TU Delft Delta Futures lab

Adaptation to sea level rise: Dutch experiences and global challenges

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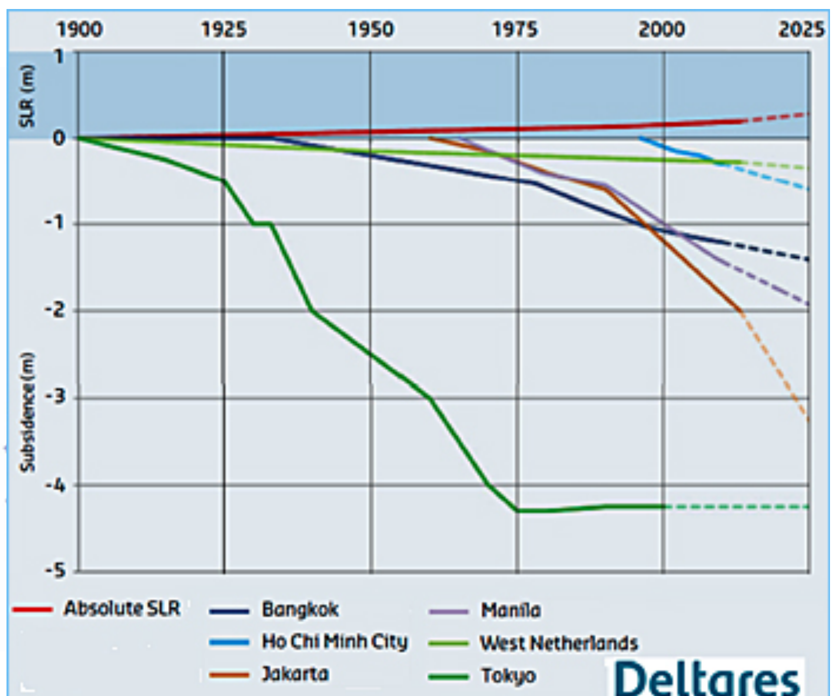
Global Policy Institute, December 1, 2020

Acknowledgements

- TU Delft: Stefan Aarninkhof, Matthijs Kok, Mark Voorendt, Ties Rijcken
- Deltares: Marjolijn Haasnoot, Ferdinand Diermanse
- ENW (Expertise Network for Flood risk): Bart Strijker, Rinse Wilmink, Carel Eijgenraam and others

Global background

- Rapid economic development in flood-prone areas
- Sea level rise and subsidence
- Frequent floods in developed and developing countries
- Worldbank study on coastal flood risks (Hallegatte et al., 2013):
  - Current Risks in coastal cities US$ 6 billion per year
  - 2050: US $52 billion per year (!?)

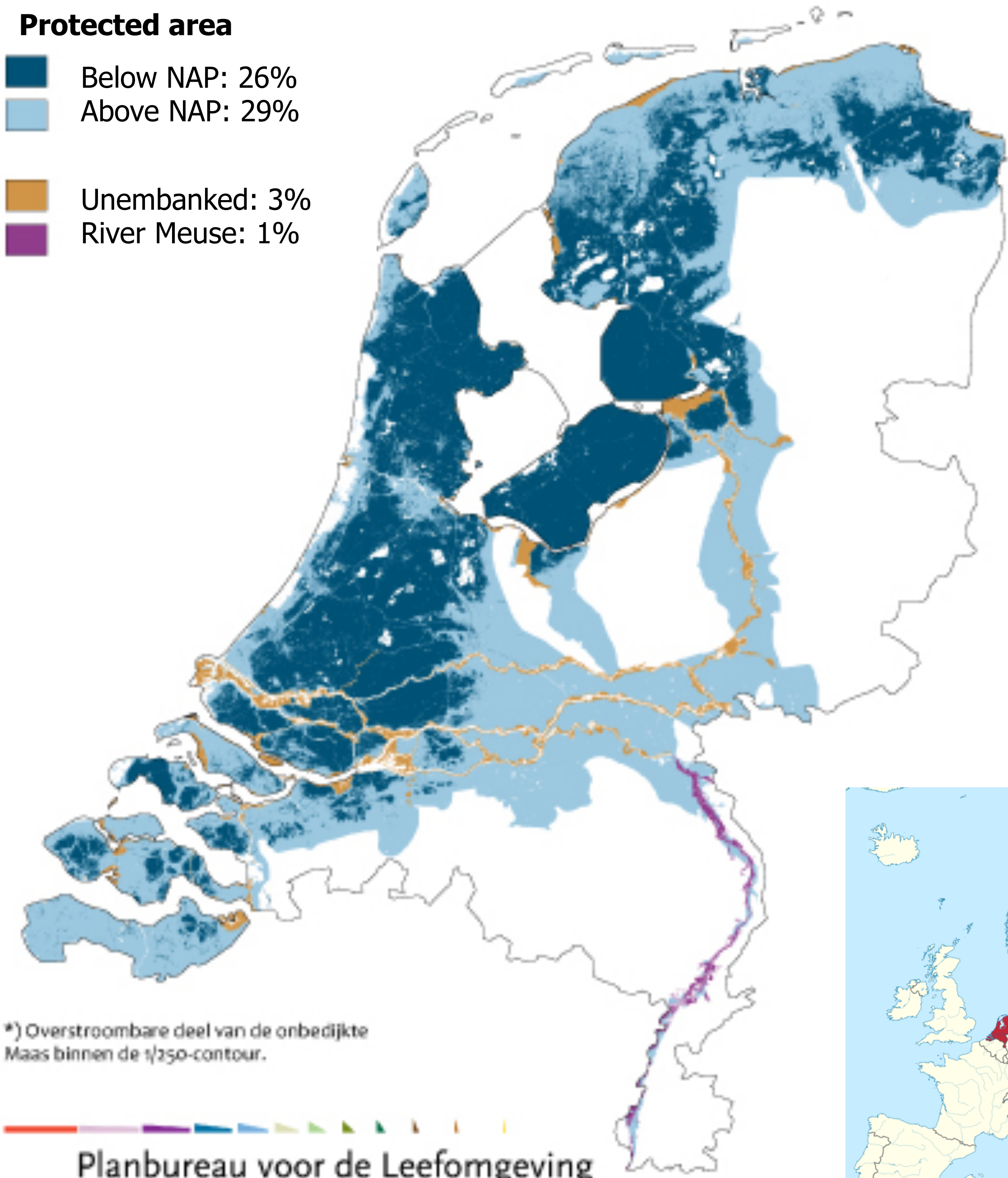


Maeslant barrier

Shanghai

N
Yangtze River
Legend
Main River
Branches
River flow direction
Potential flood threats
Pudong Int. airport
Main ports
Downtown
Hydrological stations
Water gates
Jiangsu Pro.
Wusongkou 1
2 Huangpu Park
Tai Lake
Dianshan
Appro. 200km
3 Mishidu
East China Sea
Zhejiang Pro.
Hangzhou Bay
km

The Netherlands



Overview of the flood defence system

Rotterdam

Southwest Delta

Flood management in the Netherlands

Safety standards and reinforcements

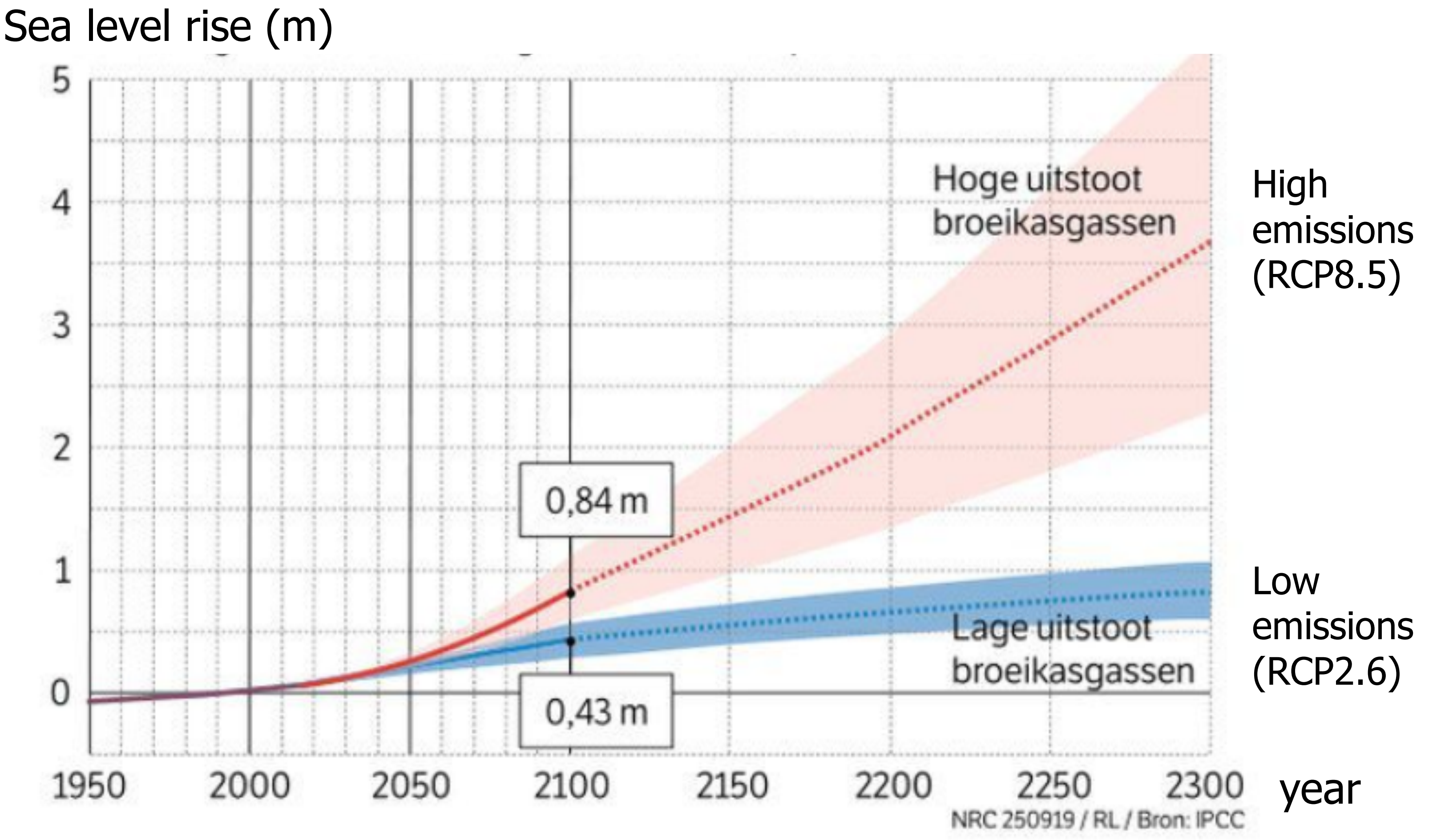
- Almost 3800 km of dikes and dams
- System largely developed after 1953 storm surge disaster
- Safety standards: Risk-based & range between 1/100 to 1/10,000 per year
- Every 6 – 12 years, national safety assessment: about 1/3 of defences to be reinforced
- Ongoing reinforcements

Flood management in the Netherlands

Organization and funding

- National Delta program and Delta fund
  - € 1 billion for reinforcements,
  - few hundred M€'s for maintenance
- Federal / national government (Rijkswaterstaat)
  - Safety standards and guidelines
  - Operation and management of storm surge barriers
  - Rivers and waterways
- Water boards:
  - Local management
  - Inspection
  - Implementation of reinforcements
  - Funding from local taxes
- Jointly: funding of dike reinforcements

Sea level rise

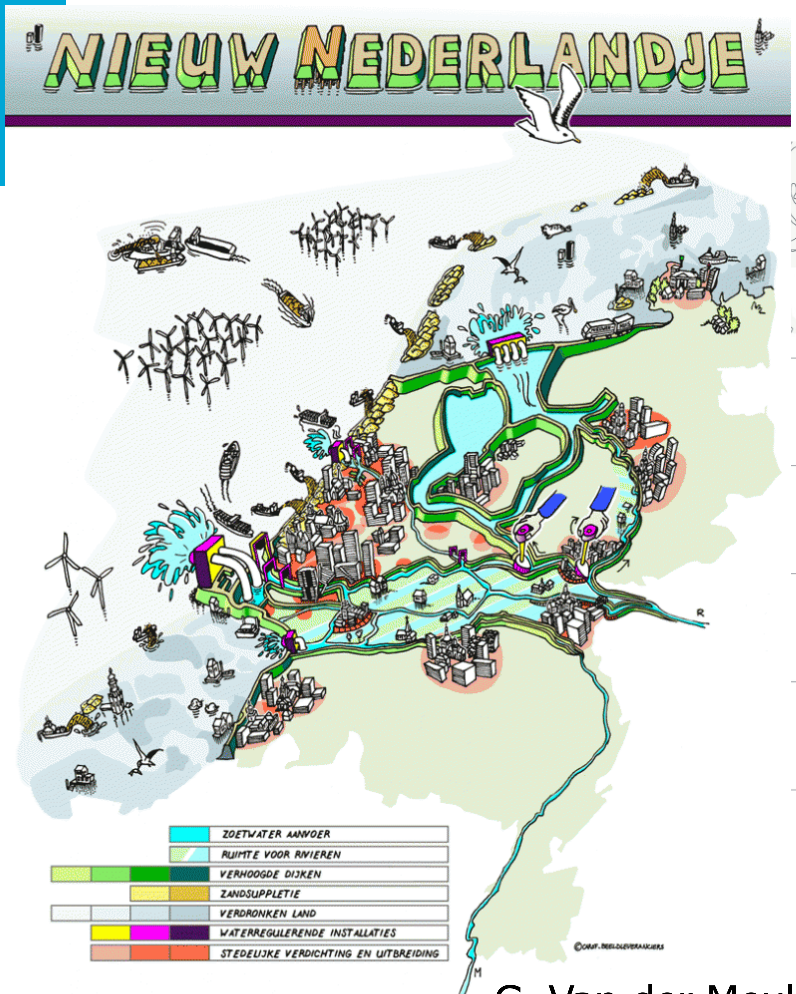


Plan B / backup plan required?

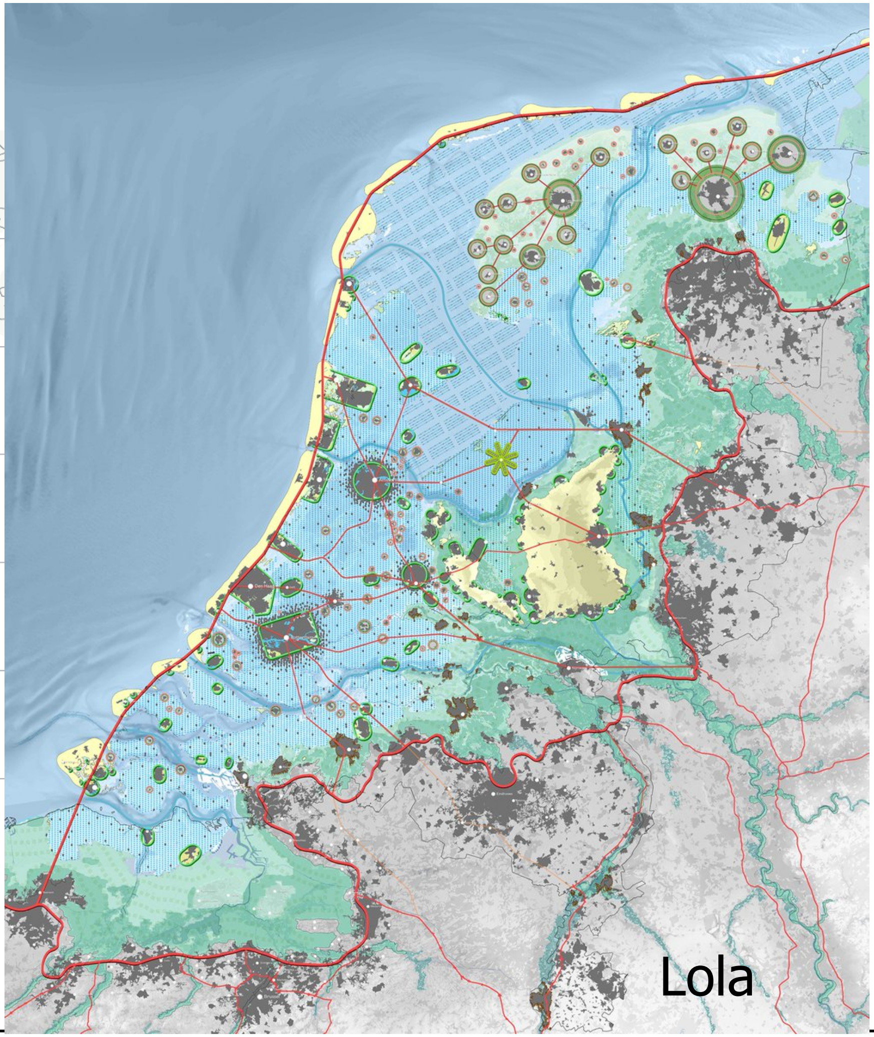
In face of rising sea levels the Netherlands 'must consider controlled withdrawal'

This is the Dutch story – where the climate crisis threatens the very existence of the country itself.

Plan B / backup plan required?



G. Van der Meulen



Source of compilation:
Ties Rijcken, Deltalinks

Key question

- Options for adaptation to sea level rise in the Netherlands?

Also briefly discussed:

- US vulnerability and “Texas case”

Overview of the flood defence system

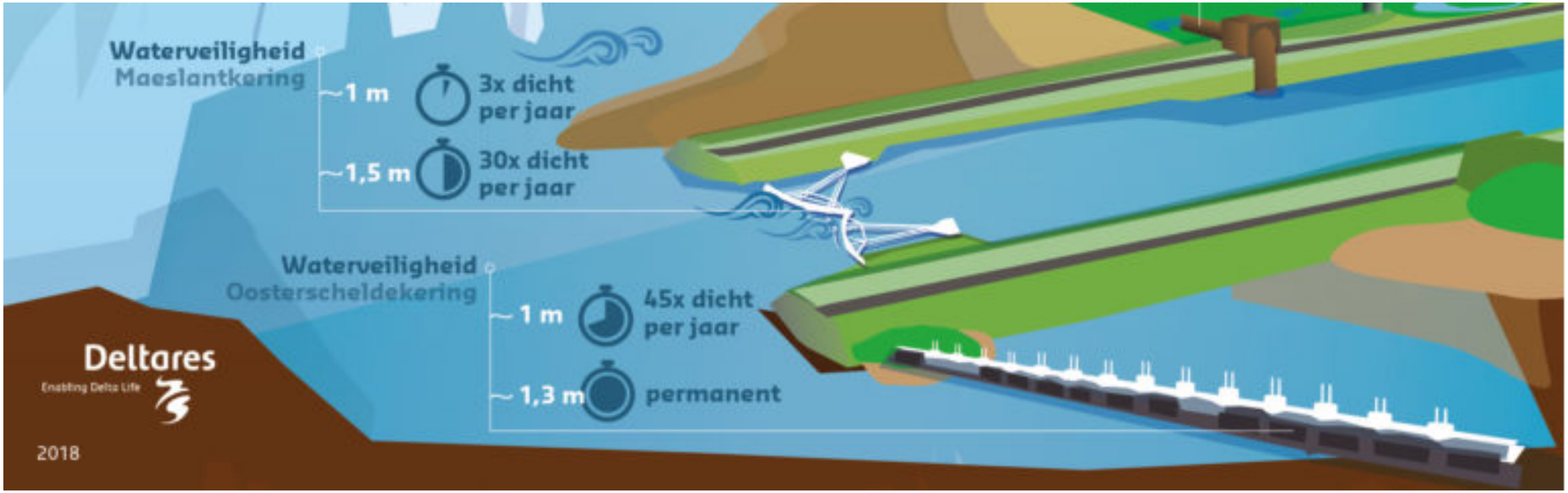
Holland coast

Rotterdam

Southwest Delta

Effects on barriers

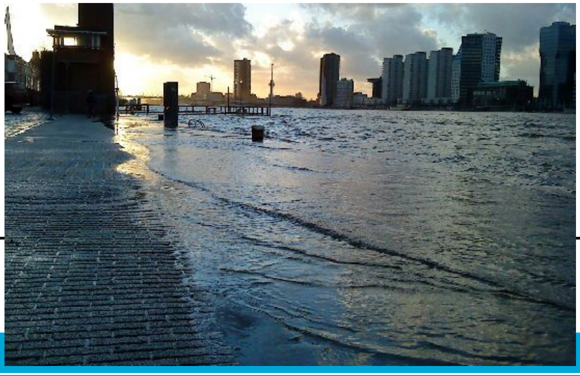
- Recent study by Deltares (2019)
- Frequency of closure of barriers as a function of sea level rise



Rotterdam - Rijnmond

- Current strategy:
  - Combination of storm surge barriers and dikes
  - Open for river discharge and navigation

- Reliability of current Maeslant barrier
  - is "just sufficient" (1/100 per demand)
  - will become less with SLR
  - Foundation? Structure? Scour protection?
- Flooding frequency of unembanked area will increase
- Options: upgraded or new barrier, dam, dike reinforcements Rdam area, ………



Rijnmond: plan Spaargaren / sluices

Bron: de Ingenieur

Rijnmond: plan Spaargaren / sluices

Source: F. Ruys on Youtube

Eastern Scheldt

Source: Wikipedia

- Storm surge barrier, dikes +
  Decaying system of intertidal flats
- Weekly closure for 1m sea level rise

- Strategic options:
  - Improvement of barrier (?)
  - (Partial) removal of barrier +
    strengthening of dikes
  - Nourishment of tidal flats

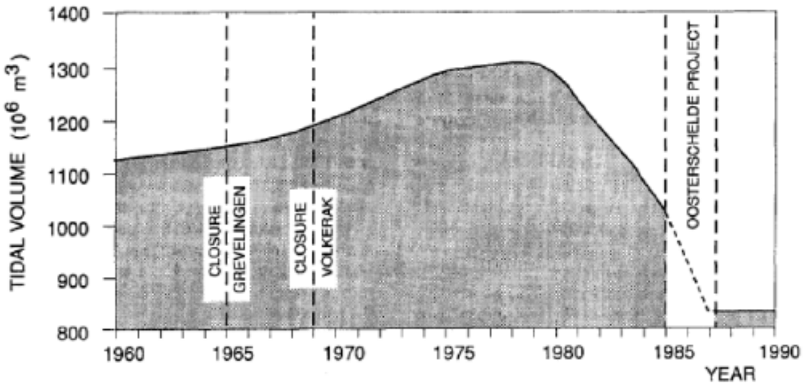


Figure 3.2: Change in tidal volume due to Delta works (Source: [Das, 2010]

Coast: nourishments

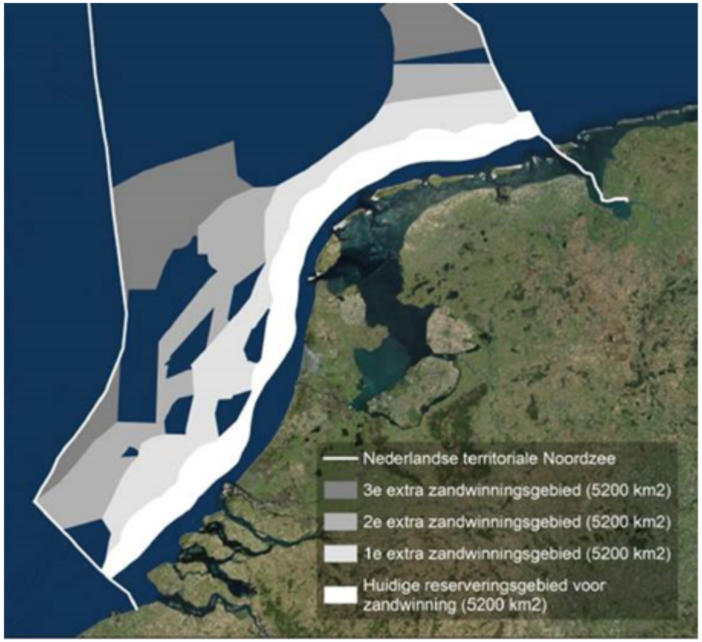
Source: Beeldbank RWS

- Nourishments: flexible strategy
- Currently ~12 Mm3 per year
  - **1m³ = 1.3yd³**
- Rule of thumb: 7 Mm3/year required per mm/year of sea level rise
  - Current 2 mm/year
  - Future 10 mm/year -> 70 Mm3/year
- Considerations:
  - Type of nourishment (mega / local)
  - Sufficient sand?
  - Environmental effects
  - Emissions and CO_2

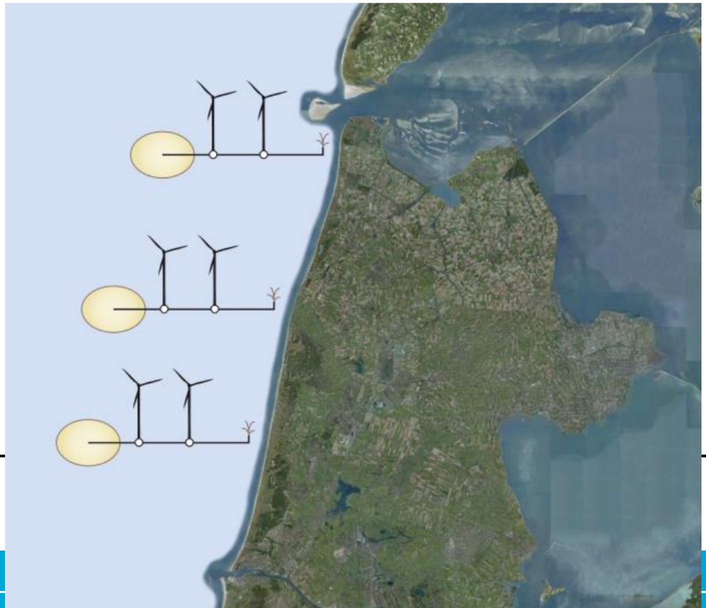
Availability of sand

- Currently: 5200km^2 for nourishment
- 10,000 Mm^3 for 2m of depth
- Sufficient for 100+ years

- Continuous dredging?
- Environmental effects?



Zandwinmolen, Sweco



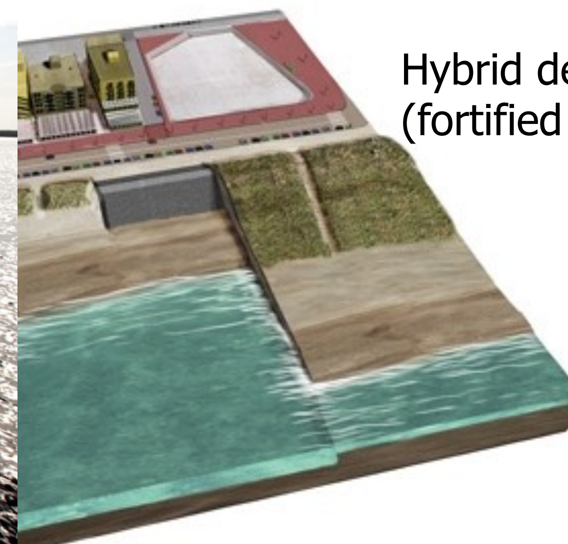
Other systems and considerations

- Limits for Wadden sediment transport capacity:
  - Western part: Max 6 mm/year SLR
  - Eastern part: Max 10 mm/year SLR
- Subsidence and salt intrusion

- Increase of:
  - Drought -> need for water retention
  - Rainfall -> urban flood risk reduction

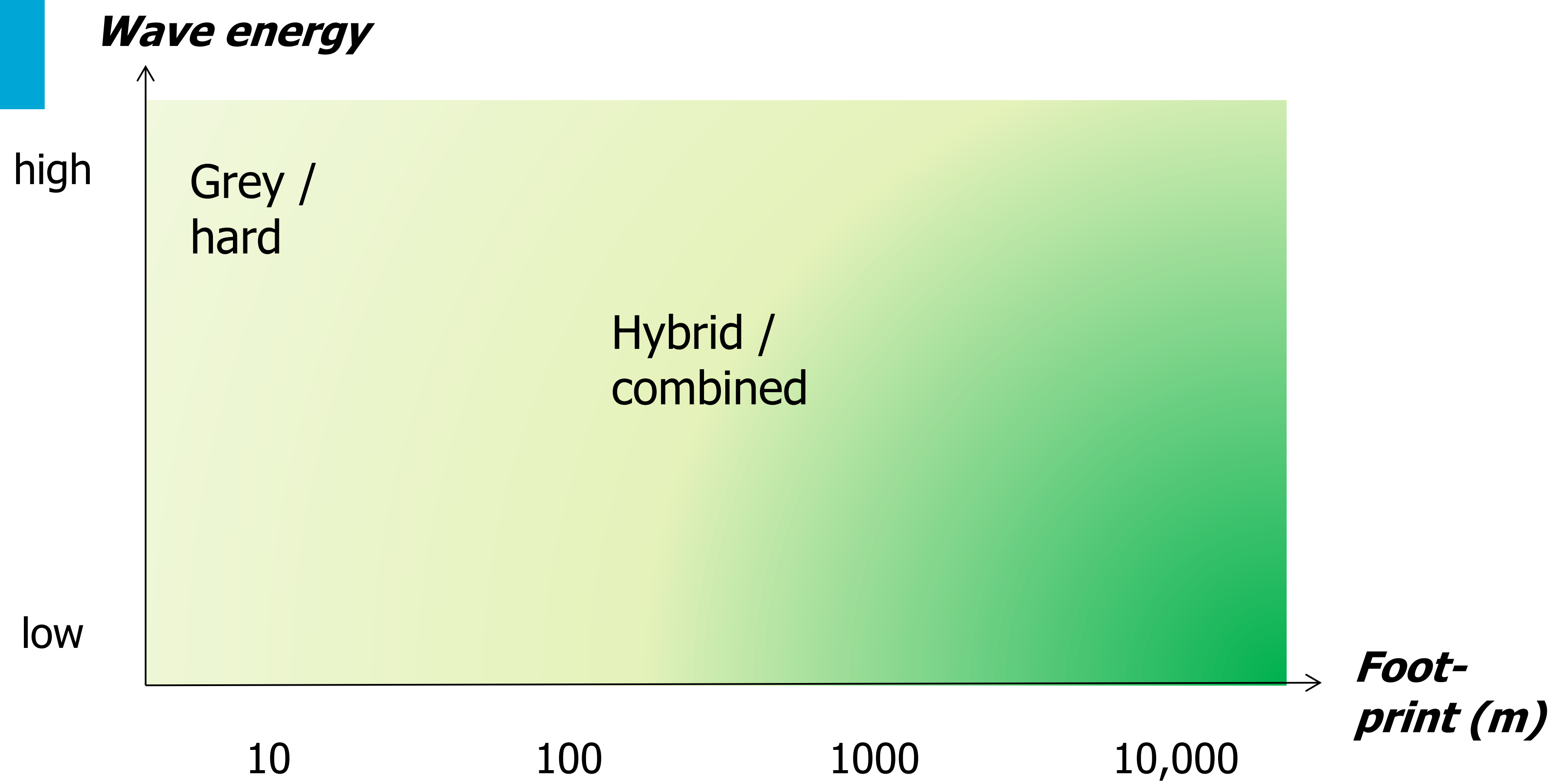
Solutions

- Conventional nourishments and reinforcements
- Multifunctional solutions, e.g. parking garage in sea dike
- Nature based flood defences



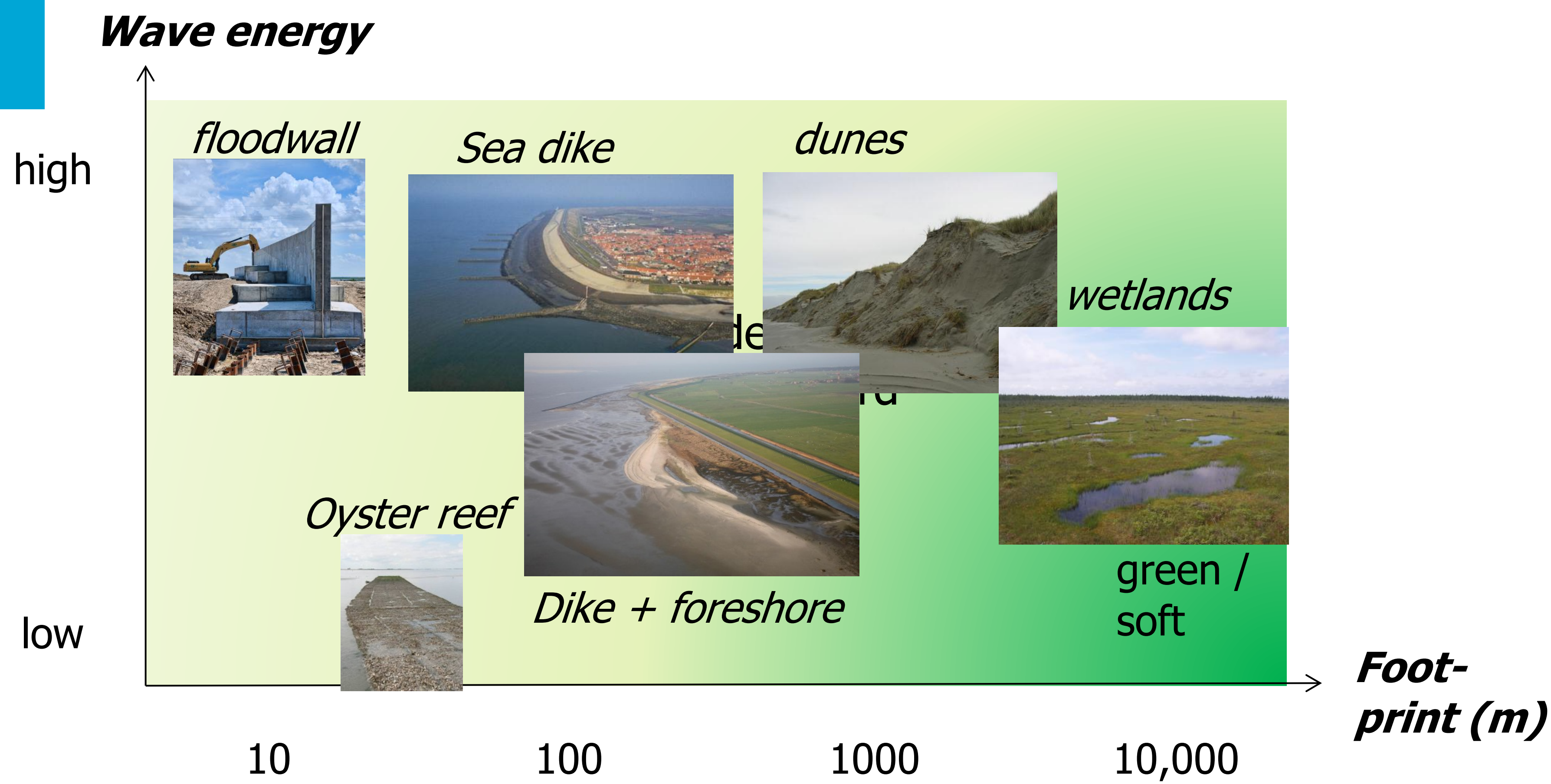
Hybrid defence (fortified dune)

Measures & solutions



Based on de Vriend et al., 2014; van Wesenbeeck, nd

Measures & solutions



Based on de Vriend et al., 2014; van Wesenbeeck, nd

Large-scale sand nourishments

Vegetated foreshores


Houtribdijk (NL)

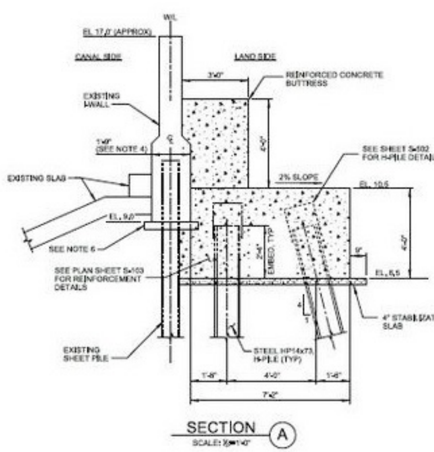

Prins Hendrikzanddijk (Texel, NL)


Emmanuelpolder, Westernscheldt (NL)

Delta design: civil engineers and architects

Source: One architecture and urbanism

Source: Dionisio Gonzalez



Challenge the future

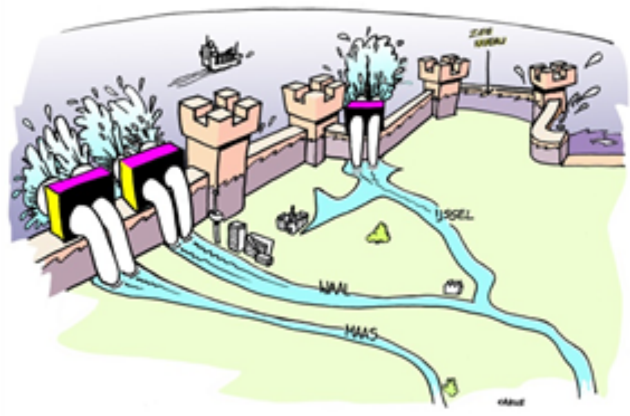
Delta Futures Lab

Fostering urbanising deltas as sources of social, ecological & economic prosperity

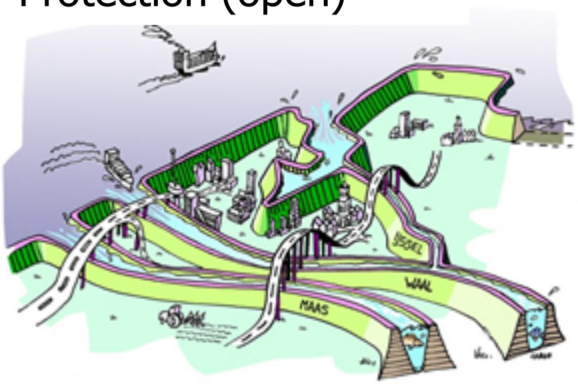
The Delta Futures Lab is an education and research network for MSc-students with the ambition to become interdisciplinary

Long-term options

Protection (closed)



Protection (open)



Seaward expansion

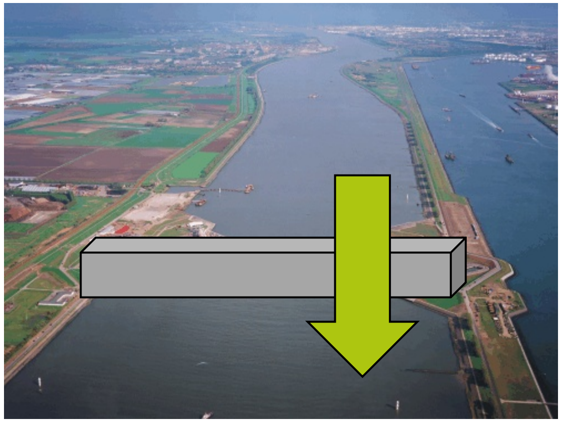
Accommodate

source: Deltares

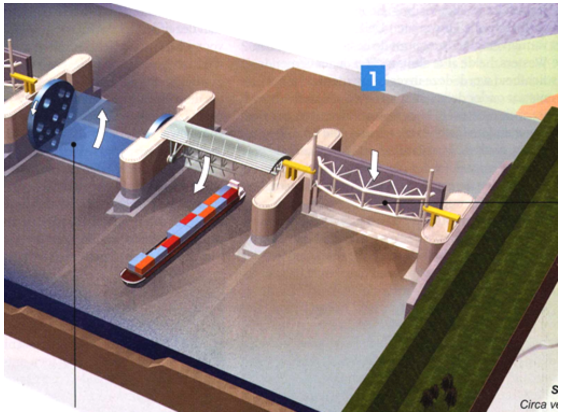
5 meter sea level rise

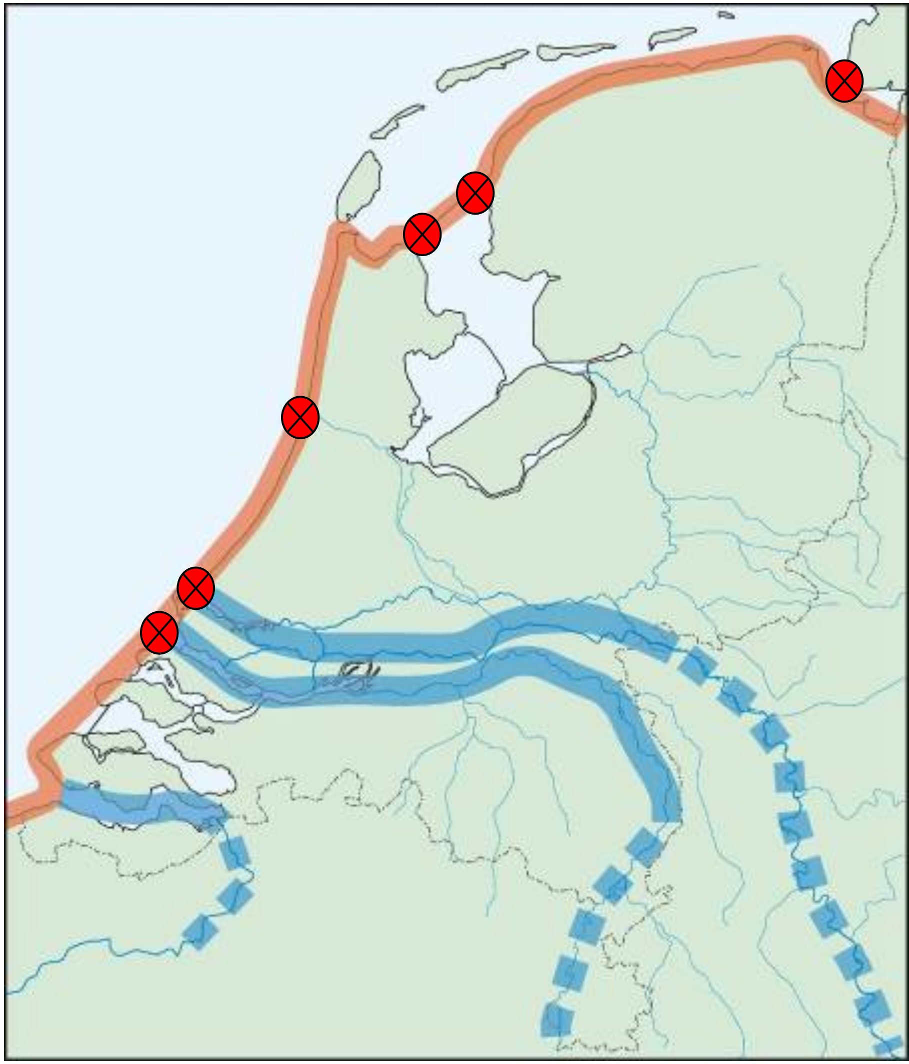
Mega-nourish-ments (>100Mm³)

Dam + mega pumps

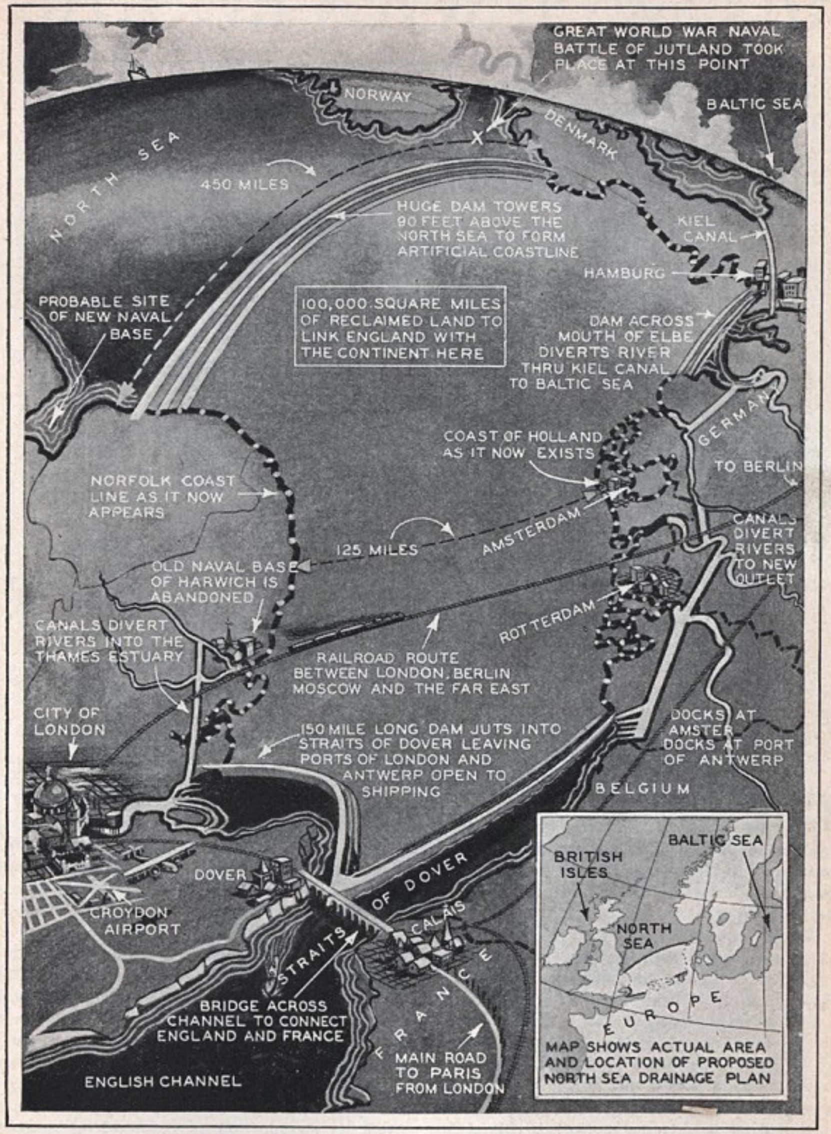


Westerschelde-barrier + pumps





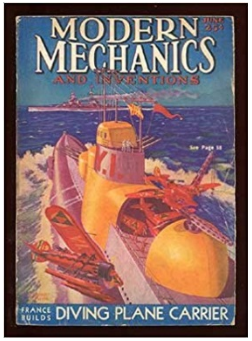
North Sea Drainage Project to Increase Area of Europe

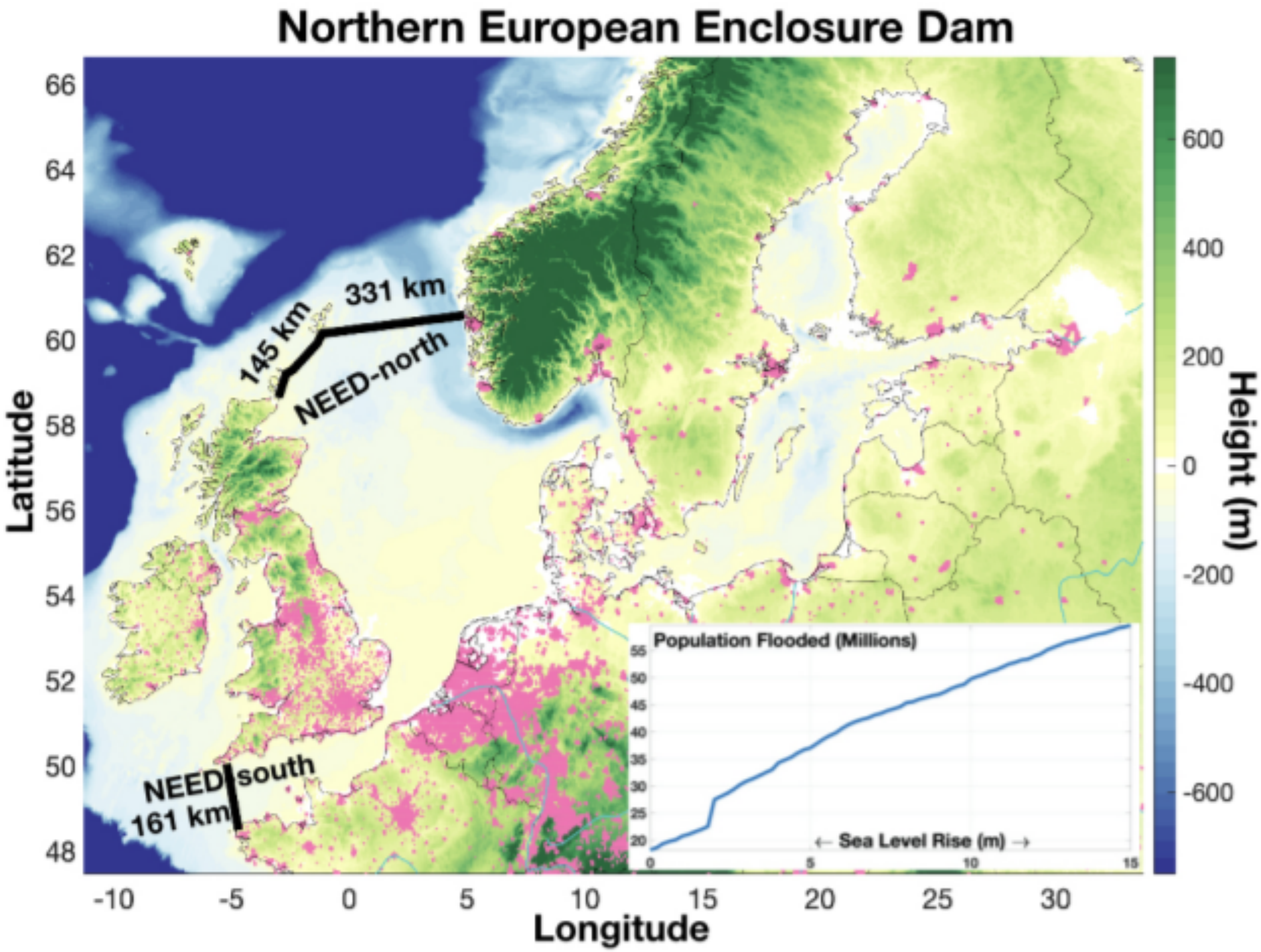


If the extensive schemes for the drainage of North Sea are carried out according to the plan illustrated above, which was conceived by a group of eminent English scientists, 100,000 square miles will be added to the overcrowded continents of Europe. The reclaimed land will be walled in with enormous dykes, similar to the Netherland dykes, to protect it from the sea, and the various rivers flowing into the North Sea will have their courses diverted to different outlets by means of canals.

Inventions for September 169

Source:

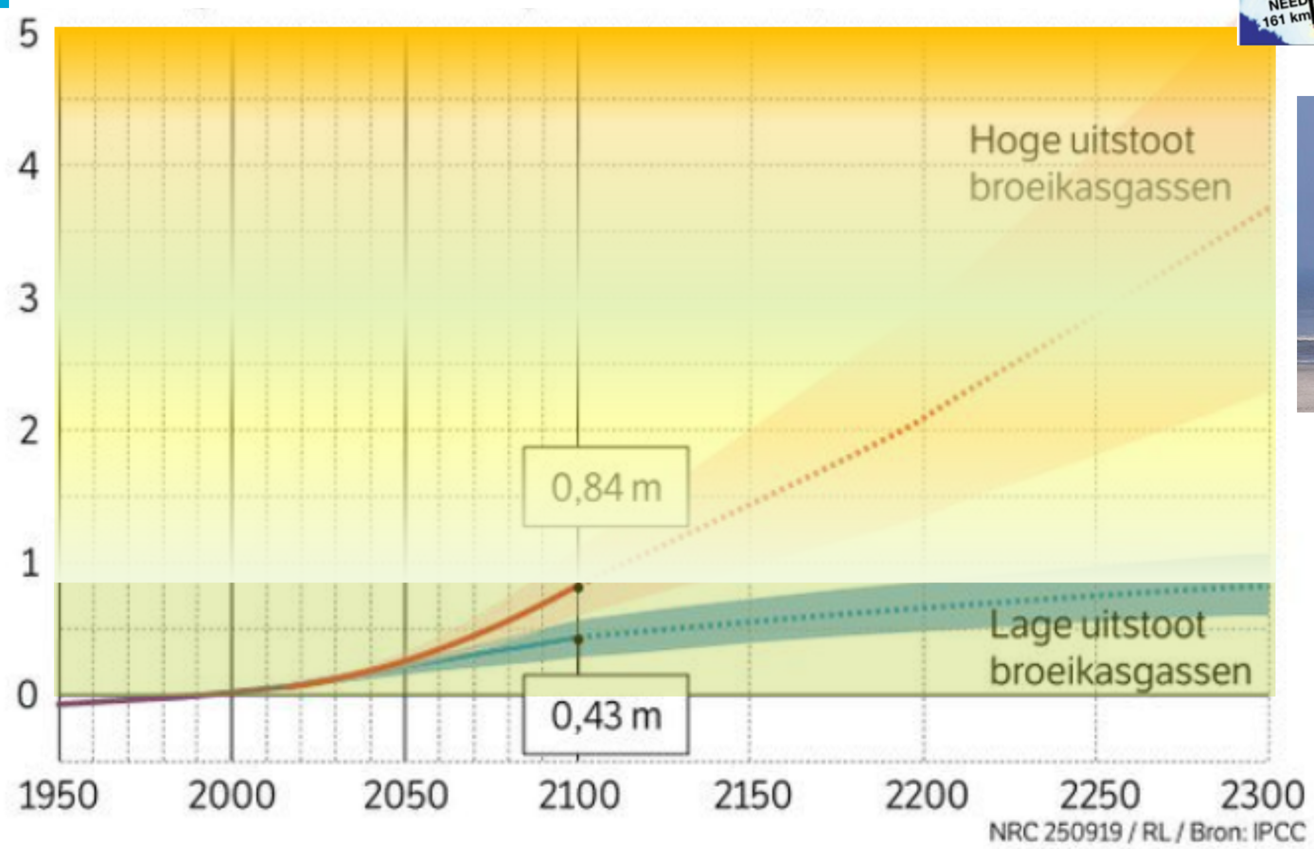


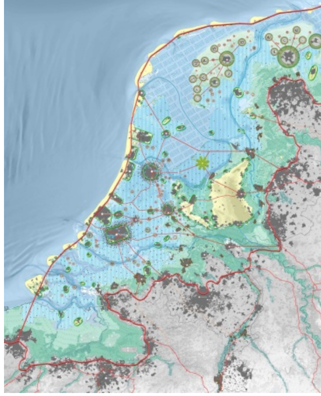


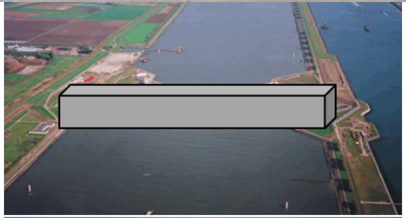
Groeskamp (NIOZ) and Kjellson (2020)

Costs: 250 – 550 B$

Recap: adaptation to SLR





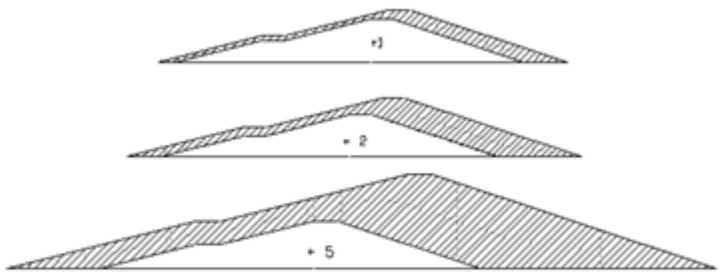


Costs and safety standards

- Current annual expenses 1 billion Euro (~0.14% of GDP)
- Additional billion needed up to 2m of SLR
- Lower the protection if:

  Δ costs > Δ economy

  (1~2% per year)
- Other factors: disasters & investments



Jonkman et al., 2013

Decision and construction time

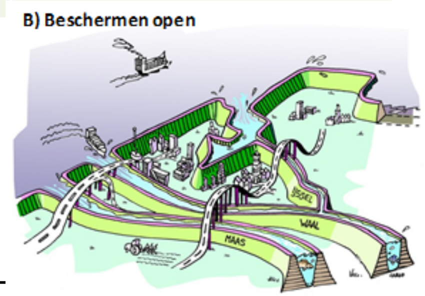
 

	Delta plan (1953 – 1997)	New Orleans (2005 - 2012)
Decision time (+ permitting)	5	1
Engineering and design	parallel	1 – 3
Construction time	30	5
System investment	12 B€	14 B$

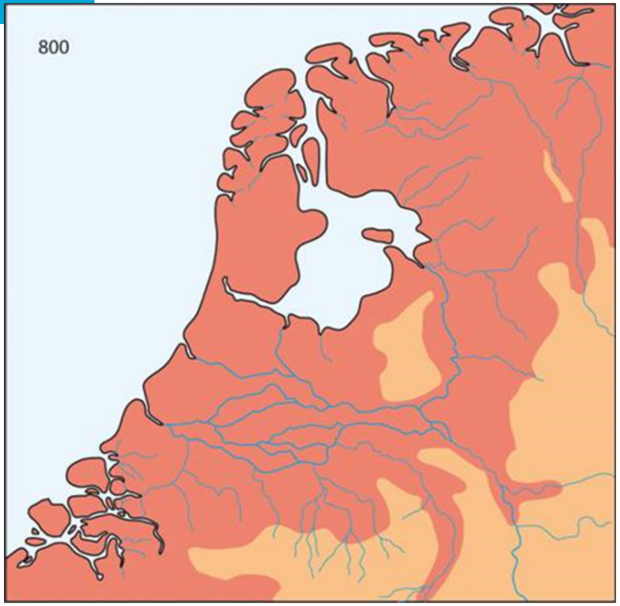
 

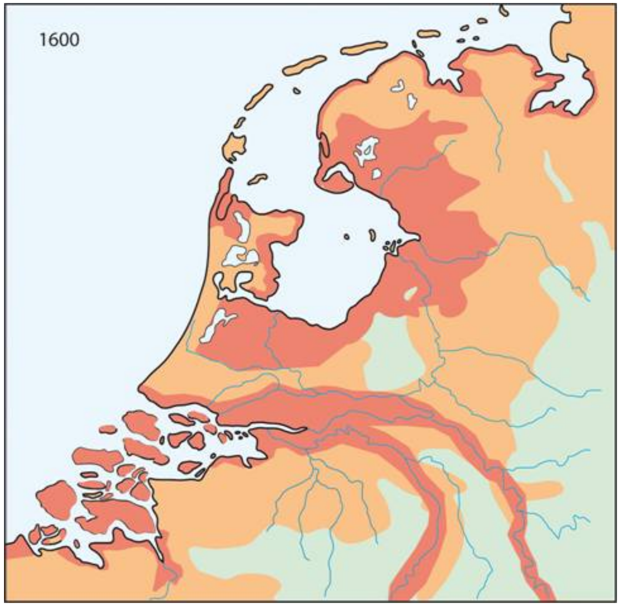
Decision and construction time

	Delta plan (1953 – 1997)	New Orleans (2005 - 2012)	Future delta plan?
Decision time (+ permitting)	5	1	> 20
Engineering and design	continuous	1 – 3	5 - 10
Construction time	30	5	> 10
System investment	12 B€	14 B$	……



Adaptation past centuries



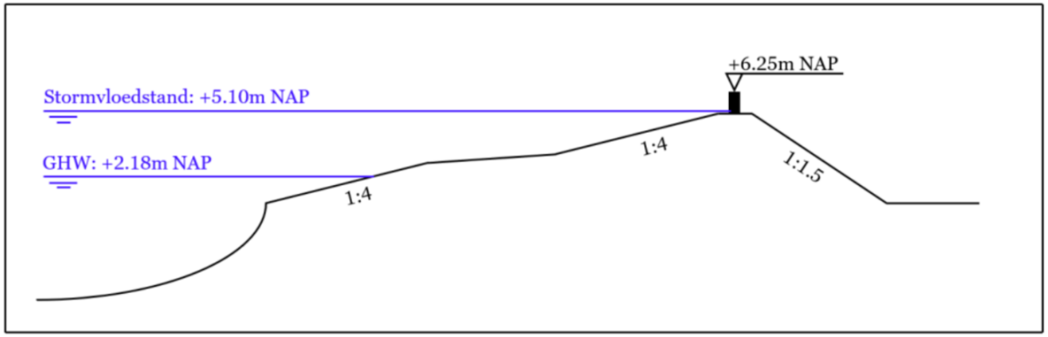


Kok et al. 2008

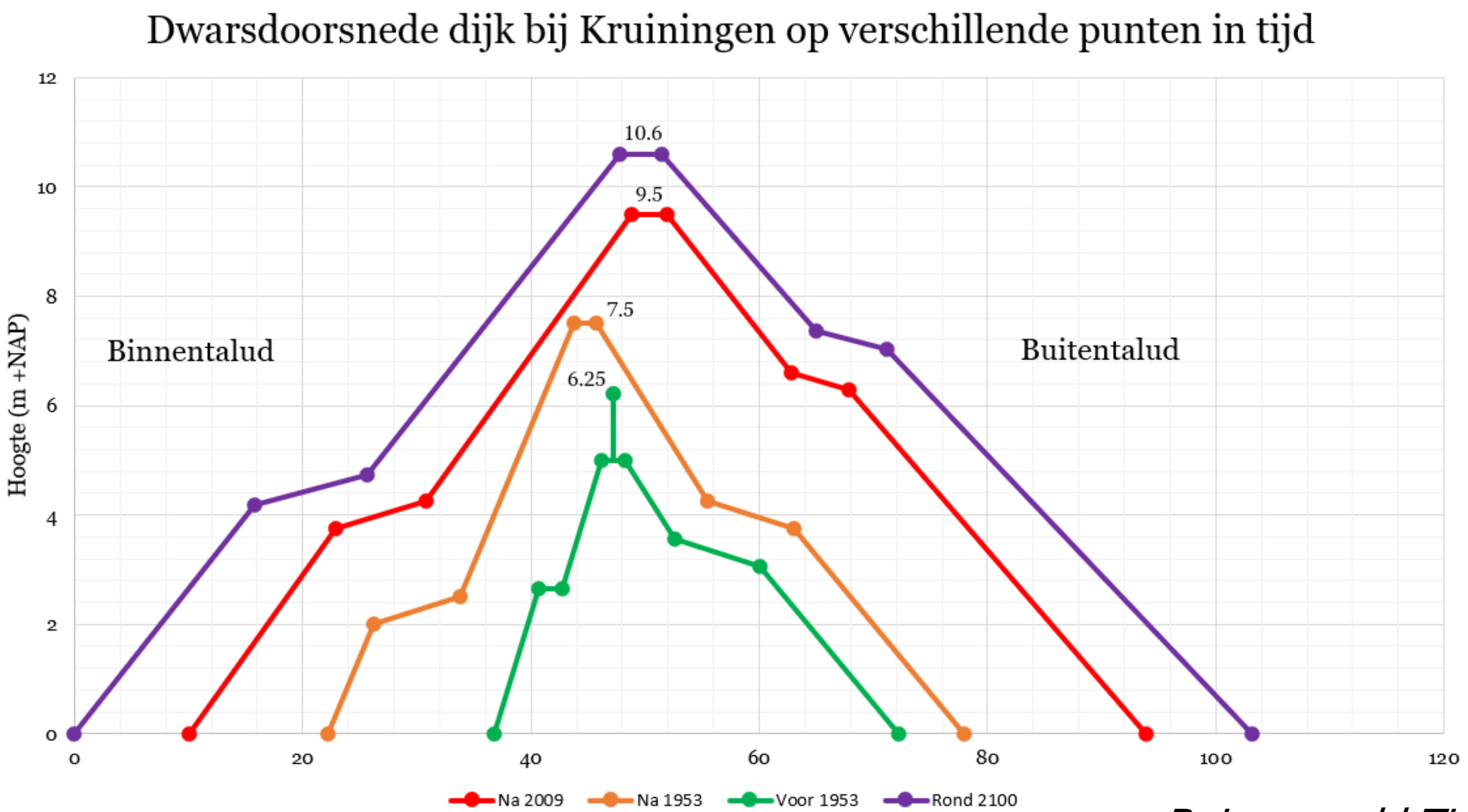
:

uncontrolled some managed

Adaptation since 1953



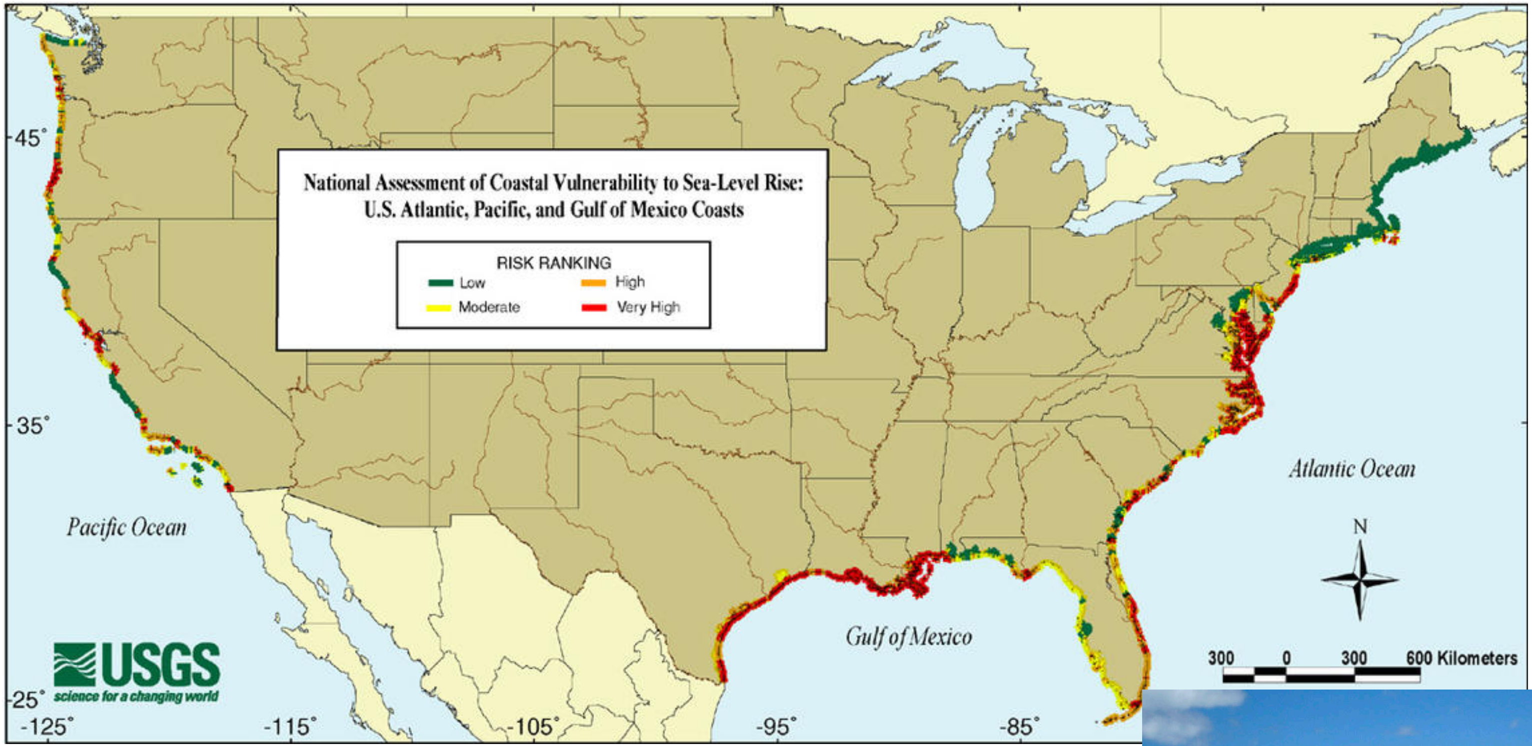
Adaptation since 1953 (2)



B. Langeveld TUD

International situation is different

US vulnerability to sea level rise



https://www.usgs.gov/media/images/coastal-vulnerability-sea-level-ri

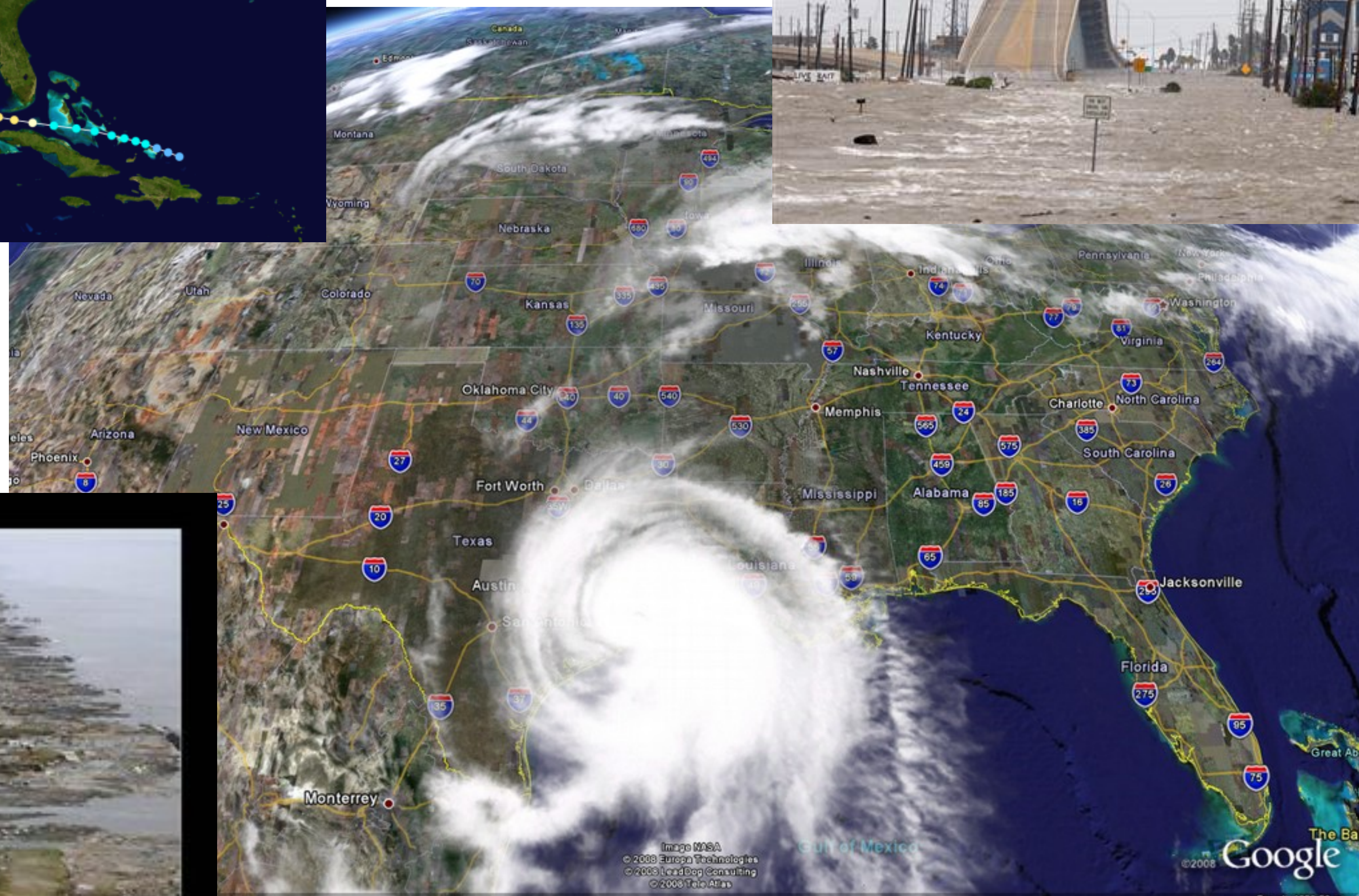
Julie G via Flickr.

US examples

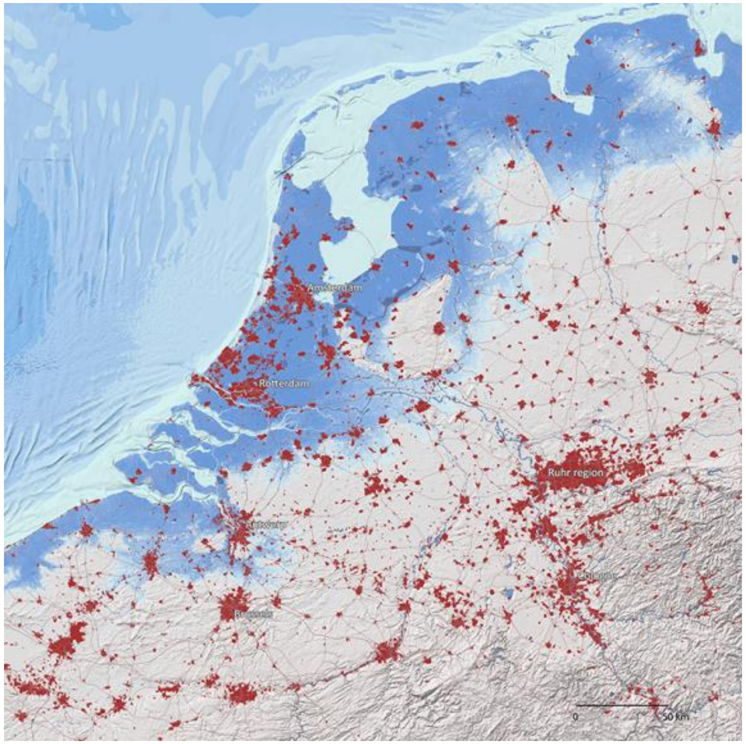
Katrina (2005), New Orleans

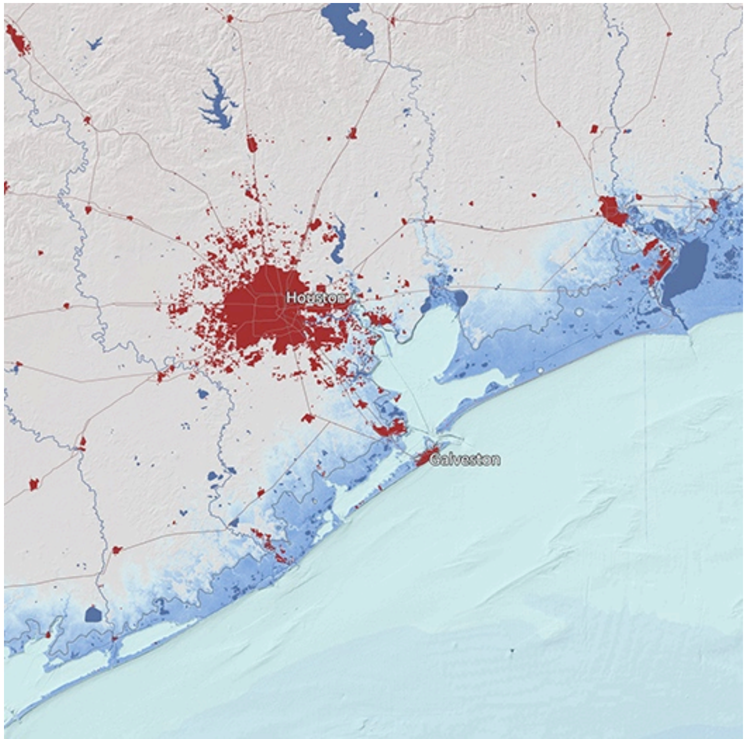
Sandy (2012), New York

Hurricane Ike (2008)



Comparison: Texas & the Netherlands





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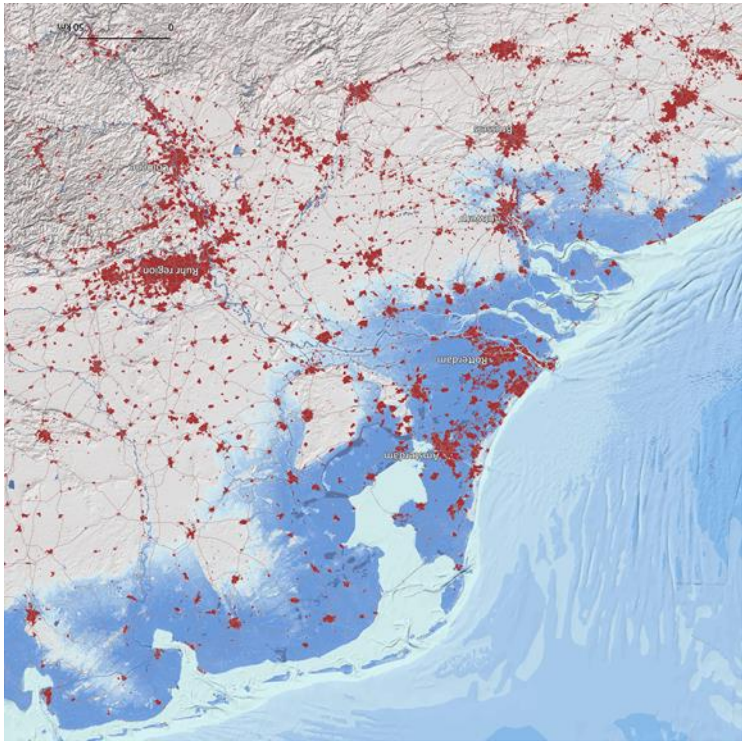
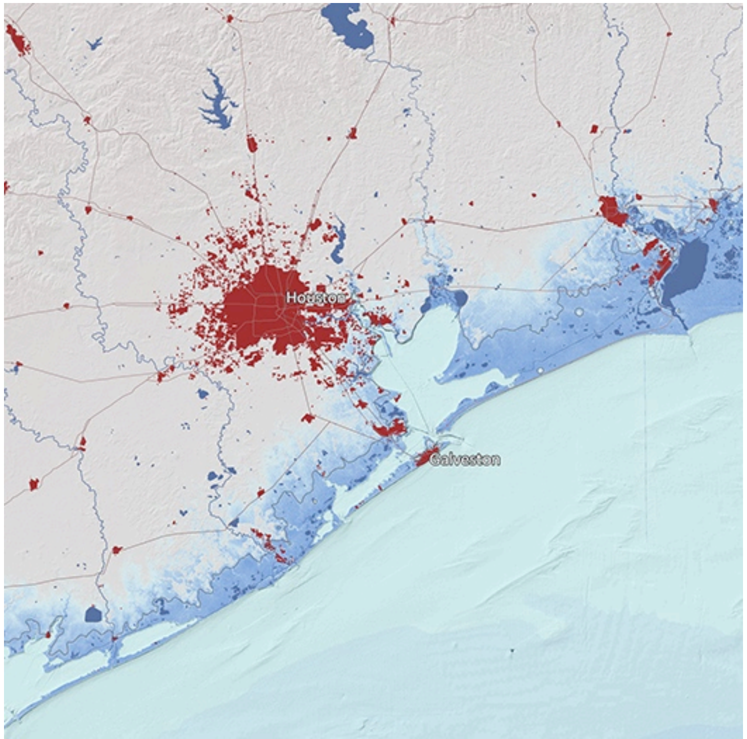
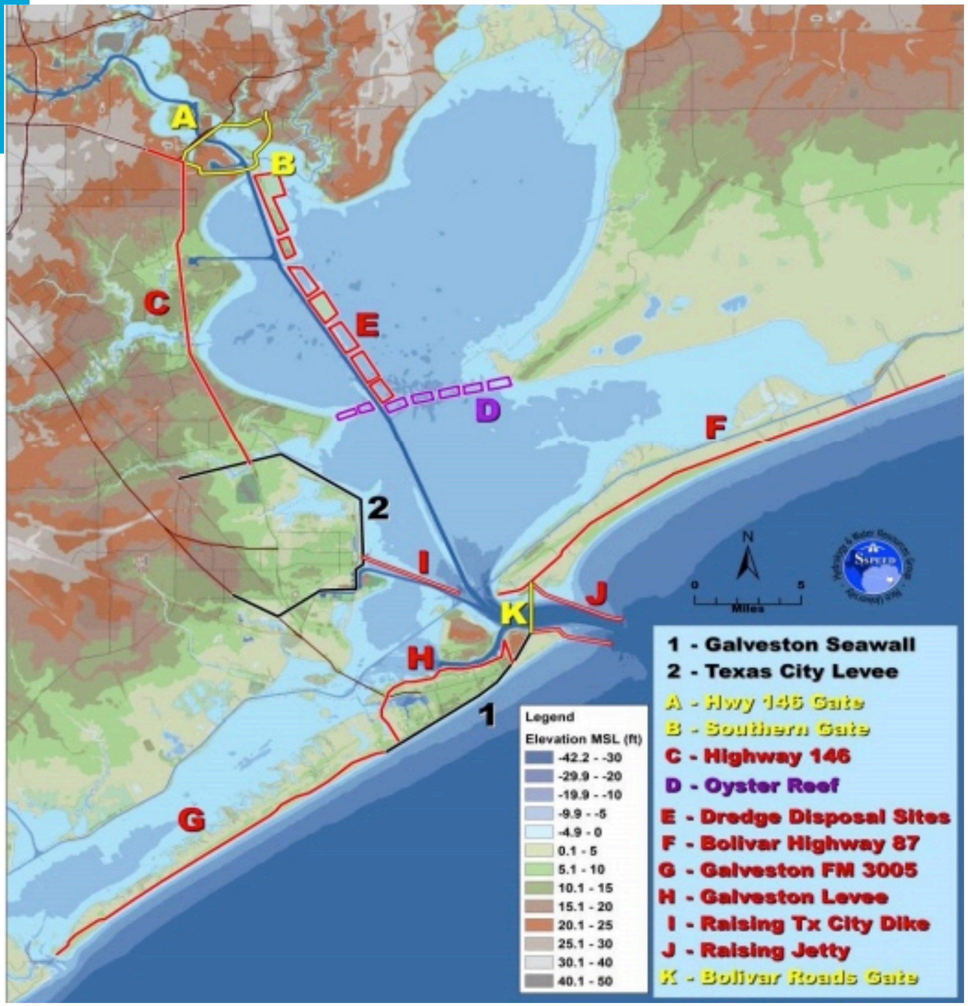
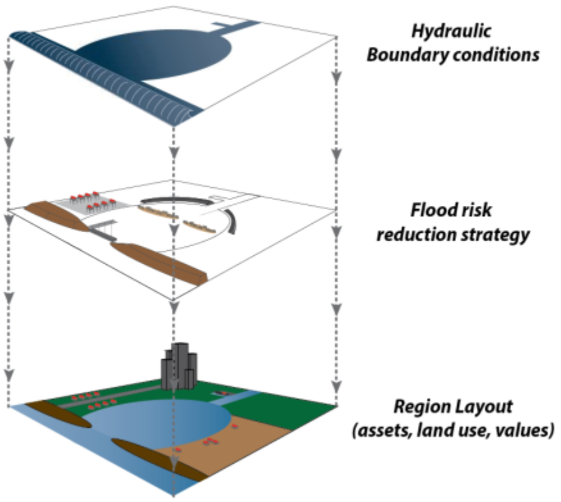
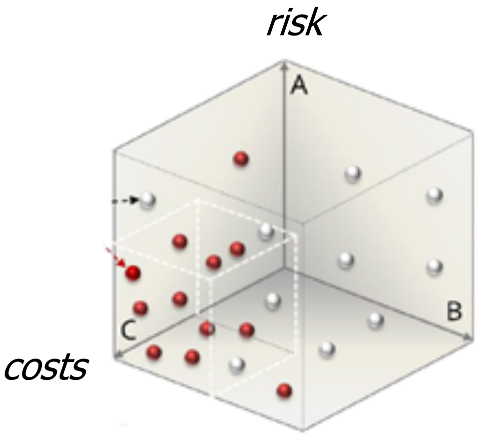




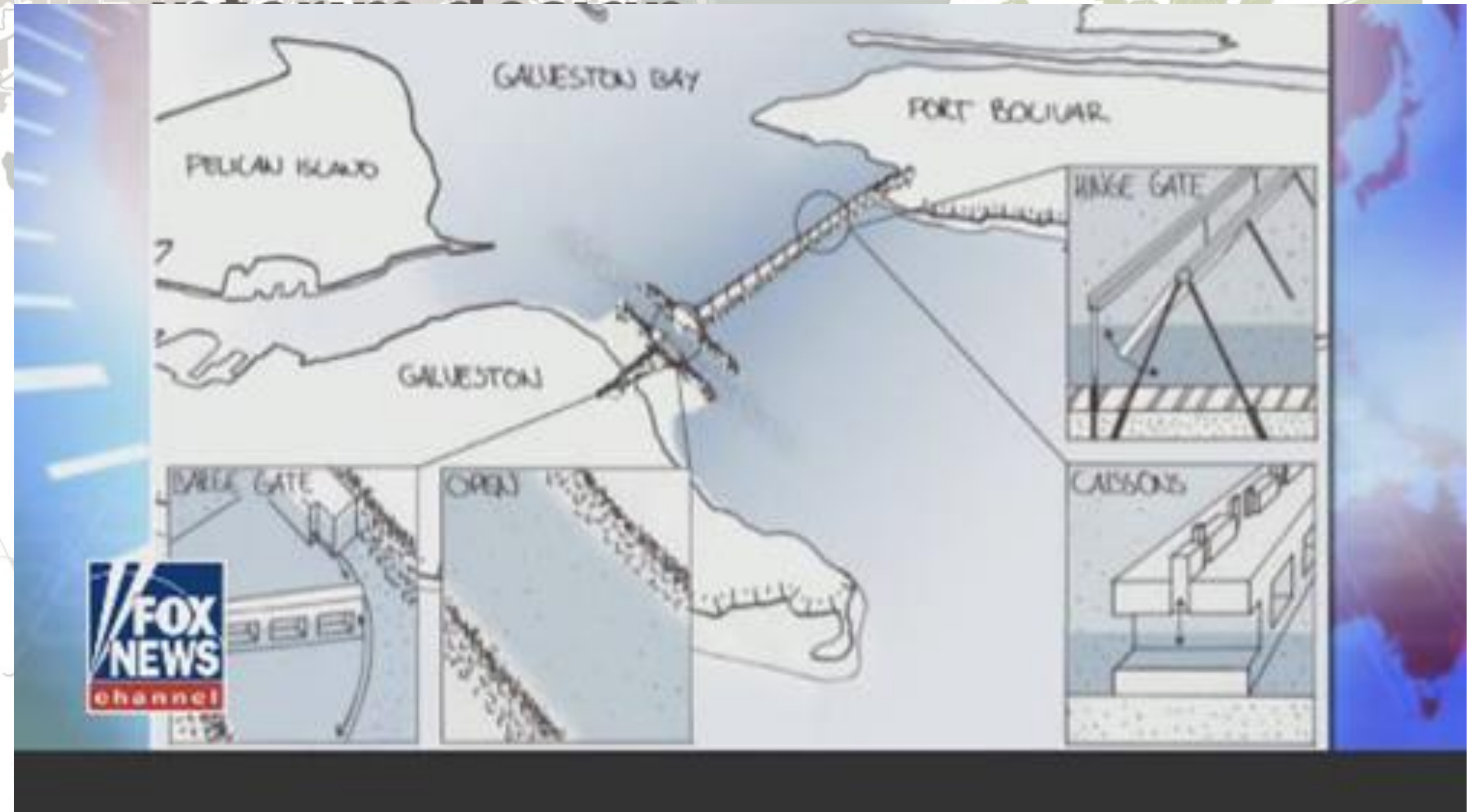
Flood risk reduction strategies





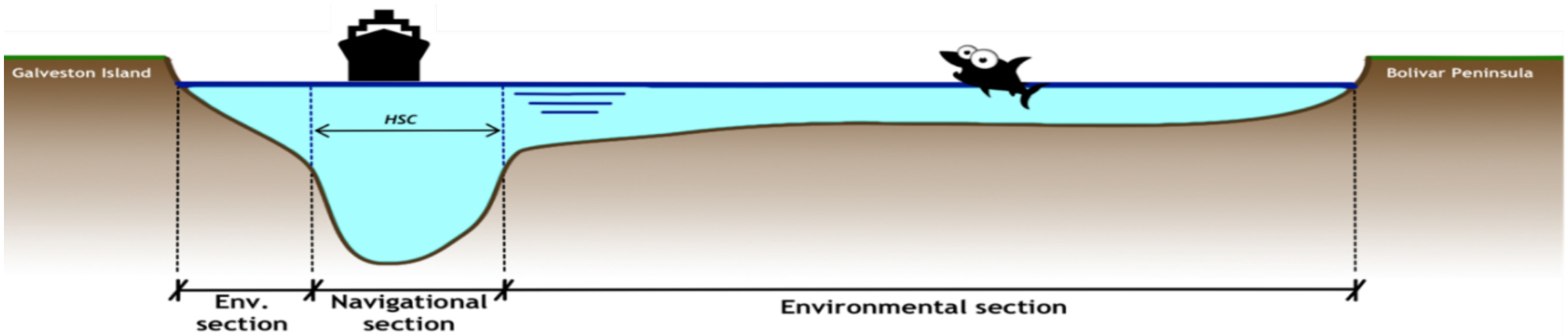


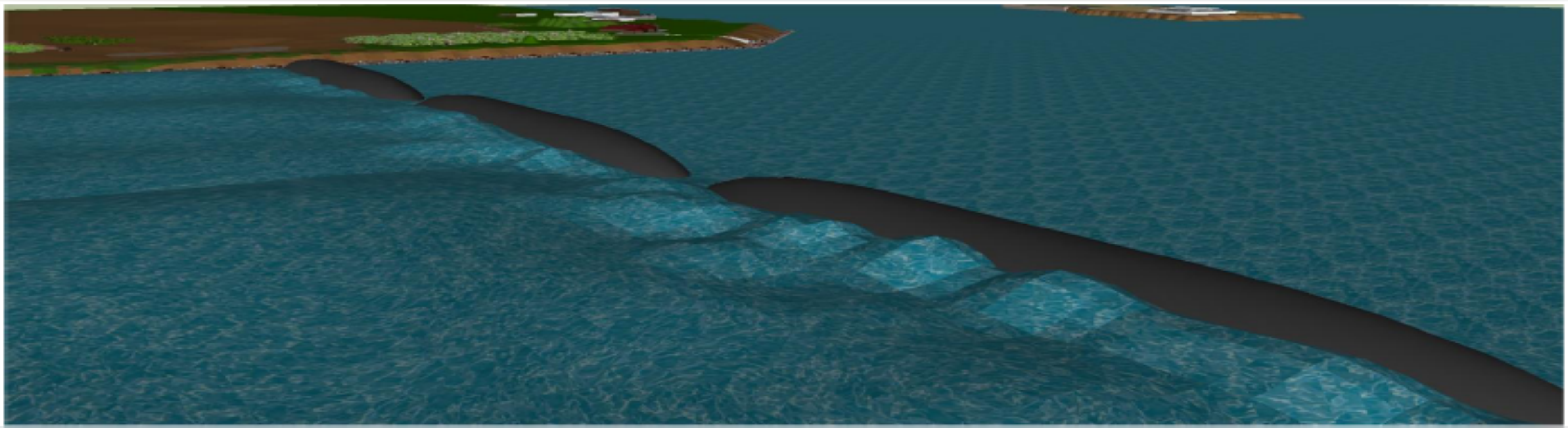
Coastal spine system



http://texascoastgeology.com/passes/bolivarroads.html

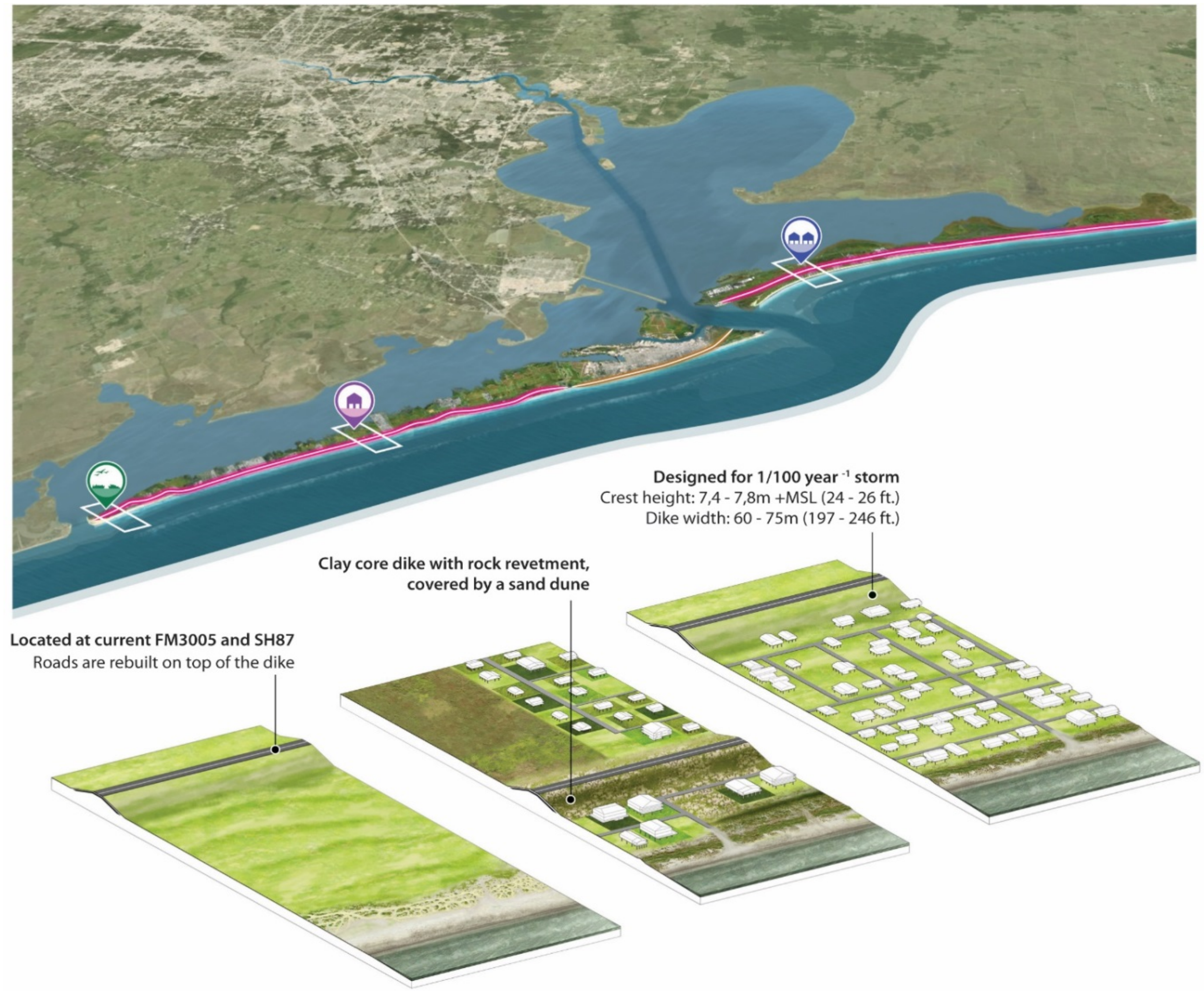
Bolivar Roads barrier

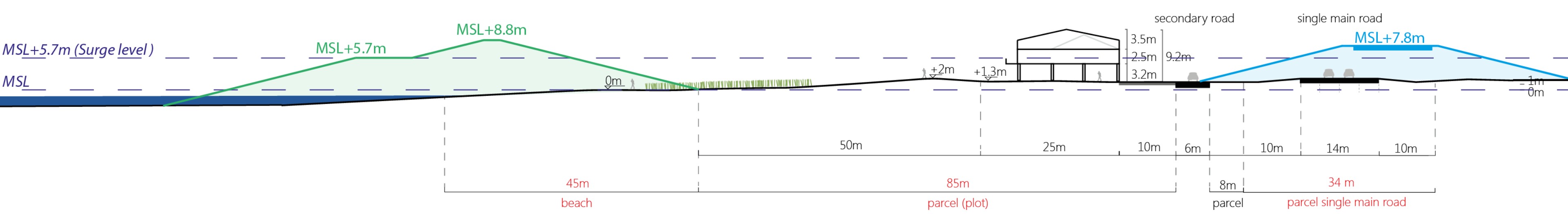




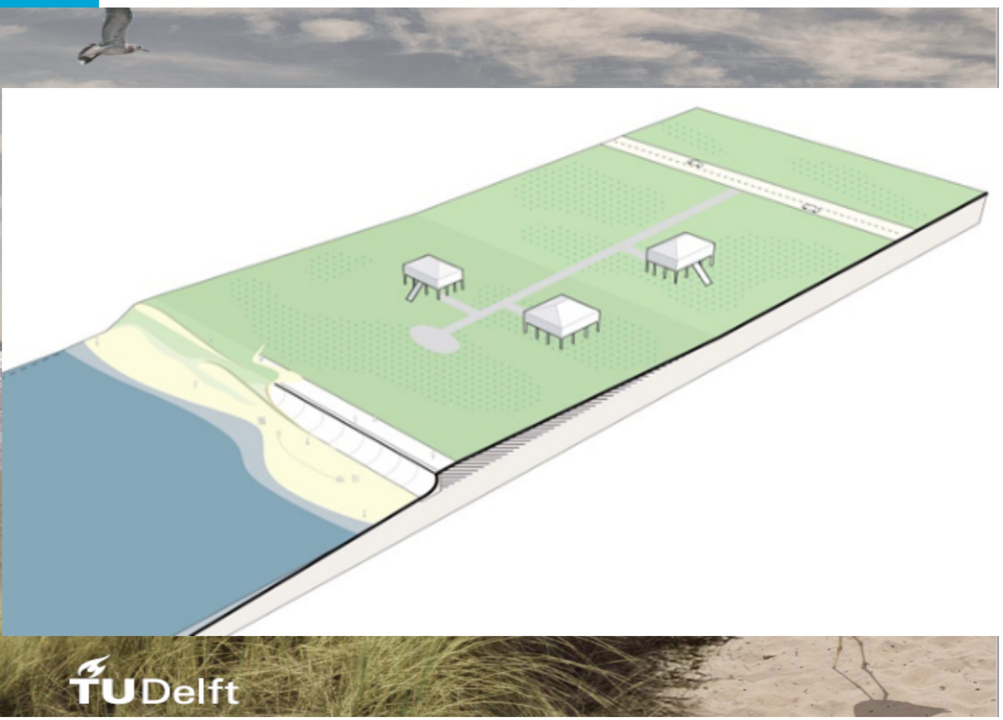

West of Galveston Sea Wall

Galveston Island - Land barrier design

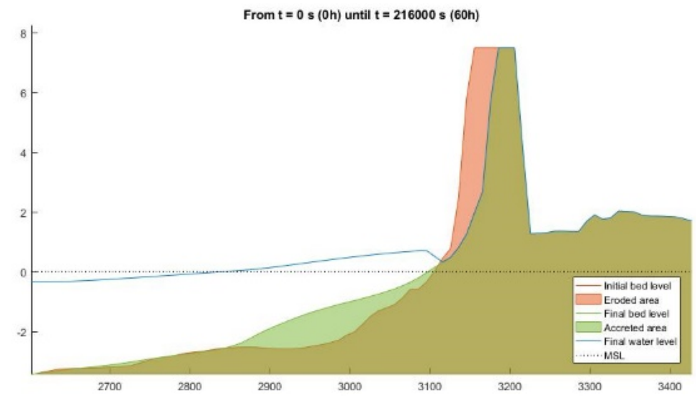




Dune design (Luis Rodriguez Galvez)



X beach modelling and iterative design



Cost estimate: 3 – 5 B$

Required maintenance dredging

Adaptation to sea level rise?

- Yes, we can! (in the Netherlands)
- Major effort, solutions available
- Planning needs decades (without disasters), start now

Next steps:

- Conceptual design of strategies for several meters of sea level
- Linking with other transitions and change
- Integral design: Engineering, architecture, planning, ecology, governance……….

- International collaboration

TU Delft   Delta Futures lab

Questions / suggestions:

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