When Disaster *Flows*

A systemic overview for climate resilient spatial framework on the Rijnmond delta region

Ganesh Umasankar | 6002463

First mentor : Claudiu Forgaci
Second mentor : Alexander Wandl
Delegate : Clarine van Oel

TU Delft BK Bouwkunde
Department of Architectural Engineering +Technology

P5 Presentation

M.Sc. Urbanism

TU Delft

“If you can’t explain to a six year old, you don’t understand it yourself”

- Albert Einstein

Personal motivation

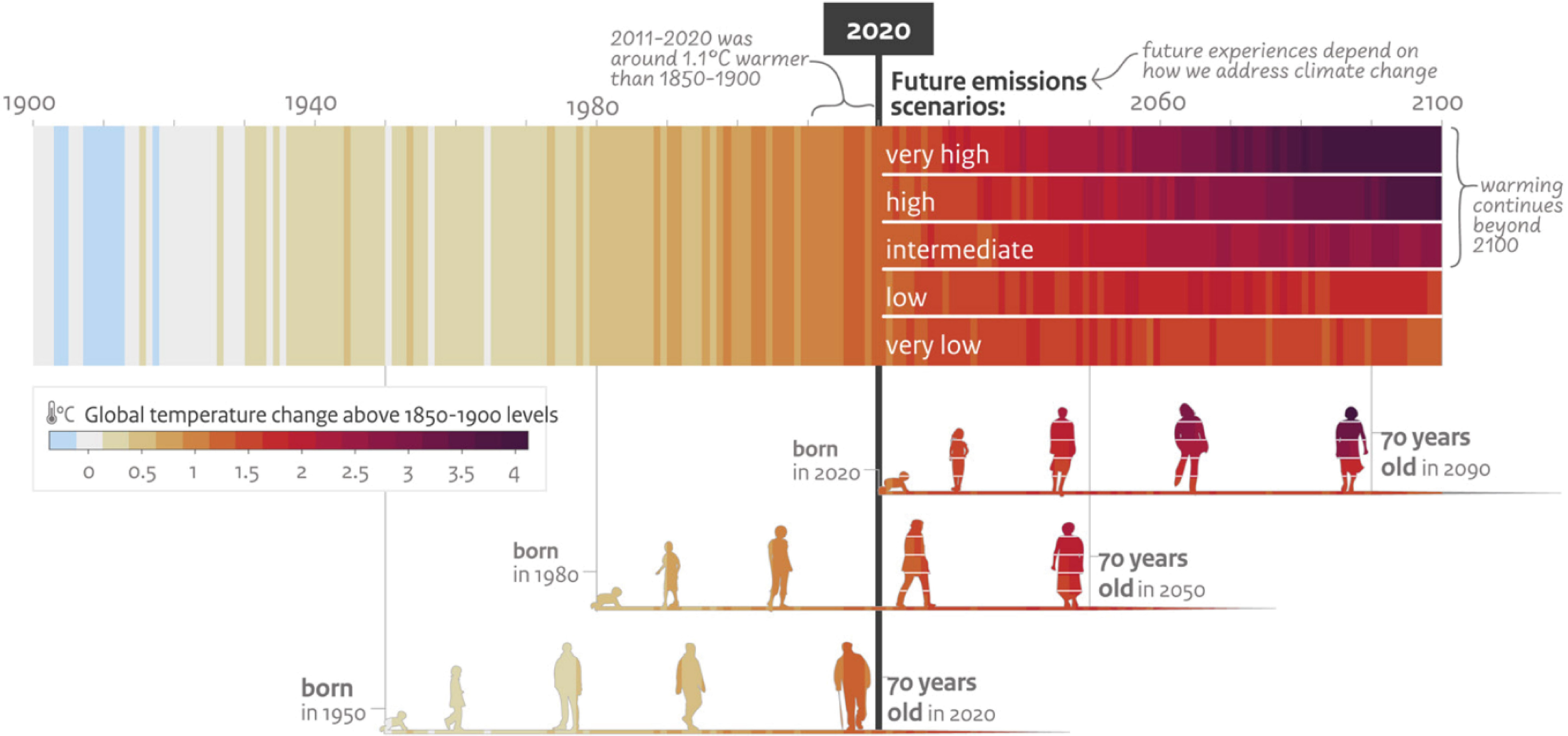
Chennai flood 2015

2015 Chennai floods
Source: Deccan chronicle

Ahr valley flood 2021

2021 Ahr valley flood
Source:Polizei/dpa

Climate change



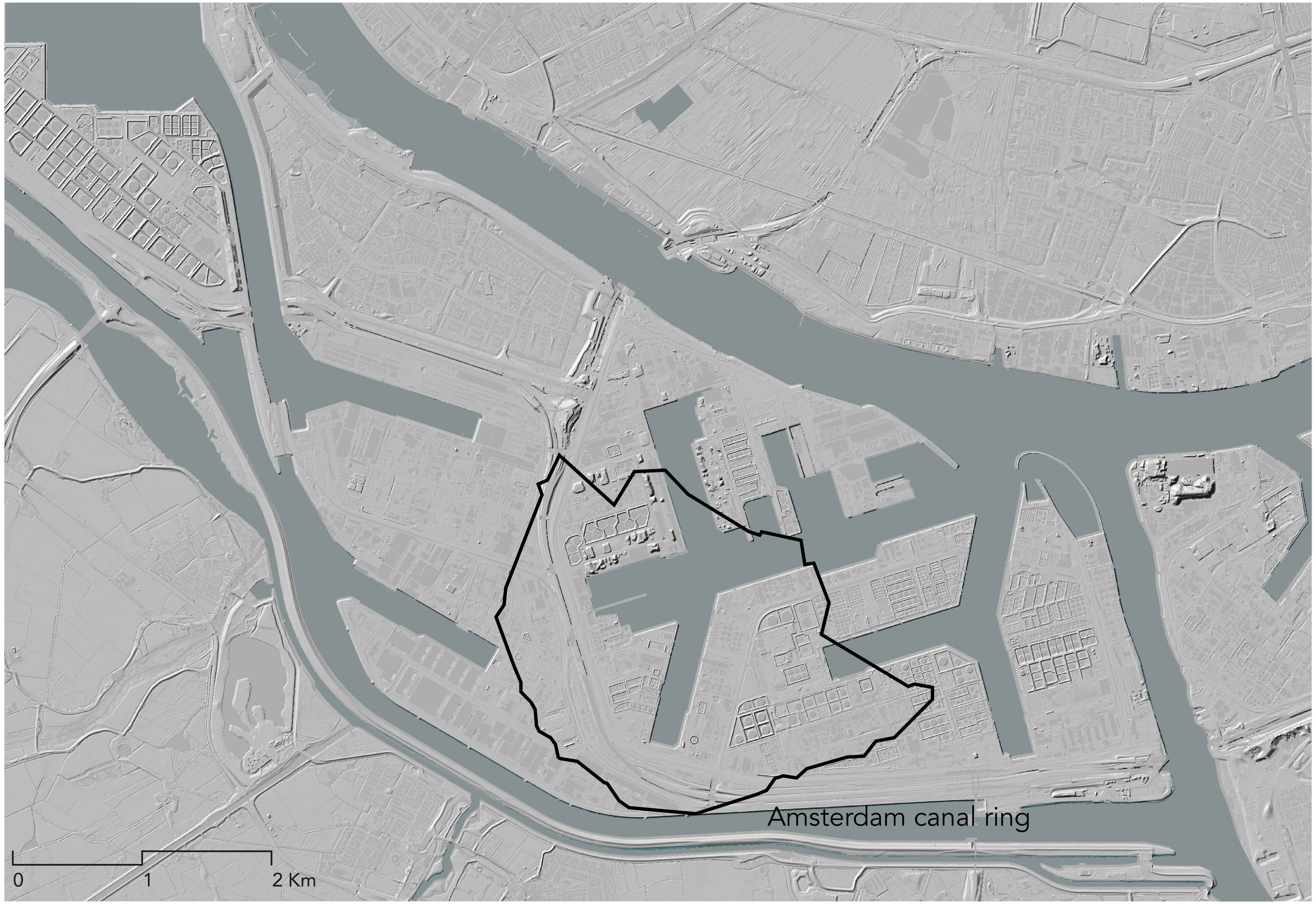
The extend to which current and future generations will live in a warmer and different world depends on choices made now and in the short term

Source: IPCC, AR6 Synthesis Report

What if?

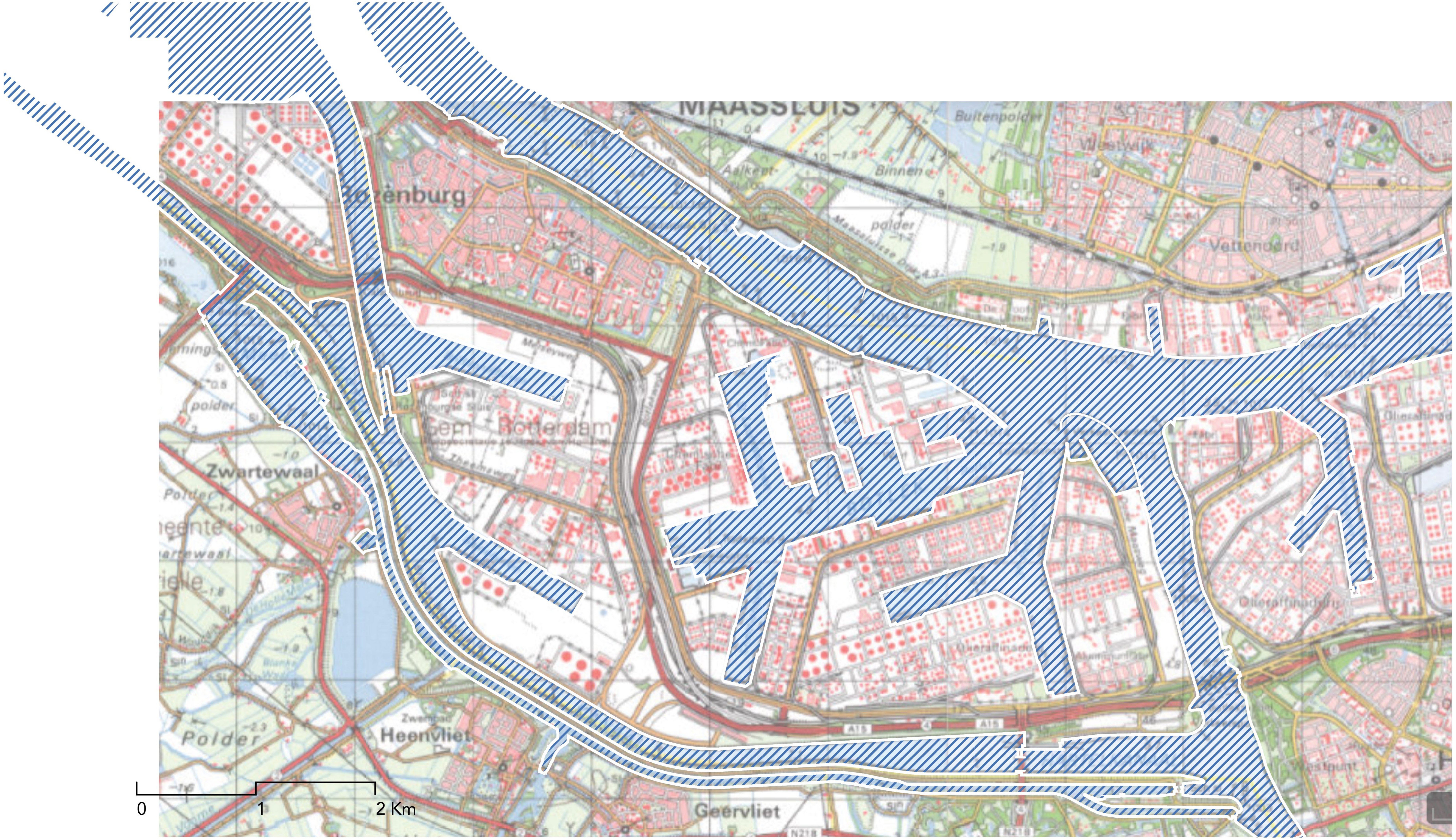
Botlek

Existing plan



Revisiting

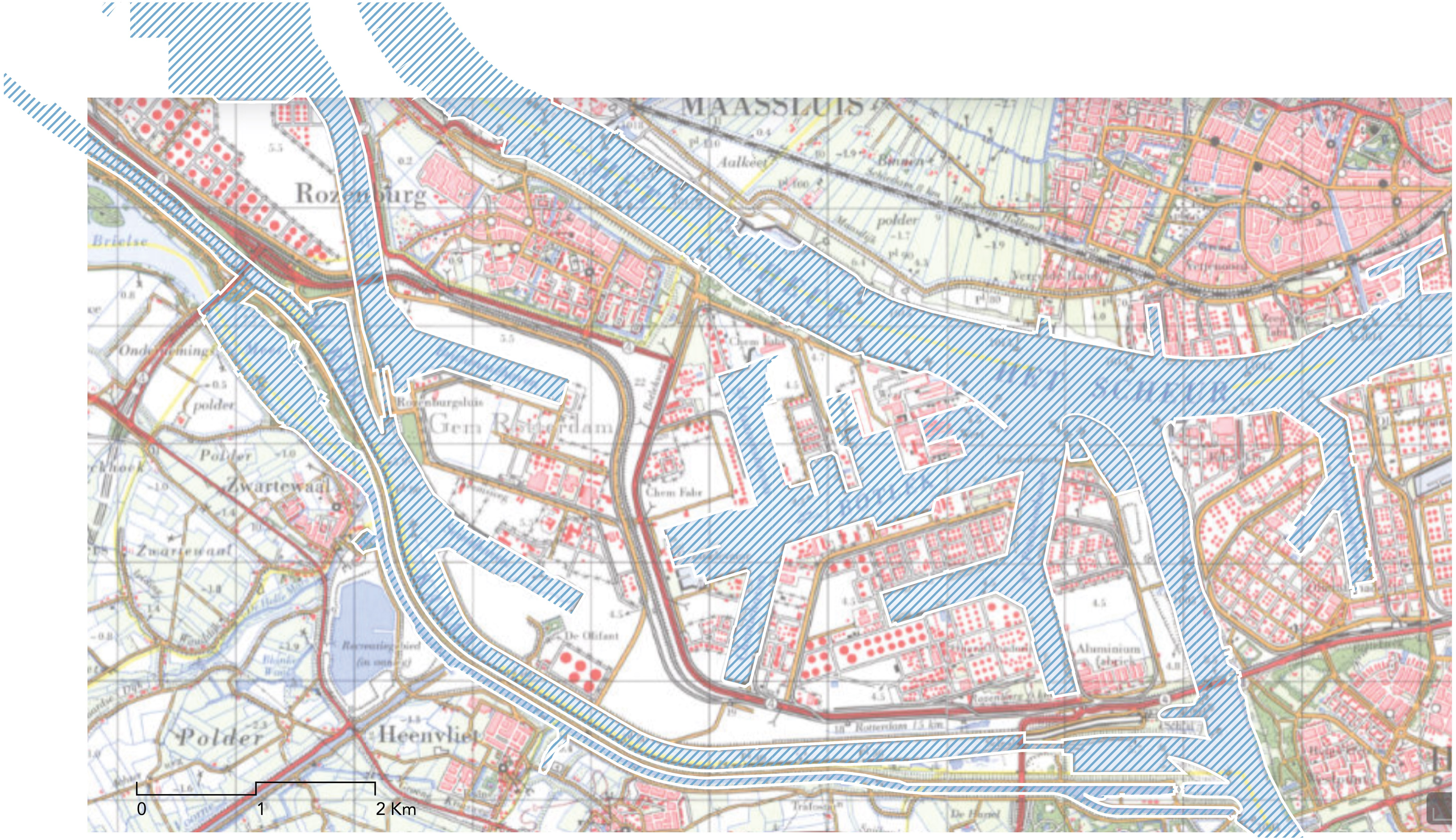
2000



Historical maps of Botlek
Source: Topotijdreis

Revisiting

1975



Historical maps of Botlek

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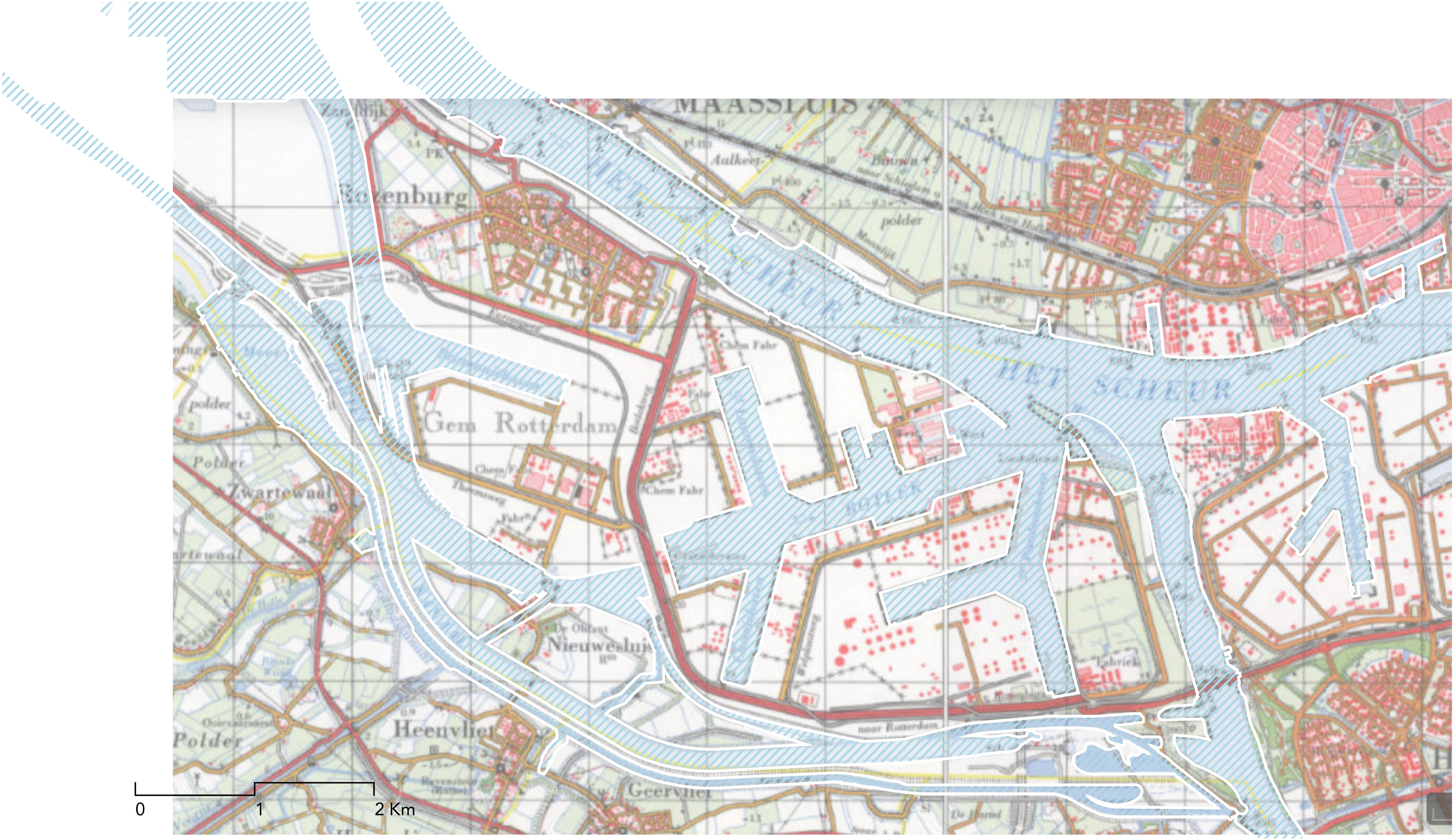
Revisiting

1969



Historical maps of Botlek
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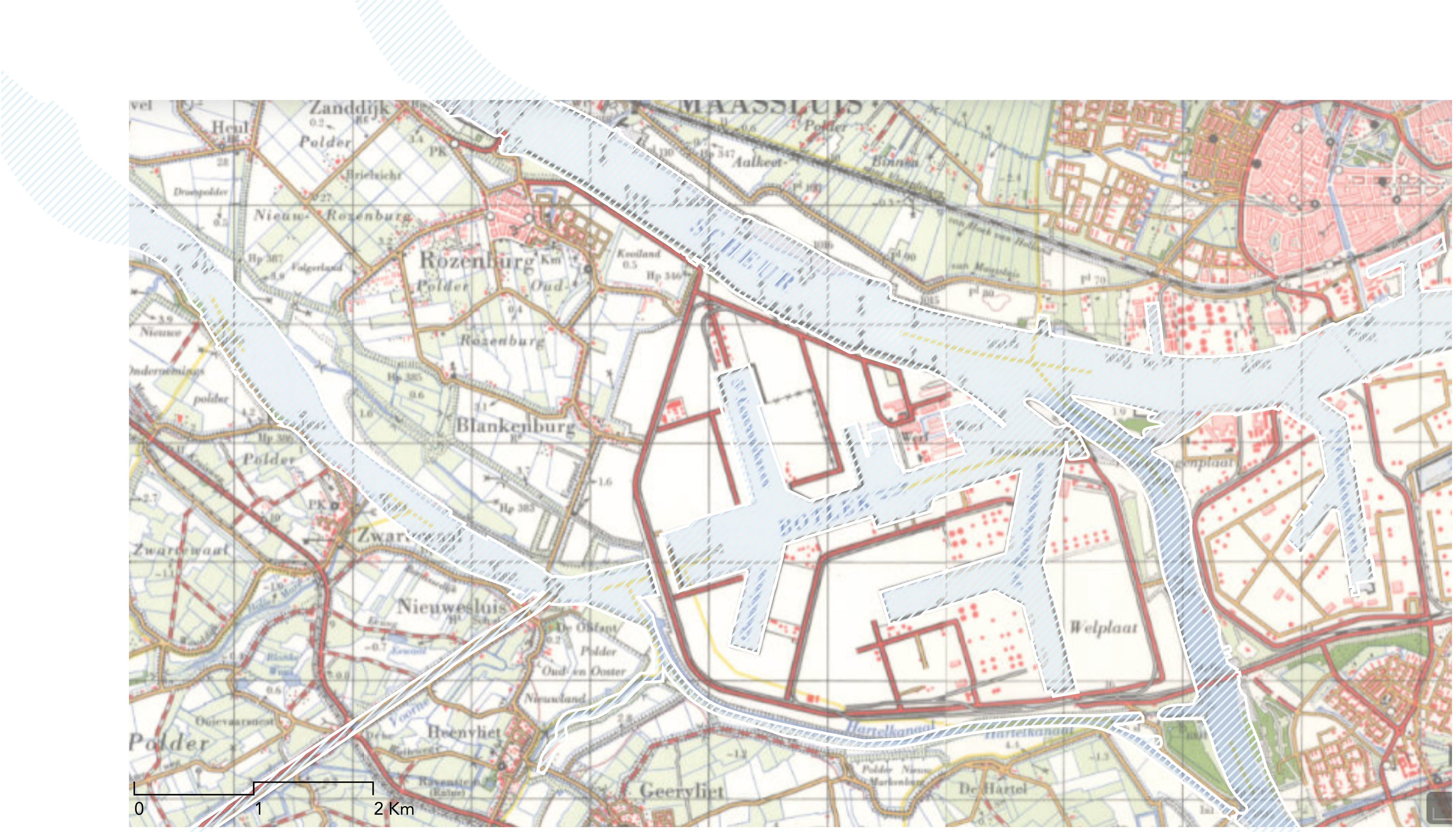
Revisiting

1967



Historical maps of Botlek
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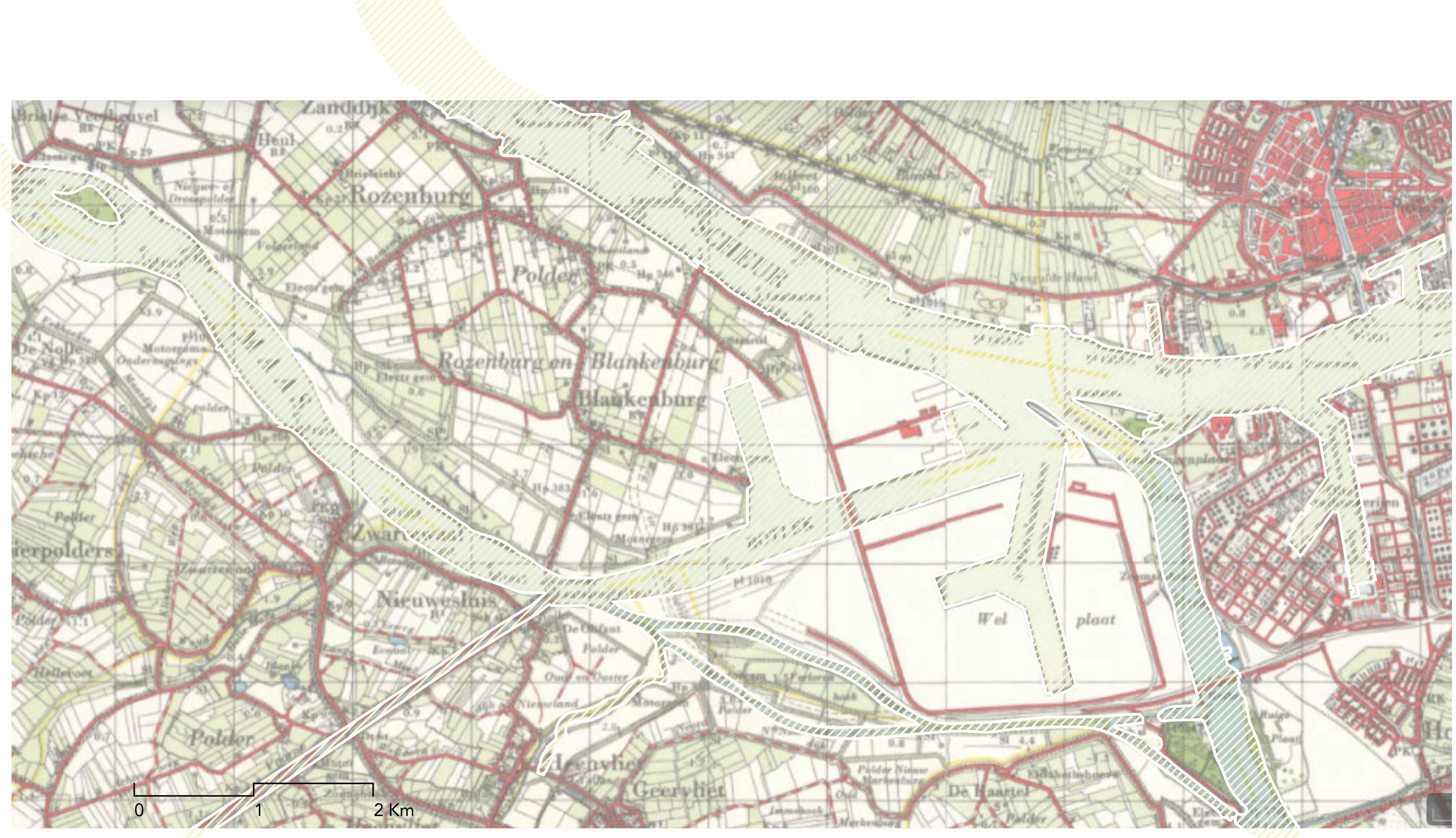
Revisiting

1958



Historical maps of Botlek
Source: Topotijdreis

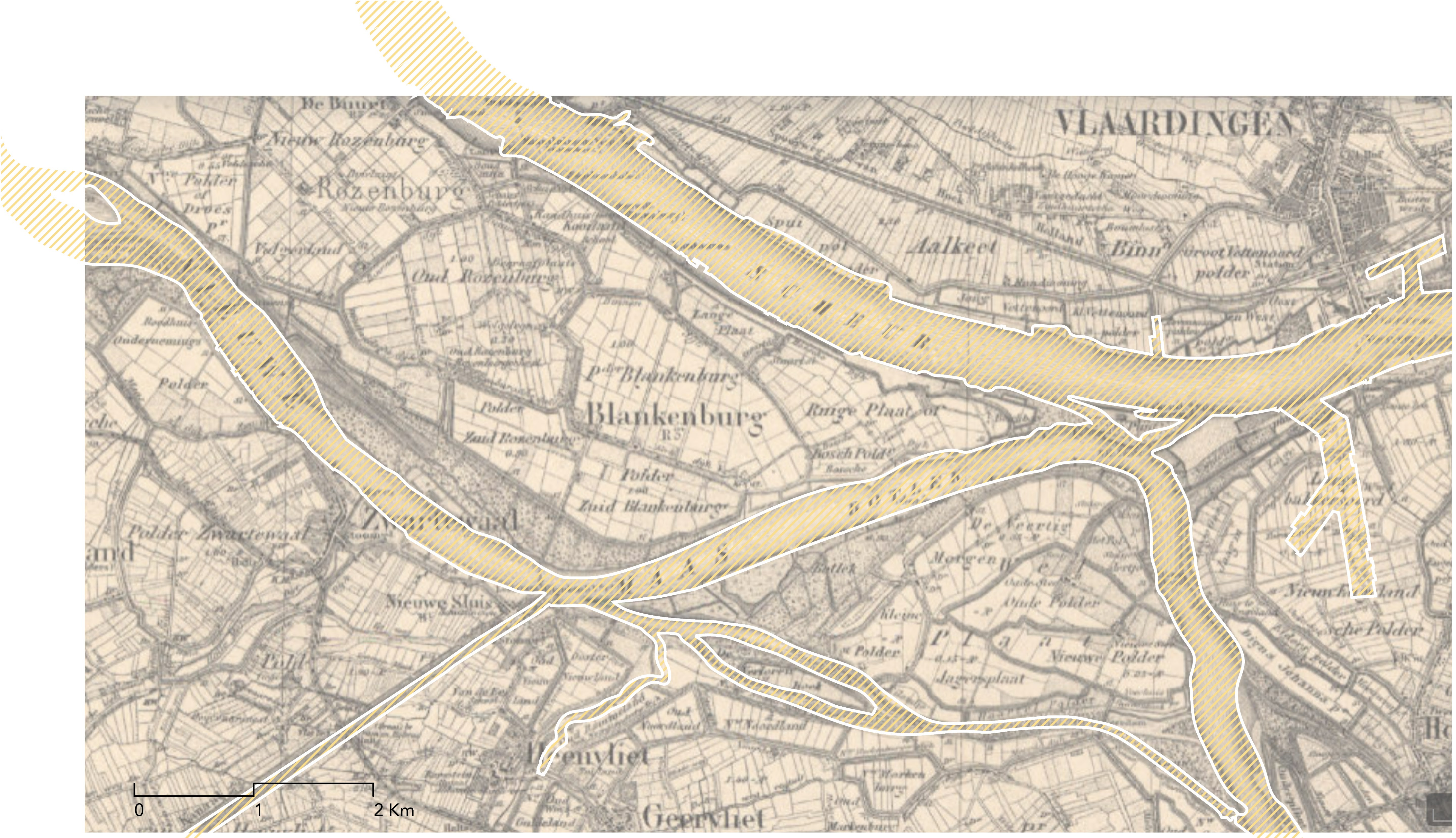
Revisiting

1940

Historical maps of Botlek
Source: Topotijdreis

Revisiting

1910

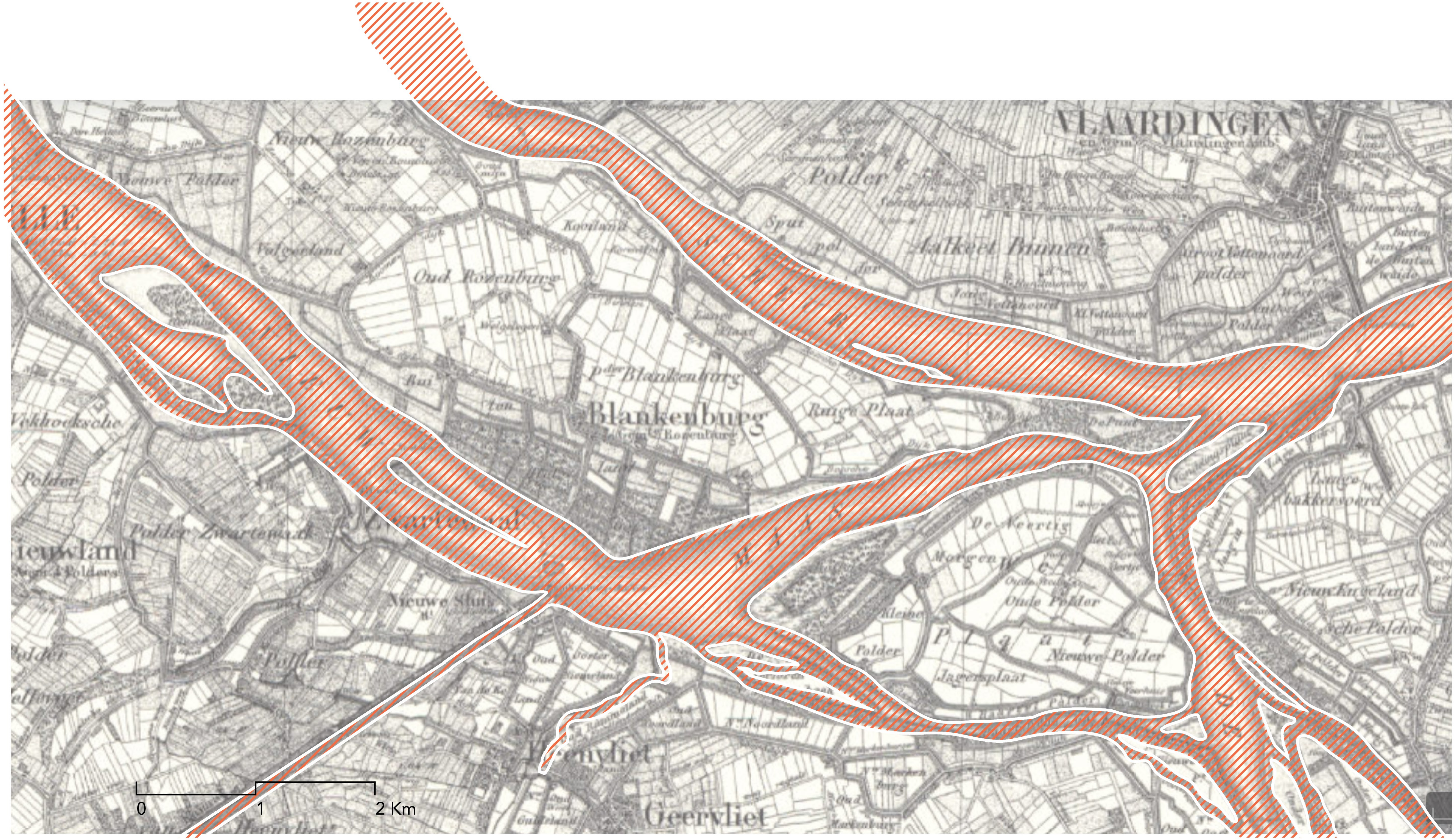


Historical maps of Botlek

Source: Topotijdreis

Revisiting

1860



Historical maps of Botlek
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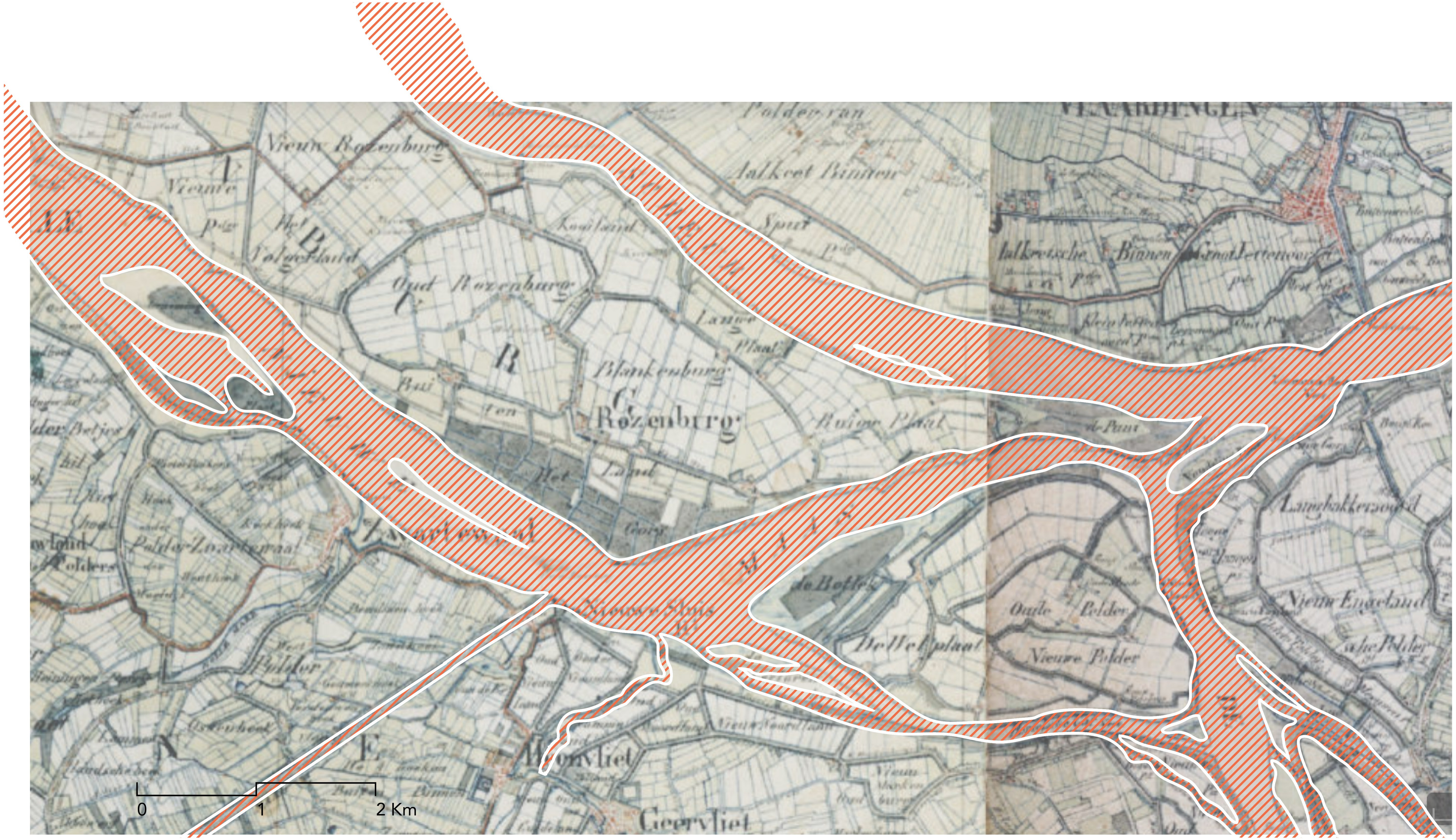
Revisiting

1840



Historical maps of Botlek
Source: Topotijdreis

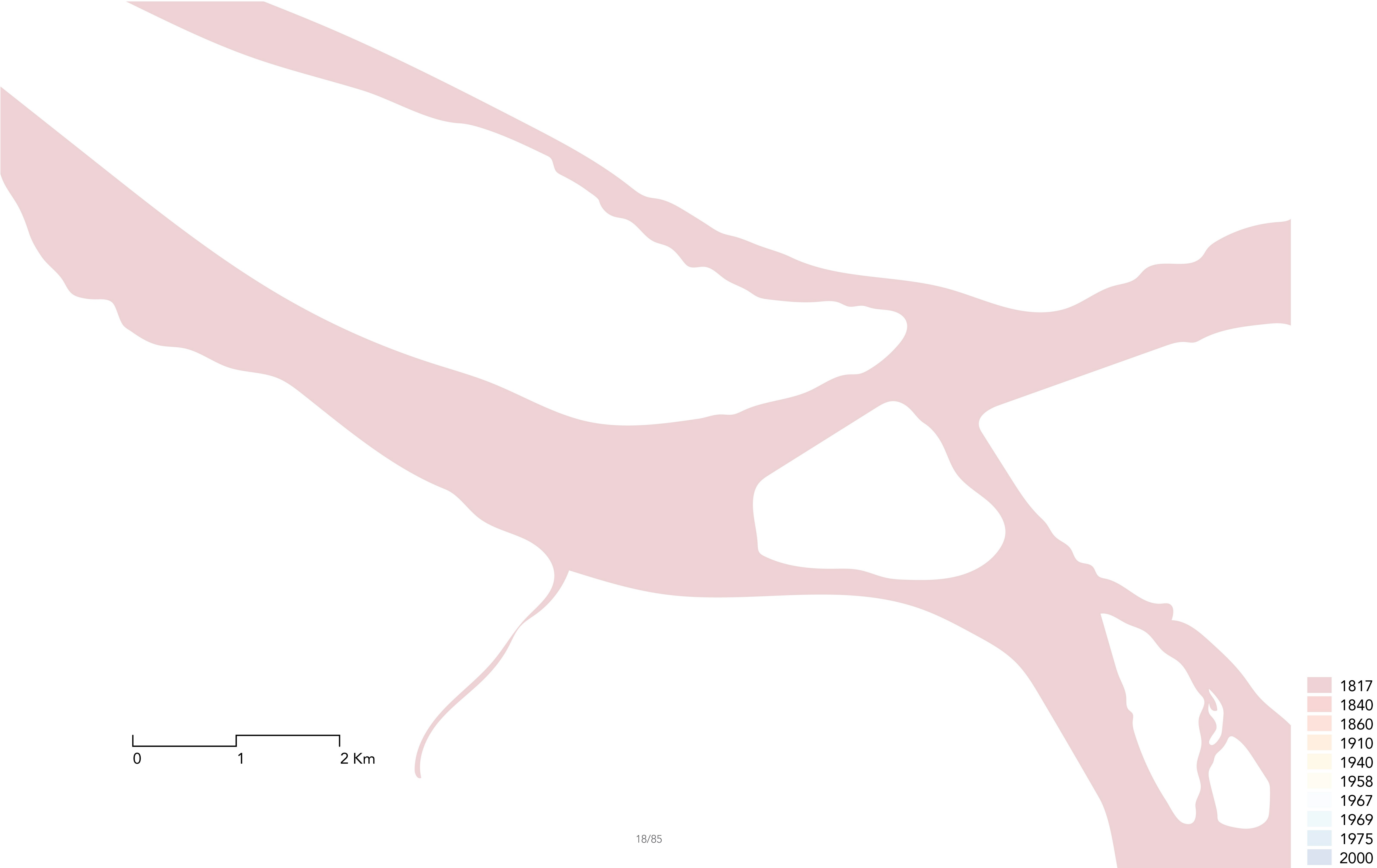
Revisiting

1817

Historical maps of Botlek
Source: Topotijdreis

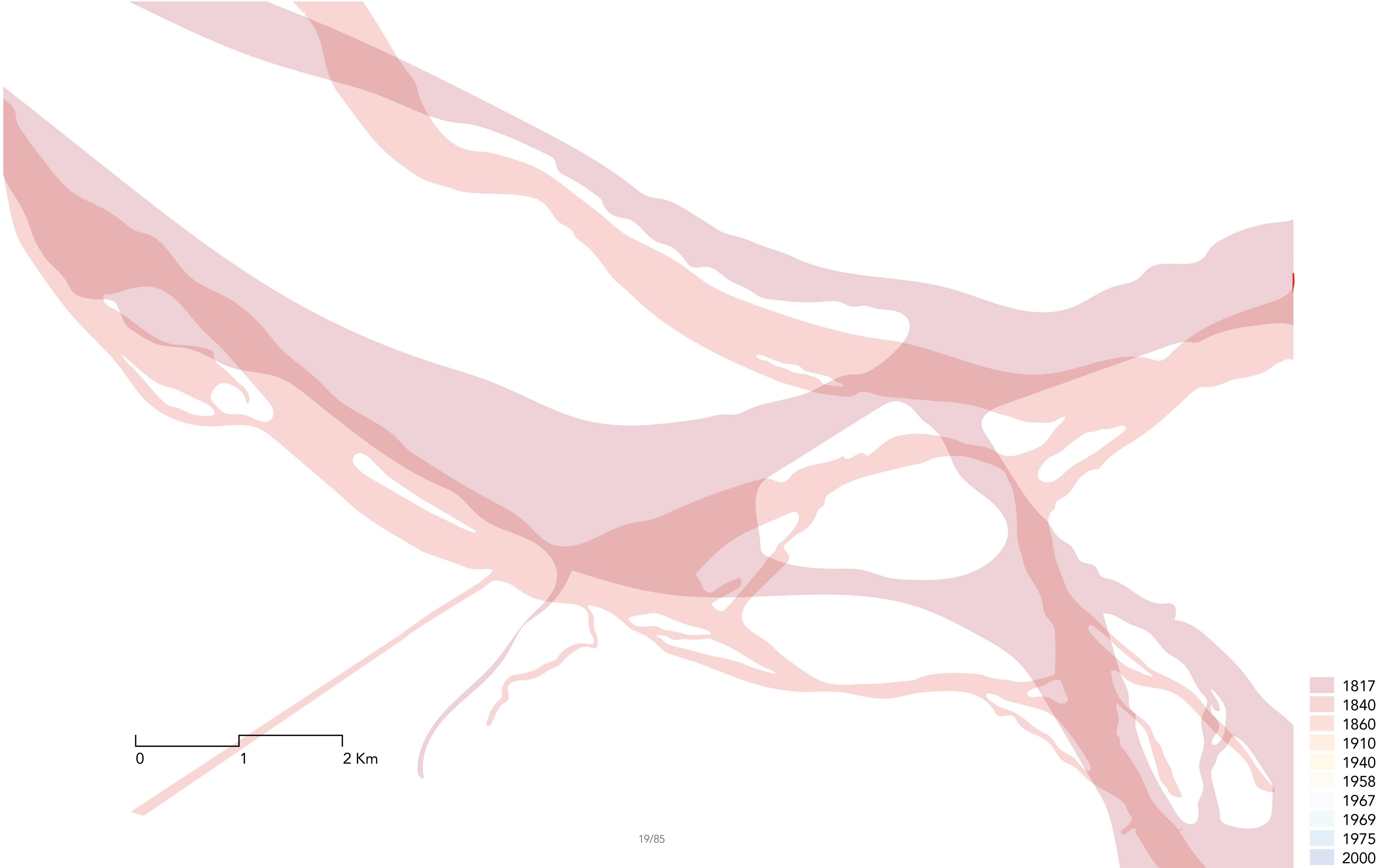
Revisiting

1817



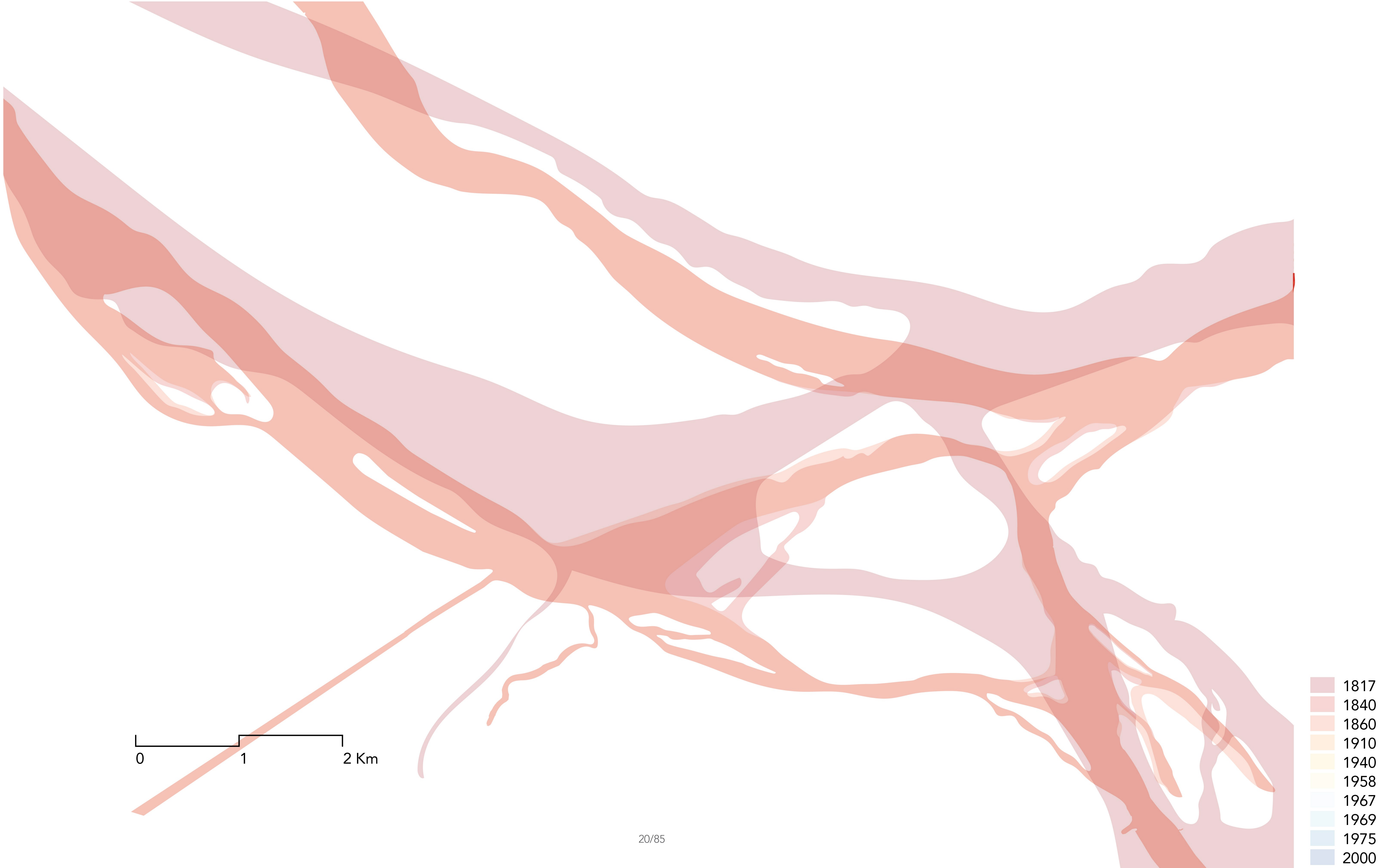
Revisiting

1840



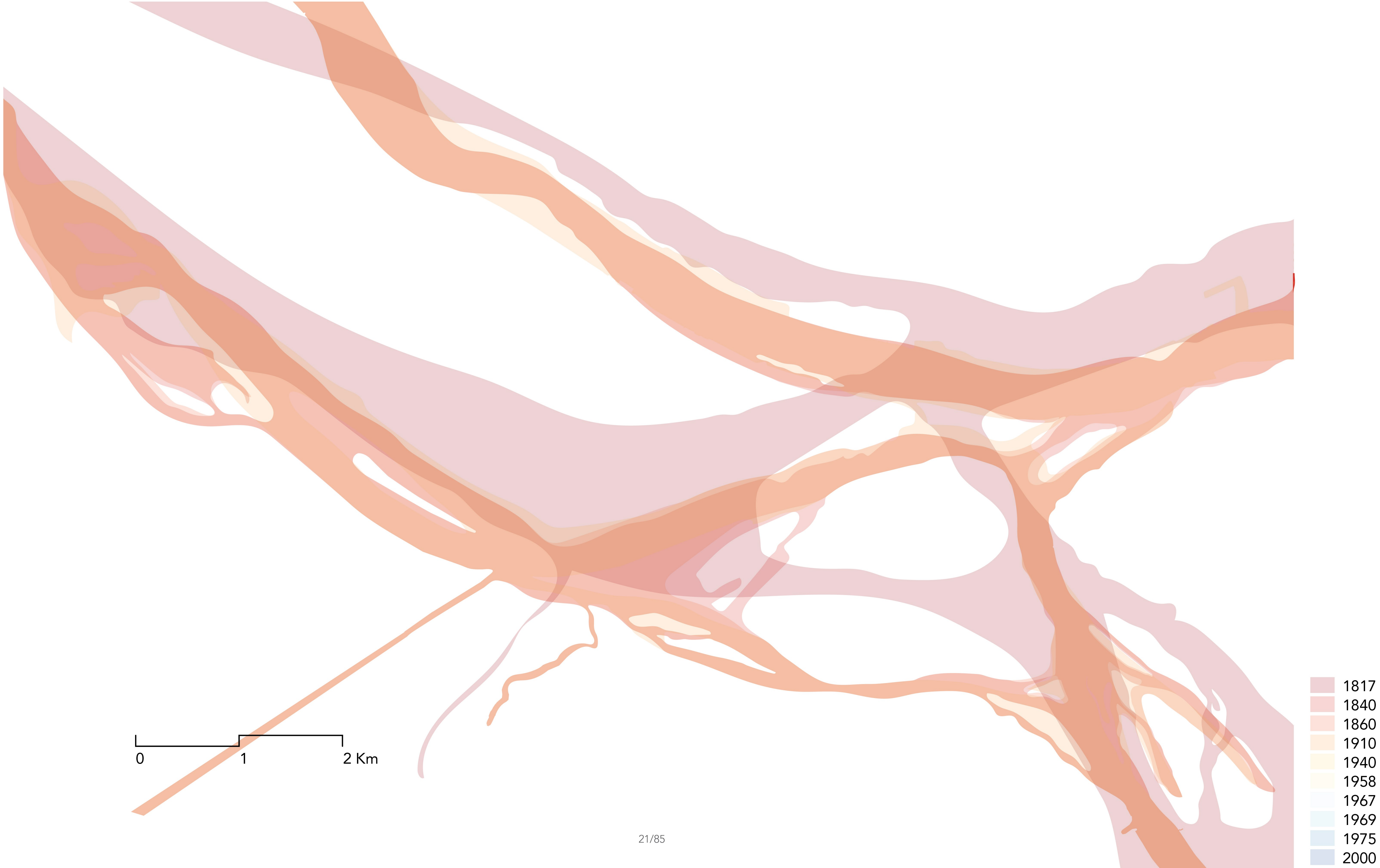
Revisiting

1860



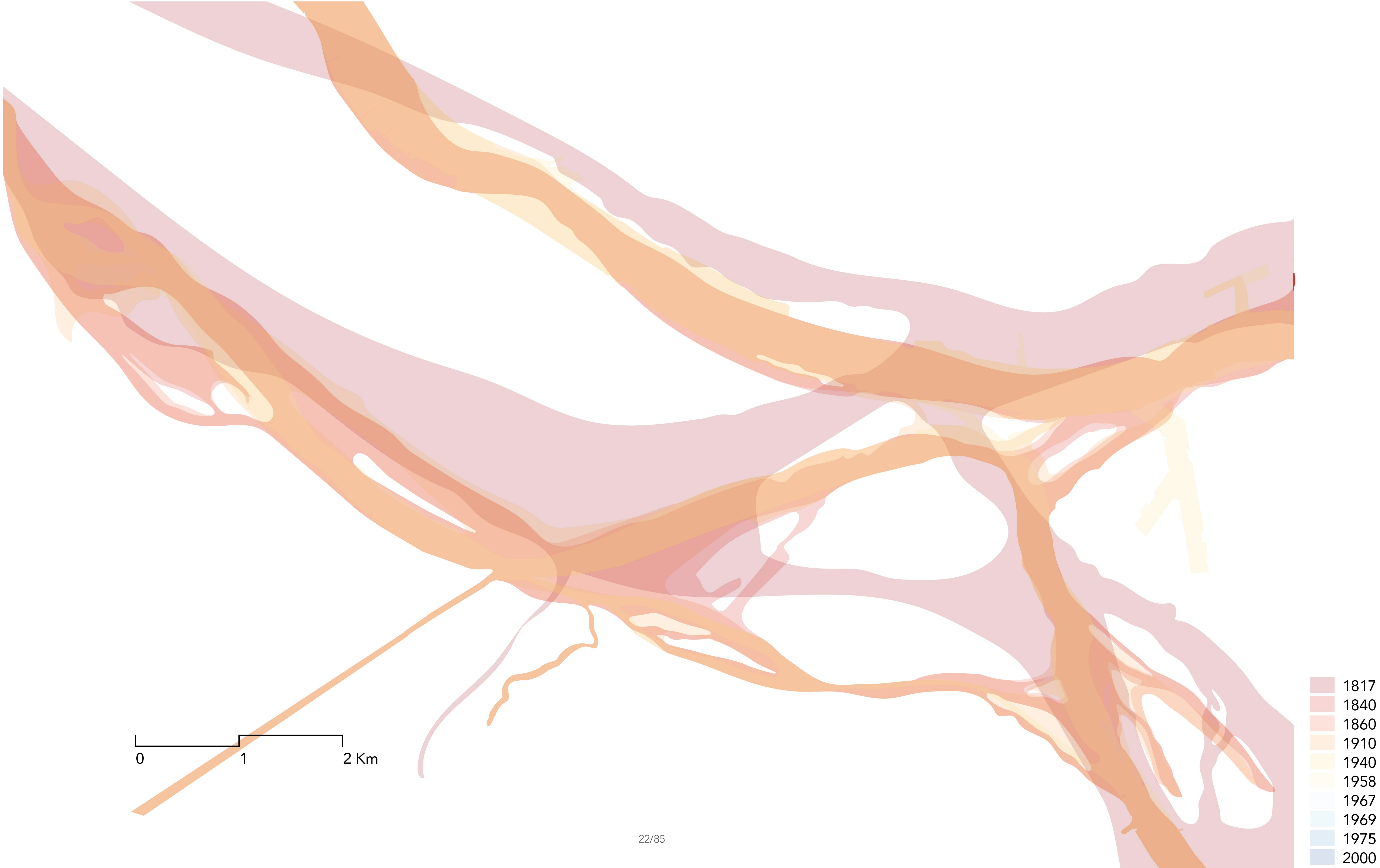
Revisiting

1910



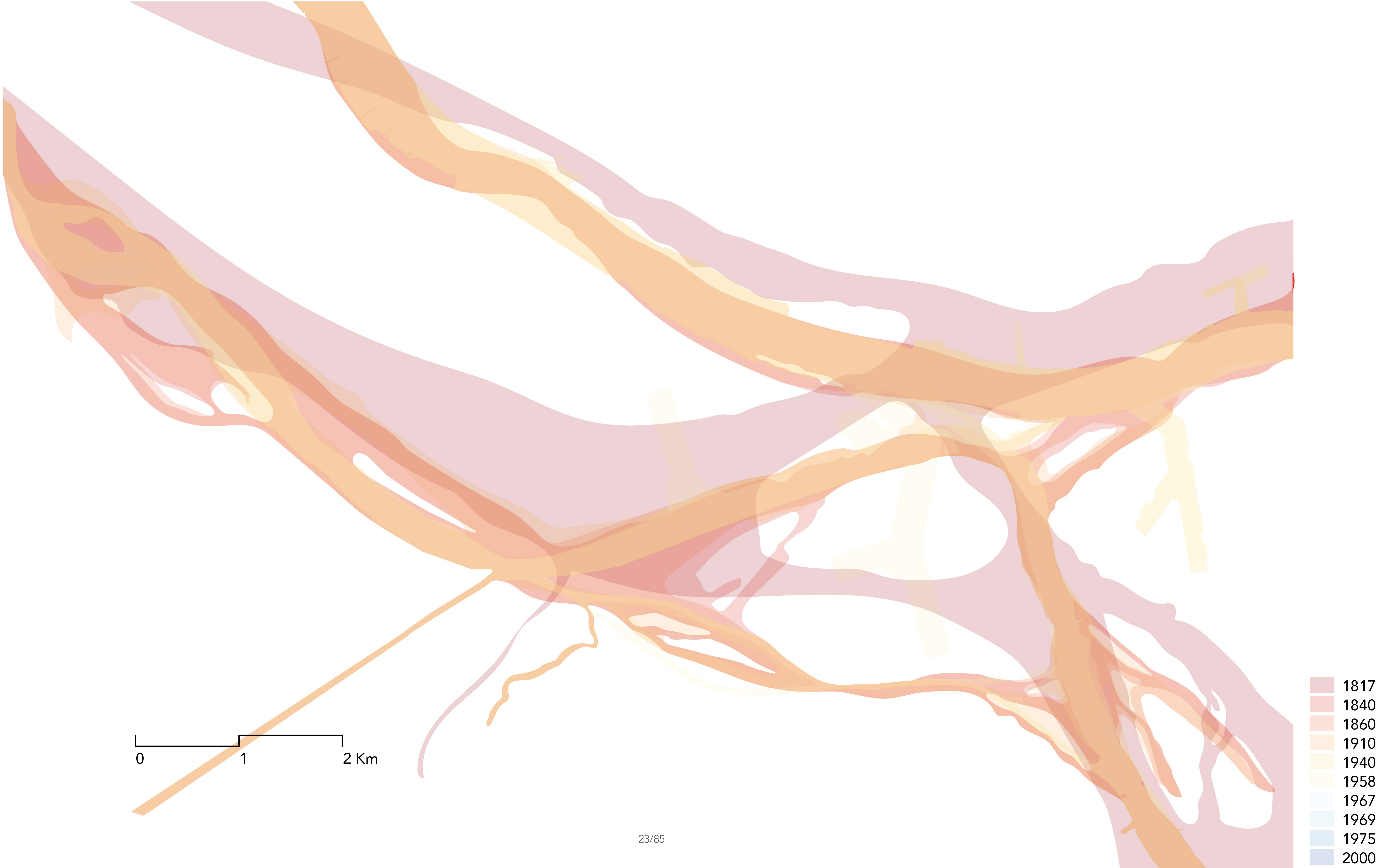
Revisiting

1940



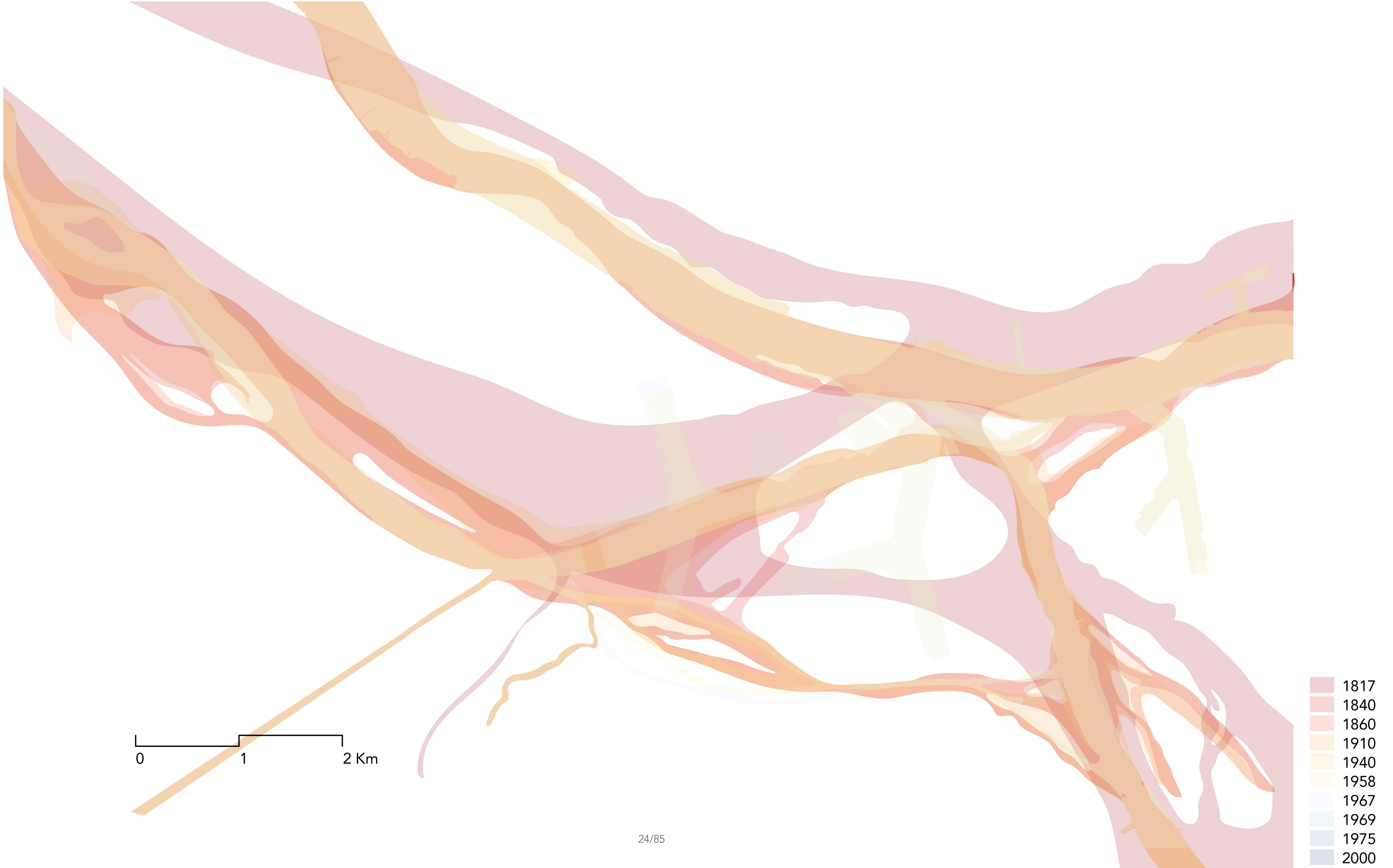
Revisiting

1958



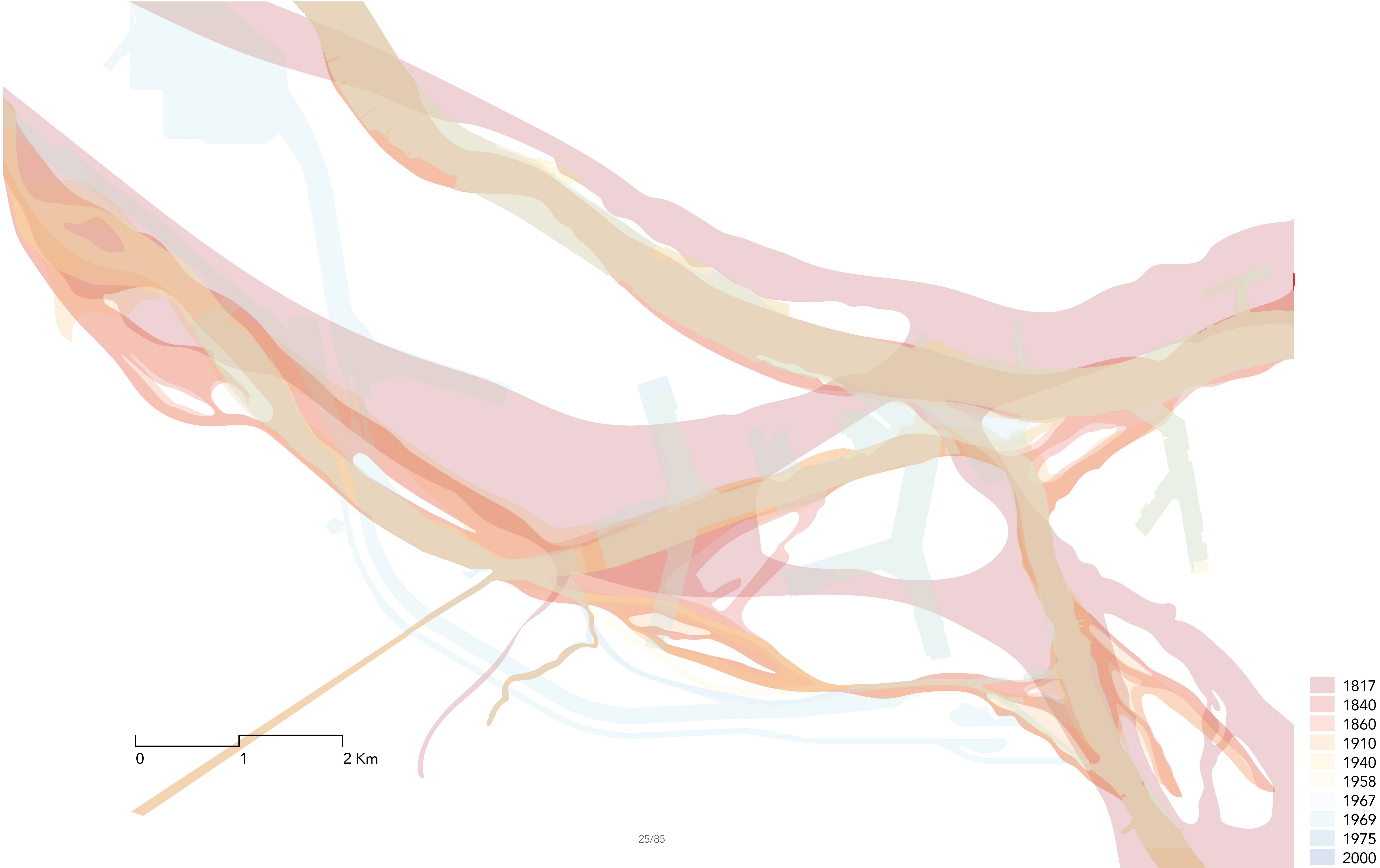
Revisiting

1967



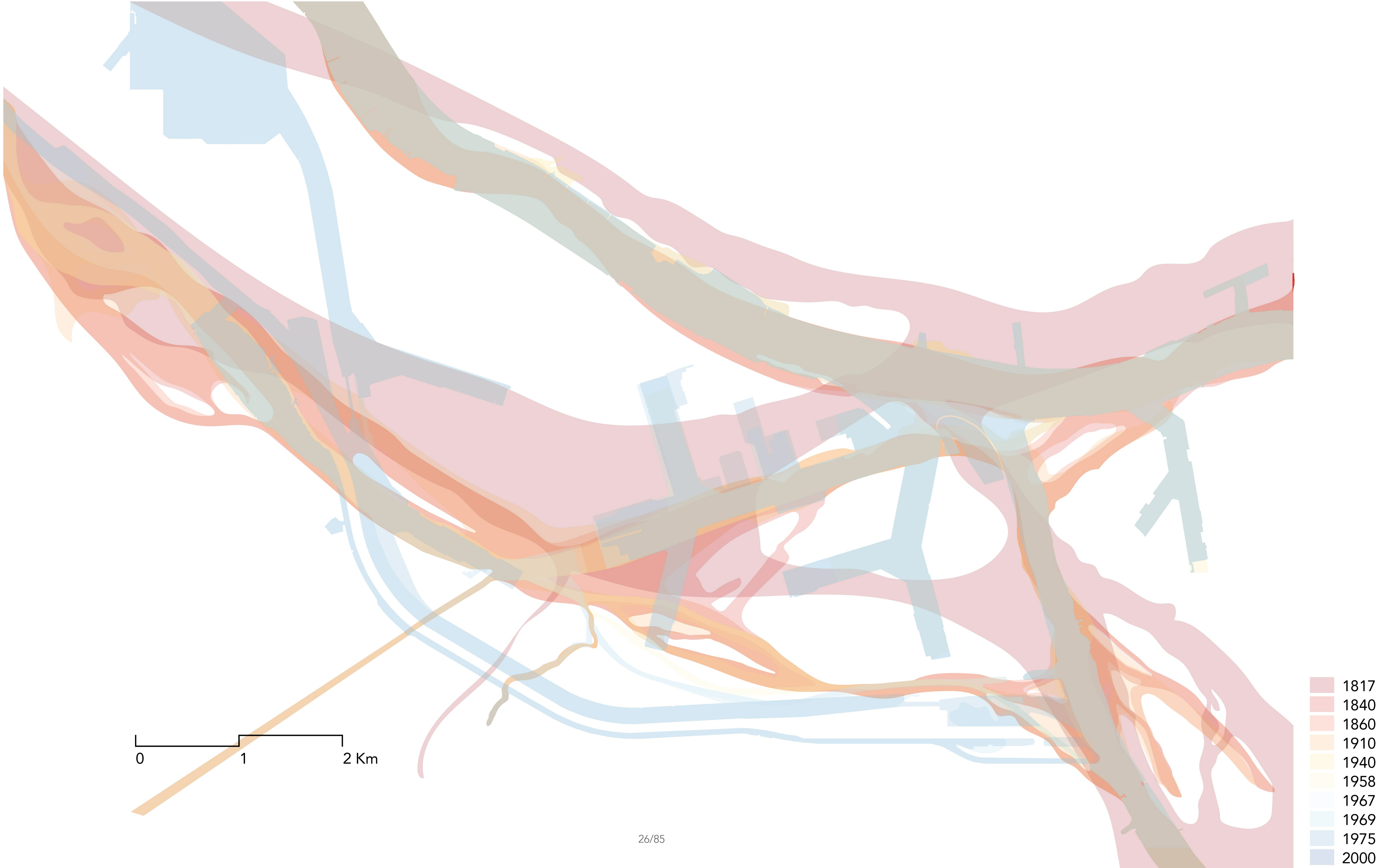
Revisiting

1969



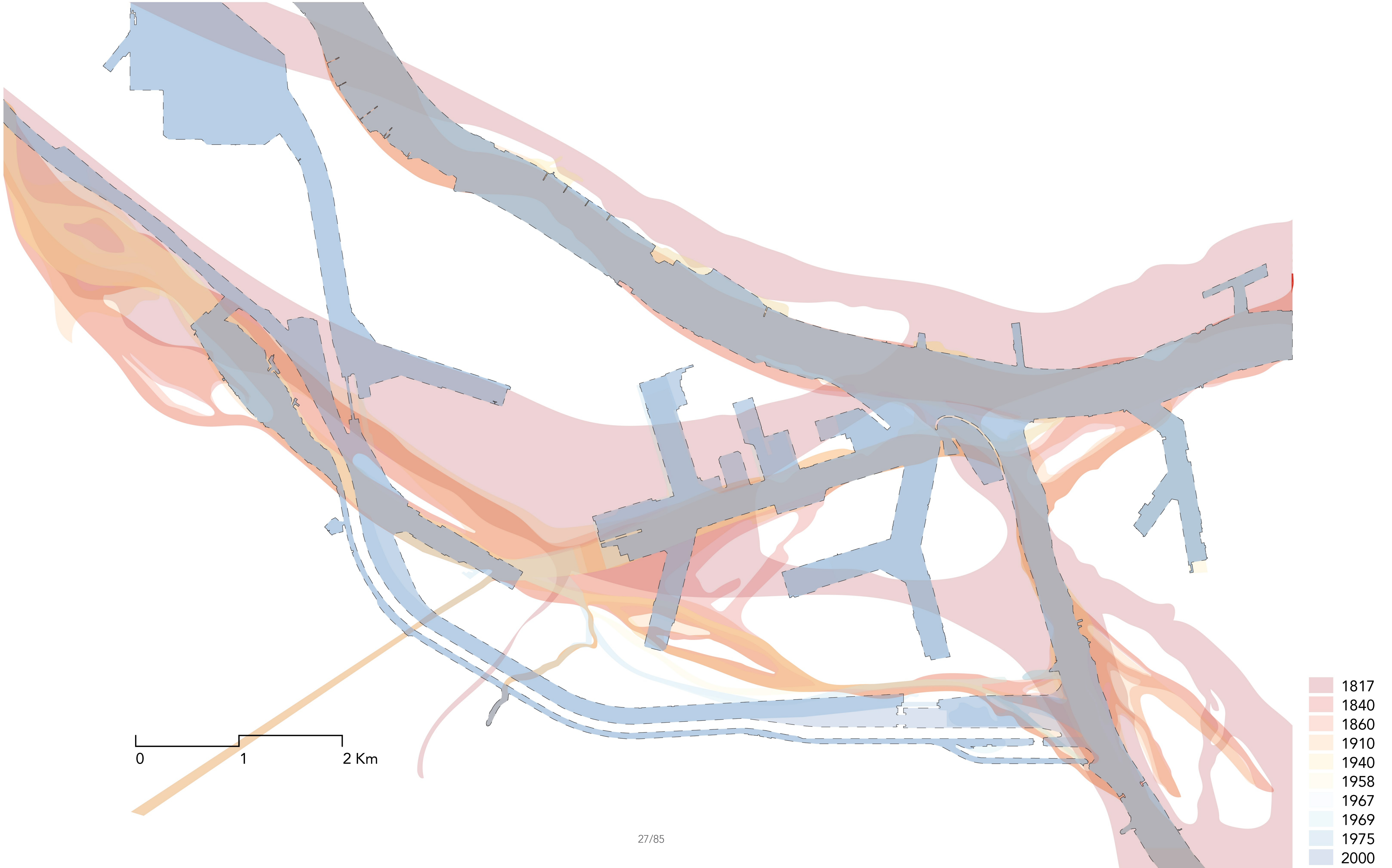
Revisiting

1975



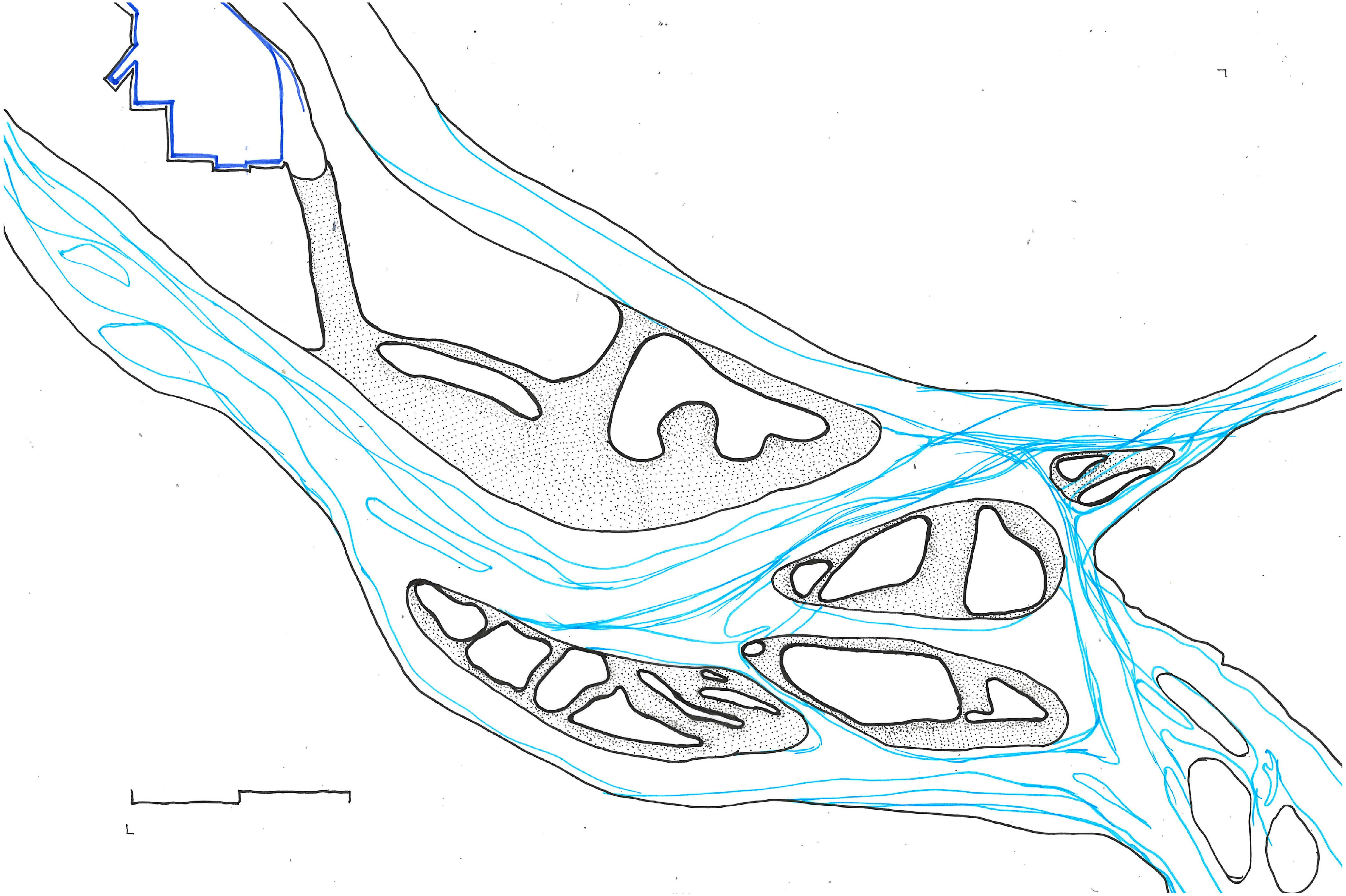
Revisiting

2000



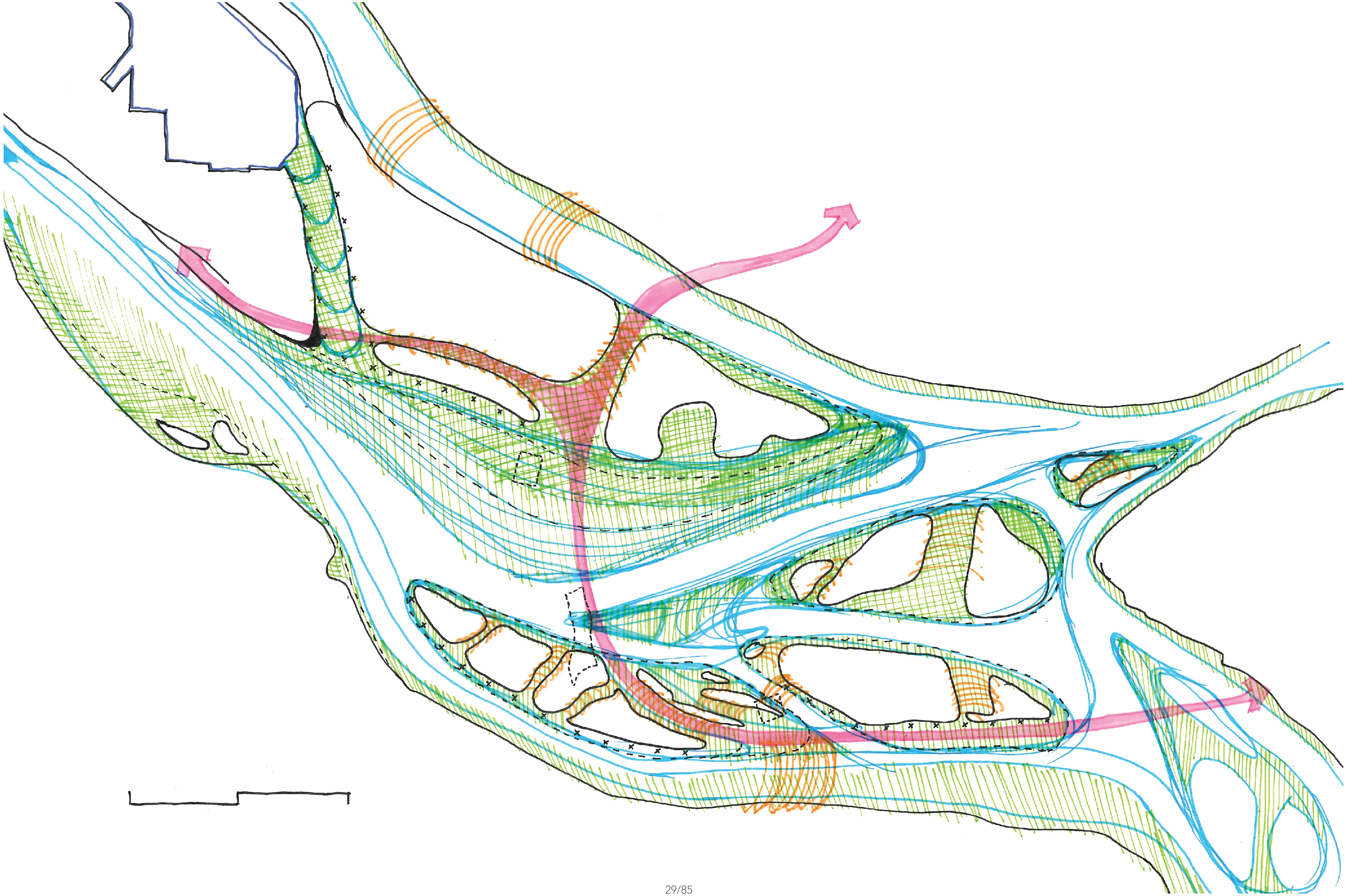
Rhine archipelago

Landform



Rhine archipelago

Scheme



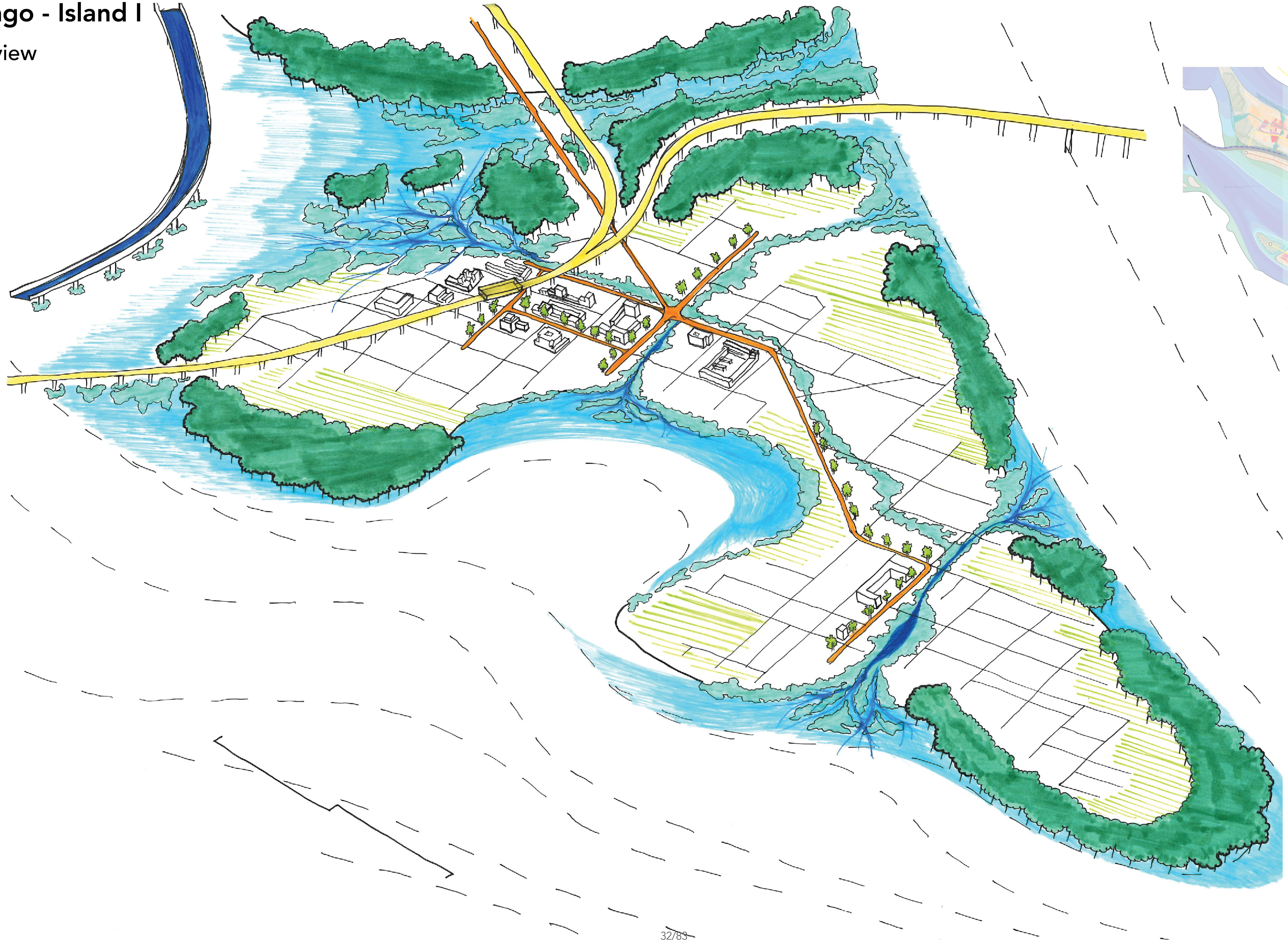
Rhine archipelago

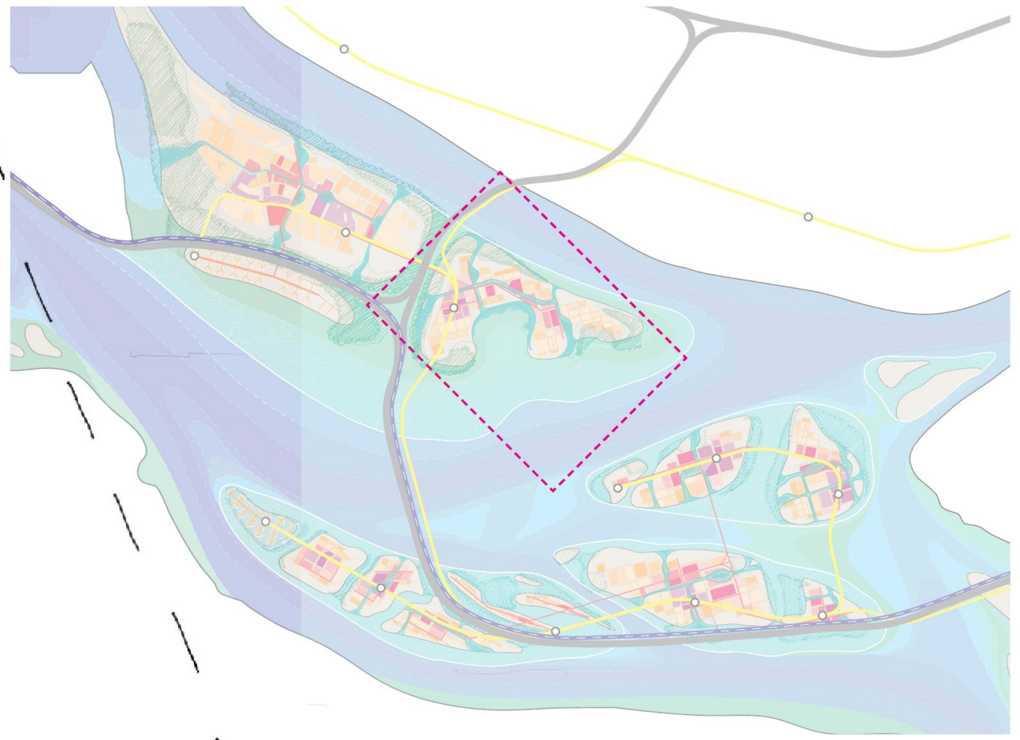
Urban development

Rhine archipelago - Island I

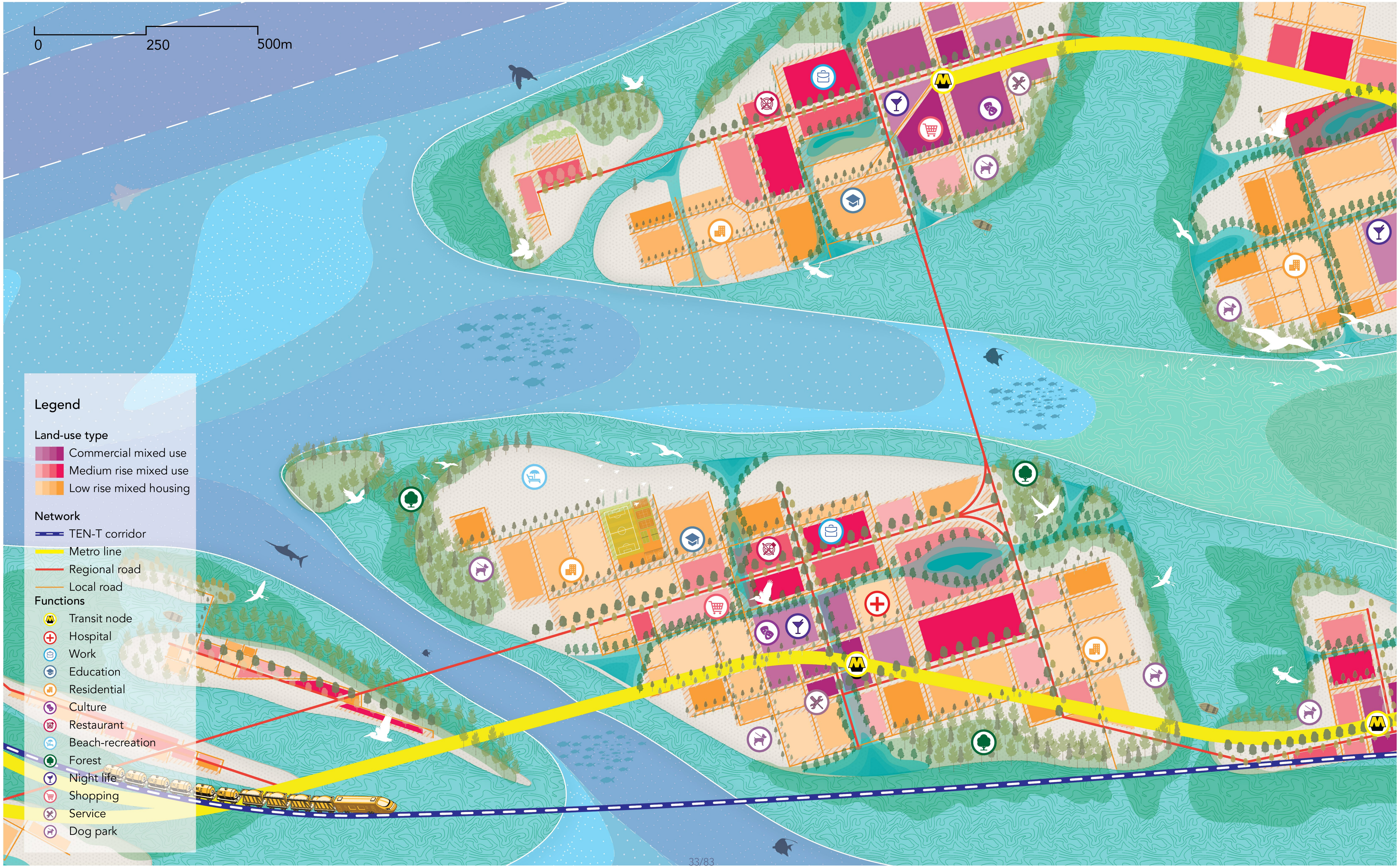
Rhine archipelago - Island I

Isometric view





Rhine archipelago - Island I

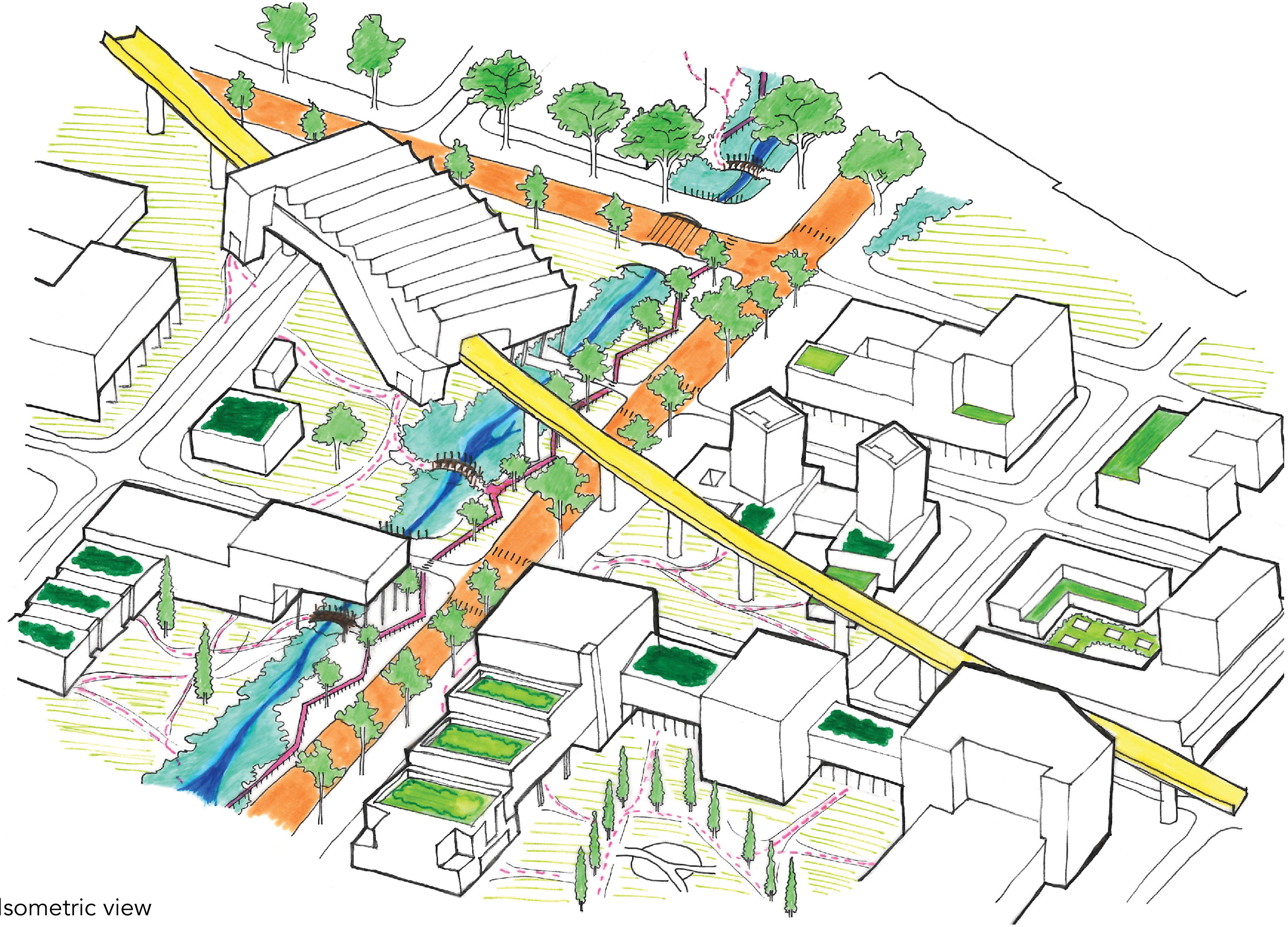


Rhine archipelago - Island I

Isometric view

Rhine archipelago

Transit node



Isometric view

Rhine archipelago

Tidal character

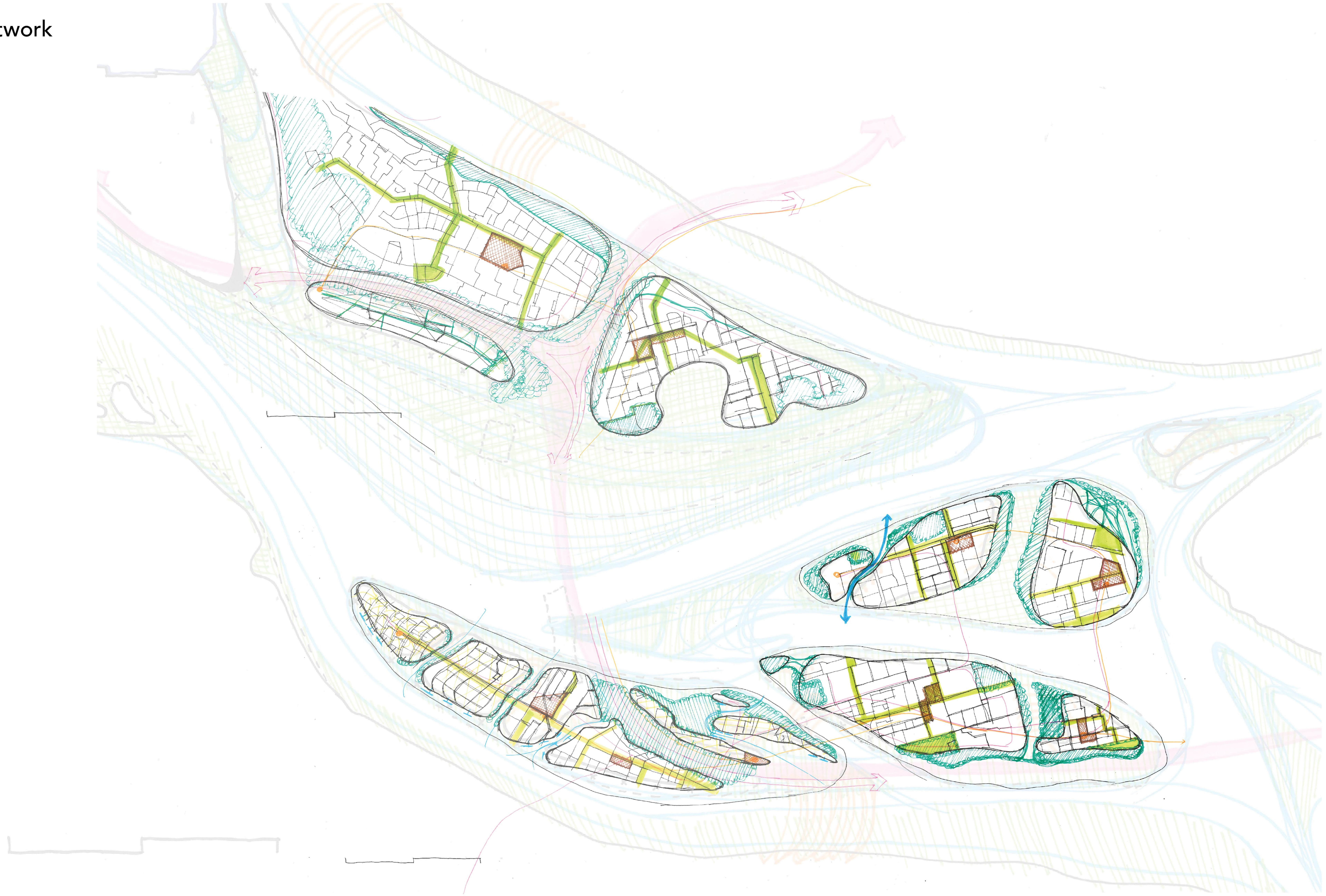
Image generated through Gemini

Rhine archipelago

Urban character

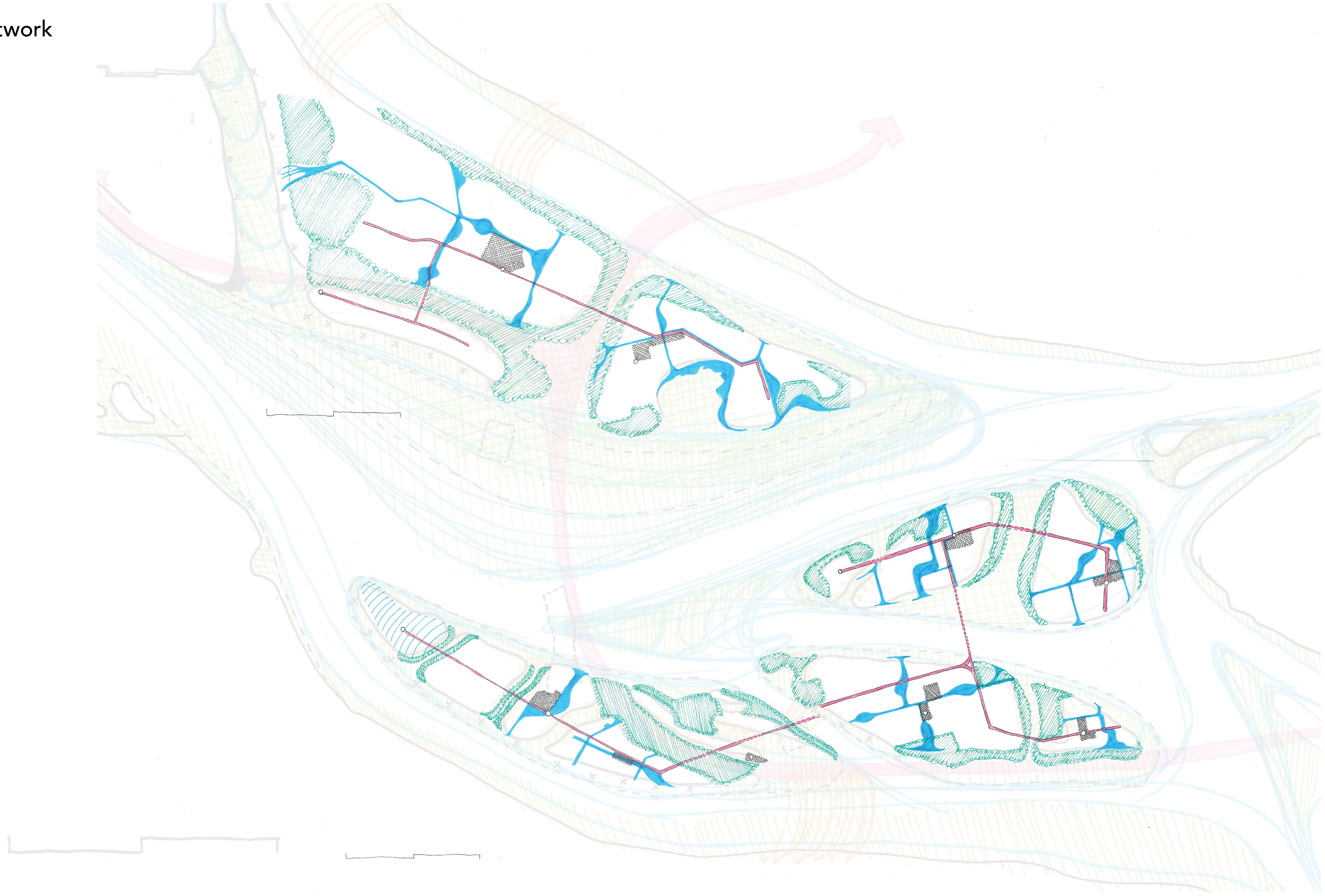
Rhine archipelago

Blue green network



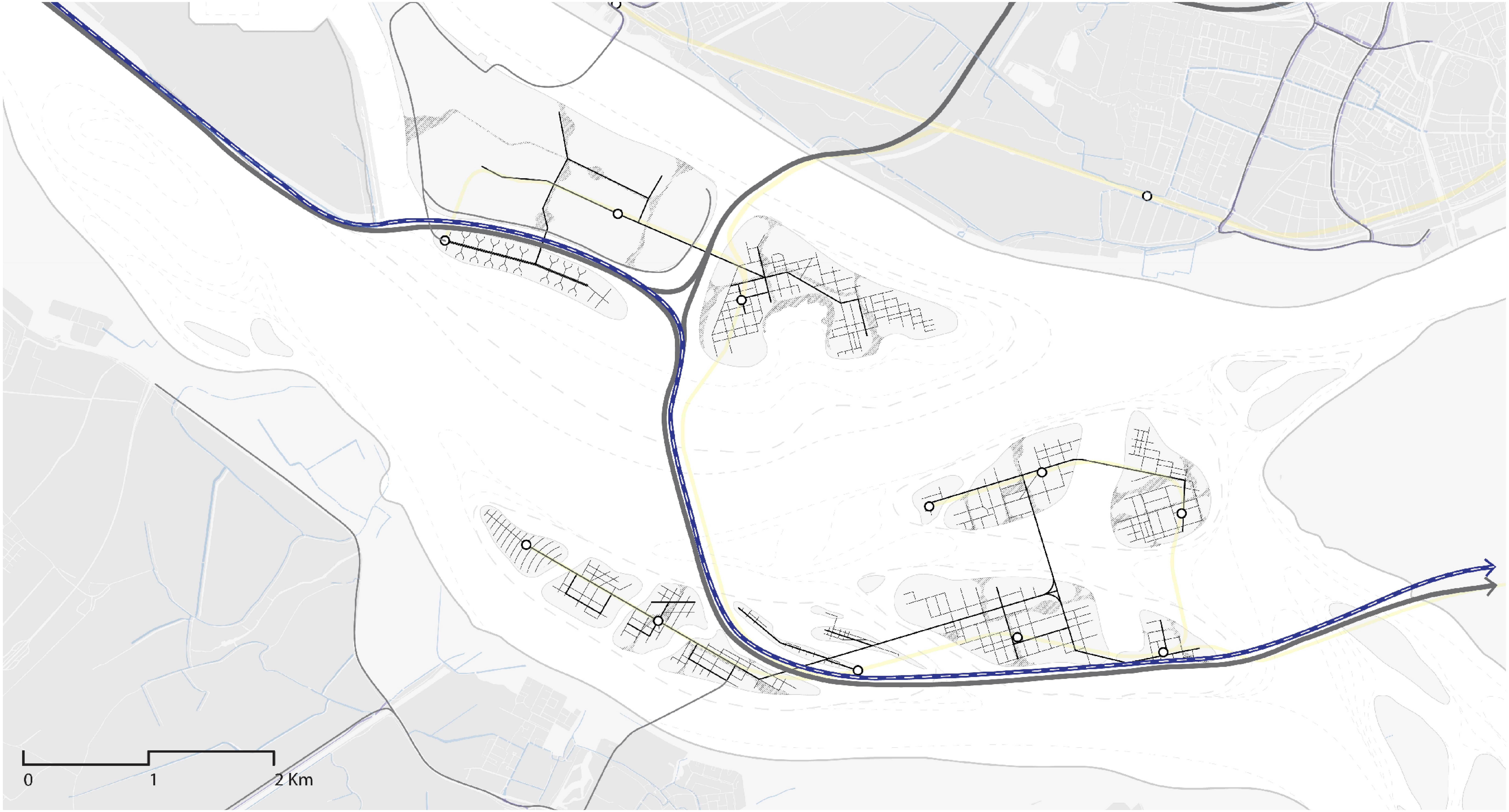
Rhine archipelago

Blue green network



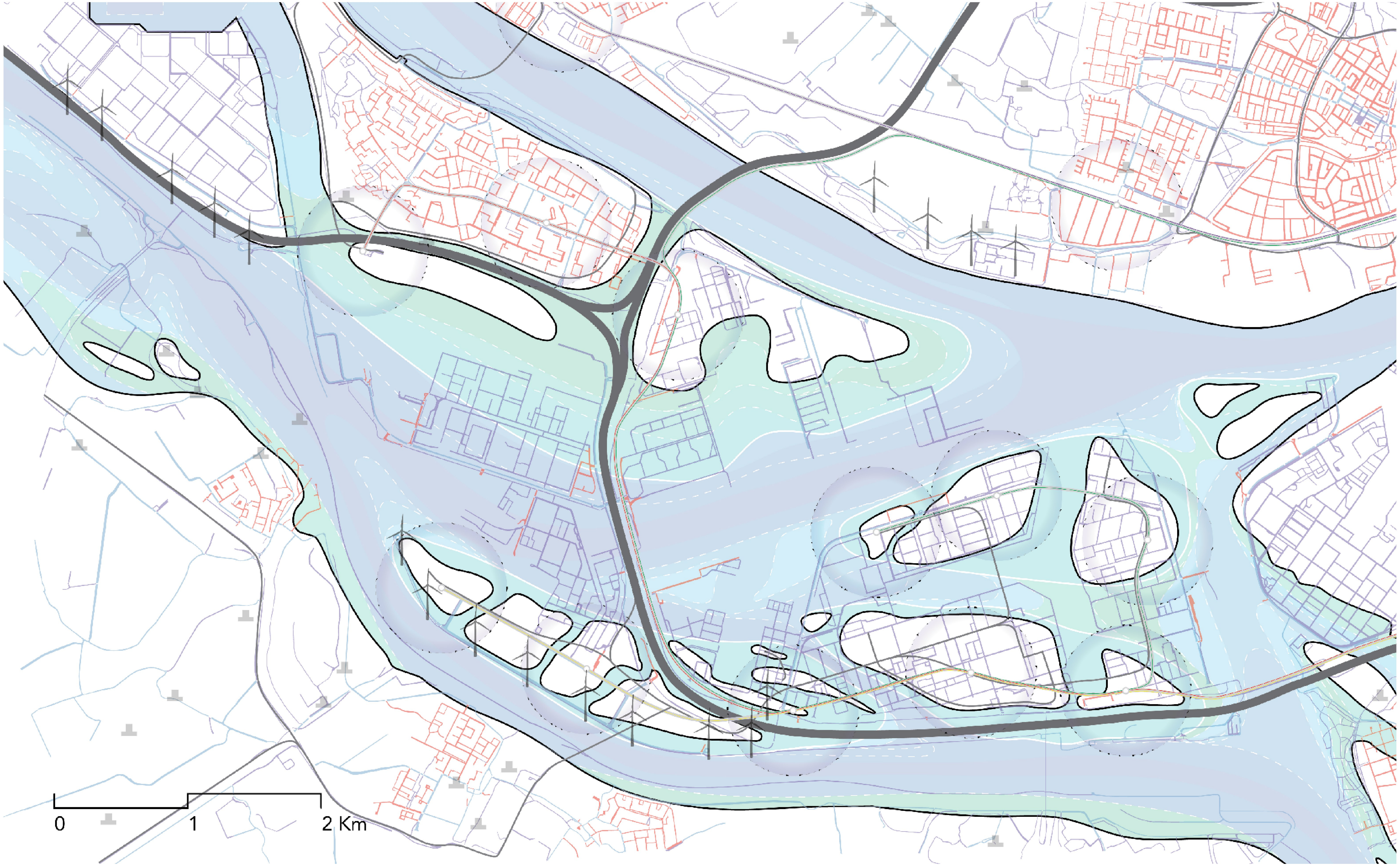
Rhine archipelago

Network layout



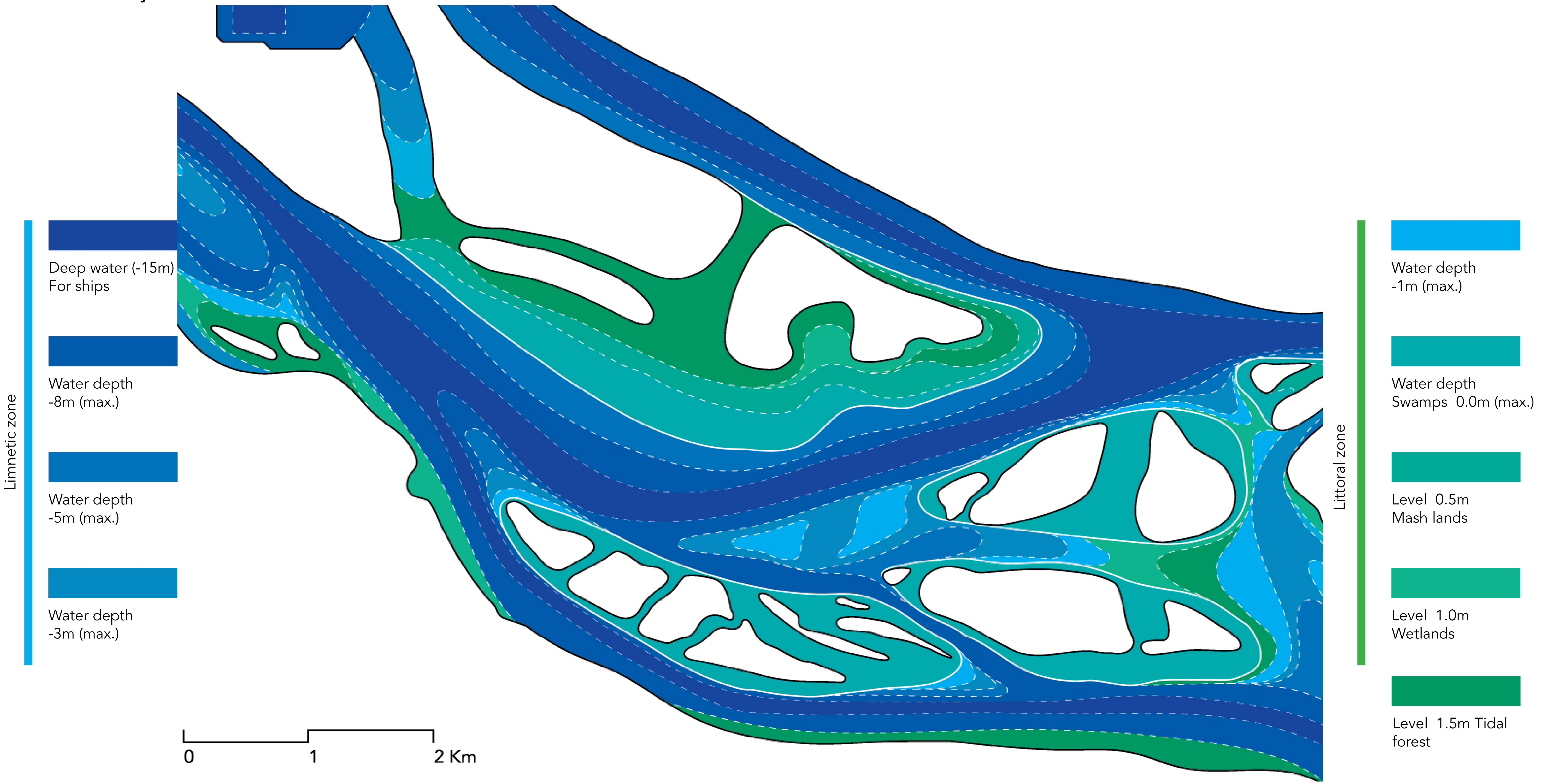
Rhine archipelago

Existing network layout



Rhine archipelago

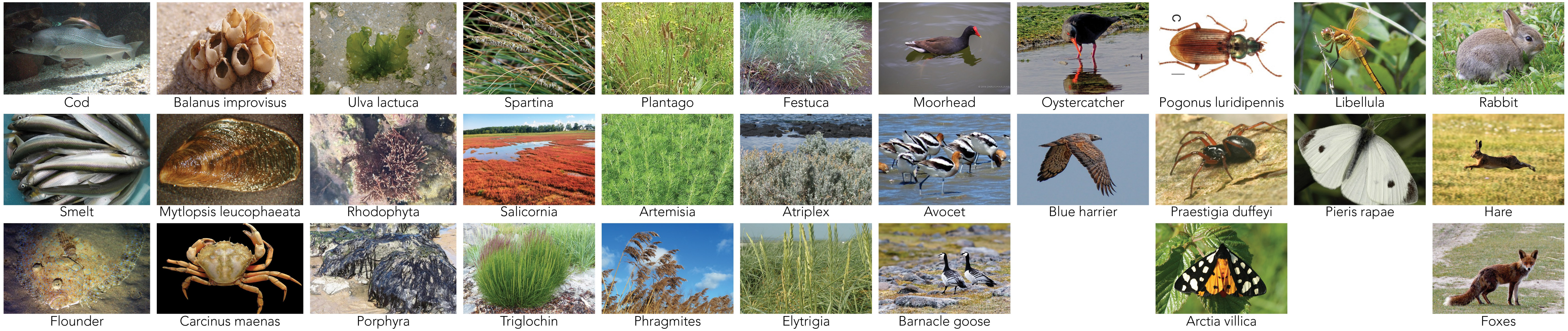
Water dynamics



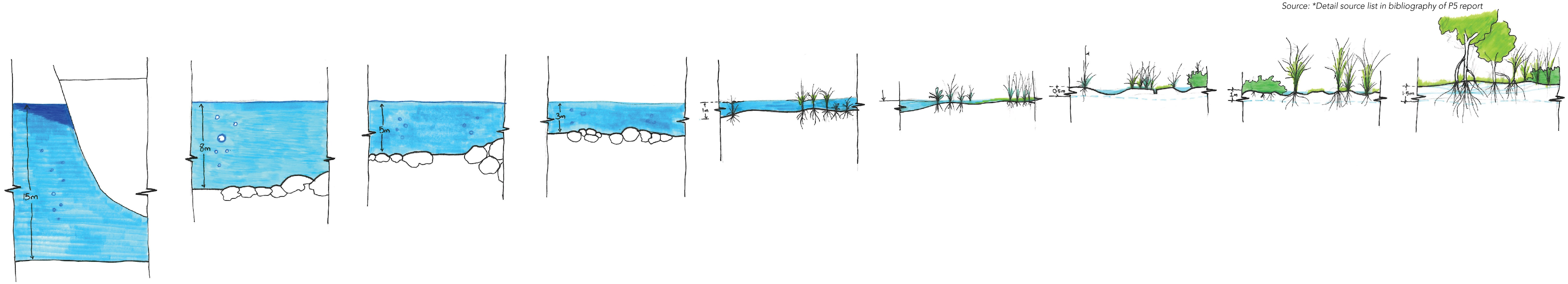
Rhine archipelago

Flora and fauna

Fish | Shell fish and crustaceans | Aquatic plants | Vegetation | Birds | Insects | Mammals



*Source: *Detail source list in bibliography of P5 report*



Deep water (-15m) For ships

Water depth -8m (max.)

Water depth -5m (max.)

Water depth -3m (max.)

Water depth -1m (max.)

Water depth Swamps 0.0m (max.)

Level 0.5m Mash lands

Level 1.0m Wetlands

Level 1.5m Tidal forest

Limnetic zone

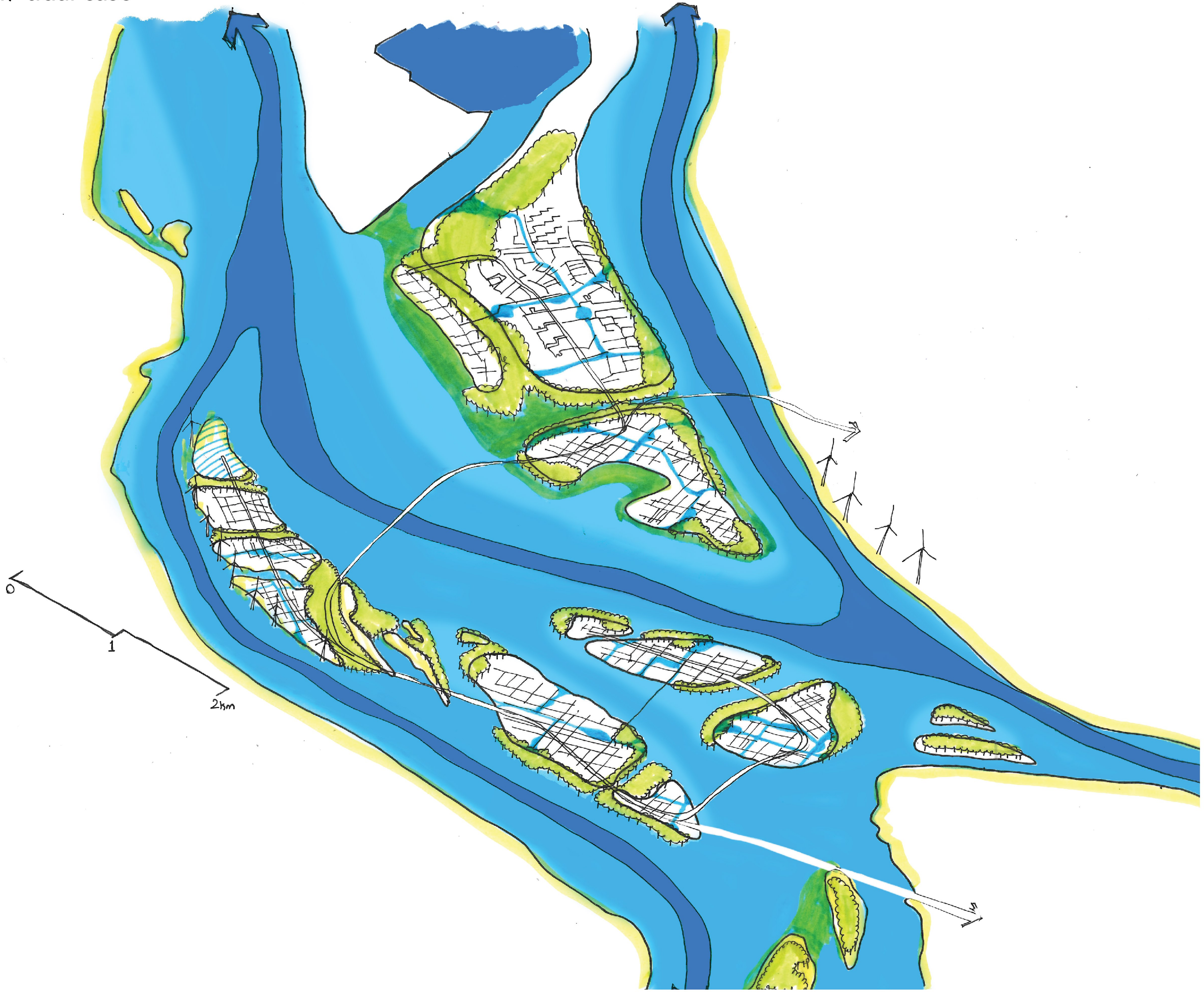
Littoral zone

Rhine archipelago

Flow dynamics - Low water/ tidal case

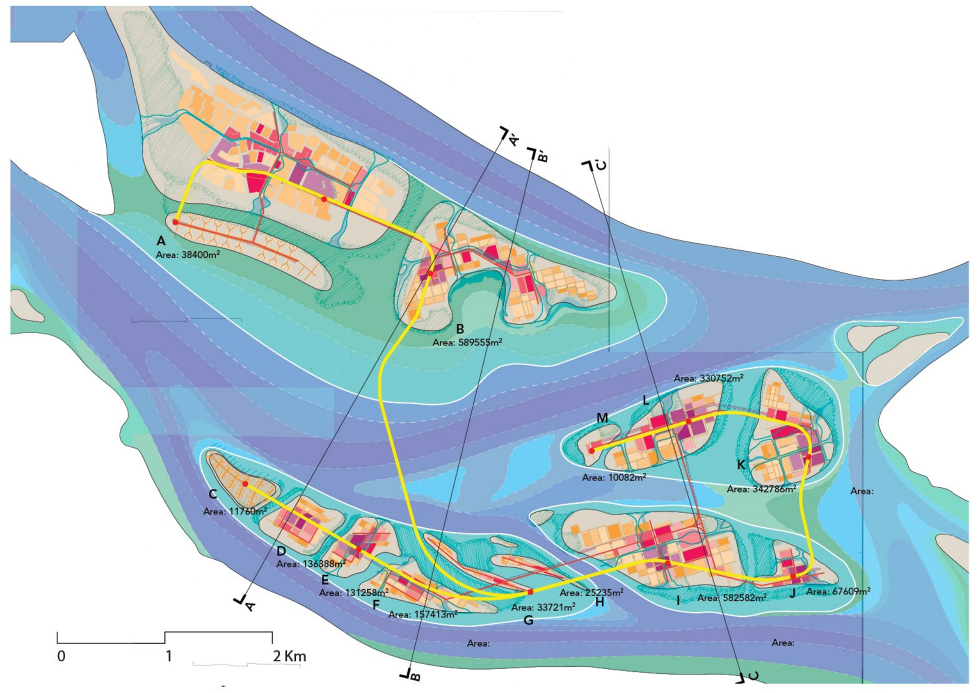
Rhine archipelago

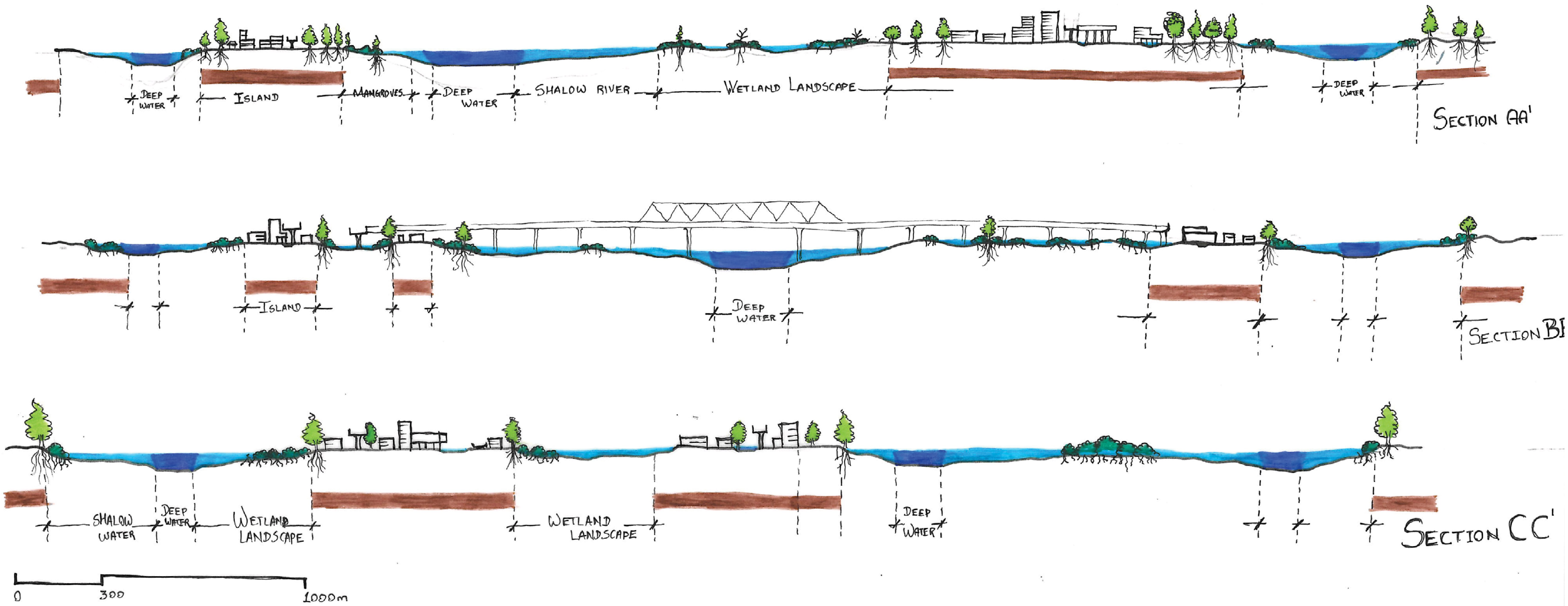
Flow dynamics - High water/ tidal case



Rhine archipelago

Section

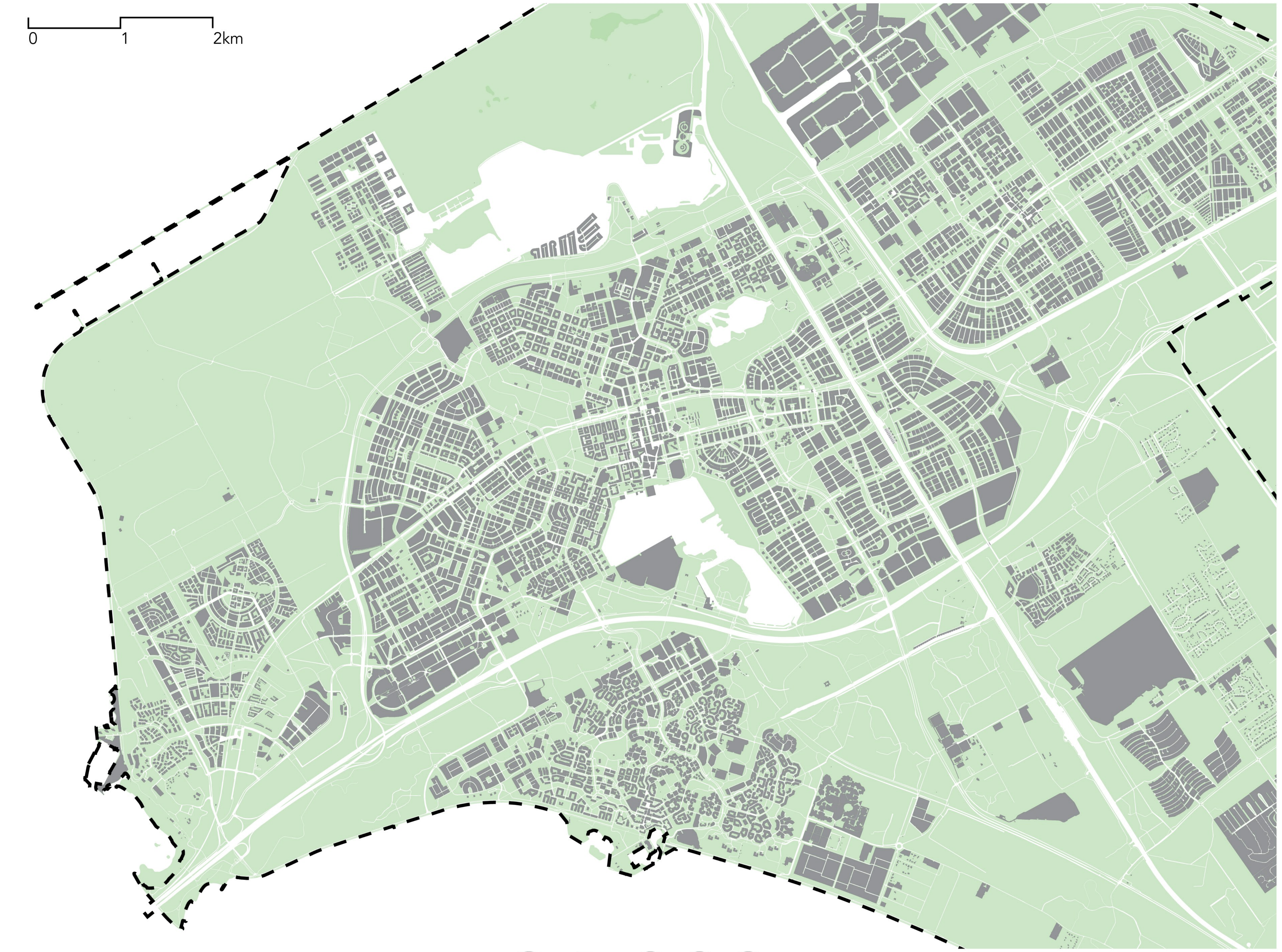




Rhine archipelago

Spatial capacity

Contrast



Almere builtup

94,000

dwellings

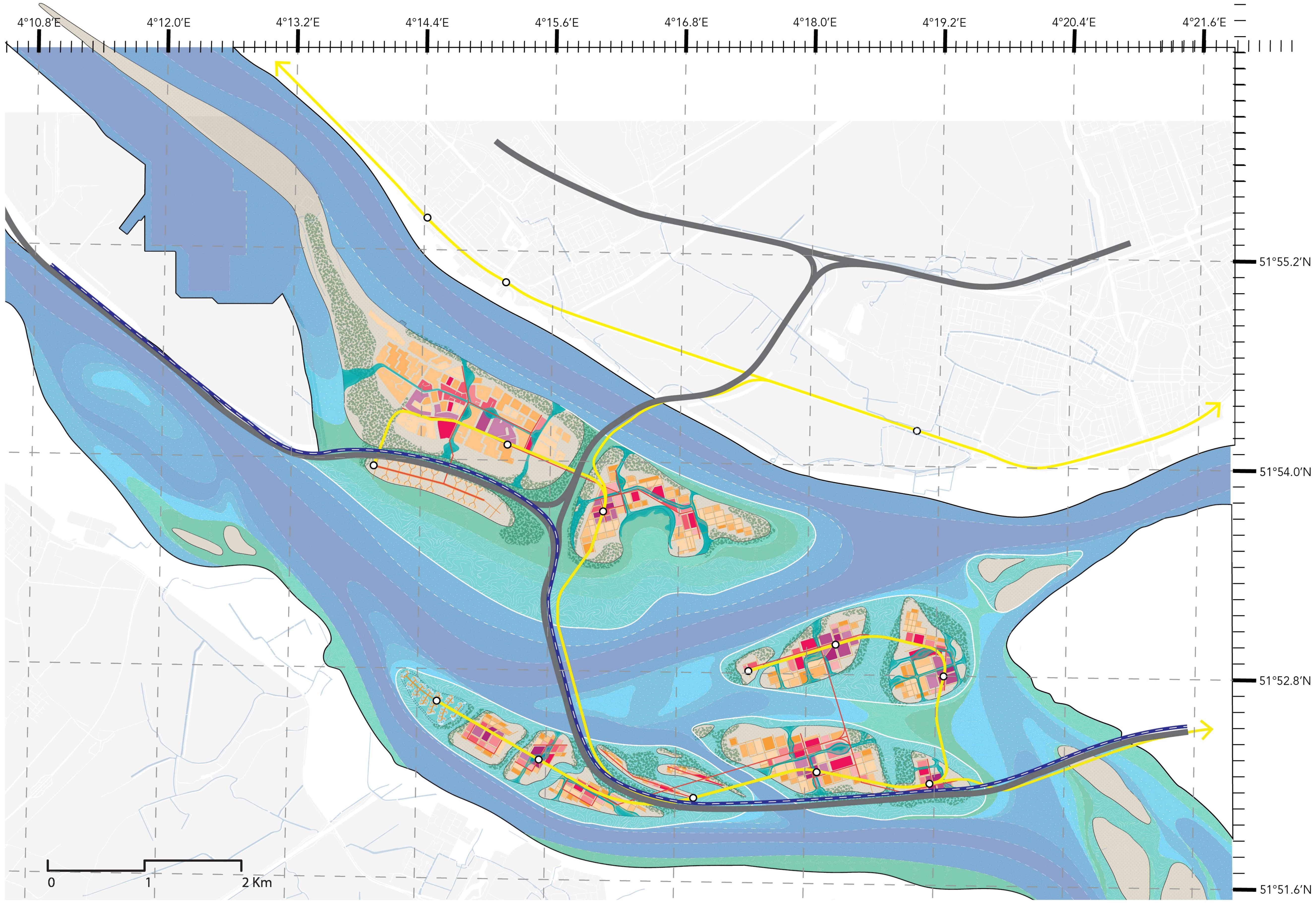
Botlek builtup

83,600

dwellings

Spatial capacity

Barcode



Total area: 36,847,923 m²

(3684 ha)

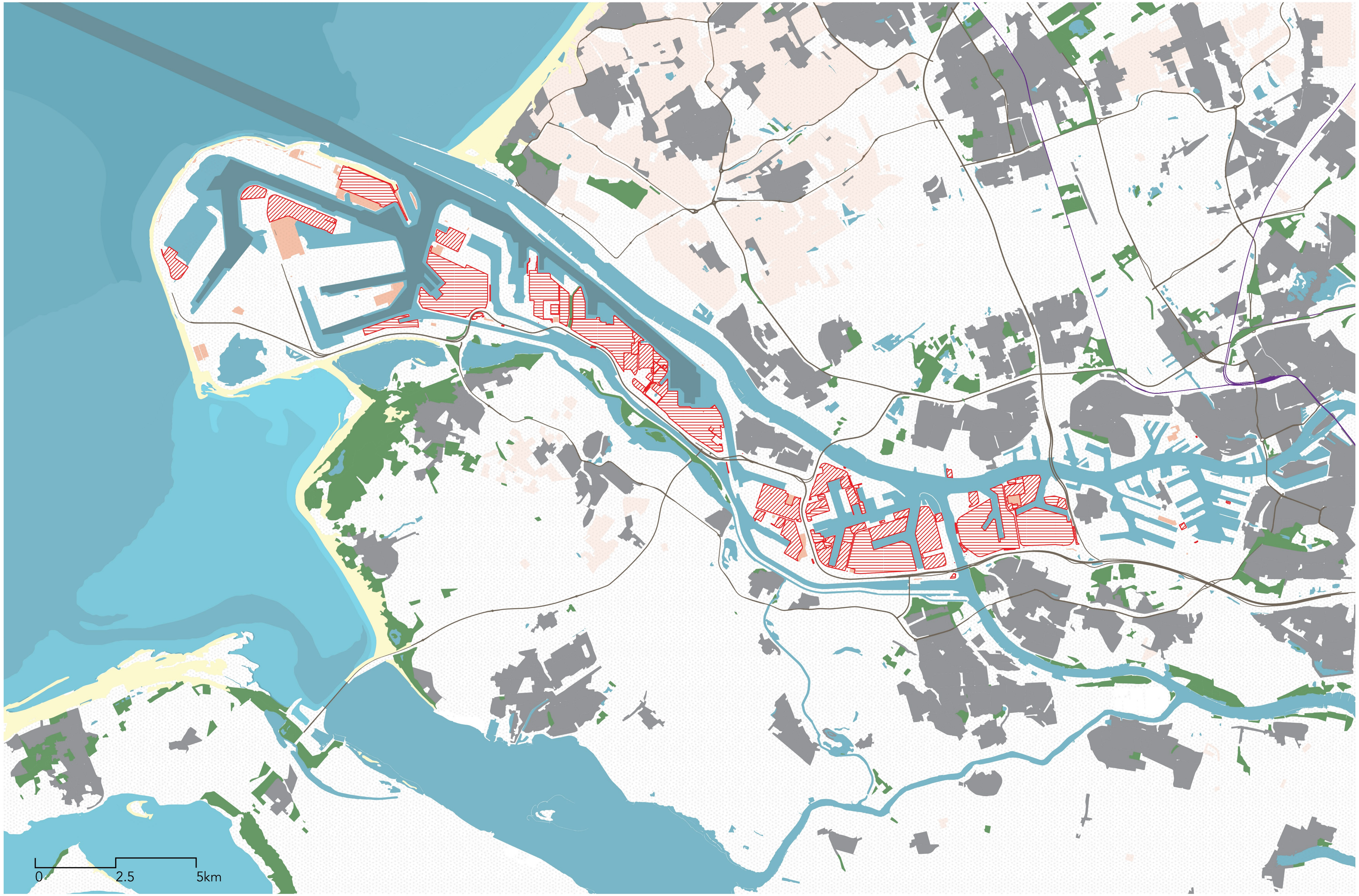
Land		Water		
Urbanised	Active green	Tidal / swamp	Limnetic zone	Maritime shipping
2,457,541 m²	5,749,680 m²	7,662,153 m²	16,170,721 m²	4,807,826 m²

Port of Rotterdam

Regional scale

Port of Rotterdam

Industries

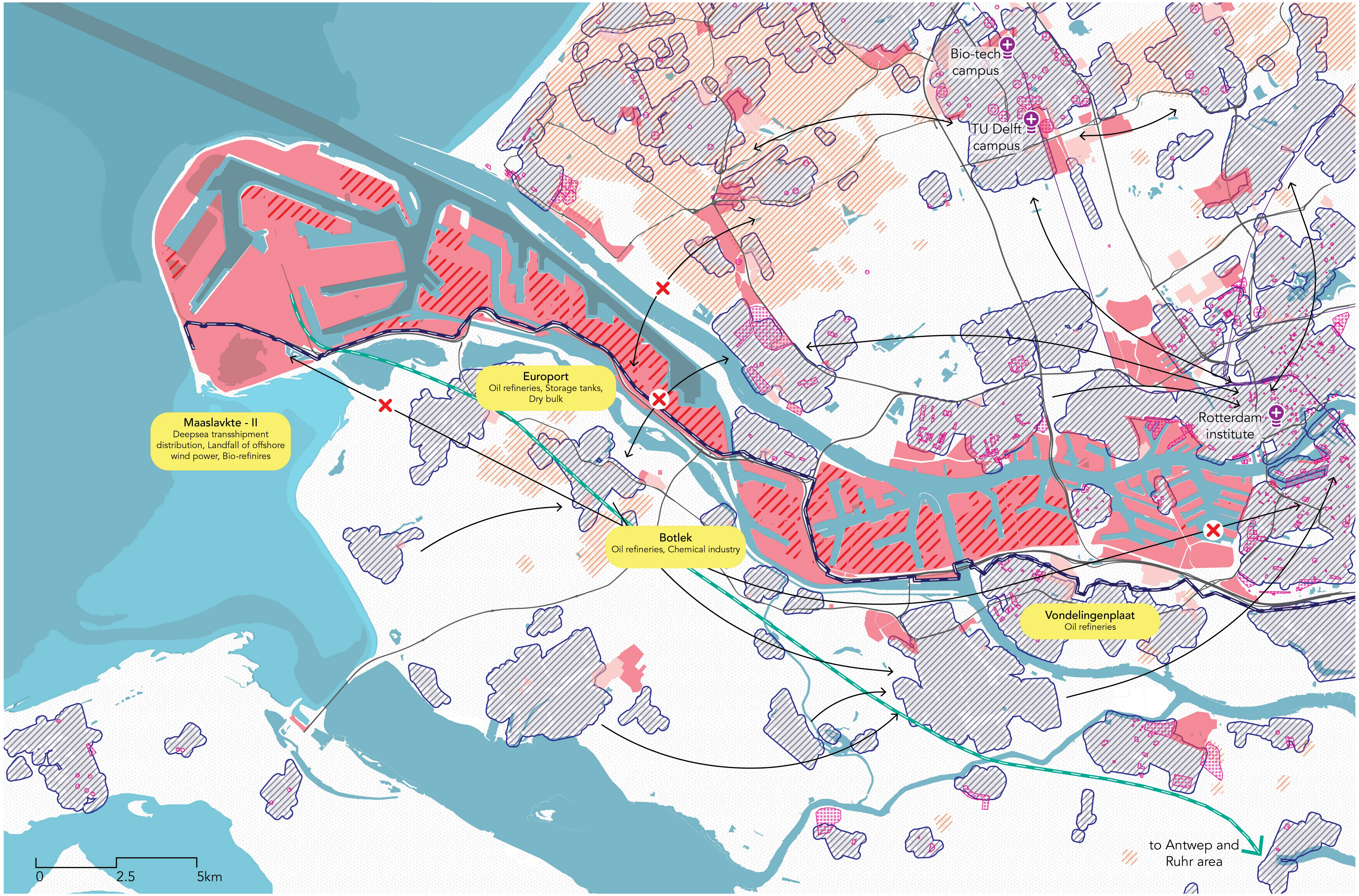


Legend

- Petroleum indusrty
- Chemical industry
- Glasshouses
- Urban
- Forest landscape
- Sand
- Deepsea maritime link
- Water
- Major roadways
- Railways

Port of Rotterdam

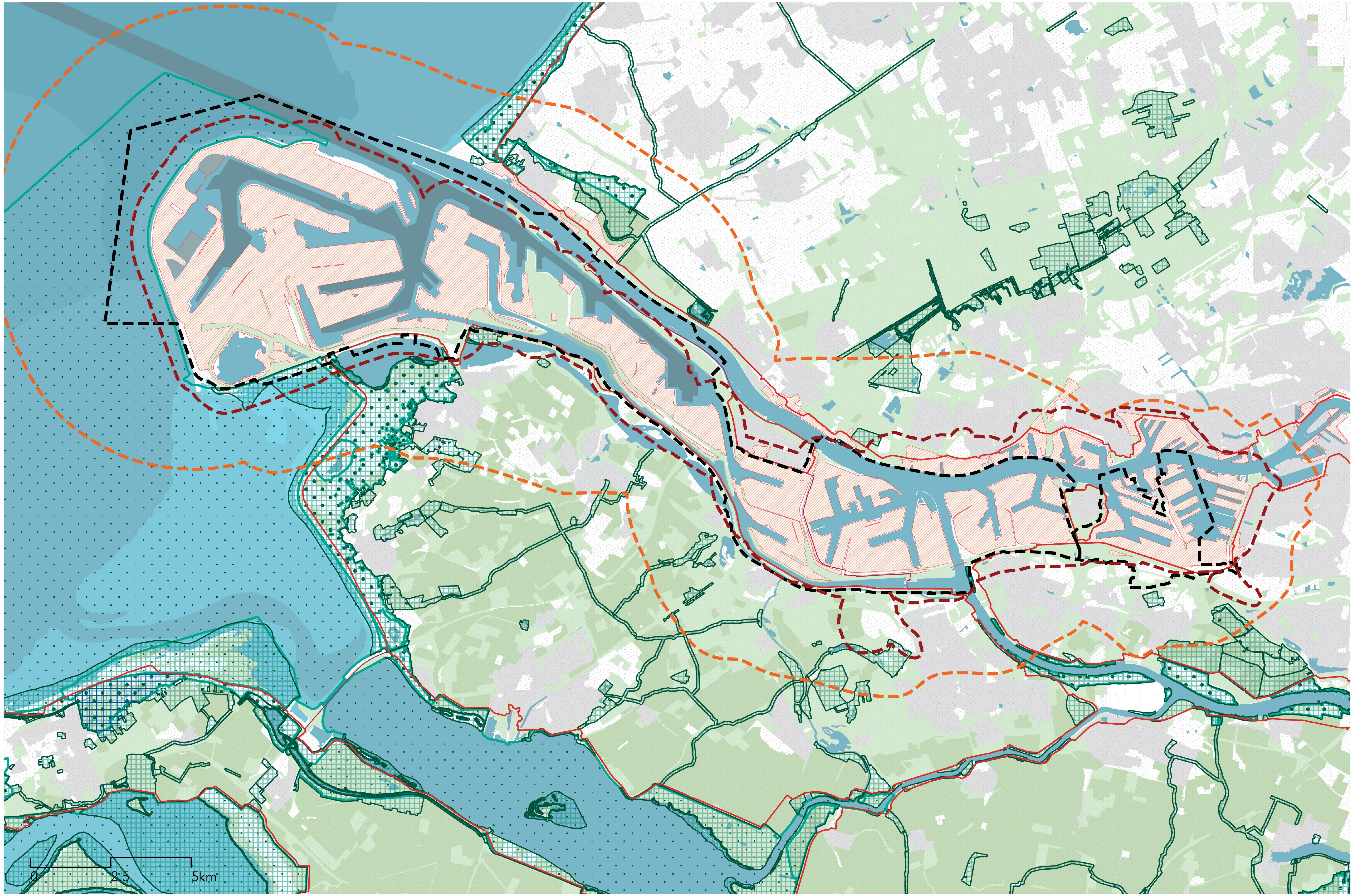
Sociological layer



Legend
- Indusrty category 4,5,6
- Indusrty category 1,2,3
- Curde based indusrty
- Urban agglomeration
- Planned housing developmnt
- Glasshouses
- Planned pipeline (could be H_2)
- Delta rhine corridor
- Innovation hotspots
- Water
- Major roadways
- Railways

Port of Rotterdam

Ecological layer

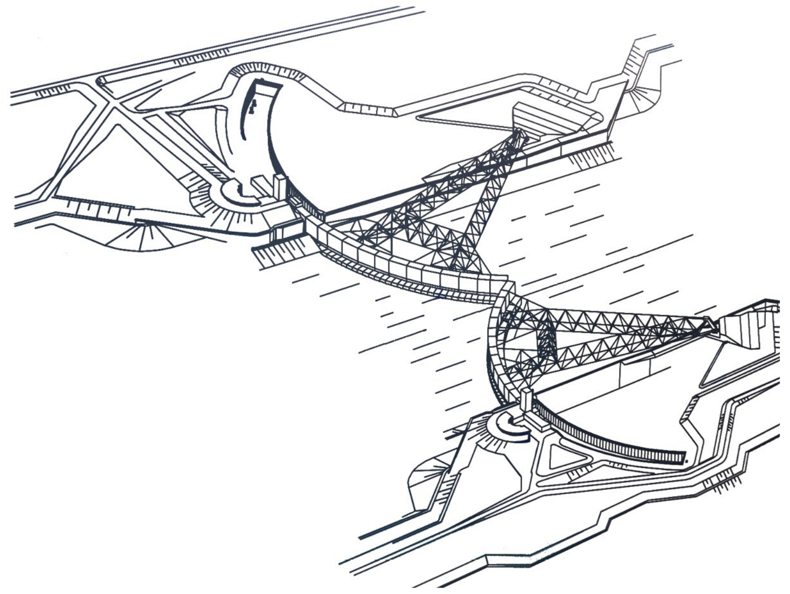


Legend

- Primary dikes
- Natura2000
- NNN
- 55db Noise contour
- Saftey contour
- Environmnetal zoning
- Port of Rotterdam
- Agricultural land
- Grassland
- Water

Port of Rotterdam

Infrastructures



Maeslantkering

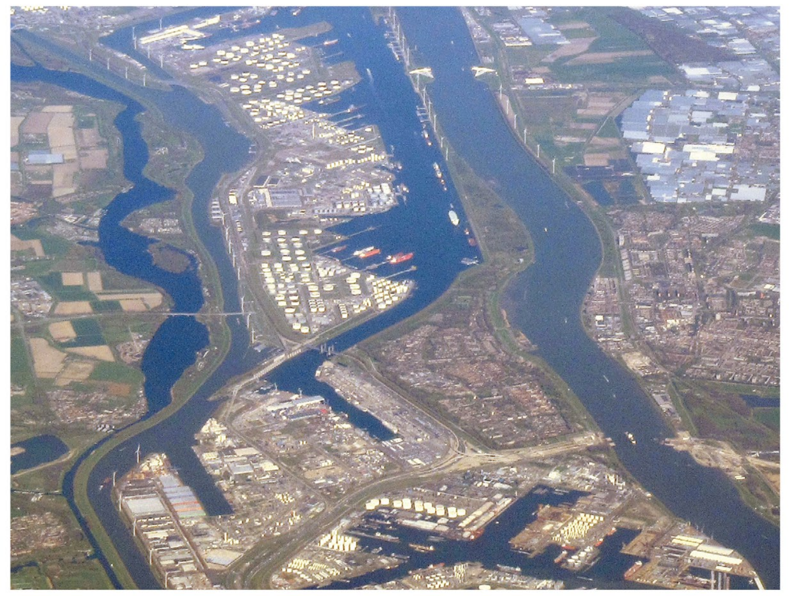
Storm surge barrier ~2075

Port contracts

Ground lease ~2050

Pipelines

Design life ~50 years



Storage tanks

Stainless steel storage tank ~ 40-60 years

Li - Batteries

Average lifespan ~15 years

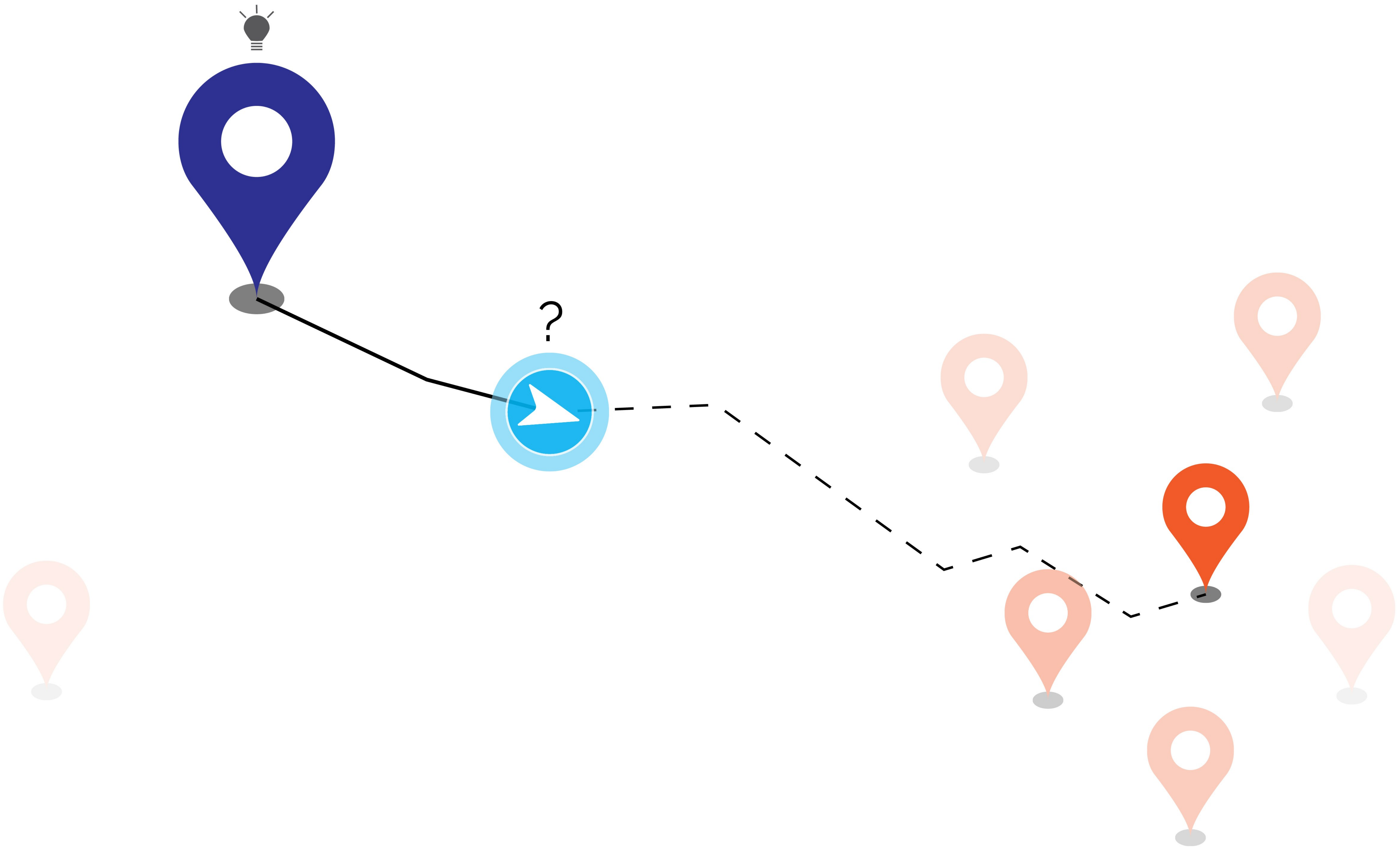
*Image source: *Detail source list in bibliography of P5 report*

Flow batteries

(Alternate energy storage)

In development (Salt based and Solid state batteries)

Adaptive pathway planning



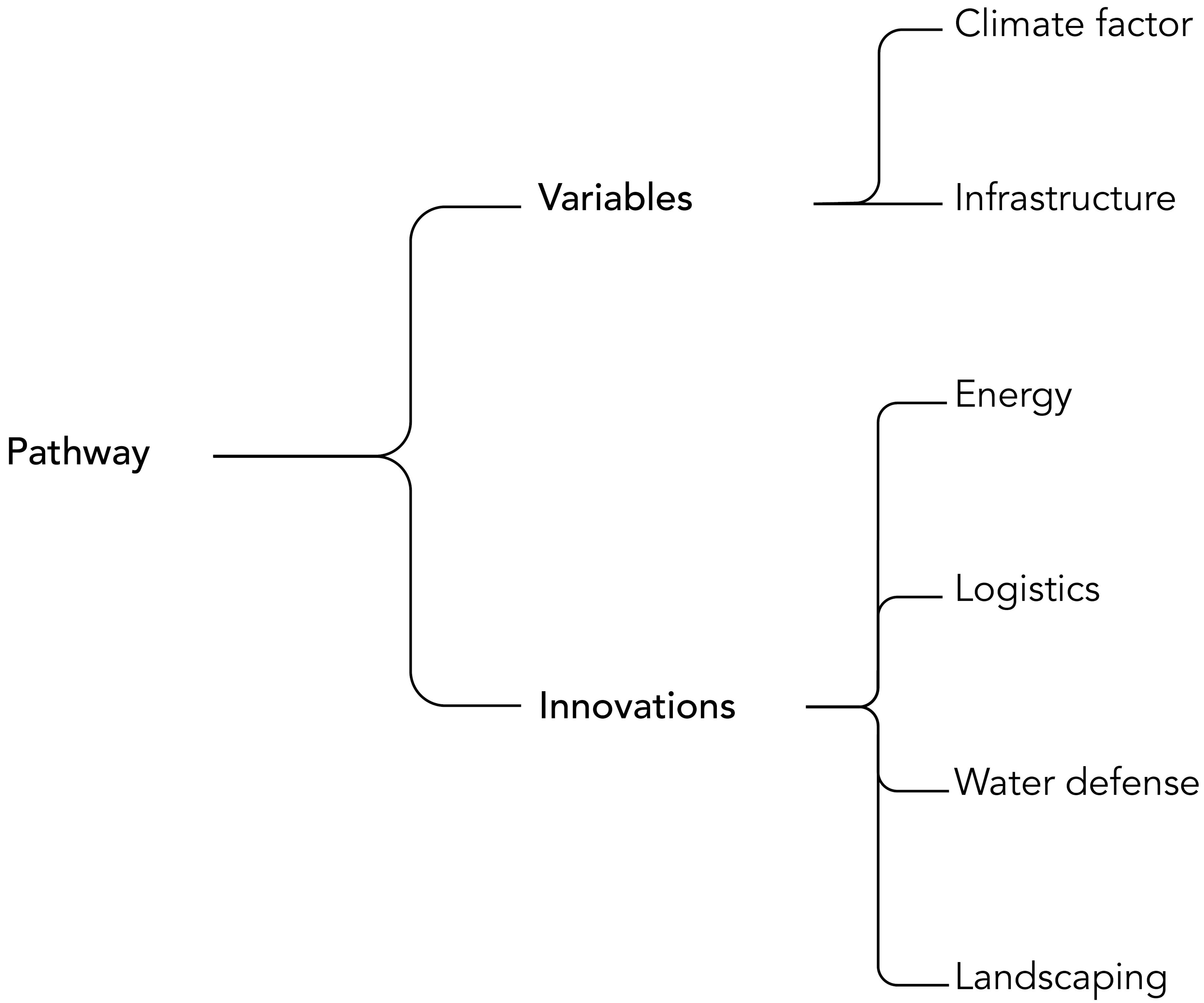
Adaptive pathway planning

Pathway

Variables

Innovations

Adaptive pathway planning



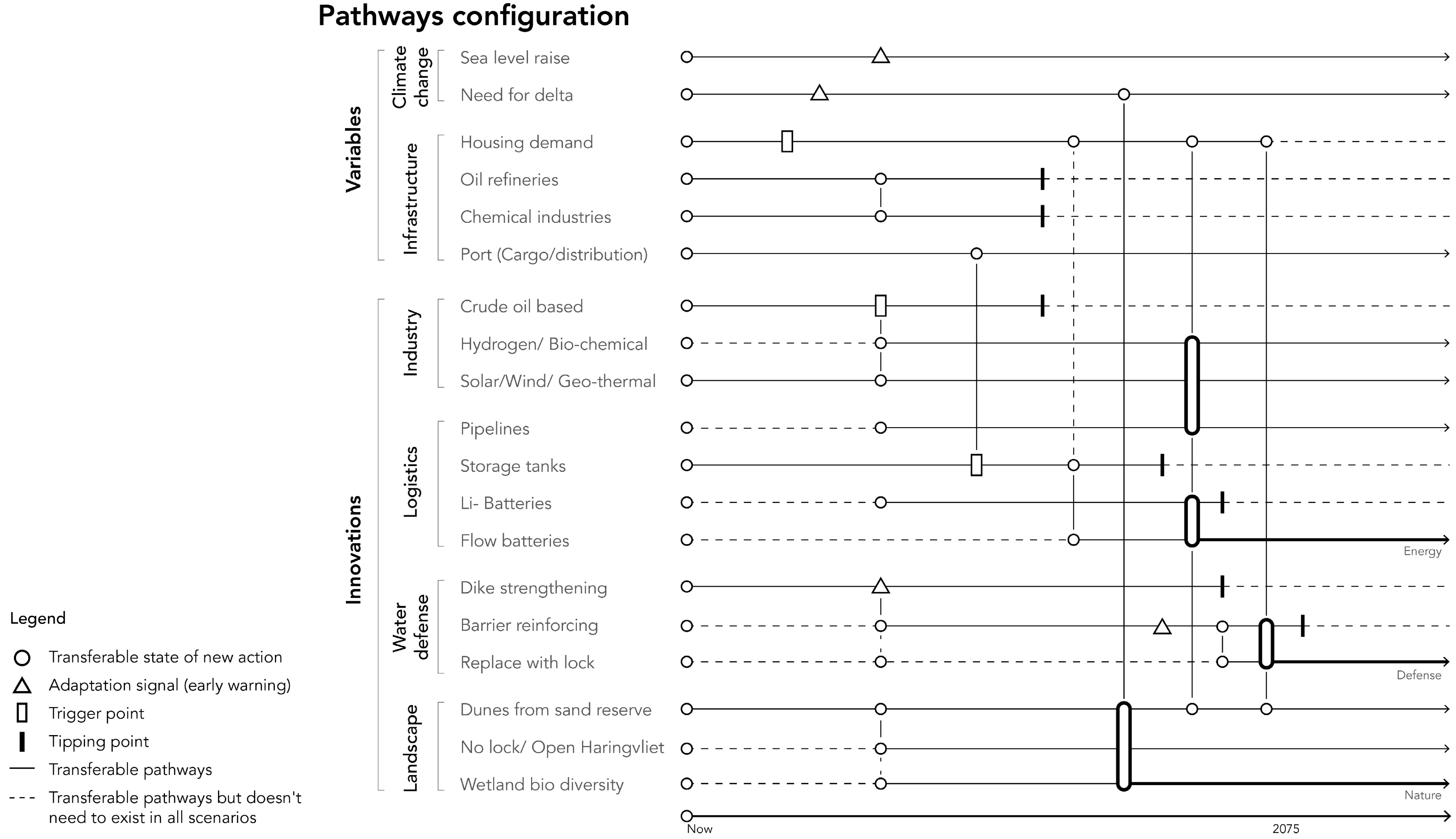
Adaptive pathway planning

- Pathway
  - Variables
    - Climate factor
    - Infrastructure
  - Innovations
    - Energy
    - Logistics
    - Water defense
    - Landscaping

- Sea level rise
- Need for delta
- Housing demand
- Oil refineries
- Chemical industries
- Port (Cargo/ distribution)
- Crude based
- Hydrogen/ Bio- chemical
- Solar/ Wind/ Geo-thermal
- Pipelines
- Storage tanks
- Li - Batteries
- Flow batteries
- Dike strengthening
- Barrier reinforcing
- Replace with bigger lock
- Dunes and sand reserve in North Sea
- Remove barrier/ Open Haringvliet
- Wetland bio-diversity

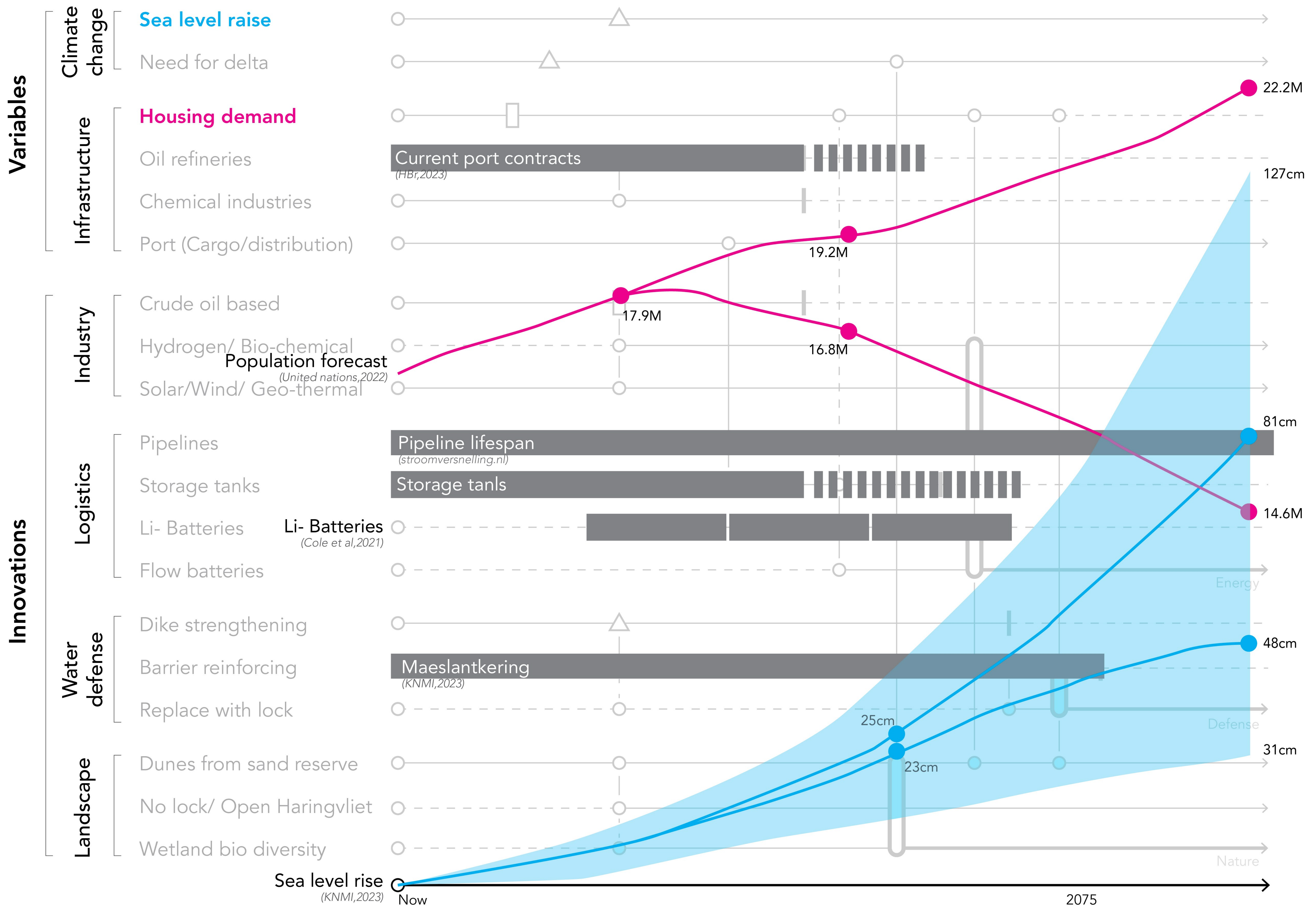
Adaptive pathway planning

Pathway configuration



Adaptive pathway planning

Climate trends + Infrastructure

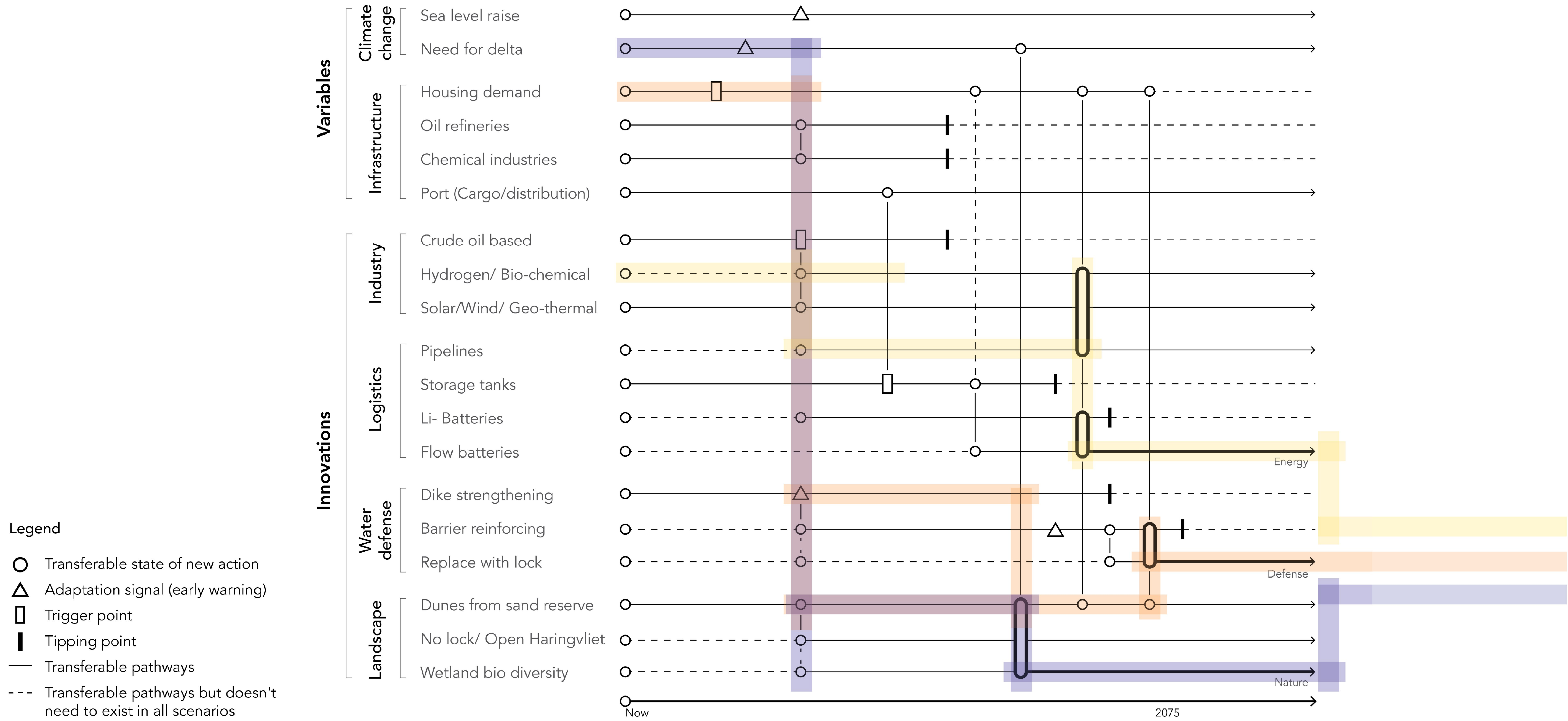


Legend

- ○ Transferable state of new action
- △ Adaptation signal (early warning)
- ▯ Trigger point
- ▍ Tipping point
- —— Transferable pathways
- - - - Transferable pathways but doesn't need to exist in all scenarios

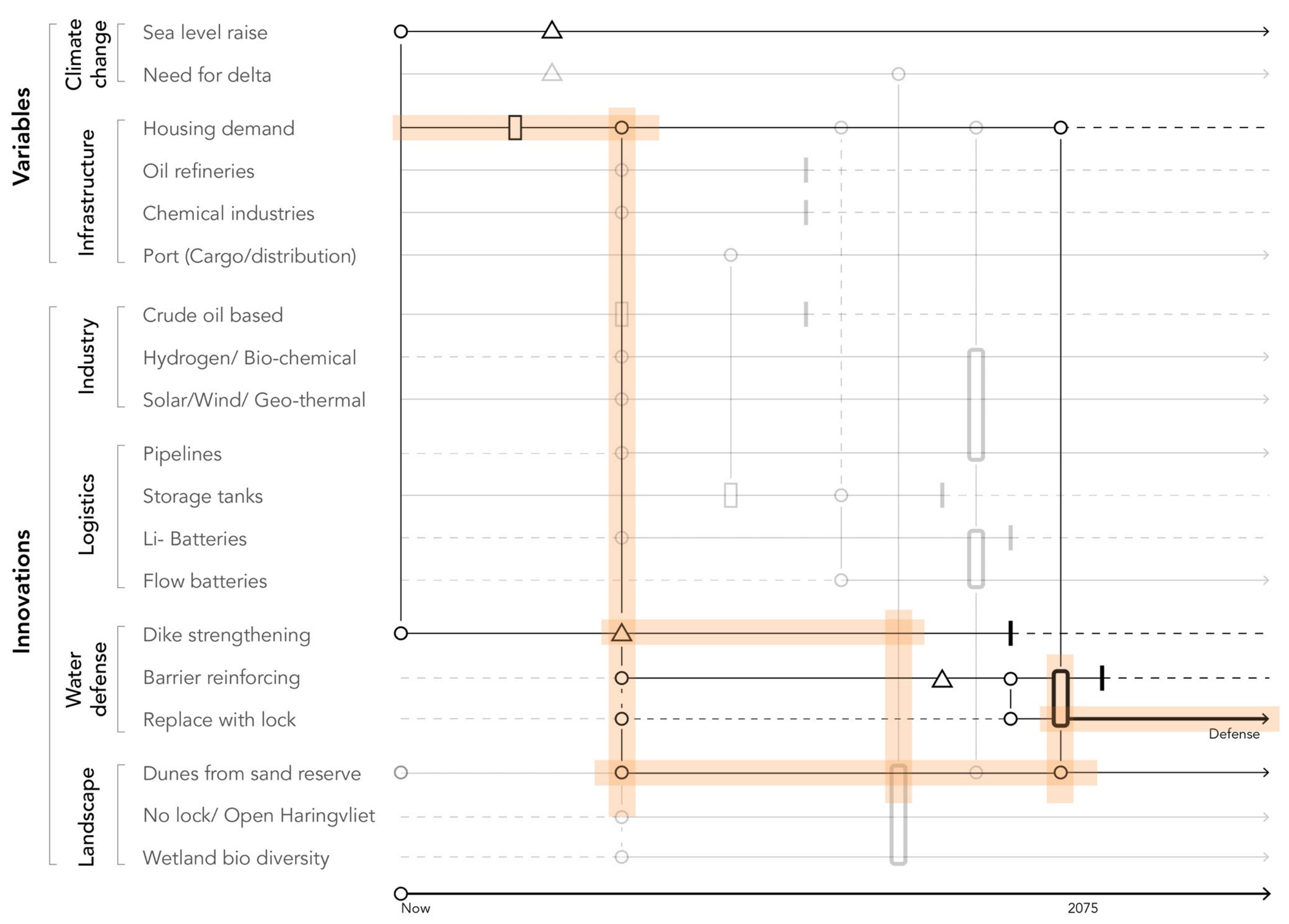
Adaptive pathway planning

Favorable pathways



Favorable pathways

Water defense focus



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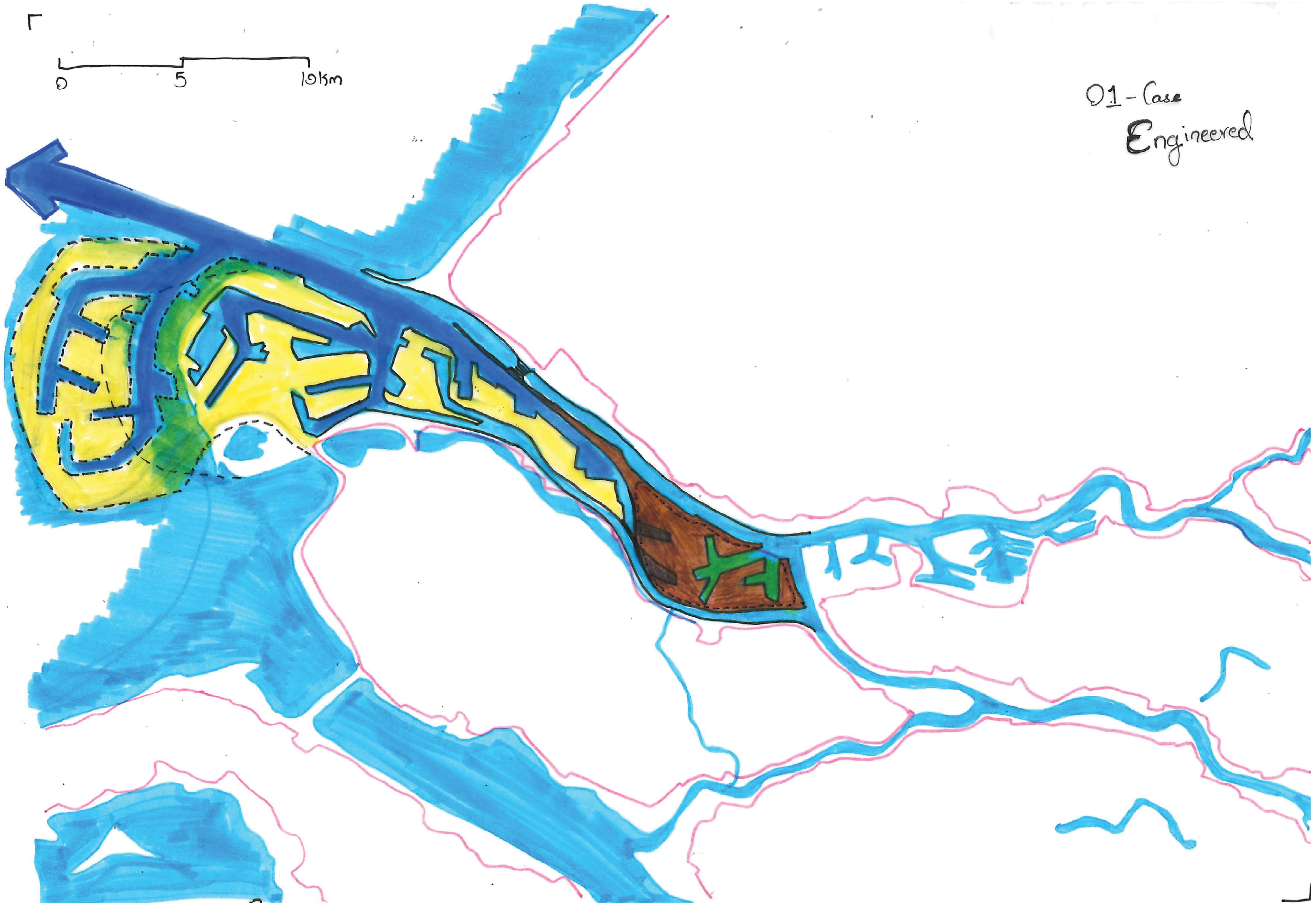
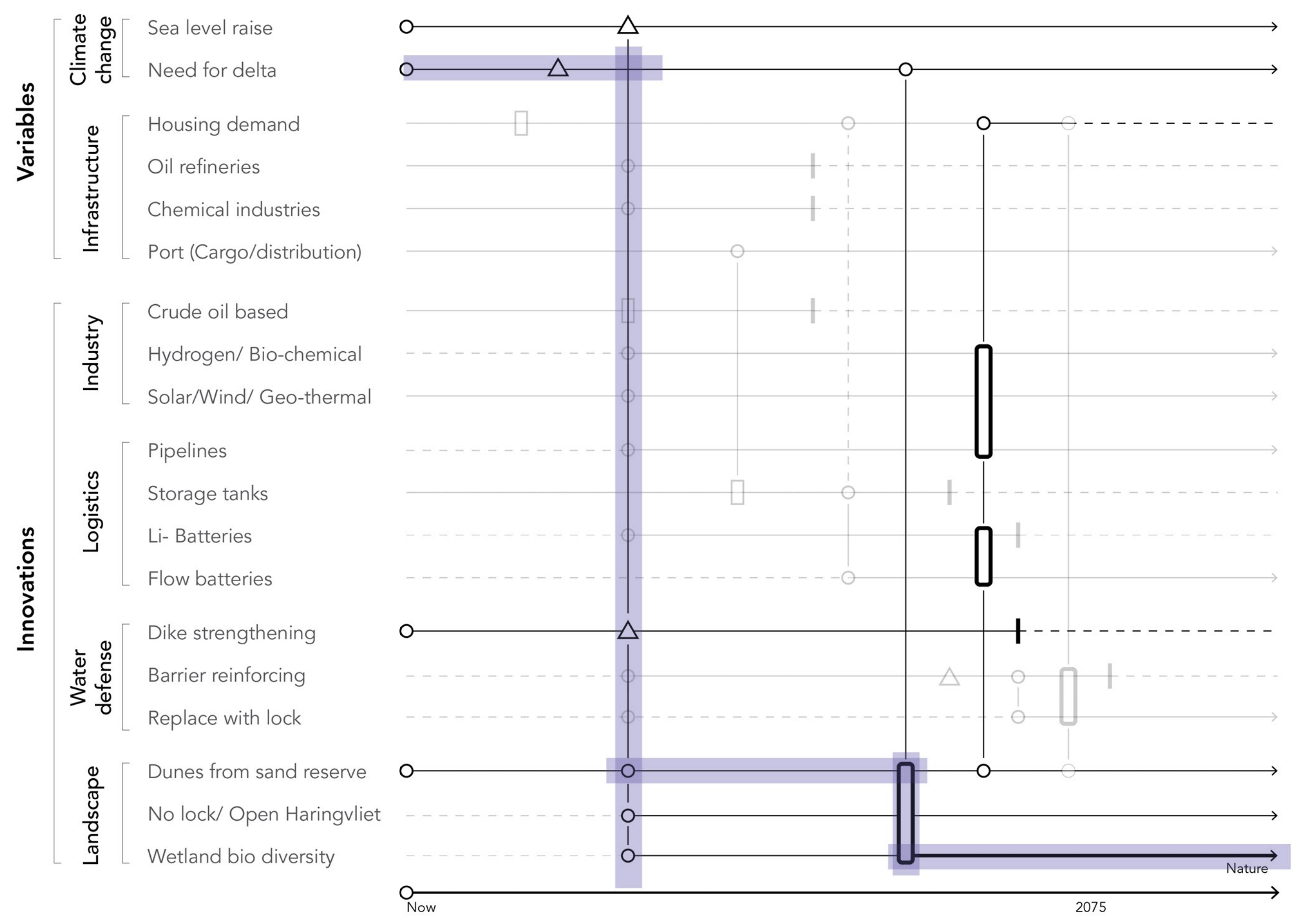


Favorable pathways

Nature focus



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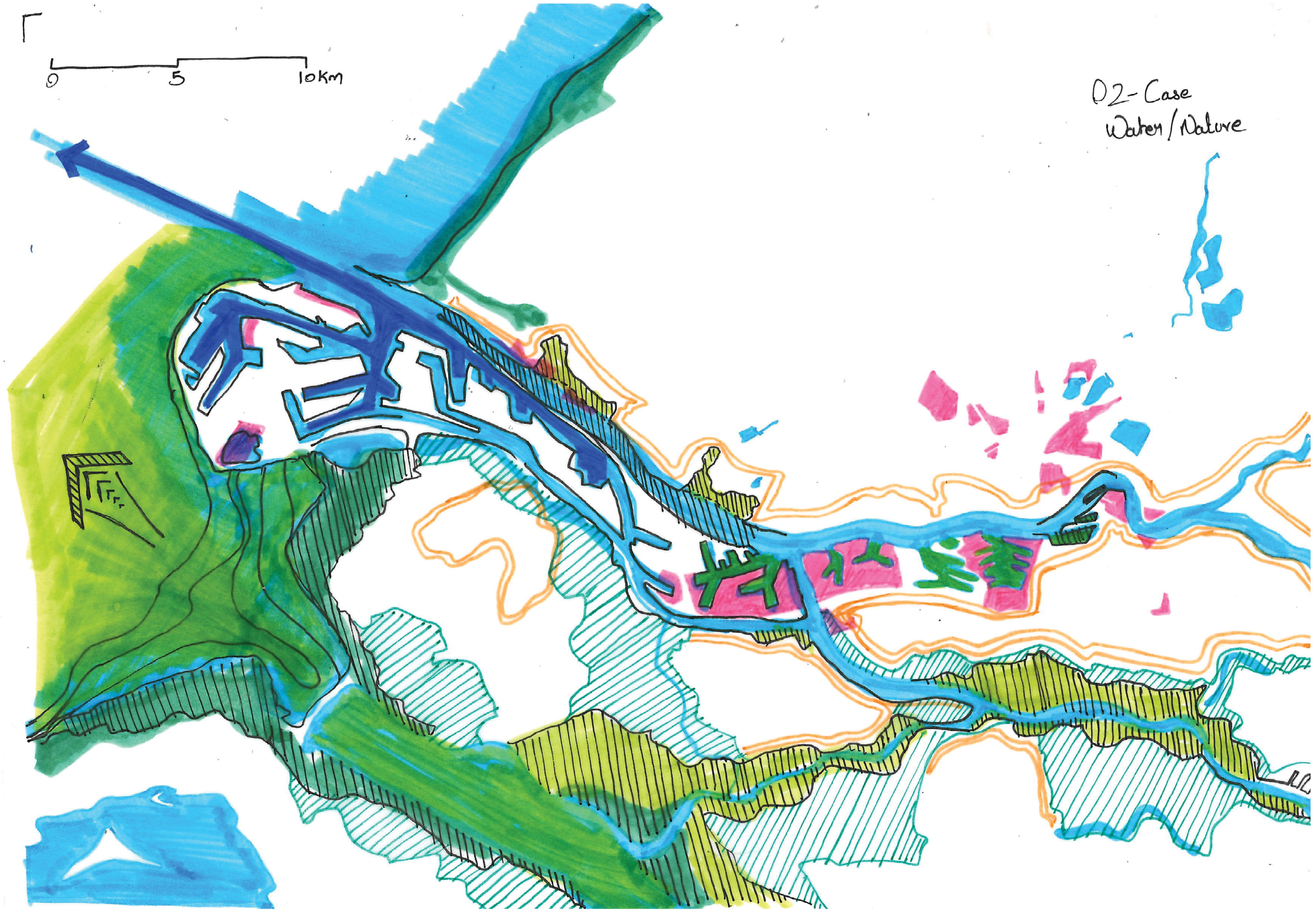
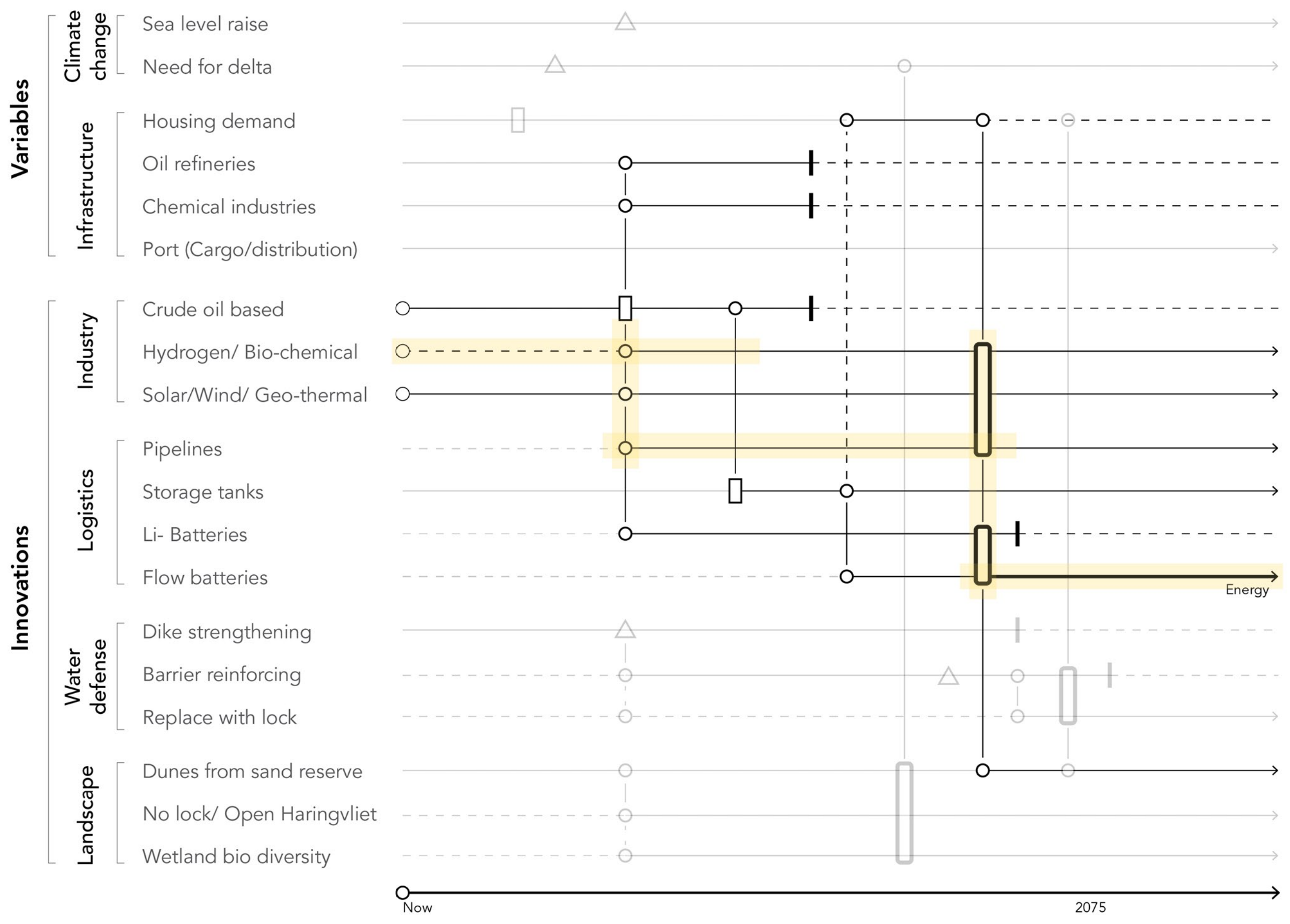


Favorable pathways

Energy transition focus



Legend

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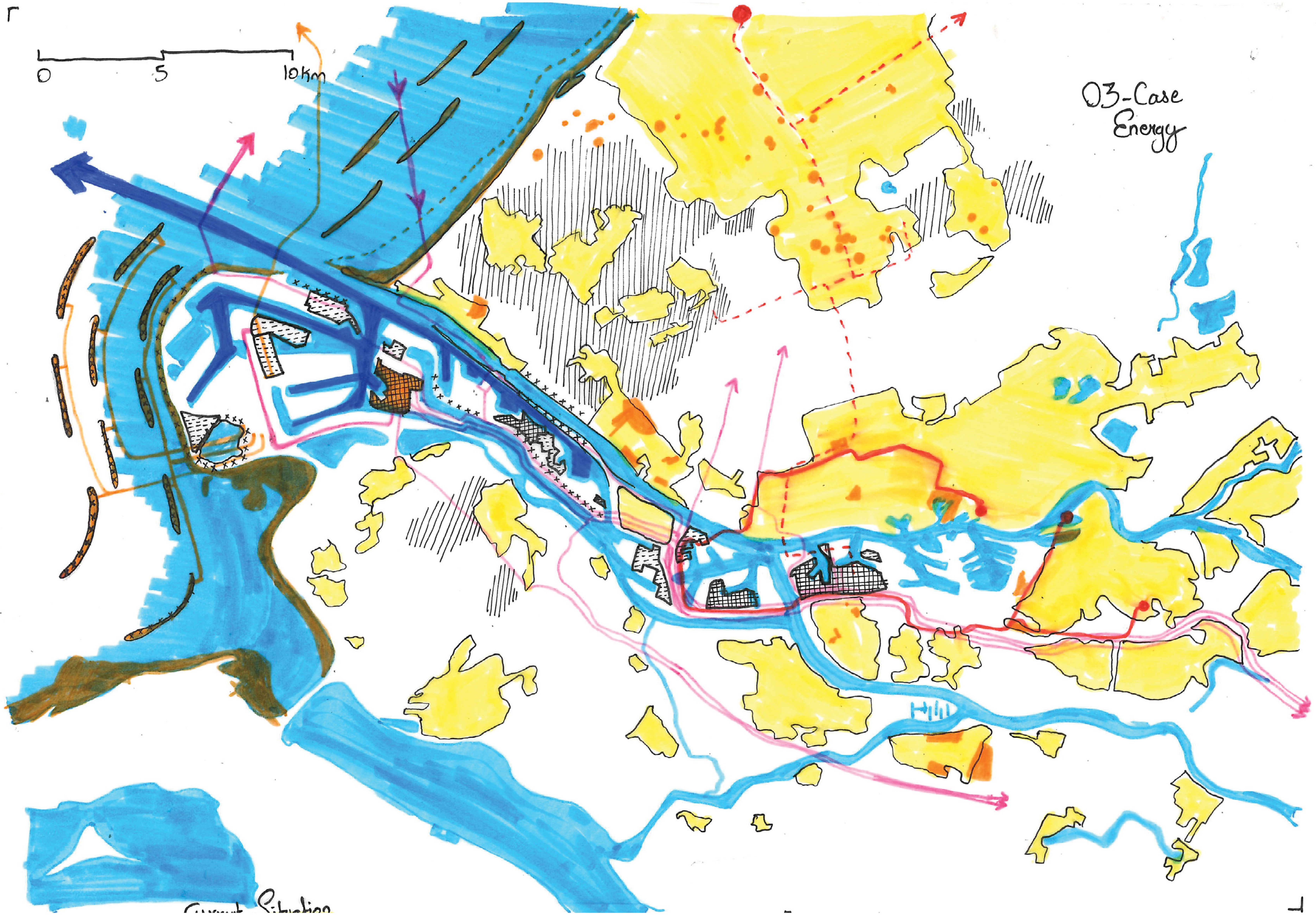
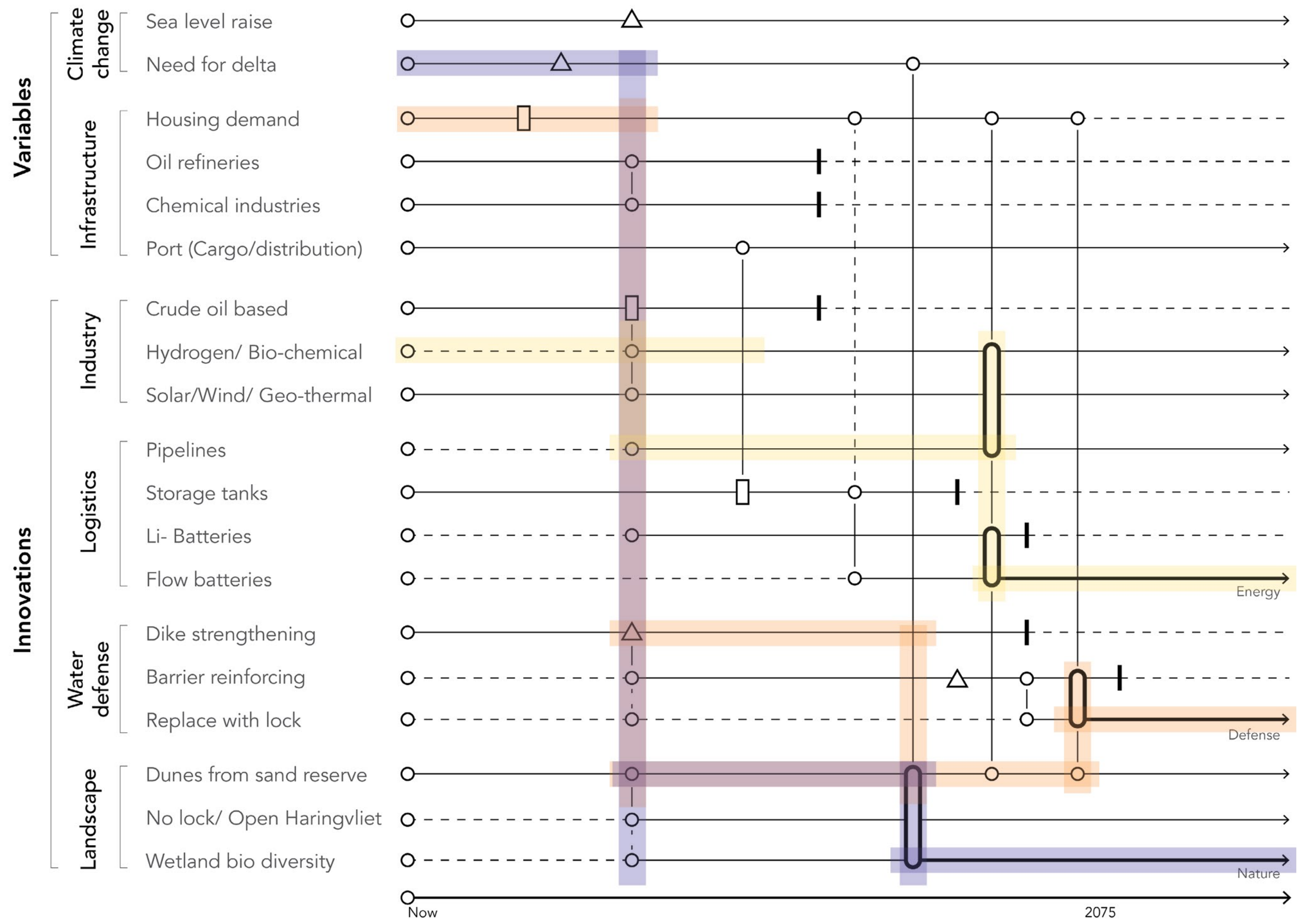


Non - conflicting pathway trends

the coastal region beyond 2075



Legend

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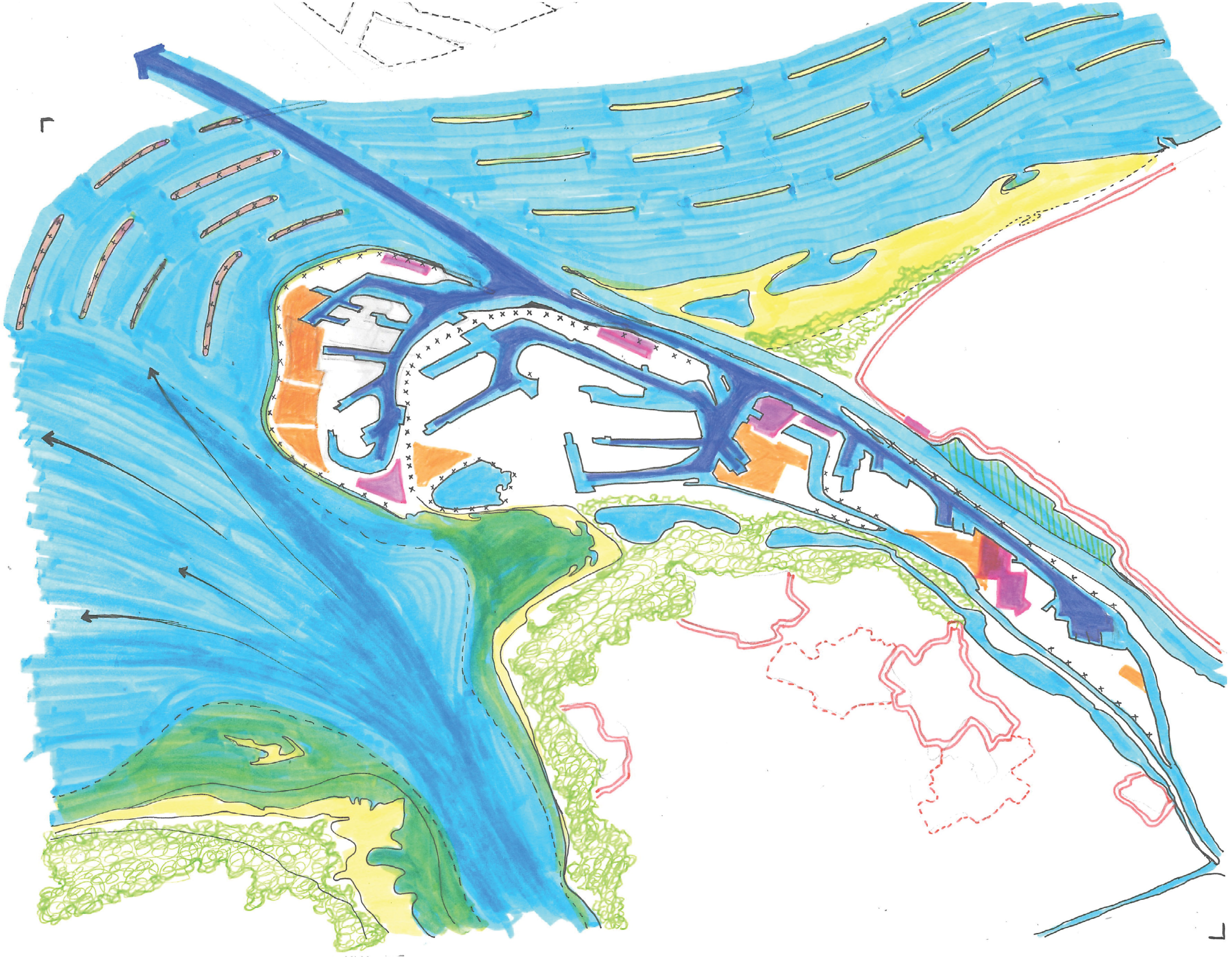
- | Tipping point
- — Transferable pathways
- - - - Transferable pathways but doesn't need to exist in all scenarios

Legend

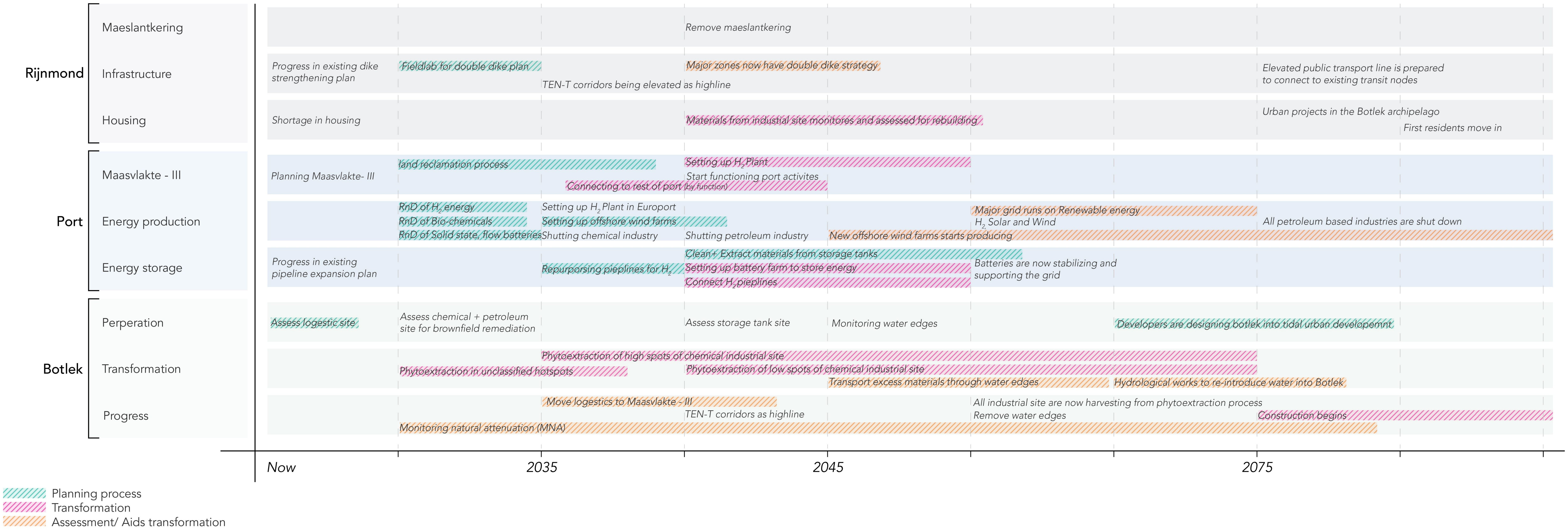
- H_2 Industry
- Electrical industry
- × Windmills
- Dikes
- Sand
- Protected biodiversity
- Deep-sea waterways
- Water



Is it possible?

Phasing

Overview



Phasing

Adaptive pathway planning

Preparation (Risk Understanding & Enabling Conditions)

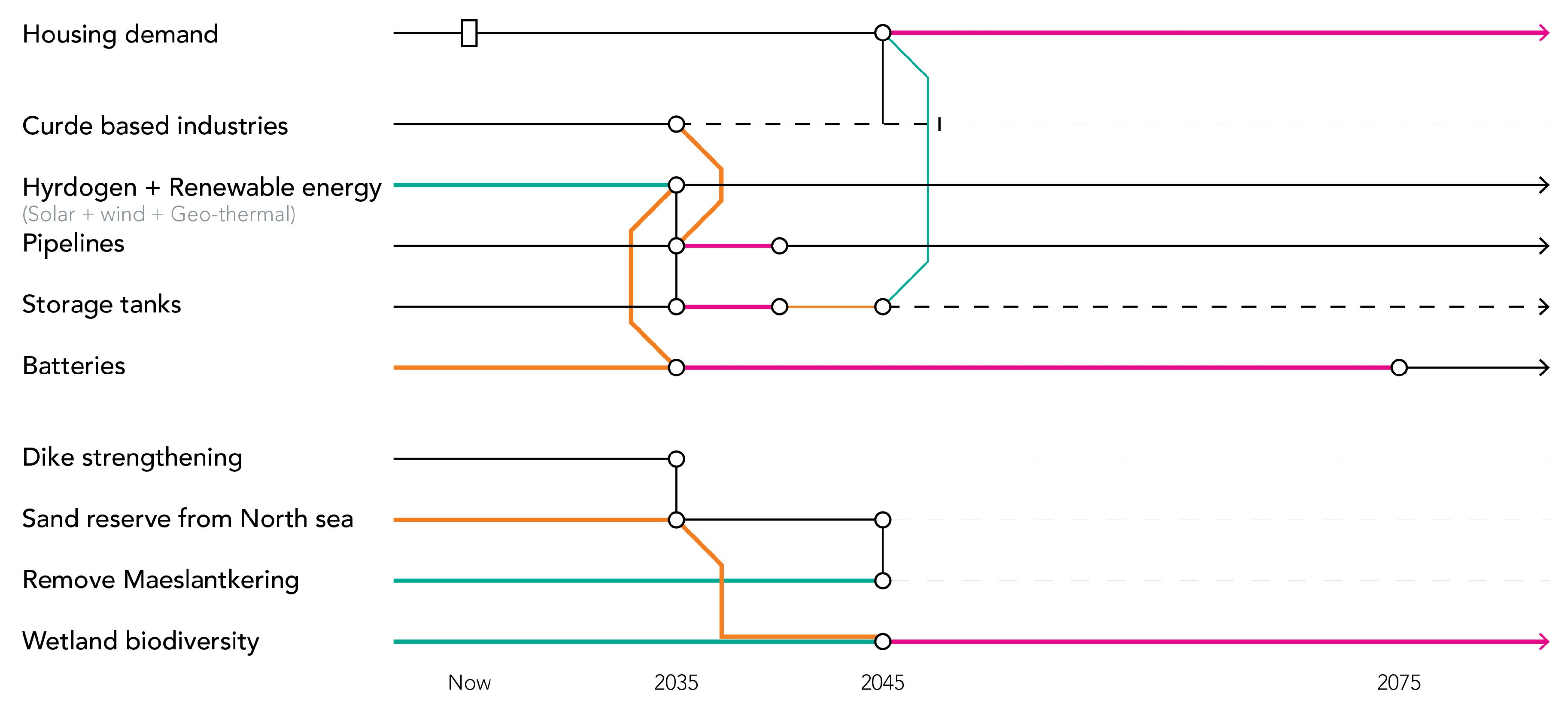
Make contamination visible, manageable, and governable, without disrupting essential operations prematurely.

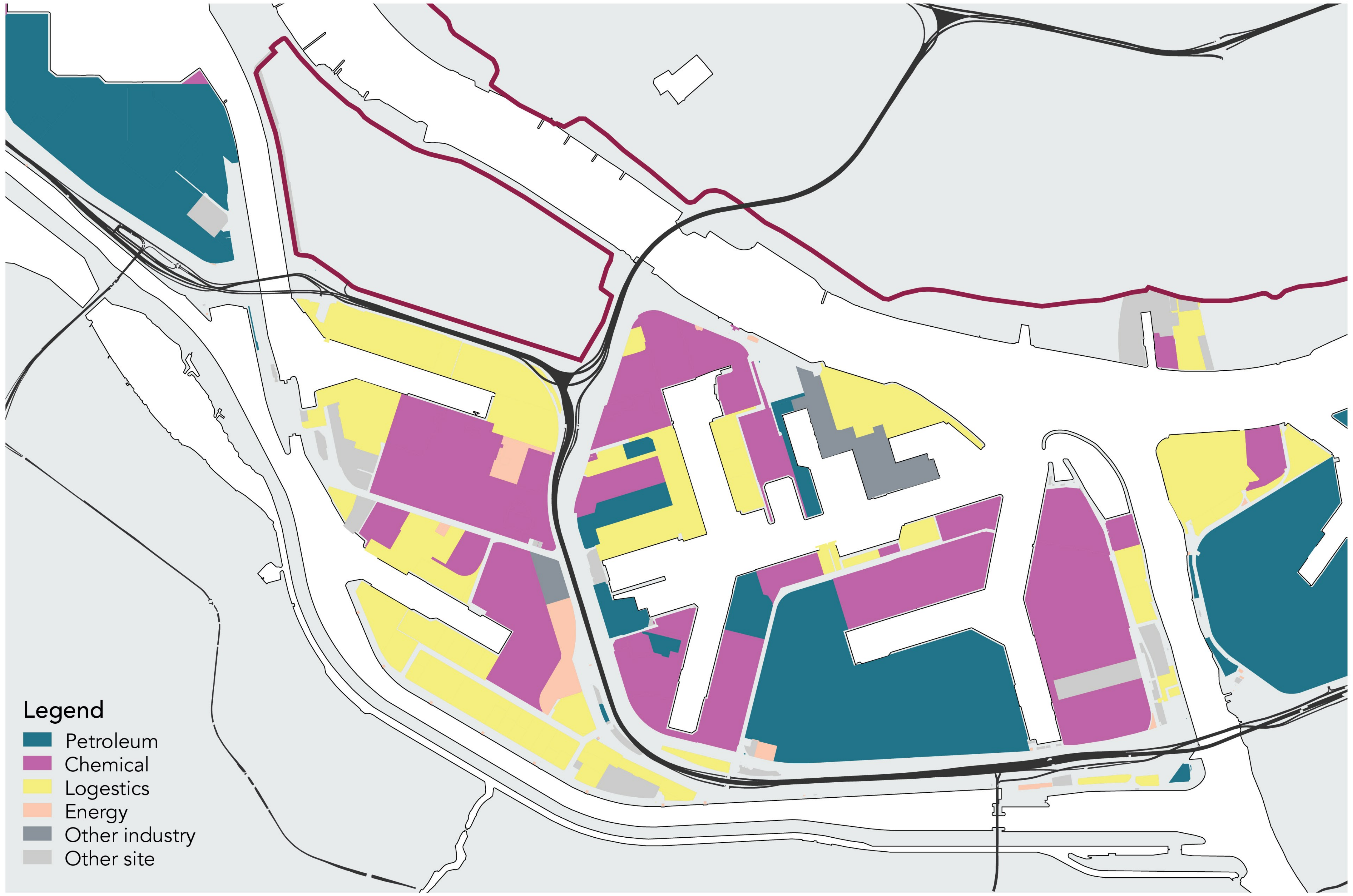
Transformation (Decontamination & Landscape Reprogramming)

Gradually reclaim land by coupling remediation with spatial and ecological transformation.

Process (Redevelopment & Long-Term Monitoring)

Make contamination visible, manageable, and governable, without disrupting essential operations prematurely.





Phasing

2035

- Built Maasvlakte-III
- Assess chemical and petroleum plant
- Assess storage tanks
- Start moving port activities to Maasvlakte-III
- Phytoextraction in unclassified hotspots
- Re-purpose pipelines
- Dike strengthening

Bio-remediation (engineered microbial degradation) (6-18 months)

Phytoextration (plant uptake and harvest) (2-5 years)

Monitored natural attenuation (20+ years)

Phasing

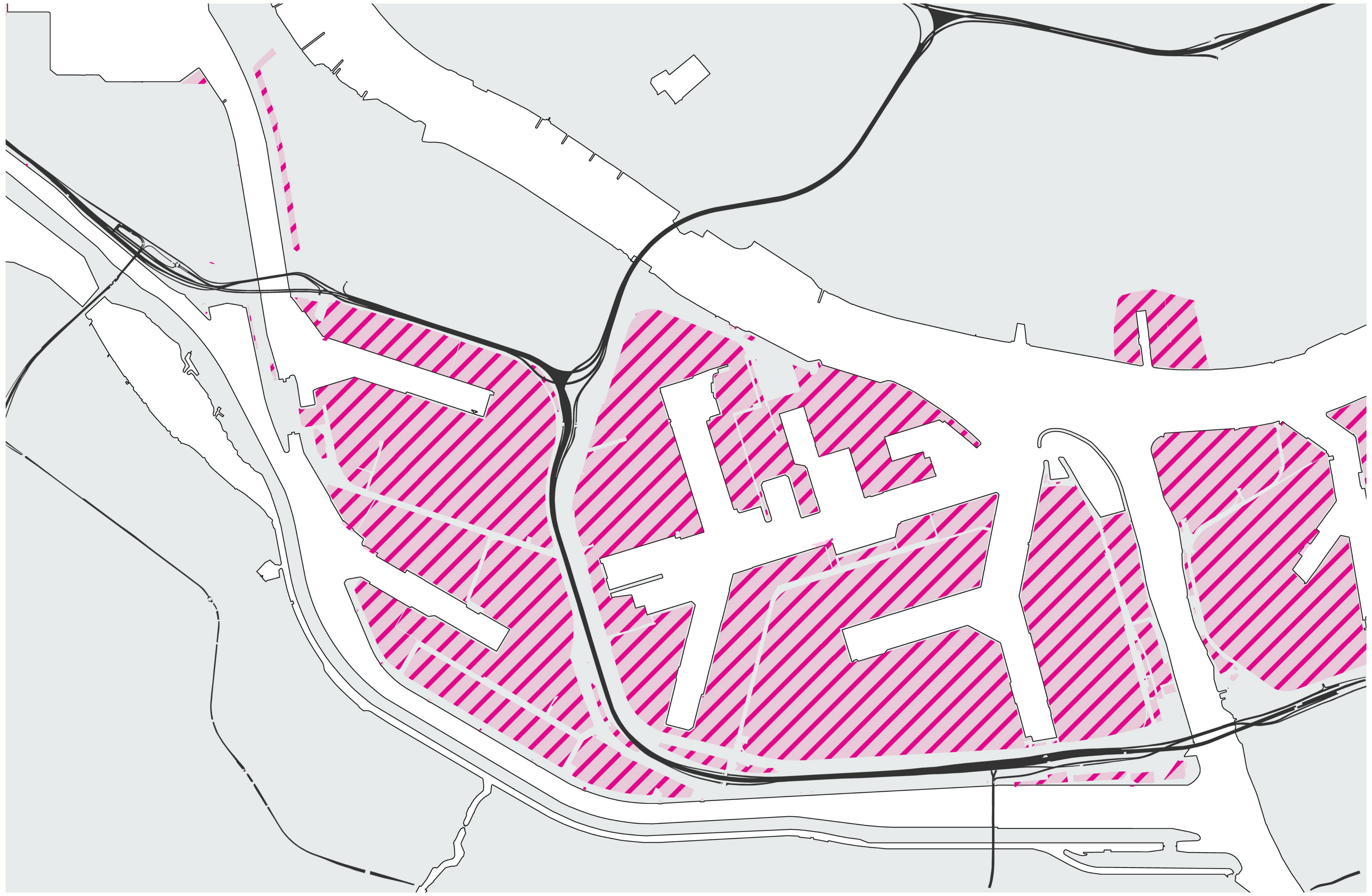
2045

- Port industries in Maasvlakte-III
- Shitting chemical and petroleum plant
- Clean storage tanks
- Make TEN-T corridors into highline
- Phytoextraction in industry hotspots (5yrs)
- Finish monitoring over lowspot (dense tree cover over)
- Remove maeslantkering
- Extract resuabel from industries

Phasing

2050

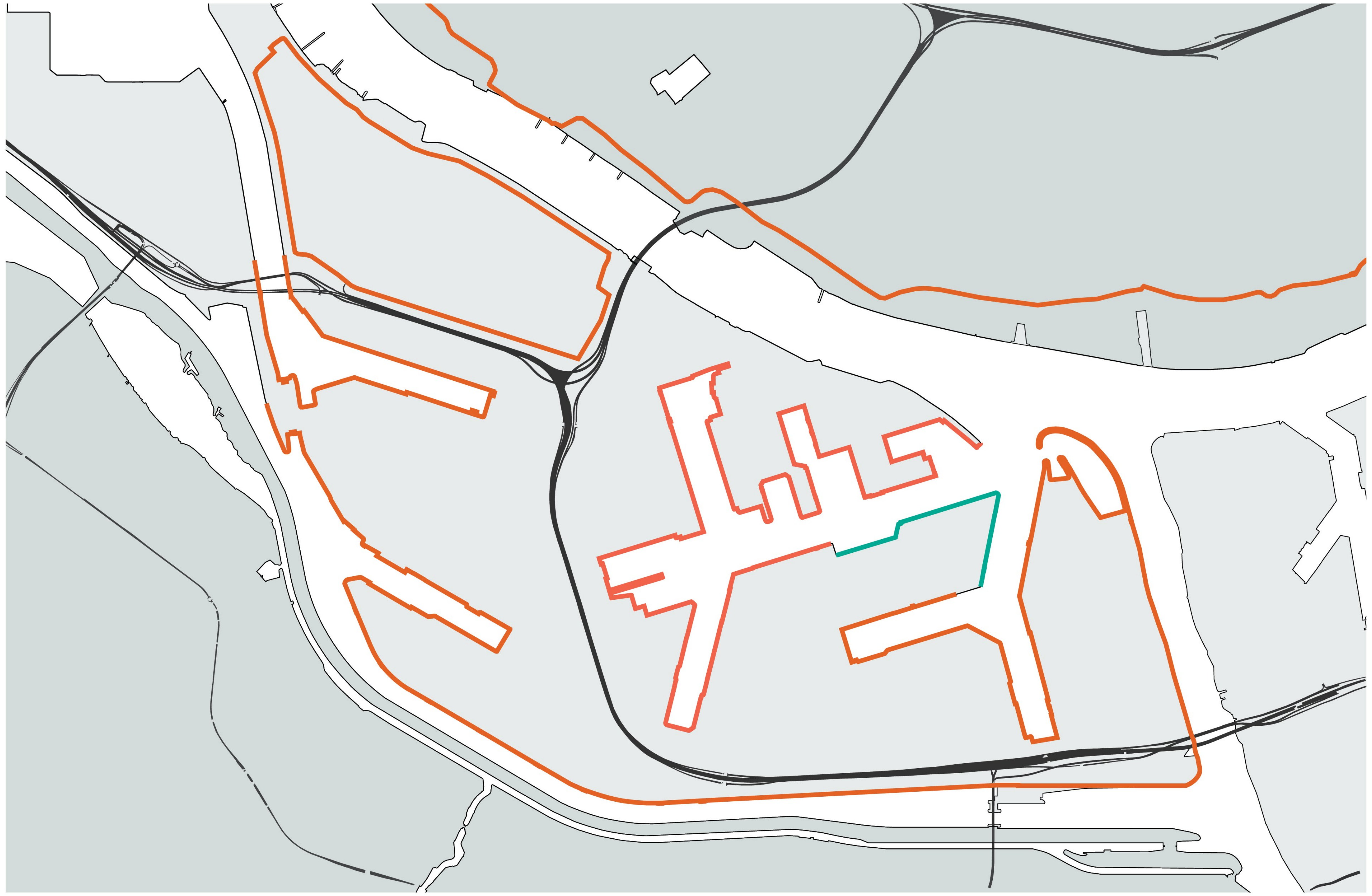
- Phytoextraction implemented in industrial site
- Remove edges
- Remediate region



Phasing

2060

- Harvest phytoextraction in industrial site
- Remove edges
- Monitor soil
- Monitor ground water quality
- Start hydrological works
- Develop transit layout



Phasing

2070

- Phytoextraction complete in industrial site
- Monitor surface and ground water quality
- Start design process for urban development
- Prototype tidal construction techniques

Phasing

2075

- Monitor and evaluate soil and surface water
- Design public spaces
- Start tidal urban development construction

New Rijnmond

the region beyond 2075

1. Delta mail

2. Connect Rijnmond

3. Open Haringvliet

4. Port and Coast

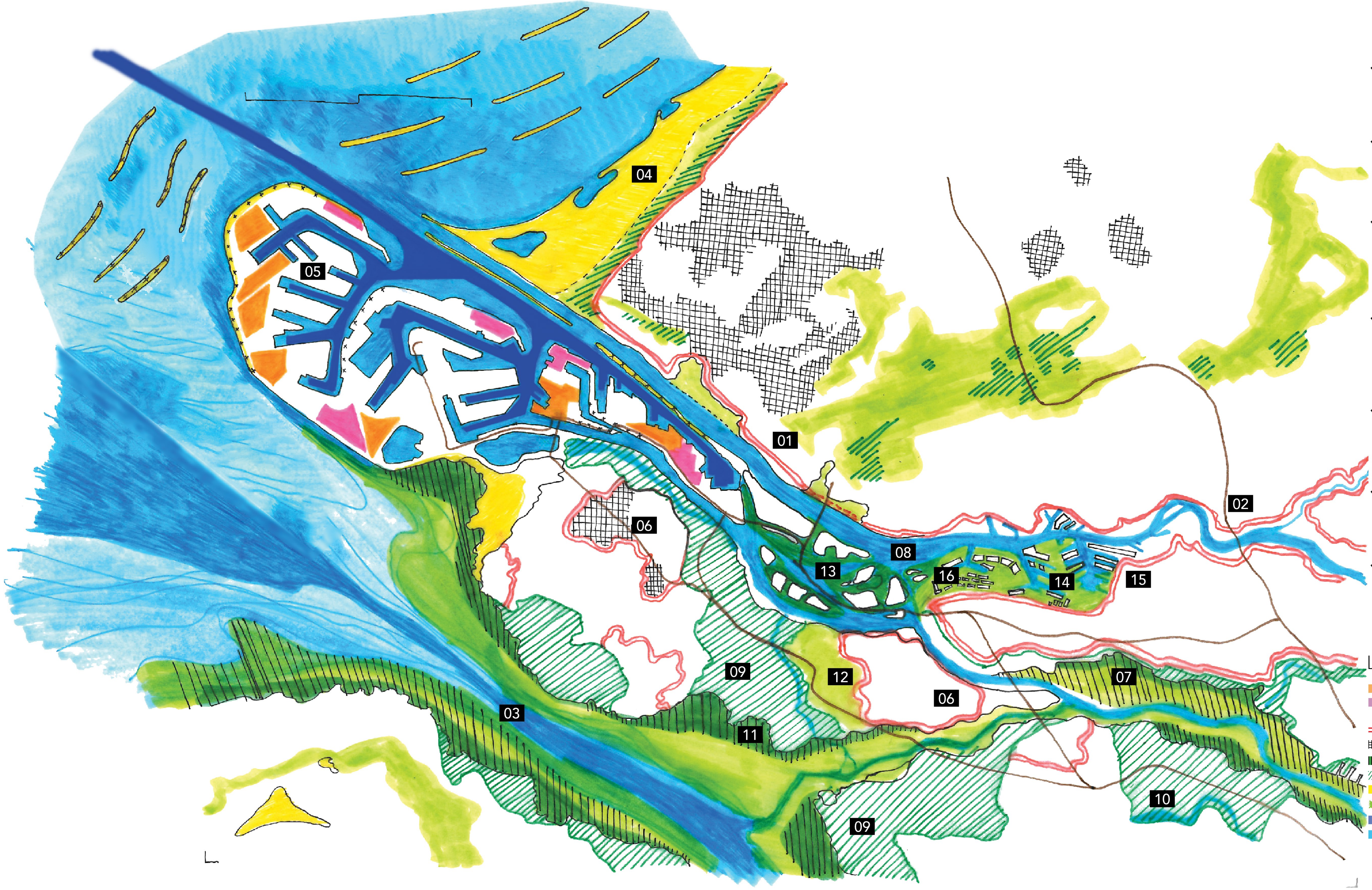
5. Relocating port

6. Protect and enclave

7. Climate buffer

8. Water buffer

9. Regional swamps



10. Freshwater buffer

11. Purification swamps

12. Wet crops

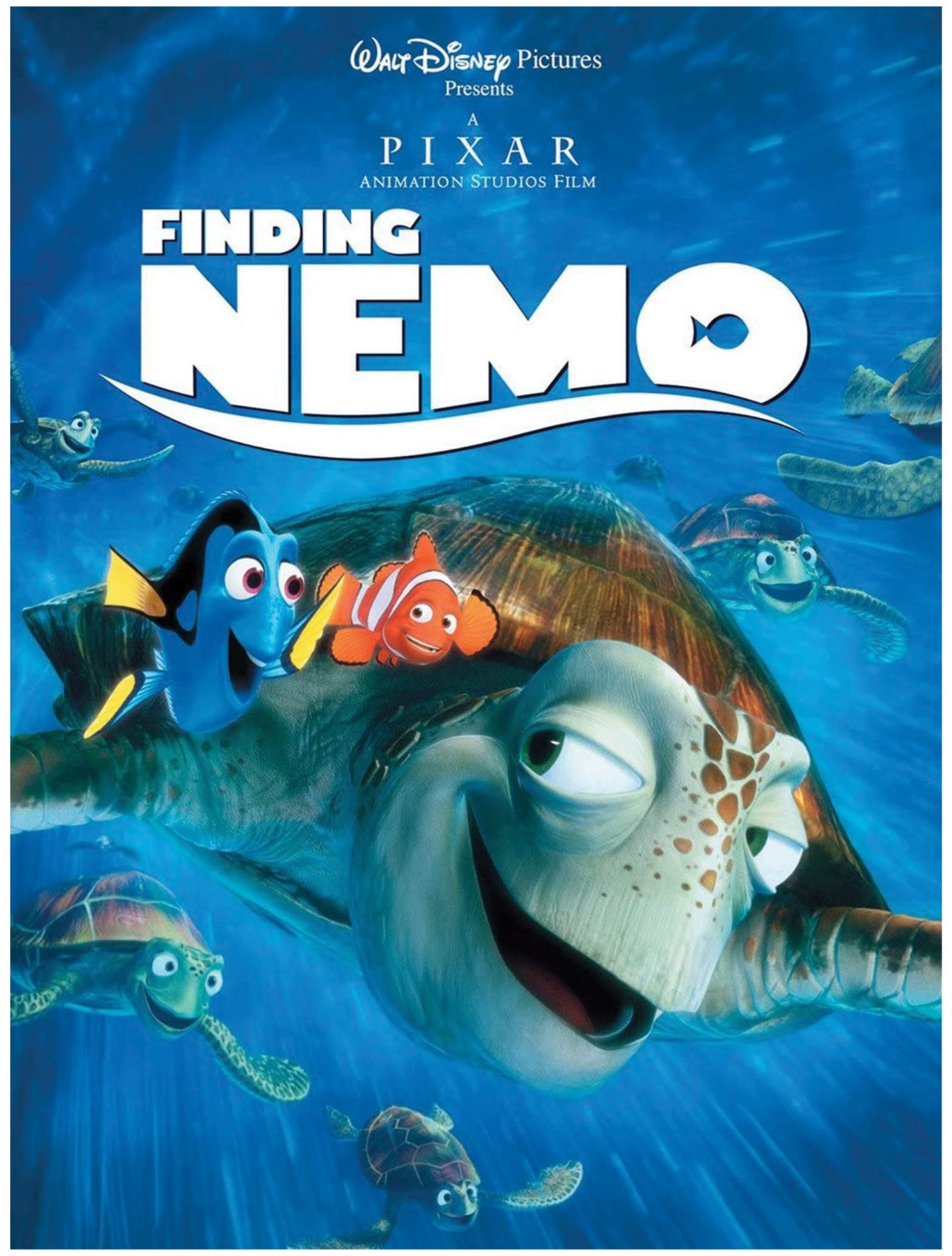
13. Botlek archipelago

14. Tidal city/ sponge city

15. Safe residential areas

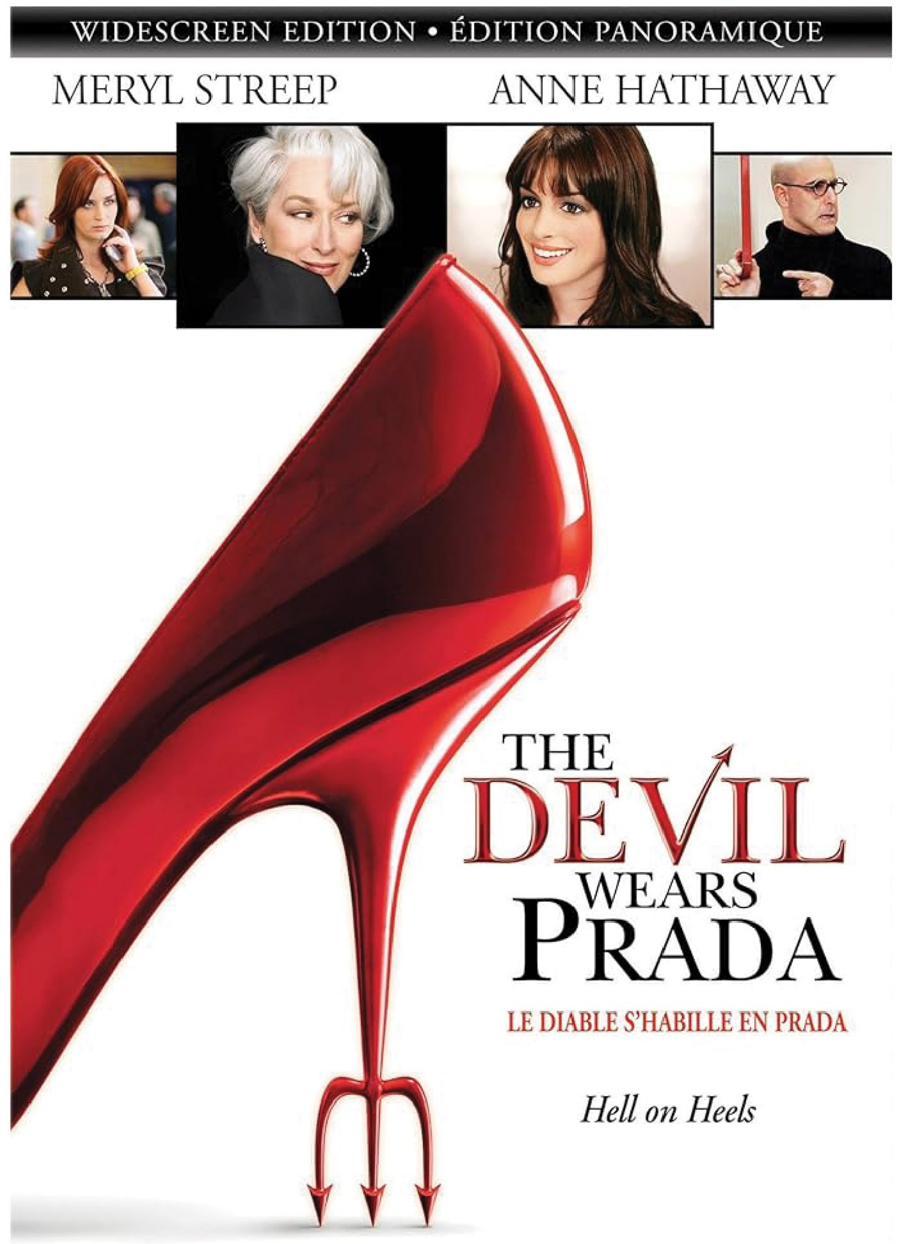
16. New water homes

How can **systemic transition** in Rijnmond region, incorporate a **disaster resilience**, **future proof region** which **enhances livability** while addressing effects of **developing climate risks**, resulting in **excess water** in the region?

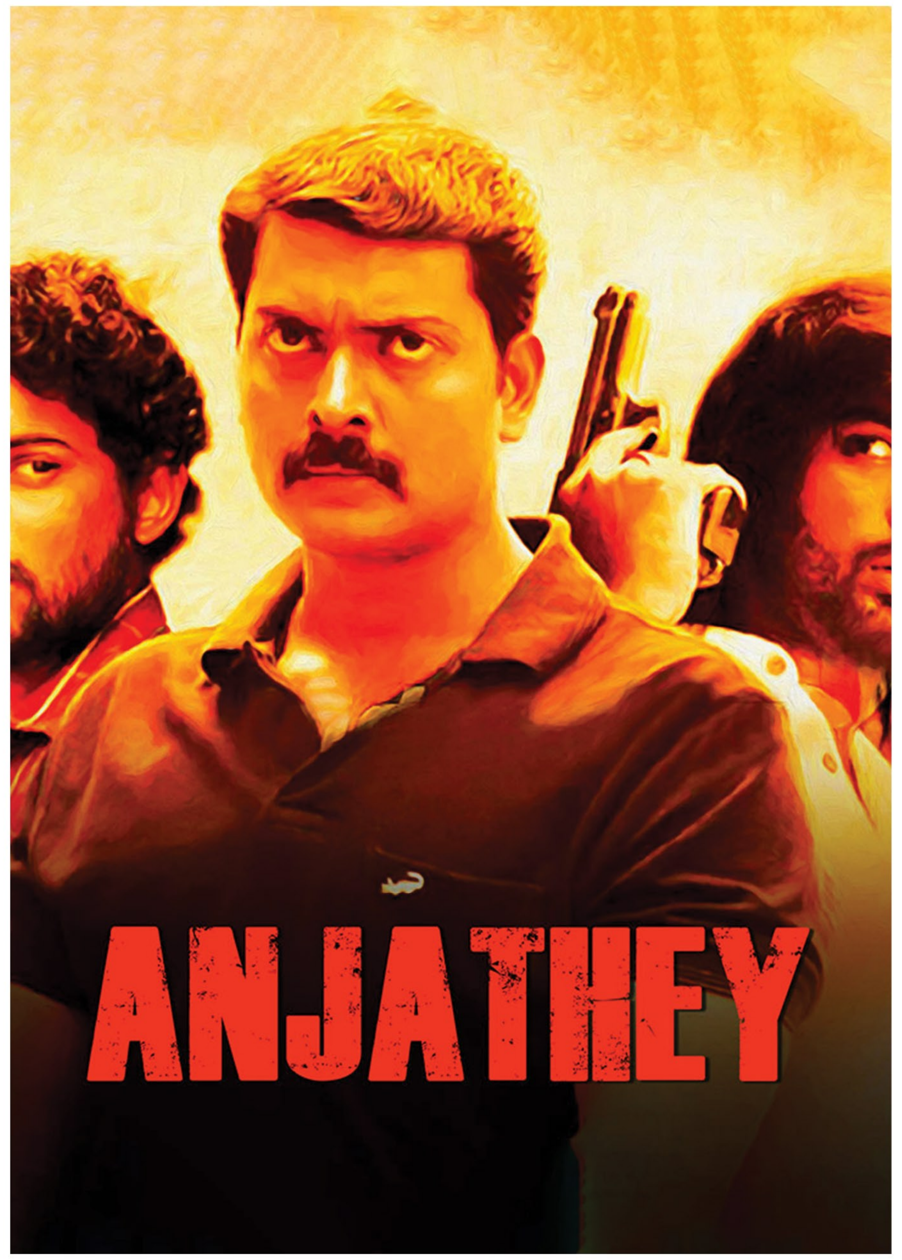


CC: Pixar Animated Studios and Walt Disney Pictures

CC: Warner Bros.



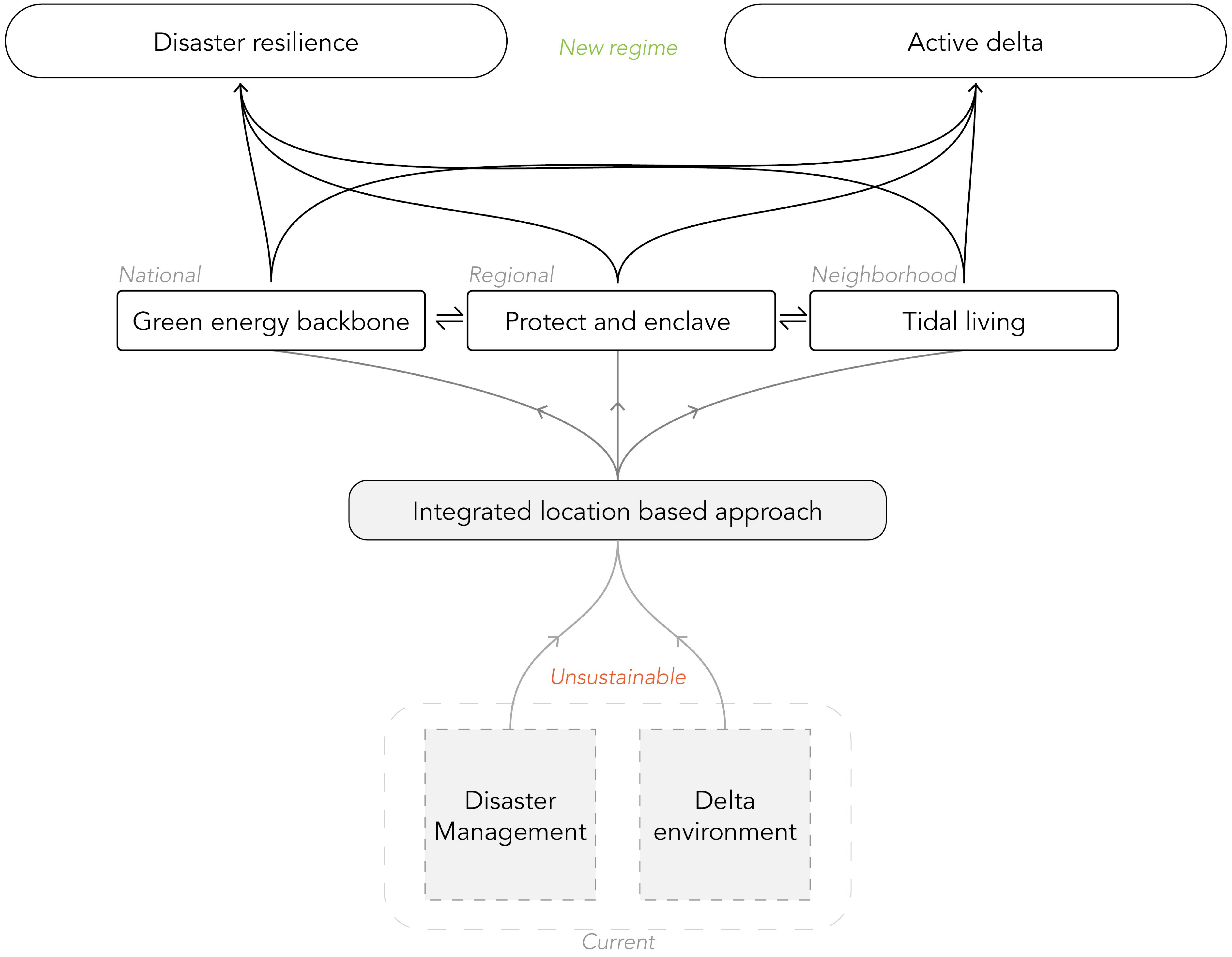
CC: Wendy Finerman Productions



CC: Nemichand Jhabak

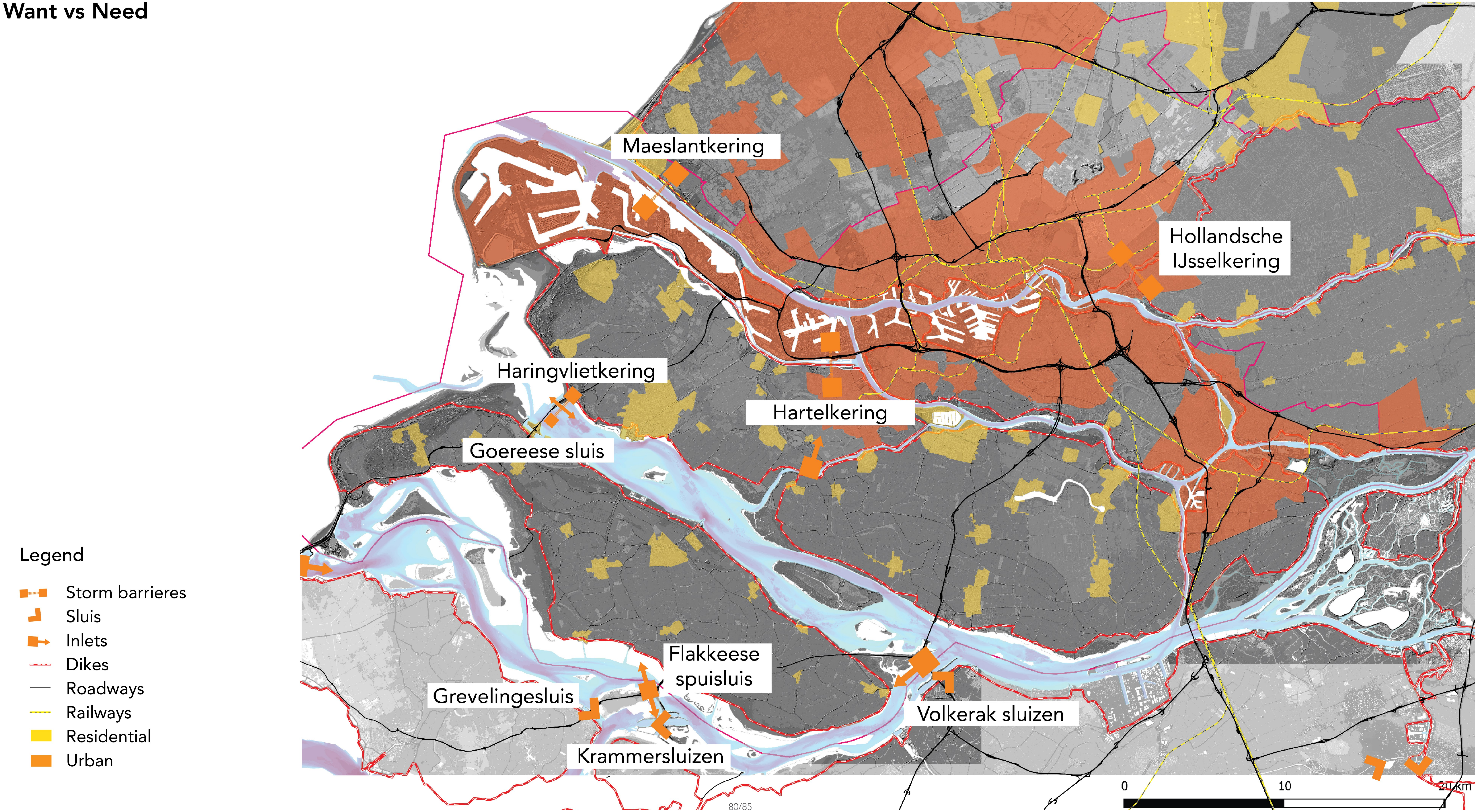
Want vs Need

Conceptual framework



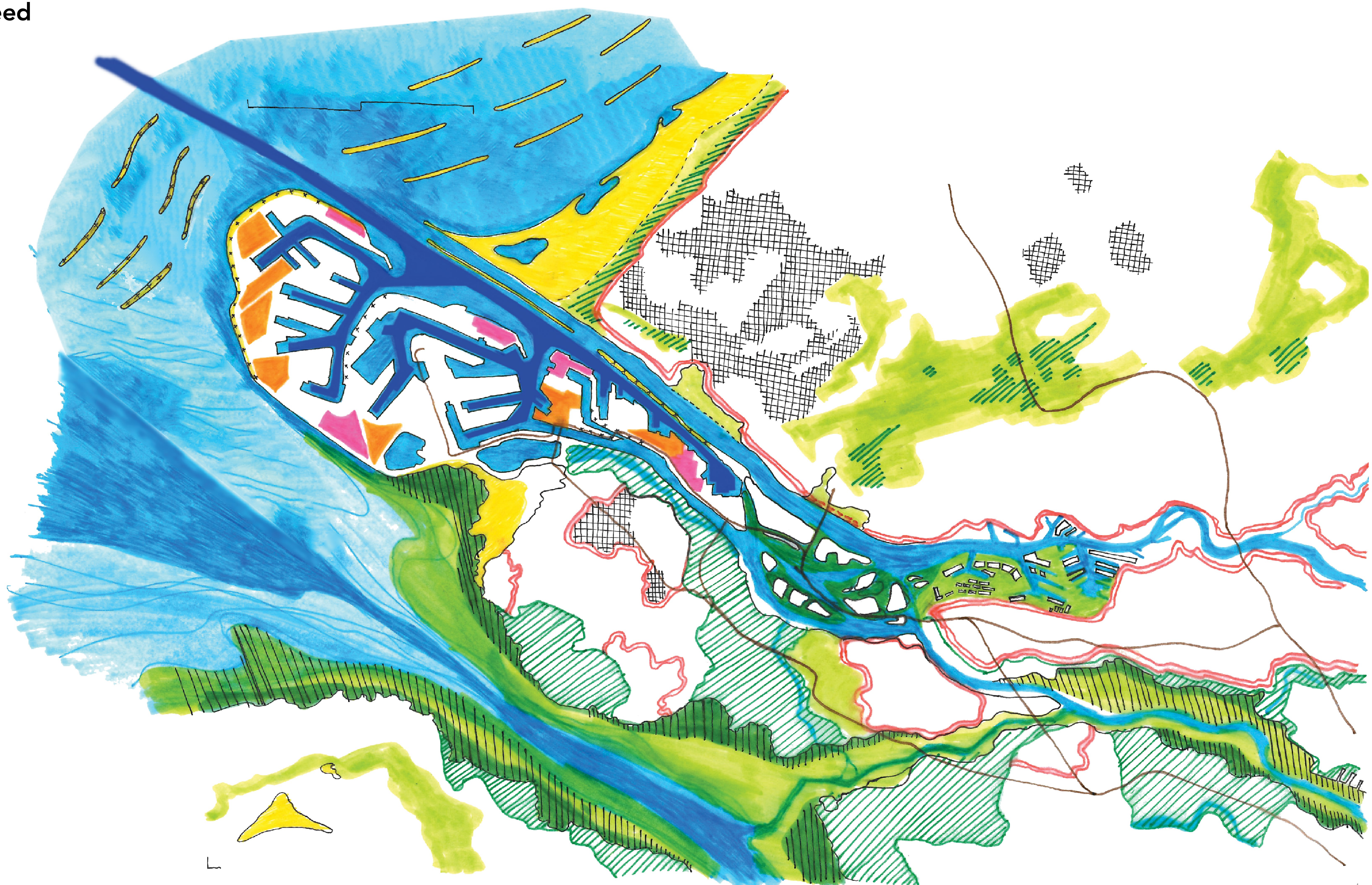
"A new island in combination with an extension of the Markerwadden (A wetland natural reserve) could be deliver a win-win both for nature and for the housing shortage." *-Rob Jetten*

Want vs Need



Maeslantkering
Hollandsche IJsselkering
Haringvlietkering
Hartelkering
Goereese sluis
Flakkeese spuisluis
Grevelingesluis
Volkerak sluizen
Krammersluizen
0
10
20 km
Legend
Storm barrieres
Sluis
Inlets
Dikes
Roadways
Railways
Residential
Urban

Want vs Need



Want

Source: Google street view

Need

Want

Source: Google street view

Need

When Disaster *Flows*

A systemic overview for climate resilient spatial framework on the Rijnmond delta region

Ganesh Umasankar | 6002463

First mentor : Claudiu Forgaci
Second mentor : Alexander Wandl
Delegate : Clarine van Oel

Thank you

TU Delft Department of Architectural Engineering +Technology
BK Bouwkunde

P5 Presentation

M.Sc. Urbanism

TU Delft

Phasing overview

Preparation

Make contamination visible, manageable, and governable, without disrupting essential operations prematurely.

Site & Risk Diagnosis
- Detailed soil, groundwater, and sediment contamination mapping
- Identification of pollutants (hydrocarbons, heavy metals, PFAS, solvents)
- Risk zoning: hot spots, buffer zones, low-risk areas

Regulatory & Governance Setup
- Alignment with environmental authorities
- Definition of clean-up standards per future land use

Spatial & Functional Decoupling
- Separate
- Active industrial zones,transition zones, future redevelopment zones
- Introduce temporary land-use buffers
- Capping contaminated soils
- Controlled access zones

Transformation

Gradually reclaim land by coupling remediation with spatial and ecological transformation.

Phased Decommissioning
- Step-by-step shutdown of refineries and tanks
- Removal of hazardous installations
- Safe dismantling and material recycling

Active Remediation Strategies

Use a combination of methods depending on contamination depth:
- Soil washing
- Bioremediation (microorganisms, phytoremediation)
- In-situ chemical oxidation
- Pump-and-treat for groundwater

Nature-Based Remediation
- Constructed wetlands for water purification
- Reed beds and marshes for hydrocarbon breakdown
- Phytoremediation landscapes

Infrastructure Transition
- Convert pipelines to new energy carriers (e.g., hydrogen)
- Remove obsolete infrastructure
- Retain adaptable industrial assets

Process

Deliver safe, productive, and resilient urban or ecological environments.

- Soil and groundwater compliance checks
- Health and safety certification for new uses
- Long-term risk mitigation plans
- Continuous groundwater monitoring
- Soil quality tracking
- Ecosystem health indicators
- Cultural reuse of industrial heritage

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- Start moving port activities to Maasvlakete-III
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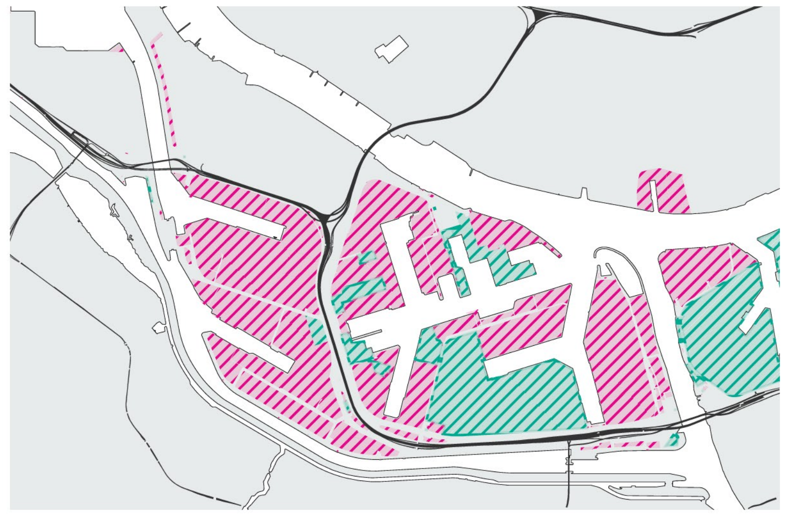

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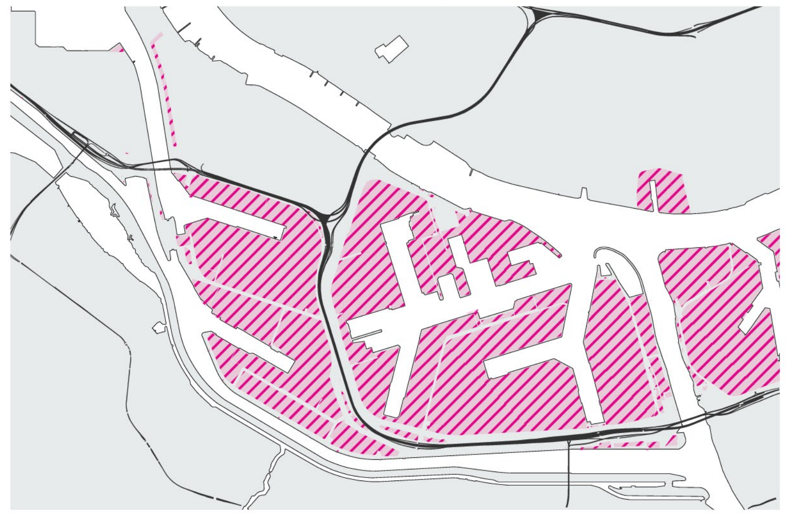

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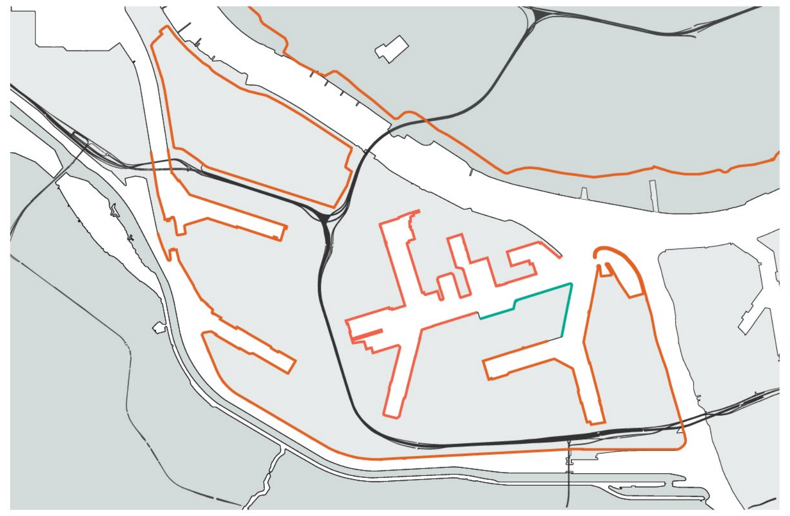

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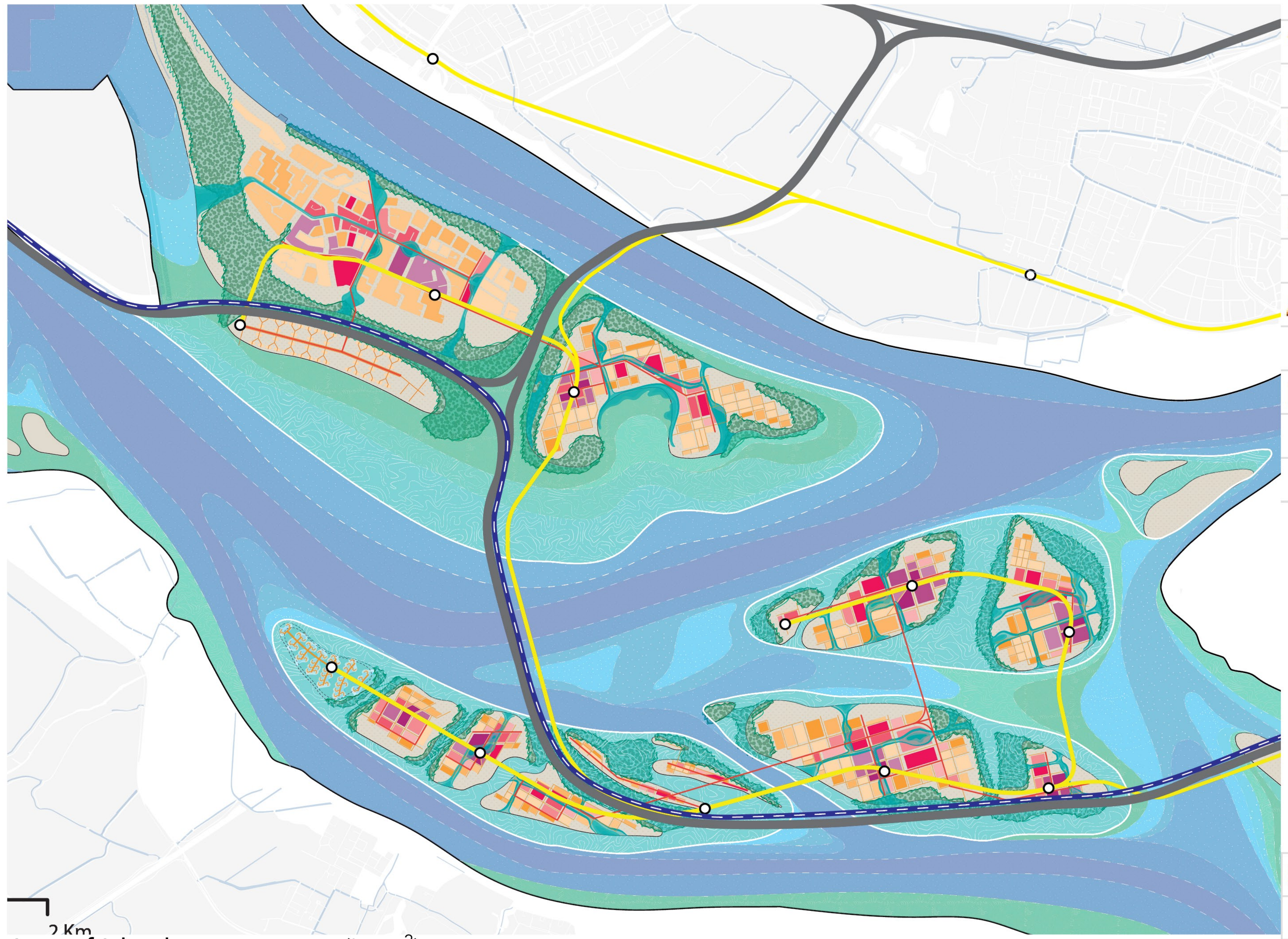


Area of Islands (in m²)

Island A	38,400 m²
Island B	589,555 m²
Island C	11,760 m²
Island D	136,388 m²
Island E	131,258 m²
Island F	157,413m²
Island G	33,721m²
Island H	25,235m²
Island I	582,582 m²
Island J	67609 m²
Island K	342,786 m²
Island L	330,752 m²
Island M	10,082 m²

Legend

Land-use type
- Commercial mixed use
- Medium rise mixed use
- Low rise mixed housing

Network
- TEN-T corridor
- Metro line
- Regional road
- Local road

	Commerical		Mixed height			Low rise		
	High desinty	Medium density	High desnity	medium density	low density	High density	Medium denisty	low density
	121892.75	264544.88	247496.22	335509.09	181706.6	480863.57	386572.05	438960.19
* 40% (builtup area	48757.1	105817.952	98998.488	134203.636	72682.64	192345.428	154628.82	175584.076
FSI value	12	10	9.375	6.25	7	5	4.25	1.375
Builtup area	585085.2	1058179.52	928110.825	838772.725	508778.48	961727.14	657172.485	241428.1045
Area per unit	200	250	35	60	144	45	70	144
Dwelling unit	2925.426	4232.71808	26517.45214	13979.54542	3533.18389	21371.71422	9388.178357	1676.584059
	3000	4250	27000	14000	3600	21000	9500	2000
83624.80217								

Source: Spatial density and mix use in the Netherlands (RUDIFUN)

		FSI	GSI	OSR	
Low raise	Low density	0.4-0.7	25-35%	0.65-0.75	Yepenburg, The hague
	Medium density	1.5-1.9	45-55%	0.45-0.55	Jordaan, Amsterdam
	High density	1.8-2.2	55-65%	0.35-0.45	Delft Binnenstad
Medium raise	Low density	1.2-1.6	20-30%	0.7-0.8	Kanaleneiland, Utrecht
	Medium density	2.0-3.0	30-40%	0.6-0.7	Ijburg, Amsterdam
	High density	3-4.5	28-36%	0.64-0.72	Rotterdam Blaak-Goudsesingel blocks

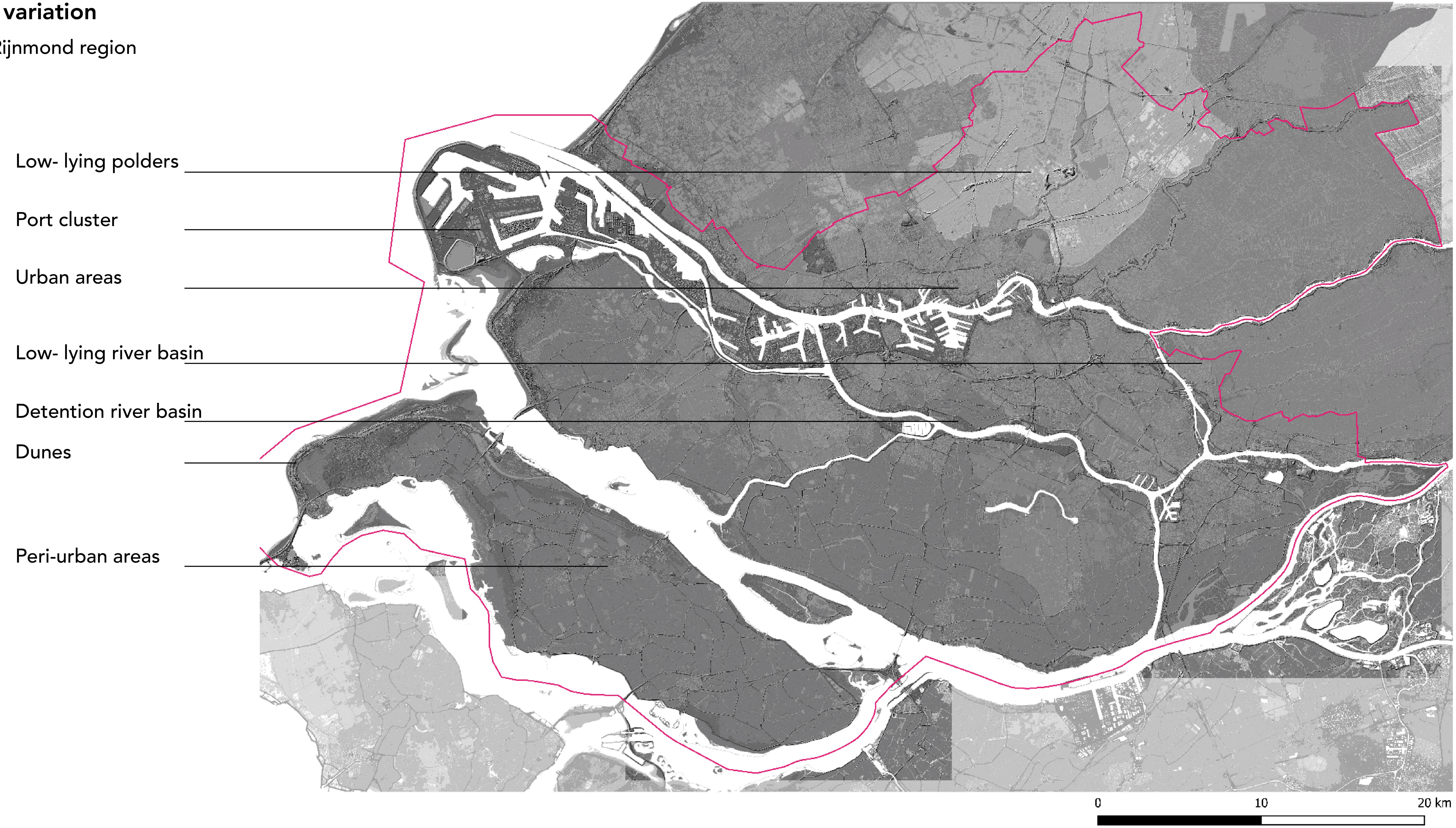
Average size of dutch household = 177m²
(world population review)

96%

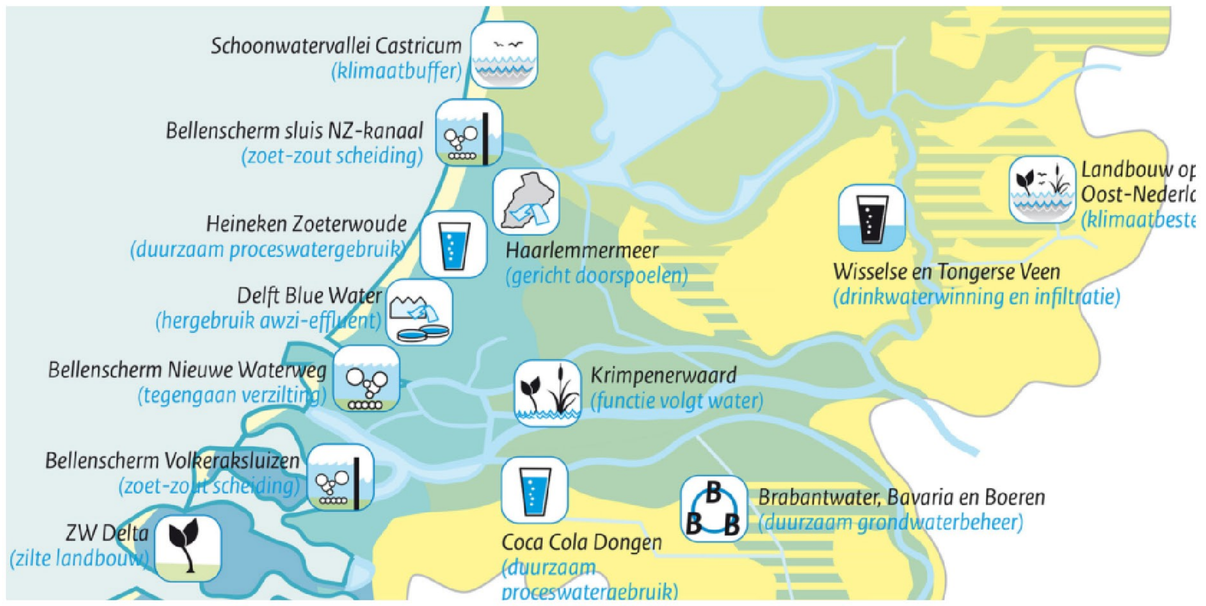
The superposition of intrinsic vulnerabilities for the complete urban extent in the Netherlands indicates that about **96% of the Dutch urban area** is susceptible to one or more climate hazards, with approximately **10% susceptible** (van Gaalen et al., 2024) to all four studied hazards which includes **heat stress, drought, water nuisance and flooding**.

Spatial variation

Rijnmond region



Current strategies





Implementation of the Delta Programme

Structural and Substantial Investments in Primary Water Defenses

Operation of Large Flood Barriers

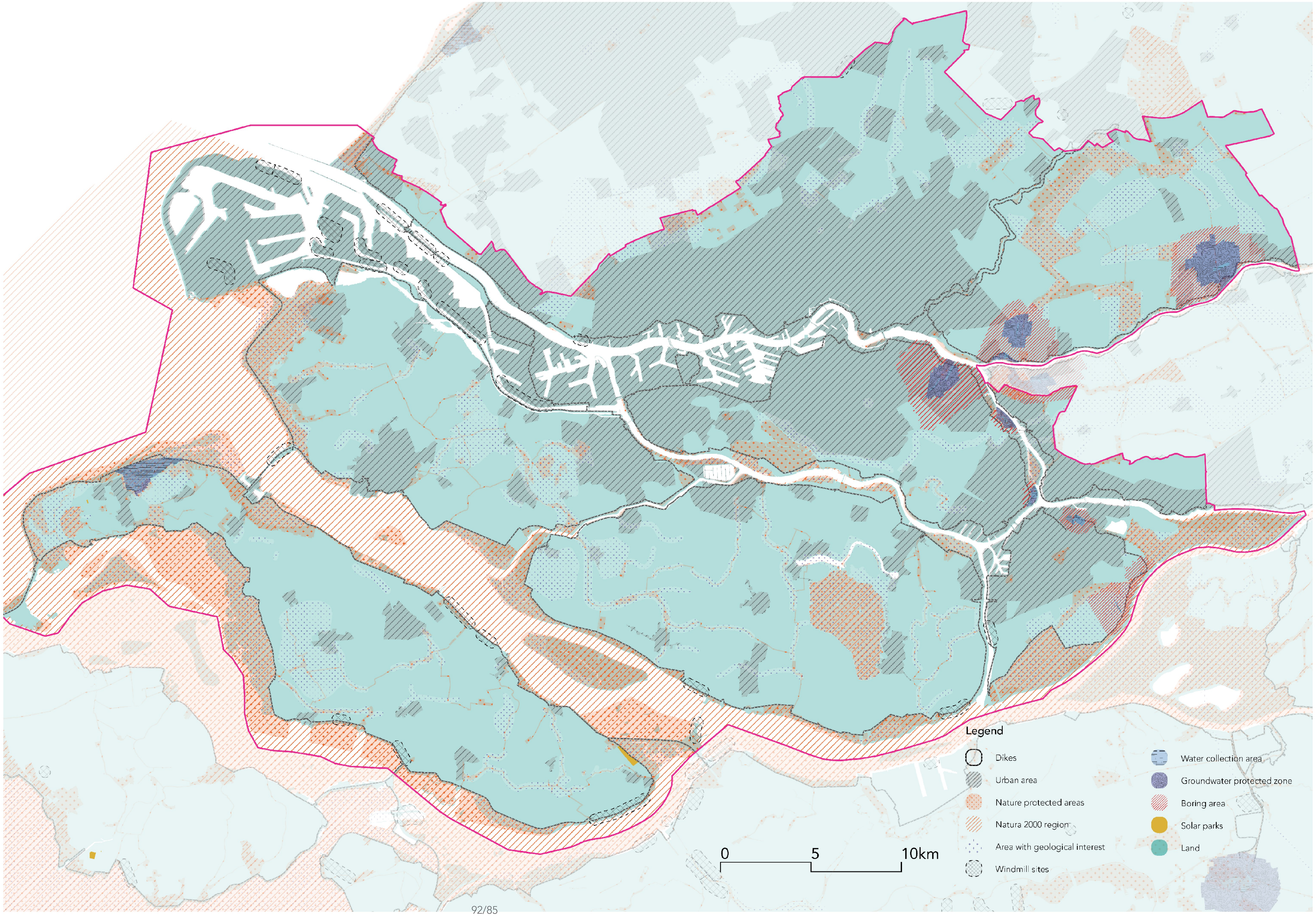
Implementation of Water Safety Standards

Layered Approach to Flood Risk Reduction

Current strategies

Protected areas

- NNN Netherlands
- Natura2000
- Area with geological interest
- Drinking water protected areas
- Heritage areas in inner cities



Research framework

Main research question

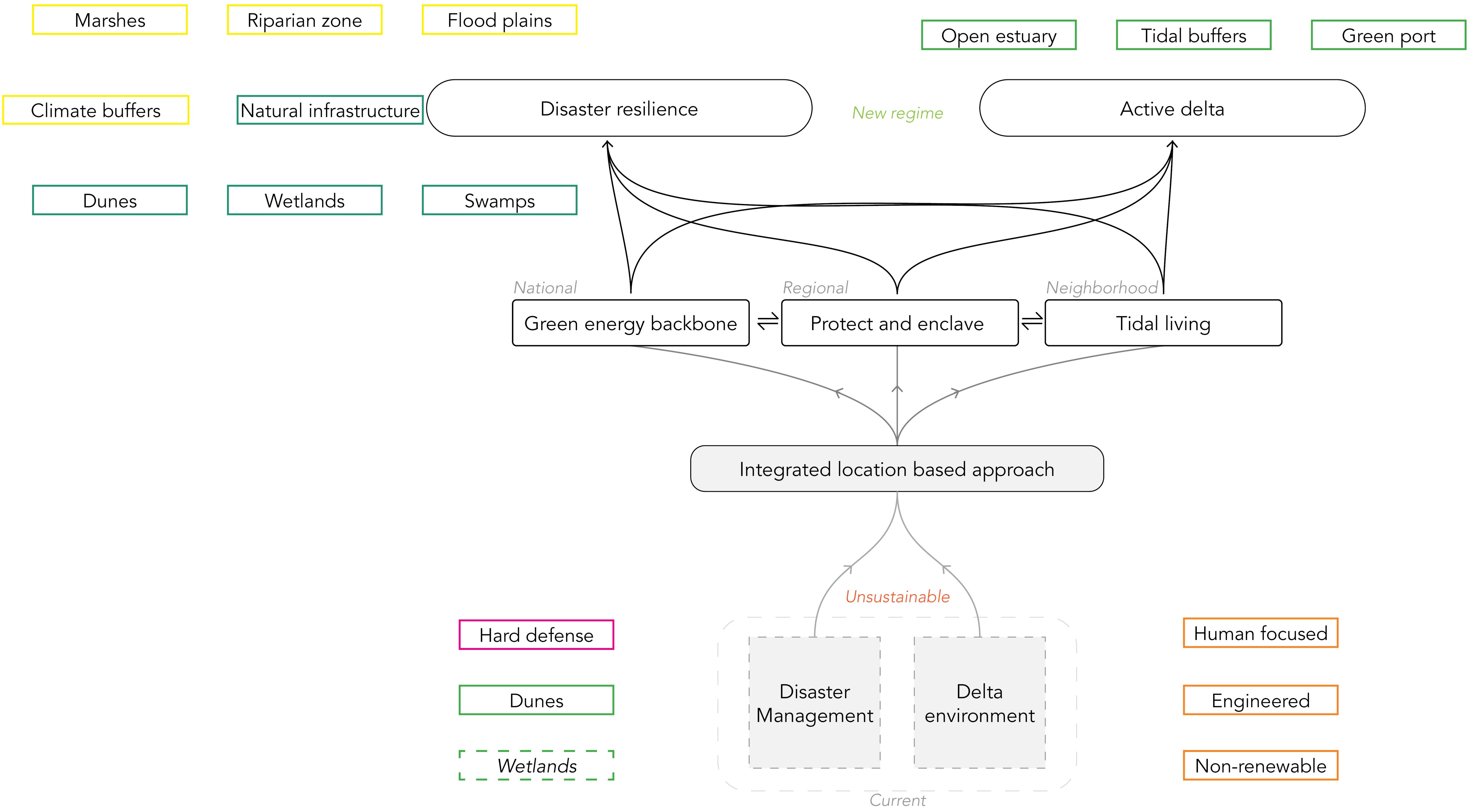
How can **systemic transition** in Rijnmond region, SRQ. 01,05

incorporate a **disaster resilience, future proof** region which **enhances livability** SRQ. 03,04

while addressing effects of **developing climate risks,** resulting in **excess water** in the region? SRQ. 02

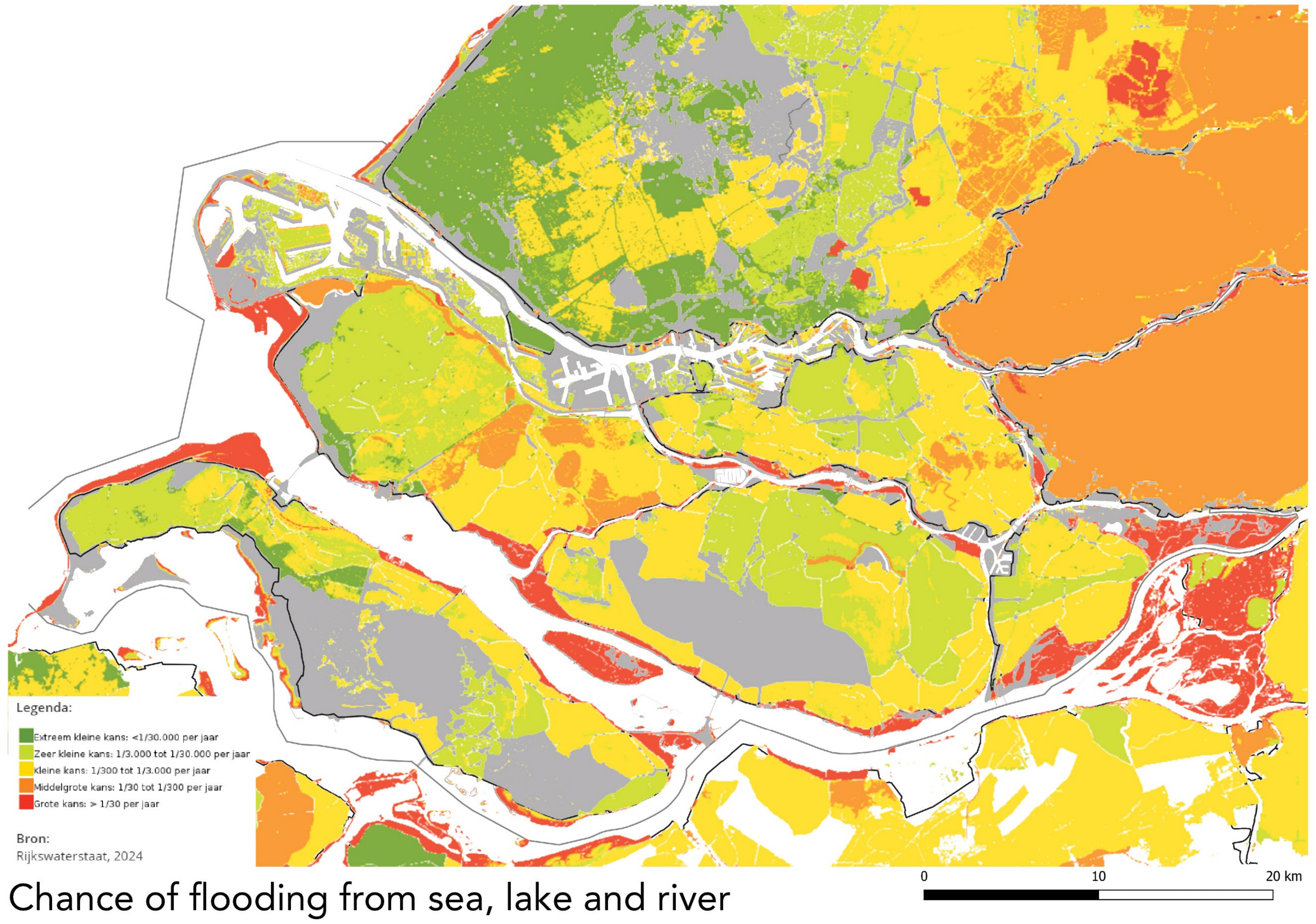
Sub research question	Methods	Literature review, document and policy review. (Analytical)	DPSIR method (Analytical)	Adaptive pathways (Design)	Research by design (Design)	Expected outcomes
SRQ.01: Which existing systems are designed to protect the region from excess water, what are their limitations and lifespan?	Literature review, document and policy review	×				Understanding of the system and region through predicted scenarios and climate forecast, this helps formulates the analytical and design framework through addressing its flaws.
SRQ.02: How does the climate risk pose a threat to the spatial environment and what are their critical pressure points?	DPSIR method, Adaptive pathways		×	×		Critical points of the region which has a huge impact on the system and the region
SRQ.03: What are the innovations and future trends which will help us achieve disaster resilience and future proof region that can be incorporated into the current transition?	Literature review, document and policy review Adaptive pathways, Research by design	×		×	×	Understanding of current trends through policy and spacialise them
SRQ.04: How are the pathways that enhances livability while ensuring water defense, enrich delta and align with sustainable energy transition configure?	DPSIR method, Adaptive pathways, Research by design		×	×	×	Adaptive pathways that help us achieve disaster resilience and future proof regions
SRQ.05: How can these pathways transform the region and how can coexist?	Adaptive pathways, Research by design			×	×	Zoom-in(s) which show how Non- conflicting pathway trends end up on human scale

Conceptual framework

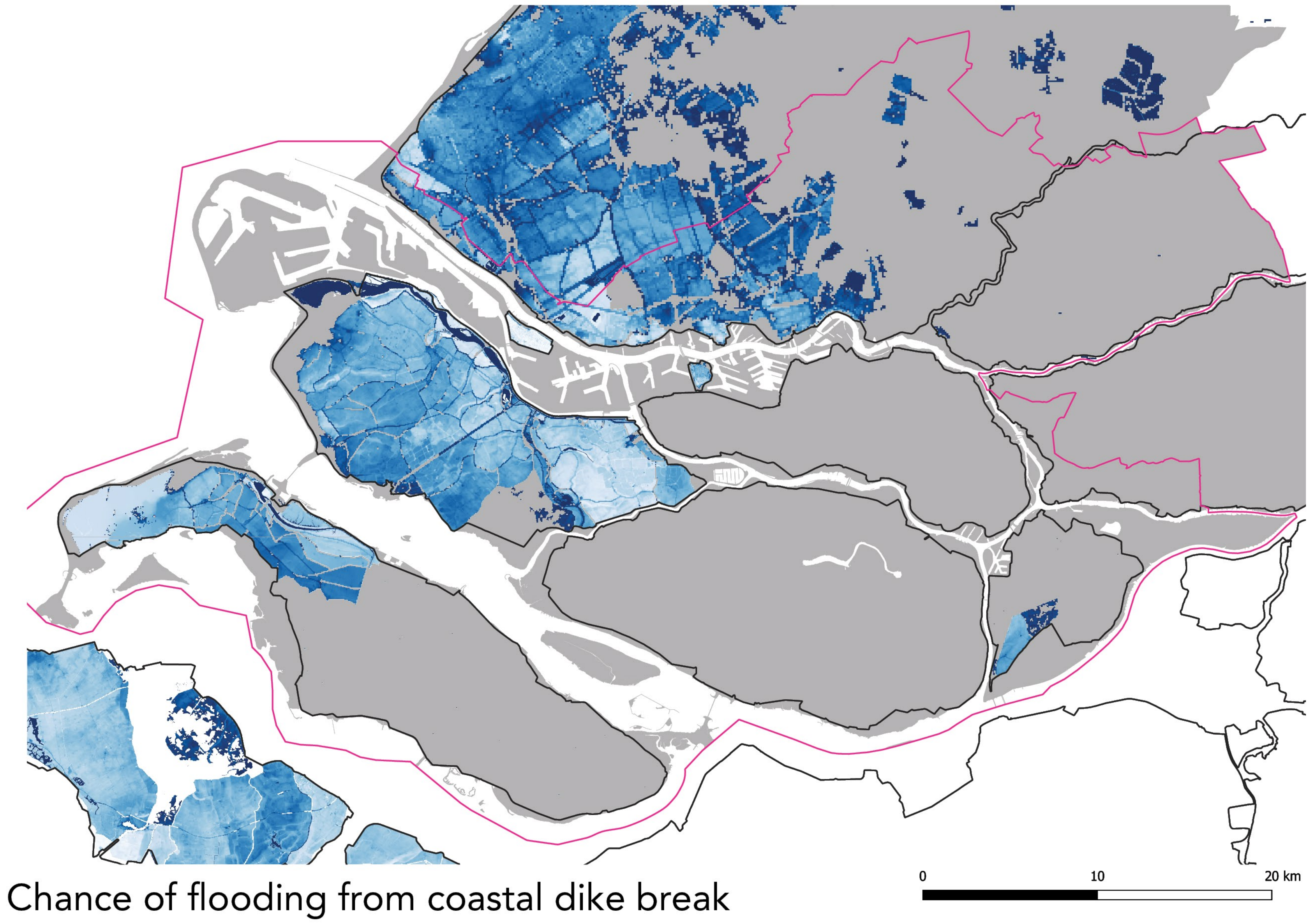


Climate scenarios

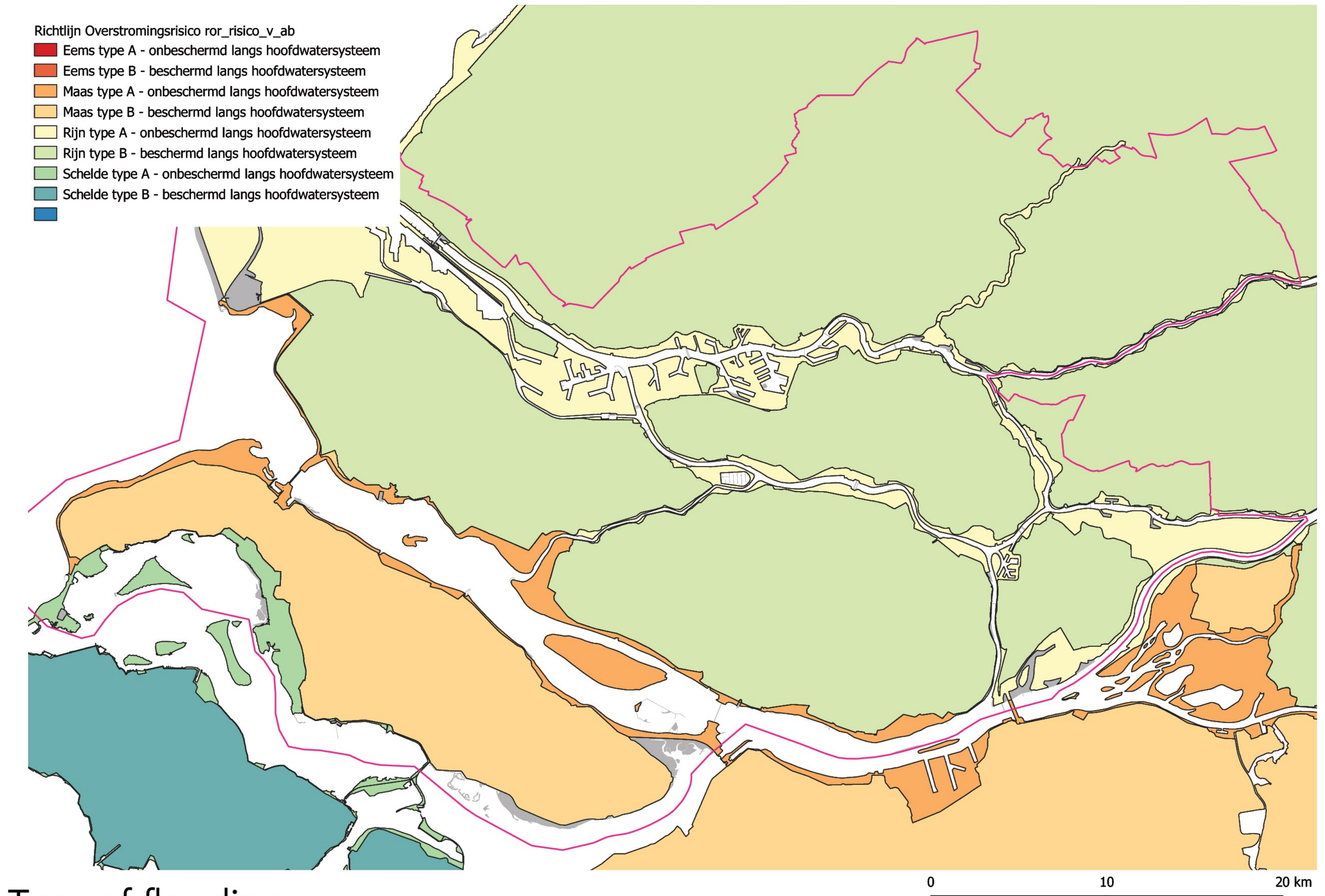
In the event of infrastructural failures



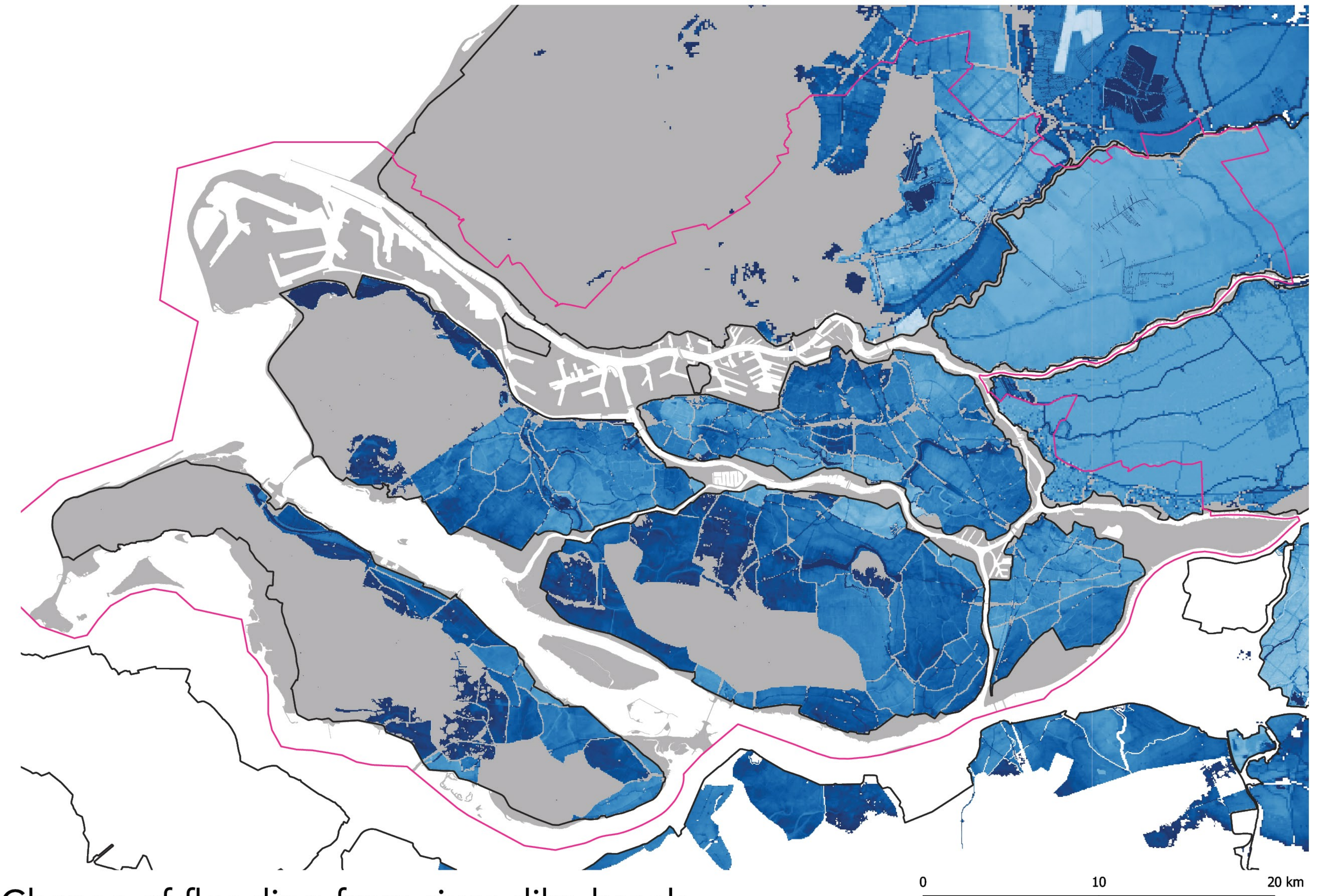
Chance of flooding from sea, lake and river



Chance of flooding from coastal dike break



Type of flooding



Chance of flooding from river dike break

DPSIR method

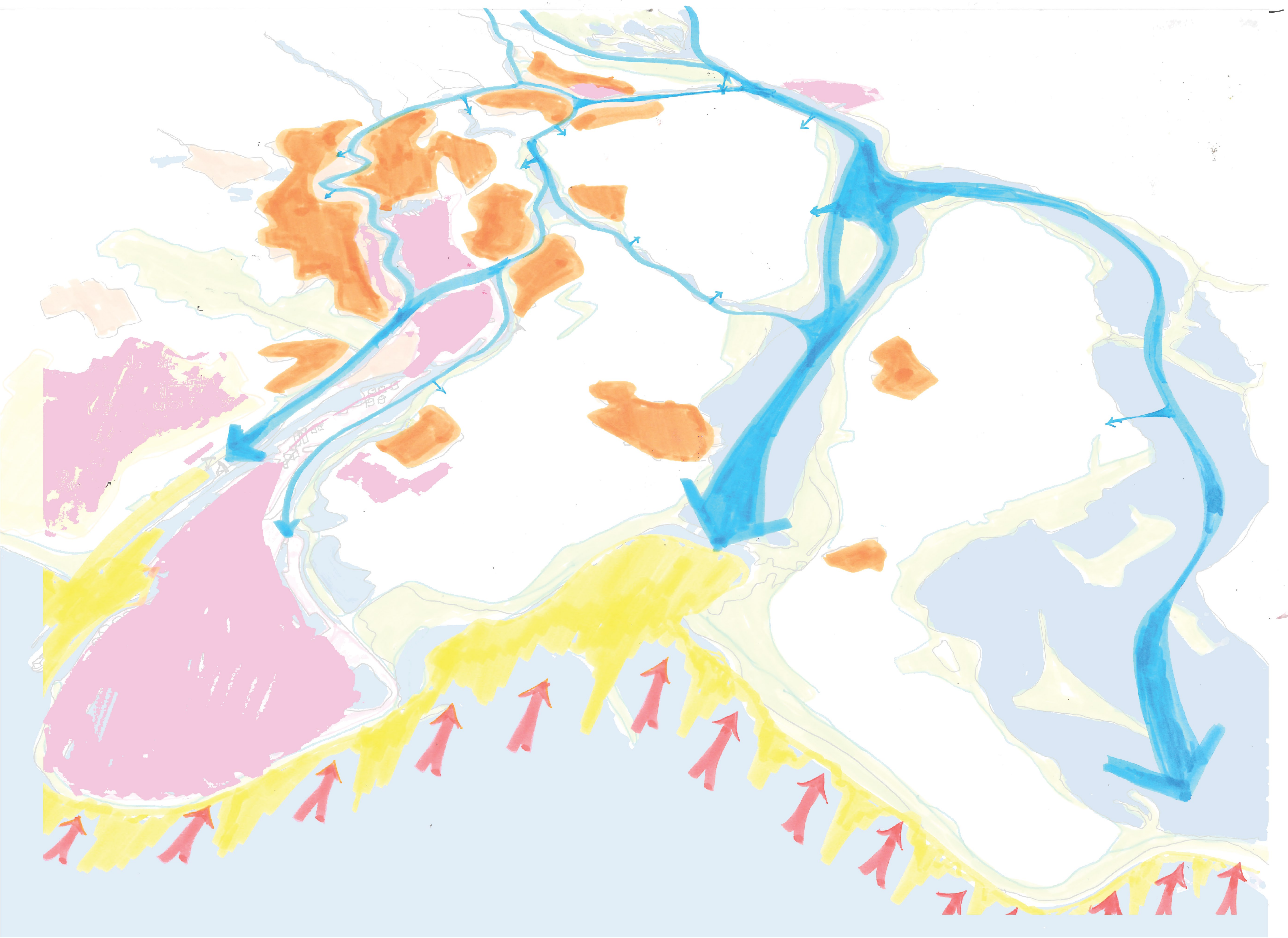
State

Driver

DPSIR method

Pressure

Impact



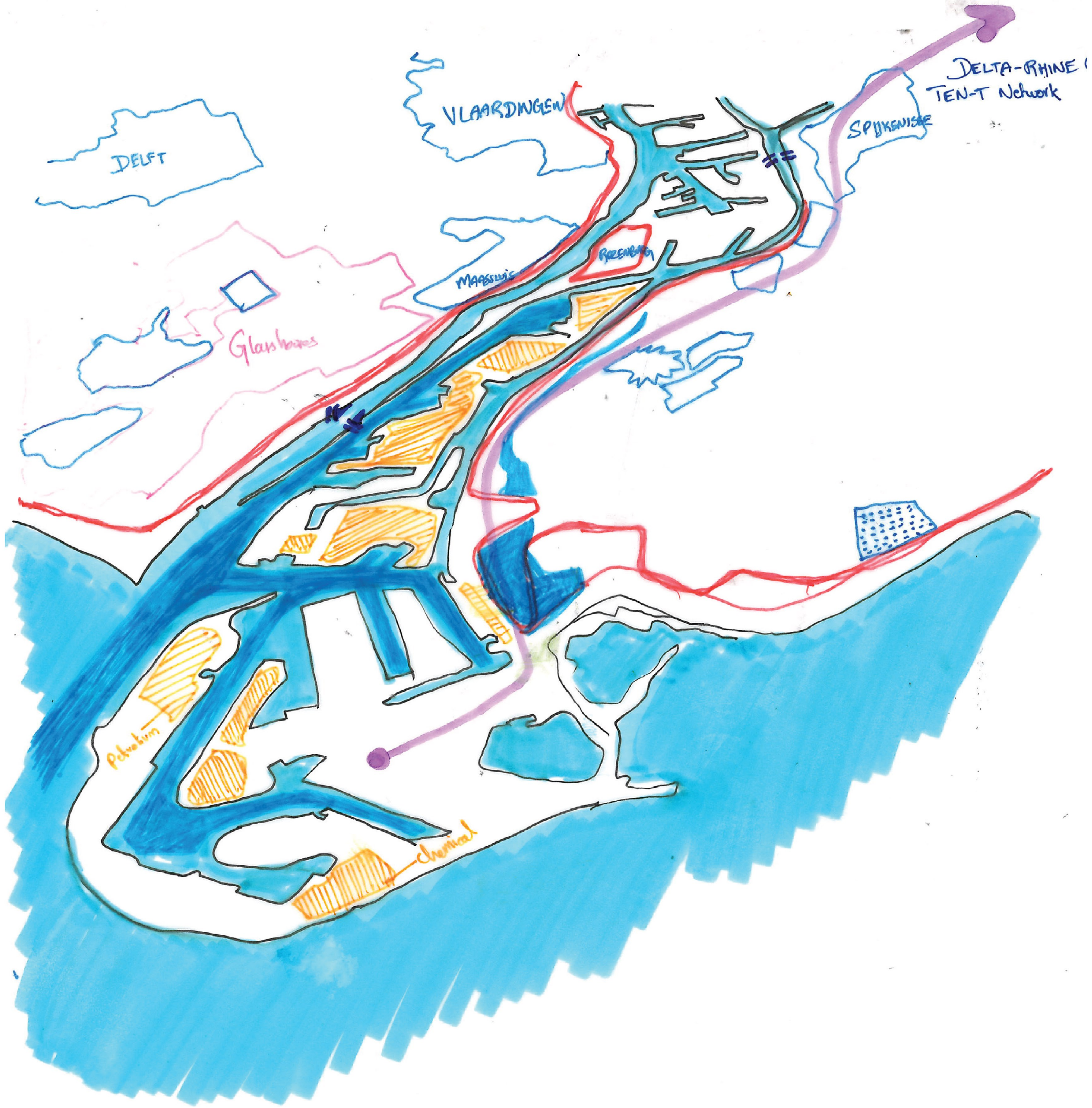
DPSIR method

Conclusion

Critical point

Method focus

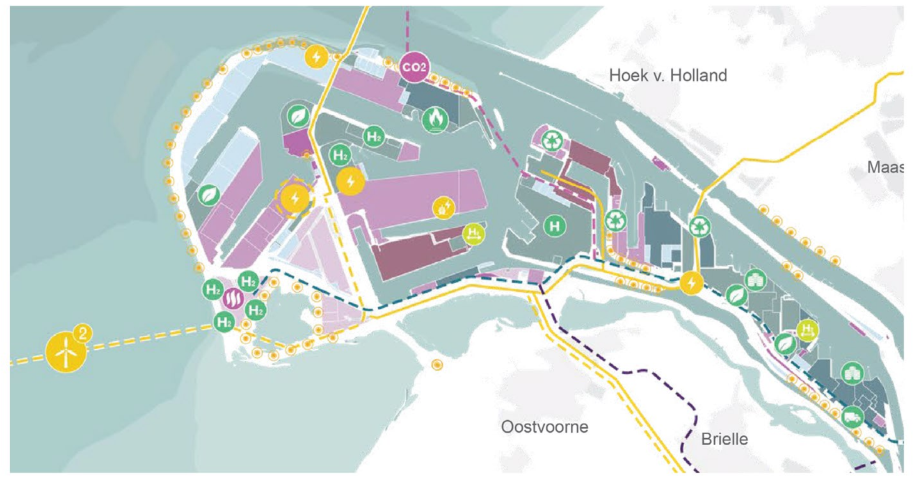
Maaslantkering - Port of Rotterdam



Outer - Dike region

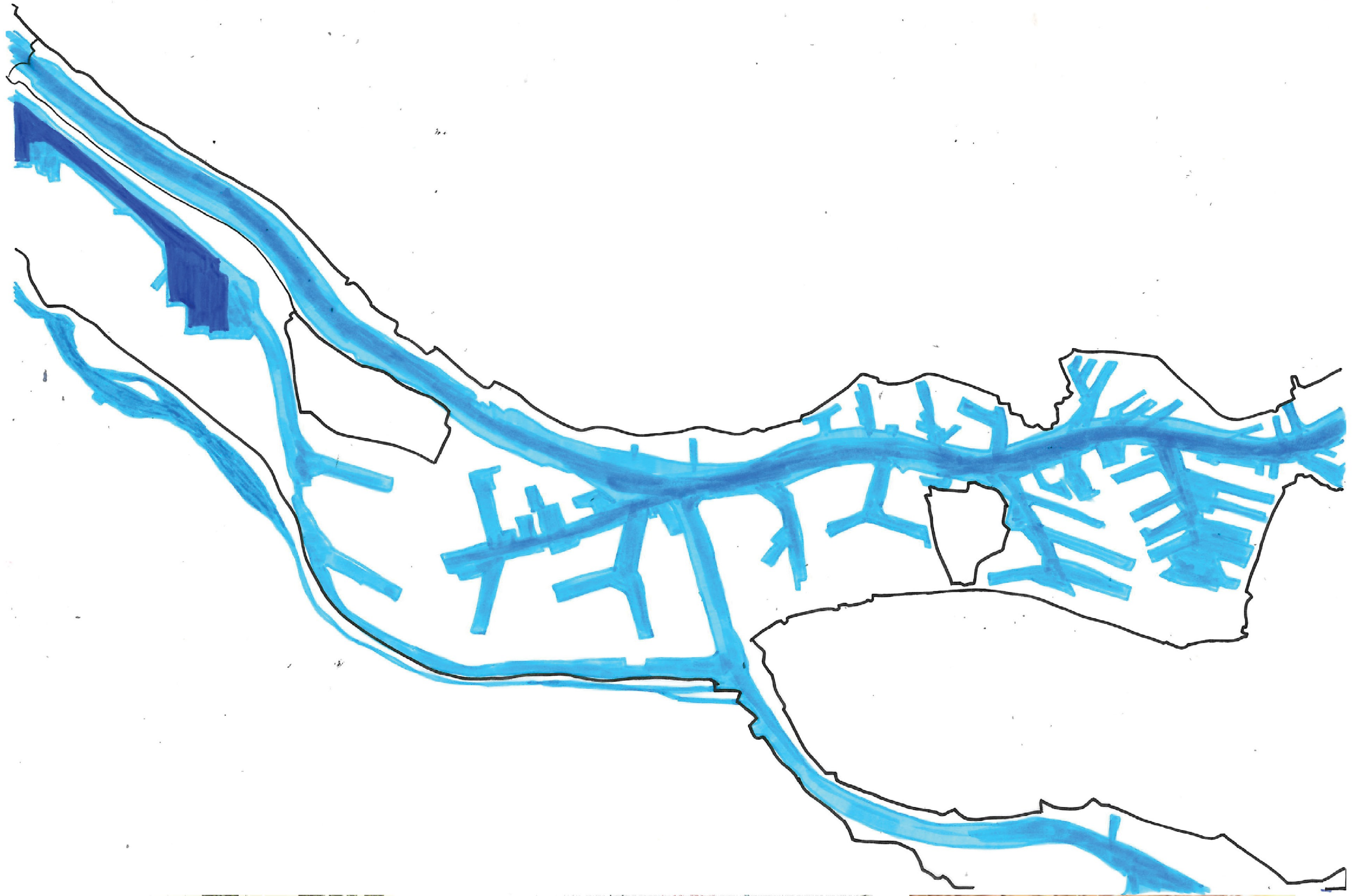
Exploration

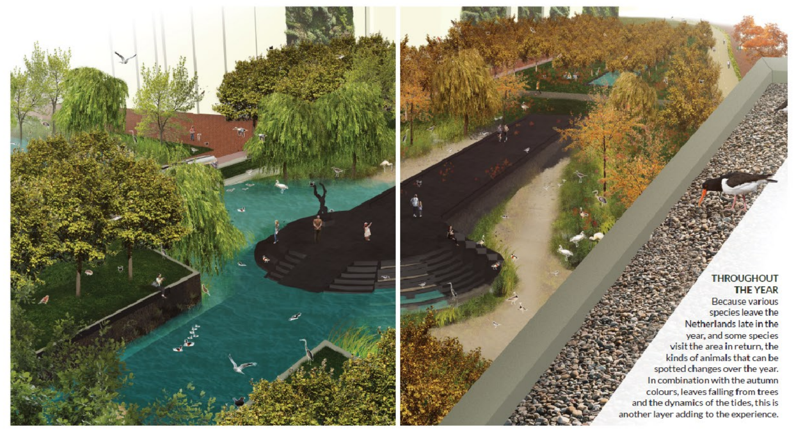
Rotterdam waterstad 2100
@De Urbanisten, Deltares (2023)



NOVEX Rotterdam harbor area development perspective
@Ministry (2023)

Neste Bio-fuel cluster
@Port of Rotterdam (2025)





Rotterdam as **Urban Tides-capes**
@Graduation thesis by Ivo Brands (2022)

Resilient rotterdam port
@Graduation thesis by Baokun Wei(2021)

Floating Area in the Maashaven
@Graduation thesis by Marisa Fang (2013)

Rijnhaven masterplan @Barcode architects

Two-stream country_Self-rising delta city
@Palmbout (2022)

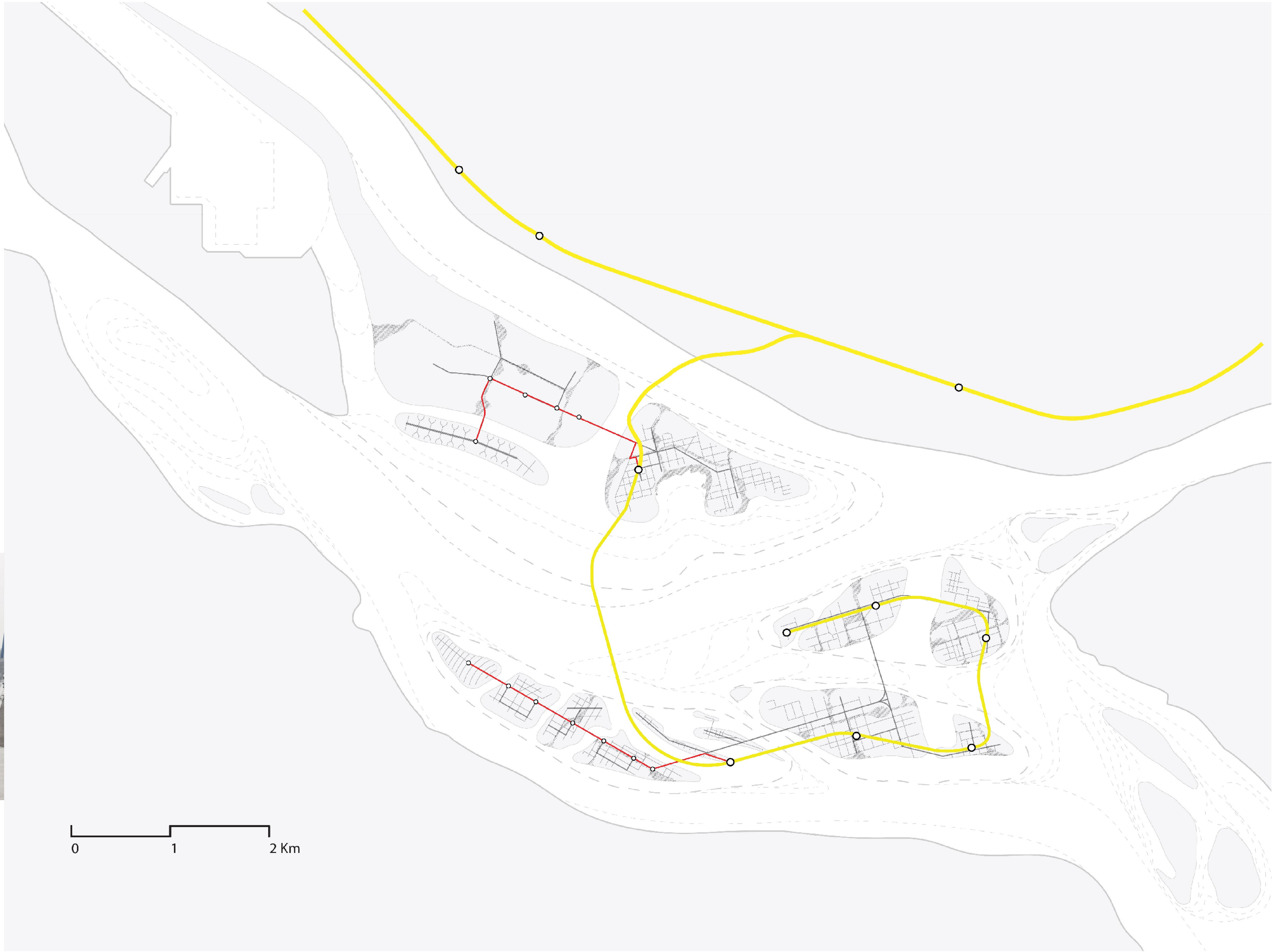
Deltapolder
@IABR discussion session (2025)

Botlek Archipelago

Mobility

Botlek Archipelago

Mobility



Park shuttle

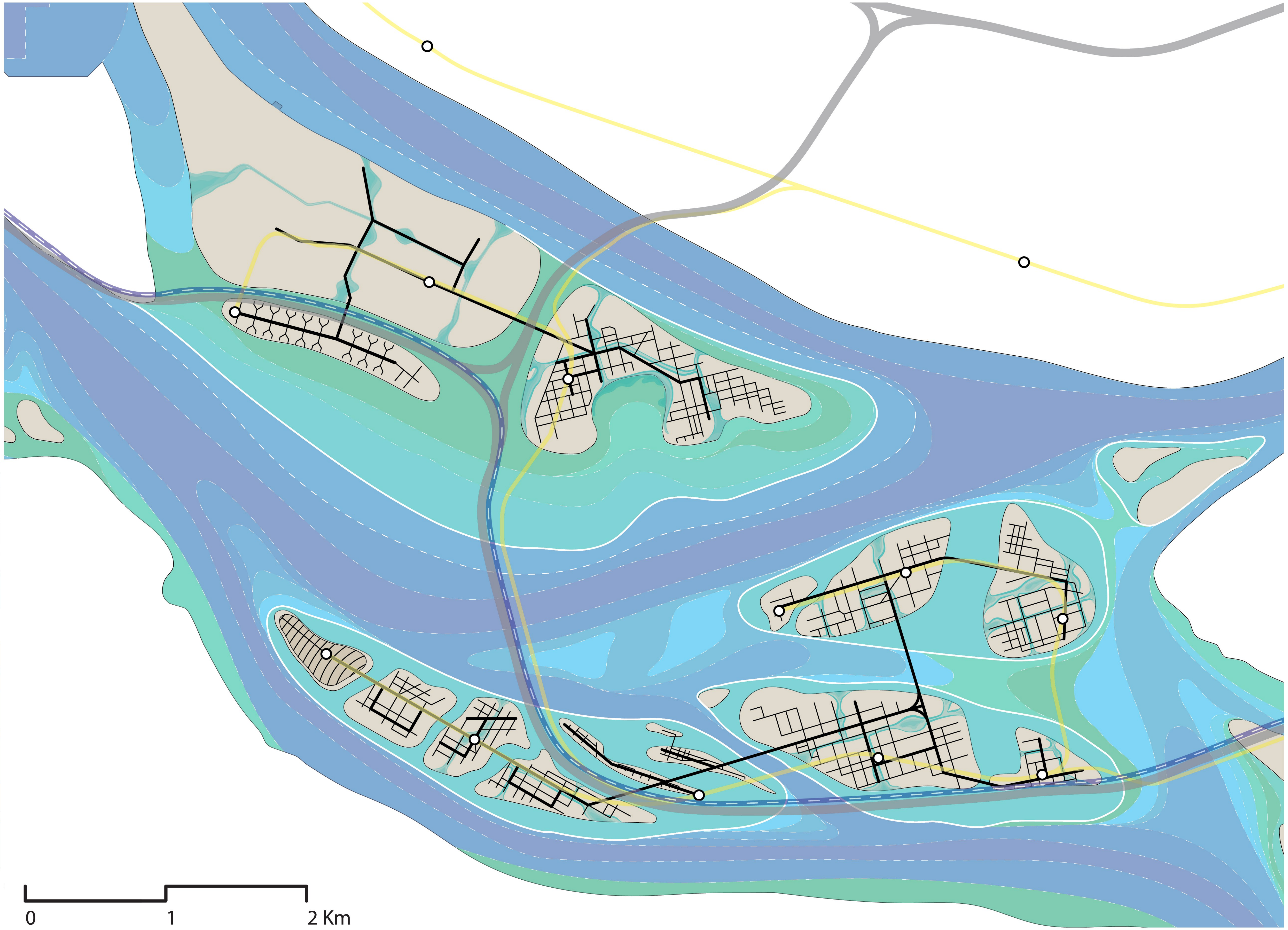
Source: By Wvdp - Own work, CC0

Botlek Archipelago

Mobility

Botlek Archipelago

Urban layout

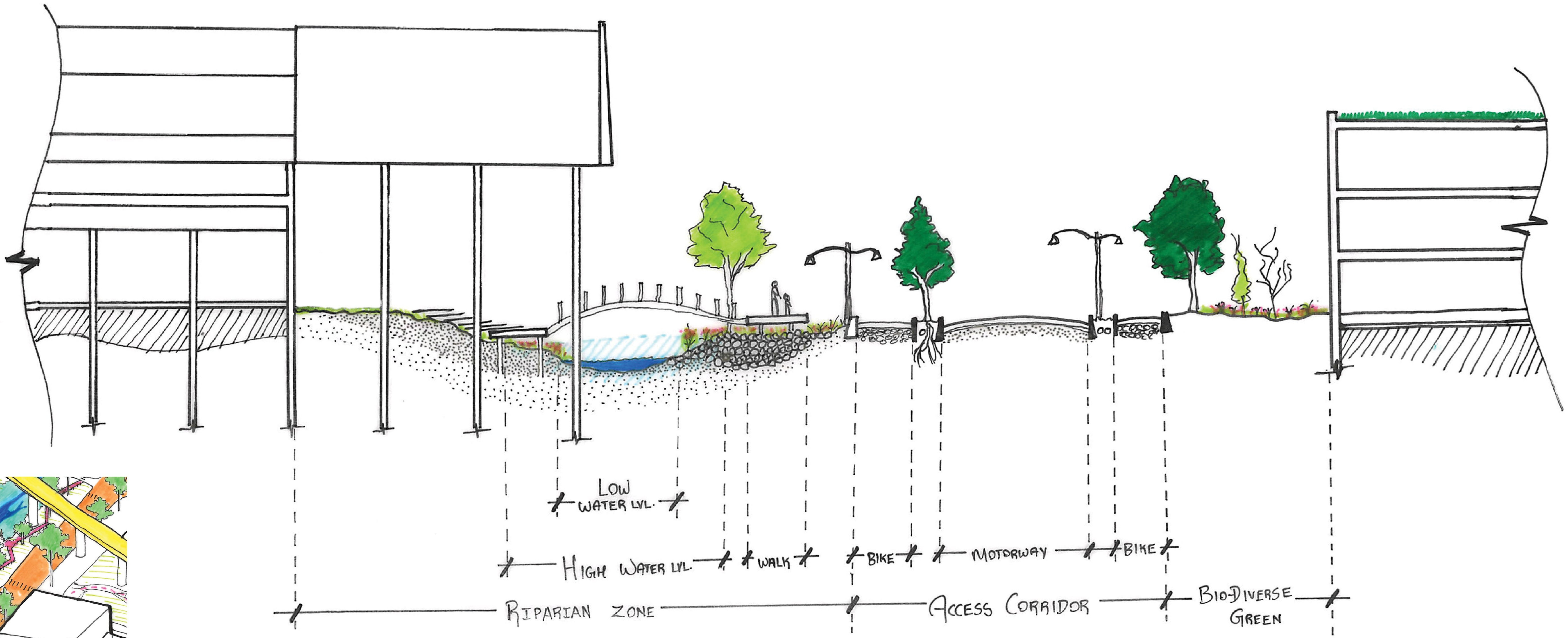


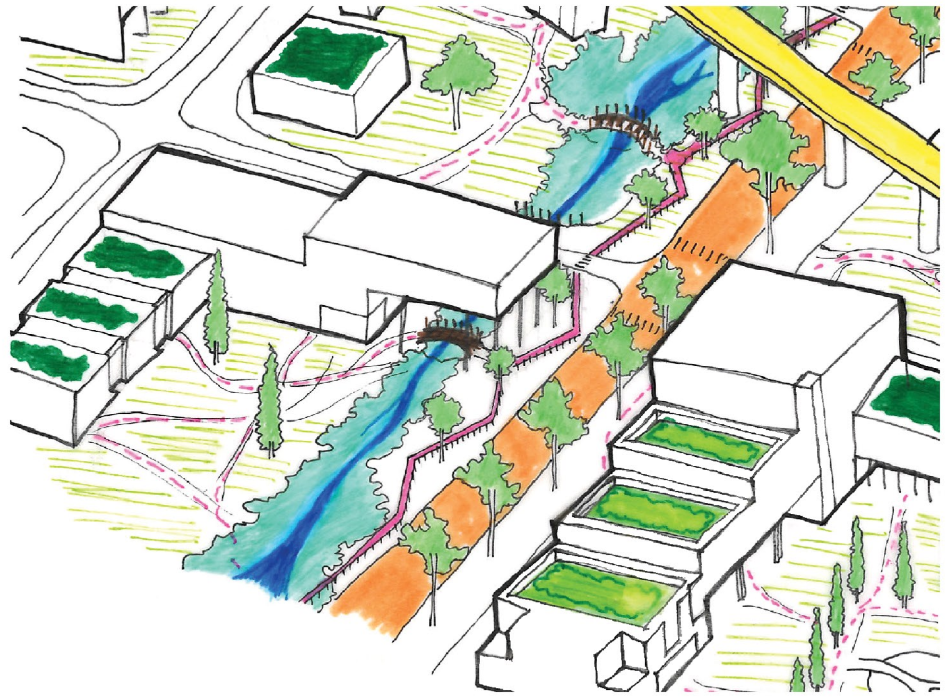
Current state

Ijburg, Amsterdam

Botlek Archipelago

Tidal character

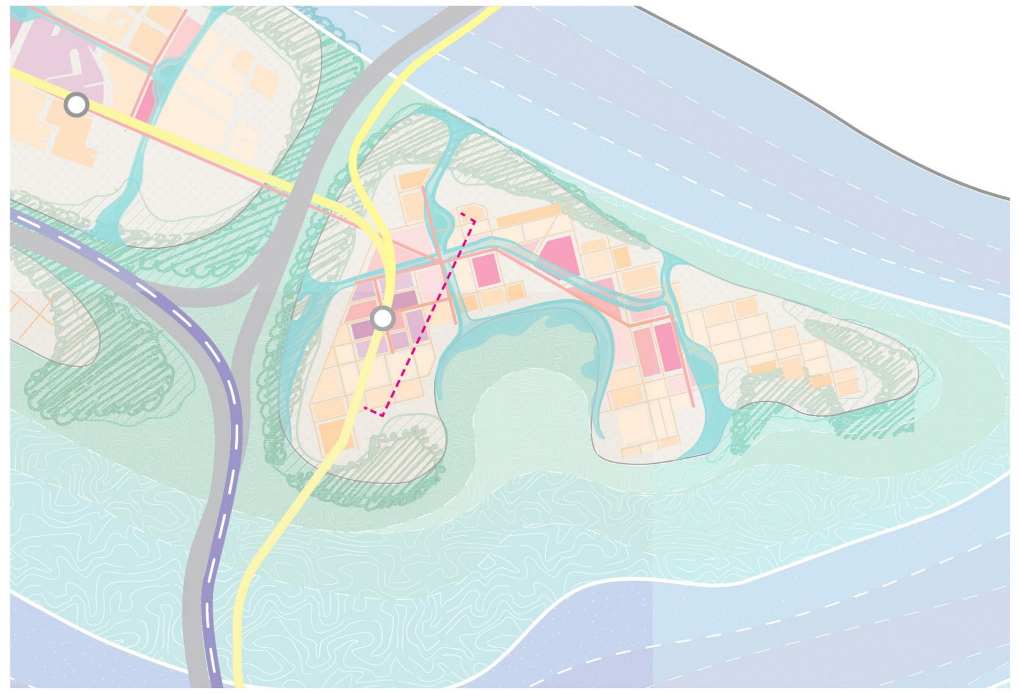




Section near transit node (Island -I)

Botlek Archipelago

Urban character



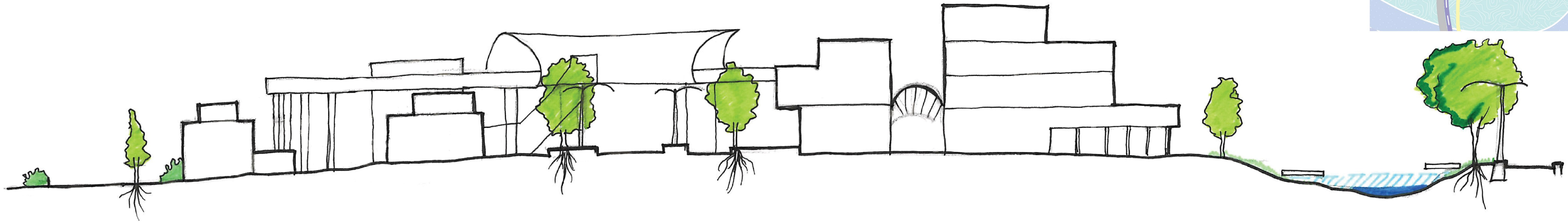
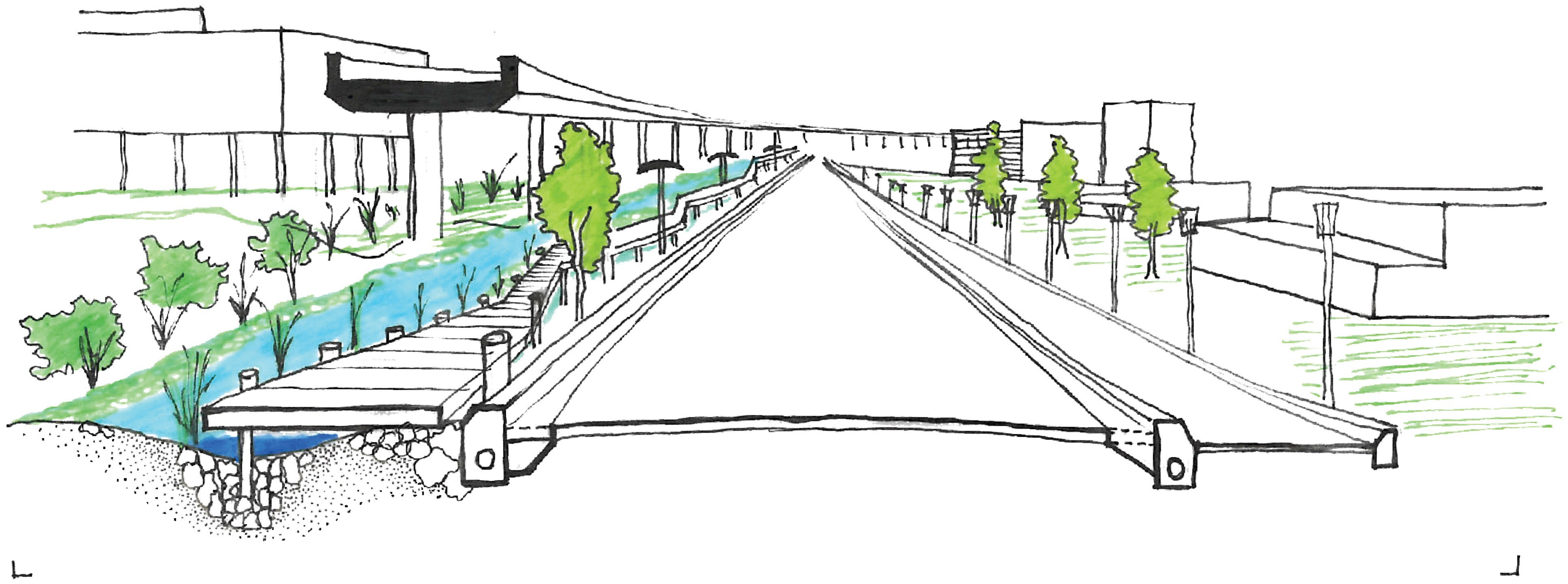


Image rendered through Gemini



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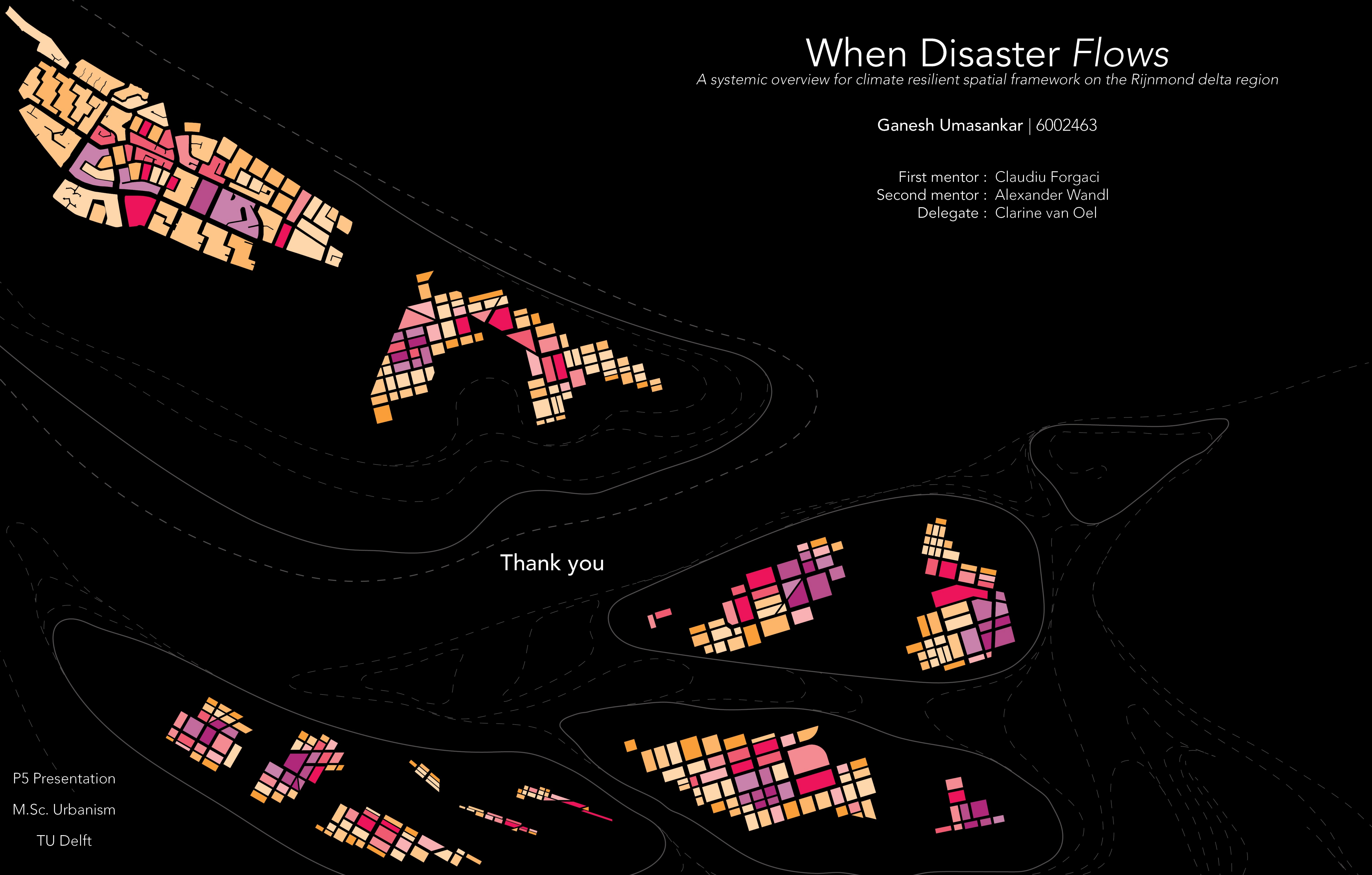

Thank you

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P5 Presentation

M.Sc. Urbanism

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