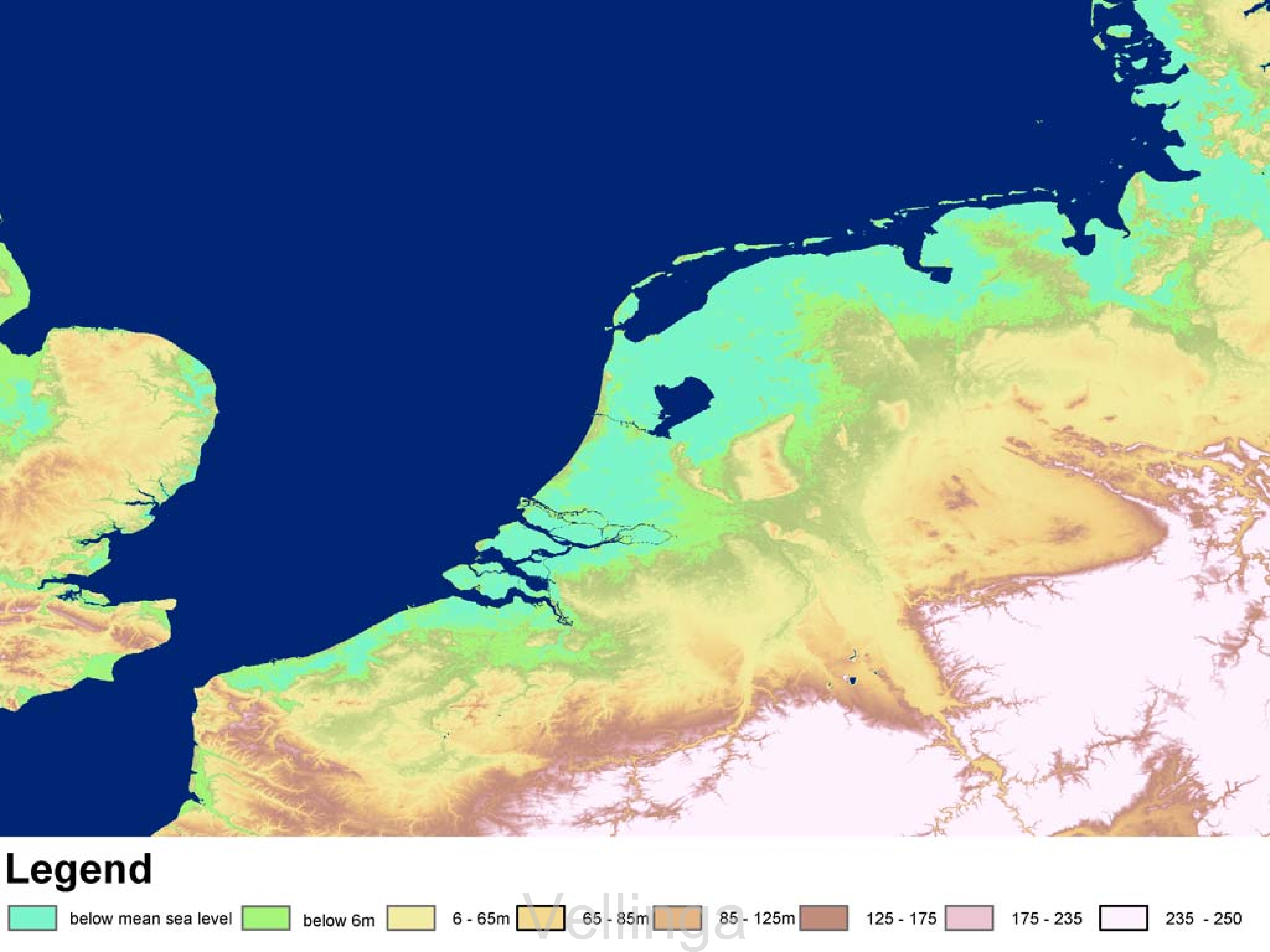
Adaptation of the Dutch Delta to a changing climate

UK-Netherlands Symposium on Coastal Defence and Flood Management

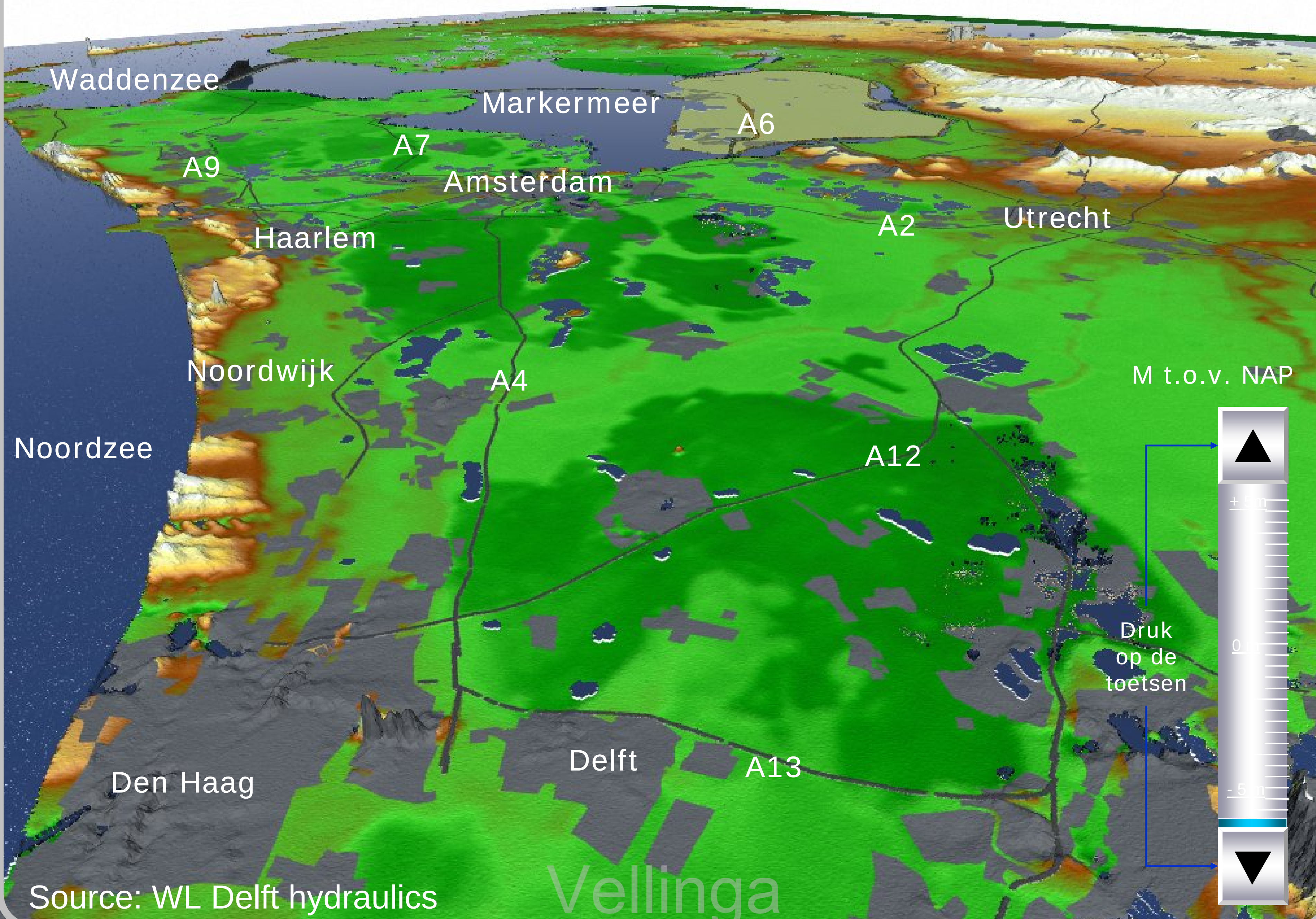
The Hague, October 9, 2007.

By prof. Pier Vellinga

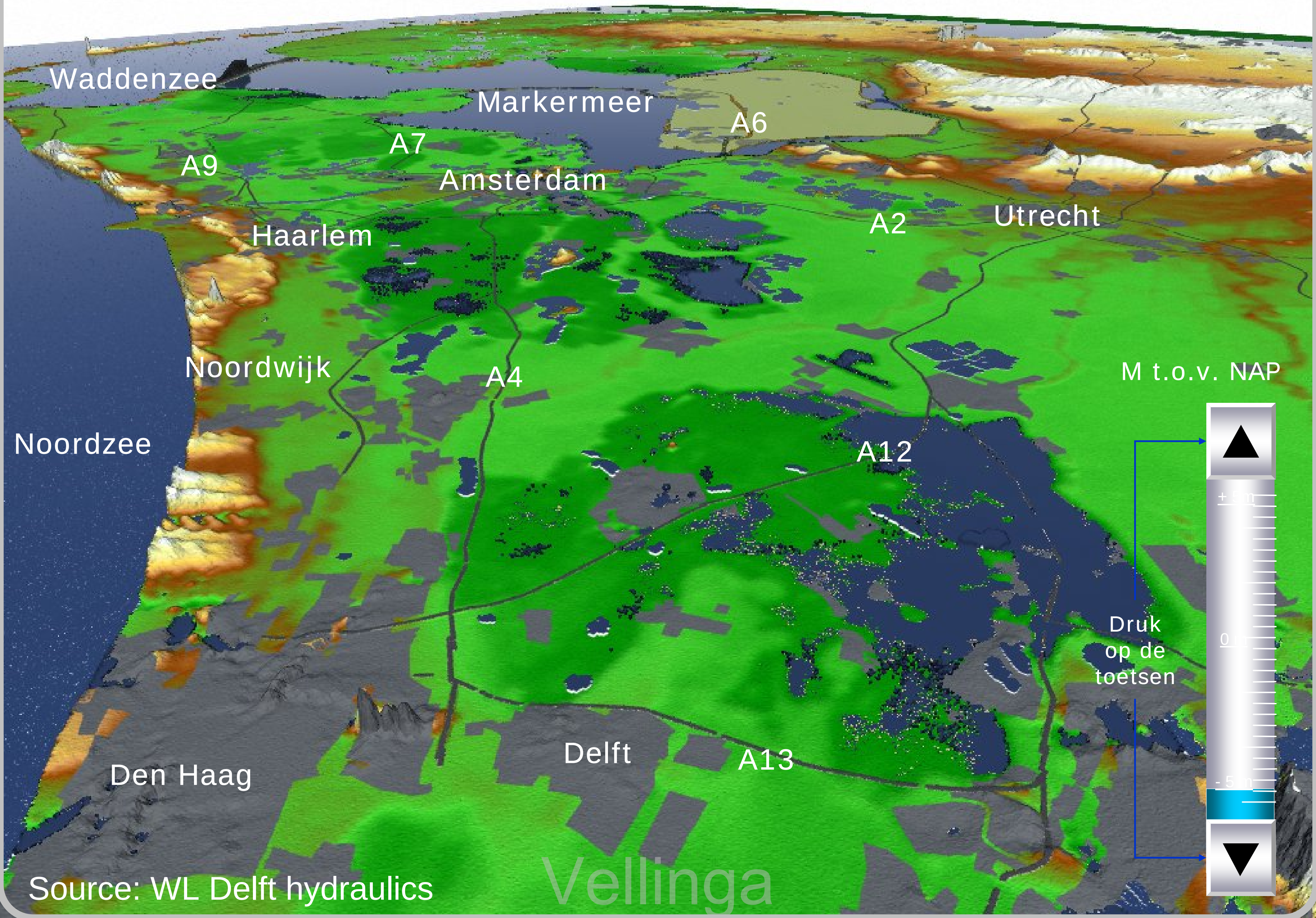
Director Climate Programme, Wageningen University and Director Climate Centre, Vrije Universiteit Amsterdam.


Legend
below mean sea level
below 6m
6 - 65m
65 - 85m
85 - 125m
125 - 175
175 - 235
235 - 250

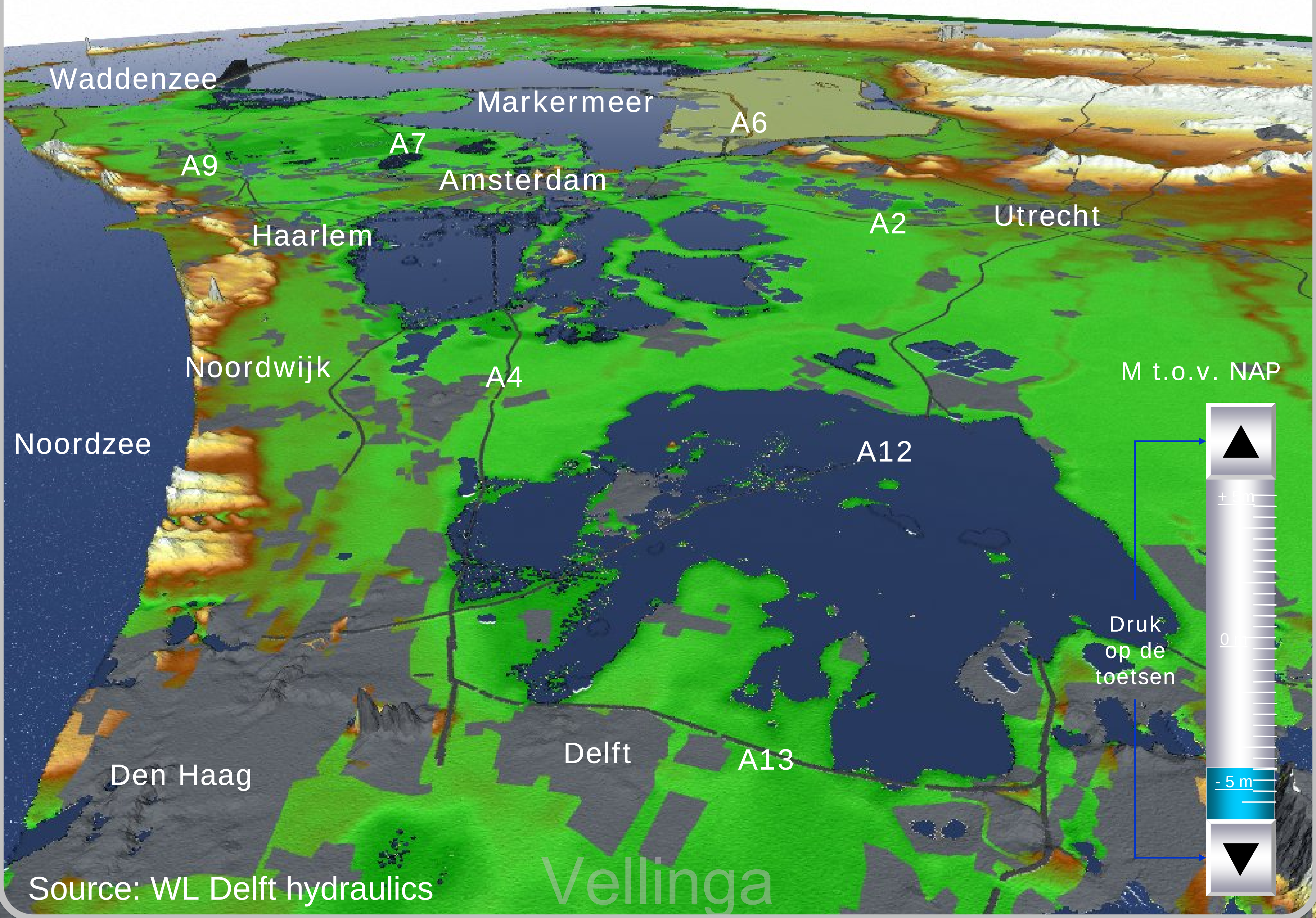
Flooded area at NAP -6.0 m



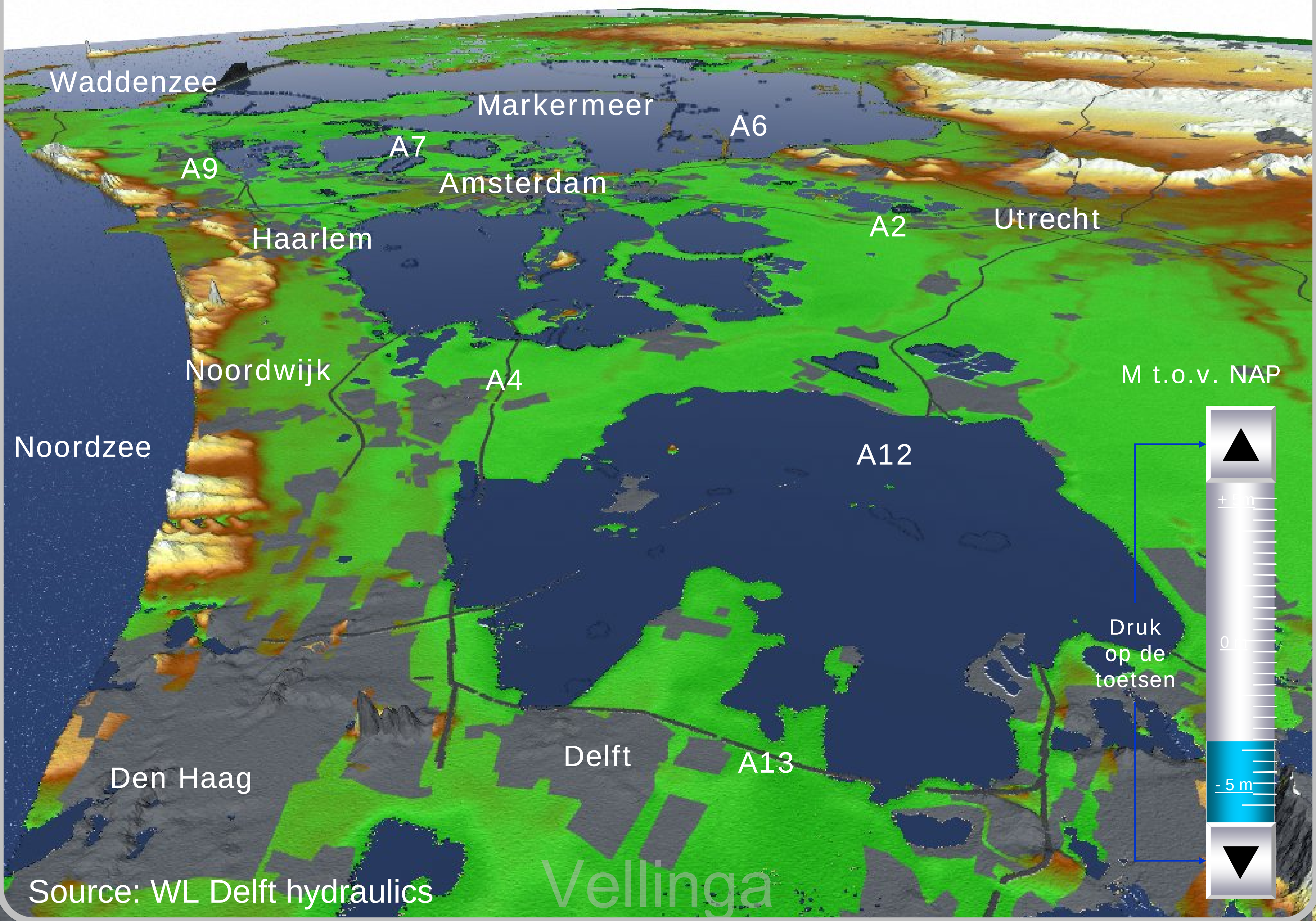
Flooded area at NAP -5.0 m



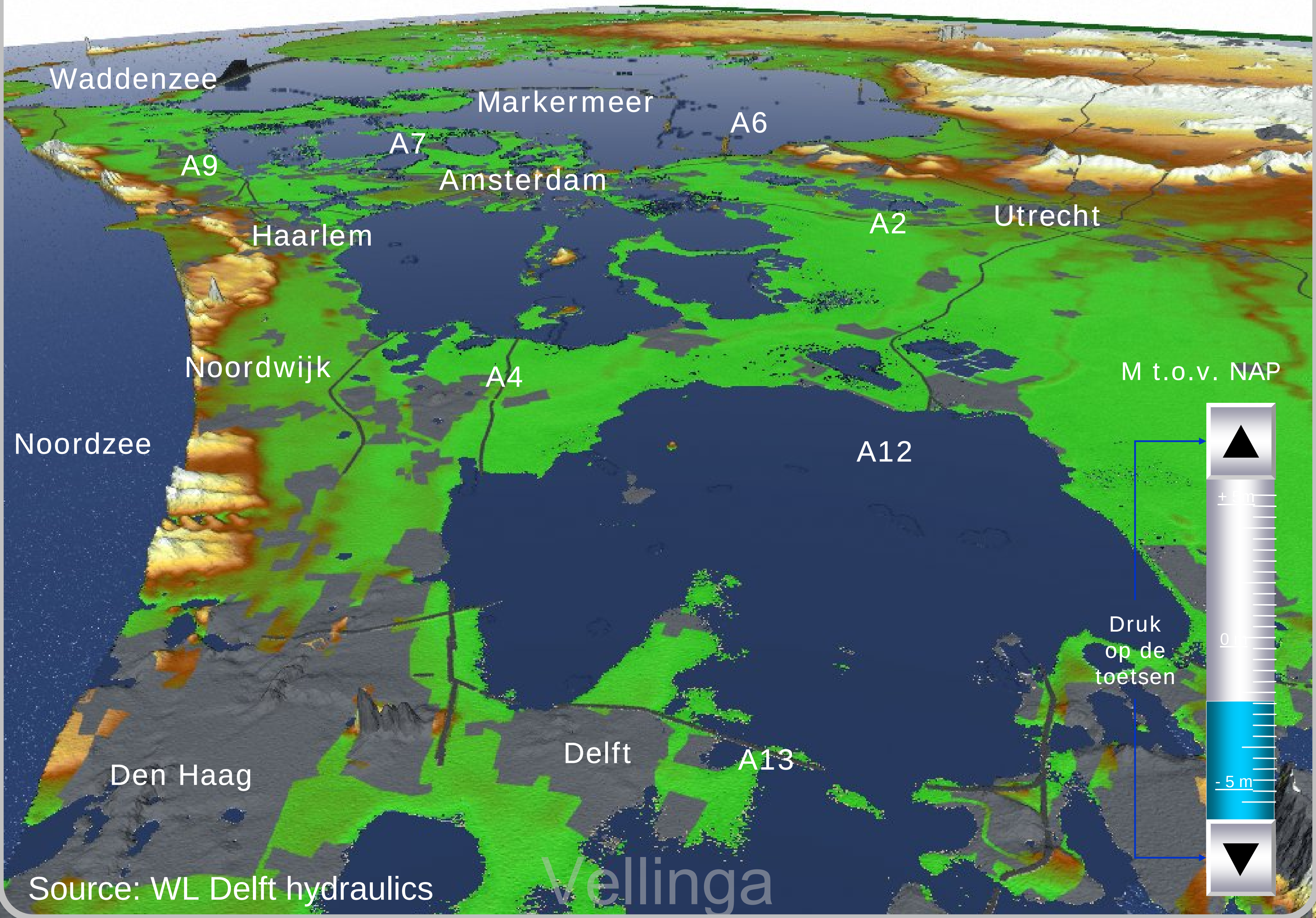
Flooded area at NAP -4.0 m



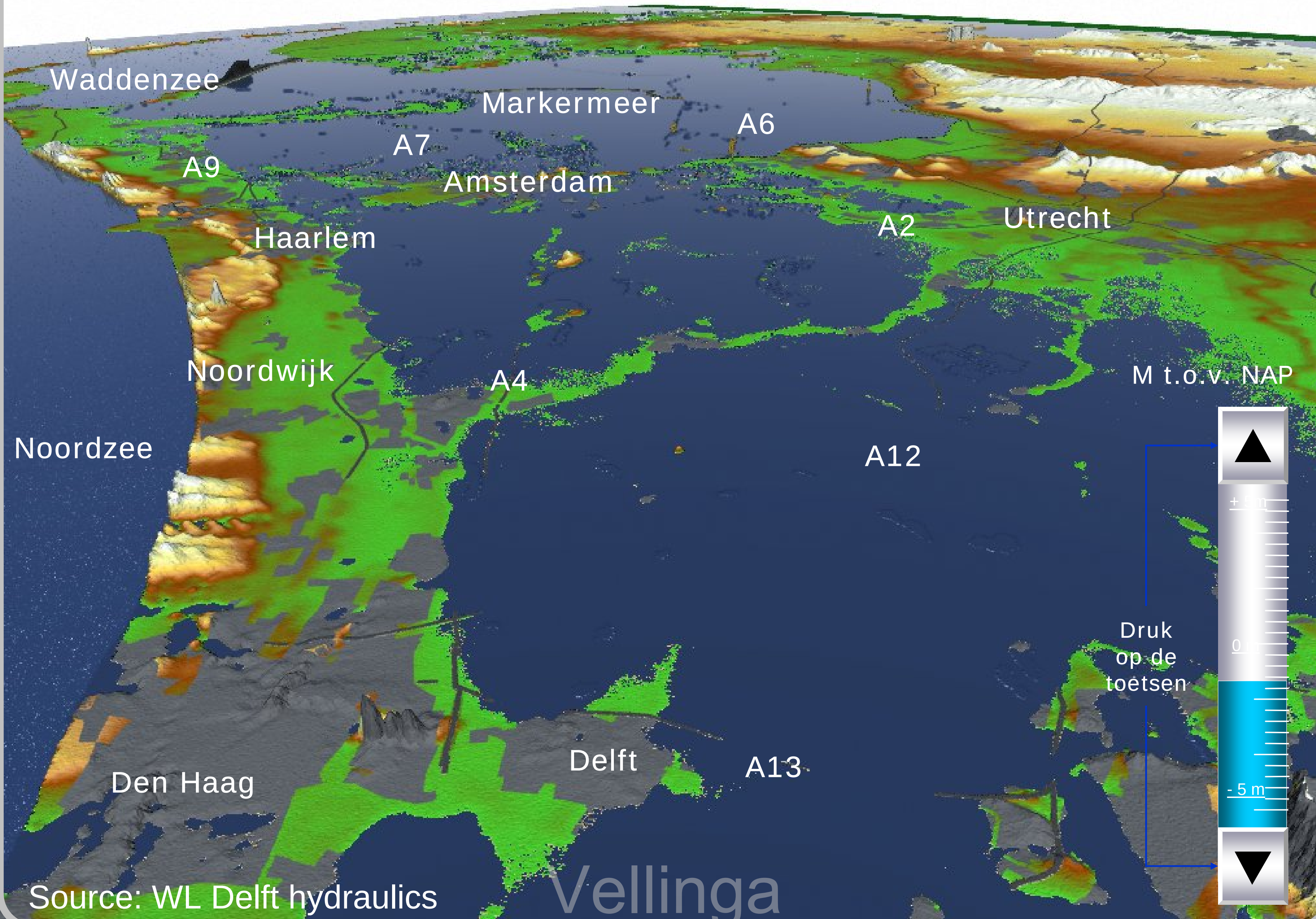
Flooded area at NAP -3.0 m



Flooded area at NAP -2.0 m



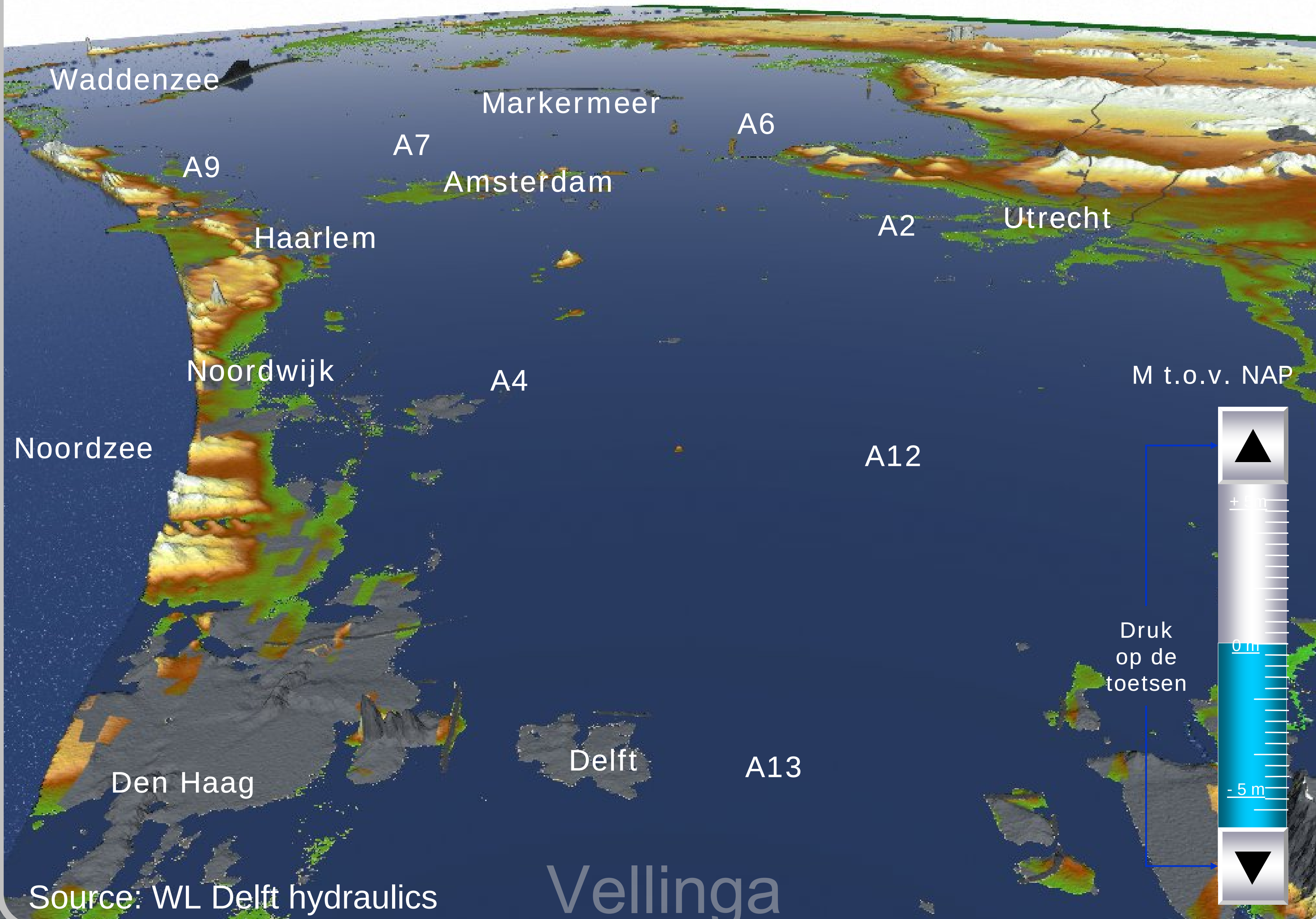
Flooded area at NAP -1.0 m



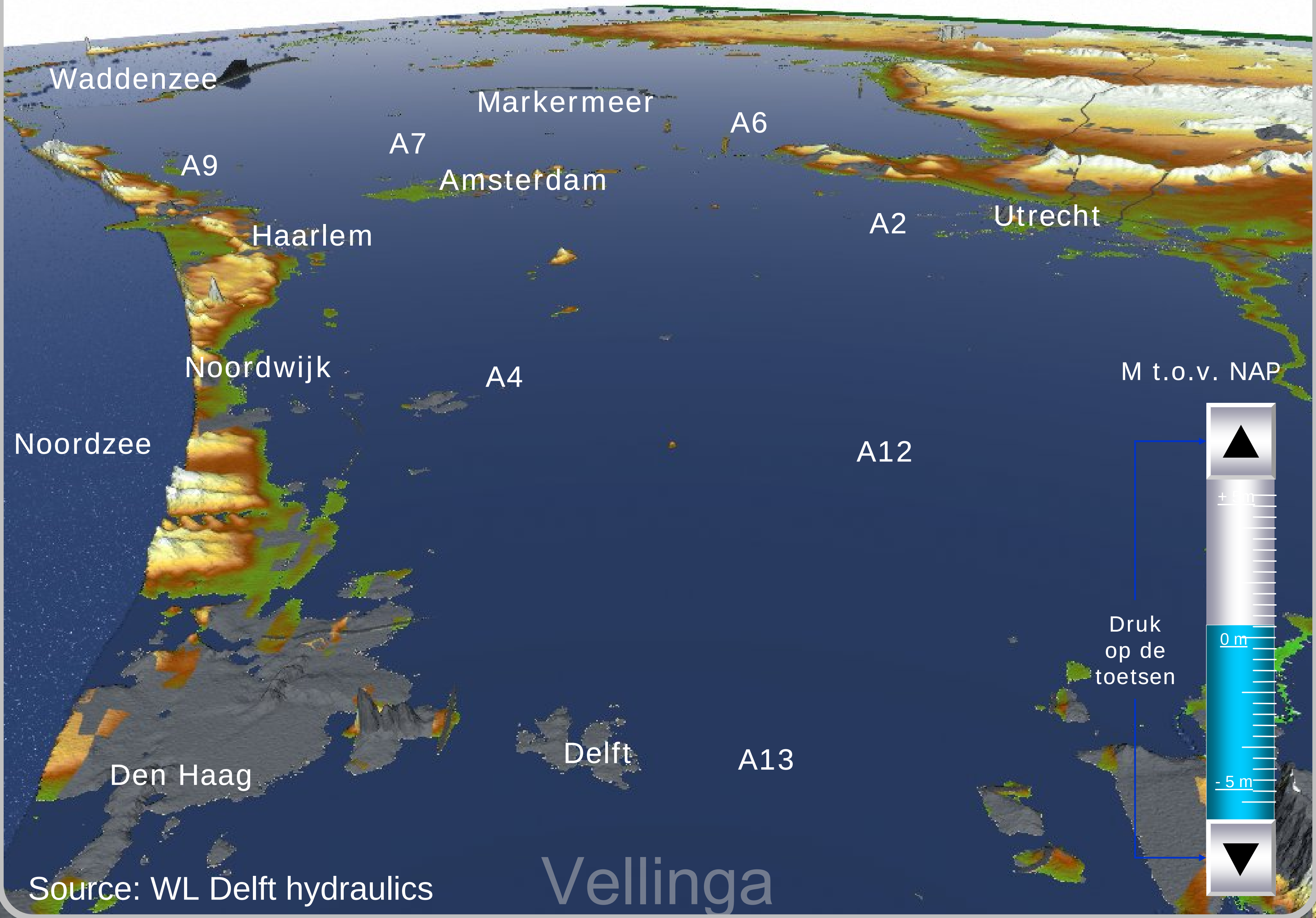
Flooded area at NAP

Source: WL Delft hydraulics

Flooded area at NAP +0.5 m

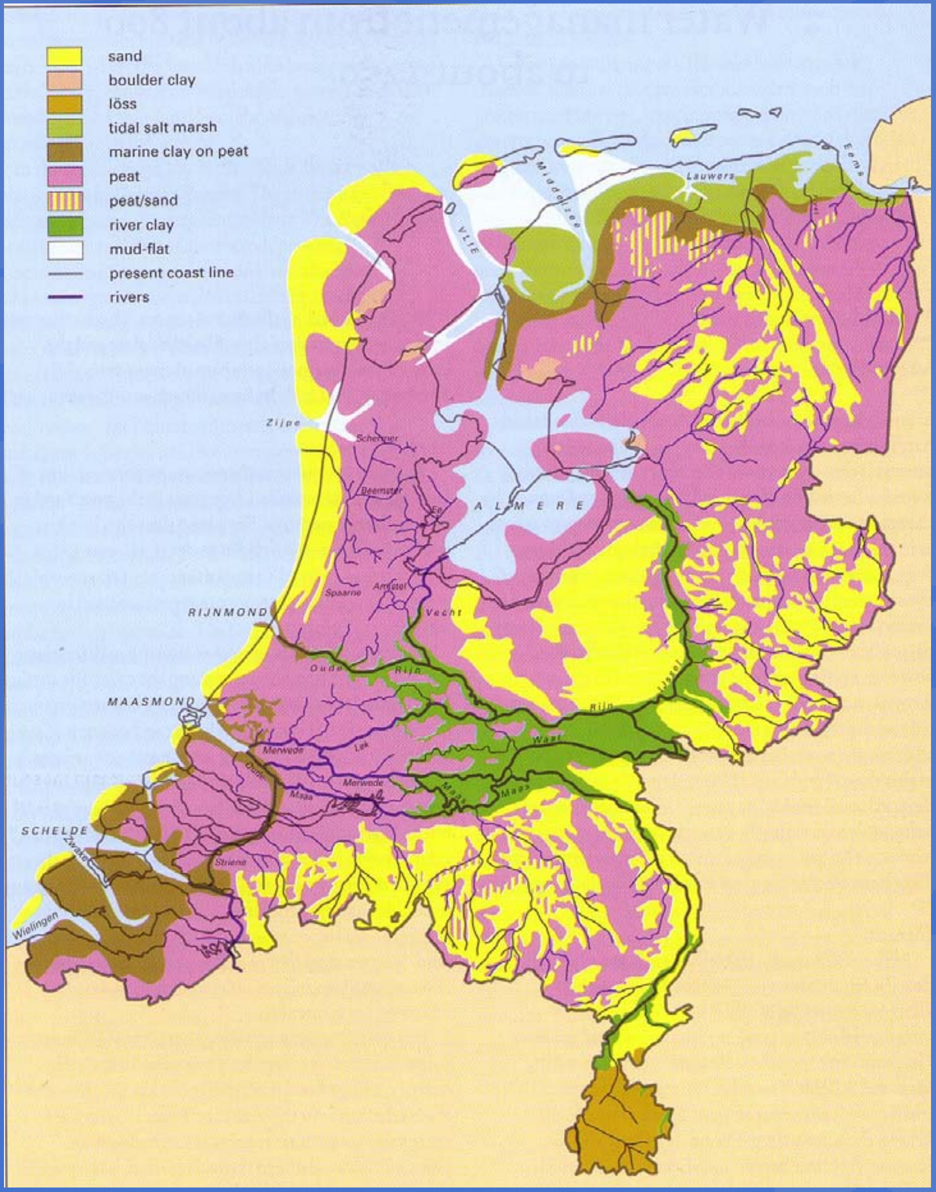


Flooded area at NAP +1.0 m



Source: WL Delft hydraulics

Netherlands at about 800 AD



Bron: *Man-made Lowlands*

Developments since 800 AD

- Eustatic sea level rise by about 1 metre
- Reclamation and draining of low lying areas with subsidence as a consequence;
- Excavation of peat;
- Reduction of sediment supply by the major rivers;
- Extreme storm surges.

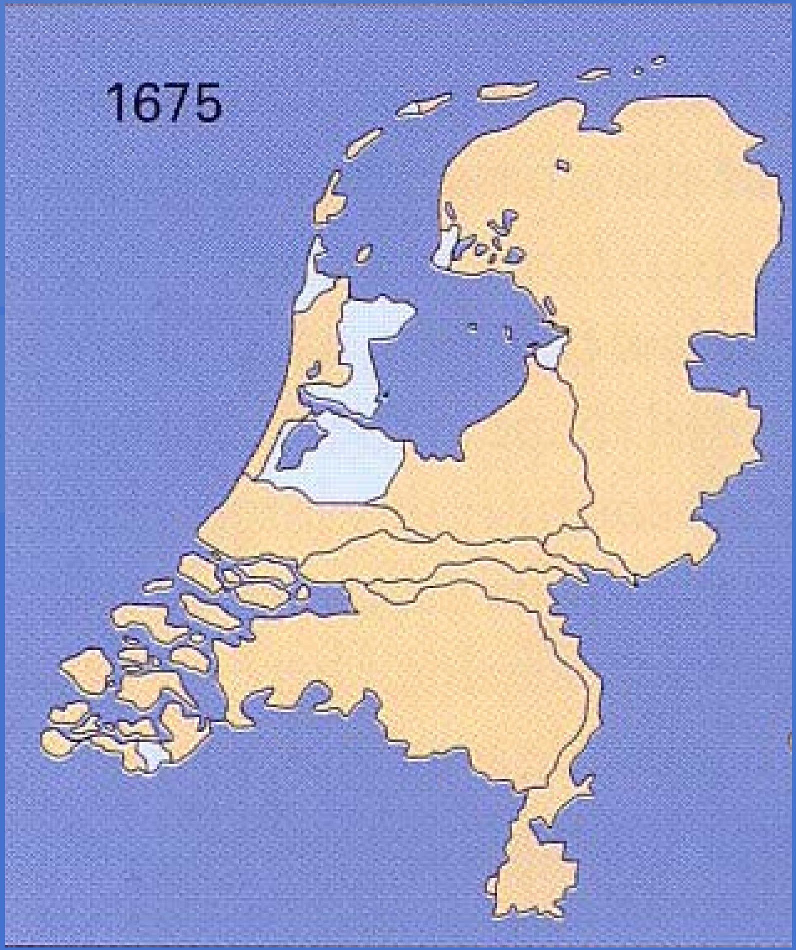
Flooding 1421

Bron: *Man-made Lowlands*

Flooding 1532

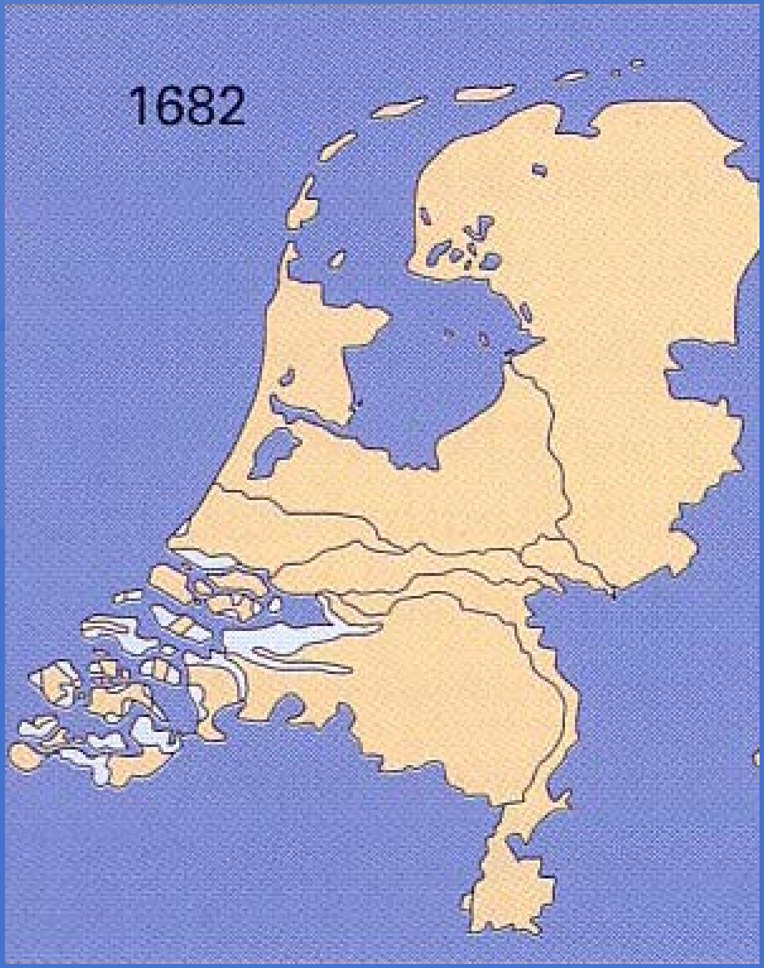
Bron: *Man-made Lowlands*

Flooding 1675



Bron: *Man-made Lowlands*

Flooding 1682

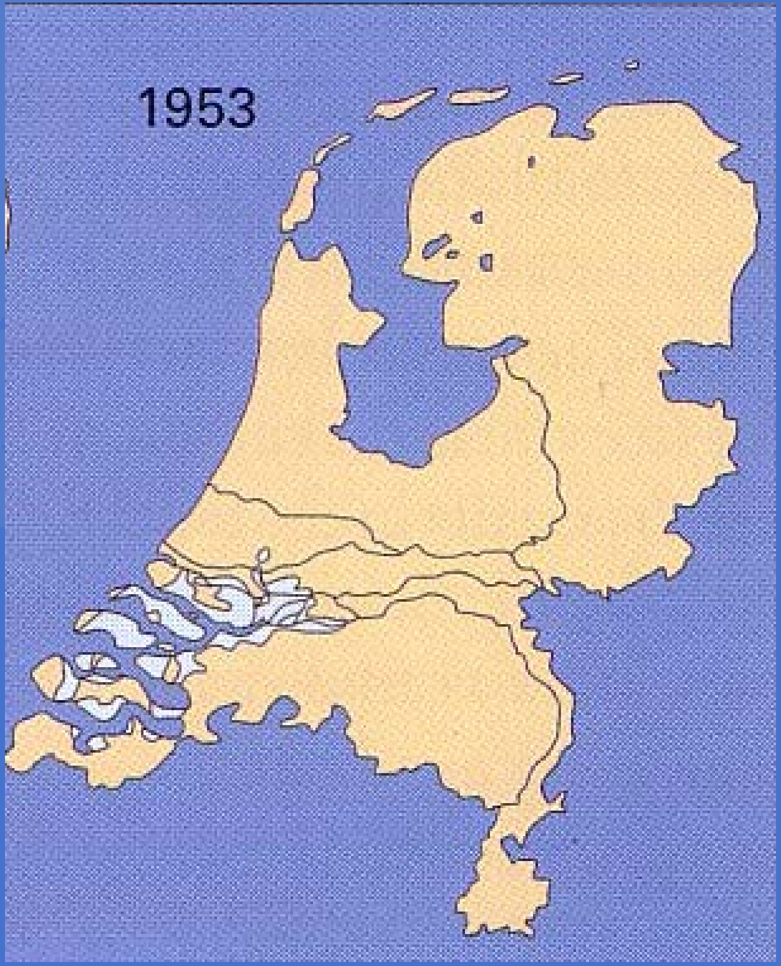


Bron: *Man-made Lowlands*

Flooding 1916

Bron: *Man-made Lowlands*

Flooding in 1953



Bron: *Man-made Lowlands*

Breaches in the coastline

1014 – Storm surge hits the Low Countries. The sea breaches great gaps in the coastline – virtually closed off at that time – between Flanders and Northern Germany.

1170 – All saints Flood. The sea breaks through the dunes at Den Helder and Texel. This creates the Zuiderzee and the Wadden Sea.

1287 – St. Lucia Flood. West Friesland is cut off from the present Friesland.

1421 – St. Elizabeth Flood. Large areas of Zeeland and Holland flooded. Dykes breached in the South Holland Waard leading to the creation of the Biesbosch.

1530 – St. Felix Flood. Disastrous flood mainly strikes Zeeland.

1570 – Second All Saints Flood. Extreme high tides, mainly in Friesland and Zeeland.

1703 – Flood disaster in North-western Europe, thousands dead.

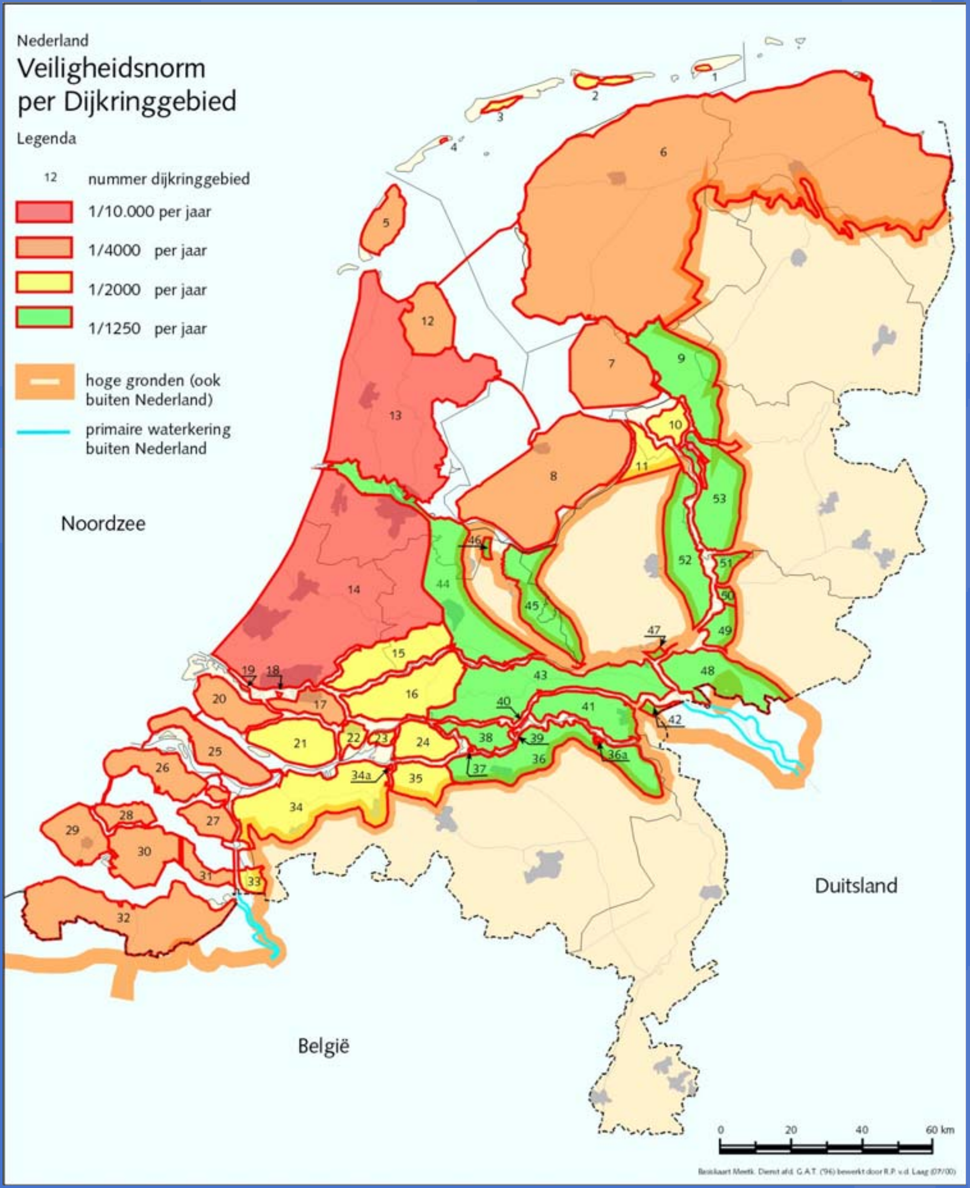
1717 – Christmas Flood. More than 10,000 killed in Northern Netherlands, Germany and Denmark.

1825 – Flooding in Northern Netherlands and Overijssel.

1916 – Storm surge combined with high water levels in rivers leads to flooding round the Zuiderzee. Proves decisive in the decision to close off and partially impolder the Zuiderzee.

1953 – Major storm surge strikes South-west Netherlands, 1835 killed. A Delta Plan must prevent any recurrence.

Dike-rings, each with a specific safety standard.



Bron: DWW Rijkswaterstaat

Meeting the safety standard means “able to withstand conditions characterized by”

Peak river discharge of

- Rhine: 15.000 m^3/s
- Meuse: 3650 m^3/s

North Sea storm surge conditions:

Stormsurge peak level: NAP +5 m

- Wave height: H_s = 7,6 m
- Wave period: $\hat{T}$ = 12 s

Changing Climate and Changing of representative extreme conditions

1. River peak discharge:

➔ Rhine: 16.000 → 18.000 m^3/s or more

➔ Meuse: 3800 → 5320 m^3/s or more

2. Sea level :

➔ North sea level: +20 – or 110 cm?

3. Storm surges:

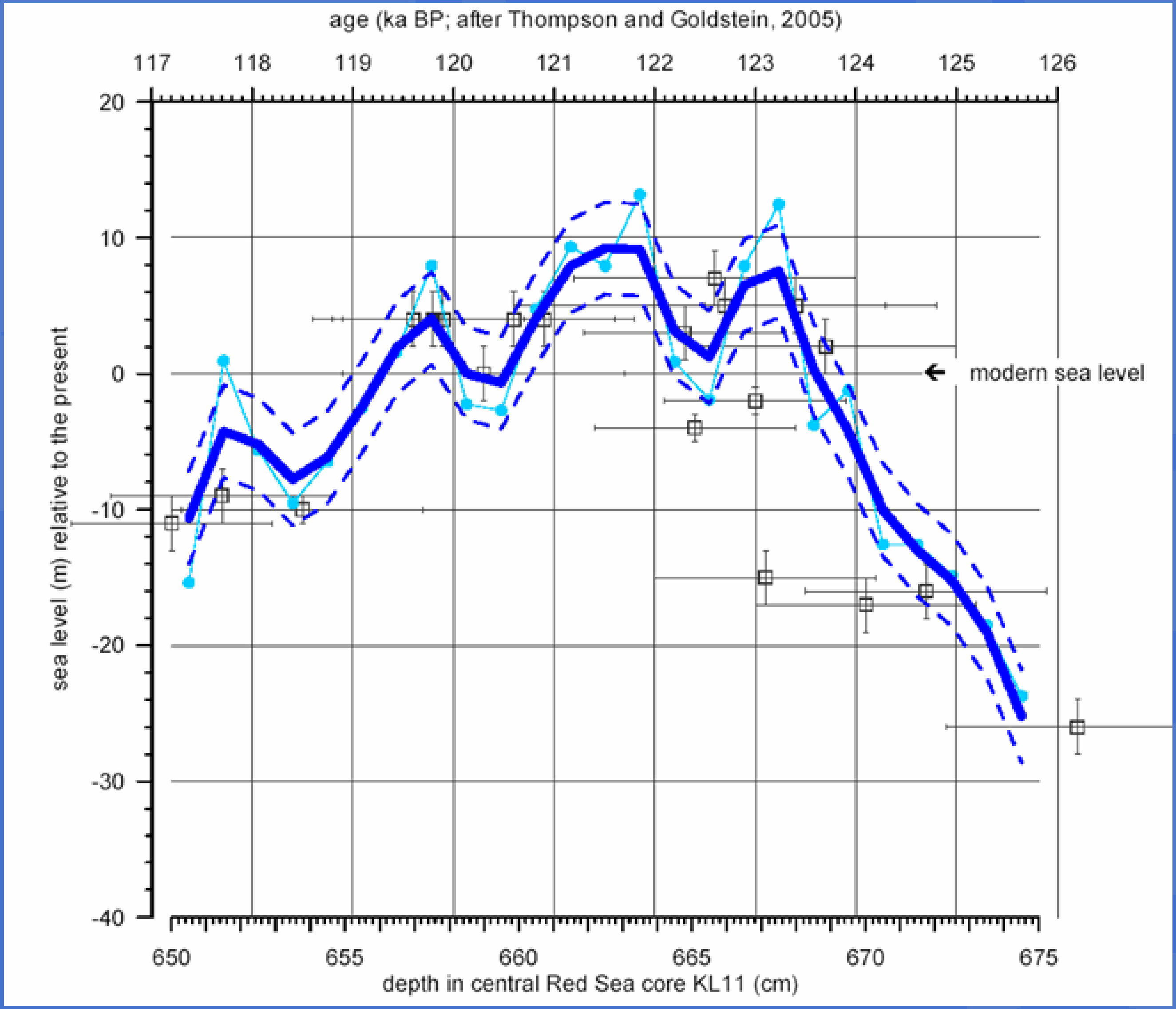
➔ Increase in maximum wind speed and related maximum storm surge level?

Sea level rise estimates for 2100

IPCC WGI Fourth Assessment Report: Global	**18 – 59 cm**
Royal Dutch Meteorological Institute, KNMI: North Atlantic	**35 – 85 cm**
“Al Gore” Greenland scenario, * case of domination of dynamic ice discharge	**50 - 150 cm**

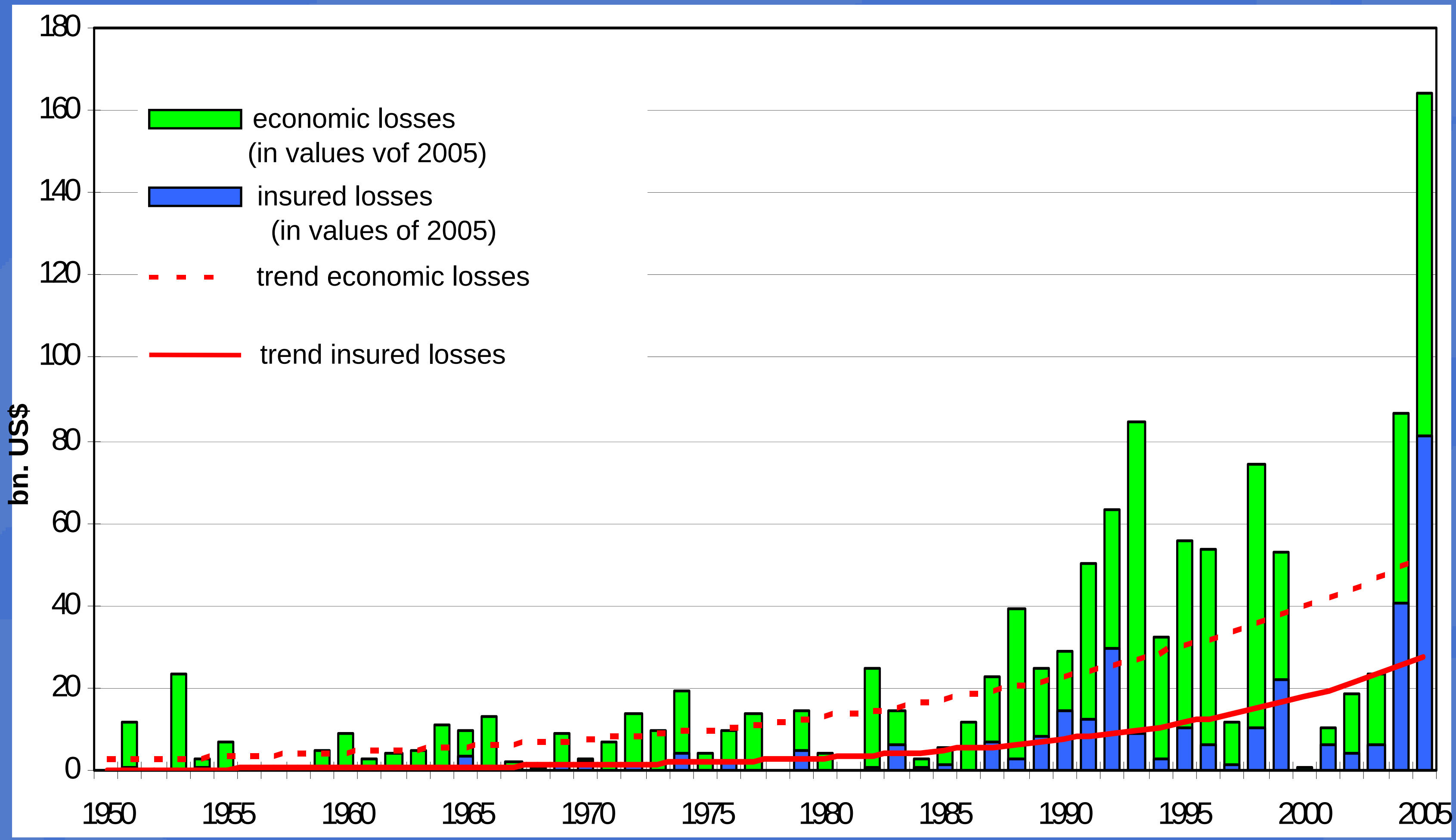
* IPCC 2007: “Current global model studies project that the Antarctic ice sheet will remain too cold for widespread surface melting and is expected to gain in mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance.”

Paleo sea level variations



Rohling et al.,unpublished, (SOC, VU)

Great weather catastrophes 1950 – 2005
Economic and insured losses



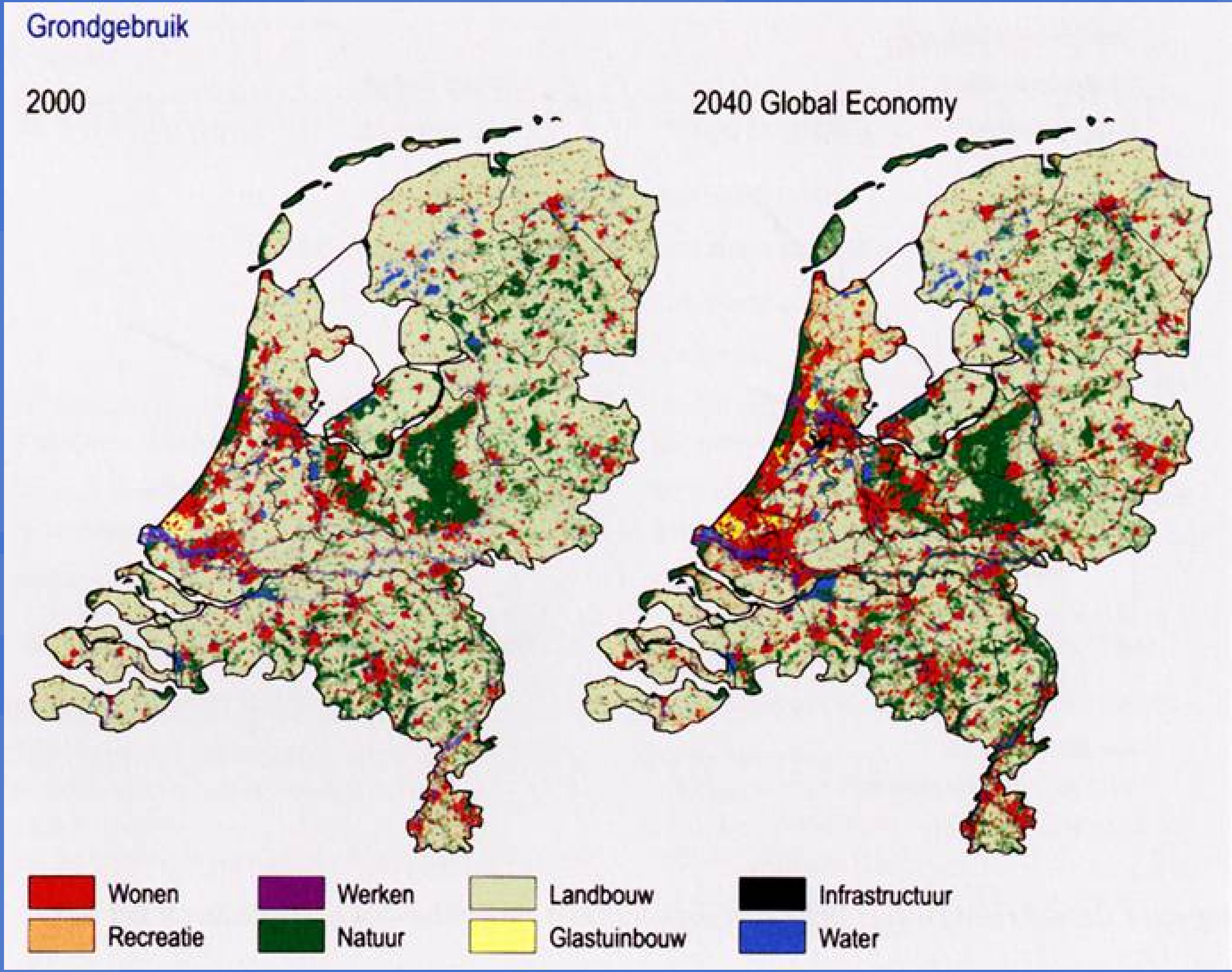
Climate Centre
vrije Universiteit *amsterdam*
www.falw.vu.nl ->onderzoekcentra -> Climate Centre VUA

Flood protection cost in the Netherlands

- The annual cost to protect the Netherlands from river and Northsea flooding,

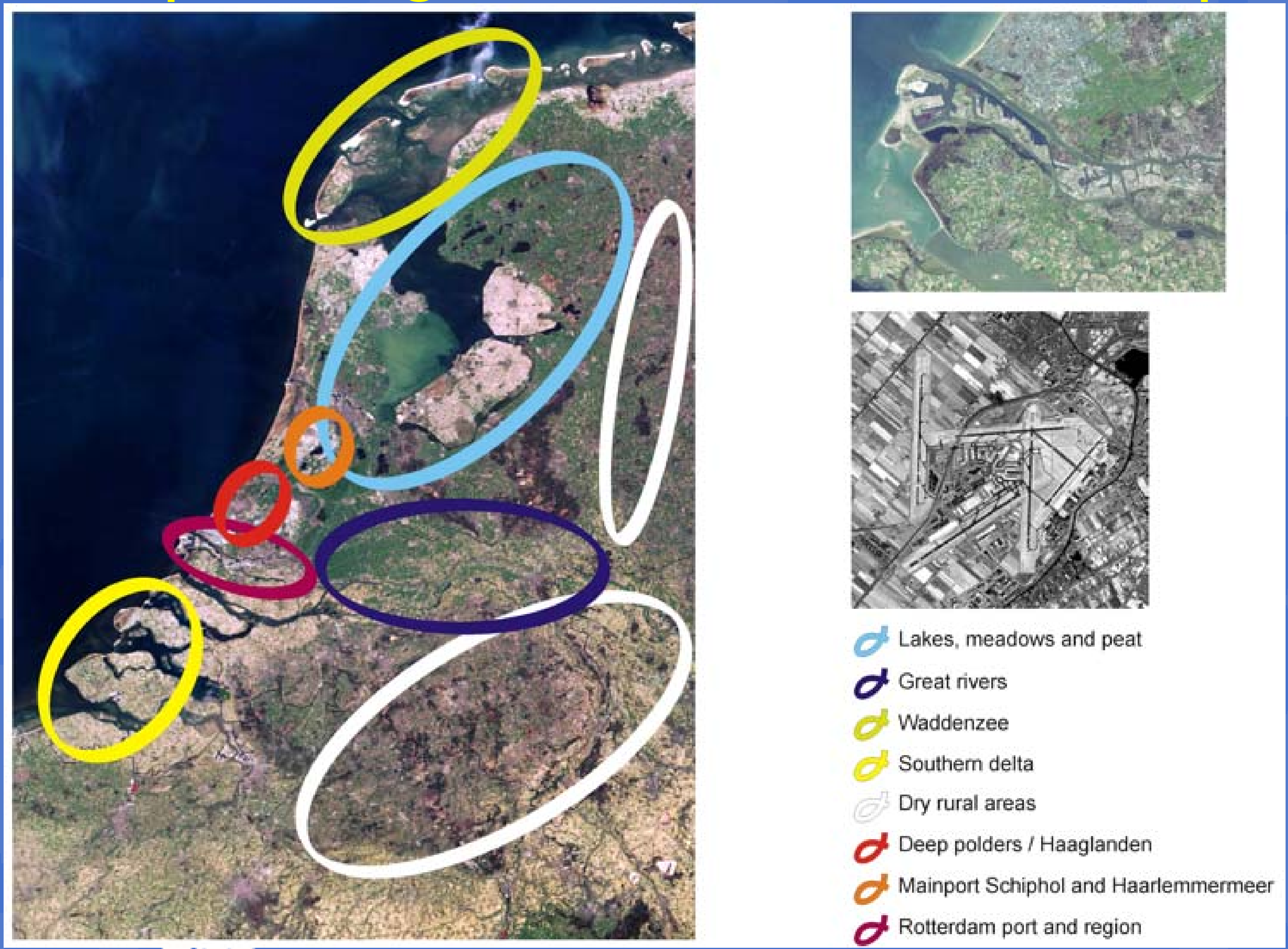
  including the historic Deltaplan and including estimates of future cost to protect the Netherlands from increasing sea level and higher peak discharges of the rivers,

  are in the order of 500 to 1000 million euro per year. This is equivalent to 0.1% - 0.2% of GDP


Grondgebruik
2000
2040 Global Economy
Wonen
Recreatie
Werken
Natuur
Landbouw
Glastuinbouw
Infrastructuur
Water

Vellinga

Climate proofing the Netherlands, hotspots

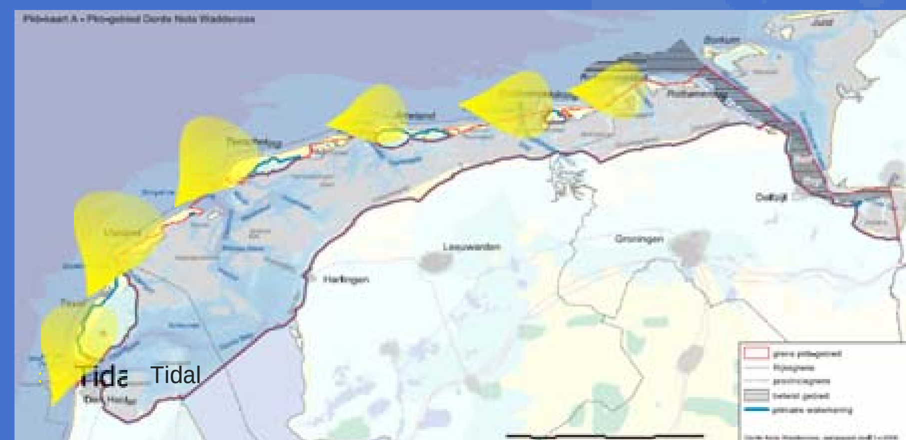


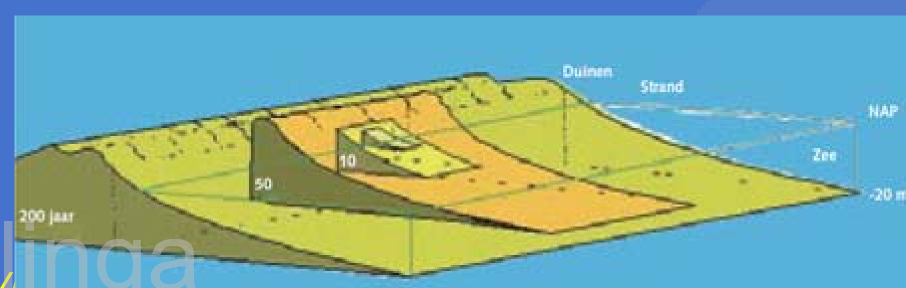
	Water: Flooding and drought	Transport	Agriculture, nature and recreation	Urban development	Energy and industry	Health	Financial services
Deep polders / Haaglanden	■	■	■	■			■
Mainport Schiphol and Haarlemmermeer	■	■	■	■			
Rotterdam port and region	■	■		■	■		■
Southern delta	■		■				■
Waddenzee	■	■	■		■		
Great rivers	■		■				■
Lakes, meadows and peat	■		■			■	
Dry rural areas	■		■			■	

Examples of Co-innovation

- Nourishment of the coastal sand-river
- "Overwash" dikes
- Offshore islands as coastal protection
- "Green river" bypass
- Nature reserves as climate and flooding buffer
- Floating cities and greenhouses
- Modern urban mounds
- Saline and brackish agriculture
- Raising the quays

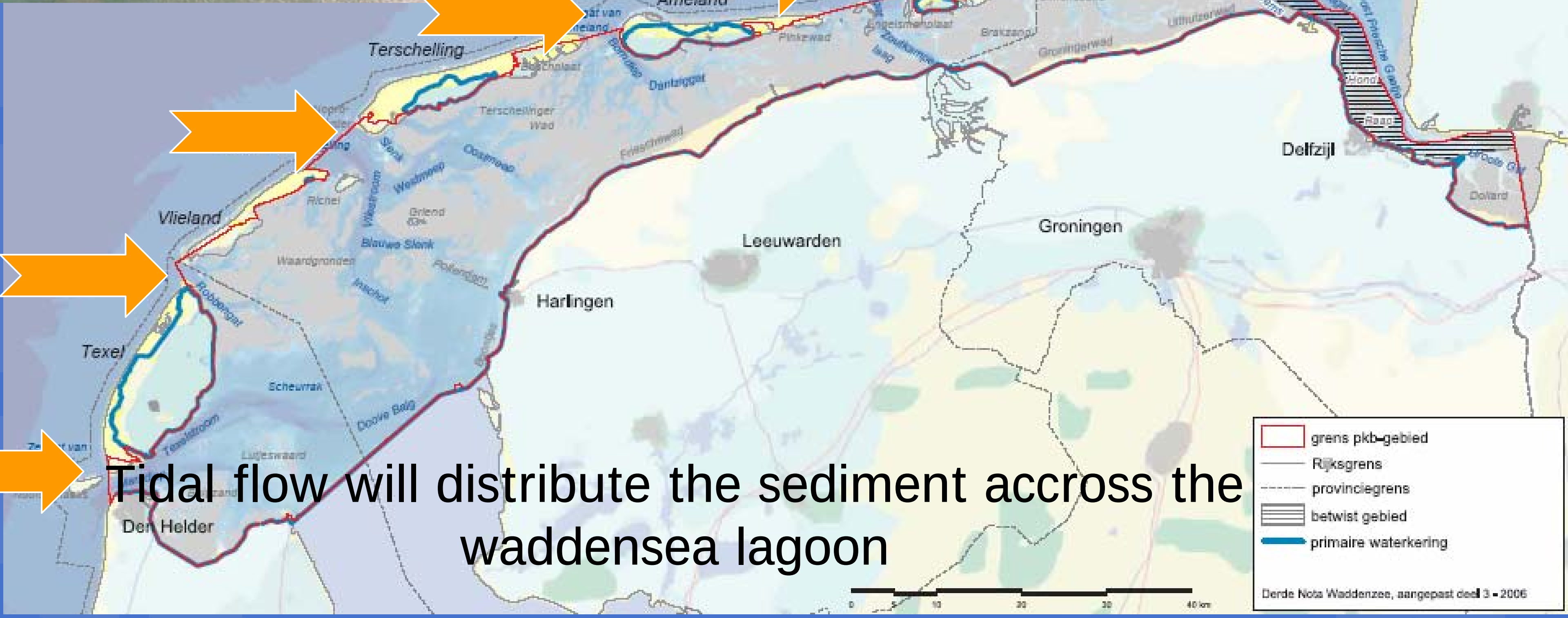
Nourishment of the coastal sand-river





Images Courtesy RIKZ

Locations for sediment nourishment



Tidal flow will distribute the sediment accross the waddensea lagoon

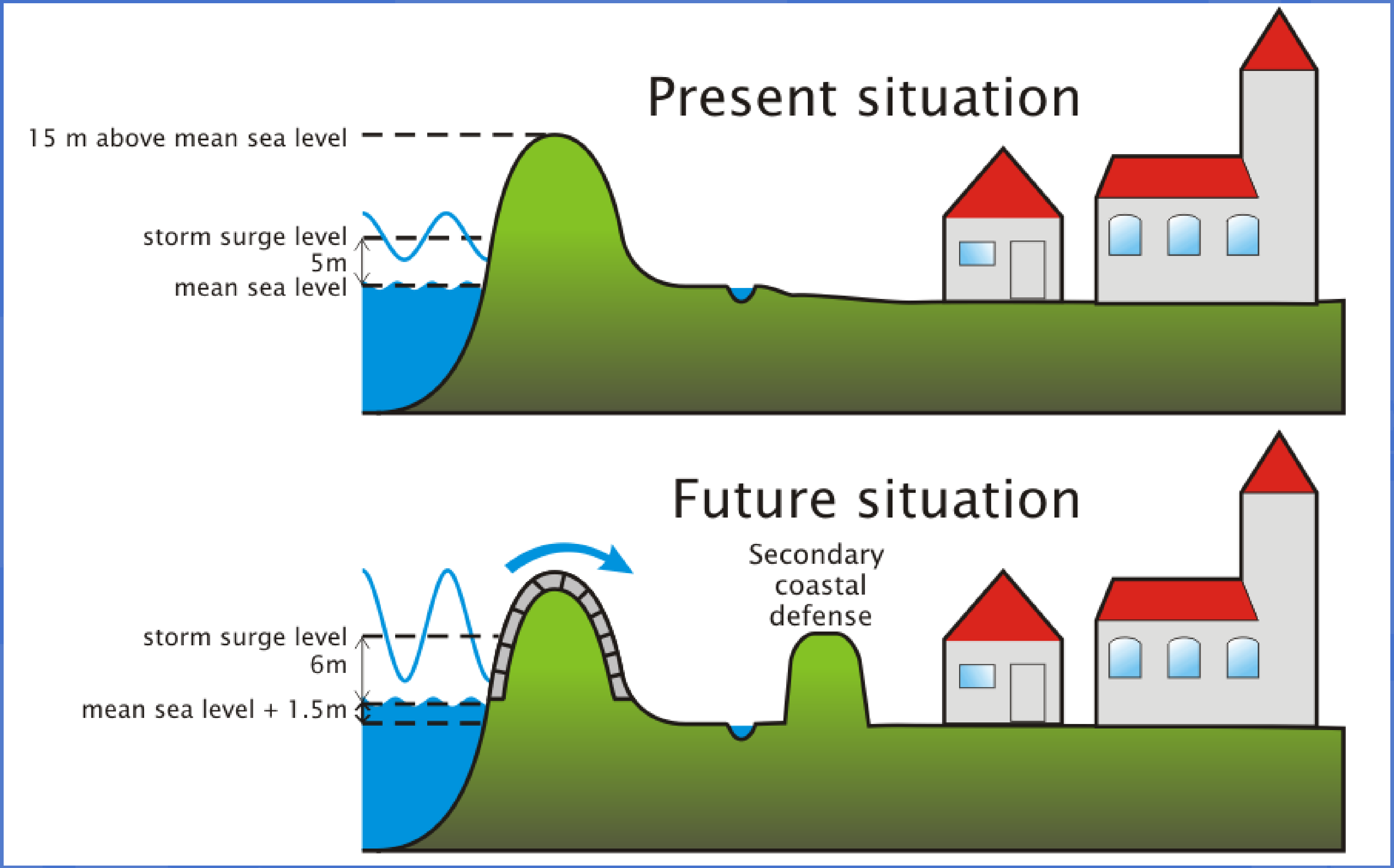
- The Netherlands part of the Waddenzee is about 2400 km2
- 1,0 m rise of sealevel would require a sediment input of 2.4 km3 in 100 years
- Equaling 24 milion m3 per year, for a 100 years

- The largest hopper dredger has a maximum capacity of 10.000 m3 per hour; 2400 hours at maximum capacity equals 24 milion m3

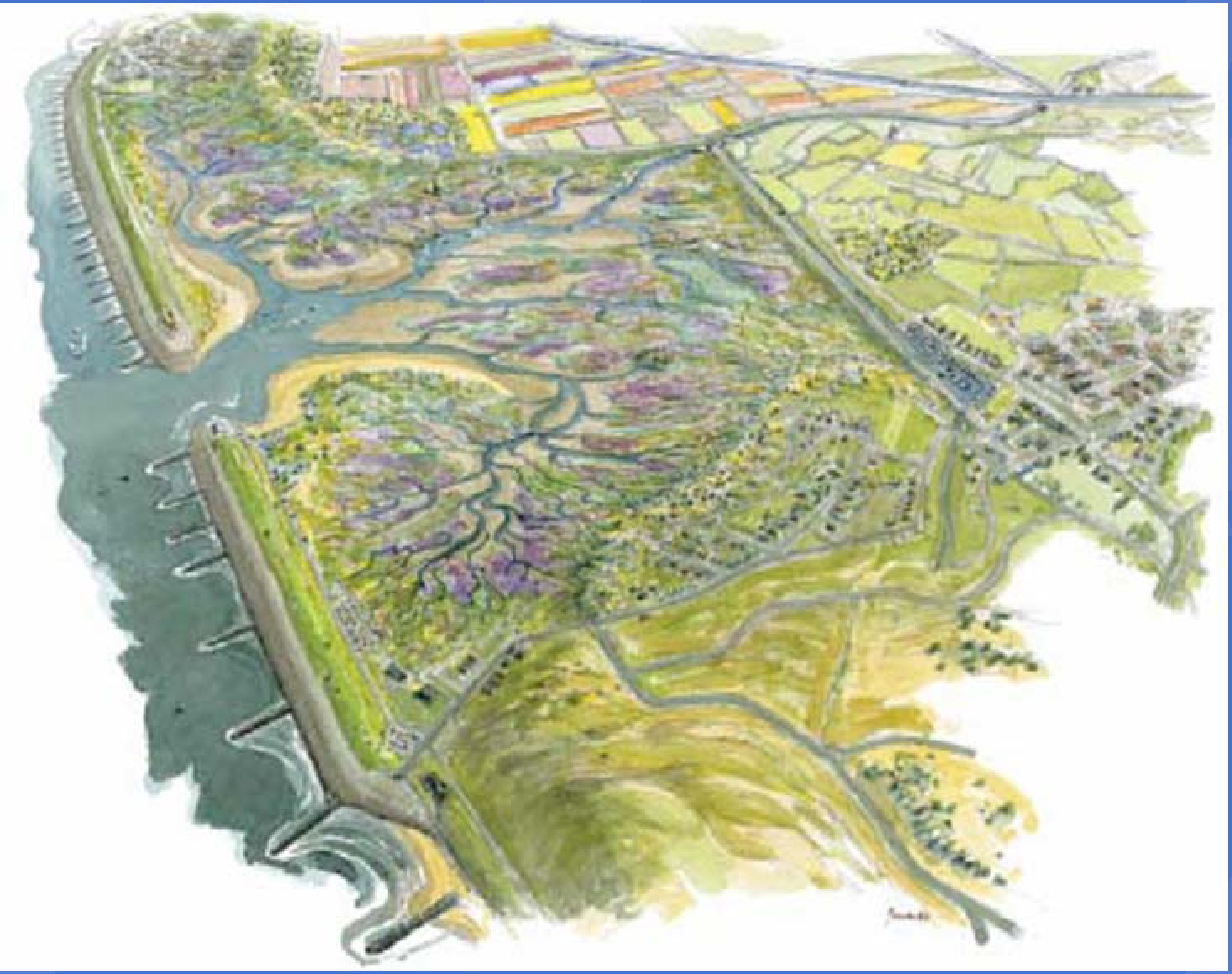
→ In conclusion permanent operation of a few large hopper dredgers can produce an amount of sediment enough to compensate the waddenzee for 1,0 meter sealevel rise in a 100 year period

Vellinga

“Overwash dikes”



Vellinga

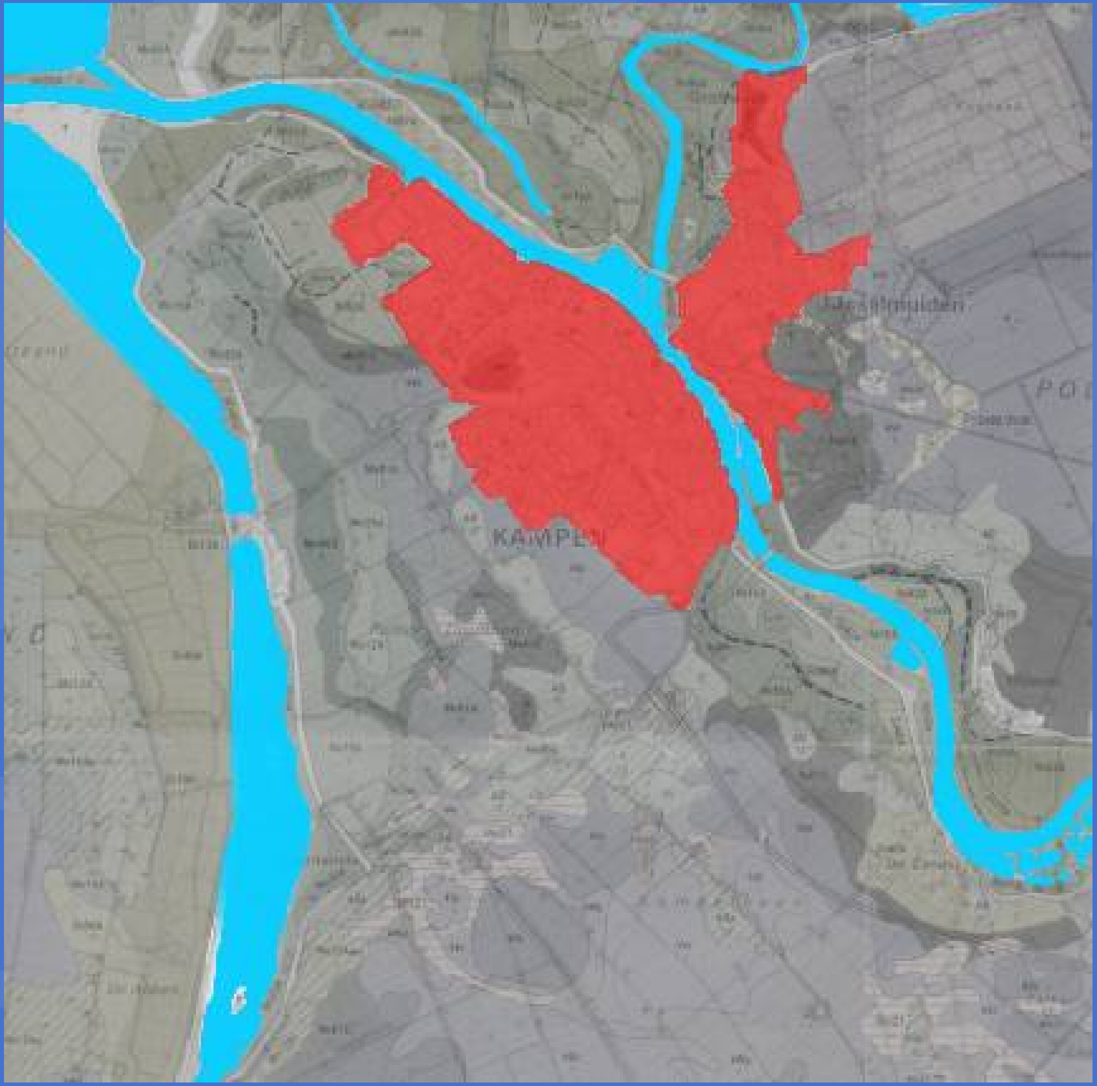


Source: Stroming B.V.

Offshore islands as coastal protection

Source: West 8

Kampen present situation



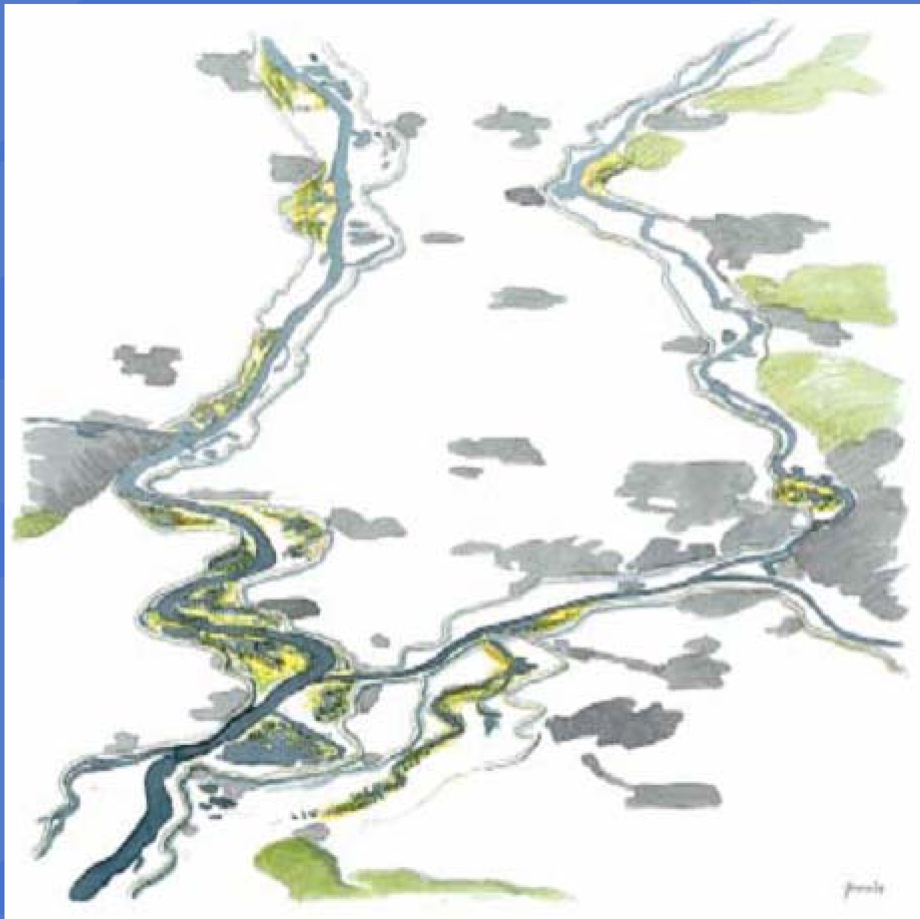
Kampen by-pass: Green river concept

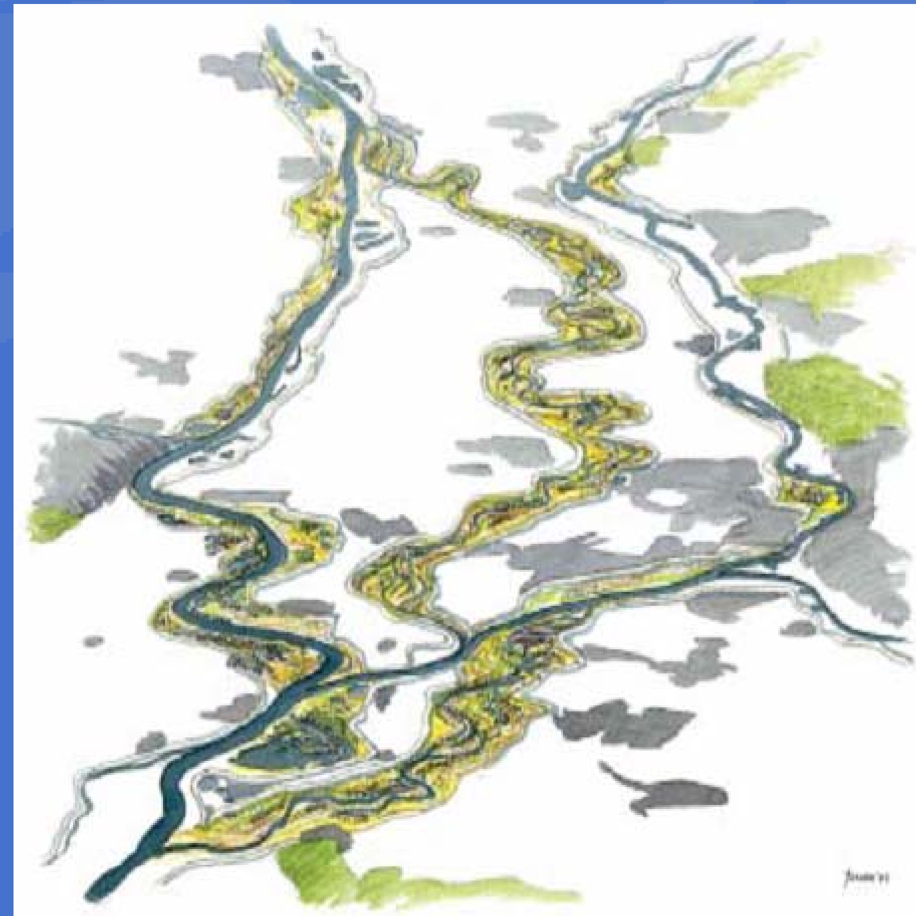
Situatie bij een normale rivierafvoer (ca 200 dagen per jaar)

Hoogwaterbeeld

Climate Centre
vrije Universiteit *amsterdam*
www.falw.vu.nl ->onderzoekcentra -> Climate Centre VUA

Vellinga





Source: Stroming B.V.

Nature reserves as climate and flooding buffer

Source: Stroming B.V.

Climate Centre
vrije Universiteit *amsterdam*
www.falw.vu.nl ->onderzoekcentra -> Climate Centre VUA

Vellinga

Source: Stroming B.V.

Floating cities and greenhouses

Image courtesy Dura Vermeer

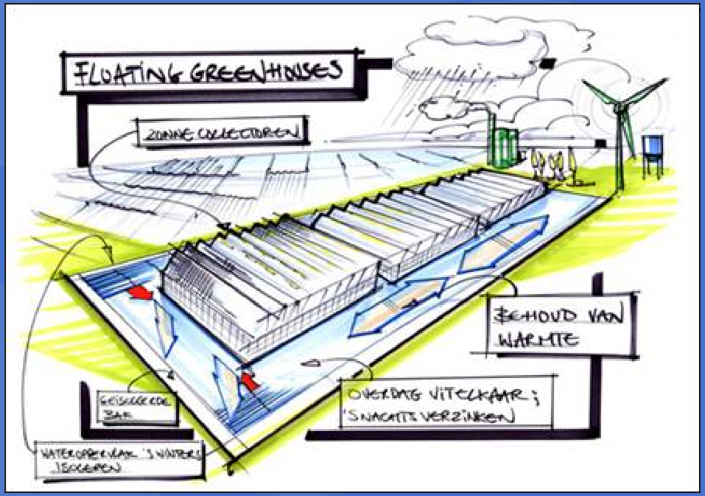
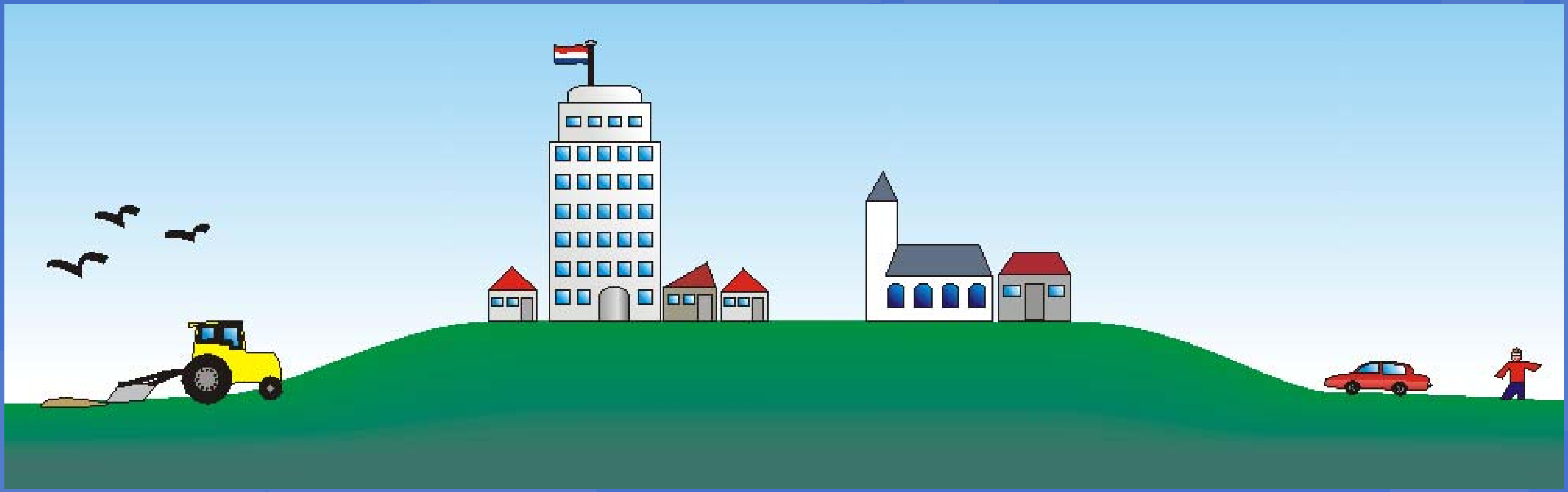


Image courtesy www.tuinbouw.nl

Image courtesy www.drijvende kas.nl

Modern urban mounds



Saline and brackish agriculture

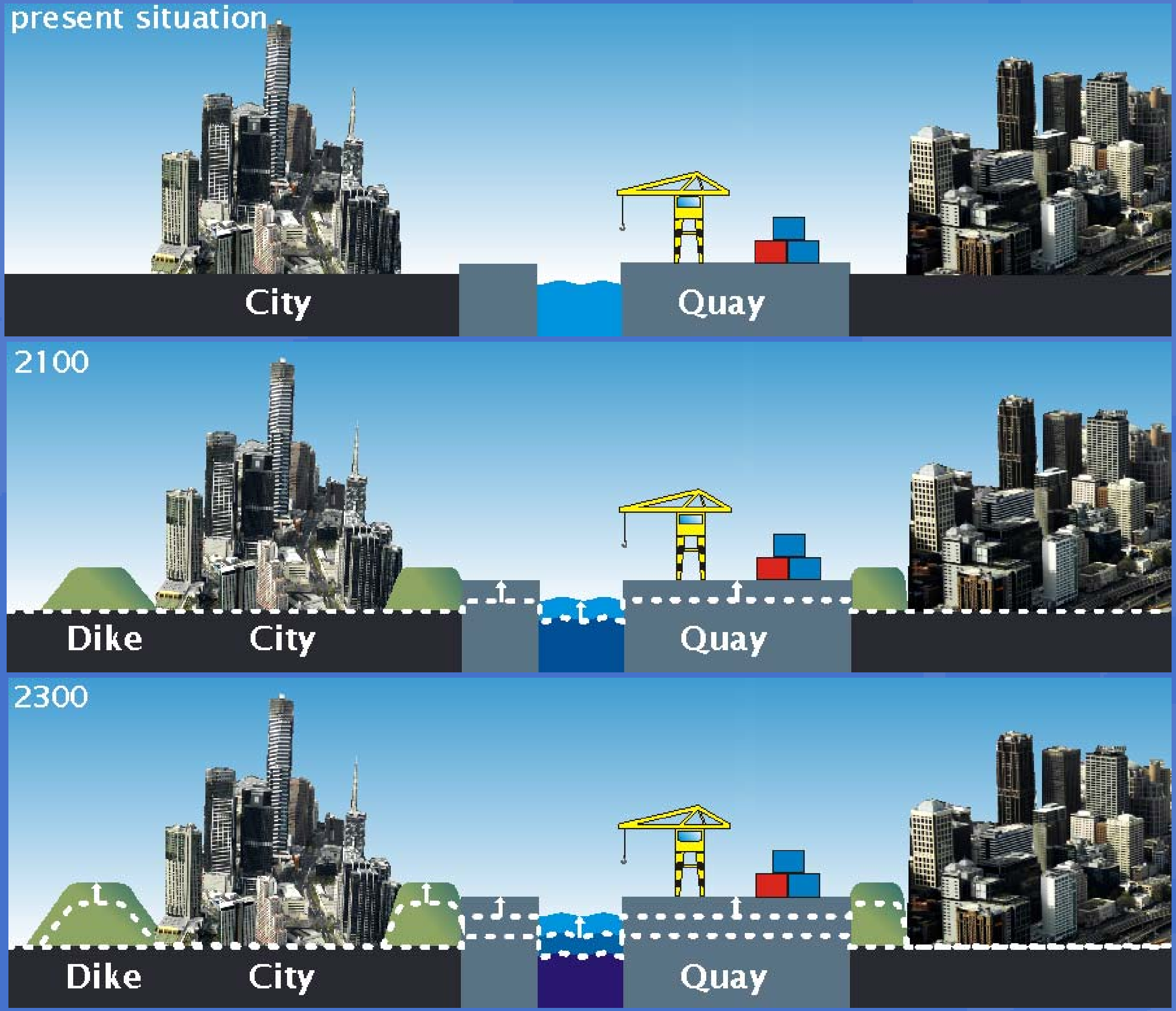
Images courtesy Arjen de Vos

Port of Rotterdam

Port of Rotterdam maritime defense walls

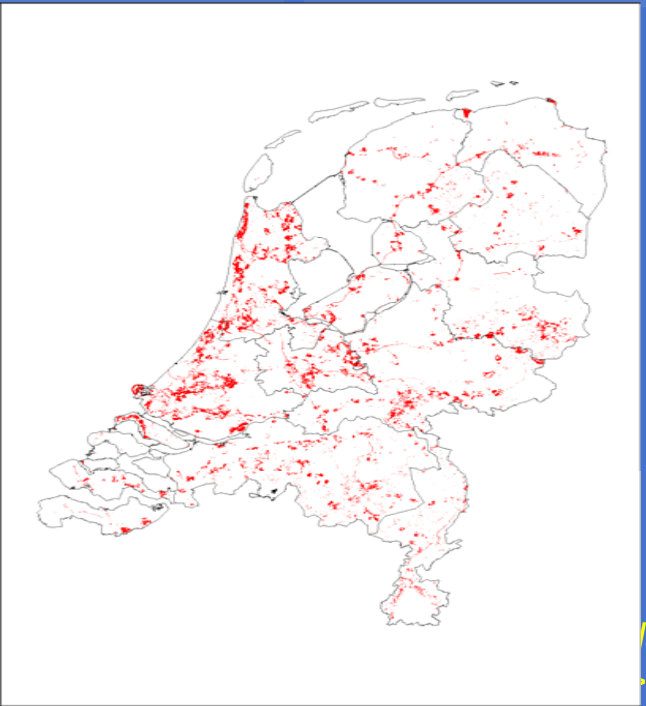
From: Nieuwenhuijze and Geldof 2005

Raising the quays

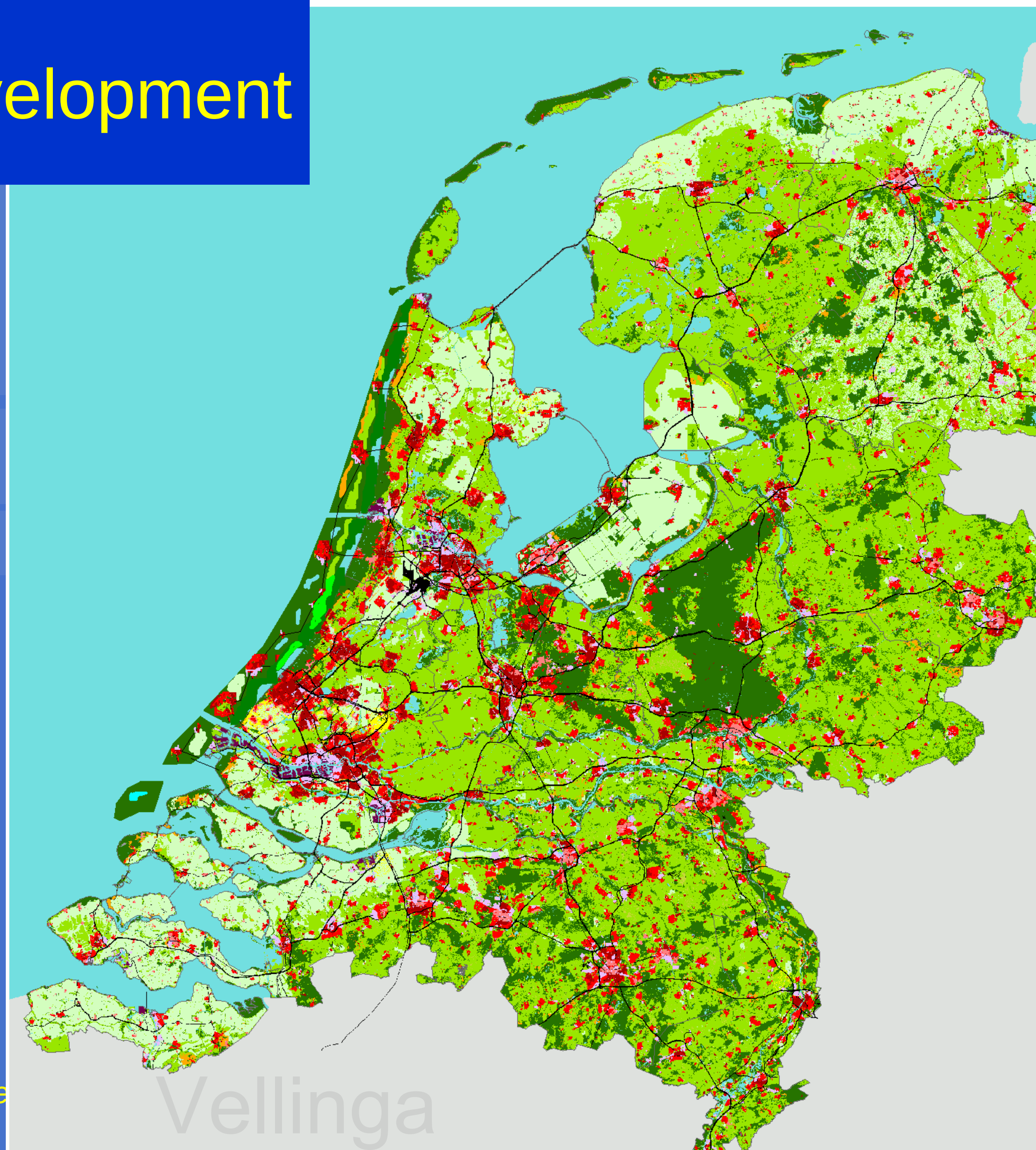


Terpen/ Mounds

Deltares + VU



Sea ward development

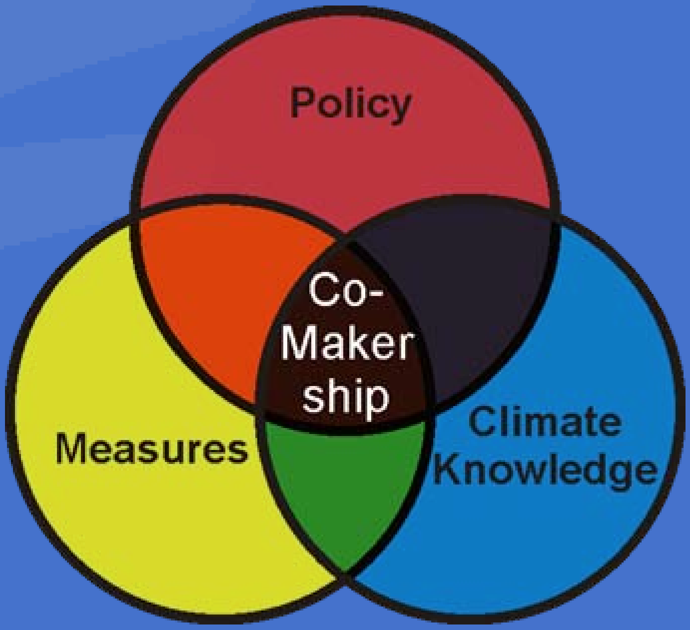


Co-makership between scientists, stake-holders and policy makers is important:

- Climate change is emerging knowledge; “vague” uncertainty regarding future climate needs to be translated into “concrete” probability terms
- The dose-response function of physical, ecological and societal systems is largely unknown
- Analysis of opportunities and threats and the generation of innovative solutions requires knowledge from three domains: science, experience and policy planning

Climate robustness is:

The ability to deal with changes in climate and weather extremes without major damage



Co-makership is:

Innovation through coöperation of scientists, stakeholders and policy-makers