

Reversed Risk

*Protective productive cycle based
on tidal force in estuarine territories*

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P5 Report

July, 2018

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Truly an honour to be part of the D-i family.

- Alexandra 2018 -

"Time and tide will wait for no man, saith the adage. But all men have to wait for time and tide."

*Charles Dickens (1844). "The Life and Adventures of Martin Chuzzlewit:
His Relatives, Friends and Enemies ...", p.169*

fig.1

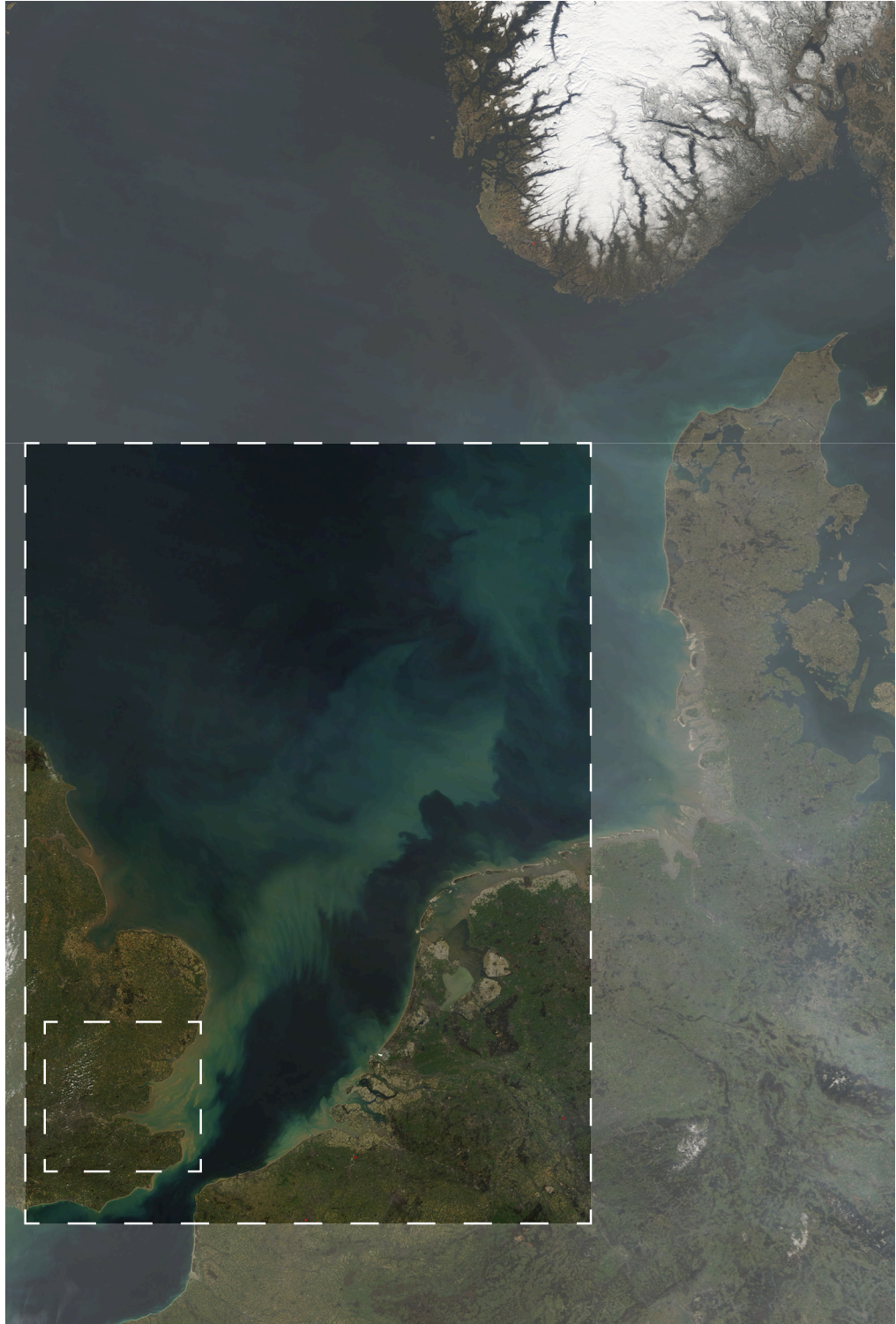
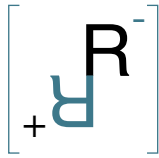


fig. 1. Thames River Plume in the North Sea,
<https://earthobservatory.nasa.gov/Search/index.php?q=north+sea>



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Research Group:

Delta Interventions

Keywords:

Climate change, energy transition, critical
energetic infrastructure, landscape infrastructure,
ecological approach, resilience,
risk assessment and response/management,
hydraulic engineering, urban water
management, open-end design



fig.2

Culemborg, Netherlands



fig.3

Friesland, Netherlands

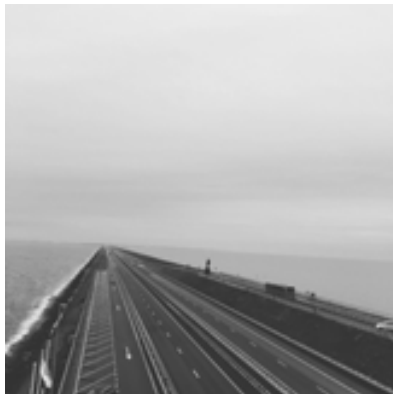


fig.4

Afsluitdijk, Den oever, Netherlands



fig.5

London Bridge, UK

fig.2-5. Images of D-i field trip, focus on the UK and Netherlands coastline, made by author

Embracing uncertainty

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Relevance

INTRODUCTION

Antithetic | Dualistic | Symbiotic

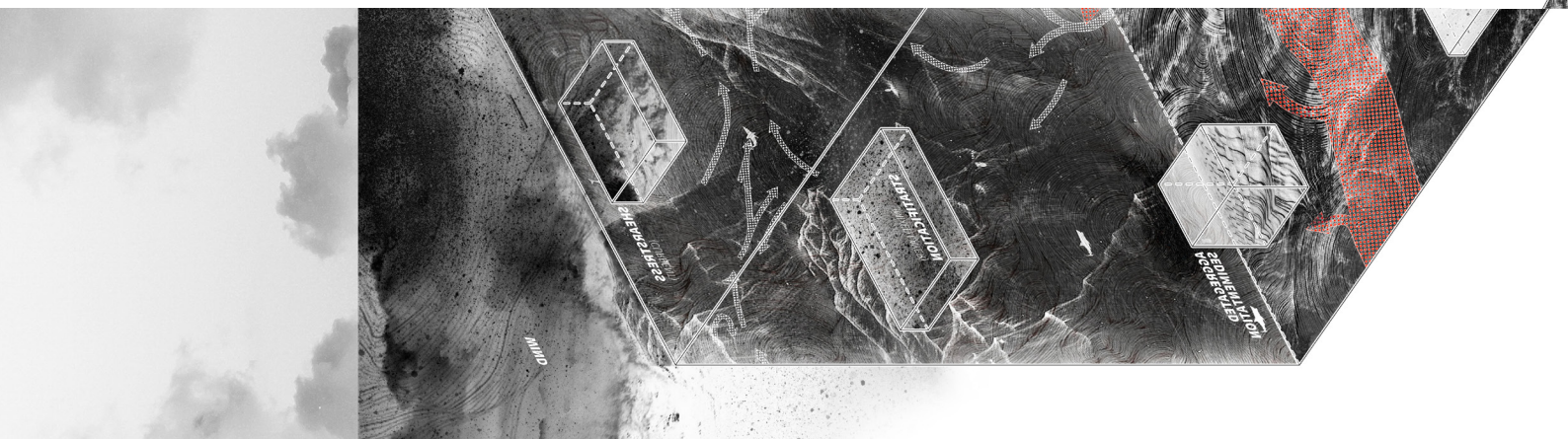
"The end of every game is a gain or a loss: but of what? What were the real stakes? At checkmate, beneath the foot of the king, knocked aside by the winner's hand, nothingness remains: a black square, or a white one. By disembodiment his conquests to reduce them to the essential, Kublai had arrived at the extreme operation: the definitive conquest, of which the empire's multiform treasures were only illusory envelopes; it was reduced to a square of planed wood."

Italo Calvino, Invisible Cities

fig.6. North Sea hydrodynamics conclusion

image - D_i group work

fig.6



Motivation

1. The wavering territories - [a paradox]
2. Political denial and individual action



_01.

Manifesto

1. The wavering territories - [a paradox]

"...the great floodgates of the wonder-world swung open..."

Hermann Melville, Moby Dick

The weaver territories - [A paradox]

fig.7

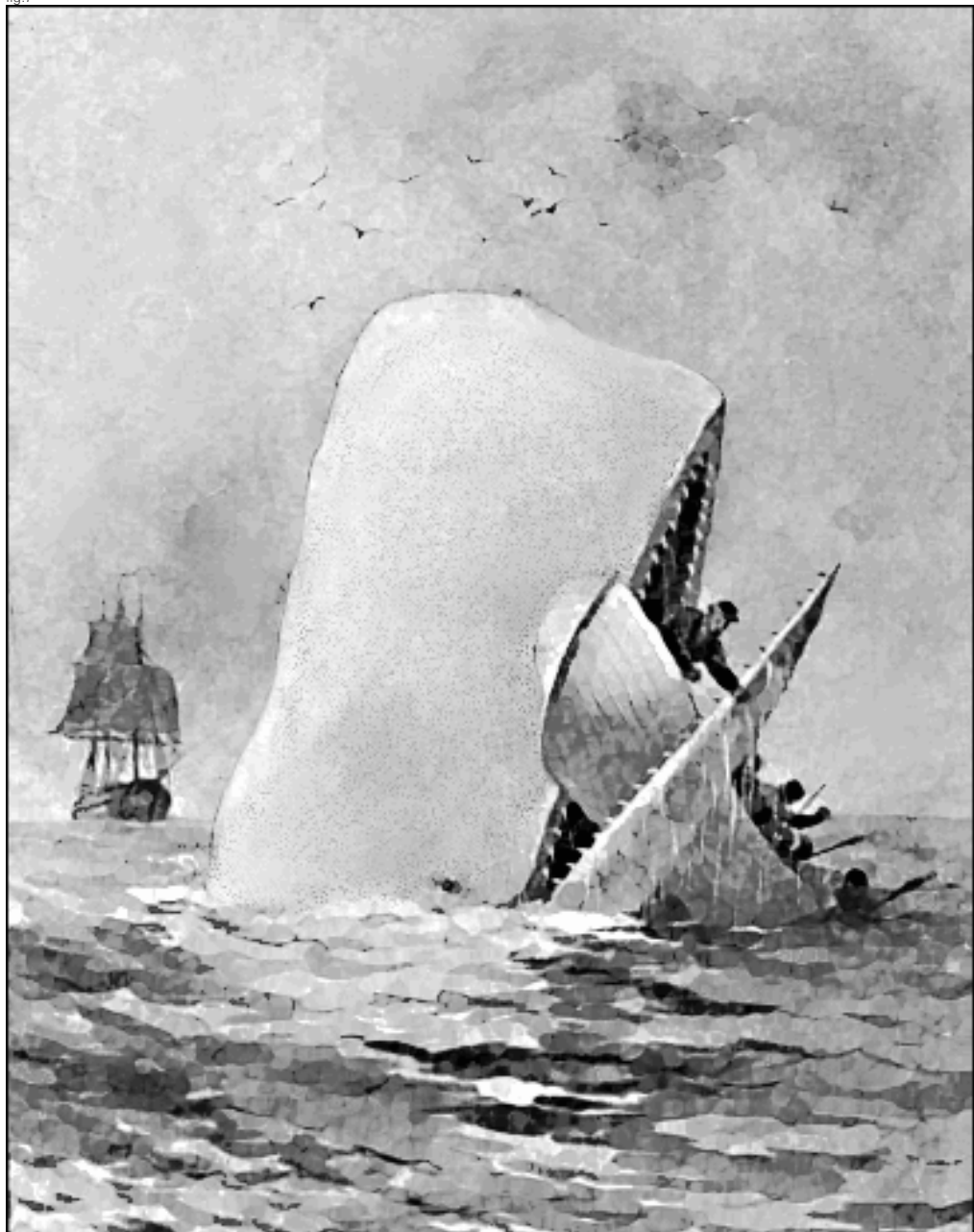
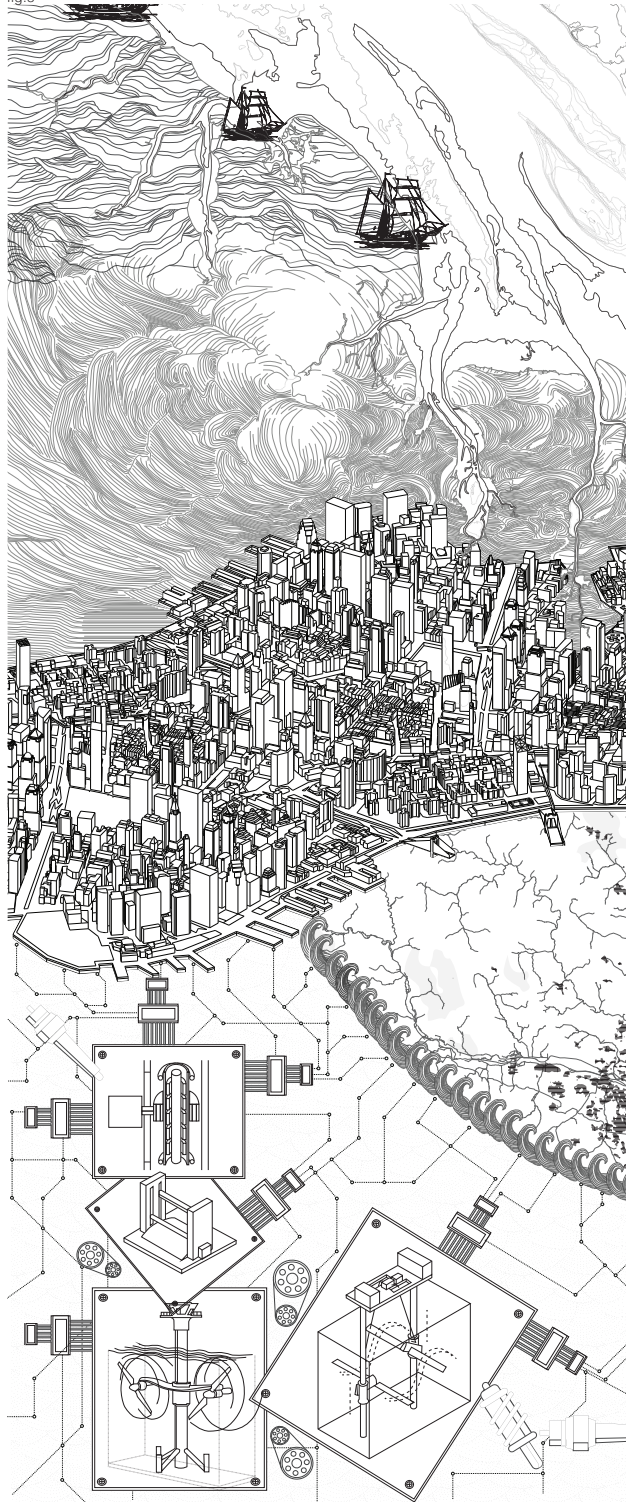


fig.7. Moby Dick- What if...

First cover of Hermann's Melville Moby Dick, https://commons.wikimedia.org/wiki/File:Moby_Dick_p510_illustration.jpg

fig.8. Reversed risk projective image, Territory as a project symposium and exhibition

fig.8



MANIFESTO

Reversed risk

The sea is a dynamic body of water, not regarded as an individual entity, but a confluence of externalities, dynamics and internal processes pressuring the limitation of the coastline into forming wavering territories, where no man is safe and no water is unsuppressed. It is precisely where the upstream river water meets the marine inflow - the hazardous, vulnerable transitional area of an estuarine territory - that stands as focus for the intervention. Constantly shifting its boundaries, it is significantly exposed to the volatility of time, hence it is subjected to change. We are nowadays facing extreme climate events that are abruptly intensifying as the urbanized world is unfit to tackle them. In a resolute attempt to regain control, intense urbanization lead to intense anthropic activities – destruction of saltmarsh, construction of artificial barriers, storm-breakers which affect the ecologic response of the natural processes reducing the adaptability range and exposing the coastal/estuarine territory to flooding risk.

Being exponentially developing, the Greater Thames Estuary currently contains 1 million properties and their inundation would result in direct damage of at least £ 97.8 billion at 2003 prices. (Dawson, 2005) However, the implications reach further than that when applying this reasoning extended through time and performance. Currently, the main flood defense applicable is the Thames Barrier, and its downstream rigid river defenses. Being an anthropic intervention, an evolutionary perspective indicates that longer time leads to higher risk, lower performance, higher vulnerability and higher investments.

In an attempt to control we isolate and raise walls for protection, yet in an attempt to advance we explore, invest and conquer. The middle ground between these two ideologies lies in the aforementioned wavering territories of flood vulnerability and their dualism. They become contested territory between water and city, between risk and potential, between confinement and development. A new hybrid infrastructure can reverse the flood risk to a profitable tidal power source, creating a protection/production cycle, simultaneously defending and “fueling” the city as well as retrieving its original investment.

_01.

Motivation

2. Political denial and individual action



Climate change dispute

fig.9.

"It's freezing and snowing in New York -- we need global warming!"

"Ice storm rolls from Texas to Tennessee - I'm in Los Angeles and it's freezing. Global warming is a total, and very expensive, hoax!"

"The concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive."

"I'm not a believer in man-made global warming. It could be warming, and it's going to start to cool at some point. And you know, in the early, in the 1920s, people talked about global cooling...They thought the Earth was cooling. Now, it's global warming...But the problem we have, and if you look at our energy costs, and all of the things that we're doing to solve a problem that I don't think in any major fashion exists."

"It's really cold outside, they are calling it a major freeze, weeks ahead of normal. Man, we could use a big fat dose of global warming!"

"Wow, it's snowing in Israel and on the pyramids in Egypt. Are we still wasting billions on the global warming con? MAKE U.S. COMPETITIVE!"



fig. 10. Public participation towards flood uncertainty



fig.9. Donald Trump quotes on Climate

Change

[http://edition.cnn.com/2017/08/08/](http://edition.cnn.com/2017/08/08/politics/trump-global-warming/index.html)
[politics/trump-global-warming/index.html](http://edition.cnn.com/2017/08/08/politics/trump-global-warming/index.html)

fig. 10. Romanian community involvment

in flood defense,

[http://www.gandul.info/stiri/care-sunt-](http://www.gandul.info/stiri/care-sunt-inundatiile-istorice-pe-carele-a-provocat-dunarea-pe-teritoriul-romaniei-12636532)
[inundatiile-istorice-pe-carele-a-provocat-](http://www.gandul.info/stiri/care-sunt-inundatiile-istorice-pe-carele-a-provocat-dunarea-pe-teritoriul-romaniei-12636532)
[dunarea-pe-teritoriul-romaniei-12636532](http://www.gandul.info/stiri/care-sunt-inundatiile-istorice-pe-carele-a-provocat-dunarea-pe-teritoriul-romaniei-12636532)


MOTIVATION

Do we need to take individual self-defense measures when facing a flood?

Romania has permanently been subjected to riverine flooding caused by extreme rainfall, rapid snow-melting leading to stern overflow and being carried out along the Danube floodplains. This annual events threatened to completely flood the Danube Delta, second largest and best preserved of the European deltaic regions. Little to no measures have been taken to prevent what it was actually a highly predictable extreme event, mostly recurrent as a consequence of spring risen precipitation values.

The Danube river flood defense system is mostly based on dams, indigent enclosures and the famous storage tanks of Iron Gates I and II which have prevented and operated within predicted water level rise, however failed to address the biggest Romanian flood events of January 1998, March- May 2006 and June-July 2010. To cope with more than 18.000ha of affected territory and to protect endangered human settlements, breaks down the downstream transverse dams had to be dug, thus questioning the efficiency of the dam structure. Additionally, with little concern on the political sphere flood management has been appointed to the small rural communities, whose response were temporary dams in the form of sand bags.

Taking into consideration that climate change is a real issue, constantly monitored by NASA, the issued predictions are alarming as the disruption of statistical distribution of weather patterns may project such extreme flooding events into a higher level of uncertainty, above the annual expectations. Moreover, these incidents also prove the changes occurring in the climatic conditions globally, leading to enhanced manifestations in the form of extreme events and progressive phenomenon such as sea level rise, temperature rise, carbon dioxide rise. However, this phenomenon of climate change is not recognized or rather not appreciated by the current global economic model (Brown, 2014) nor by the influential politic sphere. Hence, exploring governance models and policy implementation under the premise of climate change stands under tabu.

_02.

Problem field

Invisible estuarine shaping forces

Shrinking territories

Exploring the hydrodynamic power of the North Sea and revealing tidal energy formation in estuarine territories

fig.11. North Sea hydrodynamics

conclusion image - D_i group work

fig.11



Problem field

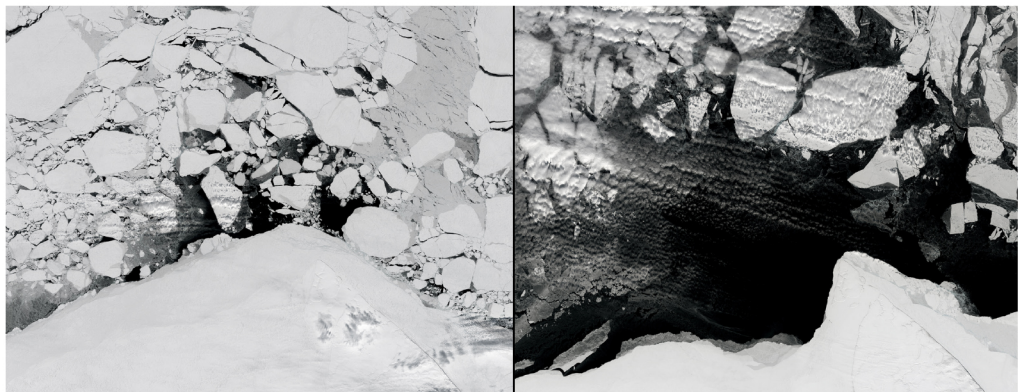
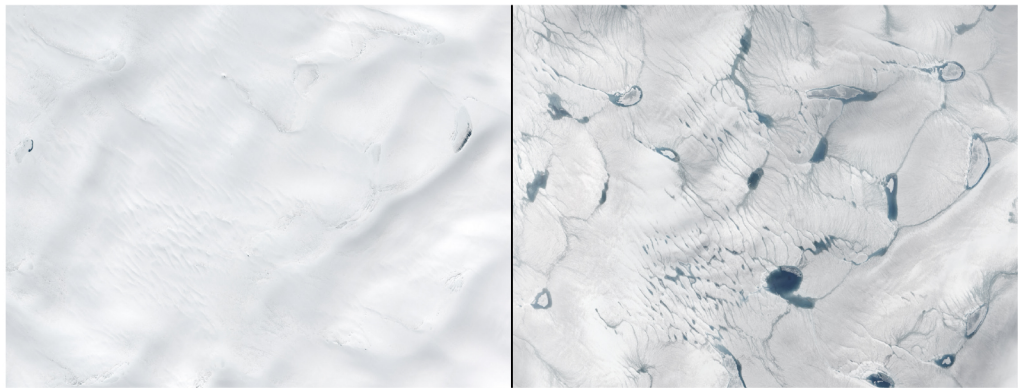
1. Disjunctive global context - climate vulnerability
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_02.

Problem field

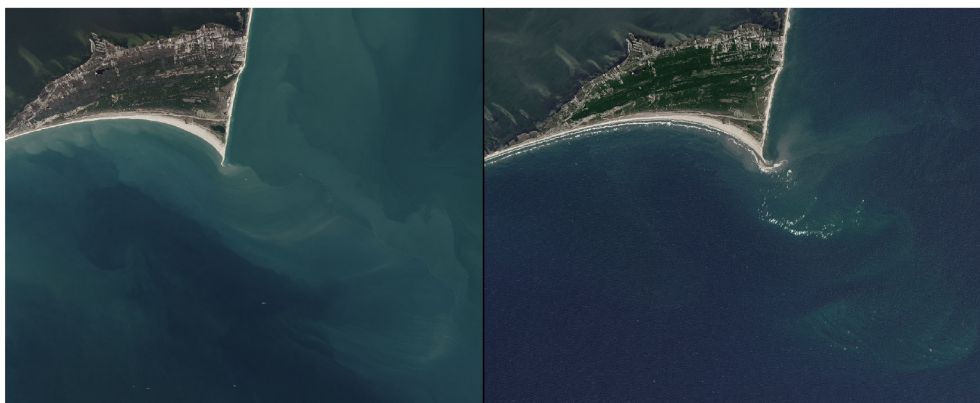
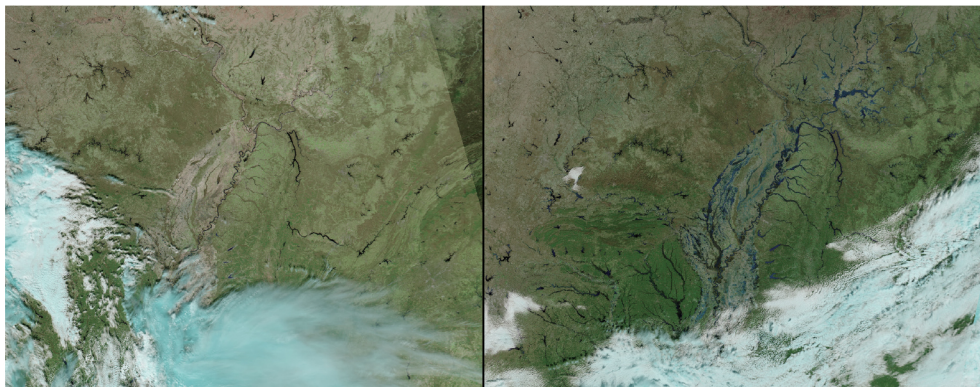
1. Disjunctive global interests - global impact



Clean energy hypothesis

The Earth's climate is currently about 0.8°C warmer than it was in the preindustrial age. The amount of CO₂ in the atmosphere now is greater than at any point in the last 800,000 years. These changes are very much related to human activity(1), one response being the Kyoto Treaty that commits State Parties to reduce greenhouse emissions. This current carbon-intensive era raises high levels of risk for future generations, specifically risks related to natural calamities with

Disjunctive global interests - climate awareness and energy transition



catastrophic outcomes and costly damages. A warming of about 2°C above pre-industrial levels mark the threshold for endangering urbanity, hence the need for coping up with this aspect of climate change is regarded as " the 2°C challenge". Therefore human-activity emissions must be reduced at a higher pace and eventually reach zero, or as the European Union set as a goal for 2050 100% renewable.

02. Problem field

2. Disjunctive global context - climate vulnerability

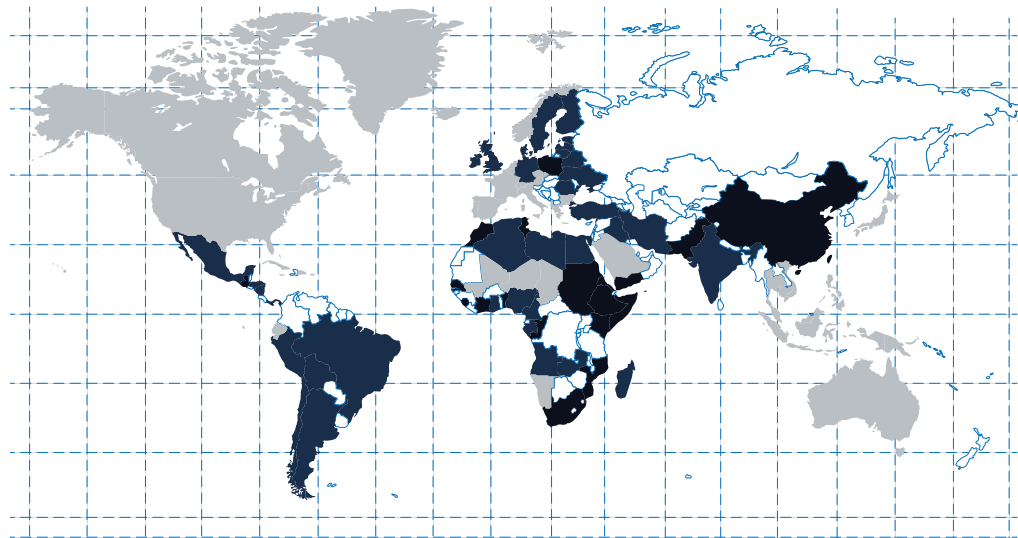


fig.12. Global flood risk vulnerability levels

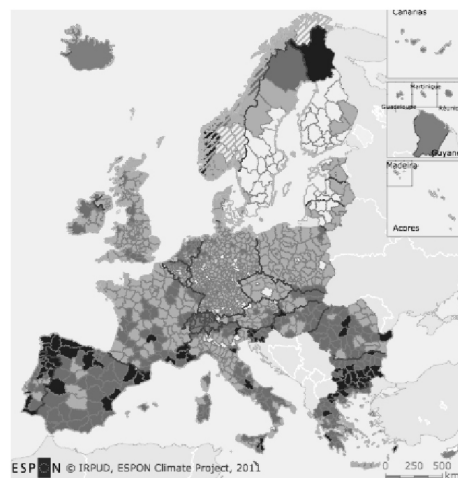


fig.13. Potential environmental impact of climate change

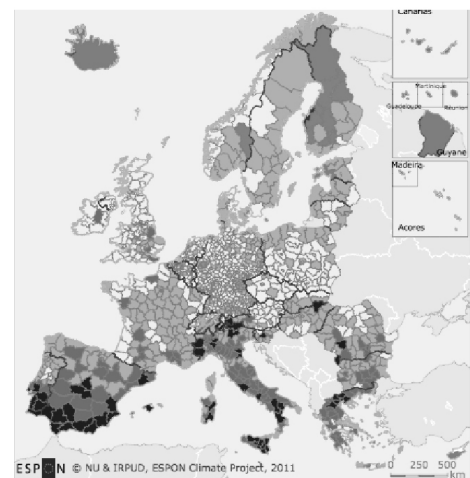


fig.14. Potential economic impact of climate change

As a consequence of climate change, the European territory will be mostly affected by medium and low economic and environmental impact, with higher effects on specific locations. Thames Estuary is therefore an area of recurrent flooding, with surface water bodies facing high risk of flooding and high level of damage.

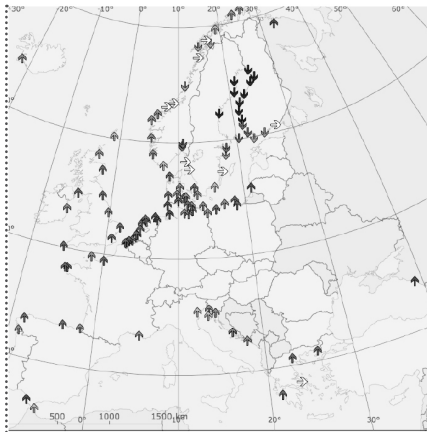


fig.15. Sea level rise tendency

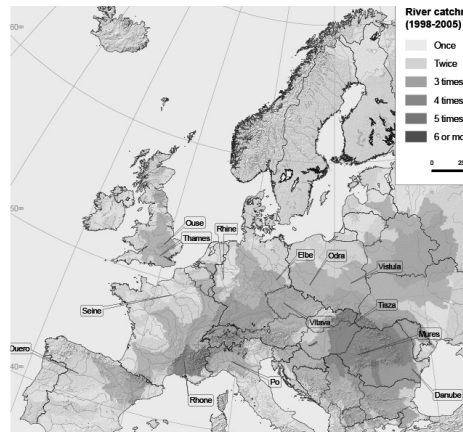


fig.16. River catchments affected by flooding

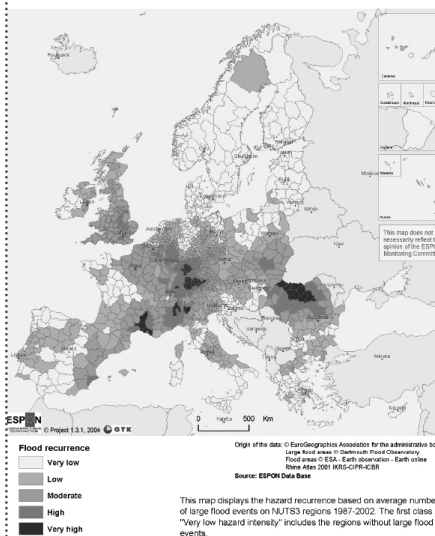


fig.17. Flood recurrence

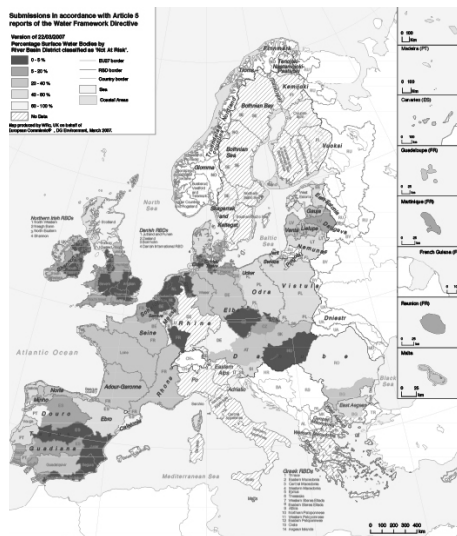


fig.18. Surface water bodies not at risk

Fig 13. 15. 16 - http://ec.europa.eu/environment/water/water-framework/facts_figures/pdf/2007_03_22_swb_no_risk.pdf
fig.14,17,18. - - <http://grist.org/climate-energy/the-16-scariest-maps-from-the-e-u-s-massive-new-climate-change-report/>

Ranking higher on the flood recurrence, river catchment overflowing, sea level rise and level of risk gradients, Netherlands and UK are considered priority territories for protective measures under the ESPON directives, however, the recent Brexit questions the further coherence of the strategic intervention plans as the question of division arises.

Problem field

3. Disjoint Governmental levels

The focus of the research is integrating three different current challenges in urban planning and design practices - the 2 degree challenge, the 100% renewable and the resilient flood defense system, however, these trends interact with the actual cultural, economic and social dynamics of a territory becoming the milieu for economic growth. An area subjected to high climatic manifestations and under intense growth pressure is the Greater Thames Estuary, dealing with both storm water surge as well as tidal surge in its struggle to protect a great metropolis in the context of hazard.

The following chapter will bring onto the table the main concerns to be addressed as well as the primary concepts on which the research

project is based, therefore it raises the challenge of revealing the synergy between climate change projections, energy transition goals, critical energetic infrastructure and the vulnerabilities they are subjected to, specifically in an estuarine territory. Further, the research aims to quantify and qualify the results within the Thames Estuary and East-London Region, by exploring the responses of hydrodynamic forces in the context of risk reduction and economic growth. The balance between the deductive and inductive approach of these interlinked systems will further result in a trans-scalar and trans-disciplinary approach that will focus on revealing the possible interdependencies between technology and governmental schemes.

Fig.19. Project fields causalities, representation by author

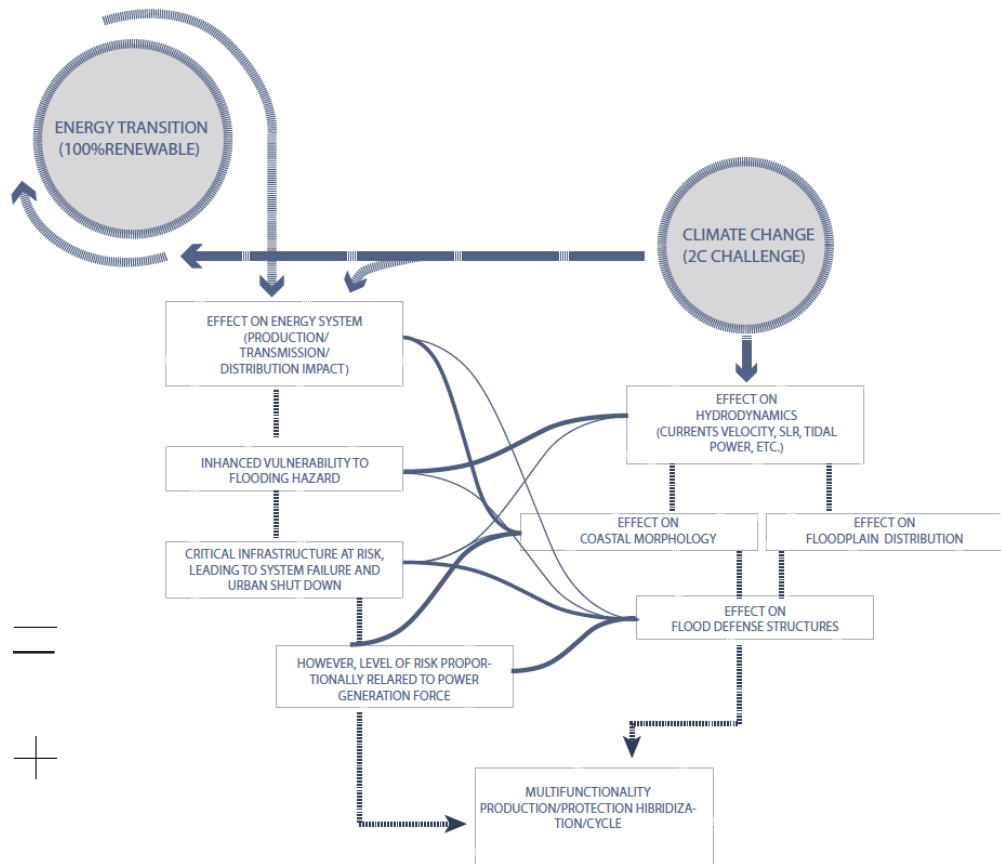


fig.19-20. Climate Change and Energy transition global trends, author representation

Fig.21. Project fields causalities, representation by author

The UK governmental hierarchy and methodology of implementation consist of one of the most detailed models of planning process, being extremely subdivided into departments. While this is beneficial for task management, the longer the chain of subordination, the higher the chance of human error and disconnection between the local effect and the global interest. Also, the specific subdivision of departments and the rigidity of their operational field leads to inter-departmental disparities.

As seen on the conceptual scale, energy interests and climate change adaptation trigger a series of events that influence each other and generating a cycle of causality. This polarizing force is not directly resulting from the British governmental hierarchy as there is not enough flexibility to integrate multiple fields and elaborate a hybrid

project, that would simultaneously respond to more than one problem field. As a result, the political interest prevails over local safety, a condition strongly affecting the municipal and local levels. Although UK government states that decreased investment in flood defense do not necessary lead to increased vulnerability to flooding events, experts challenge this view, as reductions to local authority funding may have caused exponential costs in the long run through faster deterioration. Municipalities had suffered budget cuts of more than 40% since 2010, leaving them with little or no option but to reduce or withhold funding to drainage boards, other organisations and landowners who managed river levels. Not only the existing protective infrastructure is maintained at a minimum level, but future investments are scarce, affecting the natural development of coastal zone management policies.

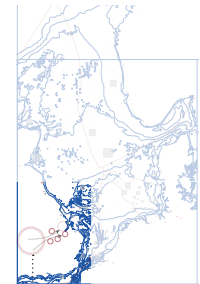


Fig.21

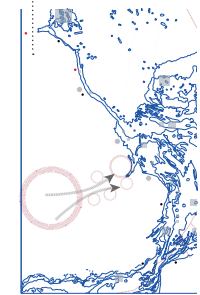
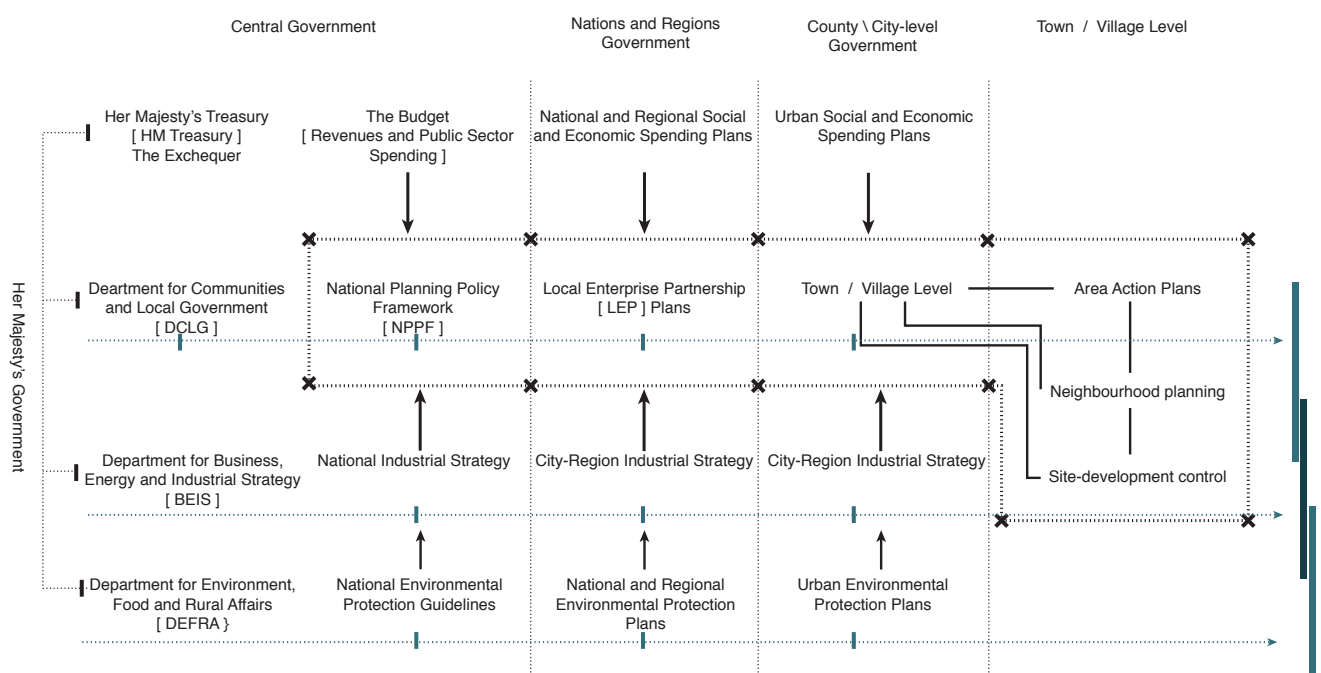


Fig.23. Dual effects - Causalities cycle - representation by author

Fig.22. British governmental hierarchy for implementation



02. Problem field

4. North Sea - a body of fuel

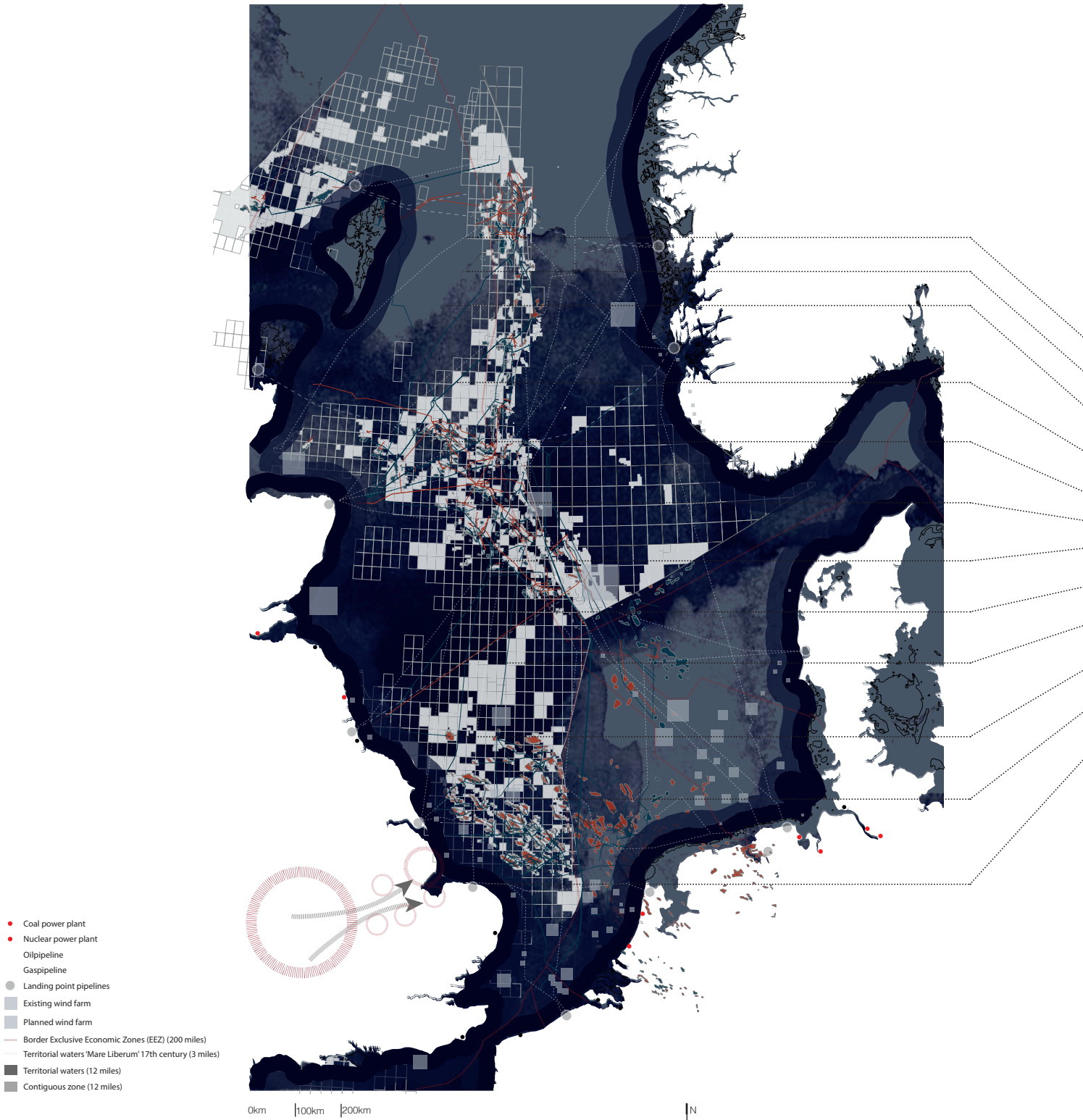


fig. 24 - North Sea current extraction conditions, representation by author based on information from D-i Group 7

NORTH SEA - LANDSCAPE OF POWER

Controlling most of the North Sea territorial waters, the UK is extensively involved in carbon-intensive extraction. The logic consequence being raising the urgency of decarbonizing the waters and take into consideration tackling the natural forces of the sea towards increasing the availability of green power and scaling up distributed generation of energy based on current conditions.

UNITED KINGDOM RENEWABLE DEPLOYMENT

- BIOENERGY 9%
- SOLAR 3%
- ONSHORE WIND 6%
- HYDRO 2%
- OFFSHORE WIND 5%

2016 - RENEWABLES 25% OF TOTAL ENERGY PRODUCTION

The hydrodynamics of the sea

The sea is a dynamic body of water, thus its understanding starts from a multi dimensional approach, describing the movement of fluids and the forces acting on solid bodies immersed in fluids and in motion relative to them – hence hydrodynamics (Merriam Webster dictionary). However, the sea is not regarded as an individual entity, but a confluence of externalities, dynamics

and internal processes as well as a multi-layered entity that interconnects the bottom, the body of water and the climate and weather conditions on the North West European shelf.

Being part of the atmospheric system of the northern hemisphere, in the North Sea case, the strongest external forces that affect it's specific dynamic are the Atlantic Ocean, the Baltic Sea, its own bottom and the coastline of the mainland (European continent). Hence, the Atlantic Ocean influences the tidal waves and currents, which is furthermore propagated into sedimentation patterns and transport of matter.

Due to the interaction between these hydrodynamic factors, the sea interacts with the coastline, producing a series of potentially harmful effects, such as turbulence, stratification, sinking, erosion. The latter is a characteristic process of the United Kingdom's coast, mostly on those sections where the currents hit the shore directly or the estuary areas, where the upstream river water meets the sea, a transition area that stands as focus for this analysis.

Another significant causality in the sea matter is time, hence change. We are nowadays facing extreme climate events that are abruptly intensifying as the urbanized world is not able to face them. 2016 measured overall 338 relevant flood events, with over 4,800 fatalities and overall losses of US \$57bn, out of which 8 were catastrophic, summing up to 21% of the fatalities and 65% of the overall losses. Although it seems only a fraction of the extensive water interventions, coastal protection is a first step towards a safer coastal city and a safer hinterland. However, the complexness of the bodies of water and the uncertainty related to them, especially in the coastal cities represent the hypothesis of this analysis. Revealing the specific coastline areas where risk is prone to happen and future design solutions are recommended to be implemented.

Problem field

4. North Sea - a body of fuel

EXISTING

FOSSIL FUEL PRESSURE

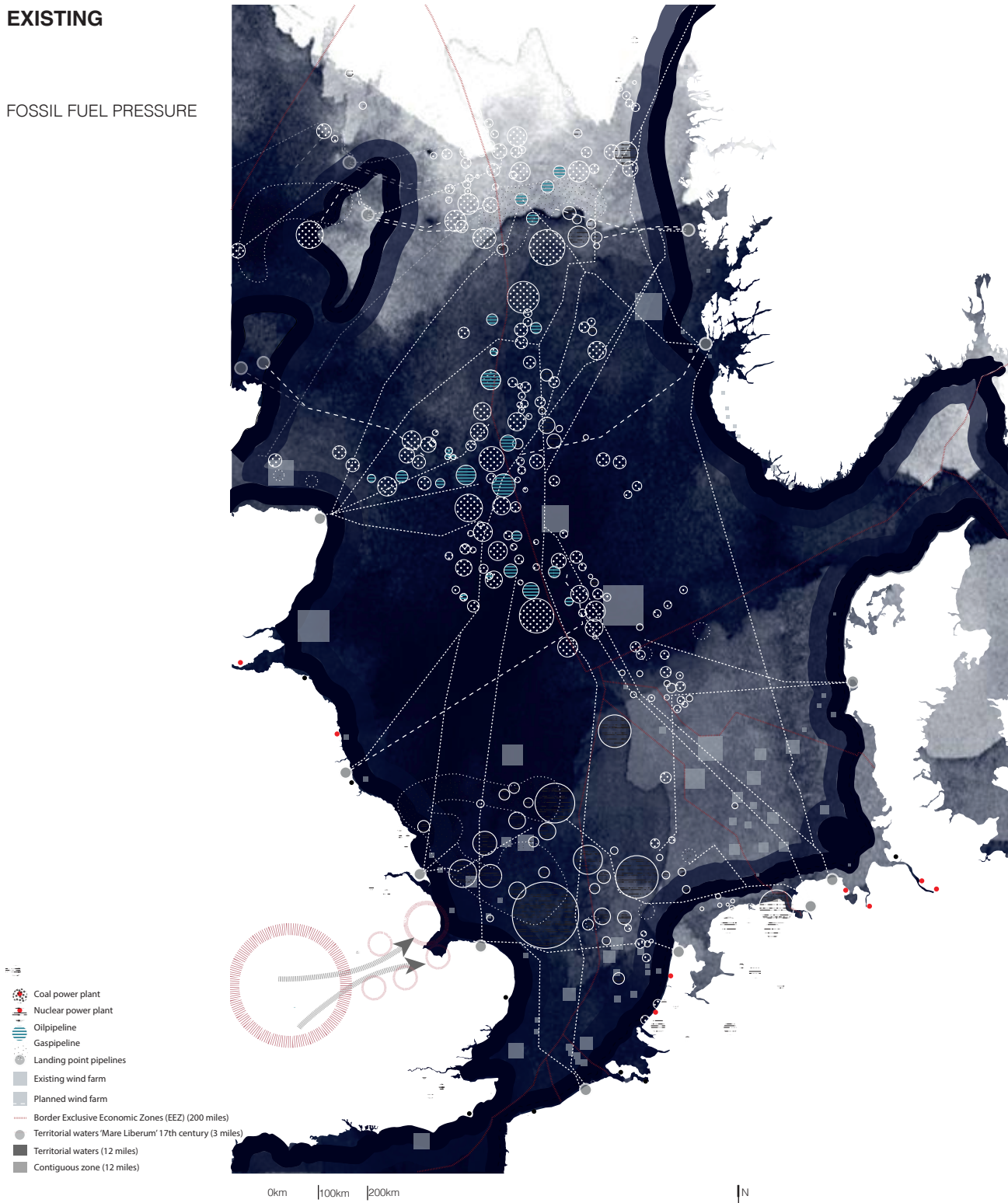


fig. 25 - North Sea current extraction conditions, representation by author based on information from D-i Group 7

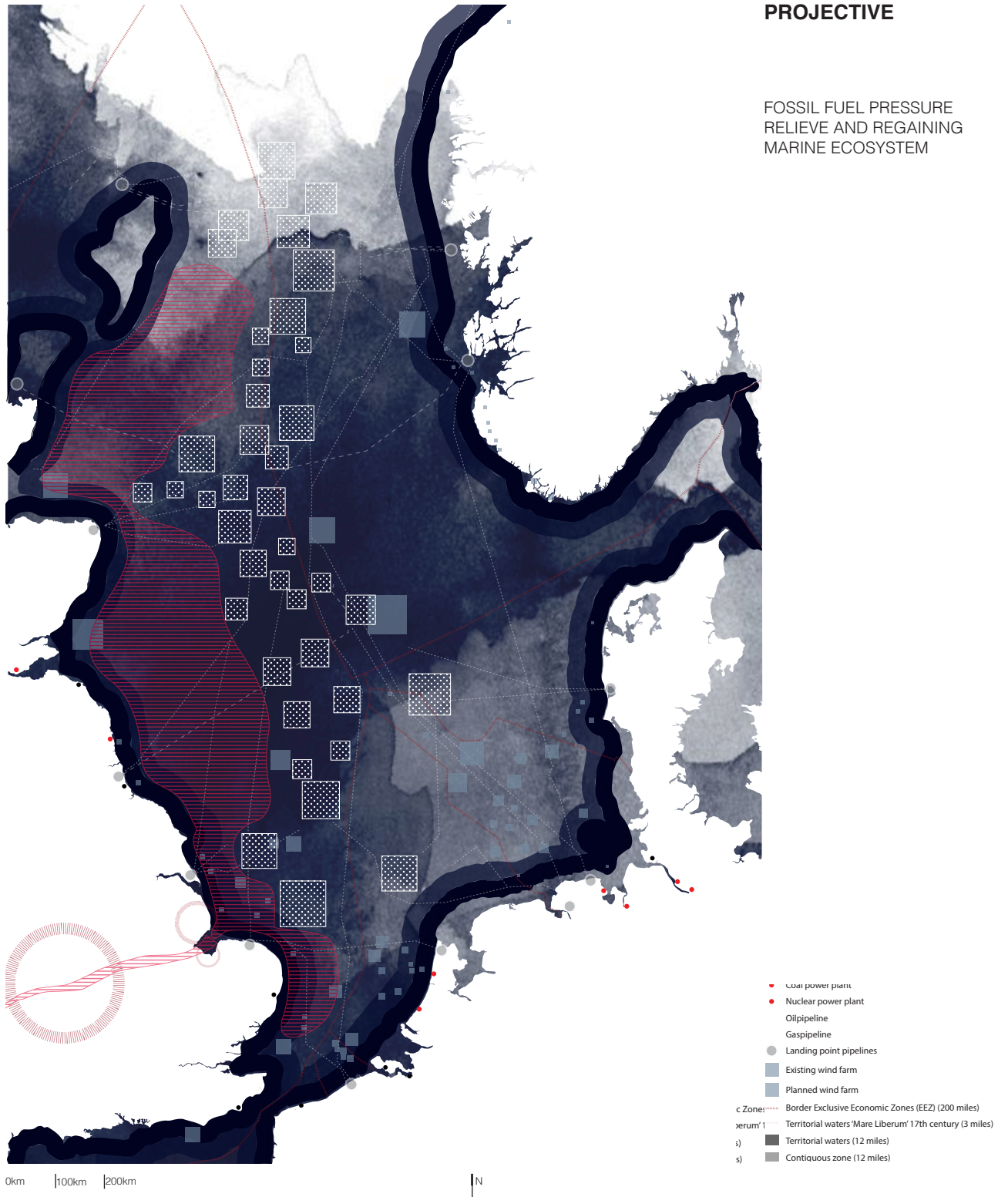


fig. 26. - North Sea projective extraction pressure, representation by author based on information from D-i Group 7

Problem field

5. Interdependent forces towards SLR - the hydrodynamic principles of the North Sea

Currents - direction and velocity

Thames Estuary as a funnel effect

Taking into consideration its direct relation to the Atlantic Ocean, the strongest currents affecting the North sea, come from the north, the Atlantic Waters and the North Sea North waters, as cold currents. However, these have an impact only on the coast of Norway. The warm currents, mostly emerging from the south (the Channel) and the Baltic Sea, combined with tidal currents impact the coast of the United Kingdom causing erosion.

The velocity of the currents is associated with bathymetry, creating rapid corridors that follow the direction of the main currents.

Source : <http://climate-ocean.com/2015/K.html>



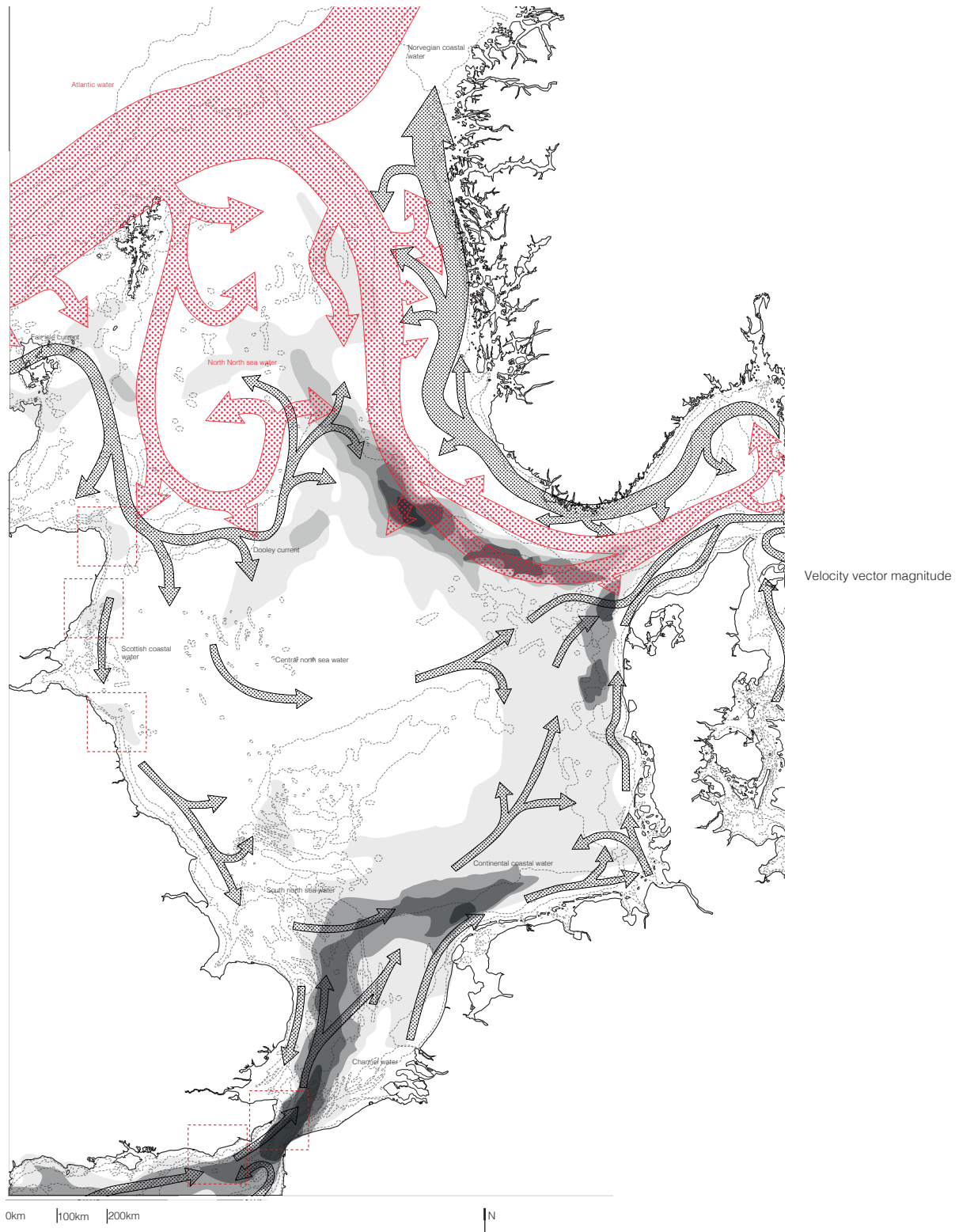


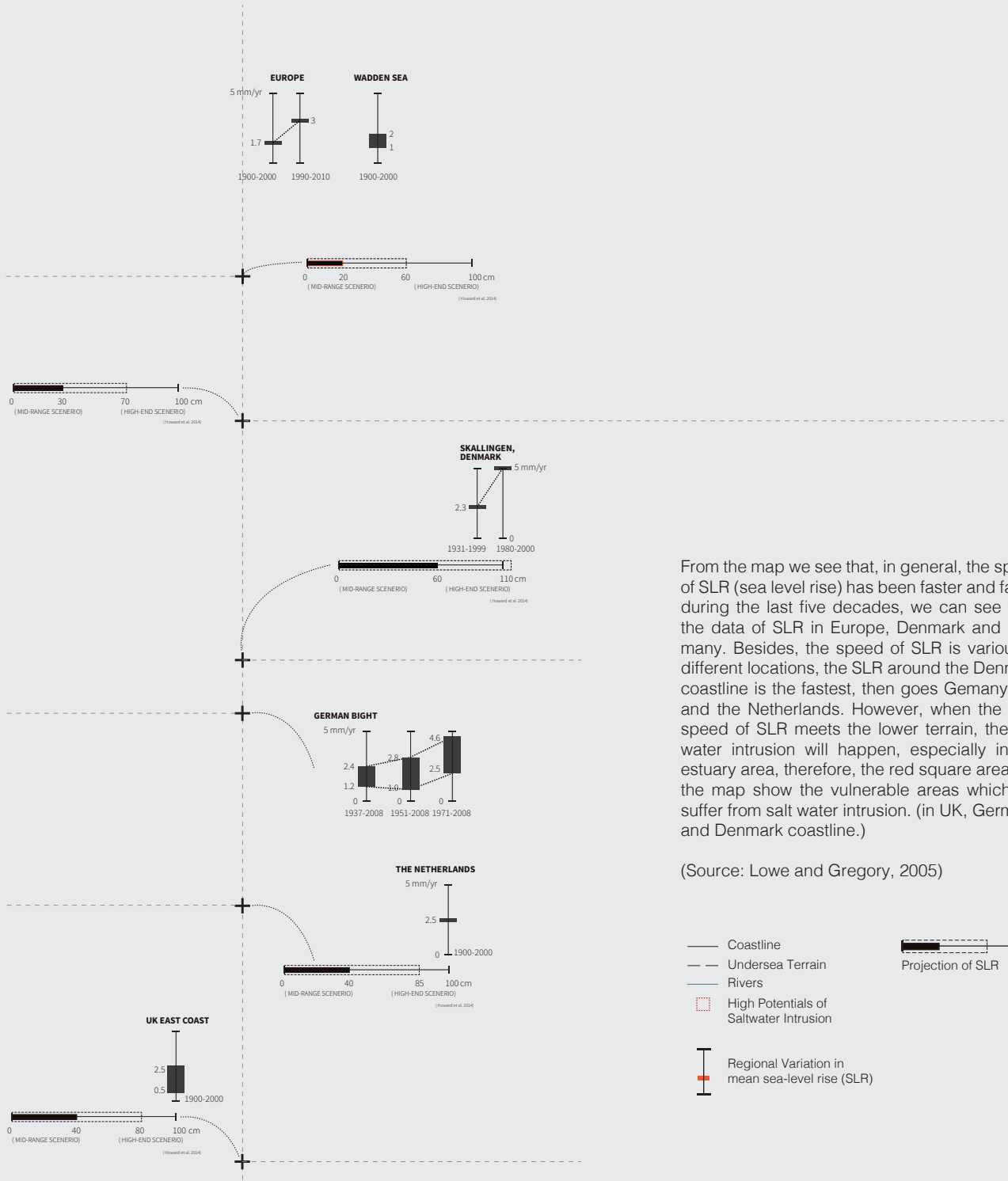
fig. 27. - North Sea currents - direction and velocity

Problem field

5. Interdependent forces towards SLR - the hydrodynamic principles of the North Sea

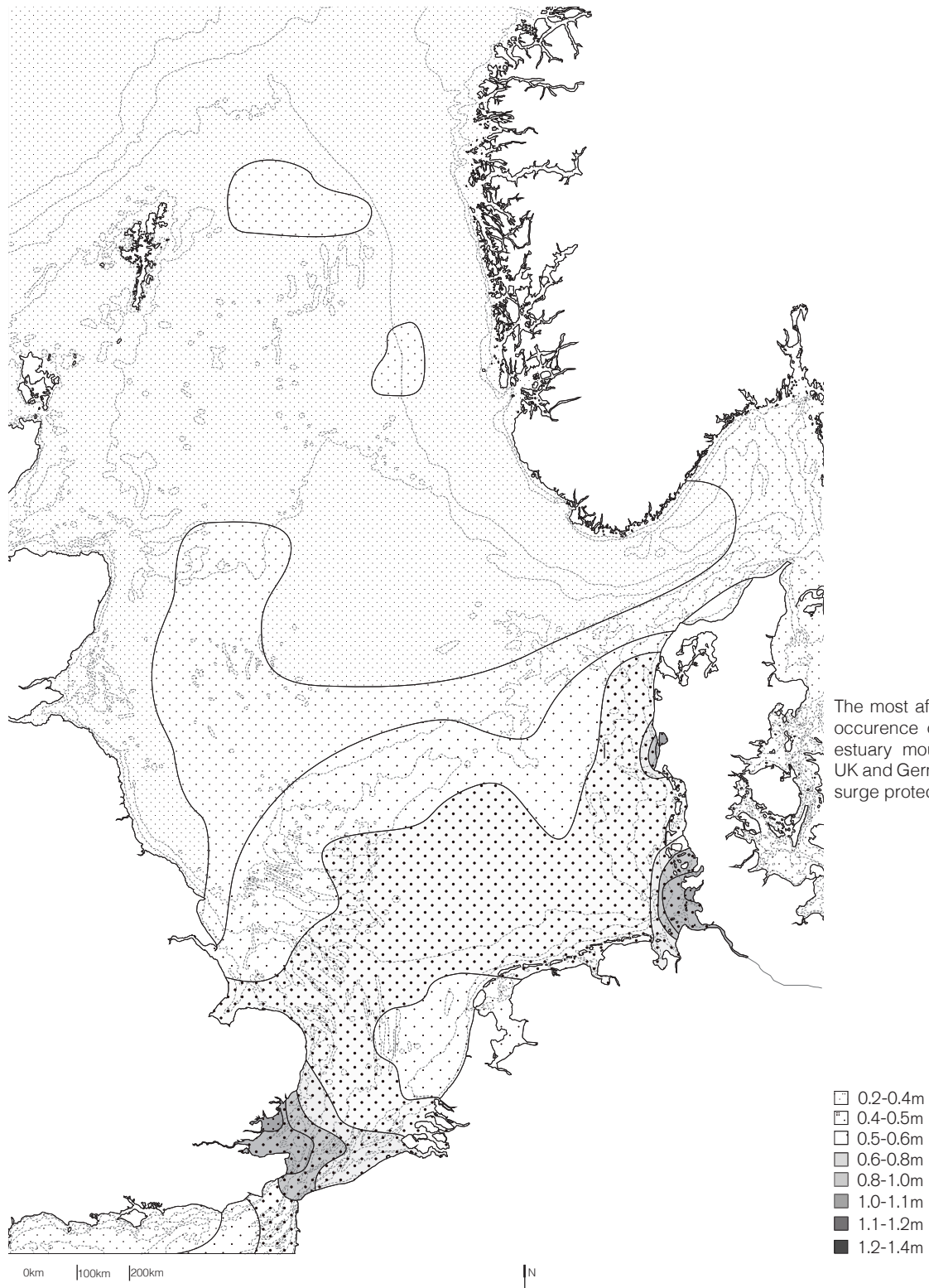
Increase in the height of a 50-year return period extreme water level event

Estuarine mouth as storm surge sponge



From the map we see that, in general, the speed of SLR (sea level rise) has been faster and faster during the last five decades, we can see from the data of SLR in Europe, Denmark and Germany. Besides, the speed of SLR is various in different locations, the SLR around the Denmark coastline is the fastest, then goes Germany, UK and the Netherlands. However, when the high speed of SLR meets the lower terrain, the salt water intrusion will happen, especially in the estuary area, therefore, the red square areas on the map show the vulnerable areas which will suffer from salt water intrusion. (in UK, Germany and Denmark coastline.)

(Source: Lowe and Gregory, 2005)



The most affected areas in the occurrence of a surge are the estuary mouths, therefore the UK and Germany need to adopt surge protective measures.

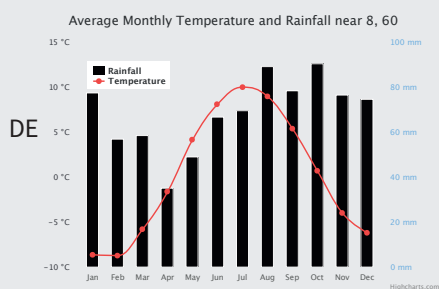
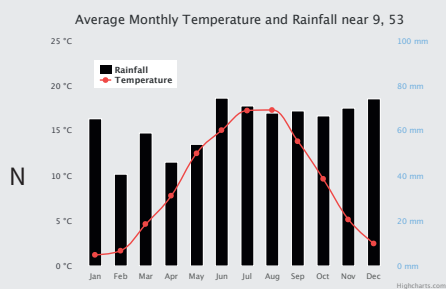
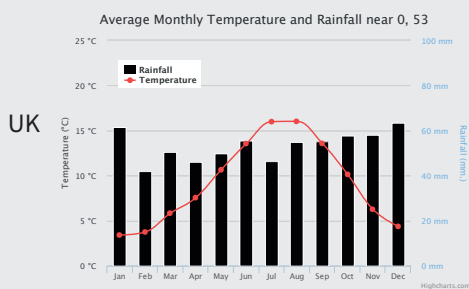
fig. 28 - North Sea increase in the height of a 50-year return period extreme water level event

Problem field

5. Interdependent forces towards SLR - the hydrodynamic principles of the North Sea

Projected precipitation flood risk 1951-2012 applied on sub-river basins





Saline | fresh water contact pressure on the river catchment level

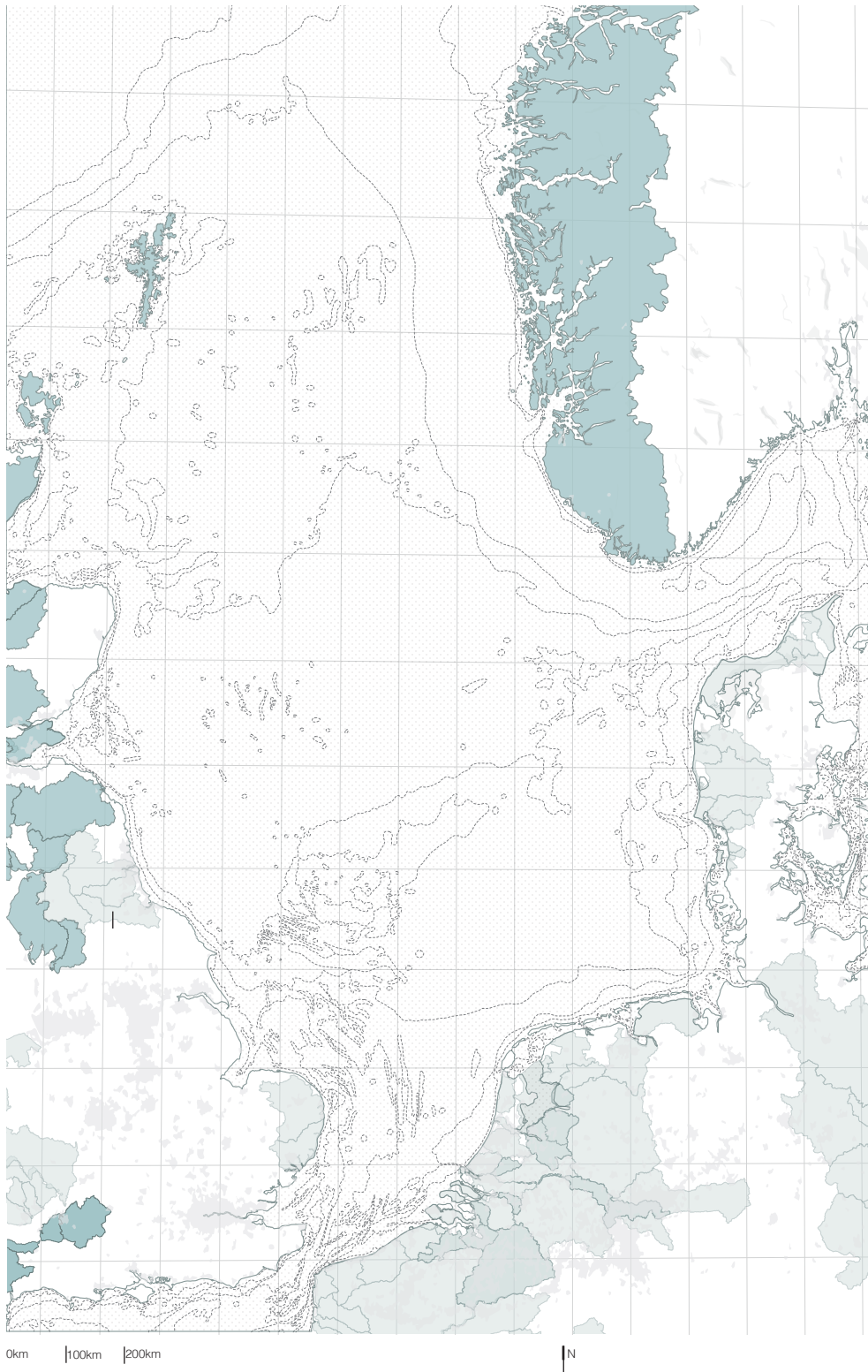


Trends in annual land precipitation are positive almost everywhere over the North Sea region for the period 1951– 2012 . The greatest increase in precipitation is observed in winter especially along the west coast of Norway, over southern Sweden, parts of Scotland and the Netherlands and Belgium.

Further inland, trends are much smaller and statistically non-significant almost everywhere, there the treat is risen by the sea level rise. however they don't pose so much threat on the mainland, but only in relation to bodies of active water that relate to the coastline. Thus, there are indications of an increase in precipitation to the north of the North Sea region and a decrease to the south, in agreement with the projected north-eastward shift in the storm tracks. In many regions, there are also indications that extreme precipitation events have become more extreme and that return periods have decreased.

Source: <http://www.globalclimatemonitor.org/>

-  North Sea
-  Land
-  Level one floodable area
-  Level 2 floodable area
-  Vulnerable urban area
-  Safe urban area
-  Coastline
-  Undersea terrain



Although not at direct risk from precipitation quantities, Thames river catchment is still under the pressure of fresh water/ marine water dualism.

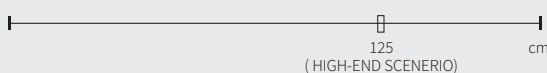
fig. 29. - North Sea projected precipitation flood risk 1951-2012 applied on sub-river basins

Problem field

5. Interdependent forces towards SLR - the hydrodynamic principles of the North Sea

Projection and influence of extreme sea level rise

Shaping a new, de-urbanized coastline

SEA LEVEL RISE PROJECTION MODELS BY 2100**1) Global analysis of Hunter et al. (2013)****2) Lowe and Gregory (2005)****3) Nicholls and Cazenave (2010)****4) Kastman et al. (2011)**

There are main three reasons causing the sea level rise, the thermal expansion of the oceans (about 1mm per year), melting of mountain glaciers around the world (about 1mm per year) and the retreat of the world's polar ice-sheets (about 0.7mm per year). Considering different locations and other effected elements, the projection models of SLR have different results. We compared four projection models which predict the sea level rise in the next 100 years, to 2100, which are study from global analysis of Hunter et al. (2013), Lowe and Gregory (2005), Nicholls and Cazenave (2010) and Kastman et al. (2011). And the most high-end model is from Nicholls and Cazenave(2010), which has the extreme value of SLR, 180 cm.

Therefore, we use this extreme value to test what will happen in the North Sea Area. From the map, we can see if there are no sea-defend facilities, half of the Netherlands, the north of Germany, west Danmark as well as south-east UK will be flooded, and the red highlight areas are the human settlements which will be flooded.

Source: Hunter et al. (2013), Lowe and Gregory (2005), Nicholls and Cazenave (2010) and Kastman et al. (2011).

- North Sea
- Land
- Flooded Area after 1.8m SLR
- Vulnerable Urban Area
- Safe Urban Area
- Coastline
- Undersea Terrain
- 1.8 SLR limits
- Wave Height

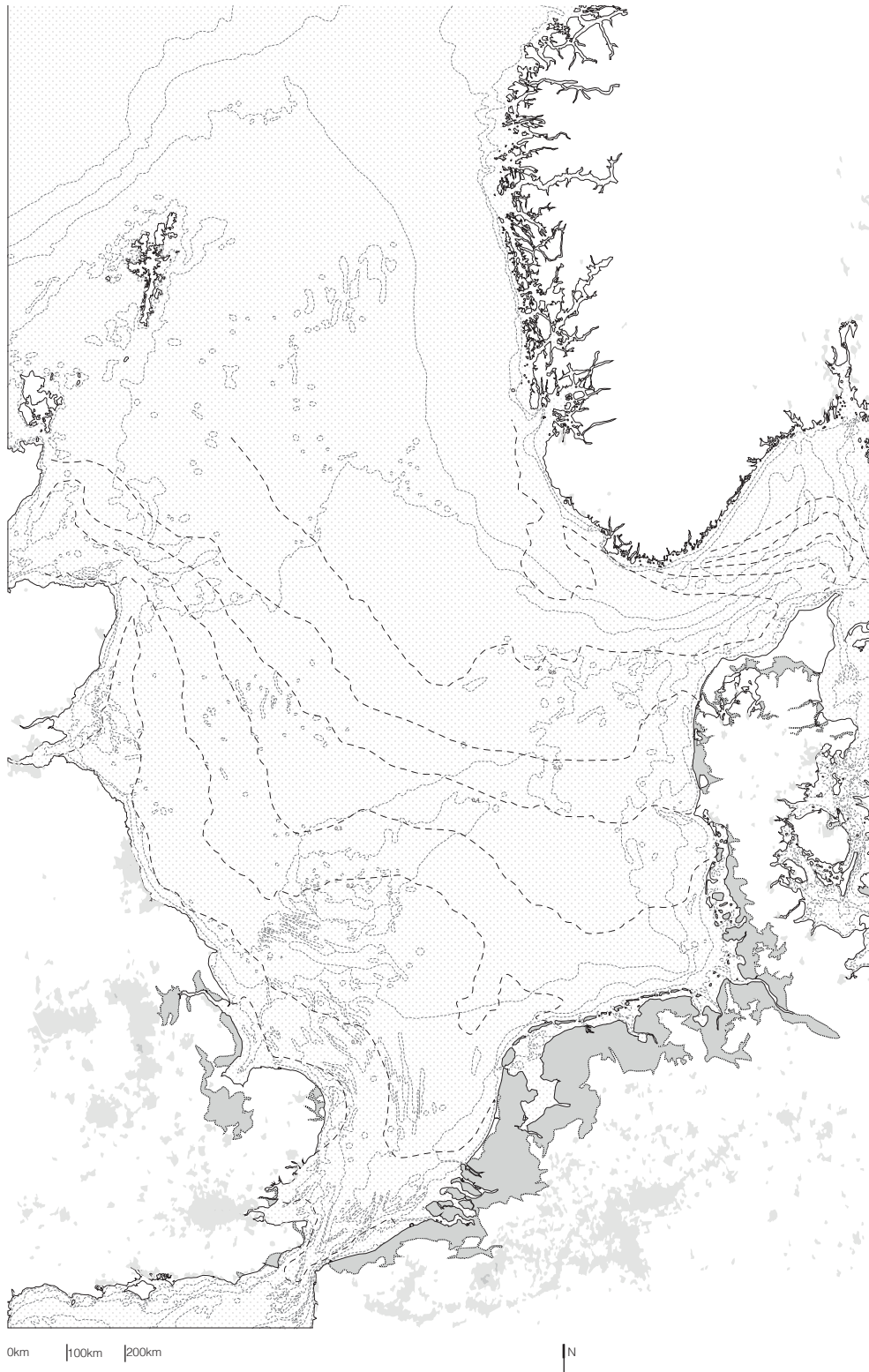


fig. 29. - North Sea projection and influence of extreme sea level rise

Problem field

6. Disrupted ecosystems

Temperature of the sea (bottom, thermocline, surface)

Shifting thermocline affecting local ecosystem distribution

From the multi-layer of the temperature of the North Sea, we can see that in different layers, the changes of the seawater temperatures are various and have different distribution mode. The thermocline is a thin but distinct layer in a large body of fluid in which temperature changes more rapidly with depth than it does in the layers above or below. In the ocean, the thermocline divides the upper mixed layer from the calm deep water below, and it also separates several ocean species in different layers. From the map we can see the most dynamic areas of temperature changes are located around the coastline of UK and the in the sea between Denmark and Norway.

Source: North Sea Climate Change Assessment (Markus Quante, Franciscus Colijn, 2016)

Bottom	Thermocline	Surface
□ 11.41-12.20	□ 5 m deep	□ 11-12
□ 10.61-11.40	■ depth of the thermocline layer(m/s)	□ 10.5-11
□ 9.80-10.60	■ 20m deep	□ 10-10.5
□ 9.00-9.79	□ low depth of thermocline layer	□ 9.5-10
□ 8.20-8.99	□ low depth of thermocline layer	■ 9-9.5
□ 7.40-8.19	□ dynamic area	■ 8.5-9
□ 6.60-7.39		— Seasonal variability:2-7
□ 5.79-6.59		
■ 4.99-5.78		
■ 4.18-4.98		

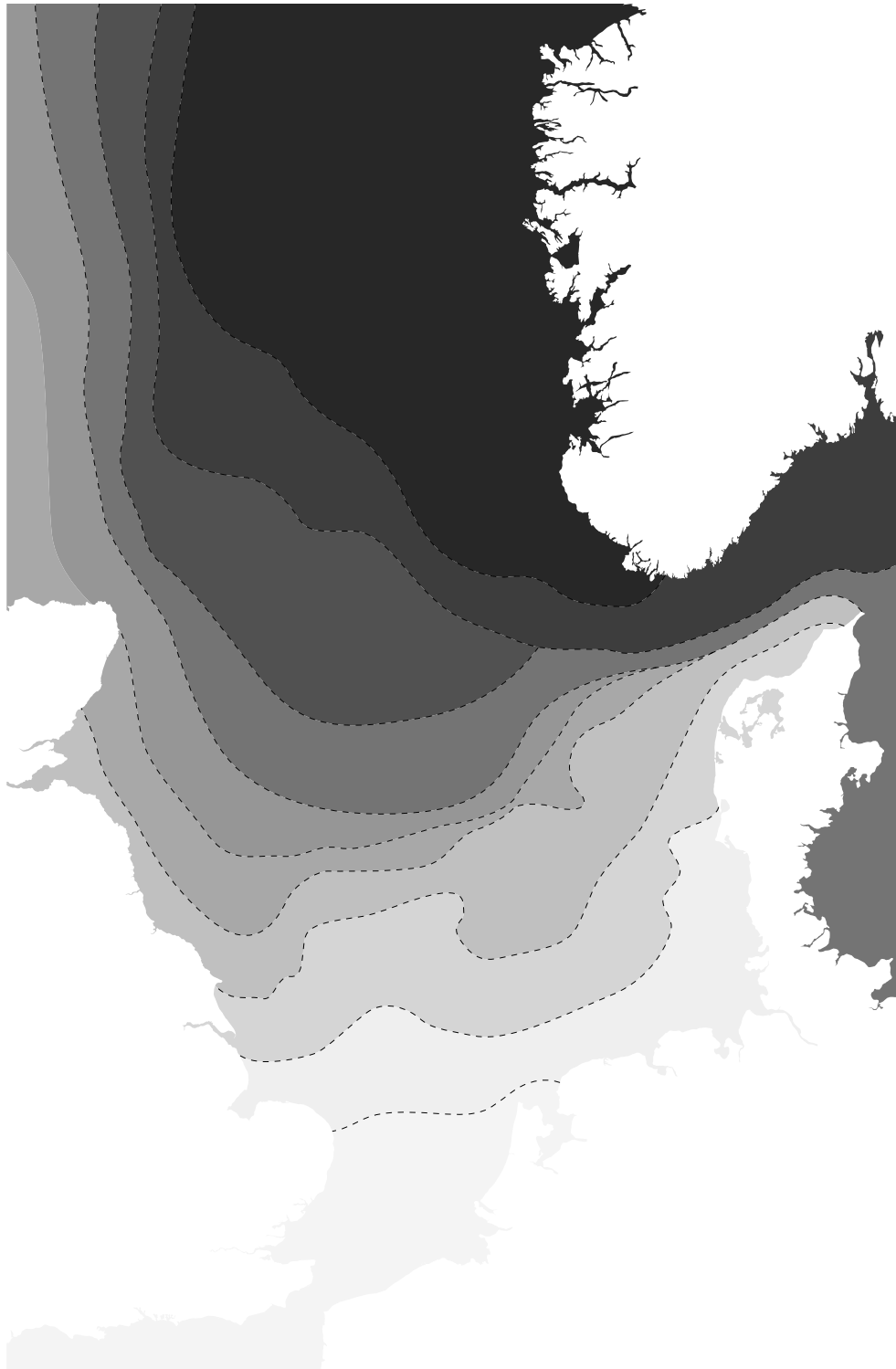


fig. 30. - North Sea temperature of the sea (bottom, thermocline, surface)

_02.

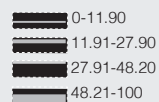
Problem field

7. Disjoint coastlines - accretion vs sedimentation

Bedload transport
Sheerstress current

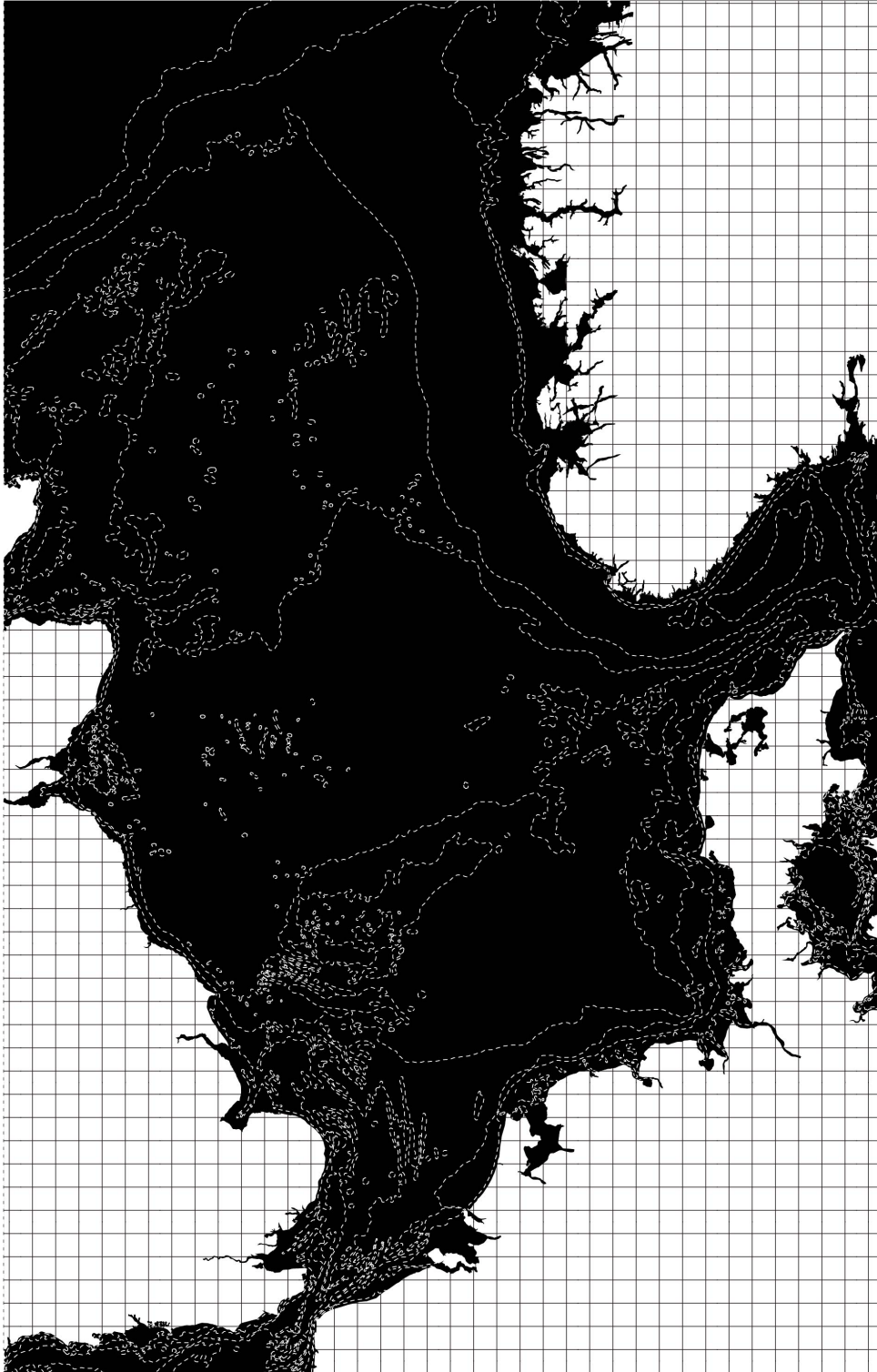
Northern bank of Thames Estuary as accretion site

Map showing the frequency of bedload transport events in the North Sea in 2006. Values are a function of median grain size and model estimates of current and wave-induced bed shear stress. The data were calculated to provide information on sediment mobility, resuspension and transport for habitat mapping and biogeochemical modelling.



Spatial distribution of the bed shear stress in the North Sea as induced by currents for the year 2006. Data represent annual average values calculated from hourly current data produced with the TRIM model. Bed shear-stress is an important quantity for sediment transport and has a potential effect on benthic faunal distributions.





0km 100km 200km

N

fig. 31. - North Sea as accretion site

Problem field

7. Disjoint coastlines - accretion vs sedimentation







Aggregated sedimentation

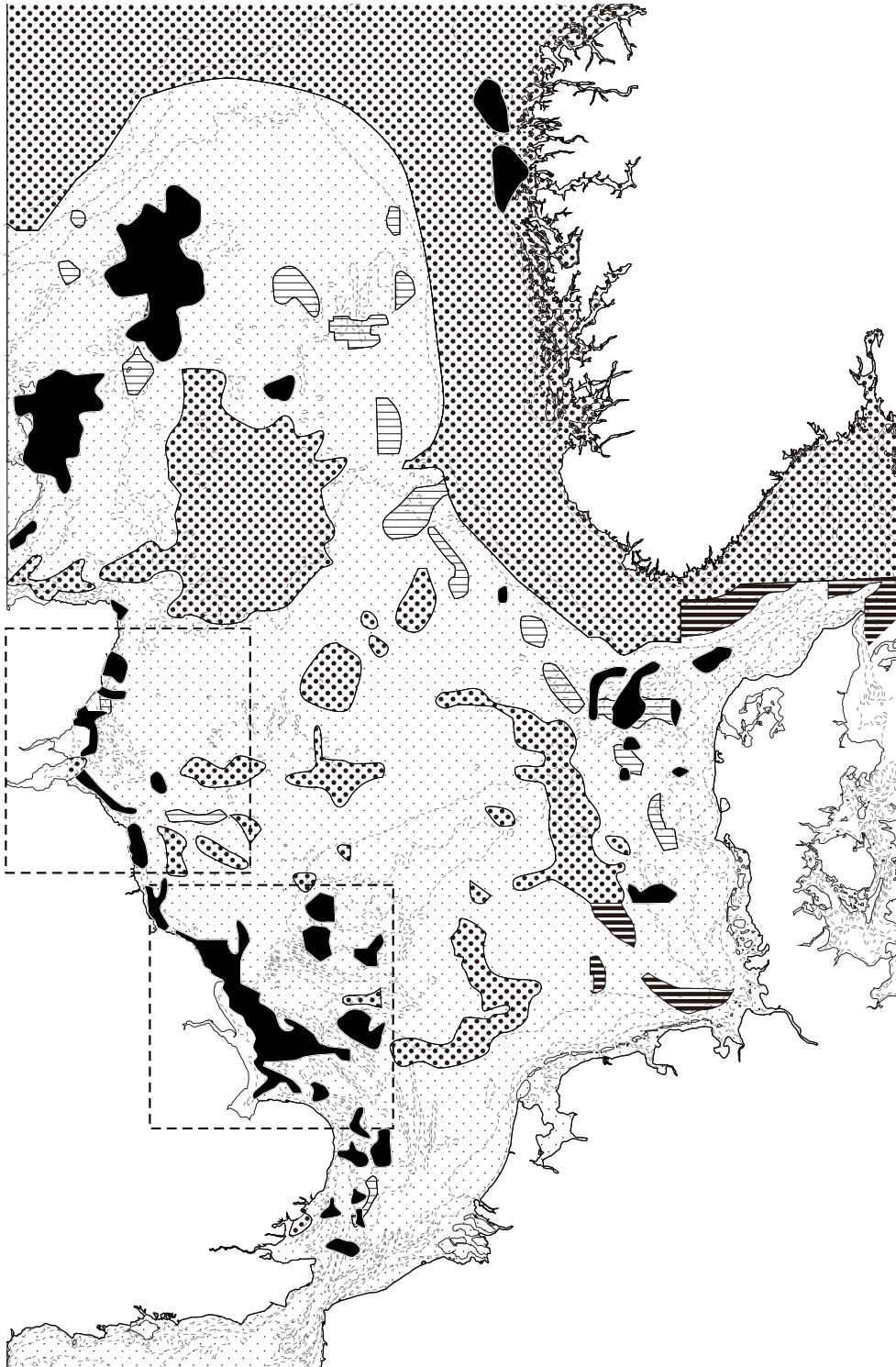
Argilous and low infiltration levels concentrated on the Thames Estuary

The map shows the aggregated sedimentation in the bottom of North Sea. In the sea bottom around the UK's coastline, the main sedimentation is formed by stones, and the sedimentation in the sea bottom around the Dutch and Germany coastline is sand, as well the mud sedimentation around the Norway coastline. Compared with the bedload transport activity, we see that the sea bottom around the British coastline will be strongly effected by bedload transport, leading to instability of the coastal conditions.

Source

Dutch Continental Shelf (RGD,1986); German Bight (Figger, 1981)
Denmark (GEUS, 1992); Dogger Bank (BGS, 1977-1993)
Oyster Ground (BGS,1977-1993)

-  Sand
-  Mud
-  Sandy gravel
-  Muddy sand
-  Stones
-  Area which will be effected by bedload transport



0km | 100km | 200km

fig 24. Precipitation

N

fig. 32. - North Sea aggregated sedimentation

Problem field

7. Disjoint coastlines - accretion vs sedimentation

Coastal exchange - River discharges

Patterns of sediment flow that facilitate coastal realignment

The character of the southeastern edge of the North Sea is dictated by the interplay of ocean, riverine and delta processes. Of sediment erosion, movement and deposition along the coast and that brought by the rivers. These river processes also alter the salinity and nutrient composition of this quarter of the North Sea stimulating the growth of algae (seaweed) species that, when blooming, de oxygenates the ocean and potentially alters habitation patterns of the fish.

Numerous rivers flow into the North Sea from the European Continent and the United Kingdom. The most important are the Scheldt, Rhine, Meuse, Eems, Weser, Elbe, Humber and Thames.

The map shows the distribution of the water of the major continental rivers on a time scale of about one year. The size of these areas is related to the volume of the river water discharged. The map shows clearly that river water does not spread equally over the whole of the North Sea, but remains in the vicinity of the coast. This is because the river water is carried away by the tides before it has thoroughly mixed with seawater.

source: North Sea Atlas for Netherlands Policy and Management

- ⚡ Key biodiversity areas
- + Key ports
- Bedload (sediment) transport
- ≡ Nutrification problem

Sources:
NOAH Habitat Atlas, <http://www.noah-project.de/>
World database of Key Biodiversity Areas, <http://www.keybiodiversityareas.org/home>
The Seas project, <http://theseasproject.weebly.com/north-sea.html>

- Humber
- ▣ Thames
- ▤ Rhine/Meuse
- ▥ Lake IJssel, Rhine/Meuse
- ▦ Eems, Rhine/Meuse
- ▧ Weser, Rhine/Meuse
- ▨ Elber, Rhine/Meuse
- ▩ Weser, Elber, Rhine/Meuse

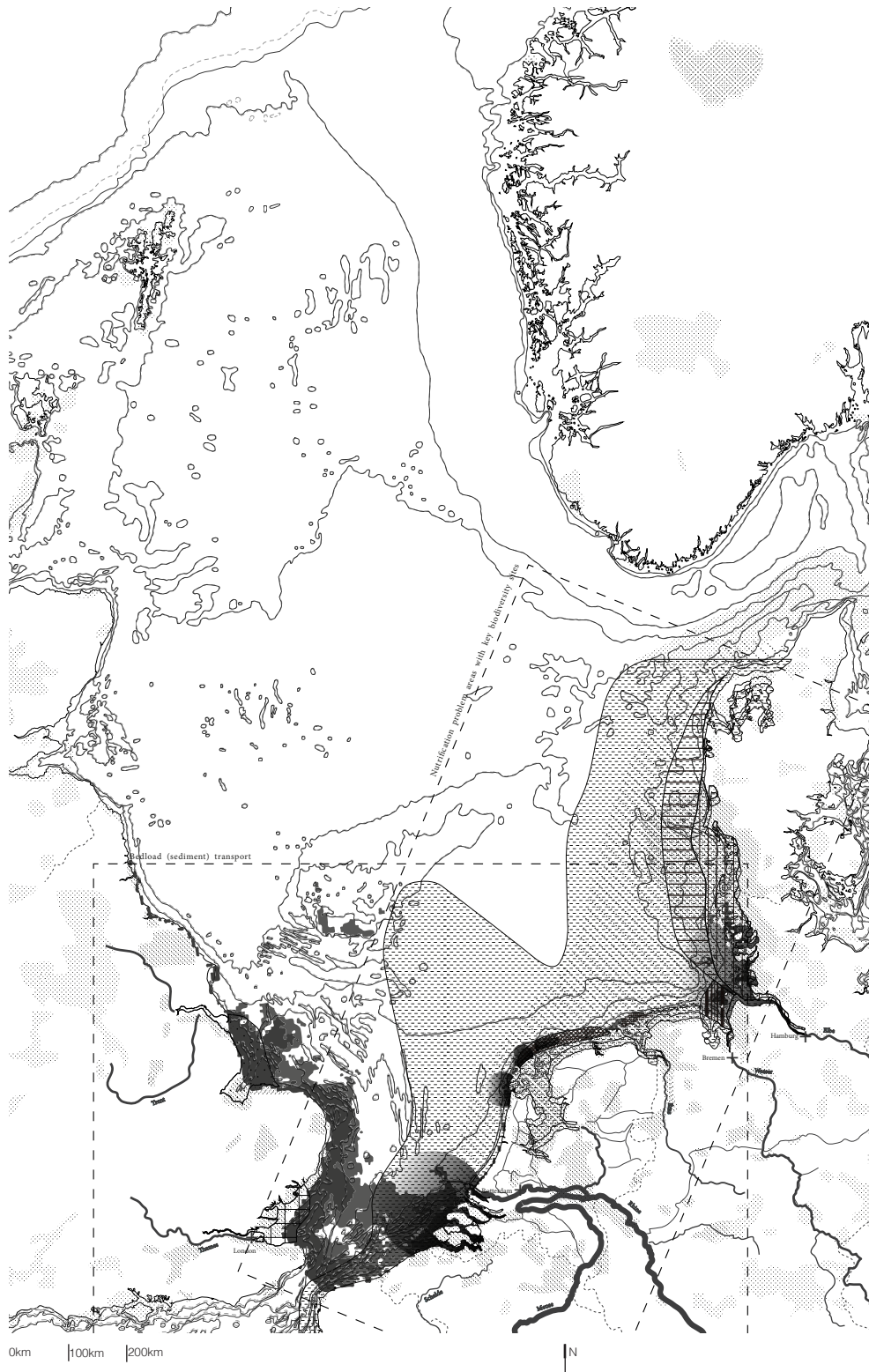


fig. 33. - North Sea river discharge

_02.

Problem field

7. Disjoint coastlines - accretion vs sedimentation

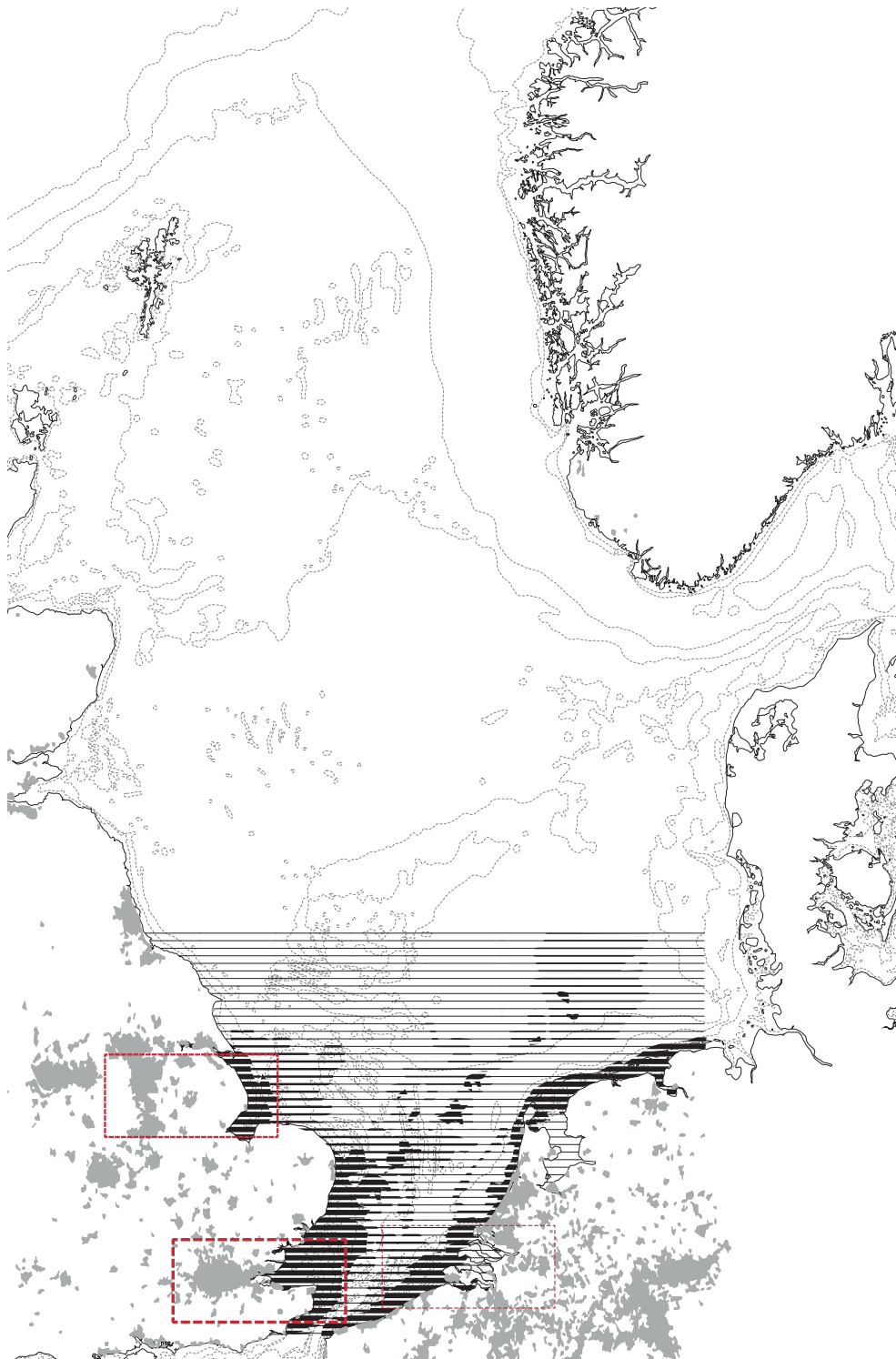
Spring-neap suspended particulate material

Patterns of dynamic flows that facilitate coastal realignment

This map shows the spring-neap suspended particulate material (SPM) cycle and highlights the important role played by tides in the surface distribution of SPM near UK in North Sea.

source: North Sea Atlas for Netherlands Policy and Management





0km 100km 200km fig 24. Precipitation

fig. 34. - North Sea spring-neap suspended particulate material

Problem field

7. Disjoint coastlines - accretion vs sedimentation

Coastline bedrock and management

Coastal erosion

The coastal erosion is affected by both sea and land, the bedrock geology influence the coastal erosion rate, the England coastline is mainly made up by soft rocks, which are eroded faster than hard rocks, and might put the coastal cities in danger. The most vulnerable area are is the coastline between Thames River and Humber River.

England take actions on coastal protection, the map shows its sea defending projects. Comparing the decision layer with the nature vulnerable area, the areas are overlapping, but there are still some gaps.




The coastline type as a collective product of nature and human, could be mainly categorized into 2 types, sandy coastline and rocky coastline, for the rocky coastline, the main problem is erosion, for sandy coastline, it is mainly about sediment deposition. The highlighted 3 estuary areas have the same characteristics, where the sandy coastline is located mainly at the north of the river and the rocky coastline is the opposite.

Bedrock source: BGS











<http://www.bgs.ac.uk/data/mapViewers/home.html?src=topNav>

Sea defending system: GOV.UK

Coastline source: JNCC

 sea cliffs
 saltmarsh
 Dunes, shingle and machair

.... No active intervention
 — Hold the (existing defence) line
 — Managed realignment
 — information not currently available
 Advance the line

 thick sandstones, siltstones, mudstones
 Chalk with flints
 Silty clay/mudstone, sandy silts and sandy clay
 neogene to quaternary rock--gravel, sand, silt and clay
 west walton, ampthill clay and kimmeridge clay
 mudstone, siltstone, limestone and sandstone
 permian rocks-- mudstone, siltstone, limestone and sandstone
 thicker coal(up)+ mudstones(lower)
 rocks(Silurian — Devonian Period)
 Sandstone, partly pebbly; subordinate siltstone and mudstone

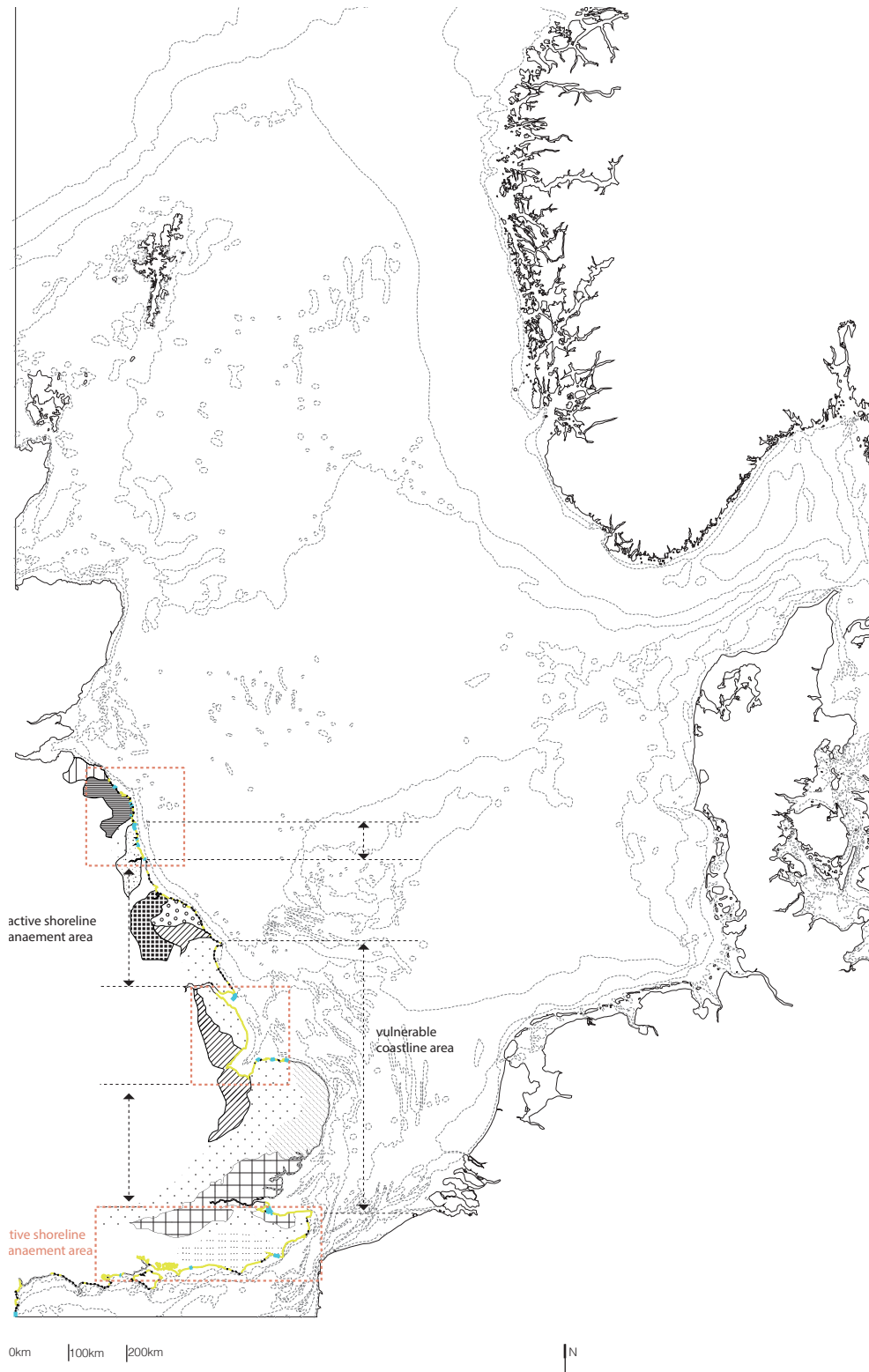


fig. 35. - North Sea coastal conditions

Problem field - the estuarine condition

8. Tidal force as main driver of change in managed realignment strategies

The role of tidal exchange and longshore movement in intervention location assessment

Coastal areas are currently under the influence of “coastal squeeze” – the applied pressure from inland – urbanization, recreation, food production and the externalities – climate change, storm danger, relative sea level. The most prone areas for these forces to interact is on the river discharge of estuarine and deltaic territories, specifically applied to downstream and mid-stream areas.

Delta is a territory of confluence of a river, creek or stream with a larger waterscape (Meyer and Nijhuis, 2014), while an estuary is a partially enclosed coastal body of brackish water with one or more rivers or streams flowing into it, directly connected to the open sea, both areas being characterized by the complex interaction of dynamic natural processes between freshwater discharge and saline water influx - such as river discharge, tidal currents, waves, sediment transport, bedload transport, sheerstress, land manipulation (Bradshaw and Weaver, 1995). The inflows of both sea water and fresh water provide high levels of nutrients both in the water column and in sediment, making estuaries among the most productive natural habitats in the world. There is a strong relation between the formation of these areas and the current endangering processes - flooding of river-eroded or glacially scoured valleys when the sea level began to rise.

fig 36. Water type dualism

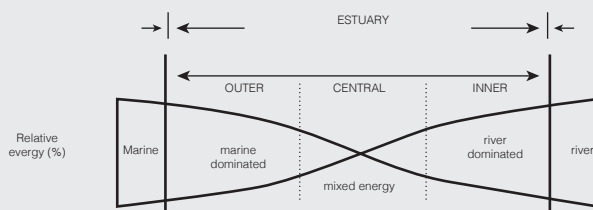
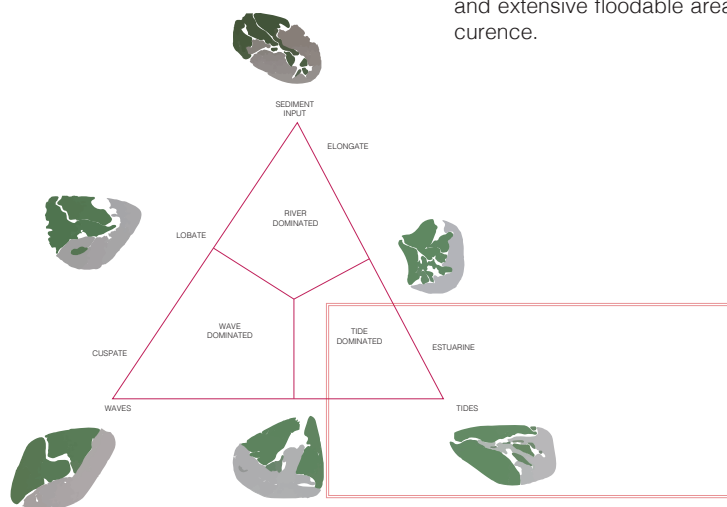


fig. 36 - Representation made by author
based on information from Coastal
dynamics course, TU delft, CIE4305,
Judith Boosboom and Marcel J.F. Stive

Estuarine typologies



The main shaping driver of the Thames Estuary is the tidal current, resulting in shifting mudflats and extensive floodable areas during storm occurrence.

fig 37. Delta typology and formation

Estuarine dynamics

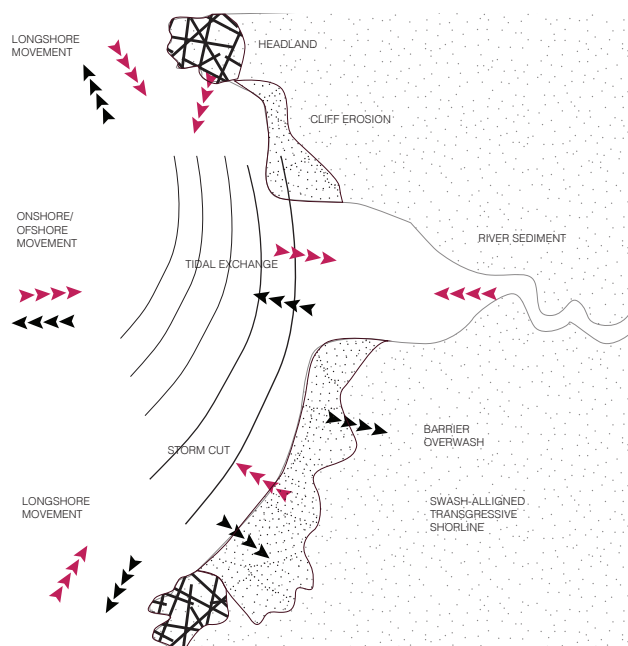


fig 38. Estuarine dynamics and forces

fig. 37-38 - Representation made by author based on information from Coastal dynamics course, TU delft, CIE4305, Judith Boosboom and Marcel J.F. Stive

Problem field - the estuarine condition

8. Tidal force as main driver of change in managed realignment strategies

The role of accretion and erosion in estuarine formation



United Kingdom - Thames estuary coastal typologies and sedimentation pattern

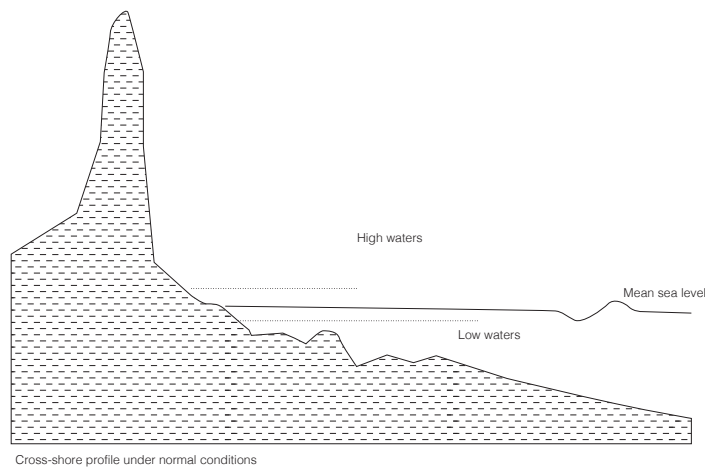


fig 39. Coastal changes in estuarine territories

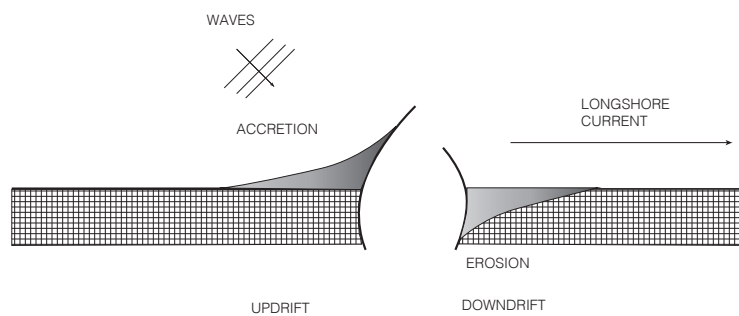


fig 40. Coastal changes in estuarine territories-
accretion | erosion

COASTAL CHANGES OCCUR IN THE CASE OF TRANSPORT GRADIENTS - UNIFORM SANDY
COAST WITH PORT BREAKWATERS

SOLUTION : sandy by-pass system

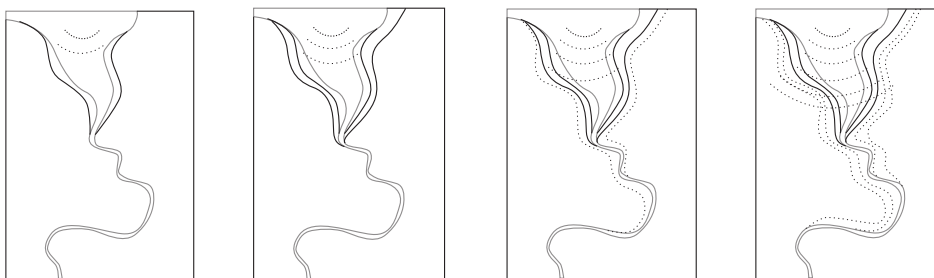


fig 41. Estuarine formation, mouth widening

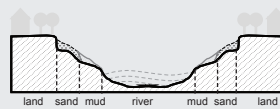
fig. 39-41 - Representation made by author
based on information from Coastal dynamics
course, TU delft, CIE4305, Judith Boosboom
and Marcel J.F. Stive

Problem field - the estuarine condition

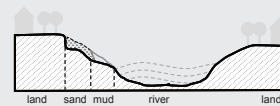
8. Tidal force as main driver of change in managed realignment strategies

The role of accretion and erosion in estuarine formation

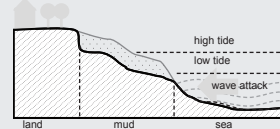
SECTION TYPE 5: Symmetry riverbed
land-sand-mud-river-mud-sand-land



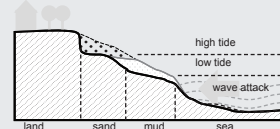
SECTION TYPE 6: Asymmetry riverbed
land-sand-mud-river-land



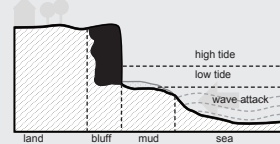
SECTION TYPE 4: land- mud-sea



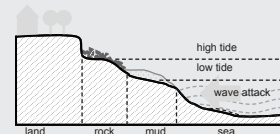
SECTION TYPE 3: land- sand-mud-sea



SECTION TYPE 2: Steep coast(cliff)



SECTION TYPE 1: Rock foreshore



Zoom-in of Coastline in Thames Estuary (1920)

Then we zoom into the coastline on Thames Estuary to see the dynamics between the land and water as well as the typologies of coastlines around the Thames Estuary. Due to the Coriolis force, the river water from Thames will slightly turn to its right side of its forward direction, therefore the sedimentation will more easily happen on the left side of forward direction of river water. That is why the north riversides have more sandbanks and mudflats than south side. We can see the north riversides are more stable than the south sides.

And there are six types of coastline in the map, shown on the tracing paper. According to the analysis above, we can define the areas which are shaped by both river and sea, and the type 1 and type 2 are more easily eroded by this correlative force.

Source: Historical map produced by Edward Stanford, 1920.

Basemap

- Sand
- Sandbanks>-3m
- - - Sandbanks:-3 to-6
- Mudflat
- Sandbank
- ▣ Land

Typology of coastlines

- TYPE 1 Rock foreshore
- TYPE 2 Steep coast (bluff/cliff)
- TYPE 3 Land-Sand-Mud-Sea
- TYPE 4 Land-Mud-Sea
- TYPE 5/6 Riverbed(Symmetry/Asymmetry)
- Areas shaped by both river and sea

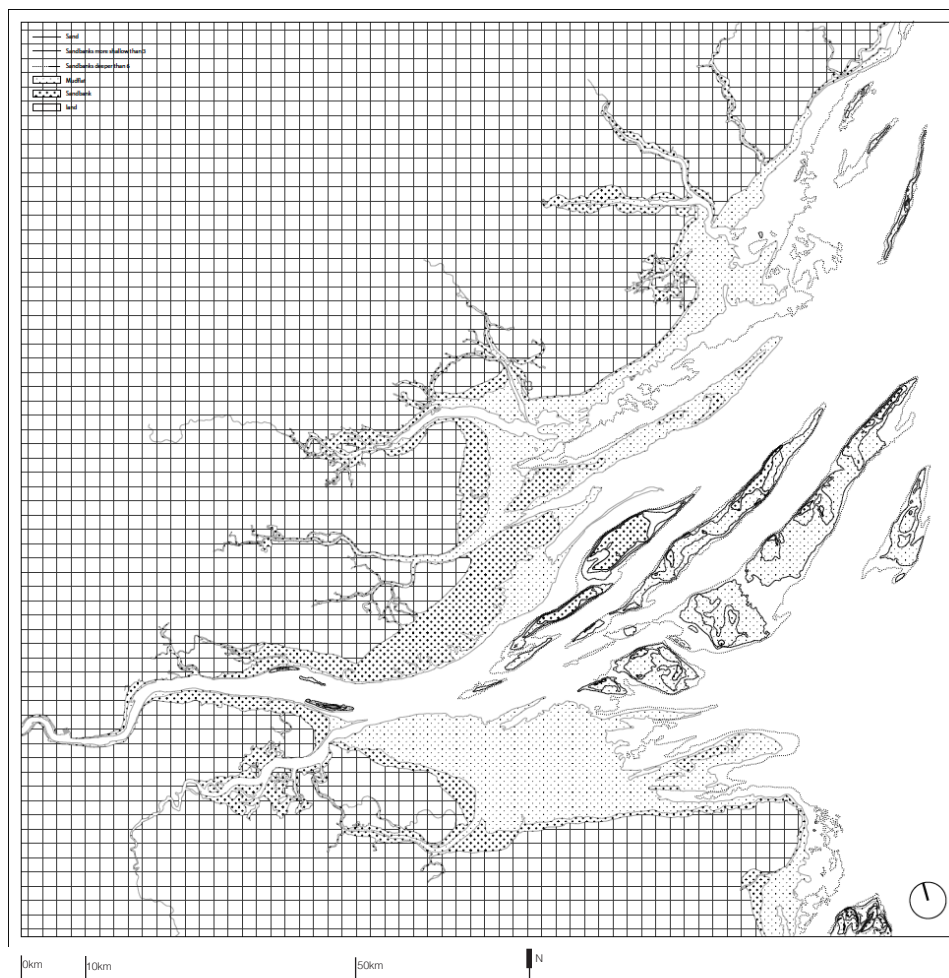


fig. 42 - Thames Estuary conditions,
Representation made by author

fig 42. Sediment pattern and navigational dredging and coastline typologies

Problem field - the estuarine condition

8. Tidal force as main driver of change in managed realignment strategies

The impact of The River Thames over North Sea waters



fig.43. Risk/ development paradox

Estuarine typologies - UK case

The banks of many estuaries are amongst the most heavily urbanized areas on a global scale. Urbanization and the strategic location that the water entity projects in relation to the global market have consequently led to a high concentration of the world's biggest cities (Nicholls, 1995) , and a considerable proportion of the global gross domestic product (GDP) (Turner et al.,1996) . In a resolute attempt to regain control, intense urbanization lead to intense anthropic activities – destruction of saltmarsh, construction of artificial barriers, storm-breakers which affect the ecologic response of the natural processes reducing the adaptability range and exposing the coastal/estuarine territory to flooding risk, beach erosion, storm surges, saltwater intrusion and siltation (Turner,1996) .

The research studio focuses on the idea of contested territories as the milieu for shaping territorial development. In this context,an important role is plyed by the geomorphological conditions and in the North Sea case, also the hydrodynamic forces, paired with the actual cultural, political and economic forces that drive and synchronize the dynamics of this territories.

The project seeks to explore the possibility of integration between the natural physical conditions and the productive landscape, through the lens of tidal force - seen as a duality of flood risk and power resource. The focus of the thesis lies with the idea of planning that tackles uncertainty, risk and production from the point of view of the tidal forces, looking precisely at the interdependency between city/landscape and power.Thus, the aim is to elaborate a policy for tidal integration specifically addressed to the tidal power resource and it's relation to coastal cities, materializing also design and engineering solutions for local authorities.

fig.43. The 'viral' photo from Whalley, apparently showing floodplain land with Planning Permission... (source unknown) <https://samuellfoxton.wordpress.com/2016/01/13/flood-risk-and-cities/>

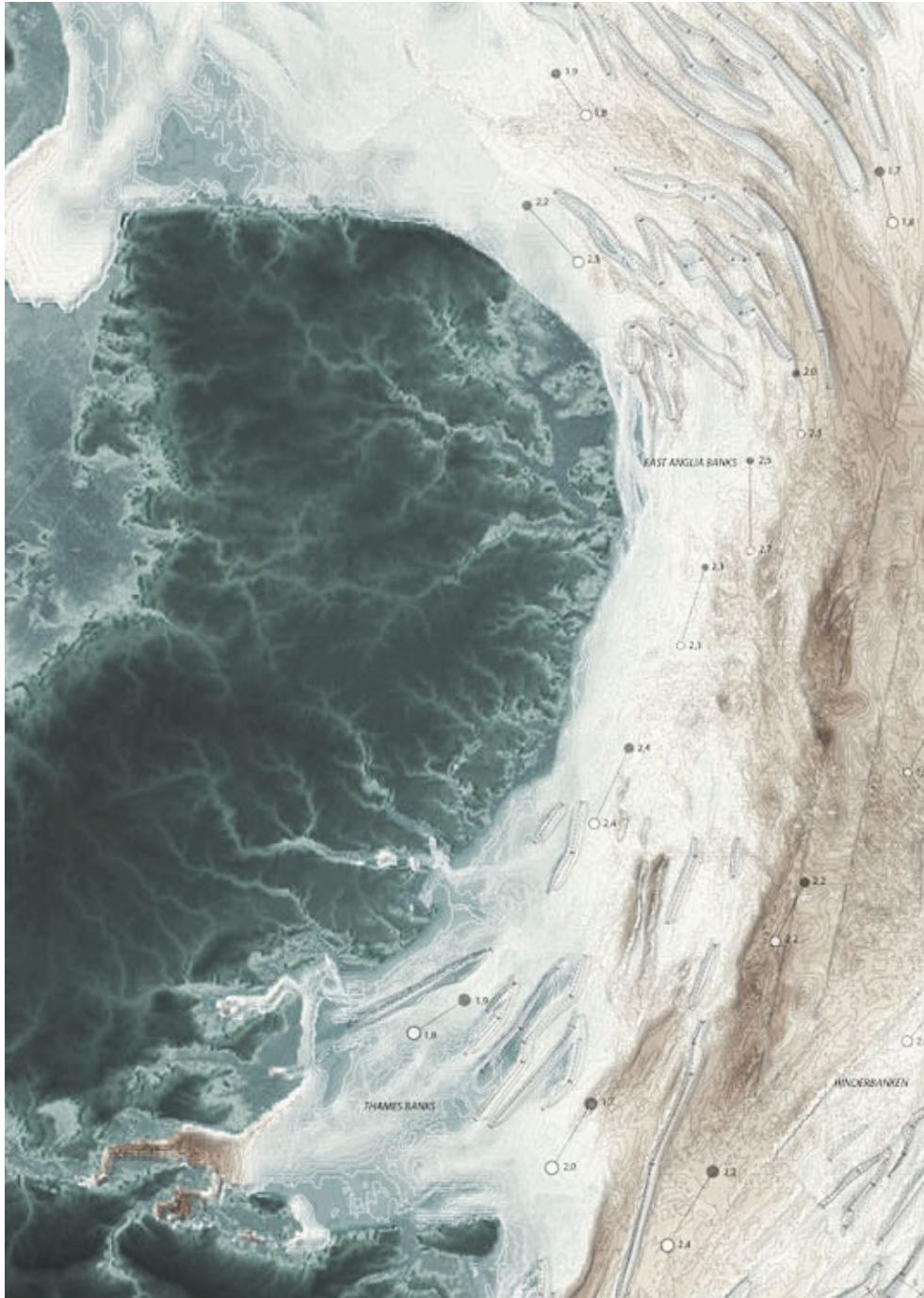


fig 44. Thames estuary plume

fig. 44 - AA school of architecture Atlas, <http://landscapeurbanism.aaschool.ac.uk/aalu/>

0km 10km

50km

N

Fluctuating tidal surge

The Thames Estuary's greatest risk comes from the tidal surge, which, seen from a productive perspective could actually be a resource for power generation. Therefore the hypothesis that arises is the transformation of a risk factor into a basis for economical growth and energetic transition. Therefore, the hydrodynamics power of the Thames Estuary is a trigger for exploring new open-end design solutions for flood defense techniques that would re-qualify the estuarine performance and mitigate risk in the Great London region by harvesting tidal power.

Returning to the origin of tidal power caption, to UK's "tide mills" of the Middle Ages, the same concepts apply today with the only difference being that they did not generate electricity in 1170. Basically, a dam was built to contain the tide when it was high. Once the tide fell, the contained water was directed into a sluice where it pushed a wood water wheel that was then used to turn machinery of varying sorts. Today, the water wheel is replaced with a steel turbine and rather than turn stones to grind grain, the turbine spins a generator to produce electricity. Starting from this practice, quite invasive, through time there have been various exploration for turning tidal currents into energy, some of which can be adapted to a flood defense mechanism, enhancing this way the economical value of the intervention.

fig 47. Tidal currents influenced by estuarine typology

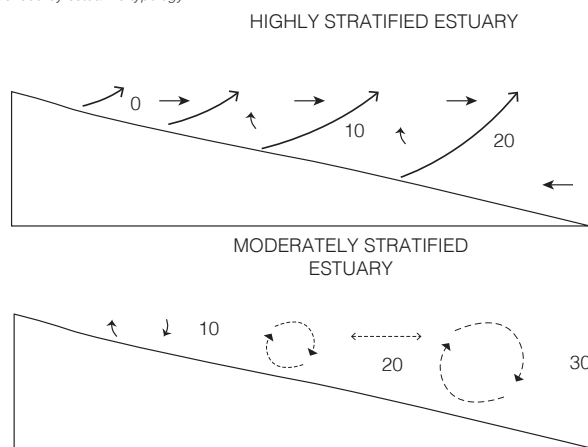


fig 45. Tidal currents influenced by estuarine typology

fig 48. Current patterns - estuarine processes

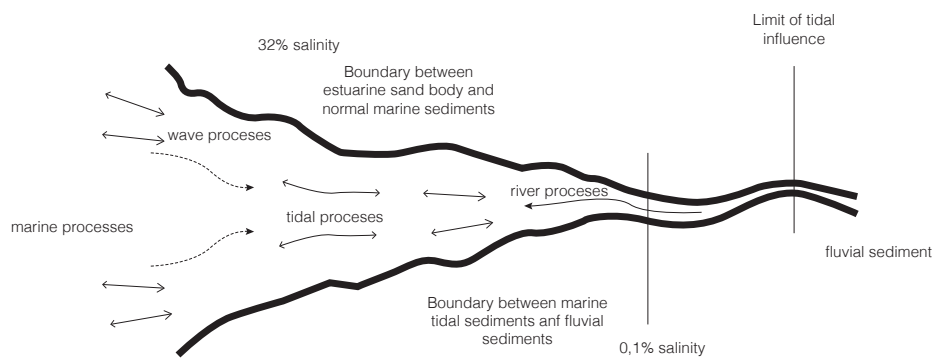


fig 46. Estuarine processes

fig 49. Tidal energy occurrence

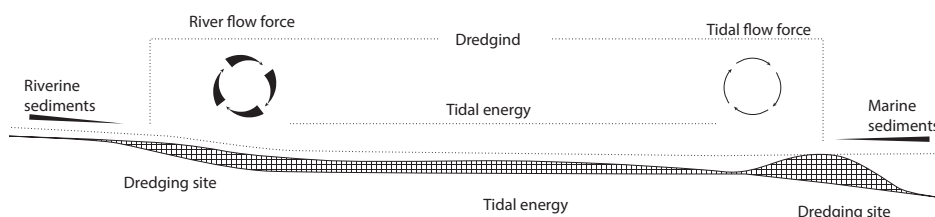


fig 47. Tidal energy occurrence

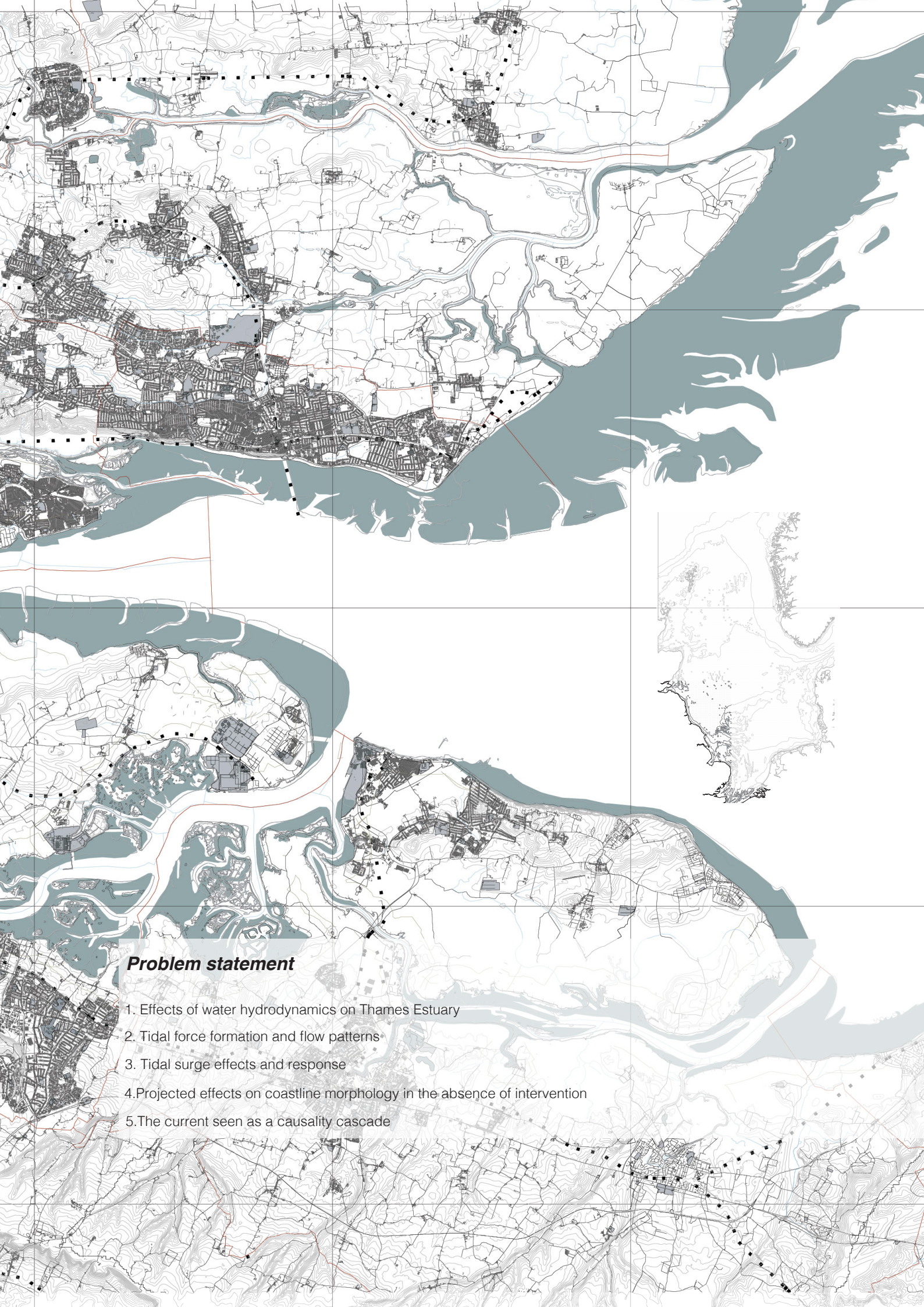
fig. 45-47 - Representation made by author based on information from Coastal dynamics course, TU delft, CIE4305, Judith Boosboom and Marcel J.F. Stive

03.

Problem statement

1. Effects of water hydrodynamics on Thames Estuary

Exploring the hydrodynamic power of the North Sea and revealing tidal energy formation in estuarine territories



Problem statement

1. Effects of water hydrodynamics on Thames Estuary
2. Tidal force formation and flow patterns
3. Tidal surge effects and response
4. Projected effects on coastline morphology in the absence of intervention
5. The current seen as a causality cascade

_03.

Problem statement - the estuarine condition**2. Tidal force formation and flow patterns**

Tidal surge occurrence



fig 50 Tidal surge path

fig. 50-52 -Extract from Thames Vision 2100, <https://www.gov.uk/government/publications/thames-river-basin-management-plan>

fig 38 - <https://www.eea.europa.eu/data-and-maps/indicators/storms-and-storm-surges-in-europe-1/assessment-1>

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Aerial footage: Thames bursts its banks flooding thousands of homes

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Thames Flooding: Cars and people trapped by rising waters after river bursts its banks

HANNAH AL-OTHMAN | Monday 11 April 2016 19:48 | 2 comments

**EXPRESS** Home of the Daily and Sunday Express

Uh oh! Cars swamped as Thames bursts its banks in West London

ROWS of cars were left flooded after the River Thames burst its banks in London today.

Based on the current movement pattern explored on the North Sea scale, in case of storm surge, the epicentre of the storm forms in the Atlantic Ocean and it is pushed along the British coastline towards the Strait of Dover. However, due to the shape of the coastline and the natural evolution of the Thames Estuary, most of the effects are being redirected towards London as a result of the Thames Estuary's funnel channeling of forces.

Recent data shows that, against the efficiency of The Tidal Barrier and the stormwalls along the River Thames, London still gets partially flooded due to tidal surge.

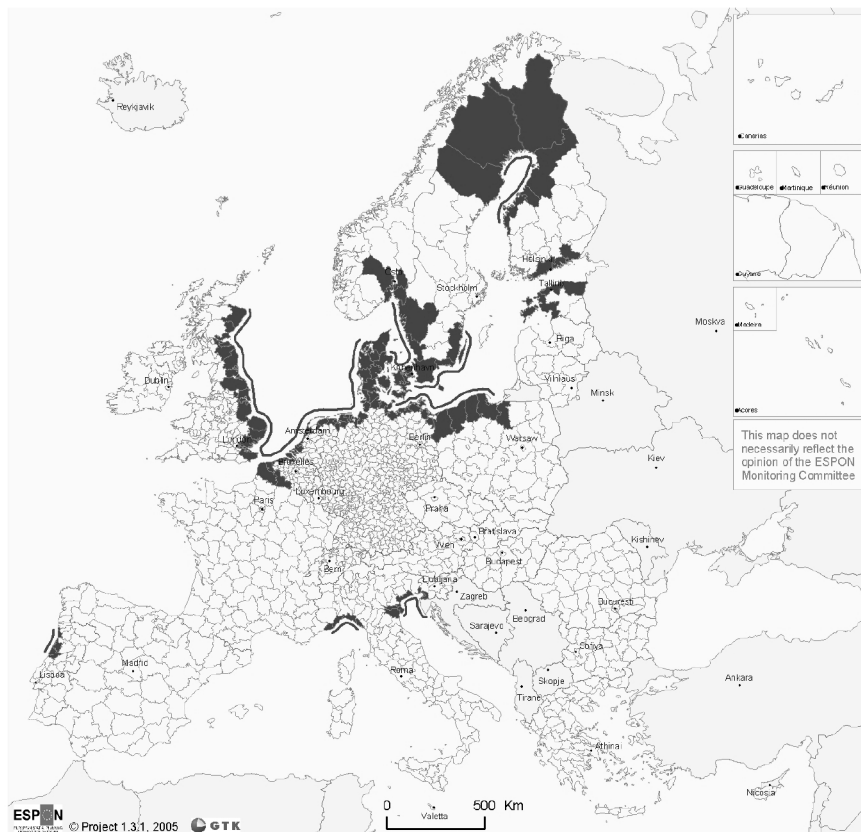


fig 51. Coastal territories at risk from tidal surge

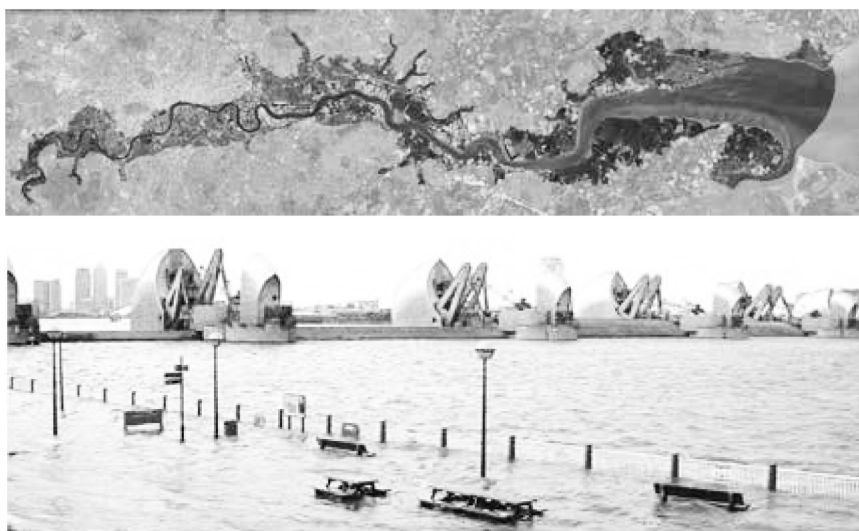


fig 52. Tidal surge effects on Thames Estuary

Problem statement - the estuarine condition

2. Tidal force formation and flow patterns

Tidal surge occurrence

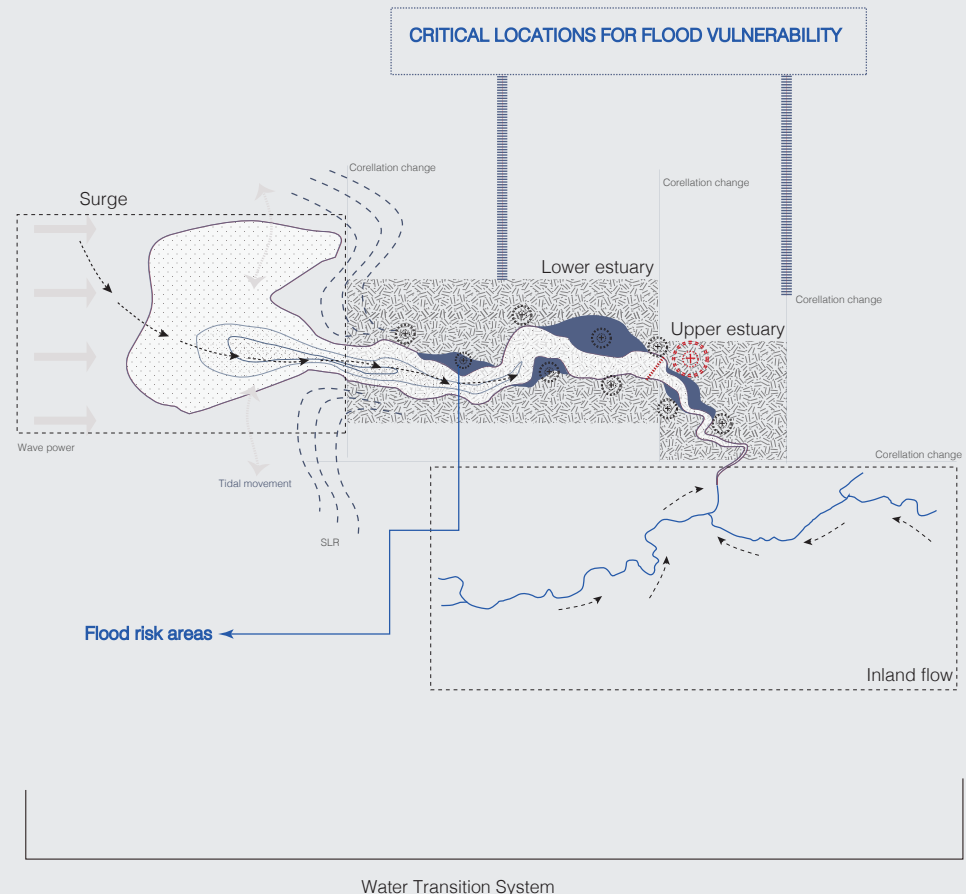


fig 53. Lower estuary water dualism

NUMBER OF TIMES THAMES BARRIER CLOSED

1980S - 4 TIMES
1990S - 35 TIMES
2000 - 75 TIMES
>2010 - 65 TIMES

Analyzing the flood risk areas, the most prone areas for bank overflowing are the lower and upper estuary territories, as they represent the confluence between fresh and marine water, this storm and tidal surge converge. This flooding principle, specifically applied on the Thames Estuary is most evident on the Thames Catchment as the banks become narrow and impermeable, resulting in local flooding. Current protection strategies revolve around hard infrastructure intervention and the uptime response of their functioning, however, they require intensive maintenance and have a limited time span.

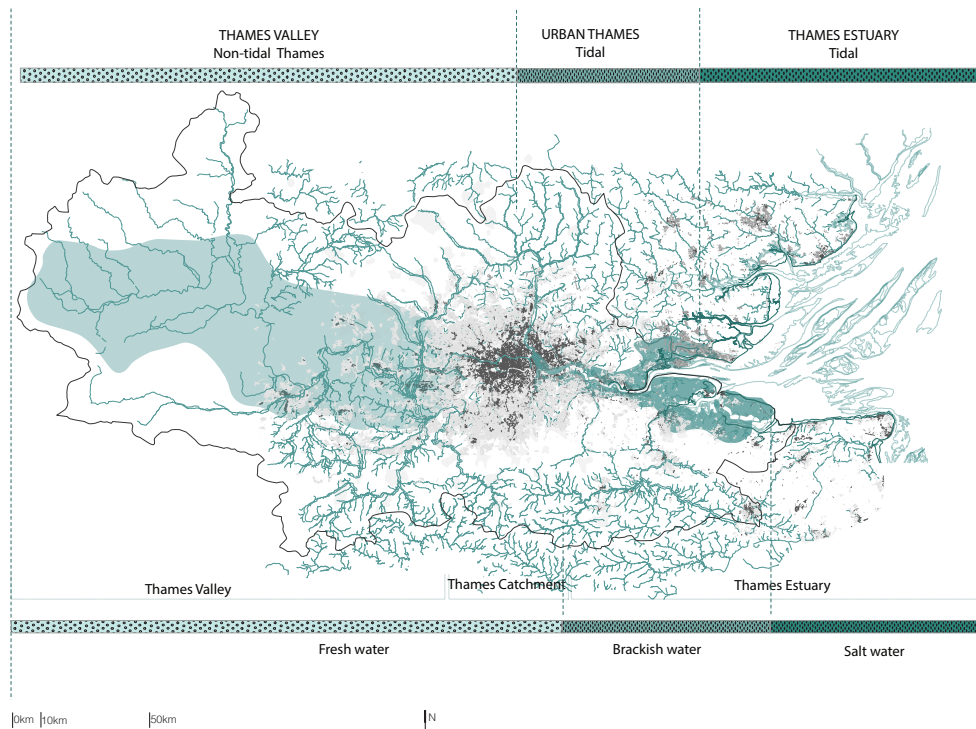


fig 54. Thames estuary saline, freshwater distribution

The main engineering protective structure is the Thames Barrier that came as a consequence of the great Thames flood of 1928 that affected London, hence in the context of the new climate change projection and energy transition challenges new hybrid protective and adaptive infrastructures have to be explored. When the Thames Barrier was being designed in the 1970s, global average sea levels were rising at about 1.8 millimetres a year and global warming was not seen as a threat, but in the past 15 years the rate has nearly doubled to about 3.1mm a year and many scientists expect it to accelerate still further. The Thames barrier is therefore limited in protective capacity.

fig.54 - representation by author , fig 41

-Representation by author from Farrels architects

_03.

Problem statement - the estuarine condition

3. Tidal surge effects and response

Current and projective protection against flooding

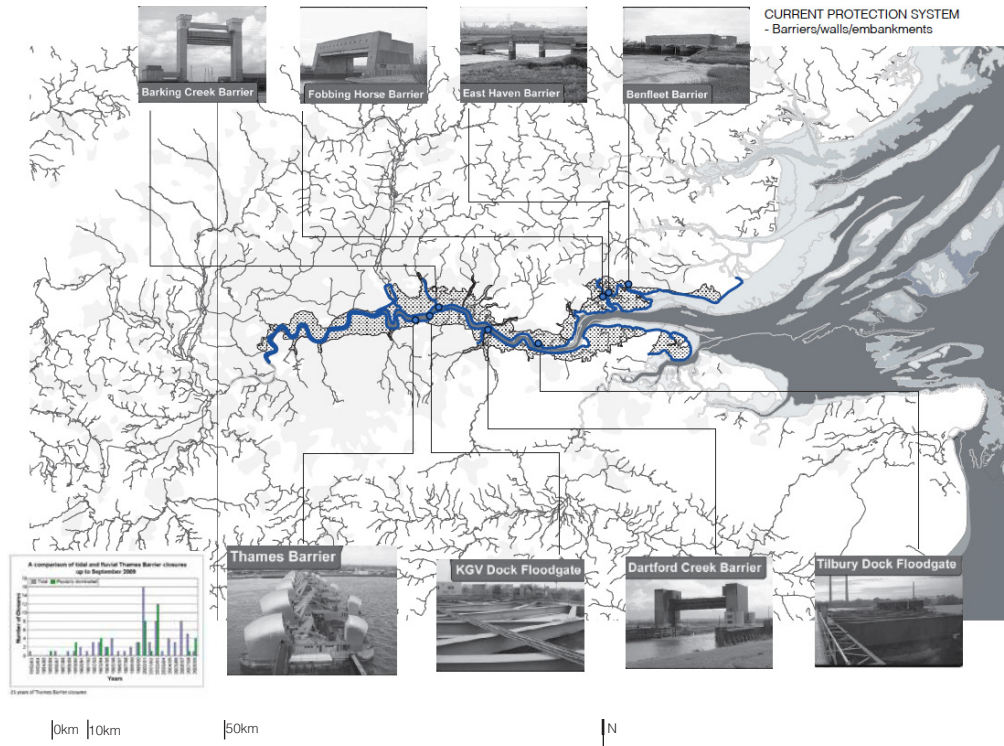


fig 55. Existing barriers and seawalls for flood protection

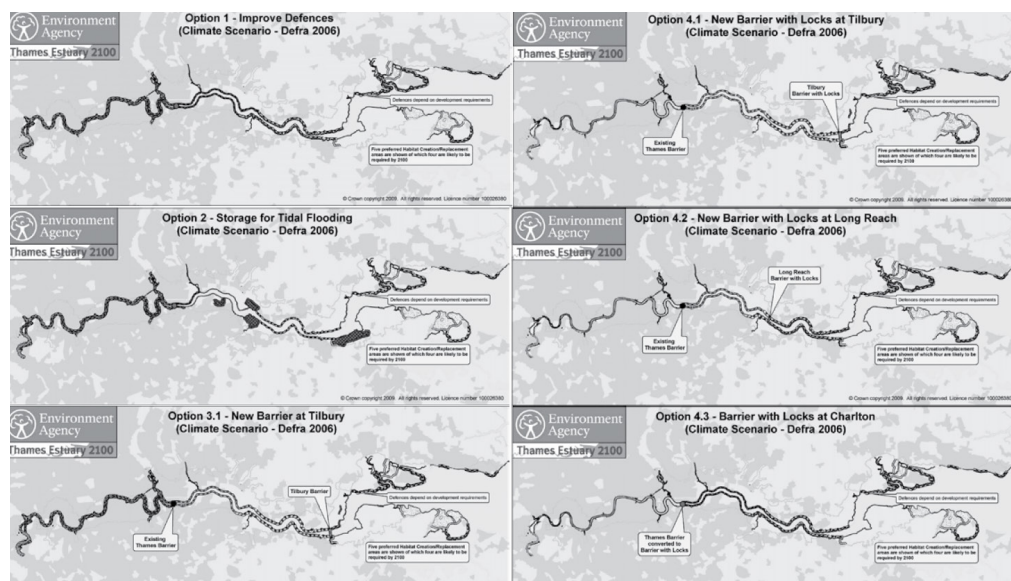


fig 56. 2100 Thames Strategy

fig. 55-56 -Extract from Thames Vision 2100, <https://www.gov.uk/government/publications/thames-river-basin-management-plan>

_03.

Problem statement- the estuarine condition

11. Tidal surge effects and impact

Critical infrastructure at risk due to tidal surge

Table 2.1 Assets and people at risk in the tidal Thames floodplain

350 sq km land area
55 sq km designated habitat sites
1.25 million residents (plus commuters, tourists and other visitors)
Over 500,000 homes
40,000 commercial and industrial properties
£200 billion current property value
Key Government buildings
over 3100 hectares of sensitive heritage sites
400 schools
16 hospitals
8 Power stations
More than 1000 electricity substations
4 World Heritage sites
Art galleries and historic buildings
167 km of railway
35 Tube stations
51 Rail stations (25 mainline, 25 DLR, 1 international)
Over 300 km of Roads

Critical infrastructure networks

'Those critical elements of national infrastructure (facilities, systems, sites, property, information, people, networks and processes), the loss or compromise of which would result in major detrimental impact on the availability, delivery or integrity of essential services, leading to severe economic or social consequences or to loss of life.' - The definition given by the UK Government for critical infrastructures in normal times. However, in times of risk, the consequences it can have on urban life are much greater, the quantification and mitigation of it being the subject of this research thesis.

In the UK, there are 13 national infrastructure sectors:

Chemicals, Civil Nuclear Communications, Defence, Emergency Services, Energy, Finance, Food, Government, Health, Space, Transport and Water. Hence, due to the high dependability of every urban function on power, the thesis focuses on the critical energetic infrastructure, as it must be the priority assessment against flood risk in order to ensure the city's ability to respond and deal with hazard.

"NEARLY 5000 SITES OF CRITICAL INFRASTRUCTURE WERE BUILT ON FLOODPLAINS AND MOST HAD LITTLE OR NO PROTECTION" - BBC NEWS

6 LARGE POWER STATIONS ARE LOCATED IN FLOODPLAINS ON THE BANKS OF THE THAMES AND MEDWAY - REPRESENTING MORE THAN 10% OF UK'S TOTAL ENERGY PRODUCTION - BBC NEWS

CRITICAL ENERGETIC INFRASTRUCTURE AT RISK ON THE THAMES ESTUARY
8 POWER STATIONS
MORE THAN 1000 ELECTRICITY SUBSTATIONS

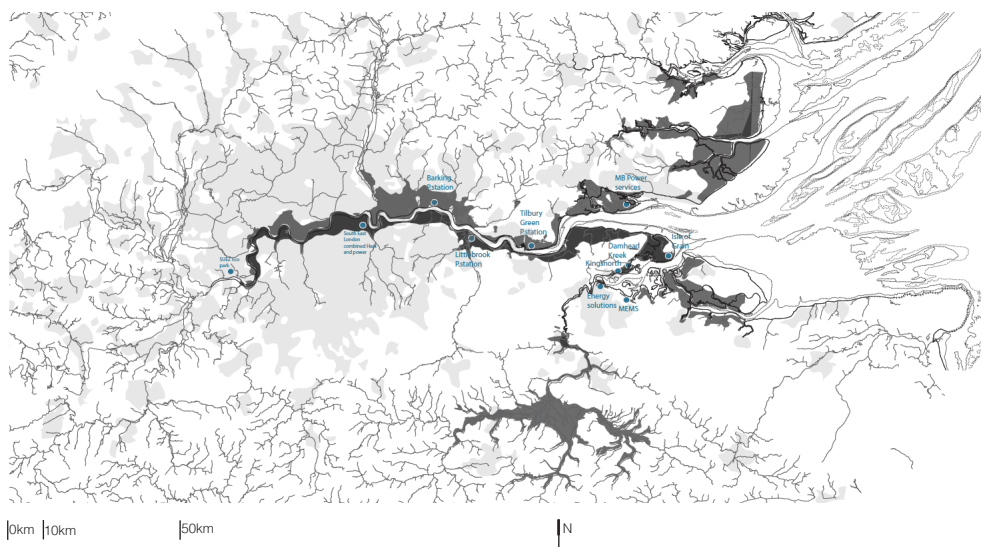


fig. 57-Representation made by author

fig. 57. Energetic system at risk

_03.

Problem statement - the estuarine condition

4. Projected effects on coastline morphology in the absence of intervention

Problem statement trans-scalarity

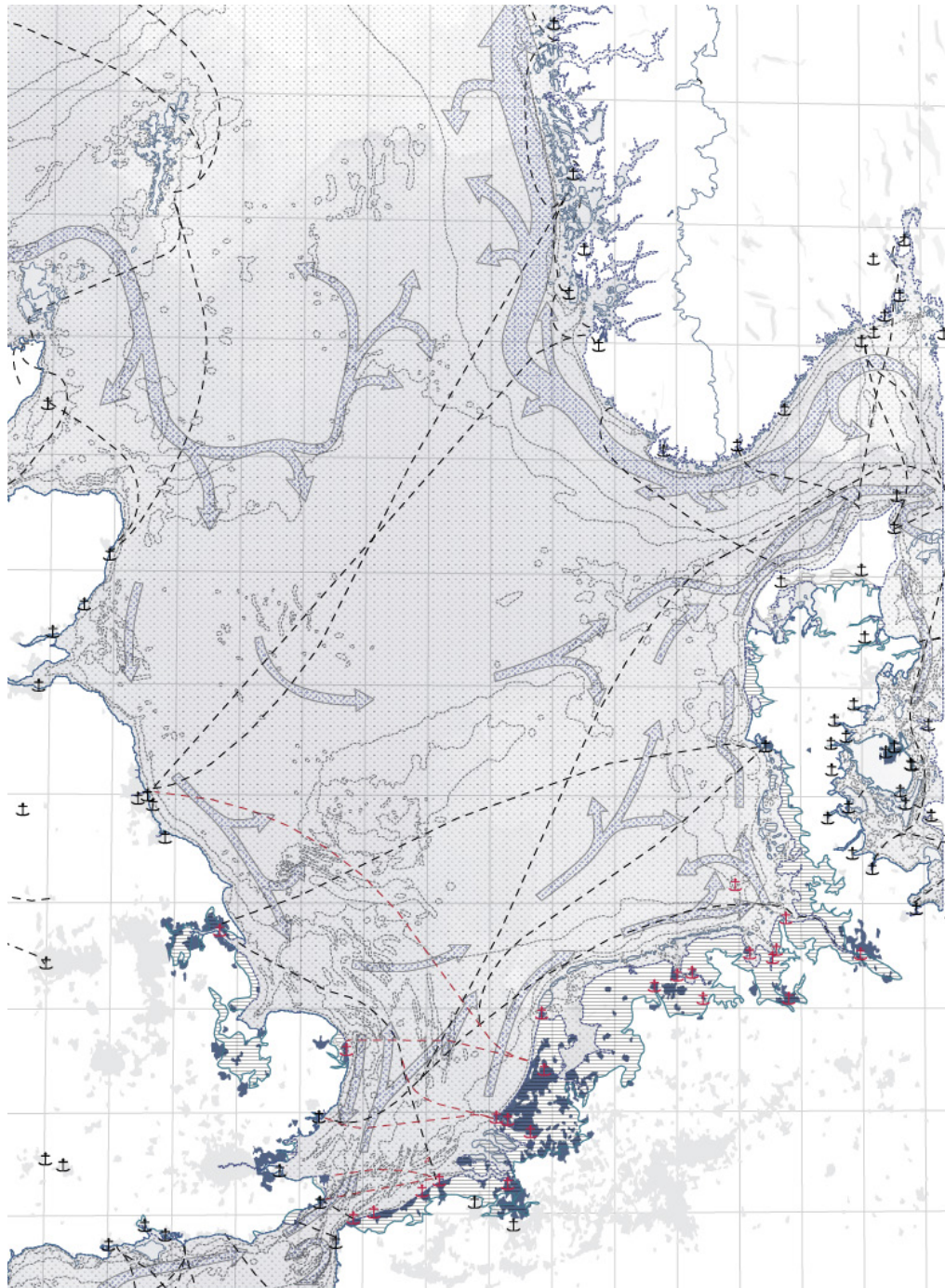


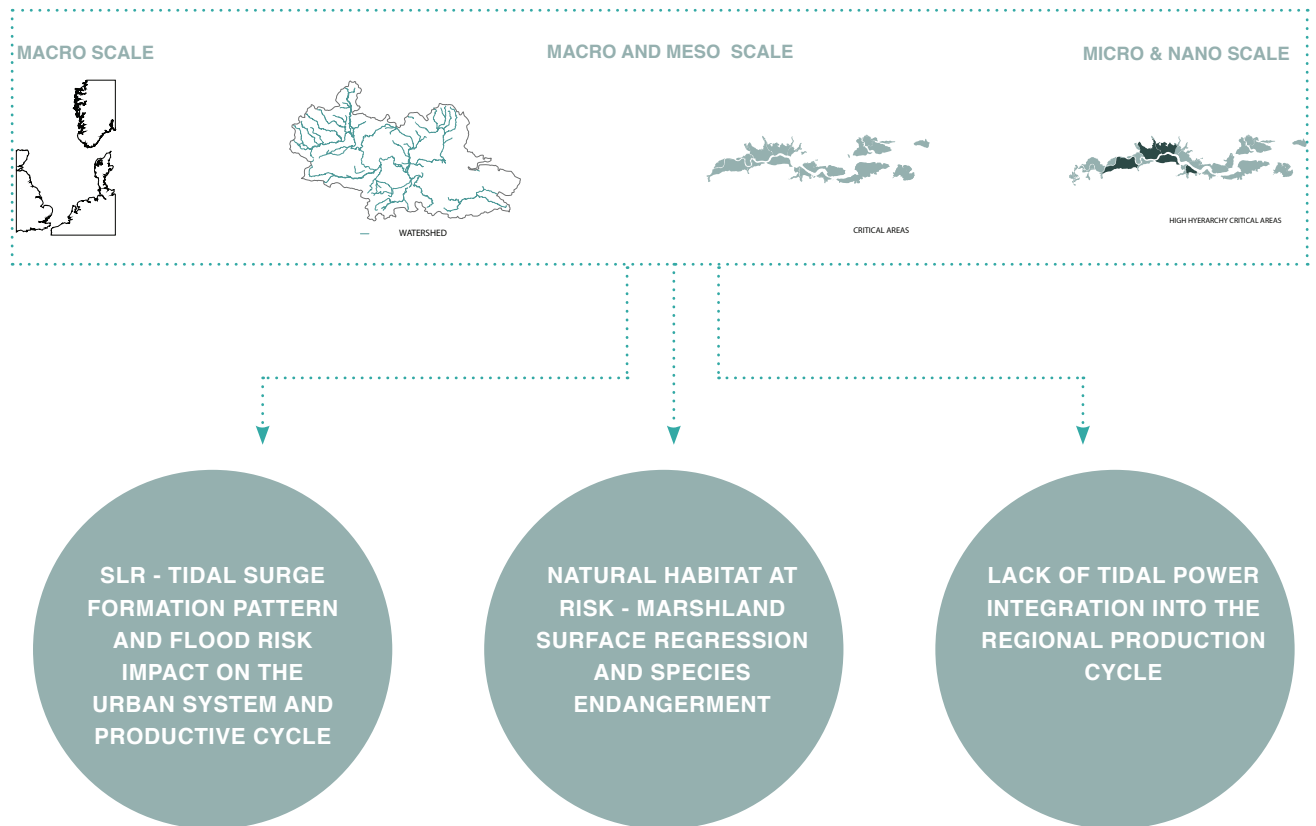
fig 58. New extreme coastline

fig. 58 - Representation made by author

0km | 100km | 200km

fig 24. Precipitation

N



Currently, The UK is working towards interventions that respond to the aforementioned risks enhanced by climate change such as - combination of groundwater withdrawal, surface water division and land-use change (wetland loss and deforestation) (Sahagian, 1994) but has yet to grow apart from the traditional protective measures - irrigation and water impoundment in reservoirs and dams, hence a new vision and capital is essential. Furthermore, an integrated approach between the fields of flood management and the energetic development will lead to alternative multifunctional infrastructure.

fig 59. Problem statement multi-scalar issue

03. **Trans-scalar approach** 5.The current seen as a causality cascade

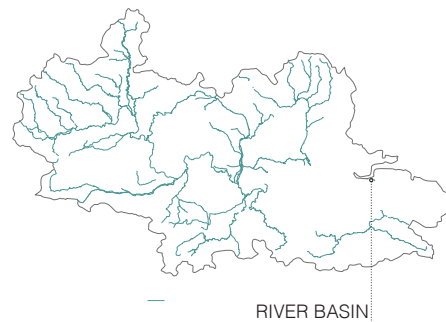
The dynamic shaping forces of the North Sea



fig.60. Hydrology projection image

Local coastal erosion, ecosystem depletion
and storm surge flooding

Responding to the multi-scalarity of the
problem statement and its complexity,
the project is focused on the dialogue
between scales, the conditions that the
context poses on the specific design area,
aiming at constructing a coherent system of
intervention areas.



Hierarchy of affected areas



CRITICAL AREAS

Priority intervention and coastal managed
realignment



PRIORITY CRITICAL
AREAS



AREA BASED
DESIGN

The key location as pilot project

fig.61. Trans-scalar approach

Hypothesis

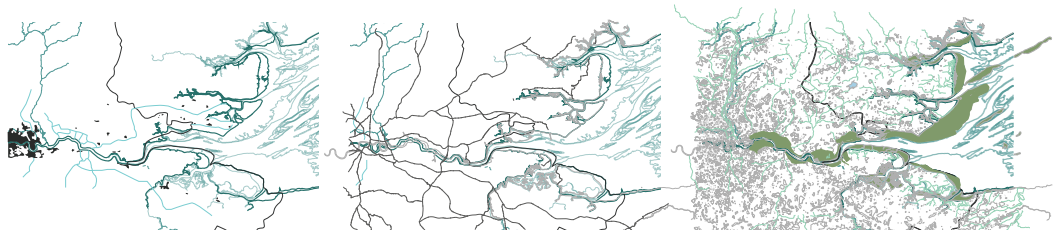
Planning shift - engineered interventions towards flood defense

Rethinking protection

Explore risk factor as potential raw material

Ecosystem depletion and urbanization pressure - reshaping protection

1858-1873



1905-1922

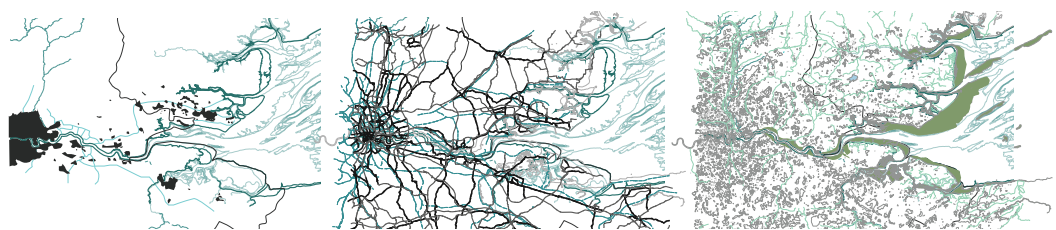


fig. 62. 3x3x3 analysis, Marshland

fig.62

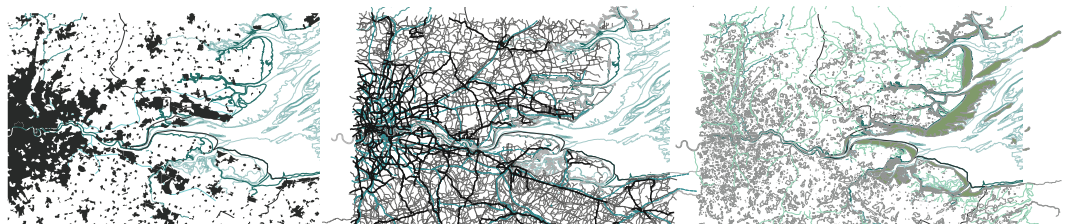
diminish

fig. 62 - Representation made by author
based on data from <http://maps.nls.uk/os/index.html>

Hypothesis

1. The 5 stages of Medieval London
2. Reference project - Space for the river

2000



Hypothesis - the English paradigm shift

1. The 5 stages of Medieval London

From hard to soft interventions towards flood prevention

The hydrodynamics power of the Thames Estuary is a trigger for exploring new open-end design solutions for flood defense techniques that would re-qualify the estuarine performance and mitigate risk in the Great London region.

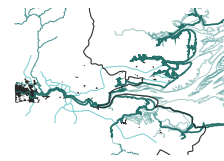
The Thames Estuary's greatest risk comes from the tidal surge, which, seen from a productive perspective could actually be a resource for power generation. Therefore the hypothesis that arises is the transformation of a risk factor into a basis for economical growth and energetic transition. Therefore, the hydrodynamics power of the Thames Estuary is a trigger for exploring new open-end design solutions for flood defense techniques that would re-qualify the estuarine performance and mitigate risk in the Great London region by harvesting tidal power.

Returning to the origin of tidal power caption, to UK's "tide mills" of the Middle Ages, the same concepts apply today with the only difference being that they did not generate electricity in 1170. Basically, a dam was built to contain the tide when it was high. Once the tide fell, the contained water was directed into a sluice where it pushed a wood water wheel that was then used to turn machinery of varying sorts.

Today, the water wheel is replaced with a steel turbine and rather than turn stones to grind grain, the turbine spins a generator to produce electricity. Starting from this practice, quite invasive, through time there have been various exploration for turning tidal currents into energy, some of which can be adapted to a flood defense mechanism, enhancing this way the economical value of the intervention.

fig.61

EXPLORATION



ECONOMY

MIDDLE AGES

18
58

18
91

ROMAN TRADING
ROUTE & PORT

The Great stink

grain/ wine exportation - one
of the busiest trading routes



NATURAL CATASTROPHES

Thames frosting

Great fire of 1666

TIDAL POWER

11
07

17
00s

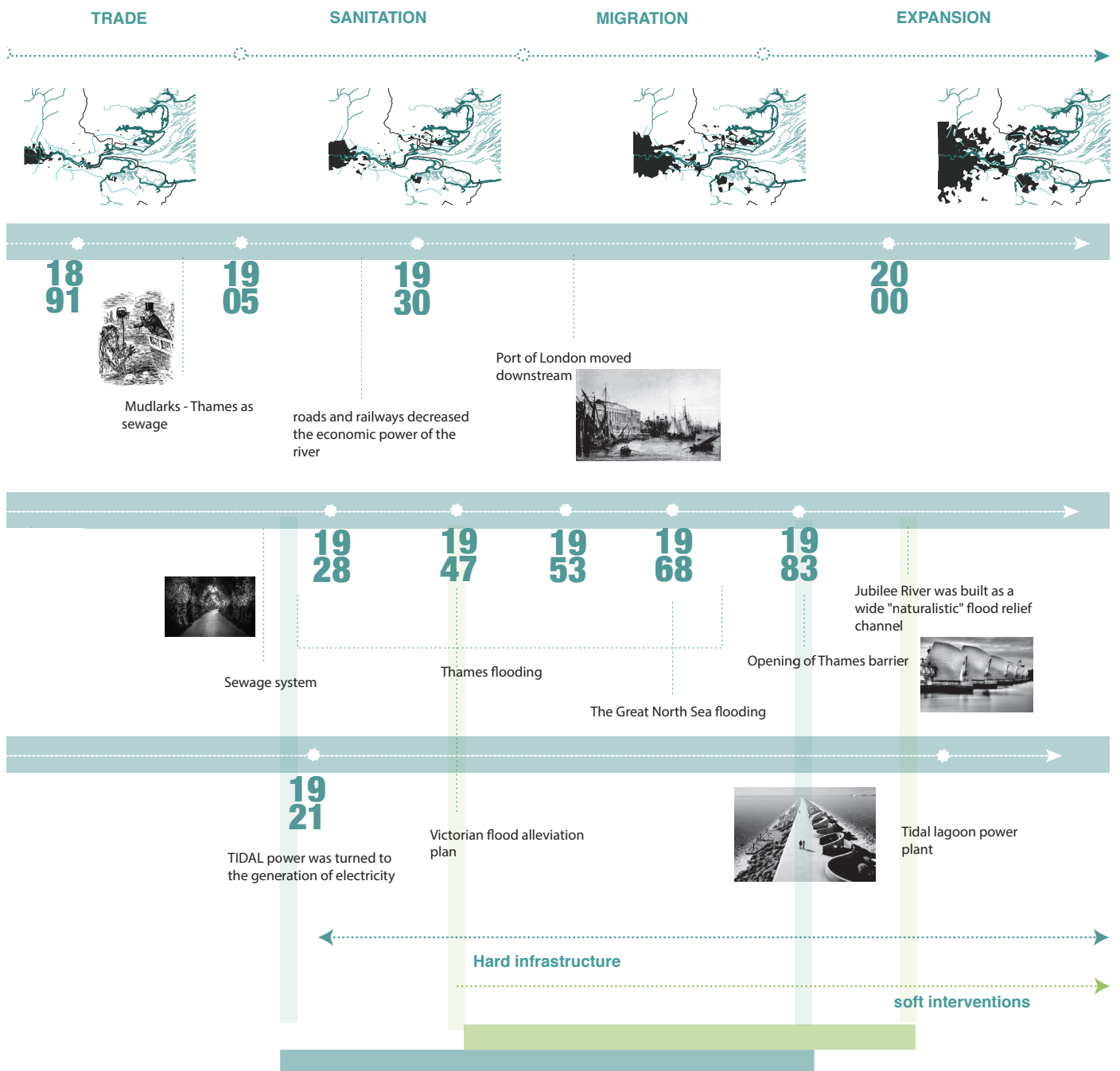
'tide mills'



France - tidal power
plant at Brittany

fig 61. Most important events in Thames estuary development

fig. 61. - Representation made by author
based on information retrieved from
wikipedia



Hypothesis - the English paradigm shift

2. Reference project

Learn from the Dutch - Space for the river applicable principles



fig. 62
fig. 62

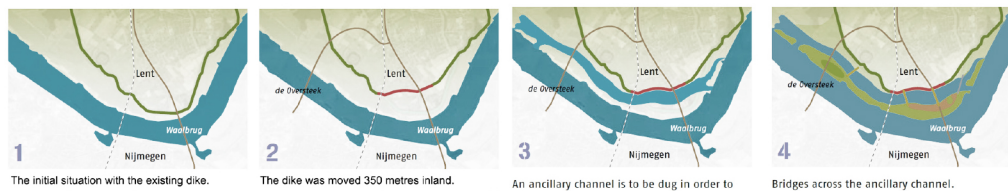


fig. 62. Room for the river project Nijmegen

fig. 63 - Extract from Room for the river project, https://www.google.nl/url?sa=i&ct=j&q=&esrc=s&source=images&cd=&ved=0ahUKEwj8-HWveDYAhXEJIAKH7tCs0QjhwIBQ&url=http%3A%2F%2Fwww.starflood.eu%2Fcities-and-rivers%2F nijmegen%2F&psig=AOvVaw3DulMKK3aAos sO_GZgDnbt&ust=1516074402825291

Risk and spatial projection

Hard I Soft flood defense structures

The current debate in the field of flood defense strategies is focused on the two different approaches – the on 'protective built infrastructure' (dikes, levees, dams) or 'adaptive overlaid infrastructure' (soft landscape edges, parks) (Kates 2006), a distinction that this research project will look more into the following chapters.

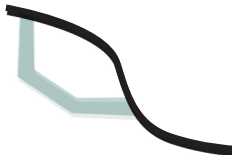
The goal of the Dutch Room for the River Programme is to give the river more room to be able to manage higher water levels. At more than 30 locations, measures are taken to give the river space to flood safely. Moreover, the measures are designed in such a way that they improve the quality of the immediate surroundings.

Every river is different and requires a tailor-made solution, however, most of the interventions act as basic guidelines tht can be reproduced for the British estuarine conditions.

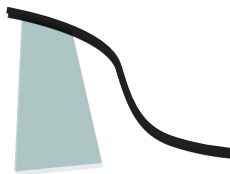
INTERVENTION TECHNIQUES

fig.63

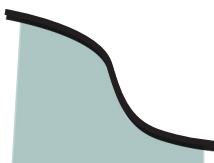
ENGINEERED BYPASS CHANNEL



FLOODPLAIN BYPASS CHANNEL



RECONNECTED FLOODPLAIN



ROOM FOR THE RIVER CONCEPTS FOR INTERVENTION

fig.64

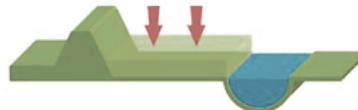
Removing obstacles



Water storage



Lowering of floodplains



Deepening summer bed



High-water channel



fig. 63. Room for the river proposed land manipulations

fig. 64. Room for the river proposed flood alleviation projects

_05.

Methodology

Bivalent paradigm

Systemic approach through trans-scalarity

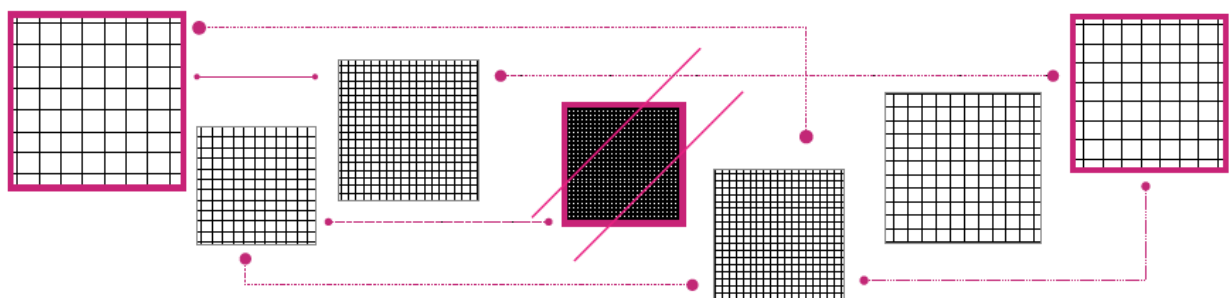
fig 64



fig 64. Conceptual multi-scalarity representation
by author

Research field

1. Trans-scalariry and the systemic approach
2. Towards a new integrated protective | productive infrastructure on the Thames Estuary
3. Methodology
4. From hydrodynamics to spatial intervention
5. A system of interlinked interventions
6. A protective productive landscape with enhanced ecosystem services



Hypothesis - the English paradigm shift

1. Trans-scalarity and the systemic approach

From tidal surge risk to productive | protective dualism

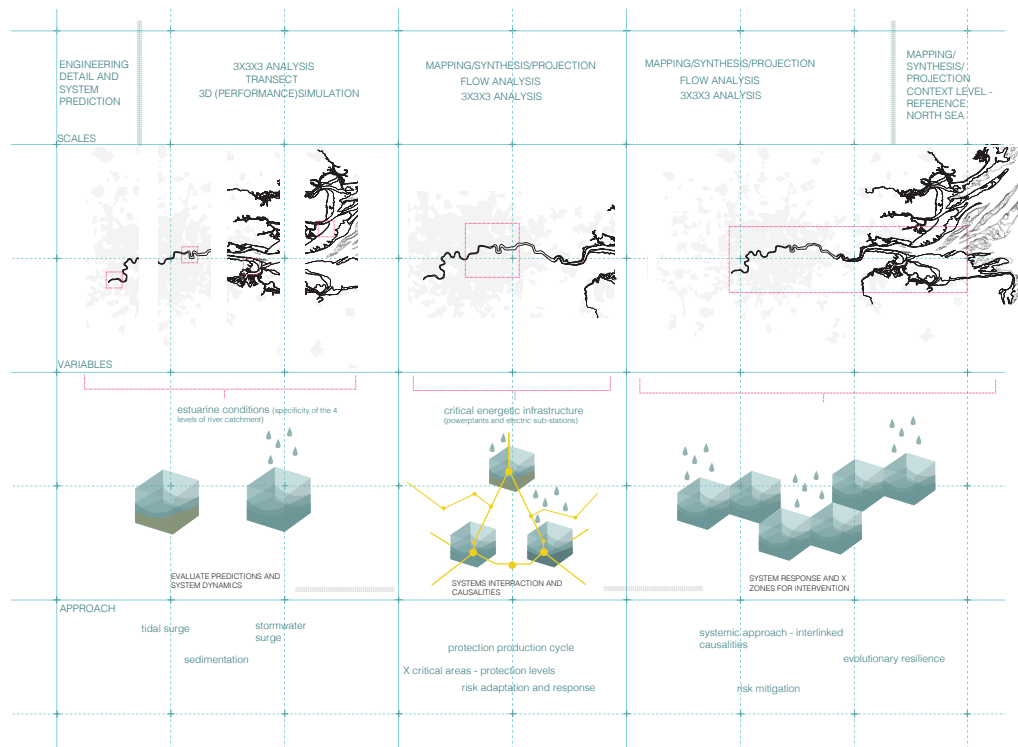


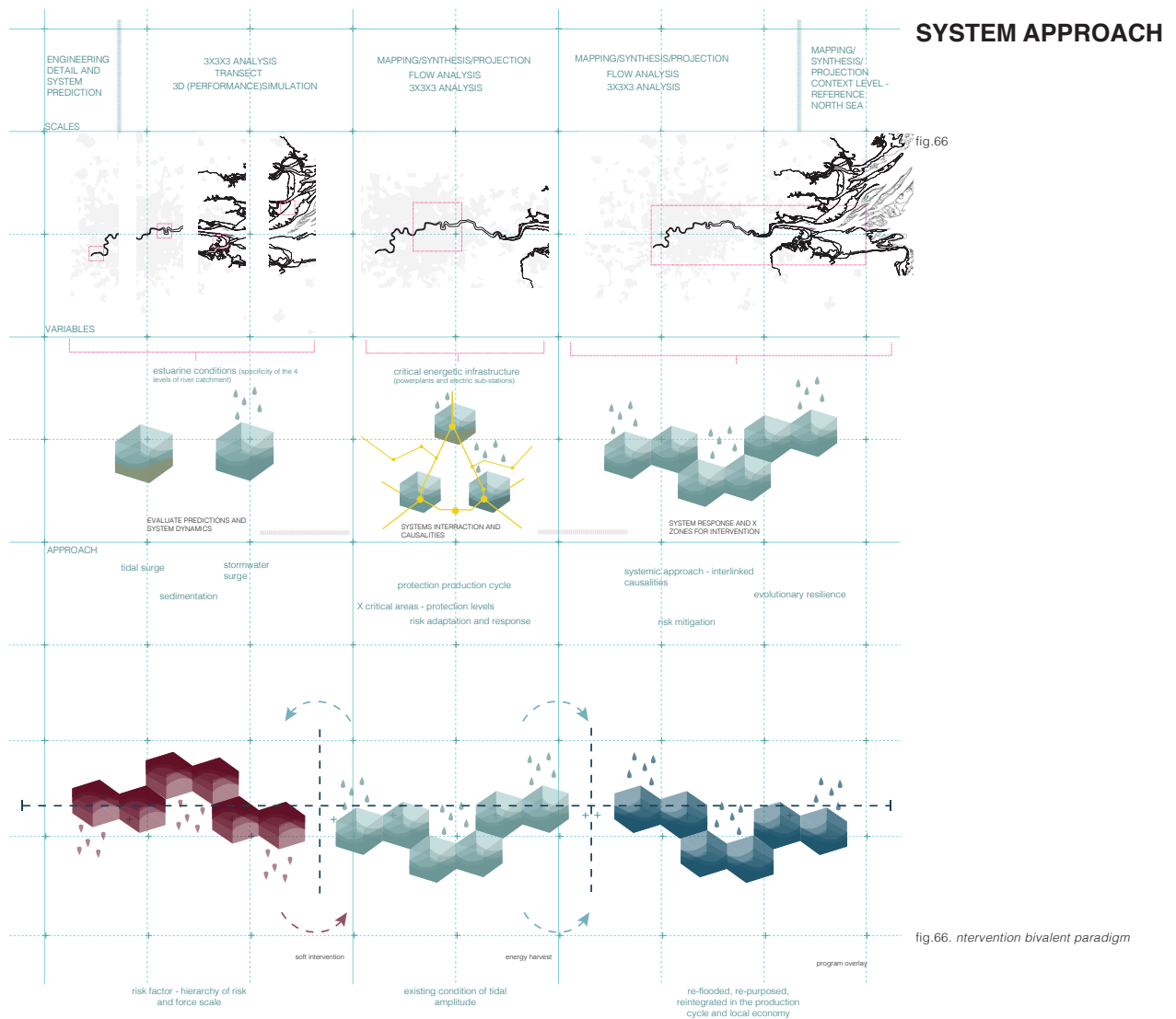
fig.65

Analysis – Synthesis –Projection

Tracing reveals the realistic conditions of a site, mapping on the other hand includes a hint of subjectivity, projecting already a design intention and a general statement aimed. Apart from that, mapping shows a bivalent expression - first, their surfaces are directly analogous to the actual surface of the earth as horizontal planes, while, the other side of this analog is the inevitable abstractness of maps, the result of selection, omission, isolation, distance and codification (Corner, 1999). Its agency lies in neither reproduction nor imposition but rather in uncovering realities previously unseen or imagined, even across seemingly exhausted grounds (Corner, 1999).

Thus the project will unfold by revealing the specificity of the three topics approached – critical energetic infrastructure system, climate change projections and impact on hydrodynamics and further on ecologic territories and flood risk assessment. Therefore, since we are talking about highly active systems, it takes a series of steps to transfer a message – de-coding, separating, classifying, quantifying, inter-relating. Mapping filters the reality through these processes, being finally subjected to Re-codification, Re-assembling, in order to reveal pre-existent conditions and project only those elements relevant for the design outcome.

fig 65. Theoretic representation of thesis approach - multiscalarity and systemic performance



As the title suggests, intertwining the conclusions and conditions revealed by the multiscale approach indicate a paradigm shift from negative to positive, as a high risk factor on the global scale is bivalent for the local scale, thus it is part of a butterfly

effect that can generate benefic effects through upscaling. The existing condition of tidal amplitude, considered a base for flash floods downtown London, can be reinvented as a primary resource for energetic decarbonizing.

fig 66. Theoretic representation of thesis approach - multiscale and systemic performance - intervention bivalent paradigm

_05.

Research field

2. Towards a new integrated protective | productive infrastructure on the Thames Estuary

Research question phrasing

How to best integrate energy transition and the dynamics of climate change through the performative design of a flood defense system enhancing the productive cycle of the Thames Estuary Region ?

Hydrology and ecology

Analysis – 1. What is the specificity of an estuarine territory in relation to hydrodynamics?

Synthesis – 2. How can hydrodynamics shape the coastline/riverbank in a highly urbanized estuarine territory?

Performance – 3. How can ongoing externalities such as uncertainty of economic shifts, transforming economic model for energy production, etc. increase the vulnerability of an urbanized estuarine territory?

Landscapes of power

Analysis – 1. What types of clean energy can be applied in estuarine territories?

Synthesis – 2. How can hydrodynamics be integrated within the urban system? How can hydrodynamics be integrated within the energy cycle? What is the pattern of production and use of power in a transitional territory?

Performance – 3. To what extent can energetic landscapes can be adapted to re-nature processes with multi-functional purposes - protection/production?

Risk and spatial projection

Analysis – 1. What is the current attitude to managing risks from tidal and storm surge in the UK? What are the urban growth variables that can influence further interventions?

Synthesis – 2. To what extent can landscape be understood and conditioned as an operative ground for energetic infrastructure system to address frequent flooding, storm surges and sea level rise?

Performance – 3. How can modulating landscape ecology and spatializing suitability contribute simultaneously to risk reduction and economic development (raised area value)?

Theoretical approach implications

Analysis (Research) – 1. What would be a precise methodological approach to identifying criteria that define vulnerability/ adaptability?

Synthesis – 2. To what extent can a trans-scalar approach reveal simultaneously governance levels of policy implementation, natural and urban system causalities as well as economic effects of hybrid critical infrastructure?

Performance (Design) – 3. What is an open-ended design process and how can it address the complexity of energetic and defense systems in urbanized estuarine territories? / What plans and systems of governance does The Thames Estuary need in order to achieve an integrated investment model between flood management and energetic production?

3x3x3 Analysis

The main purpose of this approach is to reveal the evolutionary process of estuarine transformations in order to understand the driving forces that caused them. An urbanized estuarine territory, similar to an urbanized delta, has a frame of reference for tracking change based on three main layers (Meyer and Nijhuis, 2016) - natural system of territory and water (substratum), the layer of network of infrastructure and the layer of occupation (urban patterns, agriculture). However, in this particular case, the layer of occupation will strictly be focused on productive landscapes (industrial/agricultural). Thus each layer is analyzed at three different scales, on three different time references, the comparability showing transformation patterns.

Transect

The complexity of landscape ecology and flood risk in an estuarine territory cannot only be grasped in a bidimensional drawing. In order to assess flood risk, the designer has to understand the geographic characteristics - topography, soil composition, gradient of slope and the land-water transition edge along the different sections of the estuary. The transect study becomes extremely relevant when understanding water/baks/coastline relation or working with land manipulation. Thus via a set of transects, it is easier to understand which are the prone locations for intervention, creating a systemic genome that can dictate the backbone of a strategy. Further, the transect will dictate the relation between the intervention and the served territory.

Vulnerability assessment

UNDP's Human Development Index, measures of Genuine Progress and other indicators provide comparable, transparent and meaningful information on aspects of development, though often fail to capture environmental sustainability (Neumayer, 2001; Lawn, 2003; Bell and Morse, 1999). The glossary of the TAR (IPCC, 2001, p. 995) defines vulnerability as "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.

Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity." (Adger, 2005)

A robust assessment of vulnerability can be approached as a relationship between vulnerability and adaptive capacity, revealed through a set of indicators of vulnerability and capacity to adapt to climate variability. Vulnerability depends critically on context, and the factors that make a system vulnerable to a hazard. "Nonetheless, there are certain factors that are likely to influence vulnerability to a wide variety of hazards in different geographical and socio-political contexts.

These are developmental factors including poverty, health status, economic inequality and elements of governance." However, there is also a set of variables/proxies for risk that can facilitate assessment - generic vulnerability, representing economic well-being and inequality, health and nutritional status, education, physical infrastructure, governance, geographic

and demographic factors, agriculture, ecosystems and technologic capacity.

Performance assessment

Same as resilience, performance is an abstract, often subjective concept, difficult to quantify, however, there are more mathematical approaches to define the term. Hence, based on a formula that relates runoffproducing potential of the watershed, the average intensity of rainfall for a particular length of time (the time of concentration), and the watershed drainage area) Thompson, 2006),

The excess water within a watershed can be deduced in order to be stored or infiltrated to reduce the peak discharge. Additional tools and methods : Systemic approach , Flow analysis, 3d modeling and simulation.

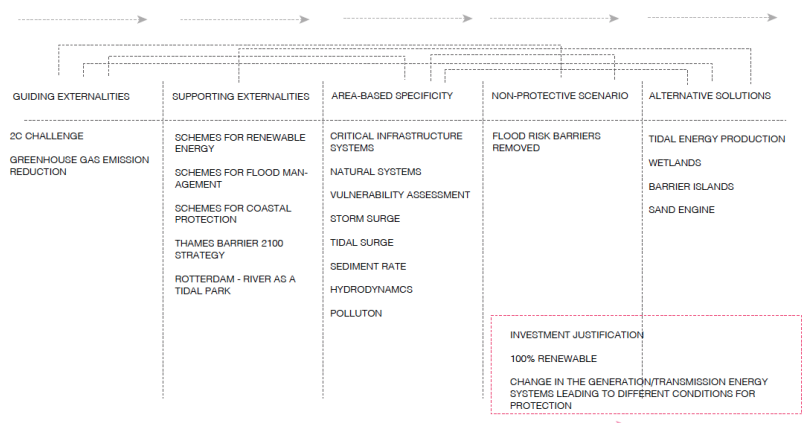
Research outcome

Developing new design solutions for flood defense structures within a strategic flood risk management plan for London and the Thames estuary through to the end of the century.

The Plan primarily looks at tidal flooding, though other sources of flooding including high river flows as a result of heavy rainfall and surface water flooding are considered.the key driver for the project is to consider how tidal flood risk is likely to change in response to future changes in climate and people and property in the floodplain.

Additional to this there is an understanding that many of the existing

flood walls, embankments and barriers are getting older and would need to be raised or replaced to manage rising water levels. The implications of a possible flooding event would not only affect the urban settlements, but the energetic critical infrastructure located within the floodplains of Thames Estuary. More than 10% of UK's power is vulnerable, hence needs alternative protection from the barrier ideology.



Design Strategy
Multi-scalar, regional approach

TIDAL SURGE STORM SURGE



fig 67. Nijmegen, Room for the river

Methodology

4. From hydrodynamics to spatial intervention

Towards a new integrated protective | productive infrastructure on the Thames Estuary

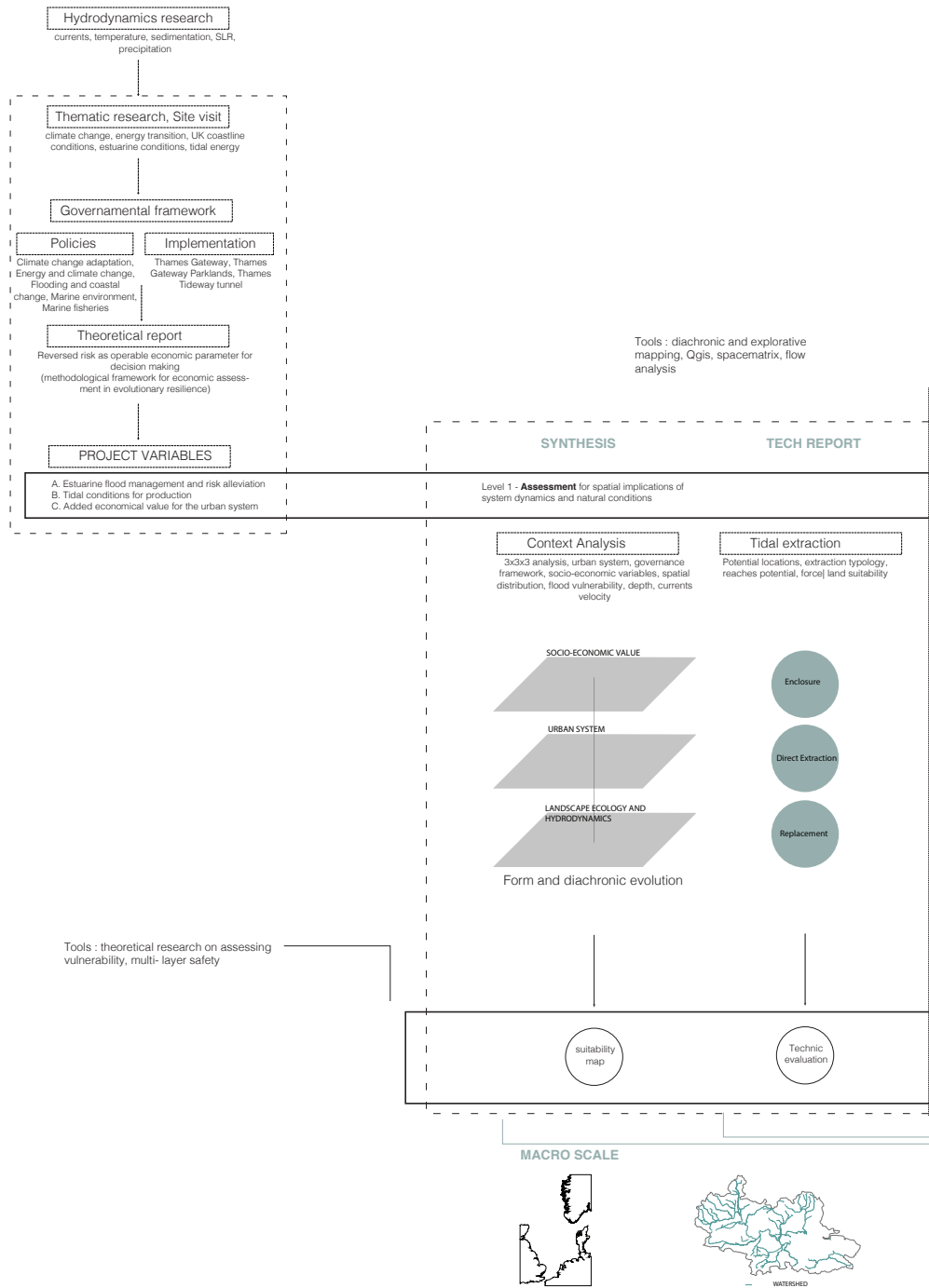


fig 68. Methodological diagram

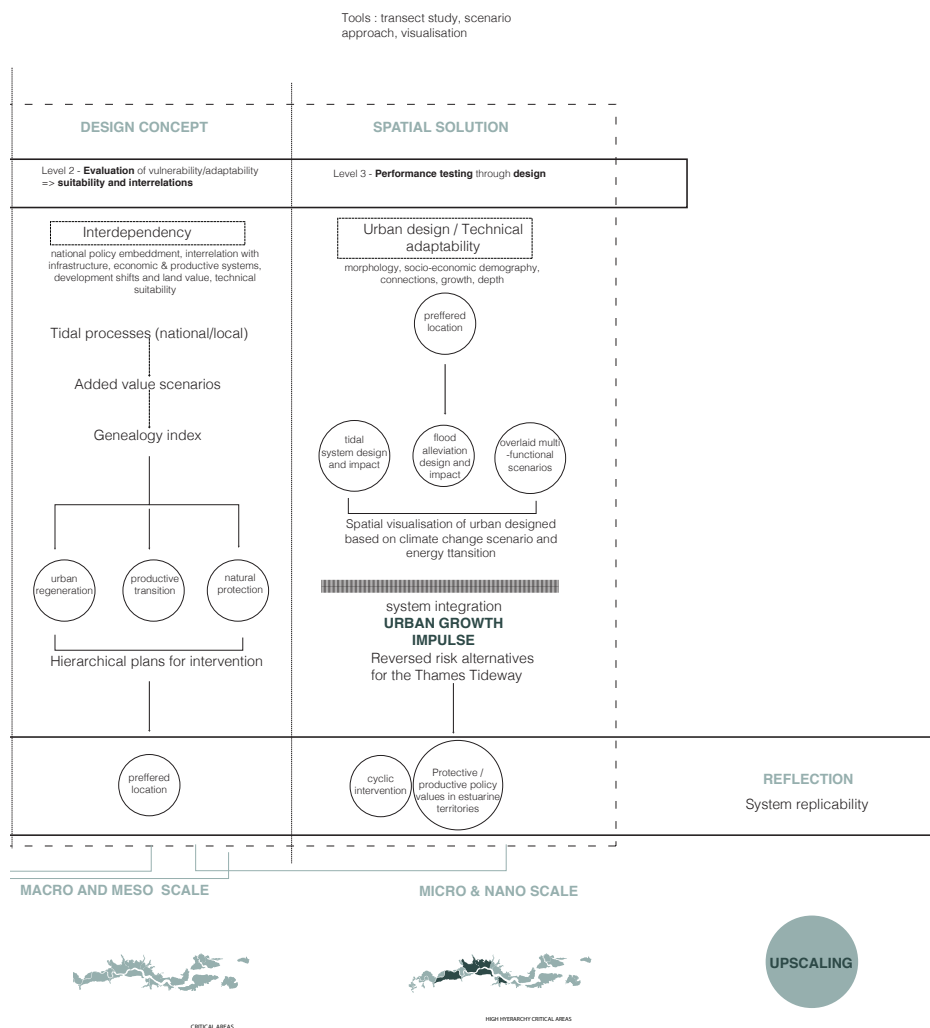


Fig.68 - Methodology and steps, Representation made by author

_05.

Expected output

5. A system of interlinked interventions

Towards a new integrated protective | productive infrastructure on the Thames Estuary

fig 69. - Intertwined nature and technology

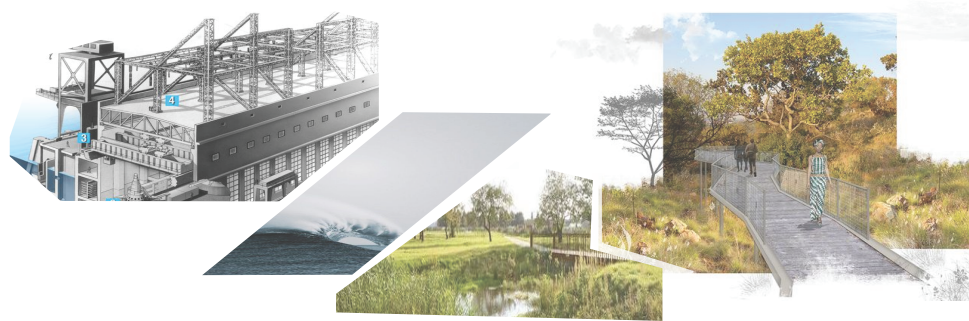
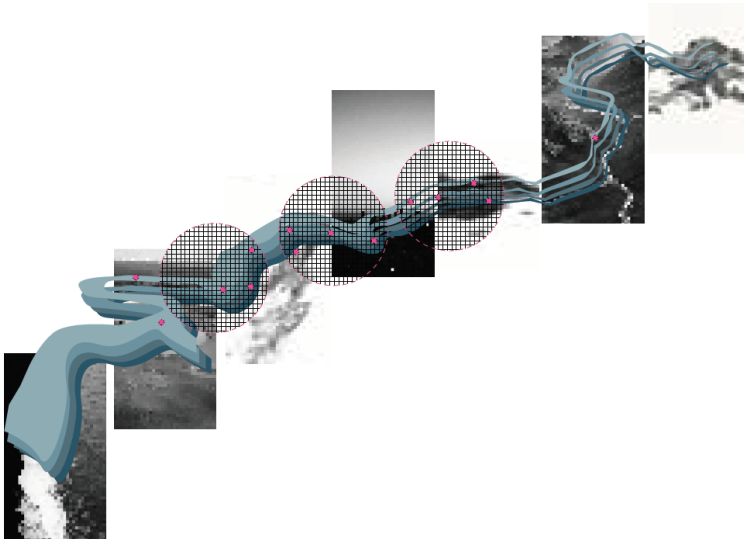


fig 70. - Generic locations for sub-cyclic economies



The preliminary intention of the research is focused on exploring open-end design solutions and regional implementation strategies such as flood risk mitigation, land use adaptability and resilience, as well as performative models that reveal the causalities between natural landscape dynamics and energy landscape, in the context of crisis, hazard, increased risk. Thus, it aims to address the planning gap between blue economy and blue-green infrastructure, through re-nature processes, combining design, engineering simulations and a planning framework meant to re-link the productive infrastructure with the urban area and function as a resource in case of extreme events.

PROJECTIVE SYSTEM APPROACH

Extensively, the project questions the sufficiency of existing tidal barriers on Thames Estuary for coping with climate change predictions, which raises the question of a new, hybrid flood defense with higher adaptable capacity. This new design techniques are meant to address a protective/productive energy cycle - critical infrastructure being a key system affected by risk and generating a domino effect on the metropolis. Thus, the multifunction stays within this new design capacity of both produce and protect the key locations of power.

fig 69. Bivalent paradigm shift conceptual representation - intertwined nature and technology

fig 70. Projects as links in an energetic productive/protective cyclic system






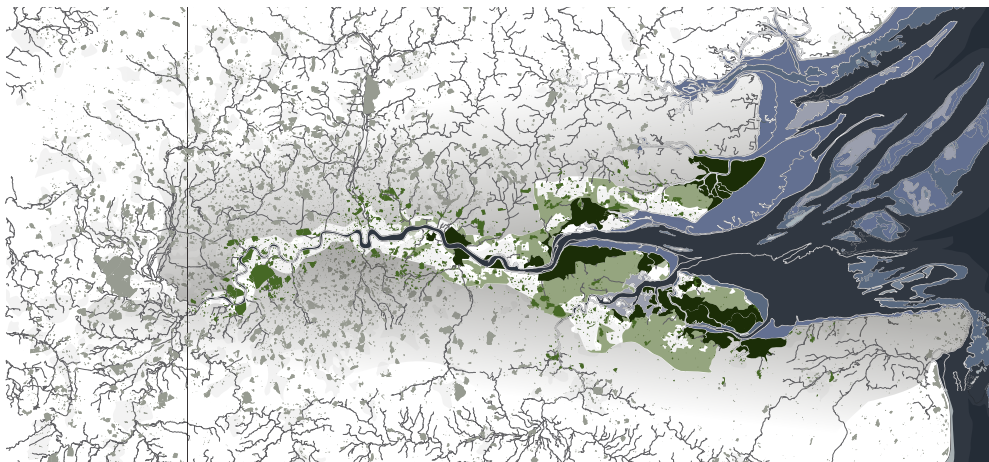
	POWERPLANT	FLOOD STORAGE BASIN FOR TIDAL SURGE	TIDAL ENERGY INSERTION	TIDAL LAND MANIPULATION	TIDAL SURGE BYPASS
ENCLOSURES		+		+	+
FLOW EXTRACTION	+		+		+
ARCHITECTURAL PROGRAM	Hydrological Changing Double Current-typed Tidal Power Generation Red power plant	Fish farm Oyster farm Shellfish farm Tidal lagoon	Bioenergy park	Tidal creek Arable horticulture Grazing marsh Natural reserve	Floodplain bypass Engineered bypass
ADDED VALUE	 SYSTEM ENERGY FEED	 AQUACULTURE	 SYSTEM ENERGY FEED	 MARSHLAND REGENERATION	 NEW LAND FORMATION

fig71. Intervention matrix



CURRENT

Fig. 72.



PROJECTIVE

Fig. 73.

Fig. 72. Existing green spaces and prospective systemic approach

Fig. 73- Projective images, Representation made by author

_05.

Expected output

6. A protective productive landscape with enhanced ecosystem services

Towards a new integrated protective | productive infrastructure on the Thames Estuary

High tide

Fig. 74.



As previously concluded, the interventions that would have most impact on the tidal power reintegration within the local productive system will take place towards the mouth of the estuary, from Tillbury, towards Southend on Sea.

As ultimately the land conditions were losing their natural value, a solution is to recreate those initial conditions in order to bring back diversity into the area. Thus, land manipulation will play an important role in restoring the marshland. For undergoing such an ample intervention additional



Low tide

Fig. 75.

analysis are needed in order to understand the sedimentation pattern that later on can be manipulated into creating new landscape conditions.

Although Germany and Netherlands lead the dredging practices on the North Sea, the important aspect of the UK dredging is that it is not only used for channel maintenance, but the resulted sediment is relocated to fight coastal erosion, a feature that can be used in later land manipulation projects.

Fig. 74-75- Projective images, Representation made by author

Reversed risk as operable economic parameter for decision making

–methodological framework for economic assessment in evolutionary resilience –

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Delft University of Technology, MsC 3 Urbanism, D-I Graduation Studio, AR3U022 Theory of Urbanism
December 13th 2017

“...the great floodgates of the wonder-world swung open...”

Hermann Melville, Moby Dick

Abstract

The banks of many estuaries are amongst the most heavily urbanized areas on a global scale. Urbanization and the strategic location that the water entity projects in relation to the global market have consequently led to a high concentration of the world's biggest cities (Nicholls, 1995)¹, and a considerable proportion of the global gross domestic product (GDP) (Turner et al., 1996)². In a resolute attempt to regain control, intense urbanization lead to intense anthropic activities – destruction of saltmarsh, construction of artificial barriers, storm-breakers which affect the ecologic response of the natural processes reducing the adaptability range and exposing the coastal/estuarine territory to flooding risk, beach erosion, storm surges, saltwater intrusion and siltation (Turner, 1996)³. Facing climate uncertainty, assessing levels of vulnerability is subjected to limited measuring, hence economic impacts are hard to grasp and can result in lack of engagement for investing in protective measures. In the case of the United Kingdom, the Environment Agency's funding for maintaining flood assets has fallen by 14% nationally, while other current trends in the energy field are attracting increasing capital. As a consequence, the Greater Thames Estuary region which currently contains 1 million properties would result in direct damage of at least £ 97.8 billion at 2003 prices in case of inundation (Dawson, 2005)⁴. Considering this scenario, the economic implications reach further when applying this reasoning through time and performance of the current defense mechanism. Hence, the paper will introduce the economic factor and merge it with progressive system evaluation in time, aiming to justify that an energetic productive capacity would close the loop of a self-financing flood protective cycle. Consequently, it will focus on revealing methods and variables for quantifying and qualifying economical impacts of risk vulnerability, building towards a potential integrated approach for investment that militates for a multifunctional flood defense infrastructure.

¹ Nicholls, R. J. (1995). "Coastal megacities and climate change." *GeoJournal* **37**(3): 369-379.

^{2,3} Turner, R. K., S. Subak and W. N. Adger (1996). "Pressures, trends, and impacts in coastal zones: Interactions between socioeconomic and natural systems." *Environmental Management : An International Journal for Decision Makers, Scientists and Environmental Auditors* **20**(2): 159-173.

⁴ Nicholls, R. J. (1995). "Coastal megacities and climate change." *GeoJournal* **37**(3): 369-379, Dawson, R. J., J. W. Hall, P. D. Bates and R. J. Nicholls (2005). "Quantified Analysis of the Probability of Flooding in the Thames Estuary under Imaginable Worst-case Sea Level Rise Scenarios." *International Journal of Water Resources Development* **21**(4): 577-591.

Key words

Vulnerability, flood defense, operability, economic indicators, methods, fit for purpose, multilayered approach

1. Introduction

Although UK government states that decreased investment in flood defense do not necessary lead to increased vulnerability to flooding events, experts challenge this view, as reductions to local authority funding may have caused exponential costs in the long run through faster deterioration. Municipalities had suffered budget cuts of more than 40% since 2010, leaving them with little or no option but to reduce or withhold funding to drainage boards, other organisations and landowners who managed river levels. Not only the existing protective infrastructure is maintained at a minimum level, but future investments are scarce, affecting the natural development of coastal zone management policies. Currently, they are working towards interventions that respond to the combination of groundwater withdrawal, surface water division and land-use change (wetland loss and deforestation) (Sahagian, 1994)⁵ but has yet to grow apart from the traditional protective measures - irrigation and water impoundment in reservoirs and dams, hence a new vision and capital is essential.

Despite the apparent deterrent to address coastal protection in a more unsuppressed and less rigid approach, also reflected in the downsize of field investments, other global trends aiming at tackling the global warming effect at an inception stage emerge. Within the 2C challenge, the global world has been concerned with energy transition, turning the level of sustainability into a competitiveness criterion, demanding increased funds. Sure, lower carbon emissions decelerate the global warming process, decreasing SLR values and risk vulnerability, making it logic to invest in reducing the cause rather than enhance protection, however, the matter is too complex, and an integrative, holistic approach between

the protective and productive fields might just as efficiently contribute, as explored in this paper. Consequently, a new hybrid infrastructure can reverse the flood risk to a profitable energy source, creating a protection/production cycle, simultaneously defending and “fueling” the city as well as retrieving its original investment.

Thus, through this paper I aim at measuring and strengthening the inter-dependability between risk and potential through multi-layered methodological approach, justifying under the question of time it's evolutionary feasibility through the economic impact evaluation. This would result in a suitability framework and spatial representation of vulnerability and investment hierarchy, turning risk and uncertainty into an urban development advantage. Precisely this leads to the relevance of the question, as it is an incipient attempt to justify how a multifunctional new defense infrastructure would be addressing two needs simultaneously, turning side effects into profit. Basically, how a territory is subjected to newton's laws of motion and by extrapolation, why cost/benefit could mitigate for an integrated approach.

2. Exploring risk and uncertainty

2.1. Resilience, adaptation and mitigation situations

The cause-effect determinism revolves around the risk concept. The quantification of risk is a central concept in climate change related literature as the research needs to be practically implemented within the political and economical schemes. However, the extreme conceptual nature of the term has lead to a failed science – policy communication, as many

⁵ Sahagian, D. L., F. W. Schwartz and D. K. Jacobs (1994). "Direct anthropogenic contributions to sea level rise in the twentieth century." *Nature* 367: 54.

researchers have failed to grasp a more objective definition (Eriksenn and Kelly, 2007)⁶. Thus, the field remains equivocal being often paired with the idea of resilience. The former, broad concept, mostly transformed into an academic metaphor (White, 2010)⁷ has a dual understanding – either refers to restoring equilibrium within an affected ecosystem, such as improving responses to hazards, or proactively adapting to potential conditions, such as water storage within the city (White, 2010)⁸. From a planning perspective, the duality translated to either reducing forcing drivers, hence mitigation or changing the conditions to reach a new normality within the ecosystem, hence adaptation. While their distinction is basically a matter of approaching climate related issues, there is also a temporal dimension attached to it – while adaptation is fit for more tangible, short term responses, mitigation addresses more pervasive, long term management agenda. Since the focus of the paper is highlight a potential cost-benefit loop from integrating flood into a complementary investment field, it will consequently focus on adaptation as a pathway for addressing hazard, exposure and vulnerability for a more tangible outcome. Also it will address explicitly the attempts of measurement and quantification for operational purposes.

2.2. Adaptation/vulnerability – from theory to operability

In recent literature, the adaptive policy has grown interest and the capacity of quantification is most of the times through the interdependency with vulnerability as a direct response. Dealing with water, we are dealing with uncertainty, basically we are still located

within the empirical debating sphere, hence vulnerability does not denote an observable phenomenon, leading to its limitation of being measured (Hinkel, 2011)⁹. Since direct measurement is not possible, a theoretical concept is more accurately grasped through its operability capacity (Patt, 2008)¹⁰. In order to become an operational term, the theoretical concept needs a method for mapping/tracing back to a combination of observable factors - this method is called operational definition.

Reducing the theoretical to a set of realistic terms, resides mostly on a set of scalar indicators, usually linear functions with direct connection to a tracing spatial condition aiming to describe the state of affairs of a complex system in simple terms (Niemeijer, 2002)¹¹. Each scalar indicator is paired with a theoretical variable, however, based on the complexity of the term at hand, a composite indicator or an index is needed, which pairs a set/vector of observable variables to one scalar theoretical variable (Hinkel, 2011)¹². The matter can even be taken further into detail by introducing a vector-valued indicator map, also known as spider diagrams or radar charts (OECD 2008) representing at least three variables on an axis, starting from a central point. Usually they are used for highly subjective and complex definitions such as “Water Poverty Index”, “Livelihood vulnerability index”, possibly even the task at hand, vulnerability to hydrodynamics.

Towards measuring vulnerability there are some key questions to be answered in order to aim for accurateness – what exactly it is to be indicated, which of the set of indicating variables is most relevant, where resides the distinction between current state and potential

⁶ Eriksen, S. H. and P. M. Kelly (2007). "Developing Credible Vulnerability Indicators for Climate Adaptation Policy Assessment." Mitigation and Adaptation Strategies for Global Change 12(4): 495-524.

^{7,8} White, I. (2010). Water and the city : planning for a sustainable future. London :, Routledge.

^{9,12,13} Hinkel, J. (2011). "“Indicators of vulnerability and adaptive capacity”: Towards a clarification of the science-policy interface." Global Environmental Change 21(1): 198-208.

¹⁰ Patt, A., P. Suarez and C. Gwata (2005). "Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe." Proceedings of the National Academy of Sciences of the United States of America 102(35): 12623-12628.

¹¹ Niemeijer, D. (2002). "Developing indicators for environmental policy: data-driven and theory-driven approaches examined by example." ENVIRONMENTAL SCIENCE AND POLICY 5(2): 91-103.

changes. Based on this, two classifications emerge – harm indicators and vulnerability indicators. In order to keep clear the focus of vulnerability which embraces, apart from the status quo, the forward-looking aspects, there are three kinds of substantial arguments fit for defining these indicators – deductive (based on existing theory), inductive (based on data from both the indicating variables as well as observed harm) and normative (based on value judgements) (Hinkel, 2011)¹³.

2.3. Relevance and hierarchy in methodological approaches

Answering these questions, raises the need for a succeeding methodology, one to select between indicators, introducing hierarchical levels and relevance values. According to approach, data gathering and index construction, the possible methodologies are Hierarchical and Similar Deductive Methods, Methods using Principal Component Analysis, Stakeholder Methods, Relational Analysis Methods, Novel Statistical Techniques (Becarri, 2016)¹⁴. So far, based on the aforementioned theoretical framework, more than 106 methodologies for identifying composite indicators have been formulated, altogether using 3209 variables, 34% of which related to the social environment, 25% to the disaster environment, 20% to the economic environment, 13% to the built environment and only 6% to the natural environment (Becarri, 2016)¹⁵.

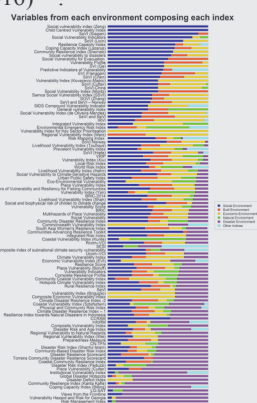


Fig. 1 – Variables from each environment composing each index (Becarri, 2016)

Despite the intense concern of the matter at hand, variable field focus from the scientific perspective, differs from the social perspective. A survey conducted in the UK aiming at assessing the preferred energy source revealed that most people are concerned with house stability, job security and environmental value. Hence natural environment should be accounted for more than 6% of indicators and the job creation possibilities should become a determinant variable, as less vulnerable relates to better production conditions and less protective investments.

2.4. Greater Thames estuary vulnerability assessment

Consequently, considering these guidelines, the attempt to measure, map and quantify the wavering territories of The Greater Thames Estuary area, mentioned in the introduction would follow a vector valued indicator basis, underlined through a hierarchical and similar deductive method which will focus on natural environment variables as well as built environment variables and economic ones towards mapping hierarchical levels of flooding vulnerability. As a result three analysis would be combined – the flooding probability from multiple sources (fluvial, pluvial and coastal), land use densities and territorial economic productivity.

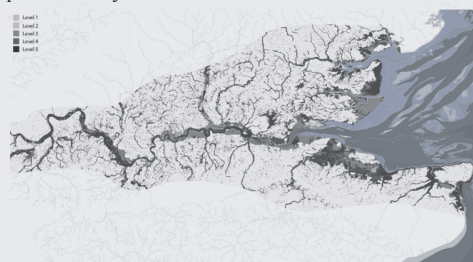


Fig.2 – Flood risk vulnerability

^{14,15} Becarri, B. (2016) "A Comparative Analysis of Disaster Risk, Vulnerability and Resilience Composite Indicators." *PLoS currents* 8 DOI:

10.1371/currents.dis.453df025e34b682e9737f95070f9b970.

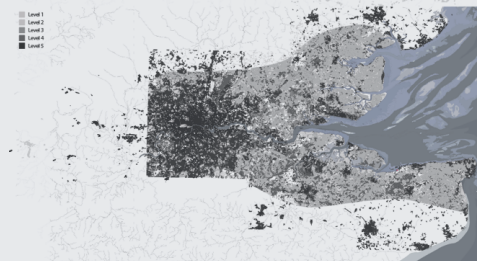


Fig.3.- Land use vulnerability

Despite aiming at a scientific measure, the variables considered could at best aim for a 40% accuracy in qualifying vulnerable areas since vulnerability and related concepts such as adaptive capacity and sensitivity themselves remain vague and inconsistently defined. Indicators serve, just as any other method, the purpose of solving a problem, or more specifically, of addressing a policy or research question. Hence, the potential of indicators can only be discussed adequately in the light of these problems, thus have to be fit for purpose (Hinkel 2011)¹⁶. While reducing ambiguity, the role of indicators in policy making has been subject to a lot of critique and is recommended to use them “symbolically” for legitimizing decisions that would have been taken anyway or the absence of indicators may be used for justifying inaction. Considering the purpose of the assessment, vulnerability measurements can vary from identifying global mitigation targets to selecting local adaptation measures (Fussel and Klein, 2006)¹⁷ and in this paper’s case is focused on mapping the most urgent areas for local adaptation interventions it is a strong starting point for rooting the intervention locations.

3. Economic indicators

3.1. Economic value evaluation

¹⁶ Hinkel, J. (2011). “Indicators of vulnerability and adaptive capacity”: Towards a clarification of the science–policy interface.” *Global Environmental Change* 21(1): 198-208.

¹⁷ Fussel, H.-M. and R. J. T. Klein (2006). “Climate Change Vulnerability Assessments: An Evolution of

“Investing should be more like watching paint dry or watching grass grow. If you want excitement, take \$800 and go to Las Vegas.” (Paul Samuelson) In dealing with climate vulnerability, the struggle is to convince that longer term profits are possible, therefore we need to prove both that the area has economic potential but also that is viable for an intervention that would generate profit. For decision makers to adopt a rational behavior and choose according to a consistent manner, the goal is to maximize the net economic benefits of investments. This solution, as seen in the governance model of The Netherlands, endorse the rationalization of the decision and become a criterion for preference based on which policies can be derived and assessed via cost-benefit analysis. (Tsimopolou, 2013)¹⁸

The complexity of assessment attached to the vulnerability concept is extended to another empirical concept – added economic value. In the planning and decision making processes, vulnerability assessment is almost never sufficient, as its main goal is a matter of cost-benefit efficiency, thus a vulnerable area is not automatically placed at the top of the hierarchical chain unless through its protection it has the capacity to generate income. However, the question raised in this paper, is not just how to assess the existing economical value of a territory and determine its protection feasibility, but to address its potential economic response under the question of time and as a result of a direct intervention, taking into consideration how can that reflect back on the urban system. Therefore, the overall primary value is time-emergence ratio. To ensure that an intervention would not only keep existing value safe, but potentiate it through the intervention itself a healthy evolving ecosystems is at stake. Furthermore, institutional arrangements should be aimed at increasing diversity and the potential for flexible response to changes in the coastal zone, unless, non-sustainable resource

Conceptual Thinking.” *Climatic Change* 75(3): 301-329.

¹⁸ Tsimopolou, V., J. Vrijling, M. Kok, S. N. Jonkman and J. Stijnen (2013). *Economic implications of multi-layer safety projects for flood protection*.

usage in coastal zones will not be reversed and damage will only increase. (Adger, 2011)¹⁹.

"In general, the higher the level of economic development and per capita entitlements provided, and the greater the economic and resource diversity within the system, the less susceptible any given coastal zone should be. Paradoxically, however, areas with higher levels of economic development, but a low coping potential, may be more vulnerable, because they have more to lose." (Adger, 2011)²⁰ Defining a suitable intervention location means reducing the possibilities to those territories with high potential for economic development and relatively high coping potentials, where an intervention would prove most effective. In economic terms natural assets in the coastal zone can yield direct use values and indirect use values, as well as nonuse values (Turner, 1991)²¹ evaluated through monetary valuation methods.

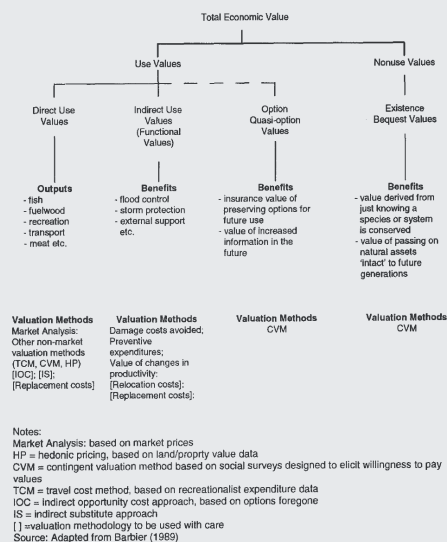


Fig.2 – Wetland evaluation methods (Turner, 1996)

3.2. Cost benefit analysis model

Cost benefit analysis is used to assist choice

^{19 20} Adger, W. N., K. Brown, D. R. Nelson, F. Berkes, H. Eakin, C. Folke, K. Galvin, L. Gunderson, M. Goulden, K. O'Brien, J. Ruitenbeek and E. L. Tompkins (2011). "Resilience implications of policy responses to climate change." *Wiley*

between alternative decisions, basically comparing the costs and the benefits that will flow from the different alternatives in order to determine which choice will bring the greater margin of benefits over investments or the greater net return for the resource involved. Based on the type of decision making, cost-benefit analysis is different from the public to the private sector, the latter being much more complex in terms of actors involved and interests to be considered.

In policy decision making, the investment reasoning revolves around the idea of change, as any geographical area where economic and social forces are producing change can lead to growth, development and added value. Still being difficult to grasp the quantification of change, alternatives focus on elaborating a numerical model, based on a number of assumptions focused on keeping the problem as simple as possible for accurate evaluation. These assumptions usually relate to externalities such as - budget restrictions, safety standards, maintenance, life span.

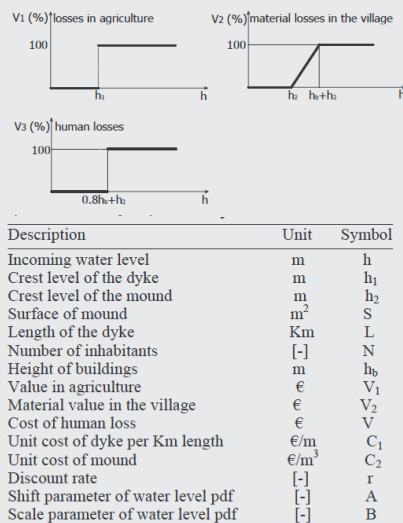


Fig.3.- Variables for losses and cost-benefit analysis variables

Similar to the vulnerability method, the variables/assumptions belong to a set of fields -

Interdisciplinary Reviews: Climate Change 2(5): 757-766.

²¹ Kerry, T. (1991). "Economics and Wetland Management." *Ambio* 20(2): 59-63.

urban settlements, productivity, capital and societal issues - as presented in the table, that cumulated can quantify the benefit and extrapolate the losses.

As it already generates a complex matrix, and the main aim is to perform a rational choice cost-benefit analysis is conducted for a fixed moment in time assessing the net present value of the project and minimizes the total cost in the system during its lifetime. Added present value refers to an economical appraisal greater than zero, its measuring being given by the following equation in the context of reduction of expected losses and no maintenance costs: $NPV = \Delta L - I$, where, ΔL = reduction of expected losses, and I = total investment cost.

As it is performed for a specific moment, the model can be replicated throughout the project's life span, revealing all possible combinations indicating in the end the combination that results in most economically viable intervention (Tsimopolou 2013)²².

4. Policy models

4.1. Multi-layer safety

In the field of flood defense management, one of the leading positions is occupied by The Netherlands, as great parts of the country lie under sea level. In the context of disaster preparation, various technical studies have been made available presenting their effectiveness in the mitigation of expected fatalities and

material damage (De Bruijn & Klijn 2012)²³. A valuable outlet of their water strategy is the forward vision for foreseeing investments not only not only in flood prevention measures, but also in measures for the mitigation of losses as stated in the National Water Plan (2009). This clause led to the development of the multi-layer safety system, multiple lines of defense (Lopez et al. 2007)²⁴, or multi-level approach based on the three safety layers classification for flood-control measures.²⁵ Layer 1 comprises measures for the prevention of flooding, such as dykes and storm-surge barriers, layer 2 comprises spatial solutions for the mitigation of losses, such as flood proofing or relocation of buildings to safer places, and layer 3 comprises emergency management measures, such as evacuation.²⁶ (Tsimopolou 2013)²⁵

4.2. Economic implications of multi-layer safety

Multi-layer safety has raised several discussions about its cost-efficiency. Previous studies have shown that combining flood-prevention with loss mitigating measures is generally speaking not cost effective (Kaleen, 2009)²⁶, however when assessed properly it can even produce profit. In order to decide whether a strategic location is fit for a multi-layer approach, more precisely it is suitable, the aforementioned methodology of variable indicators and added value applies as well. In the case of the Netherlands, most variable fields refer to the degree of public awareness of flood risk the occurrence and severity of flood events in the recent past, the value of the area that needs to be protected in terms of human life, economic assets and natural environment

²² Tsimopoulou, V., J. Vrijling, M. Kok, S. N. Jonkman and J. Stijnen (2013). Economic implications of multi-layer safety projects for flood protection.

²³ Klijn, F., K. M. de Bruijn, J. Knoop and J. Kwadijk (2012). "Assessment of the Netherlands' Flood Risk Management Policy Under Global Change." AMBIO : A Journal of the Human Environment 41(2): 180-192.

²⁴ Lopez, J., P. Kemp, N. Peyronnin, C. Dufrechou, M. Hester, P. Keddy, B. Kohl, S. Kulkarni, A. McCorquodale, M. O'Connell, J. Suhayda, B. Rogers and D. Bollinger (2008). Comprehensive

Recommendations Supporting the Use of the Multiple Lines of Defense Strategy to Sustain Coastal Louisiana 2008 Report (Version I) Multiple Lines of Defense Assessment Team.

^{25,27} Tsimopoulou, V., J. Vrijling, M. Kok, S. N. Jonkman and J. Stijnen (2013). Economic implications of multi-layer safety projects for flood protection.

²⁶ Kallen, M. J., S. P. Kuniewski, J. M. v. Noortwijk and I. O. S. Press (2009). Risk and decision analysis in maintenance optimization and flood management. Amsterdam ; IOS Press.

(Commissie Toetsing Uitgangspunten Rivierdijkversterking, 1993) and the degree of flexibility in policy-making that allows economic resources to be available for financing flood risk management projects (Tsimopolou 2013)²⁷.

Extensively, there are additional questions to be addressed in the decision making process that can be reinforced by the economic implications of an intervention. Measures with multiple functions need to be combined and later hierarchically sorted to attest whether it is recommendable to invest in a certain combination of measures or not. Furthermore, detailed analysis need to be provided in order to establish specifically the quantification of investment adequate for every variable that would maximize the expected utility of the project.

In a flood control situation, the vulnerability is a priori assessed and based on that, different solutions have to be explored, not just rely on the most mathematically viable one. The aforementioned methodology for vulnerability measuring took into consideration the classification of harm indicators and vulnerability indicators from the perspective of time – status quo versus prospective, a choice that can be extended to this particular case of determining the most suitable type of intervention. Therefore decision making comes as a triad of problems to overcome - the “accept / reject” problem, the “optimization” problem and the “prioritization” problem. From a rational determinism of preferences based on economic assessment, these problems are solved with a different utilization of the net present value criterion, as presented in the following table.

Classification of economic decision problems for multi-layered safety projects

Decision type	Evaluated object	Decision criterion
Accept / Reject	“Fixed” project	$NPV > 0$
Optimization	“Fixed” project	$NPV_{opt} = NPV_{max}$
Prioritization	Various projects	$NPV_{opt} = \max\{NPV_i\}$

Fig.4 - Classification of economic decision problems for multi-layer safety projects

5. Evolutionary resilience

5.1. Evolutionary resilience context

The term of resilience stands on three main perspectives - engineering, ecological and evolutionary. Engineering resilience refers to the ability of a system to return to an equilibrium or steady state after a disturbance. – state of stability’ (Holling, 2001)²⁸. Ecological resilience refers to the ability of these systems to absorb changes [...] and still persist’ (Holling, 1973)²⁹. The main distinction between the two referring to maintaining *efficiency* of function, versus maintaining *existence* of function (Schulze, 1996)³⁰. *Evolutionary* resilience broadens the description of resilience from the engineering and ecological views of restoring and improving, to the ability of complex social-ecological systems to change, adapt or transform in response to stresses and strains (Carpenter, 2005)³¹. Consequently, the evolutionary perspective of resilience aims to incorporate the dynamic interplay between persistence, adaptability and transformability across multiple scales and time frames in ecological (natural) systems. (Davoudi, 2012)³²

²⁸ Holling, C. S. (2001). "Understanding the Complexity of Economic, Ecological, and Social Systems." *Ecosystems* 4(5): 390-405.

²⁹ Holling, C. S. (1973). "Resilience and Stability of Ecological Systems." *Annual Review of Ecology and Systematics* 4: 1-23.

^{30,33} Schulze, P. C. (1996). *Engineering within ecological constraints*. Washington :, National Academy Press.

³¹ Carpenter, S. R., F. Westley and M. G. Turner (2005). "Surrogates for Resilience of Social-Ecological Systems." *Ecosystems* 8(8): 941-944.

³² Davoudi, S., K. Shaw, L. J. Haider, A. E. Quinlan, G. D. Peterson, C. Wilkinson, H. Funfgeld, D. McEvoy and L. Porter (2012). "Resilience: A Bridging Concept or a Dead End? "Reframing" Resilience: Challenges for Planning Theory and Practice Interacting Traps: Resilience Assessment of a Pasture Management System in Northern Afghanistan Urban Resilience: What Does it Mean in Planning Practice? Resilience as a Useful

To understand the joint empirical concepts and relate methodologies, the paper introduces the concept of evolutionary resilience precisely to stress that the system undergoes different stages of change, becoming adaptable (Schulze, 1996)³³. The *growth phase* (r) is characterized by rapid accumulation of resources (capitals), the *conservation phase* (K), growth slows down as resources are stored and used largely for system maintenance, the *creative destruction phase* (Ω) is characterized by chaotic collapse and release of accumulated capital and the *reorganization phase* (α) is a time of innovation, restructuring and greatest uncertainty but with high resilience (Pendall, 2010)³⁴.

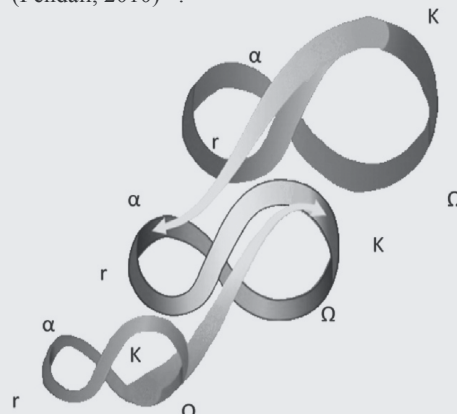


Fig.5.- The adaptive cycle (Holling, 2001)

These phases occur in 'panarchical', rather than hierarchical, cycles emerging one from the other through space (Holling, 2001)³⁵. By extension, the interrelation between vulnerability – resilience – suitability is also a similar interaction within each of the empirical concepts, the methodological reckoning narrows down through hierarchical deductions, yet within their interaction, the loops and determinations change through time as different layers are added to the external conditions.

5.2. Layer addition

Determining the location and nature of an

Concept for Climate Change Adaptation? The Politics of Resilience for Planning: A Cautionary Note." *Planning Theory and Practice* 13(2): 299-333.

³⁴ Pendall, R., K. A. Foster and M. Cowell (2009). *Resilience and Regions: Building Understanding of the Metaphor*.

intervention in a risk exposed area can follow the methodology of vulnerability assessment, combined with territorial potentialities and economic benefits, however a key factor is the adaptability through time. Understanding potentialities at a specific moment, can be extrapolated via replicability and perceived as a multi-layered policy. Apart from the prevention, mitigation and relocation approaches of the Dutch approach, an intervention's determining factor stands within it's economical overview. Thus, the least vulnerable areas that hold the most promising potential can be subjected to the economical value assessment – a cost-benefit analysis to determine the hierarchy.

Understanding a project also from its economic perspective, can become in itself a layer of intervention. However, just because it is common knowledge that usually decision making has the highest economic benefit at heart, it does not apply to all interventions, as the temporal and spatial dimension can present fluctuating conditions, shifting the focus from a specific set of variables to another. The methodology is complex and its steps tedious, mathematical, however they have the capacity, only through their assimilation, to restrain empirical entities.

The Dutch multi-layered methodology is cost-efficient and successfully applicable when dealing with uncertainty, Its layers can support each other, or can appear independently, as the external conditions change. Hence, added economic value through the characteristics/resources of a territory and also through new interventions can become an additional layer to complete the decision making and give an increment to governmental initiatives. Although advocating for an additional layer might enhance the perception on resilience, it has to be beared in mind that the main framework of reference is an adaptive cycle.

The economical layer would only support to incorporate the dynamic interplay between

³⁵ Holling, C. S. (2001). "Understanding the Complexity of Economic, Ecological, and Social Systems." *Ecosystems* 4(5): 390-405.

persistence, adaptability and transformability across multiple scales and time frames in ecological (natural) systems (Davoudi, 2011)³⁶ as well as the preparedness of a territory, reflected in the intentionality of human action and intervention.

By aiming at measuring at assessing as many empirical concepts, the outcome is not to support only the mitigation perspective, but to enhance the “social learning capacity (being prepared) for enhancing their chances of resisting disturbances (being persistent and robust), absorbing disturbances without crossing a threshold into an undesirable and possibly irreversible trajectory (being flexible and adaptable) and moving towards a more desirable trajectory (being innovative and transformative)” (Davoudi, 2012)³⁷.

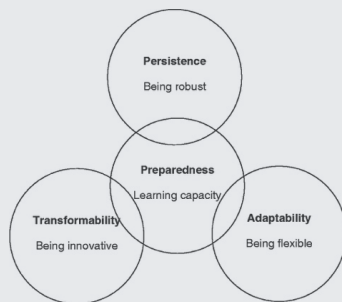


Fig.6. - Four-dimensional framework for resilience building (Davoudi, 2013)

5.3. Governance framework for climate change

Since the paper emerged from the wavering territories on The Greater Thames Estuary region, the relevance of it can be embedded into the English model for addressing climate change as approached by the draft London climate change adaptation strategy. Although it aims for resilience, their flood defense strategy

is rather focused just on mitigation interventions - “Flood *resistance* refers to taking measures to make sure that flood water cannot enter a property. Flood *resilience* refers to taking measures to minimize flood damage when a property is flooded and ensure that it can be brought back into full use as quickly as possible.” (GLA, 2010, p.120)³⁸ - however, in the beginning the paper demonstrated that there is a dualism in question – mitigation / adaptation.

The Draft Strategy ‘uses the “Prevent, Prepare, Respond, Recover” framework that results in an emergency planning model, neither general nor in direct communication to the different levels of decision making. Addressing only big scale interventions, as well as responses to sudden and extreme climate events rather than on long-term, small and incremental changes comes as a paradox to the principles of evolutionary resilience.

Precisely, the added layer of economic reckoning is supposed to prove the cost-efficiency of some interventions in relation to others, based on the idea that big influxes of capital are not necessarily needed, but just well assessed projects acting as small changes. These have the capacity to reverberate through the system and cause large effects, whereas large alterations may have negligible systemic impacts.

Although it just focuses on the added characteristics of economic measuring as an evolutionary layer in determining the suitable intervention, the paper emerges and relates to those gaps in the United Kingdom’s model to tackle uncertainty.

6. Conclusion

Focusing on the role of economic implications in assessing vulnerability and building a spatial

³⁶ Davoudi, S., A. Mehmood and E. Brooks (2011). The London Climate Change Adaptation Strategy: Gap Analysis Electronic Working Paper No.44.

³⁷ Davoudi, S., K. Shaw, L. J. Haider, A. E. Quinlan, G. D. Peterson, C. Wilkinson, H. Funfgeld, D. McEvoy and L. Porter (2012). “Resilience: A Bridging Concept or a Dead End? “Reframing” Resilience: Challenges for Planning Theory and Practice Interacting Traps: Resilience Assessment of a Pasture Management System in Northern

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³⁸

http://www.deltacities.com/documents/London_Climate_change_adaptation.pdf

suitability map, the paper's final aim is to demonstrate that vulnerability and potentiality, highly empirical concepts, can be subjected to measurements and can become strong motivations for adaptive and robust flood defense strategies in order to manage the uncertainty and minimize the impact on city's safety and economic prosperity. Talking about uncertainty, we talk about resilience, hence from this perspective, territorial systems have non-linear and unpredictable dynamics and patterns of abrupt changes (Constanza, 1996)³⁹ within which, climate-related events, such as flooding, are considered as external perturbations or disturbances, transforming resilience into a process of change, a process of embracing and evolving.

Although it might focus on a more realistic, rigid approach to empirical concepts, the paper is not referring to a standard ecological and engineering understanding of resilience, but stresses on the fit for purpose approach. Through attempting of quantifying the possibility of a territory to protect and produce, the "panarchical" cycle becomes more easy to grasp through time, policies at different governmental levels can better be related, interventions can be hierarchically distributed to the national, regional, metropolitan and local level in relation to their economic impact and to their benefit-generation capacity. Returning to the Greater Thames estuary area, the highest vulnerability comes from tidal surge, however, the energy field can reverse those values of risk into potential power. Furthermore, an infrastructure that can provide flood protection as well as produce energy from the single risk factor can become a tool of reversed risk.

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³⁹ Constanza, R., L. Wainger, C. Folke and K.-G. Mäler (1996). Modeling Complex Ecological Economic Systems: Toward an Evolutionary, Dynamic Understanding of People and Nature.

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Theoretical framework

Performative flood design

Regenerative energy cycle

fig 76



Theory

1. Project field directions
2. Relevance and time planning

Relevance

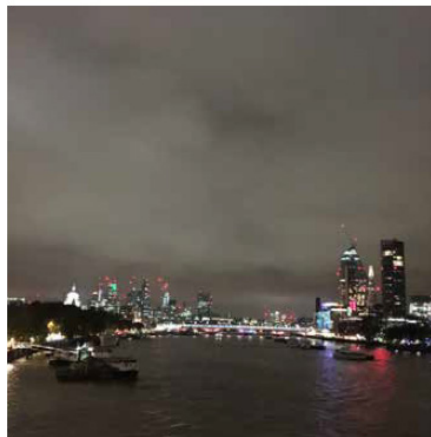


Fig.76. - Wavering territories - North Sea trip
focus landscapes of change, shots taken
by author

06. Theoretical framework

1. Project field directions

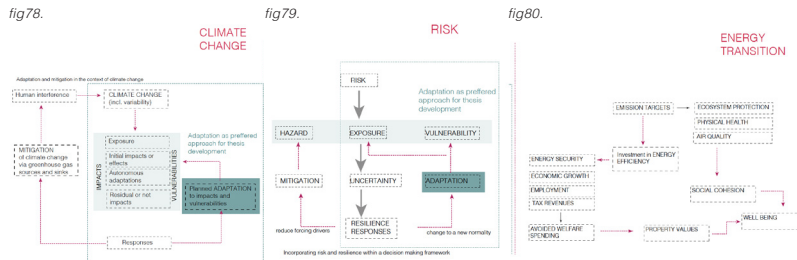


fig78. Risk operational diagram

fig77. Climate change operational diagram

fig79. Energy transition operational diagram

fig77.-79- Representation made by author
based on information from Water and the
city, Iain White

Fig. 80 - Project field directions and
considered concepts

Fig. 80.

Theoretical Framework

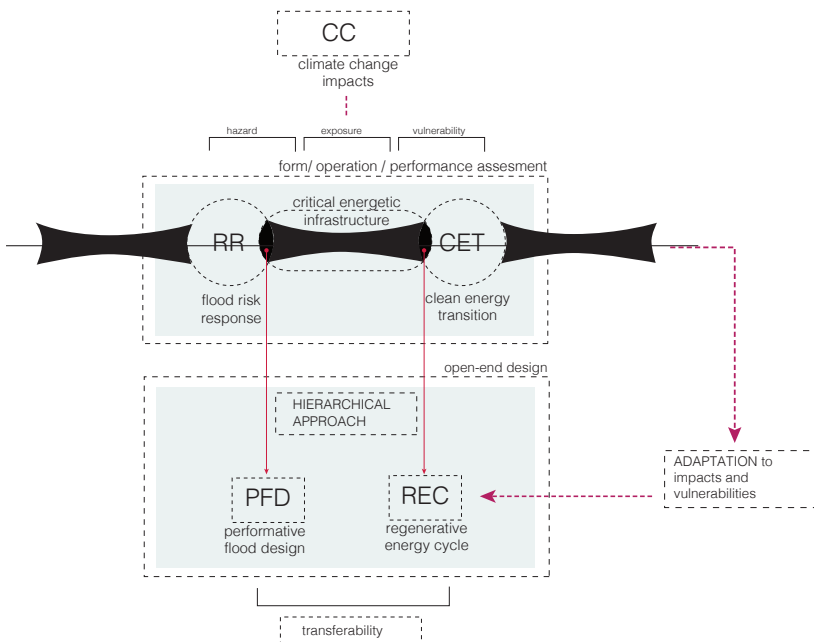
The research will be based on literature exploring the projection of climate change scenarios on estuarine territories as an incipient factor to initiate the aim of the thesis. Furthermore, the theoretical approach will be divided, on one hand into a more place-based research including papers for understanding aspects of critical energetic infrastructure, landscape ecology versus landscape as infrastructure and flood management and response and on the other hand, a more abstract approach, revealing methods and perspectives -risk - adaptability and vulnerability, systemic approach, genealogic approach, open-end design. Although the theory is aiming to embrace uncertainty and adapt to it, the main goal is to quantify and re-qualify abstract concepts that deal with prediction such as - resilience, performance, adaptability, vulnerability and apply them to design solutions that integrate flood defense interventions in energetic landscapes.

Open design paradigm

Current definitions of open design are focused on openness of technical design information and usually excludes the early stages of design (Aitamurto, 2005). The idea of an open-end paradigm resides in product development, as open source concept, or DIY concept, encouraging the personalization of the product, which can be translated into flood defense projects as room for the hazard to follow a natural course.

Scientific relevance

Current sustainability concerns address carbon, water and transit, however they are all interconnected by energy. The more optimal



the energy system responds to the natural processes of the urbanity and the natural unpredictability, the more efficient a metropolis functions. This thesis will be concerned with some of the most active research fields, such as - productive landscapes re-nature techniques, risk management, performative and systemic design, open-end design, climate resilient estuarine design.

Research adjacent focuses

MIT's LCLAU – Norman Leventhal center for

advanced urbanism as well as MIT energy initiative directly address the carbon-rising levels and the "the 2°C challenge", specifically with storage energy solutions and technical explorations on how to use water and adapt design interventions such as wetlands in order to reach their maximum operability.

The shift towards the peri-urban area is a prominent focus at MIT, becoming a test bed for clean energy, with the potential to construct a metabolic wastebelt, similar to the concept of green belt, but with the purpose of feeding the city.

Fig. 81

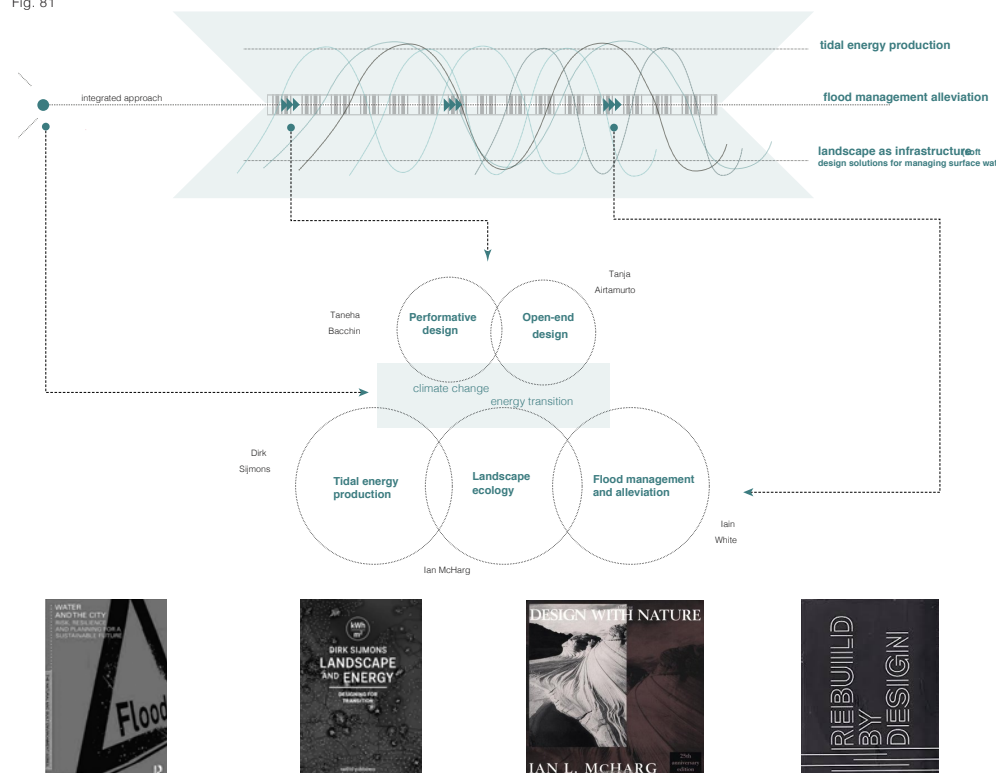


fig 81. Theoretical framework diagram

Theoretical framework

2. Relevance and time planning

Fig. 82 - Extreme scenario



fig 82. Flooded London extreme scenario
-<http://www.flood-london.com/>

Overcoming barriers and dams as flood risk solutions

Fig. 83 - Thames Barrier



fig 83. Thames barrier -<https://www.carbonbrief.org/thames-barriers-extraordinary-year-prompts-government-to-reconsider-long-term-flood-plans>

Practice adjacent focuses

The problematic of coming up with design solutions to protect energy flows has already been raised, an example of such intervention is the project elaborated by Royal HaskoningDHV, the world's second 'sand engine', located on the East Anglian coast to protect Bacton Gas Terminal and nearby communities from coastal erosion. Also, leading company in on the energy transition horizon, Elon Musk's Tesla already unveiled the plans for a 2023 project on the coast of Massachusetts

involving energy storage on an island offshore, similar to the Belgian proposal, however using battery storage provided by the tech leader.

Societal relevance

The biggest impact the research captured in this thesis proposal is going to include optimization of critical infrastructure following-up an extreme event. Although electricity generation, storage and distribution is just a part of the critical infrastructure concept, along with

telecommunications, water supply, agriculture, public health (hospitals, ambulances), transportation (fuel supply, railway network, airports, harbors, inland shipping) financial and security services, it ensures their operability.

Thus, for the society to recover, all the components of critical infrastructure must be working at full speed, requiring energy.

A design solution which would ensure the safety and resilience of the energy flow would benefit the society as a whole, helping the metropolis recovering on its own, without interruptions.

fig. 84.

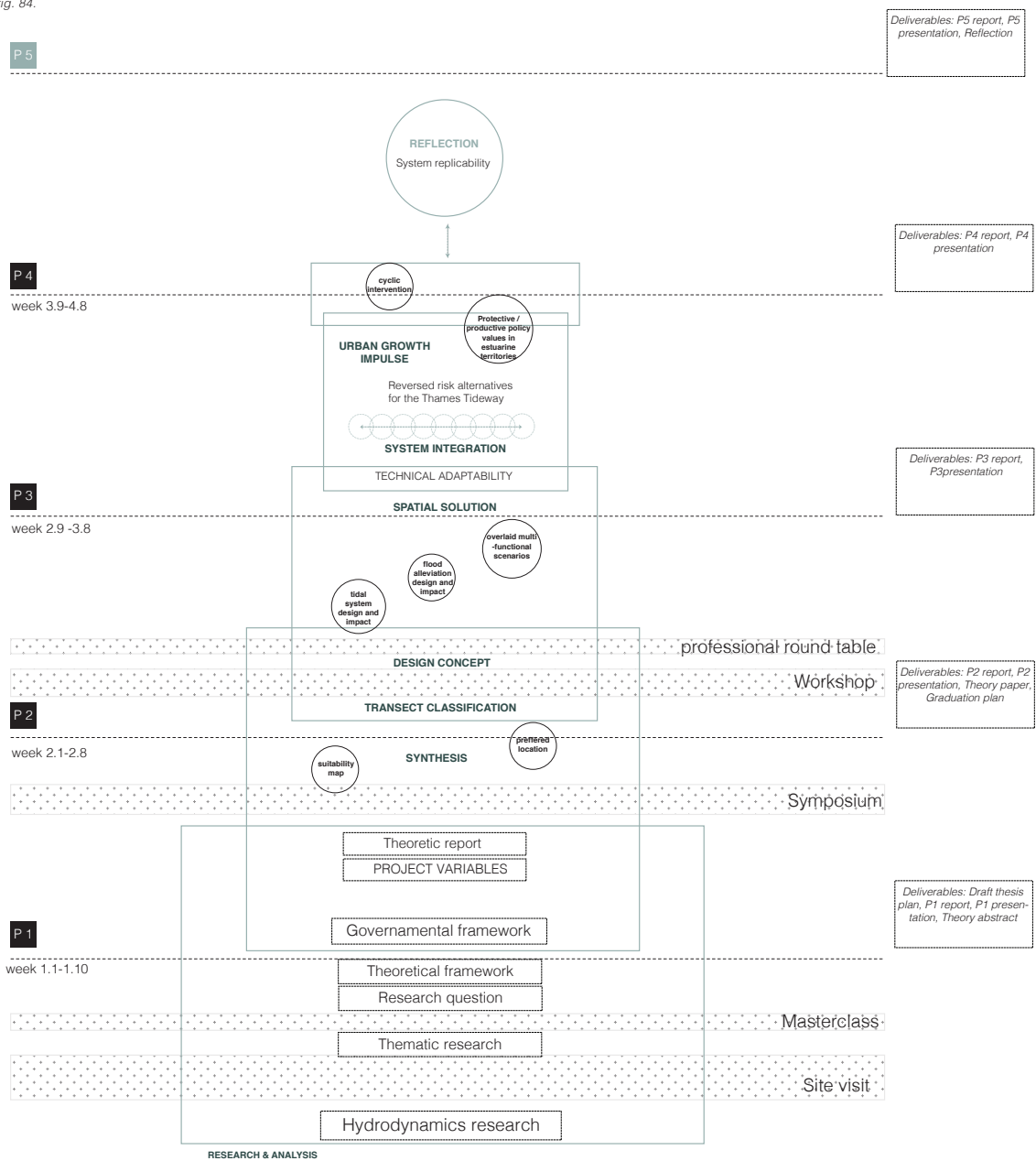


fig 84. Time planning





There is a tide in the affairs of men, Which taken at the flood, leads on to fortune. Omitted, all the voyage of their life is bound in shallows and in miseries. On such a full sea are we now afloat. And we must take the current when it serves, or lose our ventures.

William Shakespeare, 'Julius Caesar' (1599) act 4, sc. 3, l. 215

