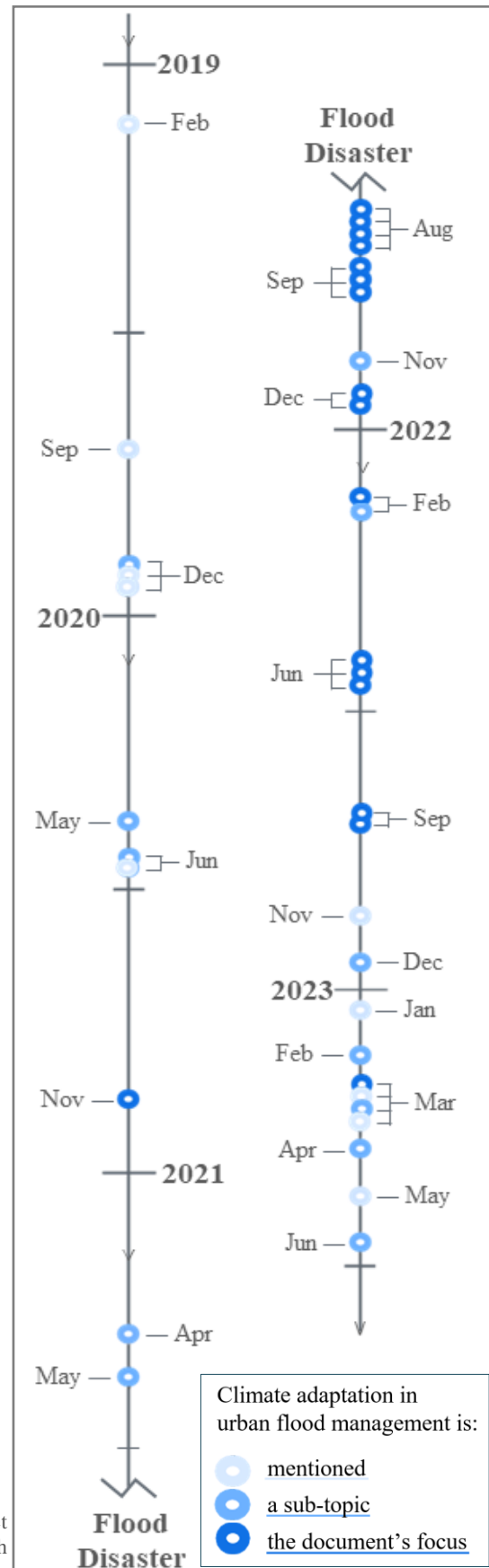


Figure 8: Timeline of all documents that are part of the target population (Appendix I). The color indicates the extent to which climate adaptation in urban flood management is discussed.

grant insight into framing of adaptation. While there are several congruences in framing, the documents from shortly before the 2021 disaster differ in the salience they grant to different aspects of the cause and solutions to flood risk in Wuppertal. Table 3 shows a summarized overview over the different framings per policy document, which were reported in detail in Appendix IV.

TABLE 2: List of documents used in the analysis from before the flooding catastrophe. Documents will henceforth be named by their indices.

Index	Date	Document Name	Authors	Content	Coded Segments
B1	12/2019	‘Proposal for Green Roofs’	Urban Administration, Department ‘Environmental Protection’	Proposal for mandatory green roof cover on newly built flat roofs	5
B2	05/2020	‘Climate mitigation concept with integrated field of action climate adaptation (IKSK)’	City of Wuppertal, Consultancy firms	Overarching strategy for climate mitigation and adaptation purposes, with measures and timeline	83
B3	06/2020	‘Sewage water and stormwater disposal concept 2021-2026 of Wuppertal’	WAW	Strategy of sewage and rainwater removal and treatment, as well as planned piping capacities	12
B4	11/2020	‘Current state of flood management’	Department ‘Environmental Protection’	Response to request about current activities on flood management by different bodies of the city administration	15
B5	04/2021	‘Proposal for surface unsealing’	Council parliamentary groups CDU, The Greens, The Left	Administration tasked with creating an unsealing plan for all unused areas, aimed at ‘land recycling’	7
B6	05/2021	‘Reporting on adaptation to extreme events’	Department ‘Urban Development’	Current adaptation efforts, centering on heat, and organizational structure of responsibilities	11

The most salient framing throughout the six documents from shortly before the 2021 disaster states that increasing extreme rains from climate change *causes* issues with flooding in Wuppertal since it exceeds the drainage design of the sewage system. The documents differ slightly in whether they explicitly name they ‘grey’ urban design with many impervious surfaces as contributing to the issue (B2 and B4), or whether these surfaces are simply feasibly adaptable to reduce pressure on the sewers (B1, B3, B5, B6). B4 adds Wuppertal’s steep topography and many streams as a main cause of vulnerability. However, these different framings do not necessarily contradict each other, but expand upon another.

Relevant *impacts* do not take a center stage in any of the documents. Among those that frame relevant impacts, focus lies on the effect of flooding on humans. Named first are impacts on human health, either directly or by threatening critical infrastructure such as hospitals and energy supply, followed by damages to economic activity. Impacts on the environment, e.g. through pollution by flood water, are only mentioned B4, reflecting the framing in the request it answers by the parliamentary group ‘The Greens’.

TABLE 3: Overview of diagnostic and prognostic framing of climate adaptation in urban flood management among the six documents from before the 2021 disaster.

I N D E X	Diagnostic - Adaptation to what?		Prognostic - Adaptation of what and by doing what?					
	Cause of adaptation issue & Attribution to climate change	Relevant local impacts	Components to be adapted	Extent of adaptation	Urgency	Intended outcome	Suitable strategies	Synergies w/ other climate hazards
B1	climate change overwhelms sewer system	n/a	Roofs of new buildings	mandatory measures needed, no retrofitting	medium	multi-beneficial improvement of urban design	greening of buildings (roofs)	heat
B2	current grey urban design and drainage not fit for several climate change hazards	human health, loss of attractiveness for both businesses and residents	sealed surfaces and compacted soils, water courses	paradigm shift in thinking and practice of climate adaptation both on the operational and administrative level	high: newly created focus on flood adaptation, but after heat	overarching principle of dynamic and flexible sustainable urban development in climate adaptation, under consideration of social justice	integrated measures under coordination of all planning dimensions: successive nature-based adaptation at the surface and improvement of infiltration through reduced sealing, both on new and existing infra-structure.	heat & drought
B3	changing boundary conditions (climate change) meet static sewer systems	sensitive infrastructure	drainage network*, (cased) water courses throughout the city	ideally change overall urban stormwater management approach	n/a	'holistic' and sustainable management of urban watercourses	decentralized and nature-based adaptation, complemented by retention basins	n/a
B4	combination of the steep topography with many streams and the grey urban design, climate change	public health, environment, cultural heritage, economy	individual object protection, sewers, and cased streams	everything possible is being done, inevitable residual risk stressed	medium: focus on limitations to adaptation	an educated population aware of the inevitable residual risk	grey infrastructure, such as channels and basins, as well as citizen information; perhaps future exploration of nature-based approaches	n/a
B5	climate change	n/a	surfaces of brownfields and fallow land	only public land that is unusable for other urban development	high	n/a	making pavement permeable and adding greenery	heat & drought
B6	climate change	n/a	n/a	extensive mandatory consideration of adaptivity in all decision-making processes	high, however more focused on heat	integratively adapted city with high living quality	nature-based adaptation for buildings and infrastructure, and multifunctional use of space	heat

*drainage network does not equal sewage network, as drainage is a more widely phrased term that encompasses all physical elements that contribute to the drainage of water from the surface in the city

With the problem and its most relevant impacts defined, the framing of needed adaptation solutions takes shape. In line with the framing of the cause, B1, B3, B5, and especially the central adaptation strategy document B2, all adopt the framing that runoff from human-made surfaces must be reduced to rein in pluvial flooding. B1 and B5 focus on specific surfaces, roofs and brownfields, respectively, and B3 points to sealed surfaces more generally. B2 lists a range of specific *components* with compacted soils or impervious surfaces. B2, B3, and B4 also mention need for adaptation of the many water courses throughout the city, especially the confined sections. B4 differs from the other documents by framing the components less as an overall structural change, but instead put a focus on adapting individual objects that are at risk, as well as mentioning needed adaptation of the sewage system. Even B3, written by the operators of the sewage system, puts less emphasis on expansion of the sewage system and technical retention mechanisms, saying that ‘(stormwater) prevention and mitigation measures in the catchment area always take precedence over retention and treatment measures’ (B3, p.16).

The *extent* of adaptation also differs between documents. B2, B3, and B6 frame the adaptation challenge as far-reaching, calling for an overall shift of thinking and practice in flood management, even calling it a transformation. B1 and B5, which are more practical proposals, envision a certain redesign but with limitations, as B1 foresees no retrofitting of green roofs and B5 limits unsealing to otherwise unusable brownfields. B4 takes another stance by giving more room to limitations to flood adaptation, reporting that all possible measures are being pursued, and that an inevitable risk remains due to Wuppertal’s location and topography, which must be adjusted to.

The *urgency* of adaptation is also framed differently among the ‘before’-documents. B2, B5, and B6 use strong wording to convey the high urgency of adaptation to flooding. However, in B2 and B6 adaptation to flooding takes the second place behind adaptation to heat. B1 does not have the same strong wording to convey urgency, and in light of the proposed extent of adaptation, the urgency comes across as medium. B4, by showing that all possible adaptation options are being pursued, also only conveys a medium urgency as the necessity to reduce risk in certain areas is still strongly recognized.

The intended *outcome* of adaptation takes similar shape between several of the documents. B1, B2, B3, and B6 all see holistic adaptation practice, where measures contribute to overall sustainable urban development, attractiveness of the city, and wellbeing of its people. B2 further adds the perspective of dynamic and flexible structures, to leave room for the visions of future generations. In these documents, heavy precipitation adaptation is not conceptualized in isolation and achieved by one-dimensional solutions, but rather seen in connection with other climate hazards, social issues, and planning processes. This cross-cutting nature requires intensive collaboration and communication between all city departments and responsible actors. B4 implicitly frames the outcome a bit narrower as a good coexistence of educated and prepared residents with the residual risk of flooding in Wuppertal.

The most *suitable approaches, strategies, and interventions* for adaptation to urban flooding are largely congruent throughout the documents. B2, B3, B5, and B6 all focus on nature-based adaptation

options that revolve around restoring natural stream courses and the natural hydrological function of the urban soil by enabling water infiltration and retention, or in the case of B1 by retaining water in roof soils and plants. This involves surface measures like laying permeable pavement, unsealing, and distributing blue-green infrastructure. For financial feasibility, this new design is primarily considered in new developments, or when routine renovations or constructions are taking place on buildings and infrastructure. B3 frames the nature-based approaches to function best with complementary ‘grey’ retention basins for extreme rainfalls, while B4 reverses the order and adopts the framing that ‘grey’ measures such as channels and basins are central, and could be complemented by nature-based, decentralized infiltration approaches. For this, B4 refers explicitly to the sponge city concept as a potentially relevant future concept. The other documents do not explicitly envision the sponge city, yet some use its vocabulary by discussing multifunctional spaces in B2 and B6. All except B4 and B5 propose solutions that weave into the fabric of the city, while B4 focuses on flood risk management through deactivation of flood risk hotspots. Most documents that frame nature-based adaptation solutions see clear *synergies* in the adaptation to heat, and in some cases drought.

4.2.2 AFTER THE 2021 DISASTER

This section reports on the results of the qualitative document analysis of the six sampled policy documents from after the flooding disaster in Wuppertal in July 2021. Table 4 contains the basic information and content of the documents, as well as their indices by which they were named in the study. Appendix V holds a comprehensive analysis of the framing of urban flood adaptation per policy document, which is summarized in Table 5. This subchapter synthesizes the individual results per document into one overview of the overall *diagnostic* and *prognostic* framing after the disaster.

Much like the ‘before’-documents, the documents written after the 2021 flooding disaster in Wuppertal do not represent a homogenous framing of urban flood management. The documents have different natures and purposes. A1-A5 explore and frame urban flood management more from an overarching strategy angle, while A6 focuses on one specific aspect of implementation, while referring to an overarching strategy. A1-A5 clearly frame the *cause* of the issue with flooding to be climate change and the increasing extreme events. A1 and A2 identify that the sewage network cannot and will not be able to cope with these future extremes, while A1 and A4 add that Wuppertal has a special vulnerability through its steep topography. A5 and A6 expand the cause of the issue by the ‘grey’ urban design, with impervious surfaces increasing pressure on the sewers.

The framing of the most relevant *impacts* of urban flooding includes public health, damage to (private) property and public infrastructure. A6 frames the impact of flooding by sealed front gardens to be that expensive stormwater removal infrastructure has to be constructed at all. Framing of the impacts again does not take center stage in any of the documents, as the impacts of flooding in Wuppertal seem to be clear.

TABLE 4: List of basic information and indices of documents used in the analysis from after the flooding catastrophe.

Index	Date	Name	Authors	Content	Coded Segments
A1	09/2021	Application Sponge city	5 parliamentary groups	Wuppertal applies to participate in NRW's sponge city model project	10
A2	09/2021	Current state of climate adaptation	Division 'urban development'	Response to request about state of implementation of B2 and statement about immediate disaster response	10
A3	11/2021	Proposal Climate Neutrality until 2035	5 parliamentary groups	Proposals to achieve climate neutrality until 2035 and expand blue-green infrastructure	11
A4	12/2021	Consolidation concept for heavy rainfall risk management	City of Wuppertal, WSW	Strategy for how to mainstream adaptation into general urban development	15
A5	06/2022	Final report of ad-hoc flooding task force	Mayor, the city's flooding task force	Plans for avoiding another catastrophe, both short-term and long-term responses listed	21
A6	09/2022	Campaign for less sealed surfaces and more heat protection	Parliamentary group The Greens	Proposal to redesign private gardens for climate adaptation & biodiversity	4

A1, A2, A3, A4, A5 all agree that the *components* in need of adaptation comprise the entire drainage system of the city, meaning that overall stormwater management must be adapted. A2 adopts the framing that the sewage system itself cannot be dimensioned to manage an extreme event as the one experienced, therefore drainage and climate adaptation must be regarded in a wider sense. A1 clarifies that any component that causes quick runoff needs to be adapted. A3 and A5 explicitly include adaptation of the water courses in the city. A6 is an implementation focused documents, that frames sealed garden surfaces to need adaptation. A1, A2, A3, and A4 frame adaptation to flooding to be a cross-cutting issue, which needs to be considered in any activity regarding urban design and construction. This means flood management does not stay in its policy area, with stormwater management in the streets, but rather becomes a consideration in all further urban development. This ties in with the framing of the *extent* of adaptation to flooding in these documents, which state that climate adaptivity must become a part of all future municipal action, A3 proposing legal requirements for all projects on public and private ground. A5 also lists a broad array of components to adapt, yet looks more at adaptation activities within the usual scope of stormwater and river management by the already responsible authorities, and refers less to the cross-cutting nature of climate adaptation. Thus, it differs slightly from the other documents in the framed extent, which does not see flood management weaving into other policy areas. The extent of adaptation in A6 is quite narrow, not because it is a practical proposal for adaptation of a single component, but because it does not suggest any mandatory measures or active incentivization of garden owners, yet only that financial support for adaptation can be granted upon request.

TABLE 5: Overview of diagnostic and prognostic framing of climate adaptation in urban flood management among the six documents from after the disaster.

INDEX	Diagnostic - Adaptation to what?		Prognostic - Adaptation of what and by doing what?					
	Cause of issue & Attribution to climate change	Relevant local impacts	Components to be adapted	Extent of adaptation	Urgency	Intended outcome	Suitable approaches, strategies, and interventions	Synergies w/ climate hazards
A1	climate change overwhelms sewage network, steep topography	n/a	drainage system, runoff must not directly enter sewers	sponge city principles applied to building, energy and traffic infrastructure planning	high: flooding the biggest climate risk	sponge city, climate adaptation is central to high quality of life	new stormwater management focused on retention and infiltration through green-blue infrastructure	heat
A2	climate change exceeds drainage system limitations	n/a	existing retention basin, general urban design as framed in B2	climate adaptivity to be considered in all municipal action	medium: acceleration desirable but not feasible, limitations stressed	reduced risk through cross-cutting collaboration, integrated climate mitigation and adaptation	combination of grey and nature-based measures, e.g. expanded retention basins and urban greening, potential of single measures is limited so adaptivity must become a part of all activity	heat
A3	climate change	health of vulnerable groups	water courses in the city, new infrastructure and buildings	adaptivity requirements for all future municipal construction projects, legal measures for private ground, changes to all watercourses	high: disaster was a 'wake-up call'	proactively adaptive city, where risk is reduced as much as possible; sponge city	nature-based adaptation in line with 'sponge city' concept complemented by grey measures, focus on blue-green infrastructure and decentralized rainwater infiltration	heat
A4	climate change, special vulnerability through topography	property damage	any possible item in urban development (see extent), new developments and existing infrastructure/ buildings	adaptation must occur in all domains of urban planning and management	medium: flooding is an exceptional risk, adaptation is incremental	climate resilient and water-sensitive city	water-sensitive urban design stressed, multifunctional spaces and urban greening are key instruments, restoring natural water retention, information for private property holders	heat & drought
A5	climate change, urban design with sealed surfaces	riverside companies, public infrastructure	management and design of water courses, overall stormwater management	current management of both fluvial and pluvial flood risk in all areas to be reinforced or reconsidered	high: report by special flood taskforce	water-sensitive city, sponge city	mixture of 'grey' and 'green' approaches for pluvial and fluvial risk, retention basins in hotspots, blue-green infrastructure and infiltration throughout the city (limitations recognized)	heat & drought
A6	ongoing sealing of private gardens	expensive stormwater measures needed	sealed garden surfaces	financial support for un-sealing can be requested by homeowners	medium: mentioned after heat	Multi-beneficial greened gardens throughout city	decentralized infiltration of stormwater, through greening of gardens	heat

The framing of the *urgency* of flood adaptation in A1, A3, and A5 is high, calling flooding the biggest risk to the city (A1), the 2021 disaster being a ‘wake-up call’ to the threat (A3), and reporting on behalf of a special flooding task force that was called to life after the event (A5). These documents convey that the city is in a state of emergency. A2 adopts a different framing of the urgency of adaptation, by reporting on current implementation of flood risk management and the limitations to it. It takes less of a ‘we have to do everything as soon as possible’ stance and gives an impression of ‘this is all we can and could do’, rooted in past experience of adaptation efforts that imply that accelerated adaptation is infeasible. A4 frames flooding to be an exceptional risk, but through the wording conveys a less pressing adaptation timeline, as it will be a continuous incremental process. In A6, the risk of flooding is named after heat adaptation as a reason for the proposal, implying that flooding is not the central adaptation challenge in Wuppertal.

The intended *outcome* of urban flood adaptation differs between the documents. A1, A3, A4, and A5 have in common that they use concepts to frame their goal (sponge city and water-sensitive city), yet do not more clearly define what these concepts mean for Wuppertal. Clear from several documents however is the vision of a city with a high quality of life, where adaptation is not one-dimensional, but contributes to overall sustainable urban development. A2 and A3 specify that in the desired future, risk is reduced as much as possible through adaptation that is collaborative (A2), and proactive (A3).

The most *suitable approaches, strategies, and interventions* to reach this adaptation goal are framed in all documents as nature-based adaptation centering around increasing water infiltration and retention of the soil, mostly by distribution of blue-green infrastructure and permeable pavements. A2, A3, and A5 frame it suitable to combine this approach with ‘grey’ flood management measures, such as retention basins in especially affected areas. A5 specifically points to the limitations to infiltration on the steep rocky slopes of the Wuppertal valley but stresses the need for underground retention space and multi-functional spaces. The latter are also regarded highly in A4. Fluvial flood management is framed in the documents also as a mixture of natural water course restoration and technical flood defenses. These strategies all recognize the strong *synergies* of nature-based flood adaptation with the mitigation of urban heat, while A4 and A5 further stress the adaptation to future droughts through increased infiltration.

4.3 PERCEPTIONS OF PROFESSIONALS IN URBAN FLOOD MANAGEMENT

The inductive coding of the two interviews with local experts (interviewee 1 (I1) and interviewee 2 (I2)) working in urban flood adaptation in Wuppertal yielded two main themes that were central to the interviews and that help to answer specific research question 3. The experts shared their own experience of perspective changes in urban flood management within the urban administration over the last years, and elucidated the main causes of change including the 2021 disaster and earlier extreme events. Furthermore, they hinted at the translation of internal processes into action, and obstacles in that process. The main results of the interviews are shown in Table 6.

TABLE 6: Interview results per theme, with relevant quotes by the interviewees (I1 and I2)

CAUSES OF CHANGE		
Influence of experienced EWEs in general	Influence of 2021 disaster specifically	Other drivers and facilitators
<ul style="list-style-type: none"> • The experience of extreme rainfall events has been a part of Wuppertal's history, which has caused the early initiation of the adaptation line of work. I2: <i>'We have many, many streams, not just the Wupper, (...) and because there have been these extreme events in the past, most recently the extreme event in 2021, ultimately my position came into existence.'</i> • A main impact of experiencing extremes in general is the elevated attention. I1: <i>'(...) the events always trigger new motivation and highlight the urgency.'</i> Interest also quickly declines again. I1: <i>'When there hasn't been a flood event for a few years, there's a bit of a lull again. The urgency always comes to the surface again when something happens.'</i> • Extreme events provide leverage for project funding. I1: <i>'If we have to ask for money from the city treasurer, then such events are what you can refer to.'</i> 	<ul style="list-style-type: none"> • The main strands of work and current central activities (HPK, hazard maps) were already established before the recent extreme and were only updated or amended in response. I1: <i>'The issue of flooding and heavy rainfall began long before [the 2021 disaster], starting at least in 2016.'</i> • There was no deeper effect on the main perspective on the issue and its solutions. I1: <i>'[The most recent extreme events] only changed our understanding slightly, of course they sharpened it.'</i> • Complementary technical and natural solutions were supported by the experience, as the soils were already saturated before the extreme, showing the limits to nature-based adaptation. I2: <i>'But then of course also against the background that if I have an event like 21, if I stick with the nature-based solutions - my nature was full and the means are then also limited.'</i> • The disaster rekindled debates on the issue and made the vulnerability apparent. Exploration of new approaches recommenced. I1: <i>'It was extremely expensive insurance-wise in 2021 (...), since then there have been more discussions again.'</i> I2: <i>'I think it had a particular impact on Wuppertal because it was hit twice in such a short amount of time and we were reminded again of climate change at a time when we were already busy forgetting the whole thing and dismissing it as an isolated event.'</i> I2: <i>'These disaster response things, the new working group things, the planned working group on water-sensitive urban development, these things, of course, then popped up.'</i> The 'sponge city' concept gained traction, although focus shifted towards water sensitive urban design. I2: <i>'We have moved away from the sponge city towards water-sensitive urban design.'</i> • The collectivity of the adaptation challenge was further internalized, increasing collaboration. 	<ul style="list-style-type: none"> • EU, national and federal state legislation and funding influence local climate adaptation. I1: <i>'So if flood protection or natural flood protection is funded, even if this is not a legal change, then this is of course a clear sign for a municipality to act in this direction.'</i> In Wuppertal, national funding funded installation of climate action coordination, or climate management. I1: <i>'I think climate management was really important, with the IKS. This actually gave it a bit of new momentum.'</i> EU water legislation has shaped fluvial flood management. I1: <i>'The Water Framework Directive is decisive for the work of the Wupperverband, and the themes of natural retention, creating floodplain landscapes and redesigning the course of rivers have been very important for at least 20 years.'</i> • Important are individuals in the urban authorities that enable new practices and processes in urban flooding adaptation. I1: <i>'[The mayor] wants to consolidate the positions that were included (...) in broader issue areas.'</i> I1: <i>'There have been many personnel changes in recent years, so there is a new head of department for green spaces and forestry, which are very important partners for us (...).'</i> • The new digital twin helps in convincing political decision-makers of the importance of adaptation by supplying data of flooding impacts. I1: <i>'What is actually bringing a lot of momentum to everything that involves heavy rain/flood protection is the digital twin, Smart City.'</i>

I2: 'We then looked at what we could do, but also how we could pool resources, because we simply don't have them all on our own and the whole thing was somehow seen more as a collective task.'

Regional cooperation was formalized to improve river flood management and share knowledge.

- Wuppertal experts were prepared to use the **window of opportunity** after the disaster.

I2: 'I think in Wuppertal you had the advantage of the 18 event that you noticed how quickly the interest in it dropped again, so that you really took advantage of the opportunities after 21, as long as the sensitivity was there, because you were affected.'

- Since 2021, the **interest** in flood adaptation has **decreased again**.

I1: 'There is the war in Ukraine, so the city is also busy with many other issues. I think the flood issues have actually fallen asleep a bit.'

TRANSLATION INTO ACTION: BARRIERS TO CHANGE

Administration functioning	Finances	Coordination
<ul style="list-style-type: none"> • Climate action is not a statutory task, and in times of clear staff shortage, any extra task is not prioritized. I1: 'If you have a staff shortage and don't actually have enough people to do it, then of course you only do your mandatory tasks for the time being.' • The city has to prioritize which topic to focus its resources on, as there are many pressing issues. I2: 'You then have this collective task of climate adaptation, heavy rainfall, extreme weather events (...) but you also have many other collective tasks, immigration, homelessness.' 	<ul style="list-style-type: none"> • Drafting of strategies is financed, yet not execution of the strategy which has to be secured through extra funding sources. • External funding comes with clear rigidities and does not allow flexible implementation of adaptation measures. Yet the city is dependent on funding. I1: 'The IKSK was written, approved by the council, was ticked off as okay by the funding body, meaning "as a city you can do it this way, but that also means you have to do it exactly this way". As climate managers, we had no chance to deviate from this, really. We had to comply with the measures because otherwise we wouldn't get any funding or, in the worst case, we'd even have to pay the money back. So it's a very rigid construct.' • Current funding limits use retrospective return periods. I2: 'But if you have extreme events and if you have climate change, then the question often arises to what extent this HQ 100, which is based on retrospective statistics, to what extent it will still be HQ 100 in 5 years' time or will it perhaps be HQ 50 by then?' 	<ul style="list-style-type: none"> • Different actors in urban flood management frame aspects of the topic differently. I1: 'WSW and WAW in Wuppertal, i.e. the municipal utilities and drainage, are very technically oriented. They still are, I would say. The understanding comes little by little.' Especially vague concepts need clear work for a uniform definition. I2: 'I have the feeling that everyone has a different understanding of each term, and that sponge city is a particularly vague concept.' • Overlapping responsibilities can make financing and execution of projects complicated. I1: 'With the number of people involved, you can already see that such meetings or the responsibility for the overall project can quickly get lost in the crowd.'

The main developments in climate adaptation in urban flood management as identified by the experts already commenced long before the most recent extreme events, as experience of heavy rainfall is part of Wuppertal's history. Throughout the years, conceptualization of adaptation to flooding changed from a very technical and little understood issue to a more holistic and systemic understanding of the problem and its solutions, with a focus on blue-green infrastructure. The remnants of and ongoing older projects are still showing this development. For fluvial flood management, nature-based approaches to increasing water retention upstream with co-benefits for biodiversity are the main approach.

The impact of the 2021 disaster on this process is thus subtle. The main strands of work were already established before 2021, and the central projects guiding current adaptation in urban flood management were already initiated. This is namely the flood protection priority concept (HPK) that identifies hotspots of flood risk, that are met with measures according to their risk, as well as flood hazard maps for information of property owners. Through the experience of extreme events, they were only updated or amended, not fundamentally changed. Extreme rainfall events in general elevate perceived urgency of the need for adaptation and can serve as a crucial argumentation tool to justify need for investments. According to the experts, the disaster of 2021 also had that effect, increasing attention and motivation for work on the topic, with new working groups emerging on comprehensive nature-based adaptation approaches (first the sponge city, then water-sensitive urban design). I2 mentioned, that the 2021 disaster also showed the limitations to nature-based approaches. Saturation of the soils even before the real extreme began reiterated the importance of complementary approaches between technical and natural solutions.

Both interviewees explained that action on urban flood management has already died down again, that the window of heightened attention closes again sometime after the disaster. New issues appear more pressing and require resources. However, this also defines the importance of the 2021 disaster, as it came fairly shortly after the 2018 event. According to the interviewees, the responsible experts were well prepared to use the window of opportunity for more ambitious flood management when disaster struck in 2021, due to the recent other extreme event. The extent of the 2021 disaster did strengthen the perception that the adaptation task has to be approached collectively under involvement of all actors. New procedures for intra-administration collaboration between departments that had started over the years is now to be formalized into official procedures. Furthermore, a regional cooperation was formalized between river management authorities. Overall, the experts showed that when looking just at the toolbox, not a lot has changed in urban flood management through experience of the most recent extremes, as most of it was already well known before. But the way this toolbox is used, how it fits into a view of the whole, that there indeed has been some development to understand adaptation as a cross-cutting, intergenerational task.

Several other factors have strong influence on the developments in urban flood management, which must be taken into account as mediating variables. Wuppertal is in a tight financial situation, which

means that supra-local funding mechanisms have a large impact on the activities in the municipality. The experts mentioned legislation and funding from the federal state, the national level, as well as from the EU. However, external funding always comes with rigidities, as there are legal funding limits that might be outdated, and the money cannot be flexibly used for adaptation projects, but exactly for what it was requested for. This can cause lock-in into implementation of unsuitable or outdated projects. Overall, the city is lacking financial and human resources to follow up on all desirable ideas. The design of a digital twin of the city, however, improves consideration of climate adaptation in administrative planning. Catalysts for change are also motivated individuals, such as the mayor and new staff in urban planning departments. However, the experts also pointed out that it is common practice that new aspirational concepts are explored, yet not translated into action. I1 elaborated that for multifunctional spaces for example, it is easier and cheaper to work out concept papers and conduct workshops and book this as working on the topic, rather than actually implementing any multifunctional spaces. Human and financial resources are lacking to shift this process from theory to action.

4.4 IMPACT OF THE 2021 FLOOD ON ADAPTATION FRAMING IN WUPPERTAL

This study tried to answer the question, whether and how the framing of climate adaptation in urban flood management has changed in Wuppertal in response to the experience of the July 2021 flooding disaster. Figure 9 shows the most common framing of the analytical categories among documents before and after the event. The most striking differences are highlighted by the frame. It is visible that especially several categories of the prognostic framing have changed from before to after. Overall, in both periods adaptation is conceptualized as part of sustainable urban development by contributing to the overall livability of the city. In both periods, nature-based adaptation approaches and measures to both pluvial and fluvial flooding are highlighted as the path to take, focusing on the distribution of blue-green infrastructure and restoration of the natural hydrological functions of the urban soil and watercourses. Changes in framing are captured more in the extent and urgency of envisioned adaptation. Visible also in the components in need of adaptation is the broadened extent of the adaptation need. While the before and after overlap in their framing of the components, after the disaster the entire function of the drainage system needs to be adjusted, which includes but is not limited to sealed surfaces. The documents point to the need for transformed thinking and practice for effective adaptation already before the disaster, but after become very clear on the cross-cutting nature of the adaptation challenge. While also mentioned before the disaster, the documents after agree that adaptivity must be a core consideration in any municipal decision-making and action, and effectively leave its restriction to the flood management policy area. The policy document timeline already showed the spike in depth and frequency of discussion of flood adaptation, and the worded urgency in the documents after the disaster show the strong increase in awareness of the risk in response to the flood.

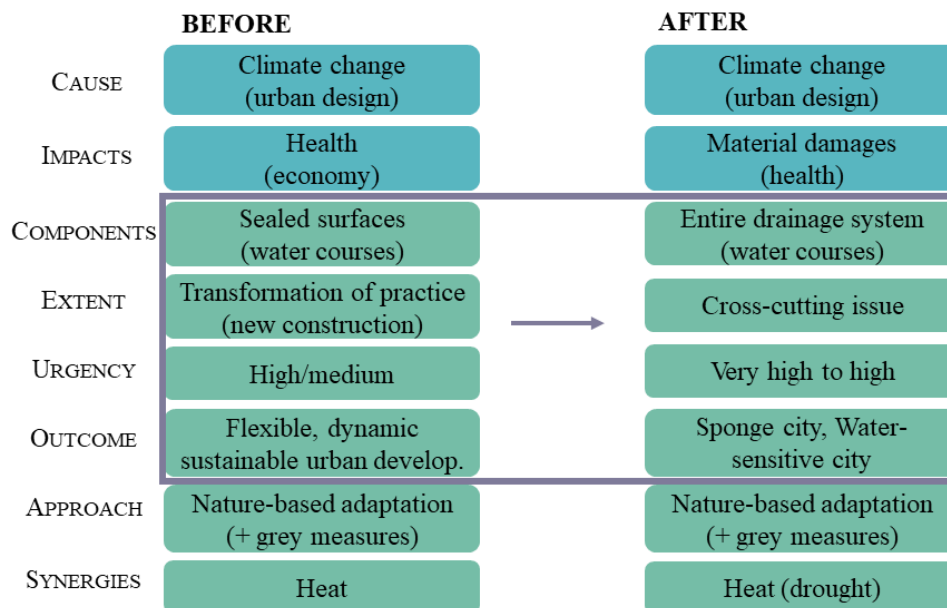


FIGURE 9: General framing per category as identified in the policy document analysis from before to after the 2021 flooding disaster.

Another interesting change in the documents from before to after is the increased salience of certain nature-based urban water management concepts, such as the sponge city and water sensitive urban design, although they are not further defined. The interviewees elucidated here, that the sponge city concept has already been abandoned again since and that they expect the water-sensitive city discourse to prevail. Overall, the interviews match the results from the document analysis, yet bring a little more nuance into the picture. The interviewees revealed that the current climate adaptation strategies for urban flood management were established well before the 2021 disaster, saying that the available tools have remained the same. This includes green measures such as swales and restored river courses. The disaster simply temporarily heightened attention and rekindled debate, although this focus has faded again, which was also visible in the document timeline. The experts however mirror the changes captured by the documents, that the sheer extent of the flooding within the city and beyond really visualized the cross-cutting nature of the adaptation challenge, and the need to institutionalize adaptation considerations in any municipal decision-making and action. However, the process of seeing flood adaptation as more of a systemic challenge involving all actors has not only started with the 2021 disaster. The experts state that urban flood management has evolved over the last years from purely an engineering issue to a more holistic co-beneficial approach centering on nature-based measures. The need for collaboration between different organs of the city authority and beyond has also become better understood. This learning process could also be observed after prior extreme events, most recently the 2018 heavy rainfall. However, it has also been observed before what this study's document timeline shows. The increased attention and discussion around flooding quickly fades again. The 2021 event's proximity to the 2018 extreme allowed experts to really use the window of opportunity after the disaster to advance work on urban flood management and secure future funding, as they were aware of the briefness of heightened attention. The water-sensitive city concept found frequently in the documents was in fact a working

group that budded up shortly after the flood, but appears to not have been fully institutionalized before the new-found urgency faded again. The interviews also point out, that this working group specifically was pushed for by an ambitious and motivated member of the administration staff, that has left the Wuppertal administration. This shows that the impact of the 2021 disaster on frames of flood adaptation is not necessarily direct, but is subject to mediating factors. The interviews indicate several of these mediating variables that are illustrated in Figure 10.



FIGURE 10: Influence of an experienced extreme event on the local framing of urban flood adaptation, as described by the Wuppertal experts.

Discussions after an extreme on the supra-local level give an indication to municipalities about what future funding will be available for, so the local framing incorporates these larger developments in its orientation. Additionally, the exchange between different actors, for example several units within the administration, or the administration and WSW or WAW affects the most salient conceptualization of adaptation.

5. DISCUSSION

5.1 EXTREME FLOODS EXPAND ADAPTATION UNDERSTANDING

The data from Wuppertal collected for this study suggest that the 2021 flood disaster did affect the framing of climate adaptation in urban flood management. This change applies much less to the available tools and strategies of adaptation, as these were already known before, but rather how these tools are used and into which larger picture they are embedded. The influence of the disaster is mediated by the exchange between different responsible organizations in Wuppertal, motivated individuals in the administration that push for certain framings, as well as the larger context, the influence of regional and national discussions on the framing of urban flood adaptation.

The findings of this study resonate with those of several previous studies, that help to understand how much the extreme experienced in Wuppertal and the following changes in flood management framing are specific to the city or represent a broader phenomenon. Rözer et al. (2022) observed a shift in academia and among flood management practitioners over the last two decades from one-dimensional engineering approaches towards more transformative practices to ‘enable all parts of the urban system to live with floods and learn from previous floods.’ These findings, echoed by Wardekker (2021), indicate that the shift from engineering to more holistic and nature-based urban flood management is broader than just the development in any locality. However, the findings of Madsen et al. (2019) suggest that flood managers in Copenhagen changed their purely technological trajectory of adaptation towards new solutions in the years following a disaster as a direct response. This in turn indicates that extreme events can indeed have the effect of initiating the change towards a more integrated practice. In Wuppertal, the experts recount that fundamental changes in urban flood management have been going on for years and do not identify the 2021 flood event as the cause for the local expression of the broader trend from more technical to more holistic approaches. The disaster was described as one of many along this process that refueled change towards a more integrated practice. That would mean that the trend towards a more nature-based, integrated flood management practice is a general trend in the field, perhaps spurred by collective experiences of the impacts of climate change, that influences local framing through supra-local discussion. Thus, this study in connection with the former work in this field indicates, that local adaptation is part of a larger system of developments and reframing of climate adaptation, in which all levels of knowledge and experienced impacts are interconnected.

The reframing of the extent of adaptation in Wuppertal happened quite abruptly. Madsen (2019) found that risk managers in Copenhagen reframed the flood adaptation process to include a wider range of stakeholders and expand their risk framing after a flood. This matches the perception of the Wuppertal interviewees, that especially the extent of the experienced flood in 2021 made apparent that climate adaptation must be on everyone’s agenda, as the impacts are complex and far-reaching. Thus, this study indicates, that the experience of an extreme event brings responsible authorities closer to framing of an adaptation approach that Rözer et al. (2022) find the most likely to be successful – involving the entire

urban system and encompassing adaptation of a wide extent of urban design and planning procedures. The Wuppertal interviews further refer to the fact, that this is not due to an extreme event creating more drivers for an integrated flood management framing among the responsible actors, but rather through turning actors away from inhibiting change.

Several studies describe the phenomenon, that after experienced extreme events a ‘window of opportunity’ opens for new deliberation about the climate adaptation challenge (Fünfgeld & McEvoy, 2011; Giordono et al., 2020; Madsen et al., 2019; Otto-Banaszak et al., 2011). This showed itself in Wuppertal through the emergence of the sponge city and water-sensitive urban design concepts in policy documents after the 2021 floods, as well as the planned working group on water-sensitive urban design. In line with the aforementioned studies, the Wuppertal case also showed that this window of opportunity closes again after the disaster. What this study adds to existing knowledge is the importance of individual motivated actors for how effectively this window of opportunity is used, as well as awareness of the volatility of the heightened attention.

While the goal of this study was to capture changes only in framing in response to a specific disaster, the overall aim was to understand what happens to urban climate adaptation when faced with a climate change impact. Singh et al. (2021) and Rözer et al. (2022) argue that the general shift in understanding of urban flood management described in the previous paragraphs is often unsuccessful in implementation by responsible institutions. Giordono et al. (2020) add, that failure to change policies and practice of climate adaptation after disaster might be more frequent than successful policy change. The interviewees shed light on this, as they were quick to move from changes that have happened in urban flood adaptation in the last years to which changes did not happen and why. Several factors affect translation of adaptation framing into practice in Wuppertal. Most salient are the issues of lacking finance and human resources. The municipal budget of Wuppertal is slim, and adaptation is not a statutory task, which means that funding for flood management can only be procured through external funding sources. These sources are pointed out in several policy documents and the interviews, that tie funding to conditions that limit development and experimentation with local adaptation practice as it is conceptualized. Furthermore, the municipal authority needs to institutionalize new workflows to effectively introduce flood adaptation outside of the flood management policy area. The understanding of co-creation of adaptation between different administrative departments is slowly growing according to the interviewees, pointing to the formalization of collaboration between the urban green space planners and the flood managers. This indicates that the Wuppertal authorities are slowly building their institutional adaptive capacity to effectively adapt to flooding, meaning their ability to respond to stressors (Bettini et al., 2015). Singh et al. (2021) highlights the importance of this process to actually achieve a system that is resilient to climatic impacts. Thus, this study indicates that extreme events can foster institutional adaptive capacity to align with the framing of the adaptation challenge.

5.2 LIMITATIONS OF THE STUDY AND RECOMMENDATIONS FOR RESEARCH

An important observation in this study is that the policy document analysis and the interviews yielded results that were not superimposable. They were not contradictory but showcased that the two data sources provide inherently different perspectives. The methods were triangulated in this study to verify each other's results but also to build on one another, which was successful. The policy documents offer a structured view of intended policies and strategies in the wording of a specific point in time (Bowen, 2009). They do not capture the 'operationalization gap' (Rözer et al., 2022) as explicitly as interviews, meaning the dynamics of translating strategy to practice, such as the barriers to implementation, the sincerity of nicely worded documents, and interactions of different stakeholders in flood adaptation. They often present an idealized version of policy, that does not necessarily give an insight into the reality on the ground (Owen, 2014). This can already be guessed from the differences in framing among the policy documents themselves. These differences stem from a variety of factors, such as the agenda and experience of the author and the purpose of the document (Owen, 2014). For example, among the 'before'-documents, B4 stands out with a narrower framing of the intended outcome, strategies, extent, and components of adaptation in comparison to the rest. This could stem from the fact that the document reports on the actual implementation efforts in flood adaptation, which is subject to several barriers and dynamics that the future-oriented often more political than practical other documents do not address. B4 resembles a sobered version of the rosier strategy documents, such as B2. The differences between the different documents reduce the validity of the observed change from before to after the event, as there is no homogenous framing before and after.

The interviews elaborate strongly on the dynamics of implementation, showing that the interviews capture the lived experience of the professionals, also making the discrepancies between theory and practice apparent and the influence of contextual factors, but being inherently subjective and personally biased (Owen, 2014). Due to the scope of this research and lack of responses, the number of interviewees is very low, which reduces the representative value of the interviews. The differences in framing among the documents and between data sources, however, highlight the importance of interviews for studying framing. For future research, this study recommends increasing interviewee numbers and diversifying the roles of the subjects, so that observation of the implementation gap does not stem from a single angle. Additionally, increasing sample sizes of documents could clarify different frames that perhaps coexist within an urban authority at the same time and analyze changes of these frames.

Selection of documents and interpretation of framing analysis are very subjective practices in general, proving that the results of this study must be supported by further studies in different localities and seen through a different set of eyes. In this study, it is possible that the single researcher distorted the pattern of framing into a certain direction subconsciously. For future studies, it is thus recommended to triangulate researchers. Despite the listed limitations, the research of this study provides interesting

insights into reconceptualization of climate adaptation in urban flood management due to experienced extreme events, that harbor opportunity for further study.

The results have practical implications as well. The experts point to the window of opportunity for advancing climate adaptation in flood management right after disasters that tends to close quickly. While perhaps unconventional, it could be useful for experts to strategically use the windows of opportunity by having a plan beforehand which barriers to decrease or for which to use the leverage of recent extreme experience. Future research could explore how experts can more effectively use the post-disaster period to advance climate adaptation and build institutional capacity, by studying the mechanisms through which these changes are enabled.

6. CONCLUSIONS

The study of the city of Wuppertal's response to the disastrous flooding in western Germany in the summer of 2021 shed light on the understudied potential of extreme events to cause changes in framing of climate adaptation in urban flood management among responsible authorities. The study determined, that framing of the local challenge is interconnected with discussions on higher levels, and the development of urban flood adaptation in Wuppertal over the last decade towards integrated and favorably nature-based approaches reflects a broader trend in the field overall. Thus, the favored strategies and tools were already defined before the 2021 flood, yet the conceptualization of how adaptation can be achieved and the needed extent of it expanded as a response. In Wuppertal a window of heightened attention opened after the disaster, that brought forth new salient management concepts and working groups, as well as activities to raise the authority's adaptive capacity and improve integrated planning procedures for flood adaptation. However, the increased urgency faded again soon, and the usual barriers to implementation, including lack of human and financial resource, inhibited further momentum. This study shows compelling evidence for the impact of extreme events on local adaptation practice. Future research could explore the mechanisms through which change is leveraged in response to an extreme event, so that adaptation practitioners can proactively prepare for an extreme and its window of opportunity to further their efforts. Because Wuppertal's experience of another flood two weeks ago shows: the next extreme is sure to come.

REFERENCES

- Abwasserbeseitigung in Der Stadt Wuppertal, Anlage 4 (2023). <https://www.wuppertal.de/rathaus-buergerservice/verwaltung/politik/stadtrecht-dokumente/7-10.pdf>
- Alves, A., Gersonius, B., Kapelan, Z., Vojinovic, Z., & Sanchez, A. (2019). Assessing the Co-Benefits of green-blue-grey infrastructure for sustainable urban flood risk management. *Journal of Environmental Management*, 239(December 2018), 244–254. <https://doi.org/10.1016/j.jenvman.2019.03.036>
- Apel, H., Martínez Trepát, O., Hung, N. N., Chinh, D. T., Merz, B., & Dung, N. V. (2016). Combined fluvial and pluvial urban flood hazard analysis: concept development and application to Can Tho city, Mekong Delta, Vietnam. *Natural Hazards and Earth System Sciences*, 16(4), 941–961. <https://doi.org/10.5194/nhess-16-941-2016>
- Applied Doctoral Center. (2023). *Developing the Qualitative Research Design*. <https://resources.nu.edu/c.php?g=1013605>
- Ara Begum, R., Lempert, R., Ali, E., Benjaminsen, T. A., Bernauer, T., Cramer, W., Cui, X., Mach, K., Nagy, G., Stenseth, N. C., Sukumar, R., & Wester, P. (2022). Point of Departure and Key Concepts. In *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 121–196). Cambridge University Press, Cambridge, UK and New York, NY, USA. <https://doi.org/10.1017/9781009325844.003>
- Bell, S., Allen, A., Hofmann, P., & Teh, T.-H. (2017). Urban Water Trajectories. In *Urban Water Trajectories* (Vol. 6). Springer Nature. <http://link.springer.com/10.1007/978-3-319-42686-0>
- Bergstrand, K., Mayer, B., Brumback, B., & Zhang, Y. (2015). Assessing the Relationship Between Social Vulnerability and Community Resilience to Hazards. *Social Indicators Research*, 122(2), 391–409. <https://doi.org/10.1007/s11205-014-0698-3>
- Bettini, Y., Brown, R. R., & de Haan, F. J. (2015). Exploring institutional adaptive capacity in practice: Examining water governance adaptation in Australia. *Ecology and Society*, 20(1). <https://doi.org/10.5751/ES-07291-200147>
- Biologische Station Mittlere Wupper. (2024). *Willkommen*. <https://www.bsmw.de/>
- Bowe, G. A. (2009). Document Analysis as a Qualitative Research Method. *Qualitative Research Journal*, 9(2), 27–40. doi:10.3316/qrj0902027
- Bowen, G. A. (2009). Document Analysis as a Qualitative Research Method. *Qualitative Research Journal*, 9(2), 27–40. <https://doi.org/10.3316/QRJ0902027>

- Bundesministerium des Inneren und für Heimat, & Bundesministerium der Finanzen. (2022). Bericht zur Hochwasserkatastrophe 2021: Katastrophenhilfe, Wiederaufbau und Evaluierungsprozesse. *Bmi.Bund.De*.
- Bundesministerium des Innern für Bau und Heimat, & Bundesministerium der Finanzen. (2021). *Zwischenbericht zur Flutkatastrophe 2021: Katastrophenhilfe, Soforthilfen und Wiederaufbau*.
- Burns, M. J., Fletcher, T. D., Walsh, C. J., Ladson, A. R., & Hatt, B. E. (2012). Hydrologic shortcomings of conventional urban stormwater management and opportunities for reform. *Landscape and Urban Planning*, 105(3), 230–240. <https://doi.org/10.1016/j.landurbplan.2011.12.012>
- Butler, D., Digman, C., Makropoulos, C., & Davies, J. W. (2018). Introduction. In *Urban Drainage* (4th ed.). CRC Press.
- Cardona, O.-D., van Aalst, M. K., Birkmann, J., Fordham, M., McGregor, G., Perez, R., Pulwarty, R. S., Schipper, E. L. F., Sinh, B. T., Décamps, H., Keim, M., Davis, I., Ebi, K. L., Lavell, A., Mechler, R., Murray, V., Pelling, M., Pohl, J., Smith, A.-O., & Thomalla, F. (2012). Determinants of Risk: Exposure and Vulnerability. In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (pp. 65–108). Cambridge University Press. <https://doi.org/10.1017/CBO9781139177245.005>
- Carter, J. G. (2011). Climate change adaptation in European cities. *Current Opinion in Environmental Sustainability*, 3(3), 193–198. <https://doi.org/10.1016/j.cosust.2010.12.015>
- Chen, A. S., Djordjević, S., Leandro, J., & Savić, D. A. (2010). An analysis of the combined consequences of pluvial and fluvial flooding. *Water Science and Technology*, 62(7), 1491–1498. <https://doi.org/10.2166/wst.2010.486>
- Chong, D., & Druckman, J. N. (2007). Framing theory. *Annual Review of Political Science*, 10, 103–126. <https://doi.org/10.1146/annurev.polisci.10.072805.103054>
- Christensen, S. (2021). *Auch städtische Gebäude, Forst und Sportplätze betroffen*. Stadt Köln - Amt Für Presse- Und Öffentlichkeitsarbeit. <https://www.stadt-koeln.de/politik-und-verwaltung/presse/auch-staedtische-gebaeude-forst-und-sportplaetze-betroffen>
- Cousin, G. (2005). Case Study Research. *Journal of Geography in Higher Education*, 29(3), 421–427. <https://doi.org/10.1080/03098260500290967>
- Crabbé, A., Wiering, M., & Liefferink, D. (2015). Adapting flood management to climate change: Comparing policy frames and governance practices in the low countries. *Journal of Water and Climate Change*, 6(1), 55–70. <https://doi.org/10.2166/wcc.2014.018>
- de Boer, J., Wardekker, J. A., & van der Sluijs, J. P. (2010). Frame-based guide to situated decision-making on climate change. *Global Environmental Change*, 20(3), 502–510. <https://doi.org/10.1016/j.gloenvcha.2010.03.003>

- Decke, H. (2023, January 13). Hochwasser in Hagen: Überschwemmungen und vollgelaufene Keller. *Westfälischer Anzeiger*. <https://www.wa.de/nordrhein-westfalen/hagen-hochwasser-unwetter-warnung-freitag-mitternacht-feuerwehr-ueberflutung-stadtteile-92024182.html>
- Demski, C., Capstick, S., Pidgeon, N., Sposato, R. G., & Spence, A. (2017). Experience of extreme weather affects climate change mitigation and adaptation responses. *Climatic Change*, *140*(2), 149–164. <https://doi.org/10.1007/s10584-016-1837-4>
- Derkzen, M. L., van Teeffelen, A. J. A., & Verburg, P. H. (2017). Green infrastructure for urban climate adaptation: How do residents' views on climate impacts and green infrastructure shape adaptation preferences? *Landscape and Urban Planning*, *157*, 106–130. <https://doi.org/10.1016/j.landurbplan.2016.05.027>
- Deutschlandfunk. (2021, July 24). *Wie wir Städte an steigende Unwetter-Gefahren anpassen können*. <https://www.deutschlandfunk.de/starkregen-und-hochwasser-wie-wir-staedte-an-steigende-100.html>
- Dewulf, A. (2013). Contrasting frames in policy debates on climate change adaptation. *Wiley Interdisciplinary Reviews: Climate Change*, *4*(4), 321–330. <https://doi.org/10.1002/wcc.227>
- dpa NRW. (2021, August 15). NRW-Städte wollen sich besser vor Hochwasser schützen. *Zeit Online*. <https://www.zeit.de/news/2021-08/15/nrw-staedte-wollen-sich-besser-vor-hochwasser-schuetzen>
- dpa-infocom. (2022, April 4). Opposition zum Hochwasser: Versagen, Verzögern, Täuschen. *Die Zeit*. <https://www.zeit.de/news/2022-04/04/opposition-zur-flut-versagen-verzoegern-taeuschen>
- Dupuis, J., & Biesbroek, R. (2013). Comparing apples and oranges: The dependent variable problem in comparing and evaluating climate change adaptation policies. *Global Environmental Change*, *23*(6), 1476–1487. <https://doi.org/10.1016/j.gloenvcha.2013.07.022>
- ElSawah, S., Mclucas, A., & Mazanov, J. (2013). Using a Cognitive Mapping Approach to Frame the Perceptions of Water Users About Managing Water Resources: A Case Study in the Australian Capital Territory. *Water Resources Management*, *27*(9), 3441–3456. <https://doi.org/10.1007/s11269-013-0357-5>
- Eriksen, S. H., Nightingale, A. J., & Eakin, H. (2015). Reframing adaptation: The political nature of climate change adaptation. *Global Environmental Change*, *35*, 523–533. <https://doi.org/10.1016/j.gloenvcha.2015.09.014>
- Fang, Y., & Jawitz, J. W. (2019). The evolution of human population distance to water in the USA from 1790 to 2010. *Nature Communications*, *10*(1), 430. <https://doi.org/10.1038/s41467-019-08366-z>

- Fekete, A., & Sandholz, S. (2021). Here Comes the Flood, but Not Failure? Lessons to Learn after the Heavy Rain and Pluvial Floods in Germany 2021. *Water*, 13(21), 3016.
<https://doi.org/10.3390/w13213016>
- Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J. L., Mikkelsen, P. S., Rivard, G., Uhl, M., Dagenais, D., & Viklander, M. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal*, 12(7), 525–542.
<https://doi.org/10.1080/1573062X.2014.916314>
- Fünfgeld, H., & McEvoy, D. (2011). *Framing climate change adaptation in Policy and Practice* (Issue September). <https://apo.org.au/sites/default/files/resource-files/2011-04/apo-nid239046.pdf>
- Gimenez-Maranges, M., Breuste, J., & Hof, A. (2020). Sustainable Drainage Systems for transitioning to sustainable urban flood management in the European Union: A review. *Journal of Cleaner Production*, 255, 120191. <https://doi.org/10.1016/j.jclepro.2020.120191>
- Giordano, L., Boudet, H., & Gard-Murray, A. (2020). Local adaptation policy responses to extreme weather events. *Policy Sciences*, 53(4), 609–636. <https://doi.org/10.1007/s11077-020-09401-3>
- Goderbauer-Marchner, G., Sontheimer, R., Maier, T., Ziegler, J., Alte, F., Lorenz, D., & Renz, C. (2015). Die unterschätzten Risiken “Starkregen” und “Sturzfluten.” *Ein Handbuch Für Bürger Und Kommunen*, 1, 296–299.
- Hausmann, J. (2022, July 4). Trier-Ehrang kämpft immer noch mit den Folgen der Flut. *SWR Aktuell*.
- Ho, L., & Limpacher, A. (2022). *The Essential Guide to Coding Qualitative Data*.
<https://delvetool.com/guide>
- Hydrotec Ingenieurgesellschaft. (2019). Hochwasser-Prioritätenkonzept für die Stadt Wuppertal – Phase 2 : Konzepterstellung. *Wupperverband, Projektbericht*.
- Information und Technik Nordrhein-Westfalen. (2023). *Bevölkerungsstand nach Geschlecht - Gemeinden - Monat (ab 2000)*. Landesdatenbank NRW. <https://www.landesdatenbank.nrw.de/ldbnrw/online?operation=previous&levelindex=1&step=1&titel=Ergebnis&levelid=1686572569556&acceptscookies=false#abreadcrumb>
- IPCC. (2022). Climate Change 2022: Impacts, Adaptation, and Vulnerability. In *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, (p. 3056)*. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA.
<https://doi.org/10.1017/9781009325844>

- Jeschke, A. (2022, July 13). "Unsere Art zu bauen hat uns so verwundbar gemacht." *Zeit Online*.
<https://www.zeit.de/green/2022-07/wiederaufbau-ahrtaal-nrw-flutkatastrophe-klimawandel>
- Junghänel, T., Bissolli, P., Daßler, J., Fleckenstein, R., Imbery, F., Janssen, W., Kaspar, F., Lengfeld, K., Leppelt, T., Rauthe, M., Rauthe-Schöch, A., Rocek, M., Walawender, E., & Weigl, E. (2021). Hydro-klimatologische Einordnung der Stark- und Zusammenhang mit dem Tiefdruckgebiet „Bernd“ Dauerniederschläge in Teilen Deutschlands im vom 12. bis 19. Juli 2021. *Deutscher Wetterdienst, July*, 16. https://www.dwd.de/DE/leistungen/besondereereignisse/niederschlag/20210721_bericht_starkniederschlaege_tief_bernd.pdf?__blob=publicationFile&v=6
- Kates, R. W., Travis, W. R., & Wilbanks, T. J. (2012). Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences of the United States of America*, 109(19), 7156–7161. <https://doi.org/10.1073/pnas.1115521109>
- Kohlbacher, F. (2006). The Use of Qualitative Content Analysis in Case Study Research. *Forum Qualitative Sozialforschung Forum: Qualitative Social Research*, 7(1), 1–30.
<https://doi.org/https://doi.org/10.17169/fqs-7.1.75>
- Kolkman, M. J., Kok, M., & van der Veen, A. (2005). Mental model mapping as a new tool to analyse the use of information in decision-making in integrated water management. *Physics and Chemistry of the Earth*, 30(4-5 SPEC. ISS.), 317–332. <https://doi.org/10.1016/j.pce.2005.01.002>
- Kordes, H., Seemann, L., & Rodosthenous, R. (2021). *Hochwasser: Chronologie des Versagens*. Monitor, Das Erste. <https://www1.wdr.de/daserste/monitor/sendungen/hochwasser-180.html>
- Kreienkamp, F., Philip, S. Y., Tradowsky, J. S., Kew, S. F., Lorenz, P., Arrighi, J., Belleflamme, A., Bettmann, T., Caluwaerts, S., Chan, S. C., Ciavarella, A., De Cruz, L., de Vries, H., Demuth, N., Ferrone, A., Fischer, E. M., Fowler, H. J., Goergen, K., Heinrich, D., ... L Otto, F. E. (2021). Rapid attribution of heavy rainfall events leading to the severe flooding in Western Europe during July 2021. *Royal Netherlands Meteorological Institute (KNMI)*, 13(July), 1–51.
<https://www.meteo.be/fr/infos/actualite/ce-que-lon-sait-sur-les-pluies->
- Lennon, M., Scott, M., & O'Neill, E. (2014). Urban Design and Adapting to Flood Risk: The Role of Green Infrastructure. *Journal of Urban Design*, 19(5), 745–758.
<https://doi.org/10.1080/13574809.2014.944113>
- Leonardi, G. (2010). Adaptation to climate change. *Environmental Medicine*, 521–530.
<https://doi.org/10.4324/9781315090467-4>
- Madsen, H. M., Mikkelsen, P. S., & Blok, A. (2019). Framing professional climate risk knowledge: Extreme weather events as drivers of adaptation innovation in Copenhagen, Denmark. *Environmental Science and Policy*, 98(March), 30–38. <https://doi.org/10.1016/j.envsci.2019.04.004>

- McEvoy, D., Matczak, P., Banaszak, I., & Chorynski, A. (2010). Framing adaptation to climate-related extreme events. *Mitigation and Adaptation Strategies for Global Change*, 15(7), 779–795. <https://doi.org/10.1007/s11027-010-9233-2>
- Michel, F., Steffen, D., Schlobinski, S., & Sander, S. (2012). Considering the Impact of Future Climate Change on the Resilience of a City - Surface Run-Off due to Heavy Storm Events in the City of Wuppertal. *17th International Conference on Urban Planning and Regional Development in the Information Society: "RE-MIXING THE CITY TOWARDS SUSTAINABILITY AND RESILIENCE?"*, *GeoMultimedia 2012*. <https://av.dfki.de/publications/considering-the-impact-of-future-climate-change-on-the-resilience-of-a-city-surface-run-off-due-to-heavy-storm-events-in-the-city-of-wuppertal-2/>
- Miller, J. D., & Hutchins, M. (2017). The impacts of urbanisation and climate change on urban flooding and urban water quality: A review of the evidence concerning the United Kingdom. *Journal of Hydrology: Regional Studies*, 12, 345–362. <https://doi.org/10.1016/j.ejrh.2017.06.006>
- Morgan, H. (2022). Conducting a Qualitative Document Analysis. *Qualitative Report*, 27(1), 64–77. <https://doi.org/10.46743/2160-3715/2022.5044>
- Müller, W., & Kruse, S. (2021). Modes of drought climatization : A frame analysis of drought problematization in Germany across policy fields. *Environmental Policy and Governance*, 31(5), 546–559. <https://doi.org/10.1002/eet.1954>
- Nikogosian, C., Winterrath, T., Walawander, E., Fischer, I., Schmitz-Kröll, D., & V Wischott. (2021). Klassifikation meteorologischer Extremereignisse zur Risikovorsorge gegenüber Starkregen für den Bevölkerungsschutz und die Stadtentwicklung (KlamEx). Abschlussbericht. *Projekt Der Strategischen Behördenallianz „Anpassung an Den Klimawandel“*.
- Nuhr, A. (2022, July 13). Stadt Land unter? – Strategien gegen Starkregen. *SWR2 Wissen*. <https://www.swr.de/swrkultur/wissen/stadt-land-unter-strategien-gegen-starkregen-102.html>
- Otto-Banaszak, I., Matczak, P., Wesseler, J., & Wechsung, F. (2011). Different perceptions of adaptation to climate change: A mental model approach applied to the evidence from expert interviews. *Regional Environmental Change*, 11(2), 217–228. <https://doi.org/10.1007/s10113-010-0144-2>
- Owen, G. (2014). Qualitative Methods in Higher Education Policy Analysis: Using Interviews and Document Analysis. *The Qualitative Report*. <https://doi.org/10.46743/2160-3715/2014.1211>
- Pedersen, A. N., Mikkelsen, P. S., & Arnbjerg-Nielsen, K. (2012). Climate change-induced impacts on urban flood risk influenced by concurrent hazards. *Journal of Flood Risk Management*, 5(3), 203–214. <https://doi.org/10.1111/j.1753-318X.2012.01139.x>

- Radhakrishnan, M., Pathirana, A., Ashley, R., & Zevenbergen, C. (2017). Structuring climate adaptation through multiple perspectives: Framework and case study on flood risk management. *Water (Switzerland)*, 9(2). <https://doi.org/10.3390/w9020129>
- Raether, E. (2022, July 12). “Es geht um Menschenleben und um Milliarden Schäden.” *Zeit Online*. <https://www.zeit.de/gesellschaft/zeitgeschehen/2022-07/ahrtaal-wolfgang-buechs-flutkatastrophe-hochwasser>
- Robinson, O. C. (2014). Sampling in Interview-Based Qualitative Research: A Theoretical and Practical Guide. *Qualitative Research in Psychology*, 11(1), 25–41. <https://doi.org/10.1080/14780887.2013.801543>
- Rosenzweig, B. R., McPhillips, L., Chang, H., Cheng, C., Welty, C., Matsler, M., Iwaniec, D., & Davidson, C. I. (2018). Pluvial flood risk and opportunities for resilience. *WIREs Water*, 5(6). <https://doi.org/10.1002/wat2.1302>
- Rözer, V., Mehryar, S., & Surminski, S. (2022). From managing risk to increasing resilience: a review on the development of urban flood resilience, its assessment and the implications for decision making. *Environmental Research Letters*, 17(12), 123006. <https://doi.org/10.1088/1748-9326/aca8bc>
- Rüth, K. (2022, July 14). Ein Jahr nach der Flut in Wuppertal: Rückblick auf Schrecken und große Hilfe. *Westdeutsche Zeitung*. https://www.wz.de/nrw/wuppertal/ein-jahr-nach-der-flut-in-wuppertal-rueckblick-auf-schrecken-und-grosse-hilfe_aid-72878741
- Schäfer, A., Mühr, B., Daniell, J., Ehret, U., Ehmele, F., Küpfer, K., Brand, J., Wisotzky, C., Skapski, J., Rentz, L., Mohr, S., & Kunz, M. (2021). *Hochwasser Mitteleuropa, Juli 2021 (Deutschland)* (Vol. 2021, Issue 1). <https://doi.org/10.5445/IR/1000135730>
- Seneviratne, S. I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., Ghosh, S., Iskandar, I., Kossin, J., Lewis, S., Otto, F., Pinto, I., Satoh, M., Vicente-Serrano, S. M., Wehner, M., & Zhou, B. (2021). Weather and Climate Extreme Events in a Changing Climate. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. <https://doi.org/10.1017/9781009157896.013>
- Singh, P., Amekudzi-Kennedy, A., Woodall, B., & Joshi, S. (2021). Lessons from case studies of flood resilience: Institutions and built systems. *Transportation Research Interdisciplinary Perspectives*, 9, 100297. <https://doi.org/10.1016/j.trip.2021.100297>
- Skougaard Kaspersen, P., Høegh Ravn, N., Arnbjerg-Nielsen, K., Madsen, H., & Drews, M. (2017). Comparison of the impacts of urban development and climate change on exposing European

- cities to pluvial flooding. *Hydrology and Earth System Sciences*, 21(8), 4131–4147.
<https://doi.org/10.5194/hess-21-4131-2017>
- Slawig, J. (2021). *VO/1196/21 Hochwasserkatastrophe in Wuppertal*.
- Sörensen, J., Persson, A., Sternudd, C., Aspegren, H., Nilsson, J., Nordström, J., Jönsson, K., Mottaghi, M., Becker, P., Pilesjö, P., Larsson, R., Berndtsson, R., & Mobini, S. (2016). Re-Thinking Urban Flood Management—Time for a Regime Shift. *Water*, 8(8), 332.
<https://doi.org/10.3390/w8080332>
- Sprague, T., & Prenger-Berninghoff, K. (2019). *Case: Wuppertal, North-Rhine-Westphalia, Germany* (pp. 147–167). https://doi.org/10.1007/978-3-319-99744-5_7
- Stadt Wuppertal. (2021). *Nach Hochwasser: Viel Lob, aber auch Schwachstellen in der Analyse*.
<https://www.wuppertal.de/presse/meldungen/meldungen-2021/juli21/hochwasser-erste-bilanz.php>
- Stadt Wuppertal. (2023). *Organigramm*. https://www.wuppertal.de/Organigramm_Stadt_Wuppertal_ab_10.2023.pdf
- Tagesschau. (2021, July 19). “Unglaublicher Weckruf der Natur.” *Hochwasser in Deutschland*.
<https://www.tagesschau.de/inland/gesellschaft/hochwasser-bayern-sachsen-103.html>
- Taherdoost, H. (2016). Sampling Methods in Research Methodology ; How to Choose a Sampling Technique for Research Hamed Taherdoost To cite this version : HAL Id : hal-02546796 Sampling Methods in Research Methodology ; How to Choose a Sampling Technique for. *International Journal of Academic Research in Management (IJARM)*, 5(2), 18–27.
- Tingsanchali, T. (2012). Urban flood disaster management. *Procedia Engineering*, 32, 25–37.
<https://doi.org/10.1016/j.proeng.2012.01.1233>
- Ulibarri, N., Valencia-Urbe, C., Sanders, B. F., Schubert, J., Matthew, R., Forman, F., Allaire, M., & Brady, D. (2023). Framing the Problem of Flood Risk and Flood Management in Metropolitan Los Angeles. *Weather, Climate, and Society*, 15(1), 45–58. <https://doi.org/10.1175/WCAS-D-22-0013.1>
- Wardekker, A. (2021). Contrasting the framing of urban climate resilience. *Sustainable Cities and Society*, 75, 103258. <https://doi.org/10.1016/j.scs.2021.103258>
- WAW. (2024). *Abwasserbeseitigung*. Eigenbetrieb Wasser Und Abwasser Wuppertal - Wasserversorgung Und Abwasserbeseitigung. <https://www.wuppertal.de/microsite/wasserversorgung/abwasser/index.php>
- Wenzel, F.-T. (2021, July 17). Vom Hoch- zum Breitwasser: neue Wege für den Schutz vor Überschwemmungen. *Redaktionsnetzwerk Deutschland*. <https://www.rnd.de/wirtschaft/neue->

wege-gegen-unwetterkatastrophen-wie-schuetzen-wir-uns-in-zukunft-vor-hochwasser-
XNTGI43KEVGUDMTMEGD2DMCZS4.html

Wilms, M. (2024, May 16). Deutsche Bürokratie – wenn Beschleunigung zum Stillstand führt. *MDR*.
<https://www.mdr.de/nachrichten/deutschland/politik/buerokratie-dokumentation-hindernis-wirtschaft-100.html>

Wirtz, B., Niehuis, C., Büttgens, B., Oprée, B., Berners, S. M., Schröer, A., & Lange, J. (2022, July 14). Der Regen, das Hochwasser, die Zerstörung. *Aachener Zeitung*. https://www.aachener-zeitung.de/nrw-region/der-regen-das-hochwasser-die-zerstoerung_aid-72745973

WSW. (2024). *Stadtentwässerung für Wuppertal*. Wuppertaler Stadtwerke GmbH. <https://www.wsw-online.de/wasser/abwasser/>

Wu, P., Christidis, N., & Stott, P. (2013). Anthropogenic impact on Earth's hydrological cycle. *Nature Climate Change*, 3(9), 807–810. <https://doi.org/10.1038/nclimate1932>

Wuppertaler Rundschau. (2022, July 6). Gutachten entlastet den Wupperverband. *Hochwasser Im Juli 2021*. https://www.wuppertaler-rundschau.de/stadtteile/langerfeld-beyenburg/hochwasser-im-juli-2021-gutachten-entlastet-den-wupperverband_aid-72484197

Wupperverband. (2023). *Wupper-Talsperre*. Unsere Anlagen. <https://www.wupperverband.de/unsere-anlagen/talsperren/wupper-talsperre>

Wupperverband. (2024a). *Über Uns*. <https://www.wupperverband.de/ueber-uns>

Wupperverband. (2024b). *Zuständigkeiten*. Unsere Aufgaben. <https://www.wupperverband.de/unsere-aufgaben>

Zhang, D., Gersberg, R. M., Ng, W. J., & Tan, S. K. (2017). Conventional and decentralized urban stormwater management: A comparison through case studies of Singapore and Berlin, Germany. *Urban Water Journal*, 14(2), 113–124. <https://doi.org/10.1080/1573062X.2015.1076488>

APPENDICES

APPENDIX I – SAMPLING FRAME DOCUMENT SELECTION

Date	Document Title and Link	Author	Status	Diagnostic Framing		
				Cause	CC Attribution	Impacts
02/2019	Betroffenheitsanalyse Hitze	GB1	Received		X	
09/2019	Antrag 14-Punkte Klimaschutzpl	Grüne, CDU	Agreed			
12/2019	Antrag Dachbegrünung	Ressort 106 - Umw	Agreed		X	
12/2019	Update Erarbeitung IKSK	GB1	Received			
12/2019	Antrag Ausrufung "Klimanotstan	Grüne, CDU	Approved			X
05/2020	IKSK	Stadt + Consultanc	Agreed	X	X	X
06/2020	Abwasserbeseitigungskonzept	WAW	Agreed			
	Anlage Abwasserbeseitigung		Agreed		X	
06/2020	Beschluss Klimacheck & Kliman	GB1	Agreed			
11/2020	Antwort Stand Hochwassermanag	Stadt, WSW, WV	Received	X	X	
04/2021	Antrag Flächenentsiegelung	Grüne, CDU, Link	Approved		X	X
05/2021	Anfrage Klimaanpassung (Fokus	GB3	Received	X	X	
08/2021	Hochwasser Bericht	WV	Received			
08/2021	Flächenmoratorium	SPD (BV Cronenb	Agreed	X	X	
08/2021	DWD Klimaprojektionen Wuppe	GB3 (DWD)	Received		X	X
08/2021	Antrag Hochwasseranpassung	Grüne (BV Elberfe	Agreed		X	X
09/2021	Bewerbung Schwammstadt	SPD, CDU, Grüne	Agreed	X	X	X
09/2021	Anfrage Umsetzung IKSK	CDU Fraktion	Received		X	
09/2021	Antwort Stand Klimaanpassung	GB3	Received		X	
11/2021	Antrag "Klimaschutz und Klimaf	CDU, SPD, Grüne	Agreed	X	X	
12/2021	HPK, SRM, Verstetigung	Ressort 106 - Umw	Agreed		X	X
	Verstetigungskonzept SRM	Ressort 106, Pech	Agreed	X	X	
12/2021	Antwort "Wasser in der Stadt"	Ressort 106 - Umw	Received			
02/2022	Antwort Entwässerung bei Bebau	Ressort 105 - Bau	Received			
02/2022	Update "Klimaschutz Klimaanpa	GB3	Received		X	
09/2022	Antrag Prüfung Anschluss- und E	Fraktion Grüne	Approved		X	
06/2022	Abschlussbericht Taskforce Hoch	Taskforce, Oberbü	Received	X		
09/2022	Antrag Versiegelung	Fraktion Grüne	Agreed	X	X	X
09/2022	Beschluss der Versickerungs-Tas	WAW	Received			
09/2022	Synopsis Klimakoordination der A	Klimakoordination	Received			
11/2022	Stufenplan Klimaneutralität 2035	GB3	Received			
11/2022	Aktualisierung STEK "Zukunft V	GB1	Agreed			
12/2022	Antrag Sachstandsbericht "Klima	SPD Fraktion	Received			
01/2023	Haushaltsplan (Band2) 2023	Ressort 403 Finanz	Received	not suited for QDA		
03/2023	Wiederaufbauplan Wuppertal	Ressort 403 Finanz	Agreed			
02/2023	Maßnahmenübersicht IKSK	Koordinierungsste	Received			
03/2023	Antrag kohärentes Handeln Klim	SPD, CDU, FDP	Agreed			
03/2023	Sachstandsbericht Klimaschutz &	GB3	Received			
04/2023	Monitoring Update IKSK	Klimamanagement	Received		X	
03/2023	Smart City Strategie	Ressort 402 - Amt	Agreed	X		
05/2023	Nachhaltigkeitsstrategie		Approved			
06/2023	Antrag "Mehr Grün in Bebauungs	Grüne	Rejected	X	X	

Prognostic Framing				Meaning / Relevance	Authenticity	Credibility	Representativeness	Selected
To be adapted	Extent/ Urgency	Best strategies	Synergies					
			X	5	yes	yes	yes	
				6	yes	yes	yes	
X	X		X	2	yes	yes	yes	X
				6	yes	yes	yes	
	X			6	yes	yes	no	
X		X	X	1	yes	yes	yes	X
X		X		4	yes	yes	yes	
X		X		2	yes	yes	yes	X
				6	yes	yes	yes	
X		X		2	yes	yes	yes	X
	X	X	X	2,50	yes	yes	yes	X
X	X	X	X	1	yes	yes	yes	X
				5	yes	yes	no	
X	X	X		1	yes	yes	no	
	X			4	yes	yes	no	
X	X	X		3	yes	yes	no	
X	X	X		1	yes	yes	yes	X
X	X			3	yes	yes	no	
X		X	X	2	yes	yes	yes	X
X	X	X		1	yes	yes	yes	X
X		X		3	yes	yes	yes	
X		X		2	yes	yes	yes	X
X		X		5	yes	yes	yes	
X		X		4	yes	yes	yes	
X		X		3	yes	yes	yes	
X		X	X	3	yes	yes	no	
X	X	X		2	yes	yes	yes	X
X	X	X	X	2	yes	yes	yes	X
X		X	X	3	yes	yes	yes	
X		X		3,5	yes	yes	yes	
				6	yes	yes	yes	
X	X	X		4	yes	yes	yes	
				6	yes	yes	no	
	X			1	yes	yes	yes	
				3	yes	yes	yes	
X		X		5	yes	yes	yes	
				3	yes	yes	yes	
X		X		3	yes	yes	yes	
X	X	X		1	yes	yes	yes	X
X	X	X		2,5	yes	yes	yes	
				6	yes	yes	no	
X	X	X	X	1	yes	yes	no	

APPENDIX II – INTERVIEW GUIDE

Question	Objective of the Question
What are in your perception the most important changes in climate adaptation in urban flood management in recent years?	Validation of results from Document Analysis
Recount main results – In which way do you agree or disagree with what I found out about the developments from policy document analysis? Prompts for resonance or disagreement and further points	Validation of results from Document Analysis
In which way do you see a connection between the July 2021 flood disaster in Wuppertal and the understanding of the issue of flood adaptation or the vulnerabilities of the city?	Connecting diagnostic framing results from document analysis to the extreme event
In which way do you see a connection between the July 2021 flood disaster in Wuppertal and changes in the desired solutions and the perceived extent of needed adaptation?	Connecting prognostic framing results from document analysis to the extreme event
My results showed that the concept of the sponge city gained popularity in the documents over the course of the last 4 years. How do you perceive this? Which impact does the experience of an extreme event play on that?	Understand the impact of an extreme event on the use and popularity of new concepts and buzzwords
In which way does the understanding of the concepts and adaptation in general align between different institutions and responsible actors? Does this change through the experience of extreme events?	Clarify the homogeneity of framing among different relevant actors, and potential conflicts that arise from absence of mutual understanding
A few years have passed since the last floods. Do you have the feeling that ambitions and plans in the city authorities have changed again? What about the perception of urgency and extent of needed adaptation?	Duration of the impact of extreme events on decision-making
Which impact do developments on higher spatial levels have on the ideas around adaptation in Wuppertal, e.g. on the national/federal government level, or through intercommunal exchange?	Map mediating variables

APPENDIX III – LIST OF USED CODES AND SUBCODES

DOCUMENTS		INTERVIEWS	
CODE	SUBCODE	CODE	SUBCODE
1. & 2. Causes	Climate Change	Barriers to Change	Bureaucracy
	Compound climate impacts		Coordination
3. Impacts	Insufficient canal system	Cause of Change	Finances
	Topography		Framing Conflicts
4. Components To Adapt	Urban Design	Earlier EWEs	Personnel
	Buildings		Facilitators
	Cased Creeks		Impact of 2021
	Emergency Response		
	Administrative Procedure		
	Green Spaces		
	Private ground		
	Public ground		
	River course		
	Roofs		
	Sealed surfaces		
5. Extent of Needed Adaptation	Sewage system		
6. Urgency of Needed Adaptation	Roads		
7. Intended Outcome			
8. Suitable Approaches/ Strategies/Measures	Green		
	Grey		
	Organization and Capacity		
	Physical Adjustment		
	Physical Redesign		
9. Synergies			

APPENDIX IV – FRAMING BEFORE THE DISASTER PER POLICY DOCUMENT

This section reports on the results of the qualitative document analysis of six documents from before the 2021 flooding disaster in Wuppertal between 01/2019 and 07/2021 (Overview in Table 2).

B1 is a proposal by the urban administration department on environmental protection, which was unanimously agreed on by the city council. It *diagnostically frames* the *cause* as increased experience of heavy rainfall events due to climate change.¹ The current drainage system lacks capacity to manage these extreme flows, which implies not a flaw in the current drainage approach, but merely a shifting of the drainage needs.² *Impacts* are not elaborated on. The *prognostic framing* of the document is in line with its title and identifies individual buildings with flat roofs as *components* to be adapted. The *suitable strategy* are greened flat roofs in the city, which have *synergies* with heat mitigation, biodiversity, and air quality.³ Thus the adaptation *outcome* is a multi-beneficial upgrading of the urban structure. The *extent* of adaptation is framed as the need for inclusion of (at least extensive) green roofing on all new flat roofs that are planned in the legally binding land-use planning. Retrofitting is not foreseen. For the *urgency* of adaptation, the benefits of green roofs for reduction of pressure on the drainage system during heavy rainfall is mentioned first, before benefits for cooling and other urban issues. However, the emphasis on urgent action in the wording is not very strong.

B2 is the still active long-term strategic document of the urban administration's climate mitigation efforts, under integration of climate adaptation strategies. This document is by far the longest and yielded the most code. In the *diagnostic framing* the *cause* of the adaptation issue is framed as a combination of increased hazard due to climate change and high vulnerability due to past and ongoing urban development. The steep topography and many creeks increase the hazard of heavy rainfall events.^{4,5} The continuous sealing of surfaces on public and private terrain heightens the sensitivity of the city to heavy rainfall events, as well as other climate hazards. The current sewage system does not have the capacity to handle peak runoff from extreme events. Depending on the section of the document, the most relevant *impacts* are listed in differing order. Overall, human health (with a special focus on vulnerable groups), and loss of attractiveness as a place for residence and business are most salient throughout the document.⁶ For the *prognostic framing*, B2 identifies any sealed surfaces and compacted soils as *components*

¹ 'With the momentous heavy rain event on May 29, 2018, and the exceptionally hot and dry summer of 2018 and 2019, the first local effects of global climate change have also become clearly noticeable in Wuppertal.' B1, p.1

² 'A green roof thus relieves the burden on the sewer system during heavy rain events and reduces the risk of flooding.' B1, p.2

³ 'Consistent green roofs can make a significant contribution to climate protection, relieve the burden on the sewer system, improve air quality and enhance the urban living space and urban design.'

⁴ 'The general discussion about potential adaptation strategies to climate change, the expected increase in heavy rainfall events and a continuing rise in land sealing have increasingly brought the need to adapt to 'urban flash floods' into focus.' B2, p.64

⁵ 'The steep topography leads to torrents during heavy rainfall events.' B2, p.121

⁶ '(...) this will have serious consequences, e.g. in terms of health protection and loss of attractiveness, both in terms of ecological and social effects. (...) In addition, Wuppertal would be weakened as a business location because it has not positioned itself for the future in good time.' B2, p.22

to be adapted, as well as cased watercourses. The *extent* of the needed adaptation is framed far-reaching, as it requires a transformation in thinking and practice in urban planning, decision-making and building.⁷ Furthermore, the document suggests several times to create guidance and regulations for any construction activities on public and private land, so that climate adaptivity becomes a central point of consideration. The *urgency* is high as heavy precipitation events are mentioned as a newly added focus of adaptation practice, which has also been influenced by ‘the general discussion on potential adaptation strategies (...)’ (B2, p.64). Overall, adaptation to flooding is conceptualized as a proactive activity, yet former experience of extreme events is mentioned as the driver for proactive adaptation.⁸ In the general section of the document, urban heat is listed and discussed before urban flooding, which implies that adaptation to extreme precipitation is not seen as the principal task. However, the *synergies* of different climate impacts (especially heat, drought and flooding) and their solutions are stressed throughout the document. Herein, the emphasis is placed on the cross-cutting nature of adaptation and the need for interconnected planning and decision-making in the form of hazard maps. Adaptation to climate impacts is embedded into the city’s overarching goal of ‘sustainable urban development’ and is framed as always increasing the city’s environmental and life quality. The *outcome* of the adaptation would be a highly proactive and continuously adaptive city, that has room for future needs and developments by employing reversible and dynamic adaptation strategies under inclusion of social justice criteria. The ‘water sensitive city’ concept is mentioned as an aspirational target, yet not further elaborated on. In line with this, nature-based adaptation approaches are identified as the most *suitable solution*, and the synergies of urban greening for both adaptation to heat and extreme rainfall, as well as overall attractiveness and resident wellbeing are stressed throughout the document. Suitable measures for flood mitigation focus on surface-based measures due to their cost-effectiveness. Wide-spread successive unsealing of existing paved surfaces, minimization of new sealing and soil compaction, and addition of underground retention space and urban greenery on the ground and buildings are central. Both smaller adjustments to existing infrastructure as well as more elaborate redesign of space during construction works are foreseen. Due to the scarcity of free space, multifunctional spaces that function both for water retention and other purposes (e.g. sports fields) are envisioned. Besides these nature-based approaches, construction of grey infrastructure, such as retention basins, is seen as necessary to reduce peak flows during extreme events.

B3 is the sewage and stormwater disposal concept by the WAW. In its *diagnostic framing*, B3 implies increasing extreme events due to climate change to *cause* the necessity to adjust the rigid sewage network to higher surface runoff.⁹ The main adverse *impact* of surface runoff is on sensitive infrastructure, which is not explicated further. Thus, the drainage network is the *component* to be adapted in the

⁷ “(...) a rethink is required in our regions to adapt to the consequences of climate change. A transformation must take place at city, district and building level in order to reduce the future impact of climate change.” B2, p.135

⁸ ‘Extreme weather events have already occurred in the Bergisch city-triangle in the past, which is why the municipalities of Wuppertal, Solingen and Remscheid have recognized a need for proactive action.’ B2, p.65

⁹ “(...) the realization that urban water infrastructure will be subject to changing boundary conditions in the future. In urban drainage, such developments carry particular weight, as changes due to e.g. increasing heavy rainfall events etc. meet inflexible systems.’ B3, p.67

prognostic framing, to improve performance under extreme conditions. Furthermore, management of open and cased watercourses (including the Wupper) needs to be adapted to improve flow properties while improving environmental status. The *extent* of adaptation includes technical adjustments to the sewage network, and several plans to evaluate and create more sustainable approaches to wastewater management. The *outcome* of adaptation is framed as ‘holistic’ and sustainable management of urban watercourses in cooperation with the different relevant institutions.¹⁰ Clean rainwater should be valued higher and be separated from dirty water and retained. Although the document is authored by the managing authority of the sewage network and carries the word water disposal in its name, decentralized and nature-based approaches to stormwater management are *suitable approaches*, that are favored over construction of retention basins and more efficient removal of runoff. The document stresses the need for renaturation of the Wupper and consideration of environmental considerations such as pollution and ecological river status. Framing of the *urgency* and *synergies* of adaptation could not be elicited.

B4 is a response by the urban administration, the WSW, and the Wupperverband to a question by the Greens’ parliamentary group in the council about potential necessity of further action on urban flood adaptation. The *diagnostic framing* of the *cause* of the adaptation issue is focused on the topography of Wuppertal and its many creeks, as well as the urban design with many sealed surfaces and encased watercourses. It is stated that the sewage network cannot drain extreme runoff from the city. Climate change and its impacts on extreme events are mentioned once, later in the document. The main *impacts* are seen on public health, the environment, cultural heritage as well as economic activities.¹¹ Further stressed are the threats to critical infrastructure by urban flooding. The *prognostic framing* in B4 identifies protection of individual assets as *components* in need of adaptation, as well as the capacity of the sewage network and cased watercourses. For the *extent* and *urgency*, it is implied that the issue is somewhat urgent, but that all possible steps at the administrative level are being taken. Simpler measures to protect from flooding such as stormwater basins are under construction, and whether further adaptation measures can be taken, under mention of the sponge city concept and blue-green infrastructure, is currently under discussion. Several limits to adaptation are outlined, such as technical and financial feasibility, or lack of space. Ultimately, adaptation is conceptualized as necessary risk reduction, however, a residual risk will always remain.¹² The adaptation *outcome* is thus framed as a more informed and sensitized population and maximal reduction of flood risk. The framing of the *suitable adaptation strategy* is implied through the listing of currently ongoing adaptation activity, which comprises construction of grey infrastructure, such as stormwater retention basins, new rainwater channels, a priority list of adaptation hotspots where targeted asset protection can be implemented, as well as information of the public

¹⁰ ‘General aims: (...) - Holistic consideration of open and piped sections of watercourses together with the water boards (...), - Developing and evaluating holistic and sustainable solutions’ B3, p.16

¹¹ “(...) the Greens parliamentary group raised several questions on flood management, taking into account the risks to human health, the environment, cultural heritage and economic activities.” B4, p.1

¹² ‘The above-mentioned measures are intended to significantly reduce the risk, but it cannot be ruled out for all affected assets. Wuppertal’s topography, dense development (high sealing), technical/financial limits and climate change with an increase in extreme weather events are the reasons for this.’ B4, p.2f

with a hazard map. Finally, potential future explorations into nature-based adaptation options are envisioned, as mentioned above. *Synergies* with other climate hazards are not included.

In **B5**, a proposal from several parliamentary groups for unsealing of surfaces, the *diagnostic framing* identifies the *cause* of the adaptation issue to be the increase in extreme weather events due to climate change.¹³ Important *impacts* are not mentioned. For *prognostic framing*, the *components* in need of adaptation are barely or unused large impermeable spaces on public ground, that are not suitable for other use such as housing or business. Further targeted are fallow (industrial) spaces. The *extent* of the proposed adaptation is limited, as only spaces on public land that are unusable to meet other needs of urban development are targeted in the document, although the *urgency* is worded strongly. As *suitable strategies* the document proposes changing the impermeable ground to more permeable coverings, as well as adding greening measures. Unused spaces should be recycled, and in the case of industrial sites potentially matched with measures for legacy contamination. *Synergies* between adaptation to different climate hazards is implied by connection of flooding, heat, and drought in the introduction of the document. The adaptation *outcome* is not framed.

In **B6**, the administration's Department 3 reported on the current activities on climate adaptation with a focus on heat to the council, answering a question by the parliamentary group of The Greens. For the *diagnostic framing*, the *cause* of the adaptation issue is clearly attributed to climate change and the ensuing extreme events. The most relevant *impacts* are not framed. For *prognostic framing*, the *components* in need of adaptation are not clearly specified. The *extent* of needed adaptation is set very wide and will require inclusion of an array of planning authorities, e.g., construction, land-use planning, or traffic management.¹⁴ Climate adaptivity is supposed to be included as a criterion in any decision-making processes in the shape of a checklist. The *urgency* is stressed to be very high,¹⁵ although adaptation to heat receives slightly more attention throughout the document and is described in more detail. The adaptation *outcome* is an adapted city, where adaptation to different climate hazards, quality of life, green roofs and traffic security is designed in an integrated manner. In line with this, *suitable adaptation strategies* approach climate adaptation as a cross-cutting topic.¹⁶ Mentioned is unsealing of paved surfaces to increase soil infiltration and retention of water, as well as greening on and around buildings, and creation of multifunctional spaces. Adaptation to heavy rainfall is seen as highly *synergetic* with adaptation to heat impacts.

¹³ "(...) the consequences of climate change such as flooding due to heavy rainfall, heat, drought and drinking water shortages are already being felt today" B5, p.1

¹⁴ 'Close cooperation involving green space, open space, urban and transport planners and the Climate Protection Coordination Office, among others, is necessary with regard to this future topic in order to think outside one's own box' B6, p.3

¹⁵ 'This current state of affairs shows very clearly - particularly in view of the fact that the problem situation is set to increase in the coming years - that there is a great need for action in many areas (...)' B6, p.5

¹⁶ 'Climate adaptation is a cross-cutting task and places high demands on networking.' B6, p.3

APPENDIX V – FRAMING AFTER THE DISASTER PER POLICY DOCUMENT

This section reports on the results of the qualitative document analysis of six documents from after the 2021 flooding disaster in Wuppertal between 07/2021 and 07/2023 (Overview in Table 4).

A1 is a declaration of Wuppertal's intention to apply as a model commune for a federal state project on sponge cities. The *diagnostic framing* of the *cause* of the adaptation issue points to climate change and the already experienced increased intensity of extreme events, as well as Wuppertal's steep topography and polycentric structure.¹⁷ The current sewage network is not capable of dealing with the peak flows during extreme events. Thus, the *prognostic framing* identifies that the overall drainage system of Wuppertal is the *component* in need of adaptation, so that rainwater does not enter the sewers directly. The *extent* of adaptation is large, as the principles of the sponge city concept are to be implemented in building, energy and traffic infrastructure planning.¹⁸ The *urgency* is high, as the document states that the currently experienced effects will worsen in the future, and clear action is needed in any scenario. The document states that especially extreme rainfall events must be adapted to, stressing their risk in comparison to other climate hazards.¹⁹ The adaptation *outcome* envisions Wuppertal as a sponge city, where climate adaptation is a central component in urban development and high quality of life. Under this most *suitable strategy* falls new stormwater management focused on retention and infiltration through greened buildings and streets, new water bodies and green spaces. This approach mitigates both flooding and heat hazards in *synergy*. The most relevant *impacts* are not framed.

A2 is the response by the urban administration to a question by the CDU parliamentary group about the current state of adaptation to heavy precipitation events and implementation of B2. The question was posed as a direct reaction to the flooding disaster. A2's *diagnostic framing* is implied, and clearly links the *cause* of the adaptation need to climate change and the ensuing increased risk of extreme rainfall events. The document points to the fact that in only 3 years, two extreme events were suffered in Wuppertal, in 2018 and 2021, that lie way beyond realistic capacities of the sewer system.²⁰ The most relevant *impacts* are not framed. For the *prognostic framing*, the document is a stock take of currently ongoing action, so it does not have a clear outlook on the *components* in need of future adaptation, but reports on the adaptation of components identified in B2, and a 'grey' retention basin that the CDU specifically asked about. It is stressed that currently ongoing or even significant additional expansion of the sewage network cannot handle the amounts of runoff experienced in the latest extreme events. The

¹⁷ 'Due to its special topography and complex settlement structure, Wuppertal is virtually predestined to act as a model city here. In the last two decades, well over a dozen extreme storms have occurred in our city.' A1, p.2

¹⁸ 'Adapting to climate change poses major challenges for our cities and municipalities, which we must address through climate-friendly urban development. (...) Climate and resource efficiency are becoming increasingly important in the realization of sustainable projects in the areas of construction, energy and transport infrastructure.' A1, p.2

¹⁹ 'Heat, storms and drought, but above all heavy rainfall events, hail and flooding require a clear strategy.' A1 p.2

²⁰ 'In order to build a system (theoretically) compatible with the two flood/heavy rainfall events of the past three years, the Wupper collector, which would be over eleven kilometers long after the expansion, would have to be extended many times over; not even a dimensioning the size of a subway shaft would have been sufficient to drain the water volumes.' A2, p.4

components are further implied in the *extent* of needed adaptation, which outlines that climate adaptivity must be considered in any administrative action due to its cross-cutting nature.²¹ The *urgency* in the document is somewhat unclear. The document mentions barriers to different measures and the implementation process, that convey the message that accelerated adaptation is desirable yet not feasible.²² The intended *outcome* of adaptation is a reduction of flood risk with an integrated approach to climate mitigation and adaptation measures. This is to be achieved through cross-cutting work among relevant actors, with active communication and coordination. The most *suitable strategies* are framed to be a combination of grey infrastructure, for example upgraded stormwater retention basins, and extensive urban greening and more decentralized rainwater management. Several of the adaptation measures outlined in B2 are under the management of the administration's departments for green spaces and forestry, and the department of environmental protection, which shows the nature-based approach to adaptation endorsed here (in line with the framing under B2). However, the document points several times to the limitations to adapting to extreme events as intense as the recent ones. *Synergies* with heat reduction are clearly mentioned.

A3 is a proposal for higher climate mitigation and adaptation efforts, giving particular room to mitigation action, by five parliamentary groups, that was unanimously agreed on in the city council. The *diagnostic framing* clearly pins the *cause* of the adaptation need on accelerating climate change and the connected extreme events. The most relevant *impacts* of flooding are on the health of vulnerable groups, such as seniors and children. The *prognostic framing* of the *components* in need of adaptation entails the course of the Wupper and its tributaries, as well as all future construction projects of buildings and infrastructure on public ground.²³ This means that the *extent* of adaptation is far-reaching, deciding to create mandatory requirements for all further municipal urban development with regards to climate adaptivity. Furthermore, changes to the legal framework of urban stormwater management are considered, to facilitate more infiltration on private grounds.²⁴ The document stresses the very high *urgency* of adaptation action, stating that Wuppertal 'must therefore implement all conceivable measures for more climate protection and climate impact adaptation as quickly as possible' (A3, p.4). The flooding disaster of July 2021 is called a 'wake-up call',²⁵ which must also affect the city's ambitions under climate mitigation. The intended *outcome* of adaptation is that Wuppertal becomes a proactive actor in adaptation and mitigation, and the population is protected from flooding as much as possible, especially

²¹ 'These new "products" aim to ensure that climate adaptation and climate protection are taken into account as comprehensively as possible in administrative action and that networking is continuous and binding.' A2, p.3

²² 'The measures have not yet been started for technical reasons (premature start of measures is detrimental to funding), but also for reasons of work capacity.' A2, p.2

²³ 'All planned major municipal projects are checked for their climate suitability (in particular protection against extreme weather events) and, if necessary, future-proofed with climate-friendly measures. (...) Further measures to renaturalize the Wupper and its tributaries are being implemented at an accelerated pace.' A3, p.3

²⁴ 'The administration is commissioned to present a new design for the mandatory connection and use of the rainwater drainage system by spring 2022, with the aim of using local infiltration.' A3, p.3

²⁵ 'There could hardly have been a worse wake-up call than the catastrophic storms in NRW and Rhineland-Palatinate in mid-July.' A3, p.4

through the city being transformed into a sponge city. This means that the most *suitable adaptation strategy* is installation of blue-green infrastructure, acceleration of the restoration of the river Wupper and tributaries, decentralized rainwater management, and more space for rainwater retention which can be complemented by ‘grey’ retention basins. *Synergies* with heat adaptation are hinted at yet not really explicated. Heat and flood adaptation are mentioned along each other, but with differing measures.

A4 is a consolidation concept with the aim ‘to bring together the topics of ‘preparedness for heavy rainfall’, ‘water-sensitive urban development’ and ‘climate adaptation’ and to make the instruments and products developed in stormwater risk management usable and to anchor them permanently in administrative action” (A4, p.7). The *diagnostic framing* frames climate change and the increase in extremes to be the *cause* of the adaptation issue, complicated by Wuppertal’s topography. The most relevant *impacts* are not clearly mentioned, solely property damage is referred to when the initial problem is outlined. In the *prognostic framing* of A4, the *components* in need of adaptation fall under a variety of different planning processes, as the *extent* of needed adaptation is very broad. Action is framed to be needed in ‘urban spatial planning, traffic infrastructure, water management and urban drainage, planning of public buildings” (A4, p.7), among others. The *urgency* of adaptation appears to be high based on the range of proposed action, yet the wording in the document speaks more of a gradual continuous adaptation process, which does not imply high time pressure. However, the document frames especially heavy rainfall events and subsequent flooding to be an issue for Wuppertal due to its topography.²⁶ The intended *outcome* of the adaptation process is a climate resilient and even more water sensitive city. The most *suitable strategy* of adaptation is anchoring climate adaptation as a principal consideration in all administrative action, and all construction of new projects, as well as retrofitting on existing infrastructure and buildings. Water-sensitive urban design is mentioned several times throughout the document as the concept to guide urban development.²⁷ Multifunctional spaces are a key instrument to achieve the objectives, also because they are seen as highly *synergetic* with heat and drought adaptation.

A5 is the final report of the ad-hoc taskforce on flooding and climate resilience, that was called to life by the mayor in response to the July 2021 disaster to analyze the events of the disaster and explore suitable solutions to address flood risk. The *diagnostic framing* of the *cause* of the adaptation issue are the ‘enormous challenges arising from climate change” (A5, p.3), well as added sensitivity to the climate hazard by the high degree of sealed surfaces in cities.²⁸ *Impacts* are not elaborated in detail, however, the special risk of many companies that have their grounds by the river is mentioned. Furthermore, the WSW, operator of the public transportation and energy infrastructure, suffered high damages during the

²⁶ ‘The frequency and intensity of heat waves and storms, especially extreme weather events with heavy rainfall, which have already flooded large parts of the city center in the past, are increasing.’ A4, p.2

²⁷ ‘Consideration of the topics of heavy rainfall precaution and water-sensitive urban development in the updating of urban development concepts’ A4, p.11

²⁸ ‘The heavy sealing of cities in conjunction with heavy rainfall events can lead to the deterioration of groundwater recharge and cause the capacity of drainage systems to be surpassed, and harbors risks that should be minimized as far as possible.” A5, p.6

disaster.²⁹ The *prognostic framing* of the *components* in need of adaptation includes a wide variety of elements, such as the river and the tributary creeks' course, the upstream Wupper reservoir, stormwater management in streets and parking spaces, as well as 41 fluvial flood risk hotspots in the city. The hotspots of main flood risk – due to the design of nearby streams, topographical attributes etc. – were captured for the first time in 2017 in the 'Hochwasserschutz-Prioritätenkonzept' (HPK; Flood protection priority plan) and amended and adjusted since then (Hydrotec Ingenieurgesellschaft, 2019). The *extent* of adaptation is very broad, as the components show, and basically encompasses all adaptation strategies from protection of individual assets to an overall change in stormwater management throughout the city. The document further foresees that a runoff model be used for new construction projects. The *urgency* of adaptation is high, as the authoring taskforce itself was called to life specifically to accelerate adaptation to flooding. The adaptation *outcome* is hinted at by mentioning the initiated working groups for a water-sensitive and sponge city. The most *suitable approaches* are framed as a mixture of grey and green measures. In several of the 41 hotspots, special water retention basins are to be constructed on public ground, and management of the Wupper reservoir upstream is supposed to be adjusted to be more prepared for both drought and flood events. For adaptation on private ground, a hazard map for extreme rainfall events supported by communication initiatives is supposed to empower landowners to contribute to the city's climate adaptation efforts on their property. Surface sealing is to be reduced by installation of greenery and permeable pavement, e.g. permeable street asphalt. These principles are to be considered in any construction activity on private and public ground. However, limitations to this approach are recognized, as the city's steep slopes and rocky base rock do not permit full infiltration in large shares of the city.³⁰ Nonetheless, the city's goal is to become water sensitive and build its sponge function, in which the growing regard for blue-green infrastructure is stressed,³¹ as well as multifunctional spaces and underground water retention space. A combination of "technical" and "green" solutions is supposed to be applied to the management of flood risk from the river.³² The *synergy* of street greening with benefits for the urban summer climate is mentioned, as well as drought mitigation through augmented groundwater recharge.

A6 is a proposal for more unsealed surfaces by the parliamentary group of the Greens that was unanimously agreed on in the city council. The *diagnostic framing* identifies the *cause* of the adaptation issue to be progressive sealing of surfaces on private property that causes surface runoff that must be removed. This has the *impact*, that expensive stormwater removal measures have to be taken. The *prognostic*

²⁹ 'Flood damage in the WSW Group amounted to a total of 3.4 million euros - albeit with a focus on the suspension railway scaffolding and railroad stations.' A5, p.5

³⁰ 'Due to its topography and the subsoil conditions, on-site infiltration is not possible everywhere in the urban area.' A5, p.6

³¹ 'These foundations for green and blue infrastructure create a good basis for aligning urban development with issues of climate resilience, which is also becoming increasingly important in the context of funding frameworks.' A5, p.6f

³² 'On the basis of a comprehensive baseline study, proposals were drawn up to improve technical flood protection and 'green' flood protection (...).' A5, p.5

framing thus identifies sealed private gardens as *components* to adapt. The *extent* of adaptation is limited, as the city grants financial support to house owners, that actively request to unseal their gardens. Adaptation to heavy rainfall is mentioned after the need for adaptation to heat as a reasoning for the proposal, which implies a medium *urgency*. The intended adaptation *outcome* is a high degree of green gardens in Wuppertal that leads to both a lower risk of flooding and overheating, as well as benefits for biodiversity. The most suitable *adaptation option* in this document is thus framed as decentralized infiltration of rainwater, which is to be contributed to by unsealing and greening of urban gardens. The strong *synergies* of this approach with heat adaptation are outlined.