



From Fresh to Salt Water

Salt Intrusion in the Delta Area of the River Rhine

Vincent Beijk

25 september 2007

Introduction

- Description of the Rhine delta
- Salt intrusion in the Rhine delta
- Effects of climate change on salt intrusion
- Possible measures
- Discussion

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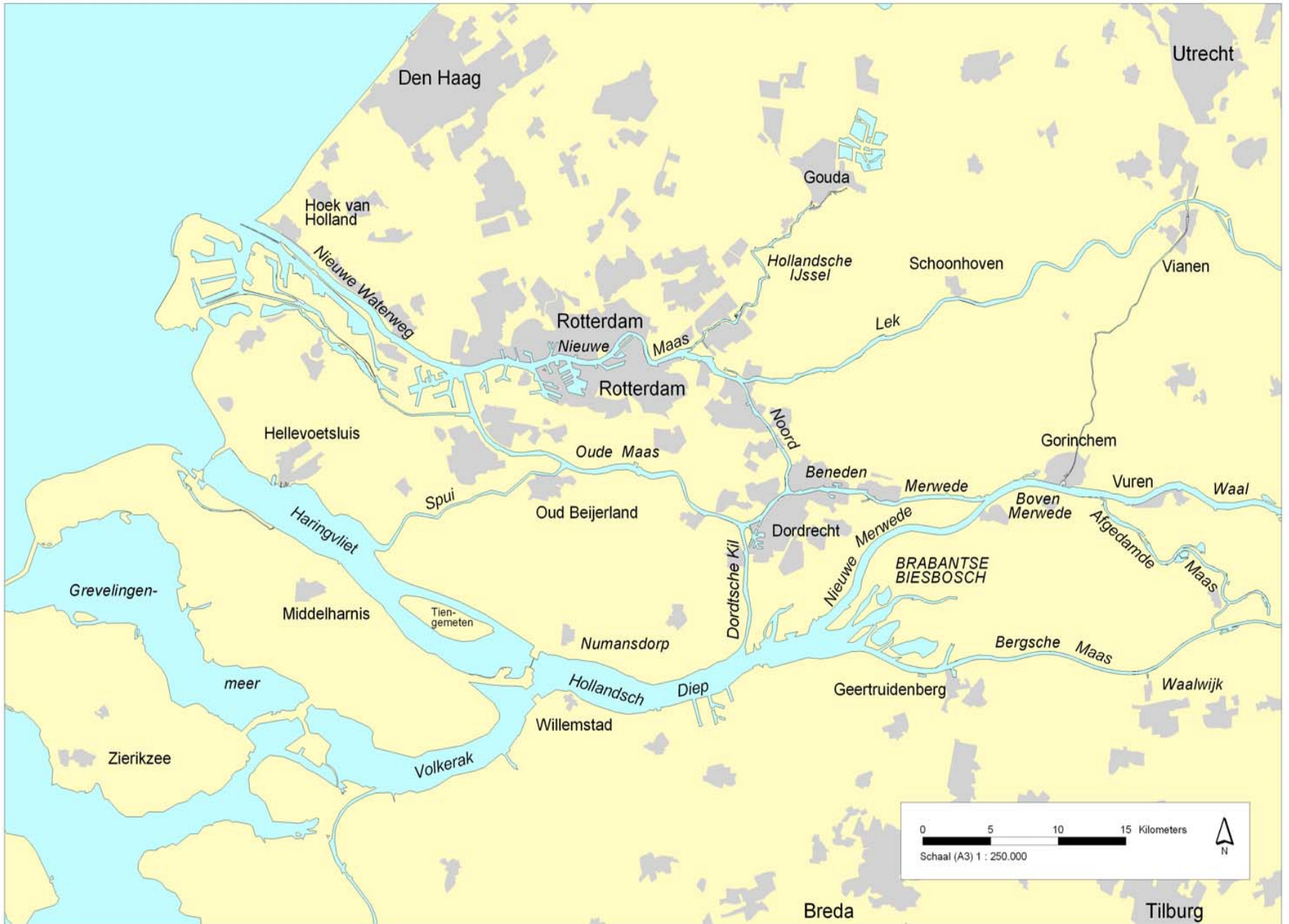
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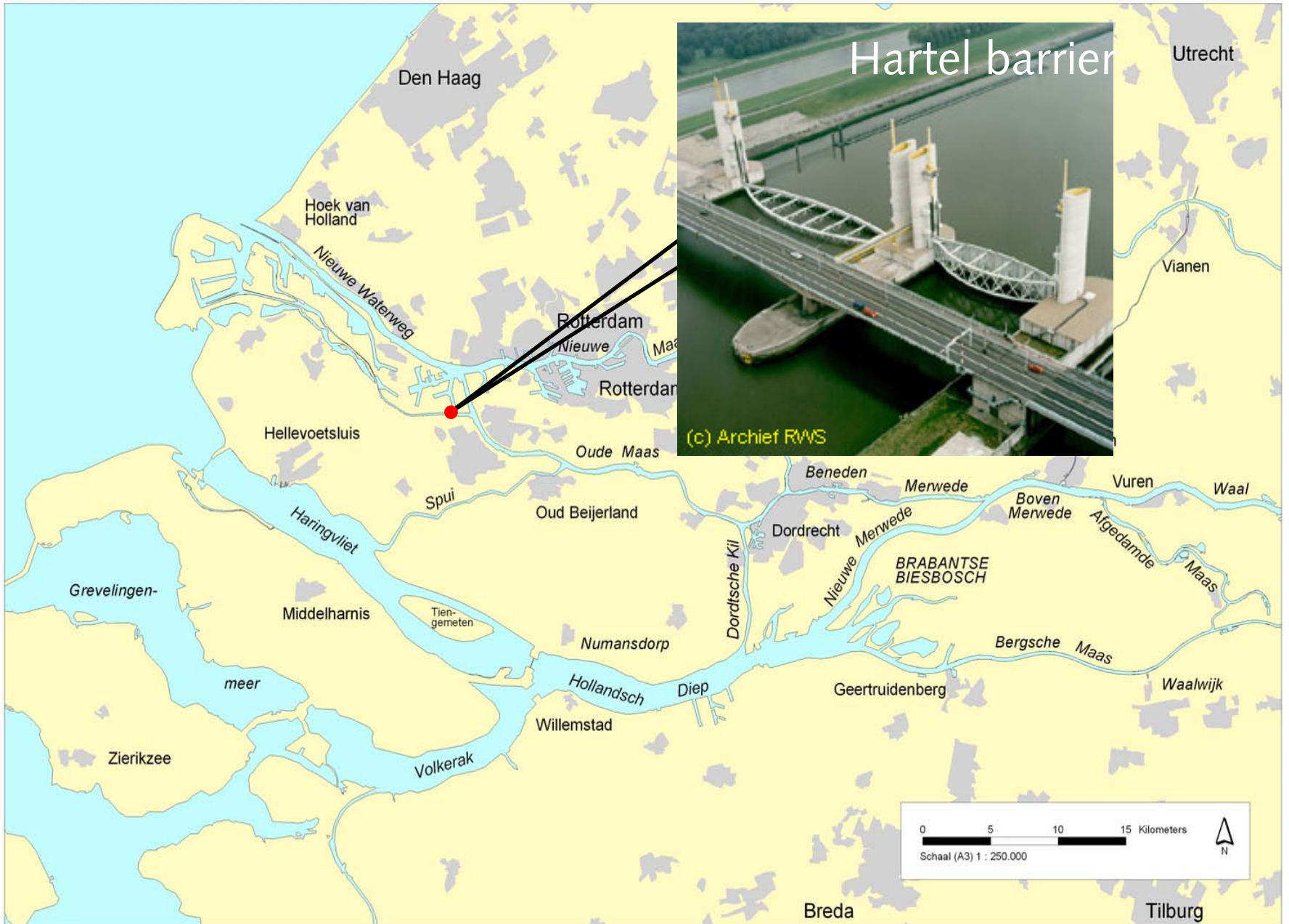
Maeslant storm surge barrier



Hoek van Holland

Nieuwe Waterweg





Hartel barrier

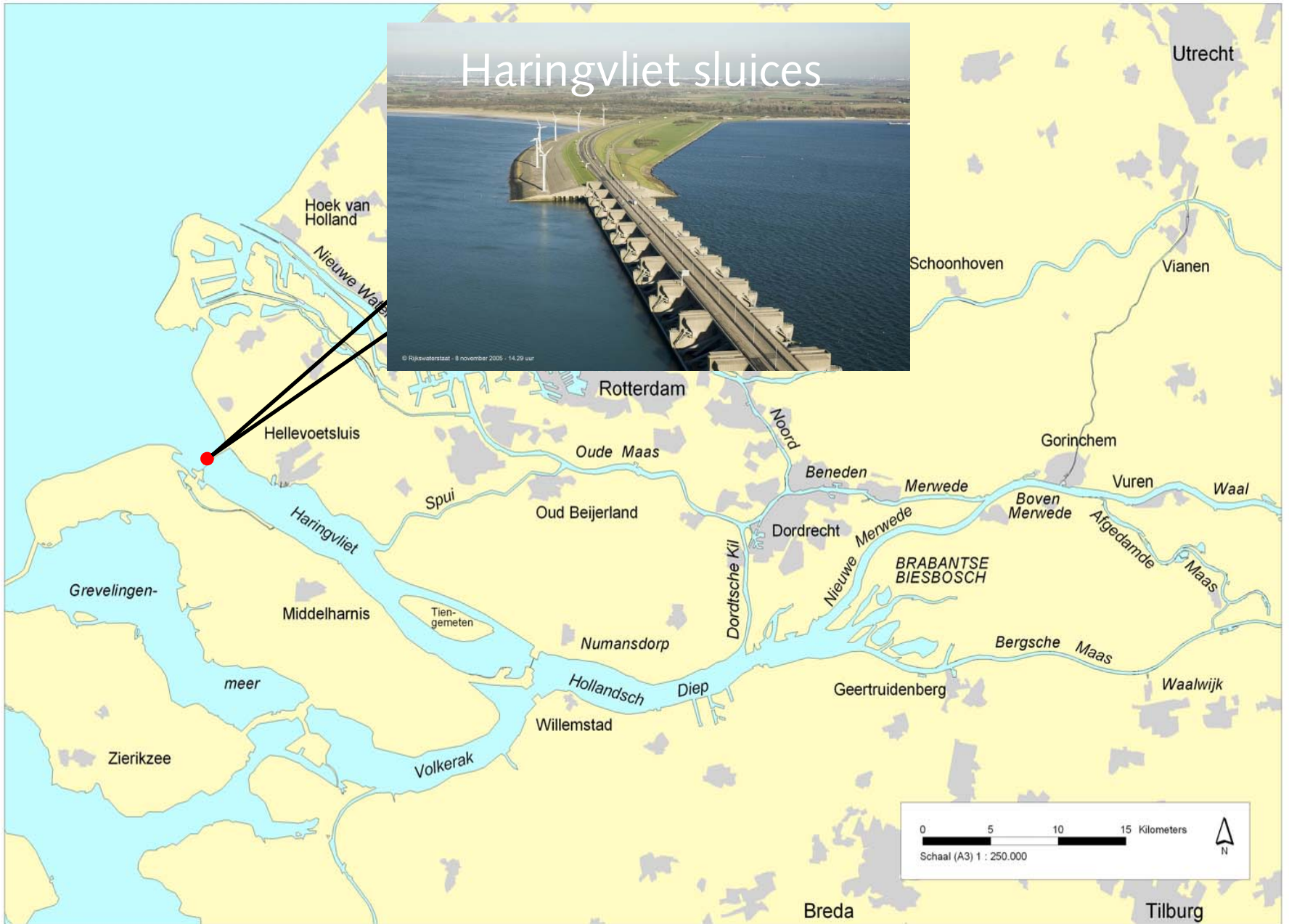
(c) Archief RWS

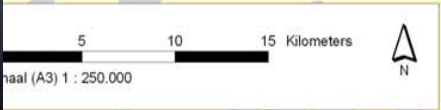


Haringvliet sluices



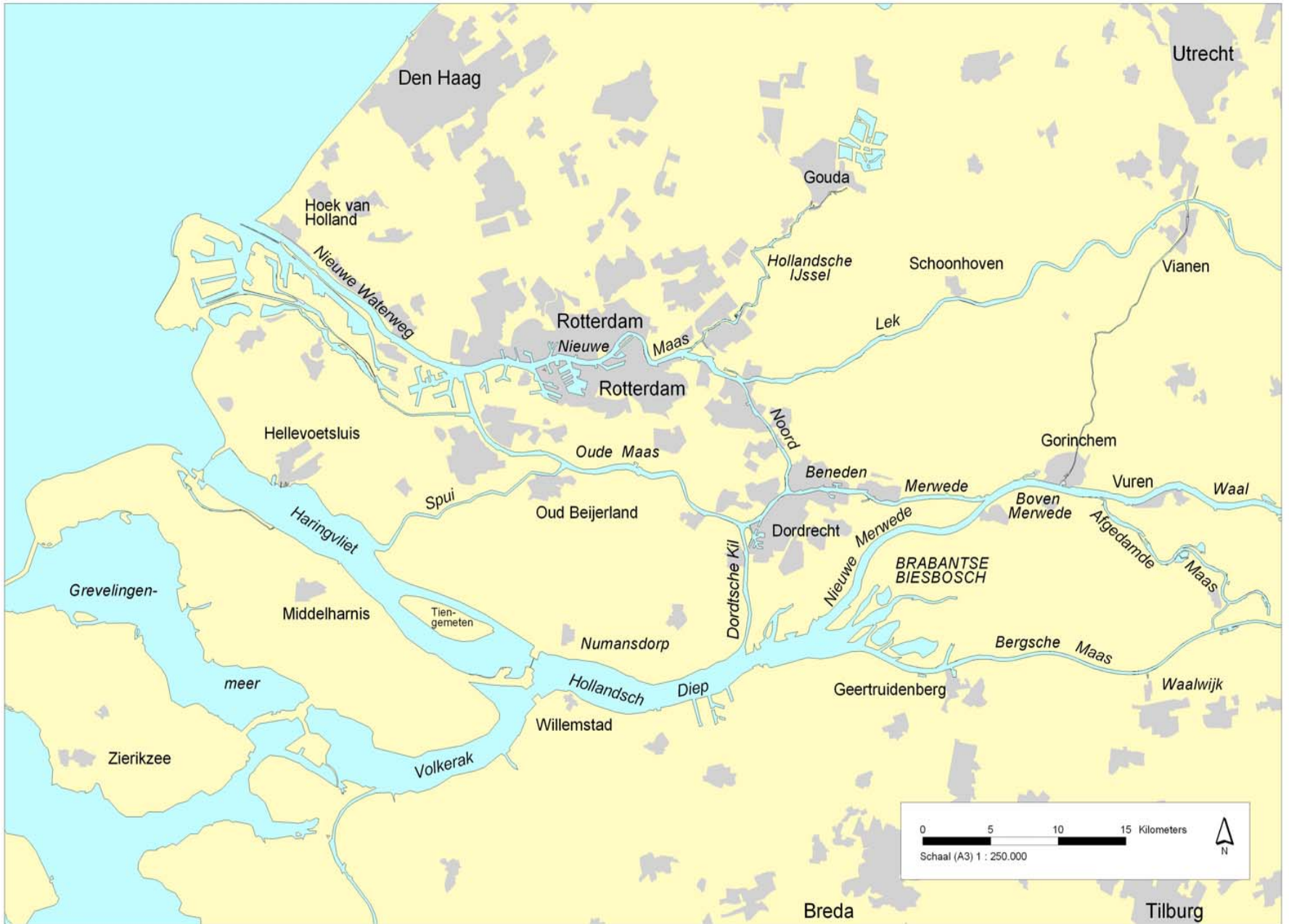
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Salt Intrusion

- Different connections between the Rhine and the North Sea
- Amount of salt intrusion in the Rhine delta is determined by different factors
- Seepage through groundwater flow



Salt Intrusion

- Different connections between the Rhine and the North Sea
- Amount of salt intrusion in the Rhine delta is determined by different factors
 - Sea level
 - Discharge
 - Geometry
- Seepage through groundwater flow

Salt Intrusion

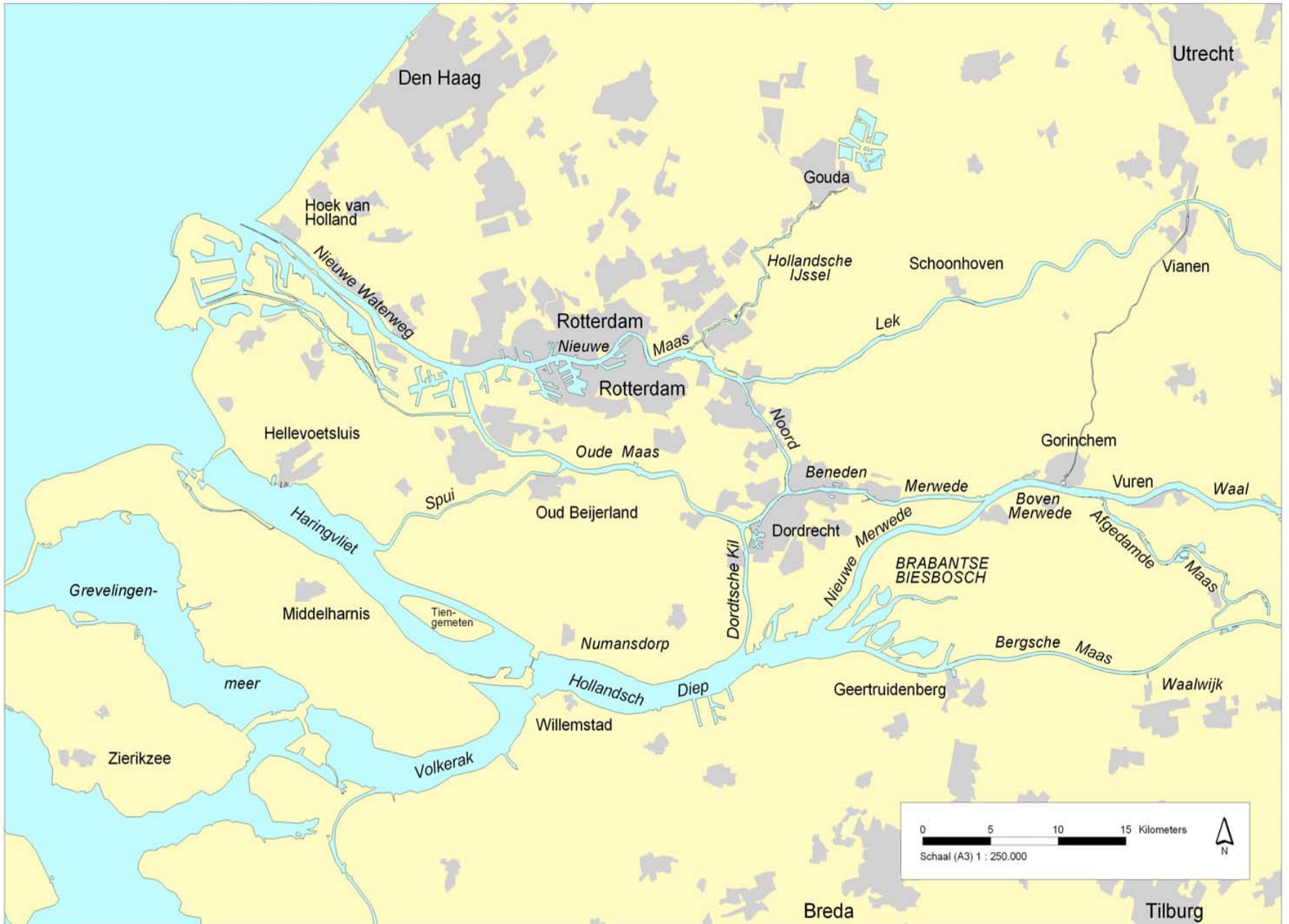
East

West



Salt Intrusion

- Different connections between the Rhine and the North Sea
- Amount of salt intrusion in the Rhine delta is determined by different factors
- Seepage through groundwater flow



Den Haag

Utrecht

Hoek van Holland

Gouda

Hollandsche IJssel

Schoonhoven

Vianen

Nieuwe Waterweg

Rotterdam

Nieuwe Maas

Lek

Rotterdam

Hellevoetsluis

Oude Maas

Noord

Gorinchem

Spui

Oud Beijerland

Beneden

Merwede

Vuren

Waal

Haringvliet

Dordtsche Kil

Dordrecht

Nieuwe Merwede

Boven Merwede

Afgedamde

Maas

Grevelingen-

Middelharnis

Tien-gemeten

Numansdorp

BRABANTSE BIESBOSCH

meer

Hollandsch Diep

Geertruidenberg

Bergsche Maas

Waalwijk

Zierikzee

Volkerak

Willemstad

Breda

Tilburg

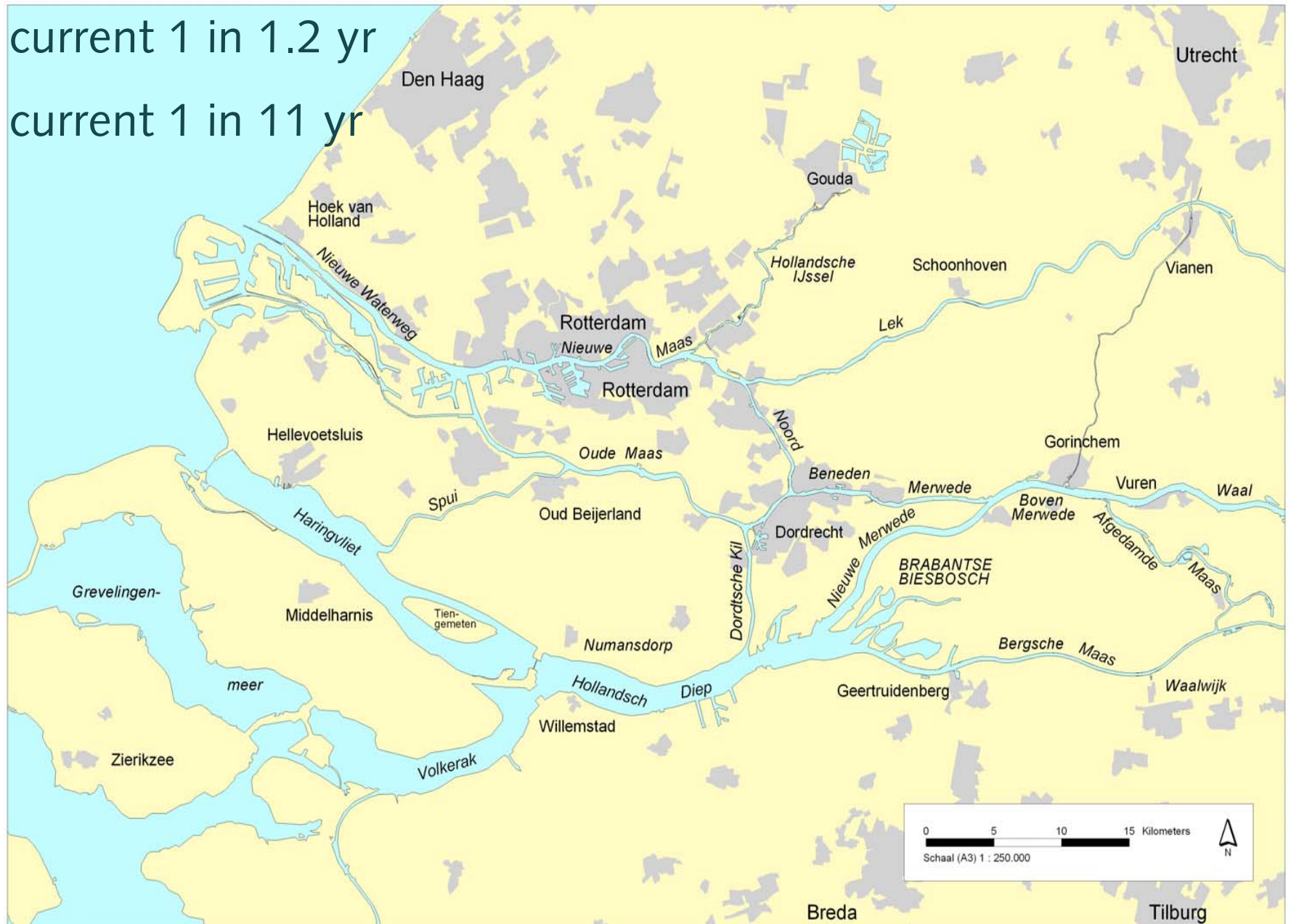
Salt Intrusion

	Characteristic year	Return period (yr)
Extreme Saline	1976	32
Saline	2003	11
Brackisch	1996	3.3
Moderately Brackisch	1994	1.6
Fresh	2002	1.2

Salt Intrusion

Return period (yr)	$Cl_{\max, \text{year}}$ (mg/l)
2	1514
5	2183
10	2626
20	3050
50	3600
100	4013

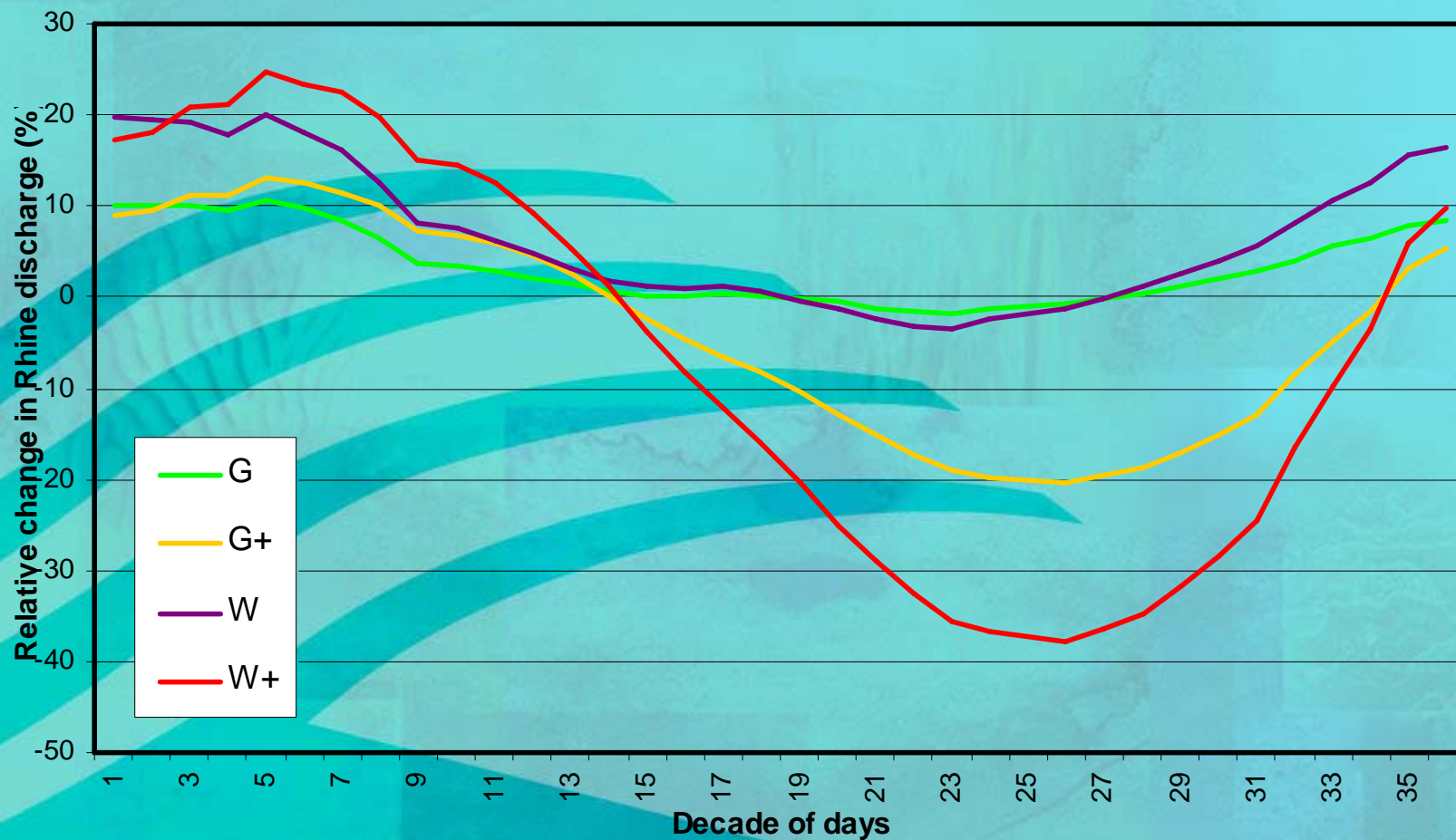
current 1 in 1.2 yr
current 1 in 11 yr



Effects of Climate Change

	G scenario	G+ scenario	W scenario	W+ scenario
Worldwide rise in temperature	+1°C	+1°C	+2°C	+2°C
Change in large scale air circulation pattern	No	Yes	No	Yes
Winter				
Mean temperature	+0,9°C	+1,1°C	+1,8°C	+2.3°C
Mean precipitation	+4%	+7%	+7%	+14%
Summer				
Mean temperature	+0,9°C	+1,4°C	+1,7°C	+2,8°C
Mean precipitation	+3%	-10%	+6%	-19%
Sea level rise	15-25 cm	15-25 cm	20-35 cm	20-35 cm

Effects of Climate Change

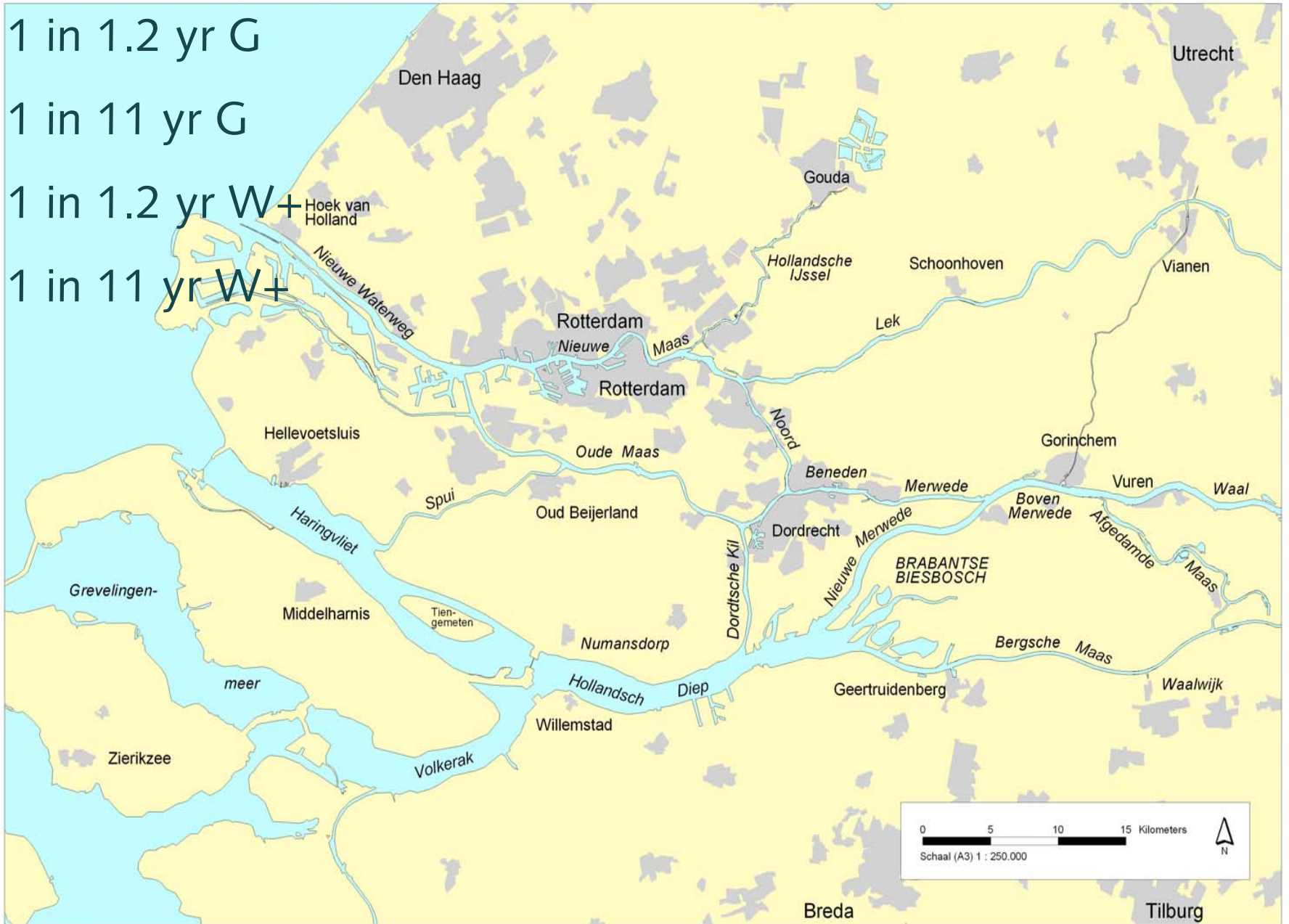


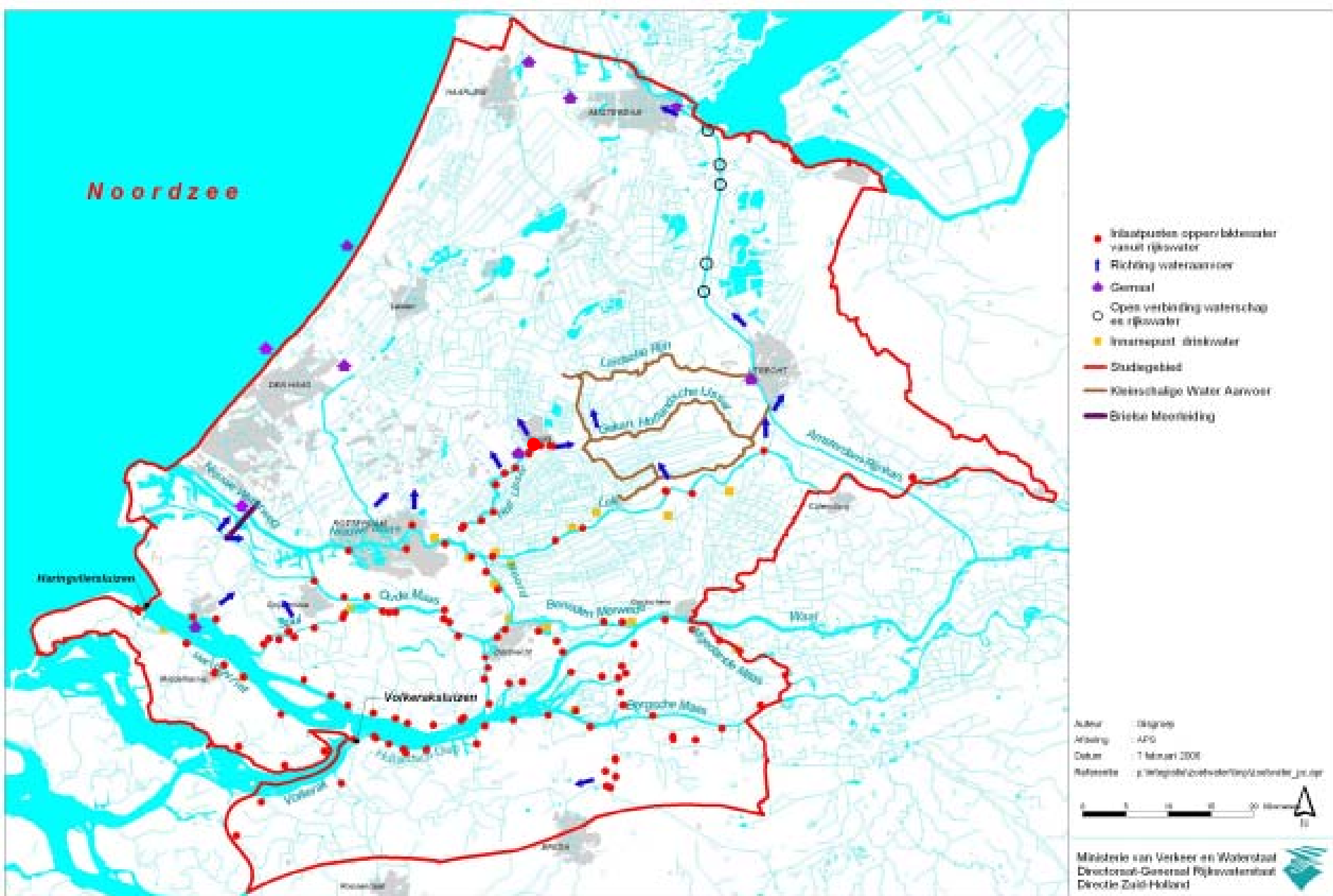
1 in 1.2 yr G

1 in 11 yr G

1 in 1.2 yr W+

1 in 11 yr W+



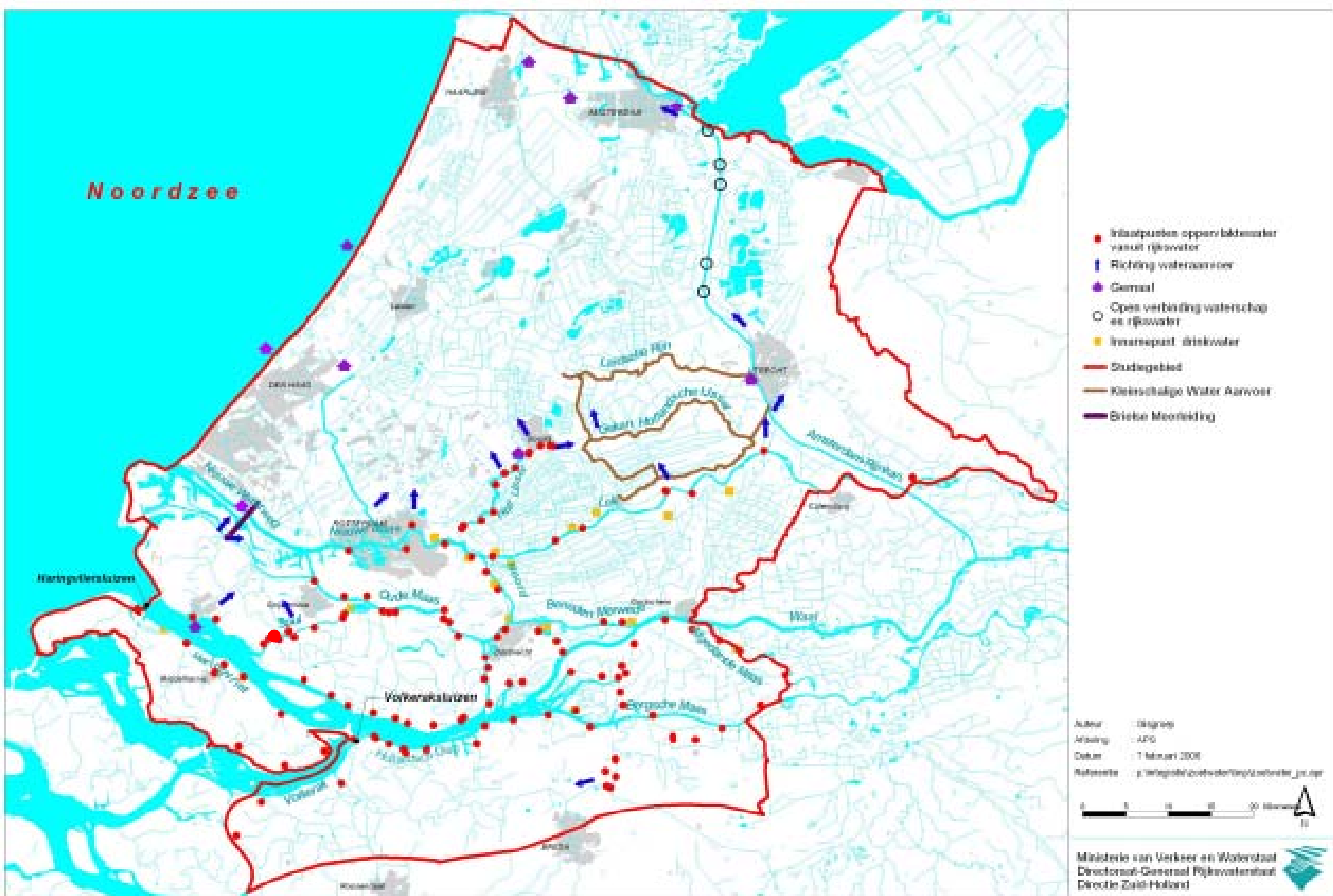


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Effects of Climate Change

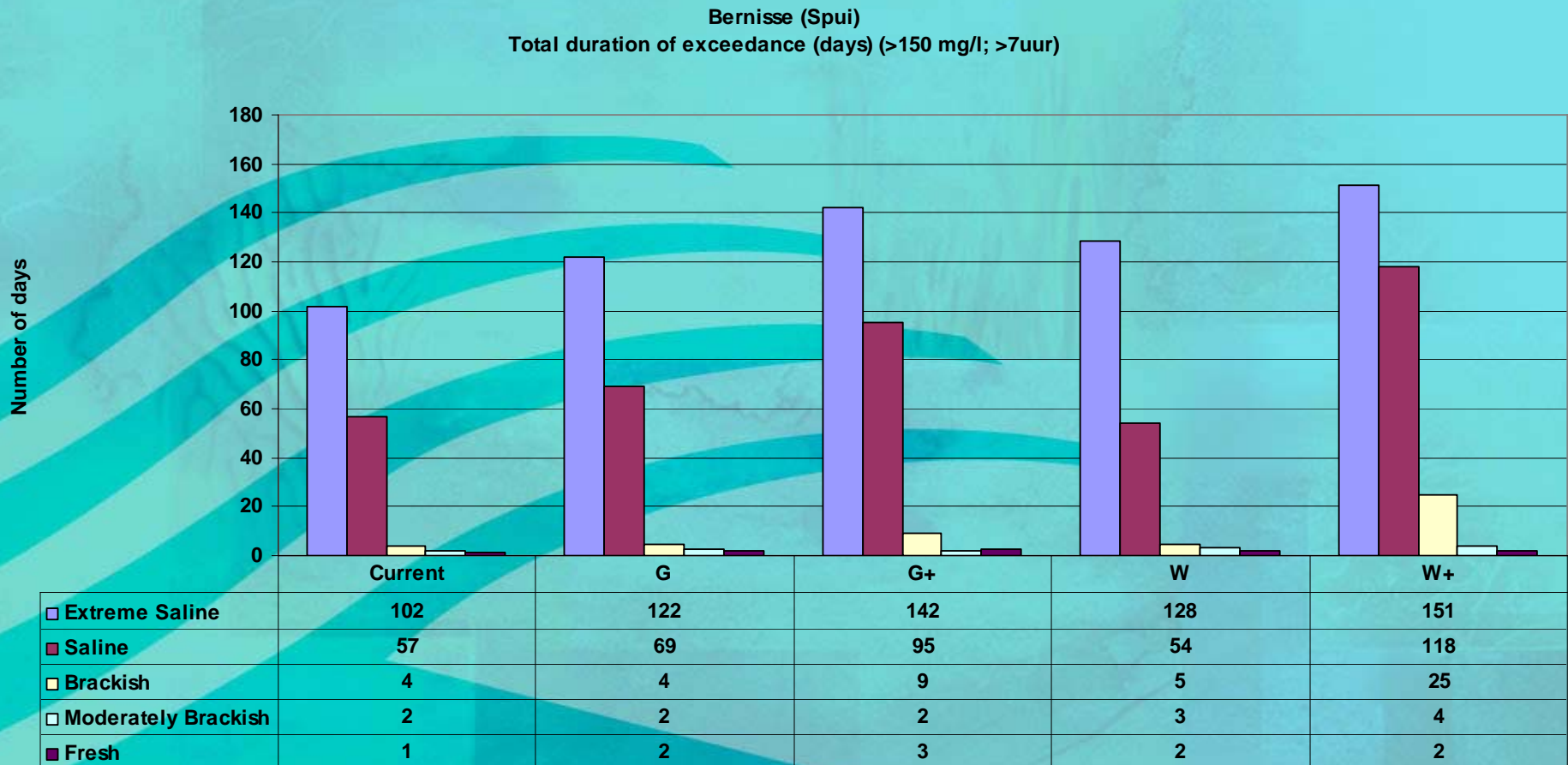
Gouda (Hollandsche IJssel)
Total duration of exceedance (>250mg/l; >48 uur)





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Effects of Climate Change



Possible Measures

- Prevention of (increased) salination through technical solutions
- Compensation of (increased) salination by technical and/or financial measures
- Spatial planning
- Alternative fresh water supply

Possible Measures

- Prevention of (increased) salination through technical solutions
 - Changing geometry of the Nieuwe Waterweg
- Compensation of (increased) salination by technical and/or financial measures
- Spatial planning
- Alternative fresh water supply

Possible Measures

- Prevention of (increased) salination through technical solutions
- Compensation of (increased) salination by technical and/or financial measures
- Spatial planning
- Alternative fresh water supply

Possible Measures

- Prevention of (increased) salination through technical solutions
- Compensation of (increased) salination by technical and/or financial measures
 - Desalination units for drinking water supply
- Spatial planning
- Alternative fresh water supply

Possible Measures

- Prevention of (increased) salination through technical solutions
- Compensation of (increased) salination by technical and/or financial measures
- Spatial planning
- Alternative fresh water supply

Possible Measures

- Prevention of (increased) salination through technical solutions
- Compensation of (increased) salination by technical and/or financial measures
- Spatial planning
 - Possibly very effective but low feasibility
- Alternative fresh water supply

Possible Measures

- Prevention of (increased) salination through technical solutions
- Compensation of (increased) salination by technical and/or financial measures
- Spatial planning
- Alternative fresh water supply

Possible Measures

- Prevention of (increased) salination through technical solutions
- Compensation of (increased) salination by technical and/or financial measures
- Spatial planning
- Alternative fresh water supply
 - Fresh water supply at local or residential level

Possible Measures

- Prevention of (increased) salination through technical solutions
- Compensation of (increased) salination by technical and/or financial measures
- Spatial planning
- Alternative fresh water supply
 - Fresh water supply at local or residential level
 - Relocation of extraction points

Conclusions

- Salt intrusion will enhance due to climate change
- The “+-scenarios” will have the largest effect
- Fresh water supply will be effected
- Social and economic consequences are still uncertain
- Feasible measures are not readily available

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Discussion