De invloed van klimaatverandering en de mens op het Noordzee systeem: Een historisch perspectief

prof. dr. ir. Mark van Koningsveld

TU Delft	**–**	**professor Ports and Waterways**
Van Oord	**–**	**program director Vox Innovation**
TS Water & Maritime	**–**	**captain of science**

Agenda

- Een aanloopje vanaf ca 1 miljoen jaar geleden
  - IJstijden en zeespiegels
- Hoe zeespiegels en rivieren Nederland vorm gegeven hebben
  - Kustlijnen en bodemopbouw
- Hoe economische factoren nu de inrichting van de Noordzee bepalen
  - Gebruiksfuncties en ruimtegebrek

- *Welkom in het Anthropoceen*

- Ter inspiratie: ‘food for thought’ vanuit recent onderzoek
  - Waar zitten we naar te kijken?
    - Systeembeelden zijn belangrijk, maar wees duidelijk over aannames

  - Wat willen we bereiken?
    - Afhankelijk van je doelen, zijn bepaalde interventies (on)geschikt

  - Hoe beïnvloeden functies elkaar?
    - Inzicht in de tradeoffs tussen functies draagt bij aan begrip tussen stakeholders

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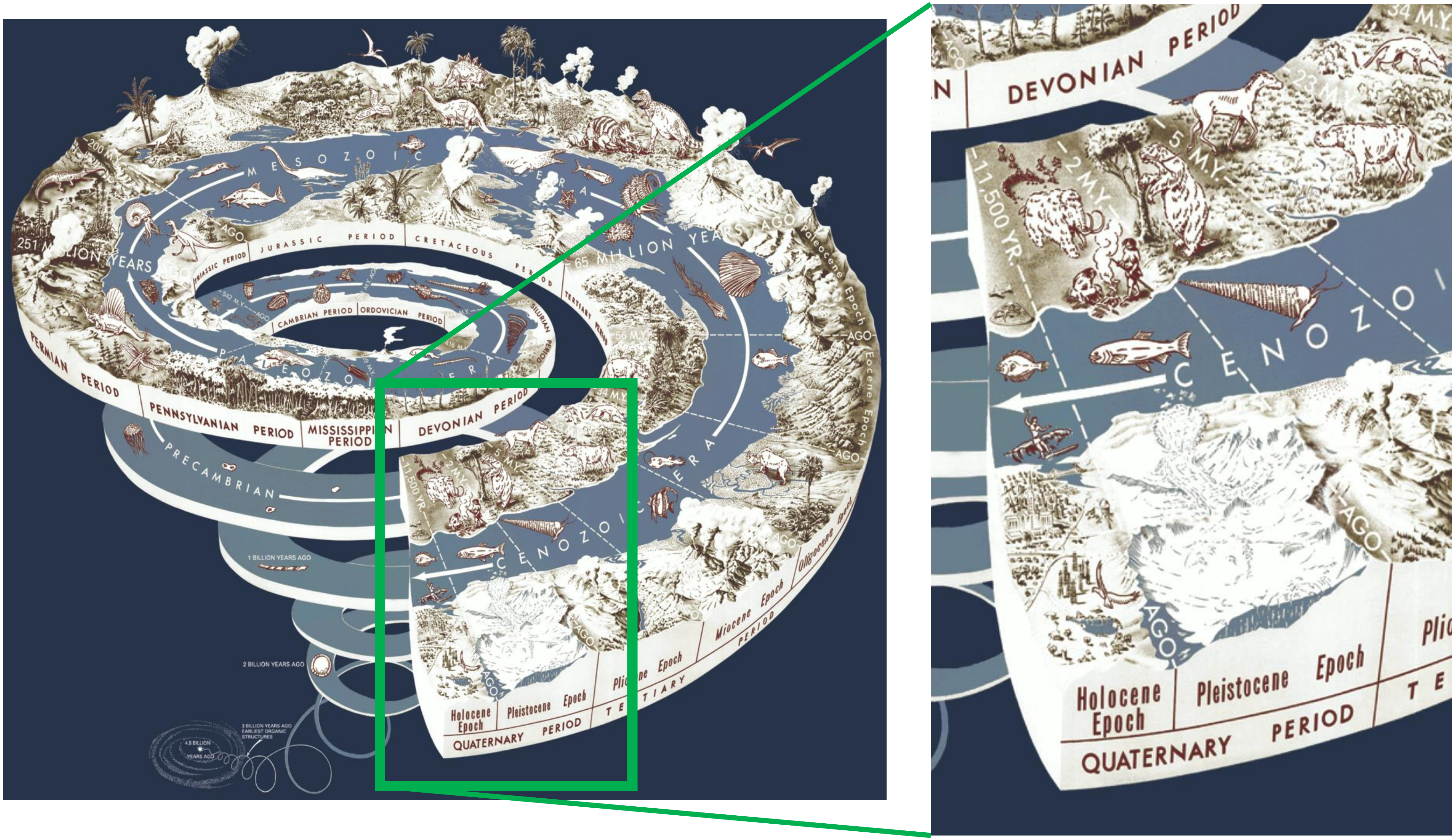
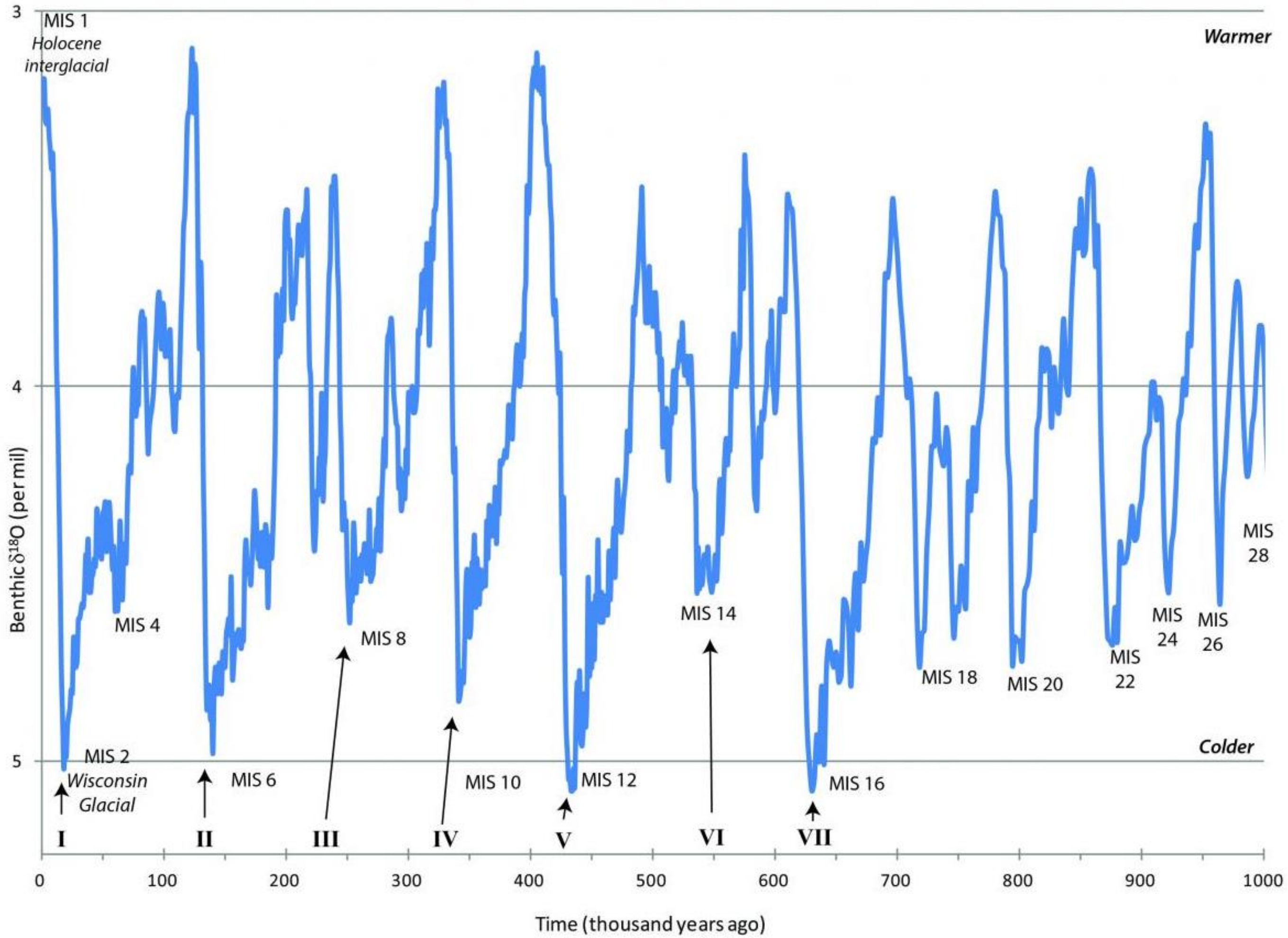


Source: “The geologic time spiral—A path to the past (ver. 1.1)” by “United States Geological Survey - Graham, Joseph, Newman, William, and Stacy, John, 2008” is licensed under CC0 and as such in the public domain (https://commons.wikimedia.org/w/index.php?curid=5597404)



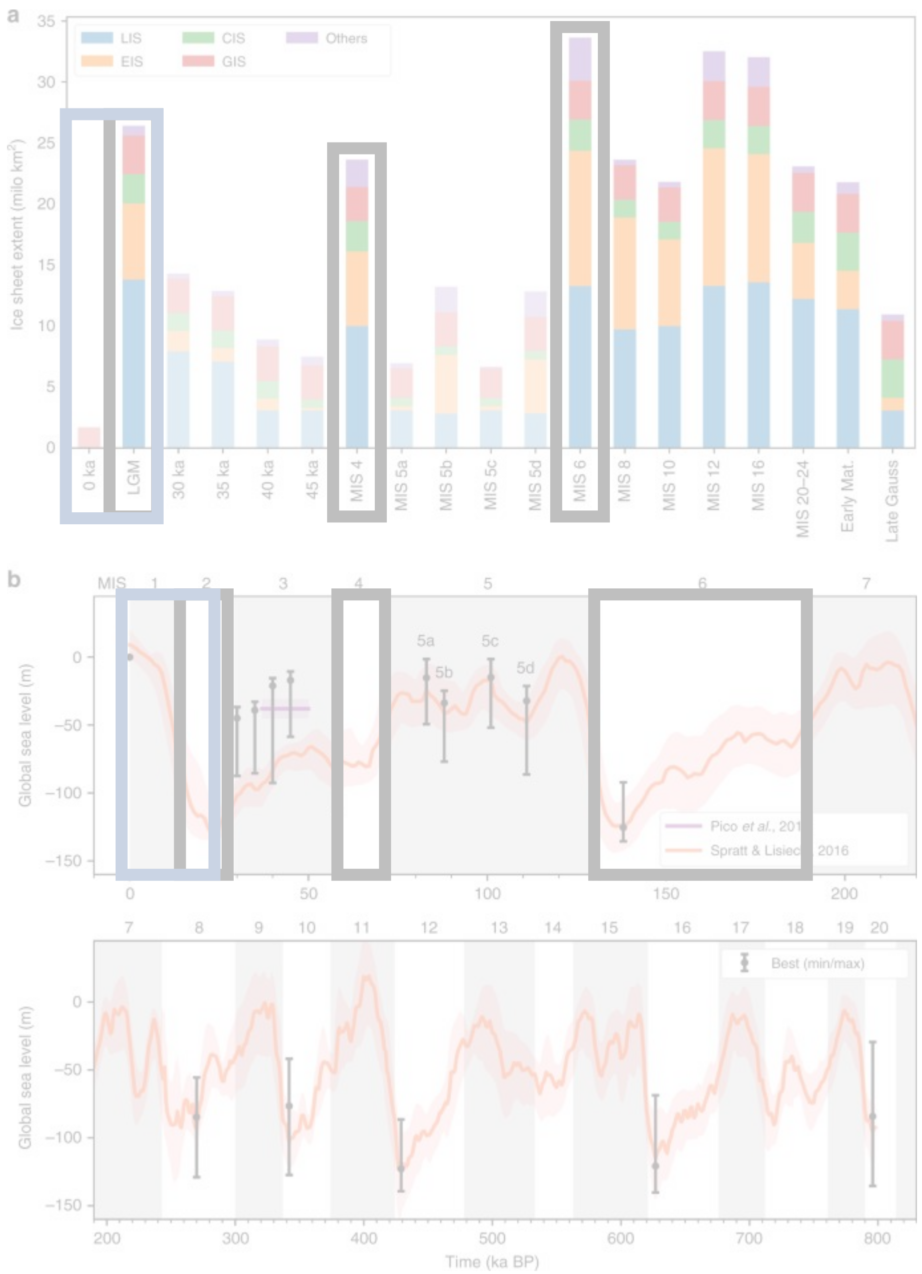
Recent work with ice cores from Greenland and Antarctica, as well as research on changes in marine isotopes, has revealed a more complex series of changes between warmer and colder global climatic conditions throughout the Quaternary.

As climates cool, greater quantities of the light oxygen isotope, $\delta^{16}O$, become concentrated in the snow precipitation that forms the continental ice sheets, resulting in ocean water that is enriched in the heavy oxygen isotope, $\delta^{18}O$. When the climate warms and the ice sheets melt, light oxygen is returned to ocean water, reducing the ratio of heavy to light oxygen.

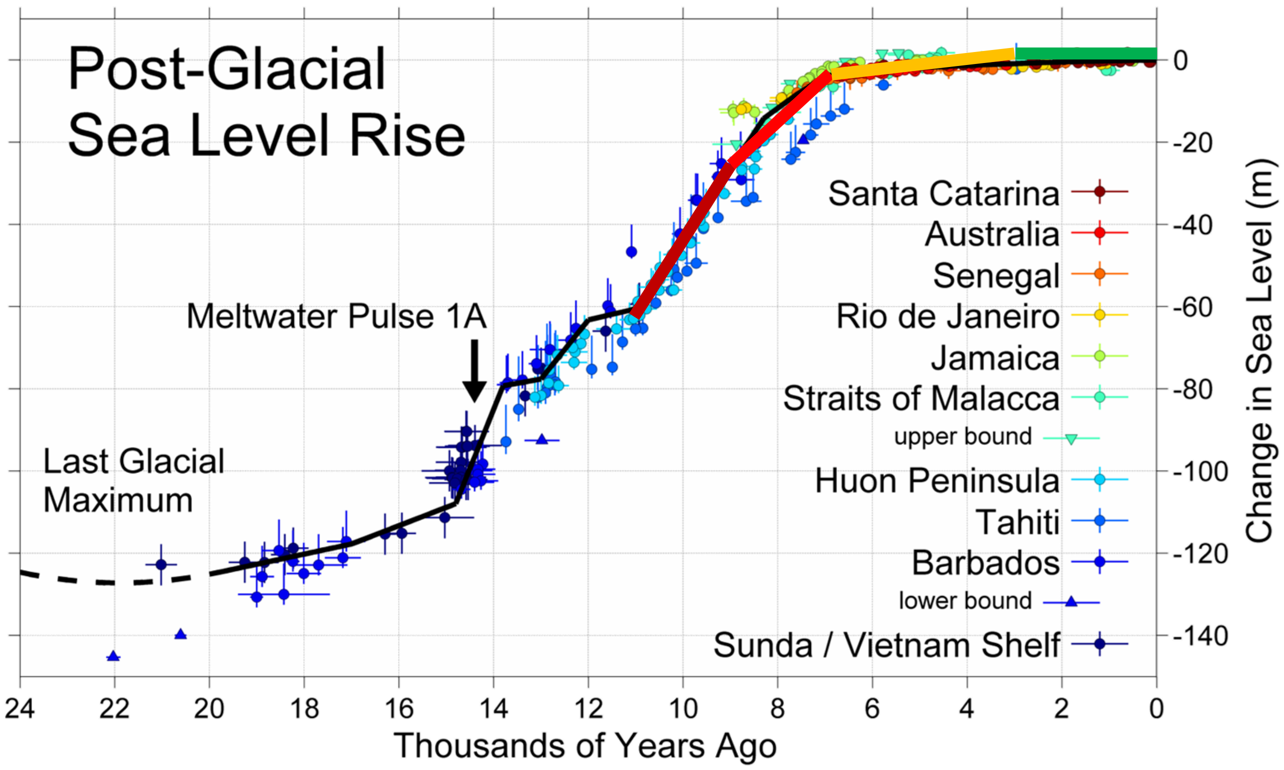
Because oxygen isotope data are used to establish these periods of warmer or colder temperature, the sequence is referred to as the **Marine Isotope Stage (MIS) timescale**, or alternatively as the Oxygen Isotope Stage (OIS) timescale.

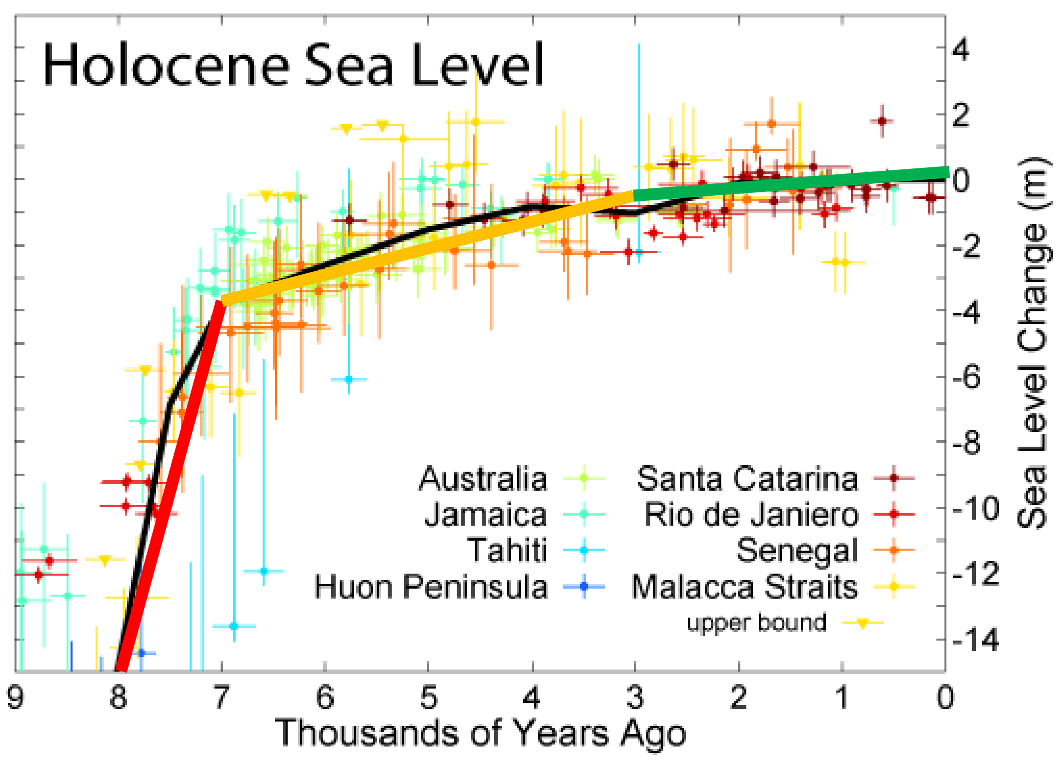
By convention, the **warmer periods are assigned odd-numbered stages**, starting with the Holocene (MIS 1), and the **colder periods are assigned even-numbered stages**, starting with the most recent glacial period (Wisconsin - MIS 2).

Source: https://iceage.museum.state.il.us/content/when-have-ice-ages-occurred

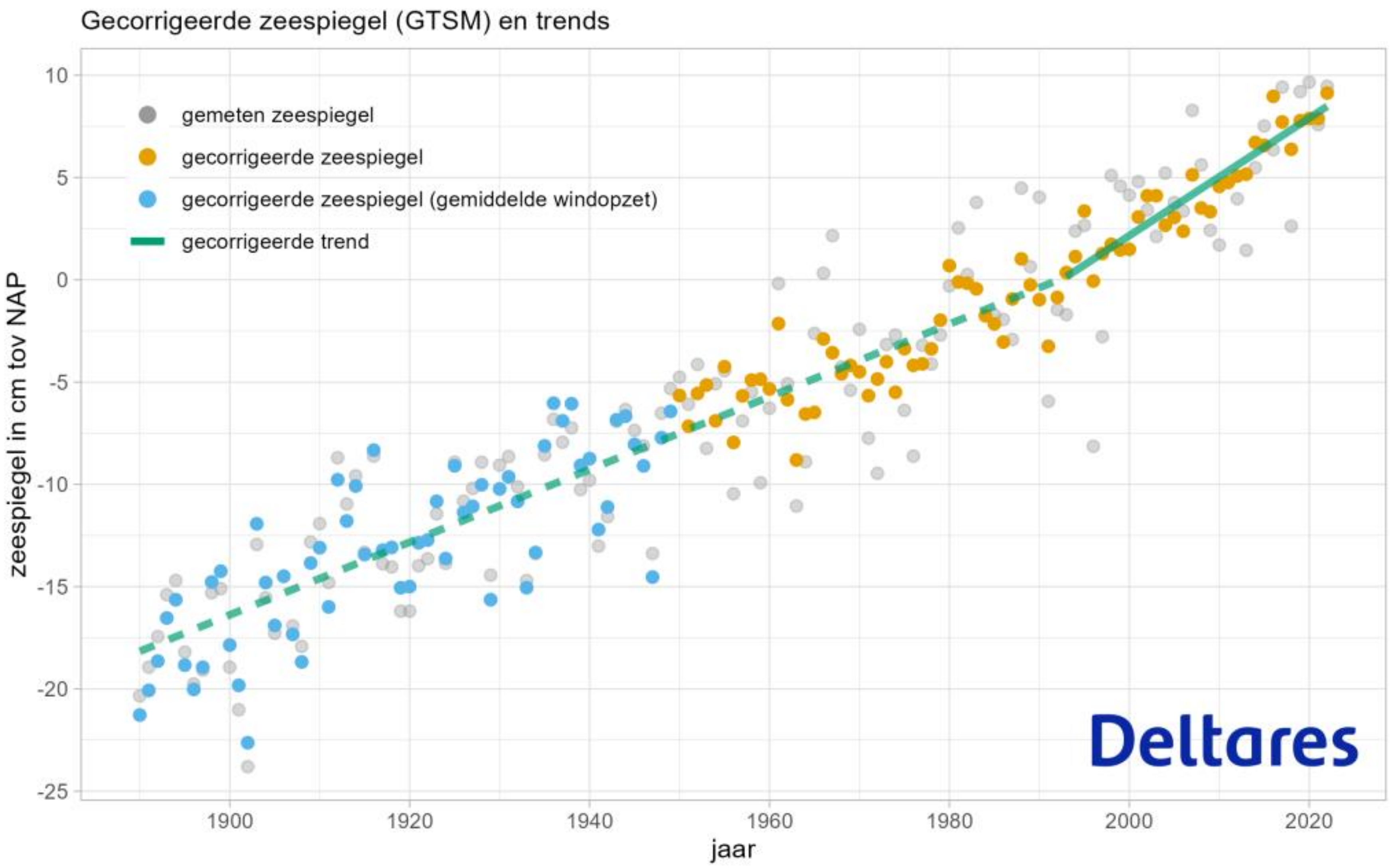


Source: Batchelor, C.L., Margold, M., Krapp, M. *et al.* The configuration of Northern Hemisphere ice sheets through the Quaternary. *Nat Commun* **10**, 3713 (2019). https://doi.org/10.1038/s41467-019-11601-2



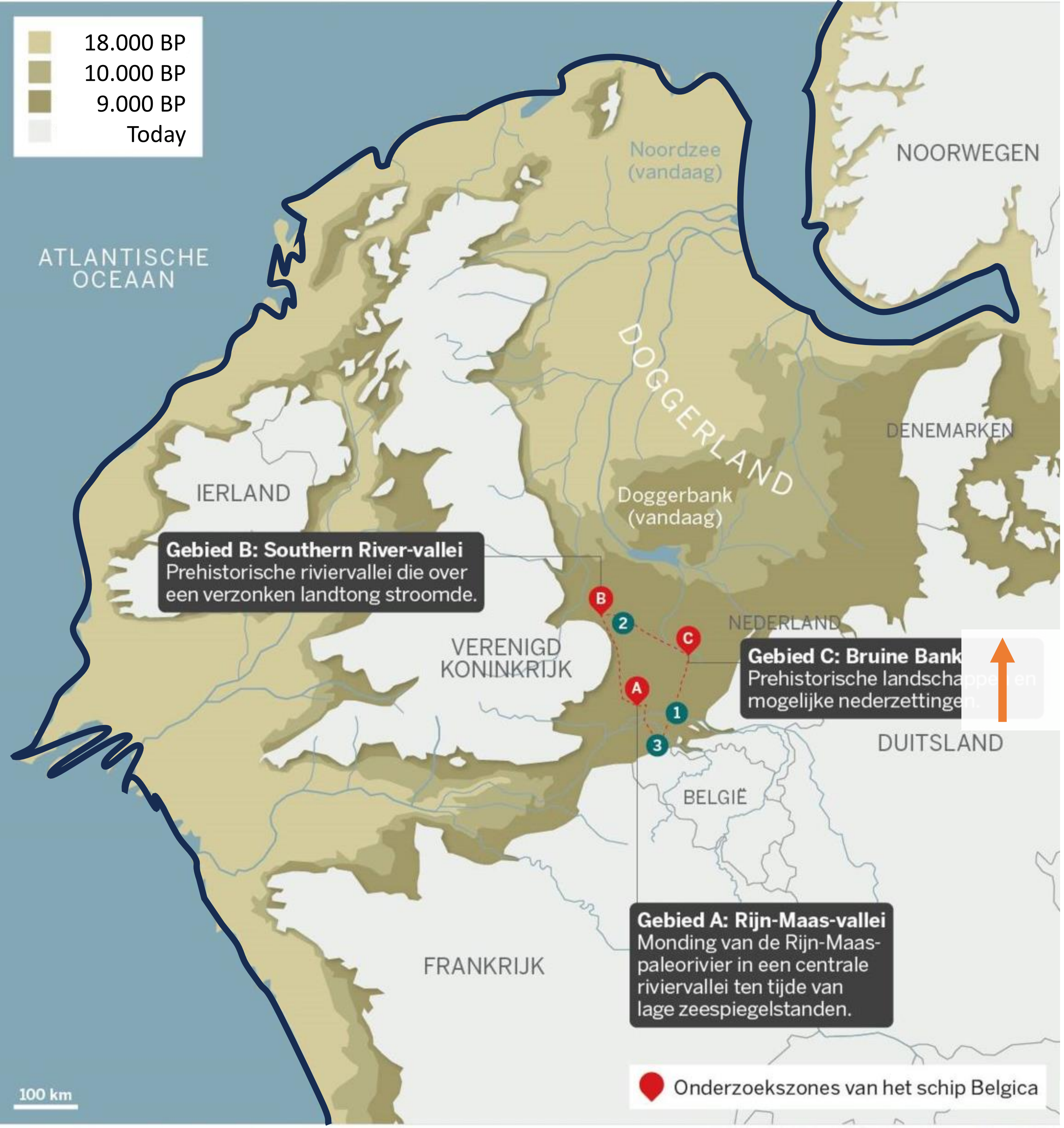


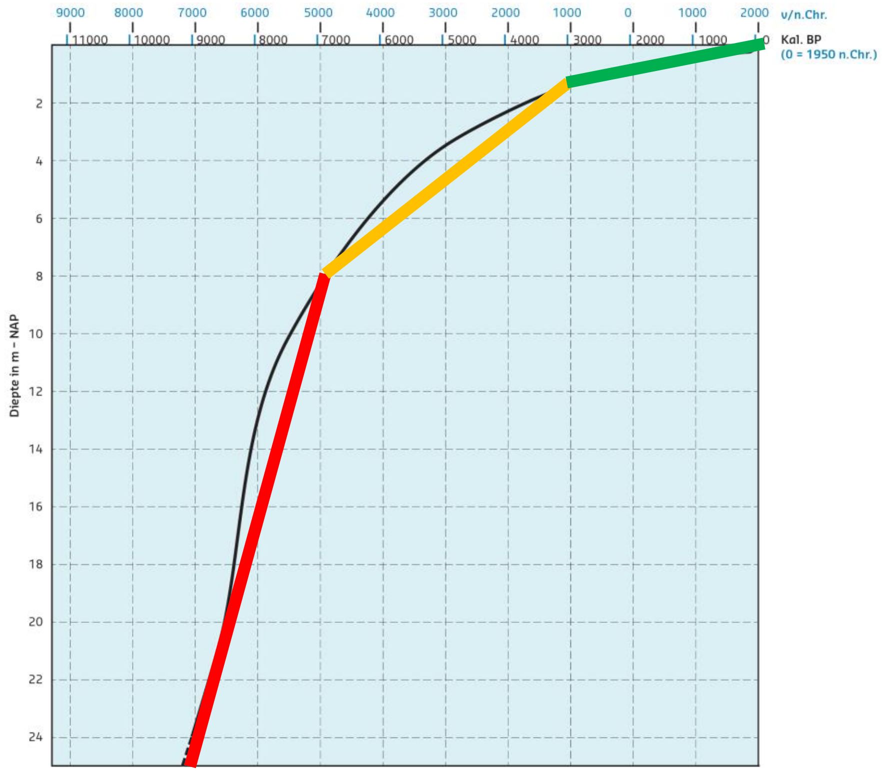
< 9000	BP	1.75 m/100y
9000 – 7000	BP	1.25 m/100y
7000 – 3000	BP	0.14 m/100y
3000 – 100	BP	0.11 m/100y



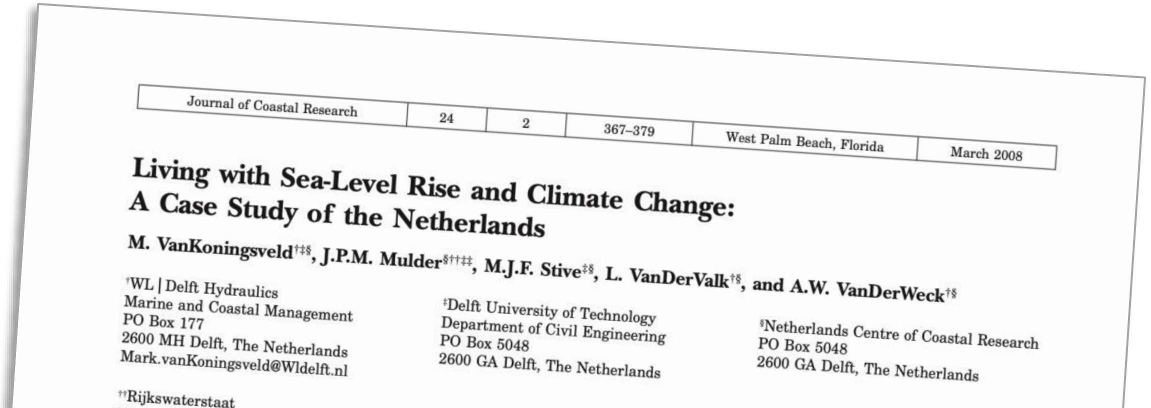
"De zeespiegel langs de Nederlandse kust kan nog steeds het best beschreven worden door **een trend van 1,8 mm/jaar tot 30 jaar geleden**, en een toename van de gemiddelde jaarlijkse **stijging naar 2,9 mm/jaar in de periode erna**."

< 9000	**BP**	**1.75 m/100y**
9000 – 7000	**BP**	**1.25 m/100y**
7000 – 3000	**BP**	**0.14 m/100y**
3000 – 100	**BP**	**0.11 m/100y**
100 – 0	**BP**	**0.18 m/100y**





18.000 yr BP



Journal of Coastal Research | 24 | 2 | 367–379 | West Palm Beach, Florida | March 2008

Living with Sea-Level Rise and Climate Change: A Case Study of the Netherlands

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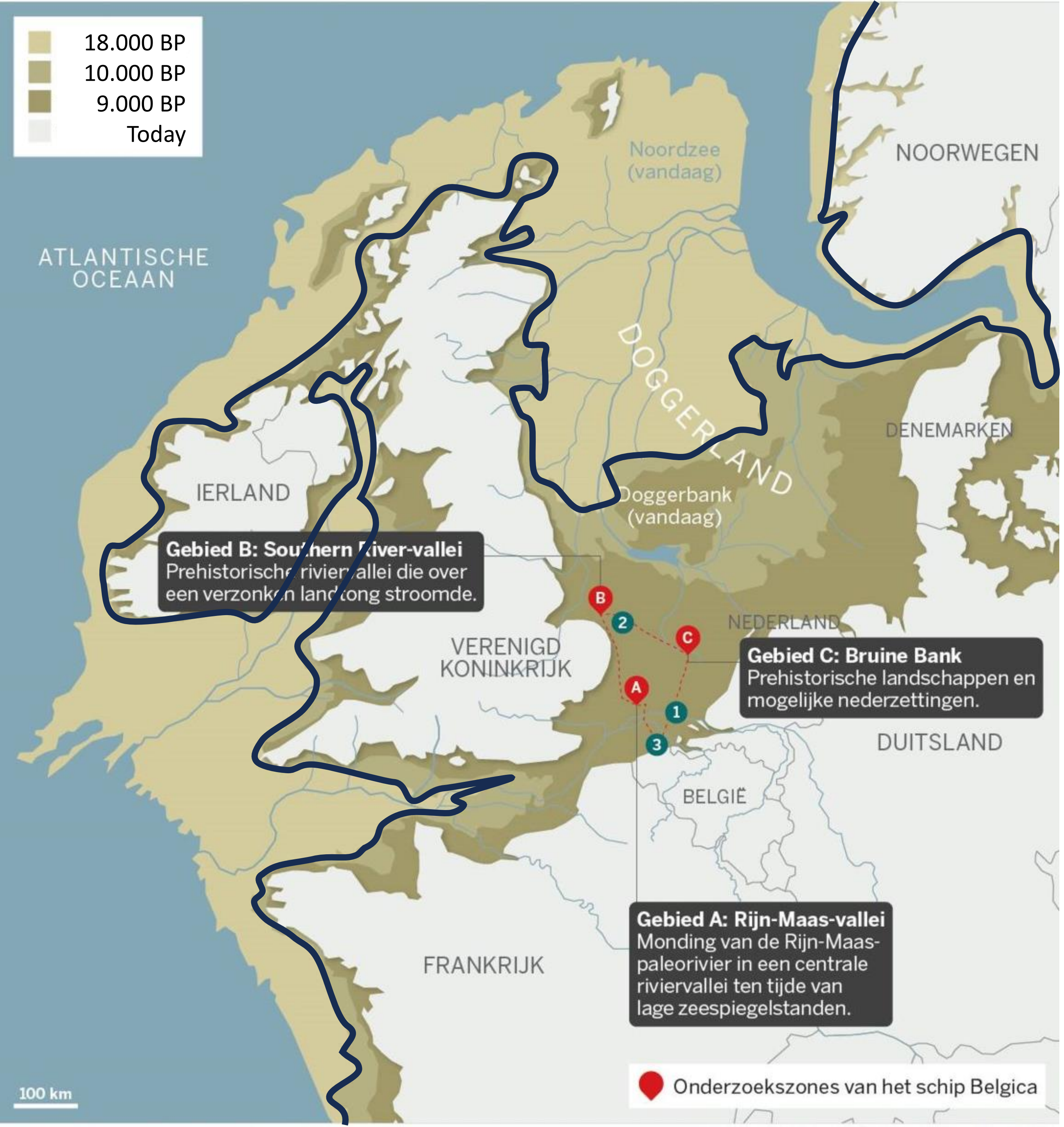
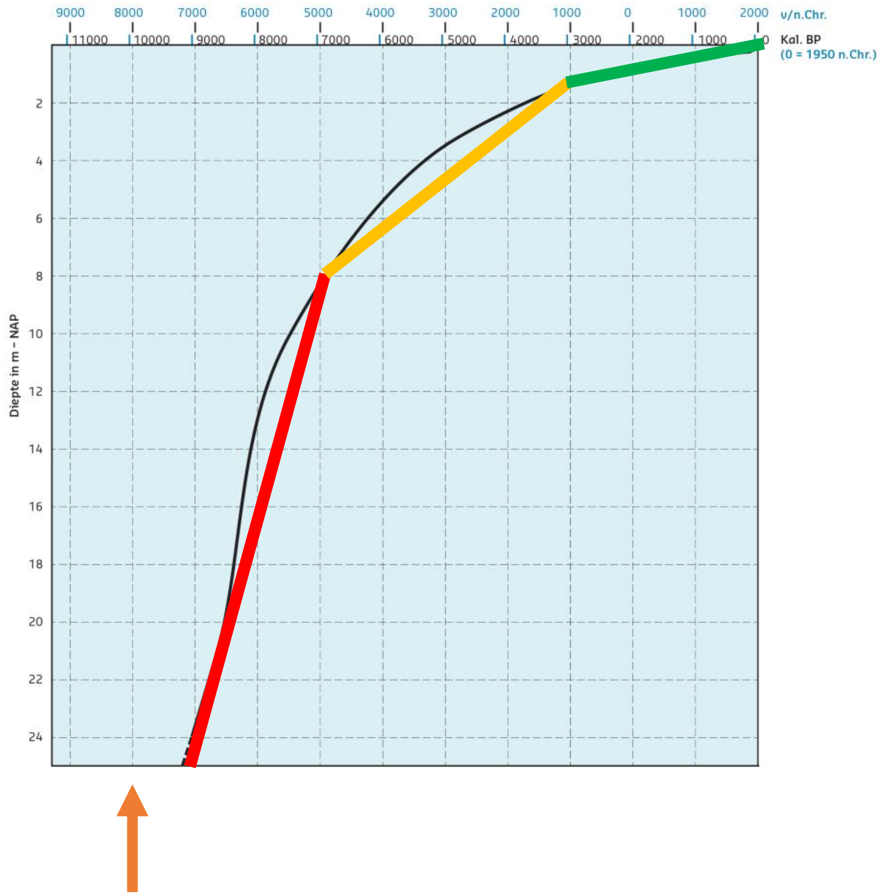
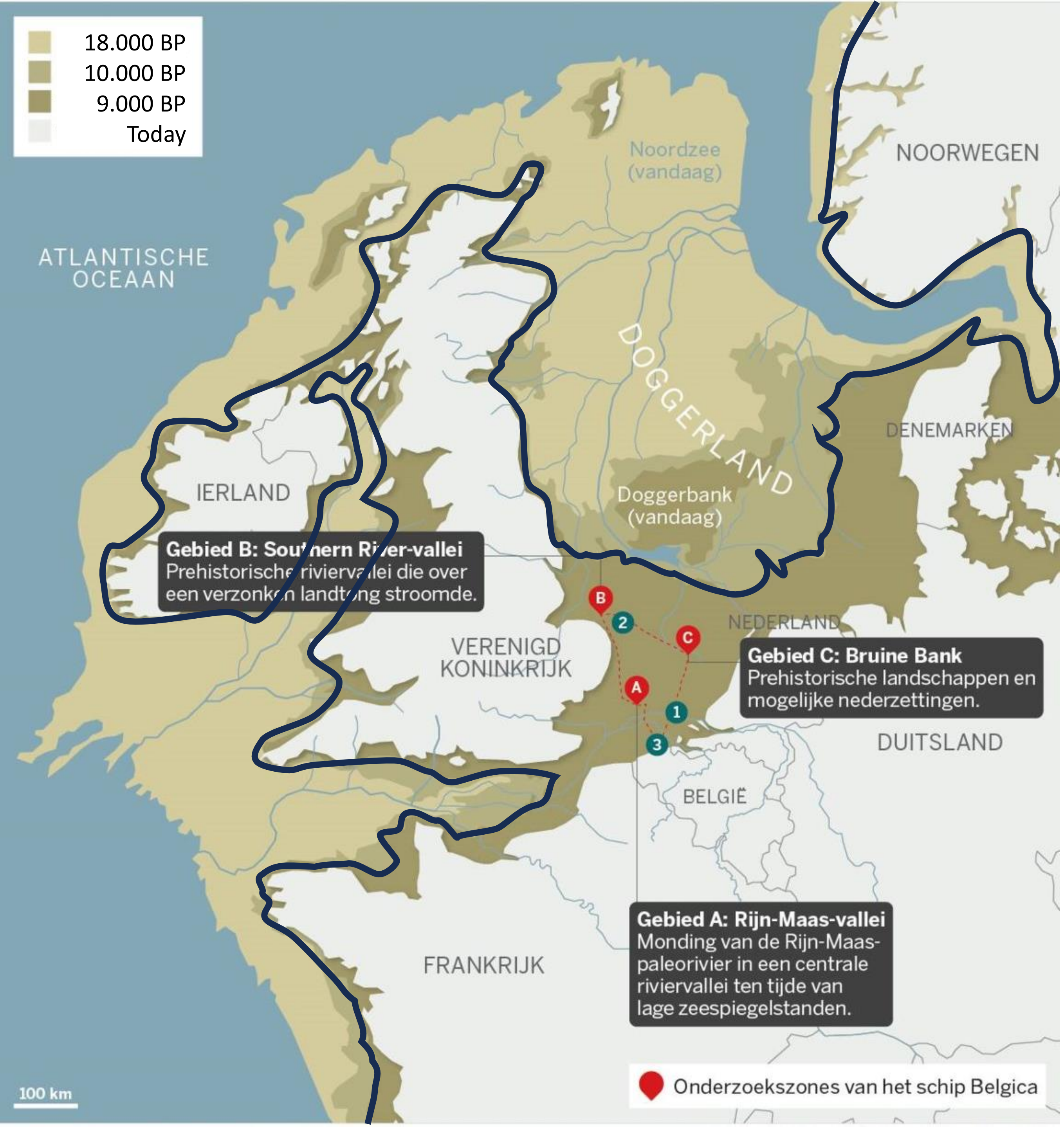
††Rijkswaterstaat

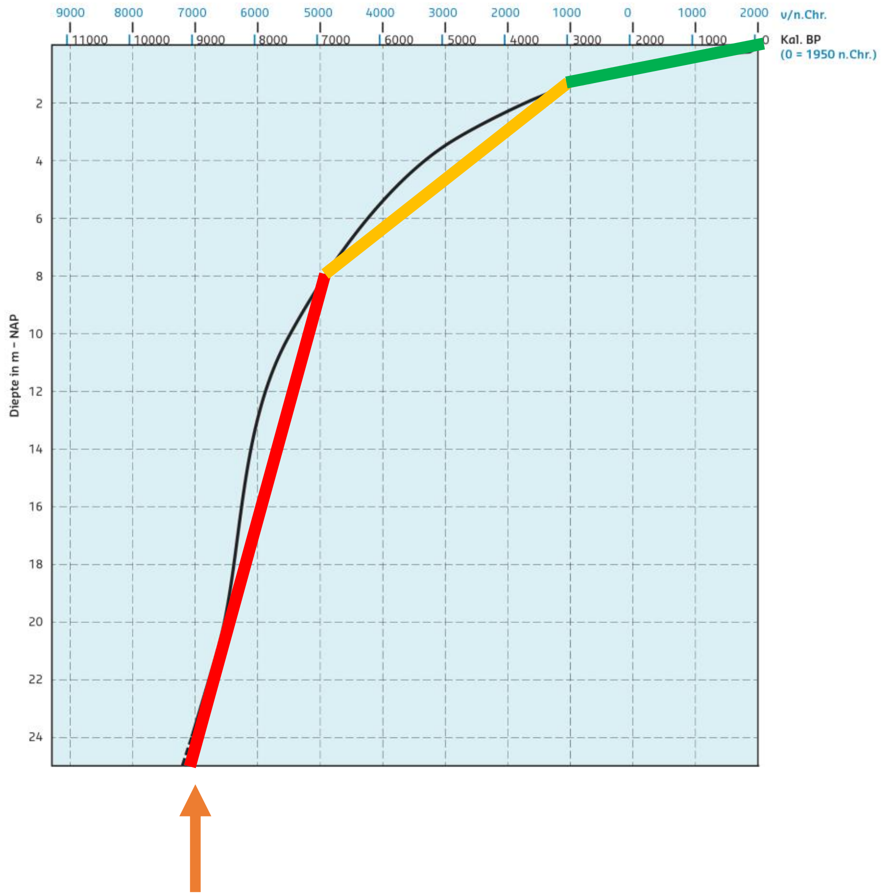




10.000 yr BP

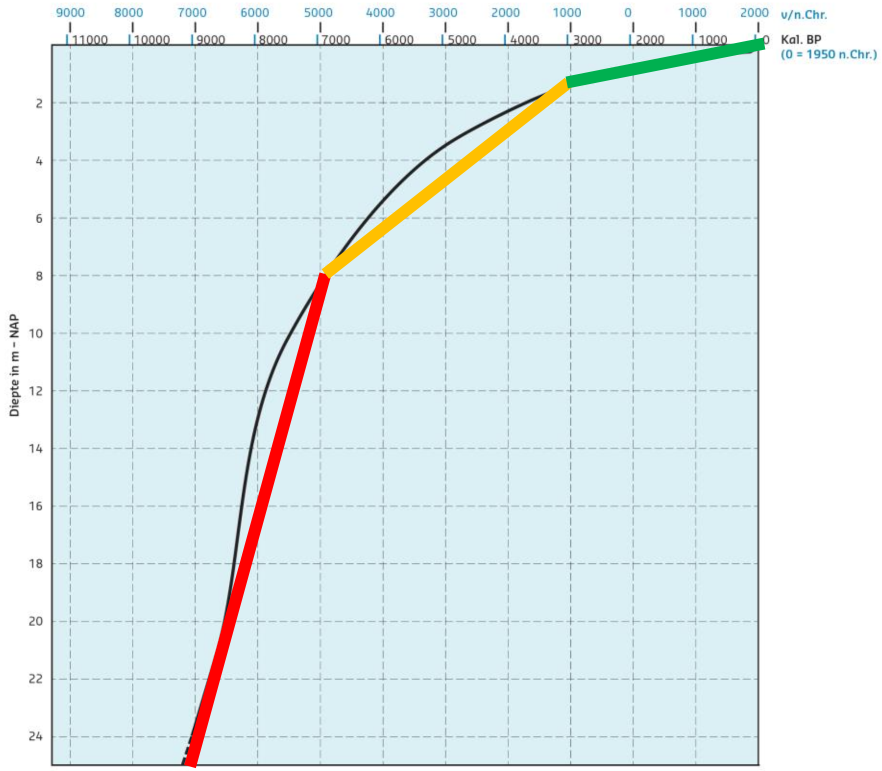
DS Infografiek | Bron: Vlaams Instituut voor de Zee (VLIZ), National Geographic





9.000 yr BP

DS Infografiek | Bron: Vlaams Instituut voor de Zee (VLIZ), National Geographic

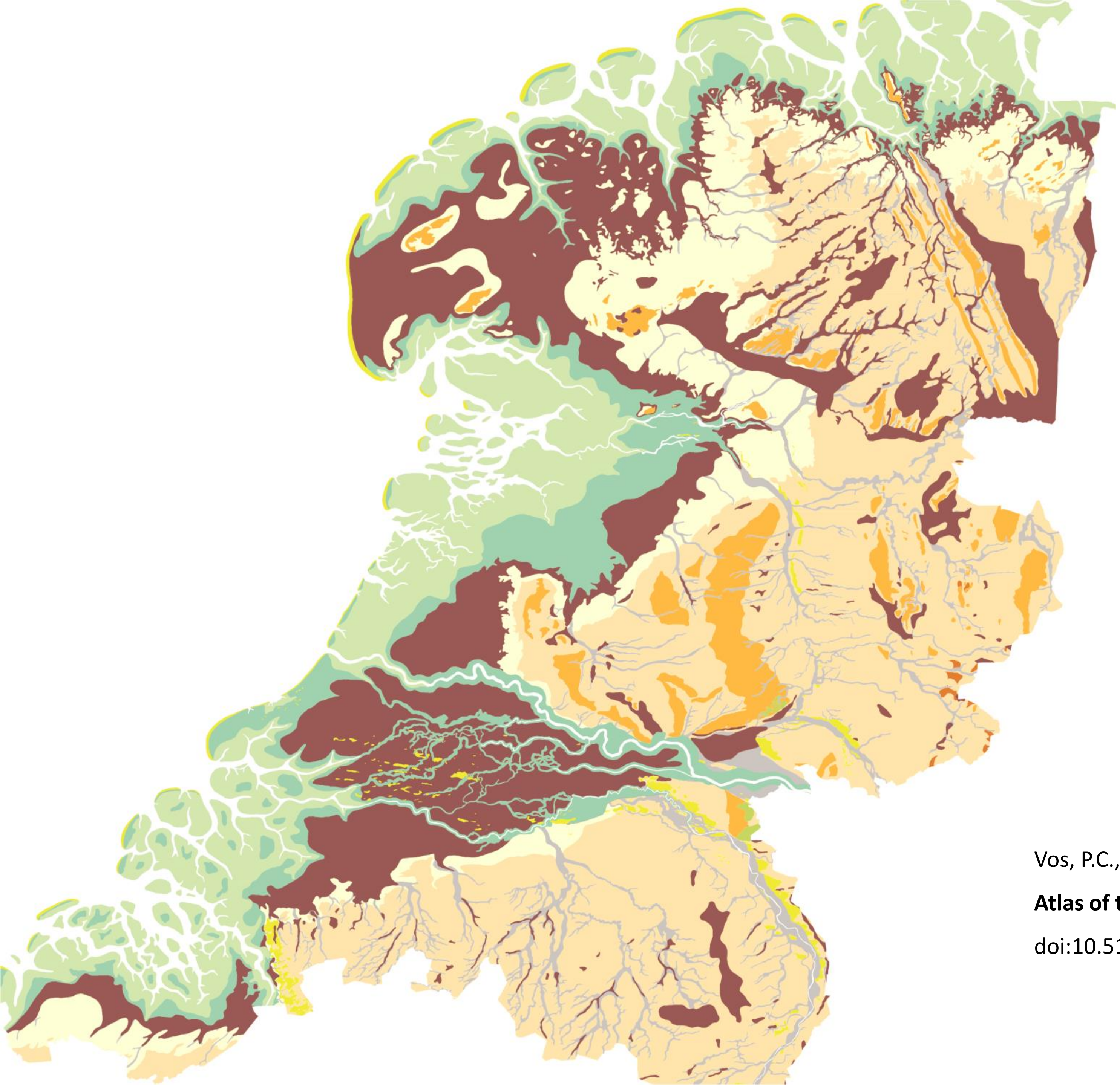


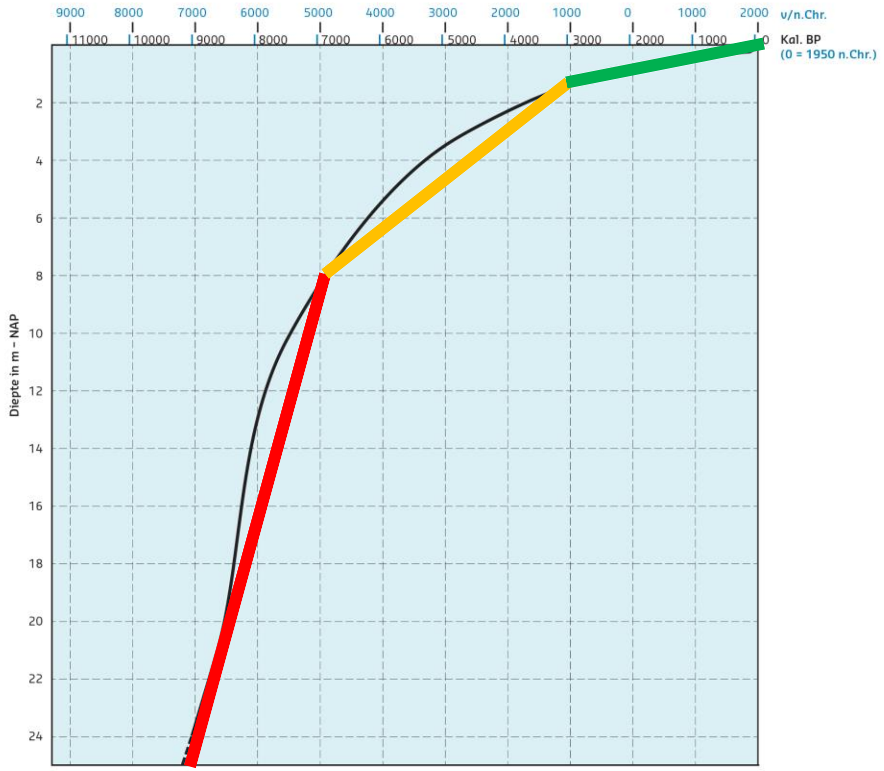
7.500 yr BP

Vos, P.C., Van der Meulen, M.J., Weerts, H.J.T. & Bazelmans, J.G.A., 2020.

Atlas of the Holocene Netherlands. Amsterdam University Press: 96 pp.

doi:10.5117/9789463724432





5.800 yr BP

Vos, P.C., Van der Meulen, M.J., Weerts, H.J.T. & Bazelmans, J.G.A., 2020.

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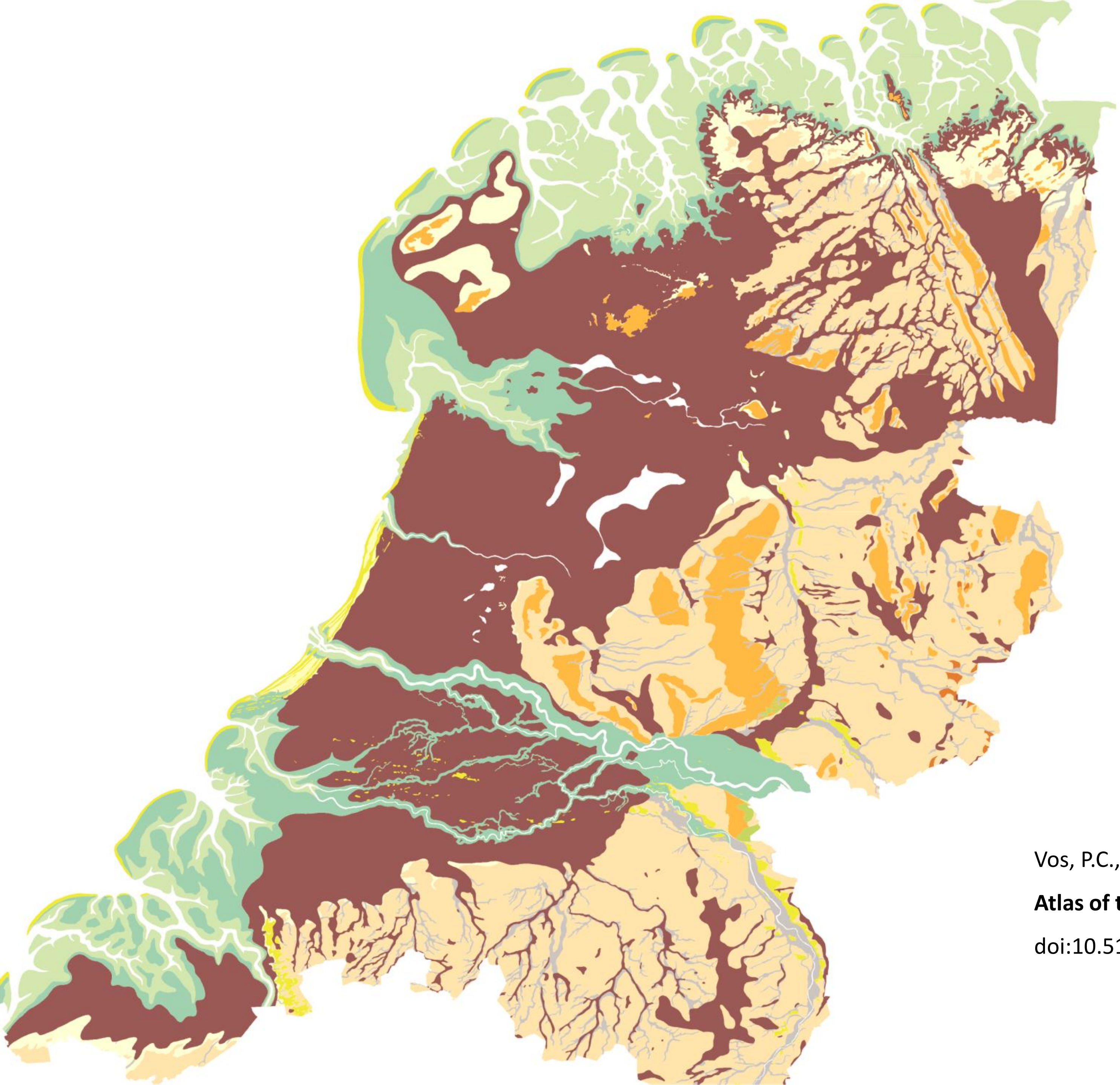

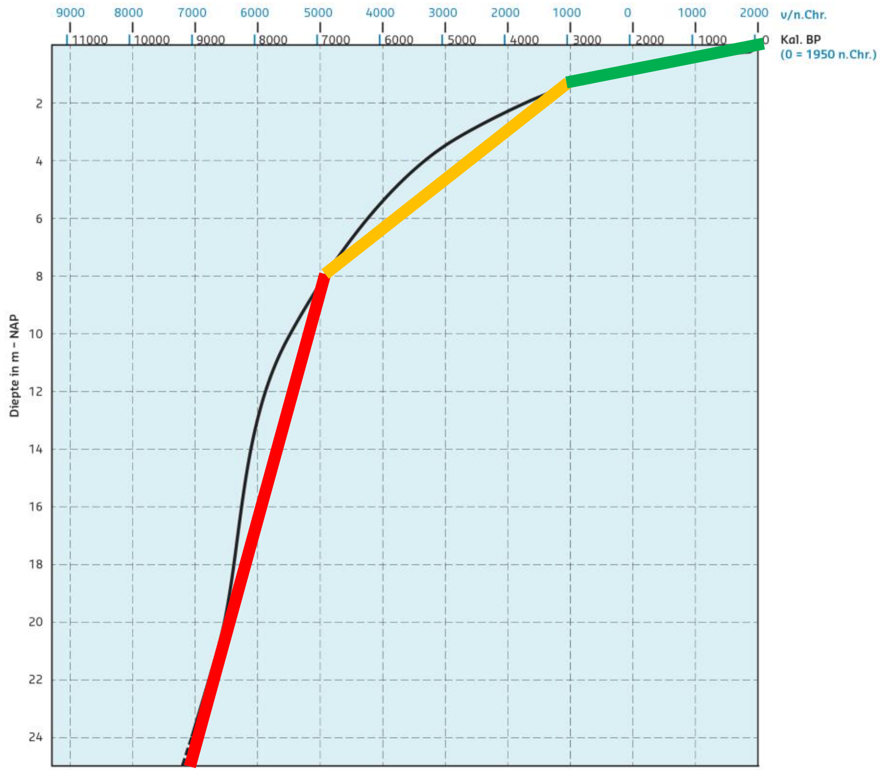

4.700 yr BP

Vos, P.C., Van der Meulen, M.J., Weerts, H.J.T. & Bazelmans, J.G.A., 2020.
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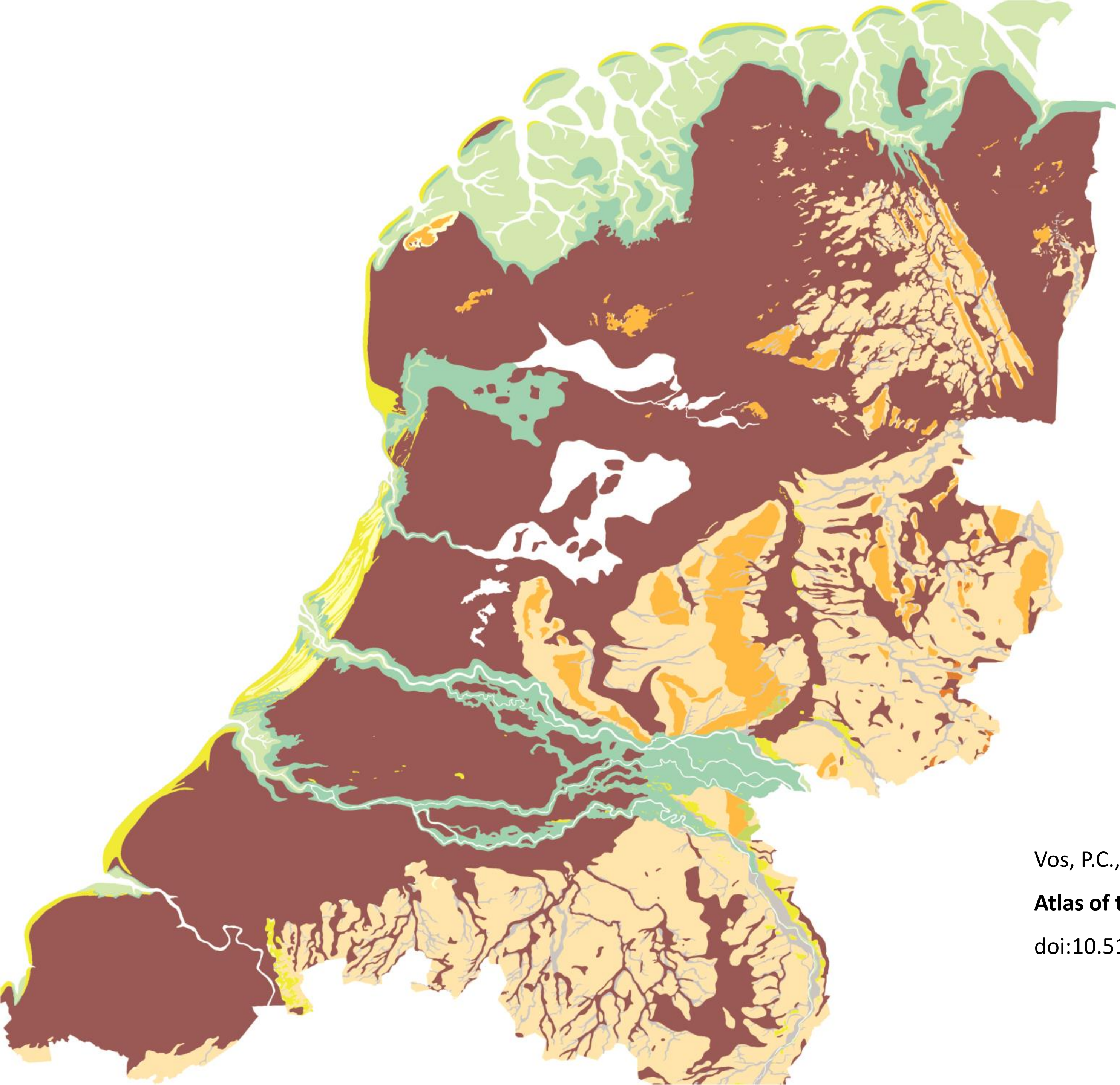

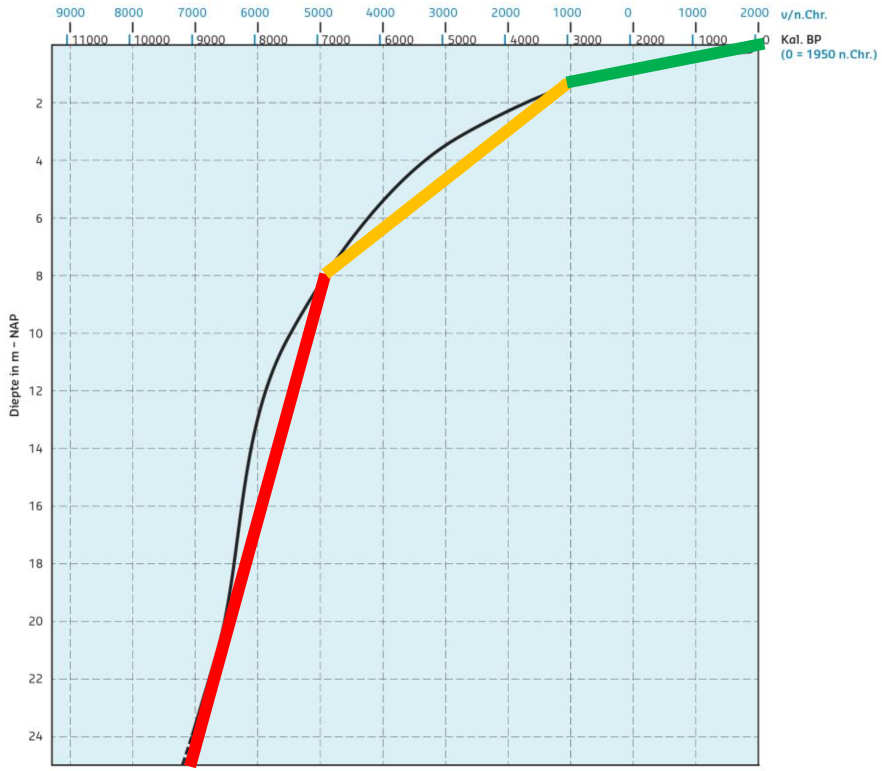

3.500 yr BP

Vos, P.C., Van der Meulen, M.J., Weerts, H.J.T. & Bazelmans, J.G.A., 2020.
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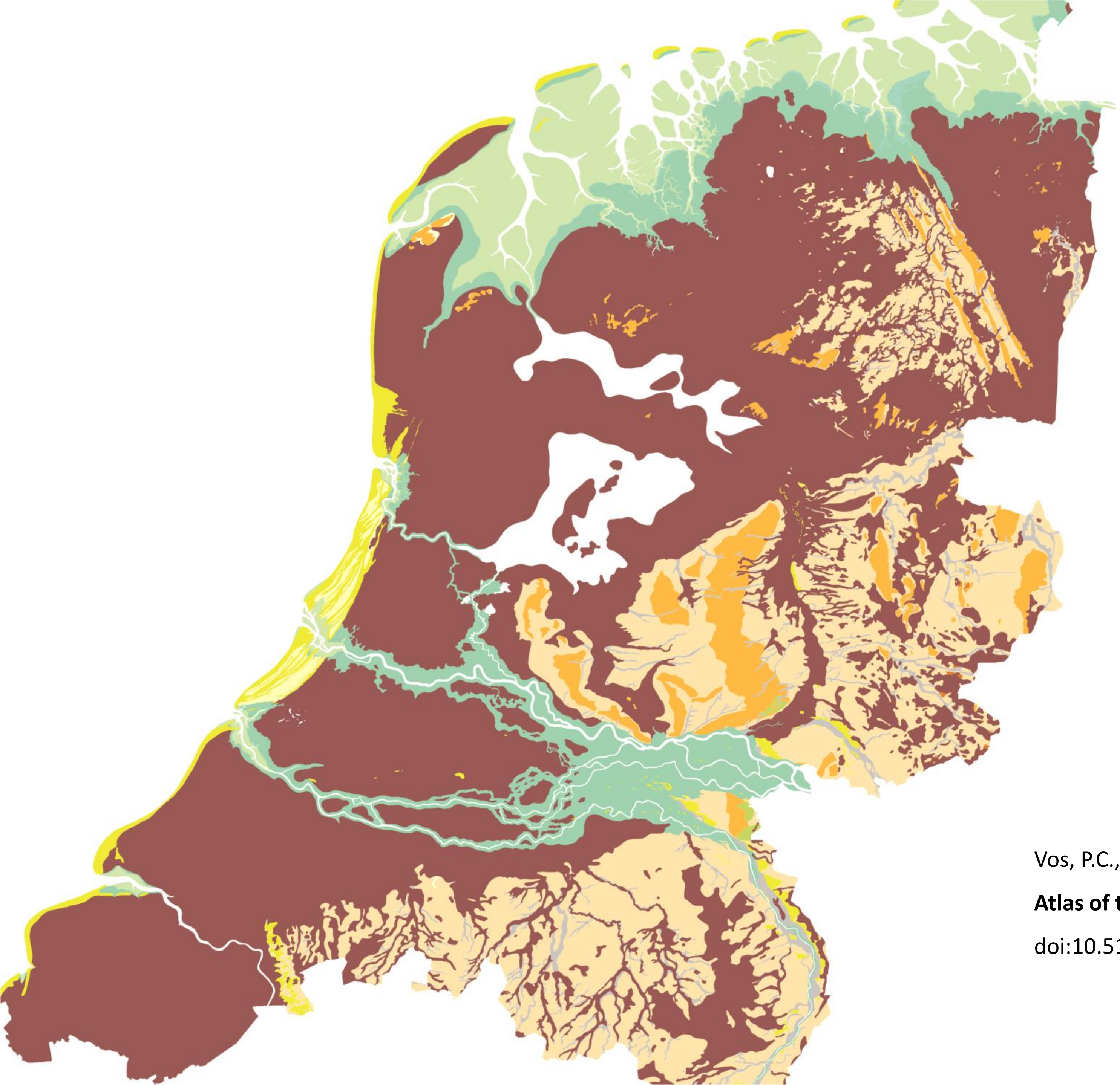

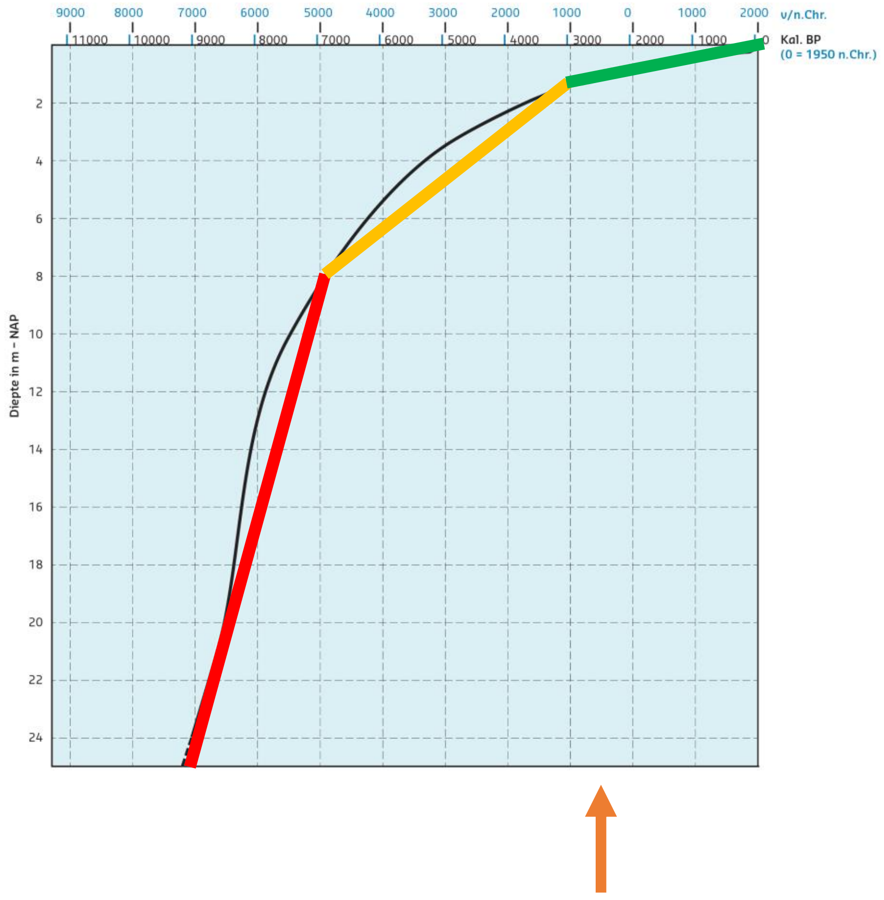

2.500 yr BP

Vos, P.C., Van der Meulen, M.J., Weerts, H.J.T. & Bazelmans, J.G.A., 2020.

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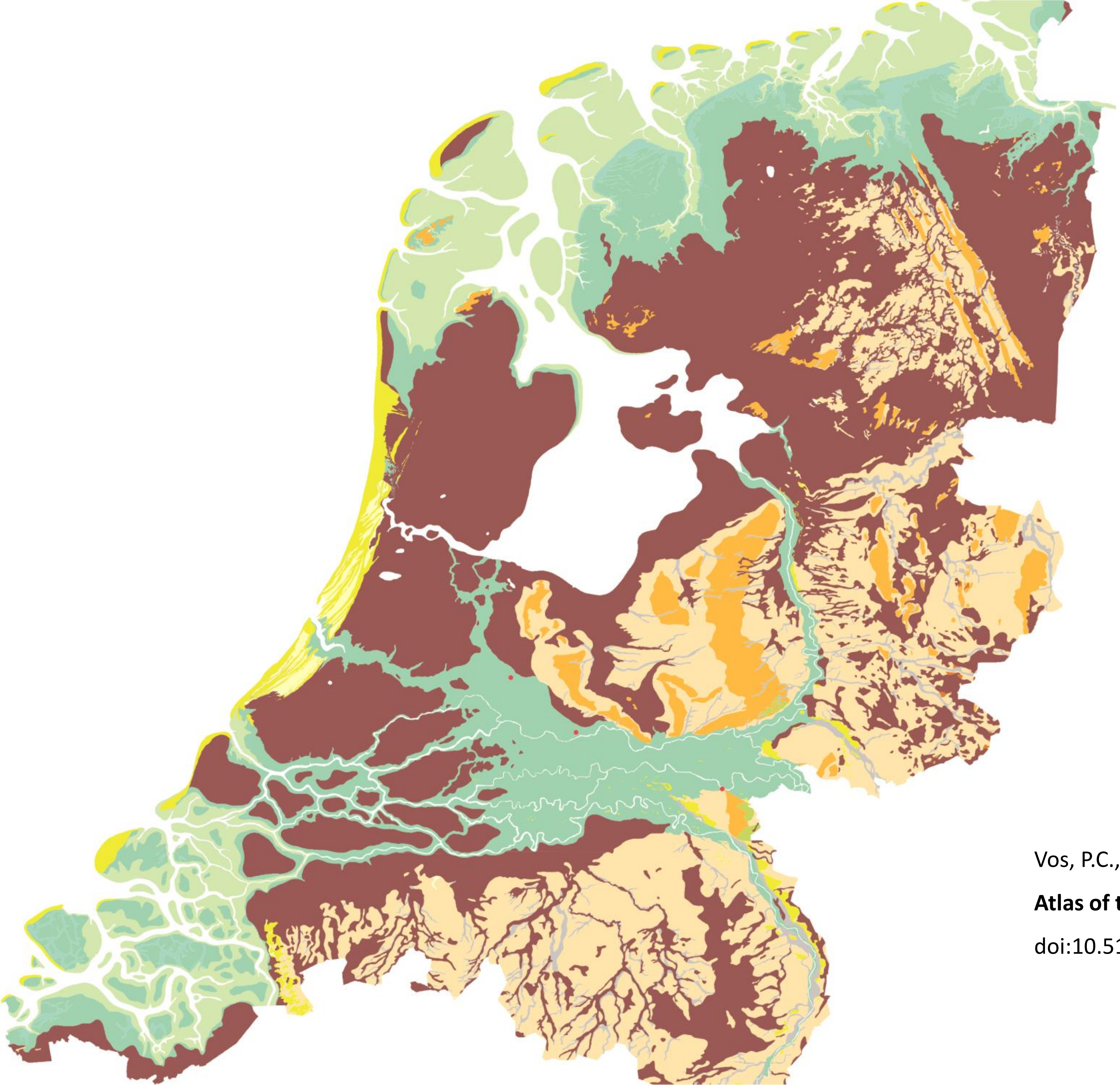

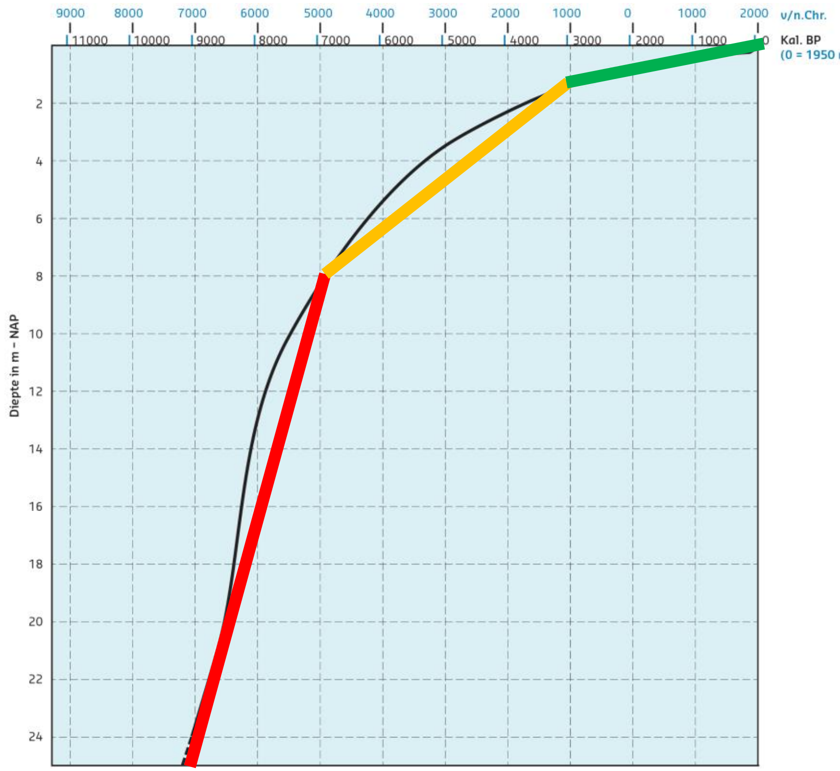

1.200 yr BP

Vos, P.C., Van der Meulen, M.J., Weerts, H.J.T. & Bazelmans, J.G.A., 2020.

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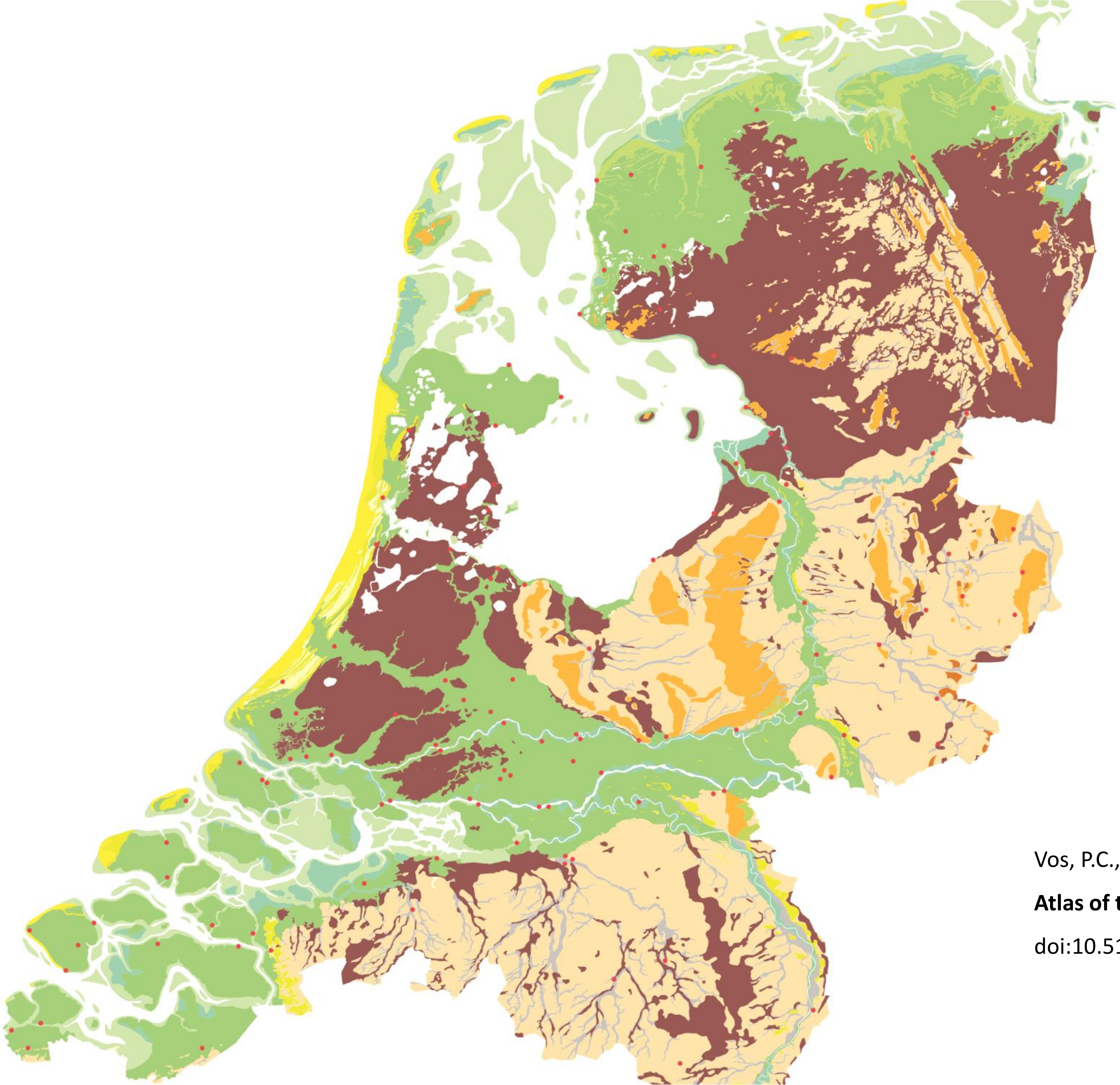

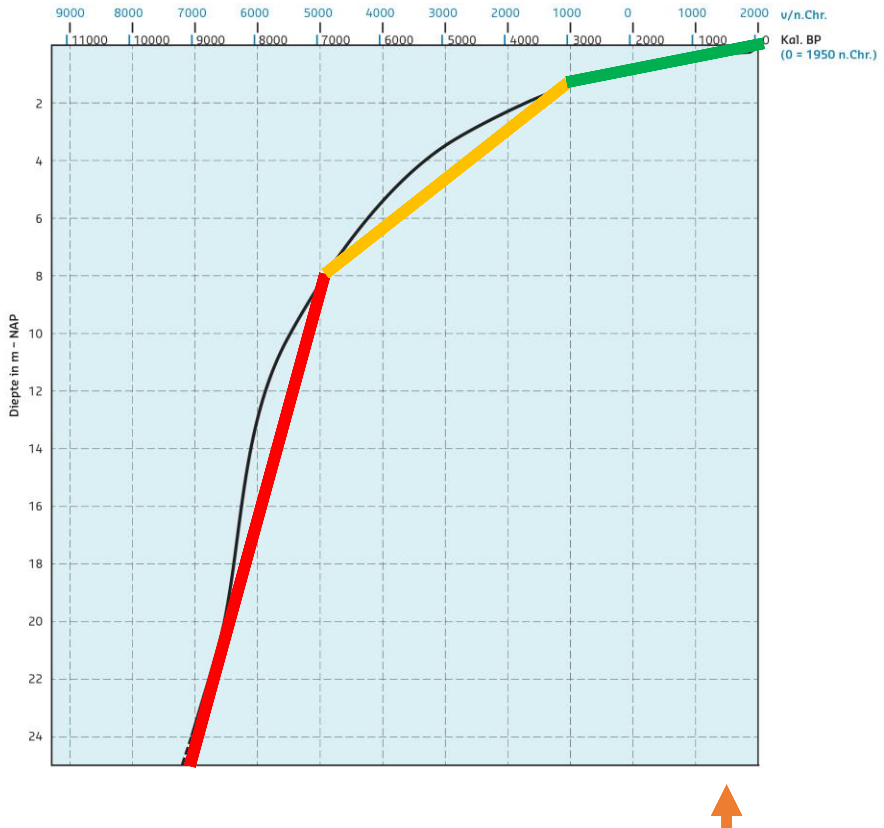

500 yr BP

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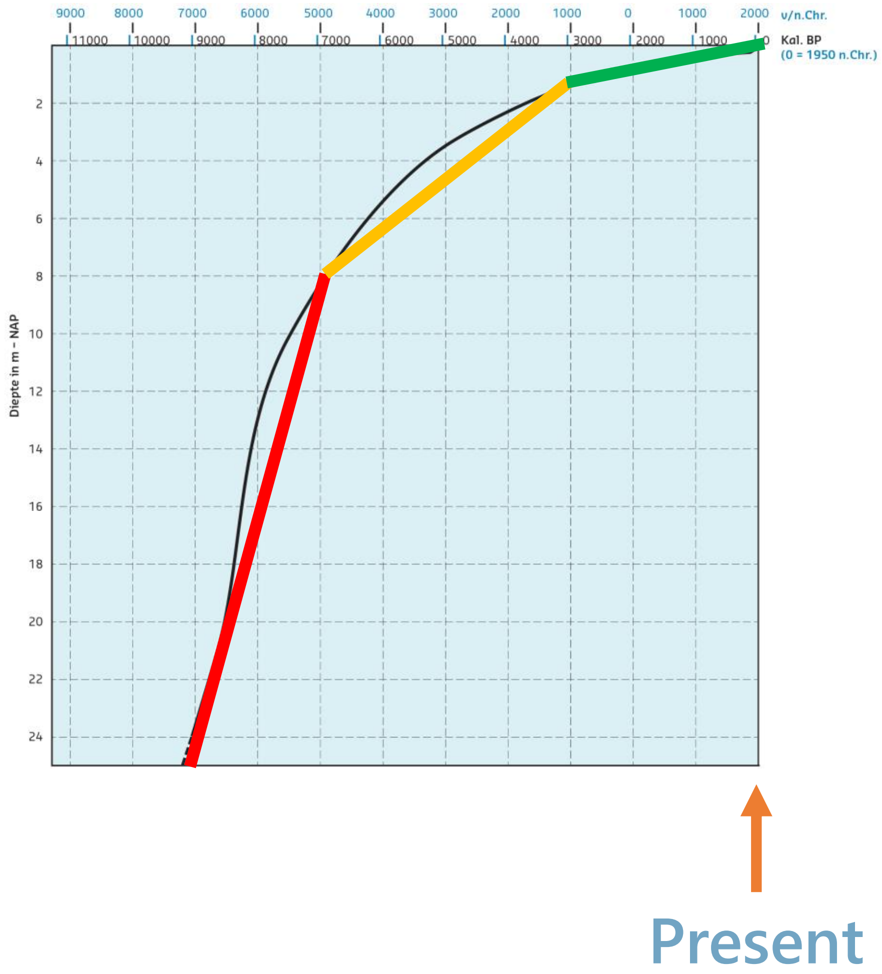

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The Hague Centre for Strategic Studies

Published in 2021

Activity		Scale[1] (2015)	Trend towards 2035
Trade and transport	Shipping lanes	3600km², 6%	slight increase
	Anchorage sites, clearways, ports	6260km², 11%	
Energy	Gas and oil platforms	161, 126km², 0.2%	sharp decrease
	Gas and oil pipelines (incl. 500m zones)	4500km², 8%	slight decrease
	Wind farms	5 parks 471 km², 0.8%	sharp increase
	Other renewables	0%	slight increase
	High voltage cables (incl. 500m zones)	<1%	sharp increase
	Carbon capture storage	0%	slight increase
Communication	Telecom cables (incl. 750m zones)	20 (active) cables, 2000km; 7%	slight increase
Industry at sea	Sand drenching	25 million m³	slight increase
Traditional fishing		EEZ except for prohibited areas	sharp decrease
Aquaculture			slight increase
Living and recreational use			approx. the same
Conservation zones		6 zones 11.020km², 19%	slight increase
Defense zones		5 zones, 4200 km², 7%	approx. the same

Spatial use of the Dutch part of the North Sea in 2015

Percentage of the Dutch continental shelf

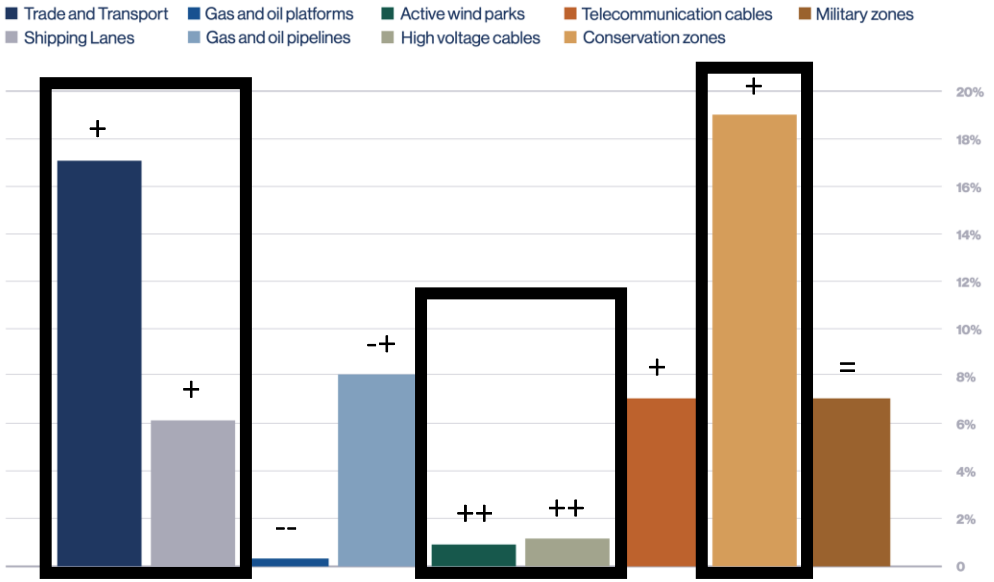


Figure 1. Spatial use of the Dutch part of the North Sea in 2015

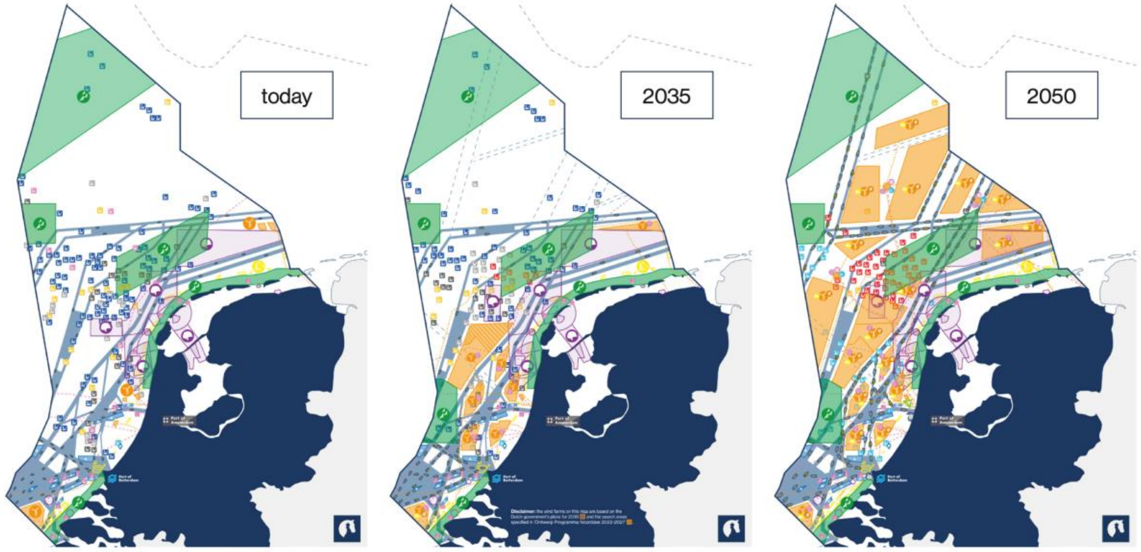
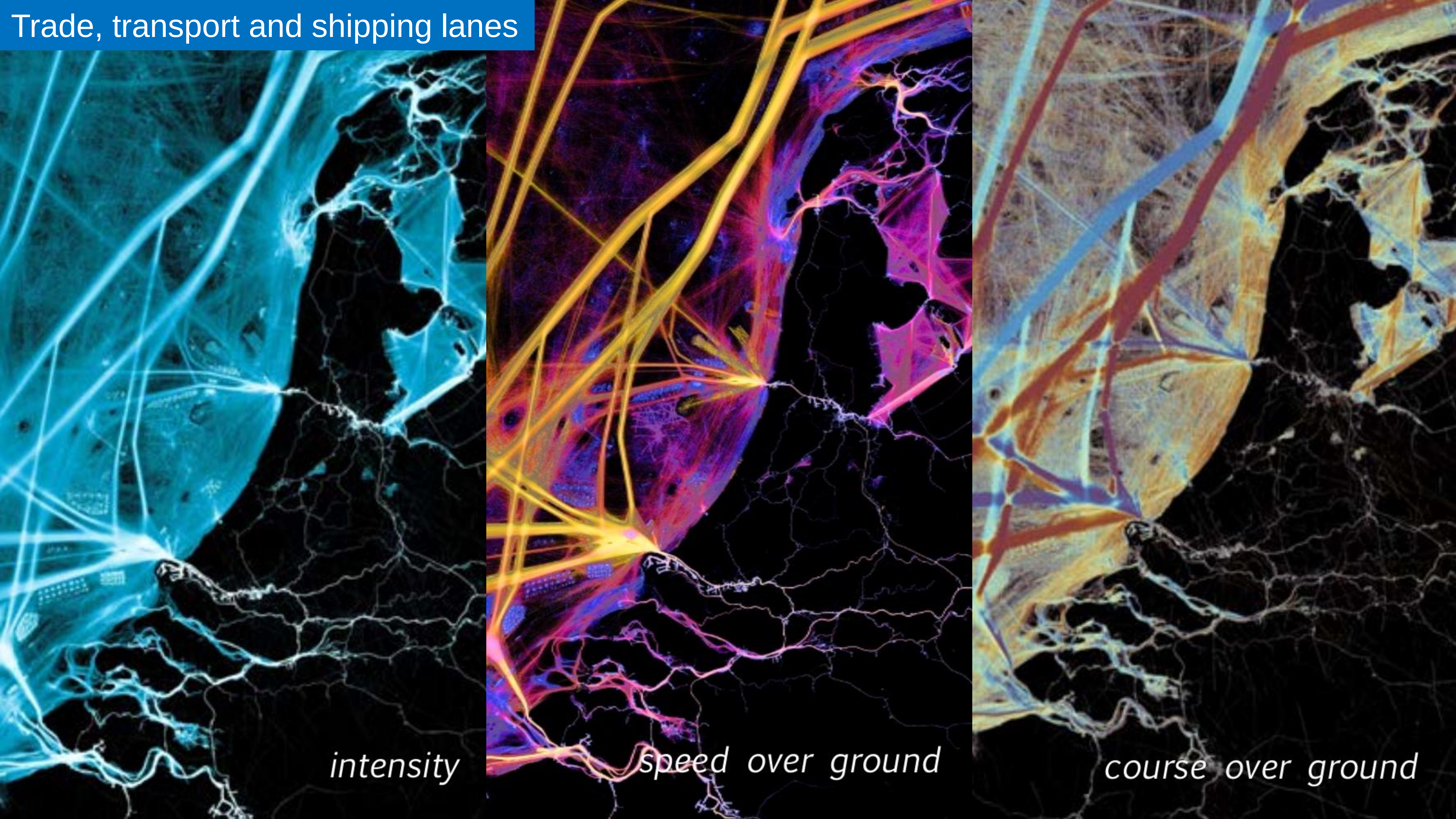


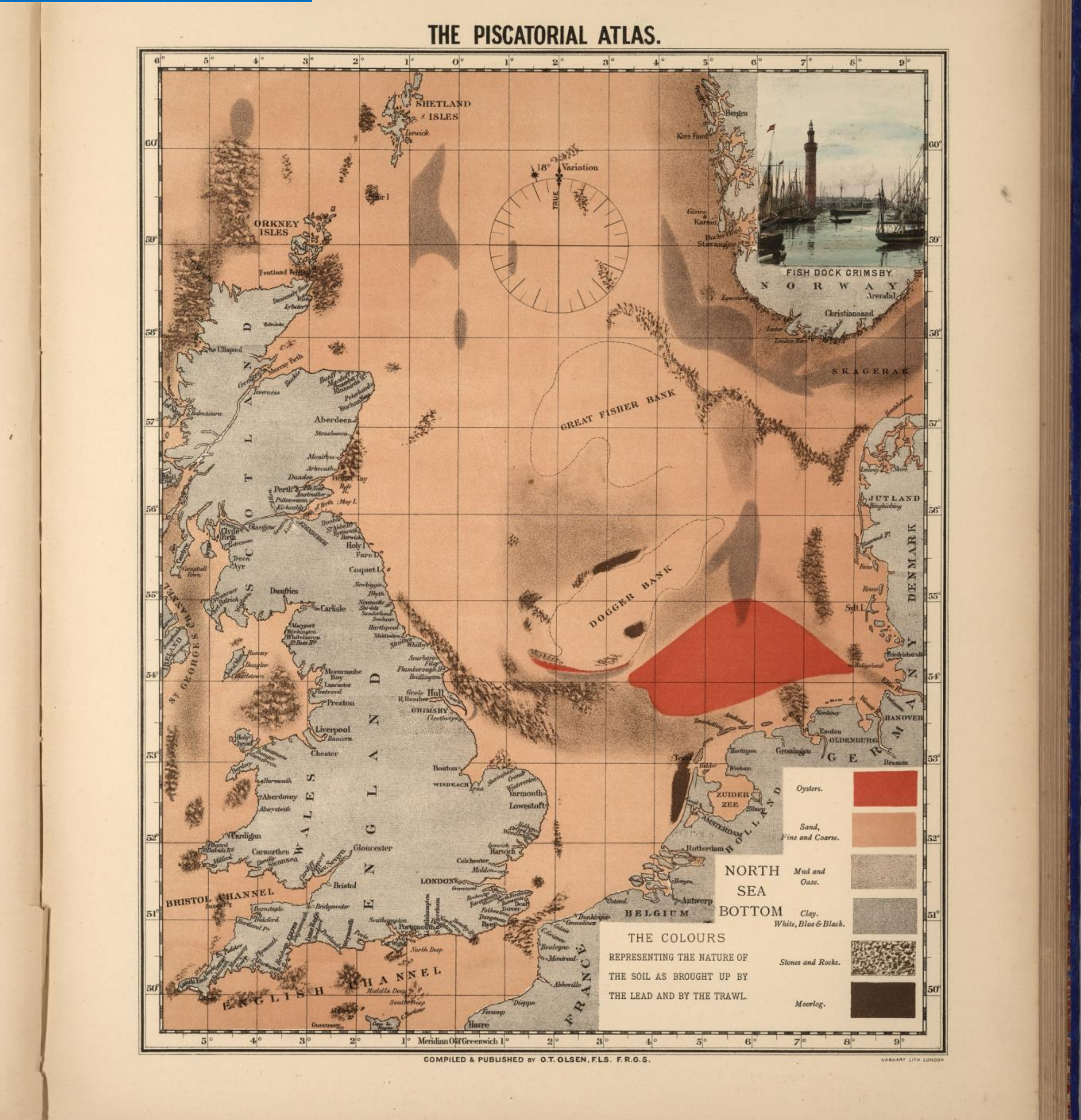
Figure 2. Projected development of users and usages in the North Sea (legend in Annex B)

Trade, transport and shipping lanes

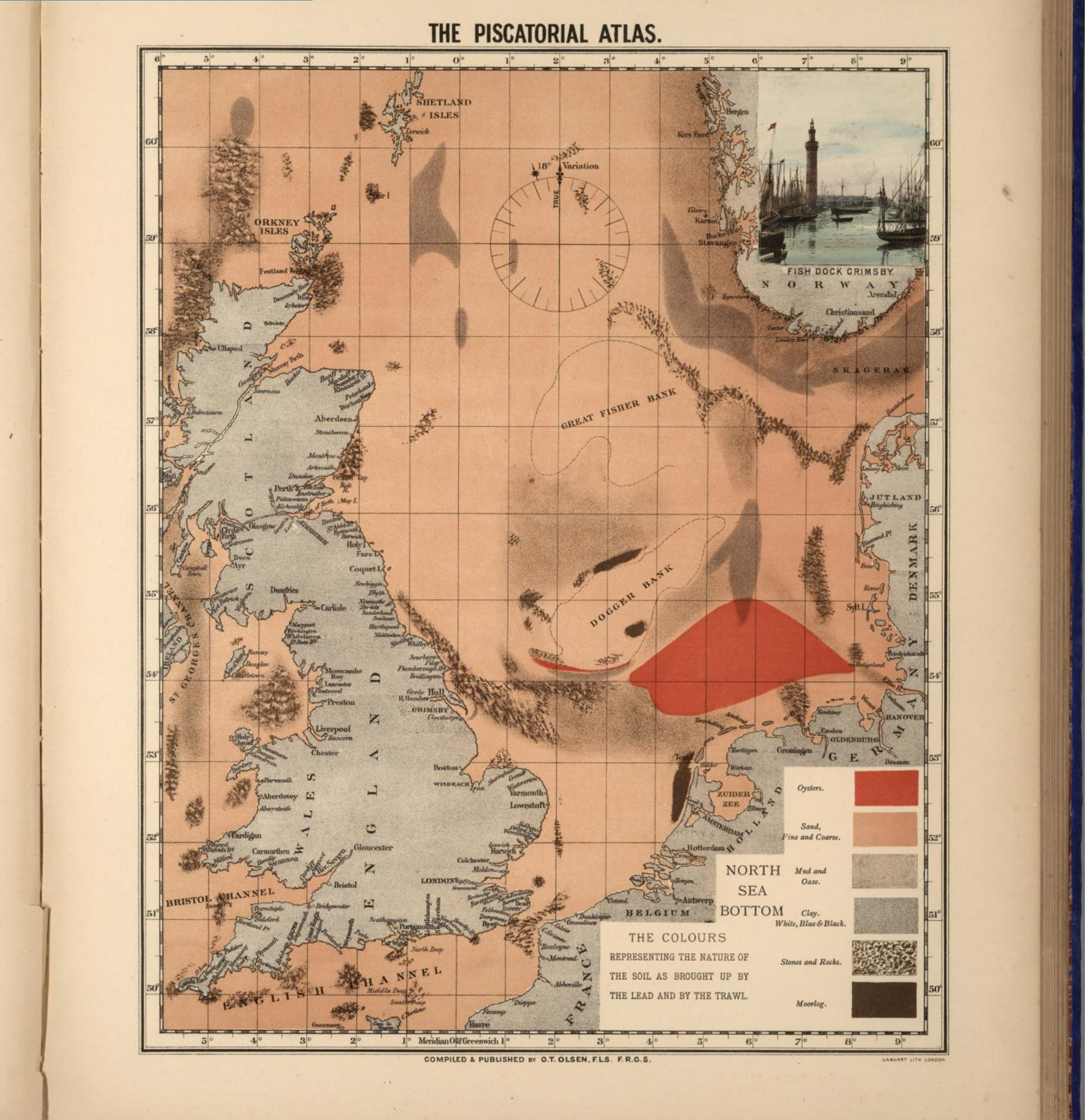


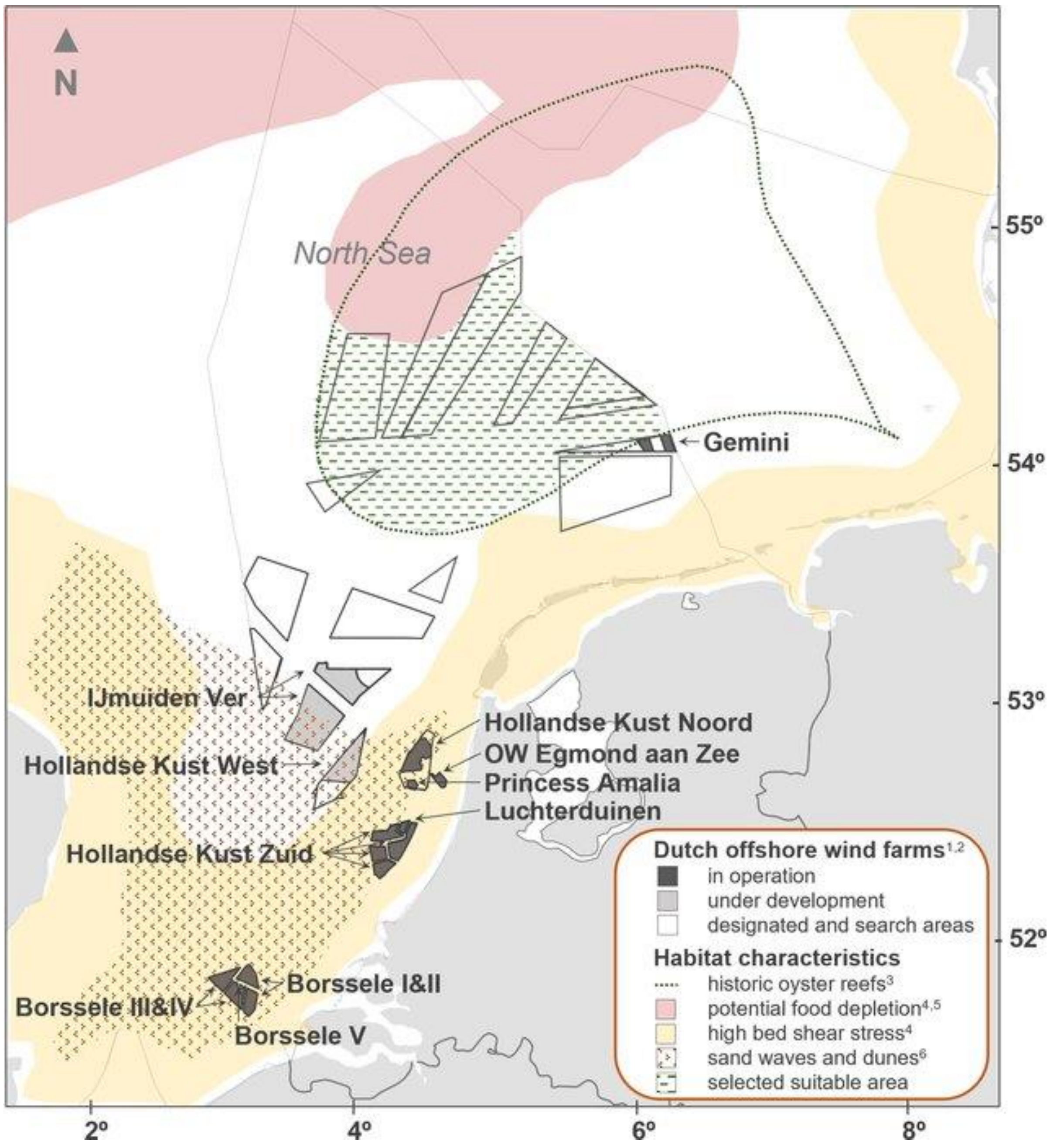
Offshore windparks and high voltage cables

Conservation



Conservation





Waar waren we ook alweer?

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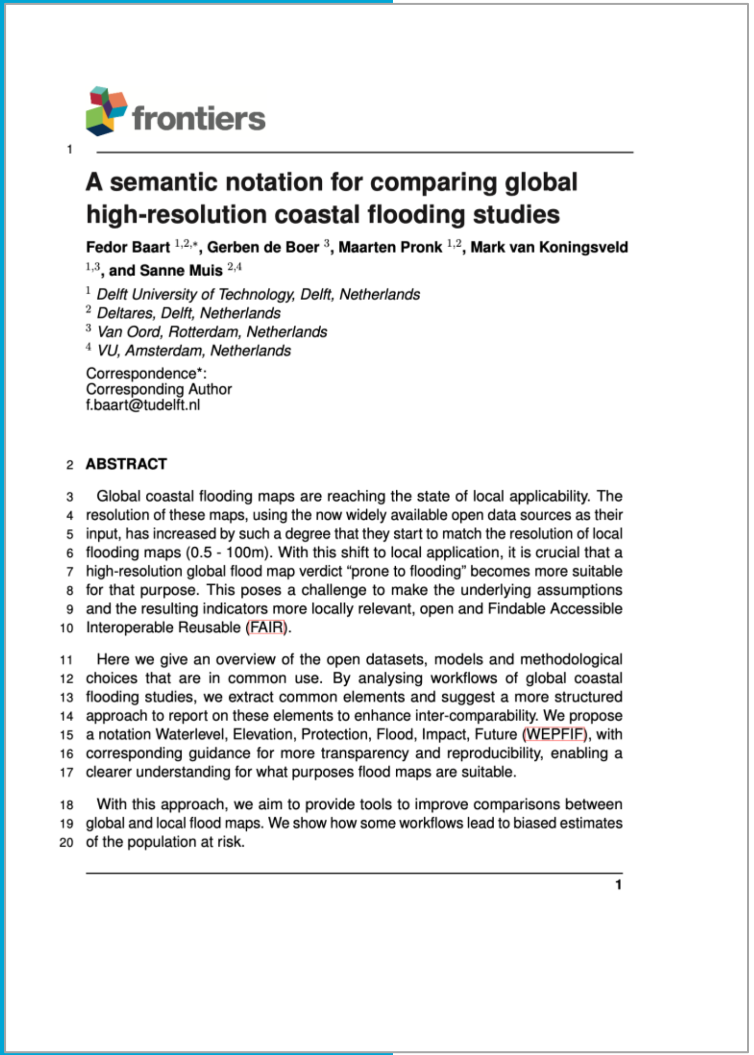
frontiers

A semantic notation for comparing global high-resolution coastal flooding studies

Fedor Baart [1,2,*], Gerben de Boer [3], Pronk Maarten [1,2], Mark van Koningsveld [1,3], and Sanne Muis [2,4]

[1] *Delft University of Technology, Delft, Netherlands*
[2] *Deltares, Delft, Netherlands*
[3] *Van Oord, Rotterdam, Netherlands*
[4] *VU, Amsterdam, Netherlands*

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Corresponding Author
f.baart@tudelft.nl

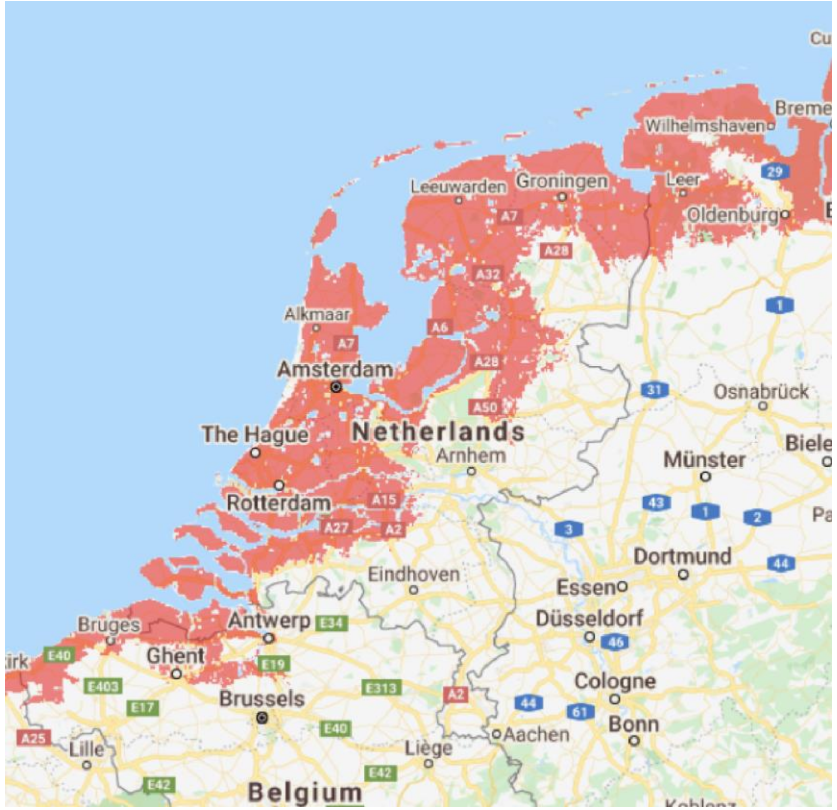
ABSTRACT

Global coastal flooding maps are reaching the state of local applicability. The resolution of these maps, using the now widely available open data sources as their input, has increased by such a degree that they start to match the resolution of local flooding maps (0.5 - 100m). With this shift to local application, it is crucial that a high-resolution global flood map verdict "prone to flooding" becomes more suitable for that purpose. This poses a challenge to make the underlying assumptions and the resulting indicators more locally relevant, open and Findable Accessible Interoperable Reusable (FAIR).

Here we give an overview of the open datasets, models and methodological choices that are in common use. By analysing workflows of global coastal flooding studies, we extract common elements and suggest a more structured approach to report on these elements to enhance inter-comparability. We propose a notation Waterlevel, Elevation, Protection, Flood, Impact, Future (WEPFIF), with corresponding guidance for more transparency and reproducibility, enabling a clearer understanding for what purposes flood maps are suitable.

With this approach, we aim to provide tools to improve comparisons between global and local flood maps. We show how some workflows lead to biased estimates of the population at risk.

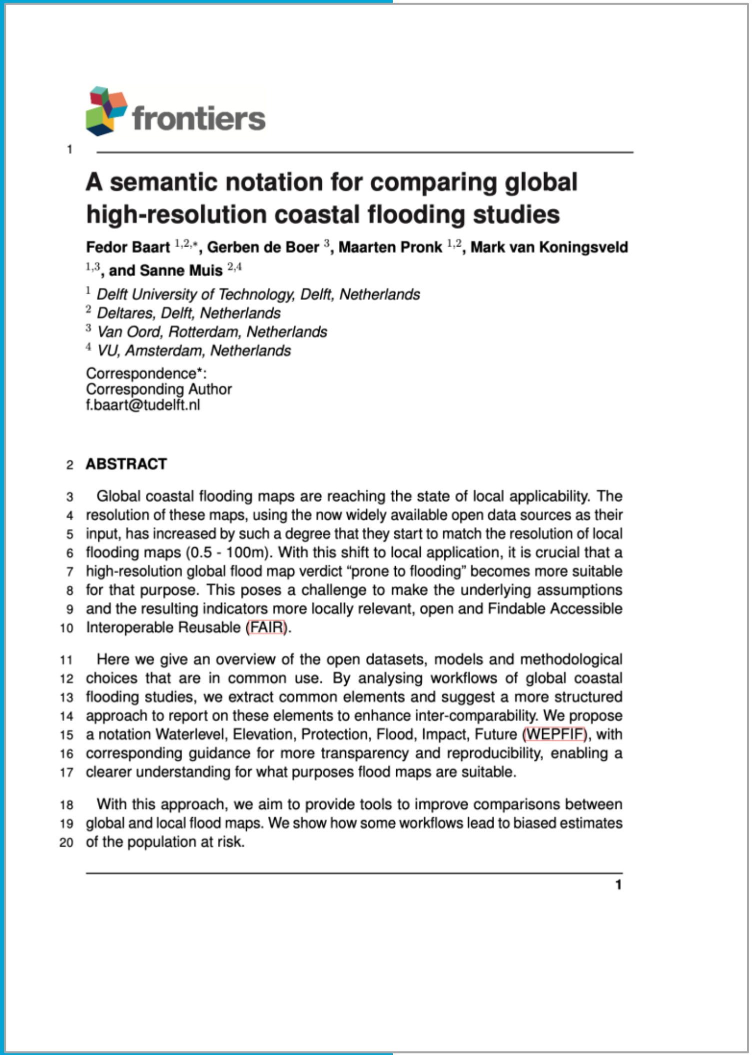
1



Twee 'coastal flooding' kaarten:
Links: globaal scenario van CoastalDEM (herhalingstijd van 10 jaar),
Rechts: lokaal scenario van Rijkswaterstaat (mozaic van scenarios met herhaling van ~10 jaar).

Baart, F, et al. (2024) A semantic notation for comparing global high-resolution coastal flooding studies. Under review.

Waar zitten we naar te kijken?



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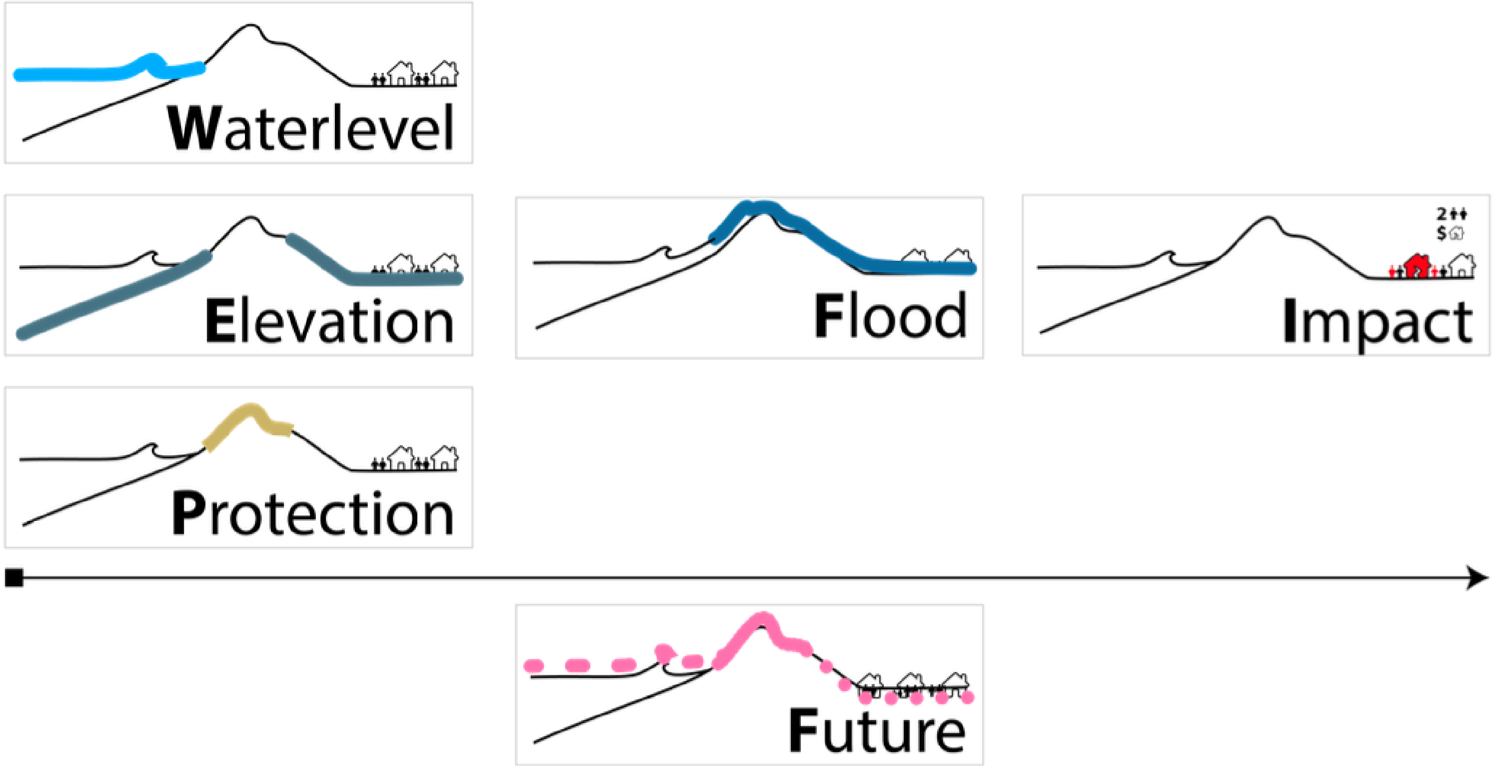

De WEPFIF notatie

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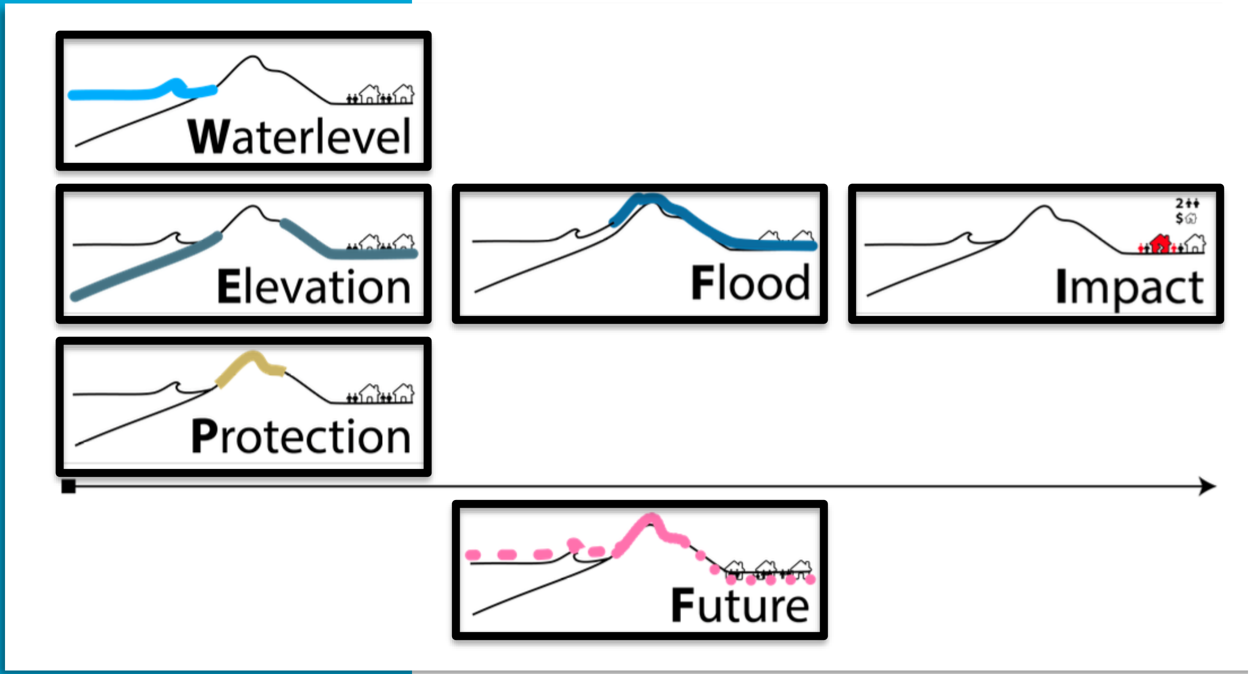

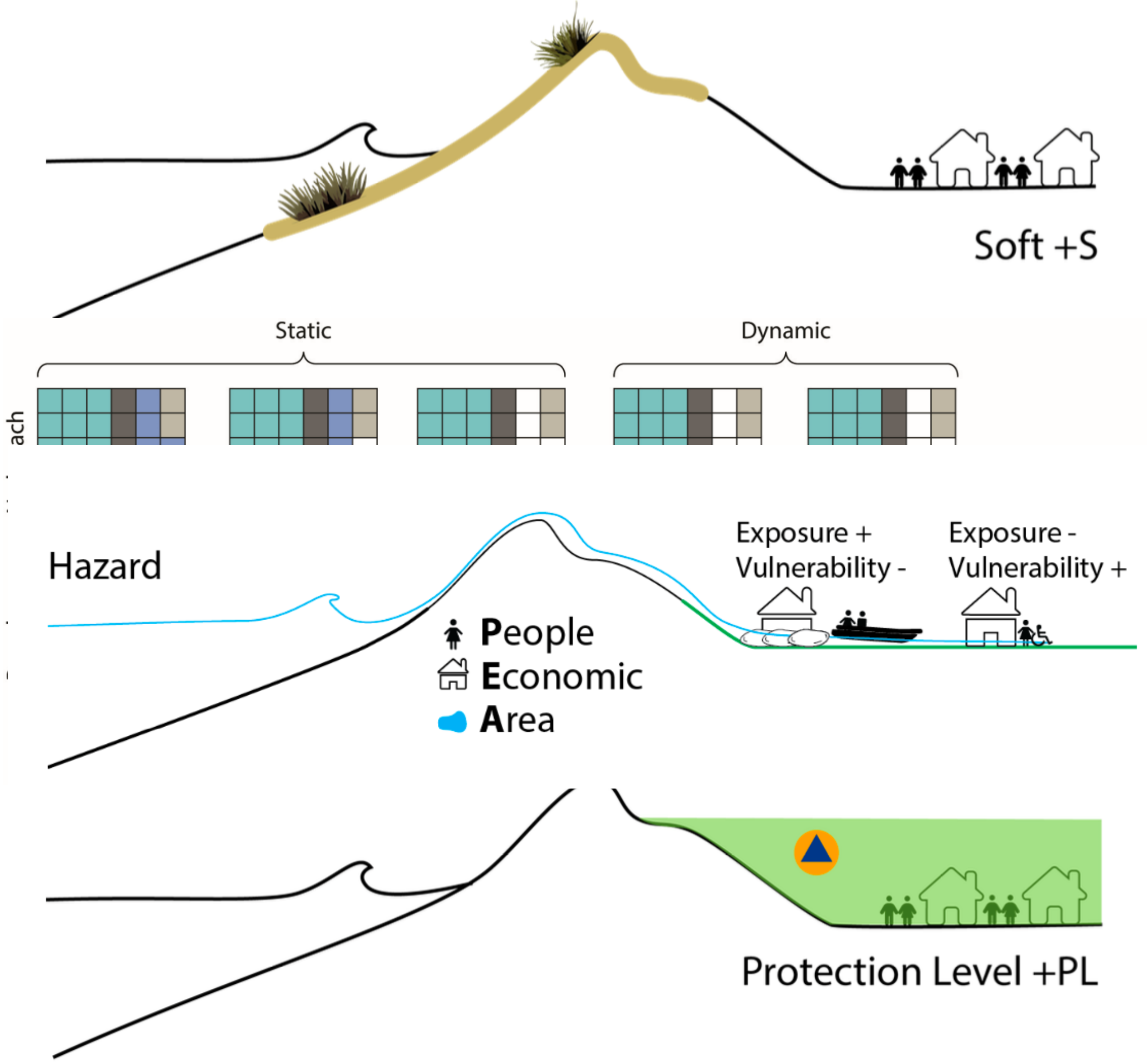

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Wat willen we bereiken?

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Defining operational objectives for nature-inclusive marine infrastructure to achieve system-scale impact

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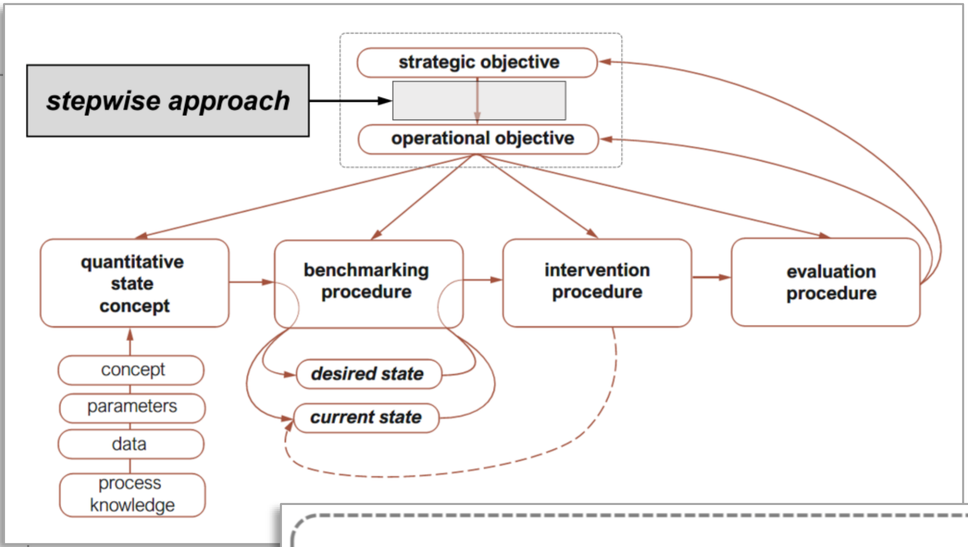
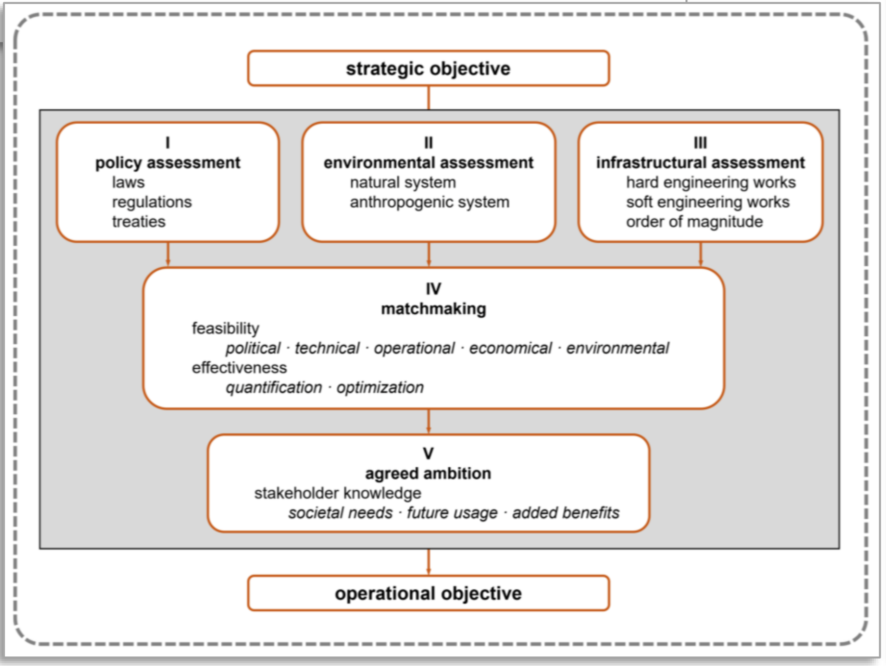
The marine environment faces continuous anthropogenic pressures, including infrastructural developments at a global scale. Integration of nature-inclusive measures in the design of infrastructural development is increasingly encouraged, but a lack of coordination results in fragmentation of project-based measures, failing to meet the desired overall effects. To realize impact at system-scale, i.e. the seascape dimension required to achieve the set objective for a selected ecosystem component, overarching policies with shared targets towards effective nature-inclusive marine infrastructure are needed. We present a stepwise approach to work towards operational objectives for promoting selected ecosystem components that can be species, habitats or ecosystem processes, in which ruling policies, environmental conditions and the use of infrastructural development are aligned, and agreement on achievable ambitions is reached. Having clear targets will provide guidance to project developers in designing the infrastructure nature-inclusive, and in setting up relevant monitoring programs to evaluate the measures taken. We demonstrate how this stepwise approach could be applied to derive operational objectives for the design of nature-inclusive marine infrastructure in the context of offshore windfarm development in the North Sea, currently one of the most prominent infrastructure developments that changes the marine environment drastically. The European flat oyster *Ostrea edulis* has been selected as target species in the case study, as its once abundant population is now nearly extinct from the North Sea due to human disturbances, and there's growing interest to restore its reefs. The application of the stepwise approach indicates the potential for oyster reef restoration in the area, based upon a clear match between ruling policy, environmental conditions, and habitat suitability within offshore wind farms. An agreement between the main stakeholders on achievable ambitions can likely be established and would translate into the operational objective to actively introduce oysters to reach an initial critical mass and optimize settlement habitat in all future offshore wind farms in an area with suitable habitat

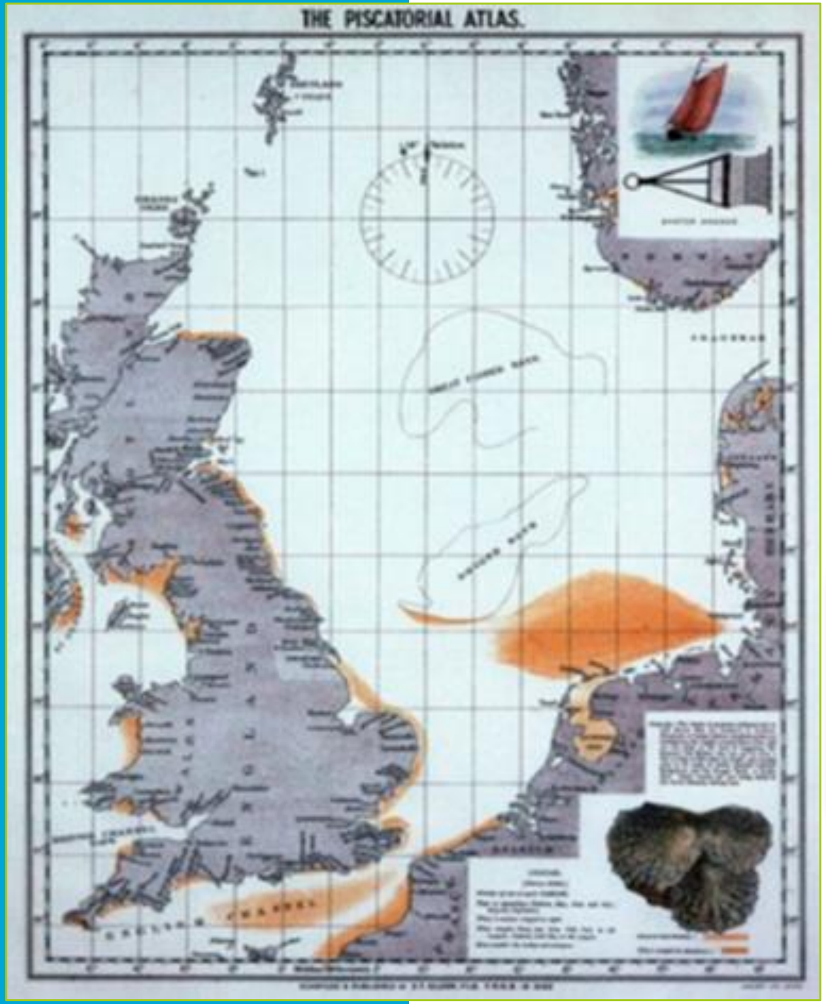




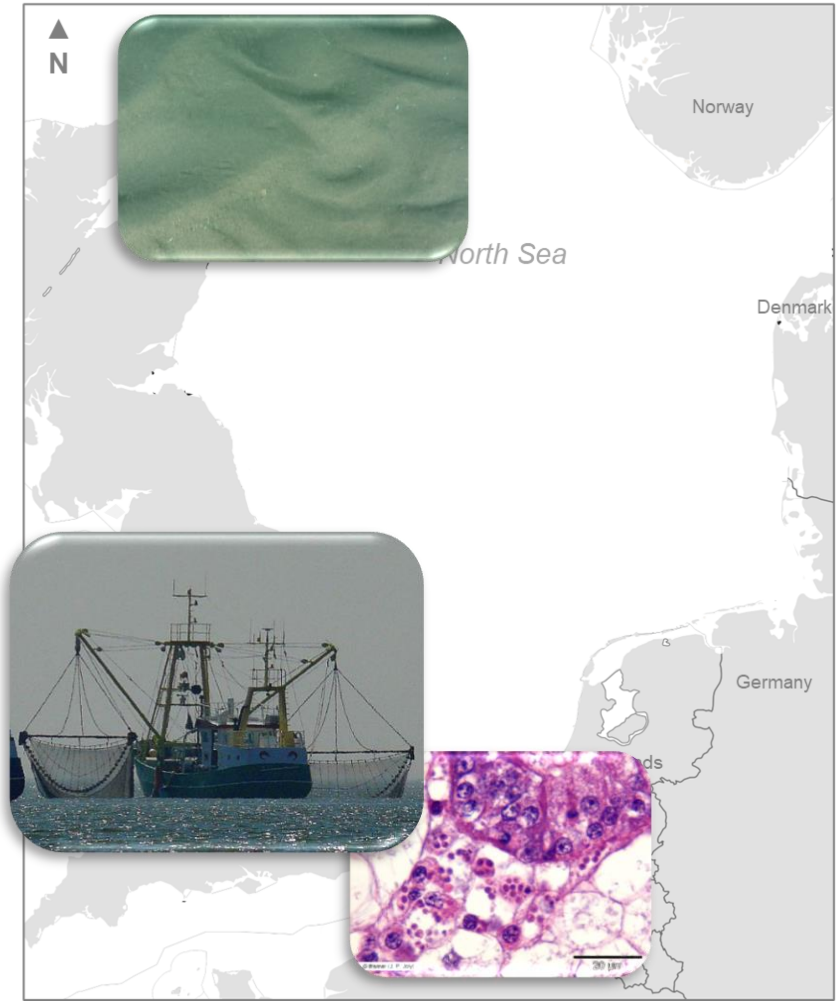
Step	Result	Source
Strategic objective:	**Development of flat oyster reefs in Dutch offshore wind farms**	
I policy assessment	MSFD target D6T5 'return and recovery of biogenic reef structures including flat oyster beds'	Ministry of Infrastructure and Water Management et al., 2018; Ministry of Infrastructure and Water Management, 2022.
II environmental assessment	Area suitability primarily based upon seabed stability (low bed shear stress, no sand waves), food availability (low seasonal stratification), historical presence.	Kamermans et al., 2018a, b; Herman and Van Rees, 2022; Van Duren et al., 2022; Stechele et al., 2023b, 2023.
III infrastructural assessment	Offshore wind farm areas offer suitable habitat by means of undisturbed seabed and hard substrate infrastructure. Optimization potential primarily in scour protection adaptations.	Kamermans et al., 2018b; Degraer et al., 2020; Ter Hofstede et al., 2022, 2023a.
IV matchmaking	Government set requirements in site decisions. Developers and scientific community showed potential through pilot studies. Cost-effective through incorporation in project design. Suitable environmental conditions present around 54° latitude. Human interventions needed to initiate self-sustaining reefs.	Staatscourant, 2019, 2022; Didderen et al., 2019; Ter Hofstede et al., 2022, 2023a; Kamermans et al., 2018a, b, 2020; Van Duren et al., 2023.
V agreed ambition	Commitment to required joint effort in focal area to create a self-sustaining oyster population with the potential to develop into a magnitude as historically present.	Probable outcome of stakeholder engagement (this paper).
Operational objective:	**Actively introduce oysters to reach an initial critical mass of 100,000 individuals and optimize settlement habitat in all future offshore wind farms in the area with suitable habitat characteristics.**	

Wat willen we bereiken?

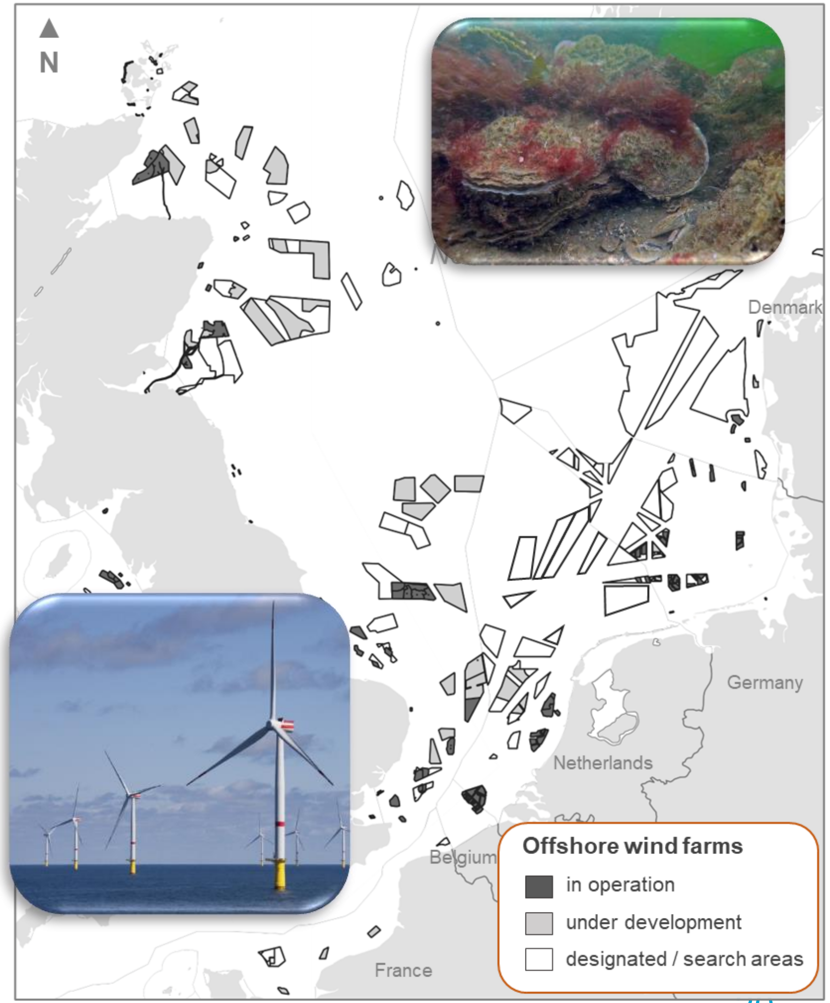
~1883
Thriving flat oyster reefs



~2000
Nearly extinct



Present
Opportunities for recovery



source: Olsen (1883)

ter Hofstede R (2024) Engineering nature-inclusive marine infrastructure. TU Delft PhD dissertation. https://doi.org/10.4233/uuid:fa230660-31cc-4ded-8b94-2aadd19038fb

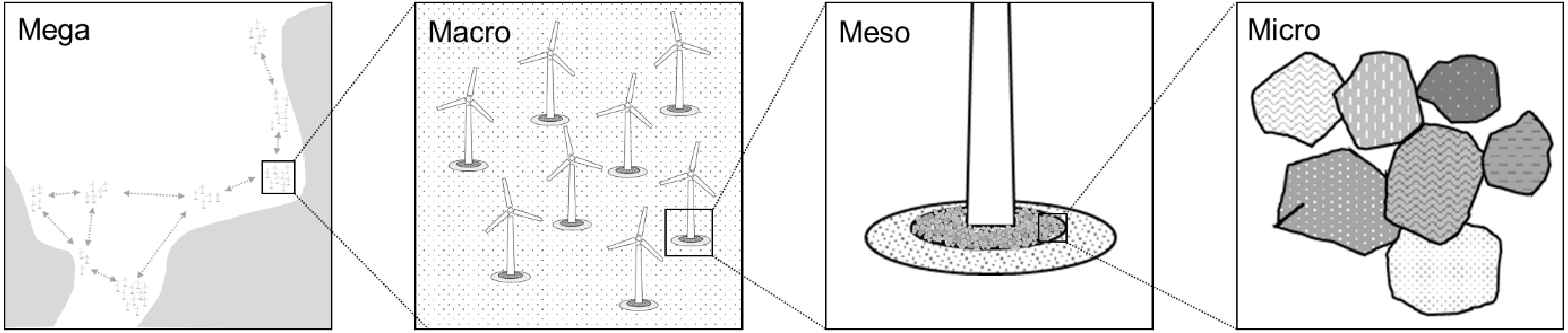
Wat willen we bereiken?

Insert broodstock to achieve recruitment

Improve seabed (e.g. add shell material) to support reef development

Adjust scour protection (e.g. shape, dimensions) to provide settlement habitat

Use materials (e.g. calciferous marble) to increase settlement rates



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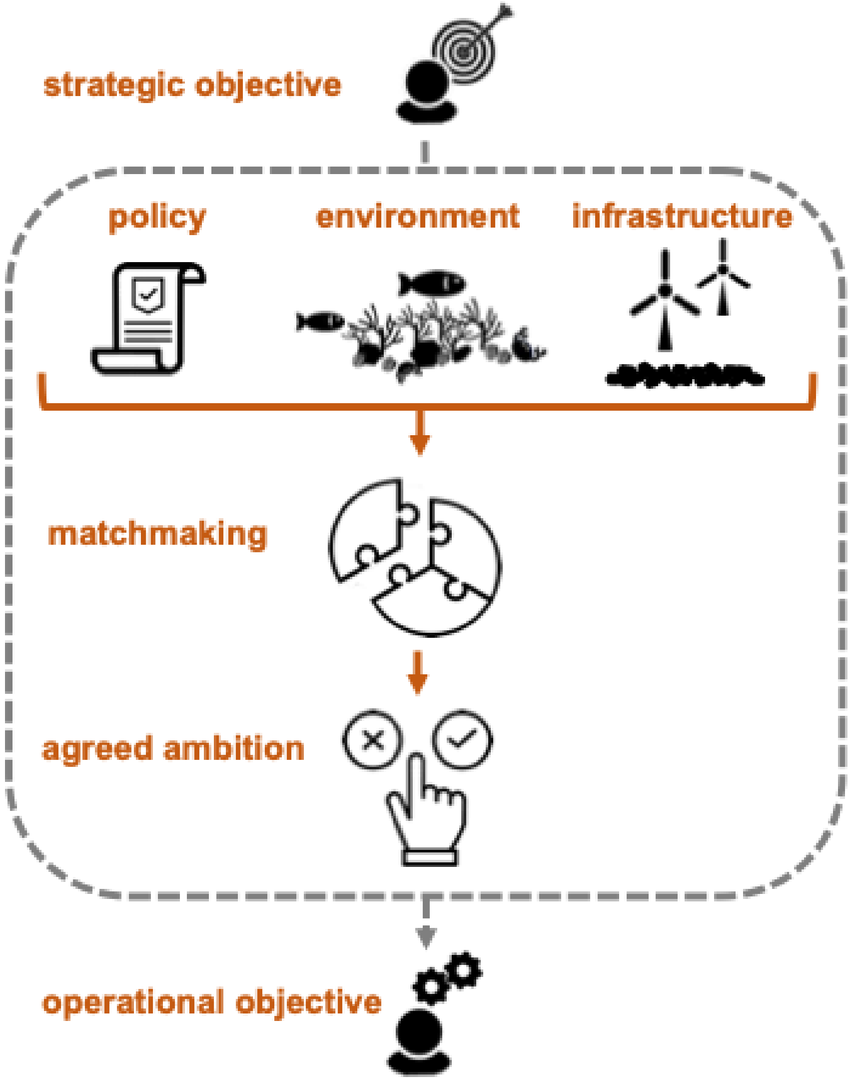
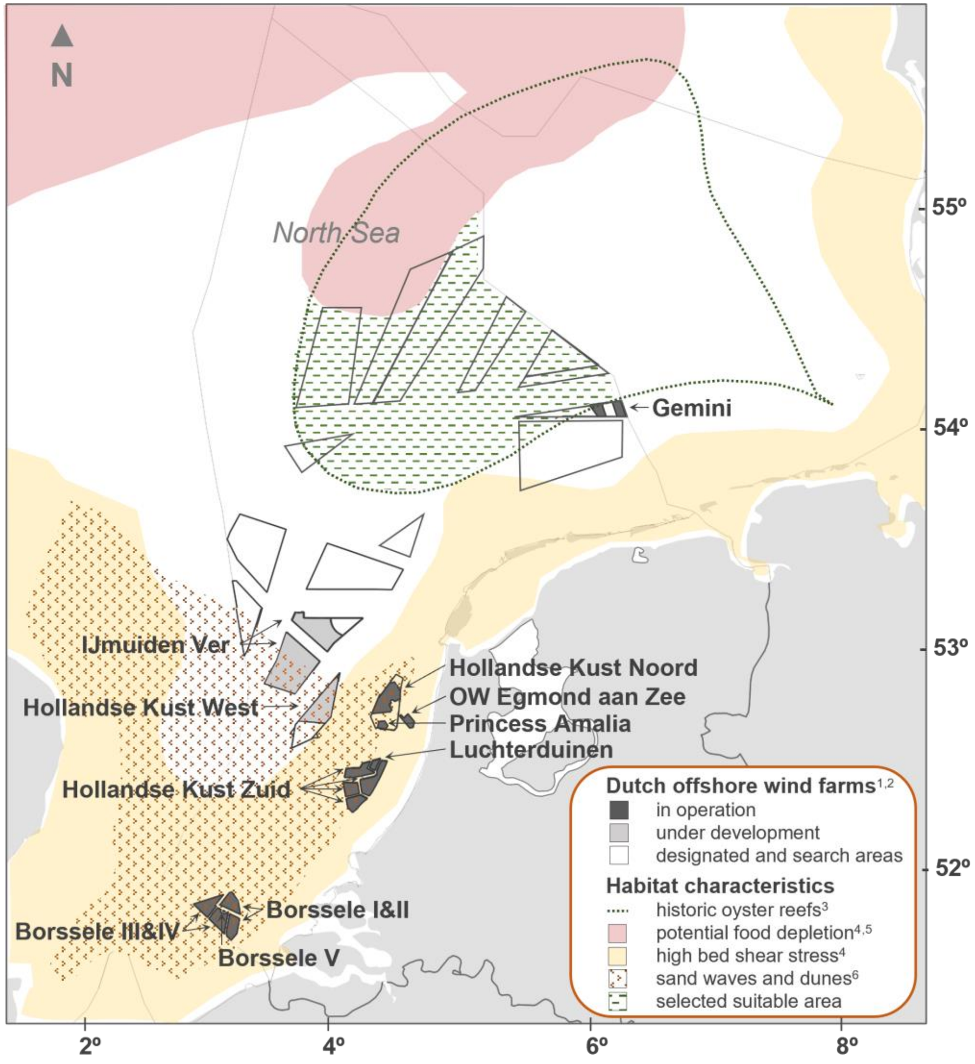
Wat willen we bereiken?





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Hoe beïnvloeden functies elkaar?

Trading off dissimilar stakeholder interests: Changing the bed level of the main shipping channel of the Rhine-Meuse Delta while considering freshwater availability

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Abstract

Climate change and socio-economic developments have generally led to highly pressured estuarine systems in which dissimilar and conflicting stakeholder interests can no longer be satisfied simultaneously, leading to trade-offs. As translating these interests into quantifiable performance indicators is cumbersome, decision- and policy-makers are often bound to qualitative trade-off assessments, potentially resulting in sub-optimal designs. In this paper, we assess the well-known socio-economic trade-off in estuaries worldwide: port accessibility versus freshwater availability. We consider the severely dry year of 2022 in the Rhine-Meuse Delta for which we assess the effects of bed level change. To quantify the trade-off, we use a general framework of performance indicators that are determined based on models, which use the output of a validated hydrodynamic model including salt transport. Port efficiency was quantified based on vessel waiting times, using a data-driven nautical traffic model. For the performance indicator of freshwater availability, we developed a metric that includes buffering capacity. The method resulted in a trade-off curve showing improved freshwater availability and deteriorated port efficiency for decreasing bed level. This trade-off curve provides valuable insights into interventions in a multidisciplinary setting, being an intuitive visualisation showcasing the (non-monetary) benefits and costs for different stakeholders with dissimilar interests. As the method could be expanded and applied further, this study aids quantitative decision- and policy-making.

Highlights:

1. We quantify dissimilar stakeholder interests using performance indicators.
2. We assess the trade-off between port efficiency and freshwater availability.
3. We apply the assessment to the highly-urbanised Rhine-Meuse Delta.
4. We address the effects of bed level change on the dissimilar stakeholder interests.
5. Our trade-off curve is an intuitive visualisation for decision- and policy-making.

Keywords: salt intrusion, freshwater availability, port efficiency, estuary, trade-off, decision-making

1. Introduction

Globally, deltas have been attractors of human activity and other forms of life alike. This is because they provide fertile soils and access to freshwater, as well as an open connection to the sea (Maul and Duedall, 2019; Pont et al., 2002). In addition, estuaries are also ecologically valuable systems due to their high biodiversity (Tangelder et al., 2017), and their calm waters function as nurseries (Breine et al., 2011; Tulp et al., 2008).

With their attractiveness, estuaries house many different stakeholders with often conflicting interests: (1) communities require fresh surface waters for drinking water, agriculture, and industry, and low water levels for safety (e.g., Temmerman et al., 2013; Wada et al., 2011); (2) ports demand sufficient water depths and low current velocities to facilitate safe operations for deep-draughted vessels (van Koningsveld et al., 2023); and (3) ecological diversity facilitates estuarine resilience (e.g., Folke et al., 2002; Loreau et al., 2003), which arises from a multitude of gradients generally present in natural estuaries (e.g., Mestdagh et al., 2020; Tangelder et al., 2017; Ysebaert et al., 2003).

Over time, humans have interfered in the estuarine system to optimise performances considered important: e.g., (1) channel deepening to improve the accessibility of the port (e.g., Best, 2019; Johnson et al., 1987); (2) closing off of estuaries for water safety (e.g., Figueroa et al., 2022; Orton et al., 2023); and (3) the creation of freshwater buffers for freshwater availability (e.g., Morris, 2013; Tönis et al., 2002). However, such large-scale interventions generally have negative side-effects for other estuarine functions not considered in the assessments (e.g., de Vet et al., 2017; van

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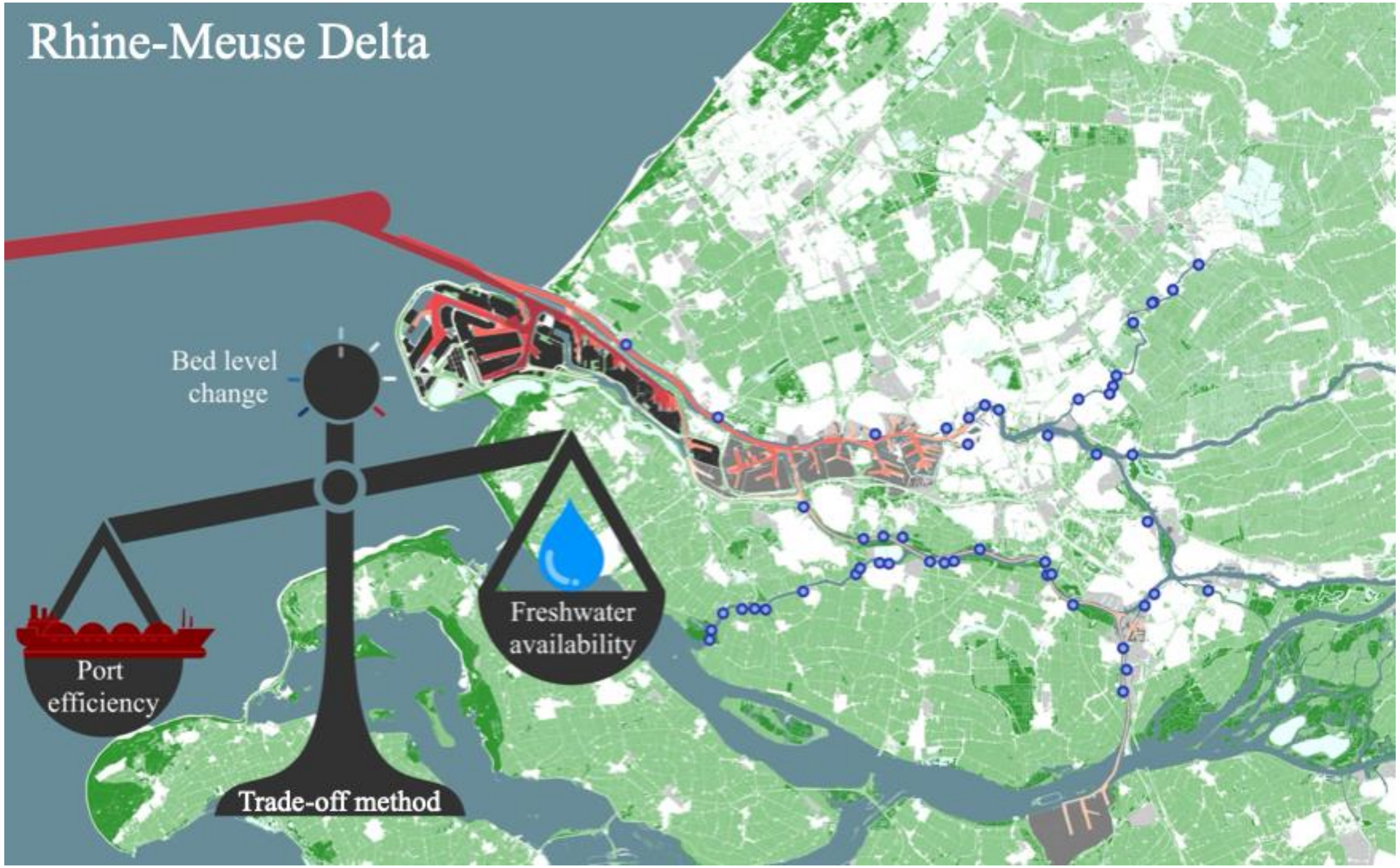

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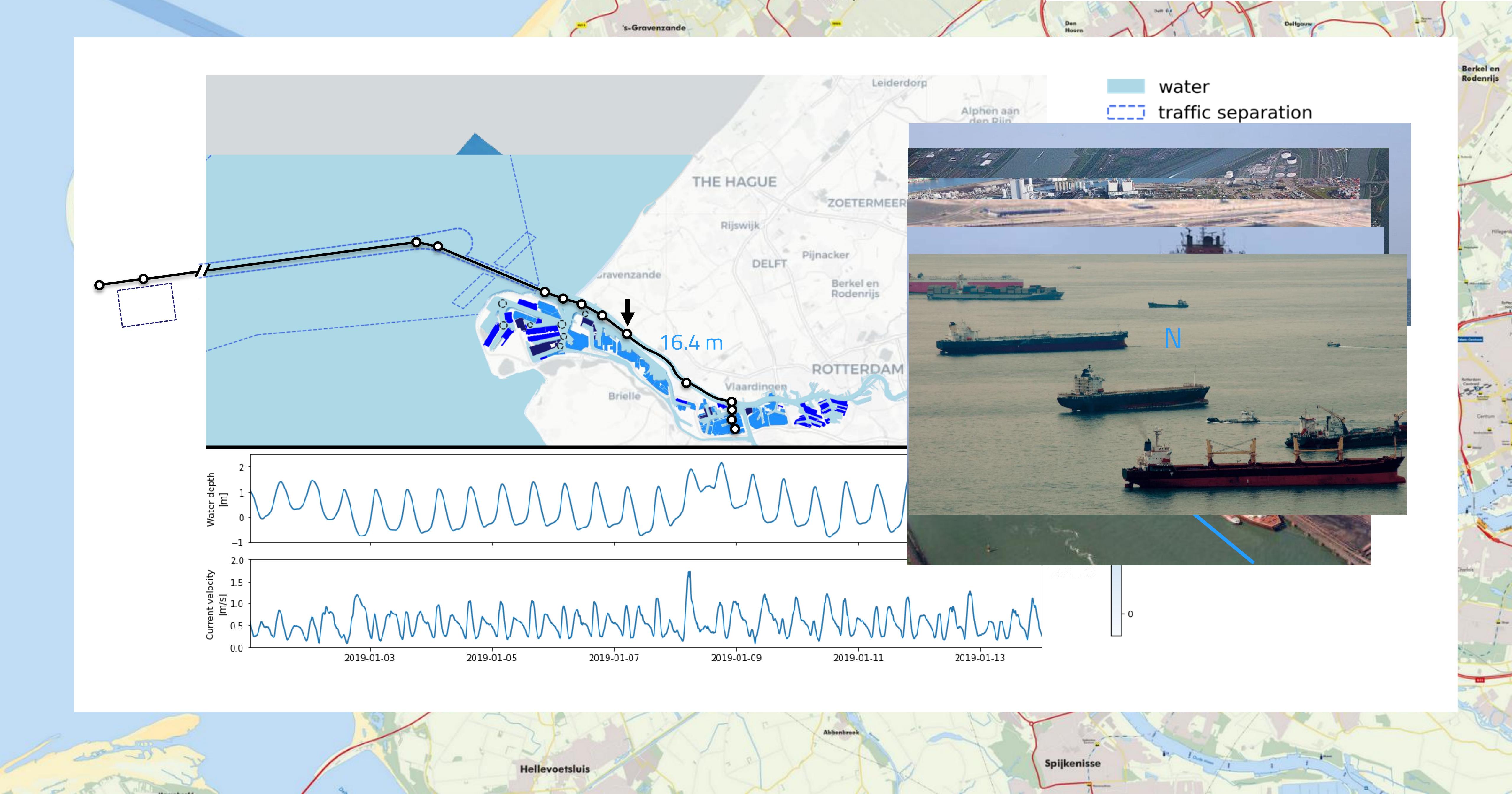
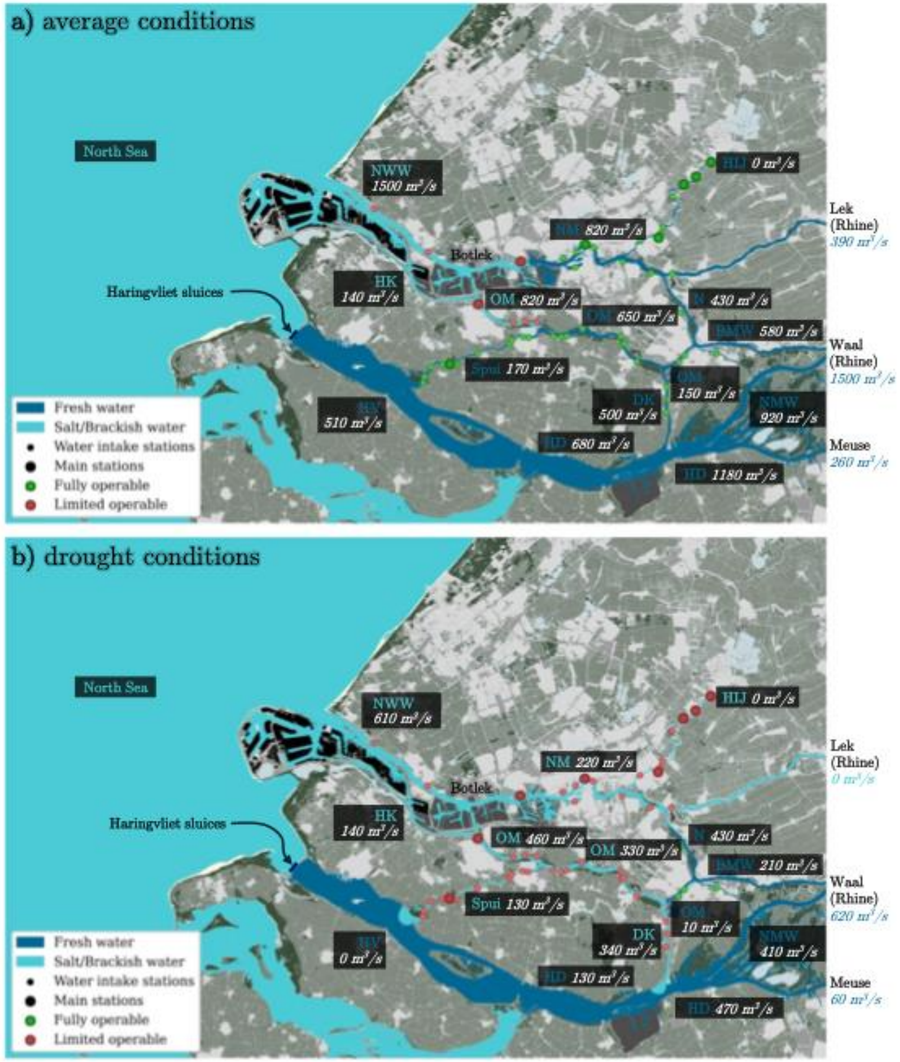
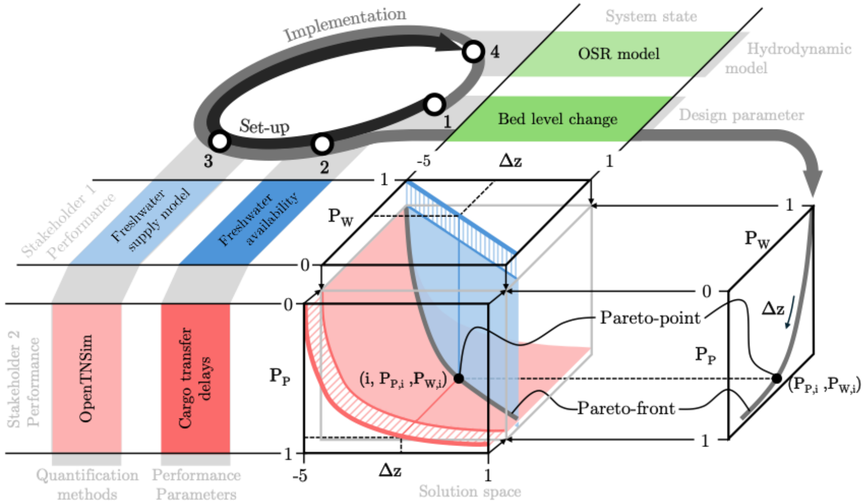
Port efficiency

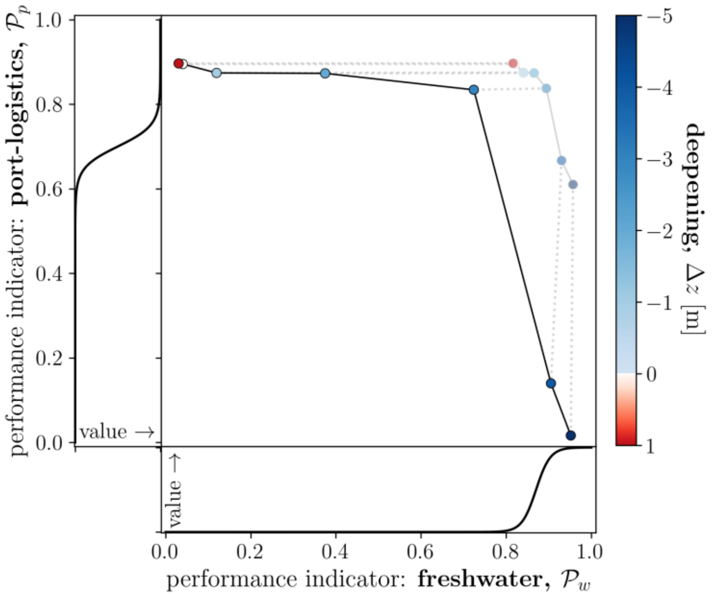
Port efficiency



Hoe beïnvloeden functies elkaar?







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Wat hebben we besproken?

- Een aanloopje vanaf ca 1 miljoen jaar geleden
  - IJstijden en zeespiegels
- Hoe zeespiegels en rivieren Nederland vorm gegeven hebben
  - Kustlijnen en bodemopbouw
- Hoe economische factoren nu de inrichting van de Noordzee bepalen
  - Gebruiksfuncties en ruimtegebrek

- *Welkom in het Anthropoceen*

- Ter inspiratie: ‘food for thought’ vanuit recent onderzoek
  - Waar zitten we naar te kijken?
    - Systeembeelden zijn belangrijk, maar wees duidelijk over aannames

  - Wat willen we bereiken?
    - Afhankelijk van je doelen, zijn bepaalde interventies (on)geschikt

  - Hoe beïnvloeden functies elkaar?
    - Inzicht in de tradeoffs tussen functies draagt bij aan begrip tussen stakeholders

TU Delft

De invloed van klimaatverandering en de mens op het Noordzee systeem: Een historisch perspectief

prof. dr. ir. Mark van Koningsveld

TU Delft – professor Ports and Waterways
Van Oord – program director Vox Innovation
TS Water & Maritime – captain of science