Resilient Medway River Landscape

Adaptive Design Strategies for a Sustainable Coastal Landscape

Graduation Project

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European Post-master in Urbanism

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July 2021

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This accomplishment would not have been possible without them. Thank you.

Abstract

Coastal areas and riverine cities accommodate the great majority of the world's population, but they are extremely vulnerable to flooding risks. In the cities next to the Medway River estuary, the capacity to adapt to flood risks had been weakened by urban development and intense industrial usage. This degrading led to the loss of flood buffers and the recreational value of the coastal landscape. Moreover, climate change threatens large areas of nationally important habitats in the estuary. Coastal habitats are likely to be submerged by the rising sea. The rise in sea level can also accelerate the natural erosion of coastal cliffs.

To address these problems, a more resilient landscape approach is needed to increase the coastal resilience. Therefore, this design-related research regarded resilience as the theoretical backbone, embraced landscape-based design approaches, including layer approach, scenario study, and mapping as research strategies.

The project developed and applied design strategies in three lower-scale sites. First, the site on the Isle of Sheppey focused on coastline protection. A nature-based offshore island structure is proposed to diminish the surf, create space for tidal habitats, and provide recreational use. Next, on the Rainham coastline, to respond to intertidal habitat loss, managed realignment and growing marshes are the key strategies to restore the dynamics of the ecosystem. Last, the study proposed a transformation scheme for the Medway city estate site to relocate flood defence, provide space for tidal rivers, and accommodate mixed-use development. Each proposal could grow with time, increase ecological benefits, and create multifunctional programs. In the end, the study framed a vision on regional development, aiming to increase the socio-ecological resilience of the Medway river landscape.

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Understanding of the system

PART 3
Towards an Adaptive River Landscape

Fig. 17th-century painting of naval vessels moored on the River Medway, viewed from Chatham with Rochester Bridge in the background. One of the intervention sites, Medway City Estate, is the peninsula in the middle right of this painting. (Image source: https://collections.rmg.co.uk/)

PART 1

Introduction

"Europe's great rivers have always been perceived with a certain degree of ambivalence. This ambivalence is rooted in the landscapes that have been shaped by the rivers over generations. They exert a unique esthetic fascination born out of combined stillness, sheer breadth and irrepressible energy. The topography of rivers, while providing protection from attack and affording a valuable vantage point, also carried the ever-present threat of flooding and pestilence.

They were held in great respect, and building development kept a safe distance from their waters. The urban taming of rivers, in particular the design of riverbanks during the Renaissance period and the (post) Napoleonic era, increased the tension between the civilizing force of the city and the water's natural energy. Over the history of urban development, this relationship has consequently undergone a continuous process of change which has seen communities in turn embracing and rejecting their heritage."

—The Appeal of Riverscapes, Thomas Sieverts, 2010

1 – Introduction

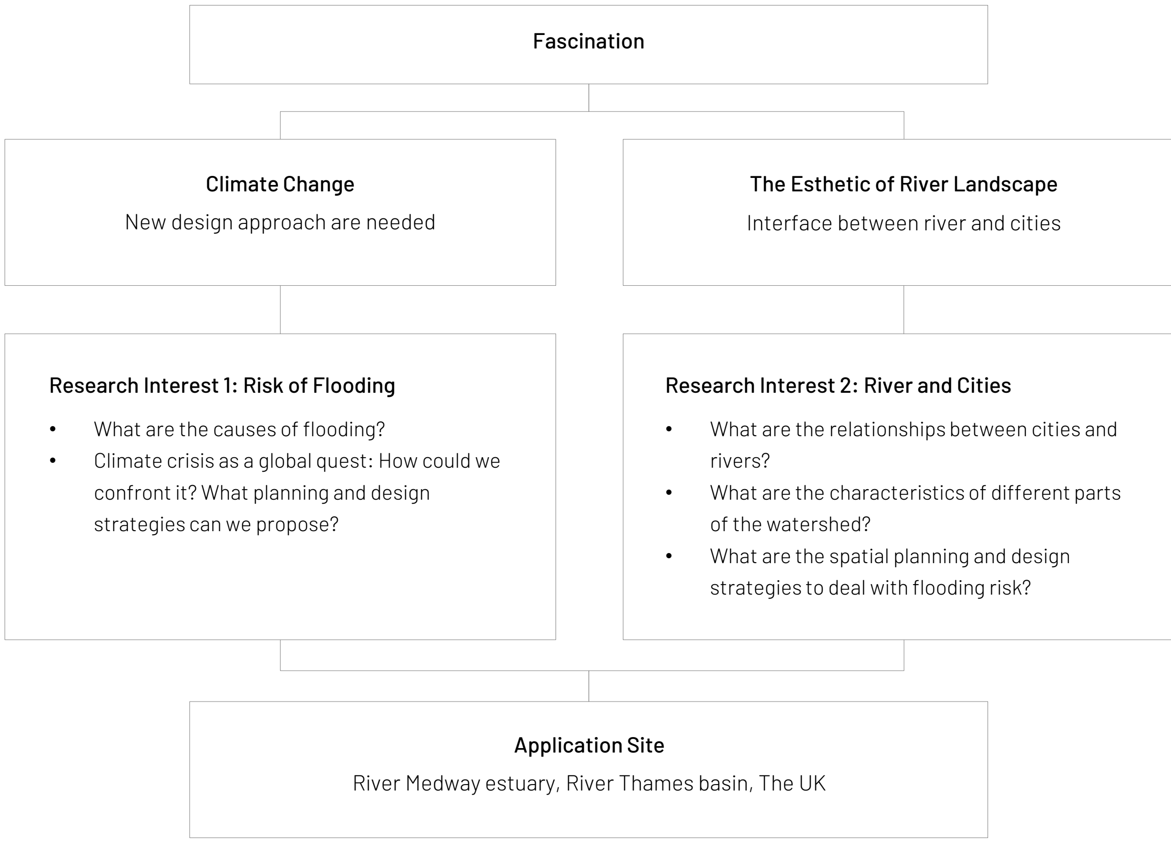
1.1 – **Motivation**

Confronting the climate challenge, new approaches to urbanization and landscape development are needed. Design strategies mitigating flooding risks have been viewed as one of the key strategies among the spatial planning and design profession.

This research is to counteract the lack of climate actions from the author's previous working experience as an urban planner in Taipei. This is a time that climate change is the defining crisis and it is happening even more quickly than we feared. The environmental effects of climate change are broad and far-reaching, affecting oceans, glaciers, and weather. Among these effects, the most urgent issue influencing the place we live is flooding. Extreme rainfall, as well as sea-level rise, increase the chance of flooding in the built environment. However, in Taipei, the author's hometown, spatial planning and design professionals have been suffering from issues of overspecialization, especially among hydraulic engineering, landscape architecture, architecture, urban design, and regional planning. There is a need to introduce integrated methodologies or working frameworks to increase the capacity of spatial planning sectors to adapt to new urban normality.

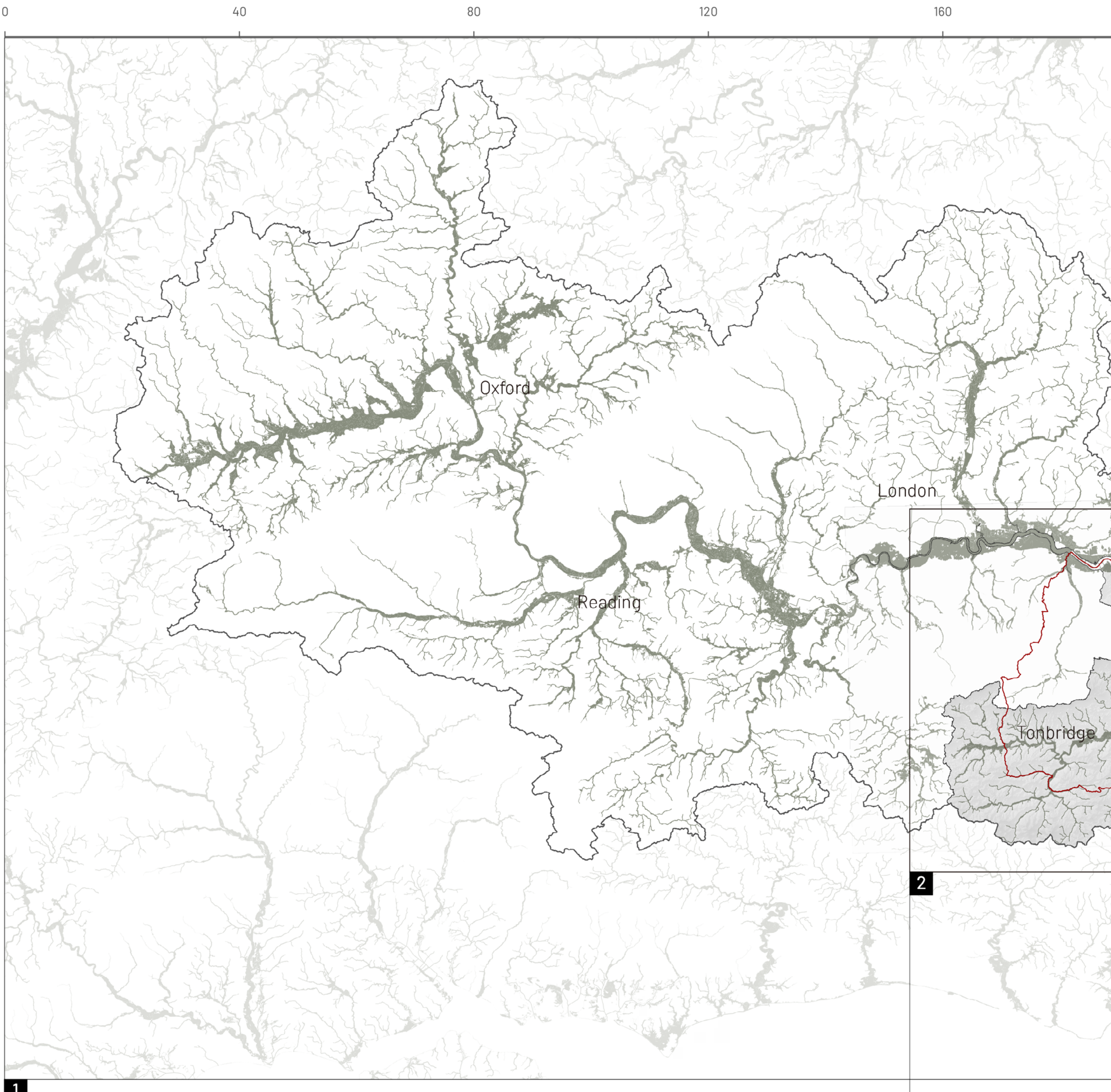
Another research interest of the author lies in the fascination with the esthetic of the river landscape. Rivers grant surrounding plains vital water resources, fertile soils, and access to water transport. These benefits attract people to settle in riverine areas. If we decompose the systems, we see the intelligence of civilization to seek a balance in creating their settlement structure with, by, and through the constructed landscape. The relationship between the built environment and nature fascinates the author. However, these riverine cities or villages are subject to floods under the context of climate change.

As the diagram reiterates, the research starts from the fascination of the esthetic of river landscapes with the author's reflection upon spatial planning and design professions under threat of climate change.



The application site is the River Medway estuary, which is part of the River Thames estuary. The reason why I selected this stretch of river landscape as the study area is inspired by the 2020 spring semester design studio: Urban transformation promoting mixed-use and climate adaptive development in the Lower Lea Valley. The studio provided me a thorough understanding of Greater London and triggered my interest in landscape-based design approaches.

The following sessions will introduce how this study is formed, from the investigation of the problem field, research questions, and critical thinking about the relevance of this study.



River Thames basin

River Medway sub-catch
North Kent (The Swale) s

1.2 – **Content of Work**

1.2.1 – **The River Medway**

The study focuses on the River Medway estuary. The River Medway is part of the River Thames basin in South East England. The River Medway has a total distance of 113 kilometers and a catchment area of 2,409 square kilometers, the second largest in southern England after the Thames. The river and its tributaries flow through largely rural areas; only a few cites, Tonbridge, Maidstone, and Medway, are the rare exceptions.

The River Medway itself initially flows in a west-east direction south of the North Downs; at the confluence of the River Beult. It turns north and breaks through the North Downs at the Medway Gap, a steep and narrow valley near Rochester, before its final section to joins the Thames estuary near Sheerness.

Major flooding events have occurred on a number of occasions in recent history and have attracted national attention, such as the flooding in Yalding in 2013/14. The catchment has suffered significant flooding in 1968, 2000/01 and more recently in 2013/14 leading flood organizations work together with communities to improve flood resilience. Generally, a total of 9000 properties (2246 homes and businesses) are at risk in the Medway catchment (Environment Agency, 2017).

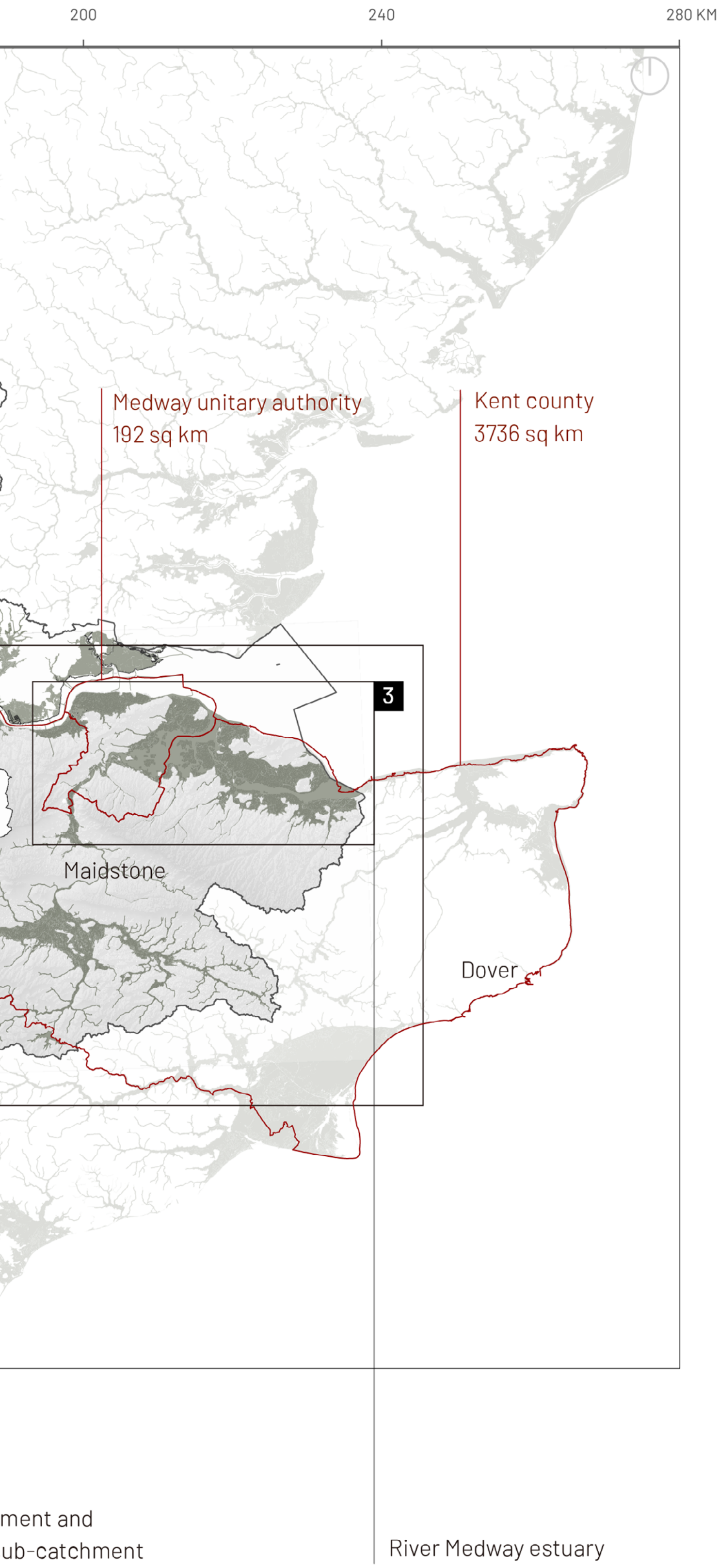
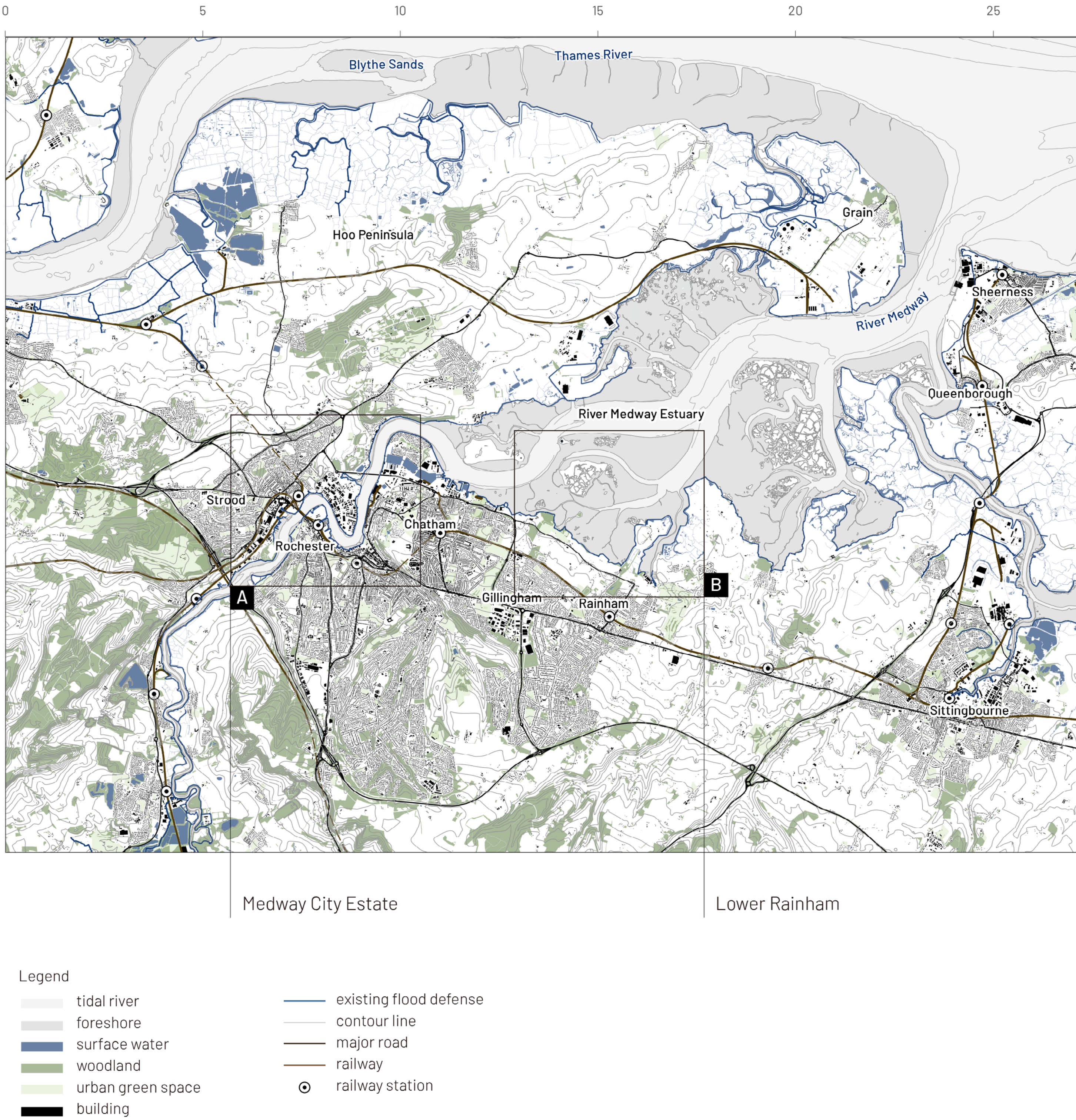
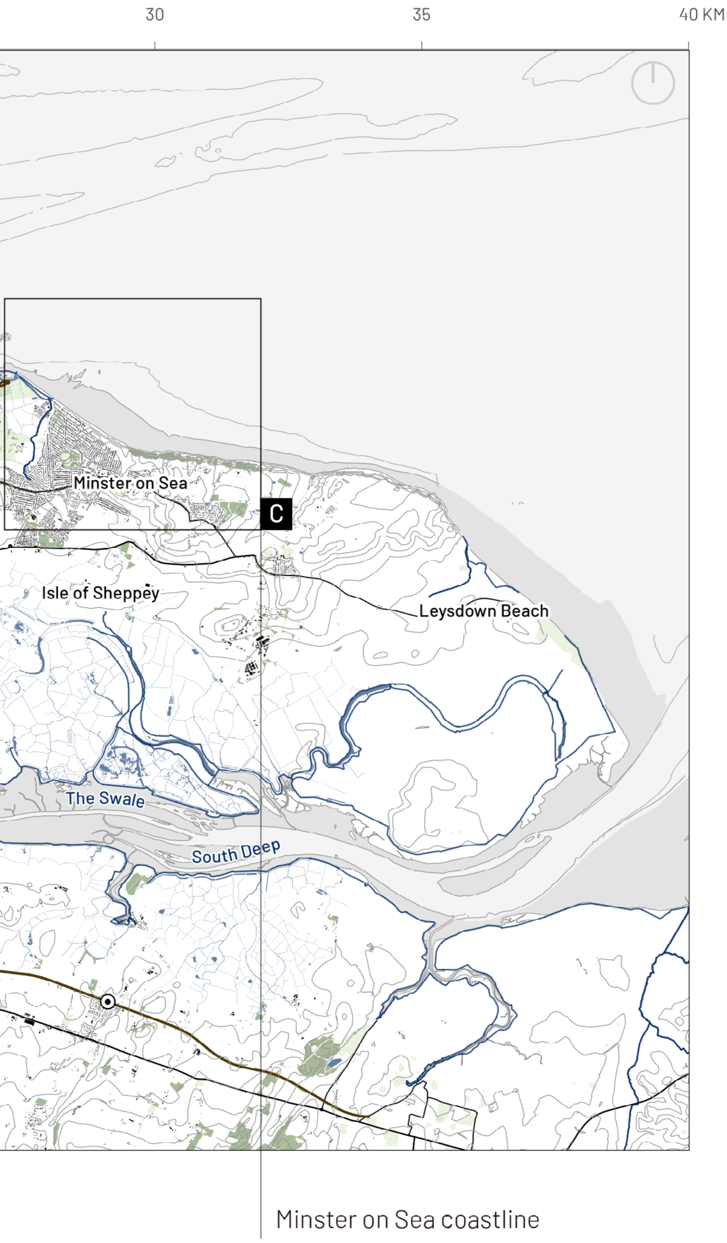


FIG. 1.1 Map of study area in the River Thames basin. Data source: OS Local and Earthexplorer. Developed by author.


0
5
10
15
20
25
Blythe Sands
Thames River
Hoo Peninsula
Grain
Sheerness
River Medway
Queenborough
River Medway Estuary
Strood
Chatham
Rochester
A
B
Gillingham
Rainham
Sittingbourne
Medway City Estate
Lower Rainham
Legend
tidal river
foreshore
surface water
woodland
urban green space
building
existing flood defense
contour line
major road
railway
railway station



1.2.2 – **River Medway Estuary**

In middle scale, this study focuses on the lower reaches of the Medway river and regards the estuary as a strategic intervention site. In this area, the most important center is the Medway towns, including Medway, Strood, Gillingham, Chatham, and Rainham, which hold historical importance due to its strategic location for the navy since the medieval period. On the north side, on the Isle of Sheppey, Sheerness began as a fort and location for repairing warships, while serving as a seaside resort in contemporary.

The river landscape consists of urbanized characteristics, priority habitats, and coastal protection issues on the Isle of Sheppey and Grain. Some selected images are shown on the next page.

After the layers analysis, three lower scale sites are selected for design exploration, which could be found in chapter five.

FIG. 1.2 Map of study area in the River Medway estuary. Data source: OS Local. Developed by author.

FIG. 1.3 Riverbank in Strood. Image source: https://www.geograph.org.uk/mapper/.

FIG. 1.4 Sea Wall near Grain. Image source: https://www.geograph.org.uk/mapper/.

FIG. 1.5 Rochester Castle. A stronger stone city wall was built to protect Rochester and the crossing at the River Medway by the Roman army in the 3rd century. It was rebuilt in the late 14th century and part of the southern and eastern walls along with a corner bastion still stand. Image source: http://www.ecastles.co.uk/rochester.html (photo: Paul R. Davis).

FIG. 1.6 Rochester high street. Source: https://www.kelly4rochesterandstrood.com/news/kelly-tolhurst.

FIG. 1.7 Medway river estuary. Image source: https://community.rspb.org.uk/.

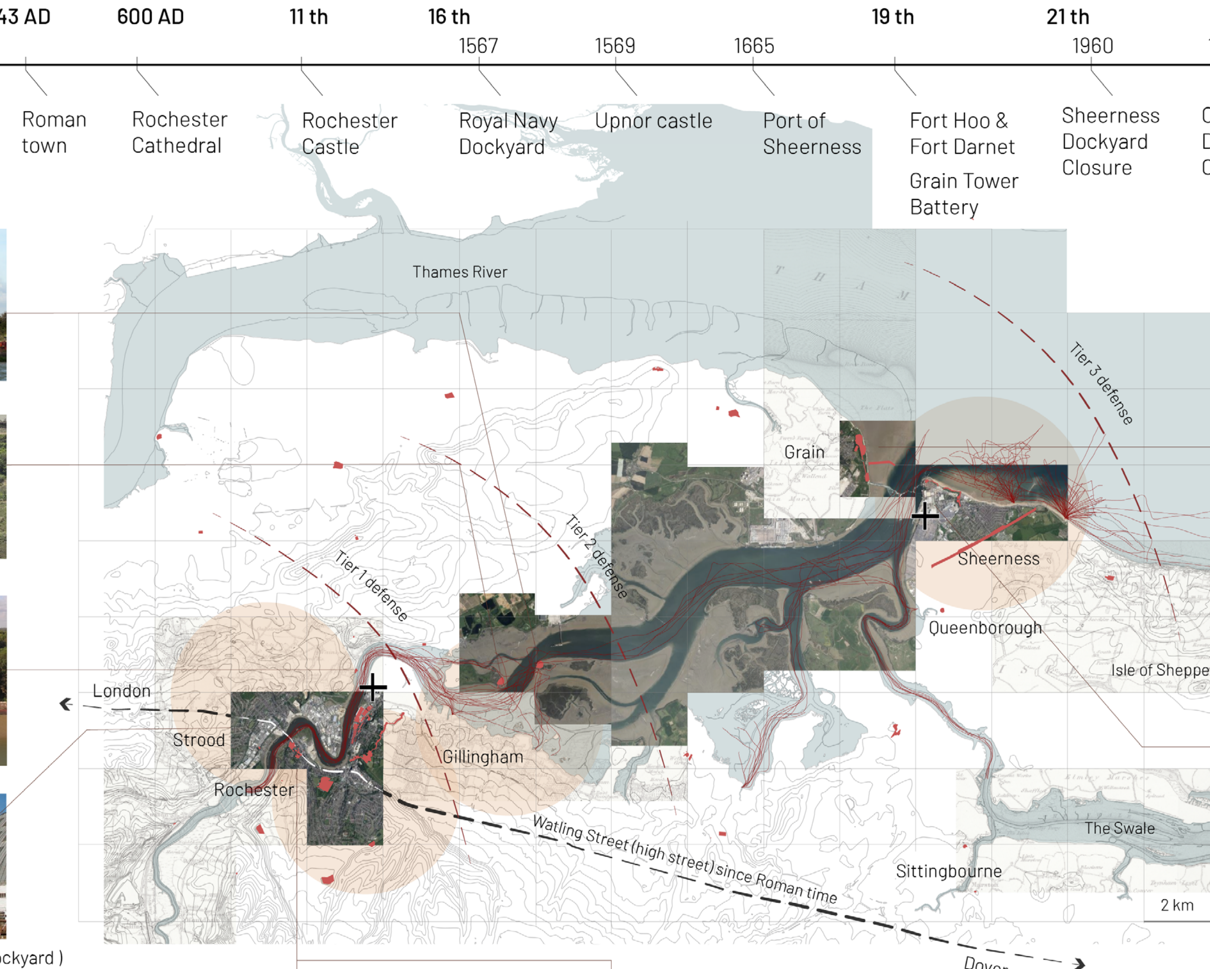
1.2.3 – **An area shaped by military and maritime history**

The River Medway Estuary is an area shaped by military and maritime history since the topography of the estuary creates a perfect vantage point for the defense. By reviewing and mapping the key events in this region, we have a better understanding of the transformation trajectory from Roman time, sixteenth century, twentieth century, and till now.

Since the Romans, Rochester's position at the confluence of the rivers Thames and River Medway has made it a hub of military activities. The geography of the Medway river creates a vantage point for defense, thus, contribute to its military importance. In the eleventh century, the iconic Rochester Castle was built by the Normans, on the site of a Roman town at the junction of the River Medway and Watling Street, which is a historic route in England that linked Dover and London. The Rochester Castle, Rochester Cathedral, and the roman high street define the center of Medway towns.

In the 16th century, Royal Dockyard was founded at Chatham. It accelerated the shipbuilding industry along the Medway River and had been the biggest employer till its closure in 1985. One of the distinguished wars in the estuary was the Second Anglo-Dutch War (1665-67) which arose from commercial and maritime rivalry between England and the Netherlands. From the painting, we could have an overlook of the topography of the river estuary and the human-nature relationship.

FIG. 1.8 An important battle in the Medway river estuary. Name of the painting: The burning of the English fleet at Chatham, June 1667, during the Second Anglo-Dutch War (1665-67). Source: Rijksmuseum Amsterdam.



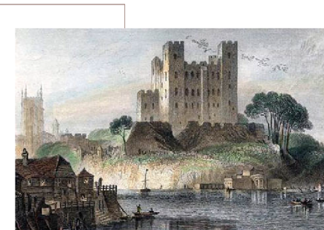

Fort Darnet

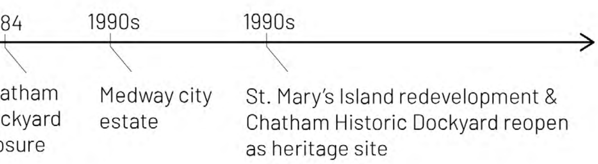

Fort Hoo


Upnor Castle


Chatham Dockyard (Royal Navy Dockyard)


Rochester Cathedral


Rochester Castle (1836)



Thirty kilometers away from Rochester, a fortress was built in Sheerness, on the Isle of Sheppey, forming tiers of defense system to protect Royal Dockyard from naval invasion. Sheerness later developed into a town after the port construction in the 19 century. Today, the port is one of the UK's main harbor importing cars and fresh produces, it also supports the manufacturing industries in Sheerness, Queenborough, and Sittingbourne. In addition to town development history, the military landscape is part of the important identity of Medway. Upnor Castle, Fort Darnet, Fort Hoo, Grain Tower Battery, these artillery fortifications become tourism attractions and are part of the cityscape.

The land use and industrial transformation were triggered by the closure of the Sheerness dockyard in 1960, and Chatham Dockyard in 1985. The latter urged the local authority to redevelop the iconical St. Mary's island. It was one of the reclamation-based coastal expansions during the 1990s. Redevelopment of the brownfield sites and former industrial land is still the key to revitalize the built environment of this region.

There is an intertwined relationship between river landscape and human development. The Rochester Castle and the Chatham Royal Dockyard are both located on the higher ground and the stable side of the river bank so that inhabitants could take advantage to defend themselves. The result of military landscape presents the intelligence of civilization to seek a balance in creating their town structure with, by, and through the constructed landscape.

Grain Tower Battery

Port of Sheerness

LEGEND

- + Port
- Heritage
- ← – High street (Watling street)
- Water activity route
- Contour line
- Tidal river and marine water

FIG. 1.9 Historic timeline of Medway towns. GIS layers: Ordnance Survey; Image of Sheerness: Oszibusz Drone Photo and Video; Other photos: Visit Medway Website.

1.3 – **Problem Statement**

Climate change in Kent and Medway

In recent times, climate change has become a major threat to this area. The Intergovernmental Panel on Climate Change predicts a warming world will lead to more extreme weather events. To understand the impact of cliamte change in the research area, this study reviewed "The Climate Change Risk and Impact Assessment for Kent and Medway (CCRIA)" published in 2017. According to CCRIA, wetter winters are likely to increase fluvial flood risk, as well as threaten large areas of nationally and internationally important habitats. Coastal habitats are potentially vulnerable to changes in erosion rates as a result of increased rainfall and inundation from sea level rise. This could impact the Sheppey Cliffs SSSI, an area of geological and botanical interest due the presence of fossils and the rare cliff vegetation Tetragonolobus maritimus.

Moreover, the projected rise in sea level can accelerate the natural erosion of coastal and intertidal habitats and alter the pace of natural geomorphological processes in coastal regions. These changes may have a significant impact on Kent's soft chalk cliffs and the vegetation communities that grow on them. Coastal grazing marshes, raised bogs, and saline lagoons are all threatened by the increases in salinity that can result from increased percolation and inundation of sea water during storm tides and flooding.

Probabilistic projections of median temperature and rainfall at 50th percentile for "Scenario RCP8.5"

	South East England						London
	Change in mean temperature			Change in rainfall			Projected sea level rise
	Annual	Summer	Winter	Annual	Summer	Winter	
2040	+1°C to 2°C	+2°C to +3°C	+1°C to +2°C	-10% to +10%	-20% to -30%	+10% to +20%	0.16-0.29m
2080	+4°C to 5°C	+5°C to +6°C	+3°C to +4°C	-10% to +10%	-30% to -50%	+20% to +30%	0.39-0.80m

FIG. 1.11 Table of climate change key figures in Kent and Medway. Source: The Climate Change Risk and Impact Assessment for Kent and Medway (CCRIA).

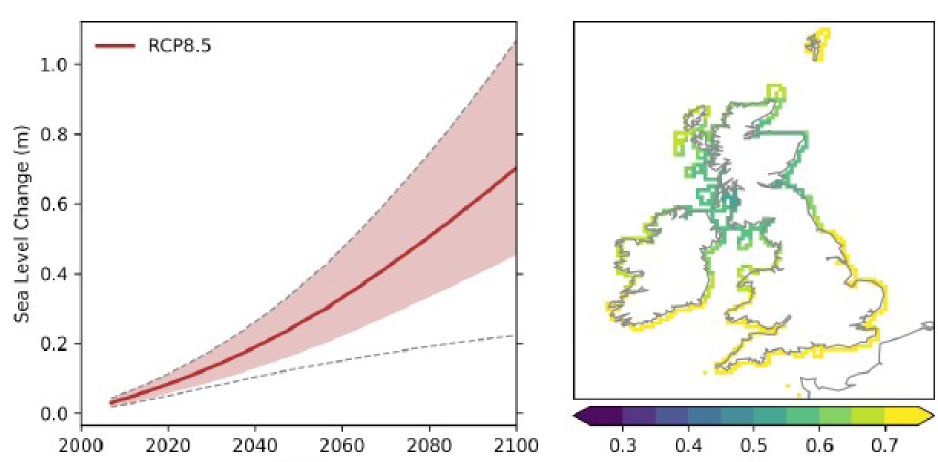


FIG. 1.10 Time series of time-mean sea level change and the spatial pattern of change at 2100 in the highest emission scenario—Scenario RCP 8.5. Time series of time-mean sea level change based on the average of 49 UK ports. The solid line and shaded regions represent the central estimate and ranges. The dashed lines indicate the overall range across RCP8.5 scenario. All projections are presented relative to a baseline period of 1981-2000. Source: UKCP18 Science Overview Report. 2018. Met Office.

FIG. 1.12 1953 Flood in Sheppey. Flood water being drained from the land by means of cuts in the river wall near Kings Ferry Bridge. Source: https://www.kentonline.co.uk/kent/news/.

FIG. 1.13 Coastal erosion: The 'forgotten' community left to fall off a cliff. July 2020. Source: BBC news. https://www.bbc.com/news/uk-england-53367000.

Threats in the Thames Estuary: sea level rise accompanied by North Sea surge

Besides the study CCRIA in the national scale, "Thames Estuary 2100 Plan" is a project established by the Environment Agency in 2002 with the aim of developing a strategic flood risk management plan for London and the Thames estuary through to the end of the century. It offers a river-specific study and comprehensive action guidelines. According to it, sea-level rise, inland water discharge, aging flood defense, and physical environment (coastal erosion and sinking) are the main challenges for the Thames estuary. Heavier rainfall plus sea-level rise could lead to extreme flooding causes by stronger storm surges which are more likely to breach the deteriorating flood defenses, which mostly were constructed 30 years ago or even earlier.

Regarding sea level rise, it is noted that climate change may cause sea level to rise by a total of up to 2 m or, 0.2 and 0.9 m in milder scenarios, according to Thames Estuary 2100. Currently, the Thames estuary has an average daily rise and fall of water levels of 7 m. In addition to daily tides, the Thamese estuary is prone to an increase in water levels caused by a North Sea surge. A surge tide entering the Thames estuary can increase water levels by 1 to 3 m and can be a major flood threat especially if this happens during a spring tide.

In this respect, the Environmental Agency outlined a range of engineered options, such as improvements of existing flood defenses and build a new storm barrier (in either Tilbury or Long Reach). However, reactions to flood risk management are not equal to providing engineering measures, but about how to enhance the resilience of the complex system, and integration of river landscape, infrastructure system, and the human dwellings. More integrated and climate adaptive approaches are needed to confront climate change and to create a more attractive environment for the coastal landscape.

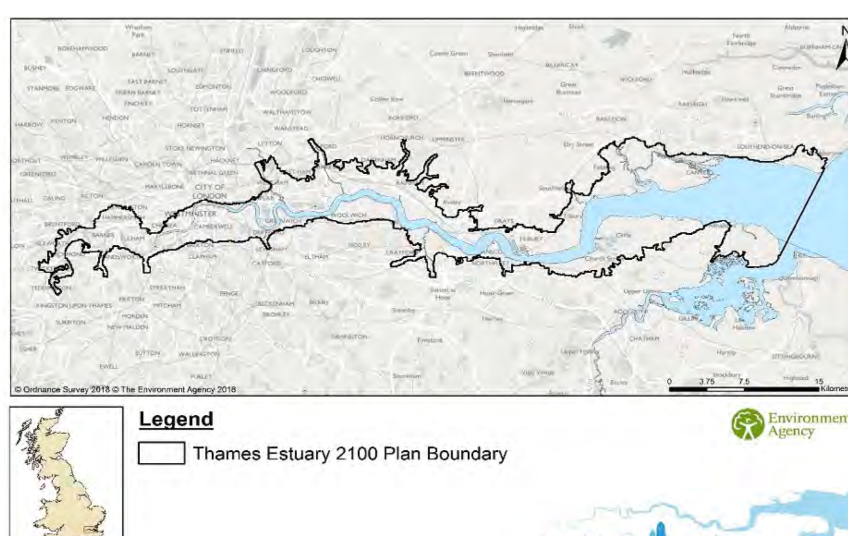


FIG. 1.14 Thames Barrier. Image source: NPAS London & South East Region.

FIG. 1.15 Thames Estuary 2100 Plan Area (Source: Environment Agency).

FIG. 1.17 1953 Flood in Canvey Island. Image source: https://theconversation.com.

FIG. 1.16 Aerial images show the extent of flooding in Yalding, a town in the upperstream of River Medway. Image source: Hawkeye Aerial Media.

Low-lying cities (Medway City Estate)

Sea level rise will lead to coastal squeeze for intertidal habitat (Grain)

Problem Statement

According to the above issues, the problem statements of this study are addressed as follows.

1 Climate change magnifies the uncertainties of flooding risks from the sea and the hinterland. Sea-level rise, inland water discharge, aging flood defense, and coastal erosion are the main challenges for the Medway river estuary. Intertidal habitats are going to be submerged by the rising sea and thus lose the ecological gradient.

2 The capacity of the Medway river estuary to adapt to flood risks and the uncertainties associated with climate change is weak due to the intensification of industrial uses, urban development, and port construction. This degrading leads to the loss of flood buffers and the loss of recreational value of the river landscape.

1.4 – **Research Objective and Questions**

In order to address the identified problem statements, I have the research objective: "Develop and apply design strategies for a more resilient Medway River Estuary addresses flooding, urban, and ecological development". Under the objective, thress sets of research questions are proposed.

Research Objective

Develop and apply design strategies for a more resilient Medway River Estuary addresses flooding, urban, and ecological development.

Research Questions

1 How does the socio-ecological system of the Medway River Estuary function?

- a How did the urban landscape adapt and transform over time?
- b What are the challenges and potentials for the Medway River Estuary?

2 What design strategies and principles are suitable for flood mitigation and socio-ecological inclusive development?

- a What design principles and strategies for resilient landscape can be applied in the Medway river estuary?
- b What are the spatial strategies for the different parts of the watershed in the Medway river landscape?

3 How to apply the design strategies and principles in Medway River Estuary to increase its socio-ecological resilience?

1.5 – **Relevance of Study**

A need for developing new design and planning approach to confront flooding risk under uncertainties of climate change

This is a time that climate change is the defining crisis and it is happening even more quickly than we feared. The environmental effects of climate change are broad and far-reaching, affecting oceans, glaciers, and weather. Among these effects, river cities, urbanized deltas, and coastal areas that accommodate the great majority of the world's population are extremely vulnerable to flooding. However, in most of the countries in the world, the spatial planning and design profession has been suffering from issues of overspecialization, especially among hydraulic engineering, landscape architecture, architecture, urban design, and regional planning. There is a need to introduce integrated methodologies or working frameworks to increase the capacity of spatial planning sectors to adapt to new urban normality.

In the time of climate change, new approaches to urbanization and landscape development are needed. Design strategies confronting flooding risks have been viewed as one of the key strategies among the spatial planning and design profession. In this research, an adaptive vision will be proposed to increase the resilience of the river landscape. In contrary to conventional master planning that has a fixed blueprint within a target year, the adaptive vision regards urban landscape as systems; therefore, it addresses design strategies by layers through time dynamics; furthermore, it takes into account the adaptability of socio-economic systems. In other words, the proposed vision addresses not only the physical spatial design but also the actors in the systems; for instance, public sectors and residents under this framework will be more aware of the uncertainties of the environment and thus have the capacity to cooperate and act by phases in the system together to influence the physical and social resilience. In this respect, my graduation project in the Medway river estuary will serve as a case study and a demonstration of design methodology in urban development.

2 – Methodological framework

2.1 – **Theory: Resilience**

Resilience is about cultivating the capacity to sustain development in the face of expected and surprising change and diverse pathways of development and potential thresholds between them (Folke, 2016).

To answer the research objective raised by this study— develop and apply design strategies for a more resilient Medway river Estuary—this research adopted "resilience" as the theoretical backbone to envision an adaptive river landscape.

The concept of resilience is often used in research in relation to the environment and ecosystem. As Folke (2016) pointed out, it is influencing the environmental sciences from agriculture to oceans as well as global environmental and climate change and in risks and disaster management. Among the families of resilience theory, this research focused on the transformative trajectory that related to flood risks.

From engineering resilience to ecological resilience

Resilience is a theory with a huge family of studies. When talking about flooding risk, we need to understand the differences between engineering resilience and ecological resilience. In some engineering fields, resilience has a narrow definition which refers to the return rate to equilibrium upon a perturbation (Folke, 2016). It concentrates on stability near an equilibrium steady state, where resistance to disturbance and speed of return to the equilibrium (Holling, 1996).

In 1973, ecologist C.S. Holling introduced the concept resilience to ecological science, the heart of these two different views of resilience lies in assumptions regarding whether multistable states exist. His discovery of multiple basins of attraction in ecosystem dynamics challenged the dominant stable-equilibrium view of ecosystems, at the the 1970s (Folke, 2016). Holling (1973) investigated how ecosystems relate to random events and heterogeneity of temporal and spatial scales and defined resilience as persistence of relationships within a system, as a measure of the ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist. In this respect, the measurement of resilience is the magnitude of disturbance that can be absorbed before the system shifting its structure to a different regime (Holling, 1996).

A forest management case of ecological resilience

A forest management case in New Brunswick[1] demonstrated what ecological resilience could be. The crisis was occurred due to the use of pesticides for budworm damage. However, available stocks of harvestable trees were decreasing because of more and more mature stands were gradually deteriorating from the pressure of moderate but persistent budworm defoliation. A sequence of adaptive responses among the actors began to develop regional forest policy in a way that engaged local industrial, environmental, and recreational goals. The examples of growing pathology are caused by the very success of achieving near equilibrium behavior and control of a single target variable independently of the larger ecosystem, economic, and social interactions. The key features in this case are integration of knowledge at a range of scales, engagement of the public in exploring alternative potential futures, adaptive designs that acknowledge and test the unknown, and involvement of citizens in monitoring and understanding outcomes.

FIG. 2.1 New Brunswick's forest. Image source: New Brunswick Environmental Network.

1 The case is adapted from: Holling, C. S. (1996). Engineering resilience versus ecological resilience. In *Engineering within ecological constraints* (pp. 31–43).

Urban resilience to flood

Based on the concept of ecological resilience, Liao (2012) proposed urban resilience to floods as an alternative framework for urban flood hazard management. Based on this understanding, urban resilience to floods is defined as a city's capacity to tolerate flooding and to reorganize should physical damage and socioeconomic disruption occur, to prevent deaths and injuries and maintain current socioeconomic identity. To make natural floodplain be a part of urban resilience to floods, flood adaptation" is advocated to replace "flood control" for mitigating flood hazards (Liao, 2012).

This theory interpretation went in parallel with the paradigm shift of flood risk management in these recent two decades. A paradigm shift is taking place in Europe in the way flood issues and flood risk governance are dealt with. This is characterised by a movement away from flood protection towards flood risk management (Evers et al., 2016). A significant consequence of this shift is the establishment of EU Flood Directive in 2006. The Directive required its member states take into account the consequences of floods next to their probability and stressed the importance of integrated flood risk management strategies. In other words, confronting flooding risk and increasing flood resilience is not equal to engineering or spatial design strategies. It requires the agency of governance systems in a larger socio-economic context.

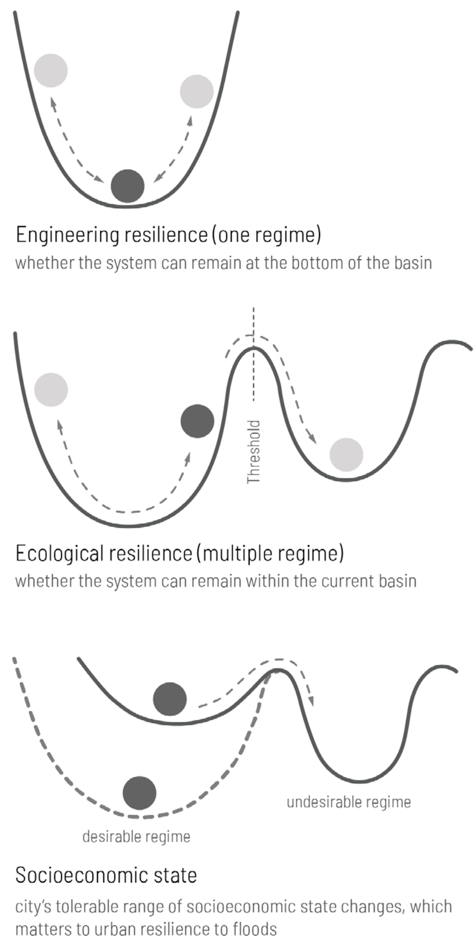


FIG. 2.2 Ball-and-cup schematic diagram of resilience. The cup represents the region in the state space or basin of attraction, in which the system tends to remain, and includes all possible values of system variables of interest. The ball represents the state of the system at any given time. Diagrams are adapted from Liao (2012).

Resilience in social–ecological systems

In this respect, we need to adopt another system of resilience theory to position "resilience" within social-ecological systems. Berkes, Folke & Colding (2000) adopted the concept of social-ecological systems as an integrated approach of human-in-nature and related the concept to resilience. As Folke (2016) pointed out, the social-ecological approach emphasizes that people, communities, economies, societies, cultures are embedded parts of the biosphere and shape ecosystems, from local to global scales, from the past to the future. Levin et al. (2013) further indicated that social-ecological systems are complex adaptive systems which possess critical thresholds, multiple drivers of change, and reciprocal feedbacks between social and ecological components. These group of definition brought the concept resilience to a wider domain. In practice, it suggested us to take into account the actors and the social layers in the system. Moreover, it revealed the time dimension and different layers that should be covered in analysis phase.

Resiliecne, Adaptability, and Transformability

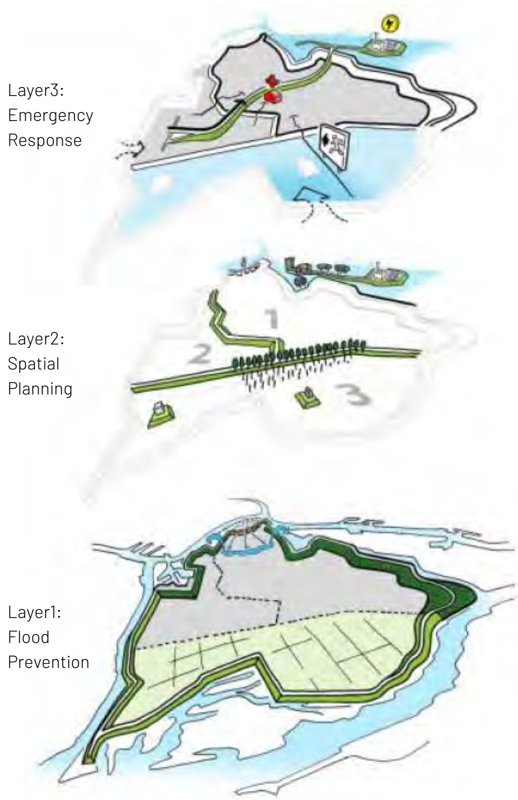
In this study, in order to make the concept resilience operational, I adopted a current definition of resilience thinking. According to Folke (2016), resilience is about cultivating the capacity to sustain development in the face of expected and surprising change and diverse pathways of development and potential thresholds between them. Under this definition, resilience as persistence, adaptability, and transformability of complex adaptive social-ecological systems is the focus, which clarify the dynamic and forward-looking nature of the concept (Folke, 2016). Then, adaptability is the capacity of actors in the system to influence resilience in a social-ecological systems, essentially to manage it (Walker et al., 2004). In relation to adaptability, transformability is about shifting development into new pathways and even creating novel ones. It is about having the ability to cross thresholds and move social-ecological systems into new basins of attractions, into new, emergent, and often unknown development trajectories (Folke, 2016).

Learning from Adaptive Framework in the Dutch delta

1. MIRT Dordrecht

To have better understanding of how the resilience concept relevant to design practice, I reviewed two cases in the Dutch delta. The first one is MIRT Dordrecht project under the Rijnmond-Drechtsteden Delta Program. The city is located at one of the most vulnerable places at South Holland province, hence it was selected to be the pilot project under the Delta Program to develop and implement flood risk management srategies base on multi-layer-safety approach.

The historic port area of Dordrecht, the Voorstraat and its northern area, would be among the first unembanked areas to flood under climate change scenario of KMNI'06 (medium scenario of the year 2100); however, strengthening this part of dike in a traditional way was socially unacceptable because it would result in years of construction in the heart of city center (Gersonius, Ashley & Zevenbergen, 2012) . These factors led to the occurrence of alternative and integrated flood risk management strategies. In 2015, the final action plan proposed a set of strategies emphasized on layers of



Legend
- Delta dyke
- primary flood defense
- compartmentation dyke
- front street
- breakthrough nature
- restrictive building policy
- cluster of nodes in vital infrastructure
  - ne waste energy plant (HVC)
  - BRZO company (most risky companies)
  - drinking water purification location
  - sewage treatment plant (WWTP)
  - high voltage switch station
- shelter
- evacuation route

FIG. 2.3 Multi-Layer Safety plan and layers of Dordrecht. Image source: Concept Gebiedsrapportage Eiland van Dordrecht (Legend was translated by author).

flood protection measures, spatial planning (compartmentalization), and emergency response. We can learned from this case that the resilience to flooding will be enhanced by multiple layers of policies and spatial actions. It also emphasized the mitigation of impact through spatial planning layout and disaster relief in addition to prevention measures.

2. Integrated Planning and Design in the Delta

The second case is the research project "Integrated Planning and Design in the Delta" (IPDD) which focused on the southwest delta region. One of the most urgent long-term and large scale questions that needed to be addressed in the coming fifty years was whether the Nieuwe Waterweg should remain the main discharge channel of the rivers Rhine and Meuse. The project elaborated a method for adaptive design and introduced a robust adaptive framework as a strategy. According to Meyer and Nijhuis (2016), adaptive framework could be regarded as an elaboration of the framework model addressing issues of time, uncertainty and shifting responsibilities; furthermore, the goal of the design process was to define a spatial framework which would be robust and adaptive both with regards to flood defense, climate change and sea level rise, as well as environmental qualities, the port economy and urban development.

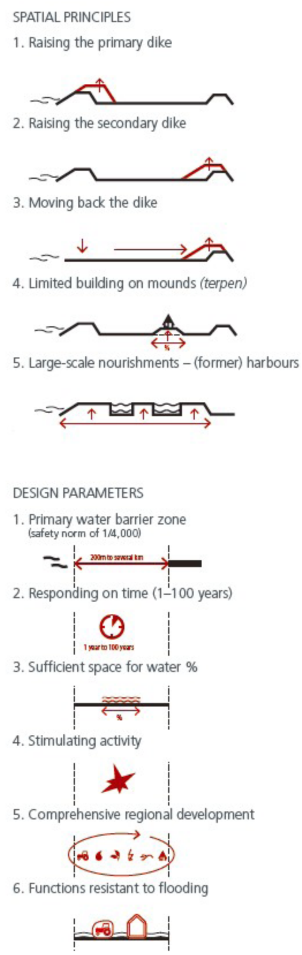


FIG. 2.4 Spatial principles and design parameters. Source: Meyer et al. (2015).

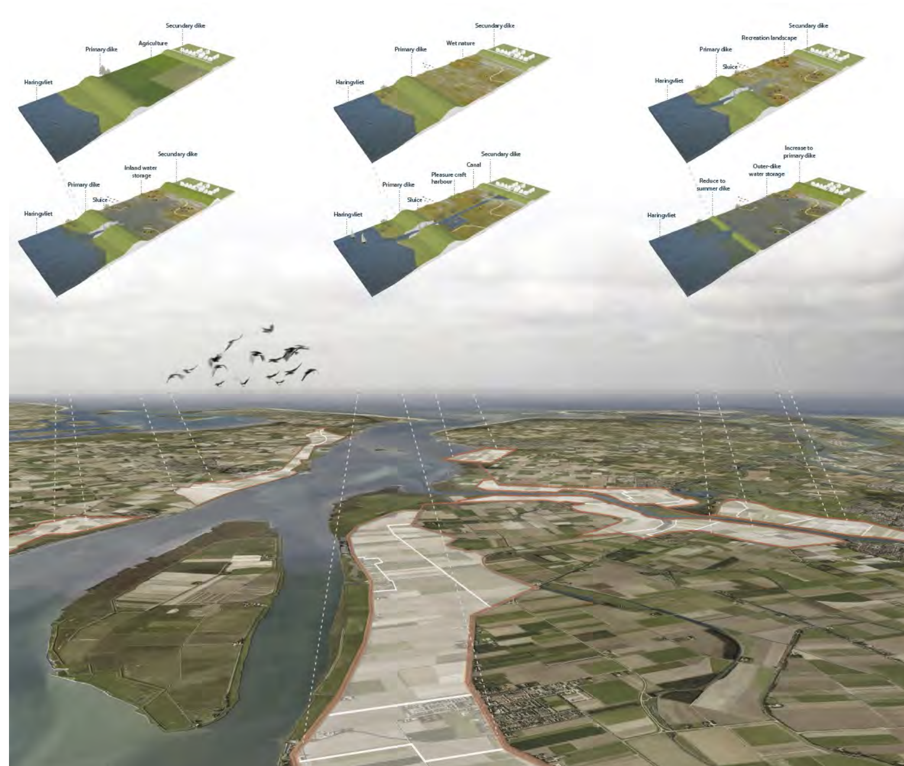


FIG. 2.5 Robust Adaptive Framework (RAF), zooming in on the Haringvliet and surroundings: Multiple design options for the zones between the current primary and secondary water barriers (cross-sections). Source: Meyer et al. (2015).

Conclusion

These above theories and cases provided us lens of inquiry to understand the landscape system, and the basis to conceive future proposals. Under these concepts, the study aimed to envision an adaptive future and introduce adaptability and transformability to address the capacity of systems to confront flooding risk, and in the long term, to increase the resilience of the Medway river estuary.

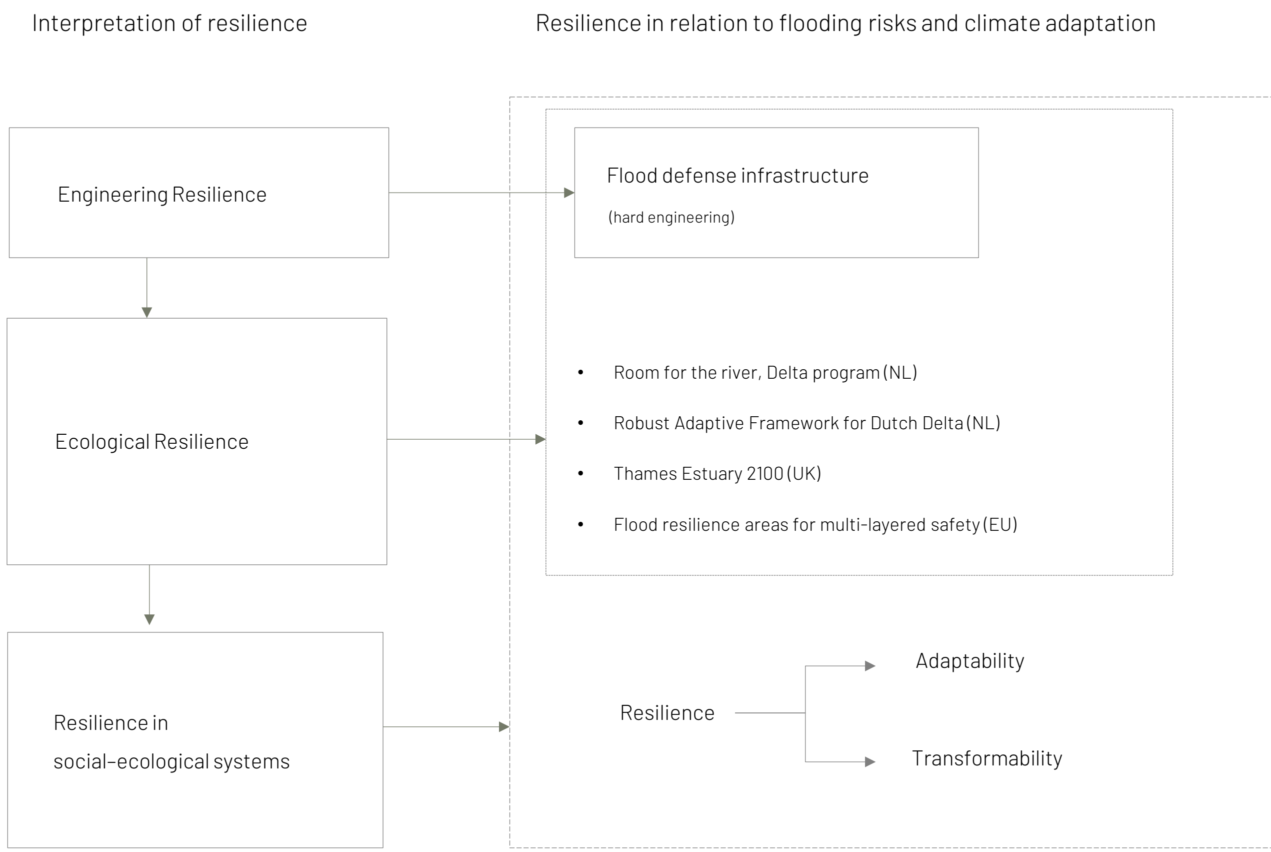


FIG. 2.6 Diagram of the interpretation and application regarding "resilience." Developed by author.

2.2 – **Research Strategies**

Landscape-based approach, system thinking, layer approach, and mapping

This study adopted the landscape-based approach as a research strategy. The landscape-based regional design aims to enhance spatial development by applying bioregional planning and design principles that view the urban landscape as an inclusive, dynamic, and complex system (Nijhuis et al., 2019). Also, it utilizes ideas from systems thinking as well as complexity theory to promote a more comprehensive form of regional planning and design that addresses the complex web of relationships making up the urban landscape (Nijhuis & Jauslin, 2015).

The above strategy is regarded as the "layer approach," which was introduced by Ian McHarg in 1969. Later this approach has been widely adopted in the Dutch planning context from 2000 onwards. As Meyer & Nijhuis (2013) indicated, urban regions can be considered to be complex systems, composed of different layers or subsystems such as the natural substratum, the infrastructure networks, and land-use patterns, each within its dynamics and velocity of change.

Besides the layer approach, the landscape-based approach is inseparable from mapping. Mapping is a powerful way to generate knowledge for planning and design. Nijhuis and Pouderoijen (2014) pointed out that mapping implied a strong forward-looking action from a perspective of sustainable development, to guide, harmonize and shape changes, which were brought about by social, economic, and environmental processes.

In summary, under system thinking, layer approach, and mapping action, the urban landscape could be decomposed into layers to understand the development process through time, the structural dynamics of layers, and the complexities of systems on multiple scales.

Scenario study

The scenario study is one of the foreseen study methodologies that are available for exploring the future in the face of the complexity and uncertainty of the environment. The scenario is based on knowledge and data about the past that are considered to be indicative of the different possible paths of future developments, based on a given set of conditions in the future (Dammers, Van den Born, Bruggeman & Van den Hurk, 2013). This method will be applied in chapter three. The aim is to investigate critical intervention locations under different sea-level rise scenarios and economic development contexts.

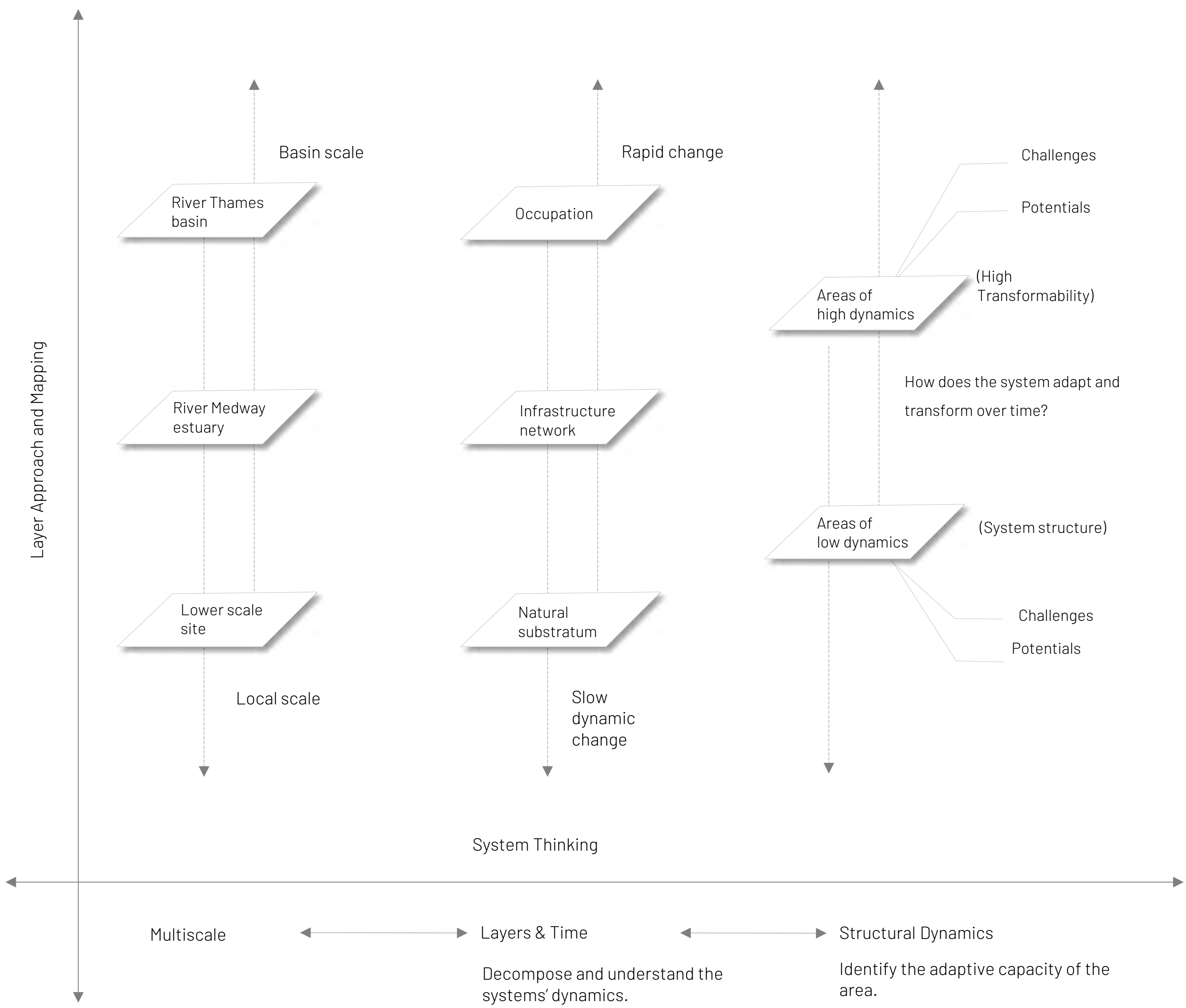


FIG. 2.7 Diagram showing the relations of research strategies in this study.

Design-related research

This research is regarded as a "design-related research", which would apply a systematic approach where "design research" and "research-by-design" are combined. According to Nijhuis & Bobbink (2012), design research is considered to be an indispensable step in research-by-design, and they constitute a heuristic approach for knowledge-based and creative design and include plan analysis, comparative analysis, experimental design study, and design study. In this respect, design is regarded as a process of discovery and invention. The research process is reflective, analytical thinking aims at data translation and interpretation into knowledge (discovery), and design thinking aims at the development of new knowledge through synthesis and spatial translation (invention) (Nijhuis & de Vries, 2019). The key concepts are shown as diagrams below.

We could assume that knowledge regarding flooding risk mitigation, ecosystem restoration, and coastal protection, will be produced in the process of design research. After the analysis phase, initial synthesis and partial solutions will be developed. Then, three lower-scale locations will serve as a testing ground in this study, to evaluate and reflect on the applicability of the design principles and strategies developed in this study, and on their impacts on a spatial configuration, natural processes, and socio-economic dynamics. Another layer of knowledge will be developed through the spatial translation process. In the end, the design exploration on the lower scale will also contribute to the larger picture, and reframe the regional development vision.

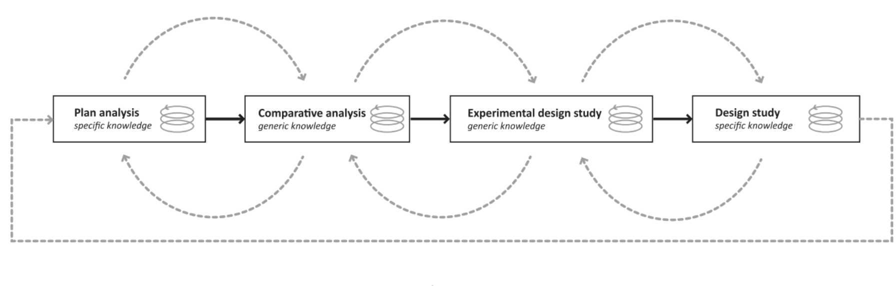


FIG. 2.9 Design research and research-by-design as incremental and iterative process. Source: Nijhuis & Bobbink (2012).

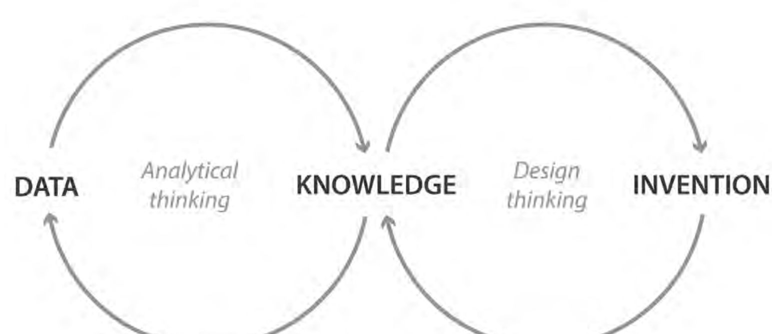
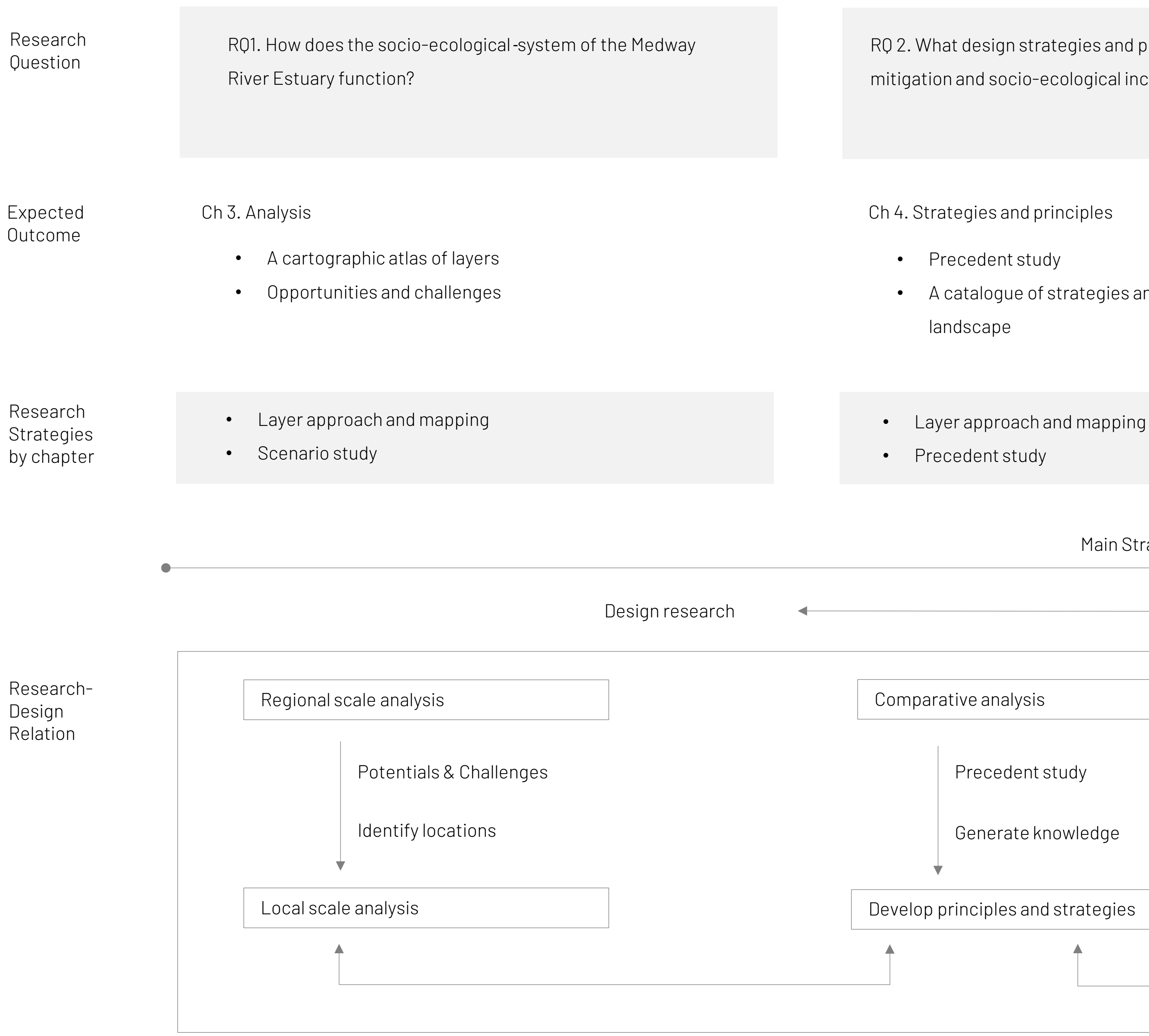


FIG. 2.8 Diagram of reflective research process. Source: Nijhuis & de Vries (2019).

2.3 – **Research Design**

To answer the research questions, design strategies mentioned in the previous section will be applied in different phases of this study as the diagram shows.



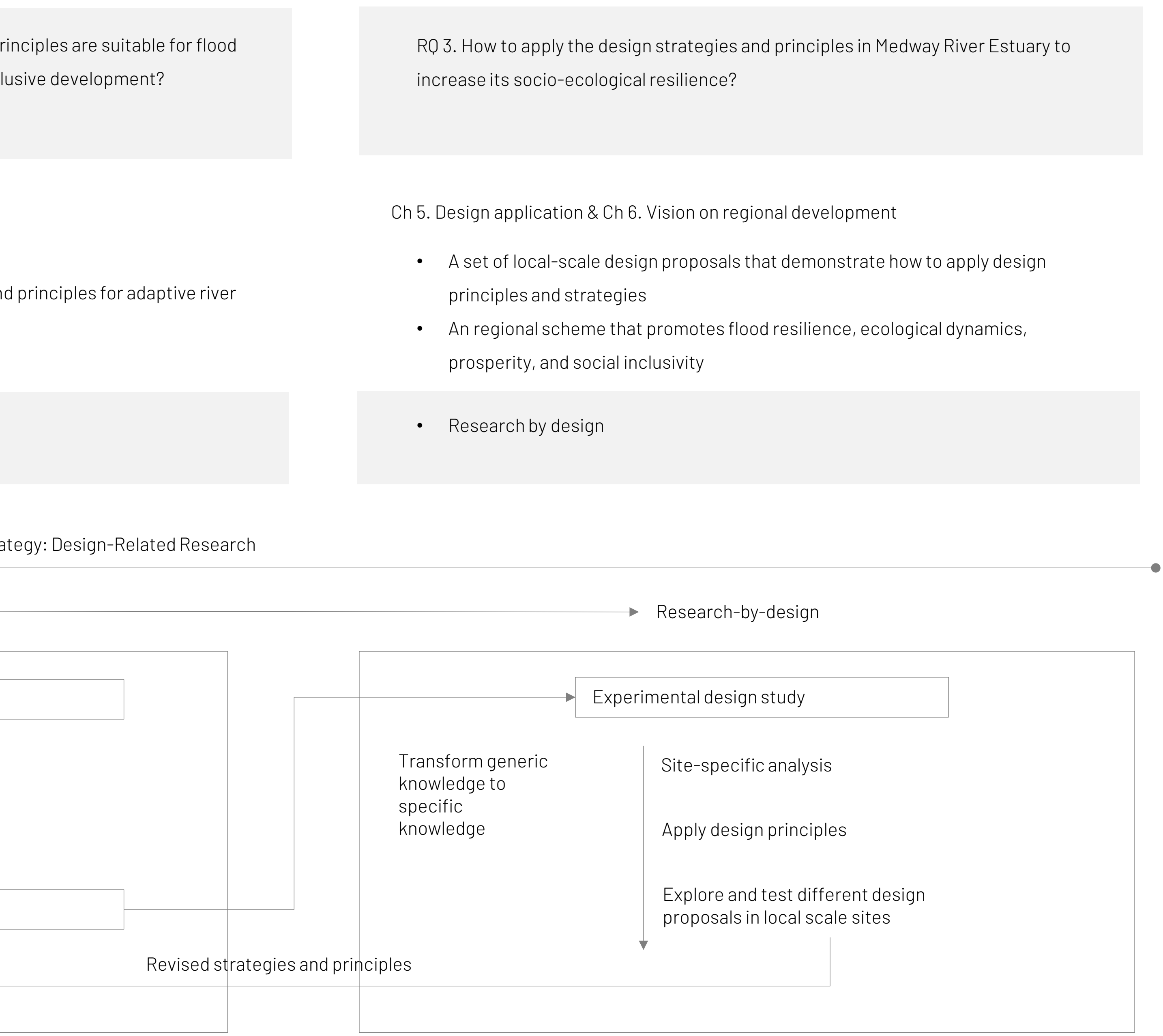


FIG. 2.10 Diagram of research design

2.4 – **Reading itinerary**

This graduation project consists of seven chapters as the diagram shows. Part one, research design, elaborates on how I plan to conduct this project. The second part focuses on mapping and understanding of landscape context. The third part shows the design process and the research outcome.

PART 1 Research Design	Chapter 1	Introduction
	Chapter 2	Methodological framework
PART 2 Understanding of the system	Chapter 3	Analysis
PART 3 Towards an Adaptive River Landscape	Chapter 4	Strategies and principles
	Chapter 5	Design exploration
	Chapter 6	Vision on regional development
	Chapter 7	Synthesis and outlook

PART 2

Understanding of the system

“On 29 May 2018, heavy rainfall was experienced throughout Medway and beyond leading to a number of reported flooding incidents. Those areas most affected are within areas where overland and surface water flow occurs relatively quickly following the onset of rain due to topography.

A number of flood incidents were reported to the council including reports of internal and external property flooding and highway flooding.”

—Medway Council, Flood Investigation Report, 2019


Collehall
Halfton
Upchurch
Frydel
Greneh
Iwade
MILTON.
Kings
Gillingham
PART
OF
Queenborow fery
SHEPEY.
SHIRENASSE
VAN
CHET
HAM
RIVIER
HOO
Stoke
Hoo
Cowling Parke
HUNDRED.
THE ILE
OF GRE:
ANE.
Nigh hafle
Cowling
St Maryes
St James
Alhallowes
SHAM
RIVIER
de malen de een na de ander daer op los, en die van 't opgeworpen Fort
wederom op onse Schepen, alsoo de Engelse dicht op de kant voor 't Fort
een Batterye hadden op geworpen, op welcken lagen 15 a 16 yſere 18
ponders. Onderwijlen quamen onse Soldaten met grooten yver onder
weldige swaerte, voorsien van hechte katrollen, daer een yſere keten over
liep, van de eene ſyde van de Rivier tot de ander streckende, in een ge-
klouncken van schaeckels die meer als de dickte van een mans arm konden
halen, aen de ſyde van Chattam ten eynde de keten lagh op 't vaste landt
petheyt, riep om quartier, en gaf 't Schip over, op 't spoor van Braeckel
drongen de Branders in, daer van de eerste met een overwonderlijcke fier-
heyt, en stoute resolutie, wat het lillen mocht, vlack voor de wint op de
keten aen sette, welcke stoutheyt soo wel slaegde, dat de keten los aen
den Grave van Hoorn, Panhuysen, &c. waren met haer sloep derwaerts
geroeyt, de Battery besichtigende, en een langewijl op 't vaste lande van
Engelande.
's Anderendaeghs den 23 vont men 's morgens dat de Engelsche de drie

3 – Analysis

FIG. 3.1 1667 Dutch Raid. Image source: https://www.trouw.nl/nieuws/michiel-de-ruyters-spectaculaire-overwinning-die-vergeten-werd

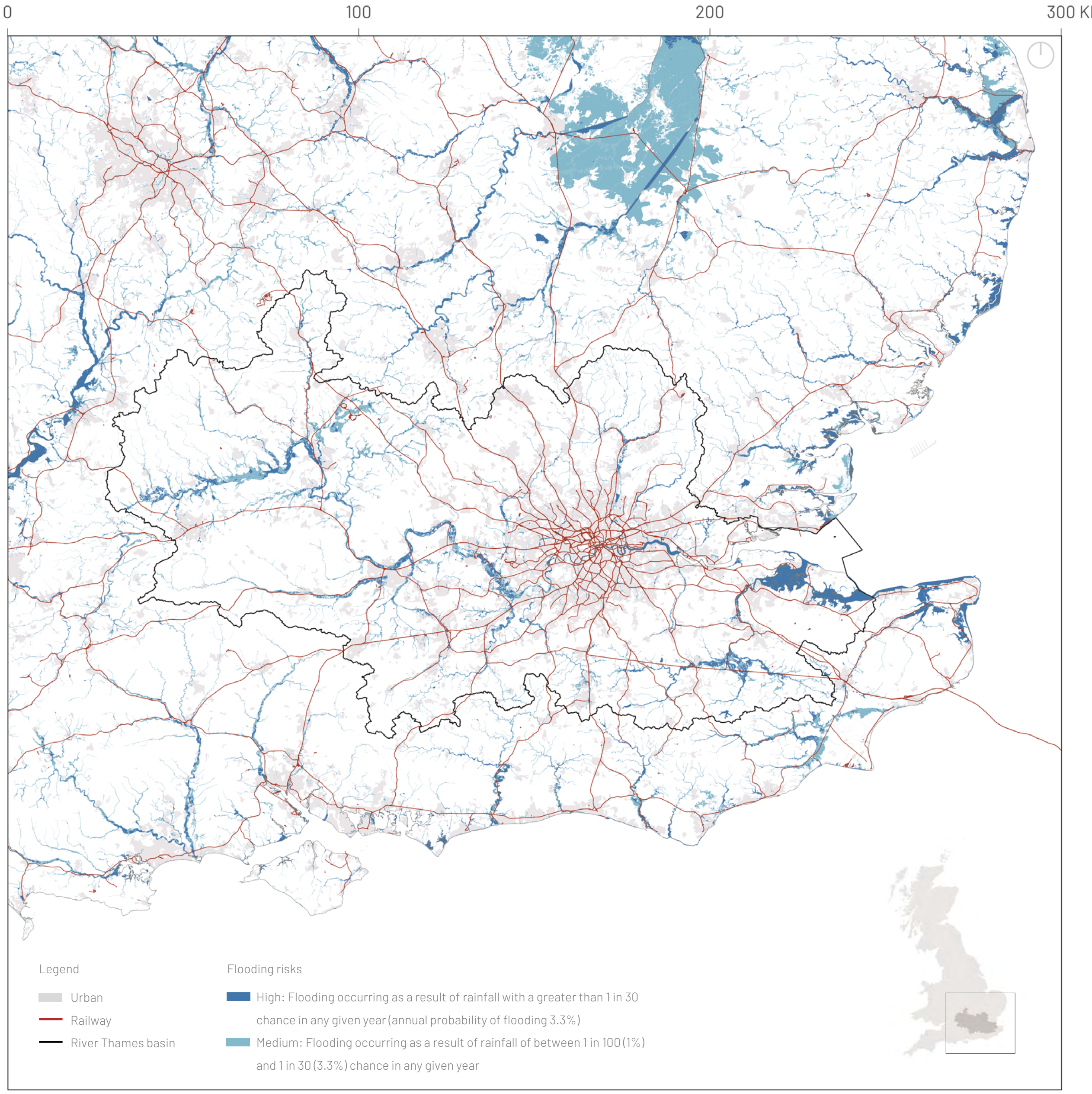


FIG. 3.2 Overview of the River Thames basin. Data source: Ordnance Survey and OSM.

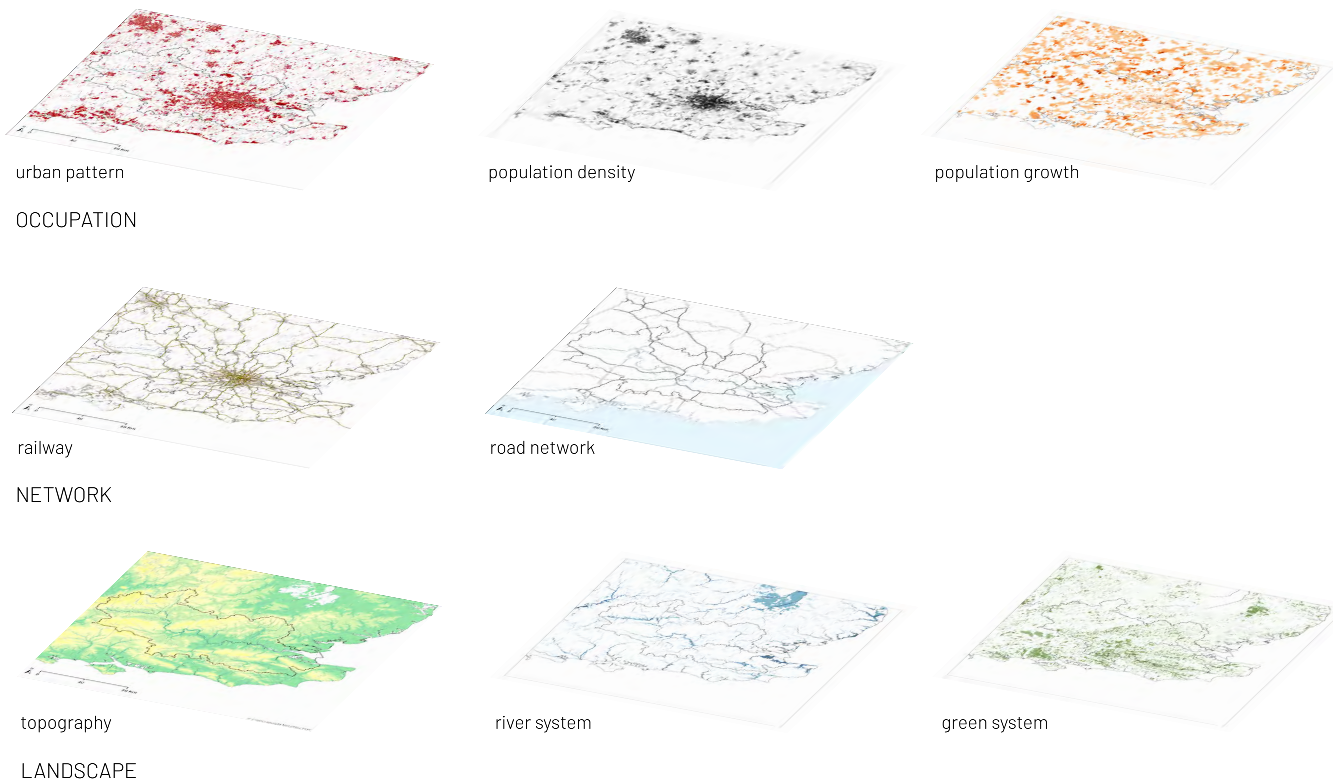
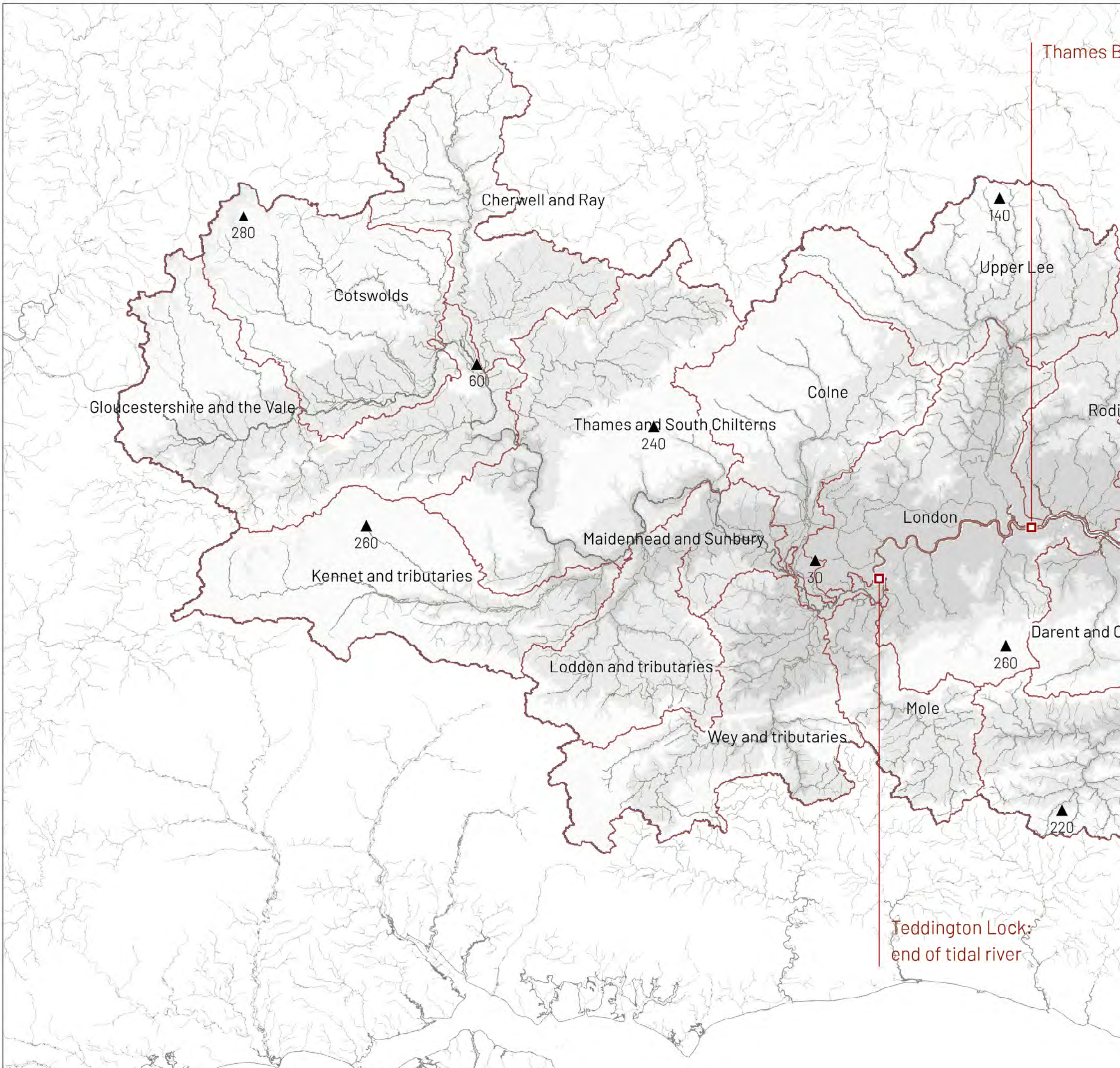
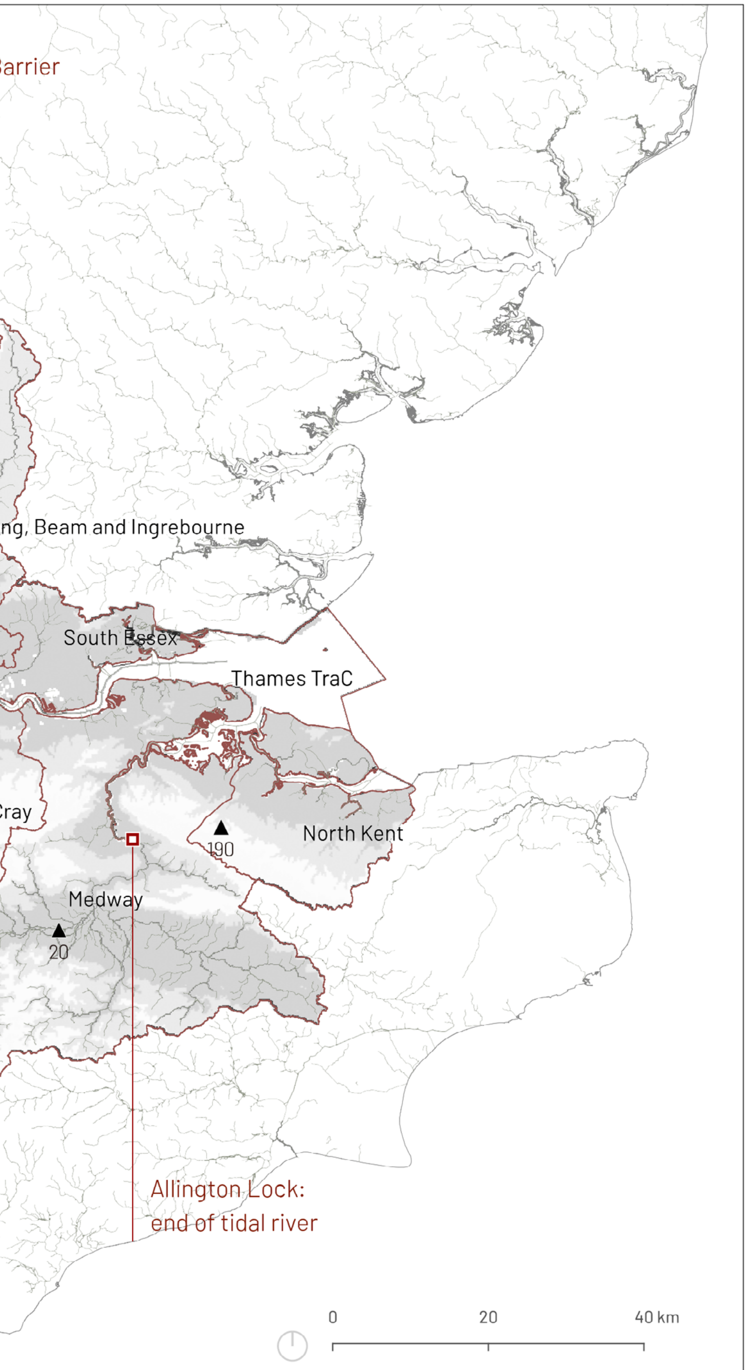


FIG. 3.3 Sample maps to show the key concept in "layer approach," the research strategy applied in this chapter. Data source: Ordnance Survey and OSM.

3.1 – **Scaling through the Thames river basin**

Mapping is the key step to understanding the River Thames basin. The River Thames is a river that flows through southern England including London. It is the longest river (346 km) in England. Its river basin district covers over 16,200 sq km. It is mostly rural to the west and urban to the east where it is dominated by Greater London. Around 17% of the river basin district is urbanized and the rural land is mainly arable, grassland and woodland (Environment Agency, 2015). There is a strong centrality or urban pattern; therefore, the network system has developed in a ring-and-radial pattern. The following section elaborated on several important layers and then zoomed in to three cities to investigate their relationship with the river.


Thames B
Cherwell and Ray
280
140
Upper Lee
Cotswolds
60
Colne
Gloucestershire and the Vale
Rodi
Thames and South Chilterns
240
London
260
Maidenhead and Sunbury
30
Kennet and tributaries
Darent and C
260
Loddon and tributaries
Mole
Wey and tributaries
220
Teddington Lock:
end of tidal river



River Thames basin

The River Thames rises at Thames Head in Gloucestershire (elevation up to 350 m) and flows into the North Sea via the Thames Estuary. From the topography map, we could learn that there are three large floodplains that accommodate urban structures, which are Oxfordshire in the upper reaches, London, and Medway in the lower reaches.

According to Environment Agency (2015), there are 17 management catchments that make up the river basin district, which include many interconnected rivers, lakes, groundwater and coastal waters; these catchments range from chalk streams and aquifers to tidal and coastal marshes. In the river basin, there are 45 navigation locks with accompanying weirs. Among them, Teddington Lock is the official upper tidal limit (elevation 4 m) (Neumann et al., 2018).

The major flood defense infrastructure is the Thames Barrier (since 1982). It is a retractable barrier system that is designed to prevent the floodplain of most of Greater London from being flooded by exceptionally high tides and storm surges moving up from the North Sea.

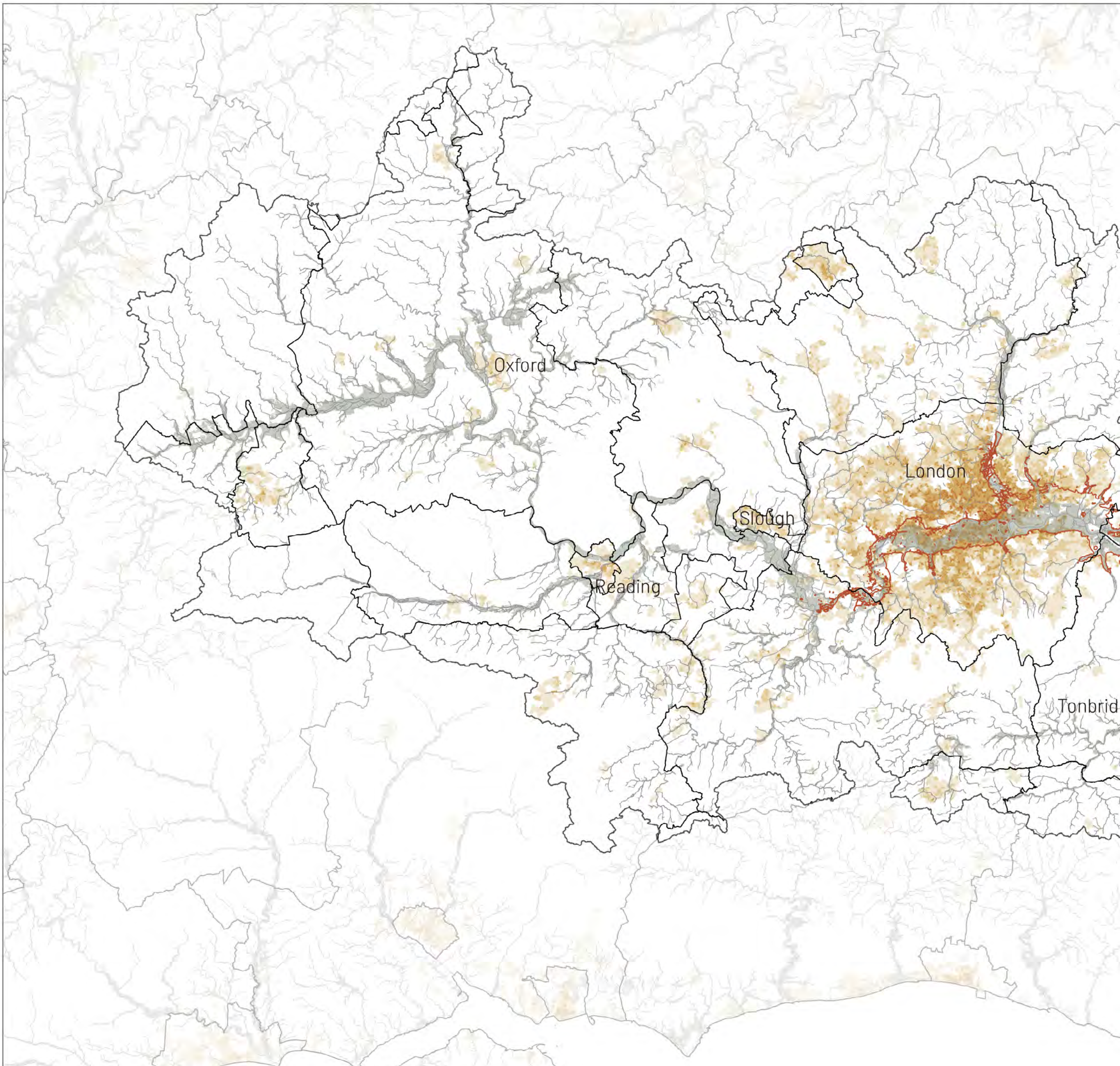
Legend

boundary of river sub-catchment

river course

lock or barrier

FIG. 3.4 River Thames basin. Data source: Ordnance Survey.

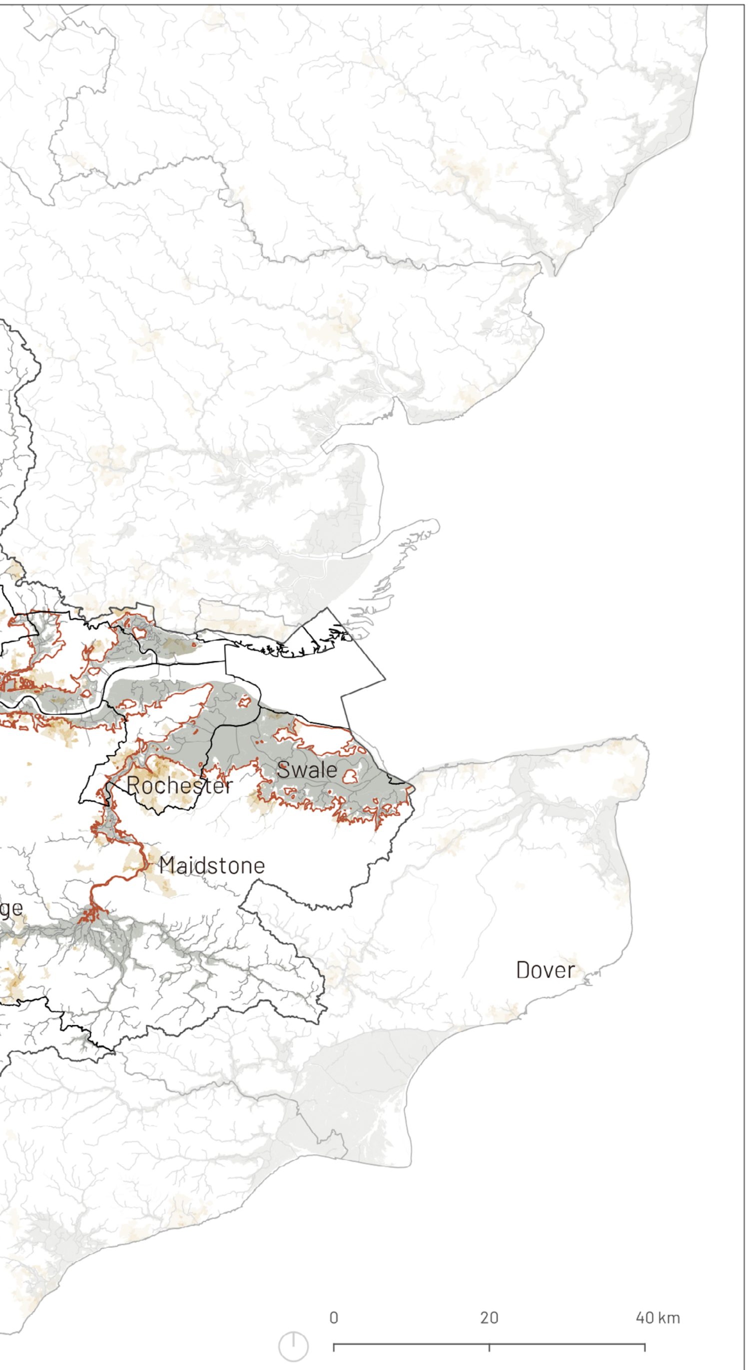

Oxford
London
Slough
Reading
Tonbrid

The built-up area in the River Thames basin

The Thames tidal floodplain forms a corridor that passes through London and eastwards through North Kent and South Essex towards the North Sea. In addition to the large number of people who live and work on the floodplains, there are vital institutional and business centers and heritage sites (Environment Agency, 2011).

Recent estimates identified more than 200,000 properties at risk of flooding from a 1:100 year event across the London basin (Environment Agency, 2009). In addition to properties at risk, London Assembly (2014) pointed out that there is an estimated of 140,000 Londoners at high risk of surface water flooding, and another 230,000 at medium risk. In addition to London, if moving toward the estuary, it is estimated that a total of 9000 properties are at risk in the Medway catchment (Environment Agency, 2017).

From the map, we can identify the area vulnerable to the flooding risk, and the 10-meter low-lying zone, which might be the area at risk under extreme climate change scenarios.



Legend

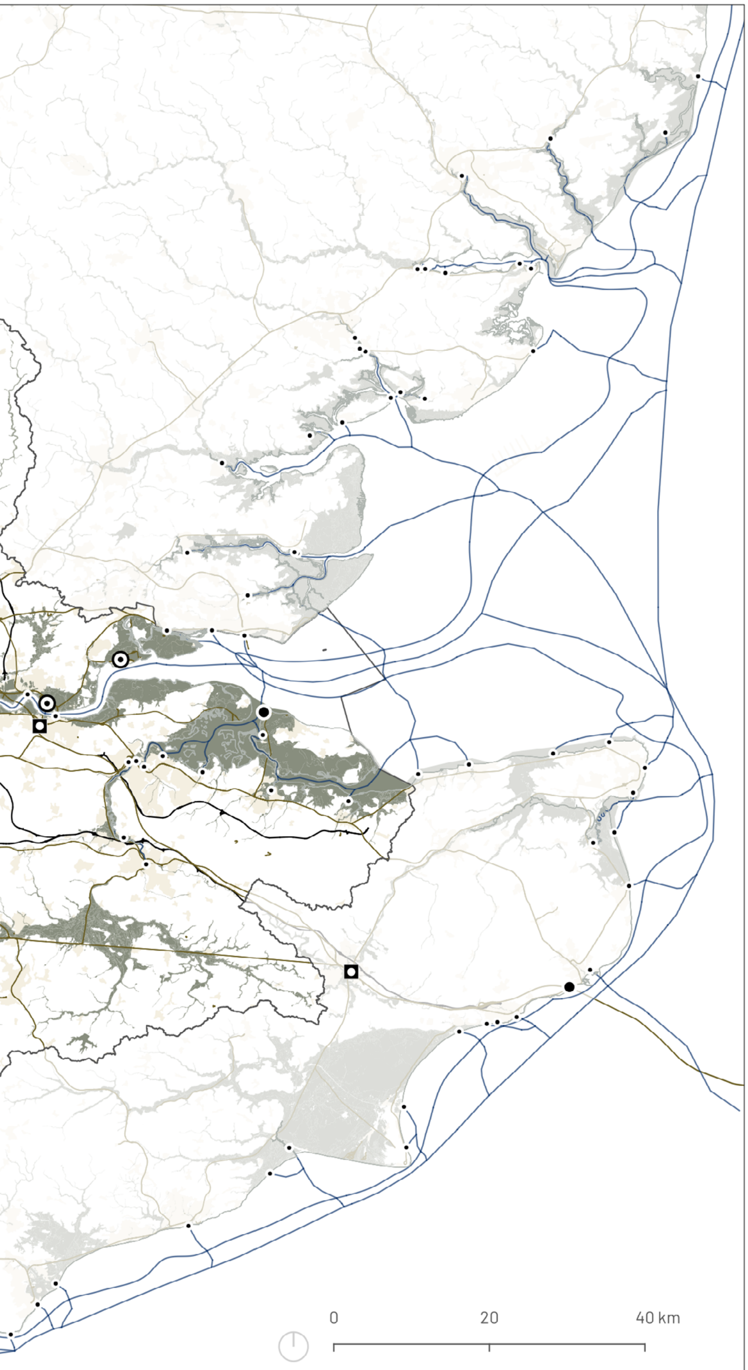
- Administrative boundary
- Extent of flooding risk (EA)
- Low-lying zone: lower than 10m (DTM)

Population density of Lower layer Super Output Areas (2019) (people/ ha)

- 0-25
- 25-57
- 57-106
- 106-186
- 186-502
- higher than 502

* Displayed in natural breaks classification

FIG. 3.5 Urban area in the River Thames basin. Data source: Ordnance Survey.



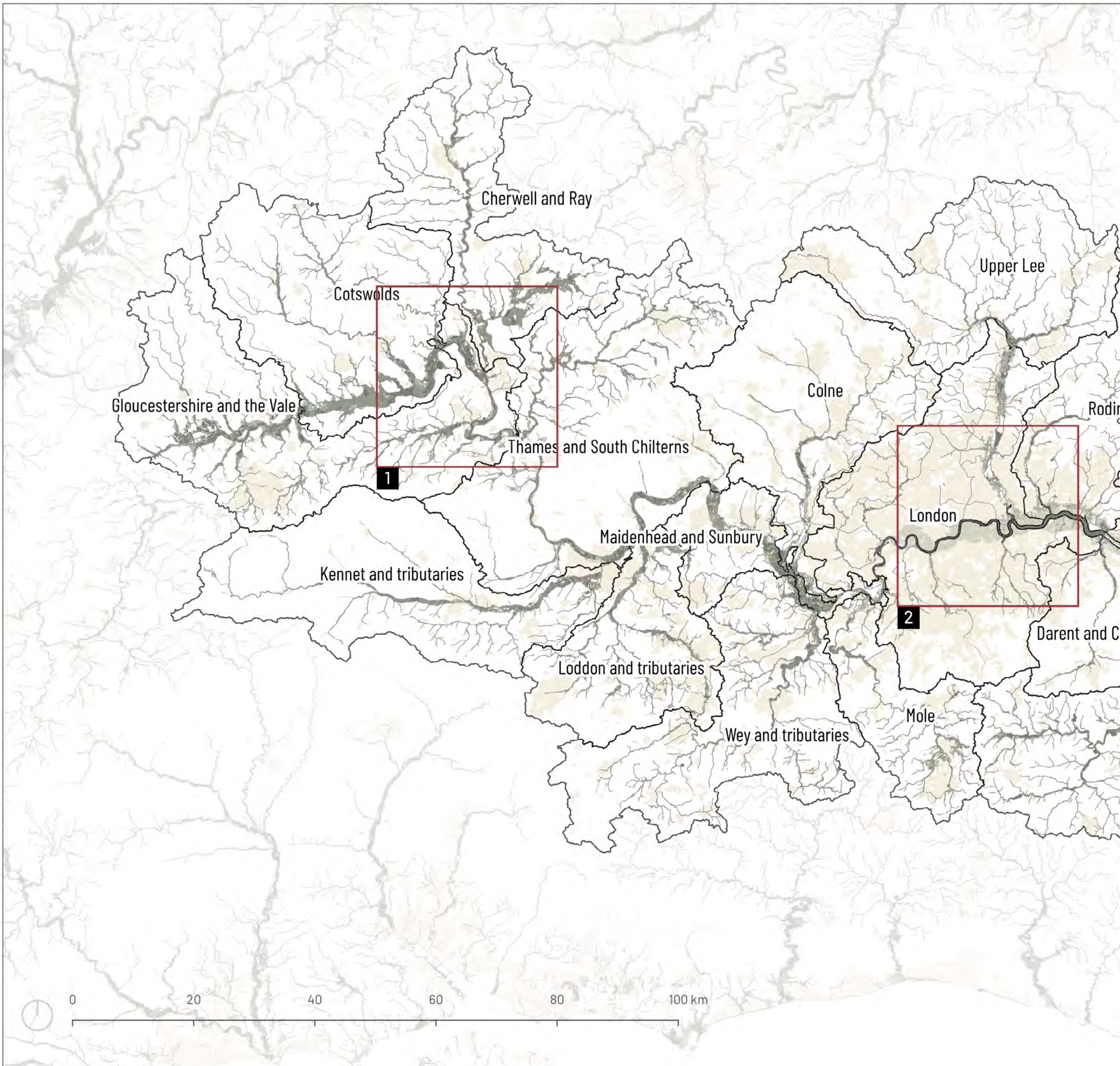
Infrastructure network

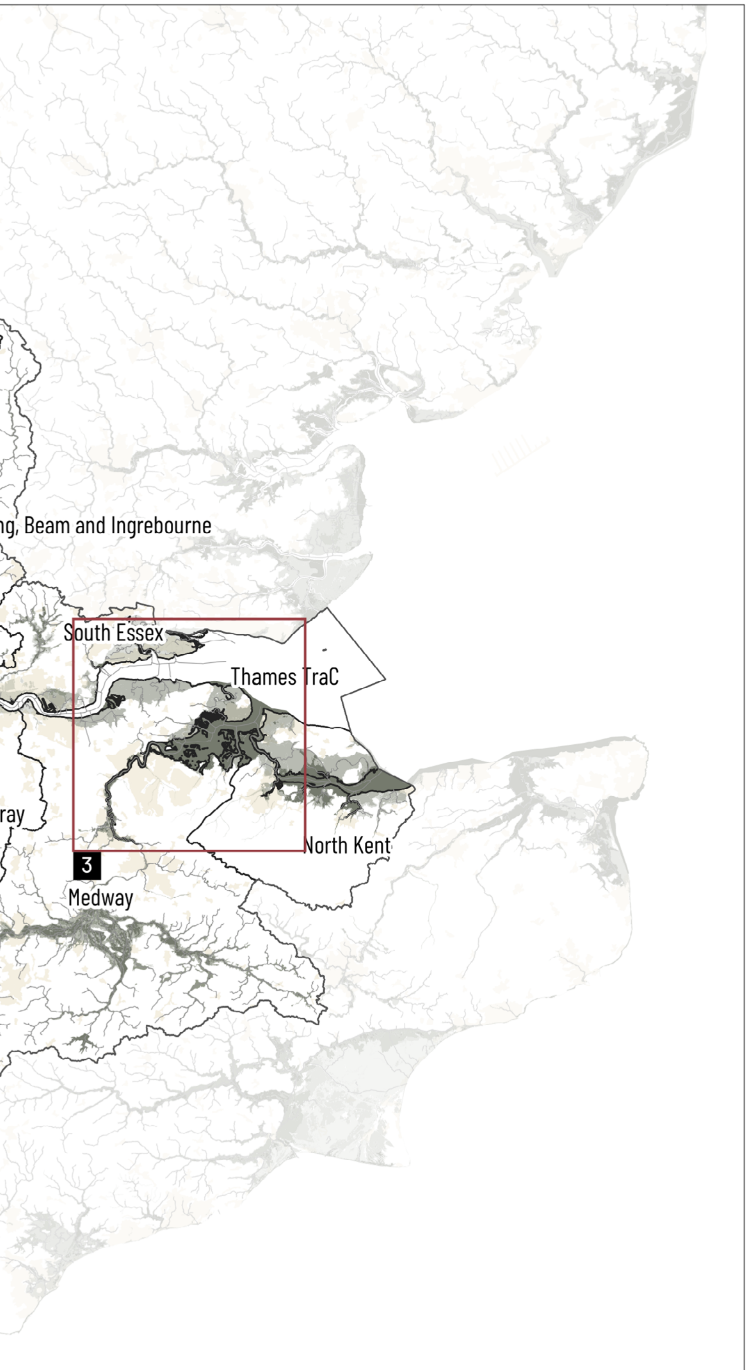
The River Thames basin comprises three international airports and two major ports: Port of Tilbury and London Gateway Port. Both ports are derived from the Port of London, which has been central to the economy of London a major contributor to the growth of the city. On the other hand, the road network system has developed in a ring-and-radial pattern with London in central. It is worth mentioning that Eurostar, the international high-speed rail, makes it possible to commute from London to Amsterdam in four hours. The Eurostar terminus is at London St Pancras International, while the other two British calling points are both located in Kent. These mobility network systems contribute to the convenience of moving within the river basin, and internationally.

Legend

- Boundary of the Thames River basin
- Extent of flooding risk
- Urban
- Railway
- Motorway
- Shipping route
- Main port
- Local port
- Historic port
- Airport
- Eurostar station

FIG. 3.6 Network system in the River Thames basin.
Data source: Ordnance Survey. Developed by author.


Cherwell and Ray
Upper Lee
Cotswolds
Colne
Gloucestershire and the Vale
Thames and South Chilterns
1
London
Maidenhead and Sunbury
Kennet and tributaries
2
Loddon and tributaries
Mole
Wey and tributaries
0
20
40
60
80
100 km



3.2 – **Comparison of the Thames cities**

Three cities in different sub-catchments of the Thames watershed are selected to be investigated their characteristics and the relationships between the cities and the river. For the upper stretch, I selected Oxford because it is the key location where three tributaries meet in the valley. The second location is the center of Greater London. Comparing to rivers in Oxfordshire, the River Thames in London is embanked and controlled. As for the estuary area, an area cross South Essex, Medway, and North Kent catchment is chosen.

Legend

Comparison site

Rivercourse

Boundary of sub-catchment in the Thames River basin

Urban

Risk of Flooding from Rivers and Sea

High: each year, there is a chance of flooding of greater than 1 in 30 (3.3%).

Medium: each year, there is a chance of flooding of between 1 in 30 (3.3%) and 1 in 100 (1%).

Low: each year, there is a chance of flooding of between 1 in 100 (1%) and 1 in 1000 (0.1%).

Very Low: each year, there is a chance of flooding of less than 1 in 1000 (0.1%).

(Source: Environmental Agency. 2020)

FIG. 3.7 comparison of the Thames cities

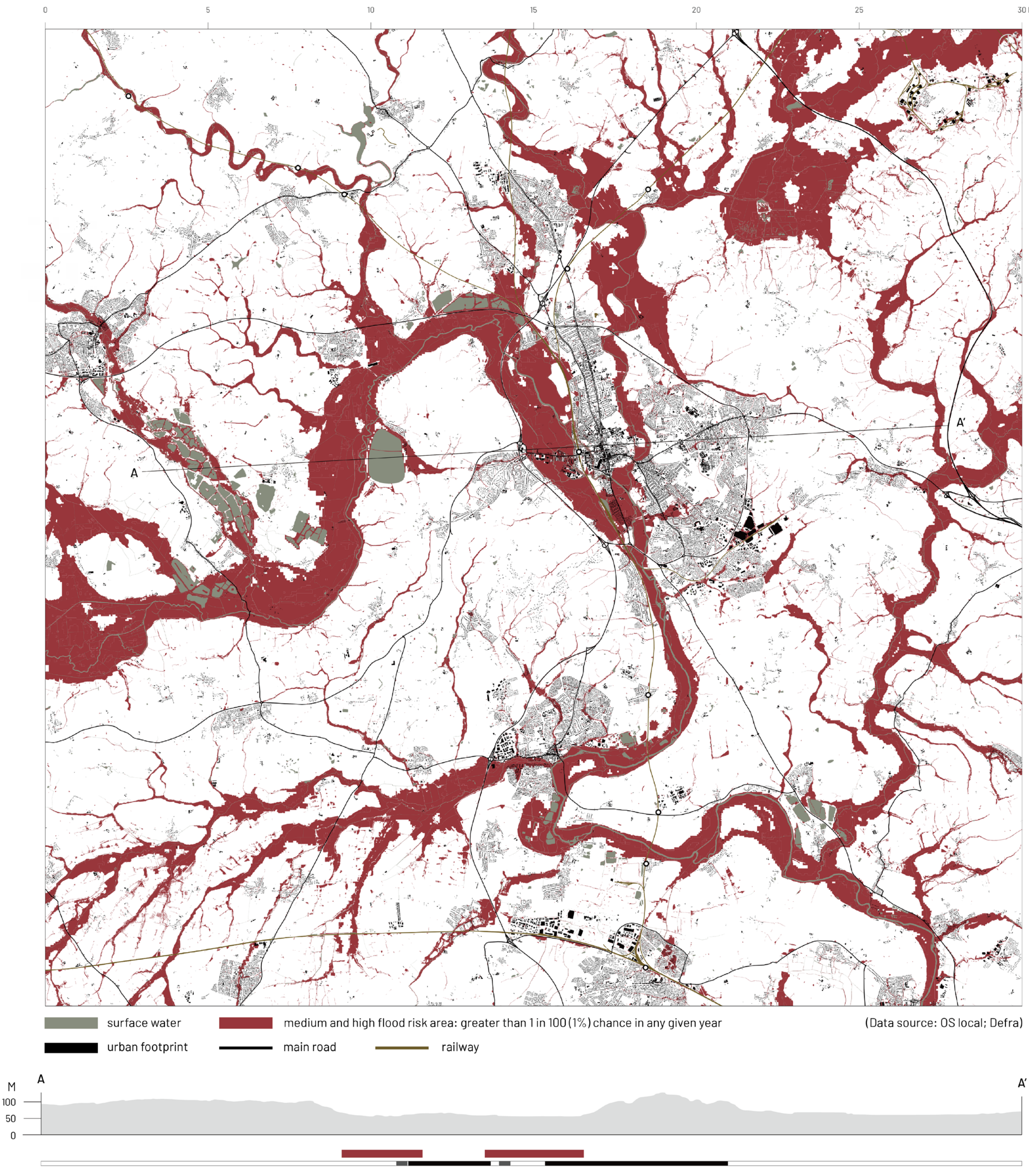
Oxford

The first selected city in the river basin is Oxford. The city is located in the middle of a wide river valley. The tributary rivers Cherwell and Thames run through Oxford and meet south of the city center. As the section illustrated, these rivers and their flood plains constrain the size of the city center; thus, the geographical characteristics acted as the backbone of the city development. In Oxfordshire, the main flooding risks are surface water runoff due to extreme rainfall and water from the hinterland.

FIG. 3.8 Oxford 2007 flood. Source: https://www.oxfordmail.co.uk/news/15427077.2007-floods-10-years-part-two-city-swamped/.

FIG. 3.9 Oxford under water. Botley Road and Abingdon Road are closed and under water. Source: https://airexperiences.co.uk/aerial-photography/uk-floods-oxford-water/.

FIG. 3.10 (opposite page) Flood risk map of Oxford. Data source: Defras and OS local.


0
5
10
15
20
25
30 KM
A
A′
surface water
medium and high flood risk area: greater than 1 in 100 (1%) chance in any given year
(Data source: OS local; Defra)
urban footprint
main road
railway
M
100
50
0
A
A′
Oxford
Headington

London

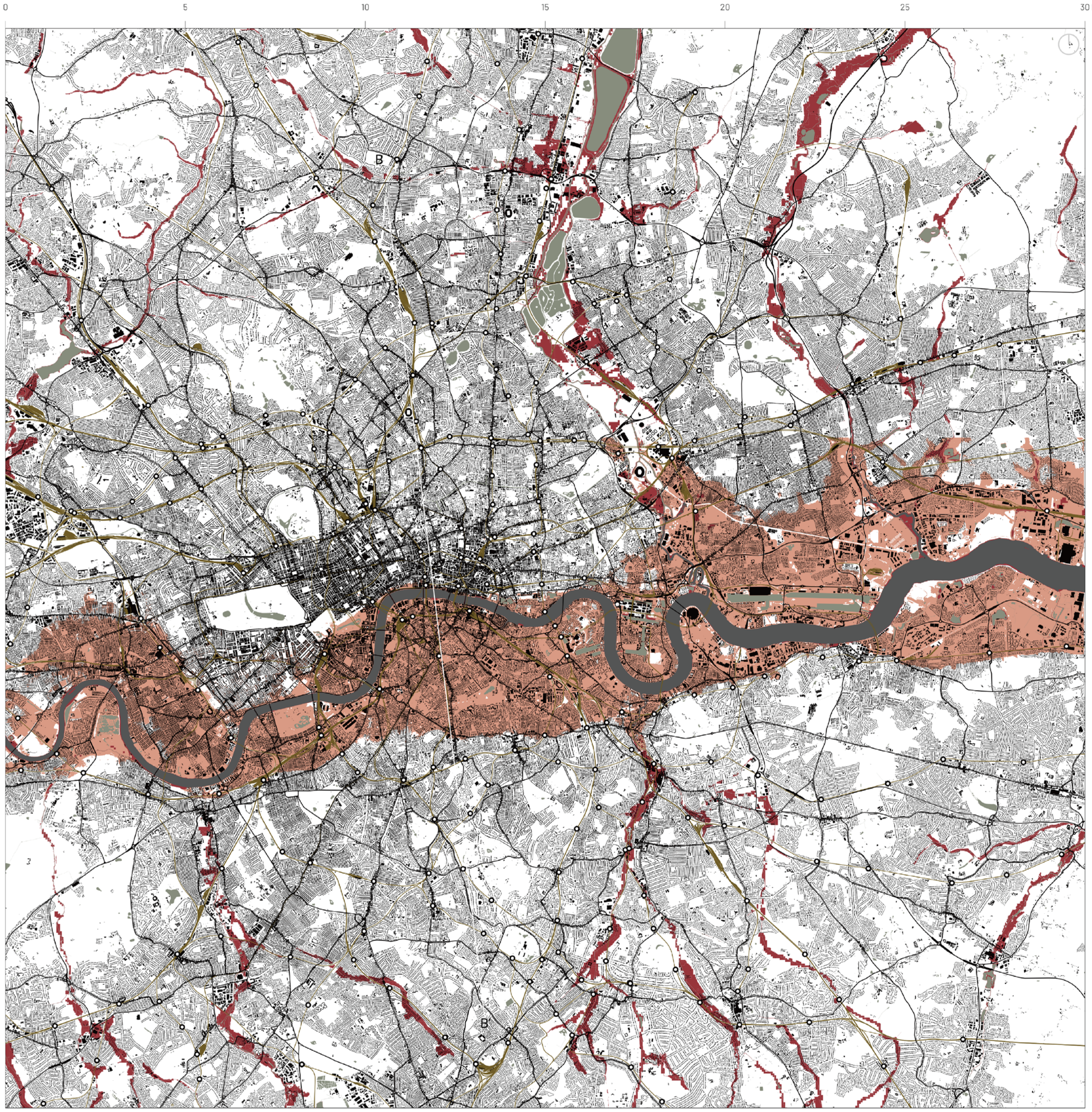
The second selected city of the Thames river basin is London. The city is located on a flat alluvial plain consisting of London clay. Compare to the unleashed river in the upper watershed, this part of the Thames river is controlled by flood defense (embankment or high ground) along the river. Its primary geographical feature is a navigable river that crosses the city from the south-west to the east. The city is protected by the Thames Barrier, a retractable barrier system designed to prevent the floodplain from being flooded by exceptionally high tides and storm surges moving up from the North Sea.

The threat of flooding in London includes pluvial flood due to impermeable surface and fluvial flooding when the Thames overtop the flood defenses.

FIG. 3.11 Tower Bridge. Image source: https://www.geograph.org.uk/mapper/

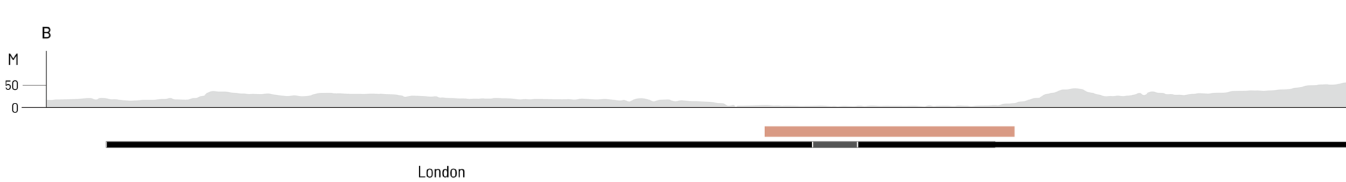
FIG. 3.12 Woolwich: Thames Barrier. Image source: https://www.geograph.org.uk/mapper/

FIG. 3.13 (opposite page) Flood risk map of London. Data source: Defras and OS local.



flood-prone lowland (+5m zone) | medium and high flood risk area: greater than 1 in 100 (1%) chance in any given year

tidal river | surface water | urban footprint | main road | railway | (Data source: OS local; Defra)



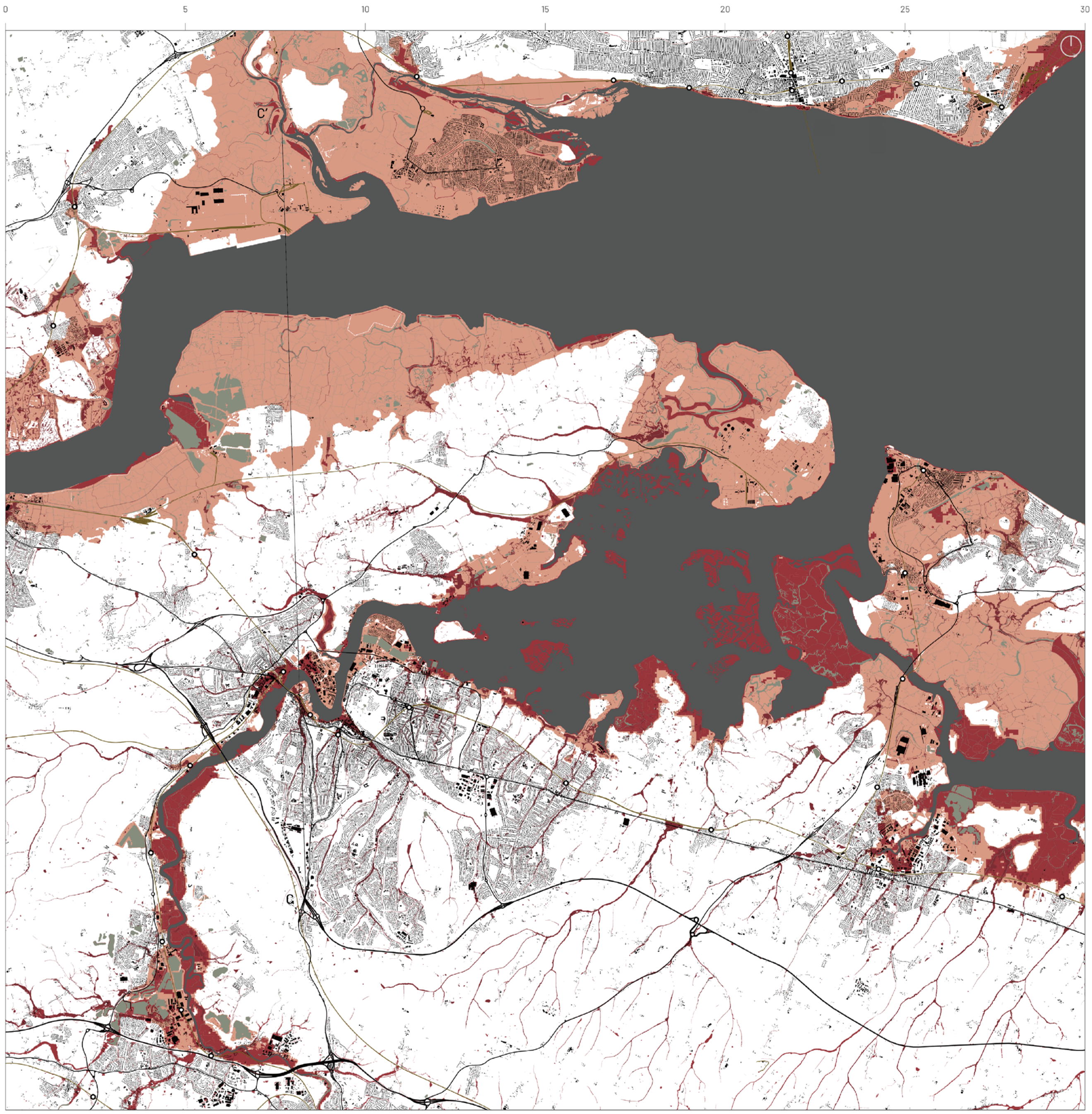
Medway

For the estuary part, this study investigated the Medway river estuary. The Medway river makes two sharp bends around Rochester and Chatham and enters the North Sea. This bending location of the river is the historic center, which is famous for naval history and a set of fortres located on the marshes or on the slope. From the section, we understand that there is a wide range of high differences, from 5 meters below to 120 meters above the sea level. Due to the complexity of geography and interface, there is a complexity of flooding risks. It is also highly vulnerable to sea-level rise. After a first round of analysis, I decided to select this area as the strategic area for further design exploration, for this area contains layers of challenges caused by flooding risk and owns a diverse interface between water and the built environment.

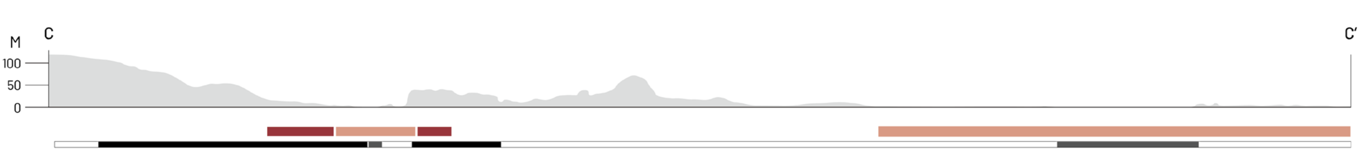
FIG. 3.14 Industrial zone in Grain, which is close to saltmarshes. Image source: https://www.geograph.org.uk/mapper/

FIG. 3.15 Medway city estate, an industrial zoneflooded by the river. Image source: https://www.geograph.org.uk/mapper/.

FIG. 3.16 (opposite page) Flood risk map of London. Data source: Defras and OS local.



flood-prone lowland (+5m zone)
medium and high flood risk area: greater than 1 in 100 (1%) chance in any given year
tidal river
surface water
urban footprint
main road
railway
(Data source: OS local; Defra)



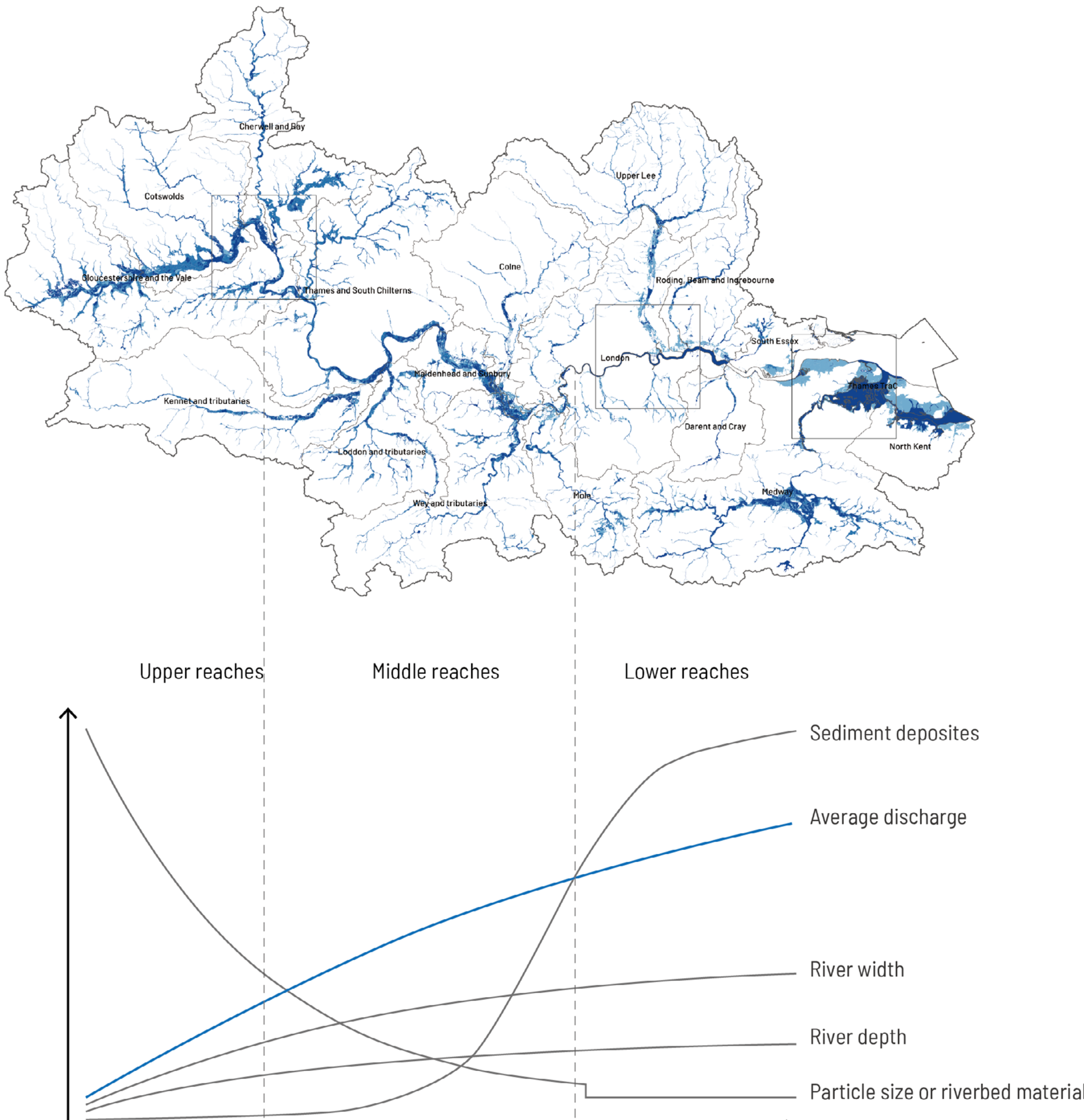


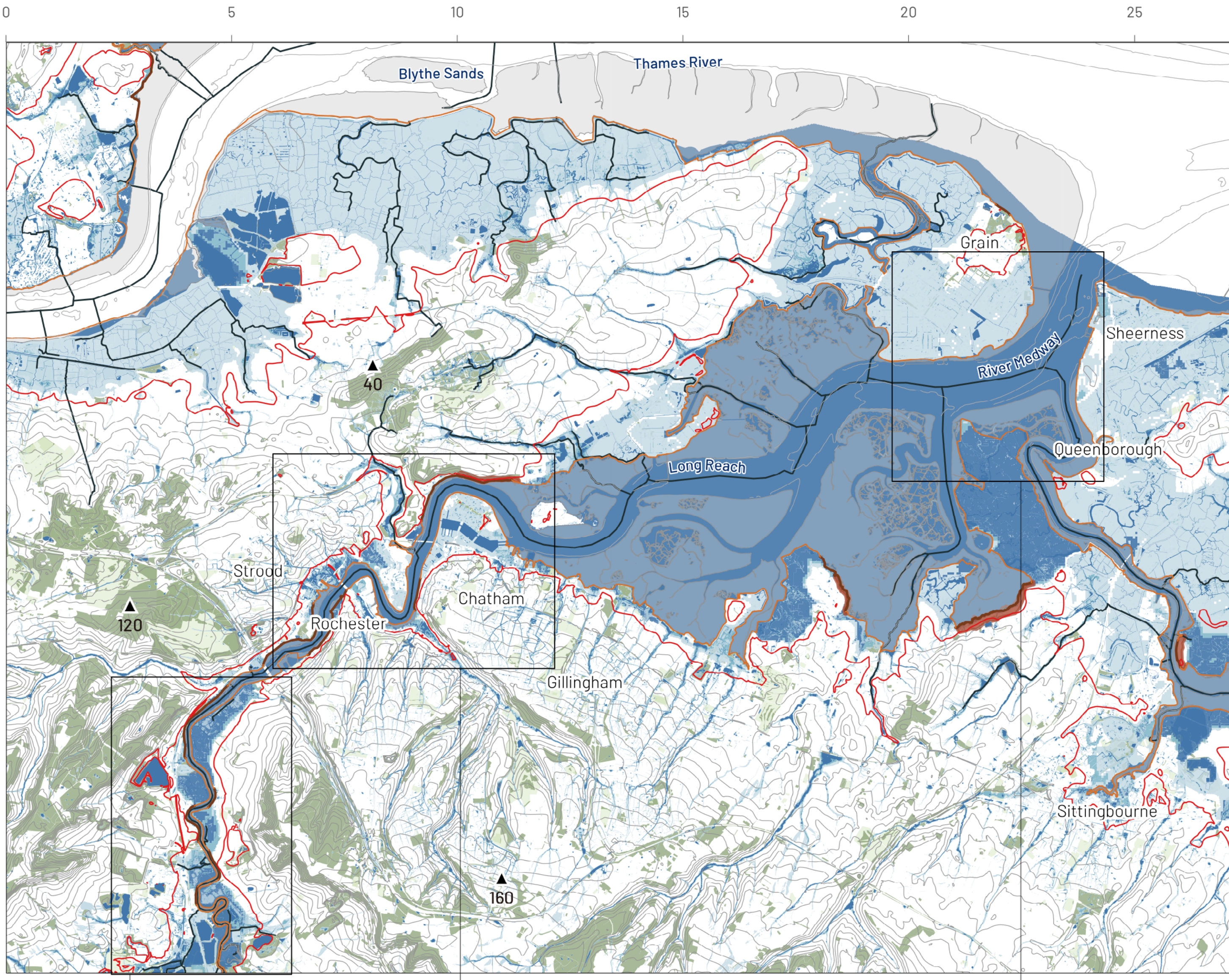
FIG. 3.17 Diagram comparing river in different parts of watershed. Adapted from Prominski et al. (2017).

Conclusion: River as a system

To summarize, after delving into three parts of the watershed, several design strategies are identified. The importance of this step is to understand the river as a system. Although the final intervention locations of this study are located in the downstream area, we still need to consider water from the hinterland. For instance, creating space for rivers and increasing the sponge capacity in upper reaches could reduce the flow rate and high water surge; thus, it could relieve the burden on downstream areas. From the next session, the study will zoom into the estuarine area.

	Upper reaches ←	→	Lower reaches
Landscape characteristics	1. Broad river valley 2. Unleashed river, relief channel 3. City locates in valley and on the high ground	1. Flat alluvial plain 2. Channelized river or controlled river 3. Barriers between river and city: dike 4. Densely populated city located on river plain	1. Wide range of geographical difference (hills, valley, alluvial plain, coastline) 2. River estuary 3. City located on the high ground, close to the river or the sea
Threats of flooding	1. Surface water runoff due to extreme rainfall 2. Water from the hinterland	1.+ 2. 3. Sea level rise 4. Flood defense branch out in populated area	1.+ 2. 3. Sea level rise and tidal surge 5. Intertidal habitat loss
Type of flooding	Fluvial flood	Fluvial flood Pluvial flood	Fluvial flood Pluvial flood Coastal flood
Strategies	1. Redesign of dike: setback/ naturalizing 2. Relief channel / green belt/ room for the river (increase retention time and space) 3. Re-forestation and re-vegetation (increase sponge capacity)	1. Drainage design in the built environment (increase retention space) 2. Redesign of dike, emphasizing on waterfront interface 3. Re-vegetation of urban green system (increase sponge capacity)	1. Redesign of dike: setback/ naturalizing (increase retention space in flood plain) 2. Coastal management 3. Restoration of tidal habitat dynamics 4. Waterfront city redevelopment

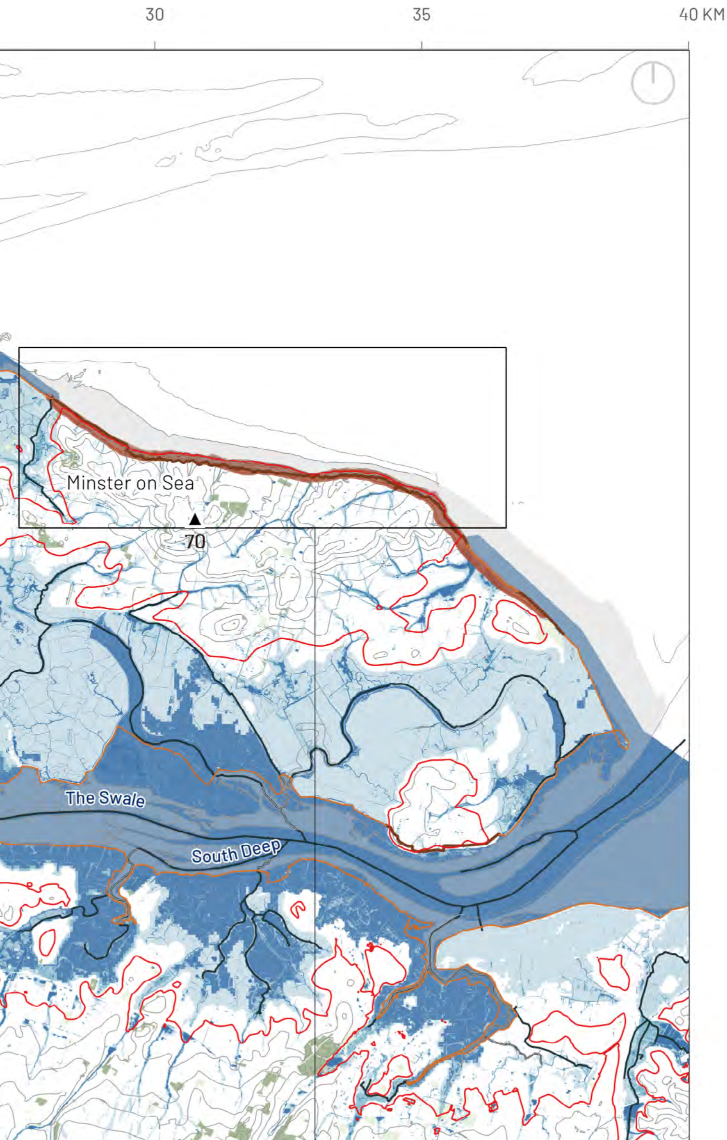
FIG. 3.18 Table. Comparison of characteristics of riverine cities.



Halling-Snodland valley
-last part of tidal river
-meanders in valley
-residential town

Bend of River Medway
-interface between valley and estuary
-floodplain underwent brownfield transformation
-major urbanization area

-River Medway joining
-The Swale joining fro



g River Thames esturay
m the west

Costal erosion on Isle of Sheppey

3.3 – **Understanding of the River Medway Estuary**

3.3.1 – **Risk of flooding**

The map illustrated the downstream area affected by flooding risk. The loss of natural, permeable surfaces over the last 50 years within urban areas has increased the rate of surface water runoff during rainfall. The Flood Investigation Report of Medway Council (2019) pointed out that the majority of urban areas where flooding was reported were within areas considered to be at high risk of surface water flooding. The storm event has been estimated to have a return period of 1 in 36 years (2.7%) which is commensurate with a medium flood risk event. Also, public and highway sewerage infrastructure is not designed to store this extent of surface water and the capacity of the network was overwhelmed. This was compounded by overland flow.

From the map, we can identify that low-lying (+10m) coastal areas undergo different extent of flooding risk, and this risk is expected to increase due to climate change. In this respect, the local authorities of Sheerness, Sittingbourne, Rochester, and Chatham need to take action. On the other hand, some of the flood-prone areas accommodate tidal habitats, such as the River Medway estuary, the south part of the Isle of Sheppey, and the right bank of the River Thames.

Legend

- rivercourse
- foreshore
- contour line (10m interval)
- low-lying zone: lower than 10m
- woodland
- open space
- coastal erosion zone

Coastal erosion risk (NCERM, 2018)

- erodible flood defense
- floodable flood defense

Risk of Flooding from Rivers and Sea (Environmental Agency, 2020)

- High: each year, there is a chance of flooding of greater than 1 in 30 (3.3%).
- Medium: each year, there is a chance of flooding of between 1 in 30 (3.3%) and 1 in 100 (1%).
- Low: each year, there is a chance of flooding of between 1 in 100 (1%) and 1 in 1000 (0.1%).

FIG. 3.19 Map of flooding risk. Data Source: Environmental Agency. Developed by author.

3.3.2 – **Tidal dynamic**

Working with tide is a critical part of this project; therefore, there is a need to map the vertical data correctly. The daily astronomical tidal range can vary from 5.8 m for spring tides and 3.2 m for neap tides (see figure on the bottom), yet there are storm surges that can raise the water even higher.

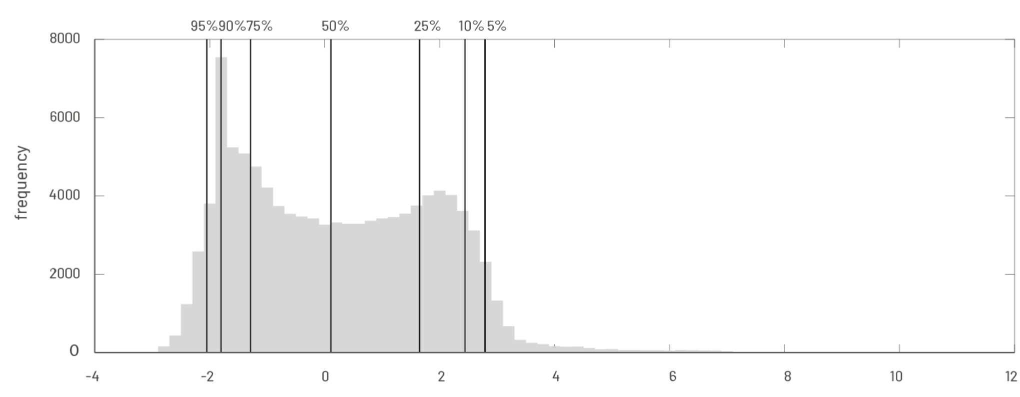
Data processing

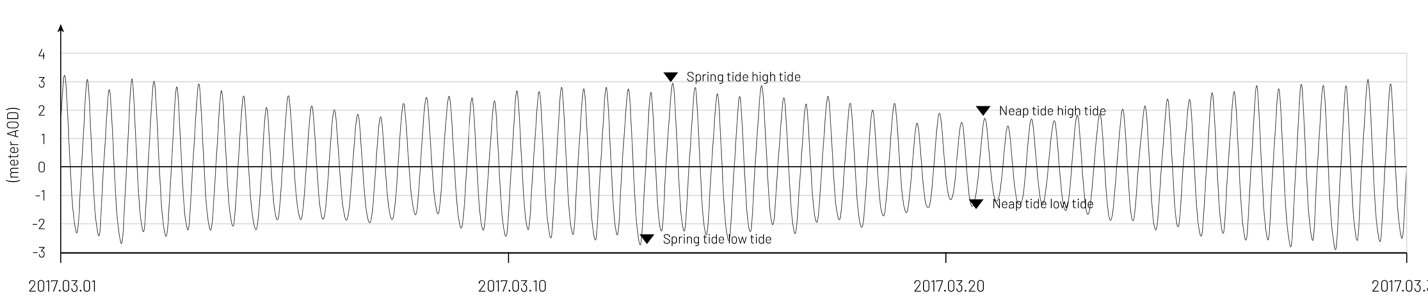
I downloaded a dataset that included three-year, around one million of the data record of Sheerness tide gauge from the British Oceanographic Data Centre (BODC). After processing the data according to percentile, we have an overview of the distribution of tidal height. For example, the 10th percentile is at 2.44 meters. In other words, around 10 percent of the time (total 36 days in a year) the water level is above 2.44 meters. The results are shown in the table and histogram.

There are two datum systems: chart datum (CD) and ordnance datum (OD), regarding tidal data. It means that the same sea level may be recorded in different datums and thus resulting in different numbers. The original tidal level data from BODC is given as a height above chart datum (ACD), approximately the lowest level due

FIG. 3.20 Histogram of sea-level recording at 15-minutes intervals in three years at Sheerness (from 2015 to 2017) converted to OD. Data source: British Oceanographic Data Centre (BODC). Sheerness tide gauge. https://www.ntslf.org/tides/datum). Developed by author.

FIG. 3.21 An example of tidal range in a month from BODC data. Developed by author.





to astronomical effects and excluding meteorological effects. For example, the tidal range is around 0 to 6 meters ACD. However, all the other shapefile and raster data downloaded from the UK open data are in the OD system, which means the tidal range is around -3 to 3 meters AOD. Therefore, I converted the ACD data from BODC by subtracting 2.9 meters (the datum difference in Sheerness) to align with the terrain provided by the LIDAR Composite DTM. This part of work played as an important basis for further design exploration in the sea-level rising scenarios.

In addition to the historic tidal data, there is a real-time prediction of the tide from the website of Tidetimes.uk. According to the Tidetimes, I identified the spring tide and neap tide of this year (2021) as the image marked.

Vegetation connected to tide

The tidal range determines the habitats connected to it. When a patch is located higher than the high tide of neap tide high tide level (around 1.8m), it is possible to accommodate vegetation. From the previous data study, we know that at this height, around 75% of the time the patch could expose to air. If it is lower, then it could be a mudflat habitat. However, if the sea level rise, the current intertidal vegetation might be flooded.

FIG. 3.22 Table: Original data and the transformation of the datum system

	Tidal height (m AOD)	Tidal height (m ACD)	Total days/year
5th percentile	2.788	5.688	18.25
10th percentile	2.440	5.340	36.50
25th percentile	1.650	4.550	91.25
50th percentile	0.109	3.009	182.50
75th percentile	-1.290	1.610	273.75
90th percentile	-1.802	1.098	328.50

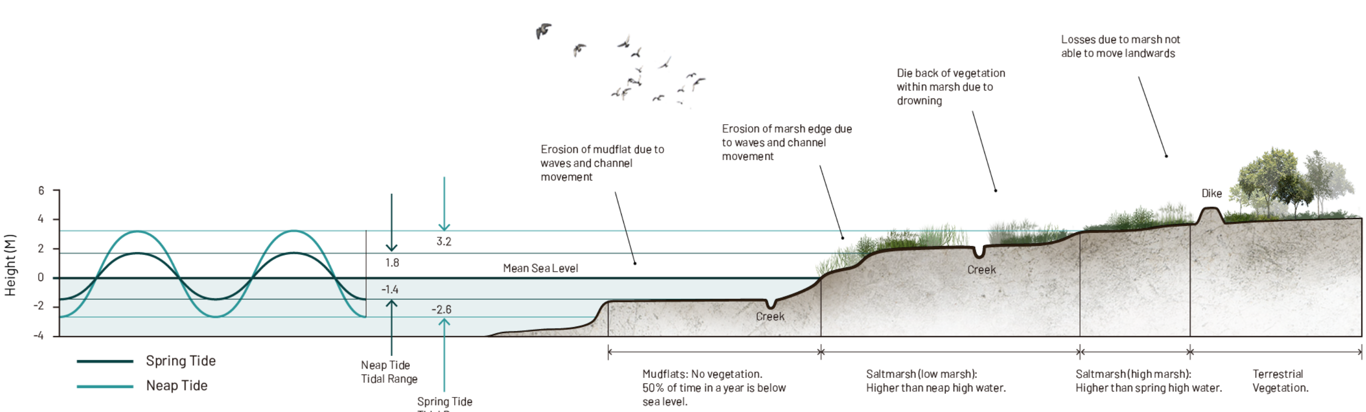


FIG. 3.23 Tidal section and habitats connected to it. Developed by author.

3.3.3 – **Scenario of sea level rise**

Sea level rising is an important factor in the scenario study. A set of synthesis map is developed to investigate the influence. From the table, we have an overview of water levels in current and different scenarios.

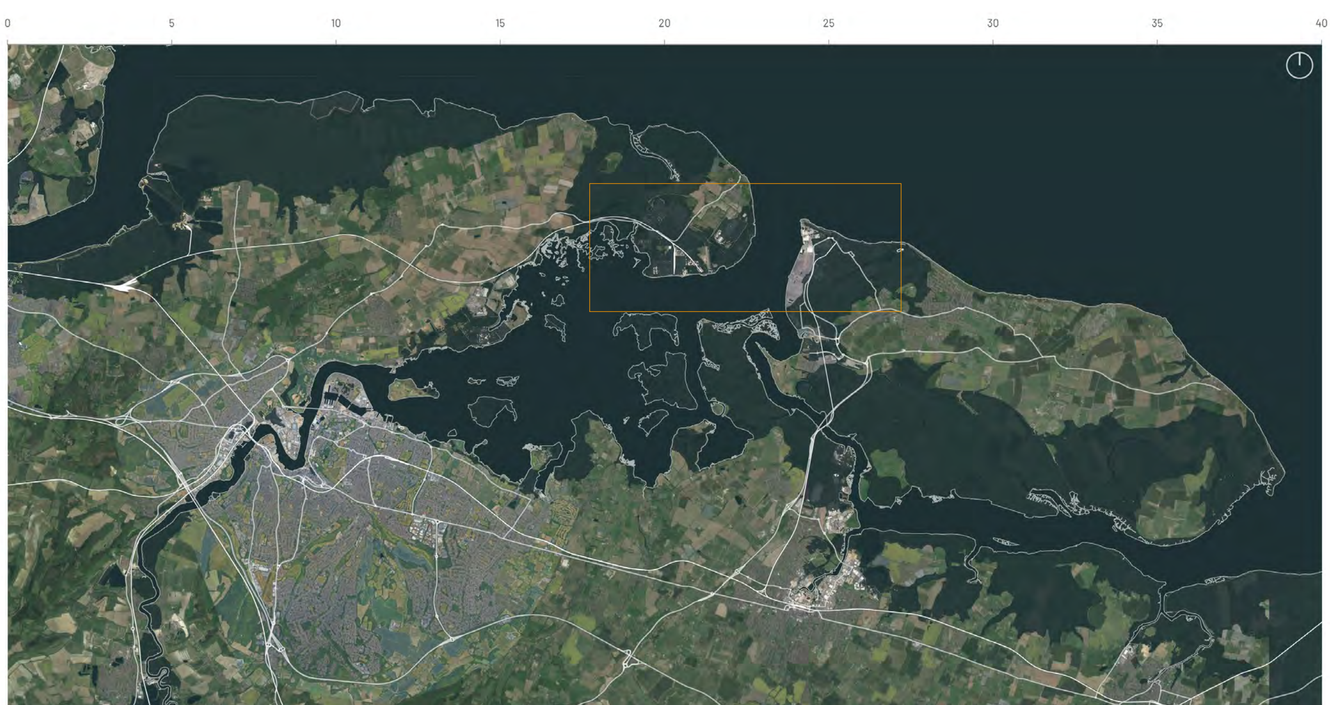
Image A shows sea level at 3 meters, which is equal to current spring tide high tide. This image highlights the current intertidal zone and points out areas vulnerable to flooding if the current flood defenses break or be flooded.

Image B demonstrates the scenario of sea-level rise 2 meters. This is the extreme projection in the Thames 2100 project. In this case, it presents clearly how coastal cities are flooded, such as Medway, Chatham, and Sittingbourne. Last, image C illustrates the condition when sea-level rise 7 meters. The influential zones are similar to scenario B but in a wider range.

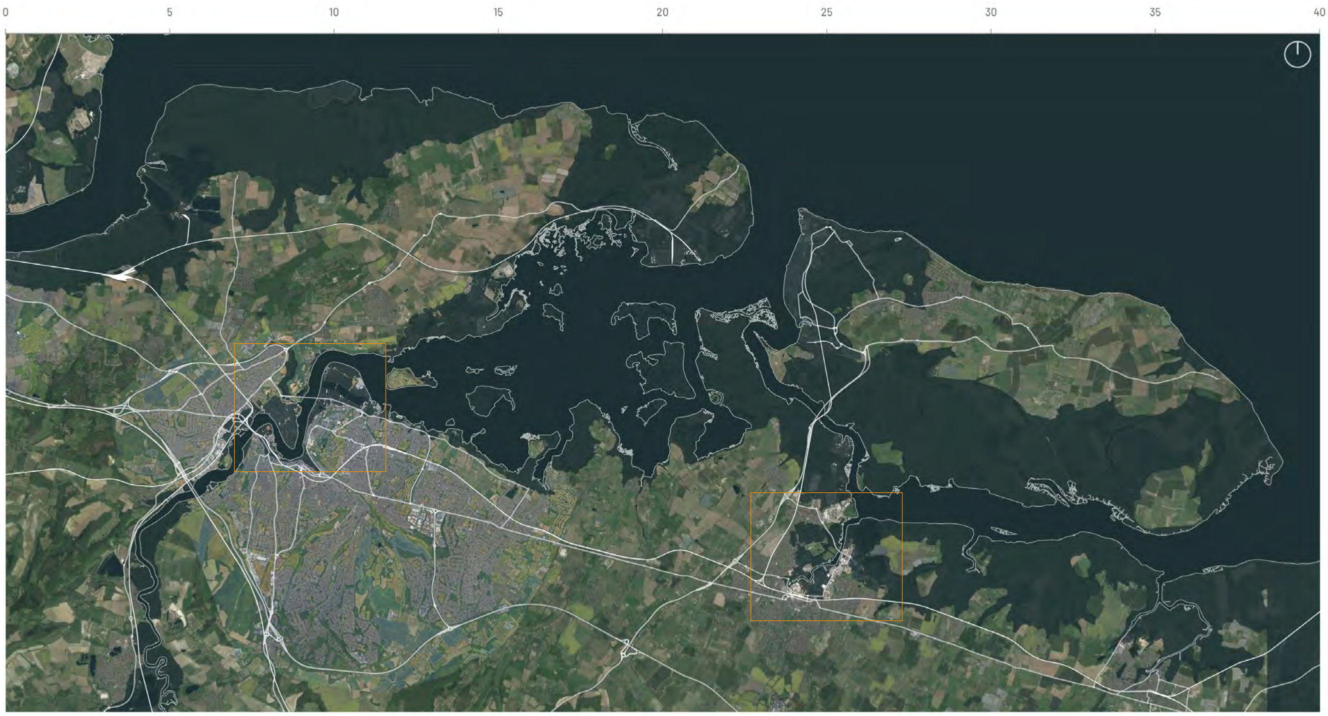
		A		B		C	
	total days in a year	current tidal height	sea level+ 0.9m	sea level+ 2m	sea level+ 4m	sea level+ 7m	
5th percentile	18.25	2.788	3.688	4.788	6.788	9.788	▶ Use this row of height for scenario study
10th percentile	36.50	2.440	3.340	4.440	6.440	9.440	
25th percentile	91.25	1.650	2.550	3.650	5.650	8.650	
50th percentile	182.50	0.109	1.009	2.109	4.109	7.109	▶ Near mean sea level
75th percentile	273.75	-1.290	-0.390	0.710	2.710	5.710	
90th percentile	328.50	-1.802	-0.902	0.198	2.198	5.198	

Official projection figure in Thames 2100 (sea level+ 0.9m – sea level+ 2m)

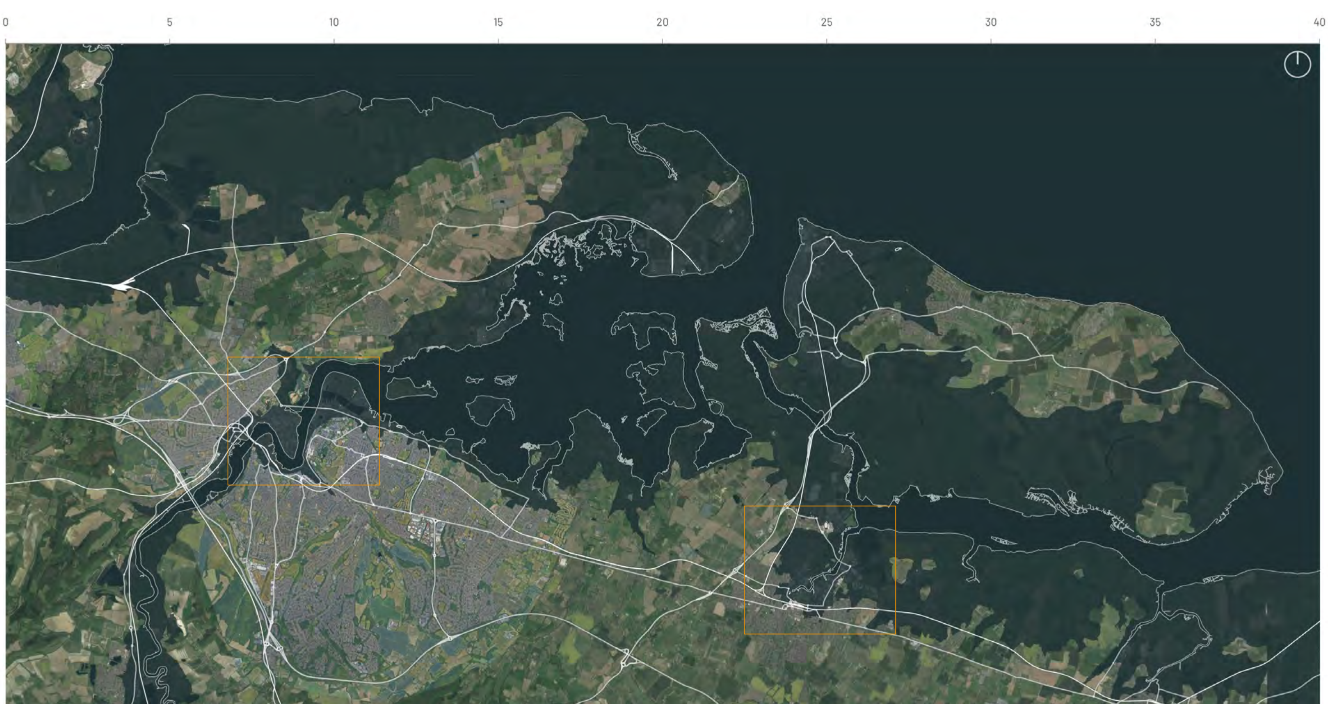
Scenarios in this project (sea level+ 4m – sea level+ 7m)



A. Synthesis map of sea level in 3 meters: Current Spring high tide



B. Synthesis map of sea level in 5 meters: Current Spring high tide+ 2meters



C. Synthesis map of sea level in 10 meters: Current Spring high tide+ 7meters

FIG. 3.24 A set of synthesis maps showing scenarios of sea level rise. Data source: LIDAR Composite DTM 2019. Developed by author. The white lines are the current road systems.

3.3.4 – **Physical environment**

Isle of Sheppey

A risk related to coastal flooding is coastal erosion or coastal retreat, whichcan be observed at the coastline of the Isle of Sheppey. The Isle of Sheppey is not an island formed by estuarine sedimentation, instead, it belongs to the British Isles, and it was separated from the mainland by the Swale Channel. From the bedrock geology map, we understood Hoo peninsula and the Isle of Sheppey belong to the Thames Group, with London clay formation. It is the youngest layer of bedrock geology, which is categorized in the Eocene lithostratigraphic group, and formed 56 to 33.9 million years ago.

Coastal erosion

According to North Sheppey Erosion Study (2011), the shoreline over much of the length of the north Sheppey coast is in retreat and has been so for centuries. This is part of a natural process that has been taking place as sea levels have slowly risen and land levels have gradually dropped, both being the long-term consequences of the last (Pleistocene) ice age. However, the current Shoreline Management Plan policy for the undefended north coast between Minster and Warden Bay indicates there is not active intervention.

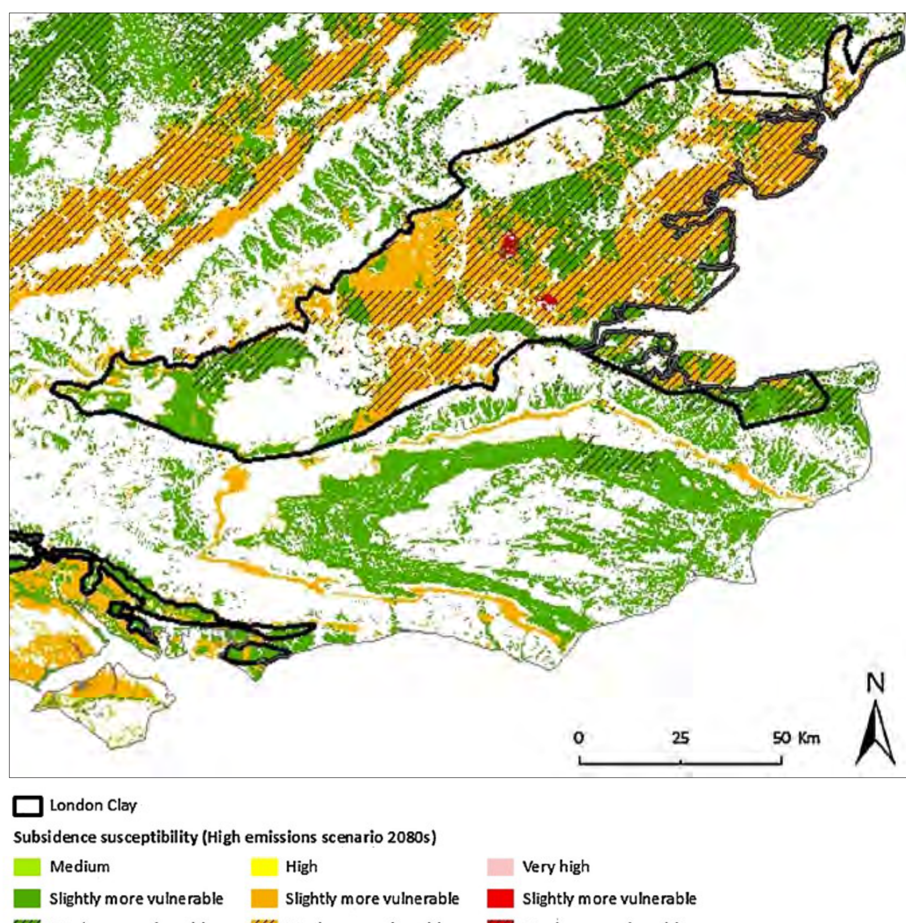


FIG. 3.25 Subsidence susceptibility classification of London Clay (high emissions 2080s). Source: Harrison et al., (2012).

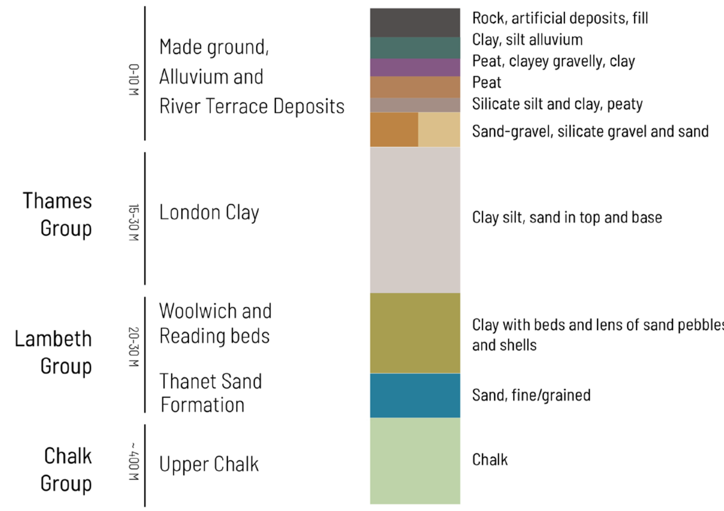
FIG. 3.26 Right. Top. Bedrock section in the Thames river basin. Adapted from Bonì et al., 2018.

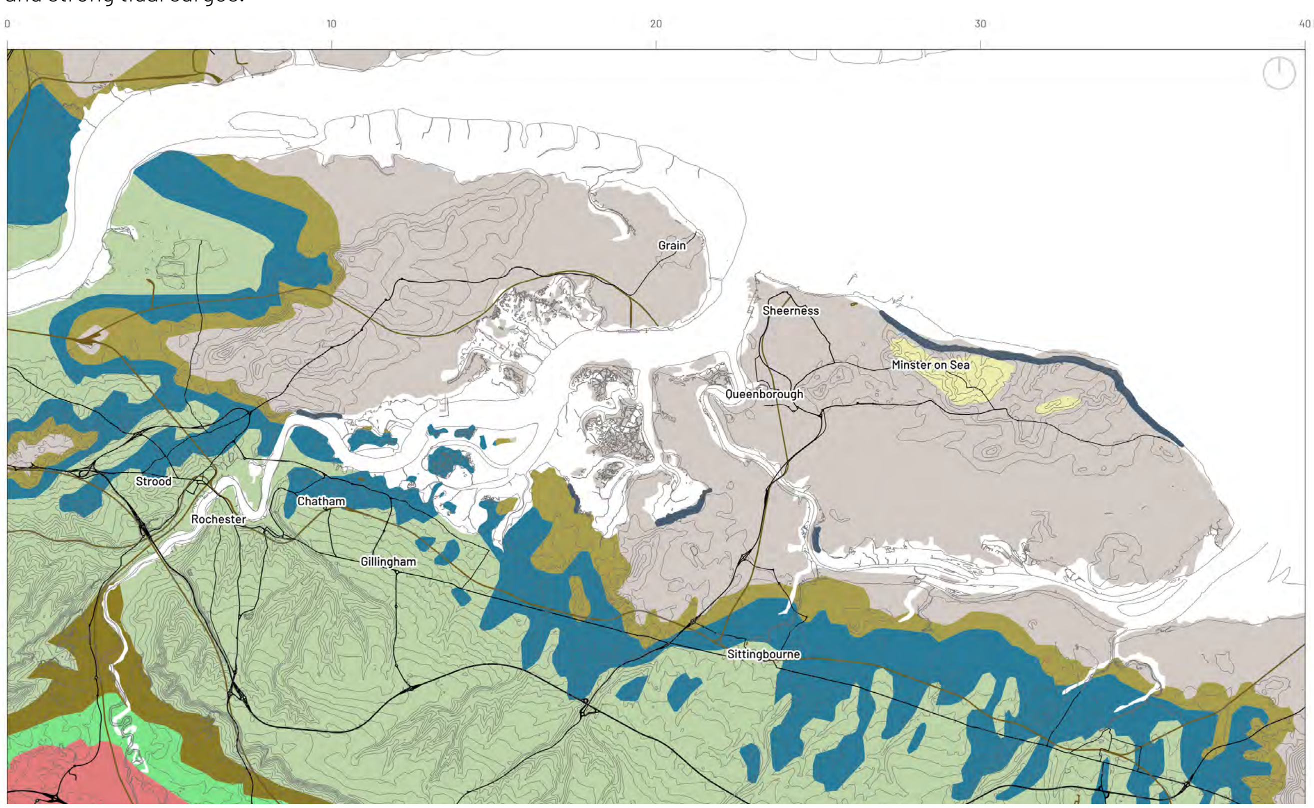
FIG. 3.27 Right. Bottom. Bedrock and coastal erosion. Data: British Geological Survey. Developed by author.

Shrink-swell behavior of clay

In the UK, London Clay is susceptible to shrinkage and swelling as environmental conditions change. Harrison, A. M., et al. (2012) pointed out that shrink-swell susceptible clays change volume in response to variation in moisture content, particularly in the upper 2m of the ground. Indications are that climate change will increasingly alter the moisture conditions that UK soils experience. For example, milder, wetter winters are predicted for the southeast of England. Therefore, the occurrence or magnitude of damage to houses, commercial buildings, and roads due to shrink-swell may change.

In sum, the above-mentioned coastal erosion on the north coastline of Sheppey is mainly caused by its physical environment and would be accelerated by sea-level rise and strong tidal surges.





Contour line

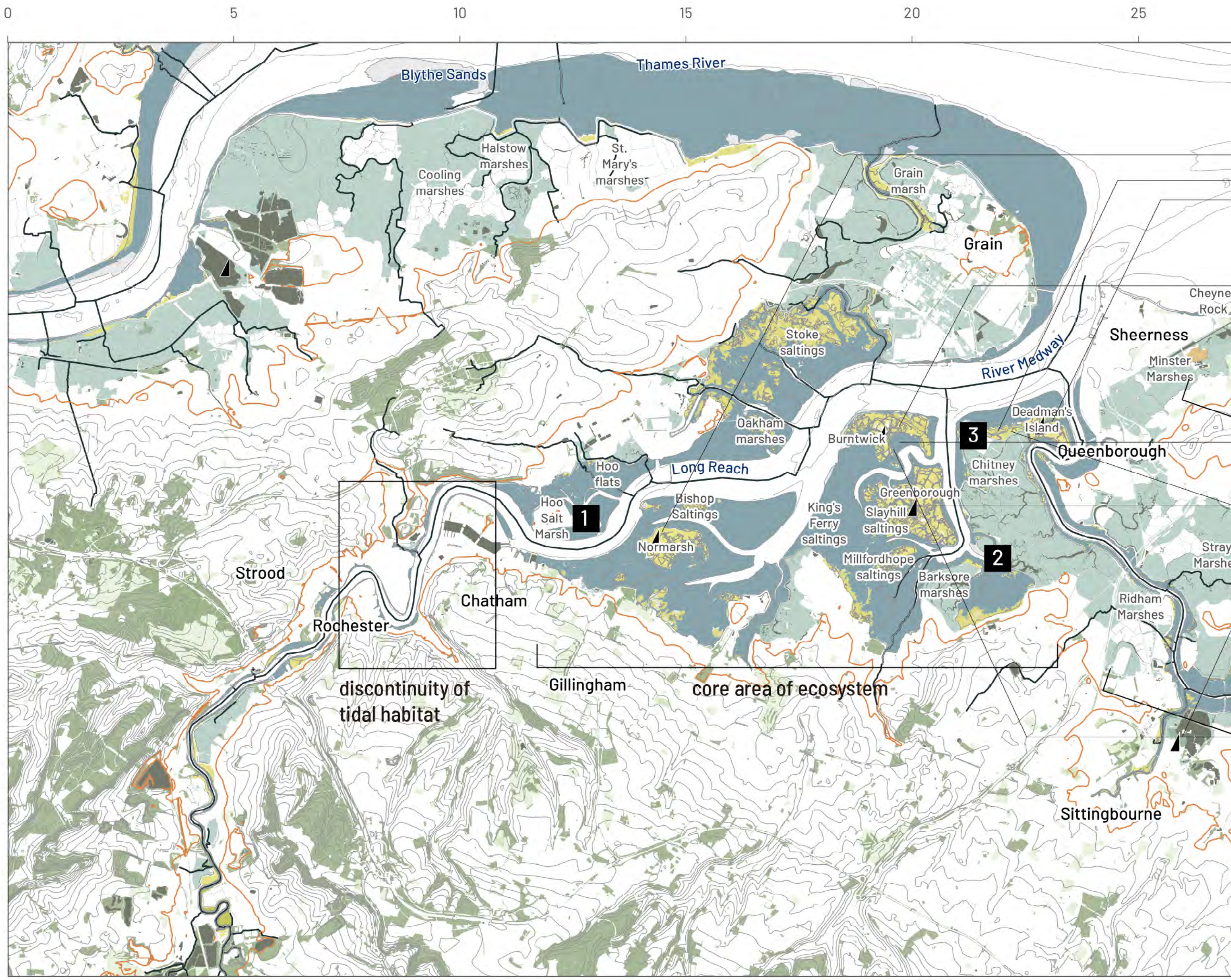
Landscape urgencies

Coastal erosion

Geology

Bedrock (625k)

- BRACKLESHAM GROUP AND BARTON GROUP
- GAULT FORMATION AND UPPER GREENSAND FORMATION
- GREY CHALK SUBGROUP
- LAMBETH GROUP
- LOWER GREENSAND GROUP
- NEOGENE ROCKS (UNDIFFERENTIATED)
- THAMES GROUP
- THANET SAND FORMATION
- WEALDEN GROUP
- WHITE CHALK SUBGROUP

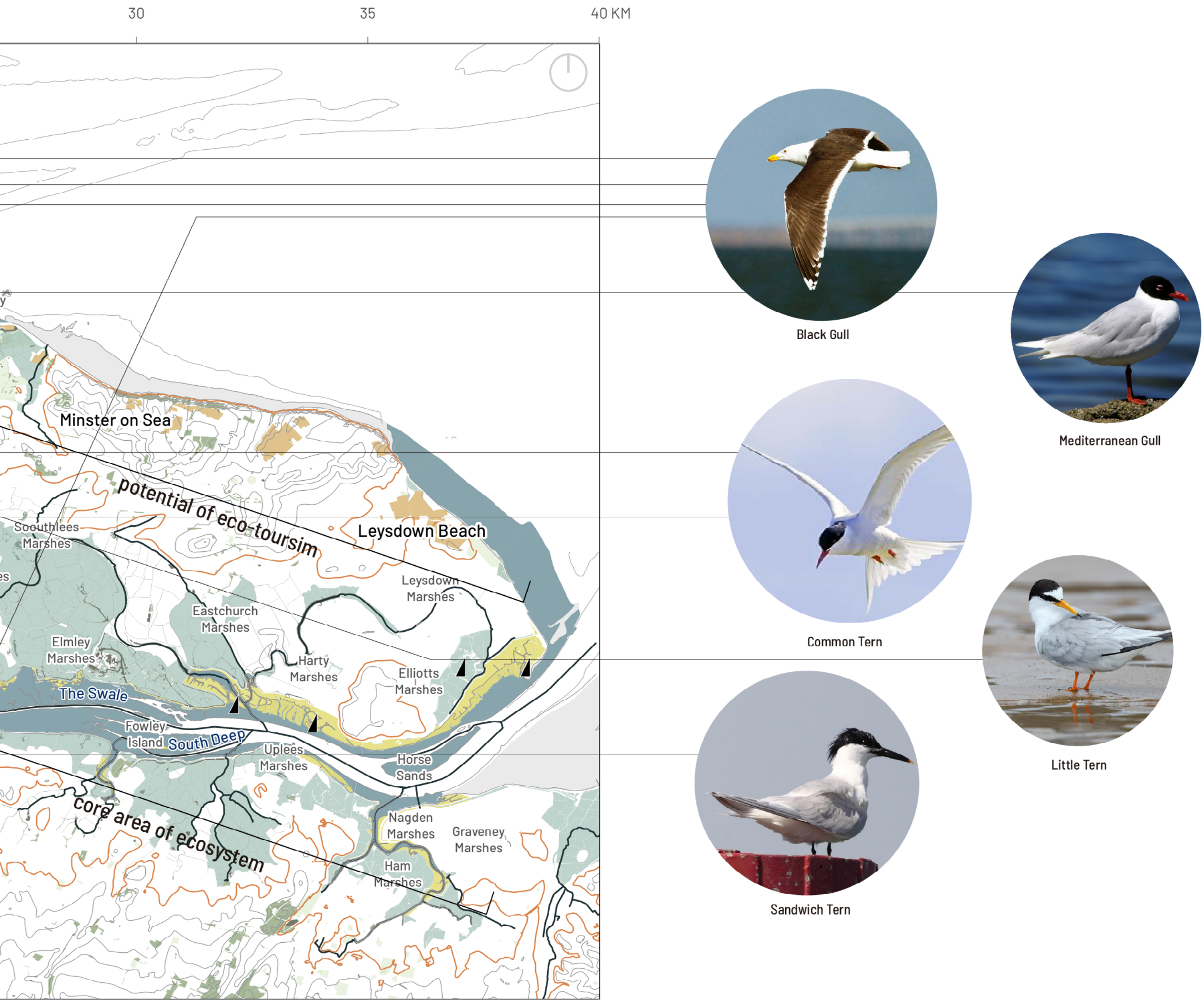


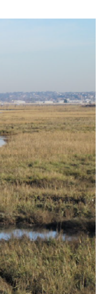
1. Hoo Salt Marsh

2. Chetney Canal Saltmarsh

3. North side of Chetney Marshes

FIG. 3.28 Map of habitat. Data source: UK open data and OS local. Image source: https://www.geograph.org.uk/mapper/.





Legend

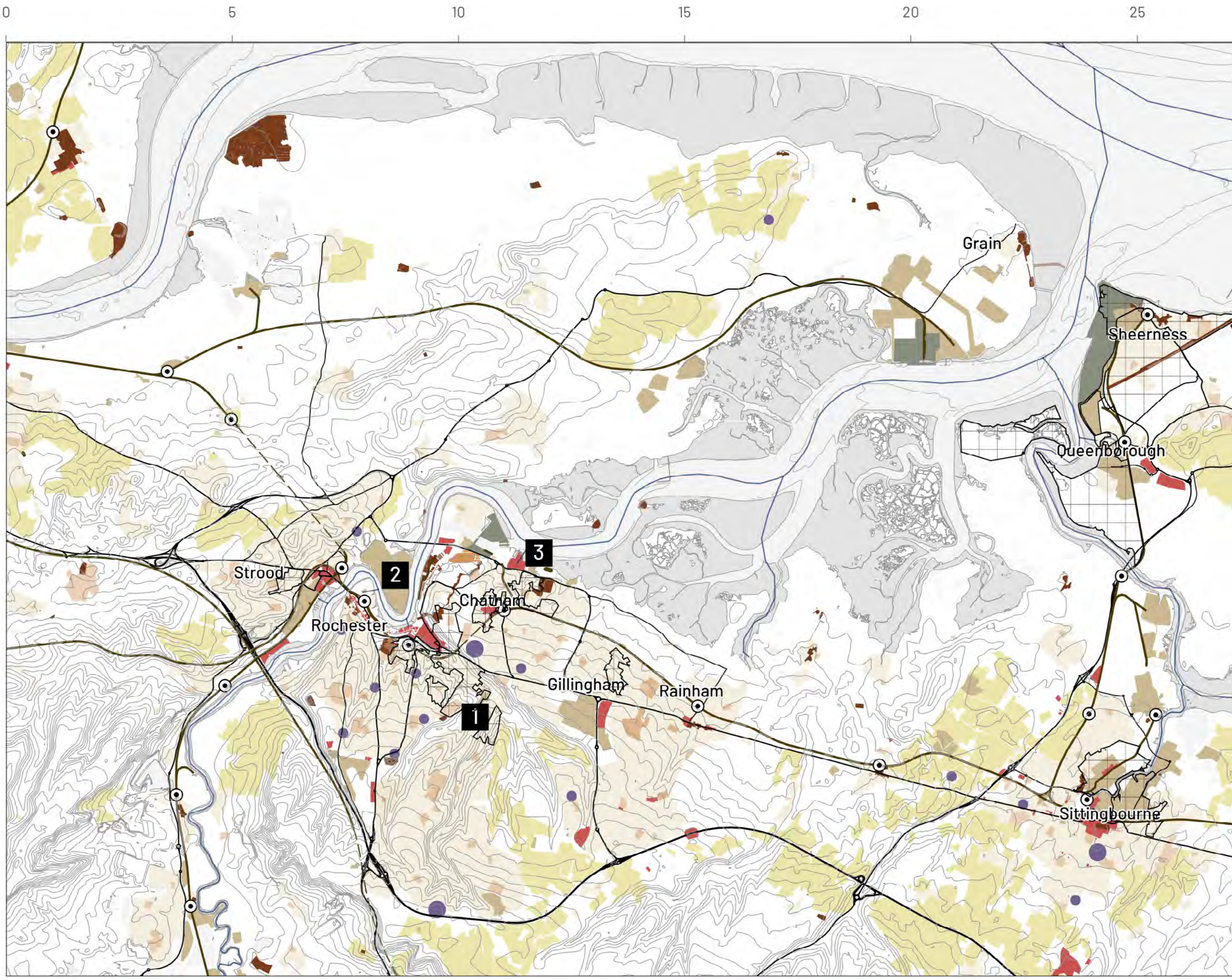
- rivercourse
- foreshore
- surface water
- contour line (10m interval)
- low-lying zone: lower than 10m
- woodland
- open space
- holiday house
- seabird nesting location (1999-2003)

Priority Habitat Inventory Central England (2020)

- coastal and floodplain grazing marsh
- mudflats
- coastal saltmarsh

3.3.6 – **Habitat**

The fine sediment from river estuary and the daily tidal difference provide a fertile environment for aquatic, reptile, and avian species. The vegetation of muddy coasts contributes multiple benefits, including attenuating wave energy, trapping sediment, reducing erosion, supporting adaptation to sea level rise, and improving water quality through filtration (Van Eekelen & Bouw, 2020). From the map, we can identify some islands and marshes, such as Normarsh, Sharfleet marsh, Slayhill saltings, and Deadman's Island, are the core area of ecological importance. However, it is also clearly that there is a discontinuity of tidal habitat around the bends of the river.

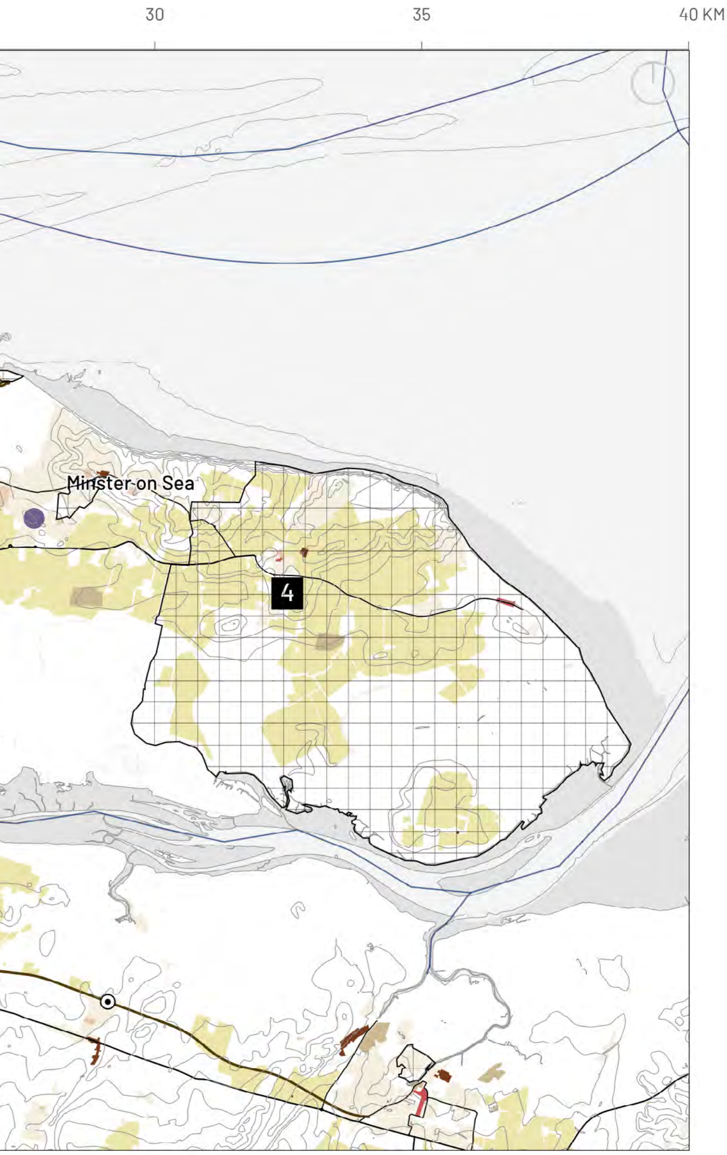


1. residential area on the slope

2. industrial zone: Medway City Estate

3. Chatham waterfront: marina and high-r

FIG. 3.29 Land use map. Data source: OS local, OSM, Corine Land Cover, and Ministry of Housing, Communities & Local Government. Mapped by author.



ise building

4. Isle of Sheppey: farm and pasture

3.3.7 – **Development issues**

The map gives an overview of the land use in the study area. From the current land use, we could identify a multifunction city center combined by Rochester, Chatham, and Gillingham. These are also surrounded by a dispersed residential zone on the southern slope. In addition to this, other cities and towns stand in the middle of landscapes or pastures and are connected by the linear network system. The remote and rural characteristics magnify the deprivation condition; for instance, some of the most deprived areas in the UK are located in Swale, according to The English Indices of Deprivation (2019).

The mono-functional land use, especially industrial and residential distribution, is one of the major urgencies for adaptive development. Introducing mixed-use programs, encouraging local employment, and enhancing community building are possible approaches to increase the social-ecological resilience of this region.

Legend

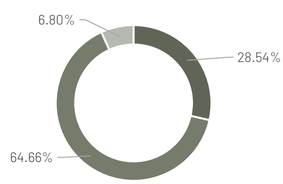
- industrial use
- retial and commercial use
- residential use
- farm
- heritage
- school
- university
- hospital
- hospice or medical care accomodation
- most deprived zone according to Index of Multiple Deprivation (2019)
- major road
- railway track
- railway tunnel
- railway station
- port area
- shipping route

Concentrated residential clusters in the vast territory

The study area covers Medway unitary authority on the west and the borough of Swale (in Kent county) on the east. Medway has about twice the population of Swale but has only half the area of Swale. Most of the population of Medway unitary authority live in the towns of Chatham and Gillingham.

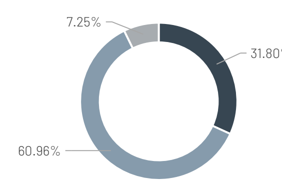
FIG. 3.30 Map, table, and pie graphs of population density. Data source: Office for National Statistics (ONS). Developed by author.

	District		Neighborhood with the highest density	
	Medway Unitary authority	Swale Borough	1. Medway 022A	2. Swale 001C
Population (2019)	278,556	150,082	2,176	1,780
Area (ha)	19,203	37,340	12.82	9.47
Population density	14.51	4.02	169.73	187.96



Medway 022A population by broad aging group (%)

0-15 16-64 older than 65



Swale 001C population by broad aging group (%)

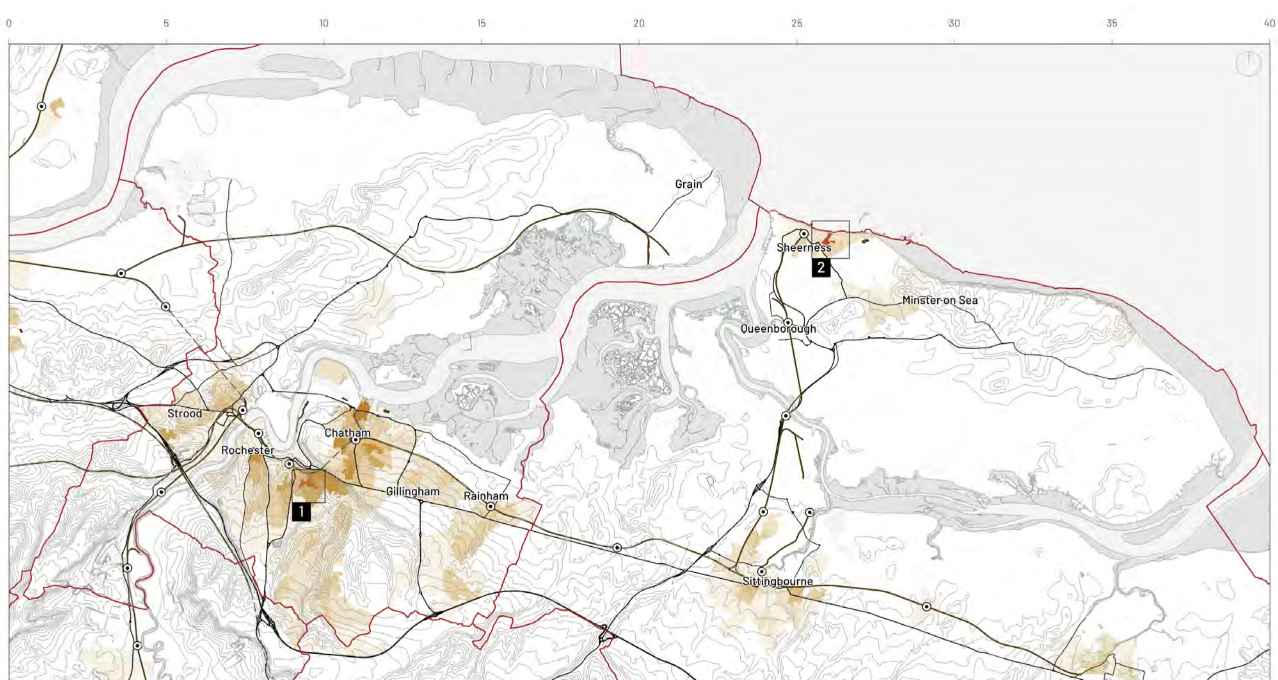
0-15 16-64 older than 65

Legend

administrative boundary

Population density of Lower layer Super Output Areas (2019) (people/ ha)

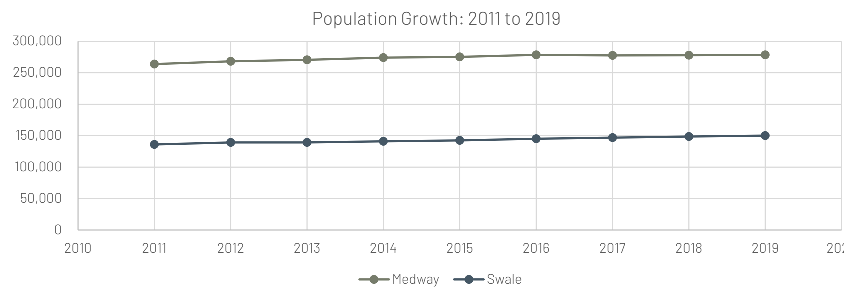
lower than 20
20-40
40-60
60-80
80-100
100-120
120-140
140-160
160-180
higher than 180



Steadily growing districts

Both Medway and Swale undergo steady population growth from 2011 to 2019. The growth rate of Swale is slightly higher than Medway. Most of the fast-growing neighborhoods are either close to industrial zones or designated as allocation sites under local plans. Migration is the main driver of population growth for Medway and Kent. According to Kent County Council (2018), between 2007 and 2016, net inward migration accounted for 72% of total population growth, and the majority of people who move into this area come from London.

FIG. 3.31 Map, table, and pie graphs of population growth. Data source: Office for National Statistics (ONS). Developed by author.



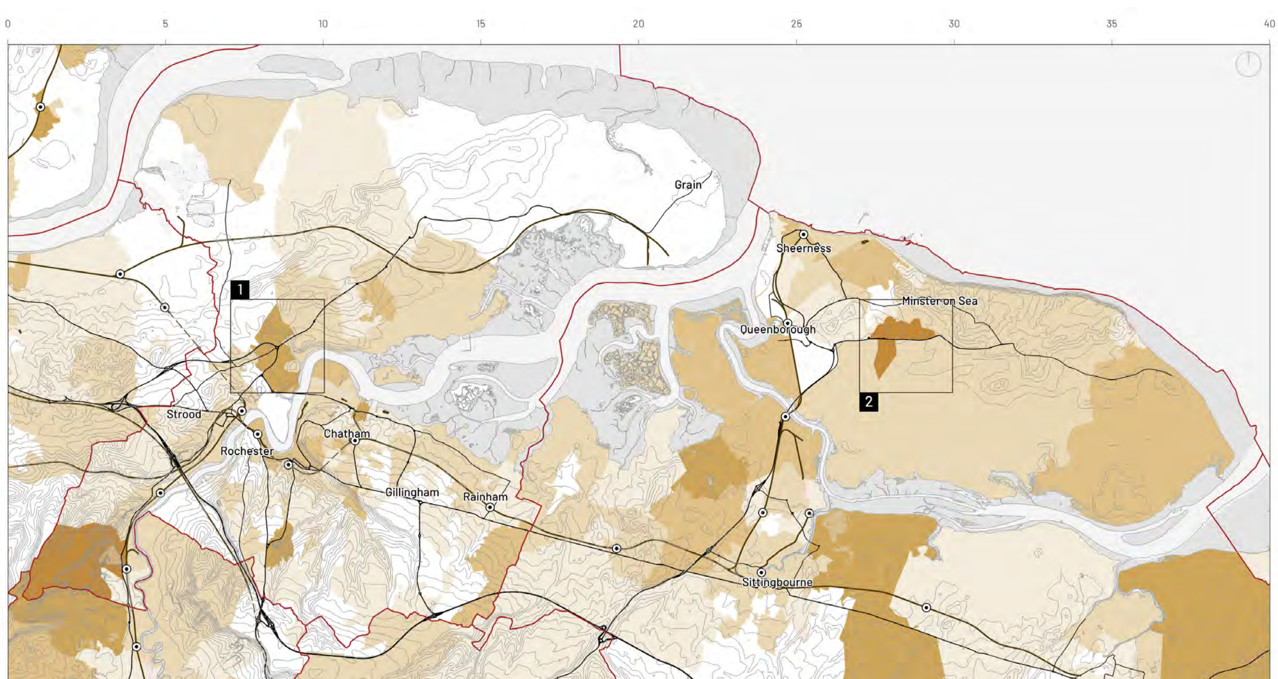
	District		The fastest-growing neighborhood	
	Medway Unitary authority	Swale Borough	1. Medway 004A	2. Swale 004G
Population (2011)	263,925	135,835	2,019	1,829
Population (2019)	278,556	150,082	2,835	3,124
Growth (2011-2019)	5.54%	10.49%	40.42%	70.80%

Legend

administrative boundary

2011-2019 population growth%

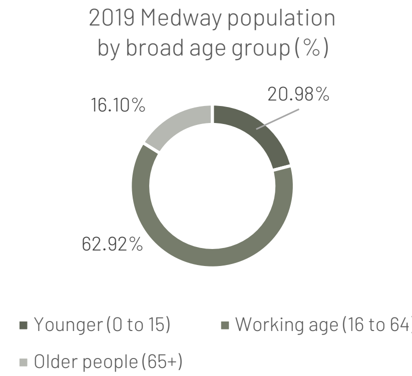
- lower than 0
- 0.0 - 6.4
- 6.4 - 17.5
- 17.5 - 35.9
- 35.9 - 61.2
- higher than 61.2

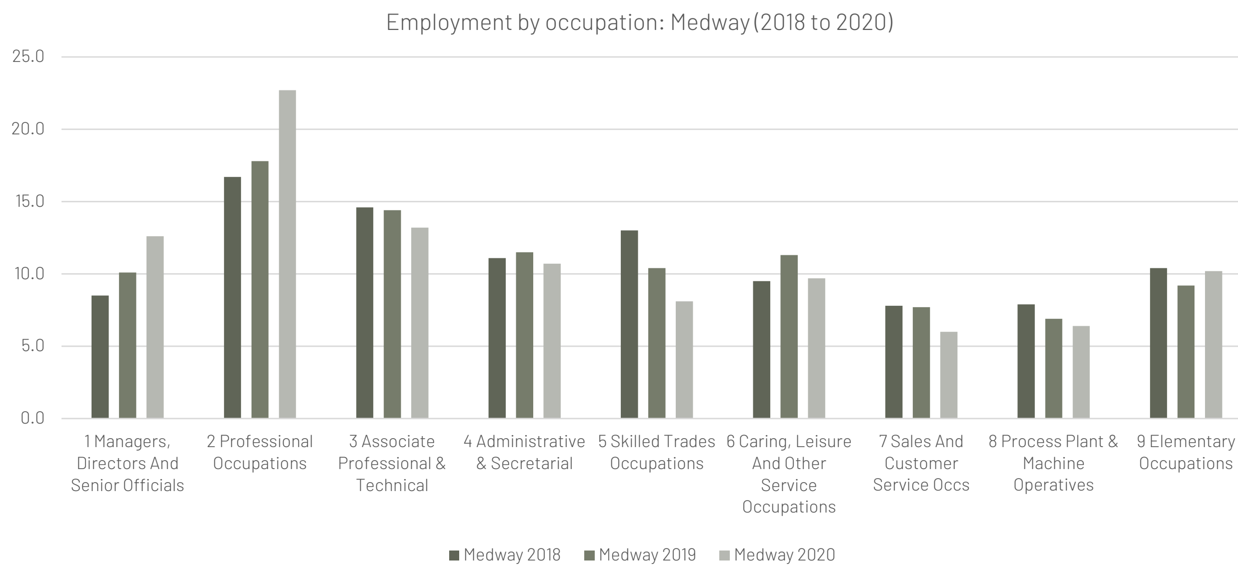


Employment by occupation in Medway

The economy has transformed from traditional manufacturing industries or service sector in Medway. From the employment of occupation data provided by Official Labour Market Statistics (Nomis), we could identify the trend of industrial transition. For example, the percentage of high-skilled employment (groups 1 and 2) increased, while the low-skilled workers (groups 7 and 8) declined from 2018 to 2020 (see the bar graph).

Moreover, the table below shows that the low-skilled workers (occupation groups 6 to 9) decreased from 51,600 to 43,400 people in these three years, which is greater than the change of economic activity population. We could assume that these workers are unemployed or move to other areas with corresponded job needs.





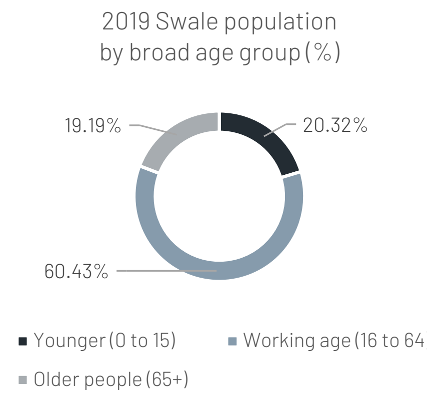
	2018	2019	2020	Growth (2018-2020)
Total population	277,855	278,556	-	-
Economic activity (aged 16-64) population	144,100	144,400	138,100	-6,000
Total of occupation group 1-5	92,600	92,100	90,200	-2,400
Total of occupation group 6-9	51,600	50,200	43,400	-8,200

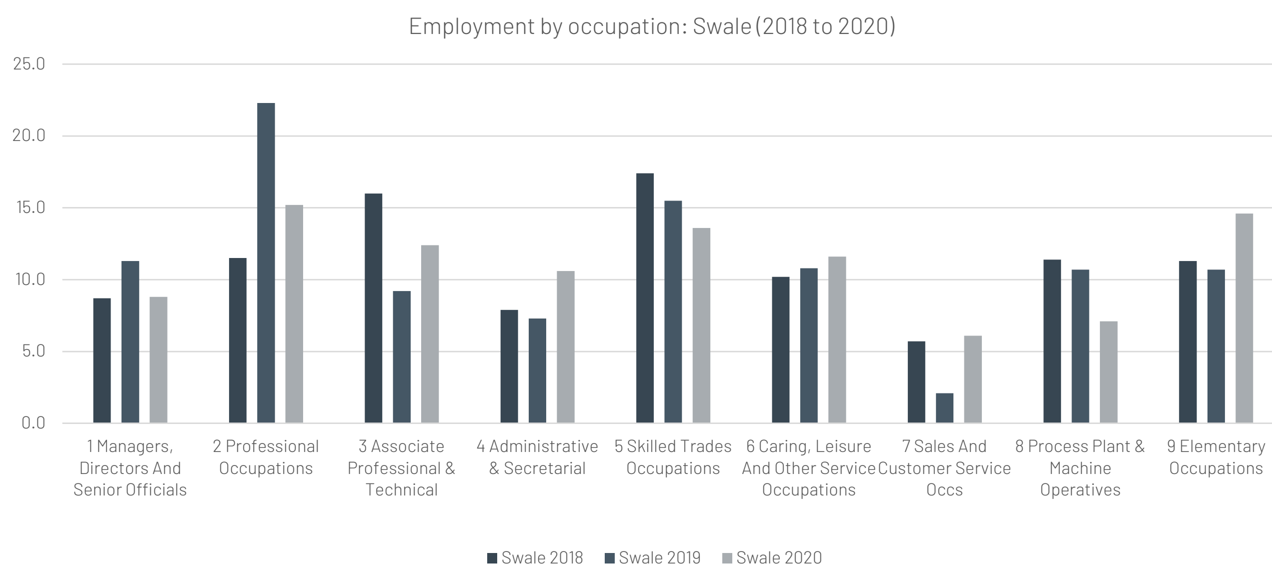
FIG. 3.32 Map, table, and bar graph of employment by occupation in Medway. Data source: Official Labour Market Statistics (Nomis). Developed by author.

Employment by occupation in Swale

Comparing to Medway, there is no apparent trend regarding the change of occupational groups in Swale. Among these groups, the categories with the highest percentage of employment are "2. Professional Occupations", "5. Skilled Trades Occupations", and "9. Elementary Occupations," each takes account of 14% to 15% of the whole.

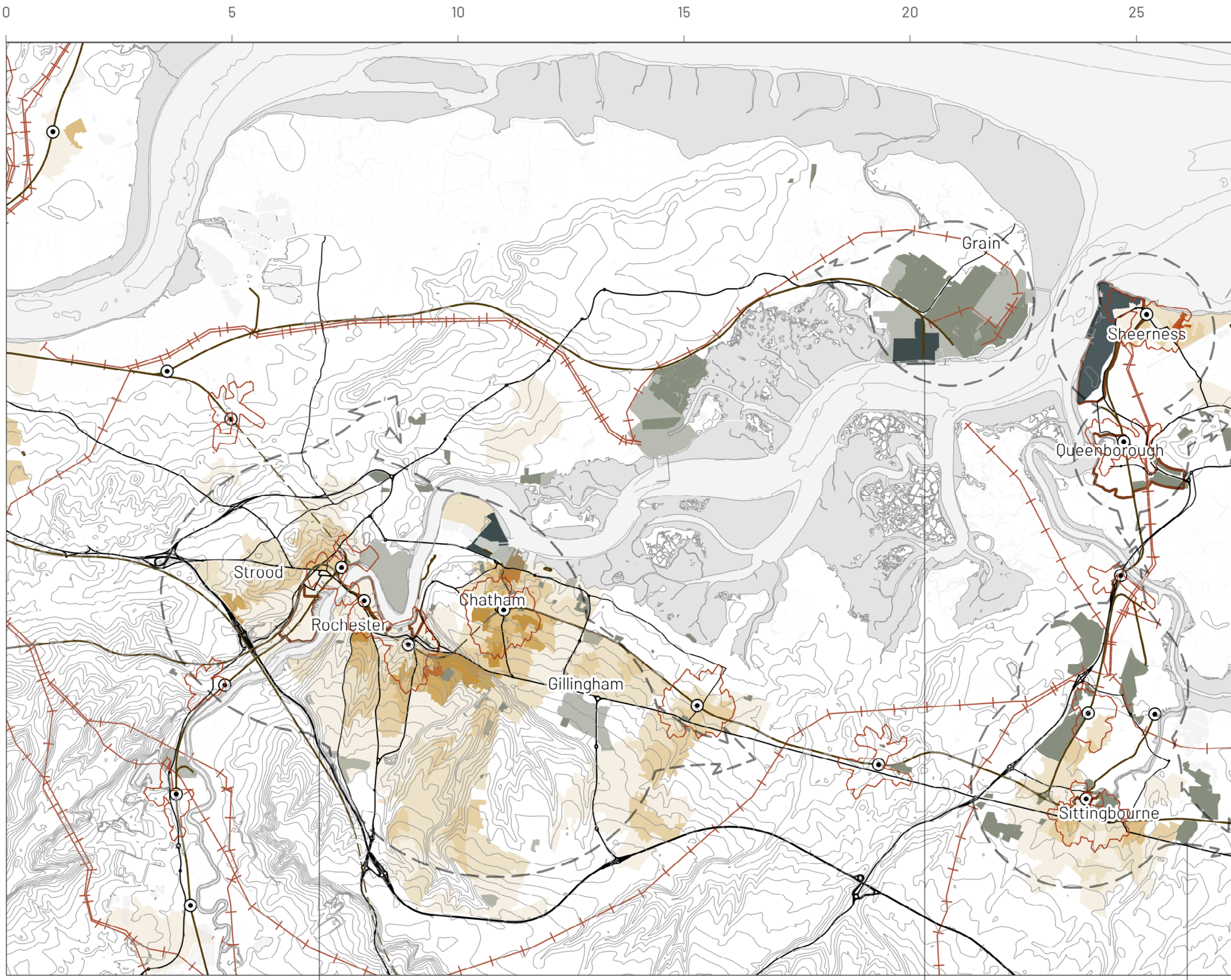
However, the demographic structure of Swale is slightly different from the one from Medway. The share of those over 65 years old accounts for 19.19% of the population in 2019. It might indicate that there is a need to increase public and health care public services or facilities.





	2018	2019	2020	Growth (2018-2020)
Total population	148,519	150,082	-	-
Economic activity (aged 16-64) population	64,500	66,600	67,200	2,700
Total of occupation group 1-5	37,100	42,900	41,400	4,300
Total of occupation group 6-9	23,300	22,500	26,800	3,500

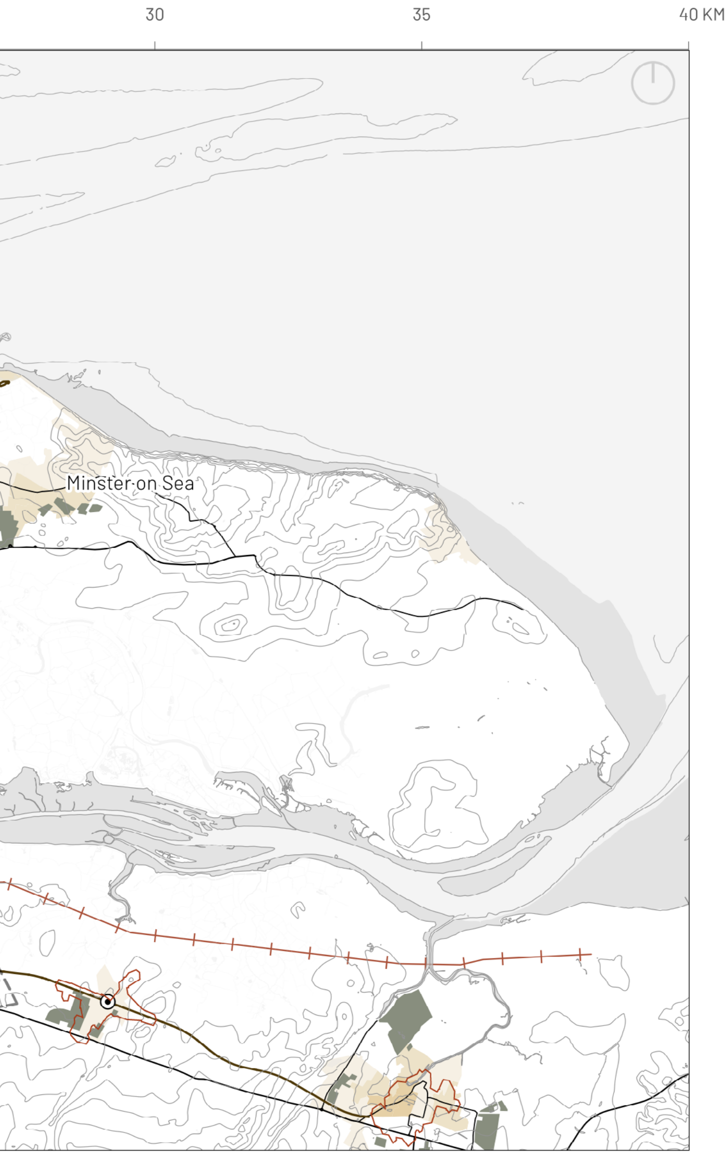
FIG. 3.33 Map, table, and bar graph of employment by occupation in Swale. Data source: Official Labour Market Statistics (Nomis). Developed by author.



Rochester, Chatham, Strood, and Gillingham industry cluster
-diverse employment type
-smaller business space in city
-industry transition: from manufacturing to service sector
-innovation potential (3 universities)

Grain
-independent zone
-power station
-port and railway
connection

Sit
-P
ar
-lo
-p
-fe



ttingbourn and Sheerness industrial cluster

ort of Sheerness: import points for fruit, timber, paper products, nd vehicles

gistic and shipping potential

ort and railway connection

eature: paper, brick, brewing, cement, steel

3.3.8 – **Economic development potential**

Economic development is greatly related to the transportation network, natural environment, and the history of the place. In the study area, the historic town center of Rochester built the basis of the current main centers of economic activity in Medway. On the other side, Sheerness and Queenborough take advantage of the deepwater port with rail freight connections, which turn out to be one of the UK's largest import points for fruit, timber, paper products, and vehicles. Connecting to Port of Sheerness, Sittingbourne also develops itself to be a critical transport and manufacturing center.

However, if we view this region through the lens of residents, we could find that the coverage of railway station service areas is relatively small. It indicates that currently there is a high dependency on private vehicles. If the network structures remain the same in the upcoming years, there is a need to encourage a transit-oriented development model, in which we could introduce mixed-use or higher density development around train stations or public nodes. Moreover, creating more local employment would be a key issue for the sustain of the local economy.

Legend

- Local Plan project site: strategic location
- Local Plan project site: employment and housing allocation
- current employment location
- port
- railway track
- railway tunnel
- railway station
- railway station service area: 1000m
- electricity transmission line

Population density of Lower layer Super Output Areas (2019) (people/ ha)

- lower than 20
- 20-40
- 40-60
- 60-80
- 80-100
- 100-120
- 120-140
- 140-160
- 160-180
- higher than 180

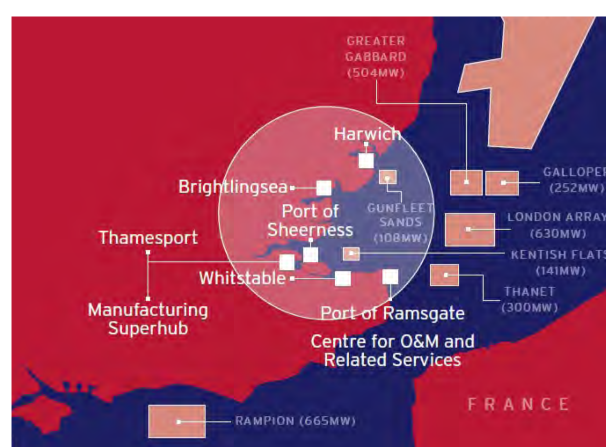
FIG. 3.34 Map of economic development potential. Data source: OS Local and Official Labour Market Statistics (Nomis). Developed by author.


Sheppey Crossing
Chitney marshes
Queenborough
Burnwick
Port of Sheerness
Grain Power Station

On the north side of Port of Sheerness, the London Thamesport at Grain is also a strategic locaiton for industrial development. Both ports are designated as manufacturing and services centers for offshore renewable engineering (wind farm) under South East CORE (SE CORE) project.

FIG. 3.35 Left. Aerial view of Medway estuary. Image source: http://leagueofaugsburg.blogspot.com/

FIG. 3.36 Bottom. Map of the South East CORE (SE CORE). The SE CORE incorporates Harwich International Port, Harwich Navyard, London Thamesport, Port of Sheerness, Port of Ramsgate and Brightlingsea. Among these ports, London Thamesport and Port of Sheerness are located in the Meday estuary. Image Source: 2015. Building Offshore Wind in England Brochure.



3.4 – **Scenario study**

Scenario study is one of the foreseen study methodologies that are available for exploring the future in the face of complexity and uncertainty of the environment. The scenario is based on knowledge and data about the past that are considered to be indicative of the different possible paths of future developments, based on a given set of conditions in the future (Dammers, Van den Born, Bruggeman & Van den Hurk, 2013). According to this, I identified two driving forces in this area as the basis axis to explore possible scenarios, which are "sea level rise" and "economic growth" (see the diagam below).

Take scenario 2 as an example, high environmental awareness is shown. Therefore, there are demands for creating diverse recreational areas and safeguarding space for rivers and habitats. Multiple local centers are enhanced due to the development of local employment.

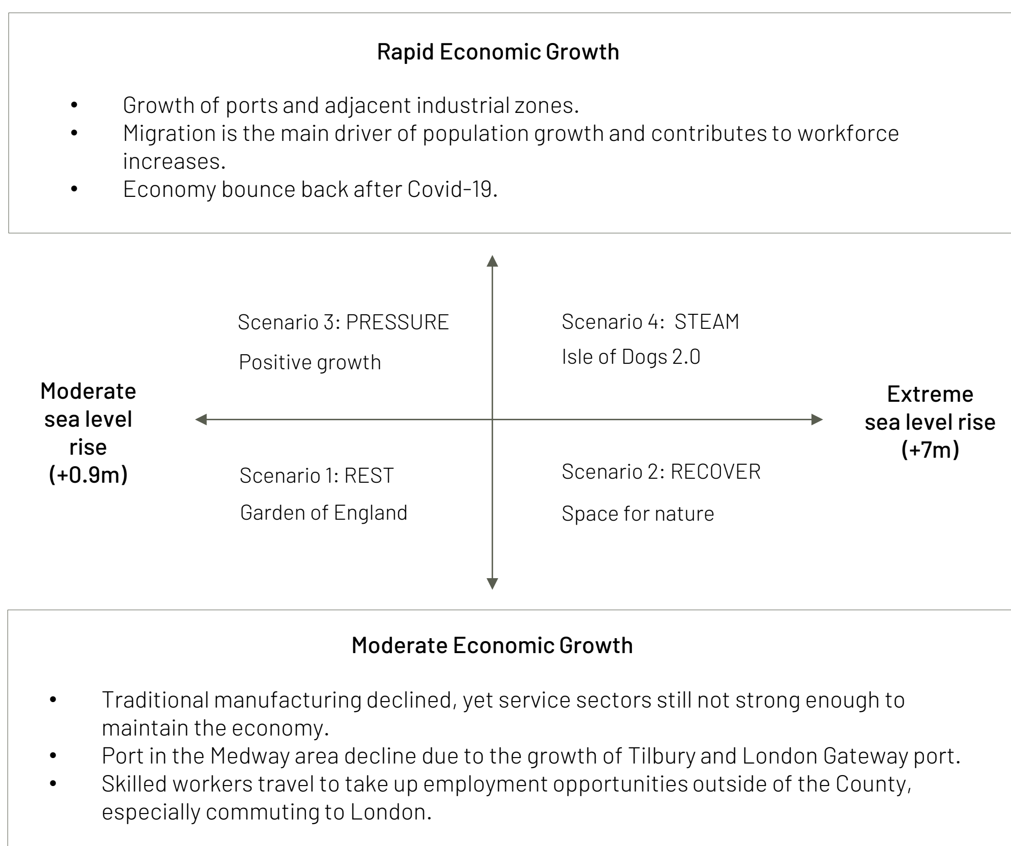


FIG. 3.37 diagram of scenario axis

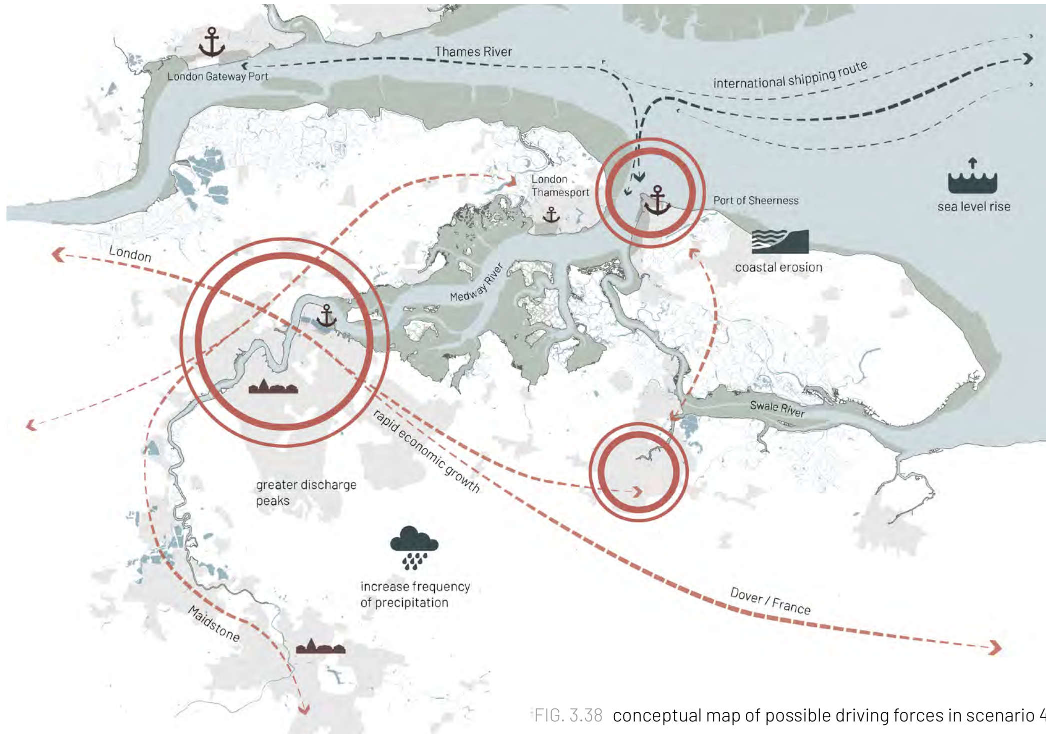


FIG. 3.38 conceptual map of possible driving forces in scenario 4

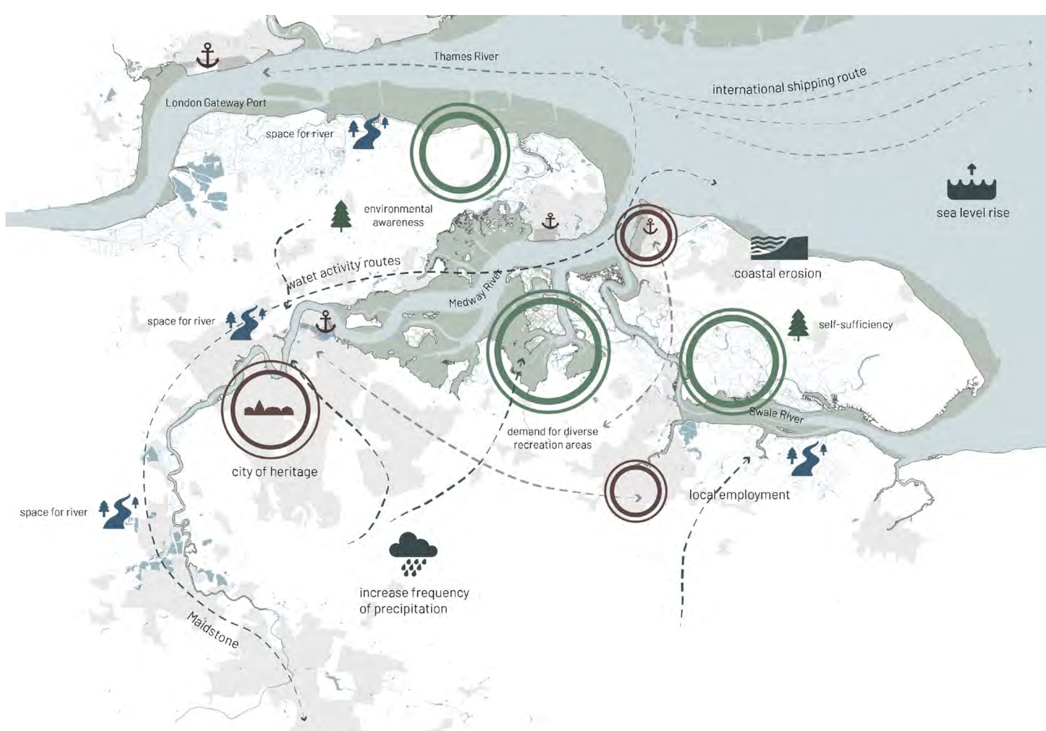


FIG. 3.39 conceptual map of possible driving forces in scenario 2

3.4.1 – **Scenario comparison**

Two scenarios are selected to identify strategic locations and to identify certain tendencies in regional scale. I decomposed the landscape into systems and elaborated the six indicators in the table below. These are the variables for design thinking.

Scenario RECOVER will undergo extreme sea level rise, yet there would be less pressure on urban development. It would allow the local authority to choose an adaptive approach for flood mitigation, such as creating space for tidal river by setting back existing flood defense. On the other hand, scenario STEAM will have significant economic growth while facing extreme sea level rise. The regional development would focus on industrial transition and the expansion of suburban towns; therefore, it would require engineered methods to reclaim new land or enhance protection infrastructure. On the following page, two drafted maps are created (in the early stage of this project) to elaborate these two scenarios.

	Scenario 2: RECOVER	Scenario 4: STEAM
Flood protection for urban area	• Adapt with nature • Create space for tidal river • Relocation of flood defense • Secure critical infrastructure	• Enhancement of existing dikes • New multifunctional barriers between islands
Coastline protection	• Naturalized coastline • Coastline nourishment	• Hard infrastructure, such as sea dike or breakwater
Economic development	• Productive landscape (agriculture and ecology tourism) • Ports in Medway area decline, due to the growth of main ports (Tilbury & London Gateway) • Industrial transition, from heavy industry to service industry: tourism and leisure	• Growth of ports and adjacent industrial zones • Develop new industrial zones and commercial centers, create new jobs • Industrial transition, from heavy industry to service industry: tourism and leisure
Land-use pattern	• Regeneration of urban centers: middle density, mixed-use, provide public facilities • Dispersed urban pattern, country life style • De-build coastal residential area	• Regenerate urban centers: high density, mixed-use • Urbanization on suburban towns • Reclaimed new land • Expansion of port area
Network	• Utilize existing infrastructure • Ensure critical infrastructure	• A new train station in Lodge Hill • New bridges to connect islands
Natural dynamics	• High environmental awareness • Tidal habitat restoration: proactively increase realignment habitat	• Low environmental awareness • Habitat restoration: maintain current reserve zone
Urban drainage	• Create retention space • Increase sponge capacity	• Discharge water • Create retention space

FIG. 3.40 Table of different layers considered in scenario 2 and 4

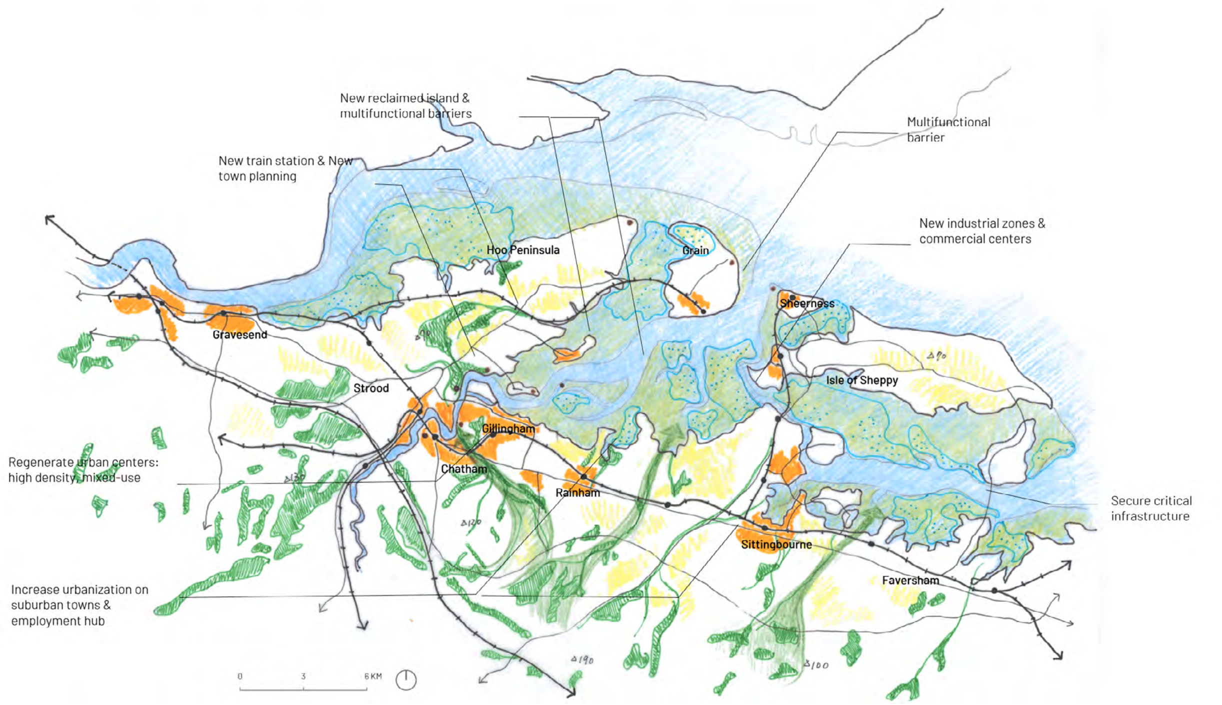


FIG. 3.41 Draft map of scenario 2

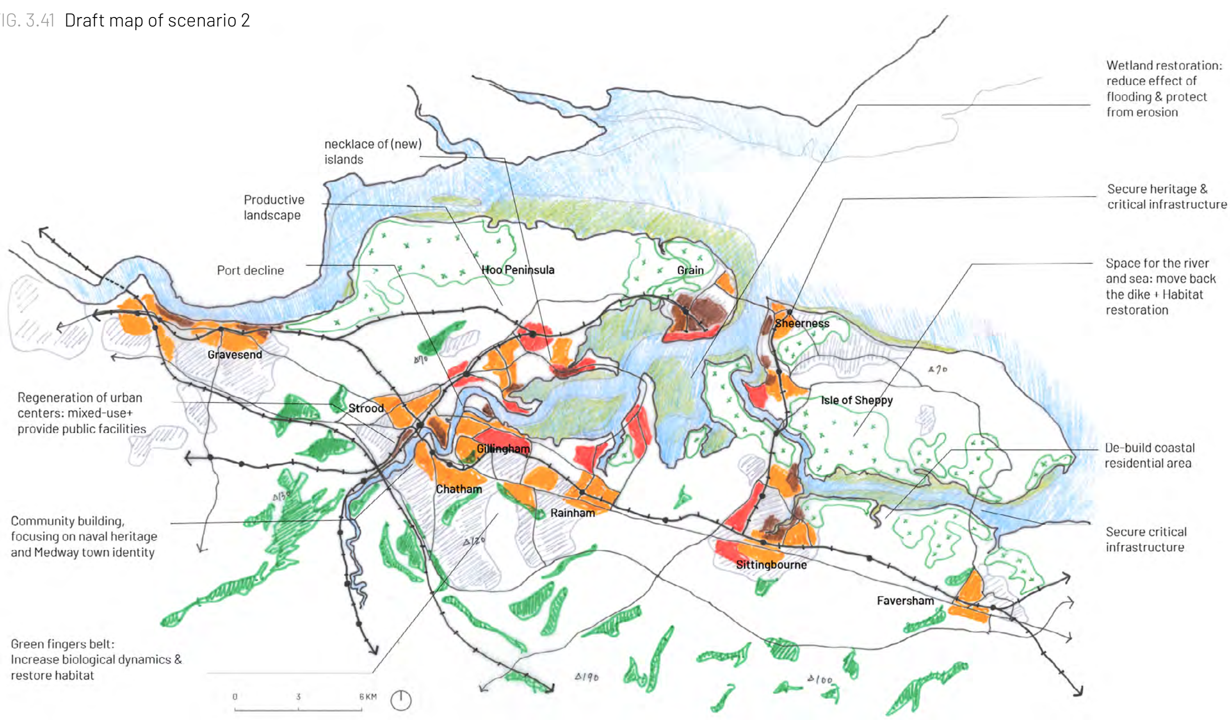


FIG. 3.42 Draft map of scenario 4

3.4.2 – **Lesson: learning from the overlapped location**

In the scenario study, I put forward some extreme conditions to look for the overlapped. Following the method adopted in the Integrated Planning and Design in the Delta (IPDD) project (Meyer et al., 2015), two categories are distinguished according to the similarities and differences.

Category 1 has areas that change in both scenarios, but in a different way and under the influence of different driving forces. For instance, areas under strategy "space for the tidal river" means in terms of sea level rise, it would be vulnerable in both scenarios. In scenario 4, "space for the tidal river" serves as a flood mitigation function, and could only select several pilot sites to implement. In scenario 2, "space for the tidal river" inherits a high environmental awareness. Thus, it would proactively increase managed realignment space to restore tidal habitats in a broader coastal zone. Another example is "industrial transition." In both scenarios, it indicates the transition from heavy industry to the service sector. However, the difference is that it implies a high-density commercial and business use in scenario 4, while it refers to eco-tourism or rural tourism in scenario 2. Areas under category 1 are considered to be the critical locations to intervene.

Category 2 indicates areas that hardly change in one scenario, but undergo considerable change in another scenario. In scenario 4, the urban expansion pressure could lead it to reclaim marshlands for industrial use or urban development. This would come with the design and construction of a new road network and bridges across the estuary. However, this is not necessary for the other scenario. The extent of development strength and whether it matches local needs should be considered. Therefore, the potential strategies under this category are optional.

From the map on the next page, I identified 4 clusters of key location, which are the intersect zone of the above categories. It would lead to the next step of this study.

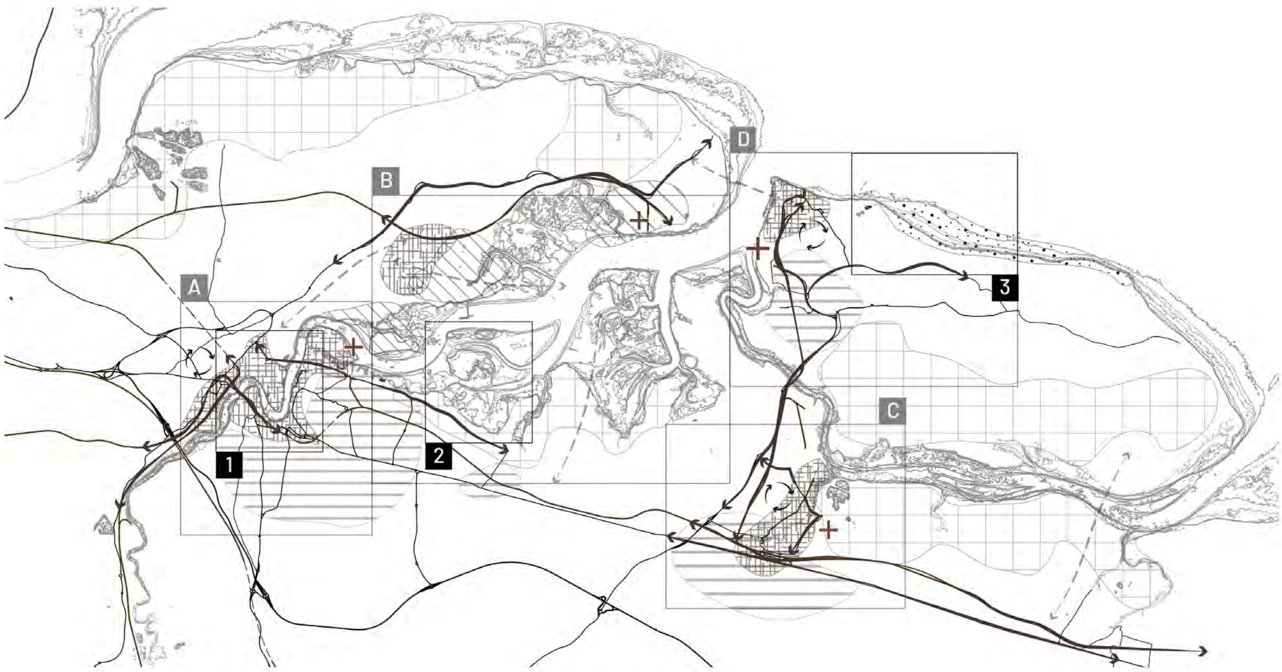


FIG. 3.43 conclusion map of scenario study

Legend

Category 1: Critical location

Areas that change in both scenarios, but in a different way and under the influence of different driving forces.

- critical road infrastructure enhancement
- space for tidal river
- flood-proof strategy for coastal city
- regeneration of urban centers
- industrial transition

Category 2: Optional location

Areas that change in one scenario, but do not change in another scenario.

- reclamation of land by connecting current islands
- expansion of port area and adjacent industrial zone
- coastline protection scheme
- new network connection

intervention site

1 Medway City Estate

2 Lower Rainham

3 Isle of Sheppey

critical cluster

A Medway and Chatham: transitional urban waterfront

B Medway estuary: restore ecosystem surrounding by industrial zones

C Sittingbourne: industry and logistic center of Swale

D Isle of Sheppey: combined issues of flood protection, port development, and livelihood safeguarding

3.5 – **Conclusion**

3.5.1 – **Urgencies**

If the sea level rises more than one meter, several railway lines and main roads will be in threat, as the yellow and blue lines on the map. In addition, those networks connecting to Grain and the Isle of Sheppey are the so-called critical infrastructure system. How to maintain or enhance these network systems is one of the main issues for transportation sectors.

Cities on the low-lying flood plain, such as Strood, Chatham, and Sittingbourne, will be flooded on a regular basis if there are no actions taken. These areas in purple color are also zones of economic importance. Design strategies and actions are needed to help these areas transform or adapt through time. The Coastal section on the North of Sheppey is facing the cliff erosion issue, which would affect the residential zone on the island.

Last, a wide range of tidal habitats, including coastal and floodplain grazing marsh, saltmarsh, and mudflats, would be submerged due to sea-level rise and extreme tidal surge. The biodiversity may decrease in important habitats, such as Elmley National Nature Reserve, the Swale National Nature Reserve, and the Medway estuary.

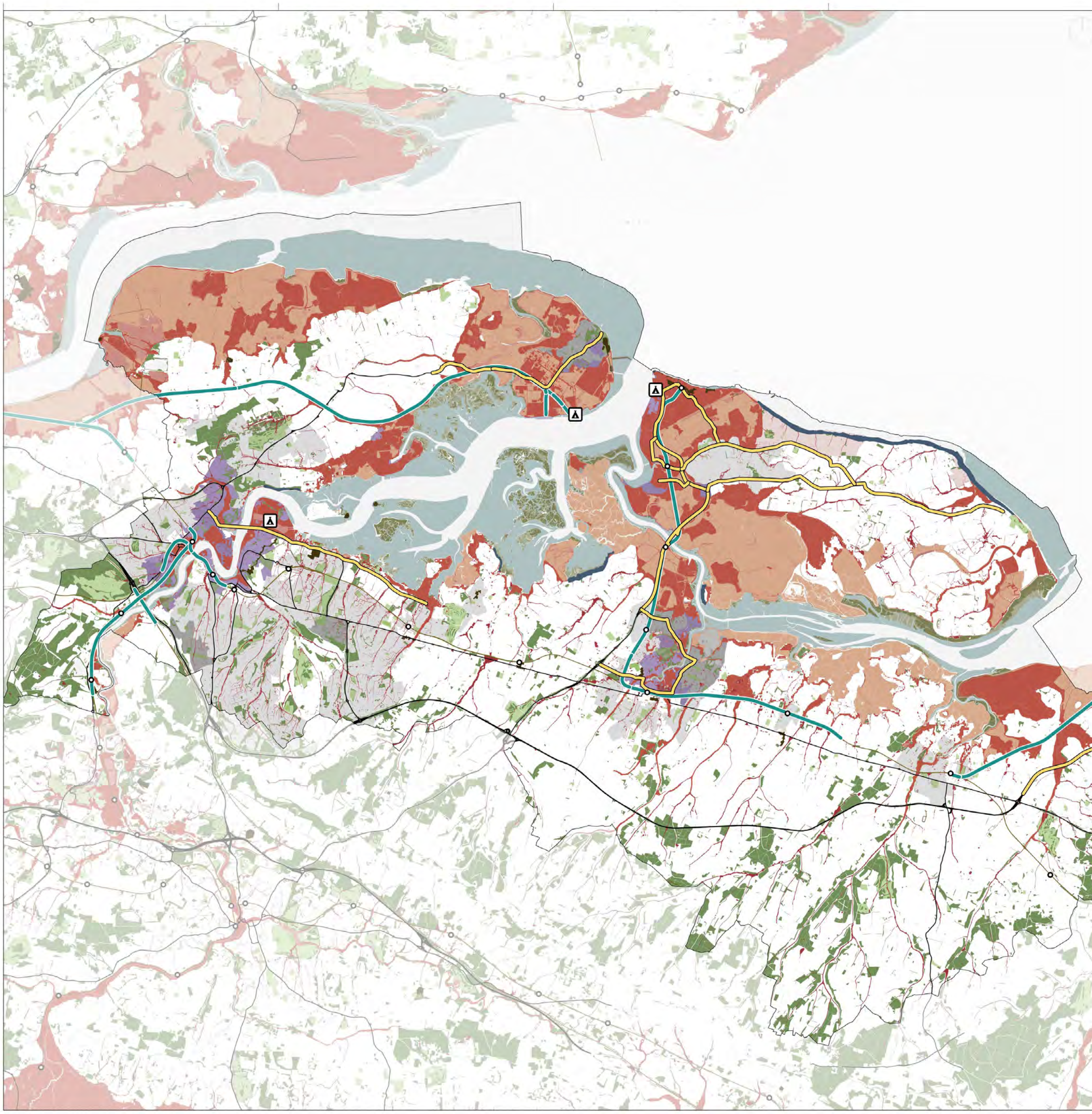


FIG. 3.44 Conclusion map of urgencies. Image developed by author.

Legend

- Surface water and tidal river
- Urban green space
- Woodland

Intertidal habitat loss

- Coastal and floodplain grazing marsh
- Coastal saltmarsh
- Mudflats
- Coastal erosion
- Medium and high flood risk area

Network

- Motorway
- A Road
- Railway line
- Train station
- Port

Occupation urgencies

- Vulnerable to sea level rise
- Vulnerable to coastal erosion

Mono-function area

- mono-function residential area
- mono-function industrial area

Urgencies of infrastructure

- railway vulnerable to sea level rise
- main road vulnerable to sea level rise
- Heritage at Risk (2020)

3.5.2 – **Potentials**

On the other hand, some of the urgencies could be transformed into possibilities. The mono-functional residential and industrial zones can be potential spots for mixed-use development. Road network sections that are in threat provide opportunities for public sectors to introduce renovating projects, such as multifunctional infrastructure. The mono-functional industrial sites and the manufacturing superhub for offshore wind farms on Hoo Peninsula could create local employment opportunities.

As for the ecological system, sea-level rise creates a driver for creating managed realignment sites to provide replacement coastal habitat to compensate for losses at locations. Coastal cities vulnerable to flooding risk could be the pilot sites to experience the adaptive waterfront design scheme. Last but not least, maritime and naval history could be the core narrative for cultural industry and tourism.

In conclusion, the urgencies and potentials illustrated in these maps will become the design assignment for the upcoming design work.

FIG. 3.45 Conclusion map of potentials. Image developed by author.

Legend

- Surface water and tidal river
- Urban green space
- Woodland
- Building

Network

- Motorway
- A Road
- Railway line
- Train station

Intertidal habitat maintenance

- Coastal and floodplain grazing marsh
- Mudflats
- Coastal saltmarsh
- potential location for (new) intertidal habitat

Industrial policy location

- Existing site
- Expansion site
- Port
- Potential offshore energy hub

Potential of development

- Flood-proof improvement
- Mixed-use development
- Relocation
- Coastal enhancement
- Conservation of heritage at Risk (2020)

3.5.3 – **Identification of lower-scale sites**

Three local scale sites are identified before principles and strategies are proposed since the development of the design toolkit is intertwined with the design exploration process.

The site selection result was a decision following the key clusters identified through the scenario study and conclusion maps of analysis. Moreover, the three sites are located on different parts of the estuary, in which they represented different interfaces of water and the built environment. The Sheppey site focuses on coastline protection, the Rainham site deals with space for intertidal habitats, and the Medway site works on the waterfront development of an urbanized area. The initial design concept and potential programs are listed in the table.

TABLE 3.1 Intervention sites on lower-scale

	Landscape typology	Urgencies	Initial Design Concept	Program
Site 1. Minster on Sea (Isle of Sheppey)	Rural: open space, pasture, and residential use	Coastal cliff erosion Mono-function landuse	Coastal protection Coastal park	Recreation and Eco-tourism
Site 2. Lower Rainham coastline	Rural: open space, pasture, and residential use	Coastal squeeze and natural erosion of the intertidal habitats	Restoration of habitat gradient Adaptive flood defense	Recreation and pasture
Site 3. Medway City Estate	Urban: industrial use	Industrial zone on flood-prone plain vulnerable to flooding	Space for tidal river Waterfront tidal park	Mixed-use development and recreation

FIG. 3.46 Potential map with strategic locations marked in the circle.

PART 3

Towards an Adaptive River Landscape

The climate extremes of yesterday are today's new normal. We must adapt to a world in which climate is less predictable and, in many cases, less favorable than it has been in the past. Unless we dramatically scale up adaptation actions, we will face immense human and social costs.

—Jaehyang So, Director of the Global Commission on Adaptation

4 – Strategies and Principles

FIG. 4.1 Yantlet Creek. Image source: geograph.org.uk.

4.1 – **Precedent study**

The precedent study is a key step connected with the development of design strategies and principles. To respond to the site-specific issues, mainly to confront flooding risk and restore interface gradient. First of all, I investigated some coastal management and tidal habitat restoration cases in the . There is a great possibility to transform the design strategies in Eems-Dollard Estuary to this project. Although they are different in scale, both locations belong to the North Sea region. Also, both sites have an urgency to restore tidal habitat dynamics and to increase flood resilience at the same time.

In addition to projects in the Eems-Dollard Estuary, also I studied several coastline protection cases in the UK in order to have references in a similar landscape environment. The catalog of precedent cases is presented on the following pages.

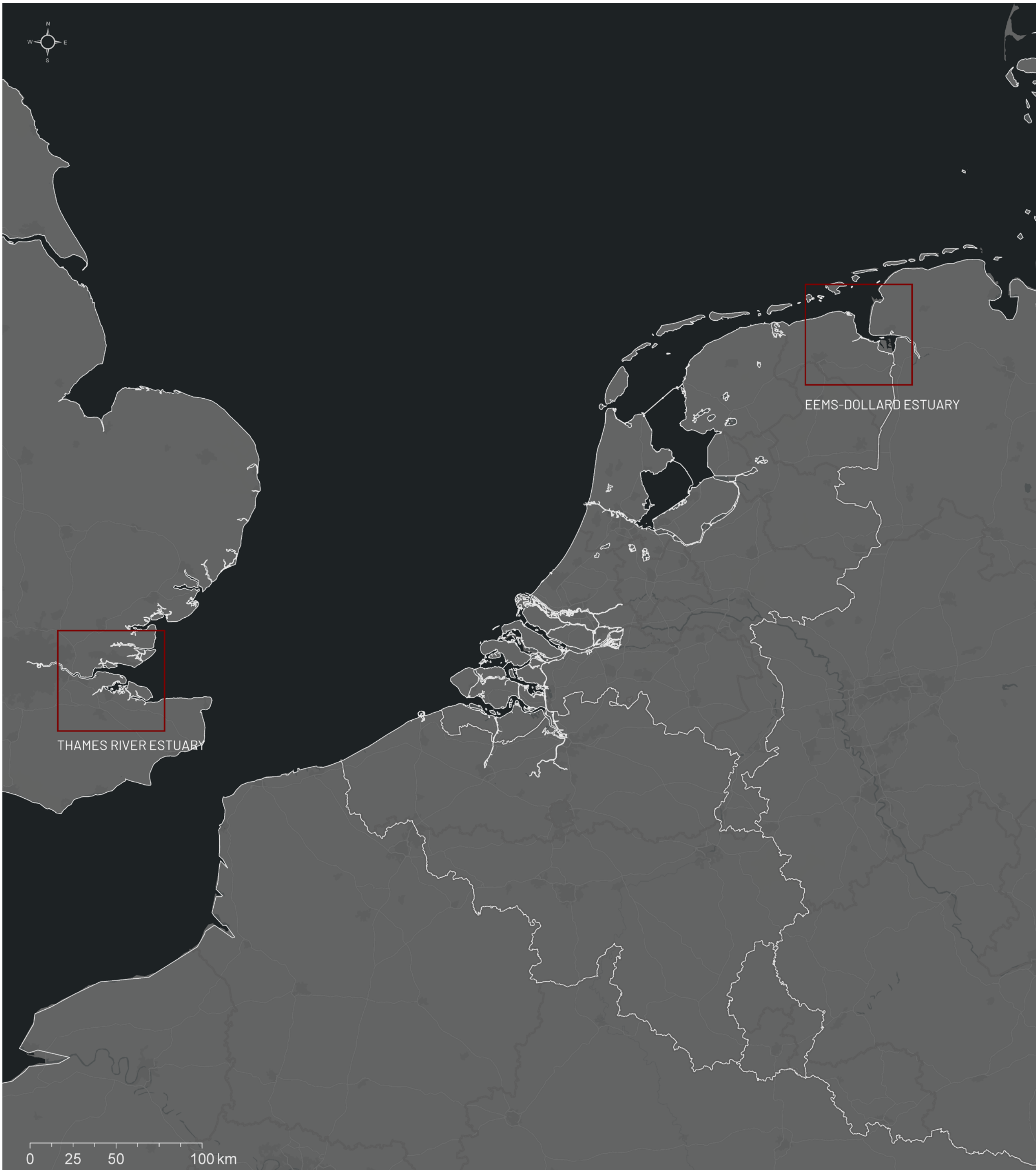


FIG. 4.2 Location of the study site and the main case, Eems-Dollard Estuary. Image: developed by author via ArcGIS Pro.

Main study case: Eems-Dollard estuary

The challenge of the Ems-Dollard estuary is restoration of tidal dynamics. It is the only estuary of the Wadden Sea, and its entire region is of ecological importance, under the protection of Natura 2000. However, in recent centuries, large areas around the Ems-Dollard have been reclaimed. This left little room for sludge to settle. In addition, the navigation channels have been made deeper and wider over time. Due to the stronger flood current, more silt enters the Ems-Dollard, while less sludge can settle. The sludge particles are constantly swirling up due to the extensive dredging and dumping. As a result of all these changes, the water of the Ems-Dollard became increasingly turbid, and the benthic life has declined. Important habitats in the Ems-Dollard, such as seagrass beds and shellfish beds, have almost disappeared. (Source of text: https://eemsdollard2050.nl/)

There are several pilot projects include sludge sedimentation outside the dikes, Eemszijlen/inner dike sludge sedimentation, double dike, etc. For example, on the coast of Delfzijl, the Marconi-Buitendike project constructed a 16 hectares saltmarsh landscape off the coast, a bird breeding island, and 13 hectares of recreational salt marsh. The aim is to improve nature by expanding habitats for animals and plants, such as salt marshes and saline grasslands. In Dollard bay, the Broad Green Dike will be reinforced with clay and silt from the Dollard. The objective is to increase the flood safety of the sea dike and solve part of the silt problem in the Ems-Dollard. These strategies demonstrated the integration of nature-based solutions and engineering methods.

FIG. 4.3 Pilot double dile (Image source: Eems-Dollard 2050)

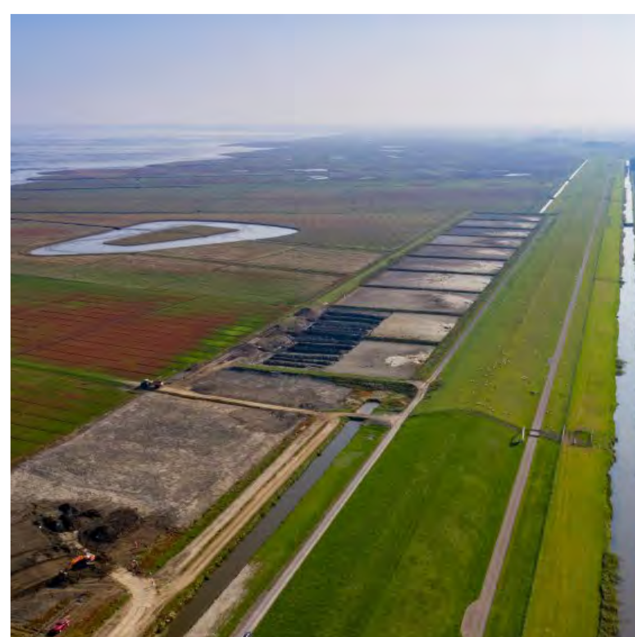


FIG. 4.4 Pilot sludge sedimentation (Image source: Eems-Dollard 2050)

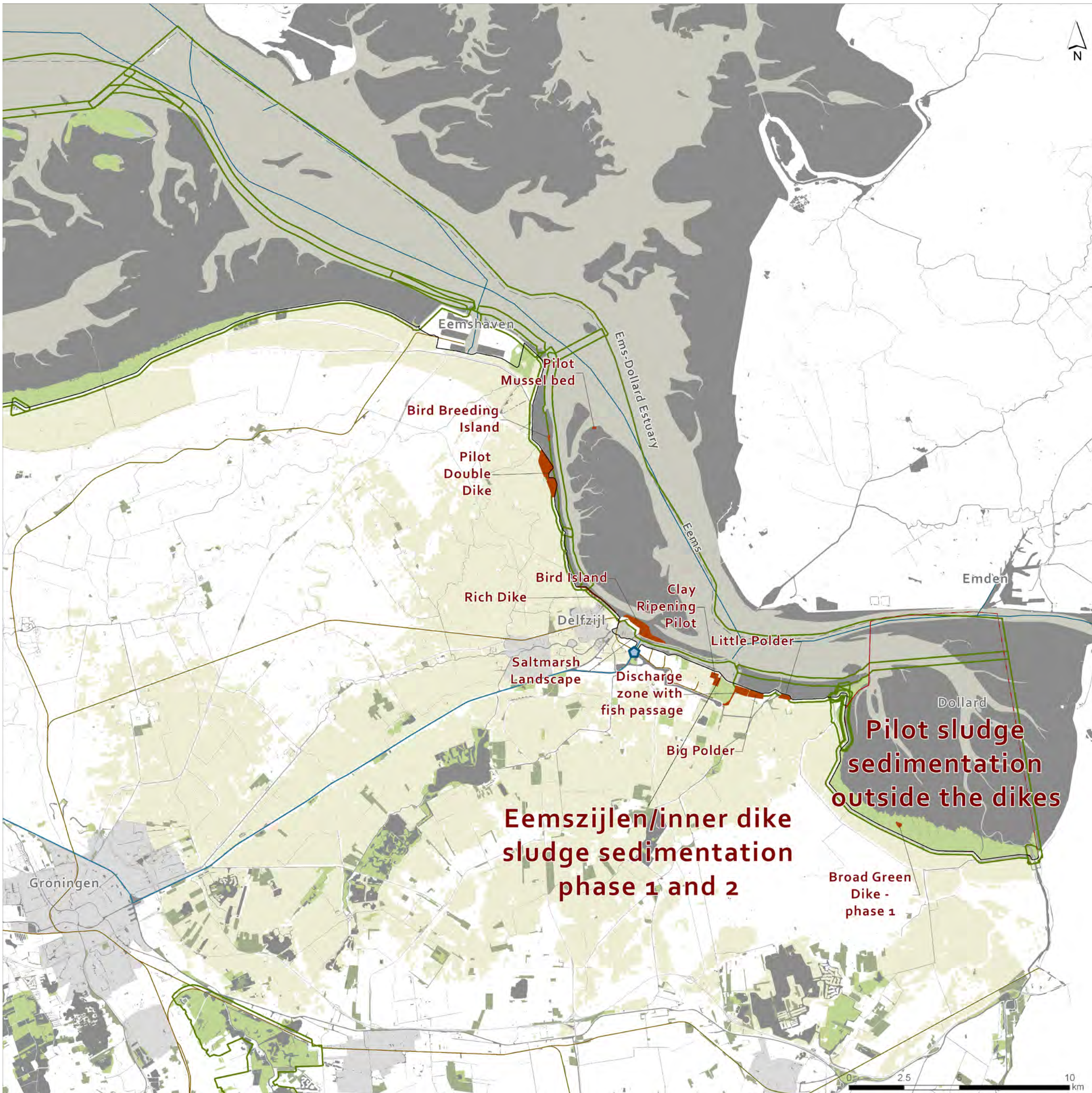


FIG. 4.5 Map of pilot sites in Eems-Dollard 2050 (Data source: Basic layer- OSM; Nature related layers-PBL Atlas; Project sites: mapped by author.)

- Pilot project
- Low-lying area (flooding depth> 2m)
- Open nature area
- Forest
- Natura 2000
- Environmental sensitive zone around Natura 2000
- Boundary of the Netherlands
- Flood defense
- Railway
- Highway
- Main waterway
- Sea corridor
- Lock
- Urban
- Surface water
- Marine water

4.2 – **Catalog of reference cases**

Restoration of tidal habitat, regional scale cases in NL

Kwelderlandschap / Saltmarsh Pilot Marconi

Location	Delfzijl, Eems- Dollard estuary, NL
Time	2021
Feature	The project restored salt marshes by reusing sludge. It improves water quality, created a nature reserve, and contributed to coastal safety and the attractiveness of the coast.

De Kleine Polder

Location	Eems- Dollard estuary, NL
Time	2019
Feature	The project aimed to restore natural gradient, create space for birds and fish, and introduce recreational areas on the urban side.

Restoration of tidal habitat, micro scale cases in NL

Floating Marsh Mattresses

Location	Markermeer, NL
Time	2019
Feature	placed close to share/ funtioned ad wave attenuator

Pre-grown Cord Grass Mats

Location	Eastern Scheldt, NL
Time	2012~
Feature	It is used in higher intertidal zone for consolidation and stabilization of tidal flats, and for the creation/restoration of pioneer salt marsh zones.

Coastline protection cases in UK

Sandscaping Scheme of Bacton to Walcott

Location	North Norfolk coast, UK
Time	2019
Feature	UK's first sandscaping scheme

Jaywick Sea Defence System

Location	Essex coast, UK
Time	1980s
Feature	Fish tail offshore coastal breakwater

Managed realignment cases in UK

Salt Fleet Flats

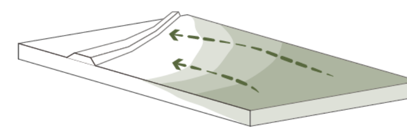
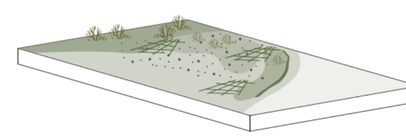
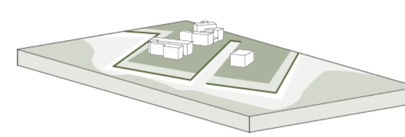
Location	Thames river, UK
Time	1997 – 2005, and 2006 – 2011
Feature	The flats was created on grazing land by reducing the ground level, using the material arising to create a new 2.4km-long flood defence embankment and breaching the existing flood defence to allow the site to be flooded.

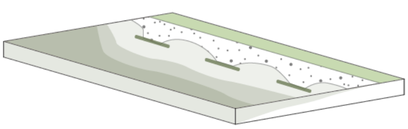
Wallasea Island Managed Retreat

Location	Wallasea, UK
Time	1997 – 2005, and 2006 – 2011
Feature	Large wetlands are reconstructed that form a nature area to compensate wetlands and bird habitat losses; a flood storage facility and a recreational area.

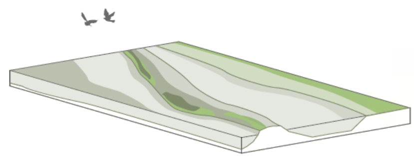
4.3 – **Strategies and principles**

After the precedent study, three sets of design strategies and principles are proposed, which are adaptive flood defense, restoration of tidal habitat, and sustainable development. In the next chapter, we will apply these design principles in local scale sites and explore design possibilities.

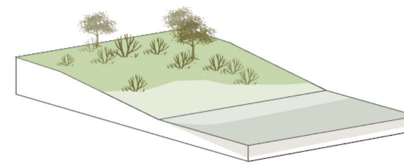
STRATEGY	PRINCIPLE
Adaptive flood defense	 dike relocation
Restoration of tidal dynamics	 growing marshes with pre-grow mats or floating marsh mattresses
Sustainable development	 living with water (function resistant)



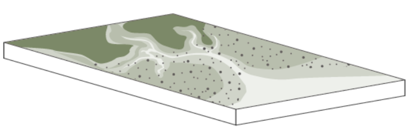
detached breakwaters



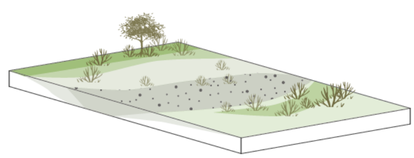
barrier islands



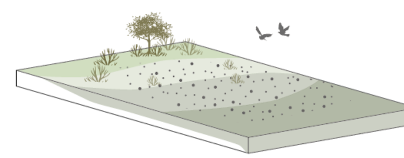
integrating vegetated foreshores



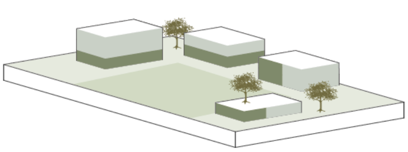
managed realignment



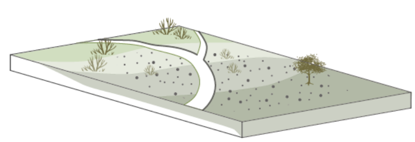
space for new habitats



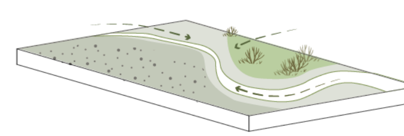
restoration of interface gradient



mixed-use development



tidal park with
recreational and leisure use



accessible waterfront

5 – Design Exploration

FIG. 5.1 A collage envisioning the close relationship between river landscape and the built environment.

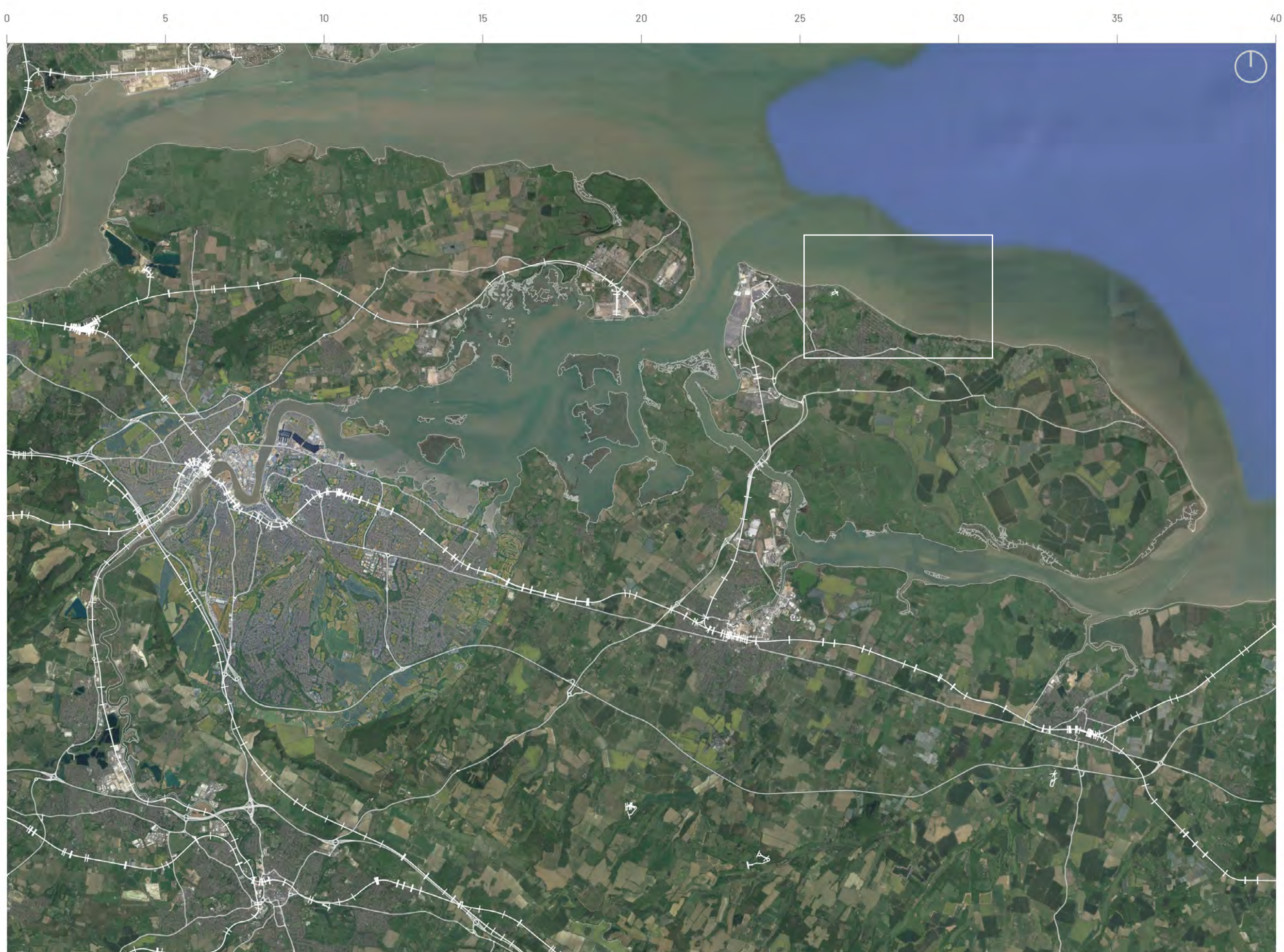
5.1 – **Site 1. Minster Coastline Management**

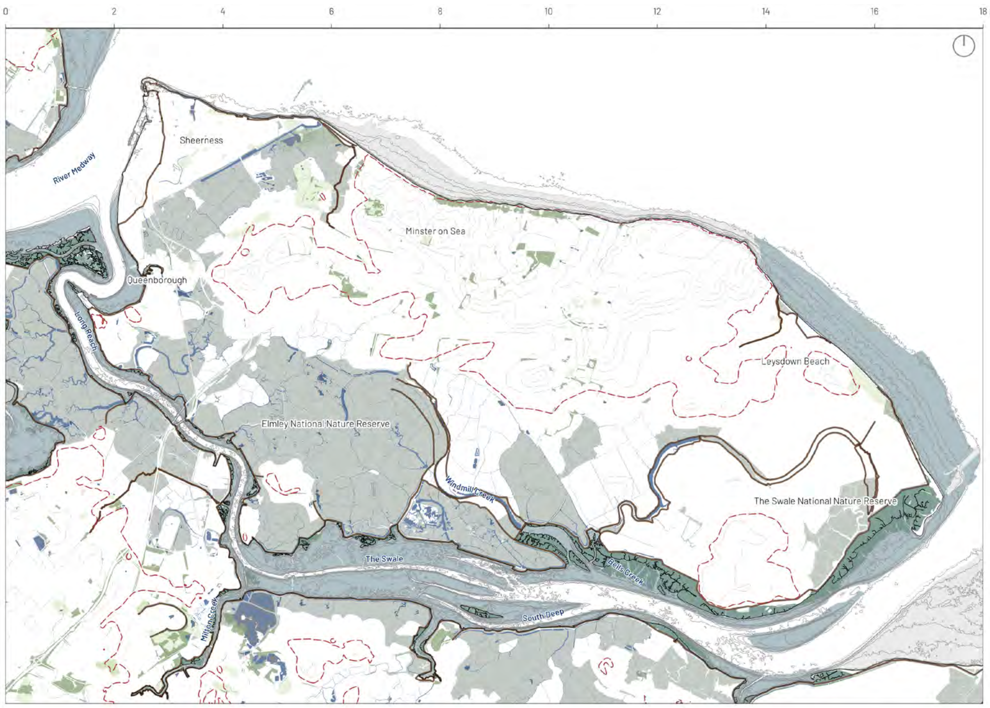
Economic activities on the north and marshland on the south

The site is located on the north coastline of the Isle of Sheppey. The design assignment is to increase the adaptability of the Minster coastline under current coastal cliff erosion and shoreline retreat issues.

The Isle of Sheppey is a place with multiple characteristics that features its port economy and accommodates villages, recreational beach, and various ecosystems. Due to its key location where coastal wetland and terrestrial habitats meet, the low-lying southern part of the island is home to two national nature reserve areas. Besides that, the main populated areas, the historic town of Sheerness and Minster-on-sea, are on the north. Minster-on-sea, which rises to 76 meters above sea level, is the main housing area of public investment according to the local plan of Swale.

FIG. 5.2 Site locaiton (Data source: OS Local.)

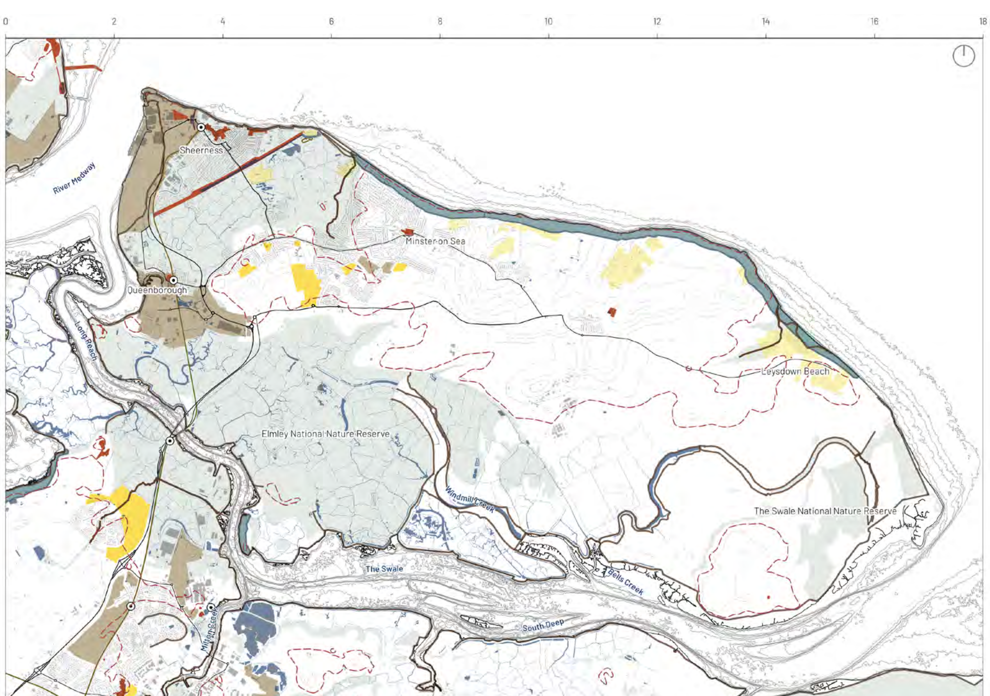




Legend

- High water line
- Satellite derived coastline
- Flood defense
- 10-meter contour line
- Green space
- Woodland
- Foreshore
- Mudflat
- Coastal and floodplain grazing marsh
- Coastal saltmarsh
- Surface water

FIG. 5.3 Overview of landscape



Legend

- Building
- Housing allocation site
- Employment allocation site
- Holiday park
- Heritage
- Surface water
- Flood risk zone
- Coastal cliff erosion
- Flood defense
- 10-meter contour line
- Train station
- Railway
- Major road

FIG. 5.4 Overview of development potential and threats

5.1.1 – **Characteristics of Sheppey coastline**

Port of Sheerness and the historic center: under protection

Port of Sheerness, positioned on the Thames Estuary, closer than Tilbury to Dover and within easy reach of Northern Europe, has deep-water access, which is perfect for ships of varying sizes coming from everywhere in the world (source of text: Peel Port Group). It is one of the UK's leading car and fresh produce importers. From the Defra's Marine Digital Elevation Model and shipping route data, we understood that the Port of Sheerness is located on the relatively deep sea location, which is around -20 meters. Due to its economic value, the port and the historic town, Sheerness and Marine Town are under sea defenses' protection (see images on previous page).

North Sheppey coast: coastal retreat and cliff erosion

On other other hand, the other coastline sections do not have protection of flood defense system. One of the reasons might related to its shallow characteristics. The potential intervention section is around 0 to -5 meters depth and has a 1 in 470 gentle slope. However, this section has long suffered from coastal retreat and cliff erosion. According to Environment Agency (2018), the summary of the cumulative shoreline retreat for the North Sheppey Cliff under a "Do Nothing" scenario, which is the current policy, all areas apart from the Leas have a high annual erosion rate, with the fastest rate of erosion occurring between Barrows Brook and Warden Point; with a total of 496m of projected retreat over the next 100 years. In general, all sections would encounter a 200 meters' retreat over the next 100 years. Therefore, according to the projection, this study identified the section near main residential cluster, Minster on Sea, as the priority section to protect.

FIG. 5.5 Bathymetric section diagram. Data source: Defra, Marine DEM.

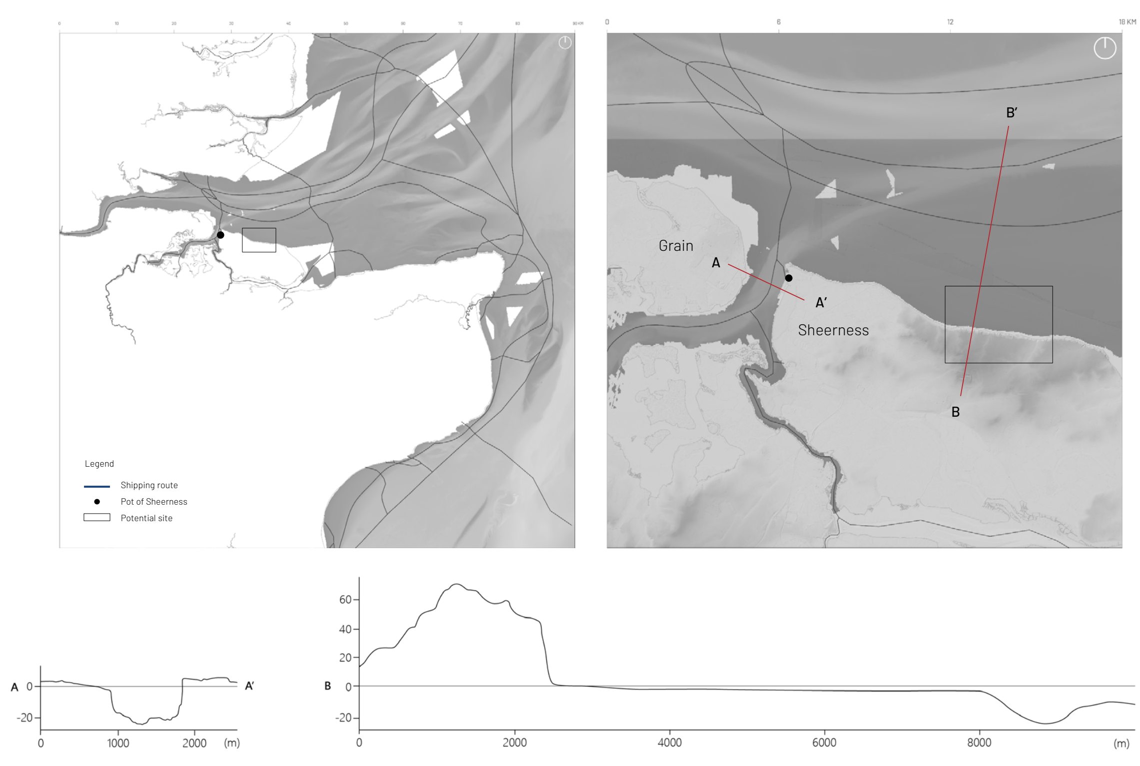


FIG. 5.6 (Top) Port of Sheerness. Image source: Oszibusz. https://www.youtube.com/watch?v=a_nYUbn42WU&list=LL&index=7

FIG. 5.7 (Bottom) The arrival of Ran Oil Rig. Image source: Oszibusz. https://www.youtube.com/watch?v=GaUkKwBvNRs&list=LL&index=16.

FIG. 5.11 Summary of the cumulative shoreline retreat for the North Sheppey Cliff under a 'Do Nothing' scenario. Source: Environment Agency. (2018). Mapped by Mott MacDonald.

Projected future cumulative retreat (m)

Year	Leysdown-on-Sea (BA8.2 & 9.1)	Warden Bay Defended (BA9.2)	Warden Bay Undefended (BA10.1 & 9.2)	Barrows Brook to Warden Point (BA 10.1)	Hen Brook to Barrows Brook (BA 10.1)	Bugsby Hole to Hen Brook (BA 10.1)	Minster to Bugsby Hole (BA10.1)	Minster Cliffs sea defence (BA 11.1)	The Leas (BA 11.1)
2015	0	0	0	0	0	0	0	0	0
2065	125	28	125	214	116	100	89	100	17
2115	290	193	290	496	269	231	206	231	38

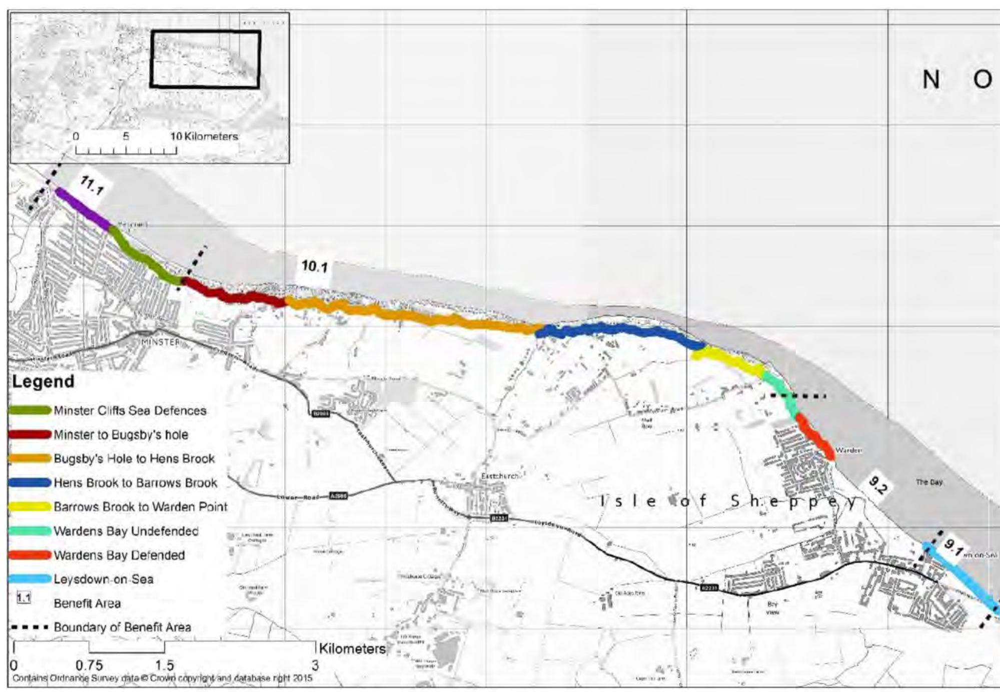
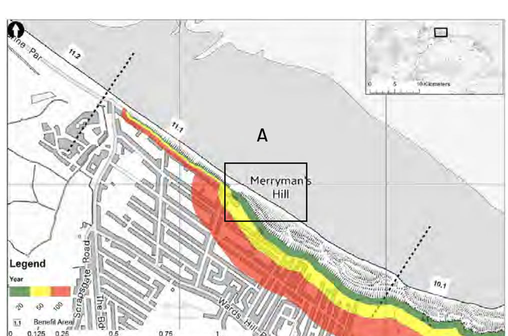


FIG. 5.10 Cliff erosion sections. Source: Environment Agency. (2018). Mapped by Mott MacDonald.



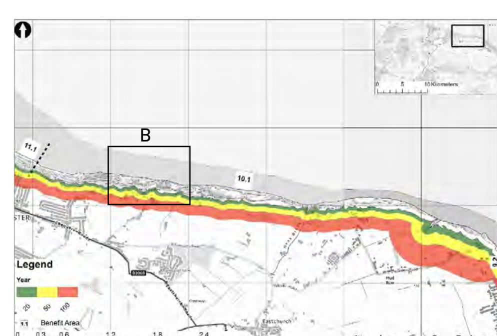


FIG. 5.8 Left: Coastal Retreat projection (Minster to Bugsby's Hole). Source: Environment Agency. (2018). Mapped by Mott MacDonald.

FIG. 5.9 Right: Coastal Retreat projection (Bugsby's Hole to Hens Brook). Source: Environment Agency. (2018). Mapped by Mott MacDonald.

FIG. 5.14 North Sheppey coast (A). Image source: Chris Crowder. Minster Isle of Sheppey.

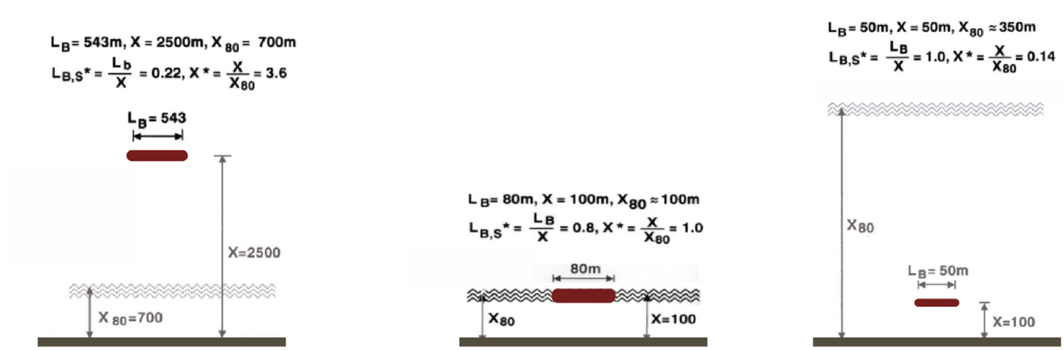
FIG. 5.13 North Sheppey coast (A). Image source: Chris Crowder. Minster Isle of Sheppey.

FIG. 5.12 North Sheppey coast (B). Image source: Sidders S. Kent Coast Walk. Minster on Sea to Warden.

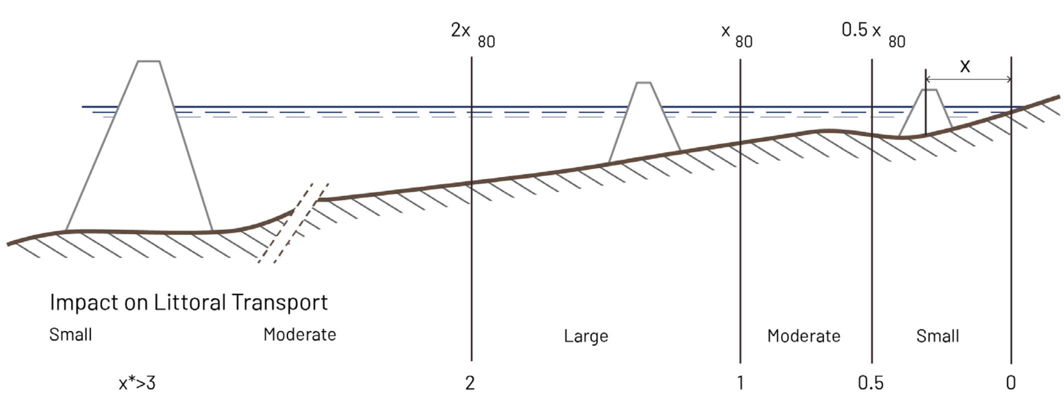
5.1.2 – **Research by design**

After identifying the intervention section, I studied flood defense systems (i.e. sea walls, breakwaters, groynes, berms, dunes, and beach nourishment), to explore possible solutions for this site. Among the defense systems, offshore breakwaters are selected as the backbone of the design. Different types of breakwaters and the design principles connected are shown as diagrams below.

The main design idea is to use artificial structures in harmony with nature. This corresponds with the nature-based solution perspective. Recently, the concept of “nature-based solutions”, “ecosystem-based adaptation”, “eco-DRR” or “green infrastructure” has emerged as a good alternative or complement to traditional gray approaches. Nature-based solutions make use of natural processes and ecosystem services for functional purposes, such as decreasing flood risk or improving water quality (World Bank, 2017). It is worth mentioning that these interventions can be completely “green” (i.e. consisting of only ecosystem elements) or “hybrid” (i.e. a combination of ecosystem elements and hard engineering approaches).

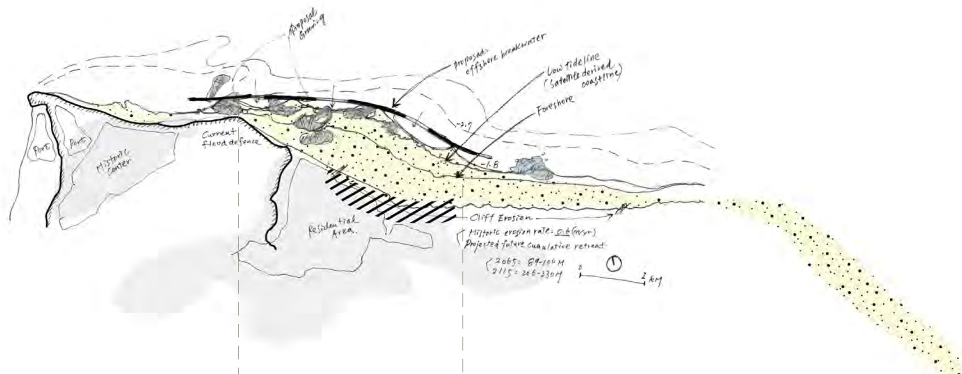


Offshore breakwater | Coastal breakwater | Beach breakwater



Dimensionless Breakwater Distance: $x^* = \frac{x}{x_{80}}$

L_B	Length of the breakwater
x	Breakwater distance to shoreline
x_{80}	Surf-zone width, approximately 80 % of the littoral transport takes place landwards of this line



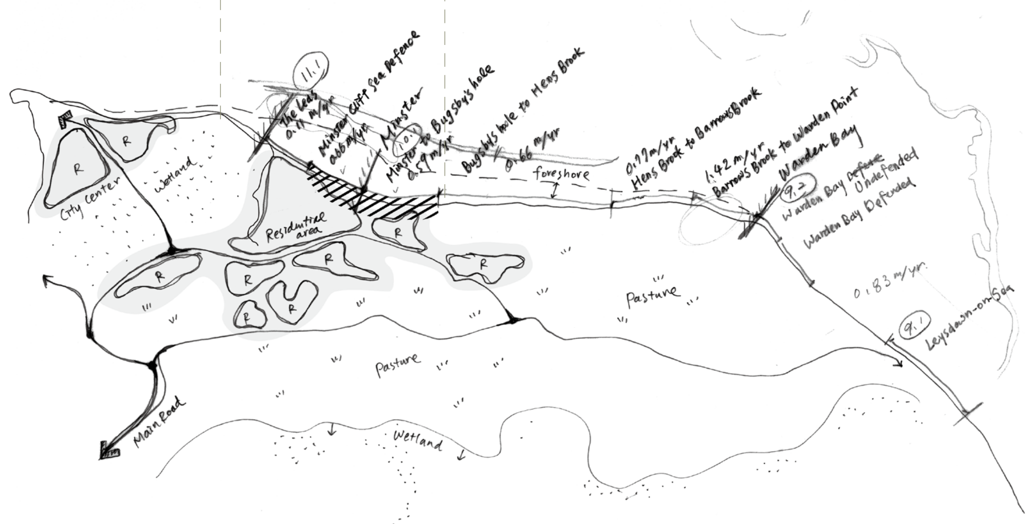


FIG. 5.15 (Left) Type of detached breakwaters. Source: DHI (2017). Redrew by author.

FIG. 5.16 Conceptual sketches mapped the potential location of offshore breakwaters and the relationship between the built environment.

According to Shoreline Management Guidelines of DHI (2017), we understand that a detached breakwater is a structure parallel, or close to the coast, built inside or outside the surf zone. It provides shelter from the waves, whereby the littoral transport behind the breakwater is decreased and the littoral transport pattern adjacent to the breakwater is modified. Based on the located distance of a breakwater, it serves different functions. This project chose "coastal breakwater" which is set in parallel (x=1) to the surf zone and serves as a shore protection measure. The sketches illustrated the mapping and design thinking process.

Under the concept of nature-based solutions, a hybrid detached breakwater system would serve as the backbone of the offshore barrier islands. After the structures are set and the preliminary mud motor system, the semi-nature system would grow with time and create intertidal habitats.


0
1
2
3
4
Sheerness and Marine Town coastline
under protection of sea defense
Minster on Sea coastline (2 km)
undefended section with coastal retreat issue
Potential zone for coastal intervention
0.5 km
0.8-1 km
Sheerness
Minster on Sea

5.1.3 – **Identification of potential zones**

The northern coast of the Isle of Sheppey is projected to have a 200m retreat over the next 100 years due to coastal erosion. As we can see from the map, only the northern coastline section, Sheerness, and Marine town are under sea wall protection. Therefore, the proposal, which focuses on Minster on sea coastline, aims to protect around 15k inhabitants (2019) and 5605 (2011 census) properties. In addition, the morphology of the offshore zone is shallow and gentle (1 / 470). It provides the potential for coastal interventions.

Legend

- Existing flood defense
- Major road
- Major housing cluster
- Potential site for interface design
- Surf zone
- Potential zone for coastal intervention

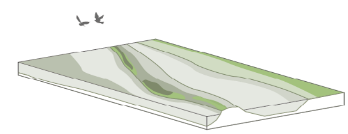
FIG. 5.17 Map of issue diagnosis


0
1
2
3
4
Space for in
habitats to
Connection with
current road system
Natural park with
observation footpath
Restoration of
landscape gradient
Sheerness
Minster on Sea

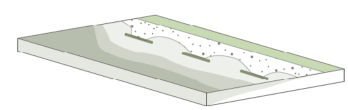
5.1.4 – **Proposal**

Nature-based interventions to increase coastal resilience

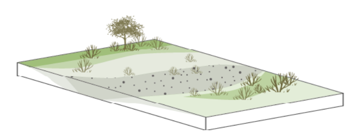
Offshore barrier islands are proposed to protect major housing cluster and create space for habitats to grow.



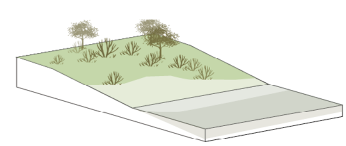
barrier islands



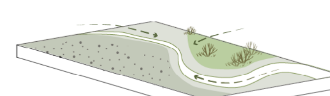
detached breakwaters



space for new habitats



integrating vegetated foreshores



accessible waterfront

FIG. 5.18 Illustrative plan and design principles

5.1.5 – **Design detail**

The sections below illustrated the relationship between the barrier islands and the current shoreline. After the breakwater structure is constructed, a shallow lagoon will be created, which will provide space for intertidal habitats. The sediment in this area would grow with time and form a mudflat landscape. On the coast side, the slope between the village and foreshore will undergo landscape programs to introduce native woodland and vegetation.

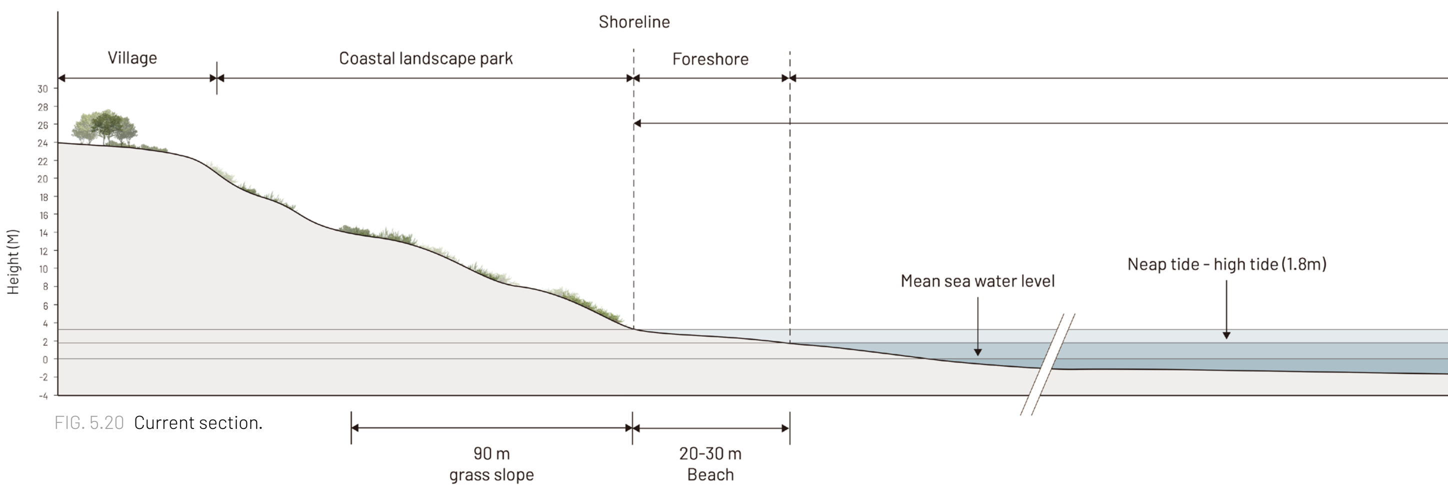


FIG. 5.20 Current section.

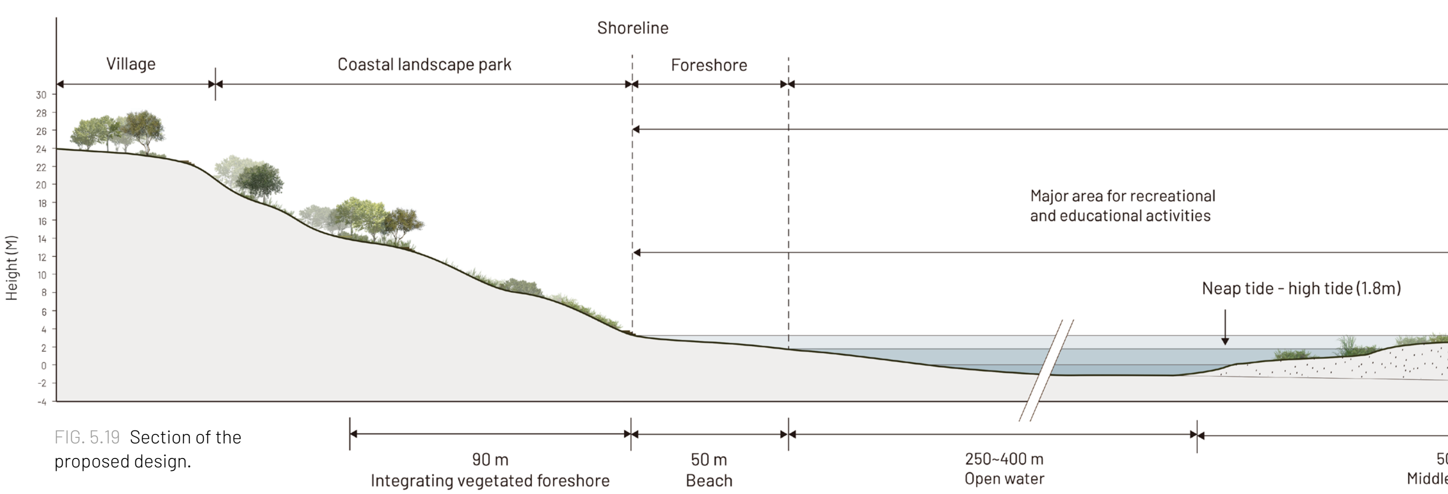
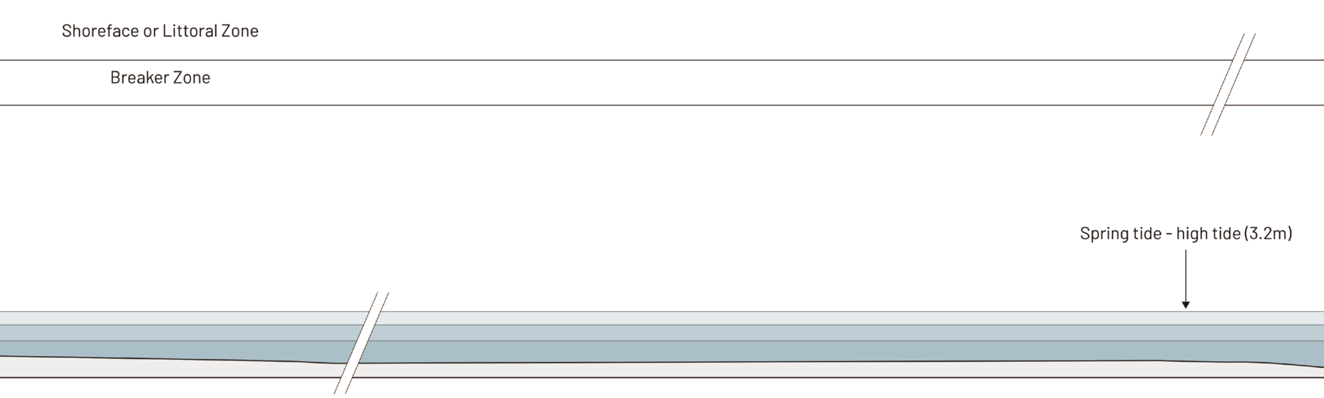
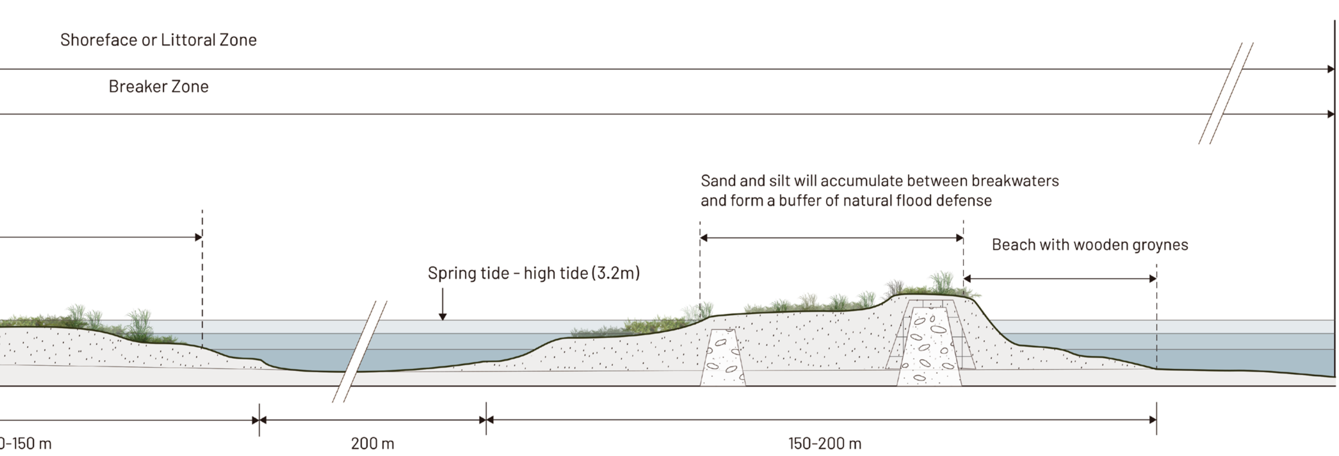


FIG. 5.19 Section of the proposed design.



Shoreface or Littoral Zone
Breaker Zone
Spring tide - high tide (3.2m)



Shoreface or Littoral Zone
Breaker Zone
Sand and silt will accumulate between breakwaters
and form a buffer of natural flood defense
Beach with wooden groynes
Spring tide - high tide (3.2m)
0-150 m
e marshland
200 m
Open water
150-200 m
Main barrier island

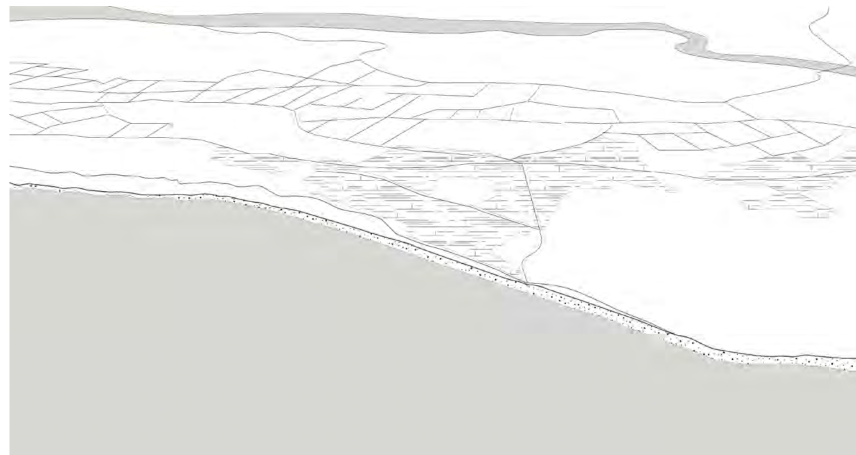
5.1.6 – **Phasing**

A growing system

From the phasing diagrams we can understand that, this will be a system that can grow with nature. In phase one, the basic structure will be set up, and deposit dredged sediment around the breakwaters. Sand and silt could accumulate between breakwaters (dam) and form a natural buffer of flood defense.

In phase two, the natural formative elements, such as wind, wave, and tide will disperse the sediment. Therefore, a mudflat landscape will form. We could also installed pre-grown cord grass mats to provide space for saltmarsh plants.

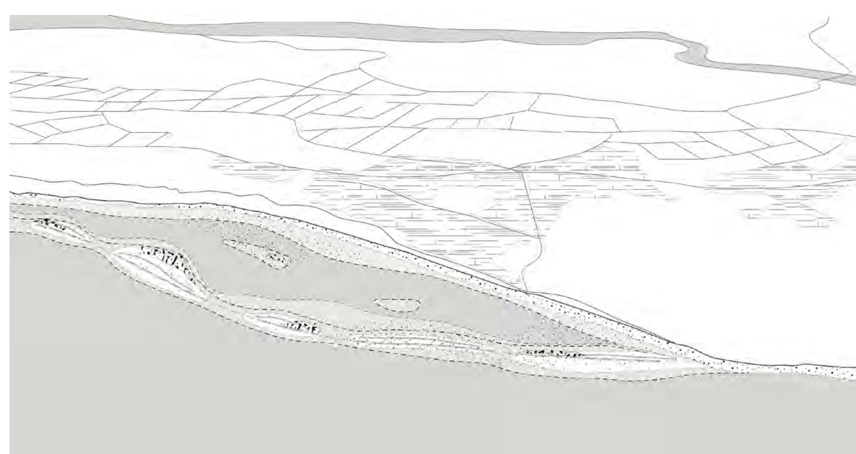
FIG. 5.21 Phasing diagrams.



Phase 0: Preparation

1. Planning.

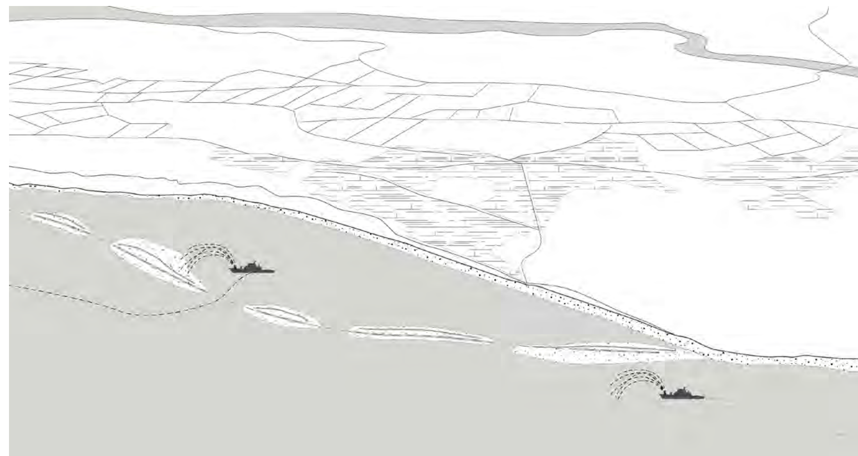
2. Stakeholder cooperation: city council, environmetal sectors, and port authority.



Phase 2: 2030-2060

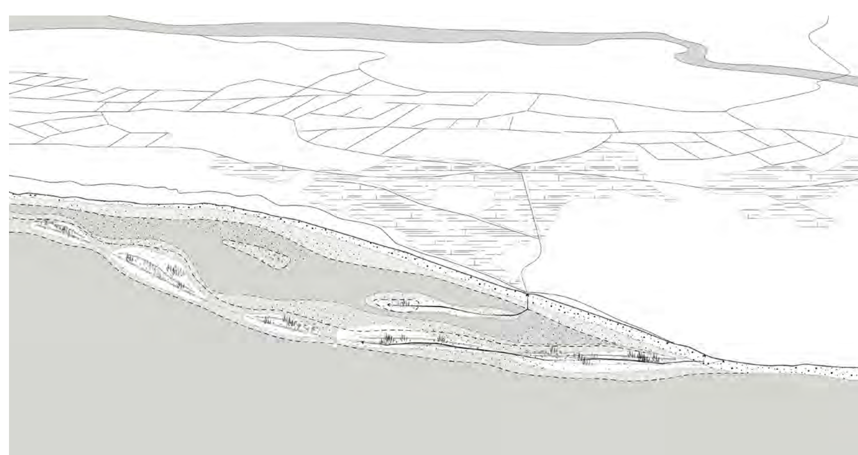
1. Wind, waves, and tides disperse the sediment along the island chain. Mudflat landscape forms.

2. Pre-grown cord grass mats are installed.



Phase 1: 2021-2030

1. Breakwater construction.
2. Mud motor: deposit of dredged sediment around breakwater.



Phase 3: 2060-2100

1. Saltmarsh plants capture the sediment and grow the marsh.
2. Development of recreational footpath.


offshore island structure:
-providing shoreline protection
-growing with nature
mudflat landscape:
space for tidal habitats
restoration o

5.1.7 – **Conclusion**

A chain of offshore barrier islands is the main design intervention on Minster on Sea coastline. It could protect the coastline from long-term erosion and retreat. At the same time, a wide mudflat landscape would be created to increase ecological benefits and provide recreational and environmental education use.

FIG. 5.22 A collage showing spatial quality on Minster beach.

5.2 – **Site 2. Lower Rainham: restoration of tidal habitat**

Introduction

This location comprises saltmarsh islands and extensive tidal mudflats (the mean tidal range is 5.6 m for spring tides). However, much of the original salt marsh has been lost through the removal of material for brick-making, land reclamation, and embanked in the last century. Furthermore, sea-level rise will accelerate coastal squeeze and natural erosion of the intertidal habitats. The design strategies focus on how to restore ecosystem, waterfront gradient, and create adaptive flood defense.

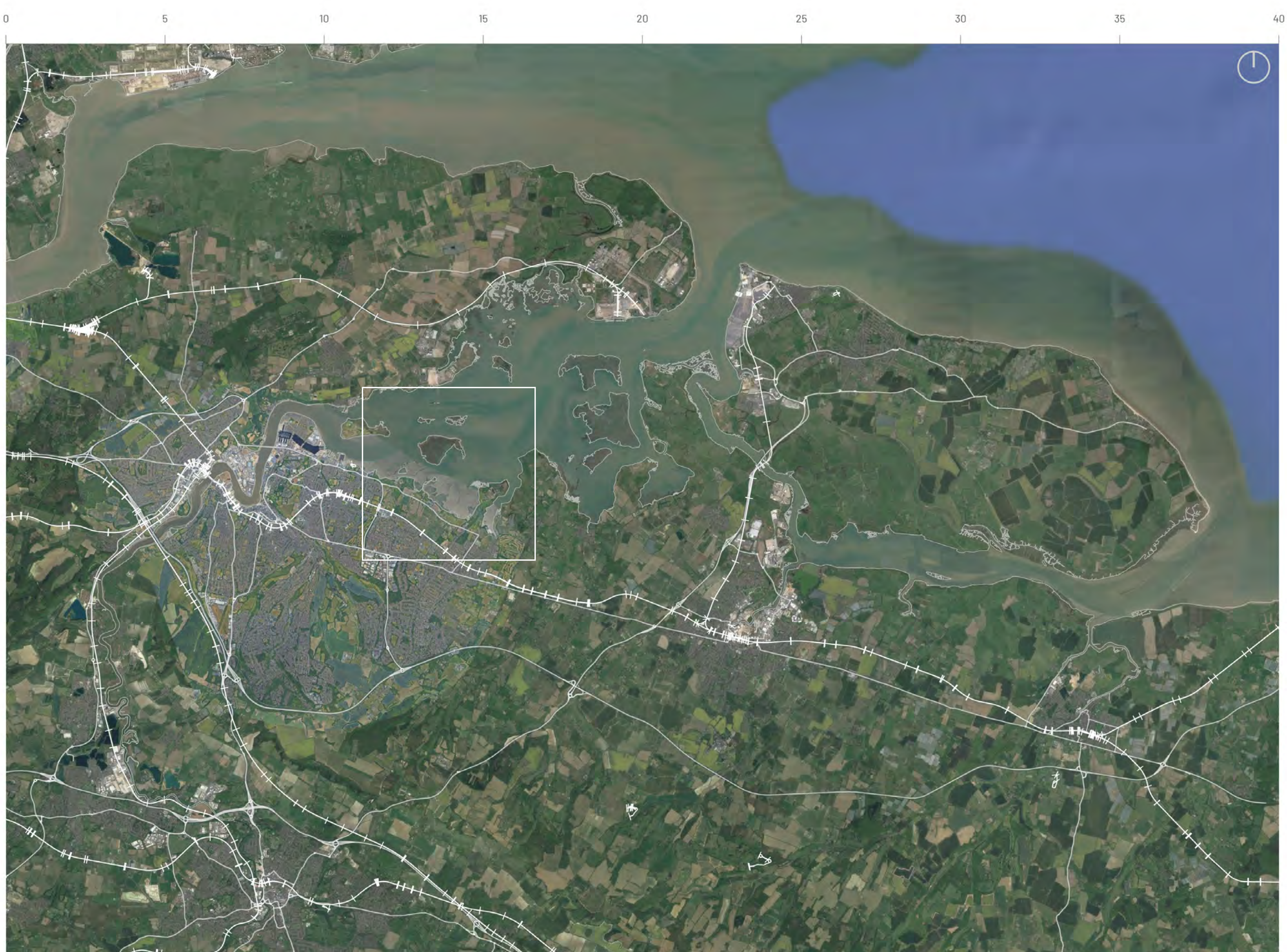


FIG. 5.23 site location.


FIG. 5.24 Saltmarsh patches between Horrid Hill and Motney Hill. Photo credit: Sylvia H.

Legend

- Tidal River
- High water line retreating zone (1885 to 1937)
- High water line retreating zone (1937 to 2020)
- High water line
- Satellite derived coastline
- Flood defense
- 10-meter contour line
- Saltmarsh
- Extent of surface flooding: 1 in 30 years
- Extent of surface flooding: 1 in 100 years
- Extent of surface flooding: 1 in 1000 years
- Green space
- Woodland
- Building
- Rainham station
- Railway
- Major road

FIG. 5.25 conclusion map of site analysis

The space for intertidal habitats, such as Normarsh and Bishop Saltings, is shrinking due to sea-level rise. It is mapped through the retreating of high water lines.

Horrid Hill, the arm-shaped natural platform, is a popular spot for bird watchers. This is also part of the Saxon Shore Way, a long-distance footpath that stretches around Kent and Sussex coastline.

Flood defense hinders the natural gradient between land and river. It will cause the losses of marshes since the marshes are not able to move landwards.

Surface water accumulates at low-lying zones near the dike structure.

The linear buffer between flood defense and the 10-meter contour line is the potential zone for intervention.

Non-irrigated arable land and pastures provide space for the transitional zone.

Rainham Business Park

5.2.1 – **Diagnose**

Shrinkage of the intertidal zone and coastal squeeze are the main urgencies in this location. From the retreat of the high tidal line, we understand that in the past 100 years, intertidal zones are decreasing, such as Normarsh and Bishop Saltings. Besides the loss of habitat in the estuary, current flood defenses also hinder the gradient between land and water. The tidal habitats are not able to move landward, and the surface flooding from the south accumulated at low-lying zones near the dike. These issues will worsen since the UKCP18 climate change projections identified that there will be an increase in sea-level rise by 0.8m by 2080 in Kent.

5.2.2 – **Design Exploration**

Initial concept

This is the first set of sketches to explore possible interventions. There is an existing gradient from the river, tidal habitat, rural houses, pastures to an urbanized area. However, a sharp edge (dike) separated the interface between the river and the built environment.

Adaptive buffer zone with growing saltmarsh patches

Redesign the dike, let the water flow, and create a transitional zone, is the initial concept proposed in the early stage of the graduation project. The goal is to realign the habitats in response to coastal squeeze. In this phase, the intervention locations were not precise yet.

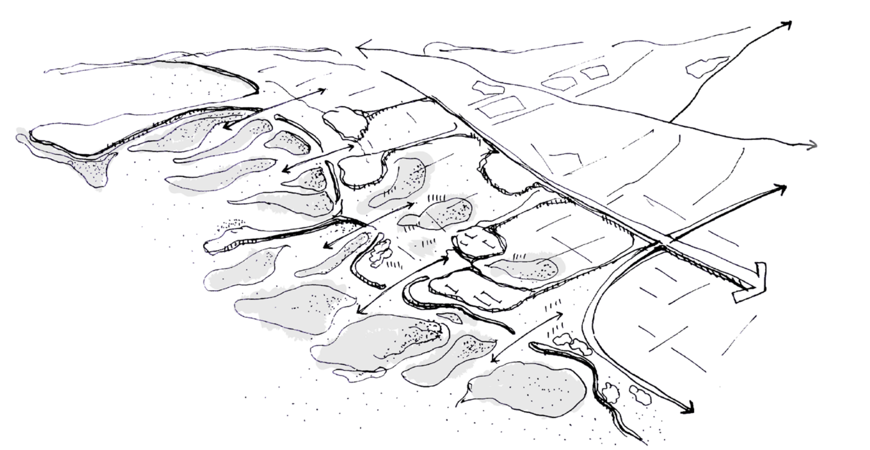


FIG. 5.26 sketches of current condition and design proposal

Hydrology study: Generating streamlines

If we redesign the current flood defenses, the tidal river and surface water system will meet. Therefore it is crucial to understand the surface flow before suitable design locations are selected.

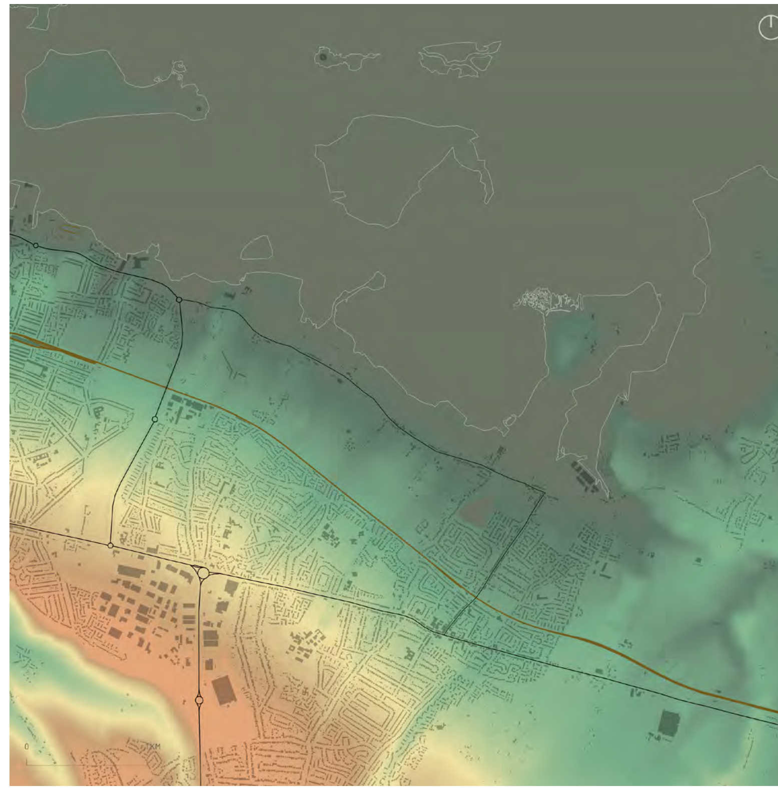


FIG. 5.27 Digital elevation model. Data source: Data.gov.uk. LIDAR Composite DTM 2019 2M.

Height (m)

-0.8	55.2
10.3	66.3
21.5	77.6
32.7	88.8
43.9	100

Streamlines are generated from the digital terrain model to mark hydrography with the hydrology toolset in ArcGIS. Through this process, I visualized the surface water flow. The streamline informed us where to implement further design actions from a landscape perspective. Based on this layer, design principles are applied to explore possible spatial forms.

FIG. 5.28 Generated streamlines and current river stream. Data source: LIDAR Composite DTM 2019 2M.

Legend

- Generated streamline
- Current river stream
- Flood defense
- Surface flooding spots

Proposals of the new interface

After the analysis of the surface water streamline, several spots are identified to have possibilities to give space to the tidal river. In addition to this, mudflat and saltmarsh clusters are also mapped to understand the relationship between them and adjacent land.

As the images showed, three proposals are introduced to accommodate the design principles. Then I decided to combine the ideas illustrated in these three sketches as the final design.

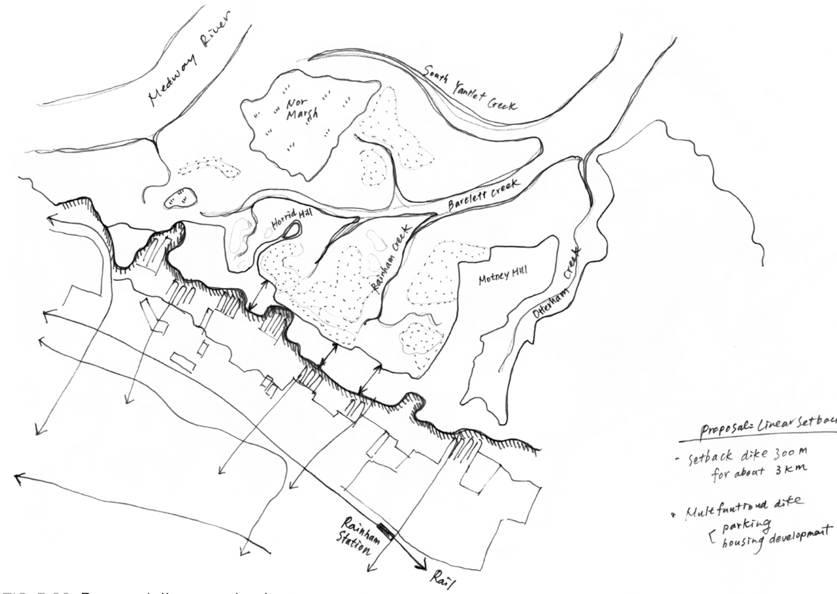


FIG. 5.29 Proposal: linear setback

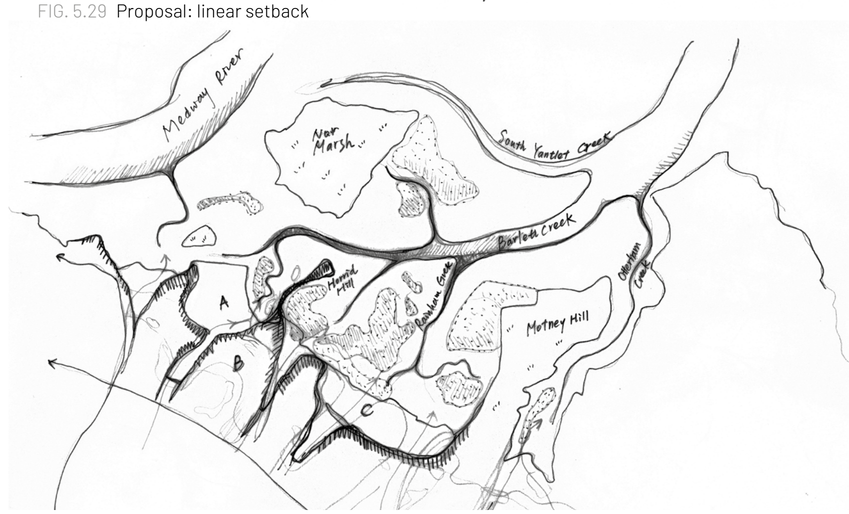


FIG. 5.30 Proposal: Cut and De-build

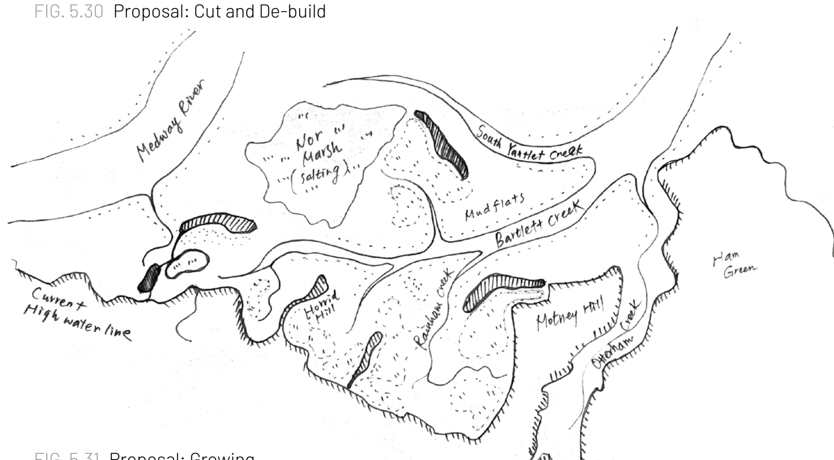


FIG. 5.31 Proposal: Growing

FIG. 5.33 Horrid Hill. Image source:Google Earth. Photo credit: Steve Hamilton

FIG. 5.32 High marshes. Riverside Country Park Copperhouse Lane. Image source: Google Earth. Photo credit: Beth Mills.

Legend

- Saltmarsh
- Potential space for saltmarsh restoration
- Potential growing direction in estuary
- Potential growing direction toward land
- Potential direction of dike relocation
- Adaptive Zone
- Current flood defense
- 10-meter contour line

FIG. 5.34 Identification of potential zones

Identification of potential zones

After serval rounds of analysis, the map illustrated the decision-making process of the final proposal.

The rural characteristics of this location give it the potential to demonstrate an adaptive interface between land and estuary. A linear zone in parallel to the current dike is identified according to the contour line and the urban structure. Then, based on the historic map, current habitat location, and bathymetry, potential zones to restore tidal habitats are marked.

Saltmarsh restoration potential locations are based on bathymetry, flow direction, and the historic pattern of saltmarsh.

Potential locations for habitats to grow toward land.

The linear buffer between flood defense and the 10-meter contour line is the potential zone for dike relocation.

growing marshes

tidal park with pioneer wetland

managed realignment (pilot)

managed realignment (reserved land)

adaptive zone (reserved land) for future climate events

adaptive flood defense

recreational or residential block

footpath and cycling path system

access to coast

Arm structures with pre-grown cord grass mats will be placed to accumulate sediments, and create habitats for saltmarsh through time.

A new footpath and bird-watch deck will be designed to add to the Saxon Shore Way.

Saltmarsh restoration sites are adjacent to the current habitat.

Lower the bank and create space for the tidal river.

Footpath and cycling path connection landscape structure.

Reserved sites for recreational use or waterfront housing development.

FIG. 5.35 Illustrative plan

5.2.3 – **Proposed plan**

Proposed landscape and network system

An adaptive zone is proposed to expand the habitat for saltmarsh; also, it will form a linear reserved zone for recreational use and waterfront residential development. Footpath, cycling path, and local roads are proposed to connect the landscape system with current structure. On the east side of Horrid Hill and Copperhouse Marsh, tidal parks combined with observation decks will be designed.

On the other hand, around Nor Marsh and Bishop Saltings, arm structures with mesh will be placed to accumulate sediments, and create habitats for saltmarsh through time.

growing marshes

tidal park with pioneer wetland

managed realignment (pilot)

managed realignment (reserved land)

adaptive flood defense

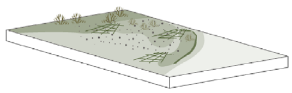
recreational or residential block

footpath and cycling path system

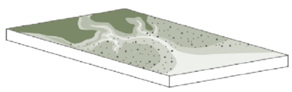
Landscape strategies

This final map identified which design principles are been applied in this location. These principles are related to each other and could be applied in multiple locations in this area. For example, dike relocation will bring ecological benefits to the adjacent zones. Depends on the location, it could help to restore the intertidal ecosystem or provide new programs, such as space for waterfront housing development. In general, the intervention will improve the public space quality in the waterfront area, recreate the interface, and restore the dynamics of the ecosystem.

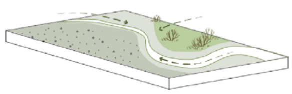
As the diagrams below show, there will be two types of adaptive interface proposals. One is directly setting back the dike to create space for tidal river, the other one is creating wetland parks that integrated with current adjacent land use. In the next section, a pilot site of managed realignment is selected to elaborate its design detail.



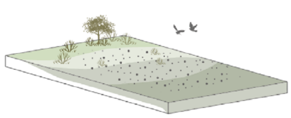
growing marshes with pre-grow mats
or floating marsh mattresses



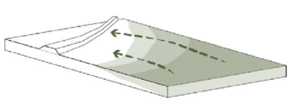
managed realignment



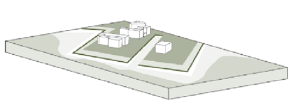
accessible waterfront



restoration of interface gradient

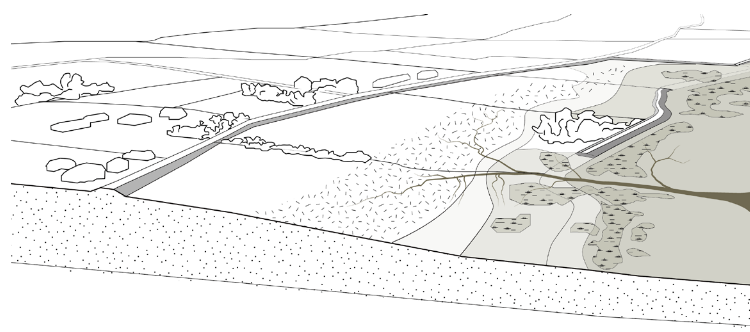


dike relocation

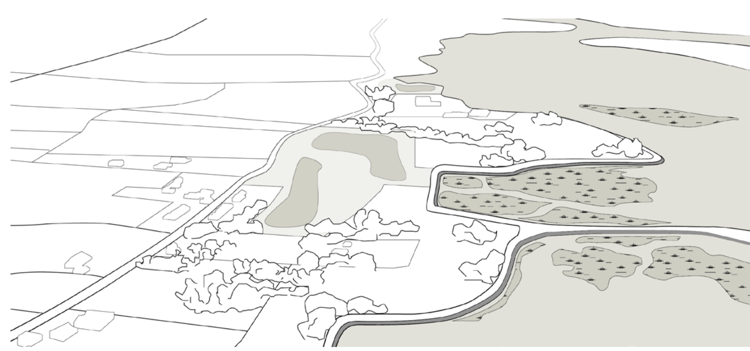


living with water
(function resistant)

FIG. 5.36 illustrative plan and design prinicples



A. Managed realignment



B. Wetland park

5.2.4 – **Pilot of the adaptive interface**

One of the proposals for the adaptive interface is "managed realignment." This proposal aims to respond to the coastal squeeze issue. The key is to relocate the current flood defense (hard interface) and create a natural gradient for intertidal habitats to grow towards land.

The section shows the spatial relationship of a pilot site. The current flood defense is suggested to remove at this location because the inner part of the land currently is lower than the spring tide high tide level; therefore, it has the potential to accommodate tidal habitats. By relocating the flood defense, it can increase an additional 18 hectares of the intertidal zone for habitats to adapt to sea-level rise in the following century.

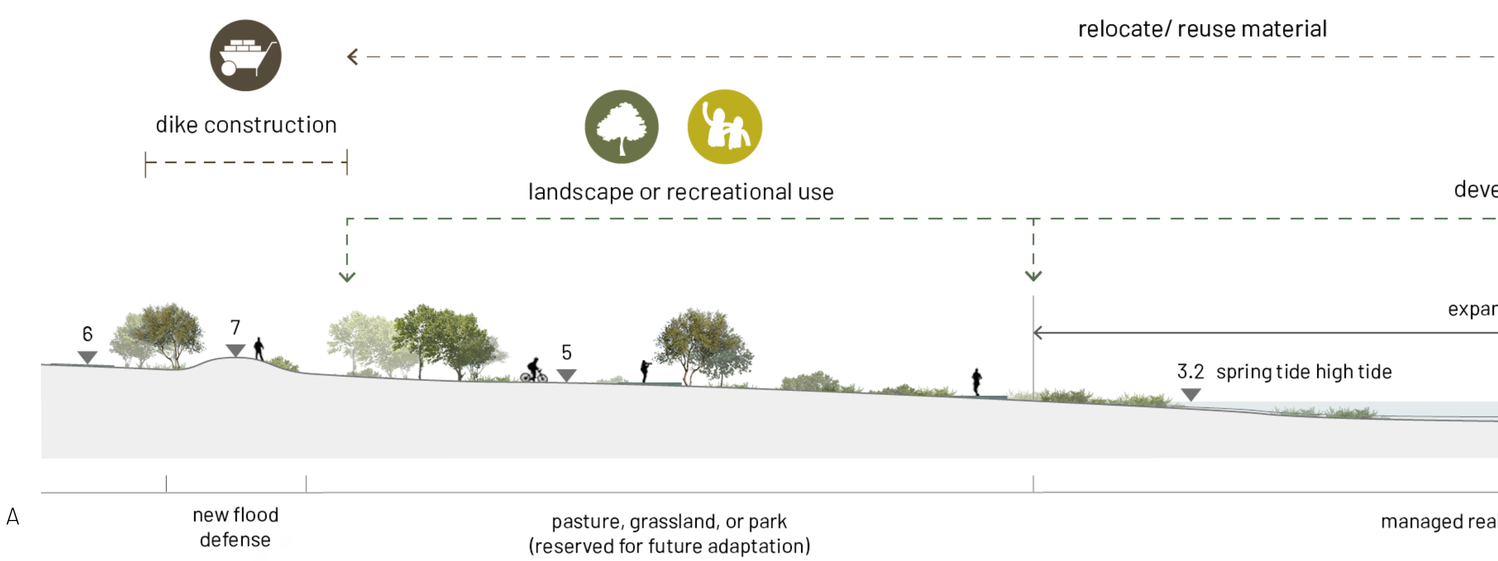


FIG. 5.37 section

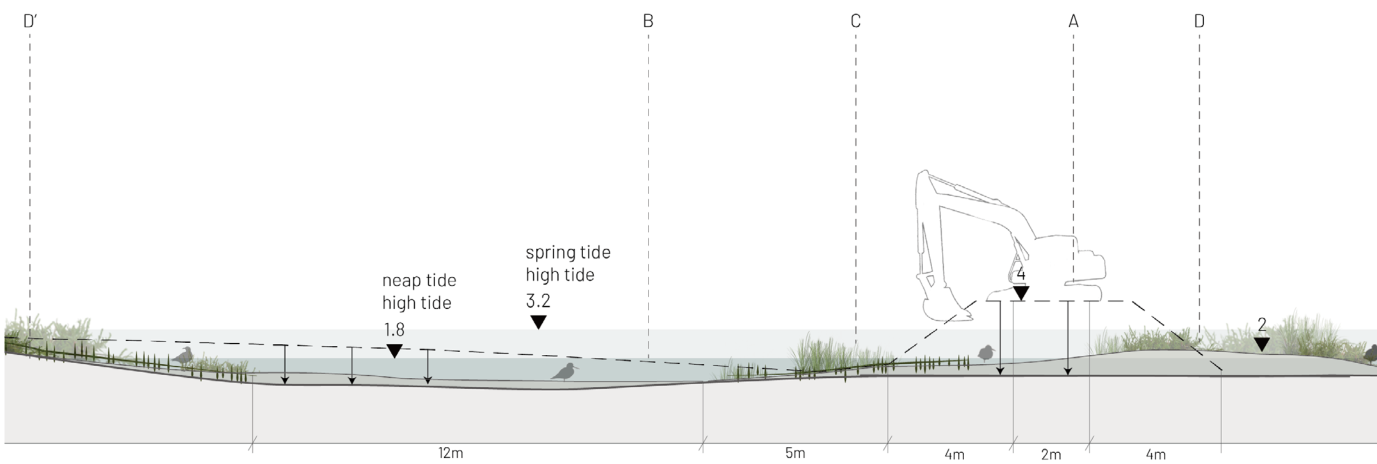
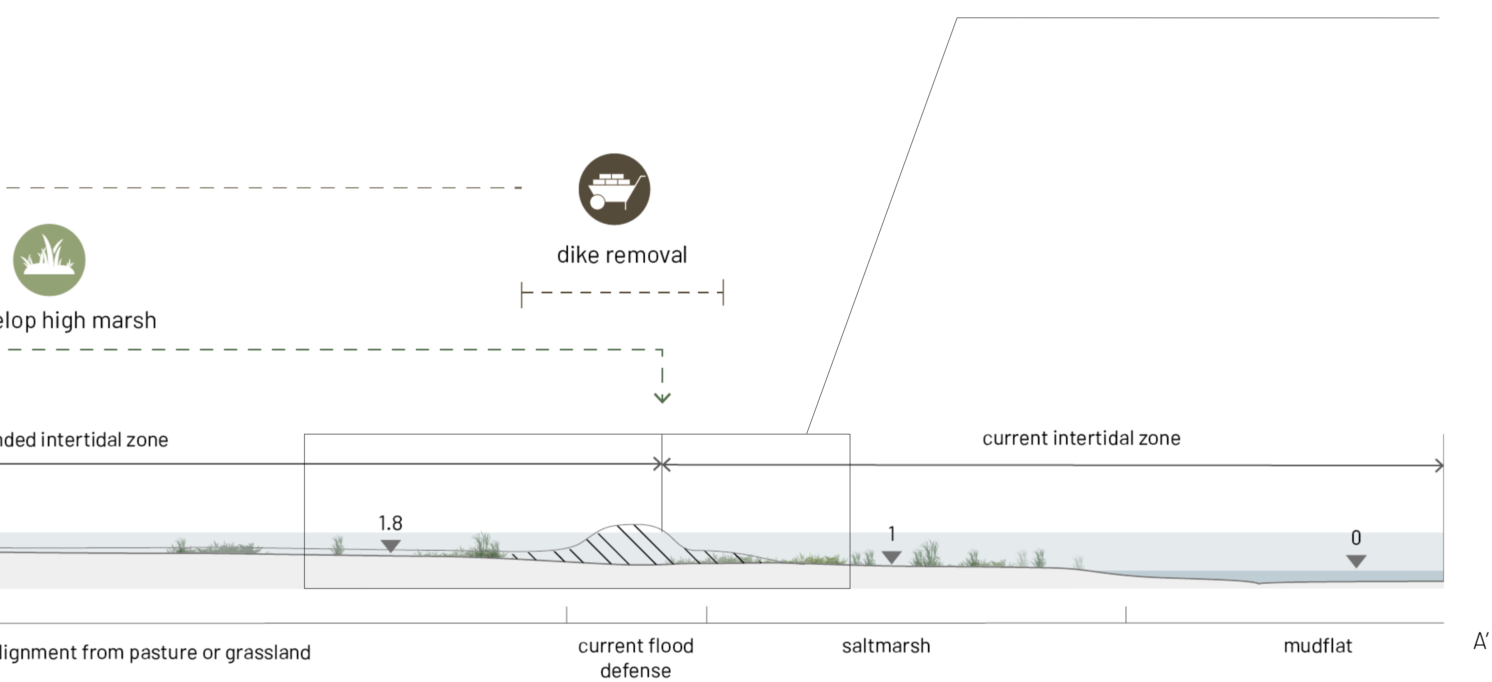


FIG. 5.38 Design detail of the dike relocation proposal

A. Remove current dike structure
B. Excavate surface ground to align with existing marshes
C. Place pre-grow marsh mattresses
D. Potential new ecological gradient



5.2.5 – **Phasing**

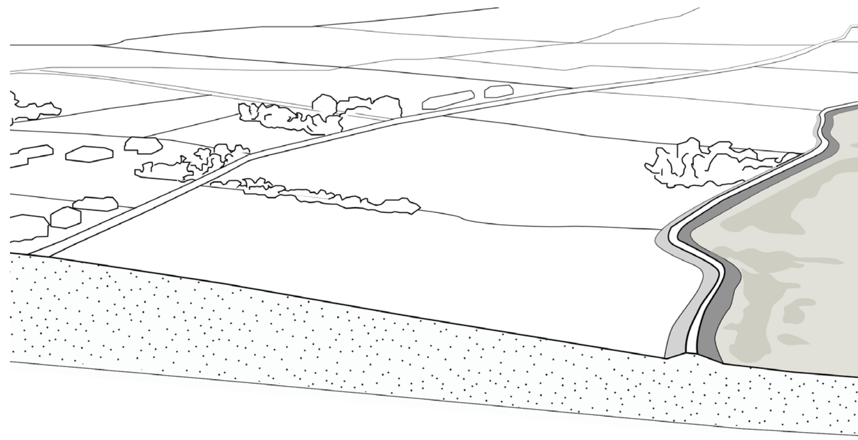
A growing system

From the phasing diagrams we can understand that, this will be a system that can grow with nature.

This location on the Rainham coastline is select as a pilot for managed realignment. In the preparation phase, it is important to have stakeholders' meetings and form partnerships. Since the proposal will change the current land use, it is crucial to communicate well about the practicality of zoning transformation.

In phase two, after the new flood defense is constructed, we could excavate the current dike structure (partially) and let the water flow in. In the final phase, this site can increase a total of 18 hectares of the intertidal zone, for habitats to adapt to sea-level rise in the following century.

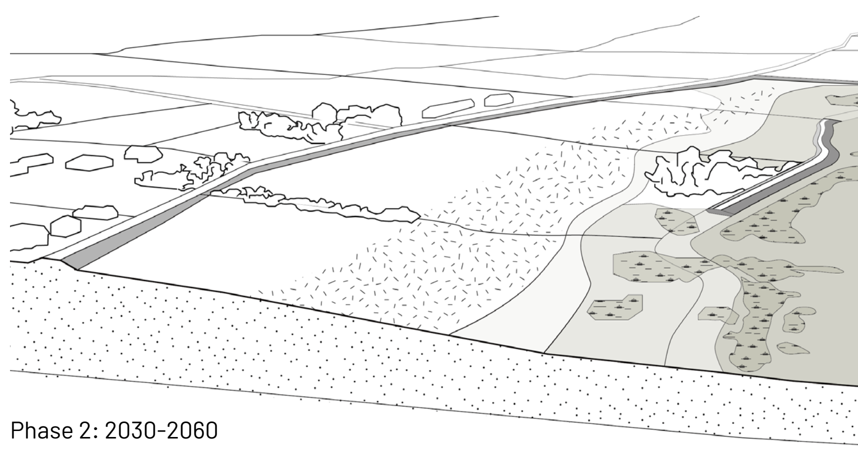
FIG. 5.39 Phasing diagrams.



Phase 0: Preparation

1. Planning.

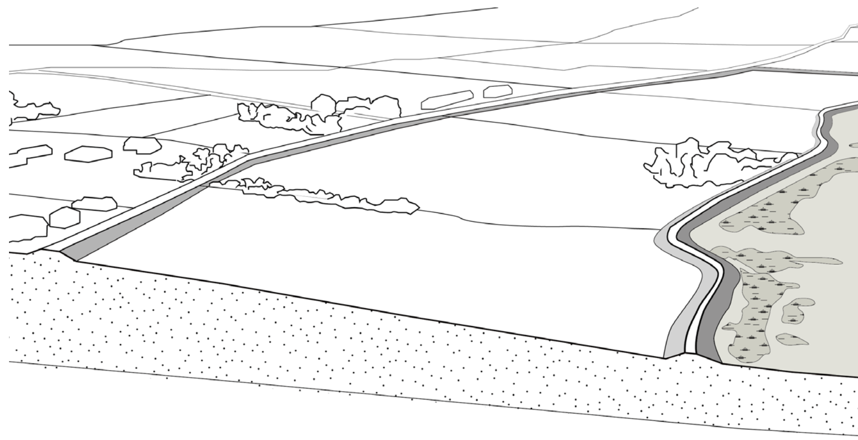
2. Stakeholder cooperation: city council, environmetal sectors, and land owners.



Phase 2: 2030-2060

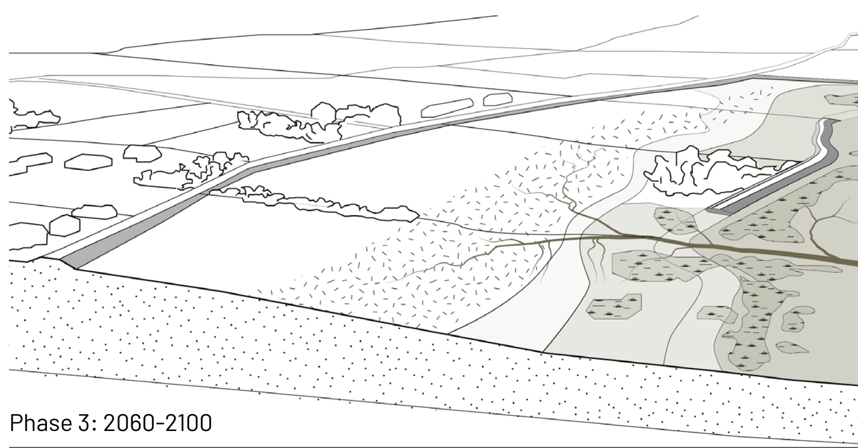
1. Excavate current dike structure. Reuse the materials to enhance aging dikes.

2. Excavate surface ground to align with the height of existing marsh patches.



Phase 1: 2021-2030

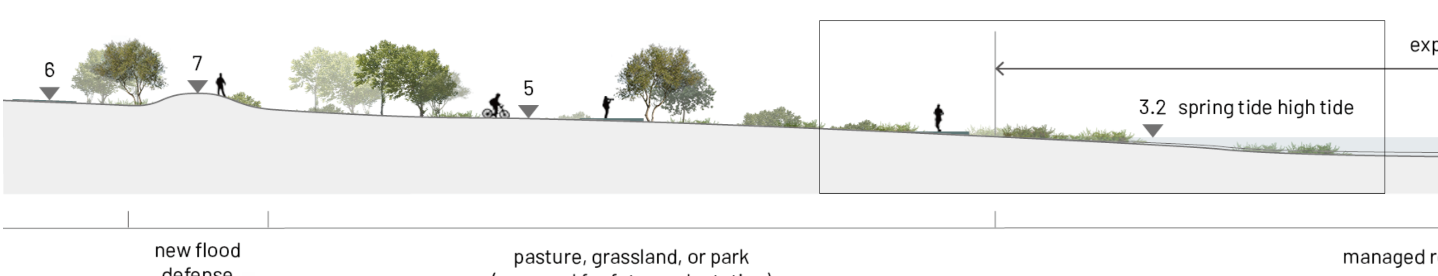
1. Building the new flood defense.
2. Site preparation: transform landuse and plan for future road system.

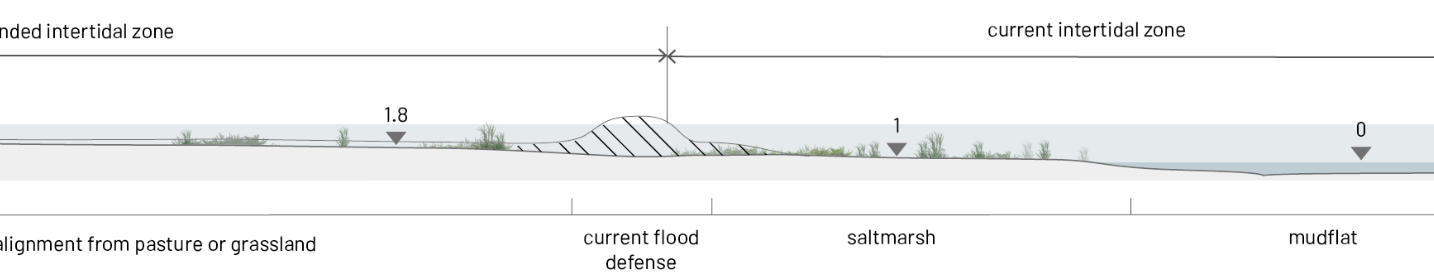


Phase 3: 2060-2100

1. Place pre-grown marsh mattresses on coastline.
2. Space for intertidal habitats to grow.
3. Programming for recreational use.

FIG. 5.40 A collage of the Lower Rainham coastal landscape.




nded intertidal zone
current intertidal zone
1.8
1
0
alignment from pasture or grassland
current flood defense
saltmarsh
mudflat

5.2.6 – **Conclusion**

The design strategies of the Lower Rainham site focused on how to restore the ecosystem, waterfront gradient, and create adaptive flood defense. The aim is to increase the adaptability of the natural environment to respond to sea-level rise by de-building the hard infrastructures.

In the end, pilot will restore the dynamics of the ecosystem and increase ecological dynamics, the vegetation can trap sediment, improve water quality, reduce wave energy, and adapt to sea level rise. We can envision here to be a fertile environment for aquatic, reptile, and avian species.

FIG. 5.41 A collage of the Lower Rainham coastal landscape. Image developed by author.

5.3 – **Site 3. Medway City Estate, adaptive urban waterfront**

Introduction

Medway City Estate is a privately developed industrial zone located on the bent of the Medway river. It faces flooding threats from the tidal surge or direct rainfall. Besides the natural challenge, historical development has further magnified its vulnerability. This low-lying area had long been a flood plain until the 1980s, in the past two decades, industrial land use has weakened its flood adaptability. The right image showed how the area is flooded by the tidal river.

The location is of economic importance since it is adjacent to the core of Rochester, Strood, and Chatham. The current industrial land use also provides it high transformability due to the large plots and monofunctional use.

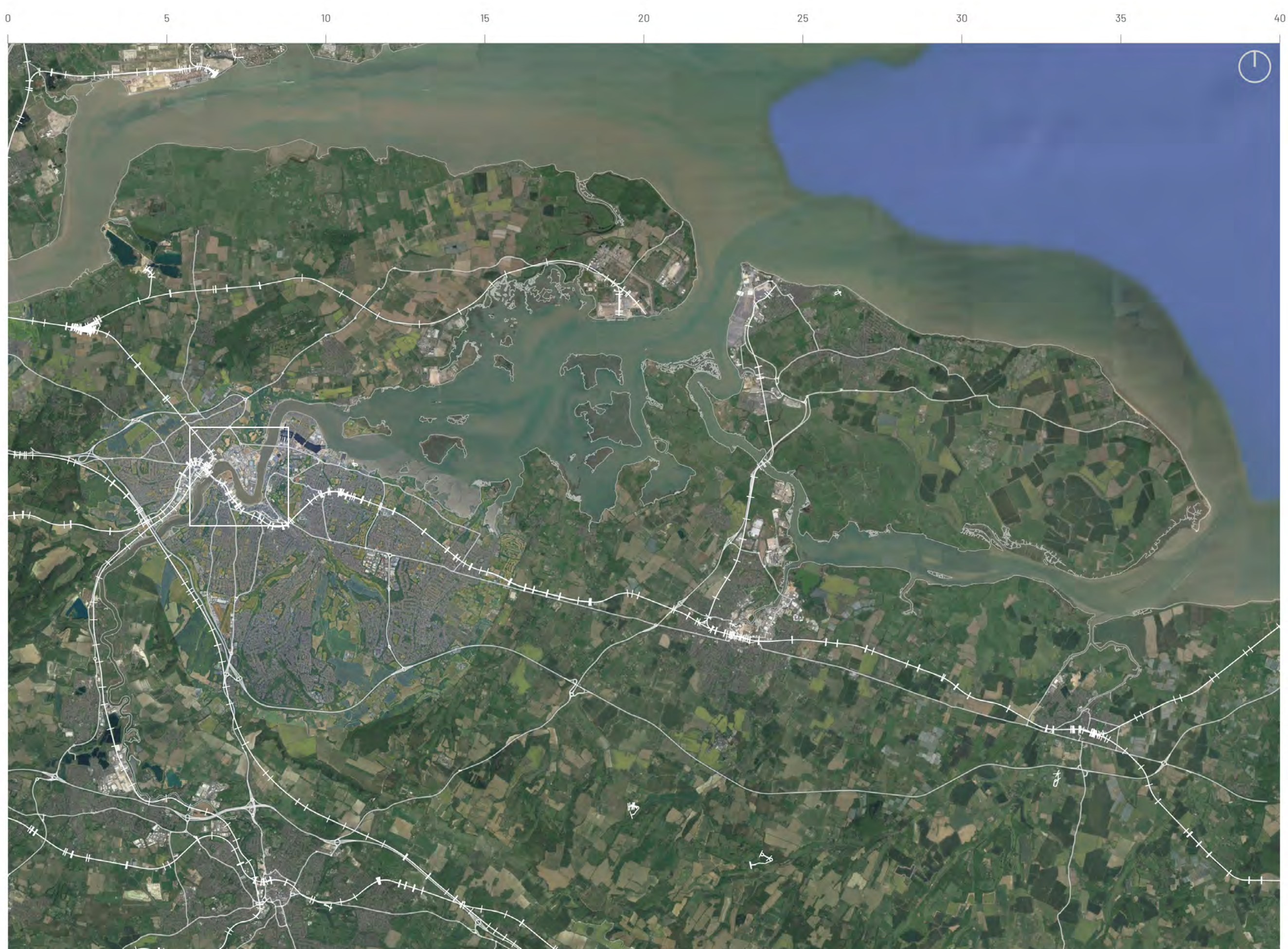
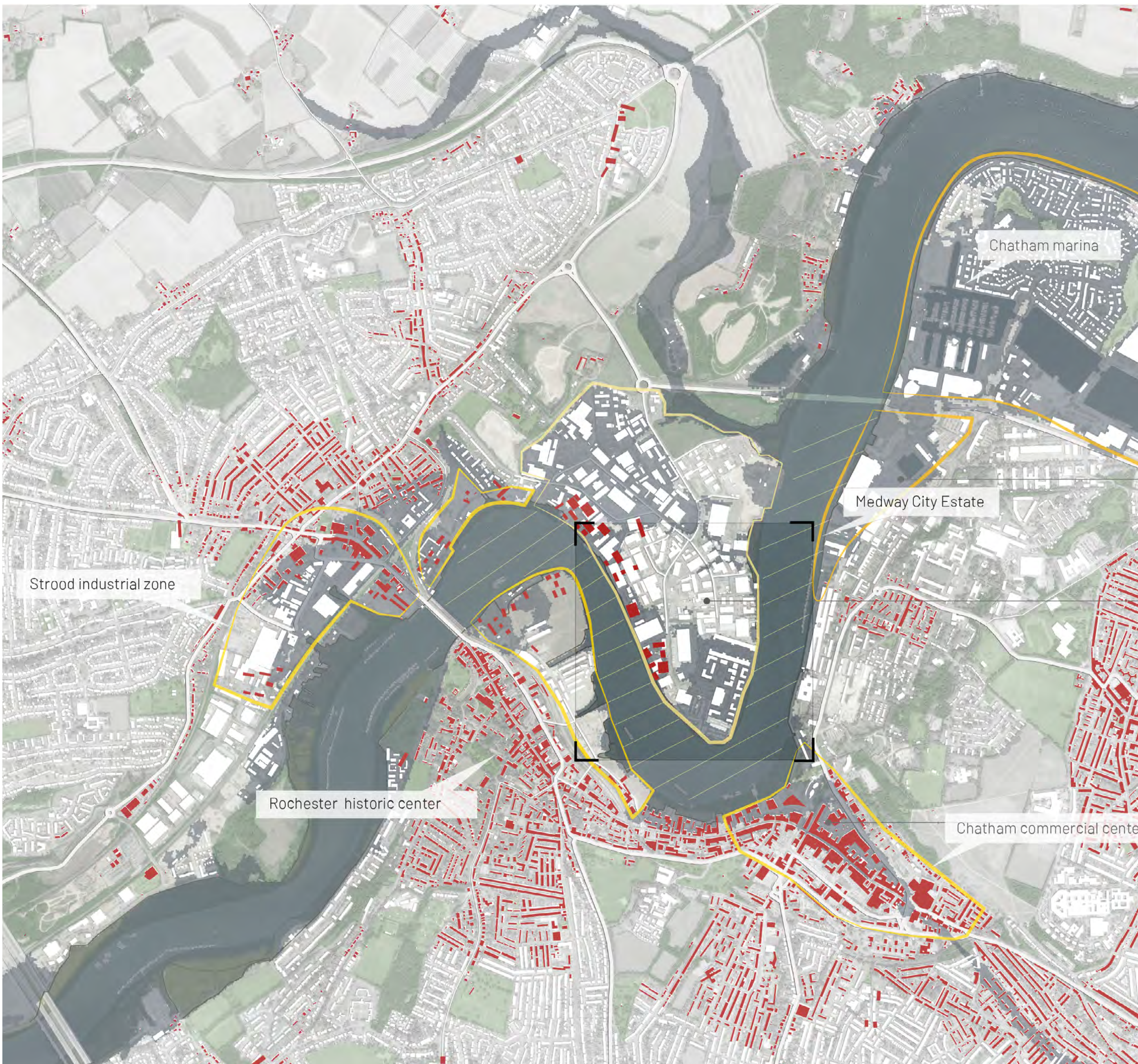


FIG. 5.42 site location

FIG. 5.44 Medway estate flooded in 2020. Image source: Twitter@Kent_999s.

FIG. 5.43 Rochester castle, high street, Medway City Estate, and Chatham historic dockyard.
Image source: http://www.ecastles.co.uk/rochester.html (photo credit: Paul R. Davis)



Legend

- flooding risk zone (Environment Agency)
- coastal mudflat
- discontinuous part of tidal habitats
- building in 1885 (OS historic map)
- Transformed: redevelopment due to closure of Chatham dockyard in 1984
- Transforming: designated sites in Local Plan
- Un-transformed: industrial use

5.3.1 – **Identification of potential zones**

Coastal areas along the River Medway have been transforming in recent 30 years. As we can see from the map, on the right bank of the river stands the main urban area, including Rochester and Chatham center. Coastal zones are at risk of flooding and most of the land is industrial use. Some are already transformed from brownfields to residential areas (Chatham marina), some are designated as strategic locations in Local Plans. However, there is no specific proposal for the Medway City Estate.

Redeveloped into:
-St. Mary's Island: residential use
-Chatham marina
-Commercial Port of Chatham

Chatham Historic Dockyard:
Maritime heritage

Medway City Esate
-used to be marshland till the 1980s
-currently an industrial zone

Chatham, Rochester, and Strood water-front: designated as strategic locations in Medway Local Plan

5.3.2 – **Design Exploration**

Understanding of waterflow

The same as the Rainham site, if we relocate the current flood defense, freshwater and brackish water will meet. Therefore it is crucial to understand the water flow before suitable design locations are selected.

After generating streamlines from the digital elevation model, we identified certain locations that are critical to ecological systems.

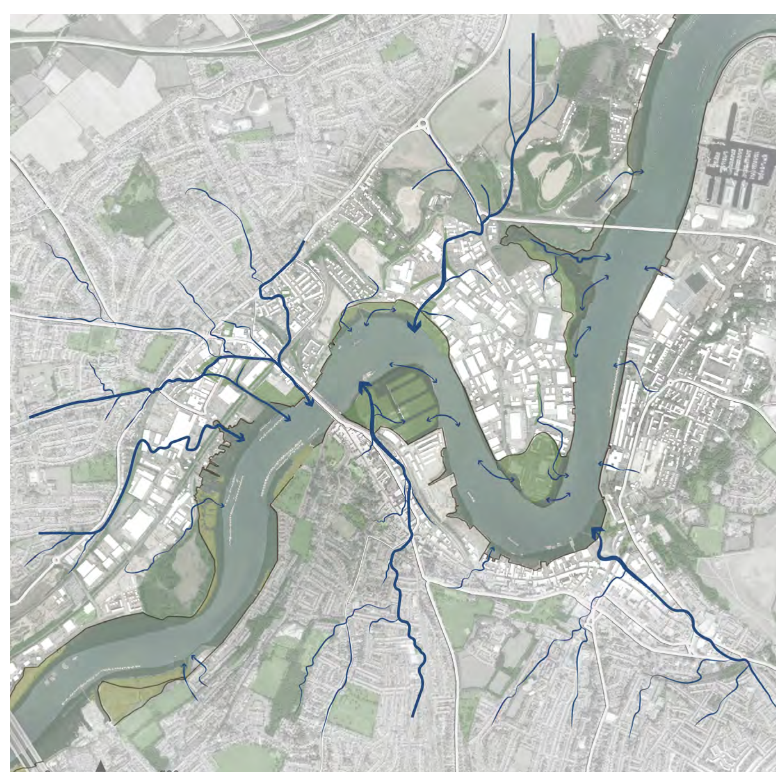


FIG. 5.45 Generated streamline and current urban structure

FIG. 5.46 Generated streamline and proposed landscape system

Understanding of waterflow

An initial design concept is to create space for tidal river and enhance the flood defense line. Three spatial configurations are proposed as the sketched shown.

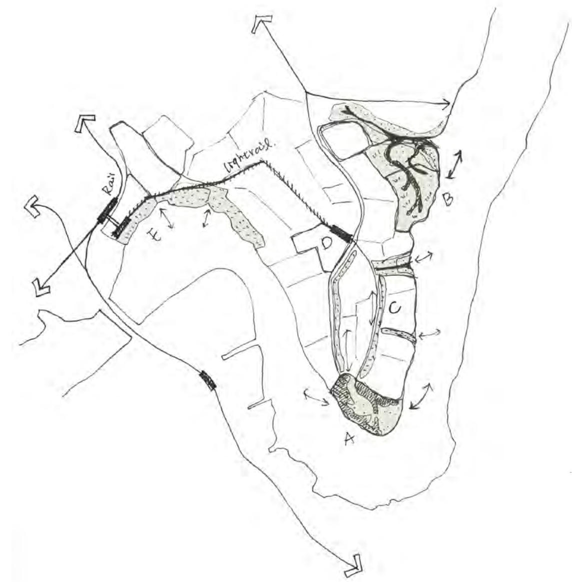


FIG. 5.47 Partial intervention: keep the configuration of current landuse and plots.

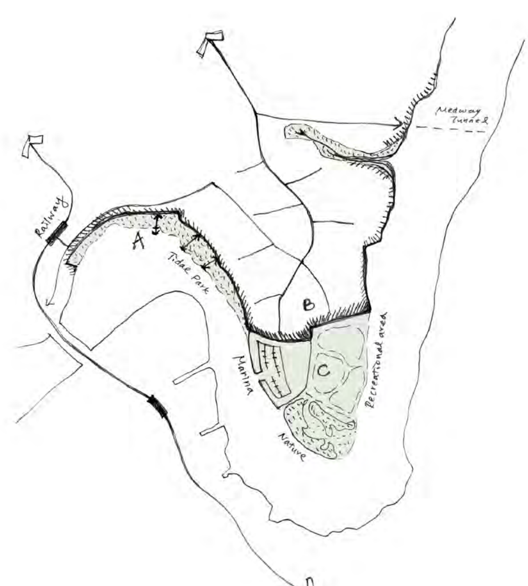


FIG. 5.48 Direct setback:This proposal keeps the developable area in a "complete" shape as much as possible and shorten the length of the new flood defense, to reduce engineering costs.

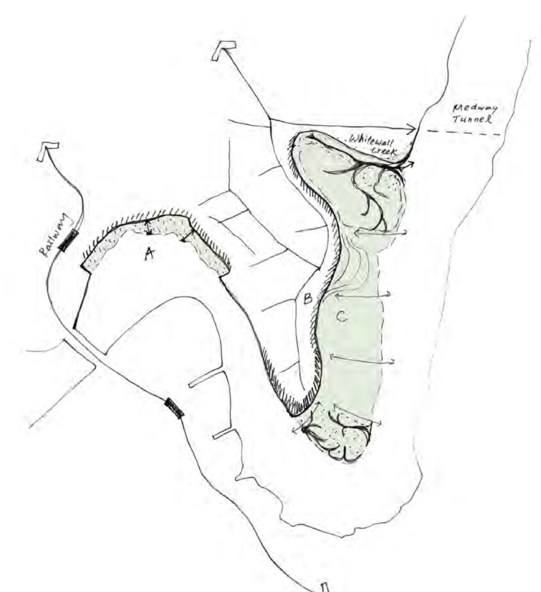


FIG. 5.49 Retreating according to historic layout. The east side of the site, which is marked in green, was marshland 40 years ago. See the photo on the next page.

FIG. 5.50 Medway city estate in 1939. Image source: Historic England.

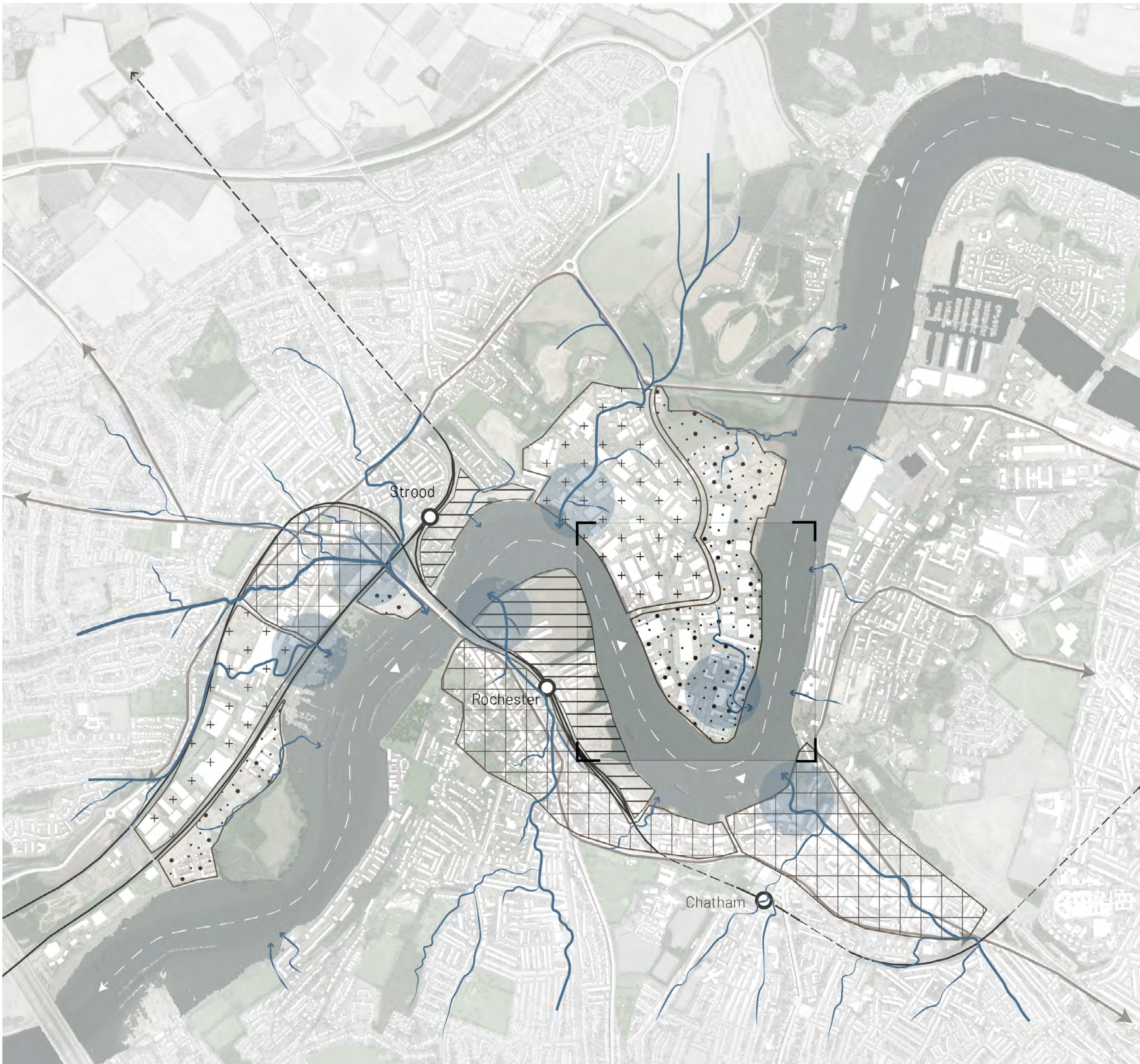
FIG. 5.51 Medway city estate in 2021. Image source: Google satellite.

A. Medway city estate

B. Chatham historic dockyard

C. Rochester castle

D. Rochester cathedral



Legend

adaptive zone: space for tidal river	main road	streamlines	
brown field: potential allocation site	railway	critical interface	
core of mixed-use development	railway tunnel		
industrial transition	railway station		
pilot site	shipping route		

FIG. 5.52 Development strategies

Development strategies

After issue identification and design exploration, several development strategies for this area are proposed as below. In the next section, I selected one of these sites as the pilot to elaborate on design detial.

1. Adaptive zones provide space for tidal river and restore tidal dynamics

2. Brownfields serve as relocation or allocation sites among adjacent development

3. Mixed-use development at city centers provide key services for the adjacent residential areas

4. Riverfront developments need to improve landscape quality and create recreational added values

Medway tidal park

- river (during low tide)
- mudflat: lower than 1.8m
- saltmarsh: higher than 1.8m
- marina
- mixed-use of commercial and industrial zone
- footpath in tidal park
- flood defense and multifunctional community space

5.3.3 – **Pilot: Medway Tidal Park**

This map illustrates Medway tidal park as the pilot. In summary, Medway City Estate, an industrial zone located on a low-lying floodplain, is vulnerable to tidal flooding and sea-level rise. To increase its future adaptability to floods and keep the economic resilience, new landscape structures are introduced by setting back the flood defense. Then, mixed-use developments are encouraged for the preparation of long-term industrial transition and business allocation due to new development.

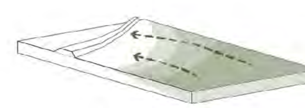
Mixed-use and recreational program:
Retail center, marina, and boat clubs.

Flood defense landscape park, with
multi-purpose meeting spaces

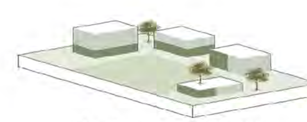
Tidal park: space for tidal river.
Service center of the new nature reserve.

FIG. 5.53 Illustrative plan (during low tide)

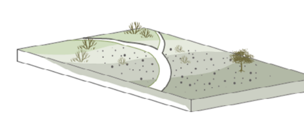
restoration of interface gradient



dike relocation



mixed-use development



tidal park with
recreational and leisure use

accessible waterfront

Legend

- pilot site
- main road
- secondary road
- railway
- railway tunnel
- shipping route
- heritage
- railway station
- tourist attraction

FIG. 5.54 Network system (during high tide)

5.3.4 – **Recreational network**

In addition to flood mitigation and ecosystem restoration, Medway tidal park will serve as a "node" that can enhance the current recreational network and create added values for tourism in this region.

	Attractions
Heritage	Rochester Castle, Rochester Cathedral, Chatham Historic Dockyard, Upnor Castle, Fort Amherst, Great Lines Heritage Park
Core of water activity	Chatham marina, Medway tidal park marina
Landscape	Medway waterfront, Saxon Shore Way
Ecological education	Medway tidal park

	Mobility types for different users
Leisure and holiday tourists	yachting, sailing, biking
Youth tourists	public transportation (train, bus)
Local commuters	train, bus, automobile

5.3.5 – **Implementation**

One of the reasons to select this location for intervention is the high transformability. This study identified some criteria of transformability as the table shows. For instance, a mono-function use industrial site usually would have fewer stakeholders. If the current open space ratio is high (i.e. higher than 25%), it is more likely to transform directly or is easier to divide into phases. The current uses in this site are mainly logistics, stakeholding, and distribution. This type of land use does not necessarily locate at a certain location, yet needs a larger (or cheaper) space for processing and shipping. In sum, these plots have higher transformability, therefore, they could be transformed in the first phase.

High ← Transformability → Low

Land use	Mono-function (industrial use)	Mixed-use (industrial, retail, office use)
Stakeholder	Single	Multiple
Plot size	Larger than 2000m2	Small than 2000m2
Open space ratio	Higher than 25%	Lower than 25%

FIG. 5.56 Criteria of transformability identification. Developed by author.

FIG. 5.55 Possible plot division. Developed by author.

1. Automobile & vehicle repair

2. Logistics/ stockholding/ distribution

3. Offices

FIG. 5.57 Images of current landuse (source: Google street view)

Phasing

The phasing process is proposed after the analysis of plot transformability. Several open spaces in a single-use plot could be developed into wetlands in the first phase. Then, the linear plot adjacent to the River Medway is suggested to develop into a landscape structure.

In the second phase, after the relocation of the industries (the relocation sites of current industries could be the brownfields adjacent to this zone), we could connect the pioneer wetlands to become part of the river system. At the same time, new infrastructure systems, such as a marina and the new flood defense, also need to be carried out.

The last phase is the programming period. After the landscape and infrastructure network system is set, we could develop the mixed-use zone adjacent to the new flood defense landscape park. Several community spaces could also be developed inside the tidal park. The tidal park will become a place with mixed-programs for recreational use by combing a marina, boat clubs, and adventure centers.

Phase 1: 2021-2040

1. Relocation and stakeholders' collaboration.
2. Several open spaces in a single-use plot could be developed into wetlands.
3. The linear plot adjacent to the River Medway is suggested to develop into a landscape structure

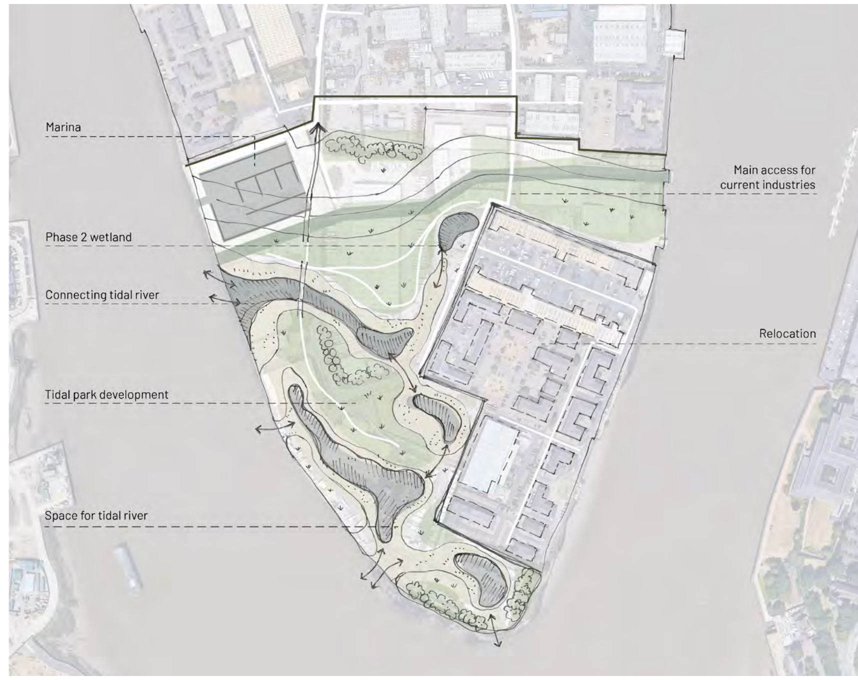
FIG. 5.58 Conceptual sketches of implementation phase. Developed by author.

Phase 2: 2040-2070

1. Relocation and stakeholders' collaboration.

2. Connect the pioneer wetlands to become part of the river system.

3. Construct infrastructure systems, such as the marina and the flood defense.



Phase 3: 2070-2100

1. Programming.

2. Develop mixed-use zones adjacent to the new flood defense landscape park.

3. Develop community spaces/ classrooms inside the tidal park.

5.3.6 – **Design detail**

The image below illustrates a key section in the design proposal, which includes a new flood defense and a central waterway connecting the River Medway.

The zoom-in section shows the potential phase of implementation of the waterway. To create the space for the tidal river, the first phase is to excavate current building ground to create a pioneer wetland. The second step is to expand and deepen the wetland area and create a water channel. The lowest part is suggested to reach -2 m (AOD) so that this new water channel could accommodate daily tidal range and inundation, aligning with River Medway.

The waterfront of this waterway is designed to be a naturalized interface. To develop this, we could insert pre-grow mats with cord grass to provide a suitable environment for habitats to grow.

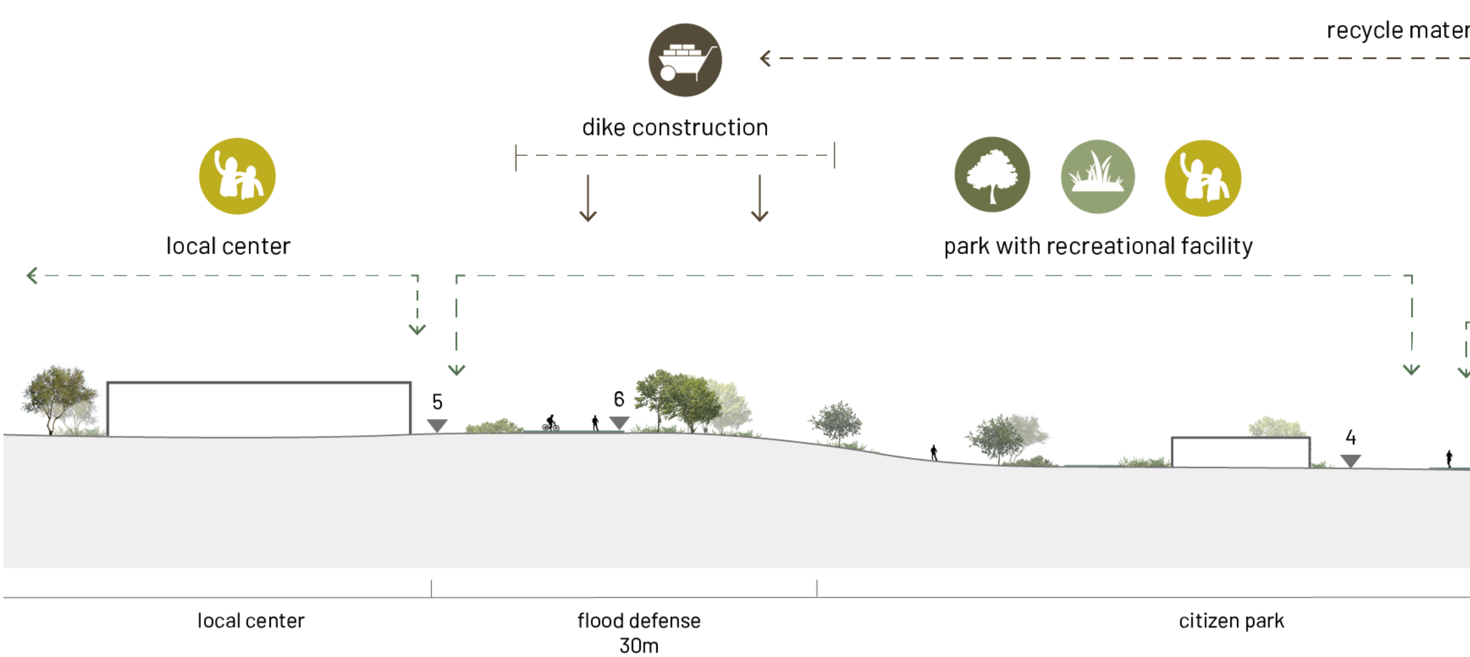
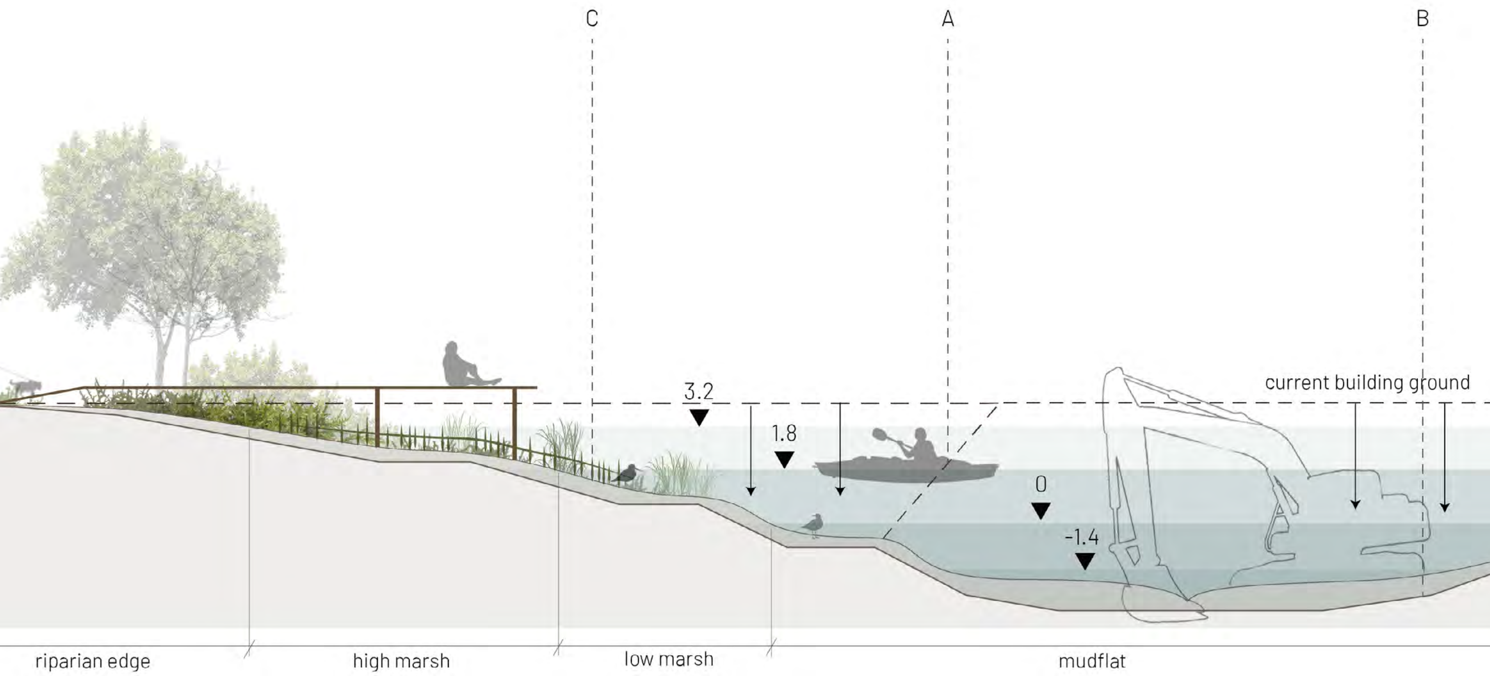
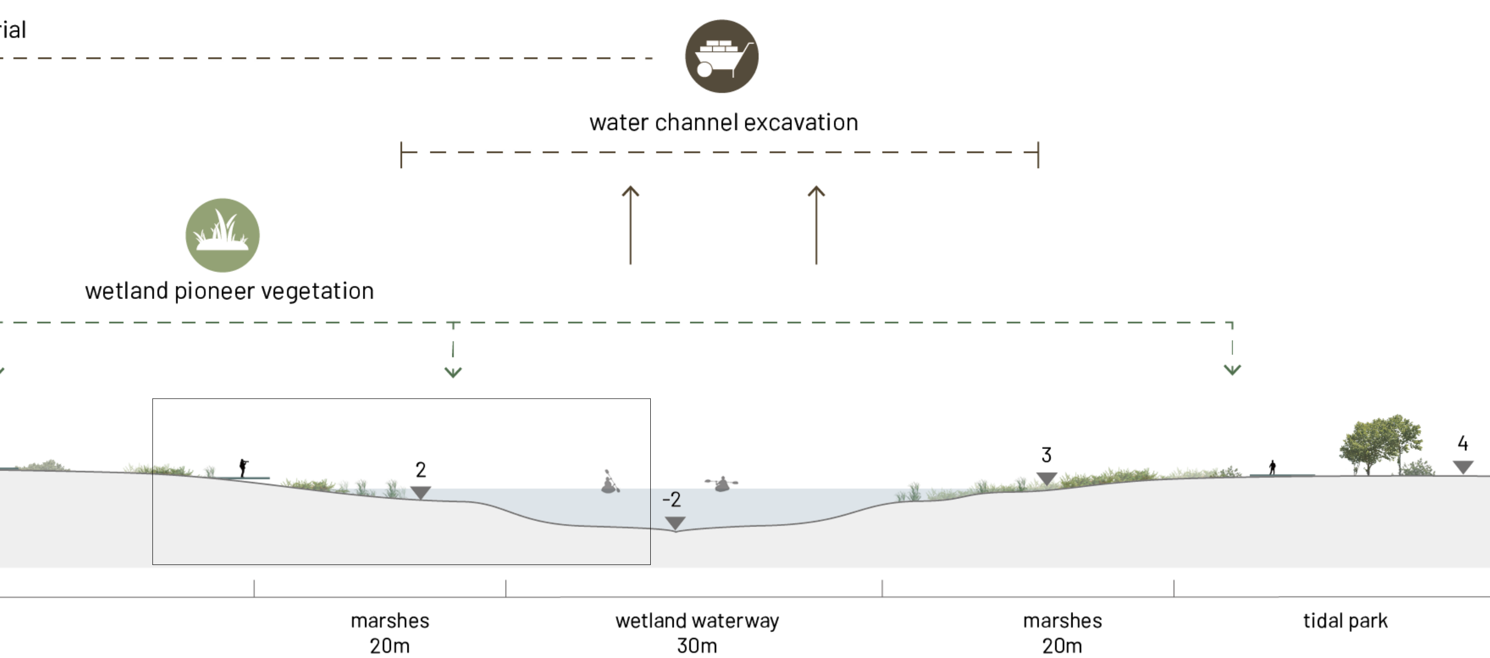


FIG. 5.59 long section



A. Excavate and restore wetland
B. Excavate deeper and connect other wetlands to create water channel
C. Riparian vegetation
D. Tidal park development




flood defense landscape park
multif

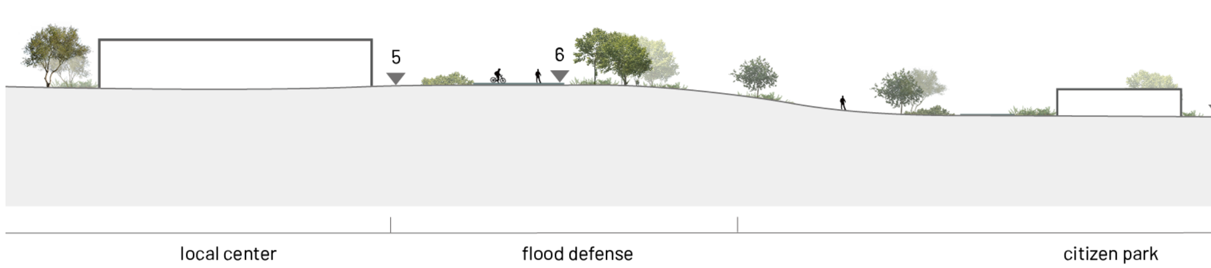
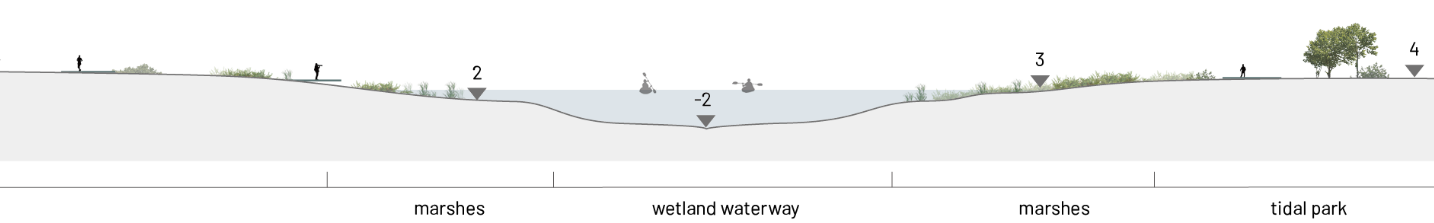

5
6
4
local center
flood defense
30m
citizen park

FIG. 5.60 A collage showing future atmosphere



5.4 – **Conclusion**

Medway City Estate, an industrial zone located on a low-lying floodplain, is vulnerable to tidal flooding and sea-level rise. To increase its future adaptability to floods and keep the economic resilience, new landscape structures are introduced by setting back the flood defense. Then, mixed-use developments are encouraged for the preparation of long-term industrial transition and business allocation due to new development.

To conclude this chapter, Medway City Estate, Lower Rainham waterfront, and Minster on Sea coastline, these three locations demonstrated how the design strategies and principles can be applied in lower-scale, and from urbanized context to the rural area. Each site started from a specific issue regarding sea level rise, yet they ended up in a coherent vision, that is, to increase the adaptability to climate events and to create a more resilient coastal landscape.

FIG. 5.61 A collage of Medway tidal park.

cooperation between stakeholders
Flood Mitigation
Socio - Economic Development
Ecosystem Development
Adaptive interface
Robust waterfront
Coastline protection
Sponge capacity
Industrial transition
Transit -oriented development
Key infrastructure enhancement
Risk management system
implementation and review
adaptive management
Restoration of intertidal ecosystem
Maintenance of seabird habitat
Safeguarding agriculture
Enhancement of ecological gradient in valley
HIGH TIDE
LOW TIDE
tidal range (m)
4
3
2
1
0
-1
-2
-3
3.2m (high water springs)
1.8m (high water neaps)
-1.4m (low water neaps)
-2.6m (low water springs)

6 – Vision on regional development


Grain
Hoo Peninsula
Sheerness
Strood
Chatham
Gillingham
Rochester
Rainham
Sittingbourne
Allington Lock
5 KM
Adaptive zone
Adaptive urban waterfront
Coastal protection
Space for tidal river
Search location for water reter

6.1 – **Landscape strategy**

The vision for regional development is proposed to increase the resilience of the Medway river estuary as the map shows. Since the river is a system, the vision covers strategies for different stretches.

First, the river valley, from Allington lock to Rochester, is a transitional section between the tidal zone to upper stream landscape. The focus lies on maintaining sufficient space for tidal river mitigation and surface water retention.

Second, the Medway pilot site located on the river bend near Rochester demonstrates the adaptive urban waterfront strategy. By flood defense relocation, it will create a tidal zone park functioning as a flood buffer and restore ecological dynamics. At the same time, this intervention could accelerate the industrial transition from the supportive manufacturing industry to the service sector and tourism.

Then, the Rainham shows the importance of tidal habitat restoration and serves as the pilot for an adaptive zone in the rural area. These design proposals are closely connected to natural formative elements and are expected to transform in a longer phase. The landscape quality of the Rainham coastal region will increase and the habitats will be able to adapt to sea-level-rise scenarios.

The river flows through the Medway river estuary, joins the Thames river estuary, and enters into the North Sea near the Port of Sheerness. Another fold of coastal urgencies, which is coastal erosion, are shown on the Minster coastline. To safeguard the adjacent residential zone, maintain economic development on the island, a chain of islands is proposed to enhance the north coastline. It will also form a mudflat landscape for the ecosystem to grow with nature.

In summary, the design strategies in these pilot sites not only address site-specific issues but also can contribute to the larger systems of regional development. Other strategies related to agriculture, industry, and mixed-use development will be elaborated in the following section under the framework of "flood mitigation," "ecosystem development," and "socio-economic development."

FIG. 6.1 Vision on regional development. Lower-scale pilot sites are marked in circles.

6.2 – **Initial guidelines for implementation**

The vision for a resilient Medway estuary contained three sets of strategies: flood mitigation, ecosystem development, and socio-economic development. As the diagram is shown, each circle consists of sub-actions. In addition, an adaptive development needs to take into account the temporal, legal, and organizational dimensions to work as a system to increase the adaptability of the region. The following section will show these three schemes with some implementation suggestions.

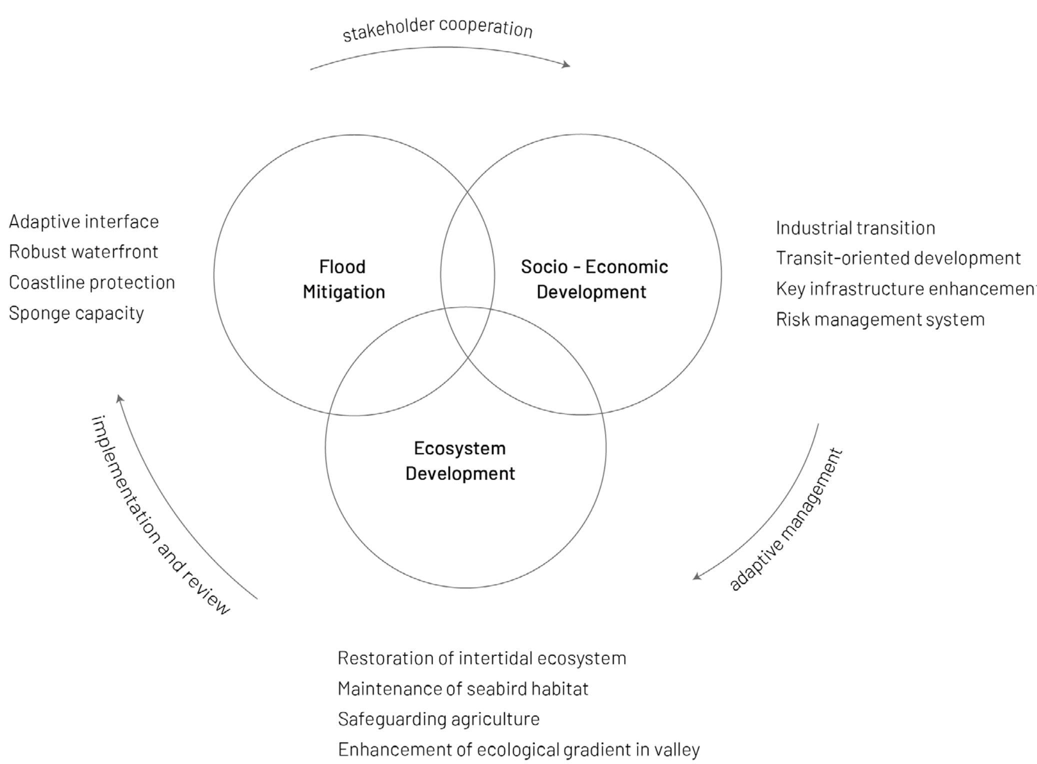


FIG. 6.2 Landscape strategy (spatial dimension).

FIG. 6.3 Governance dimensions related to project implementation.

Key stakeholders related to flooding risk

The proposed strategies needed to be grounded in the actual context. The study took the proposed flood mitigation scheme as an example, compared the proposed flood mitigation scheme with the current institutional framework, and examined the possible responsible sectors.

From the table, we understood that there is a gradient in the responsible sectors, from the national government to the local district council. In general, Environment Agency is the key party in charge of flooding risk-related policies. Then, on the river basin scale, each river catchment is responsible for local risk management strategies, which provide guidelines on the policy level. Then, these strategies will be carried out by the local city council. It is noted that coastal erosion management is a duty of the district council if there is no pilot coastline protection project in each specific district. Stakeholders' analysis would be a critical part to continue working on if this project could be developed further.

Policy ↔ Planning ↔ Implementation

<table>
<tr><th></th><th>National - Regional</th><th>Regional - Local</th><th>Local – Partnership</th></tr>
<tr><td>Flood defense
Adaptive interface
Robust waterfront</td><td rowspan="3">Department for Environment, Food & Rural Affairs

Environmental Agency</td><td>River Thames Catchment
River Medway Catchment
North Kent Rivers Catchment</td><td>County council</td></tr>
<tr><td>Coastline and shoreline protection</td><td>Medway Estuary and Swale shoreline plan</td><td>District council</td></tr>
<tr><td>Sponge capacity
Water retention
Surface flooding</td><td>Flood risk management strategy</td><td>County council
District and borough council
Water companies (i.e.Thames Water)
Reservoir owners</td></tr>
</table>

FIG. 6.4 Proposed flood mitigation actions and the possible responsible sectors under current institutional framework. Reference: Kent Local Flood Risk Management Strategy Report, 2013.

6.2.1 – **Flood Mitigation**

Adaptive interface, robust waterfront, coastline protection, and sponge capacity are the main aspects covered in this scheme. These strategies are specifically developed for different parts of the watershed and tailored based on the urbanized gradient. The table below shows the suggested implementation steps.

For instance, the transformation speed is slower for the coastline protection (pilot: Minster on Sea coastline) project, due to its technical complexity and expense of infrastructural works. It is suggested to start this project from the first phase, so in the third phase, it would develop to be a stable environment allowing habitats to grow.

Increasing sponge capacity is another type of strategy that focuses on landscape enhancement in the middle and upper reaches of the river. It could include projects to store water within the landscape or reforestation, in order to reduce the flood peaks. The change might take place in decades and require long-term monitoring of the influence.

Another strategy to mention is the "search location of water retention site." These linear zones marked on the map are the routes of current surface water flow. They flow through the valley and enter the urbanized areas. Although this is not elaborated in the study, it is still an important strategy confronting climate change, for it is expected to have wetter winter and hotter summer in Kent and Medway till 2080 (CCRIA, 2017).

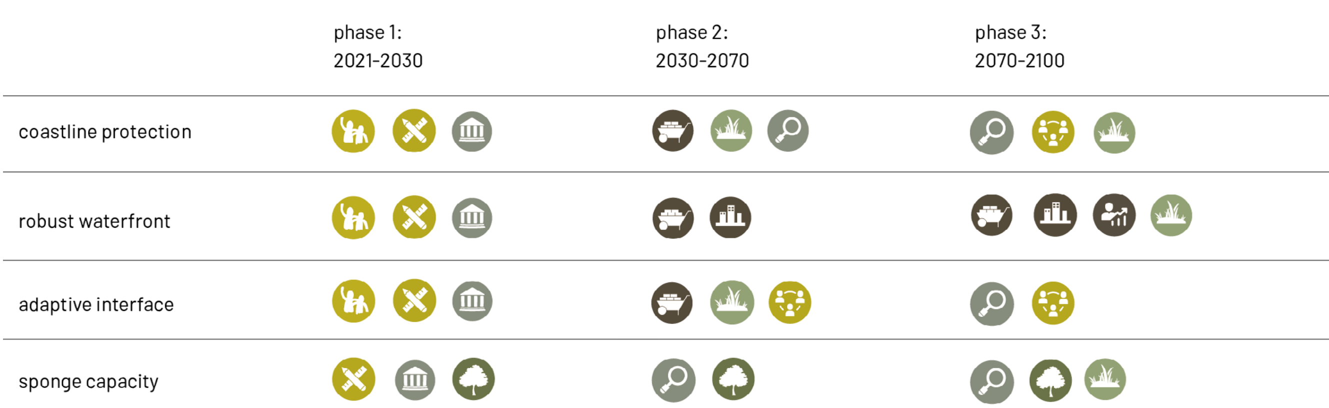


FIG. 6.5 Suggested phase of implementation for flood mitigation scheme.

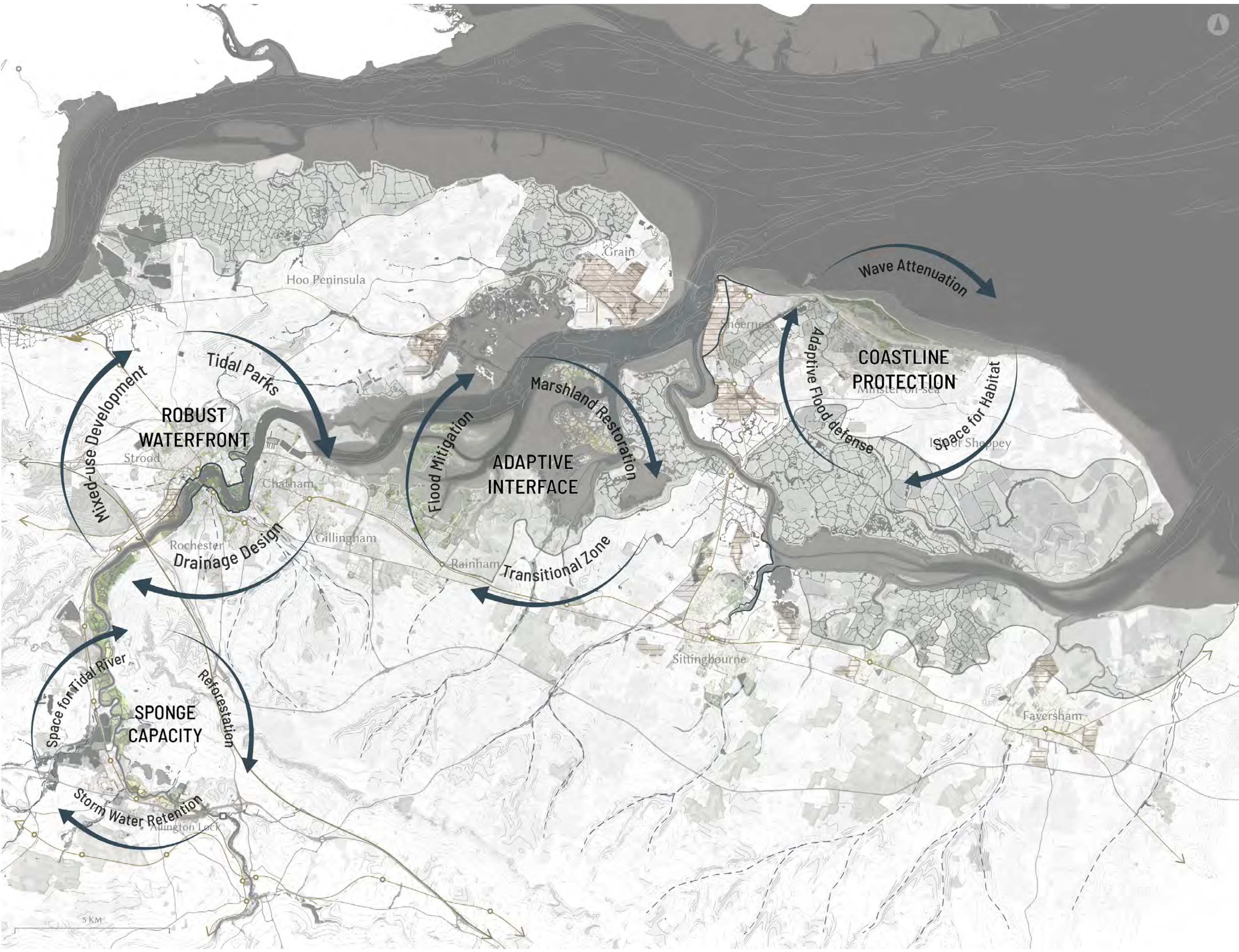


FIG. 6.6 Flood Mitigation vision map

- Adaptive zone
- Adaptive urban waterfront
- Coastal protection
- Space for tidal river
- Search location for water retention site

6.2.2 – **Ecosystem Development**

Ecosystem development reflects the integration of natural dynamics in this study. The design solutions in response to flooding risk and sea-level rise would also contribute to ecosystems, and create ecological benefits in this region.

In this scheme, key habitats are indicated, such as the restoration of tidal habitats and maintenance of territorial habitats. Among these strategies, a broad area of intertidal habitat realignment and restoration of saltmarsh is proposed. In addition, another critical location is the river bend at Rochester and Chatham, it plays the role of ecotone that diverse habitats meet, especially terrestrial and riparian ecosystems.

This development scheme is correlated with the location indicated in the flood risk mitigation strategy since the layers are intertwined. Therefore, it will be critical to identify key locations and draft the implementation plan in phase one before the relocation of the existing flood defense.

Key stakeholders for ecosystem development are Medway County Council, Kent County Council, the Kent Nature Partnership, and district authorities. According to the Climate Change Risk and impact assessment for Kent and Medway (2017), these public sectors have been working to improve the management of habitats and minimize habitat fragmentation, and this action needs to continue to minimize climate impacts on biodiversity.

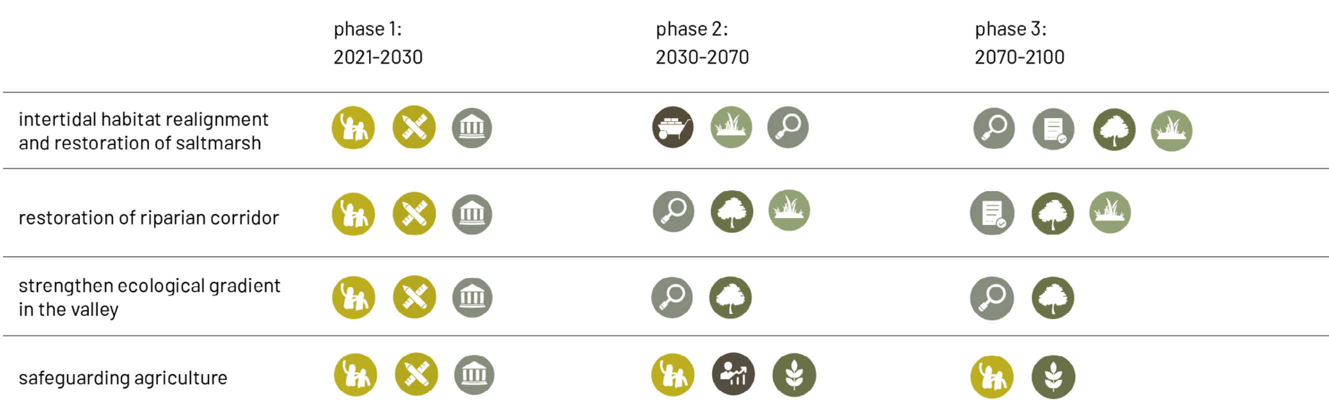


FIG. 6.7 Suggested phase of implementation for ecosystem development

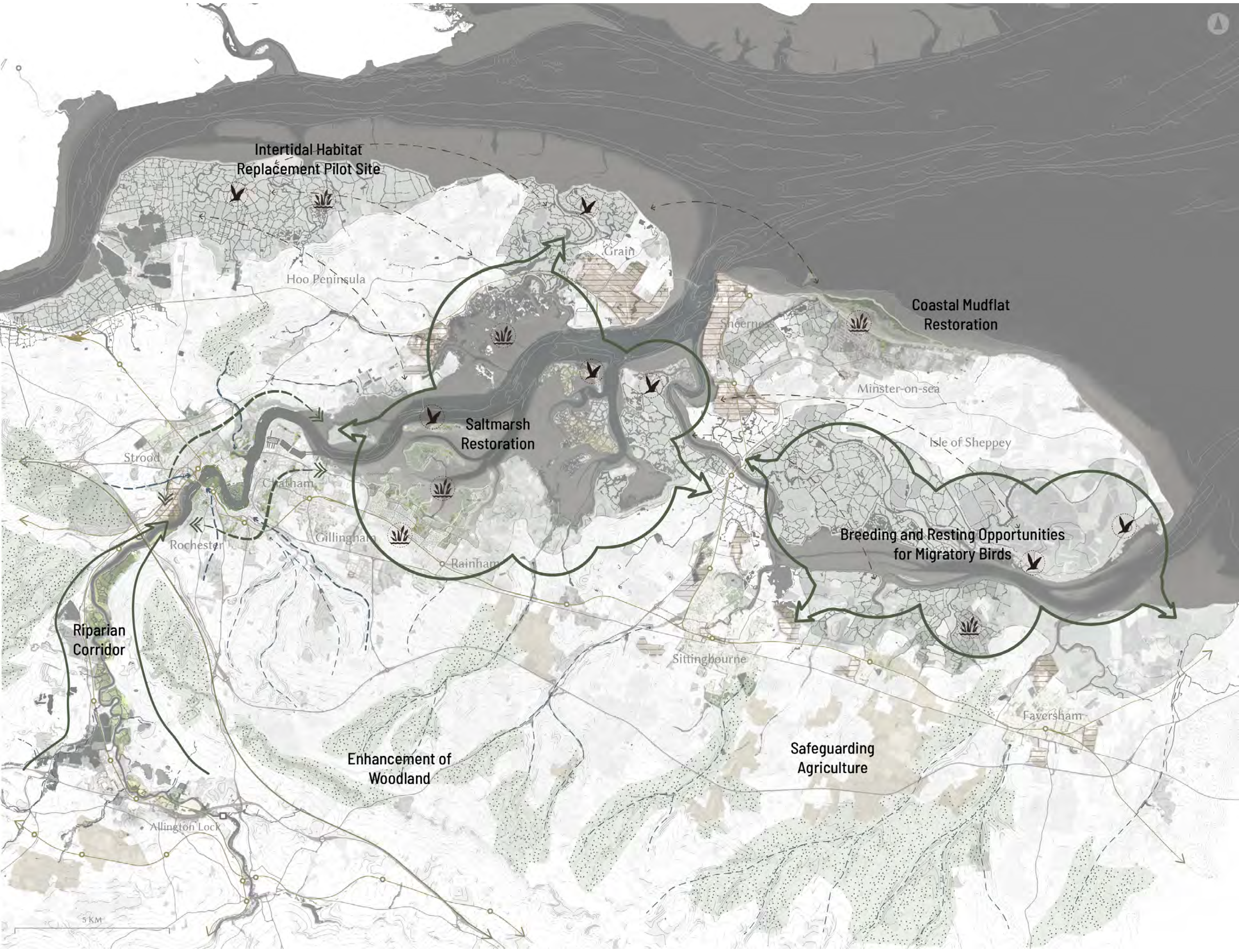


FIG. 6.8 Ecosystem Development vision map

- Core areas of ecosystem
- Ecotone dynamics
- Tidal habitat restoration
- Enhancement of woodland
- Safeguarding of agriculture
- Strengthen ecological gradient in valley
- Seabird moving route
- Breeding and resting space for seabird
- Proposed saltmarsh restoration site

6.2.3 – **Socio-Economic Development**

The socio-economic development scheme will contribute to long-term prosperity and human well-being. The strategies contain aspects of industry development, transit-oriented (urban) development, key infrastructure enhancement, and risk management system. The urban development strategies are the conclusion from middle-scale analysis; for instance, the mixed-use development strategy aims to respond to the mono-function zoning issue. Moreover, the scheme combines strategic locations identified in the current Local Plan. Overall, it would serve as advice at the policy level.

The risk management strategies consist of different public facilities' provision and soft programming aspects, such as emergency response and recovery. These actions would need stakeholders' cooperation, citizen participation, or empowerment. It is worth mentioning that alliances under these ideas have been working for some years, such as Medway Flood Partnership. In recent years, River Medway is also included as one of the 15 pilot projects in "Flood resilience areas for multi-layered safety (FRAMES)" for the North Sea Region. It is crucial to include the current projects and develop spatial strategis connecting to them.

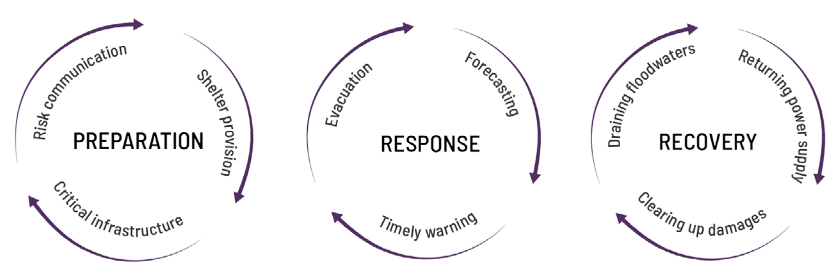


FIG. 6.9 Adaptive risk management mechanism diagram. Adapted from FRAMES.

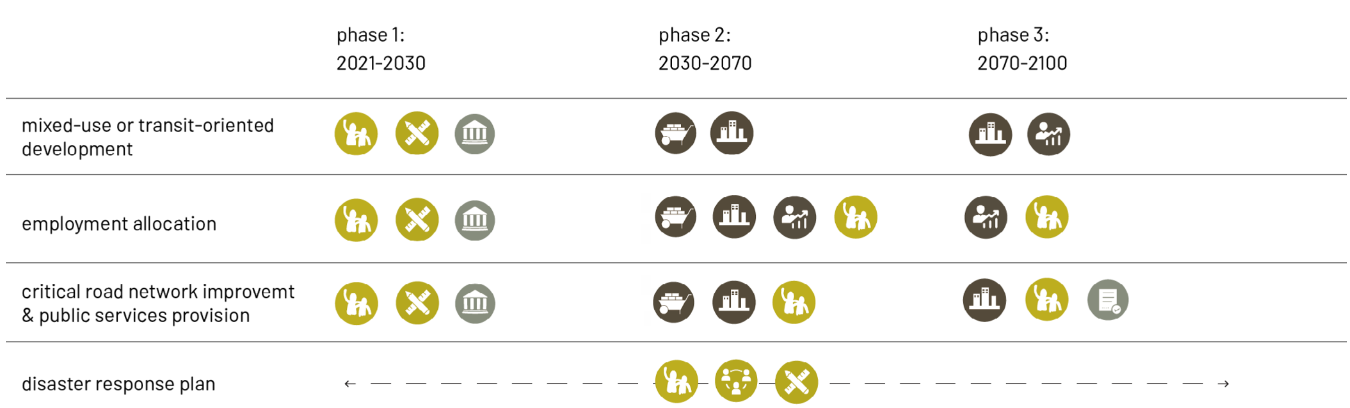


FIG. 6.10 Suggested phase of implementation for socio-economic development

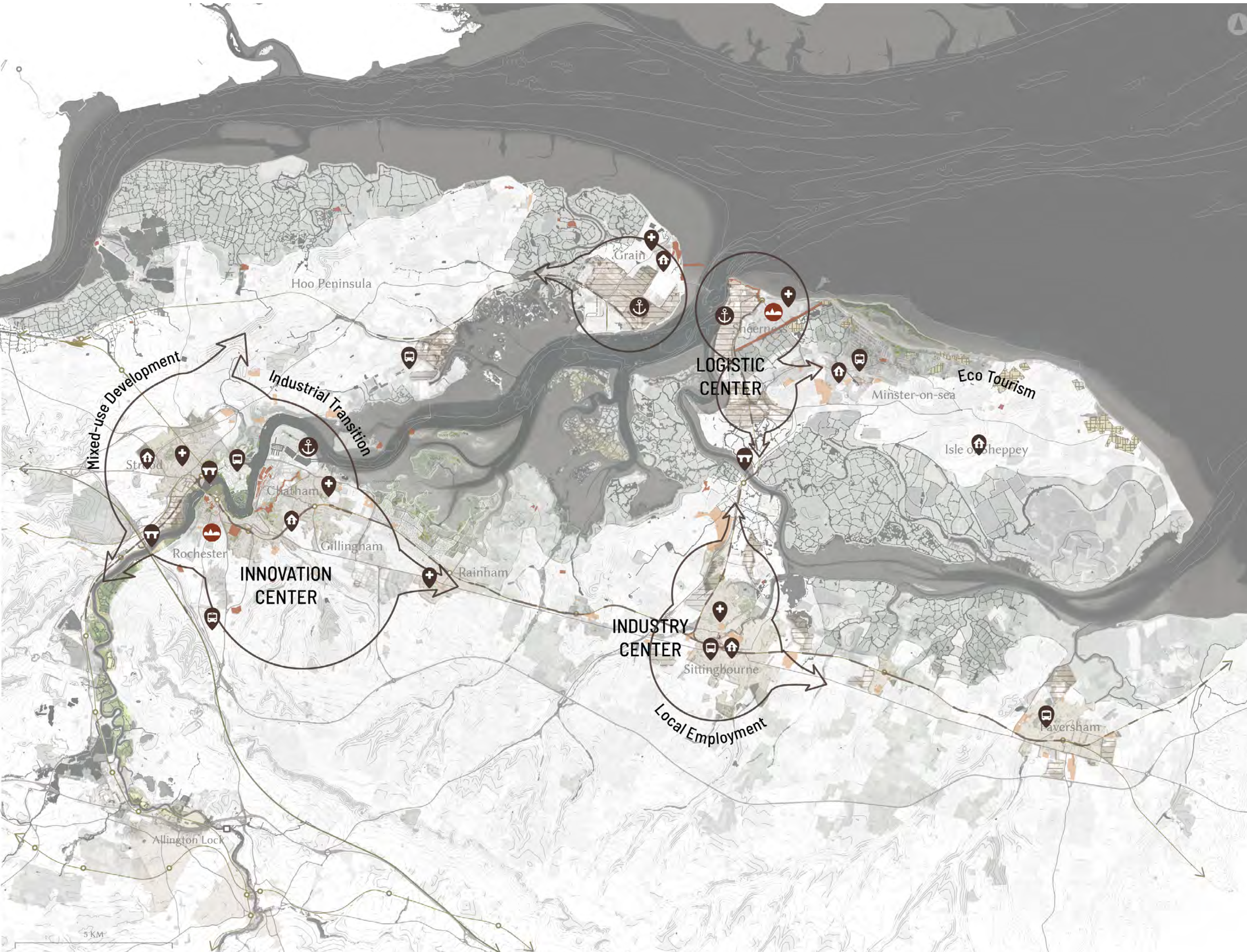


FIG. 6.11 Socio-Economic Development vision map

- Mixed-use development
- Transit-oriented development
- Industrial transition
- Housing allocation (Local Plan)
- Holiday chalet site improvement
- Public service (shelter) provision
- Public service (medical center) provision
- Public transportation improvement
- Critical infrastructure (bridge) maintenance
- Critical infrastructure (railway) maintenance

6.3 – **Conclusion**

This vision map for regional development aims to provide guidelines for a more resilient River Medway Estuary to address the risk of flooding and related phenomenon that would be magnified by extreme climate events. The vision embodies flood mitigation, ecosystem development, and socio-economic development three aspects, which could adapt through time and, and therefore, increase the resilience of this region.

Resilience is the capacity to adapt to uncertainties. From the environmental perspective, it refers to the space that the natural ecosystem can develop (adapt) either staying in its current regime or expand its regime to accommodate multiple stable statuses. From the Anthropocene point of view, resilient urban development indicates continuous socio-economic development. These could be regarded as complex adaptive systems include aspects of local job opportunities, industrial transition, comprehensive infrastructure network, housing provision, etc. Moreover, resilient urban development can posse multiple drivers of change and bounce back to a balanced condition. In the context of this study, it refers to an ideal society that capable of adapting to flooding risk or transforming their built environment to live with nature.

Another crucial factor for resilient development is system thinking under the time dimension. Therefore, the vision could be separated into three layers with suggested implementing steps and governance aspects. Finally, the three lower-scale sites demonstrated how design principles proposed in this study can be applied.

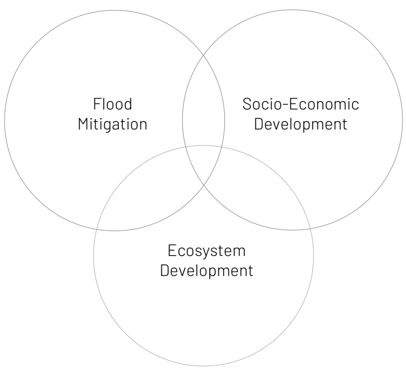


FIG. 6.12 Diagram of key strategies

TABLE 6.1 Intervention sites on lower-scale

	Landscape typology	Urgencies	Design Strategies
Site 1. Minster on Sea (Isle of Sheppey)	Rural: open space, pasture, and residential use	Coastal cliff erosion	Barrier islands and coatal nourishment Coastal park Recreation & Eco-tourism
Site 2. Lower Rainham	Rural: open space, pasture, and residential use	Coastal squeeze and natural erosion of the intertidal habitats	Restoration of habitat gradient Adaptive flood defense
Site 3. Medway City Estate	Urban: industrial use	Industrial zone on flood-prone plain vulnerable to flooding	Space for tidal river Waterfront tidal park Mixed-use development

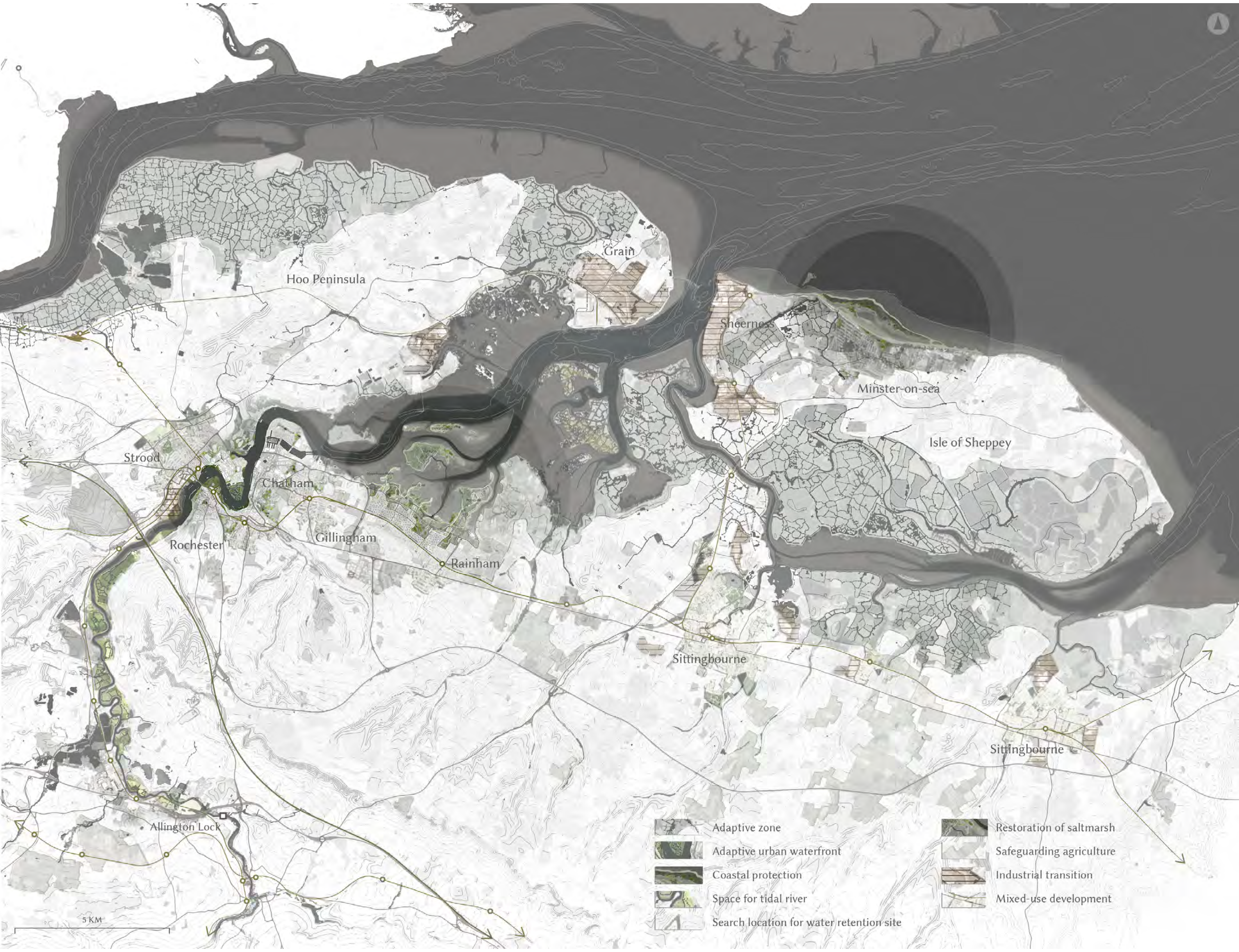


FIG. 6.13 Vision on regional development


11367. - ROCHESTER CASTLE.

7 – Synthesis and Outlook

FIG. 7.1 Rochester Castle being used as a public park in the 1890s.
Image source: Wikipedia.

This graduation project is an attempt to demonstrate how adaptive design strategies can contribute to climate adaptation actions with landscape-based approach and urbanism methods learned in the EMU program. Below are reflections of research outcome, research methods, contributions, limitations, and lessons learned.

7.1 – **Conclusion**

The following parts examined the results by checking if the original research questions are answered adequately.

Research question 1. How does the socio-ecological system of the Medway River Estuary function?

The study regarded urban landscape as a complex system. Therefore, to understand the forces behind landscape system and the possible impact of climate change, the study decomposed urban environment to occupation, network, and substratum sub-systems.

Chapter three elaborated the multiscale analysis from the Thames River basin, the Medway River catchment to the Medway River estuary. The research boundary (river basin) in each scale is selected consciously to understand how river performs in different reaches. A set of preliminary strategies are identifies to confront flooding risks. Then, the study zoomed in to the Medway River estuary research area and analyzed aspects regarding urban development, such as mobility, habitats, demography, economic, flooding, geography, etc. Driving forces for future scenarios are illustrated as part of supportive elements for decision making. With the above spatial analysis, this chapter is concluded by urgency map and opportunity map, which serve as my design assignments.

Research question 2. What design strategies and principles are suitable for flood mitigation and socio-ecological inclusive development?

To respond to the challenges and opportunities, the study proposed a set of design principles and strategies for coastal wetland restoration, waterfront development, coastline protection, and sustainable urban development in chapter four. These principles are derived from precedent studies and existing principles. For instance, I studied some coastline management cases in the UK and the North Sea basin countries to understand what interventions are taken to enhance coastline and to learn from the natural formation of the coastal system. Furthermore, since this study endorses natural-based design solutions, design principles built up by EcoShape programs, in the book “Building with Nature”, are regarded as a key reference to this research as well. The final set of design principles are generated to respond to the sites in the Medway River estuary. There is a possibility to expand and transfer the toolkit to other design assignments in other contexts.

Research question 3. How to apply the design strategies and principles in Medway River Estuary to increase its socio-ecological resilience?

Design exploration is a critical phase of this project because I adopted "design" as a powerful instrument to explore possible solutions in spatial ways. With the help of the proposed principles in chapter four, I drafted two to three proposals for each site. This is the beauty of principles and typologies because they could take on different forms. I also realized that there can be multiple suitable solutions for each location. It is worth mentioning that the final proposal of each site does not exclude other alternatives but the combination that could lead to a more resilient future; for instance, it could provide space for tidal river and add on more ecological benefits as well. The three locations demonstrated how adaptive design strategies could be applied spatially.

After the design exploration in chapter five, regional schemes for sustainable development are elaborated in chapter six. The scheme consisted of three aspects: flood mitigation, ecosystem development, and socio-economic development. The knowledge generated through the design process is reflected in the regional schemes of flooding mitigation and ecosystem development. Since the urban landscape is a complex system, I believe by adopting the proposed design in the three sites could help and support the societal resilience and risk management system, and create a more climate-adaptive development. Although the socio-economic aspect is not the main focus of this graduation project, it still plays a crucial role to increase resilience in the region. The proposed socio-economic development scheme could remain as a recommendation for further work. In conclusion, the proposed design strategies applied in three locations could shape the larger system, and increase its socio-ecological resilience.

The diagram on the following page showed how the study results are connected to the research questions. Also, it illustrates the iterative process of "design research" and "research-by-design" adopted in the process.

Research question

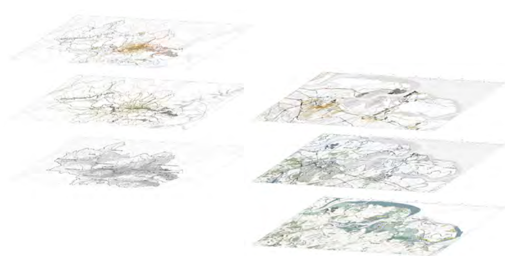
How does the socio-ecological-system of the Medway River Estuary function?

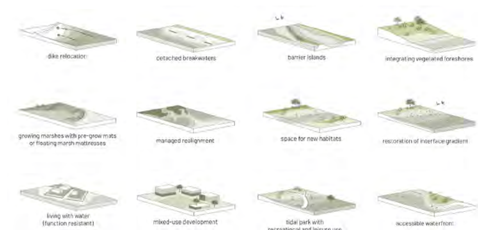
What design strategies and principles are suitable for flood mitigation and socio-ecological inclusive development?

Chapter 3: Analysis

Chapter 4: Strategies and principles

Research outcome





Research-design relation

Design research

Regional scale analysis

- Potentials & Challenges
- Identify locations

Local scale analysis

Comparative analysis

- Precedent study
- Generate knowledge

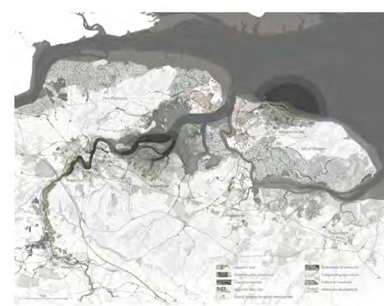
Develop strategies and principles

FIG. 7.2 Reflection of research outcome and research-design relation

How to apply the design strategies and principles in Medway River Estuary to increase its socio-ecological resilience?

Chapter 5: Design application

Chapter 6: Vision on regional development



Research-by-design

Experimental design study

Transform generic knowledge to specific knowledge

Site-specific analysis

Apply design principles

Explore and test different design proposals in local scale sites

Conclude the study outcome in regional scheme

Revise principles and strategies

7.2 – **Reflection**

7.2.1 – **Research-design relation**

Research-by-design, or experimental design study, played a key role in this project. It is about studying through design using knowledge acquired by design research (Nijhuis &Bobbink, 2012). As the diagram suggests, it is an "iterative process". The knowledge learned from regional-scale analysis informed us the design assignments needed to be answered in local scale sites. Nevertheless, the analysis did not stop at this phase, as design exploration started, another round of investigation was carried out according to the site-specific condition.

Since the sites are all located in the intertidal zone. It is important to investigate the natural process and integrate the knowledge. The natural process includes aspects such as geology, hydrodynamics, morphology, and ecology. There are different emphasis on each location. For example, in the Rainham site, the identification of potential locations for saltmarsh restoration required a comprehensive understanding of the formative elements of landscape, such as bathymetry, topography, and the seasonal tidal range. Based on this, we could identify which locations are above the sea level at a certain percentage of the time in a year and are suitable for plants to grow. Also, the analysis of surface water flow led to the design decision of the alternatives of dike relocation. On the other hand, there is a coastline protection objective in the Sheppey case. Therefore, an extra study of the type of flood defense infrastructure is carried out. These are site-specific elements needed to study, understood, analyzed, and map. In conclusion, research-by-design not only refers to the process of applying and testing design solutions, but also a process of generating knowledge.

7.2.2 – **Relevance, scientific context and contributions**

The major contribution of this graduation project is the development of design principles for a sustainable coastal landscape and the application of proposed design principles in the UK context and a broader North Sea region. By adopting the research-design method, this project demonstrated a system of design approaches from understanding, analysis, design study, application, and long-term implementation schemes. As for resilience development, this project addressed issues of flooding risk, intertidal habitat loss, and coastal erosion, and integrated landscape design with ecosystem conservation and restoration.
In addition, this project focused on "public spaces" and "natural environment", which are long be neglected in the UK's development mechanism, which is driven by private developers. Under the current spatial planning institutional framework, the local governments produce "local plans" as guidelines for developers. However, there is a gap between the institutional layers. As a result, the adaptive design strategies proposed in this project play a significant role to develop a socio-ecological resilient environment by integrating different development aspects. It has high possibilities

to increase the awareness of public sectors, spatial professionals, and the public to cooperate, respond to the flooding risk, and take action.

7.2.3 – **Limitations**

There are limitations encountered during the development of this graduation thesis, including data acquisition, lack of fieldwork, and lack of multi-disciplinary cooperation, and the transferability of design results.

Among these aspects, lack of fieldwork might have a bigger influence. A resilient socio-ecological system should be built in a conversation between several and different actors and integrate local perspectives and know-how. Methods such as interviews or workshops could help to understand the needs of the locals. Due to the limitations of this work in project scale and time, neither of these was carried out. Therefore, the main approaches for the me to understand the site are based on data in geographic information systems and second-hand information, such as policy or technical reports. This is an unavoidable limitation of such an individual project carried out in an academic setting, especially since the study is carried out in the Covid-19 lockdown period. However, we can still keep in mind that stakeholders' communication is a necessary process in practical work.

Another limitation is the multi-disciplinary cooperation or appropriate assessment of design proposals. The sites in the project focused on landscape design and regional planning. However, most of the design proposals include modifications of flood defense infrastructure. It would be comprehensive if I could work with or consult hydraulic engineers or biologists to increase the practicality of this project.

Last but not least, the transferability of the design results is a crucial part to discuss. The design strategies and principles developed through this project could be considered part of the sustainable design toolkits or design with nature solutions, but it might not be able to directly transfer to a random location. We might reuse the same research framework, but need to critically consider the context-dependent factors, such as differences in climate, landscape, as well as differences in cultural and institutional systems.

7.2.4 – **Lessons Learned**

Learning from natural formation principles

The study of natural formative elements informed us of design principles and suitable design decisions. It is of critical importance to understand the type of coast and how diverse habitats are connected to it because the research area is an estuarine environment, and the final design assignment is to increase the adaptability of the coastal system.

When designing a landscape with nature-based solutions, it is important to keep in mind that natural dynamics, in both temporal and spatial dimensions, would determine the final design results. For example, the final shape of the barrier islands in Sheppey may differ from what is built initially. The design proposal only decided where the fixed part should be located, but the other proportion could develop and evolve to the shapes as the nature taking over. In other words, there would only be an ever-evolving process but a final constant form of the island system. It is a system designed by the designer, but nature will continue working on it. Besides, an adaptive management mechanism, such as a mud motor, is also needed to increase coastal resilience decades later. In this respect, I would regard my proposal as an open-ended design. The contribution of this study is not the illustrative plans, but the design process and adaptive design principles generated from them.

Role of urban designer

As an urban designer, adopting a landscape-based approach and design-research method in a project are new experiences for me. Comparing to the typical urbanism approach that puts most of the emphasis on the study of urban typology, zoning, or certain social-economic phenomenon, this project started from the understanding of landscape systems. It was inspiring to understand the natural formative elements and to extract design principles from nature. In addition, in this design-based research, the proportion of "design exploration" is high. In the project, design is used as a powerful instrument to integrate knowledge.

As I mentioned in the motivation, I believe that there is a need for developing a new design and planning approach to confronting flooding risk under the uncertainties of climate change. Through the development of this graduation project, I believe the new approach I am looking for is the integration of landscape and urbanism expertise. Urban designers and landscape architects are the groups of professionals most suitable to deal with it because we are experienced in working through multiscale and deal with wicked development issues. Our jobs are planning and designing public spaces and the public domain. Moreover, most of the time, spatial planning and design are inseparable from politics. These characteristics make us sensitive to the change of our living environment, the ever-changing social context, and the uncertainties of climate change. Though in the academic environment, especially in the architecture department at TU Delft, design approaches in these two fields are blurred and integrated to some extent, there still are spaces to improve in real-world design practice. I expect myself to be the hybrid designer who can keep elaborating on the landscape-based design approach, and devoting myself to improving our living environment.

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