Double Degree Master Program:
`Water and Coastal Management` & `Environmental and Infrastructure Planning`

Master Thesis

Dealing with Coastal & Fluvial Floodings in Urban Areas

A case study in Bremen and Hamburg of operationalising and implementing `Flood-Risk-Management-Strategies` based on their coastal location

Sources presented in the reference list

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Executive Summary:

Adequate adaptation to climate change is crucial for those consequences that can no longer be prevented, such as the increasing risk of flooding in the future. As resistance towards flooding is seen as inadequate in dealing with the growing threat, a transition from the traditional flood approach towards FRM is thematizes in the literature. In addition to the probability, the possible consequences are also taken into account and are related to the term 'flood-resilience'. This is defined in more detail by the three key dimension (robustness, adaptability, and transformability).

Thereby, this thesis focuses on case study research within the research areas of Bremen and Hamburg that are affected by increasing coastal and fluvial floodings and characterized by the FRM-agenda in Germany since 2009. Here, different implemented design-strategies in dealing with possible flooding events are identified and described in detail.

The results indicate the 5 different design-strategies \`No response\`, \`Advance\`, \`Protection\`, Accommodation\` and \`Ecosystem-based adaption\`, that are linked to different FRM-strategies depending on the context and are characterized by several barriers. These relates mainly to effects of the limited transferability of adapted measures and are characterized by aspects of path-dependency in the larger setting. Subsequently, the results of the case study will be more closely related to the key dimensions of flood resilience in a broader view and aspects between theory and practice are discussed. The thesis concludes with six final recommendation and a future outlook.

Keywords: Bremen & Hamburg, Urban environment, Coastal and Fluvial Floodings, Flood-Risk-Management-strategies, Flood-Resilience, FRM-Agenda

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List of Abbreviations

BIS: `Behörde für Inneres und Sport` - `Municipal Office for the Interior and for Sport`

BremWG: `Bremisches Wassergesetz` - `Bremen Water Act`

BRPH: `Länderübergreifender Raumordnungsplan für den Hochwasserschutz` - `Federal state-wide spatial development plan for flood protection`

BUE: `Behörde für Umwelt und Energie` (Hamburg) - `Authority for Environment and Energy`

BUKEA: `Behörde für Umwelt, Klima, Energie und Agrarwirtschaft` (Hamburg) - `Department for Environment, Climate, Energy and Agriculture`

BWs: `Bemessungswasserstand` - `Design-Water-Level`

FGG Weser: `Flussgebietsgemeinschaft Weser` - `River Basin Community Weser`

FGG Elbe: `Flussgebietsgemeinschaft Elbe` - `River Basin Community Elbe`

FNP: `Flächennutzungsplan` - Land use plan``

FRM: `Hochwasserrisikomanagement` - `Flood Risk Management`

FRMD: `EG-Hochwasserrisikomanagement-Richtlinie` - `EC Flood Risk Management Directive`

FRMSs: `Flood Risk Management Strategies`

GAK-act: `Gesetz über die Gemeinschaftsaufgabe "Verbesserung der Agrarstruktur und des Küstenschutzes"` - `Law on the Joint Task "Improvement of Agricultural Structure and Coastal Protection“

GPK 1: `Generalplan Küstenschutz Niedersachsen/Bremen – Festland` - `General Plan Coastal Protection Lower Saxony/Bremen – Mainland`

GPK 3: `Generalplan Küstenschutz Niedersachsen/Bremen – Schutzdeiche` - `General Plan for Coastal Protection in Lower Saxony/Bremen - Protective dikes`

HWaG: `Hamburgisches Wassergesetz` - `Hamburg Water Act`

LaPro: `Landschaftsprogramm` - `Landscape Program`

LAWA: `Bund/Länder-Arbeitsgemeinschaft Wasser` - `German Working Group of the Federal States on Water Issues`

LSBG: `Landesbetrieb Straßen, Brücken und Gewässer` - `Agency for Roads, Bridges an Water`

NLWKN: `Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz` - `Lower Saxony Water Management, Coastal Defense and Nature Conservation Agency`

SKUMS: `Senatorin für Klimaschutz, Umwelt, Mobilität, Stadtentwicklung und Wohnungsbau` (Bremen) - `The Senator for Climate Protection, Environment, Mobility, Urban Development and Housing`

SUBV: `Senator für Bau, Umwelt und Verkehr` (Bremen) - `Senator for Construction, Environment and Transport`

WHG: `Wasserhaushaltsgesetz (Deutschland)` - `Water Resources Act (Germany)`

Chapter 1 - Introduction

1.1. Background

Climate change, such as the secular rise in sea level, the increasing unpredictability of frequent storm surges and inland floodings and heavier precipitation in highly sealed area, increases the need for adapted and improved flood protection in urban areas. At the same time, many of the world's largest cities are located near the coast, and these cities, home to a lot of people, businesses, and ecosystems, are particularly at risk. Thereby, extreme weather events have always existed, but climate change is increasing their severity, frequency, duration, and spatial extent. Last year's flood disaster in western Germany and this year's storm surges in northern Germany have once again demonstrated the enormous forces that floods exert. Due to several severe floods in the past (especially in 2002 and 2013), the traditional flood approach in Germany was no longer considered reasonable in the long run and a change in approach and political orientation towards a more Flood-Risk-Management (FRM) approach is formulated step by step, based on European requirements from 2007. In this context, the aspect of FRM is closely related to the aspect of \`flood resilience\`, which has been described in detail in the scientific literature over the last decades with different ideas and concepts. Thereby, the focus is not only on the traditional flood protection anymore, which is described with the narrative of \`fight against the water\`, but also tries to take the possible consequences of floodings into account and reduce them with a more adaptive approach and the narrative \`living with the water\`. The current debate is about finding long-term solutions that are both robust and flexible, and that can be integrated into the urban landscape that is characterized by lock-ins and path-dependency, due to developments in the past in relation to resistance to change.

1.2. Societal and Scientific Relevance

The increasing use of the term \`flood resilience\` and the needed change in dealing with increasing flooding patterns has been described in different literature over the last decades with various ideas and concepts. This paper tries to build up on this conceptual framework by focusing on the actual design implementation of flood protection in the urban environment of two selected cities with a coastal relevance. In other words, this thesis tries to investigate in which ways these concepts and ideas described in the literature are applied in an urban environment, that is highly characterized by limited space and a specific changing policy framework. The scientific relevance of this work ties into other examples such as Restemeyer (2015) and Karasch (2021) by directing the discussion of the concept of resilience from exploring the meaning of the concept towards a more acting and shaping \`resilience\` in practice. In doing so, this thesis will help uncover possible barriers and limitations in implementing design-strategies in these urban environments and provide a focused overview of the extent to which concepts and strategies described in the literature are being actively implemented.

The societal relevance is basically in informing practice with additional insights of how resilience is implemented and should be implemented. In the city of Bremen about 86% of the city-area and in Hamburg more than 325,000 people, numerous workplaces and store goods and commodities are potentially threatened by floods due to the interaction in the river system, growing urbanization and increasing climate change. Therefore, it is necessary to address the issue of increasing uncertainties, especially in the case of increasing flooding events and rising sea levels, in practice, by also taking the current measurements into account, compare them with the theoretical context and indicate possible barriers.

1.3. Research Objectives and Research Questions

The aim of this thesis is to compare scientific described concepts of `creating resilience` and the current implementation of design-strategies in the field. Hence, this thesis is focusing especially on the three key-dimensions of flood resilience `Robustness`, `Adaptability` and `Transformability` and examines the extent to which these can be achieved and supported through the implementation of certain design-strategies in the field. Thereby, the two research areas of Bremen and Hamburg are investigated, that have been defined by traditional flood control over a longer period in the past and are currently part of the FRM-agenda in Germany. Similar to Restemeyer (2015), the goal is to take the general resilience discussion a step further by not only focusing on the definition of resilience as a theoretical concept, but also by putting the concept into practice and seeing how cities are `doing` flood resilience in their current situation and what we can learn from that.

Based on these objectives the following research questions (table 1), consisting of one main research question, and supported by several secondary research question, are crucial along this thesis and will be answered in a targeted and chronologic way along this thesis.

Table 1: Overview of the Research Questions (created by the author)

Primary Research Question	
To what extent is the theoretically described aspect of building `flood resilience` being actively applied in the implementation of design-strategies within the FRM-Agenda in the urban areas of Bremen and Hamburg, to successfully respond to the increasing vulnerability to potential flooding events?	
Secondary Research Questions	**Research Focus**
2.1. Why is there a need for a transition in dealing with floodings and what defines aspects of `FRM-Strategies` and becoming `flood resilience` in the scientific literature?	-> Chapter 2
2.2. In which way are the cities of Bremen and Hamburg affected by the increasing uncertainty of possible flooding events? What specific challenges arise due to their urban environment?	-> Chapter 3
2.3. How are both cities dealing with the increasing pattern of coastal and fluvial flooding within their urban environment? To what extent are their projects and infrastructures framed in the broader framework of the FRM-Agenda in Germany and what characterize the new agenda in comparison with older strategies?	-> Chapter 4
2.4. Can we indicate barriers and problems between the theoretical ideas/concepts/key-dimensions described in literature and the design-oriented implementation in Bremen and Hamburg?	-> Chapter 4 and 5

2.5. Can we identify specific differences between the two research areas (Bremen and Hamburg) and between the selected cases in the way they try to cope with coastal and fluvial floodings?	-> Chapter 5
2.6. To what extent can both cities help each other to implement specific steps/projects for more flood-resilience design-approaches? Are their specific recommendation for similar areas that are useful to consider?	-> Chapter 5 and 6

1.4. Reading Guide

This thesis consists in the following on five sequential sub-chapters (figure 1).

Firstly, the focus is on the existing literature to create a conceptual framework. By that, chapter 2 characterise the key-dimensions of `Flood Resilience` and different `FRM-Strategies` discussed in the literature, based on the considered transition towards an FRM-approach. In addition, various design strategies associated with the coastal location are presented, which are examined in contrast in the following chapters.

The third chapter introduced the selected research areas of Bremen and Hamburg and the methodological framework. Thereby, a case study with eight cases within the two research areas is dominating and supported by documents research on directives and regulations in the German context connected with the changed FRM-agenda. The methods consist mainly of (planning) document analysis, that are supported by websites, articles, and project presentations in the public. Building up on this, several interviews with experts and responsible persons were conducted to get a more detailed view in the field of practice.

Chapter 4 is concentrating on the result. Besides a detailed introduction of different regulations and directives connected to the FRM-agenda, the results of the case study are presented. The cases are afterwards compared with each other in chapter 5, before being discussed together with the literature and different barriers that arise during the analysis on a larger scale. Based on this, the discussion ends by classifying the results into a broader framework by defining the key dimensions of resilience in comparison with indicated barriers.

Finally, chapter 6 is concluding with final recommendations, a short reflection, and a future outlook, that is concentrating on additional research to continue the thematic perspective used in this thesis.

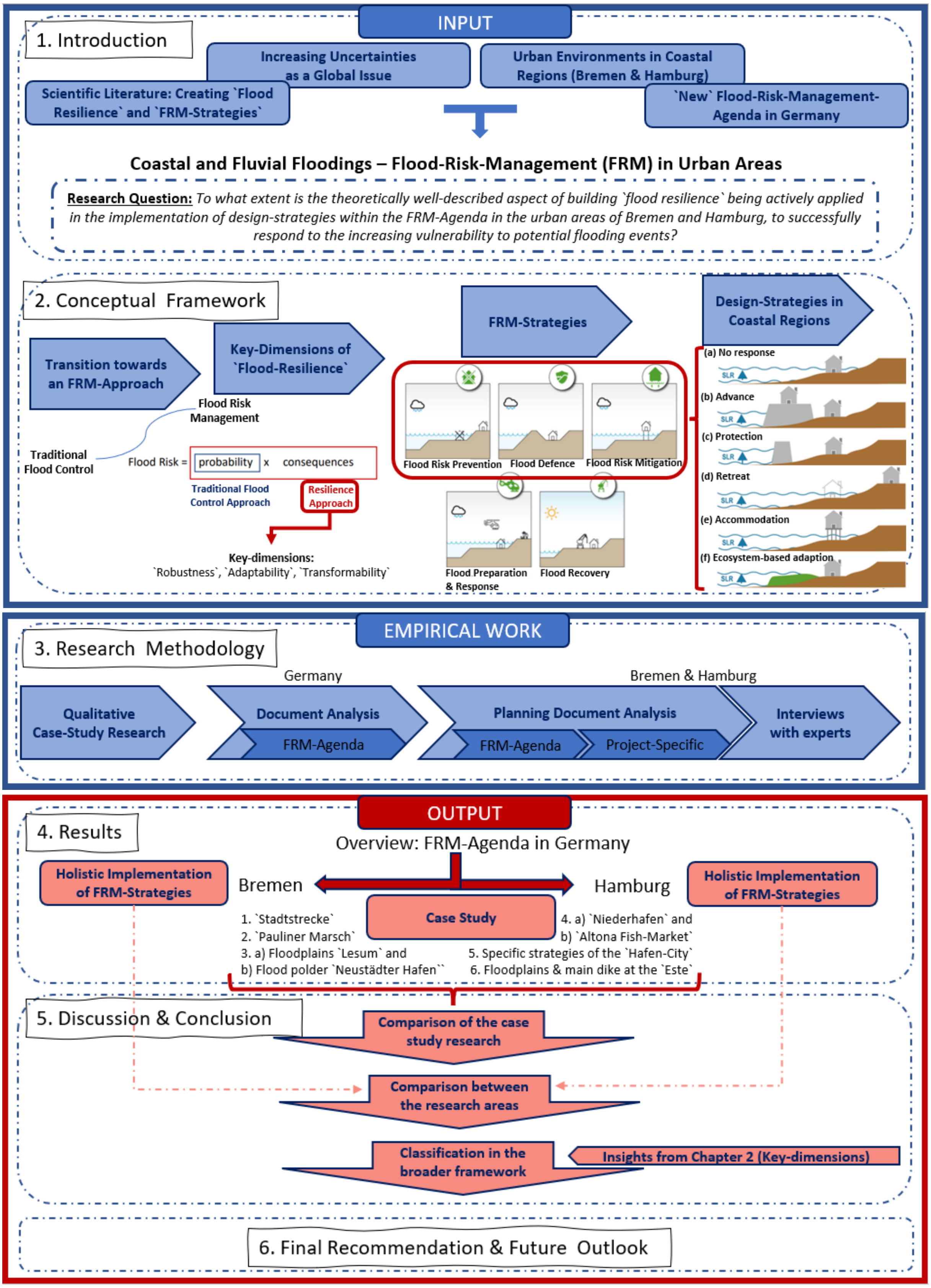


Figure 1: Outline of the thesis (created by the author)

Chapter 2 – Conceptual Framework

This chapter is introducing the conceptual framework of this thesis to create a scientific basis. In the process, various concepts and strategies discussed in the literature are addressed in order to examine and discuss them in more detail in comparison with the implementation in practice at a later discussion. In a first step, the different concepts that are connected to each other are described in detail in sub-chapter 2.1 to 2.4. Based on this, sub-chapter 2.5 defines the conceptual scope for this thesis, that is additionally visually summarized in figure 9.

2.1. Uncertainties as an Increasing Pattern – Raising Numbers of Flood Events

Globally, the number of extreme events has increased over the last century and the consequences of climate change such as sea level rise, longer periods of precipitation, more intense rainfall or dry seasons will further increase in the future (Scott, 2013; White, 2010). In this context, extreme weather events have always existed, but climate change is increasing their severity, frequency, duration, and spatial extent (Duit & Galaz, 2008, Grothmann et al., 2021). The longer the time horizon is considered, the bigger is the uncertainty (Roovers & van Buuren, 2016). In the case of flooding, the trends of expected sea-level rise, changing precipitation, and continued urbanization in coastal regions are particularly significant and characterized as persistent problems (Schoeman et al., 2014). Thereby, trends like sea level rise, more intense rainfall, and an increase in storm surges are also determined as `Known unknowns` that are rather certain events where no exact numbers exist (Termeer and van den Brink, 2013). In current climate projections, further sea-level rise is considered relatively certain, with unchanged greenhouse gas emissions of up to 110 cm globally in 2100 (SKUMS, 2020a). Thereby, water has already risen by 15 cm in the past century and is currently rising twice as fast (SKUMS, 2020a).

In coastal zones and delta areas, water challenges often occur in the form of flooding. But the type of flooding that urban environment needs to deal with can differ. Thereby, different flood types ask for different precautions and measures, as factors such as geography, meteorology, and hydrology, influence the type of floods that occur (Sörensen et al., 2016, Depietri et al., 2012). The main types of floods that occur in coastal urban areas are `coastal flooding`, `fluvial flooding` and `pluvial flooding` (figure 2; Vojinovic, 2015). Another type of flood that can occur is due to groundwater exceedance that will not be considered in more detail in the further course.

Coastal flooding is caused by heavy storms or due to the failure of coastal protections. They are resulting from extreme tidal conditions caused by extreme weather events, such as a storm surge at sea where water overflows low-lying land (Rosenzweig et al., 2018; Vojinovic, 2015). Cities in coastal zones or delta areas are vulnerable to coastal flooding, as these cities are low lying and therefore easily affected by these floods. A characteristic of coastal flooding is that the water level rises and drops with the tide (Schuchardt et al. 2007). The rising sea level will increase the vulnerability of these areas even more and might even lead to permanently flooded areas in coastal regions.

Fluvial flooding is the result of overtopping or breaching of the flood defence of rivers, caused by excessive rainfall or heavy snowmelt, and ice jams where rivers exceed their capacity and overflow (Rosenzweig et al., 2018; Vojinovic, 2015). For holistic flood management the upstream and downstream of the river needs to be included in the process, which makes it complex (Sörensen et al., 2016). In contrast to the other two types, pluvial flooding often occurs locally. After a short period of intense rainfall this type of flood can occur (Vojinovic, 2015) and is the result of limited drainage capacity or a slow velocity of the infiltration into the ground (Rosenzweig et al., 2018; Vojinovic, 2015).

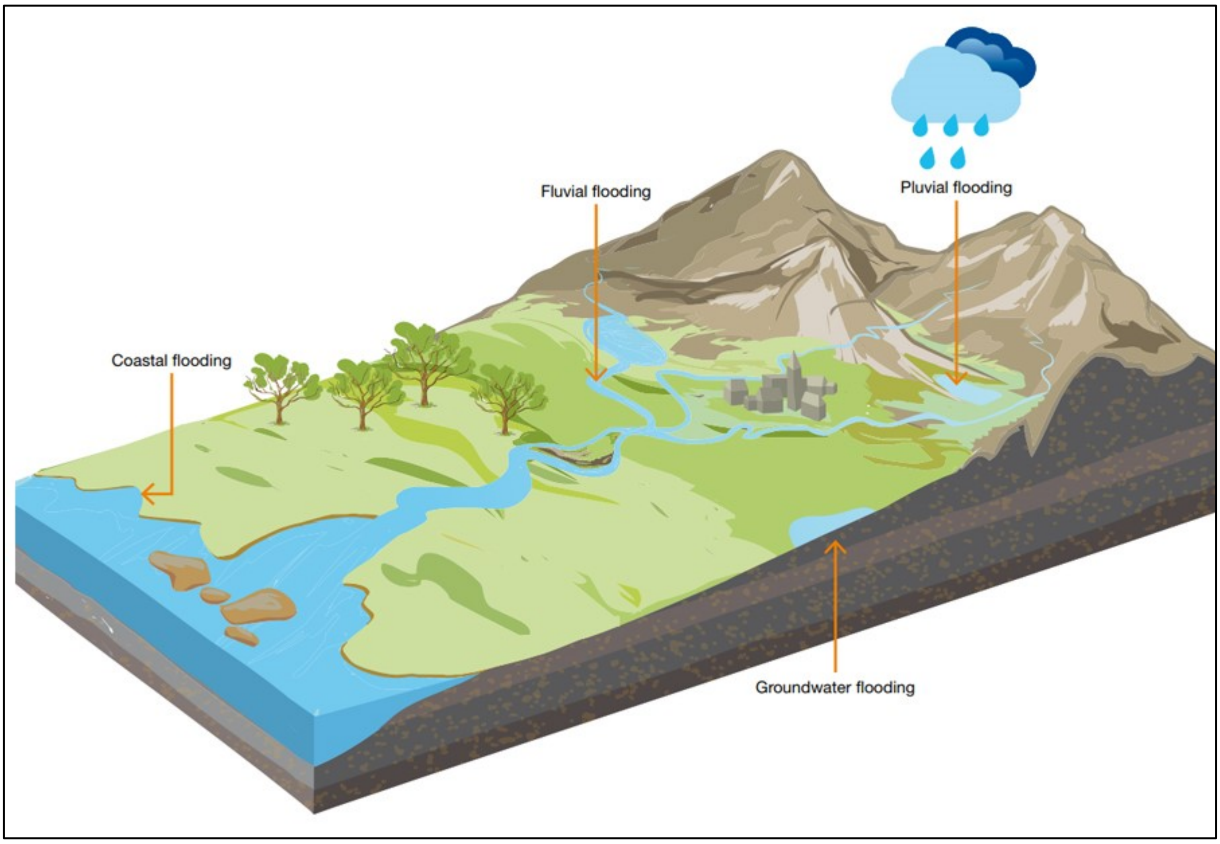


Figure 2: Different types of floodings (Wavin UK, n.d.)

2.2. From the `Traditional-Flood-Control` towards `Flood-Risk-Management`

2.2.1. Traditional-Technical-Paradigm

The `traditional-technical-paradigm` has dominated the flood control in the past and is characterized by certain elements in the literature, summarized under the term `fighting the water` (Schoeman et al., 2014). The resistance approach focuses on hard defence measures, like dikes, dams, and storm surge barriers (Meijerink & Dicke, 2008) to reduce the local flood probability and protect the inland from disturbance and damage (Burrell et al., 2007). Structural measures and especially its visibility result in a common sense of safety (Kundzewicz & Kaczmarek, 2000; Vis et al., 2001) behind the measures, and promoted the economic position of the areas enormously, due to urbanization and economic development in flood prone places.

This sense of safety is risky because structural measures can fail in function and aspects of `path dependency` and the `levee effect` comes into account (figure 3). Both concepts dealing with the idea, that the interaction of continued urban growth and a lack of conscientious planning increase the likelihood and severity of urban vulnerability to flooding in the urban environment (Zevenbergen et al., 2008). It is undisputed that dikes in the river region or at the coast need to be strengthened where they are too weak to meet the new standards. But the dikes are being built higher and higher in response to the increasing river discharges do not break the vicious circle of the `levee effect`. As a result, the areas becoming increasingly vulnerable. Eventually, a possible flood will be accompanied by ever higher water levels, with ever greater consequences. (CRa, 2018)

Moreover, the existing infrastructure behind the dike line orientate itself at this trend, whereby critical infrastructure is being built in certain areas of risk. Because infrastructure is also characterized by very long lifetimes, spontaneous and flexible changes are hardly possible due to the path-dependency, because the decision-making ability is limited due to decisions and developments from the past. (Seto et al., 2016)

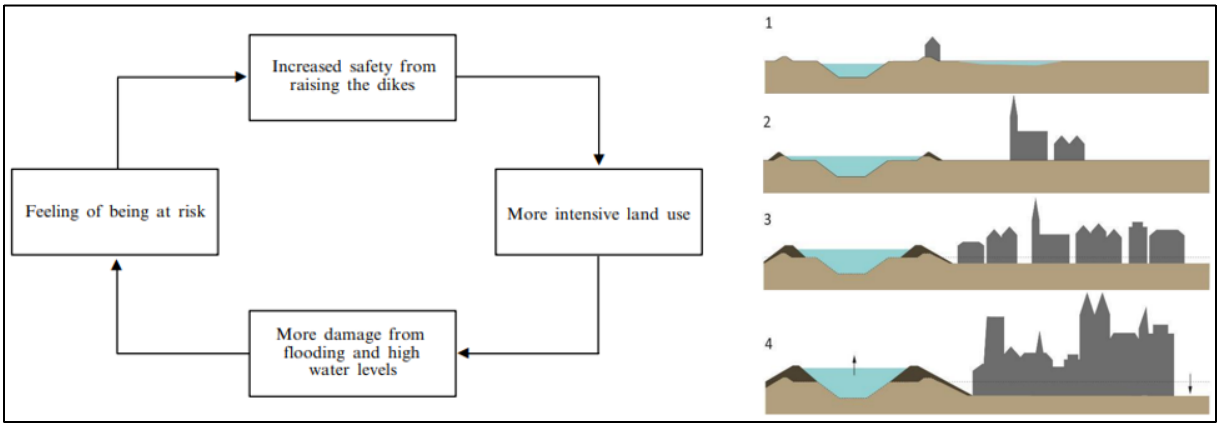


Figure 3: Left side: `Control Paradox` (Wiering, 2006; based on Remmelzwaal and Vroon, 2000); Right side: `Levee effect` (CRa, 2018)

2.2.2. Transition Theory

In recent decades, a consensus has emerged in literature that the exclusive application of traditional flood control measures is an inadequate response to increasing risks and is therefore no longer considered sustainable in the long term due to the increasing patterns of uncertainty as persistent problems (Hooijer et al., 2004; Schoeman, 2014; Vis et al., 2003). Furthermore, the `traditional-technical-paradigm` is criticized by a lack of stakeholder participation and cross-sectoral approaches, which are seen as inevitable in the current debate to achieve a shift towards a more adaptive and integrated coastal policy in a changed governance-structure (Schoeman et al., 2014). The necessary changes go hand in hand with a necessary transition theory that is discussed in this sub-chapter, to create alternatives for the introduced `levee effect` and the further development of `past-dependency`-issues with increasing consequences.

Transition is about change, about transformation into a new state and is explored as transition management in the scientific literature. The transition literature is included here to provide an overview of the transition from the `traditional flood approach` towards `Flood Risk Management` (figure 4) that is also described with the narratives from "keeping the water out" to "living with the water` in different literature (Schoeman et al., 2014). Transitions are transformational processes where the structure or institutions of a society change (Rotmans et al, 2001; Jerneck & Olsson, 2008). Due to this, transition research seeks to "integrate insights from fields such as complexity science, innovation research, sociology, and environmental science to better understand large-scale systemic changes in social systems" (Loorbach et al., 2015, p.49). Based on introduced challenges, water-related problems becoming increasingly complex also in connection with their social functions. Transition theory is partially rooted in complex adaptive systems (CAS) theory, which in turn is embedded in complexity theory. Complexity theory indicates the change at different steps that are not linear and views equilibria as multiple, temporary, and moving parts (Duit & Galaz, 2008). By considering transitions from the CAS perspective, transitions are system transformations between the two equilibria with a period of irreversible change (Rotmans, 1994). This change can be rapid and sharp, but the transition can also be slow and steady (Duit & Galaz, 2008). Along this process the political dimension plays a decisive role (Huitema et al. 2011).

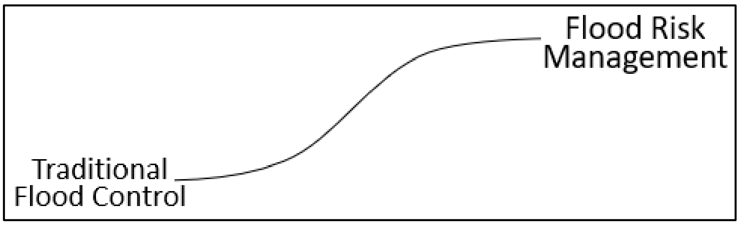


Figure 4: Simplified illustration of the required transition towards FRM (created by the author)

2.2.3. Towards `Flood-Risk-Management`

As introduced in the section before, the combination of the traditional flood control in combination with the `levee effect` and the increasing demands on flood protection due to climate change have increased the potential effects of flood events. This increasing risk relates not only to the increasing probability of flooding but also to the potential consequences of flooding. This issue of increasing consequences is not addressed by the traditional flood control approach in the sense that the need of a transition in water management is inevitable towards FRM (figure 4 and 5). As a result, more holistic approaches to risk management are being introduced that focus on the consequences of flood hazards. These newer approaches include a shift from purely sectoral to integrated thinking, or, in other words, from purely water management to a more comprehensive approach of integrating urban planning as a means of keeping vulnerable land uses out of flood-prone areas (Woltjer & Al, 2007; Restemeyer et al., 2015). By that, this trend is nearly connected with the term `flood resilience` in different literature and is introduced in the next sub-chapter.

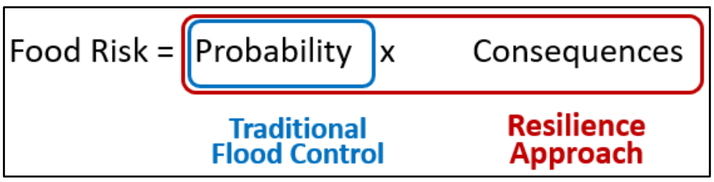


Figure 5: Simplified illustration of the required FRM-Approach (created by the author)

2.3. Flood Resilience

The concept of resilience is considered as a promising framework for incorporating risk and uncertainty into planning and has become increasingly important in the scientific literature in recent decades (Davoudi, 2012; Scott, 2013; White, 2010). Resilience seeks to sustain function and services across a wide range of future conditions by adapting and transforming to change while managing failures in a systematic way to limit damage and costs during extreme events, and in the urban environment goes closely with more adaptive and long-term infrastructure planning (Folke et al., 2010). In this context, the concept is often brought in the context of climate resilience and can be seen as very complex and multi-layered, referring to overarching aspects such as climate resilience in specific environments (Tyler & Moench, 2012). Based on the research question this thesis is concentrating on the aspect of `flood resilience` in the following. Flood resilience is gaining recognition worldwide and is broad in scope, focusing on adaptation next to water security (Forrest et al., 2020).

2.3.1. The Term `Resilience` - A Changed Meaning over Time

In this context, the term `resilience` has been used differently in literatures over time, evolving from a clear physical meaning (engineering resilience) to multi-equilibrium (ecological resilience) and evolutionary resilience (figure 6; Davoudi, 2012).

The `engineering` understanding focused more on objects or materials view, with the ability of objectives to spring back after bent or stretched (mechanics). It is dominated by a single equilibrium, in other words the `resistance of a material to shocks`. Compared to this the `ecological` understanding is dominated by multiple equilibria and defined by ability of ecosystems to absorb changes and continue (ecology). What these two types of resilience have in common is that they use the idea of equilibria, of bouncing back to `normal` circumstances (figure 6). This definition stuck when the concept it used in social science. In this sense, resilience is used to `preserve what we have and recover to where we were` (Davoudi, 2012, p.302).

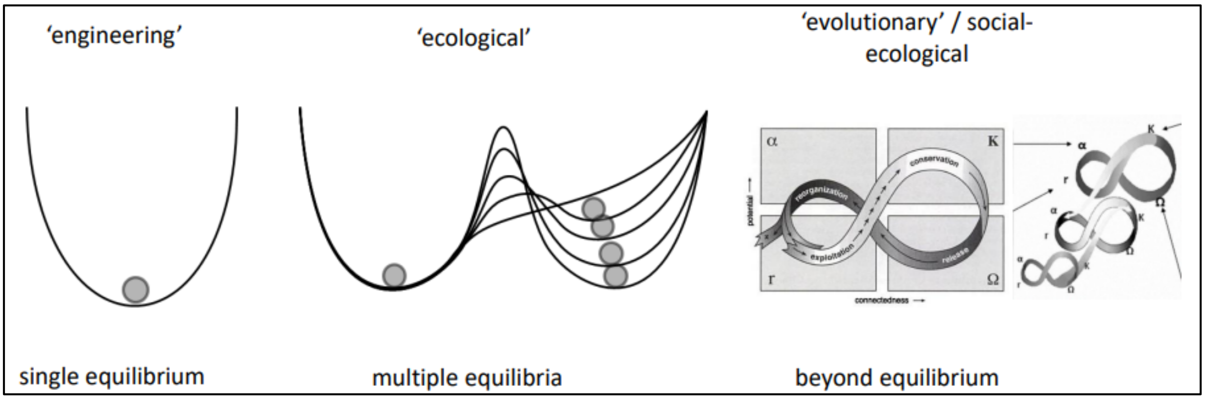


Figure 6: Three different understandings of resilience (Davoudi, 2012)

Nevertheless, the `engineering` and `ecological` resilience are seen too simplistic for our current complex society (Davoudi, 2012). Both understandings implies that there is an optimal state whether this is about bouncing back to or bouncing towards a new one. However, in a complex social-ecological system that consider the system for example as conceived `complex, non-linear, and self-organising, permeated by uncertainty and discontinuities` (Berkes & Folke, 1998, p. 12; Davoudi, 2012) an optimal state does not exist (Liao, 2012). Therefore, evolutionary resilience (or social-ecological resilience) includes the idea of change, adaptation, or transformation (Davoudi et al, 2013), also understand as the ability to absorb disturbance, of self-organisation and to learn and adapt and created an inter-disciplinary field of research. Here, the social science with the ability of groups or communities to cope with and adapt to stress is considered.

Applying this idea to the urban environment, resilience to flooding requires a city to take the necessary precautions to prevent flooding, but also to adapt land use so that it suffers less in the event of a flood disaster. Given the need for change in flood risk management, resilience can therefore be seen as a promising approach to dealing with the unpredictability of climate change and future flood risk in cities. In this context, resilience implies a diversification of FRM measures and an expansion of responsibilities through new governance arrangements between the state, the market, and civil society as a joint effort of water management, spatial planning, and disaster management. In order to look at these diversifications in more detail, the next aspect takes a look at specific key-dimensions of the term `resilience` (Restemeyer et al., 2015).

2.3.2. Key-Dimensions of `Flood Resilience`

The term `flood resilience` is characterized in the current literature by three key-dimensions (Restemeyer et al., 2015). Besides the aspect of `Robustness` which already took an important role in the traditional-flood-approach, the terms of `Adaptability` and `Transformability` are increasingly considered as important.

Robustness

`Robustness` refers to the ability to resist, absorb, or withstand shocks, in other words, to reduce the likelihood of a potential flood (Restemeyer et al., 2015). This approach has been the main idea of the traditional flood approach (chapter 2.2.1) and focuses on engineering and spatial measures. Consequently, it requires strong water management and expert knowledge in engineering and planning and requires social acceptance and strong political and financial support for large structures/infrastructures. In the current resilience strategy, it is considered as a key-dimension alongside adaptability and transformability (Restemeyer et al., 2015). Thus, robustness is a part of resilience, but focusing mainly or exclusively on robustness may reduce overall resilience with aspects of the `levee effect` or `path-dependency` (chapter 2.2.2). Citizens in cities with strong flood defence strategies are generally less aware of flood risks, and policies may provide a false sense of security and citizens are less prepared and may have difficulty adapting to a new situation (CRa, 2018; Liao, 2012). Nevertheless, it remains a central key-dimension of the resilience approach.

Adaptability

`Adaptability` is the ability to make adjustments in the system that reduce the potential consequences and damages of floods (Restemeyer et al., 2015, Pelling et al, 2011). Key aspects are, for example, preventing vulnerable land use in flood-prone areas, flood-proofing buildings and infrastructure, warning and evacuation systems, or flood insurance/reconstruction funds (Hegger et al., 2014). In contrast to robustness, it requires not solely changes in physical areas but also changes in social areas such as closer cooperation between water management, spatial planning, and disaster management to create shared legal responsibility (public and private). The necessary social acceptance and political support for adaptation and a risk-based approach go together with adaptability. Each flooding event should be seen as an opportunity to learn and make adjustments to better prepare for the next flood (Liao, 2012).

Transformability

`Transformability` is the transition to a new system when environmental, economic, or social structures make the existing system unsustainable to promote social change. In the case of flood resilience, the shift from `fighting water` to `living with water` is an often-used narrative (Restemeyer et al., 2015, Schoeman et al., 2014). It refers to a period of chaos and uncertainty in which a system shifts toward a new state. Here, aspects of risk communication and awareness building among private actors and public actors are especially needed such as public campaigns or consensus building. Transformability requires creativity and openness to new knowledge, new interdisciplinary networks and learning organizations and actors of change/leadership and is therefore closely related to aspects of transition (chapter 2.2.2). In this context, the literature also distinguishes in the concept of transformability between transition with incremental change and transformation described by radical change (Pelling et al., 2011). In the following, the transformability framework is considered as transition to clarify that it calls for a change over a period, thus acknowledging that people, their behaviours, and their values generally do not change radically.

2.4. Flood-Risk-Management-Strategies

2.4.1. Five types of Flood-Risk-Management-Strategies

Floods are highly unpredictable, due to the interaction between the physical and the human system, therefore preparing for such disturbances is difficult (Raadgever et al., 2018). Thereby, the use of different strategies gives the opportunity to minimize the probability of flooding as well as the consequences that possible floodings will have (Raadgever et al., 2018). These 'Flood Risk Management Strategies' (FRMSs) are used to deal with the overall flood risk and can be distinguished from each other by the different focus they have on flood risk (Hegger et al., 2013).

In general, a distinction is made between the probability of flooding, the consequences of flooding and the recovery after floods (Hegger et al., 2014, Matczak et al., 2015). Within these phases there are five different FRMSs that can be distinguished from each other, that are 'defense', 'prevention', 'mitigation', 'preparation' and 'recovery' (figure 7; Raadgever et al., 2018; Hegger et al., 2013;

Matczak et al., 2015). Table 2 gives an overview of the FRMSs and the possible measures representing these strategies. It is argued that diversification, coordination, and alignment of these FRMSs will make urban areas more `flood resilient` (Driessen et al., 2016; Hegger et al., 2013).

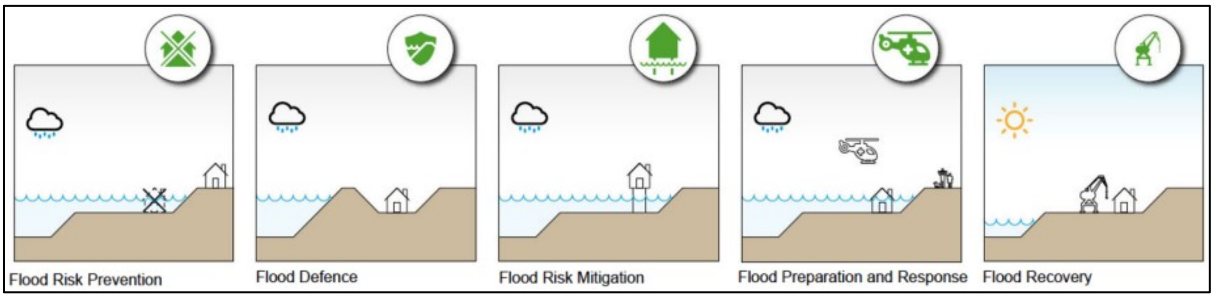


Figure 7: Five types of FRM-strategies (Driessen et al., 2016)

Each of the FRMSs has its own focus and approach to reducing flood risk (Raadgever et al., 2018; Hegger et al., 2014) and are important at different stages of the flooding. `Prevention`, `Defence` and `Risk Mitigation` are strategies that are concentrating on the implementation before the possible flooding event. `Flood risk prevention' aims to reduce the consequences of a flooding by minimizing the exposure to potential flooding through prohibiting or discouraging development in flood prone areas. The use of `Flood defence`-measures aims to reduce the possibility of flooding through infrastructural flood defence and is orientation on aspects of the discussed traditional flood approach. The flood risk mitigation strategy on the other hand, tries to reduce the consequences of flooding by taking different measures within the area at risk. Differently to these strategies, the `Preparation and Response`-strategy is not only implemented before the possible flooding, but also active during a flood event. Specific aspects are for example disaster management or evacuations plans. (Raadgever et al., 2018; Hegger et al., 2014)

Lastly, the `Flood-recovery`-strategy is focusing on different measurements/tools after the flood event, such as reconstruction and insurances (Hegger et al., 2014). These aspects will not be discussed further in the following thesis.

Table 2: Overview of the five types of FRM-Strategies (Adapted from Hegger et al. 2014)

Strategy	**Prevention**	**Defence**	**Mitigation**	**Preparation**	**Recovery**
Approach	Reduce exposure to floods - `Keeping people away from the water`	Reduce probability of floodings - `Keeping water away from the people`	Reduce vulnerability of floodings		
Measures	Proactive spatial planning and land use policies of contribution, zoning	Technical and spatial measurements -> Dikes, dams, upstream retention areas	Smart design of flood prone areas -> flood-roof-spatial planning and infrastructure	Emergency management -> developing early warning systems, evacuation plans	Facilities a good and fast recovery after a flood event -> rebuilding plans, compensation, or insurance system

2.4.2. Specific Design-Strategies in Coastal Regions

Regarding the coastal focus within this thesis this chapter concentrate in the following on six design-strategies in coastal regions based on Oppenheimer (2019; figure 8):

a) No response
b) Advance
c) Protection
d) Retreat
e) Accommodation
f) Ecosystem-based adaption

These strategies are building up on the FRMS by further subdividing the introduced strategies of `Prevention`, `Defence`, and `Mitigation`, that focus on the implementation of measures prior to the potential flood event (chapter 2.4.2), into different design-strategies that can be implemented and indicated in the field.

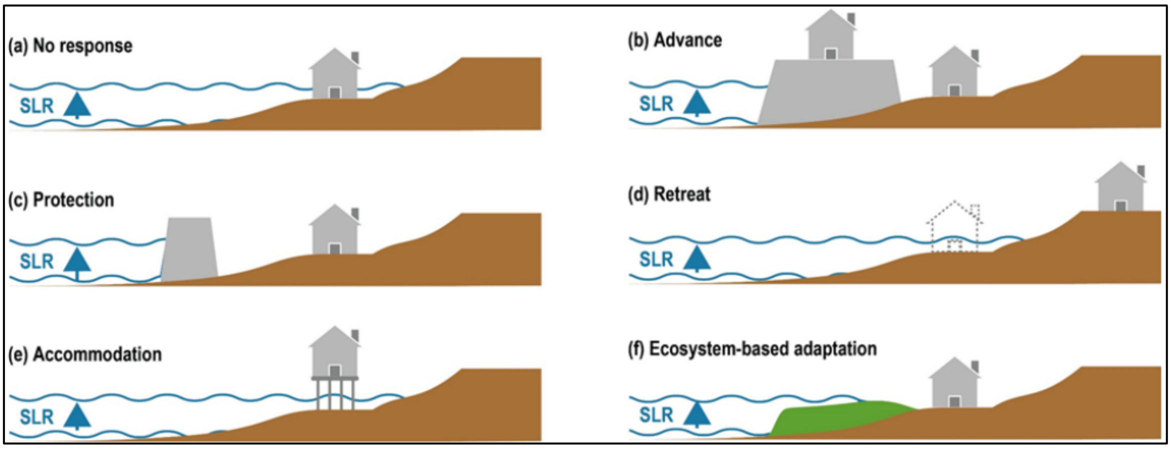


Figure 8: Design-Strategies in Coastal Regions (Oppenheimer et al., 2019)

(a) No response

This design-strategy refer to the spatial design of a specific area. This concerns areas that are not characterized by the protection of one of the following strategies (b-f) and consciously accept that these areas are regularly flooded. Other aspects that are not connected with the spatial design, such as an appropriate approach of risk communication, can play a decisive role.

(b) Advance

This design-strategy creates new land by building seaward, reducing coastal risks for the hinterland and the newly elevated land. This includes different approaches, like land reclamation above sea levels by land filling with pumped sand or other fill material or planting vegetation with the specific intention to support natural accretion of land and surrounding low areas with dikes (Donchyts et al., 2016; Oppenheimer et al., 2019). In the following, it refers mainly to cases outside the main dike line that are obtained during waterfront redevelopment of former harbours areas or similar projects.

(c) Protection

The design-strategy `Protection` reduces coastal risk and impacts by blocking the inland propagation and other effects of mean or extreme sea levels. The focus is on reducing the probability of a possible flooding event and can include hard and soft protection measures. Hard protection measures are for example dikes, seawalls, breakwaters, barriers, and barrages to protect against flooding and erosion (Nicholls, 2018). Soft sediment-based protection measures are for example beach and shore nourishment or dunes. Sometimes ecosystem-based adaption (EbA; see below) also falls in this category, and the three subcategories are often applied in combination as so-called hybrid measures. (Oppenheimer et al., 2019)

(d) Retreat

The design-strategy `Retreat` has the aim to minimize coastal risk by moving exposed people, assets, and human activities out of the coastal hazard zone. This approach can include the different forms of migration, displacement, or relocation. In the following the focus is on relocation, as this thesis is focusing on measurements before the flooding event happens. Here, relocation, which characterized a managed retreat realignment, is typically initiated, supervised, and implemented by governments from national to local levels and usually involves small sites and/or communities. (Oppenheimer et al., 2019)

(e) Accommodation

The design-strategy `Accommodation` includes diverse biophysical and institutional responses that try to mitigate coastal risk and impacts. The focus is on reducing the vulnerability of coastal residents, human activities, ecosystems, or the built environment. In other words, it is concentrating to reduce the consequences of a possible flooding event, thus enabling the habitability of coastal zones despite increasing levels of hazard occurrence. Accommodation measures for erosion and flooding include for example building codes, raising house elevation (e.g., on stilts), lifting valuables to higher floors and other changes in the current land-use. In addition, institutional accommodation responses include aspects like emergency planning or insurance schemes. (Oppenheimer et al., 2019; Wong et al., 2014)

(f) Ecosystem-based adaptation (EbA)

This design-strategy provide a combination of protect and advance benefits based on the sustainable management, conservation, and restoration of ecosystems (Van Wesenbeeck et al., 2017). Additionally, EbA is also referred by various other names, including natural and nature-based features, nature-based solutions, ecological engineering, or green infrastructure (Oppenheimer et al., 2019; Pontee et al., 2016).

2.5. Conceptual Scope of the Thesis

Based on the broader framework and the different concepts introduced in this chapter, the scope of this thesis is concentrating in the following on specific key-elements out of it. Firstly, this thesis is focusing on only two specific types of floodings, coastal and fluvial floodings and their connection with the urban environment at a coastal location. This is specifically addressed in more detail in chapter 3.1. by introducing the research area in detail.

In dealing with coastal and fluvial flooding, the three introduced concepts of `key-dimensions of flood resilience`, `FRM-strategies` and `Design-strategies in coastal areas` are relevant in the following. Thereby, the scope of this thesis chooses a different order than introduced in the chapters before. The aim is to define specific design-strategies as indicated in figure 8 in the field. The indicated design-strategies are initially allocated primarily to visible design, to simplify the assignment of selected cases in practice. Subsequently, these design-strategies are examined in more detail in relation to theory and practice, and aspects of the various FRM-strategies assigned to them. Based on that, the aim is to see to what extent these implementations in practice go hand in hand with the key-dimensions of `robustness`, `adaptability` and `transformability` and which barriers and issues limit the creation and support of these necessary dimensions in the long run in the urban environment on a broader scale. The consideration of key-dimensions is initially limited to the individual cases, and at a later point is characterized with additional information within the larger framework of the research areas, highlighting various barriers and problems between theory and practice. In the end, from a literature perspective this thesis should be able to help with the question of the extent, to which different design-strategies and FRM-strategies can help to create/support the key-dimensions in the long term to make research areas progressively more resilient and what specific barriers and issues hinder this process.

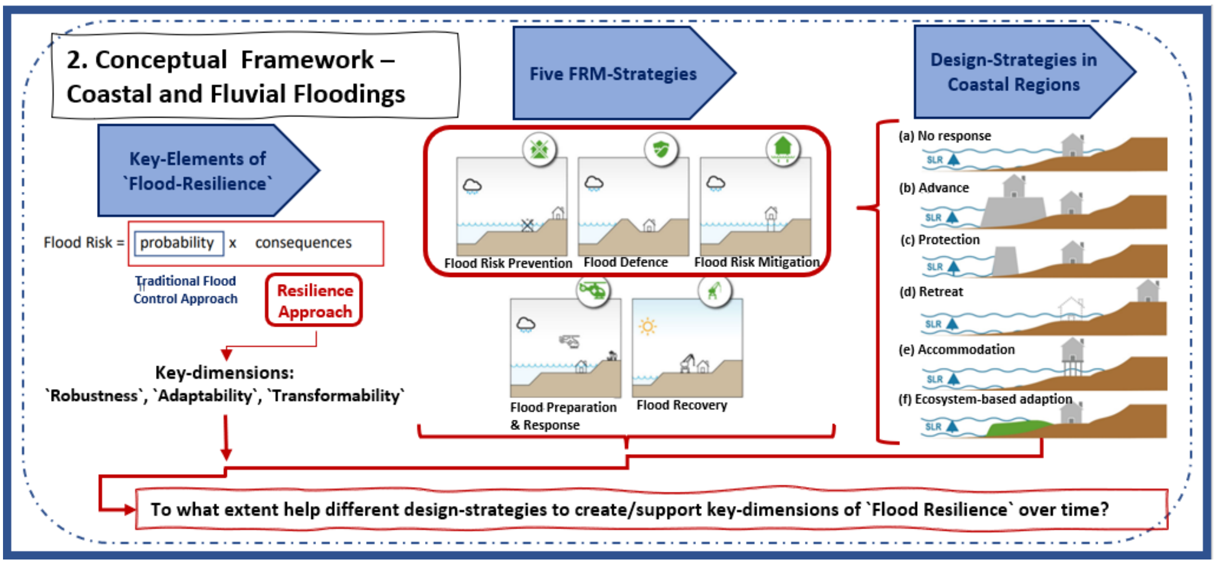


Figure 9: Overview: Conceptual Framework (Created by the author)

Chapter 3 – Research Areas and Methods

This chapter is focusing on the defined research area and the methodology. By that, the thesis is concentrating on the two research areas Bremen and Hamburg. Hence, the first part of this chapter characterizes both cities with their respective river basins, their coastal location, and the relevance of possible flooding in the urban environment by answering the secondary research question 2.2.

In a second step this chapter focuses on the methodology, that consists of several aspects. Firstly, a document analysis on the regulations and directives at the European, National and Federal-state level, to support the classification of the following case study in a broader framework. This will be followed by case study research within the selected research areas. In total eight defined cases (four cases for each city) with similar thematic focuses will be qualitatively investigated. The data collection focuses first on the analysis of documents and building up on this with interviews with selected experts and forms the basis for the subsequent discussion.

3.1. Introducing the two Study Areas of Bremen and Hamburg

As selected areas of interest the city-states of Bremen and Hamburg will be examined in this thesis. The cities are located in the north-west of Germany and are the biggest urban environments in this area that are affected by the trend of increasing coastal flooding. Thereby, both cities can be assigned to the coastal regions of Germany based on figure 10, that will be a central aspect for the following analyse.

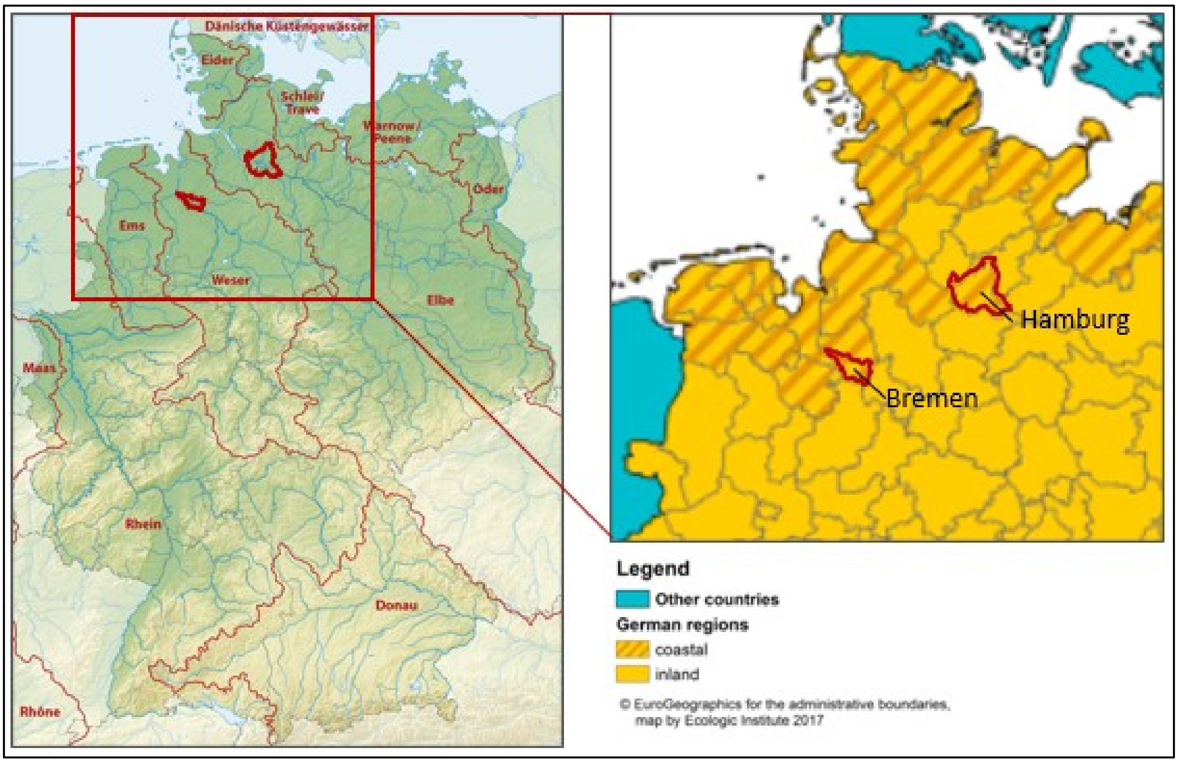


Figure 10: Geographical location of the research areas Bremen and Hamburg, their river basin, and the characterization as a coastal region. (Created by the author based on wikipedia.org (n.d.; left side) and coastal-management.eu (n.d.; right side))

Bremen and Hamburg distinguish from other cities in Germany as they are city-states. As the responsibility for flood protection in Germany is given to the federal states both have their own water act (BremGG & HWaG) and measures in dealing with floods (Lange & Garrelts, 2008). A comparison therefore offers the opportunities to not only recommend general fields of improvement but also draw lessons from each other (Nadin & Stead 2013; Dolowitz & Marsh 1996). Here, Bremen and Hamburg were chosen due to their similar characteristics. The cities have been affected by various flood events in recent decades and climate change, such as secular sea level rise, more frequent storm surges and heavier rain events, increase the need for adapted and improved flood protection. Moreover, both cities have enormously increased their vulnerability to possible flooding themselves to create an economically strong location. Next to the rise in sea level, the vulnerability of floodings has increased specifically due to the increased tidal effect of the Weser and Elbe (figure 30), which can be attributed to the deepening of the rivers (Schuchardt et al. 2007).

The city of Bremen

The city-state Bremen has an area of 326,7 km^2 and around 580.000 citizens. The city is characterised by its location at the Weser and its proximity to the North Sea (figure 34). In the current situation the city is affected by possible floodings from two directions. On the one hand, fluvial floodings due to its inland location and the river Weser with different tributaries (SKUMS 2020a). Hence, a fluvial flooding in the Middle Weser can result from snowmelt or heavy precipitation in the upper reaches of the Werra, Fulda, Leine and Aller rivers. The catchment area of the Weser covers 49,000 km^2 and Bremen is located in the tidal section of the whole river system, the `Tideweser` (figure 34; FFG Weser, 2021). On the other hand, the location is characterized by the influence of the coastal location. During strong storms, the water from the North Sea is pushed into the Weser, whereby the river water is dammed up against the direction of flow. The high-water wave that forms is reinforced by embankments and deepening measures on the Weser and after about one and a half hours, the storm surge reaches the urban area of Bremen (FGG Weser, 2021). The interaction of the tide, the level of the Weser, and possibly heavy rainfall events is decisive for the development of potential flooding.

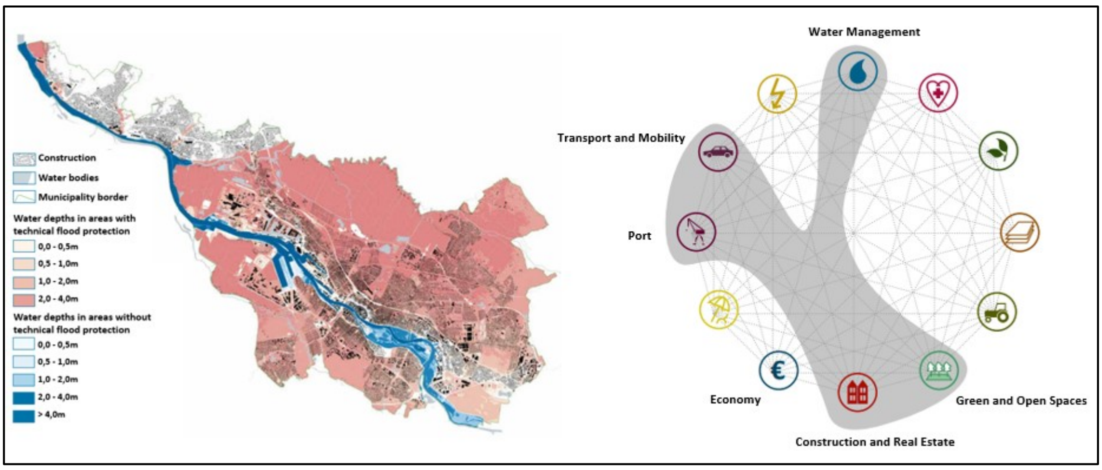


Figure 11: Left side: Flood risk in the municipality of Bremen (SUBV, 2018); Right side: Affected sectors by storms and storm surges (SUBV, 2018)

Based on this possible floodings Bremen's vulnerability is increased as a densely populated urban areas and critical infrastructure. Currently 86 % of Bremen's area is potentially affected with 530.000 inhabitants. The area is protected by 160 km of flood protection systems (80 km against storm surges; SKUMS 2020b). Due to that, the dikes were regularly raised to an average height between 7.20 m in Bremen-North and 10.50 m in Habenhausen, as the tidal range in Bremen has increased from 0.2 to over 4 metres in the past 130 years (figure 30; Schuchardt et al. 2007; FGG Weser, 2021). Therefore, currently all possible areas such as residential and commercial areas and additional public and cultural infrastructures within the main dike line are potentially affected (figure 11)

The city of Hamburg

The city state Hamburg has an area of 755.000 km^2 and around 1.9 million citizens. The city is characterized by its location at the river Elbe and is proximity to the North Sea (figure 35). Similar to Bremen, Hamburg is in the current situation affected by fluvial and coastal floodings (LSBG, 2012b).

Fluvial floodings can result due to the catchment area of the river Elbe with an area of nearly 150.000 km^2. Similar to Bremen, Hamburg is located at the tide-influenced section of the Elbe, where also different tributaries enter the system (figure 35, FGG Elbe 2021). On the other hand, Hamburg is affected by coastal floodings, due to the increasing trend of storm surges. The tidal effect of the North Sea has increased from 1.9 m to 3.6 m due to the deepening of the Elbe in the past (Schuchardt et al. 2007).

In the current situation, nearly half of the city's area is potentially at risk from flooding and more than 325,000 people live in this area (figure 12; right side). Moreover, more than 165,000 jobs are located in this area and goods worth more than 10 billion euros are stored here, why it is important to find robust and long-term solutions to prevent flooding in the long term, also in connection with other sectors (BUKEA, 2021; LSBG, 2012b).

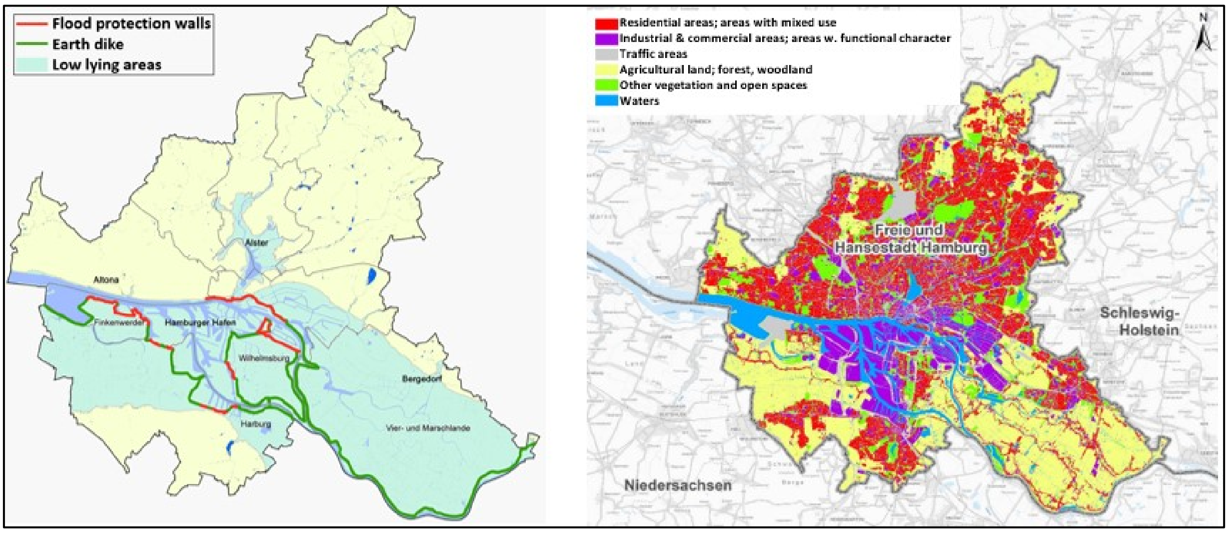


Figure 12: Left side: Food risk in the municipality of Hamburg (BUKEA, 2021); Right side: Land use plan Hamburg (BUKEA, 2021)

3.2. Research Methodology: Case-Study Research

3.2.1. Qualitative research approach

Based on the research objectives introduced in chapter 1, this thesis is concentrating on case study research that allows an in-depth analysis in both selected cities, which makes it a useful method for this study (Yin, 2014). In doing so, the qualitative research approach supports `seeking a contextualized understanding of phenomena, explaining behaviour and beliefs, identifying processes, and understanding the context of people's experiences` (Hennink et al., 2020, p. 17). It requires a small number of cases and collects data through document analyses and in-depth interviews (Yin, 2014). The defined criteria for the case study are introduced in the next section.

To create a broader framework, this thesis is also focussing on one supporting analysis that helps to frame the results of the case study in a larger scale. This supporting element is a document analysis, that focus on specific regulations and directives within both research areas on a more holistic view. Here, documents, such as the GPK 1 & 3, the BremWG and HWaG, FRM-plans and effective land use plans, and landscape programs for both research areas are investigated (figure 13).

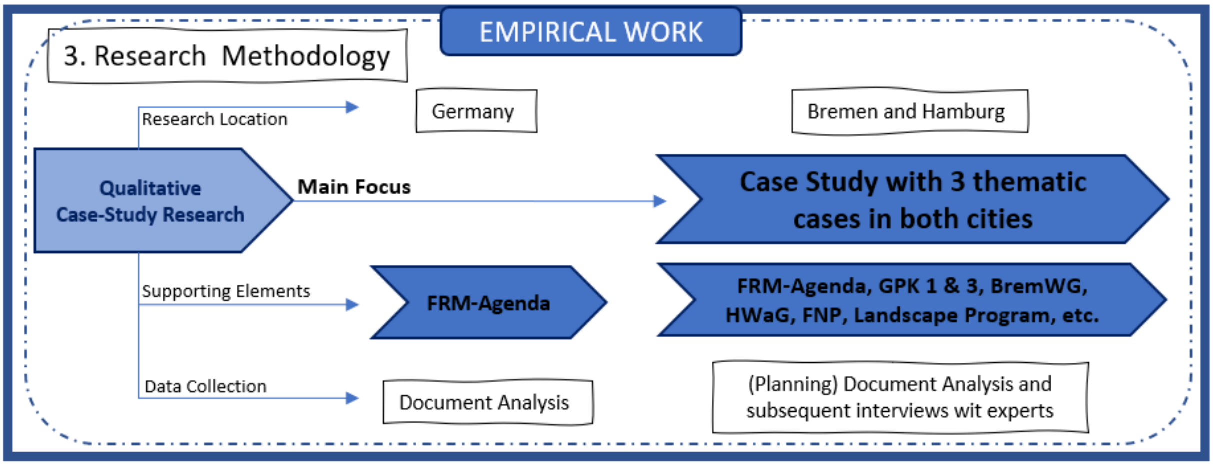


Figure 13: Overview: Research Methodology (created by the author)

3.2.2. Case Selection Criteria

In case study research it is important to establish suitable case selection criteria, as the usefulness of the results largely depends on choosing a relevant research setting (Yin, 2014). This sub-chapter is concentrating on formulate specific case-selection-criteria as a first important step of the research, to create a pool of persuasive cases. In the following the defined and relevant criteria are introduced and summarized in table 3.

The main reasons for selecting a case should be, that is has specific or shared characteristics that are of interest for the study (Gagnon, 2010). The idea behind choosing the case studies is to find the most informative cases, not to develop a statistically representative sample. This allows to draw conclusion from the set of cases. Due to this, the first criteria defined the investigated cases as current projects or existing infrastructure that are explicitly affected and designed to reduce or handle flood risks, and/ or raise awareness for the flooding-issue and play a role in the current handling with floodings.

Furthermore, the cases need to be located in the described research area of chapter 3.1. and are mainly driven by public authorities. The background here is that flood protection is considered a federal-state task in Germany, and with the implementation of the FRM-agenda this thesis focusses on this sub-field. Moreover, case study research can only be successful if the researcher obtains the necessary information about the cases. The availability of data is therefore an important factor in choosing cases. The thesis in this point refers mainly to existing planning documents, which can be supported by websites, media and identified experts.

A next important part that needs to be considered in the case selection criteria is the fact, that this thesis looks for case studies in two different research areas and tries to investigate different approaches and strategies. Hereby, it is necessary that this research has a variety in the selected cases, but at the same time is comparable between both cities. To achieve this, three priorities field of interest were established in the search of the cases, that must be represented in at least on case in both cities and is based on the design-strategies introduced in chapter 2.4.2.

1. Cases that are dealing with the existing main dike line (Focus on the design-strategies \`Protection\`, and \`No response\`)
2. Cases that are exemplary for an accommodated land-use (Focus on the design-strategy \`Accommodation\` and \`Advance\`)
3. Cases that are exemplary for existing floodplains, polder, barrages, or room for the river (Focus on the design-strategies \`Ecosystem-based adaption\` and \`Retreat\`)

Table 3: Defined and relevant criteria for the selected cases (created by the author)

Defined/Relevant Criteria	**Definition**
Projects/Infrastructures that are dealing with/are affected by the currently increasing issue of floodings	The case can be characterized as a current project or an existing infrastructure, that is explicitly affected and designed to reduce or handle flood risks, and/ or raise awareness for the flooding-issue.
Public site	The case is connected to public authorities.
Specific Location	The case is located within the urban areas/municipality of Bremen or Hamburg.
Availability of Information	Public planning documents are available for the cases and additional information can be obtained through websites, media coverage, and identified expert interviews.
Variety within the Projects	The cases differ in their physical characteristics, focusing on different design-strategies introduced in chapter 2, especially in figure 8.
Comparability between both cities	The cases in both cities can be characterized with the same thematic framework concerning possible flood events. The three main focuses of investigation are characterized and compared between both cities in more detail in table 6. - Cases that are dealing with the existing main dike line - Cases that are exemplary for an accommodated land-use. - Cases that are exemplary for existing floodplains, polder, or barrages.

3.3. Introducing the Case Studies

Considering the available time and capacity, this thesis is concentrating in the following on eight different cases as scholars recommend to study four to ten cases for multiple-case studies (Gagnon, 2010). These eight different cases are selected to support the analyses of this thesis within the cities of Bremen (four cases) and Hamburg (four cases) and are based on the defined and relevant criteria in table 3. In this sub-chapter the selected cases will be introduced, and a short overview is visible in table 4 and figure 14 and 15.

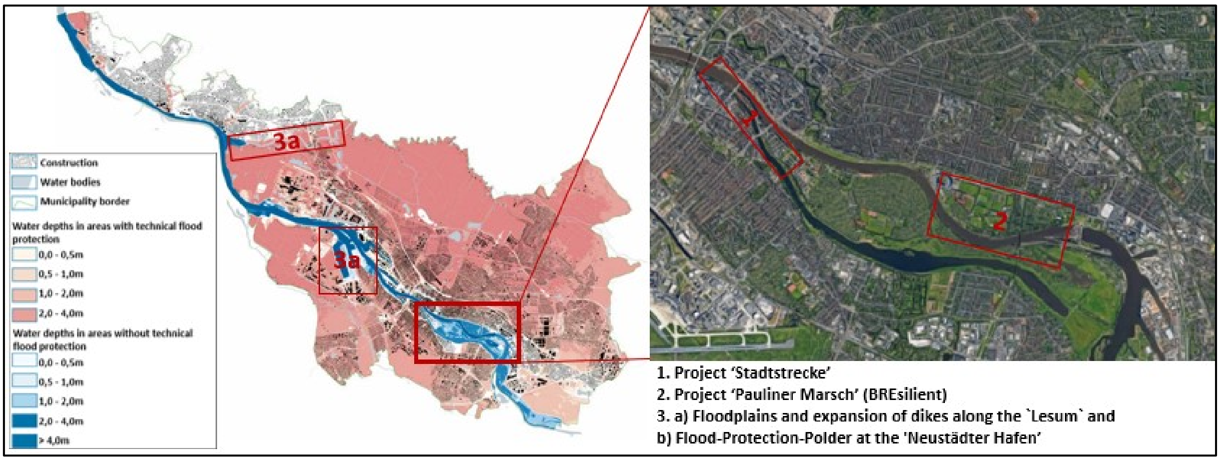


Figure 14: Selected cases in Bremen (created by the author, based on SUBV (2018; left side) and GoogleMaps (right side))

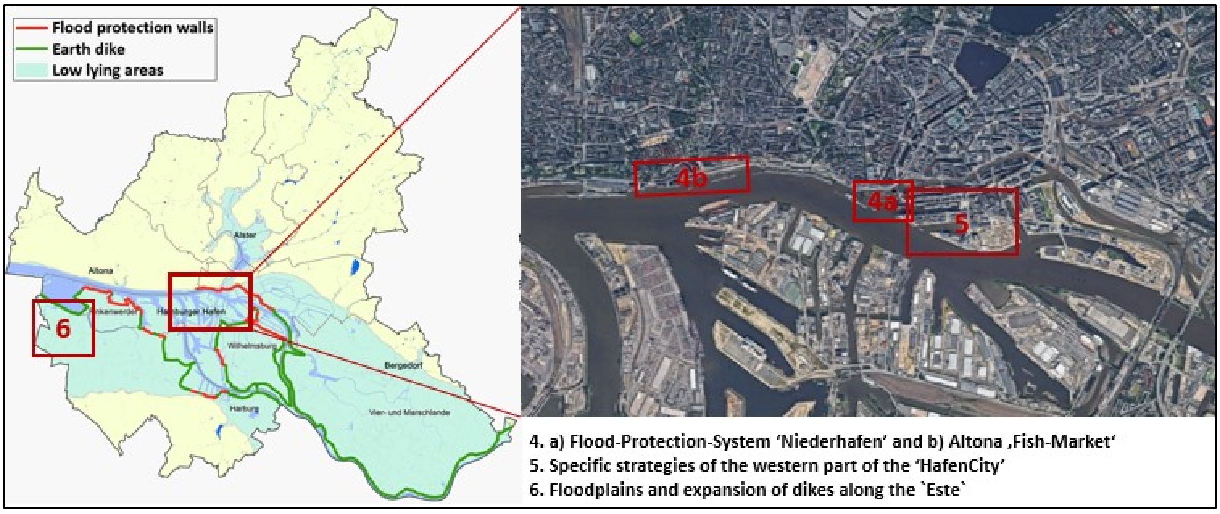


Figure 15: Selected cases in Hamburg (created by the author, based on BUKEA (2021; left side) and GoogleMaps (right side))

1. <u>Project `Stadtstrecke`</u>

The project `Stadtstrecke` is a 2 km dike line in the district `Neustadt`, that needs to be redesigned and strengthened as part of the GPK 1 (Bremischer Deichverband am linken Weserufer, 2016). Based on a feasible study the current dike line was indicated as insufficient, due to safety deficiencies regarding the height and stability. Therefore, the dike line is in need to be redesigned, to improve the necessary flood protection (Krebs, 2021). Thereby, the project is located in the urban centre of Bremen (figure 16) where different interests and sectors meet each other. The SKUMS as the responsible party tried to find sensible solutions together with citizens and local stakeholders in different workshops as part of the `Deichcharta` (Krebs 2021). The planning process started in 2010 and is still in the planning phase (figure 16; Krebs, 2021)).

Figure 16: Overview of the project `Stadtstrecke` (created by the author based on Krebs (2021) & Bremischer Deichverband am linken Weserufer (2016))

2. Model area `Pauliner Marsch` as part of the wider program `BREsilient`

The `Pauliner Marsch` is a model area that is located outside the main dike line (figure 14) and is a sub-project within the wider program `BREsilient` (figure 17). Since the area is located outside of the main dike, it is affected by possible flooding events from the Weser (SKUMS, 2020a). The aim of the model area is to develop ideas and measures together with citizens and local actors to raise their awareness and create an adapted land-use in the long-term. The area is mainly used by sports clubs and allotment gardens (SKUMS, 2020a). As part of the `BREsilient`-programme, it tries to prepare the city of Bremen together with additional projects, measurements and involved stakeholders for extreme weather events in the future, that are increasingly affecting Bremen (SKUMS_a, n.d.).

Figure 17: Overview of the model area 'Pauliner Marsch' (created by the author based on SKUMS (2020a) and GoogleMaps)

3. Floodplains at the `Lesum` and Flood-Protection-Polder at the `Neustädter Hafen`

The areas along the river `Lesum` and the Flood-Protection-Polder at the `Neustädter Hafen` are two `Hochwasseraufnahmeräume` (Flood recording areas) with different focus (figure 18). The river `Lesum` is exemplary for the tributaries `Ochtum` and `Wümme` with a focus on fluvial flooding. The rivers are characterized by barrages that restrain water in the river in case of a storm surge. Hence, the secondary dike lines along these tributaries were investigated, based on GPK 3, and will be strengthened in the future (NLWKN, 2020). The flood protection polder at the `Neustädter Hafen` on the other hand, is an area of 84.7 ha that can create space for coastal floodings and functions as a nature conservation area since 2014 (NLWKN, 2020; SKUMS, 2013).

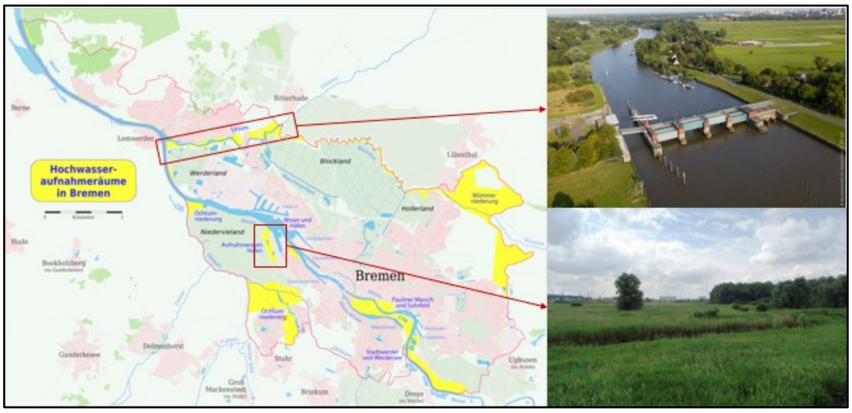


Figure 18: Overview of the `Lesumsperrwerk` and the `Neustädter Hafen` (created by the author based on SBU (2003), BAW (2019) & Brinkmann (2014))

4. New Flood-protection-system at the `Niederhafen` and the `Altona Fish-Market`

The `Altona Fish-Market` and the `Niederhafen` are two areas that are located at the northern site of the Elbe within the urban environment and are geographically close to each other (figure 15). However, there are differences between the areas dealing with possible floodings. The `Altona Fish-Market` is regularly flooded between October and March and has no existing dike line (Fischmarkt Hamburg-Altona GMbH, n.d.). At the 'Niederhafen', a flood protection system was successfully renewed by the LSBG between 2012 and 2019. In the process, the promenade was raised up to 8.90 metres to offers protection against floods (figure 19; LSBG, n.d). In contrast, the areas of the `Altona Fish-Market´ focuses primarily on risk communication (Fischmarkt Hamburg-Altona GMbH, n.d).

Figure 19: Overview of the project `Niederhafen` and the `Altona Fish-Market` (created by the author based on LSBG (n.d,), Ingenieurbüro Dr. Binnewies (2022) and ndr.de (2019))

5. Selected strategies of the western part of the `HafenCity`

The `HafenCity` is Europe's largest inner-city urban development project as a model for the new sustainable European City on the Water (HafenCity Hamburg GmbH, 2006). The area was created outside the main dike line and therefore needs alternative, adapted solutions against possible flooding events. The master plan `HafenCity` was established in 2000 for the western part and in 2010 for the eastern part of the area, and in total 157 ha of former harbour and industrial area were redeveloped for housing, service areas, educational facilities, etc. To create a flood-protected area, various concepts such as a `dwelling mound solution`, `elevated roads`, and ´Flutschutzgemeinschaften`(flood protection communities) were implemented and characterize this specific area. (Figure 20; HafenCity Hamburg GmbH, n.d.)

Figure 20: Overview of selected strategies of the 'HafenCity' (created by the author based on HafenCity Hamburg GmbH (n.d.) and Restemeyer (2015))

6. Floodplain at the river `Este` and expansion of the main dike line

The `Este` is a tributary that is affected by coastal and fluvial flooding and flows into the Elbe in the western part of Hamburg (figure 21; BUKEA 2021). Thereby, it is exemplary for different areas/tributaries indicated in figure 21, that are affected by the risk of fluvial flooding, when their barrages are closed during high water events (BUKEA, 2021; LSBG, 2009). Therefore, the area along the river is characterized by a secondary dike line, floodplains, and green spaces. In this context, the secondary dikes play an increasing importance in the discussion of how to deal with these areas in the long-term. Based on the FRM-agenda, this dike lines will be expanded in the long term, as areas behind the main dike lines move further into focus (hamburg.de; BUKEA, 2021) In addition, the main dike line next to the barrage of the Este in the districts `Cranz` and `Neuenfelde`, that is affected by coastal flooding, will be adjusted due to increasing requirements from the HWaG (REGE Hamburg n.d.).

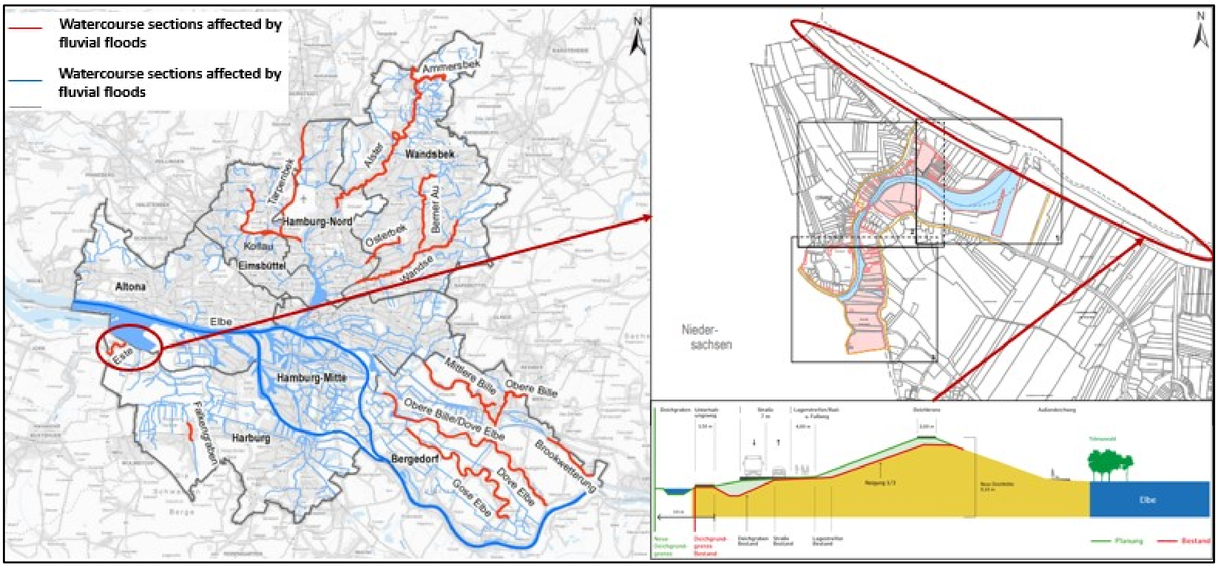


Figure 21: Overview of floodplain areas in Hamburg (fluvial floodings) and the projects at the `Este` (created by the author based on BUKEA (2021), BUE (2017) and REGE Hamburg, (n.d.))

Table 4: Overview of the selected cases in Bremen and Hamburg (created by the author)

Case	**Brief Description**
1) Project `Stadtstrecke` (Bremen)	The 2 km main dike-line along the area `Stadtstrecke` has to be raised/renewed due to the `GPK 1`, as it does not satisfy the protection requirements for the current review period.
2) Modell Area `Pauliner Marsch` as part of the broader `Bresilient`-Program (Bremen)	The model area `Pauliner Marsch` is aproject that combines intensively leisure activities by the citizens in an area that is highly affected by possible floodings outside the main dike line. It is framed in the broader program `Bresilient`, that is created by the SKUMS and focus on climate adaptation for the future with different stakeholders.
3a) Floodplains `Lesum` and 3b) Flood-Protection-Polder `Neustädter Hafen` (Bremen)	The area along the `Lesum` is exemplary for the management of the tributaries of the Weser in the municipality of Bremen with a focus on floodplains and barrages. The `Neustädter Hafen` is a flood polder in the west of Bremen (seaside) with an area of 84.7 ha, which is part of a new nature reserve.
4a) Flood-Protection-System `Niederhafen` and 4b) Area/Infrastructure at the `Altona Fish-Market` (Hamburg)	The flood protection system `Niederhafen` is a redesigned and increased promenade between `St Pauli Landungsbrücken` and `Maunwall`, based on the `Deichverodnung` (dike ordinance) The infrastructural area of the `Altona Fish-market` on the other hand is used for various events like the fish-market, but often affected by flooding as it has no dike line.
5) Specific aspects of the western part of the `HafenCity ` (Hamburg)	The `HafenCity` is a huge project of urban waterfront revitalisation outside the main dike line in Hamburg that needs to be specific adapted to this location. Various aspects such as a `dwelling mound solution`, `elevated roads`, and ´Flutschutzgemeinschaften`, play special roles in a more adaptive approach.
6) Floodplain at the river `Este` and expansion of the main dike line (Hamburg)	The floodplain `Este` are exemplary for in total 10 areas that were directed as floodplain areas in 2017 based on the new FRM-Agenda. Additionally, the area `Este` is connected with the rehabilitation of the main dike line at the `Cranz` and `Neuenfeld`.

Focus of investigation	Bremen	Hamburg
Cases, exemplary for the flood protection line	1) Project `Stadtstrecke`	4a) Flood-Protection-System `Niederhafen` and 4b) Area/Infrastructure at the `Altona Fish-Market`
Cases, exemplary for an accommodated land-use	2) Modell area `Pauliner Marsch` as part of the `Bresilient`-Program	5) Area/Infrastrucutre of the western part of the `HafenCity`
Cases, exemplary for existing floodplains, polders, or barrages	3a) Floodplains `Lesum` and 3b) Flood-Protection-Polder `Neustädter Hafen`	6a) Floodplains `Este`

3.4. Data Collection Framework and Techniques

The data collection framework and techniques of this case study are following different rules to gathering evidence according to Yin (2014). Firstly, they are based on several sources, that allows to analyse a variety of information, identify patterns, and come to valid results. Mainly they are based on different documents and websites, and subsequent interviews with selected experts are building up on that. In addition, it is important to maintain a chain of evidence to show the reliability of the data. In other words, to structure how the data was collected and allow to track the evidence from the start of the research to the conclusions. The study therefore includes information about the circumstances of data collection. Details about the analysed documents and conducted interviews are provided in the following sub-chapters. Moreover, a database was created to store the collected data in a structured way. A summarized overview can be found in appendix D.

3.4.1. Document Analysis

The main approach to gathering data for this thesis focused on a variety of documents, such as official planning documents, official websites, or management plans. Moreover, there are two different areas of interest in the selection process. The first area of interest has a more holistic view, that focuses on different regulations and directives from European to federal-state scale. By that, documents such as coastal protection plans, water acts, FRM-plans, effective land use plans, and landscape programs will be examined and are presented in appendix A.

The second area of interest is case study research and concentrate on the selected cases presented in chapter 3.3. Here, it is necessary that the documents on the one hand provide insight into the physical nature of the case (projects or existing infrastructures) and on the other hand also providing information about aspects like the planning process, possible barriers, and responsibilities. This thesis focused mainly on 2-3 documents per case, which are presented in appendix A and are supported by the documents above.

3.4.2. Semi-Structured Interviews

To support the document analyses four interviews with selected experts were realized. The interviews built up on the initial analysis of the documents and have a slightly different focus in both research areas. In Bremen, the first interviewee (Imke Rolker) had a more holistic view on FRM in Bremen and insights on the different investigated cases as responsible at SKUMS. The second interviewee (Lucia Herbeck) had more insight on one specific projects (Case 2), as this is framed in a broader program of interest. In Hamburg the first interviewee (Frank Nohme) had an internal focus as part of the BUKEA and the second interviewee (Britta Restemeyer) had a more external background from the University of Groningen, with insights in the term ´flood resilience`. This specific structure and information about the interviewees are presented in table 5.

In order ask precise questions but allows considerable leeway for the respondent and the development of the interview (Atteslander et al., 2010) this thesis conduct semi-structured interviews as the basis for data collection. This is considered as useful, as information's about informants' experiences is usually not provided in direct answers to the interviewer's questions, but rather in casual explanations and aspects that come up on the side (Gagnon, 2010). Based on this, an overarching interview guide was developed that was slightly adapted for each interview. The main points along the interview guide are presented in appendix B.

All interviews were conducted via video-meetings in `Zoom` and `GoogleMeet` and the German language. This allowed the respondents to express their experiences and knowledge without a language barrier, due to their German background. Moreover, all interviews were recorded and transcribed to have the content easily assessable as a written text for the subsequent analysis.

Table 5: Overview of conducted interviews with the thematic structure (created by the author)

Selected Interview Partner	**Why? (Topic of interest)**	**Date**
Dr Lucia Herbeck SKUMS, Bremen	Responsible at SKUMS for the selected project/model area `Pauliner Marsch` that is also framed as a specific project in the larger program called `BREsilinet` with the aim to create joint preparation for the climate change in Bremen	28.06.2022
Imke Rolker SKUMS, Bremen	Responsible at the SKUMS for flood protection and coastal protection and together with another staff member responsible for the implementation of the FRM-Directive. Additionally responsible for the update of the GWK 1 and the determination of possible floodplains	30.06.2022
Frank Nohme BUKEA, Hamburg	Responsible at BUKEA for the FRM in Hamburg. Additionally act as a representative of Hamburg in the committees of the FGG Elbe and the LAWA	22.06.2022
Dr. Britta Restemeyer Rijksuniversiteit Groningen	Scientific expert from the university of Groningen with an overall background on the city of Hamburg and the use of the term `flood resilience` in urban areas	11.07.2022

	Internal Background (Holistiv view)	**Internal Background (Project-specific)**	**External Background**
Bremen	Imke Rolker SKUMS	Dr Lucia Herbeck SKUMS	
Hamburg	Frank Nohme BUKEA		Dr. Britta Restemeyer Rijksuniversiteit Groningen

3.5. Data Analyses and Interpretation

To analyse the collected data a database was created, and a shortened overview is visible in appendix D, that was build up based on the following steps. To analyse the map of data, Gagnon (2010) recommends going back and forth between three activities: purging the data, coding it, and analysing it.

In a first step the data was purged. In this step not relevant sections of the documents and interviews were removed based on Gagnon (2010). In the next step, the data was coded based on deductive and conductive codes. Coding is a widely used technique for qualitative data analysis (Gagnon, 2010). Here, a code is assigned to a selected part of the data, such as a part of a transcript (Kuckartz, 2016). Codes function as labels to issues, topics, or concepts in the data (Hennink et al., 2020). They summarize text segments in one or a few words and helps to describe, explain, systemize, and organize the data. Before working through the documents and interviews, the researcher developed a set of theory-based, deductive codes (Kuckartz, 2016). This set of codes was developed based on the existing scientific literature. While coding the interviews and documents, the researcher developed complementary data-driven, inductive codes (Kuckartz, 2016). These labels captured other relevant issues that came up spontaneously and an overview of the coding scheme is presented in appendix C.

For analysing the data, the search for emerging patterns is important. In other words, looking whether evidence from various sources converges towards similar conclusions (Yin, 2014). Already during the data collection process, different patterns and possible explanations were indicated and formed the basis for a detailed case analysis guided by the research interest. In addition, the different cases were compared. This was done by selecting categories relevant for the research questions and then looking at differences and similarities between the cases (Gagnon, 2010). Annex D presents the resulting table that summarizes and compares the findings from the different cases. Guided by the research interest on the implementation of different design-strategies, the comparing table includes information on:

- Focus on Coastal and/or Fluvial Flooding
- Indicated Design-strategy and allocated FRM-Strategies
- Important intersections with the `Land use plan` and `Landscape program`
- Classification of key-dimensions `Robustness`, `Adaptability`, and `Transformability`
- Risk communication, and involvement of citizens and local stakeholders
- Classification to different regulations and directives on the broader scale
- Status of the cases and transferability to similar areas within the city
- Barriers/Problems

Chapter 4 – Results/ Implementation in Practice

This following chapter is concentrating on the result, gained by the document analysis and the subsequent semi-structured interviews. Besides that, the aim is to answer the secondary research questions 2.3 and 2.4. In a first sub-chapter, this part is focusing on the given regulations and directives on different government levels and focus specifically on a changed approach since 2007, when the European Flood Risk Management Directive (FRM-Directive 2007/60/EC) came into force and was implemented in the German context.

The second part is characterising the defined cases (chapter 3.3.) within the selected research areas of Bremen and Hamburg. All projects and infrastructures are characterised in detail in the same chronological order. Firstly, a focus is set on the status of the cases and a classification based on the introduced regulations and directives. In the second part, the implemented design-responses and the corresponding FRM-strategies based on the conceptual framework (chapter 2) are defined. The third sub-part focusing on a classification of the different cases related to the introduced key-dimensions of `flood resilient`. As a last sub-part, emerging barriers and issues for the specific cases are named and discussed later. An overview of the summarised results is presented in the appendix D.

Finally, sub-chapter 4.2.7. gives an overview of the respective design-strategies. Here, the different case studies, the respective FRM-strategies and additional information are assigned in table 6 and provides the initial basis for the first discussion.

4.1. `New` FRM-Agenda in Germany

4.1.1. Regulations and Directives on European, National and Federal-State Level

European Level

In 2007, the European Union adopted the FRM-Directive 2007/60/EC with the stated aim of establishing a uniform framework for reducing flood risks in Europe. The background of this step was, that since the end of the 1990s a series of devastating floods had caused considerable damage in many parts of Europe, for example in the river basins of the Danube or the Elbe and that it is foreseeable that the flood risk in Europe will continue to increase, due to climate change (bpb, 2013). The aim of this guideline is to provide a framework for the assessment and management of flood risks in order to reduce the adverse consequences on human health, the environment, cultural heritage and economic activity in the Community' (p. 29; Europäische Union, 2007). To achieve this goal, the directive takes the following main approaches into account (Europäische Union, 2007; bpb, 2013):

- The FRMD aims at a comprehensive management of flood risks. It is not only concerned with classical protective measures, such as the construction of dikes or retention basins. Rather, it covers all fields of action that directly or indirectly serve to reduce flood risks.
- In the case of watercourses, the entire river basin from source to mouth, including all tributaries, is considered.

- All activities to implement the Directive must be coordinated across state, national and administrative borders.
- The Directive does not prescribe specific targets and measures but leaves their concrete definition to the EU Member States.
- The maps and plans drawn up to implement the Directive must be regularly reviewed and updated.

National Level

In general, the `Grundgesetz` regulates the responsibility within the state, which in principle initially lies with the federal states. Focusing on flood management, Article 91a (1) defines the improvement of coastal protection `as a joint task, that the federal government must participate in coastal protection measures` (Bundesministerium der Justiz, 2022). In the course of coastal protection, the GAK-act focuses on `measures to increase the safety of the coasts of the North Sea and the Baltic Sea as well as the flowing surface waters in the tidal area against storm surges (coastal protection)`. It considers the possibility of different types of funding and the implementation of a framework plan to improve coastal protection (GAK, 2020).

In addition, the FRM-Directive 2007/60/EC were implemented in the national WHG in §§ 72 to 81, what sets the basic requirements for flood protection in Germany. The WHG regulates the flood management, by defining in a first step the terms flooding and flood risk. Thereby, `Floodings are the temporary inundation of land that is normally not covered with water by surface waters or by seawater entering coastal areas` (§72 WHG, 2017) and `Flood risk is the combination of the probability of occurrence of a flood event with the potential adverse flood consequences to human health, the environment, cultural heritage, economic activities, and significant property` (§73 WHG, 2017). The subsequent sections focus specifically on the assessment of flood risks, the preparation of hazard maps and risk maps and the risk management plans, which are described in more detail in the next sub-chapter. However, the assessment of flood risks and the determination of risk areas are carried out in relation to the river basin districts, based on the WHG. Additionally, the topic of floodplains is discussed in detail, as they are subject of special protection regulations based on the WHG. Floodplains are `areas between surface waters and dikes or embankments and other areas which are flooded or flooded through during floods of surface waters, or which are used for flood relief or retention` (§76 WHG, 2017). Special protection regulations are assigned to designated floodplains according to §78, which are partly introduced in chapter 5.

In addition, in 2017 the `Bundesraumordnungsplan Hochwasserschutz` (BRPH) was implemented and plays a decisive role in the interaction with other sectors. According to interviewee 3No, urban planners should "already take flood concerns into account when planning development areas. They should grab the risk areas and look at them, and wherever there are risk areas, they should either not build critical infrastructure at all or build it in such a way that it is flood-proof or can be evacuated. And critical infrastructure can be anything, it can be traffic routes, but it can also be facilities, schools, hospitals, power supply, drainage supply, so everything that is critical Infrastructure.”

Federal-state Level

On the federal state level, the implementation of measures is in the focus, which is also legally prescribed by various aspects. Both examined federal states have a WHG (BremWG, HWaG) and within these directives different ordinances are defined.

In Hamburg, the HWaG determines the construction and maintenance of flood protection facilities including their defence, the dike inspection as well as special legal bases for measures in case of concrete flood danger. In addition, there are restrictions on residence in areas at risk of tidal flooding, residential construction in particular is affected. The dike order is of particular importance in this respect. The minimum structural requirements for public flood protection facilities, the dimensions they may have and what must be observed in their maintenance and monitoring are all regulated by the dike regulations. Since these facilities are the responsibility and property Hamburg, they are primarily addressed to the responsible authorities. (HWaG, 2022)

Similar to Hamburg, the BremWG in Bremen specifies the requirements for flood protection, such as requirements for ensuring flood protection, designation of conservation and maintenance obligations, and regulations on procedural issues (see §§ 57 ff. BremWG). In addition, Bremen is nearly connected with Lower Saxony and both federal states together establish general plans for coastal protection. In the following, especially GPK 1 and 3 are interesting. GPK 1 is concentrating on the determination of the dike heights on the German North Sea coast of Lower Saxony and Bremen, with the help of detailed determination of the existing heights of the flood protection structures, the local design water levels (BWs) and the necessary protective heights of each section. In addition, GPK 3 is focusing on the protective dikes above the barrages. (BremWG, 2020)

In addition, this directive of dealing with possible floodings must be coordinated with other sectors in an urban environment. Here, aspects from the land use plan and the landscape programs must be taken into account and will play a role in the following results and discussions.

4.1.2. Implementation of the FRM-Agenda in Germany

This sub-chapter is focusing especially on the FRM-agenda in Germany as a main area of interest for this thesis, based on the FRMD and introduced in the WHG. Here, the water bodies are to be managed according to river basin districts (§7 WHG). Thereby, river basin/catchment areas are indicated as area `from which all surface runoff enters the sea via surface waters at a single river mouth, estuary, or delta` (§3 WHG).

It is designed to be a joint effort between the state and the federal states. Firstly, uniform requirements for Germany are determined at the federal and state level (LAWA level). Here, common rules are regularly laid down, by taking concerns of the federal states into account. Measures for preventive flood protection, risk prevention, flood forecasting, behavioural precautions (precipitation forecasts, early flood warning, especially for small catchments), recommendations for action in case of low water, climate change/water management issues are processed and coordinated. The work of this committee coordinates the regulatory activities of federal flood control directives (WHG). (LAWA, 2020)

A list of measures (LAWA, 2020) is regularly drawn up with various sub-topics such as avoidance, protection, precaution, restoration/regeneration, review, and conceptual measures, at serve as a basis for implementation at the federal-state level. Based on this, the competent authorities of the federal states coordinate their water management planning and measures among each other, insofar as this is required by the interests of river basin management. The FGG Weser is responsible for the Weser and the FGG Elbe for the Elbe (FGG Weser, 2021, FGG Elbe 2021).

The Implementation in the practice takes place in three steps on the federal state-level, which are repeated regularly and determined by the WHG (§73-75). In a first step, risk areas on inland waters and the coast were identified/determined. In a second step, the risk areas are to be presented in their areal extent in flood risk and hazard maps. In a third step flood risk management plans will have to be drawn up describing the measures with which citizens and those responsible can counter the dangers of floods. A review and update of the steps will take place every six years and an overview is visible in figure 22. (FGG Weser, 2015, FGG Elbe 2015)

In addition, four overall objectives of the flood risk management plan are fixed, and the progress is monitored (FGG Weser, 2021, FGG Elbe 2021):

- Overall objective 1: Avoidance of new risks (in the run-up to a flood) in the risk area.
- Overall objective 2: Reduction of existing risks (in the run-up to a flood) in the risk area
- Overall objective 3: Reduction of adverse consequences during a flood event
- Overall objective 4: Reduction of adverse consequences after a flood event

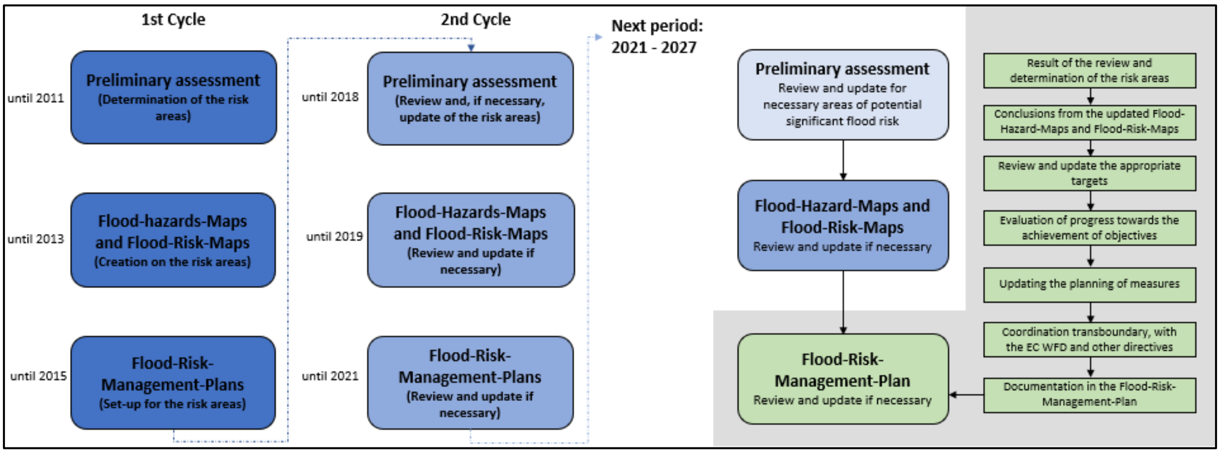


Figure 22: Left side: Review and update cycle of the building blocks of the FRM; Right side: Steps in setting up and updating the FRM-plan (created by the author based on BUKEA (2021) and FGG Weser (2015))

4.2. Case Study Results

4.2.1. Project `Stadtstrecke`

Status of the case and classification of the current relevance

The planning process for the project `Stadtstrecke` started in 2010, based on the GPK 1. Regarding a geotechnical investigation in 2012, it was determined that not only the height of the dike, but also the stability was considered as not sufficient to guarantee the necessary requirements of the rising BWs (Bremischer Deichverband am linken Weserufer, 2016). Hence, a first feasibility study was started in 2013 and followed by the 'Deichcharta`. The `Deichcharta` was designed by the SKUMS as a citizens' dialogue, that included dike walks, information events, concept workshops and surveys of passers-by. In reference to this, an urban development competition was held, and the winning design was selected and followed by a second feasibility study started in 2020 (Krebs, 2021). Thereby the focus along this planning process is not solely on flood protection, but also to open the process for additional sectors such as urban and open space, traffic development and other concerns in a complex urban environment. In the current planning process, a total of six different design approaches are envisaged along the planning area, (figure 23; Krebs, 2021).

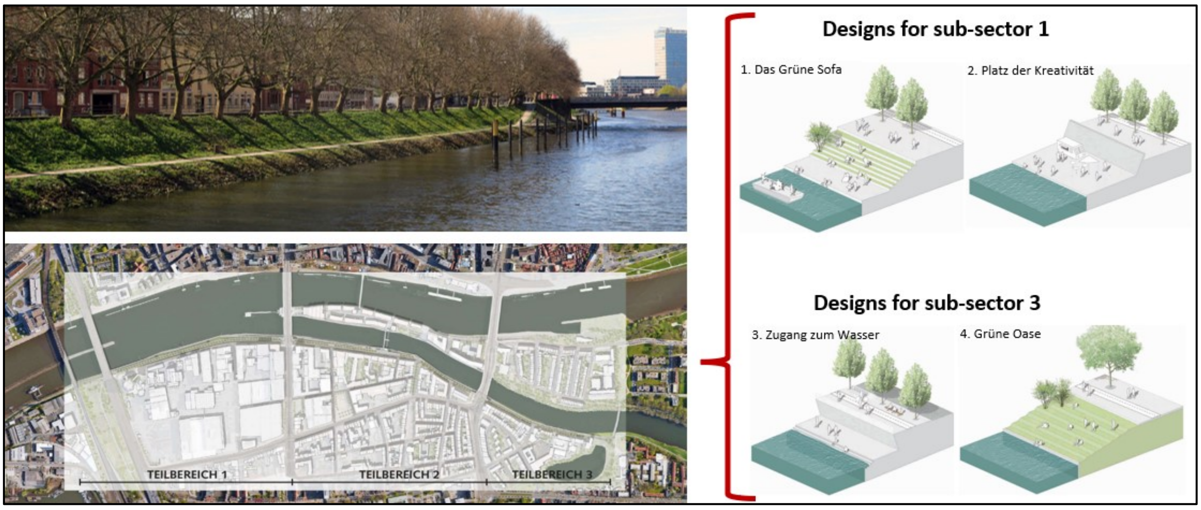


Figure 23: Specific Design-Approaches for the project `Stadtstrecke` (Krebs, 2021)

Implemented FRM-Strategies and Design-Strategies

The dominant design-strategy within this project is `Protection`, visible in figure 23, to create the necessary robustness in this part of the city (Krebs, 2021). Due to the high vulnerability of the hinterland characterized by commercial and residential areas (FNP_B, 2014), there is limited room for additional measurements, as retreat is no relevant option (Bremischer Deichverband am linken Weserufer, 2016). Nevertheless, the communication with the citizens, locale stakeholder and actors from other sectors plays a major role during the whole process (Krebs, 2021), whereby `Flood Defence` and aspects of `Flood Preparation and Response` are assigned FRM-strategies.

Key-Dimensions of `Flood Resilience`

As indicated, the project is mainly focusing to create `robustness` for this part of the dike line, regarding the GPK 1 and the increasing BWs (Krebs, 2021). Creating `adaptability`, as it is defined and introduced in chapter 2.3.2, is implemented to a limited extent. One the one hand, the `adaptability` is increasing as the renewed dike line is adapted and different measurements to integrate the citizens such as information's boards, workshops and creating awareness were implemented (Krebs, 2021). On the other hand, the focus is only on reducing the possibility and not on reducing possible consequence of flooding events, due to limited space. These observations on `adaptability` also have an impact on the classification of the `transformability`, which is classified as limited, although it indicates isolated aspects that are part of a slow transition. This refers to the participation of the citizens and stakeholders in the plaining process, the interaction with additional sectors and the specific design-ideas (figure 23), that thematize the narrative of `living with the water` in this part of the city for the future (Krebs, 2021).

Barriers and issues concerning flood resilience

Along the planning process two main issues/barriers were indicated. Firstly, the issue of flood protection in a complex urban environment with limited space. In this context, the urban hinterland of the `Stadtstrecke` is dominating by commercial and residential areas, seen as extremely vulnerable (FNP_B, 2014). Due to the limited space, additional design-strategies next to a renewed dike line are not feasible. Moreover, the traditional earth dikes are not feasible in this area anymore and alternative design-solutions are necessary with huge investments.

Secondly, the project `Stadtstrecke` has currently a long timeframe, due to the interactions with different stakeholders and sectors, and is still in the planning process. The planning phase started in 2010 and the first feasibility study was based on the guidelines of GPK 1. Due to the new IPCC report, this is no longer sufficient as the BWs increased, and the feasibility studies must be adjusted during the process. According to interviewee 1, "there are also planning statuses, where the planning approval decision is nearly finished and the project is about to be executed and then it is built as it was determined in 2007 in GPK 1, although it is not sufficient in the long term and need to be adapted at a later point again".

4.2.2. Model area `Pauliner Marsch` as part of the `BREsilient`-Program

Status of the case and classification of the current relevance

The model area `Pauliner Marsch` is part of the current program `Bresilient`, which was initiated by the SKUMS with the aim to make Bremen more climate resilient together by including different stakeholders (SKUMS, n.d.). It consists of different project, such as the `Pauliner Marsch`, which deals especially with flood protection. The model area builds up on aspects of the FRM-agenda by further developing an area that is designated as a flood-prone area (SKUMS, 2020a). Thereby, the `Pauliner Marsch` is an important recreational area, dominating by green spaces with different uses, e.g., allotment gardens, sports clubs, and areas of the landscape program (FNP_B, 2014; LaPro_B, 2015; SKUMS, 2020a;). Furthermore, the area is protected from flooding to a limited extent of 5.5 m (SKUMS, 2020b). The long-term goal is according to interviewee 1, "to make local people aware of flooding, so that they can learn about it and learn how to deal with such events." In doing so, an attempt was made to gradually make this area more resilient by completing various workshops with citizens and local stakeholders and continuing to adapt its land-use (SKUMS, 2020a). Next year the project will end with a storm surge partnership. According to interviewee 1, the goal is to "keep the circle of stakeholders together in the long term in order to generate long-term exchange".

Implemented FRM-Strategies and Design-strategies

Based on the section above the dominating design-strategies in this model area are `Accommodation` and `Ecosystem-based adaption` as the documents are indicating an adaptive, limited land-use with connection to the LaPro (FNP_B; 2014, LaPro_B, 2015; SKUMS, 2020b). Furthermore, a clear focus on risk communication with different introduced measurements is indicated, based on the respective framework outside of the main dike line. Transferred to the FRM-strategies, this model area includes aspects on `Flood Risk Prevention`, `Flood Risk Mitigation` and `Flood Preparation and Response`. Moreover, `Flood Defence` has a subordinate role, as the upstream dike line is at 5.50 m, and the area is only affected by higher storm surges and protected by lower water levels. (SKUMS, 2020a)

Key-Dimensions of `Flood Resilience`

The model area is especially concentrating on the key-dimensions `adaptability` and `transformability`. The case has an adaptive land-use concept, due to the requirements of the model area, and the vulnerability can be classified as low within this area of risk (FNP_B, 2014; SKUMS, 2020a). In addition, flood preparation and response are built up gradually and shall end with a flood partnership in the long-term. Moreover, it makes the possible effects of future storm surges visible in a broader scale and will be extended to other areas along the Weser (figure 24). The dimension `robustness` is limited, but plays nevertheless an important role, since the model area is protected up to heights of 5,50 m, and the hinterland is protected by the main dike line (SKUMS, 2020a).

Barriers and Issues concerning flood resilience

Based on the documents analysis and the conducted interviews two main issue/barriers are indicated. Firstly, the model area and the applied concepts are concentrating on areas outside the main dike line. Hence, they are only limited transferable to areas within the main dike line (figure 24), although this would be part of the idea of the FRM-agenda.

Secondly, dealing with local stakeholders and citizens is difficult and has to grow slowly. Interviewee 2 explained that "it took a bit of time to reach people and there are always groups of actors that you address every now and then and no one comes. Especially when it comes to predictions, it is sometimes very technical and not easy to understand." Moreover, it is particularly difficult to reach people and local actors in times when flooding events did not happened lately (interviewee 1).

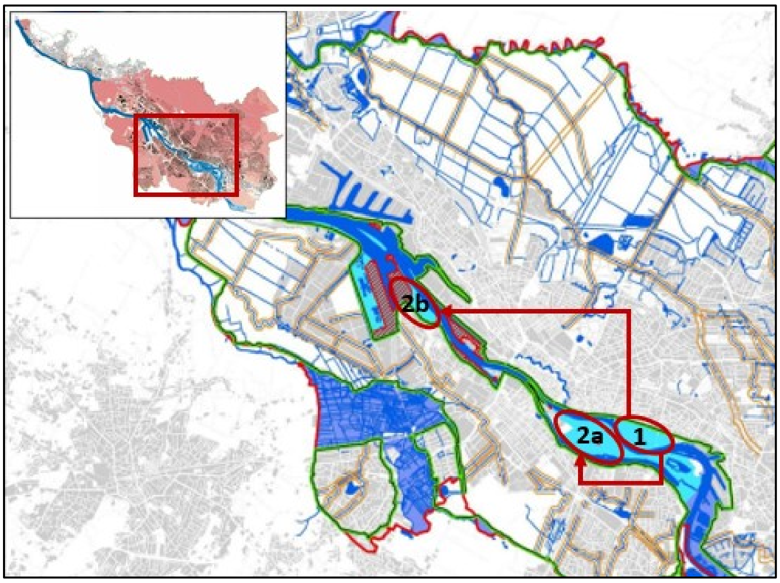


Figure 24: Overview of the areas where the concept/ideas should be transferred to (1. `Pauliner Marsch`, 2a. `Stadtwerder` and 2b. `Rablingshausen`; created by the author based on LaPro_B (2015))

4.2.3. Floodplains `Lesum` and Flood-Protection-Polder `Neustädter Hafen`

Status of the cases and classification of the current relevance

The flood protection polder 'Neustädter Hafen' is a nature reserve that covers 84.7 ha. It is under protection since 2014 and was originally intended as an expansion area for the harbour built in the early 1960s. As a result of the construction of storm surge barriers at the tributaries, the area was established as a flood protection buffer in 1971. It is diked based on the BWs and provided with an overflow sill to the Weser. The area is irregularly flooded by high water in the Weser and small, partial areas of the nature reserve are used agriculturally as wet grassland. (FNP_B, 2014; LaPro_B; 2015; SKUMS, 2013)

The `Lesum` is a sub-catchment area which flows into the Weser in the northwest of Bremen (figure 14). Sub-catchments are defined by the WHG as `an area from which all surface runoff enters a surface water body at a certain point via surface waters` (§3 WHG). Since 1979, the tributary is no longer directly affected by storm events due to the `Lesumsperrwerk` (barrage) (NLWKN, 2020). In addition, the river is characterized by floodplains and green spaces along the protective dike line (FNP_B, 2014; LaPro_B, 2015) to give the river space during high water, since the barrage is closing (NLWKN 2020). Thereby, the dike line at the `Lesum` is currently subject of the GPK 3, that deals with flood protection systems above the existing barrages, defined by the BremWG. The aim is to achieve protection against flooding that is as equivalent as possible along the whole dike line (NLWKN, 2020). Regarding GPK 3, it was determined for the `Lesum` that the height of the dike line is sufficient, but the slope of the 3.8 km dike line is too steep and will be adjusted from 2025 onwards (NLWKN, 2020).

Implemented FRM-Strategies and Design-Strategies

The implemented design-strategies in these two cases are similar and focus on `Protection` and `Ecosystem-based Adaptation`. The `Neustädter Hafen` is designed as a polder to create room for potential floodings, and the hinterland is protected by a main dike line based on GPK 1 (SKUMS, 2013). The measurements at the river `Lesum` concentrate on the interaction of both considered flood types. The `Lesumsperrwerk` focus on protection against coastal floodings and the protective dike line behind it on fluvial flooding when the river cannot be drained due to high water (NLWKN, 2020). In addition, both areas are (partly) characterized by floodplain areas and gives the river room with ecosystem-based strategies (FNP_B, 2014, LaPro_B, 2015). Hence, the FRM-strategies `Flood Defence`, `Flood Risk Mitigation` and `Flood Risk Prevention` are defined in both cases.

Key-Dimensions of `Flood Resilience`

Both areas focus similar on the introduced key-dimensions, as all three dimensions are indicated. The `robustness` in a way, that the dike lines have clear requirements based on HWaG and BremWG. In addition, the protective dike lines along the `Lesum` will be strengthened from 2025 onwards based on the GPK 3. This aspect also increases the dimension of `adaptability`, which is additionally linked to the limited land-use (room for the river) due to the connection with the `LaPro` and the establishment of floodplains. In the case of `transformability`, the measurements at the river `Lesum` take up measurements of the FRM-agenda, by focusing more strongly on areas behind the main dike line and is together with the `Neustädter Hafen` connected with the narrative `room for the river`.

Barriers and Issues

These cases indicate one main barrier/issue. As 86 % of Bremen is potentially affected by flooding the city is characterized by a complete dike line throughout a highly dense area (FNP_B, 2014). Thus, the transferability of these ecosystem-based adaption is limited to the given conditions, in other words to area outside the main dike line.

4.2.4. Flood-Protection-System `Niederhafen` and Altona `Fish-Market`

Status of the cases and classification of the current relevance

The case `Niederhafen` and the `Altona Fish-Market` are two cases that are geographically nearly connect (figure 15) but have different implementation approaches. The `Niederhafen` was dominating by a huge project between 2012 and 2019, by raising the flood protection system between 1.60 m and 1.90 m. Currently it has a hight between 8.60.m and 8.90 m and meet the requirements of the current BWs and the HWaG. The LSBG was responsible for the planning process and the design had the central approach of opening the promenade to the urban environment and to the water in a transferring sense. (LSBG, n.d.)

The `Altona Fish-Market` is an area that is not protected by a dike line. As a result, the area is regularly flooded during storm surges. Sub-areas are already affected by floodings at high tides between 2.90 m (parking lot Neumühlen) and 3.50 m (Fish-auction Hall) and the primarily focuses in dealing with floodings is risk communication (Figure 31; BUKEA, 2018; Fischmarkt Hamburg Altona-GmbH, n.d.). The area is characterized by a low vulnerability, defined by a limited use of citizens compared to other areas (FNP_H, 2022) and the hinterland is not affected by potential floodings.

Implemented FRM-Strategies and Design-Strategies

Although both areas are geographically close to each other (figure 14), very different design-strategies have been implemented. The project 'Niederhafen' is concentrating on 'Protection' while the 'Altona Fish-Market' is initially assigned to the design-strategy 'No response'. However, on closer examination it becomes clear that the strategy at the `Altona Fish-Market` is much broader. Based on the documents, aspects of the FRM-strategies 'Flood Risk Mitigaton', 'Flood Risk Prevention' and 'Flood preparation and Response' are identified, due to a (timely) limited land-use at the former harbour area compared to other areas and a focus is on a structured risk communication (Fischmarkt Hamburg Altona-GmbH, n.d.; FNP_H, 2022). In contrast, the `Niederhafen` focusing only on `Flood Defence` and protects the hinterland dominating by commercial and residential areas (FNP_H, 2022).

Key-Dimensions of `Flood Resilience`

Like the different strategies indicated, the two cases are focusing on different `key-dimensions` based on the sections before. At the ´Niederhafen´ the focus is on `robustness` with the renewing promenade, that is adapted to the current requirements (LSBG, n.d.). Additional indicators for the dimension `adaptability` were not indicated. In addition, the aspect of transformability can be classified as limited, as the response is focusing on robustness, but the new-design approach with the promenade includes aspects of the narrative `living with the water` (LSBG, n.d.).

This is different for the case `Altona Fish-Market`. Here, the aspect of `robustness` plays a subordinate role, and the focus is on `adaptability`. In particular, the aspects of limited use on different levels (time and intensity) and the clear focus on risk communication play a major role in making the area less vulnerable and enabling the 'no response` design-strategy in a structured manner. In terms of `transformability`, this area can play an important role in the broader scale, as it regularly shows the effects of storm surges and can gain understanding for flood protection measurements by citizens and stakeholders.

Barriers and Issues

Within these two examples one main issues/barriers is dominating. Both cases are limited transferable, although there are completely differently structured. Firstly, projects like the `Niederhafen` are huge investments and not feasible along the whole dike line of a city, especially in areas outside the city centre. Secondly it is difficult to create low vulnerability in urban areas such as the `Altona Fish-Market`, that is dominating by his former use as a port area, especially when the hinterland is also affected by possible flooding events.

4.2.5. Specific aspects of the western part of the `HafenCity`

Status of the case and classification of the current relevance

The `HafenCity` is a huge project started in 2001 and focusing on a huge waterfront redevelopment of former harbour areas. It is located in the tide-influenced area of the Elbe and outside of the main dike line (figure 15 & 25). The original ground levels of the 157 ha were between 4.50 m and 6.50 m and did not provide sufficient protection against storm surges (HafenCity Hamburg GMbH, 2006). Regarding the economic development, the embankment of the new urban area would have had the major disadvantage that the necessary constructional run-up would have delayed the development of the area for several years. Thus, a so-called `dwelling mound solution` was developed, which provided for the elevation of the areas and development paths to a ground level of at least NN + 7.50 m (HafenCity Hamburg GMbH, 2006, Restemeyer, 2015). This elevation affects public roads, squares and promenades as well as the base floors of the buildings. The area along the waterfront can be used as publicly accessible space. Thereby, Hamburg developed a special flood protection concept to enable attractive waterfront living by residential and commercial areas and additional public and cultural infrastructures (FNP_H, 2022) while still providing sufficient safety for the people living and working there (BSE, n.d).

To create that, a completely new act, the so-called `Flutschutzverordnung` (flood protection ordinance), had to be passed by the Senate to allow living in the `HafenCity`. Apart from legal changes, the `HafenCity` also establishes a new institution to operate the flood gates within the buildings, the so-called `Flutschutzgemeinschaften` (flood protection communities). All property owners within a building complex are automatically part of it. Every `Flutschutzgemeinschaft` has a `Flutschutzbeauftragten` who is the main contact person and who is responsible for putting the flood gates in place when a storm surge is expected. (Restemeyer et al., 2015)

Implemented FRM-Strategies and Design-Strategies

Based on the section above, the `Advance`-strategy is predominant in this case. Due to the size of the area, the intensive use by a variety of sectors and the encapsulation from the main dike line, it is supported by a variety of measures associated with the `Protection` and `Accommodation` strategies. Regarding the protection, the `dwelling mound solution` was implemented, which differs from the main dike line and was adapted due to the BWSs from 2000 up to 7.50 m (interviewee 3). The accommodation has been developed by a lot of different measurements, also with the background of creating vulnerable infrastructure within a risk area. In addition, the `Flutschutzgemeinschaften ` plays an important role at the risk communication. In this combination the following FRM-strategies can be assigned: `Flood Defence`; `Flood Risk mitigation` and `Flood preparation and response`.

Key-Dimensions of `Flood Resilience`

By focusing within the project scope, all three key-dimensions are indicated in a highly developed manner. Focussing on the `robustness`, the `dwelling mound solution` ensures flood defence, as the height was set to 7.50 m in cooperation with BUKEA related to the BWs (7.30m) from 2000 (interviewee 3). Concerning the `adaptability`, a lot of different measurements were indicated. This focus is not only on the probability but also on the consequences of a possible flooding event, such as elevated roads or temporarily installable flood gate. Hence, it includes key aspects towards FRM (Figure 5) and with the responsibilities further developed by the `Flutschutzverordnung`, the `transformability` is indicated as high (BIS, 2021; HafenCity Hamburg GMbH; 2006)

However, this concept offers only a limited aspect of `adaptability` concerning the `robustness`, as the `dwelling mound solution` cannot be readjusted to the changing BWs like the existing main dike line (interviewee 3). Furthermore, by scaling out of the project on the larger frame of the city the dimensions `adaptability` and `transformability` lose some of their significance, Then, the measures relate only slightly to strategies behind the main dike line (on possible consequences), since immense vulnerable infrastructure outside of the main dike line was built in a risk area, which was previously characterized by lower vulnerability (HafenCity Hamburg GMbH; 2006, FNP_H, 2022).

Barriers and issues

Based on the previous sections, two barriers/issues are defined in this project. Firstly, the lack of adaptability of the implemented `dwelling mound solution` compared to the main dike line, that becomes visual in figure 25. This figure shows the different hights of the western and eastern part of the `HafenCity` and the currently planned district `Grasbrook` that increased in later projects up to 2.2 m (interviewee 3). According to interviewee 3, `this is no problem for the next decades as there are additional measurements, but on the longer term it becomes problematic`.

The second aspect is the two-pronged approach of `adaptability` and `transformability`. On the project scale, the project is characterized by a lot of different measurements. In addition, these measurements/strategies focus on both reducing the possibilities and the consequences of possible floodings events, and thus retain key aspects towards FRM (figure 5). Nevertheless, the project itself has brought the whole vulnerable infrastructure to this area of possible risk, and the question remains whether this will be effective in the long term in such a vulnerable place.

Figure 25: Comparison of the flood protection height in the HafenCity and the Grasbrook (created by the author based on GoogleMaps and information's from the interviewee 3)

4.2.6. Floodplain areas `Este`

Status of the cases and classification of the current relevance

The case `Este` is exemplary for the indicated catchment areas in figure 26, that are dealing with fluvial and coastal floodings (BUKEA, 2021). The catchment area of the river Este covers a total of about 365 km². In Hamburg, however, the share is only 2 % and the catchment area touches the urban area of Hamburg in the west in the district `Cranz` (LSBG, 2012a). The only water body in this catchment is the `Este`, that is completely diked in Hamburg. In the dealing with the tributaries, the focus in the past was mainly focusing on the built barrages to minimize the influence of costal floodings in the rivers. In the current planning phase, the secondary dike lines behind the barrages are considered and will be adjusted in the coming years (LSBG, 2009). The `Este` is characterized by floodplain and green areas along the dike line and the hinterland by residential areas, partly with special designation through the right of first refusal for the City of Hamburg, and commercial areas (FNP_H, 2022; LaPro_H, 2021).

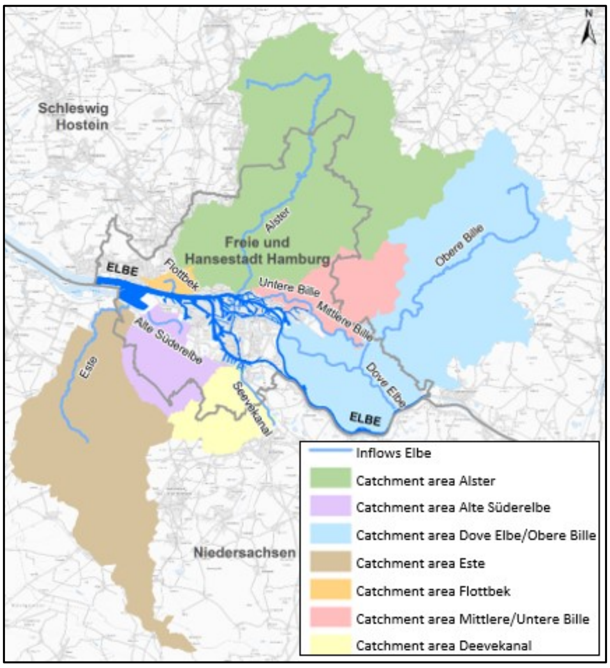


Figure 26: Overview of the different sub-catchment areas that enters the river Elbe in Hamburg (BUKEA, 2021)

For coastal flooding, an increase of the dike in the districts `Cranz` & `Neuenfelde` is planned, which is the main dike line where the river Este enters the Elbe. The 3.2 km long dike will be raised by 70 cm to a height between 9.00 and 9.40 m. An additional focus is to strengthen the dike lines in such a way, that they can easily be raised/adapted further in the future. The planning area begins in the west at the state border with Lower Saxony and bordered to the north by the `Mühlenberger Loch` with is a protected area. In addition, the traffic situation will also be optimized during the dike project. (REGE Hamburg n.d.)

Indicated FRM-Strategies based on the implemented Design-Strategies

The indicated design-strategies in these areas are focusing mainly on `Protection` and `Ecosystem-based adaption`. The protection focuses on coastal und fluvial flooding, and both will be further expanded in the future, due to increasing requirements of the HWaG. In addition, it is supported by the protected area in the north of the study area and various floodplains along the `Este`, that are associated with restricted land-use by other sectors (FNP_H, 2022; LaPro_H,2021). Due to that, the FRM-strategies `Flood Defence`, `Flood Risk Mitigation` and `Flood Risk Prevention` can be assigned here.

Key-Dimensions of `Flood Resilience`

Concerning the key-dimensions all three are indicated. `Robustness` is present, due to the planned expansion of both, the main dike line at the Weser and the secondary dike lines along the `Este` in the long-term. By that, the main dike line along the Weser is already prepared for a further increase (REGE Hamburg, n.d) in the future and the `Este` is dominated by floodplains and restricted land use (FNP_H, 2022; LaPro_H, 2022). This indicates `adaptability` and in connection with the FRM-agenda main aspects of `transformability` by focusing on areas behind the main dike line.

Barriers and Issues

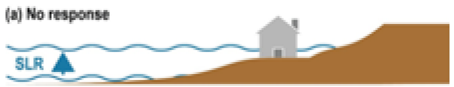
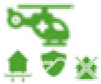
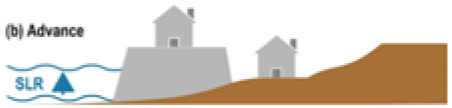
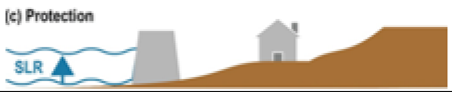
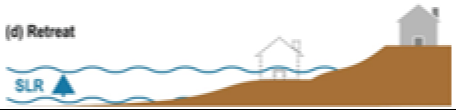
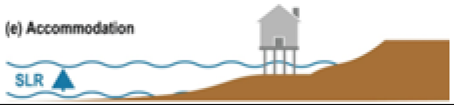
In this case, two barriers/issues are indicated in dealing with flooding events. Firstly, the expansion of earth dike needs increasing space, based to the defined regulations (specific slope) of the HWaG (Deichverordnung). Especially at the secondary dikes along the tributaries, this problem is increasing as various areas are privately owned and the responsible authority must gradually try to develop these areas for the expansion of the dike line in the long term.

Second, the extent of floodplain areas is defined primarily on tributaries and is limited feasible for coastal flooding along the Elbe River toward the North Sea. This aspect is supported by a statement from interviewee 3, who explains that it is important from the flood protection view `to keep the dike line as short as possible, although this gets in the way of additional measures such as space for the river in an urban context with a limited distance to the sea.` The background here is mainly the high effect of the tide (figure 30) and the negative benefit-cost analysis (interviewee 3).

4.2.7. Summarized table of case-study research focusing on the indicated design-strategies

Based on the first results of the different cases introduced in the previous subchapters, table 6 was developed and presented in the following. This focus is on the different design-responses investigated in the cases and forms the basis for the first part of the following discussion.

Table 6: Overview of the indicated design-strategies (based on figure 8) in connection with the selected cases, the FRM-strategies and additional information's (created by the author)

Design-Strategies (based on figure 9)	**Selected Cases**	**FRM-Strategies**	**Additional information's in more detail**
	4b) Altona ‚Fish-Market'		- Focus is on preparation (risk communication) as the most important tool - Only feasible for small areas and hardly transferable, due to clear limits, as the land-use and the timely use must be adapted - Adjacent area in the east protected by dike line - More options in Hamburg as less percent of the areas are possibly affected
	5) 'HafenCity' 2) Parts of the `Pauliner Marsch`		- Limited room due to the river situation - The focus is on adapted use outside the existing main dike line. However, this trend does not replace the main dike line for areas behind it in Bremen and Hamburg. - very different approaches: `HafenCity` created new upstream infrastructure (housing, industry, etc.) and intensive use, `Pauliner Marsch limited use and focus on timely use, - decoupled from the main dike line with the `dwelling-mound concept` and a limited upstream dike line
	1) `Stadtstrecke` 3a) Lesum and 3b) `Neustädter Hafen` 4a) `Niederhafen` 5) HafenCity 6) `Este` with the districts `Cranz` and `Neuenfelde`		- Adapted regularly due to the BWs and increasing trend based on IPCC, all cases affected - Dominant tool, that has to deal with increasing issues, limited space and interaction with other interest/activities as main barriers. Therefore, differences between locations in urban centre (`Stadtstrecke`) with completely new dike-designs and outside the centre (`Este`) with prescribed hight and width for the earth dike - Barrages at tributaries and main river as demarcation between coastal and fluvial flooding - Secondary dyke line with an increasing importance due to FRM-Agenda
	3b) Parts of the 'Neustädter Hafen'		- Limited, punctual visible in connection with Landscape program - Focus on areas that were not intensively used before
	2) ‚Pauliner Marsch' 5) 'HafenCity'		- Focus mainly on projects outside of the main dike line - very different measurements, such as limited, adapted land-use, flood risk communication, elevated roods etc. - connection with ecosystem-based adaption as an adapted land-use - Other infrastructures behind the main dike line in a notable slower transition (BRPH), but not concern all sectors
	2) ‚Pauliner Marsch' 3a) Floodplains `Lesum` 3b) 'Neustädter Hafen' 6) Parts of the Floodplains `Este`		- connection with `Landscape Program` - focus on floodplain-areas, such as room for the river between river and dike (fluvial flooding) and polder (fluvial and coastal flooding)

Chapter 5 – Discussion and Conclusion

This chapter is building up on the result represented in chapter 4 and continues with a discussion. The discussion is structured in three sub-chapters which are discussed chronologically and lead to the conclusion, visible in figure 27. Firstly, the focus is on the indicated coastal design-strategies, introduced in chapter 2.4.2 and table 6 and the detailed allocation and comparison of the various cases. Secondly, the focus is on a broader view, with a more holistic comparison between the two selected research areas of Bremen and Hamburg. Along this discussion, different main topics in dealing with floods are dealt with chronologically. In a third subchapter, the key-dimensions of resilience presented in the literature and in chapter 2.3.2. are examined in more detail and evaluated in a broader framework by additionally discussing the barriers and problems that arise between theory and practice.

Overall, the chapter aims to answer the last two secondary research questions (see sub-question 2.5. and 2.6.) and to open the field to address the main research question in a concluding part.

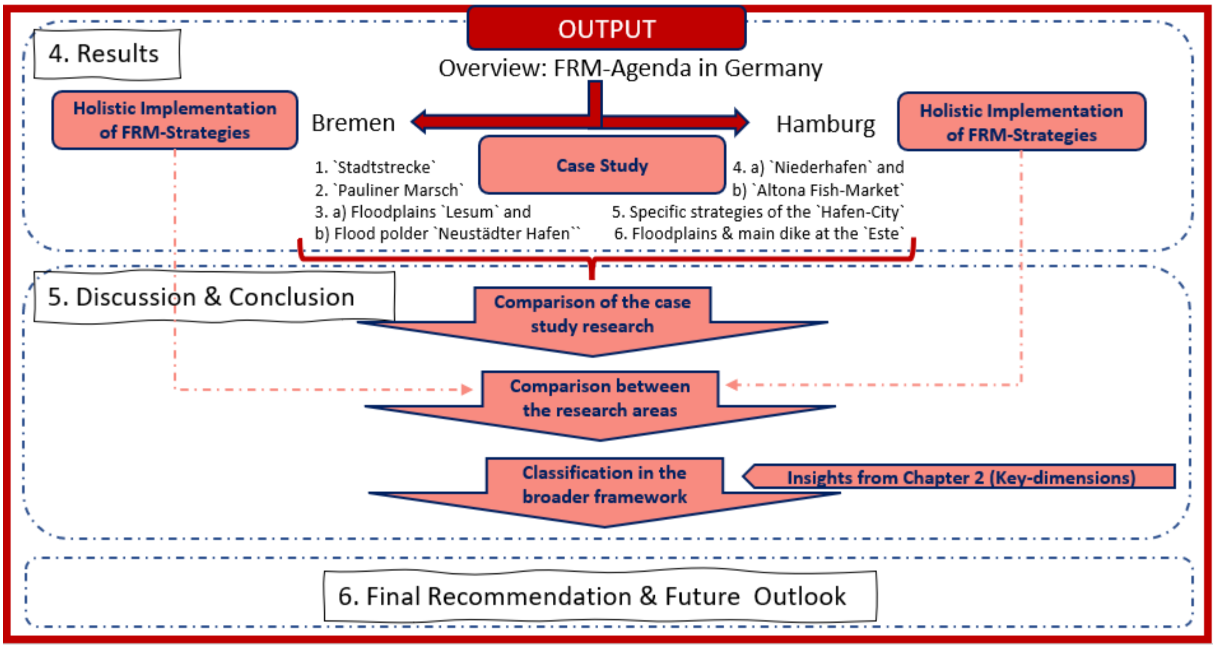


Figure 27: Structure of the discussion (created by the author)

5.1. Comparison between the investigated cases focusing on allocated design-strategies

Based on the results of the case study research eight different cases with detailed information's are assigned to at least one, partially several defined design-strategies. A short overview is represented in table 6 and the basis for the following discussion. For this purpose, the six introduced design-strategies are examined in detail by comparing the various cases. The discussion is mainly based on the analysis of the documents and is supported by specific statements and inputs during the interviews.

No response

This strategy is indicated in one investigated case, the Altona `Fish-Market` in Hamburg, as this area is regularly affected by floodings below the indicated height of a storm surge (BUKEA, 2018). In combination with the increasing trend of flooding within the urban environment, this was unexpected, but on closer examination it becomes clear that the `No-Response`-strategy in this case refers solely to the first visual consideration. The area sets a focus on the FRM-strategy `Preparation and Risk Communication` which are defined at different levels, based on the expected water level values (figure 31). Moreover, the use in this area is adapted in a way, that activities such as the fish-market take place at specific times and the vulnerability of the hinterland is very low (FNP_B, 2014).

To sum up, this area which is assigned to the `No-Response`-strategy, includes a combination of the FRM-strategies `Flood Risk Prevention`, `Flood Risk Mitigation` and `Flood Preparation and Response`, whereby the area is regulated in a very controlled manner. No comparable cases were identified, as it is limited feasible to transfer to an urban environment with a more vulnerable hinterland.

Advance

This strategy can be assigned to two cases, which address the design-strategy in different ways. Thereby, both cases differ from the classic description that was characterized in chapter 2.4.2, mainly because of the river situation in this research area that is limited in space for an upstream use. In Bremen the model area `Pauliner Marsch` is outside the main dike line and is limited used by different sports clubs and allotment gardens as introduced in the results. With an upstream dike line of 5.50 m, it creates limited protection, and an adapted land-use and risk communication was indicated, that keep the vulnerability and possible consequences low. Compared to this smaller project, the western part of the `HafenCity` is the second case assigned. Like the `Pauliner Marsch`, there is a clear focus on different measurements connected to flood risk mitigation and control e.g., in the form of the `Flutschutzgemeinschaft`, and additional measurements presented in chapter 4.2.5., deviating from measures behind the main dike line. Differences are that the area is much larger, and is re-designed in a new way, whereby the vulnerability of the area increased a lot due to enormous investments and new infrastructure in a risk area.

In summary, the `Advance`-strategy is defined in this thesis as areas outside the dike line that offer limited protection for the hinterland, due to the limited space of the river and the already existing main dike line. Therefore, the areas are not part of the larger framework and allows for different strategies and concepts to be tried out and ideas of flood resilience to be tested. This takes different forms within the two research areas, that is particularly visible in the different handling with the term `increasing/lower the vulnerability`.

Protection

This strategy is visible in all investigated cases but is characterized differently. Firstly, cases where the protection is the dominating tool and distinguish between coastal and fluvial floodings. The project `Niederhafen`, the `Stadtstrecke` and parts of the `Este`-case are primarily oriented towards coastal floodings. Hereby, the protection strategies are based on the prescribed directives BremWG and

HWaG with increasing requirements based on the increasing BWs. In this regard, new challenges and design approaches are indicated in urban centres as existing dike lines require more space and are partly replaced by dike protection walls (`Stadtstrecke`), that focus in the indicated cases on the narrative of `living with the water`. In areas outside the urban centre, the existing earth dike lines are adapted in the traditional way and partly already prepare for additional expansions in the future (main dike at the Este). Next to this, the tributaries `Lesum` and `Este` are oriented towards coastal and fluvial floodings, based on the BremWG and HWaG. These are primarily protected by barrages and the expansion of the secondary dike lines/protective dikes are planned for the next decades (GPK 3).

Secondly, cases were identified, where the protection is not the dominate tool. Here, the `HafenCity`, which is cut off from the main dike line, the `Pauliner Marsch` the polder 'Neustädter Hafen' and the `Altona Fish-Market` are relevant cases. However, a closer look at the results shows that protection is important in all of them, except from the `Altona Fish-Market`. In the ´HafenCity`, the flood protection concept is based on the `dwelling-mount concept`, that was adapted to the BWs (interviewee 3). The other two areas, which are characterized by low vulnerability and agreed to being flooded, are limited protected, but the vulnerable hinterland is protected by the main dike lines (GPK 1).

Retreat

This strategy is hardly indicated in the defined cases. The exception are areas that can be assigned via the connection to `ecosystem-based adaptation`-strategies. This indicates especially the `Neustädter Hafen` and the `Pauliner Marsch`, which are characterized by a low vulnerability and limited land-use based on the result. Retreat is seen here as an approach where urban and economic development is restricted to allow water and nature. Nevertheless, these cases do not represent the `Retreat`-strategy in the sense as it is described in chapter 2.4.2, since it concerns cases, which were never used in an intensively way.

Accommodation

The design-strategy `Accommodation` is nearly connected with the discussed `Advance`-strategy as the focus in the indicated cases is in the first line on projects outside of the main dike line. Especially the `Altona Fish-Market`, the `HafenCity`, the `Neustädter Hafen` and the `Pauliner Marsch` and parts of the tributaries are indicted here, as the other cases focusing dominantly on the `Flood Defence`. The measurements within the indicated cases are very different and refer to their respective framework, which also connects to the differ in vulnerability. While the cases of the `Altona Fish-Market`, the `Pauliner Marsch` and the `Neustädter Hafen` keep the vulnerability slightly low with different measurements introduced, the `HafenCity` created a lot of room for incoming infrastructure and citizens and is therefore dependent on significantly larger and multiple measures. Moreover, it becomes clear that the aspects of `Flood Preparation and Response` play a decisive role in each of these areas, that are directly connected with the land-use of citizens. In addition, the strategy is partly connected with the `Ecosystem-based adaption`-strategy discussed in the following section.

Ecosystem-based adaption

This strategy is indicated in the cases of the 'Neustädter Hafen', and partly in the 'Pauliner Marsch' and the considered tributaries of the Weser and Elbe, as part of the areas are linked to floodplains (WHG) or the LaPro. The `Neustädter Hafen` and the `Pauliner Marsch` focus on the main river Weser and the other cases with the tributaries mostly on fluvial floodings. In terms of the FRM-strategies, `Flood risk prevention` and aspect of `Flood risk mitigation` can be assigned and are supported by `Flood defense` since it is indicated as an adapted, limited land use and the hinterland is protected by the main dike lines/secondary dike lines. This adapted land-use with nature is thereby also a form of adaptability and can be nearly connected with parts of the `Accommodation`-strategy above. In addition, it is connected to parts of the `Retreat`-strategy, by seeing retreat as an approach where urban and economic development is restricted to allow water and nature, also without a radical change in the land-use.

5.2. Comparison between the research areas Bremen and Hamburg

In this sub-chapter the thesis is concentrating on differences on a broader scale by focusing on the two selected research areas Bremen and Hamburg. In addition to the discussed design-strategies, the eight investigated cases were assigned to three thematically related subject-areas, prior to the analysis, in order to establish comparability. These are the following sub-topics, introduced in chapter 3.2.3.:

1. Cases that are exemplary for dealing with the existing main dike line.
2. Cases that are exemplary for an accommodated land-use.
3. Cases that are exemplary for existing floodplains, polder, or barrages.

These subtopics will be discussed in the following. To support the findings of the document analysis, different inputs of the interviews will be discussed here, and the discussion occasionally distinguishes between coastal and fluvial floodings.

Dealing with the existing main dike line

Coastal vs fluvial flooding

In dealing with the existing main dike, measurements are implemented very similarly in Bremen and Hamburg and both cities are focusing strongly on the `Flood Defence`-strategy, indicated in the case study, as they are dominated by long dike lines that reach together nearly 300 km. In both areas, a distinction is made between coastal and fluvial flooding, which was supported by the installation of barrages between the main river and the tributaries.

The developments at the main dike lines are primarily oriented towards the effects of coastal flooding in both cities, as this creates the biggest risk to the main dike line due to the rising sea level, the increasing tidal effect (figure 32; Schuchardt et al. 2007) and experience from the past. The effects of fluvial flooding are classified lower in these parts of the river (interviewee 3; interviewee 1). In the current situation the main dike line in Bremen and Hamburg are characterized by hights between 7.20 m and 10.50 m. Thereby, the expansion of the main dike line is based on the BWs defined in the BremWG and HWaG and additional increases are already scheduled for the coming decades in both cities, that will build up on the currently ongoing construction plans.

Differences can be seen between the continuity of the dike line as in Bremen 86% of the city is affected. In Hamburg, the southern area is predominantly affected, leaving areas in the northwest of the river without a necessary dike line for the hinterland (figure 29). Hence, in Bremen, the construction of the dikes is visible along the complete city, while in Hamburg there are punctual areas that must be considered less strongly. This became especially clear in the comparison between the ´Niederhafen` and the `Altona Fish-Market`, which are characterized by their geographical proximity, but choose completely different design- and FRM-strategies. Thereby, the 'Altona Fish-Markt' can predominantly concentrate on its own area and the 'Niederhafen' has to support the hinterland. Cases like the `Altona Fish-Market` are not flexible transferable but can be an important tool to regularly representing the potential risk on the broader scale.

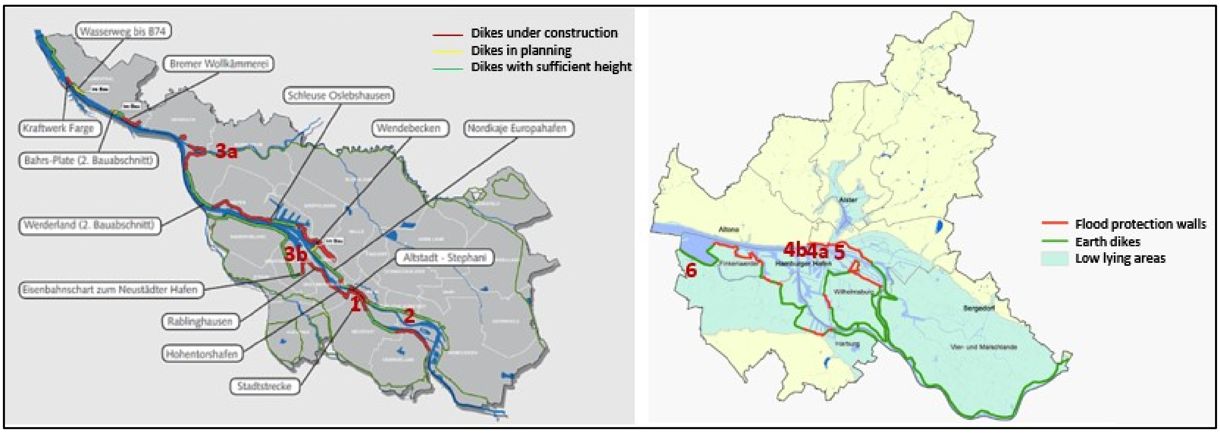


Figure 28: Left side: Existing dike line in Bremen (SKUMS_b, n.d.); Right side: Existing dike line in Hamburg (BUKEA, 2021)

Along the tributaries, the secondary dike lines/protective dike lines are dominating in both cities and both research areas are dealing similar with these areas, represented in the `Este` and `Lesum`. The secondary dike lines along the tributaries are lower in height and have not been raised since the barrages were expanded, as they were no longer affected by the coastal flooding and concentrating on storing fluvial flooding. In the current discussion, these secondary dike lines are increasingly relevant in both cities. Based on the FRM-agenda, these secondary dikes have been subjected to a review and will be selectively reinforced from 2025 onwards. A problem that occurs in both cities is the fact, that some areas behind the secondary dike line are not owned by the city and are necessary in the future as the dike lines will also increase in the wide (interviewee 1).

Centrally vs externally located dike line

In the analysis of the case study research, differences between the handling of the dikes in the urban centre and in areas that lie more outside were indicated, especially between the cases `Este`, `Niederhafen` and `Stadtstrecke`. Here, different factors come together, such as the limited space in the urban centre and the increasing BWs. The traditional dike lines (earth dike lines) are subject to clear requirements and besides the respective height a certain width and slope is assigned in order to grant the stability (BremWG, HWaG). Consequently, these dikes are less feasible in the urban centre in the long-term. One difference between both research areas is, that in Bremen a large part of the dikes are earth dikes, while in Hamburg a large part has already been developed as flood protection walls (figure 29). This is accompanied by major challenges and investments for Bremen, which is illustrated by the example of the `Stadtstrecke`, characterized a project with strongly vulnerable hinterland and limited place for the dike line. At the same time this opens the field for new measurements and possibilities to introduce the narrative `living with the water`. The traditional dike lines are characterized by a clear separation between water and land. These new projects could open this area for additional sectors of urban planning such as urban and open space, traffic development and other concern, like introduced in the `Stadtstrecke`, which increases the awareness of the citizens and stakeholders from different sectors.

Accommodated land-use

Outside the main dike line

In dealing with adaptive land use, a clear differentiation between the areas outside and along the main dike is evident in the case study and is even stronger recognizable by a more holistic view.

Outside the main dike line both cities act differently concerning an adapted land use. In Bremen, areas outside the main dike line are predominantly characterized by limited uses, such as green spaces, allotment gardens and connections to the landscape programs as indicated in the 'Pauliner Marsch' or the 'Niederhafen'. In Hamburg, where the area outside the main dike line is generally larger (figure 29), a different handling has been indicated. On the one hand it is dominating by large harbour areas and on the other hand projects like the `HafenCity` and the `Grasbrook` are visible. Here, immense investments are being made to bring commercial and residential areas into this area, that are redesigned by a high number of different measures, that try to create resilience for their environment. The resilience idea focuses strongly on the respective project, where a lot of useful parameters of `flood resilience` are implemented, and less on the larger frame of the city. Therefore, these areas outside the main dike line are dominating by different FRM-strategies like `Flood Risk Prevention`, `Flood Defence`, `Flood Risk Mitigation` and `Flood preparation and Response` implemented with different design-strategies and are specific focusing on the project scope and include aspects of reducing the possibilities and the consequences. Especially in the term of `Flood preparation and Response` and Flood Risk Mitigation` these areas outside the dike line can be of importance for the larger scale, because they are decoupled from the larger frame and can try things out, such as the model area `Pauliner Marsch`.

Scope of projects and involvement of people and local stakeholders

When looking at the scope of the different projects outside the main dike line, further differences between the two research areas become visible. In Bremen, the focus is more on smaller projects, where local actors and additional sectors are taken into account, such as the `Stadtstrecke` or the `Pauliner Marsch`. In Hamburg larger projects are introduced and the citizens are less involved, like the `Niederhafen` or the `HafenCity`. However, in both areas there is a huge focus on flood preparation and response (not indicated for the `Niederhafen`), where the interaction with the citizens and locale actors is of immense importance and are partly actively taken into the responsibility, such as the `Flutschutzgemeinschaft` at the `HafenCity` or the `Sturmflutpartnerschaft` at the `Pauliner Marsch`.

Existing floodplains, polder, or barrages

Coastal vs fluvial floodings

Concerning the fluvial floodings both research areas are very similar in terms of existing floodplains, polder, or barrages. The exemplary investigations at the `Lesum` and the `Este` indicates that the tributaries are characterized by barrages and floodplains and room for the river are visible. This is also supported by the more holistic view and the connections to the FRM-agenda, the GPK 3 and the landscape programs.

However, along the main rivers, which are affected by coastal floodings, different characteristics between the two research areas are indicated. Here, the Weser is dominated by various floodplains, such as the studied cases `Pauliner Marsch` or the ´Niederhafen`, and additional areas are indicated in the LaPro (figure 31). In Hamburg there are no similar floodplains along the Elbe indicated and the `ecosystem-based adaption` is solely dominated by floodplains along the tributaries.

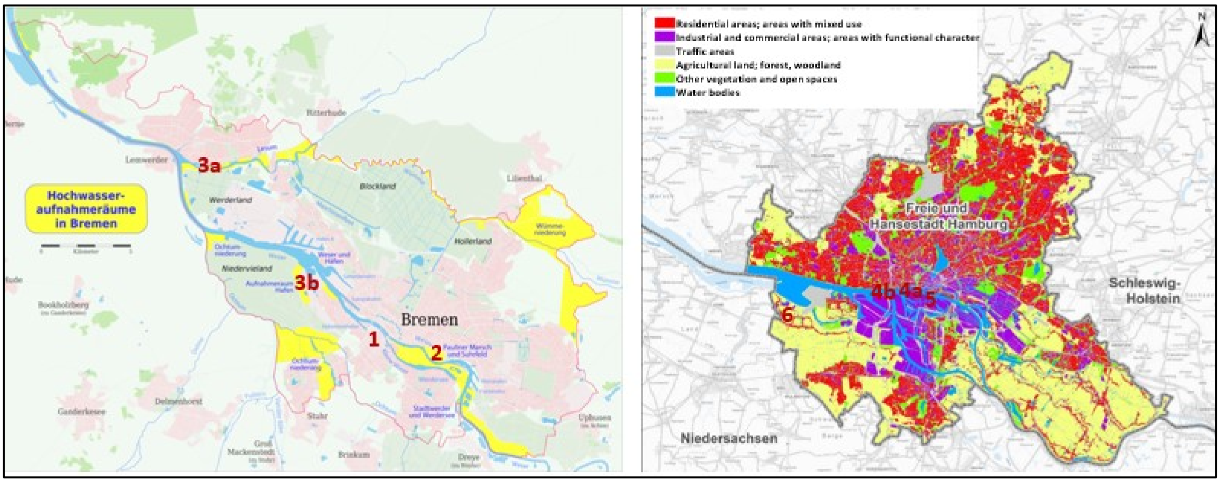


Figure 29: Left side: Overview `Hochwasseraufnahmeräume` (flood recoring rooms) in Bremen (SBU, 2003); Right side: Land use plan Hamburg (BUKEA, 2021)

Ecosystem based adaption vs increasing economic development

This goes along with one additional observation that goes hand in hand with the use of areas outside the main dike line. In Bremen, areas outside the main dike line are predominantly characterized by limited uses, such as green spaces, and connections to the landscape programs as indicated in the 'Pauliner Marsch' or the 'Niederhafen' and supported by the more holistic view. In Hamburg, a different consideration is indicated in the areas outside the main dike line as introduced before and `ecosystem-based adaption` does not play a relevant role. However, Hamburg is also characterized by a different dike line that is less narrow and provides more space for the river along the harbour areas that are at risk during floods (figure 29).

5.3. Classification in the broader frame focusing on the Key-Dimensions

This subchapter focuses on the key characteristics of resilience: robustness, adaptability, and transformability, as already compared in the data analysis focusing on the different cases. In this chapter, the focus is a bit broader with the goal of making a basic statement about the implementations within both cities, based on the results and discussions before and connect it with some barriers indicated throughout the case study.

Robustness

`Robustness` is implemented quite similarly in both research areas and is at the broader consideration the dominant `dimension`. Further extensions of the dike lines are already planned, which will follow the ongoing planning processes of GPK 1 and the current projects in Hamburg as well as the strengthening of the secondary dike line along the tributaries.

Thus, there are differences between fluvial and coastal flooding. Secondary dikes are more likely to be raised slightly, as in the example of the `Lesum`, where the focus is on strengthening the dike line in the coming years. Here, measurements along the dike lines are seen as measurements alongside others, such as floodplains, green spaces along the river and are extended as a second robustness line with respect to the main river due to possible failures of the barrages. In comparison, the scale of "robustness" implemented along the main river is much more pronounced, illustrated in figure 30. It shows that in addition to the BWs, the dikes are increased by the expected sea level rise and precautionary measurements and is reinforced by the new developments of the IPCC report. In addition, the dikes in Hamburg have increased significantly since the 1962 flood and the dikes are much higher than in subsequent floods.

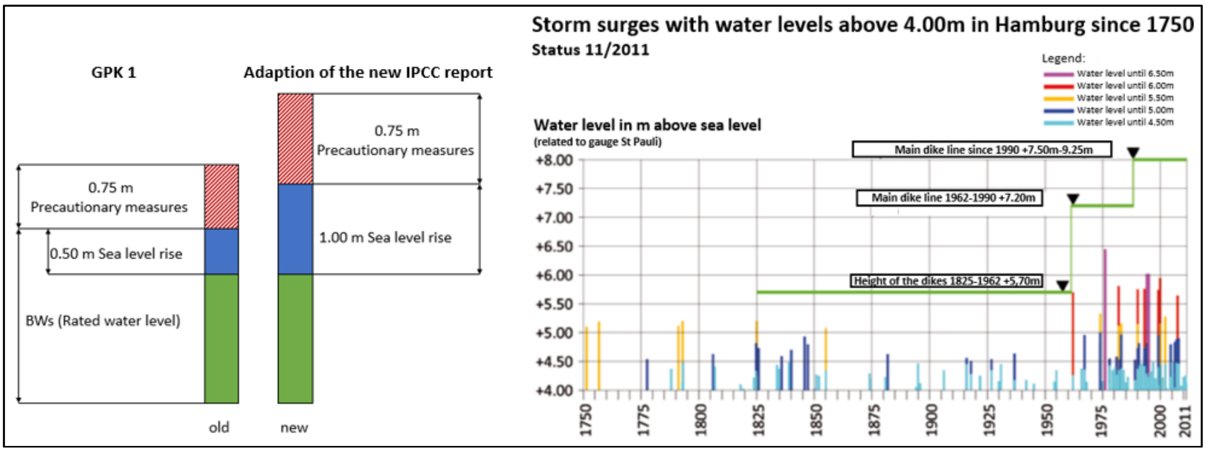


Figure 30: Left side: additional increase of dike lines based on GPK 1 and additional requirements due to the latest IPCC report (prepared by author based on Krebs (2021)); Right side: overview of flood events in Hamburg and the development of the dike line in Hamburg (LSBG, 2012b)

This indicates the immense importance of "Robustness", which plays the dominant role in both research areas by dealing with coastal flooding along the main river, due to the path-dependency and the pronounced `levee effect` introduced in earlier sections (figure 28). Huge investments are needed here as a first main barrier. Considering the investments made in the last decades, the regulations in the GAK and the aspect, that these urban areas are characterized by enormously vulnerable infrastructure and citizens, further investments will be hedged in the future, as there is a political understanding of the need for these measures (interviewee 3). With links to the case study, this is visible in huge planning process, such as the `Niederhafen` or the `Stadtstrecke`.

Additionally, these leads to a second main barrier. This sense of security, which is also conveyed to the public, means that citizens and stakeholders are generally less aware about flood risks, and policy makers can provide a false sense of security. Therefore, citizens are less prepared and may have difficulty adapting to a new situation (Liao, 2012). This is stated as a problem that needs to be addressed in various measures and is visible in most of the investigated cases related to coastal flooding, especially in the implementation of `Flood Preparation and Response`-strategy. This refers especially to the interaction with the two dimensions `adaptability` and `transformability`.

Adaptability

`Adaptability` on the broader frame is difficult to categorize precisely, since it was implemented differently in the cases. However, in the cases studied several measures have been implemented that increase the `adaptability` of the respective area, since they are specifically linked to the idea of reducing the consequences besides the focus on solely `robustness`. A distinction needs to be done between the areas outside the dike line and along the dike line.

Along the dike line, the implementation of various measures is limited and has to deal with the local-context and the interaction with `robustness`. Here, re-design of various infrastructures can be of decisive importance (figure 31) to increase the possibilities of implementing `adaptability` measures. An example is the `Stadtstrecke`, that is characterized by a process of transformation from an earth dike line towards a flood protection wall. During this re-design-process, there is room for measures, such as integrating urban planning, increasing awareness among citizens and local actors, or implementing the narrative of `living with the water` by creating space for citizens along the dike line at the waterfront. By focusing solely on persistence or adaption of existing earth dikes there is less room for measurements in these areas connected to path-dependency. Of course, these involve huge investments, but development shows that earth dikes are a limited long-term solution in high-density areas, and possibilities of investments are given due to the GAK and issues of necessity.

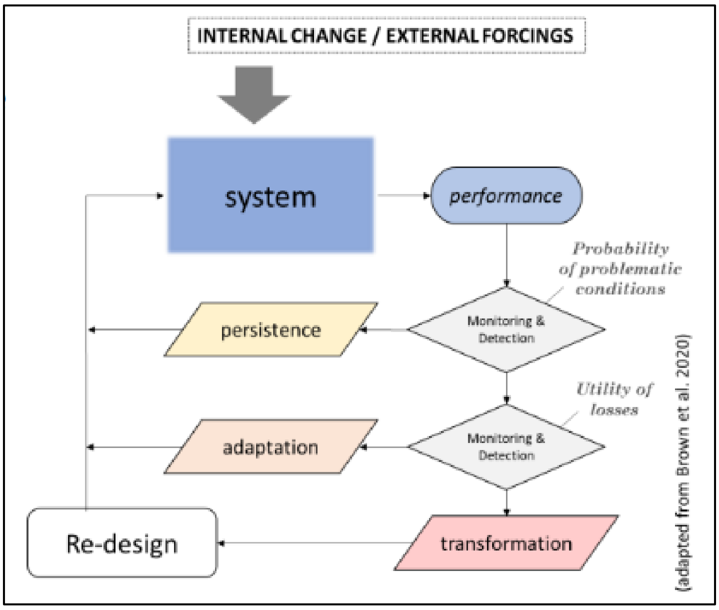


Figure 31: Resilience by design (Brown et al., 2020)

Outside the main dike line is more room for experimenting different measures. In the case study, five different design-strategies were identified: 'No response', 'Advance', 'Accommodation', 'Protection' and `Ecosystem-based solutions`. These could be assigned to different FRM-strategies, sometimes with different constellations. Thereby, `Flood Preparation and Response` is playing an increasing role in the consideration, which is very important also with regard to the fact that the robustness is still very high in both cities (Liao 2012). There is also a difference between the two cities in the way vulnerability is dealt with. It is kept very low in Bremen with ecosystem-based adaptation and the combination of limited land-use that is coordinated with the surrounding urban environment. On the other hand, the `HafenCity` is an interesting example of how measures for large infrastructural areas can be created and adapted with different considered barriers.

In conclusion, the importance of experimentation along a transition is important, that can be implemented in areas outside the main dike line with a clear focus on measures that include `adaptability`. The goal would be to implement them on a larger scale in other areas of the city afterwards, or to be seen as examples for the implementation in other cities and countries.

Transformability

Similar to the `adaptability` it is very difficult to define this term in a broader frame as it is a very slow process and not all aspects of social change have been addressed during the analysis. However, based on the document analysis and the case study, various aspects, and important tools of `transformability` are summarized. The most important aspect is the implementation of the FRM-agenda into directives and regulations, which is a central step for a transformation on different levels. In this regard, the FRM-agenda has already brought many positive aspects of `transformability` into play, particularly in the areas of communication between different federal states and stakeholders, increasing involvement of areas behind the dike line to reducing possible consequences, the identification of new risk areas along smaller rivers, and regular monitoring on local up to large catchment area-scale. This is also reflected in the measures taken in connection with the various cases. In particular, risk awareness is much more thematized and integration with other planning areas, as in the case of the `Stadtstrecke`, should be emphasized. Overall, Bremen is slightly ahead in terms of communication and more sustainable implementation, but nevertheless both areas are characterized by aspects of path-dependencies, which means that different development are slower in specific areas in the urban environment and needs to be implemented more based on their local context. Since dealing with flooding is an ongoing task, it remains to be seen how it will develop in the future and to what extent the ability to change infrastructures and areas with connection to path-dependency can be further promoted.

Chapter 6 – Final Recommendations and Future Outlook

6.1 Conclusion and Final Recommendations

To sum up, planners in both areas need to adapt to the conditions that currently exist, but this thesis shows different ways of implementation and adaptation on the ground to overcome the increasing barriers presented. To continue this slow trend, this paper concludes with 6 short recommendations that are considered important for a gradually increase of resilience step by step in the long run.

- Create adapted solutions on the locale scale along the main dike lines by connecting flood protection with urban planning sectors (approach of integrating urban planning)
- Use areas outside the main dike line as areas for experimenting, learning and awareness raising. Create room for the river with low vulnerability, that can be experiments by citizens.
- Prevent further lock-ins. No construction of new critical infrastructure in risk areas or areas outside the dike line (is oriented to the BRPH)
- Amplifiers of communication also across state borders to learn from each other
- Intensification of monitoring, repeated review and adjustment of dike lines based on BWs (review period of 10-15 years).
- Use extreme weather events to address the increasing problem at larger scales

6.2 Reflection and Future Outlook

In the regard of the used methodology, the case study has proven to be a useful method to investigate this field of interest, as it gives a deeper insight into different implementations in the field and thus makes them comparable between the research areas. Also, the linkage with the previous document analysis as indicated as useful, as it helps to place the results in a larger framework in a later discussion and conclusion. However, there is additional room, where further investigations would improve the depth and expressiveness of this thesis. One main reason is here, that the case study selected the cases, based on three different fields of interest (existing main dike line, accommodated land-use, existing floodplains, polder, or barrages). Regarding this, the thesis identifies major differences between more centralized and decentralized dike lines, the adaptability inside and outside the main dike line, and floodplains along the main river and the tributaries. This includes aspects that were not always closely related to each other at the thematic level. The stronger focus on individual parts of these aspects would help to deepen the implied discussion and would be interesting fields of studying to in depths the results of this thesis. Especially with the background that the challenges due to climatic change are not decreasing, the whole field of interest is a permanent task, which has to be monitored and improved also in the next decades.

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Upper left side: https://www.focus.de/wissen/natur/meteorologie/vorsicht-an-der-nordsee-sturmflut-droht-am-wochenende-tief-rudolf-bringt-schauer-und-viel-wind-in-den-norden_id_24399257.html

Upper right side: https://www.weser-kurier.de/bremen/bei-flut-in-der-pauliner-marsch-anwohner-warnen-sich-gegenseitig-doc7fbpi888zmp1l4m5loqh

Right side: https://www.tagesspiegel.de/gesellschaft/panorama/orkan-sabine-im-newsblog-sturmflut-in-hamburg-fischmarkt-unter-wasser/25526618.html

Lower left side: Krebs (2021). Projektvorstellung: Hochwasserschutz für die Bremer Neustadt

Lower right side: https://www.genevaassociation.org/sites/default/files/flood-risk-management-germany.pdf

Appendix

A: Document analysis

Table 7: Selected documents with a holistic focus in both research areas (created by the author)

	Selected Documents (Document name, references, and translation)
European/ National scale	**Legal basis** ➔ Richtlinie 2007/60/ES des europäischen Parlaments und des Rates über die Bewertung und das Management von Hochwasserrisiken (Europäische Union, 2007) - `Directive 2007/60/EC of the European parliament and of the council on the assessment and management of flood risks` ➔ Wasserhaushaltsgesetz (WHG, n.d.) - `Water Resources Act`
Bremen (overall view)	**General plan for coastal protection and Bremen Water Act** ➔ Küstenschutz Band 1: Generalplan Küstenschutz Niedersachsen/ Bremen – Festland (NLWKN, 2007) - General Plan for Coastal Protection for Lower Saxony/ Bremen – 1. Mainland ➔ Küstenschutz Band 3: Generalplan Küstenschutz Niedersachsen/ Bremen – Festland (NLWKN, 2020) – General Plan for Coastal Protection for Lower Saxony/ Bremen – 3. Protective Dikes ➔ Bremisches Wassergesetz (BremWG, 2020) - `Bremen Water Act` **Flood-Risk-Management Directives** ➔ Hochwasserrisikomanagementplan 2015 bis 2021 (FGG Weser, 2015) - `EC Flood Risk Management Directive 2015-2021` ➔ Hochwasserrisikomanagementplan 2021 bis 2027 (FGG Weser, 2021) - `EC Flood Risk Management Directive 2015-2021` **Land use plan** ➔ Flächennutzungsplan Bremen (FNP_B, 2014) - `Effective land use plan Bremen` ➔ Landschaftsprogramm Bremen - Teil Stadtgemeinde Bremen (LaPro_B, 2015) - `Landscape program Bremen - Part municipality Bremen`
Hamburg (overall view)	**General plan for coastal protection and Hamburg Water Act** ➔ Gewässer und Hochwasserschutz in Zahlen (LSBG, 2012a) - `Water bodies and flood protection in figures` ➔ Sturmflutschutz in Hamburg: gestern – heute – morgen (LSBG, 2012b) - `Storm surge protection in Hamburg 'yesterday - today – tomorrow'` ➔ Hamburgerisches Wassergesetz (HWaG,n.d.) - `Hamburg Water Act` **Flood-Risk-Management Directives** ➔ Hochwasserrisikomanagementplan 2015 bis 2021 (FGG Elbe, 2015) – ´Flood Risk Management Plan for the German part of the river basin district Elbe for the period from 2015 to 2021 according to § 75 WHG´ ➔ Hochwasserrisikomanagementplan 2021 bis 2027 (FGG Elbe, 2021) - ´Flood Risk Management Plan for the German part of the river basin district Elbe for the period from 2021 to 2027 according to § 75 WHG´ **Land use plan** ➔ Flächennutzungsplan Hamburg (FNP_H, 2022) - `Effective land use plan Hamburg` ➔ Landschaftsprogramm Hamburg (LaPro_H, 2022) - `Landscape Program Hamburg`

Table 8: Selected documents with a more specific view on the selected cases (created by the author)

Cases study	**Selected Documents** (Document name, references, and translation)
1. 'Stadtstrecke` **(Bremen)**	➔ Generalplan Küstenschutz – Deichstrecke (Bremischer Deichverband am linken Weserufer, 2016) - `General plan for coastal protection – Stadtstrecke: Feasibility study for planning sections 1 to 3 ` ➔ Projektvorstellung: Hochwasserschutz für die Bremer Neustadt (Krebs, 2021) - ` Project presentation: Flood protection for Bremen's `Neustadt`
2. Model area `Pauliner Marsch` as part of the `BREsilient`-Program (Bremen)	➔ Hochwasserrisikovorsorge für die Pauliner Marsch – Situationsanalyse (SKUMS, 2020a) - `Flood risk prevention for the Pauliner Marsch - Situation Analysis` ➔ Hochwasserrisikovorsorge für die Pauliner Marsch – Gefährdungsanalyse (SKUMS, 2020b) - `Flood risk prevention for the Pauliner Marsch - Hazard analysis`
3. a) Floodplains `Lesum` and **b) Flood-Protection Polder `Neustädter Hafen`** **(Bremen)**	➔ Küstenschutz Band 3: Generalplan Küstenschutz Niedersachsen/ Bremen – Festland (NLWKN, 2020) – General Plan for Coastal Protection for Lower Saxony/ Bremen – 3. Protective Dikes ➔ Landschaftsprogramm Bremen - Teil Stadtgemeinde Bremen (LaPro_B, 2015) - `Landscape program Bremen - Part municipality Bremen` ➔ Ein neues Naturschutzgebiet für Bremen: Der Hochwasserpolder am `Neustädter Hafen` (SKUMS, 2013) - `A new nature reserve for Bremen: The Flood Polder at `Neustädter Hafen
4. a) Flood-Protection-System 'Niederhafen' and **b) infrastructure at the Altona `Fish-Market`** **(Hamburg)**	➔ Neubau der Hochwasserschutzanlage Niederhafen (LSBG, n.d.) - `New construction of the Niederhafen flood protection system` ➔ Elbpromenade mit Hochwasserschutz und Parkebene – Hamburg Niederhafen (Ingenieurbüro Dr. Binnewies, 2022) - `Elbe promenade with flood protection and parking level - Hamburg Niederhafen` ➔ Wasserstände, Sturmfluten, Sollhöhen in Hamburg - Am Beispiel des Pegels St. Pauli (BUKEA, 2018) - `Water levels, storm surges, target heights in Hamburg - The example of the St. Pauli gauge   ➔ Hochwasserschutz (Fischmarkt Hamburg-Altona GMbH, n.d) - `Flood protection`
5. Selected strategies of the western part of the HafenCity **(Hamburg)**	➔ Hafencity und Speicherstadt – Sturmflut-Hinweise für die Bevölkerung (BIS, 2021) - `Hafencity and Speicherstadt - storm surge advice for the public` ➔ HafenCity Hamburg - Neuauflage: Der Master Plan (HafenCity Hamburg GMbH; 2006) - `HafenCity Hamburg - New edition: The Master Plan` ➔ Die Innenstadt rückt an die Elbe – HafenCity (BSE, n.d.) - `The city center moves closer to the Elbe – HafenCity`
6. Tributary ´Este´ **(Hamburg)**	➔ Gewässer und Hochwasserschutz in Zahlen (LSBG, 2012a) - `Water bodies and flood protection in figures` ➔ Hochwasserschutz für die Hamburger Binnengewässer (LSBG, 2009) - `Flood protection for Hamburg's inland waters` ➔ Hochwasserschutz für Hamburg: Ertüchtigung des Cranzer und Neuenfelder Hauptdeiches (REGE Hamburg, n.d.) - `Flood protection for Hamburg: Upgrading the `Cranz` and `Neuenfeld` main dike`

B: Interview Guide

This interview guide is translated from the original created German versions used in the interviews.

Table 9: Interview guide (created by the author)

Sub-Topic 1 – Introduction
➔ Background Interviewer: Personal background, topic of the thesis, purpose of the interview ➔ Consent for recording and use of the interview ➔ Introduction interviewee: Could you please briefly introduce yourself and your tasks within your job?
Sub-Topic 2 – Assessment of different flood risks
➔ Comparison between coastal, fluvial, and pluvial floodings in urban environments ➔ Which do you currently see as the biggest challenge for your specific location?
Sub-Topic 3 – Flood-Risk-Management-Agenda
➔ To what extent is the new approach with FRM noticeable in the specific city? ➔ Who is responsible for the measures (LAWA, FFG, etc.)? ➔ Which role plays the FFG for the city with the specific issue of possible coastal floodings?
Sub-Topic 4 – Design-Strategies
➔ Keywords \`increasing dike-lines\`: For what period are the current dike increases sufficient? Are further increases already planned for the next decades? ➔ Keyword floodplains: Clear focus on inland waters? Are there considerations for storm surges as well? ➔ Keyword retreat: Are there areas in the city where, due to the increasing challenges, certain demands that existed before, such as residential buildings, had to be postponed? ➔ Keyword accommodation: outside vs inside of the main-dike line ➔ Keyword large projects vs smaller projects
Sub-Topic 5 – Additional Case related question
➔ Specific questions regarding the cases studied on each city
Sub-Topic 6 – Closing
➔ Anything you would like to add or ask? ➔ Arrange sharing of additional project materials and contacts ➔ Thank you for the interview

C: Coding Scheme

Table 10: Coding Scheme (created by the author)

Field of interests	Deductive Codes	Inductive Codes
Regulations/ Directives	European level National level City/Federal-State level Interactions between these levels	
FRM-Strategies	Flood Risk Prevention Flood Defence Flood Risk Mitigation Flood Preparation and Response (Flood Recovery)	
Barriers	Physical barriers Financial barriers Regulatory barriers Institutional barriers	
Handling depending on different times	Dealing in the past Current strategies Handling in the future	
Connectivity, collaboration		Citizens/local stakeholder
Controversies		Political priorities Conflicting uses Costs Communication
Practicalities		Contact persons Relevant projects Useful sources

D: Case Study Results

1. Bremen

Table 11: Data Matrix – Bremen (created by the author)

	1. Project `Stadtstrecke`	2. Model area `Pauliner Marsch` as part of the `BREsilient- Program	3a). Floodplains at the river Lesum	3b). Flood-Protection-Polder `Neustädter Hafen`
Coastal/Fluvial Flooding	Focus mainly on coastal floodings	Focus mainly on coastal floodings, but connection with fluvial flooding	Focus on both, coastal & fluvial floodings	Focus mainly on coastal floodings
Design-Strategy (First View)	(c) Protection	(e) Accommodation	(c) Protection (f) Ecosystem-based adaption	(f) Ecosystem-based adaption
FRM-Strategies	Flood Defence	Flood Defence (limited) Flood Risk Mitigation Flood Preparation and Response	Flood Defence Flood Risk Mitigation Flood Preparation and Response	Flood Risk Prevention Flood Defence
Land use plan	Vulnerable hinterland, with commercial and residential areas	Green spaces outside the main dike line with sports fields and allotments	Green spaces and natural areas along the dikes, hinterland partly residential areas	Natural areas with special landscape conservation significance
Landscape program	No direct connection; Compensation areas necessary	Part of the area connected to the program	Part of the area connected to the program	Nature reserve
Robustness	Yes, as the dike line will be renewed, based on the requirements in the GPK 1 and the current development of the BWs.	Limited, as the height of the upstream dike line is set at 5.50 m. Hinterland is secured by the main dike line.	Yes, as the dike lines and barrage are adapted at the BWs. Additionally, the protection dike line along the river Lesum will be strengthened based on GPK 3	Yes, as it is a polder to give the river more room, if necessary and is secured by the main dike line, that is based on the GPK1 and the BWs.
Adaptability	Limited, new dike line but only focusing on reducing possibilities and not the consequences for the hinterland. But connects different sectors with floodings and include the citizens/locale stakeholders actively, also with risk communication.	Yes, as the area has an adaptive land-use concept, due to the requirements of the area. Thereby, the vulnerability is low in this area and the awareness of actors and risk communication is increasing.	Limited, but address an important aspect. Protective dike line is adjusted, and the space behind the main dike line is considered more strongly. In addition, more room for the river along the tributaries.	Yes, as the specific land-use is adapted to a possible flooding event in this area, as it is a nature reserve. No additional land-use and therefore a low vulnerability.
Transformability	Limited, as the focus is on reducing the possibility of floodings with the designed dike line, but a new way of doing this process with more integration of different stakeholders, citizens and sectors is visible. Step towards narrative `living with the water` from the design-perspective.	Yes, as the focus is on living with the water as a potential flooding has no immense impact und becoming more and more resilient is adapted on with different measurements together with local actors.	Increasing, as the space behind the main dike line is considered more strongly.	Limited, as it is one specific area that is highly adapted, but similar examples on the broader scale were not indicated

Risk communication	Yes, visible in the workshops and presentations for the citizens and additional measurements, like information panels and additional information's on specific websites	Yes, visible in the workshops and presentations for the citizens and additional measurements, like set up information panels and additional information's on specific websites	Projects focus primarily on expansion of the dike line to ensure safety	Not assessable (not relevant for this area as it is set as a nature reserve)
Involvement of citizens, local stakeholders	Yes, as we the `Deichcharta` opens room for citizens and stakeholders to participate.	Yes, is in important tool here, as it acts as a model area to try out different things. Citizens and local stakeholders are part of the planning process.	Limited, as projects focus on dike expansion and therefore is concentrating on informing.	Not assessable (not relevant for this area as it is set as a nature reserve)
To what extent involved in the broader scale, regulations & directives	Project is part of the GPK 1, but requirements are increasing due to the increasing challenges with the BWs, based on the newest IPCC report.	Part of the FRM-agenda with risk areas and hazard maps. Additionally, part of the Landscape program and the wider program `BREsilient` to create resilience in the urban environment.	Part of the GPK 3 and the FRM-agenda, whereby the space behind the main dike line is considered more strongly.	Nature reserve area and part of the Landscape Program
Current status of the projects/ infrastructure	Planning basis started already in 2010, but due to various conflicts of use, participation of citizens and local stakeholders and different feasibility studies, the project is still in planning process.	Project will conclude next year with a `Sturmflutpartnerschaft`. In addition, there are plans to transfer this project to similar areas along like `Stadtwerder` or `Rablinghausen`.	Lesum (barrier) for protection against coastal flooding was completed in 1974. Protective dike line along the Lesum will be adapted based on GPK 3 from 2025 onwards.	Area was directed as nature reserve in 2014
Similar areas within the city	Yes, it is exemplary for dealing with the main dike line in the complex urban centre with different interests and sectors.	Concepts will be implemented to other areas based on the interviews. But it is only transferable to areas outside the main dike line	Yes, area is exemplary for the tributaries `Wümme` and `Ochtum` with similar characteristics.	No additional case was indicated.
Barriers/ Problems	1. Limited space for additional measurements 2. increasing BWs due to the newest IPCC report within the planning process	1. Not transferable to areas within the main dike line 2. Sensitization of citizens and local stakeholders sometimes difficult	No barrier indicated	1. Limited area, that is difficult to transfer to other locations, as has to be inside the main dike line

2. Hamburg

Table 12: Data Matrix – Hamburg (created by the author)

	4a). Flood-Protection-System \`Niederhafen\`	4b). Area/Infrastructure of the Altona \`Fish-Market\`	5. Specific aspects of the western part of the \`HafenCity\`	6. Este
Coastal/Fluvial Flooding	Focus mainly on coastal floodings	Focus mainly on coastal Flooding	Focus mainly on coastal Flooding	Focus mainly on fluvial floodings, but also in connection with coastal flooding
Design-strategy (First view)	(c) Protection	(a) No response	(b) Advance	(c) Protection (f) Ecosystem-based adaption
FRM-Strategies	Flood Defence	Flood Mitigation Flood Preparation and Response	Flood Defence Flood Mitigation Flood Preparation & Response	Flood Defence Flood Risk Mitigation Flood Preparation & Response
Land use plan	Vulnerable hinterland, with commercial and residential areas	Less vulnerable, due to mixed construction areas and partially time-limited use	Vulnerable area, with commercial and residential areas and additional public and cultural infrastructures.	Residential areas, some of which are protected by special regulations, green areas and commercial areas.
Landscape program	No direct connection	Limited, as landscape program is not indicated in the connection with flood protection	Limited, as landscape program is not indicated in the connection with flood protection	Yes, specific areas are part of the landscape program
Robustness	Yes, as the dike line was increased and provides protection against floods between 8.60 m and 8.90 m, based on the required measurements (BWs).	Limited, as the area is not protected by a main dike line and is regularly flooded. It is already affected between 2.90m at the Parking spot \`Neumühlen\` and 3.50m at the Fish Auction Hall. Adjacent area to the east is protected by a dike line.	Yes, as the area was adapted at the BWs from 2001 with the \`mound\`-concepts on 7.50 m. However, the height cannot be adjusted subsequently.	Yes, as the exiting main dike line, will be adapted due to the BWs. In addition, the expansion of secondary dike lines is considered.
Adaptability	Limited, as the renewed dike line offers adapted safety, but is only focusing on the possibility and not on the consequences of a possible flooding.	Yes, if we focus on the uses within this area that will be possible flooded the consequences are low -> low vulnerability In addition, Flood Preparation and Response is very detailed and effective	Limited. On the one hand a lot of different measurements such as elevated roads, urban dwelling mounds and the \`Flutschutzverordnung´. On the other hand, the height of the area is not adjustable, and the land-use is enormous.	Limited, but address an important aspect. Protective dike line should be adjusted in the long term, and the space behind the main dike line is considered more strongly. In addition, more room for the river along the tributaries.
Transformability	Limited, as it is a huge project that concentrating on reducing the possibilities of a flooding and not the consequences. Nevertheless, step towards \`living with the water\` are indicated from the design-perspective.	Limited, as these areas are regularly flooded and can thereby help to frame the floodings issue regularly as important and necessary. Nevertheless, area not exemplary for a land-use on the larger scale.	Limited, as it indicates aspect of living with the water and adapted measurements but brought an area with a potentially high vulnerability into this area, that is characterized by flooding risks.	Increasing, as the space behind the main dike line is considered more strongly.

Risk communication	Not indicated	Yes, main tool in this area, and based on different measurements like \`Böllerschüsse\` and warnings via radio, sirens, and local public address vehicles.	Yes, important tool in this area. Keyword: \`Flutschutzemeinschaft\` and flood preparation and response	Projects focus primarily on expansion of the dike line to ensure safety
Involvement of citizens, local stakeholders	Limited, focus during the project on informing citizens and locale stakeholders	Important tool for the Flood Preparation and Response and focusing on informing.	Limited, focus during the project on informing citizens and locale stakeholders	Limited, focus is mainly on informing.
To what extent involved in the broader scale, regulations & directives	Dike renewal based on the dike ordinance and the increasing BWs	Not indicated	Not indicated, as the project was stared in 2001. Nevertheless, it orients at regulations and directives like the BWs and the \`Flutschutzordnung\`	Part of the FRM-agenda and the dike ordinance.
Status of the projects/ infrastructure	Project was finished in 2019.	Existing infrastructure, that is not planned to change in the next decades.	Start of the first construction phase in 2001 and the whole idea is to be extended to the other side of the Elbe, the \`Grasbrook\` area.	The main dike line will be adapted in a current project and the secondary dike line in the long-term.
Similar areas within the city	Exemplary for flood protection in an urban centre, however, in the larger scale no comparable case is indicated.	Not indicated	Like the new project \`Grasbrook\` on the opposite side of the Elbe	Like additional tributaries in Hamburg visible in figure 22
Barriers/Problems	1. Transferability limited due to enormous projects/investments	1. Transferability limited on the broader scale	1. Flood protection not adaptable to the rising BWs as the main dike line. 2. The opposite of retreat as it brings a lot of land use and potential vulnerability to an area that is subject to flooding.	1. Space for the secondary dike line is limited, and the public does not own all the necessary land

E: Additional Figures

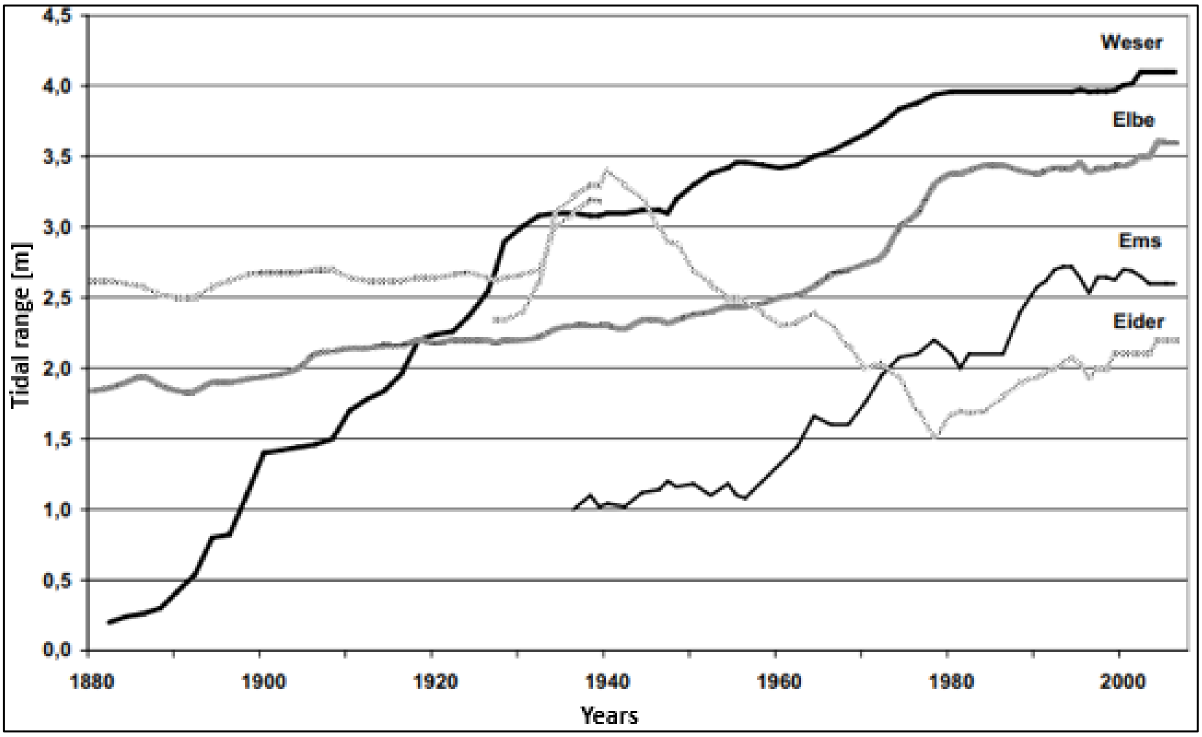

Figure 32: Changes in tidal range in the Eider, Elbe, Weser, and Ems (Schuchardt et al. 2007)

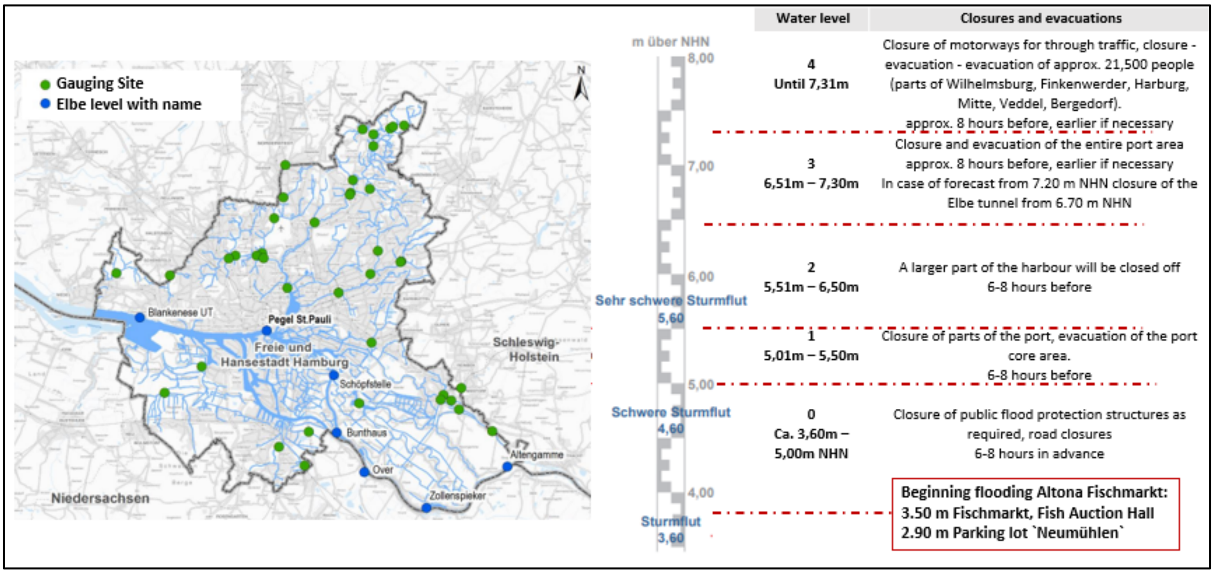

Figure 33: Overview of the gauging sites in Hamburg and information's about closure and evacuation at specific water levels (created by the author based on BUKEA (2018) and BUKEA (2021))

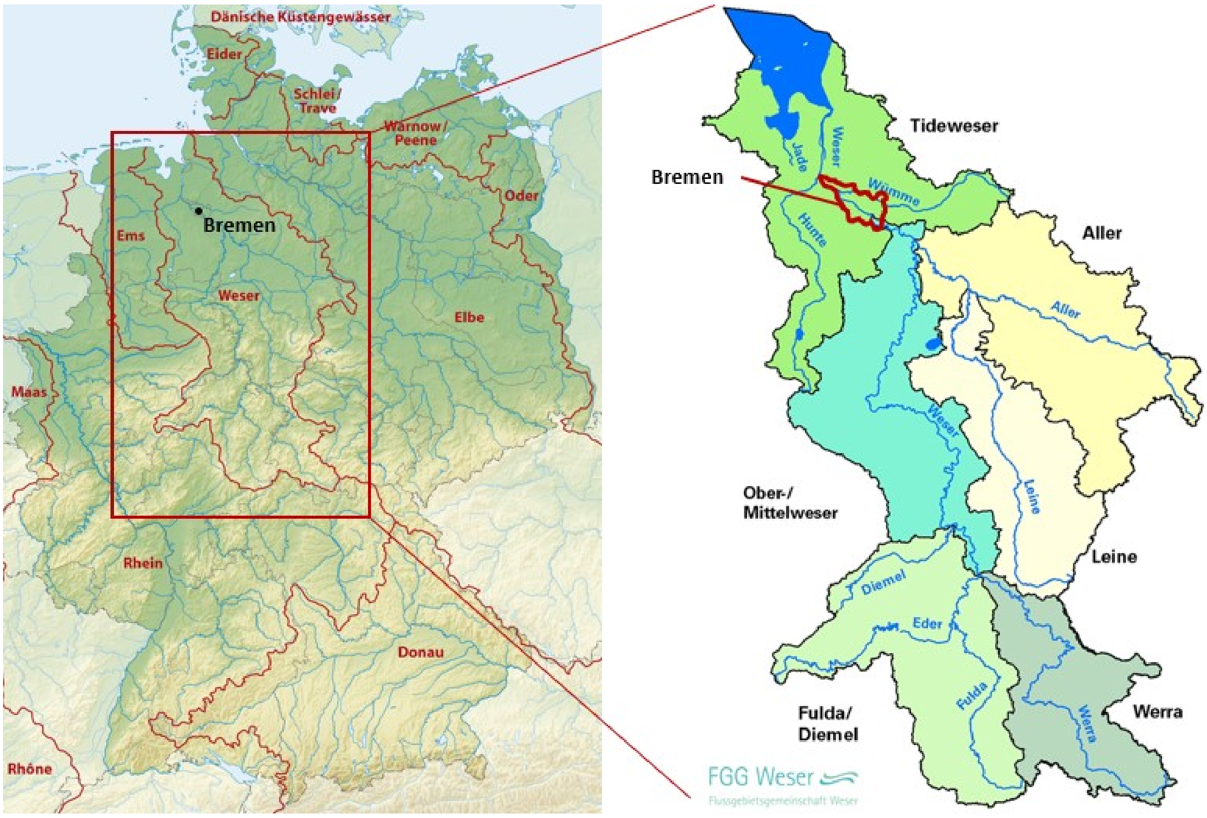

Figure 34: Overview of the River Basin of the river Weser, defined by several sub-areas (created by the author based on wikipedia.org (n.d.) and FGG Weser (2015)

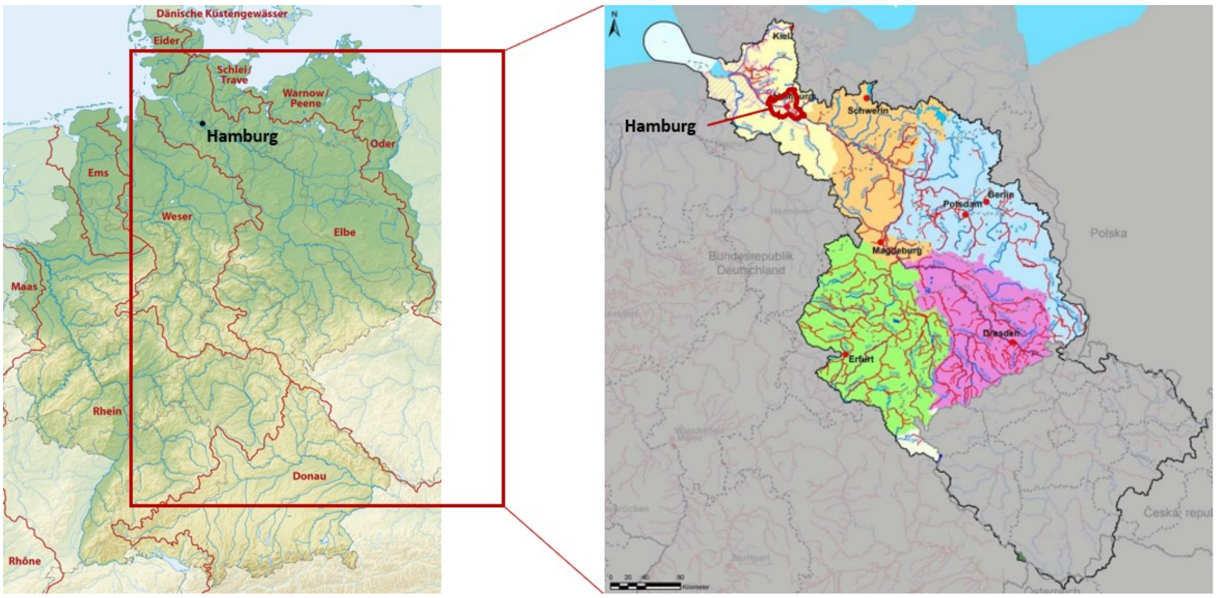

Figure 35: Overview of the River Basin of the river Elbe, defined by several sub-areas (created by the author based on wikipedia.org (n.d.) and FGG Elbe (2015))