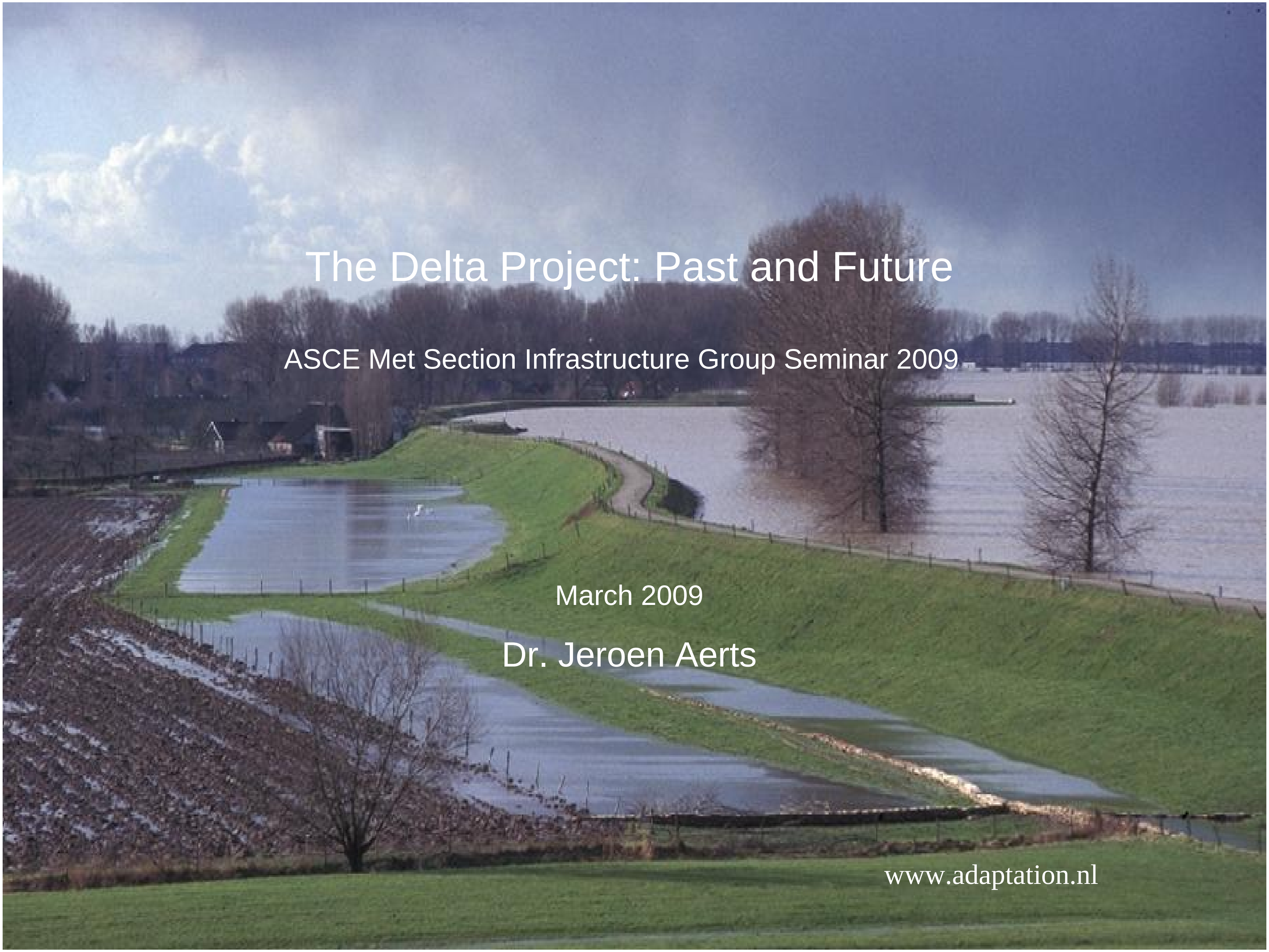

The Delta Project: Past and Future

ASCE Met Section Infrastructure Group Seminar 2009

March 2009

Dr. Jeroen Aerts

www.adaptation.nl

Content

1. Geographical location

2. History of Delta project

3. Climate Change: New Delta Project

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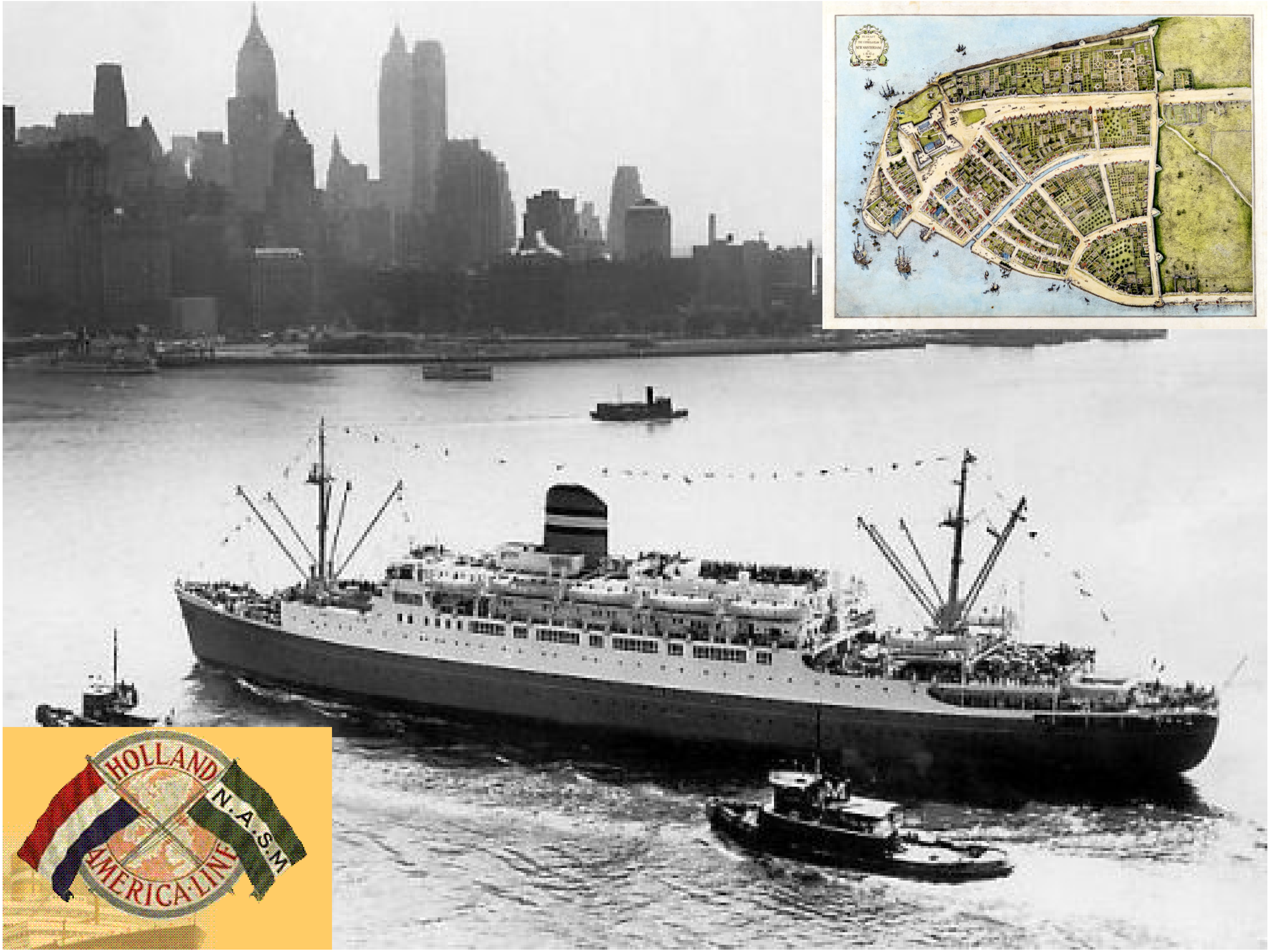
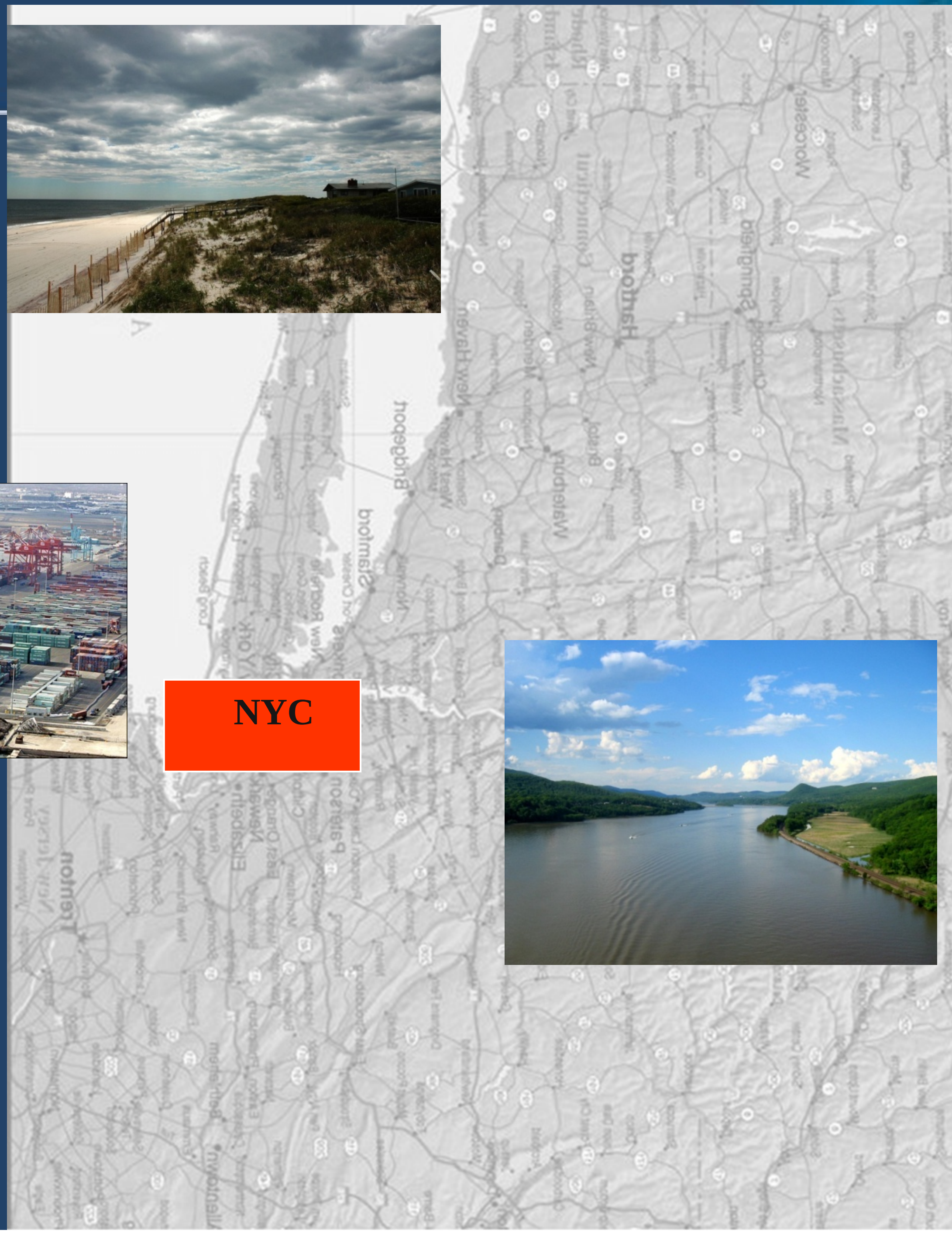
Norway
Sweden
Scotland
Denmark
Ireland
Netherlands
England
Germany
Rotterdam
Rhine
Belgium
Main
Mosel
Neckar
Meuse
France
Rhine

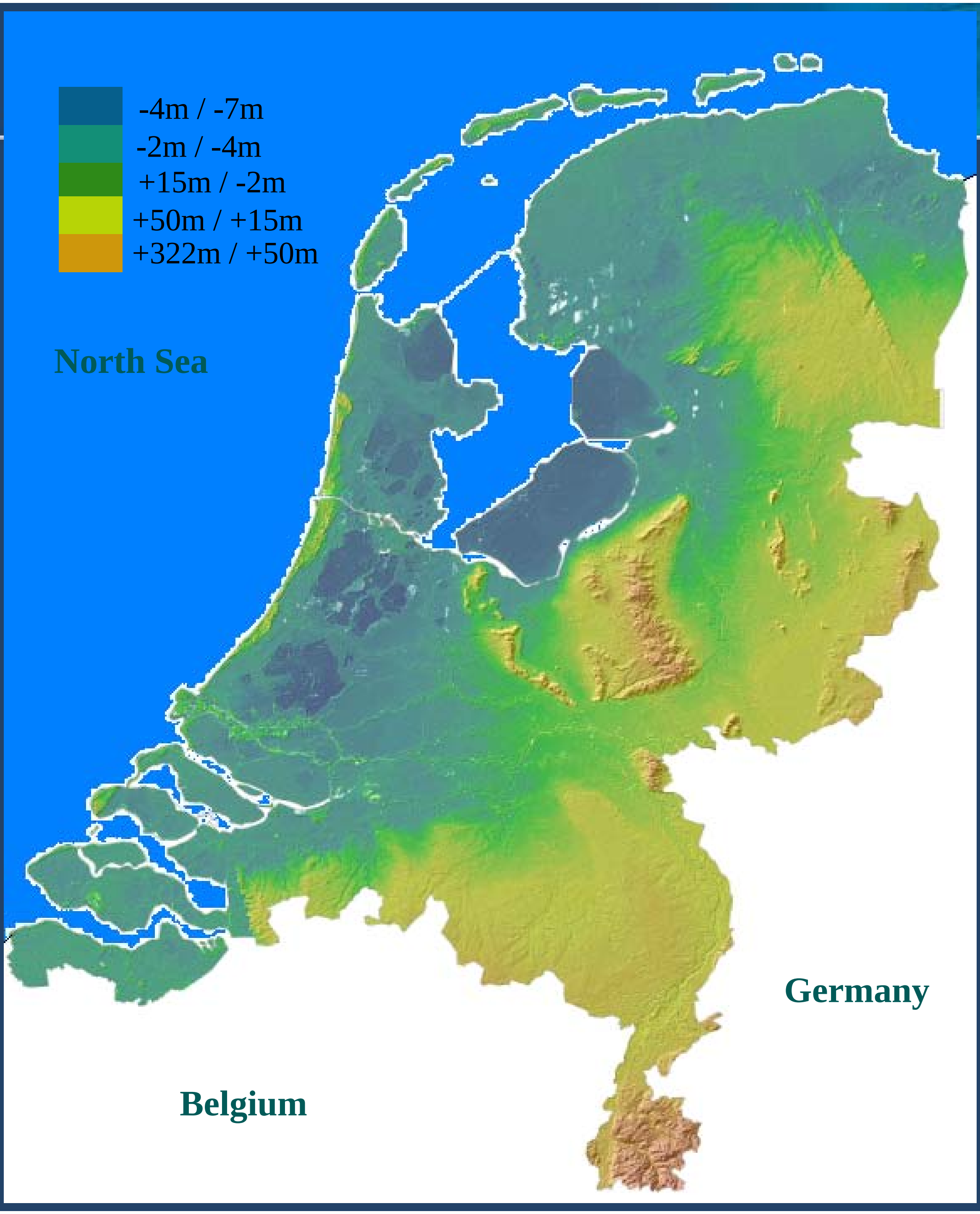

HOLLAND
N.A.S.M
AMERICA-LINE


Albany
Troy
Massachusetts
Worcester
Springfield
Chicopee
Holyoke
Hartford
New Britain
Bristol
Connecticut
Rhode Island
Waterbury
Meriden
Danbury
New Haven
West Haven
Bridgeport
Norwalk
Stamford
Port Chester
New Rochelle
Yonkers
Paterson
Clifton
Passaic
East Orange
Newark
Jersey City
New York
Elizabeth
Bayonne
Long Beach
Trenton
New Jersey
Allentown
Bethlehem
Atlantic Ocean


Atlantic Ocean
Albany
Hartford
Springfield
Worcester
Connecticut
Massachusetts
New Haven
Bridgeport
Stamford
Waterbury
New York
Newark
Elizabeth
Paterson
Trenton


NYC

R'dam

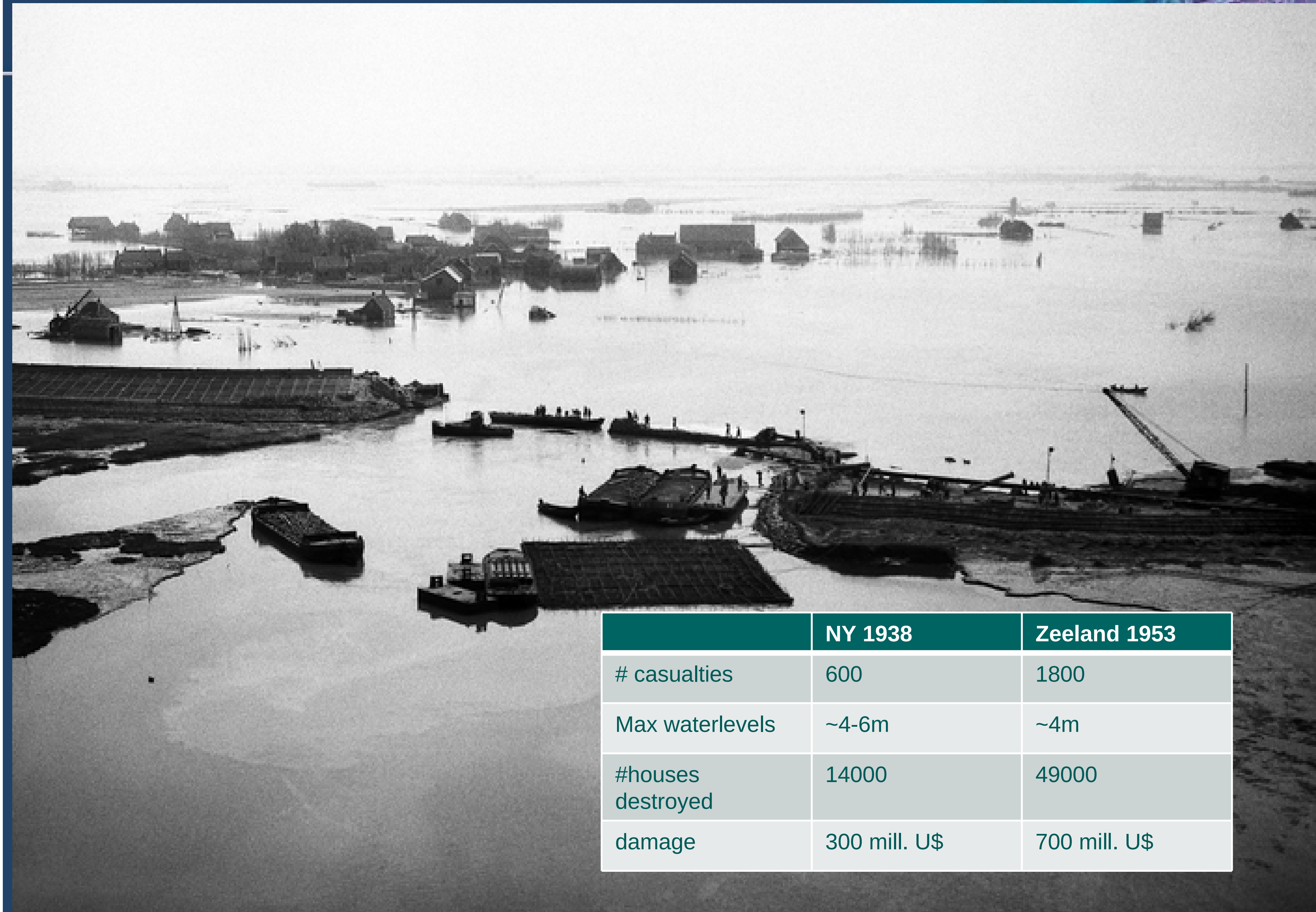

-4m / -7m
-2m / -4m
+15m / -2m
+50m / +15m
+322m / +50m
North Sea
Germany
Belgium

Flood 1855

1938 Hurricane

1953 SW Holland ('Zeeland')


Hitler Says Army Will March Against Czechs
SOUTHBRIDGE EVENING NEWS
DEATH TOLL NEAR 600; WARN AUTOS
Half Billion Loss In N. E. States
Appeal to Keep All Cars Off Streets
WARNINGS
THANKS



	NY 1938	Zeeland 1953
# casualties	600	1800
Max waterlevels	~4-6m	~4m
#houses destroyed	14000	49000
damage	300 mill. U$	700 mill. U$

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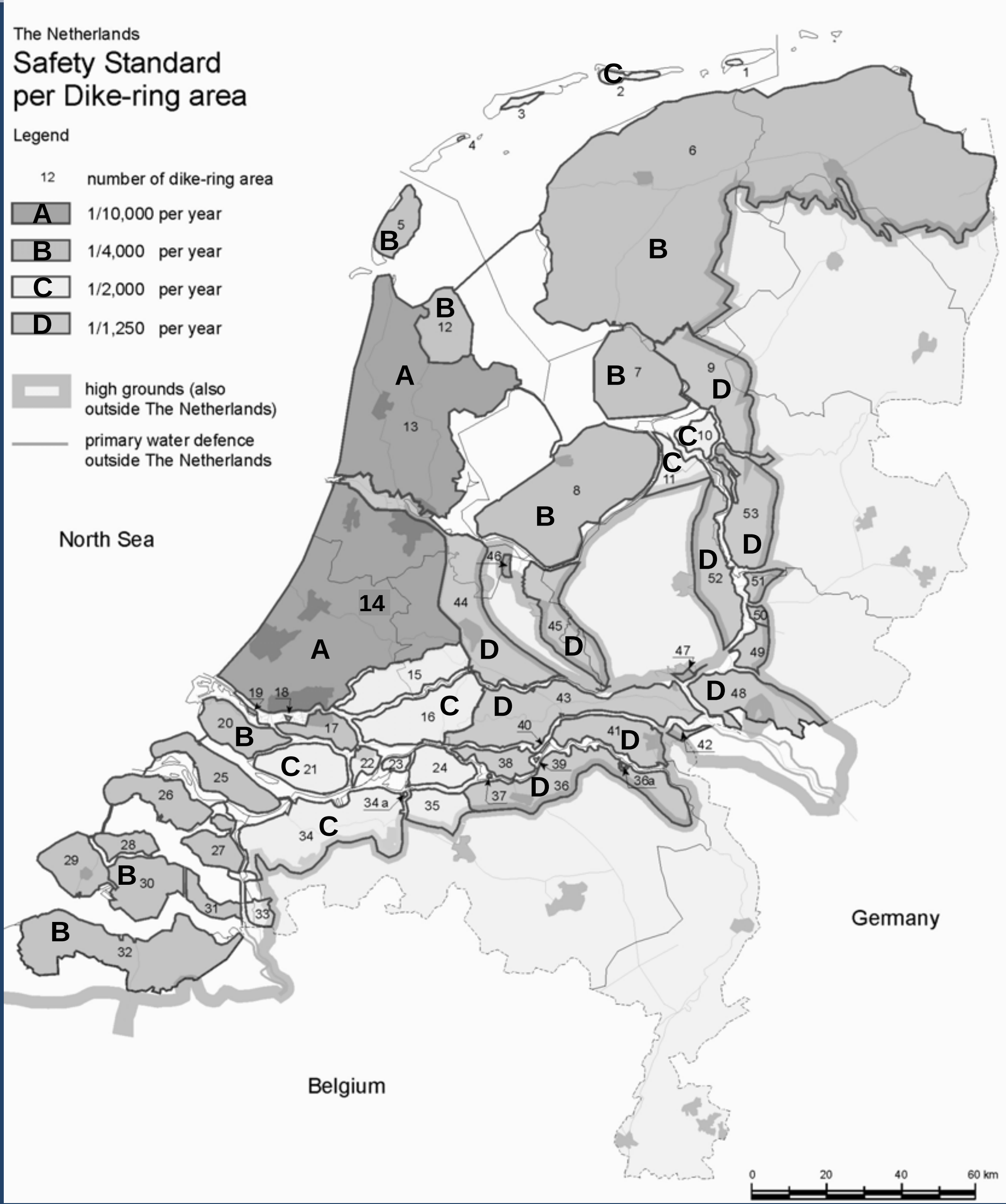
Delta-act → Delta Plan



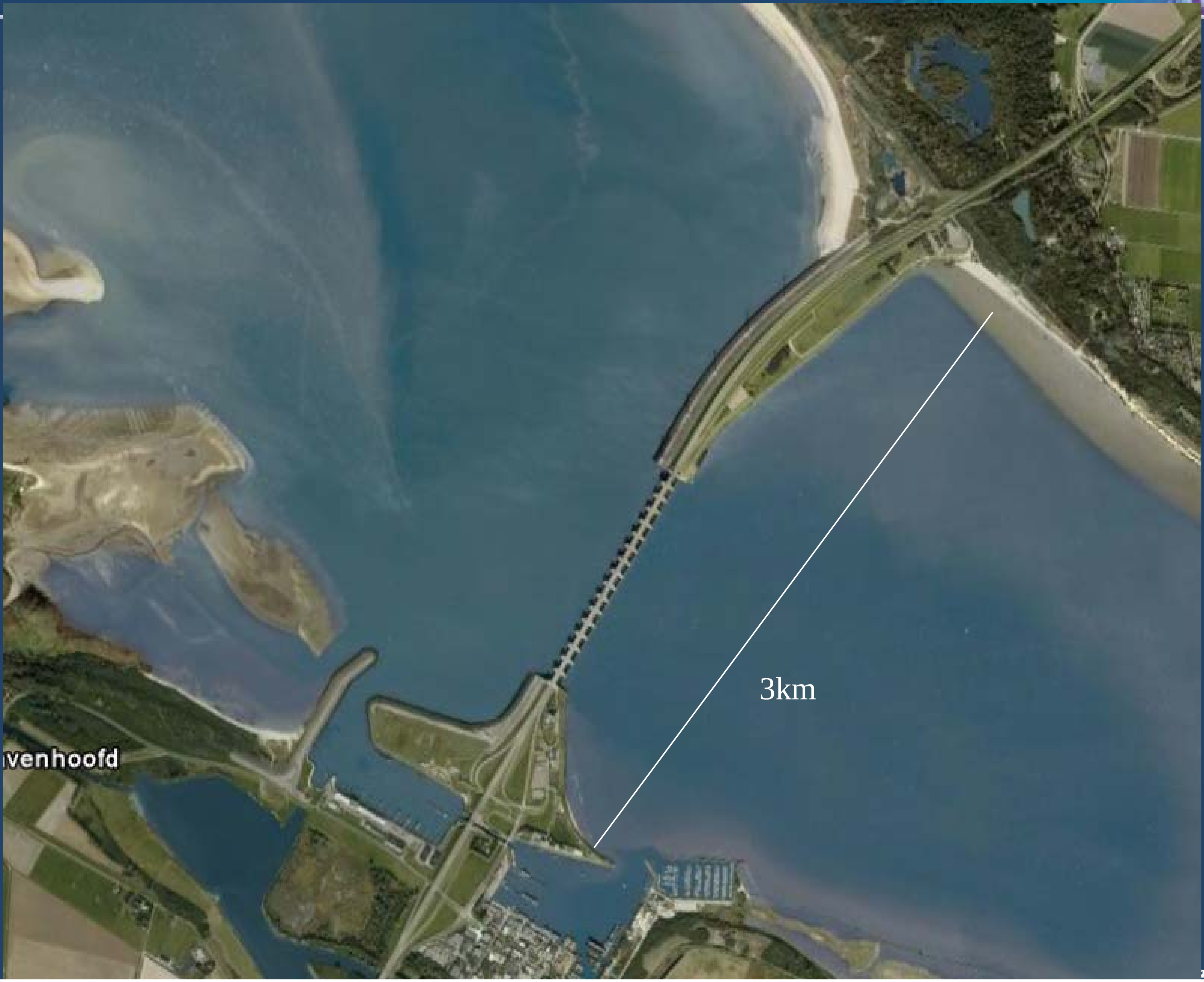
Series of dams and barriers

Arguments for Delta plan

- Full protection: Storm surge may not happen again
- Dams & barriers shorten the coastline : raising 1000 km of dikes is more expensive
- Create fresh water reservoirs & protection against salt intrusion
- Fresh water as potential for recreation


Brouwersdam
© Rijkswaterstaat - 8 november 2005 - 14.09 uur

Haringvliet Sluices


3km
venhoofd


Haringvliet sluices

Haringvliet sluices

Value of Estuary: Eastern Scheldt Barrier

Eastern Scheldt barrier: 3 barriers over 3 km

Maeslantbarrier; Accessibility Rotterdam harbor

Construction costs	Year in operation	Net present value 2007 million € [Disc rate 2%]	Net present value 2007 million € [Disc rate 4%]
Storm Surge barrier Hollandse IJssel	1954	98	126
Haringvliet barrier	1961	1,464	1750
Brouwersdam	1961	353	421
Hellegatsplein and Volkerak sluices	1961	477	570
Grevelingen dam	1961	165	197
Storm Surge barrier Oosterschelde	1986	3,850	6161
Compartmentworks	1984	837	1295
Canal through Zuid-Beveland	1984	915	739
Maeslant storm surge barrier	1997	477	559
Europoort barrier and Hartel barrier	1997	253	259
Total costs [Billions Euro]		8,9	12,1

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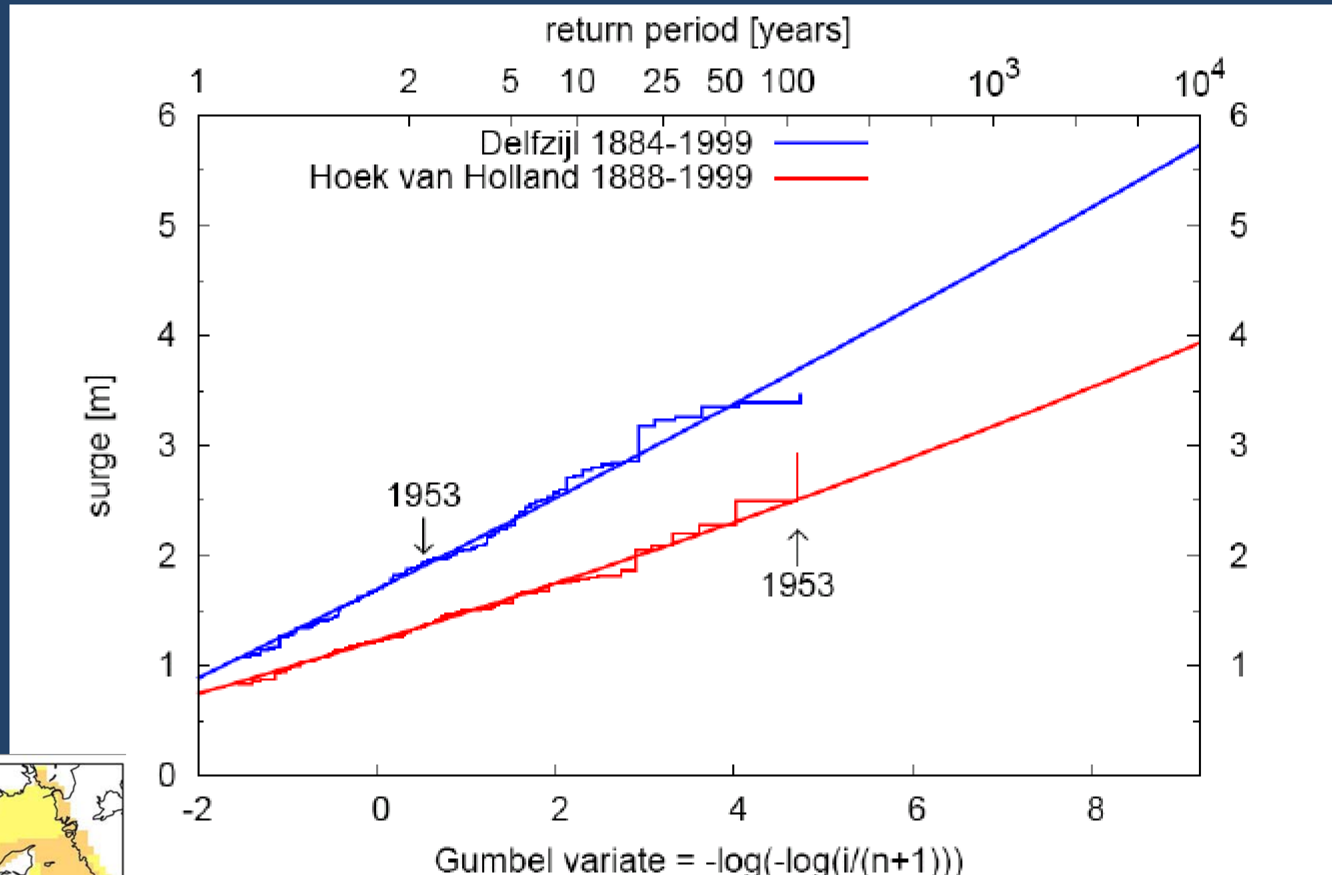
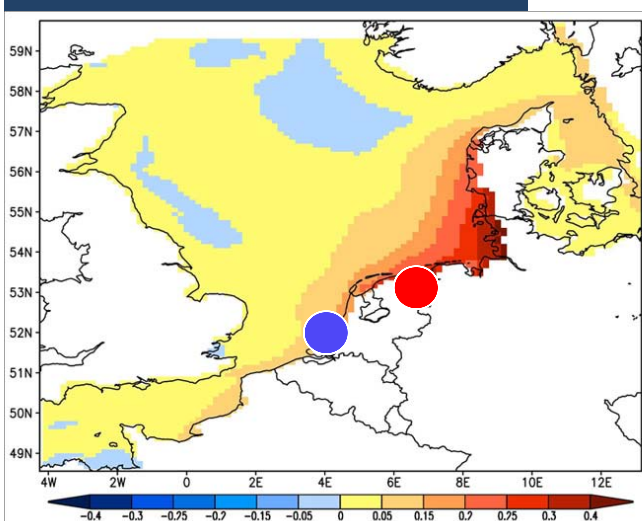
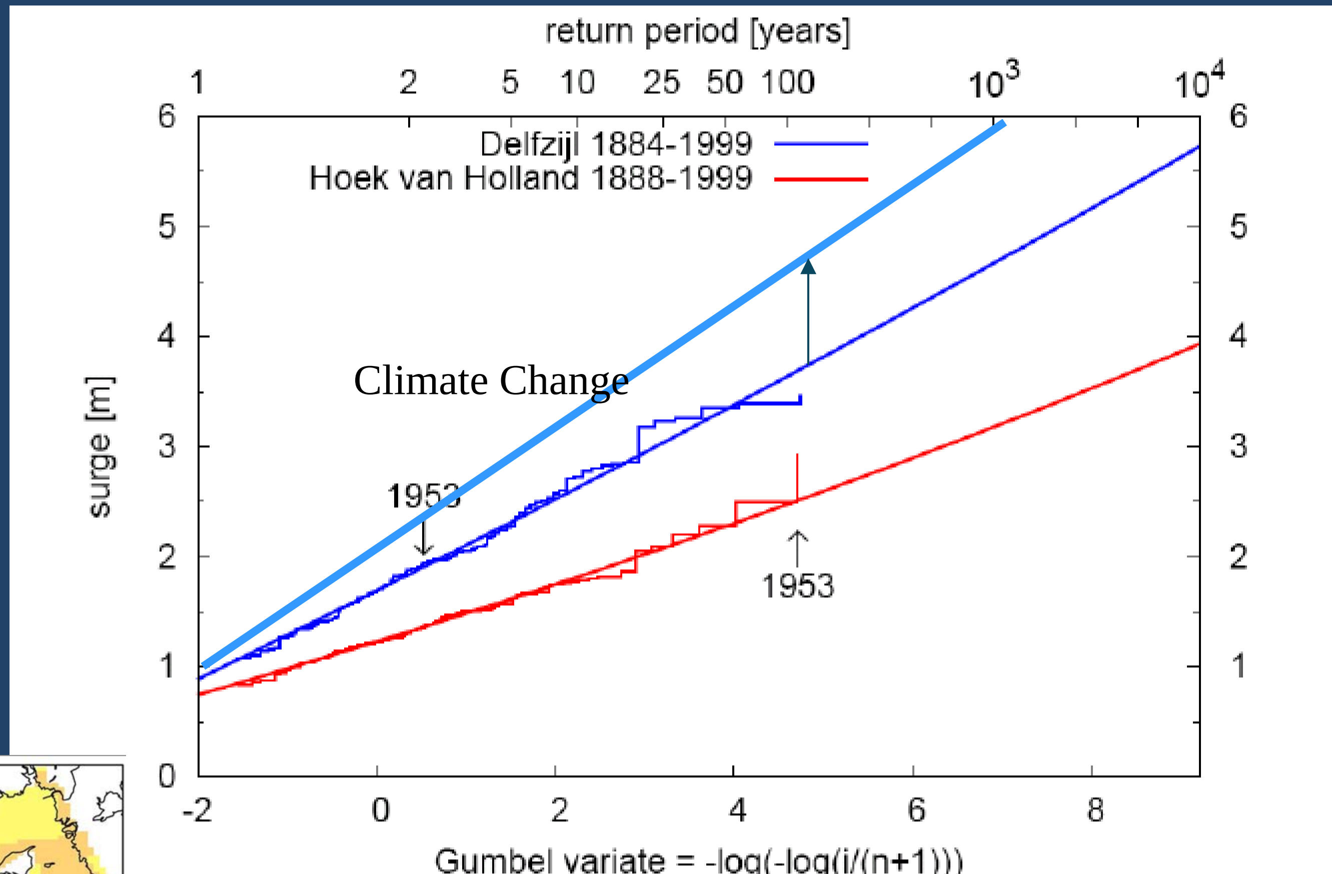
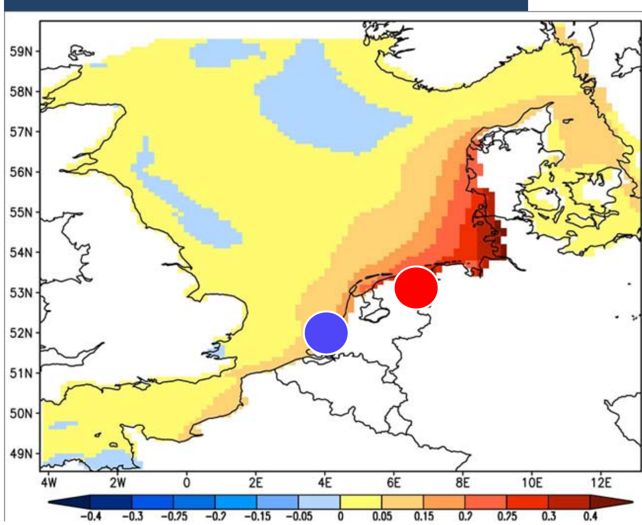
Climate Change / Sea level rise



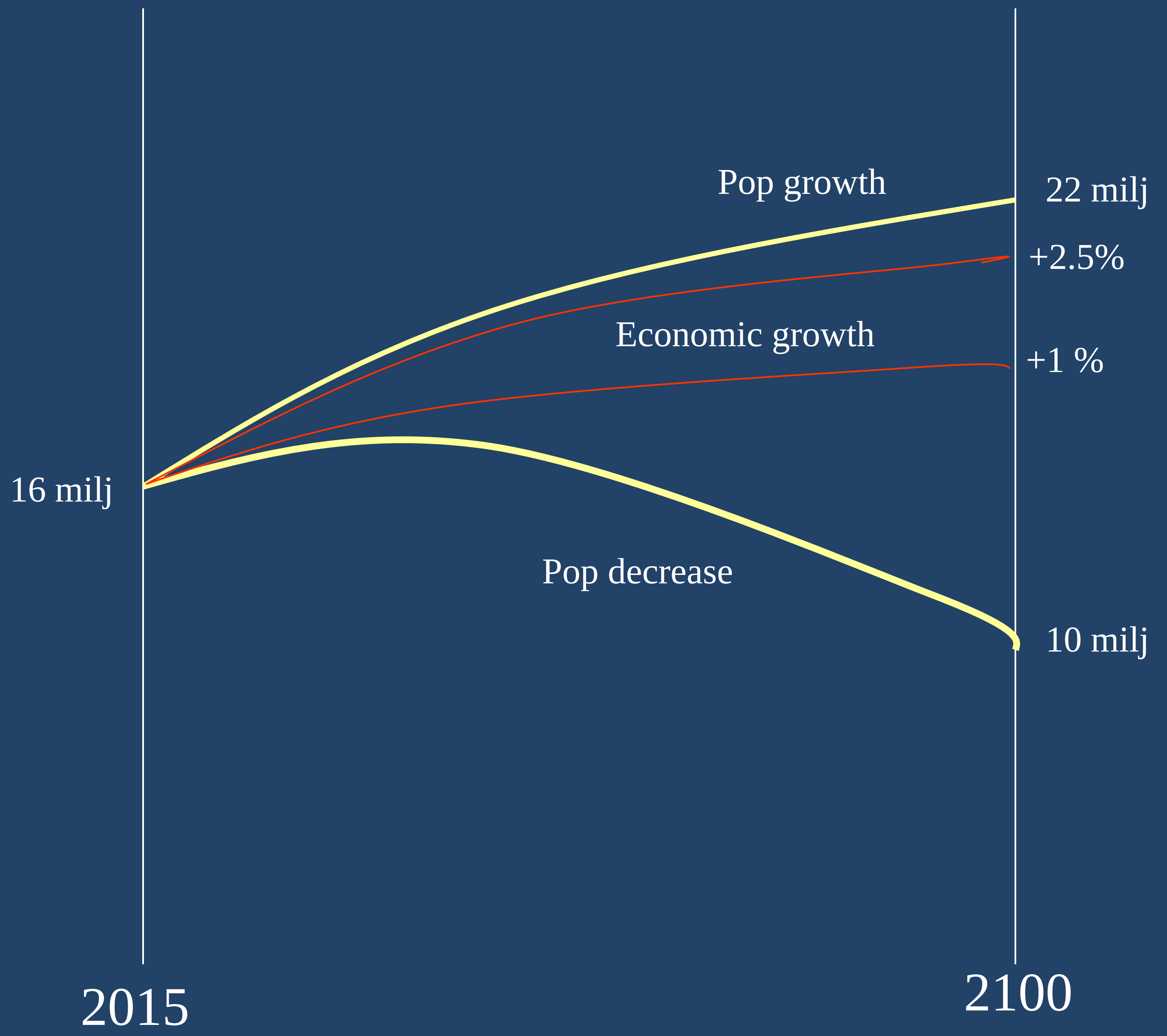


Climate Change / Sea level rise





Socio Economic trends




Rotterdam 1684


Rotterdam 1940


Rotterdam 2000
http://takeoff.to/rotterdam

landgebruik

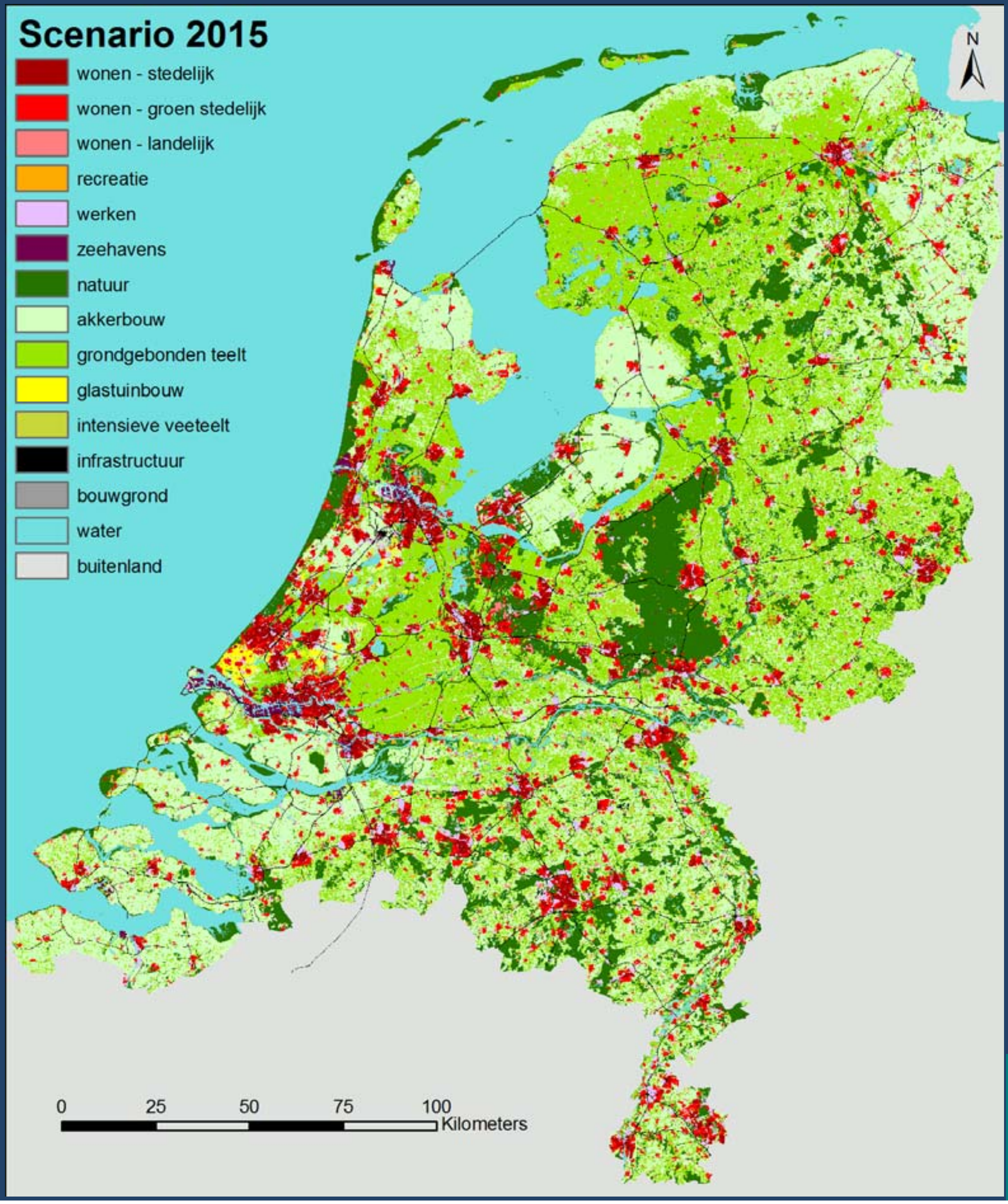
"Gezicht op Nieuw Amsterdam" by Johannes Vingboons (1664)

landgebruik

landgebruik

Land use 2015

16 Mil. inhabitants

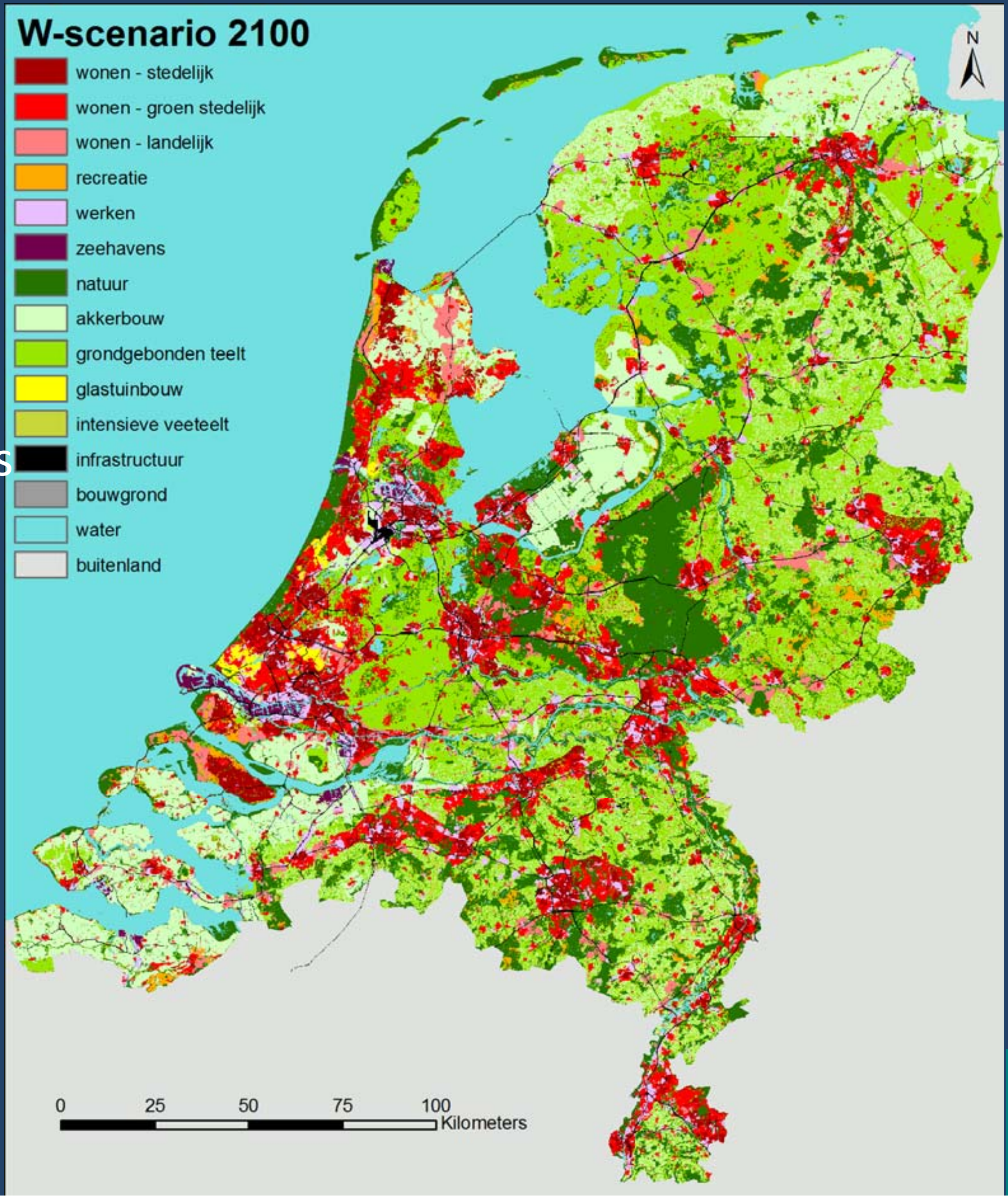


Source: project Aandacht voor Veiligheid 2007

www.adaptation.nl

Land use 2100

22 Mil. inhabitants



Source: project Aandacht voor Veiligheid 2007

www.adaptation.nl

Risk based approach

- Socio – economic impacts:
  - Casualties
  - Direct damage
  - Indirect damage
- Probability of an extreme flood
- Risk = probability * damage

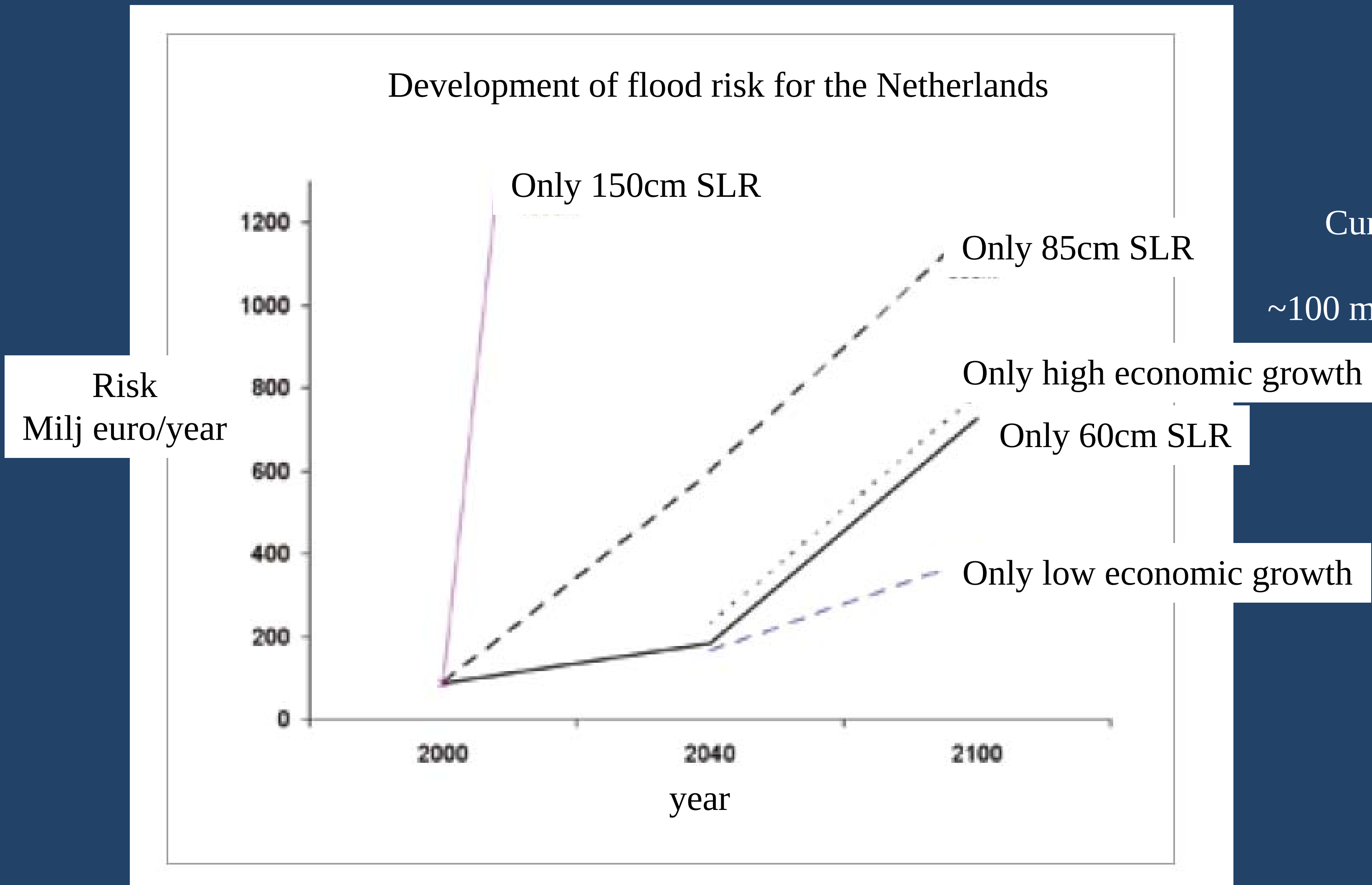
Resilience

- Adaptive capacity (o.a. finance, recovery, governance ….)

City	Current Exposure		Approximate Protection Standard (Return period in years)	Annual Average Risk (Residual Risk)	
	Population (000)	Assets (US$ bil)		Population (000/yr)	Assets (US$ bil/yr)
London	397	60	1:1000	0.4	0.06
Shanghai	2,353	73	1:1000	2	0.07
Osaka	1,373	216	1:300	4.6	0.7
New York	1,540	320	1:100	15	3.2
Tokyo	1,110	174	1:1000	1	0.174
Amsterdam	839	128	1:10000	0.08	0.013
Rotterdam	752	115	1:10000	0.08	0.011
New Orleans	1124	234	1:200[11]	5.1	1.168.4

Nichols et al, 2008

Risk : probability * Damage



Current risk:

~100 milj. Euro/year

Uncertainty

Source: http://info.insure.com, 2002

Top 10 worst places for an extreme hurricane to strike

Rank	Location	Possible insured losses*	Potential total economic losses**
1	Miami/Ft. Lauderdale, Fla.	$61.3 billion	$122.6 billion
2	New York City, N.Y.	$26.5 billion	$53 billion
3	Tampa/St. Petersburg, Fla.	$25.1 billion	$50 billion
4	Houston/Galveston, Texas	$16.8 billion	$33.6 billion
5	New Orleans, La.	$8.4 billion	$16.8 billion
6	Mobile, Ala.	$6.0 billion	$12 billion
7	Boston, Mass.	$5.1 billion	$10.2 billion
8	Biloxi/Gulfport, Miss.	$5.1 billion	$10.2 billion
9	Myrtle Beach, S.C.	$4.3 billion	$8.6 billion

Source: cnn 2007

U.S.

Tools: Save | Print | E-mail | Most Popular | [+] Feedback

Hurricane Katrina SPECIAL REPORT

» Rebuilding | Storm & Flood | Help Center | People

New Orleans files $77 billion claim against Corps

POSTED: 2:47 a.m. EST, March 2, 2007

SPECIAL REPORT

STORY HIGHLIGHTS
- Thursday was last day for residents to file claims under Federal Tort Act
- Bush visits Gulf Coast region, vowing to "stay committed" to recovery
- Corps has six months to either accept, settle or reject claims
- Corps designed levee system that was supposed to protect the low-lying city

Adjust font size:

NEW ORLEANS, Louisiana (CNN) -- The city of New Orleans filed a $77 billion damage claim against the Army Corps of Engineers Thursday for flooding that inundated the city when levees failed after Hurricane Katrina in August 2005.

Erosion: work with nature

NY area:	+/- 4 million m3 sand/ year
Netherlands:	+/- 20 million m3 sand/ year

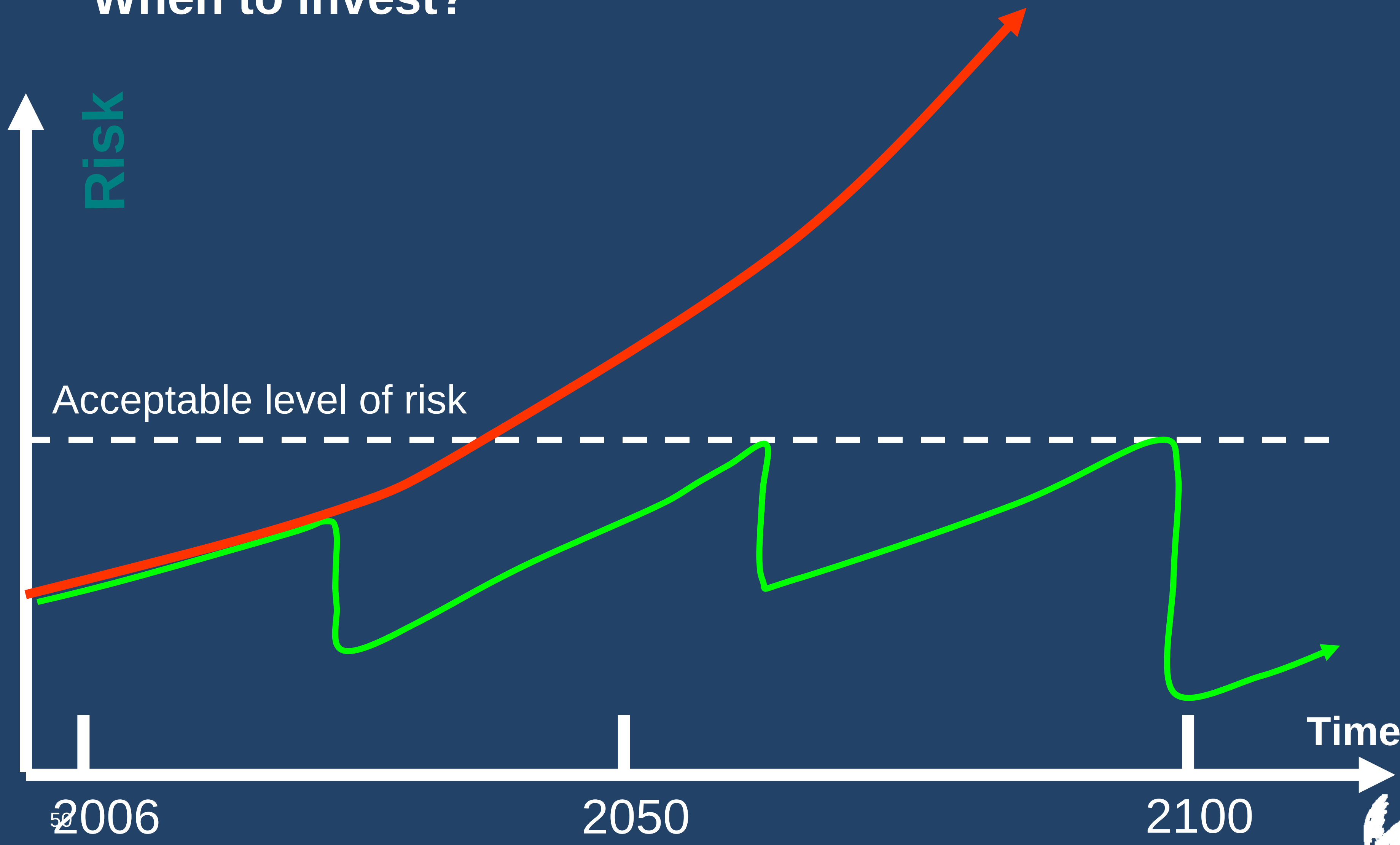
New Delta PLan

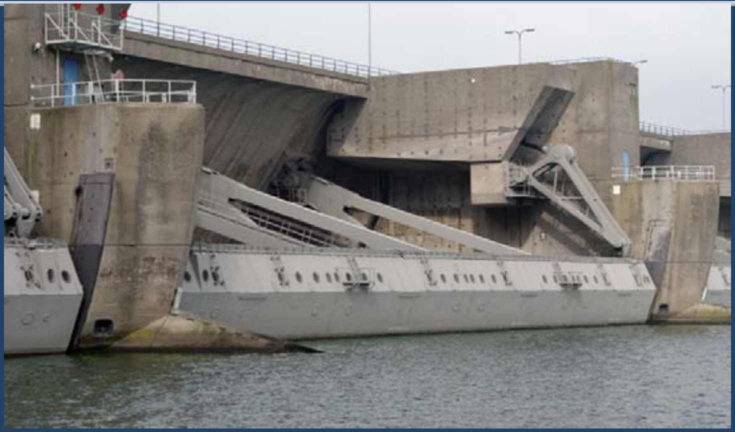
Building codes, Innovation in Architecture

Costs of adaptation

	Scenario's				
	2040	**2100**	**2100**	**2100**	Far Future
SLR [cm]	24	60	85	150	500
Max Discharge Rhine [m3/s]	16.800	18.000	18.000	18.000	18.000
Max Discharge Meuse [m3/s]	4200	4.600	4.600	4.600	4.600
	Costs [Billions Euro's]				
Re enforcement Levees					
	2,7	5,5	5,5	5,5	5,5
	1,3	4,2	4,2	4,2	4,2
[Billions Euros]	0,2	1,8	2,6	6,1	36
Beach nourishment					
	1,9	6,4	9,1	16,0	25
	1,1	3,8	5,4	9,6	?
	0,1	0,4	0,6	1,1	?
[Billions Euros]	1,9	2,3	2,6	3,4	8
Total [Billions Euros]	**9**	**24**	**30**	**46**	**>80**

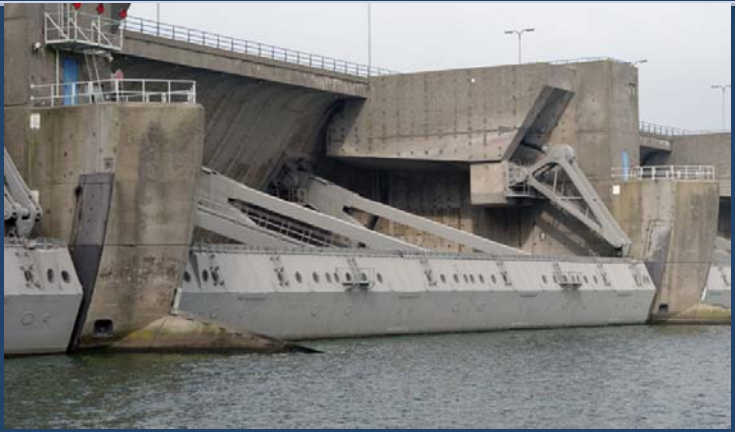
When to invest?





Original costs in 1970: 1,5 Billion Euro’s (2007)

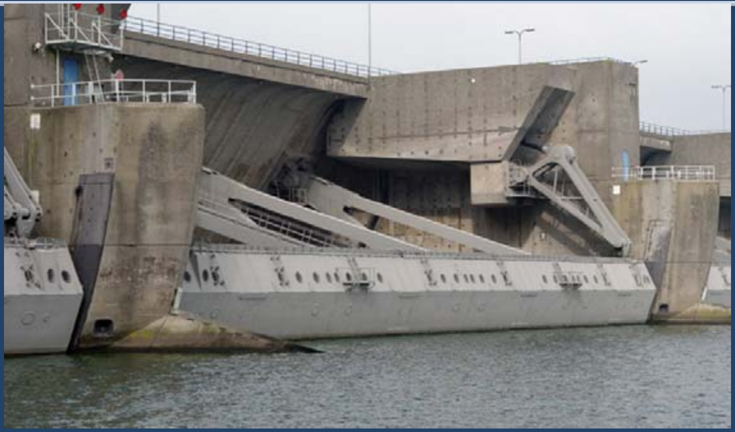
Option 1. Replacement of doors for 60cm = 100 Million Euro
Option 2: replace whole barrier = 1 Billion Euro’s



Lifetime barrier = 100 years

Design criteria in 1970 = 20cm sea level rise in 100 years

→Barrier is 50 years old: “ only10cm sea level rise to go”
→ With a SLR of 60cm/100years, the barrier would not fit design criteria in ~2025
→ In 2025 invest 100 Million Euro to replace doors (replacement whole barrier in 2070-2120)



However: If SLR is 150cm

then replacement of whole barrier would be much earlier,
and hence, replacing only doors in short term is not an option

Conclusions

- Barrier concept works, but adjustments needed:
  - Environmental aspects
  - Shipping
- Working with nature
  - Beach nourishment
  - River widening
- Architecture / building codes
- Climate change poses new challenge
  - How to design measures such they are flexible to accommodate different future scenario's

Thanks!

www.adaptation.nl

www.deltacities.com