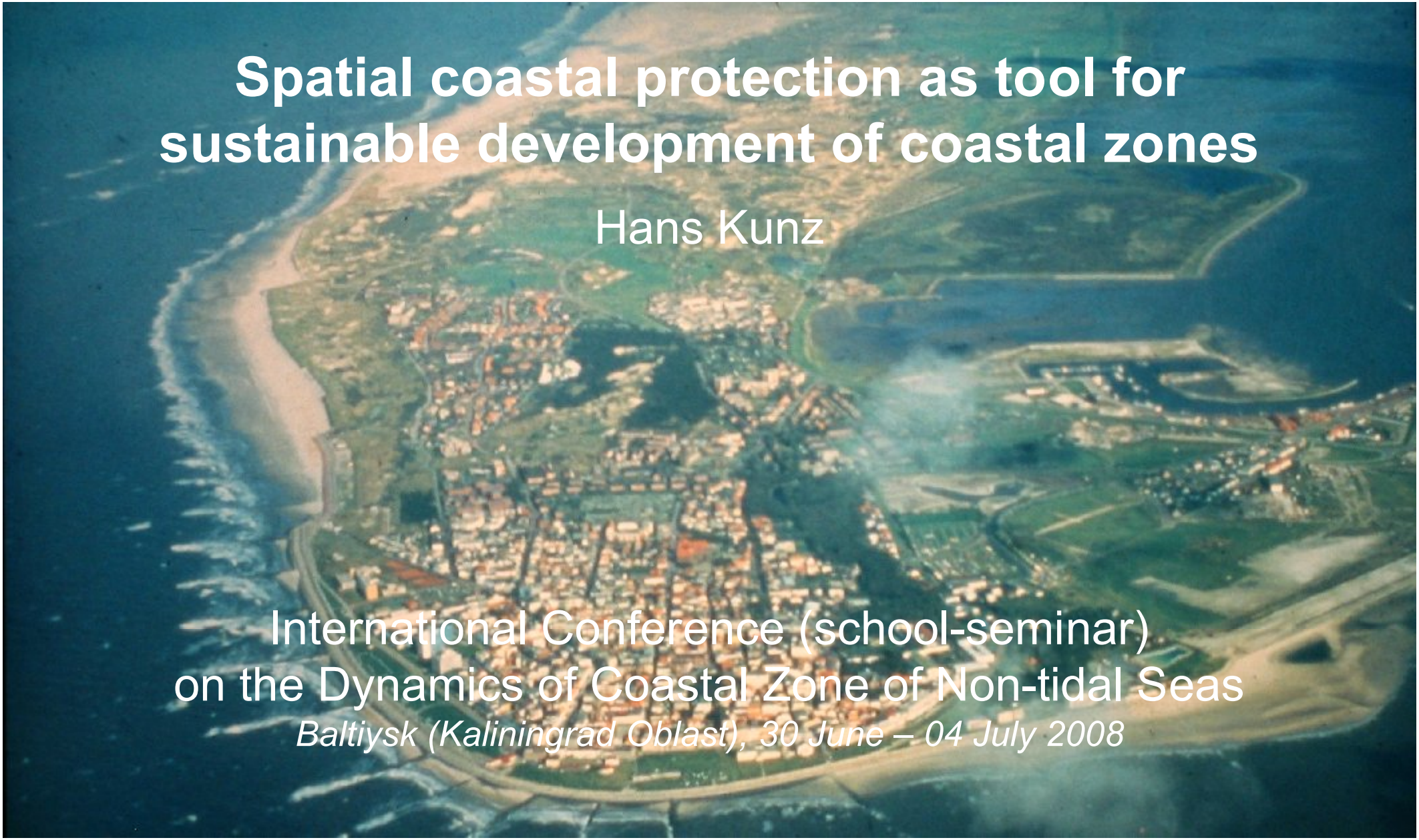


Spatial coastal protection as tool for sustainable development of coastal zones

Hans Kunz

International Conference (school-seminar)
on the Dynamics of Coastal Zone of Non-tidal Seas

Baltiysk (Kaliningrad Oblast), 30 June – 04 July 2008

Spatial coastal protection as tool for sustainable development of coastal zones

Remark: According to the focus of the conference, the presentation will concentrate on interactions between natural impacts and defence responses of the coastal society. The case studies are located in the North Sea with tidal conditions. However, presented results and conclusions can be transferred to non-tidal areas in general.

- **Coastal protection** comprises the control of **"erosion"** and **"flooding"** .
- **Claim** (vision) of a **Coastal Society** for coastal protection:
  - **control of erosion:** no losses of land – stop erosion and create new land!
  - **control of flood :** no failure of the existing "defence line" – guarantee safety!
- **Spatial coastal protection** allows and asks for flexible responses according to the side specific requirements of the extant or planned land use .
- Decisions of the Coastal Society on coastal protection means are (have always been) based on a complex process which is effected by multifarious factors.

Views on the Coastal Area
Key Factors for the Process towards Spatial Coastal Protection

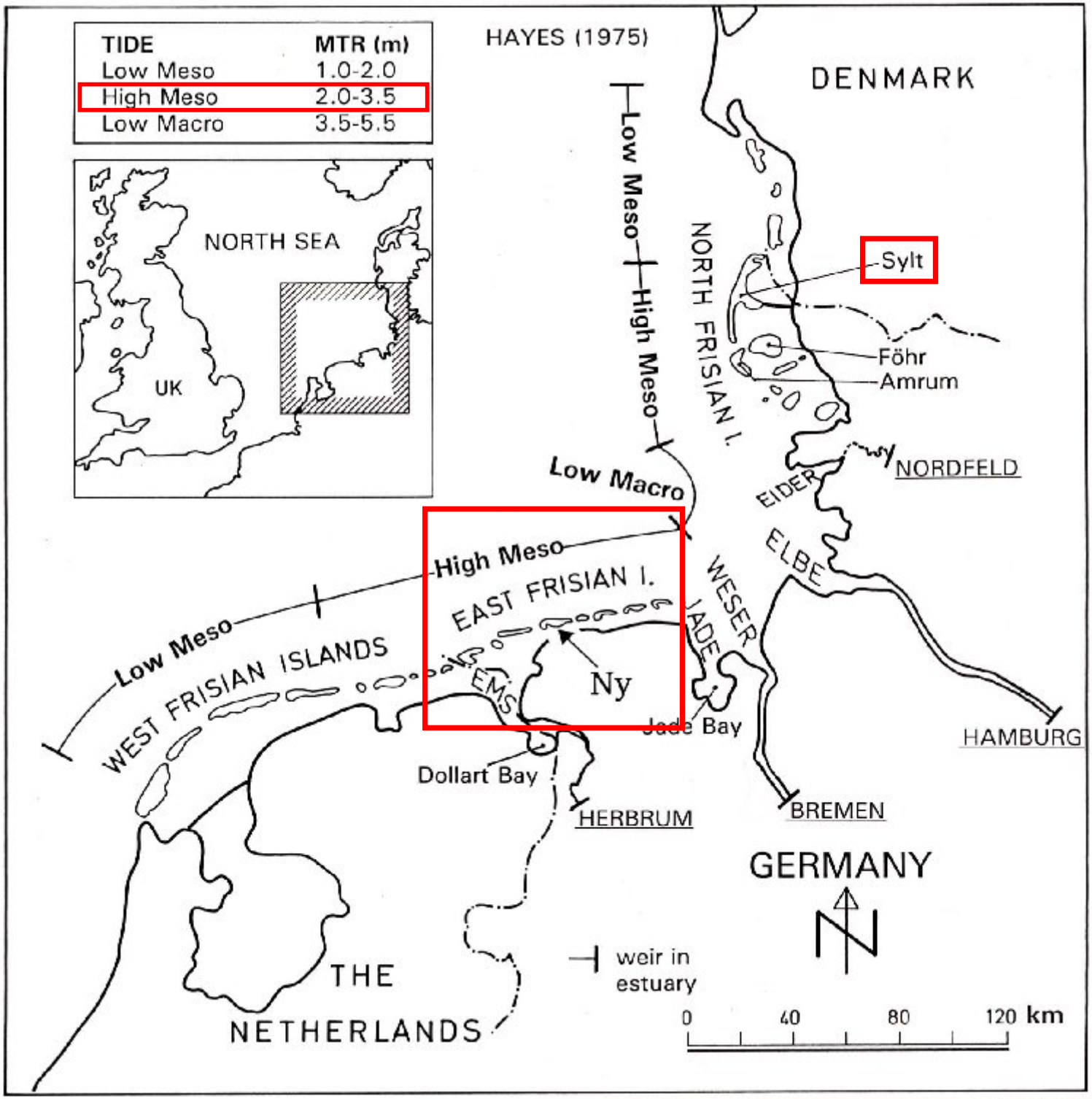
Interaction of "Natural Conditions" & Coastal Protection Responses

- Juist Island
- Norderney Island/West

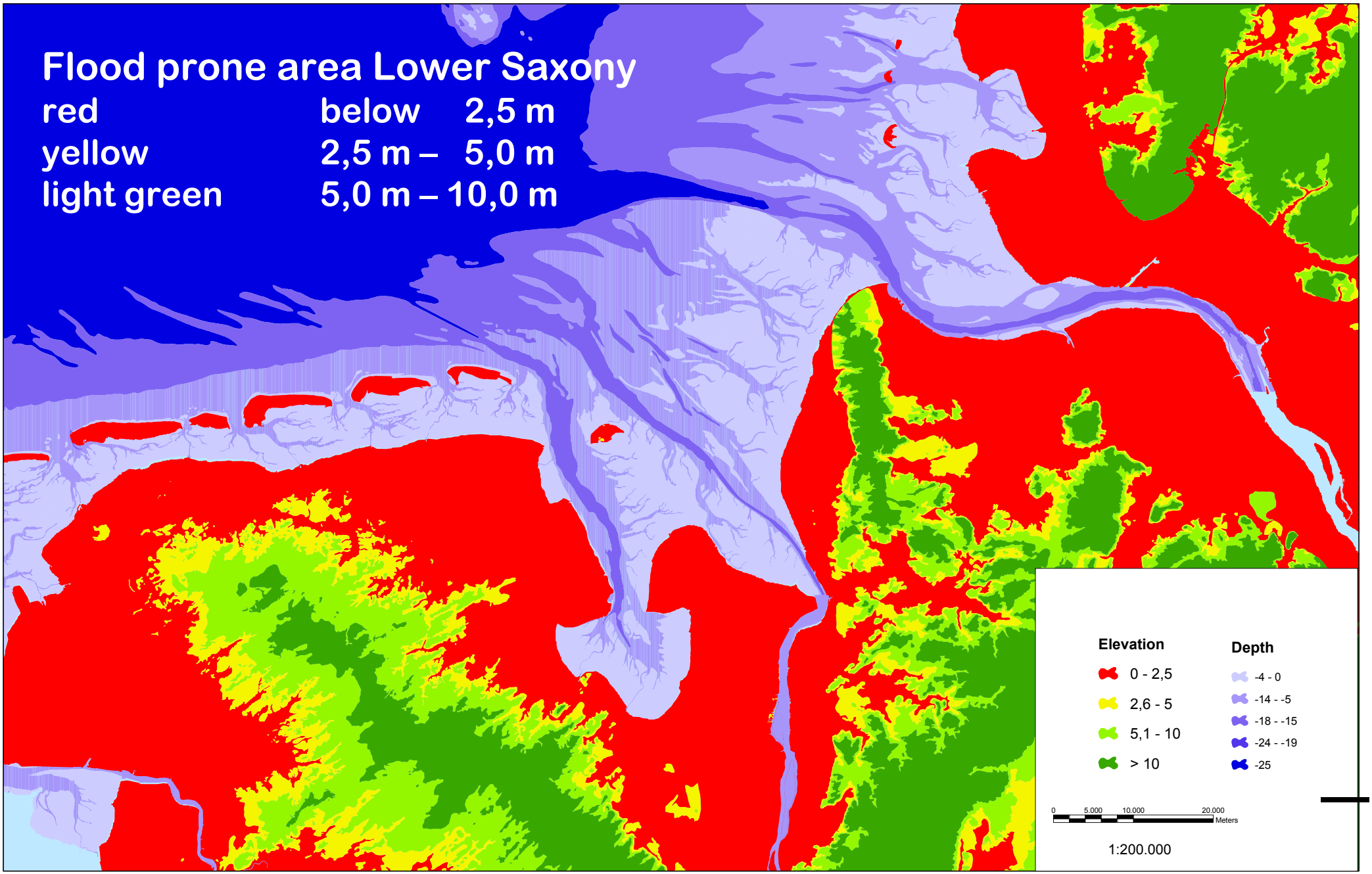
Long-term/Large-scale morphological investigations on "Coastal Steepening" (German Bight, North Sea)

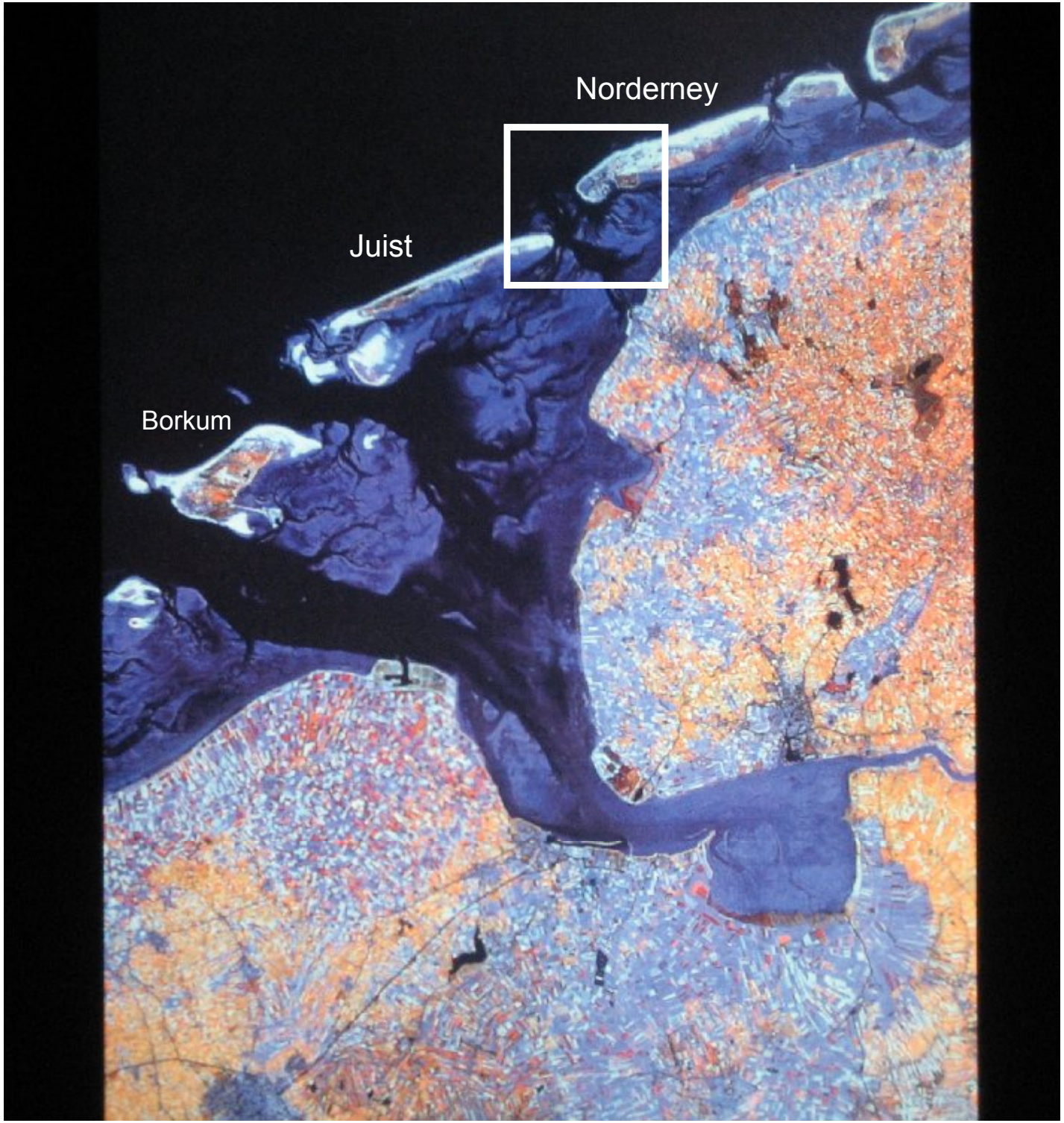
- Development Flood Defence Line (Dike)
- Case Study CZM – Ley Bay

From One Line Flood Defence to Flexible Spatial Coastal Protection


TIDE
MTR (m)
Low Meso
1.0-2.0
High Meso
2.0-3.5
Low Macro
3.5-5.5
HAYES (1975)
NORTH SEA
UK
DENMARK
Low Meso
High Meso
Low Macro
NORTH FRISIAN I.
Sylt
Föhr
Amrum
NORDFELD
EIDER
ELBE
WESER
JADE
EAST FRISIAN I.
High Meso
Low Meso
WEST FRISIAN ISLANDS
EMS
Ny
Jade Bay
HAMBURG
Dollart Bay
HERBRUM
BREMEN
GERMANY
THE NETHERLANDS
weir in estuary
0
40
80
120 km

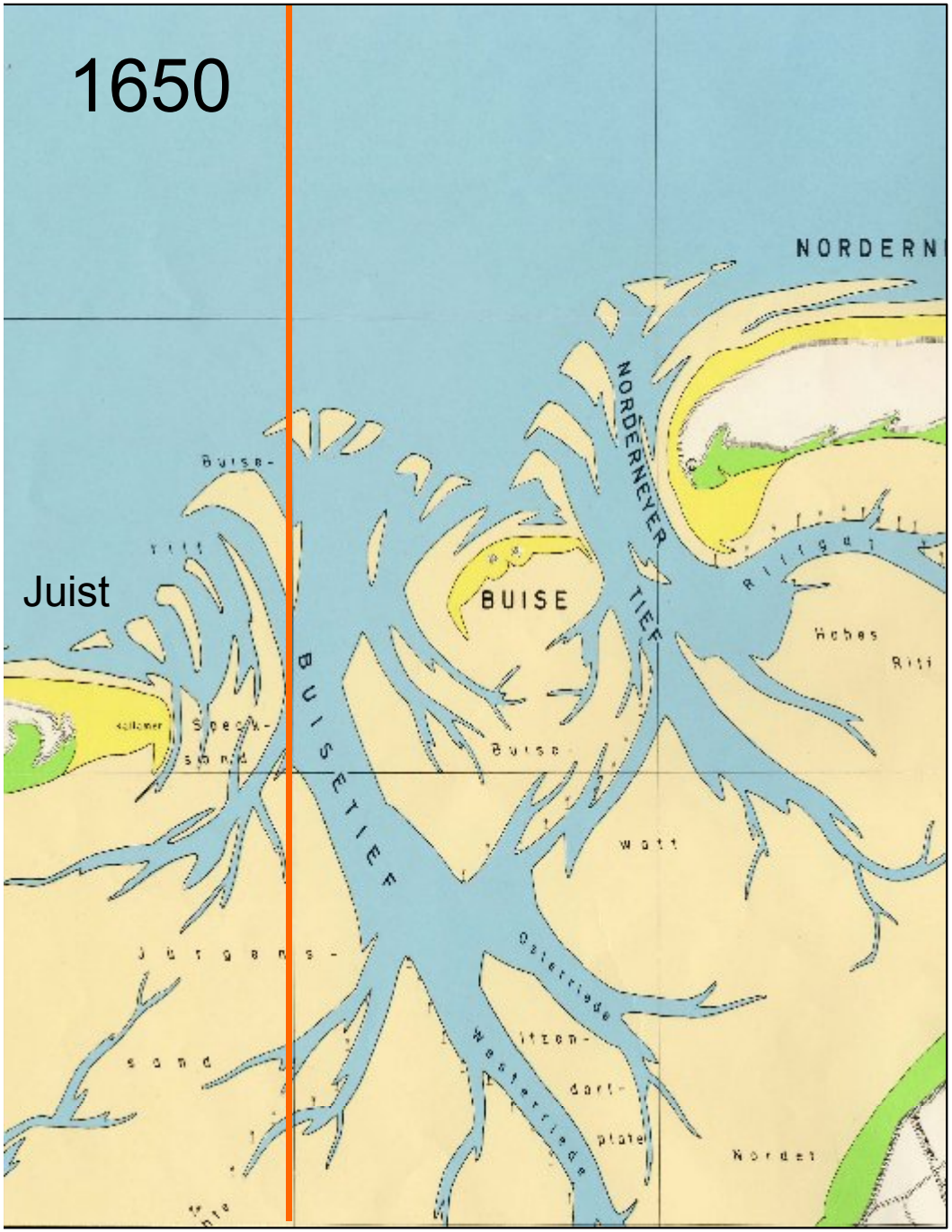
Satellite Image Sylt and
Föhr / North Frisian Island

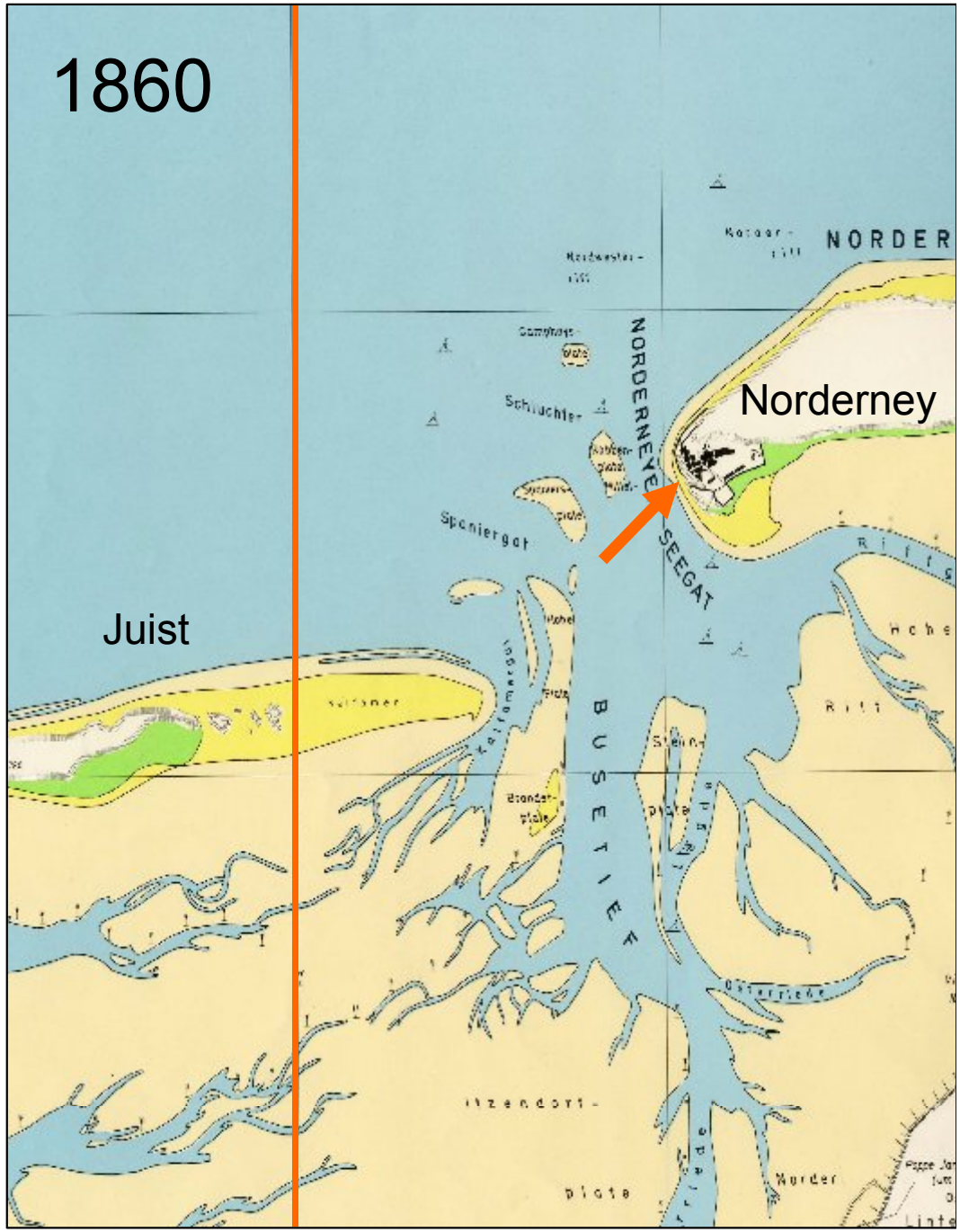

Flood prone area Lower Saxony
red below 2,5 m
yellow 2,5 m – 5,0 m
light green 5,0 m – 10,0 m
Elevation
0 - 2,5
2,6 - 5
5,1 - 10
> 10
Depth
-4 - 0
-14 - -5
-18 - -15
-24 - -19
-25
0 5.000 10.000 20.000
Meters
1:200.000



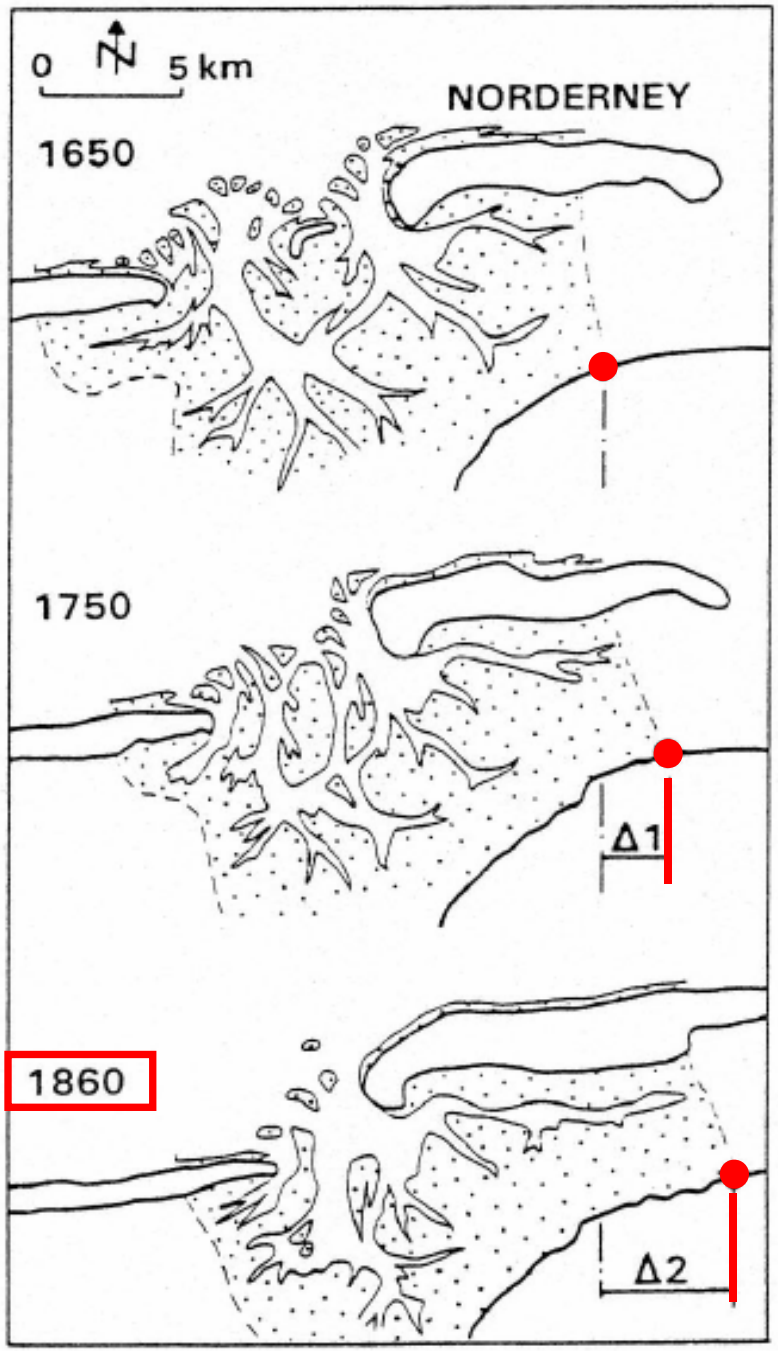
East Frisian Islands,
Western part

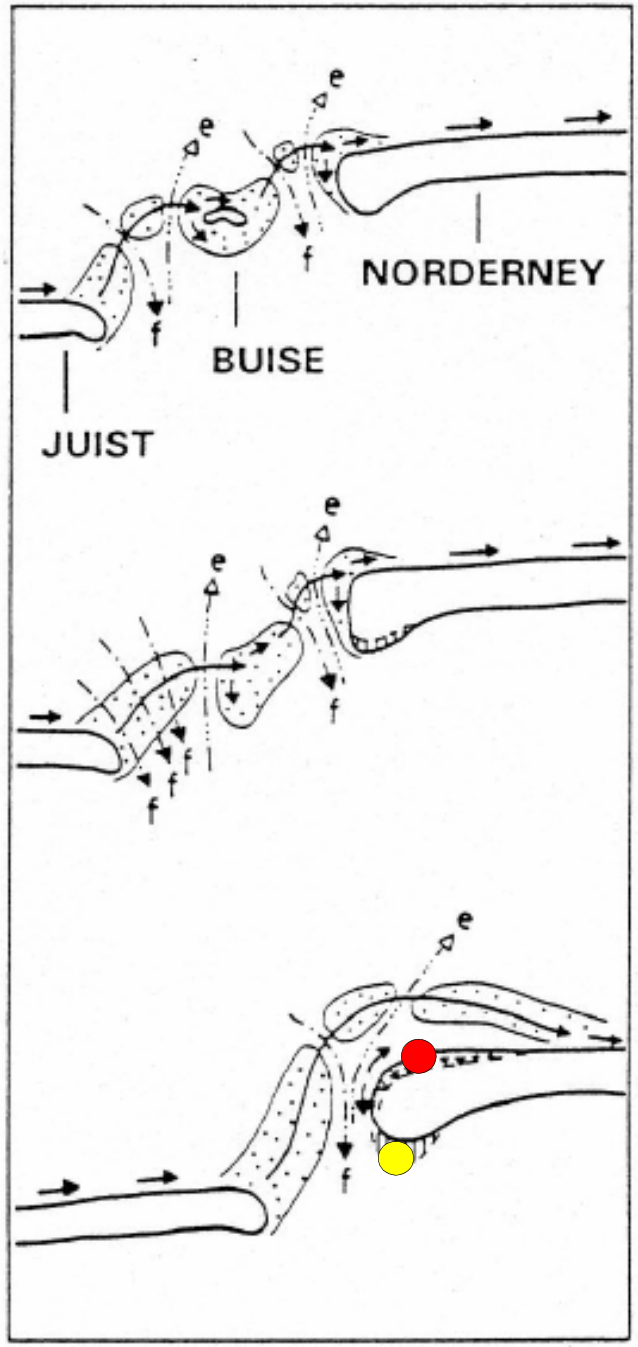
Development of the Tidal Inlets between Juist and Norderney





Morphological development Norderney Island (West)





barrier-island

shoal (plate) system

tidal flat-catchment area of the Norderney-Seegat (inlet)

divides "Norderney" (watershed)

Δ migration of "Norderney"-watershed

f flood — e ebb-current

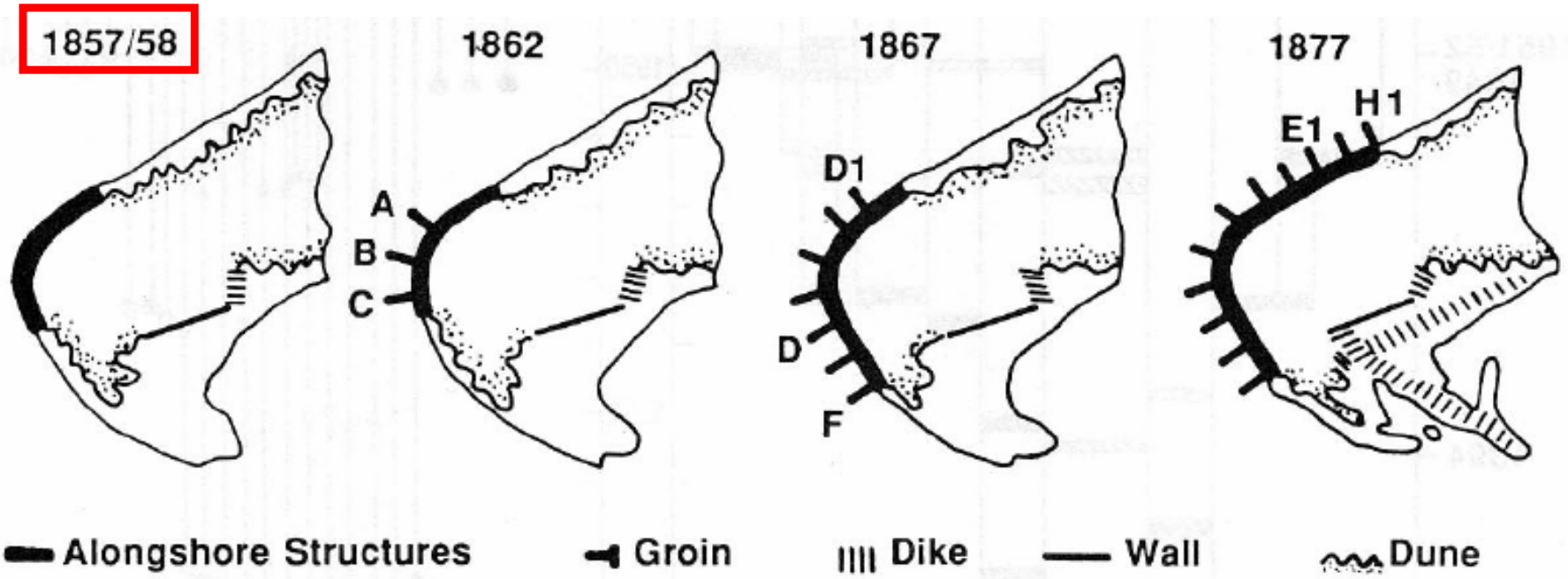
erosion — accretion

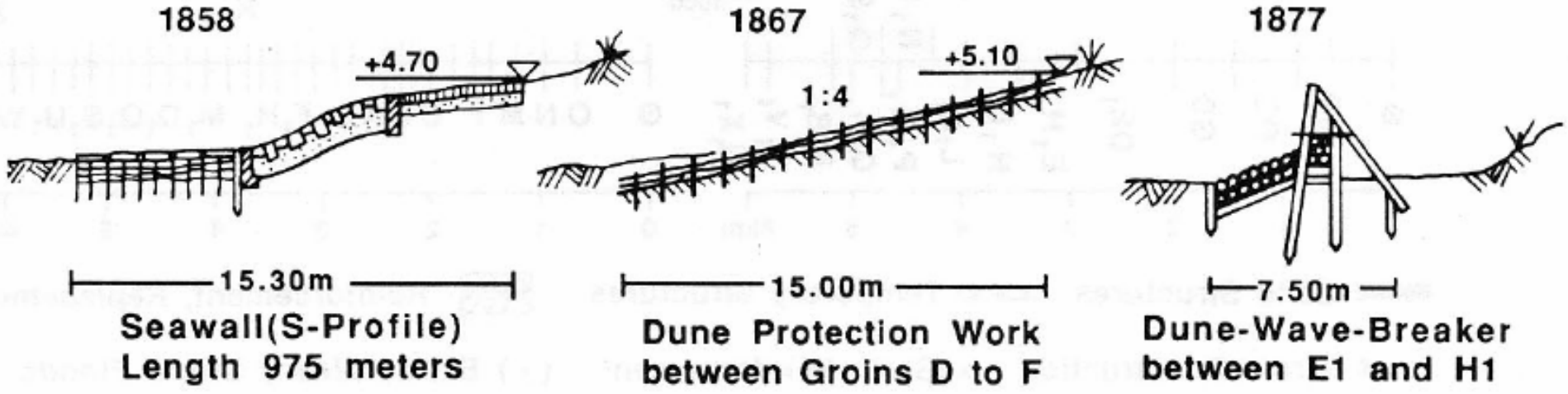
island — shoal system

longshore sand transport (littoral drift)

adapted from Luck (1975)

Development of Coastal Protection on the Western Spit of Norderney



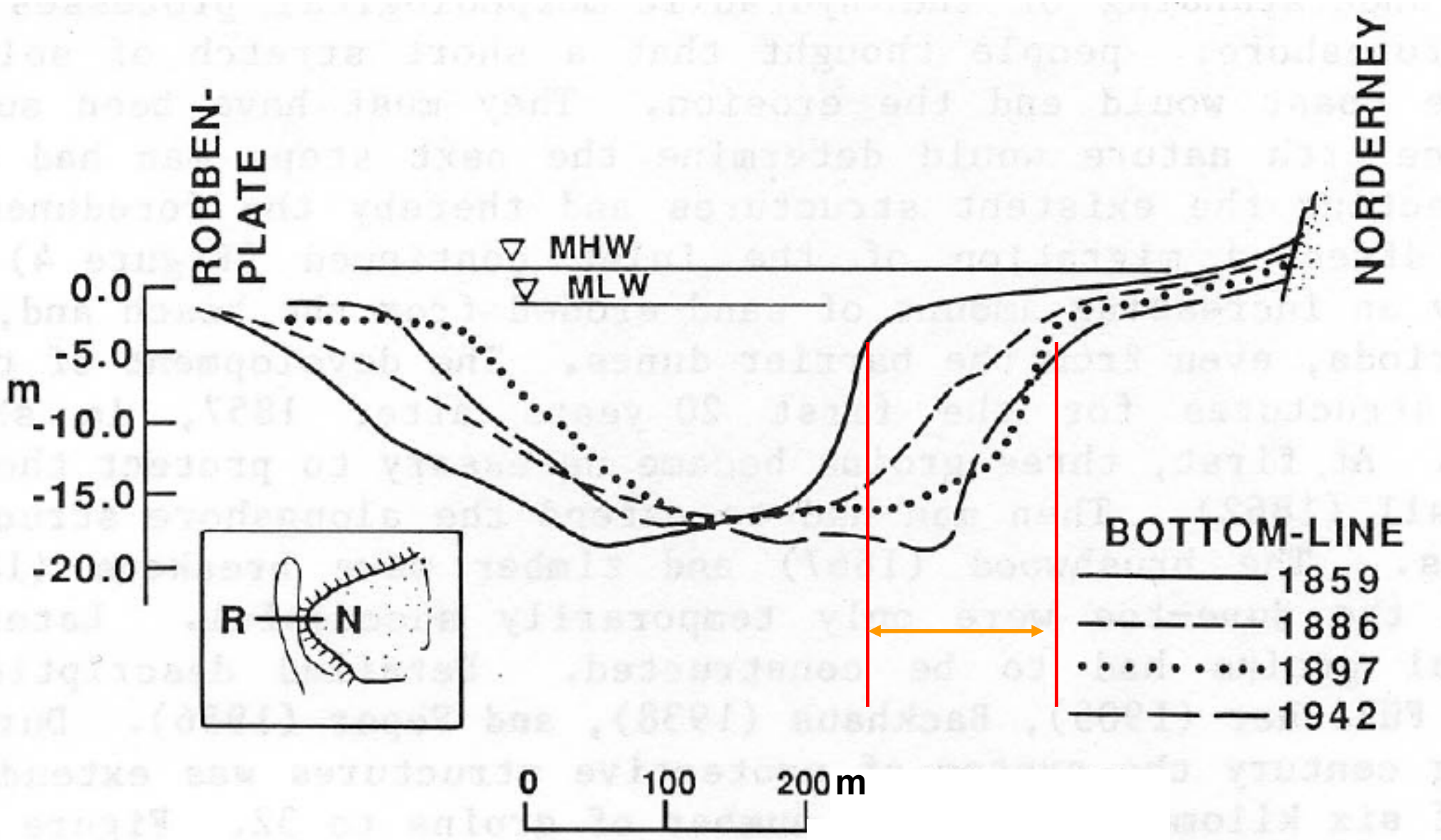


Norderney: Sea wall from 1857/58 (S-profile, lime-stone) with added food protection (basalt) in a status of severe beach erosion

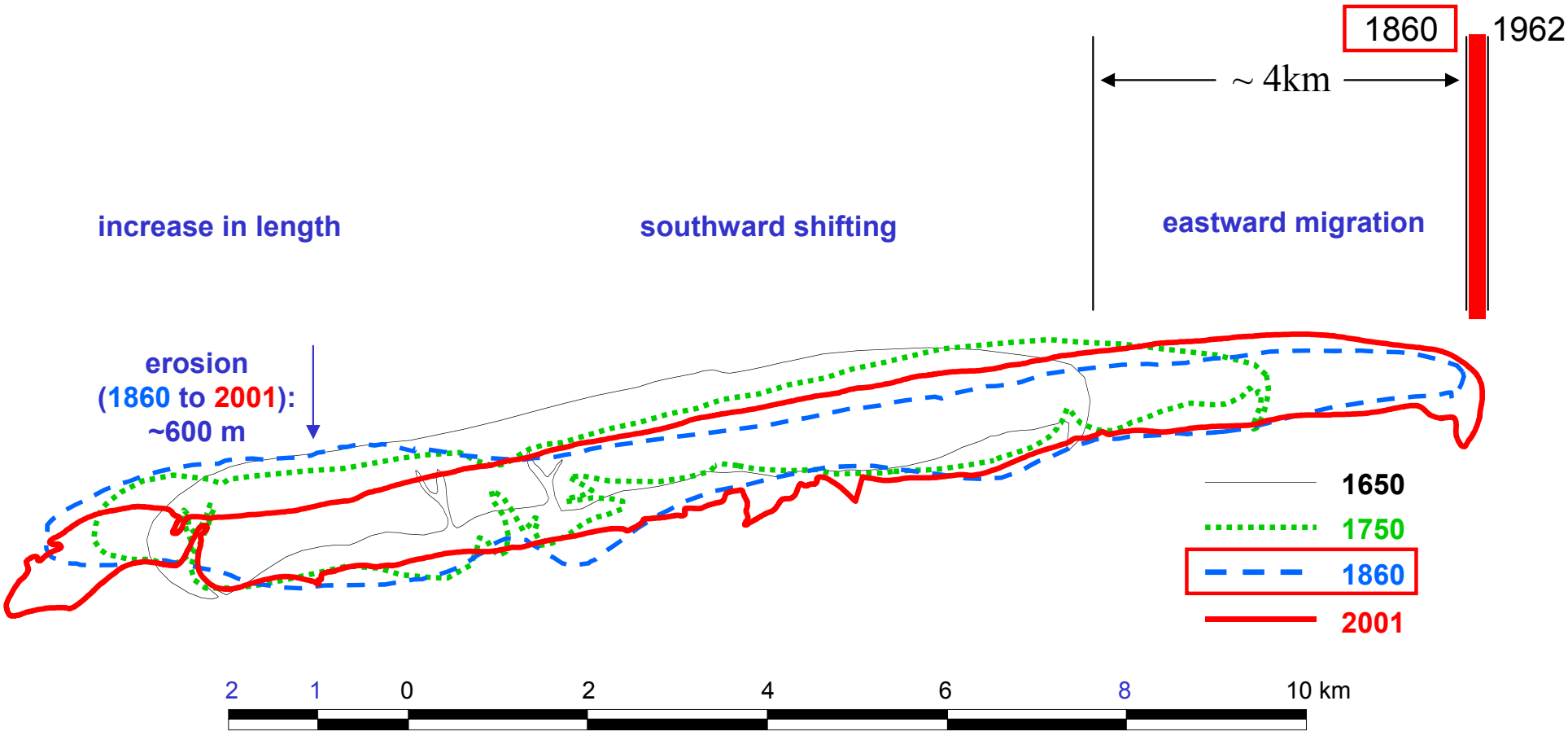
Reef Bow Norderney – Sand Bar System during extreme Low Water Level

Norderney: Combined protection system (sea walls, groynes, beach restoration)

Migration „Norderney Seegat“ (cross-section) - 1859 to 1899/1942
Example for the interaction „Nature / Coastal Protection“

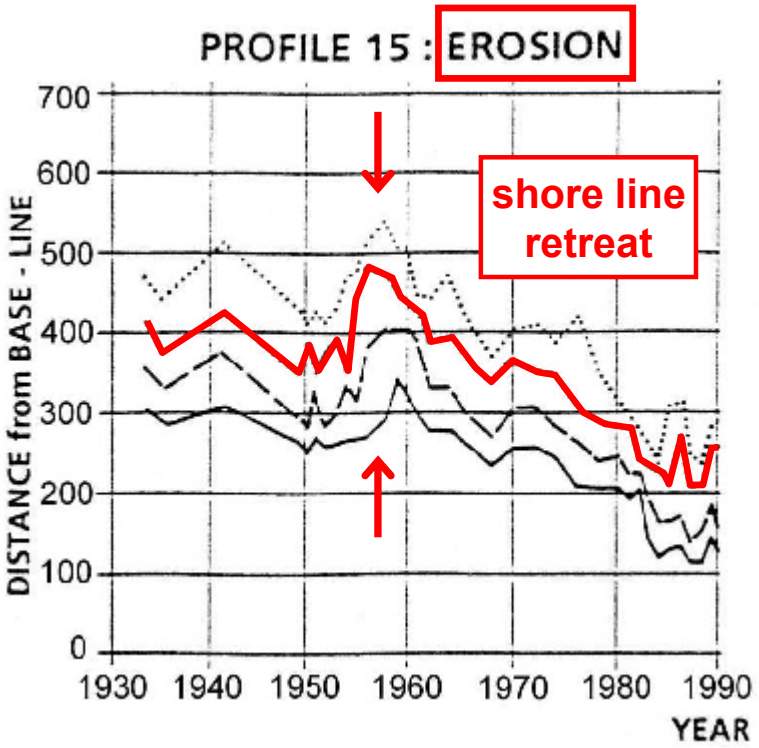


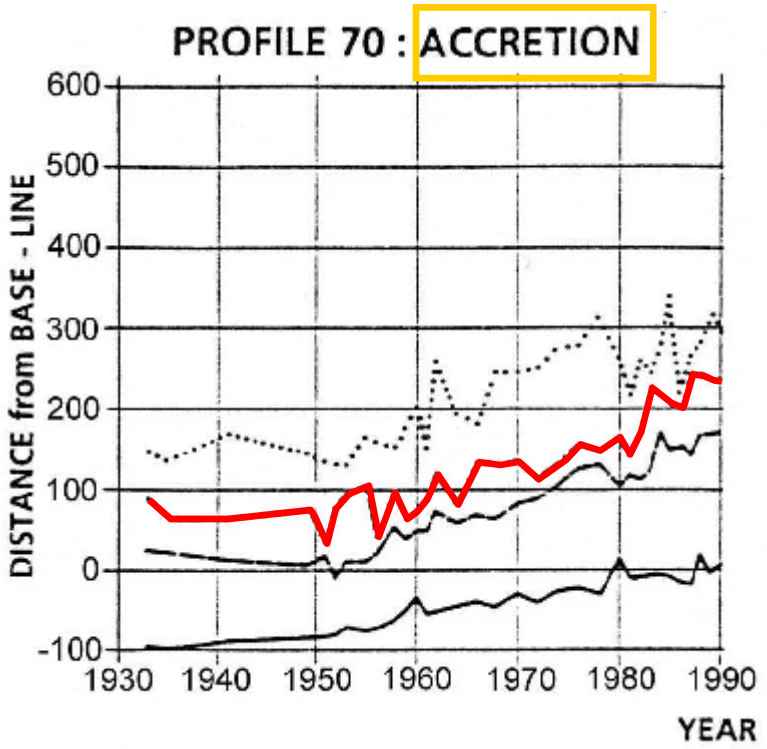
Development of Juist/East Frisian Island from 1650 to 2001 – loss of natural dynamic "movement" (islands and linked watersheds)

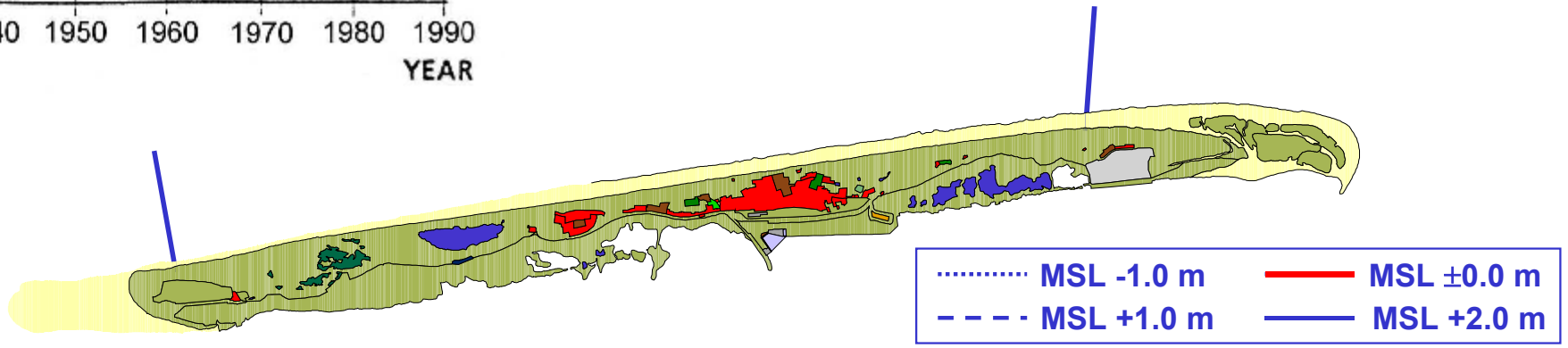


source: Homeier (1964)

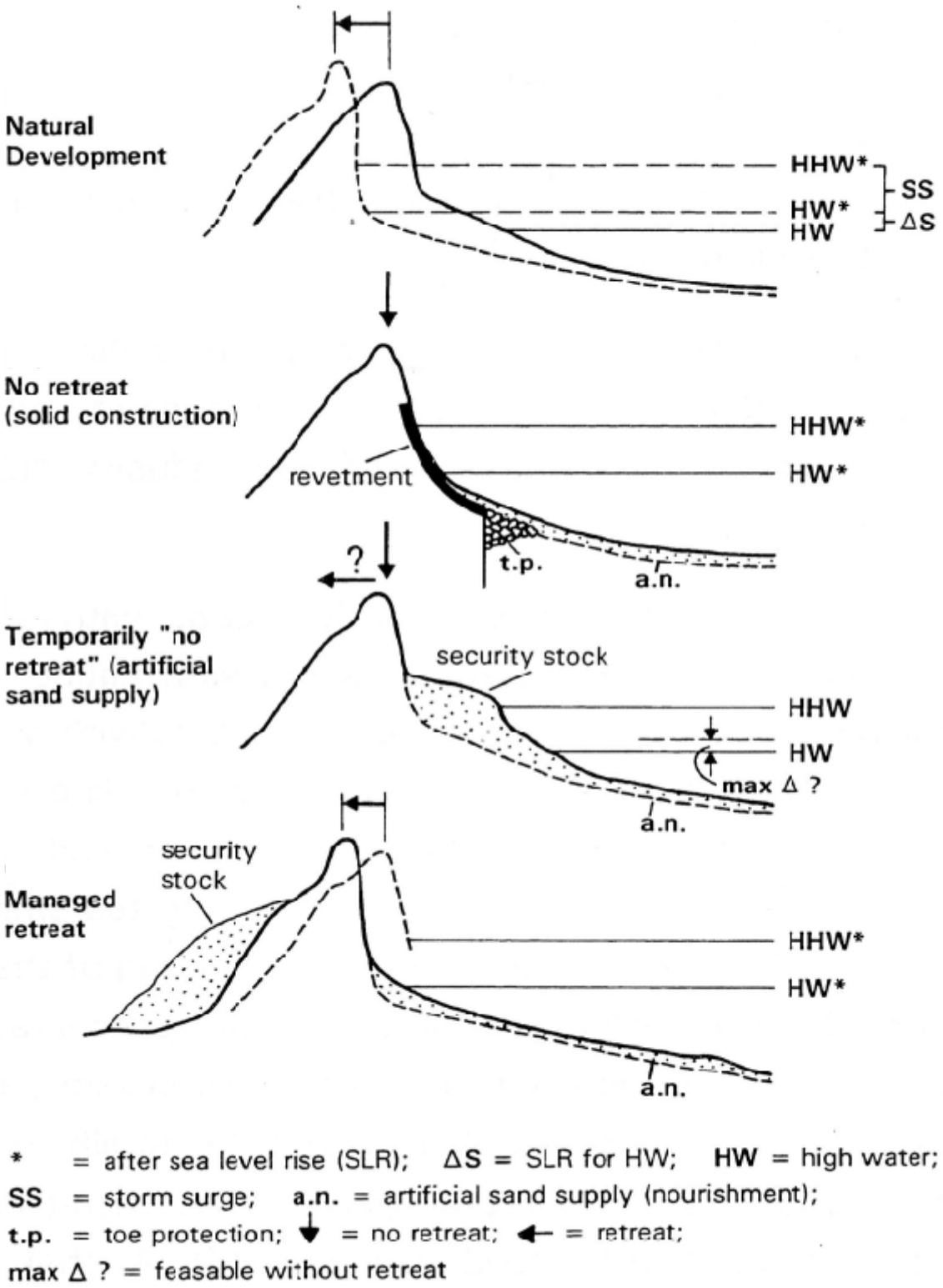
Long-term development of beach and shore on Juist Island: Time-Distance Lines







Aerial View Wangerooge
(East Frisian Island)



* = after sea level rise (SLR); ΔS = SLR for HW; HW = high water;
SS = storm surge; a.n. = artificial sand supply (nourishment);
t.p. = toe protection; ↓ = no retreat; ← = retreat;
max Δ ? = feasable without retreat

dynamic, natural

"hold the line"
solid constructions
static, non-flexible

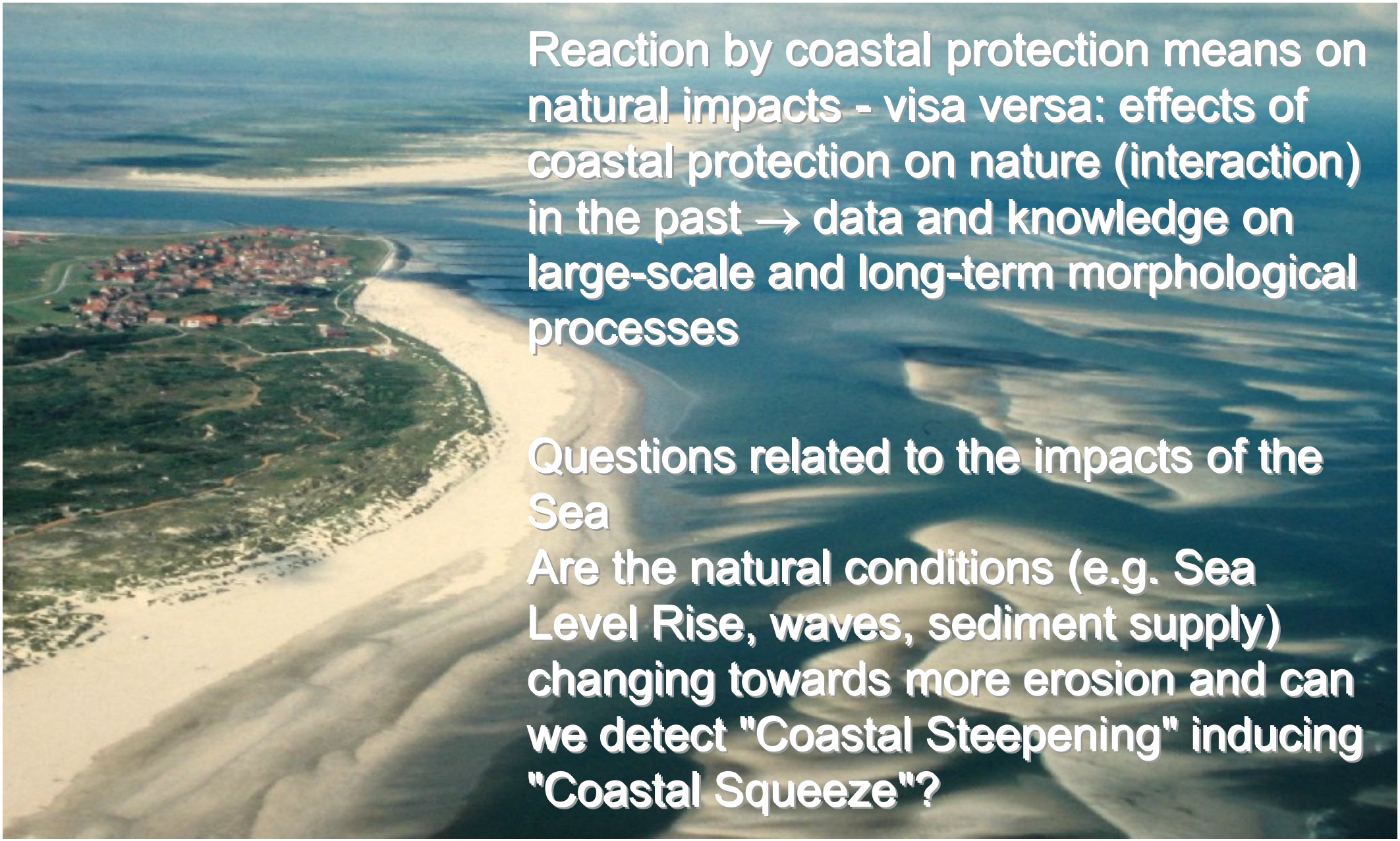
hold the line
"soft" means
semi-static, flexible

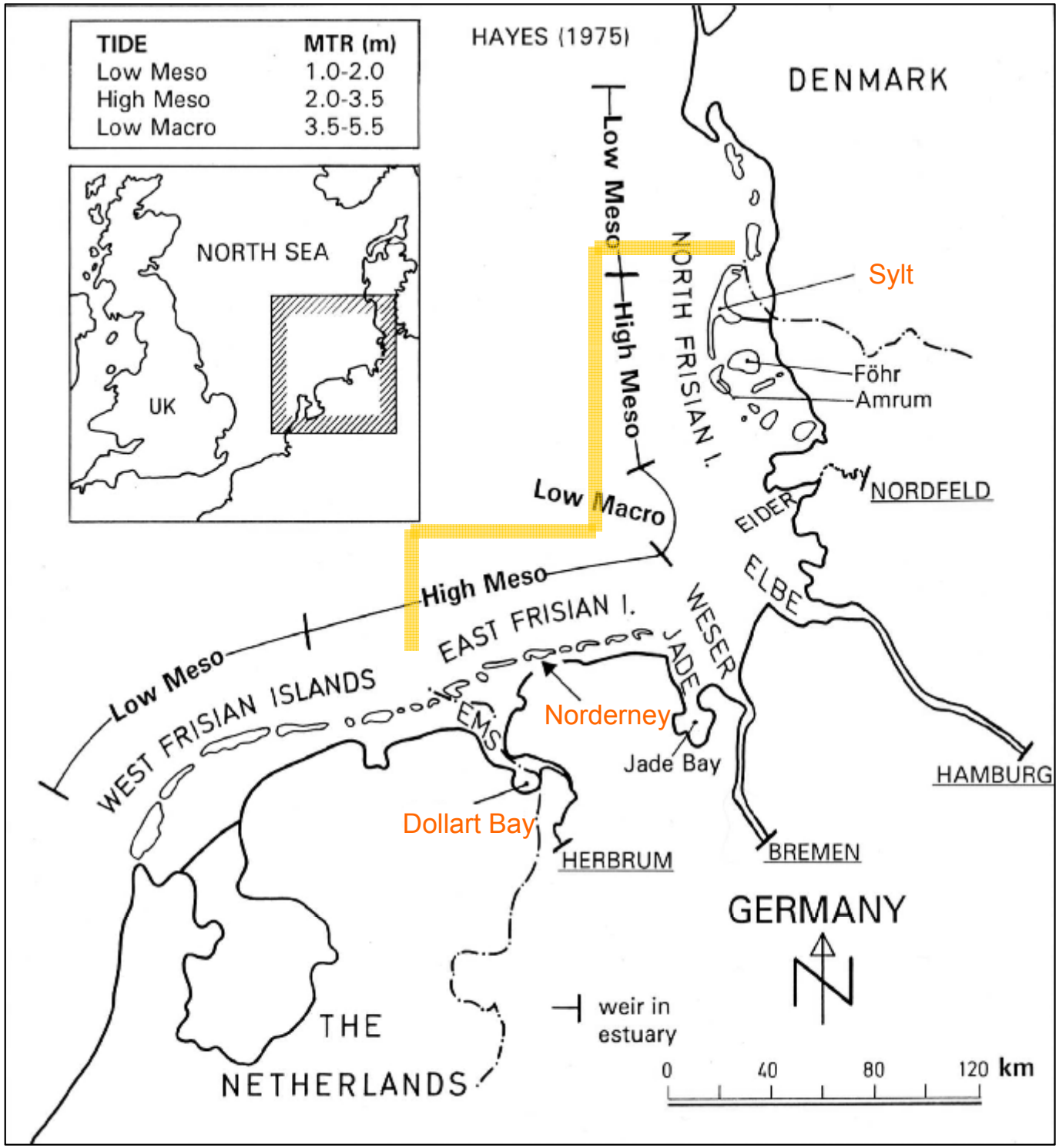
managed retreat
semi-dynamic
flexible

Dune Protection


dunefoot 2090
optimistic estimate
pessimistic estimate
lunefoot 1987
50 m
150 m
sea level rise
0.6 m/cen

Juist West – Managed Retreat as flexible response to beach- and dune-erosion


Reaction by coastal protection means on natural impacts - visa versa: effects of coastal protection on nature (interaction) in the past → data and knowledge on large-scale and long-term morphological processes
Questions related to the impacts of the Sea
Are the natural conditions (e.g. Sea Level Rise, waves, sediment supply) changing towards more erosion and can we detect "Coastal Steepening" inducing "Coastal Squeeze"?



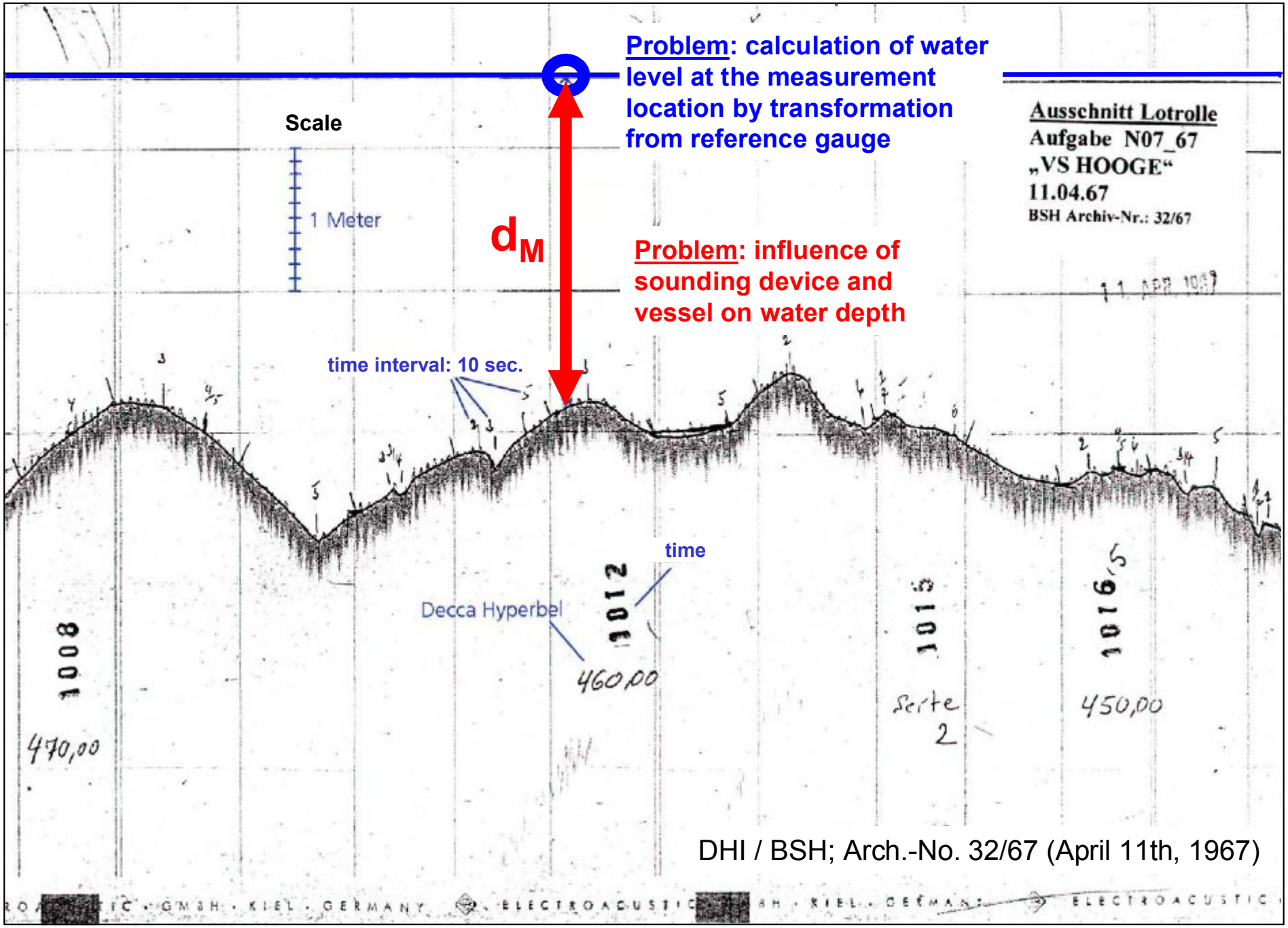
Location map of the German Bight with parts of The Netherlands and Denmark

Bathymetric Data
1949 to 1997
(DHI/BSH)

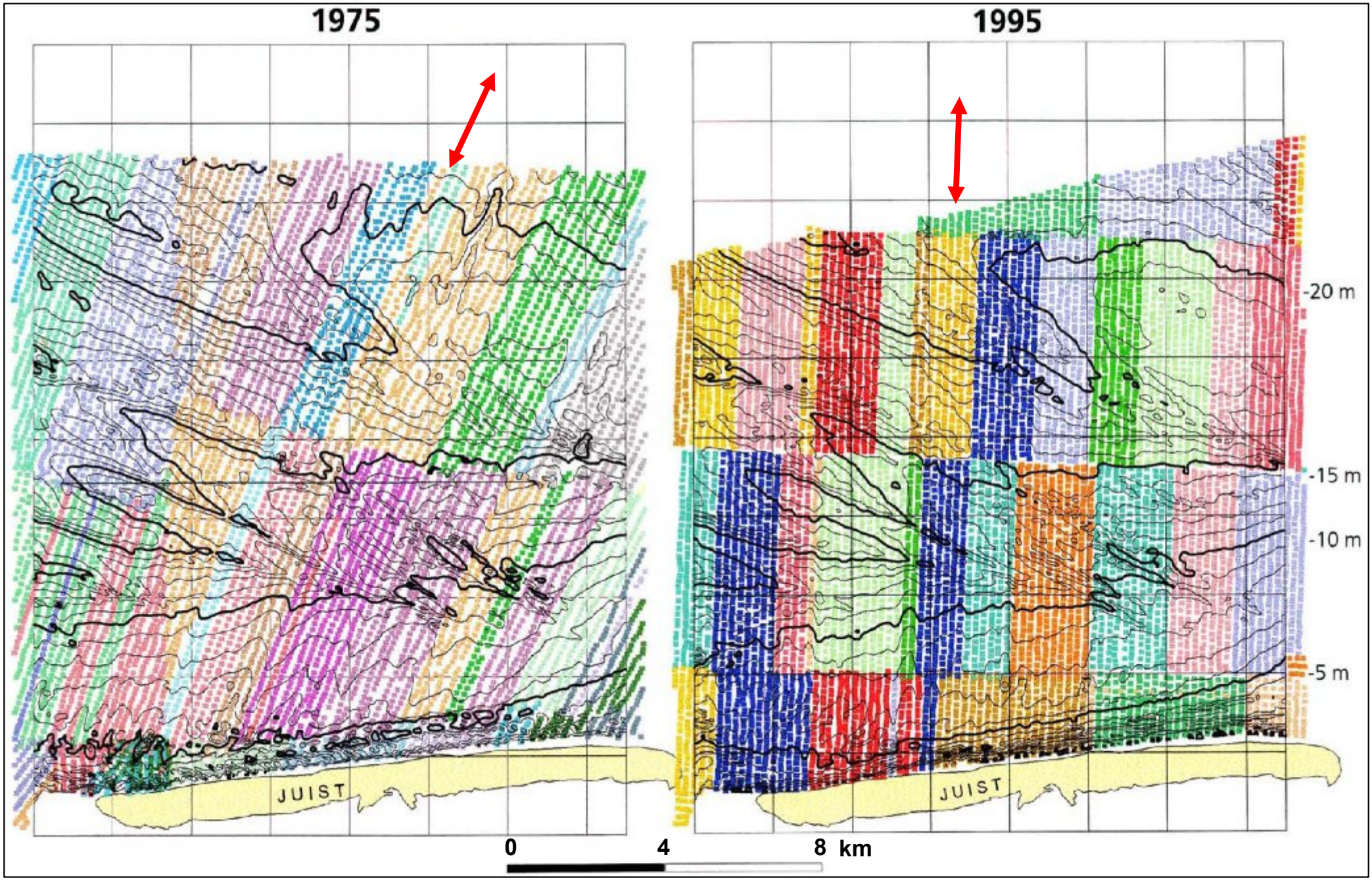
Investigation Area

Echo sounding plot: accuracy problems with data from the past

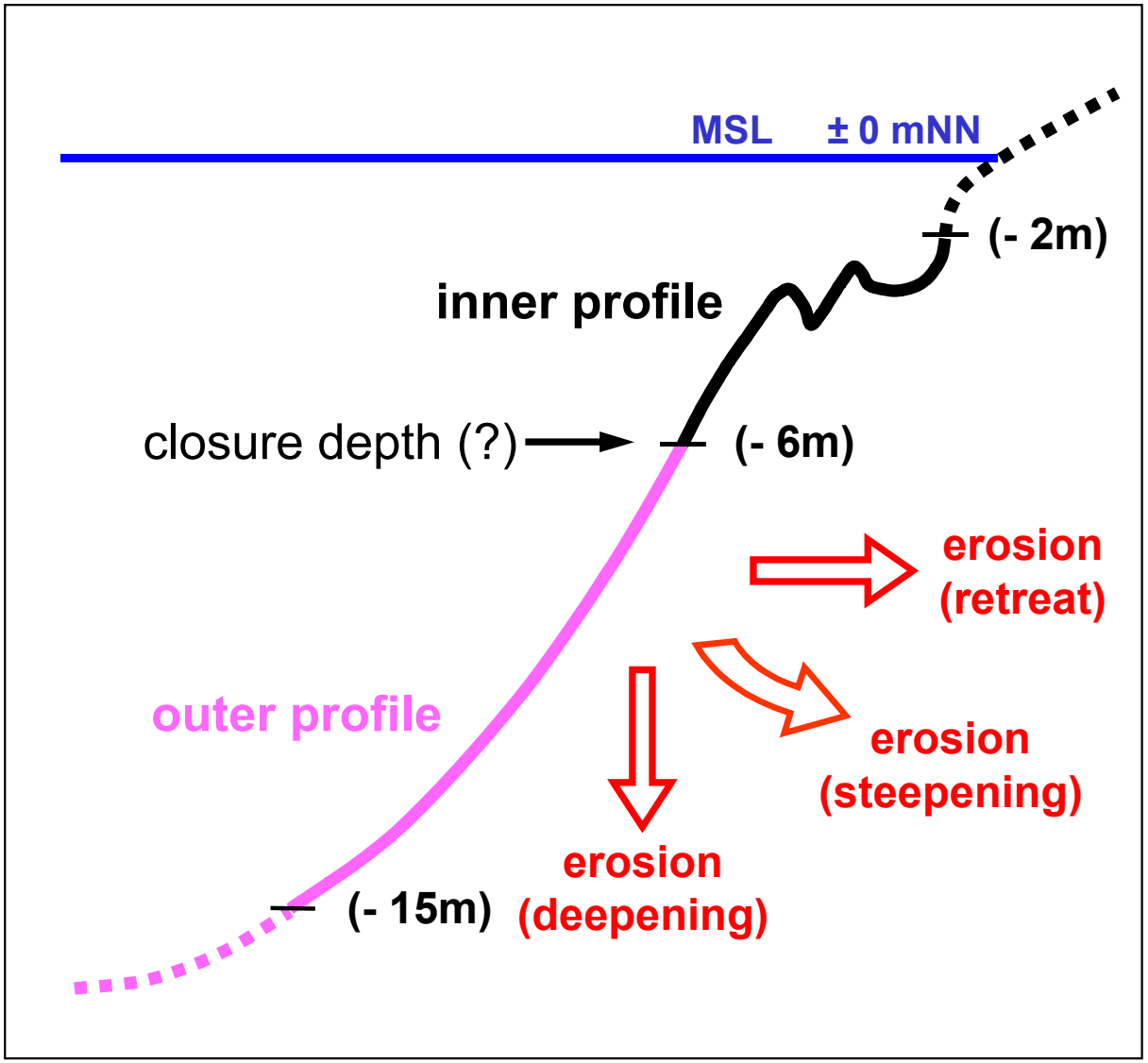
(before GPS)



Tracks of sounding surveys (DHI/BSH)
Shore face of Juist / East Frisian Islands



Erosive profile changes: Retreat, Deepening, Steepening



Effects of Erosion:

Retreat

Horizontal displacement of the entire profile (no slope change) **or profile-sections with different retreat rates** (characteristic changes of slope)

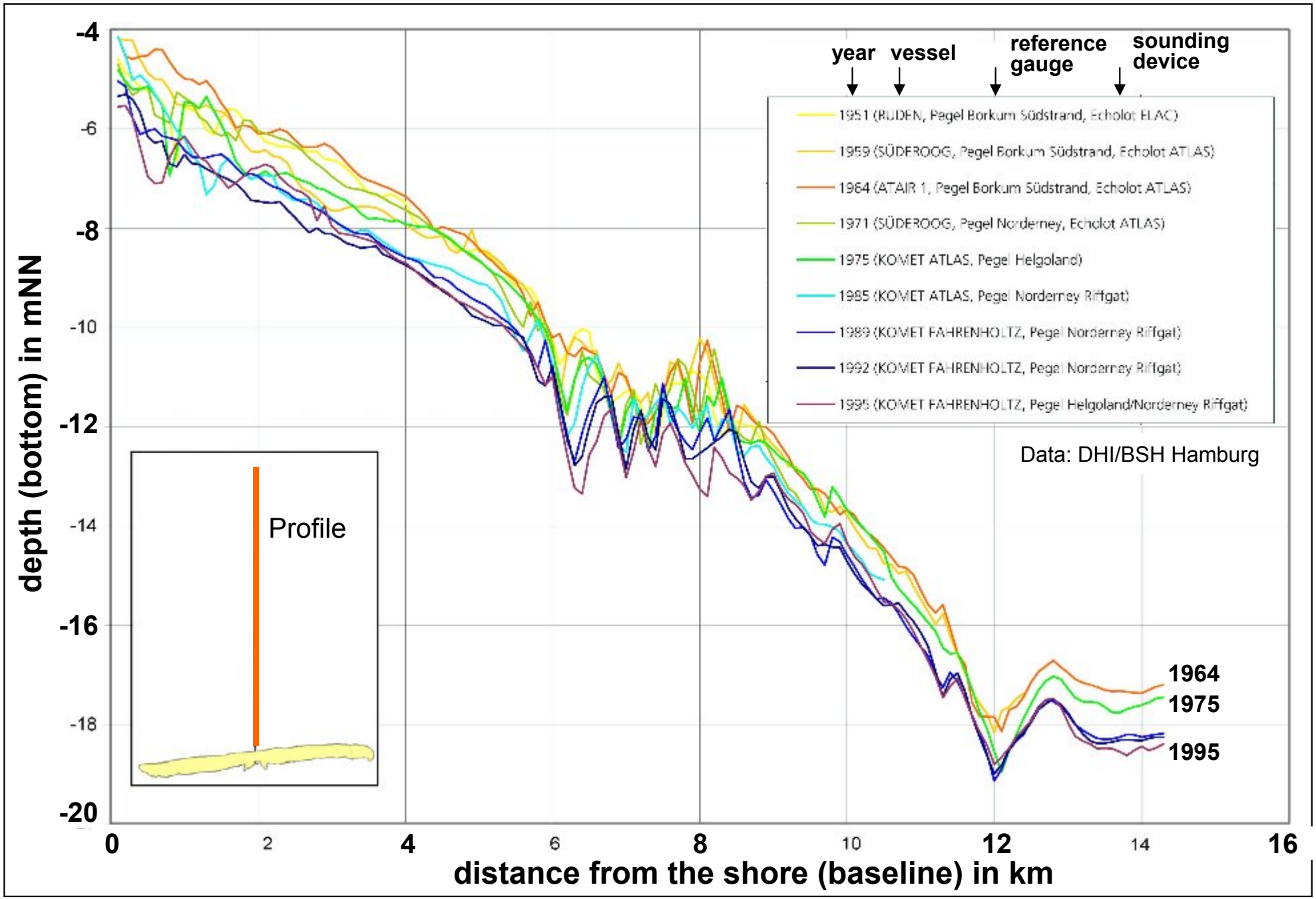
Deepening

Profile changes in vertical direction.

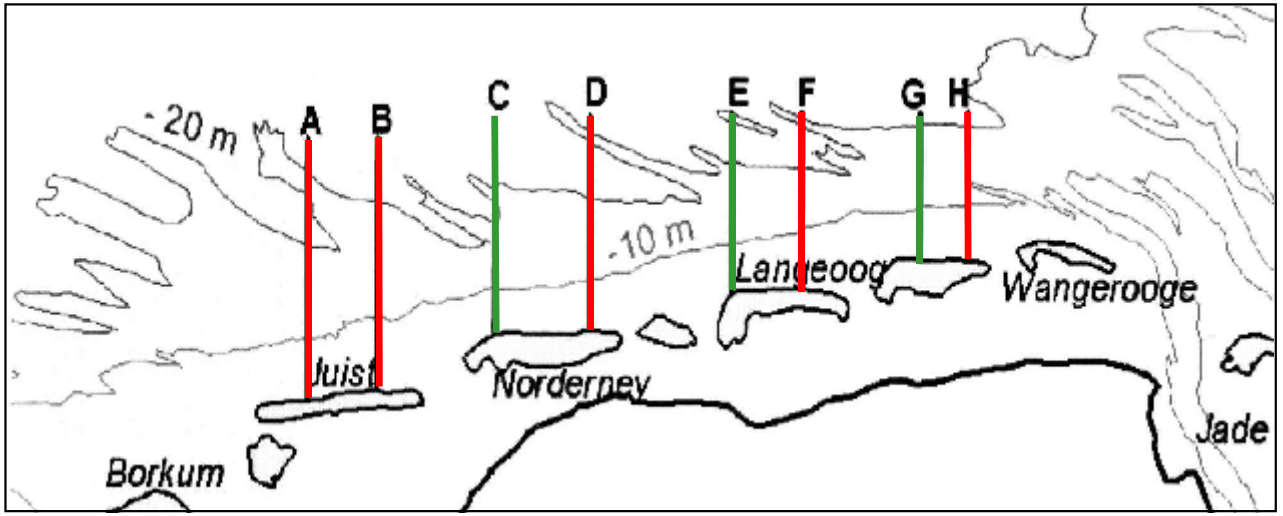
Steepening

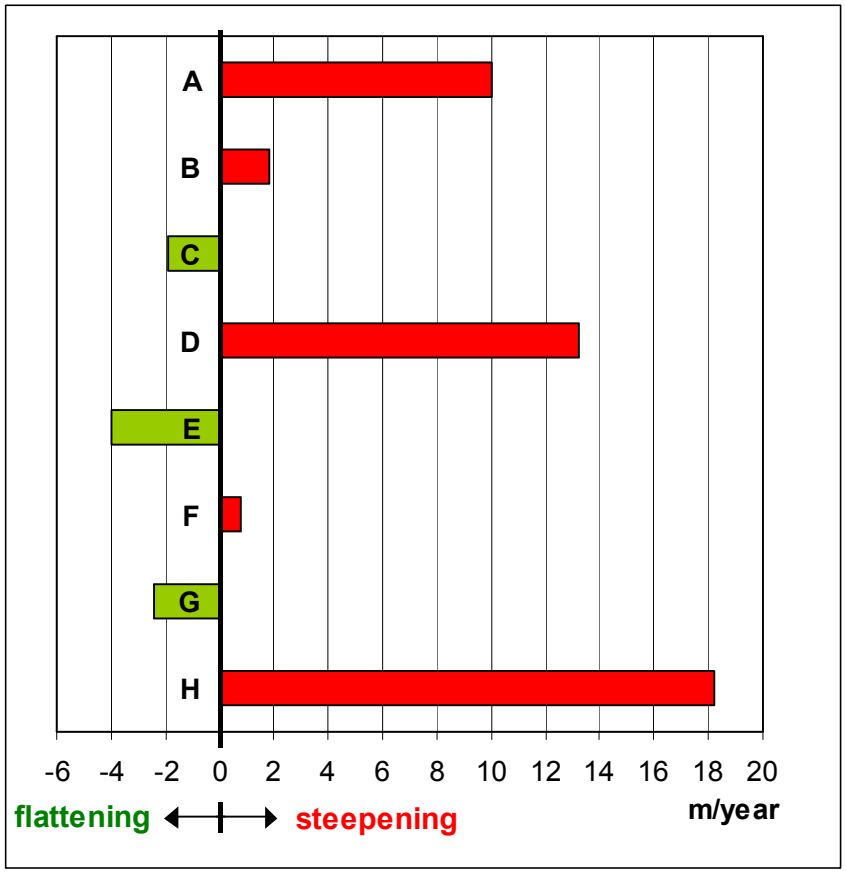
Combination of “retreat” and “deepening”, calculated as **difference between the retreat rate** in **outer profile** and **inner profile**

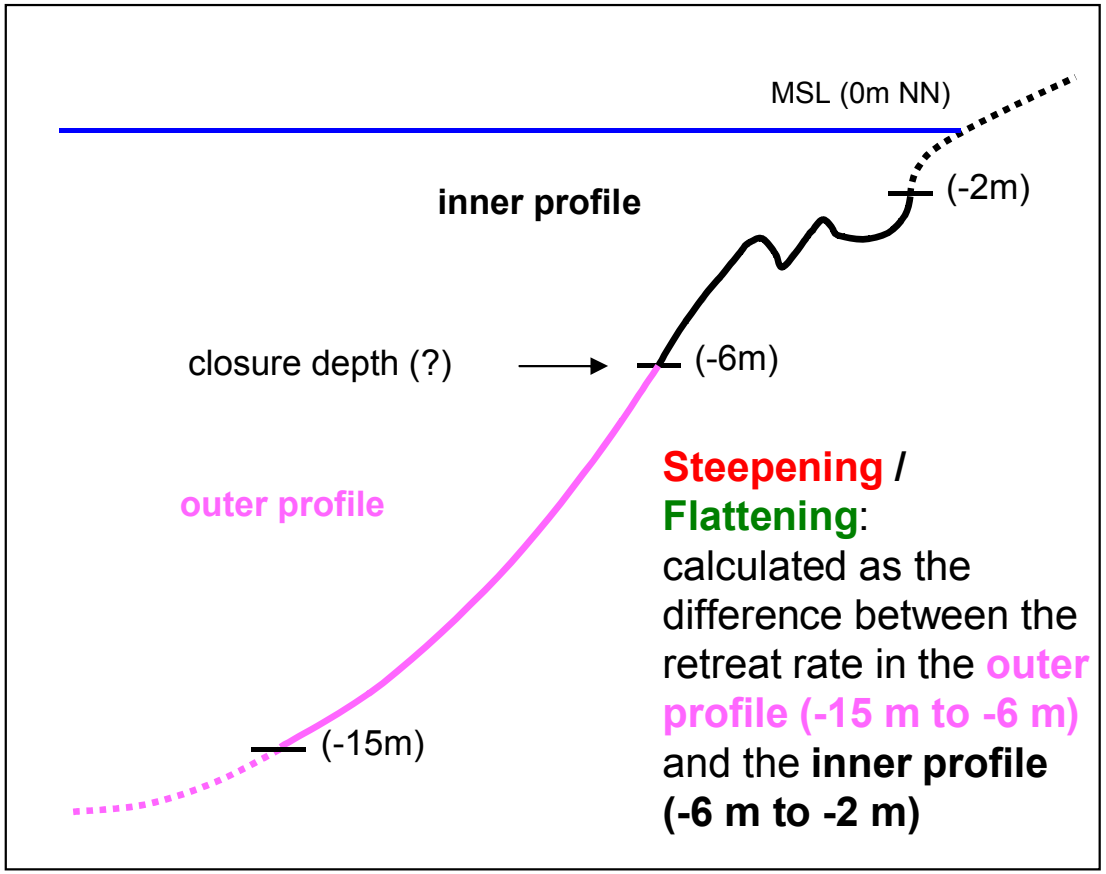
Development of a profile (cross-shore) between 1951 and 1995
Shoreface of Juist / East Frisian Islands



Profile changes (steepening, flattening) in the shore face of the East-Frisian Islands

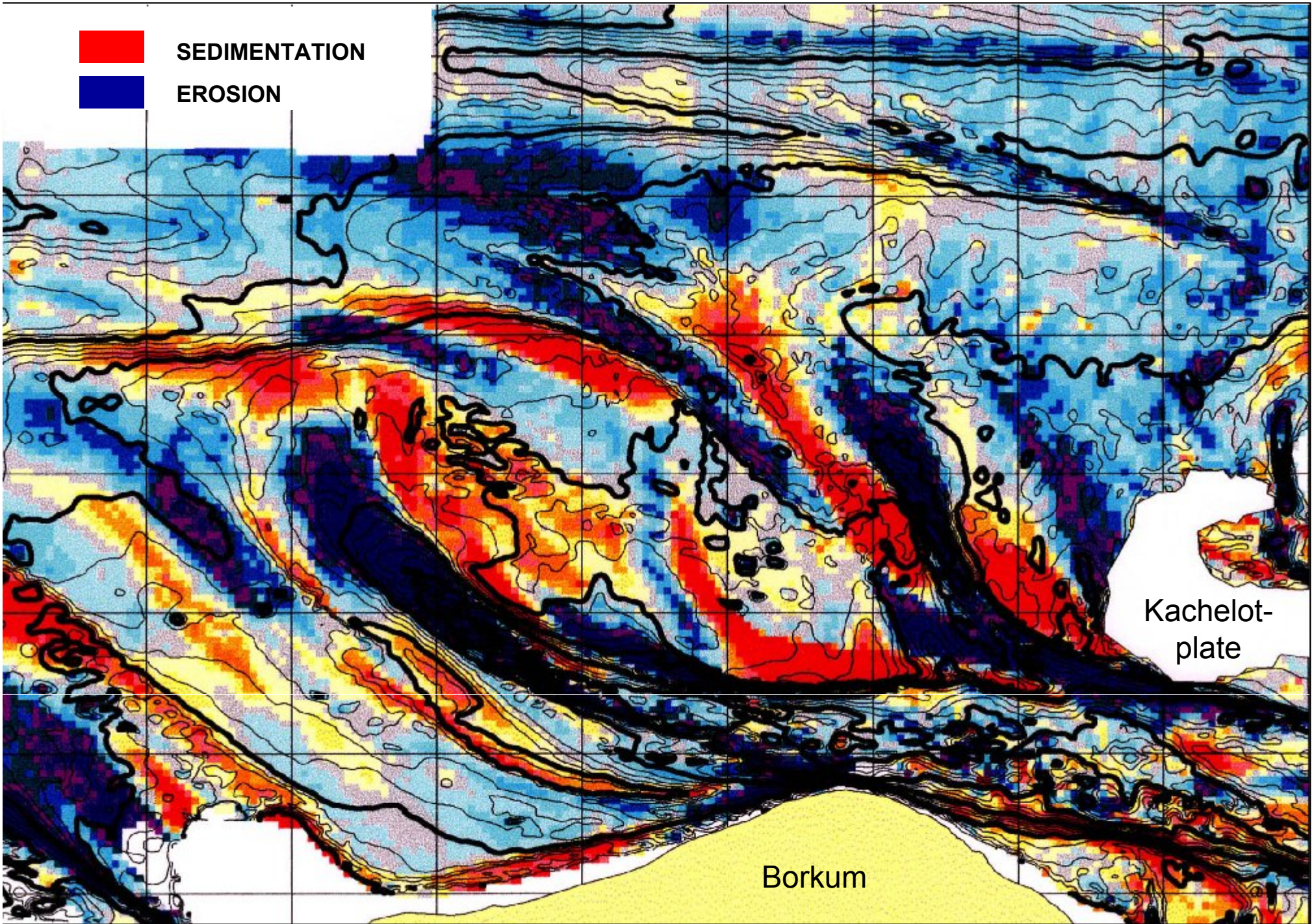






Source: NSCMG-WG 1999

Erosion/Sedimentation of the Shore Face (1975 – 1995)
East Frisian Island Borkum

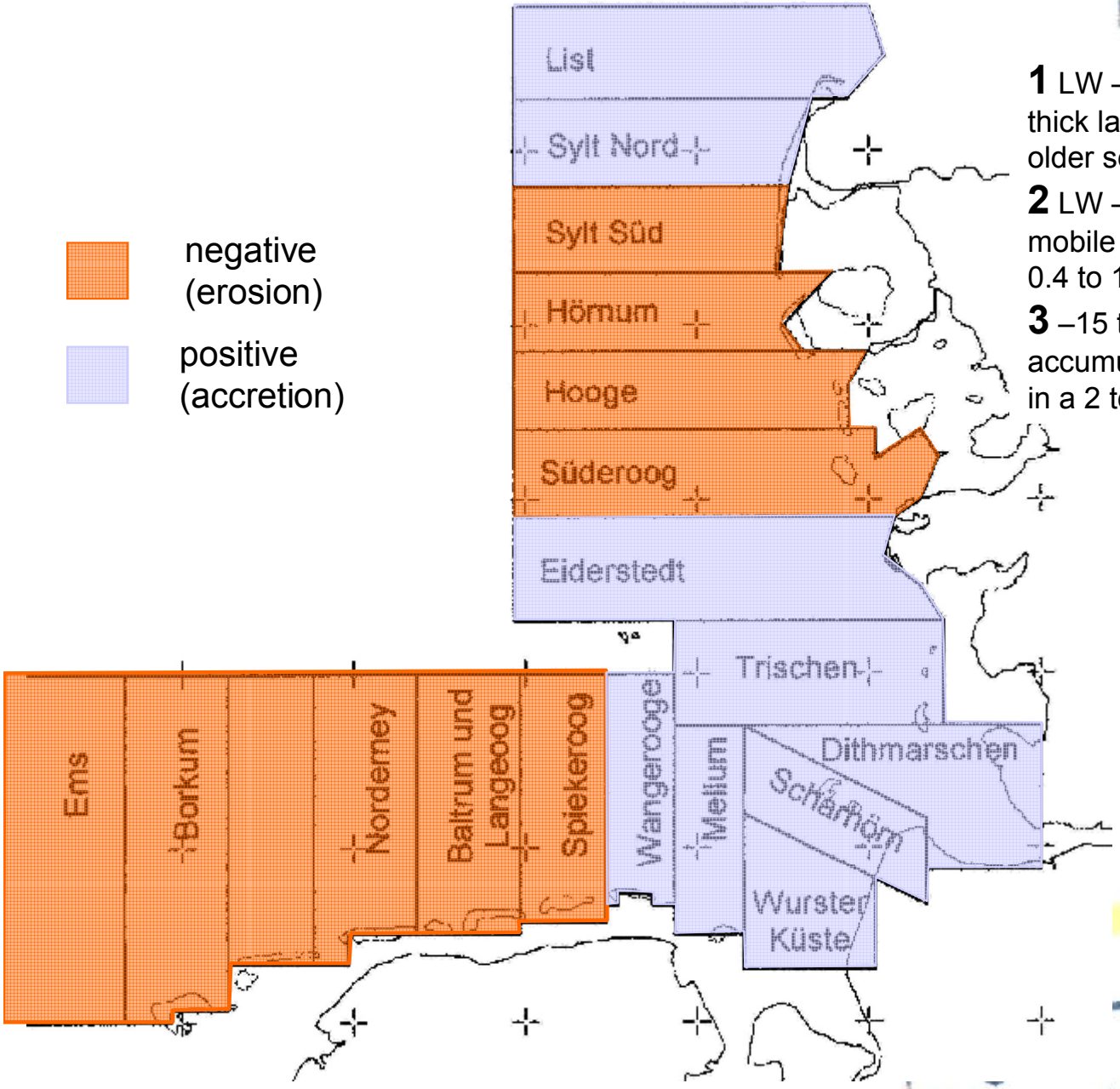


Data: BSH Hamburg; Source: FSK (1999)

Mass balances for the Southern North Sea / German Bight

negative (erosion)

positive (accretion)

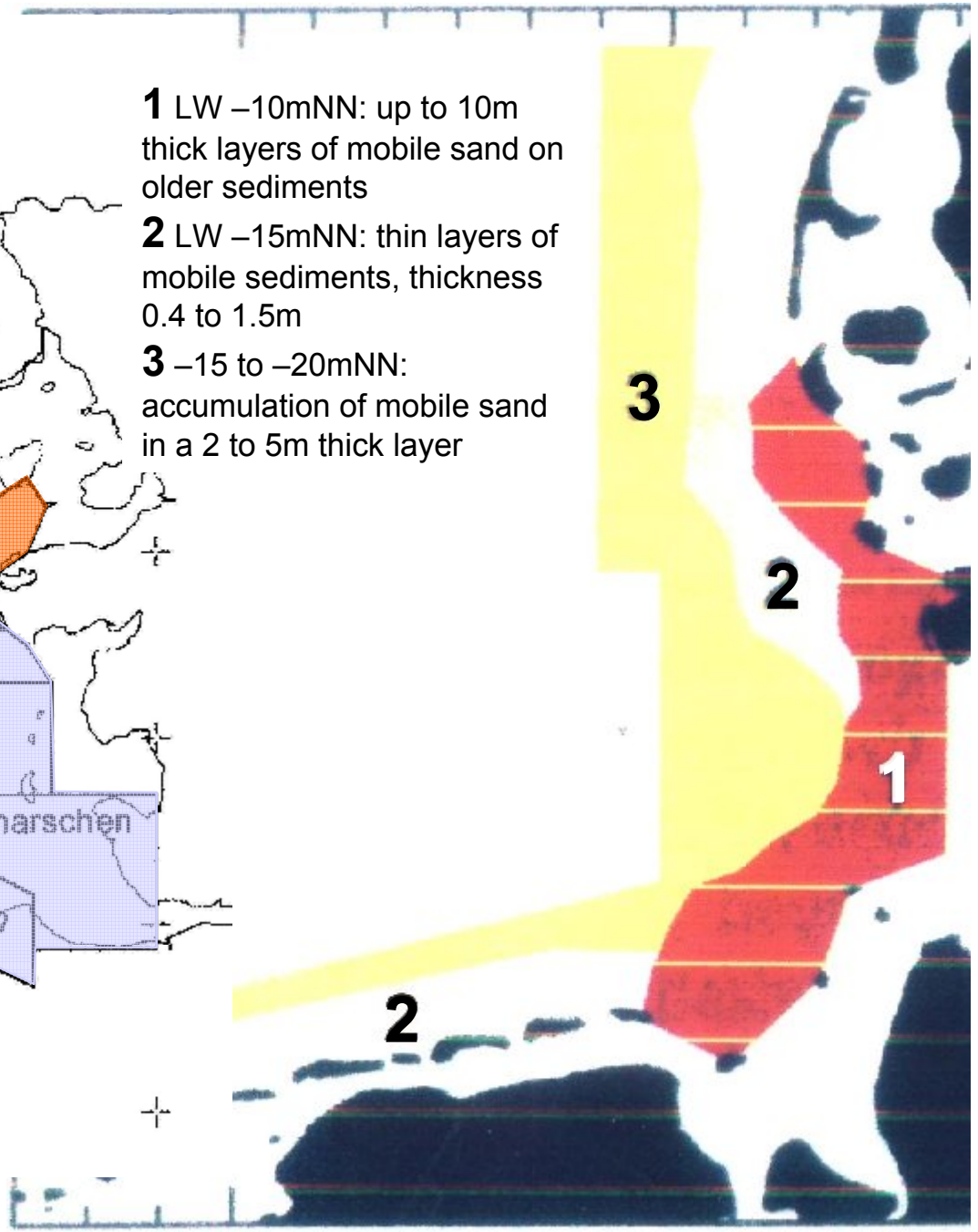


source: Kunz (2002)

1 LW –10mNN: up to 10m thick layers of mobile sand on older sediments

2 LW –15mNN: thin layers of mobile sediments, thickness 0.4 to 1.5m

3 –15 to –20mNN: accumulation of mobile sand in a 2 to 5m thick layer

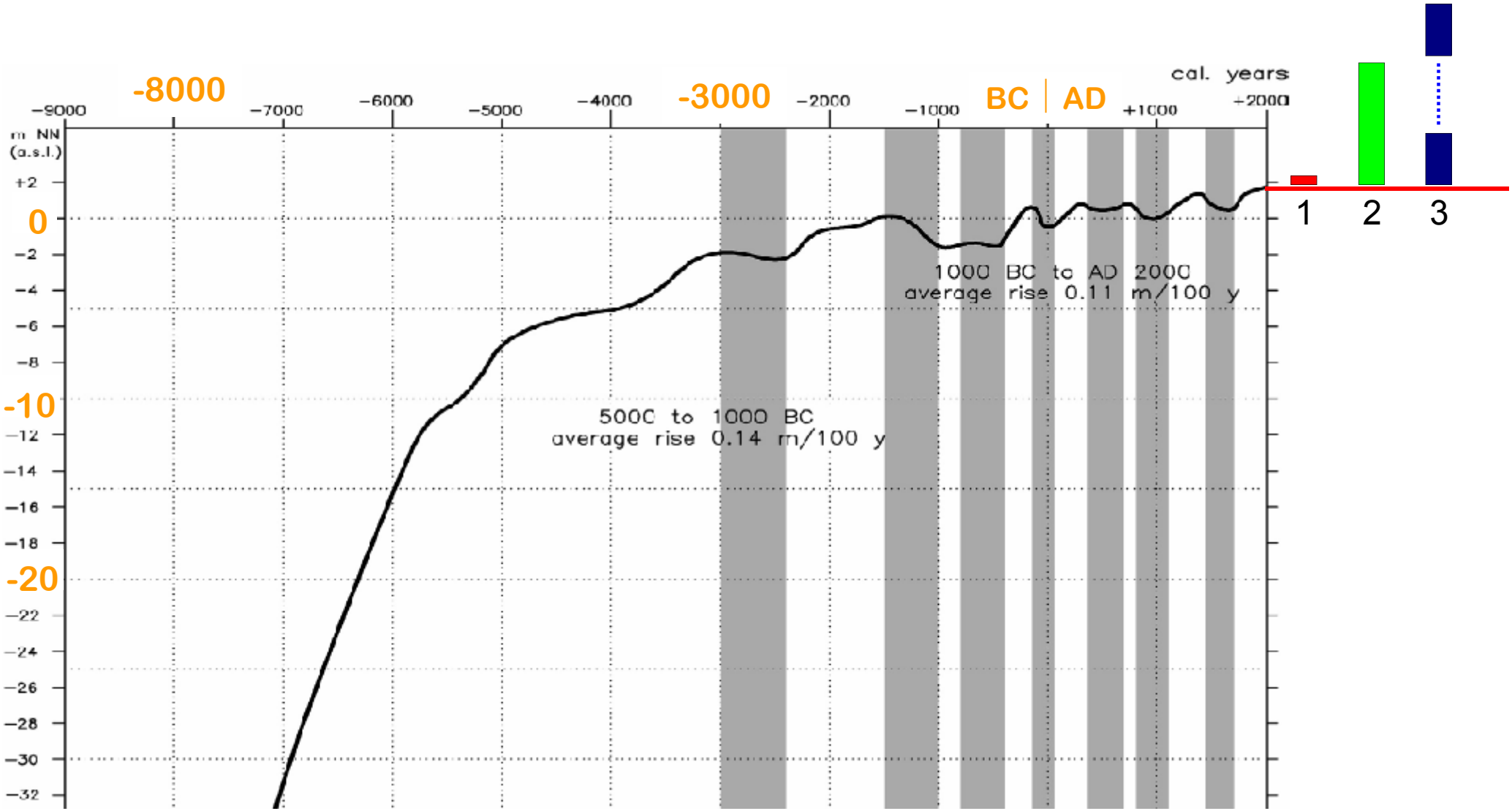


source: Zeiler & Figge (1998)

Lessons learned

- **Application of nautical bathymetric data for morphological investigations**
  - ⇒ **Data verification is essential: hidden systematic & random errors**
  - ⇒ **Missing accuracy of bathymetric data has to be considered**
    - → **mean values for defined "calculation areas"**
- **Results (first approximation)**
  - ⇒ **Trends of erosion / accretion detected and phenomenon of "coastal (profile) steepening" confirmed**
  - ⇒ **Significant littoral transport in deep areas**
    - → **no confirmation of "closure depth"**
- **Correspondence**
  - ⇒ **"Distribution of Mobile Sand" (*Zeiler & Figge 1998*)**
  - ⇒ **"Profile Steepening" (*Laustrup et al. 1999*)**

Sea Level Curve for the Southern North Sea and Estimations of Future Sea Level Rise



after Behre (2007)

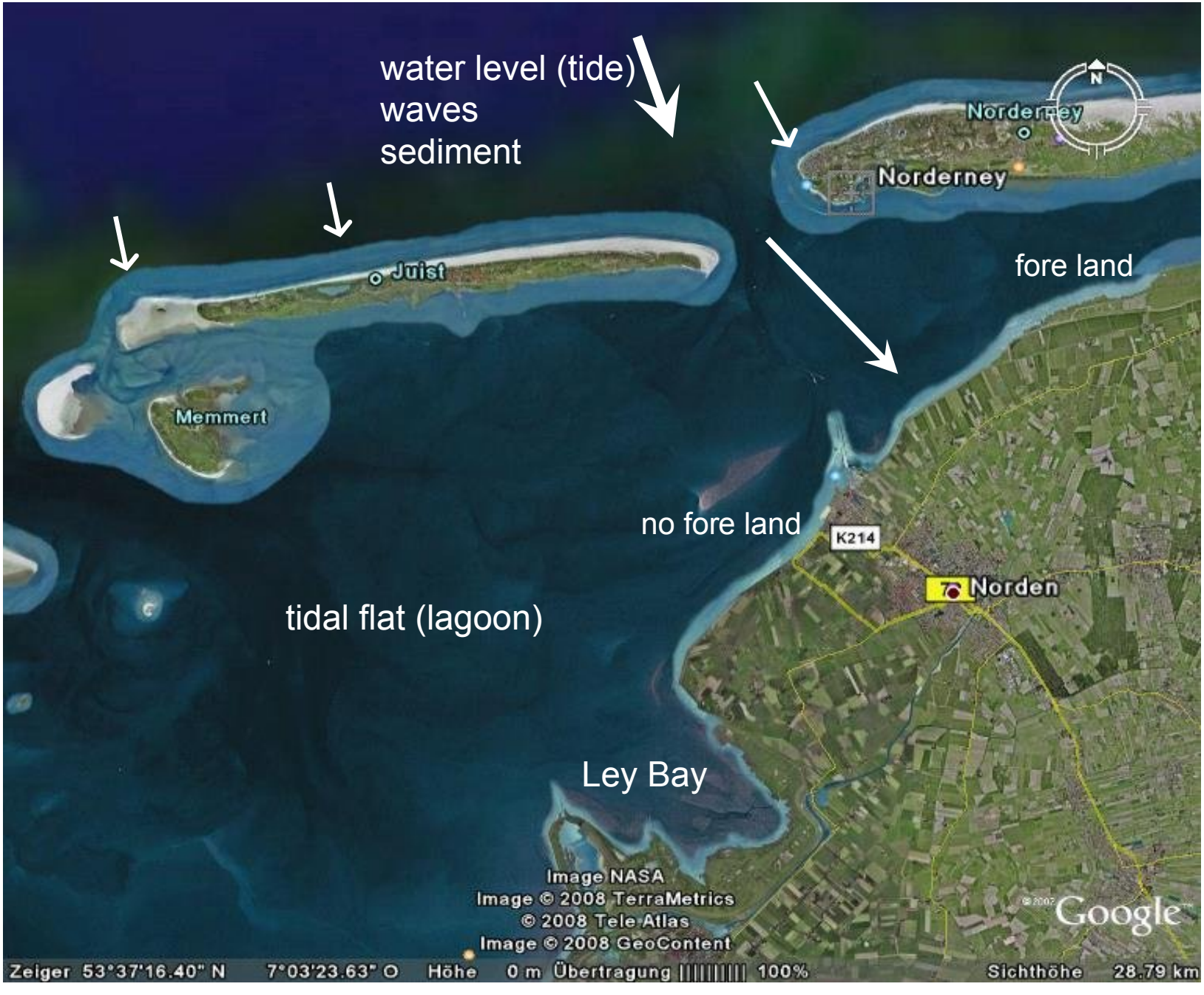
MSLR ~0,15 m/100y

1 – IPCC ~0,60 m/100y

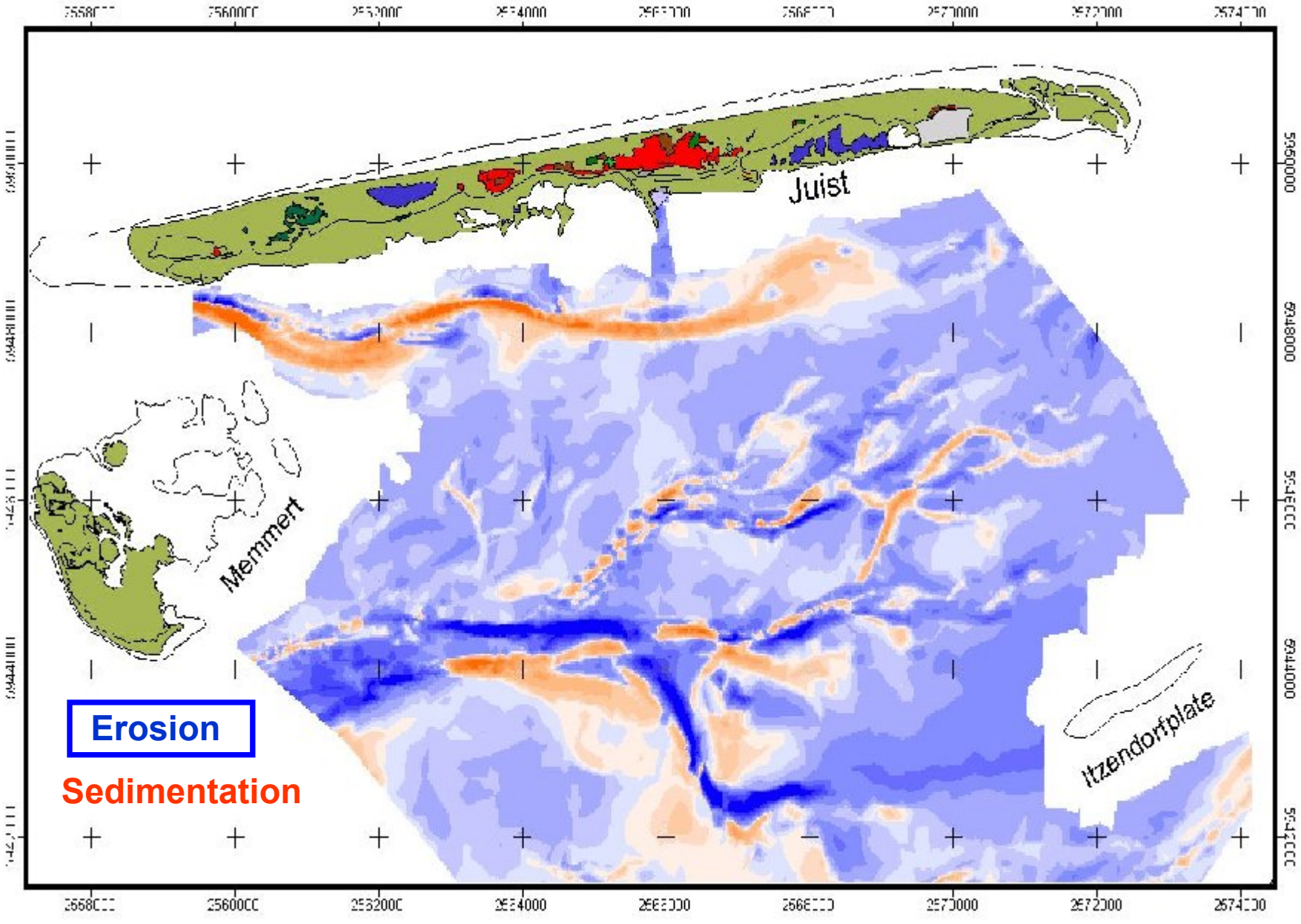
2 – Greenland ~ 7,50 m

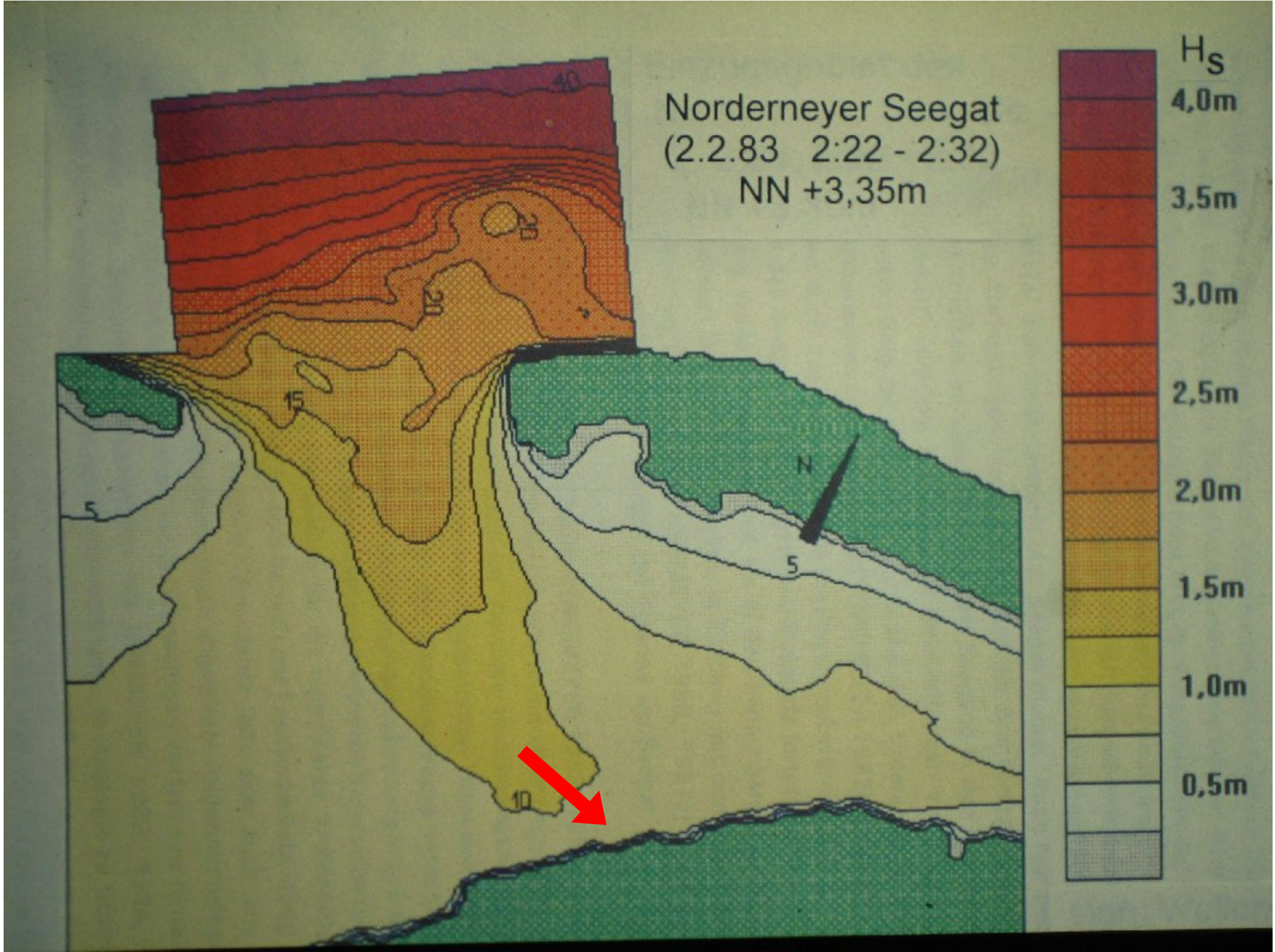
3 – World ~75,00 m

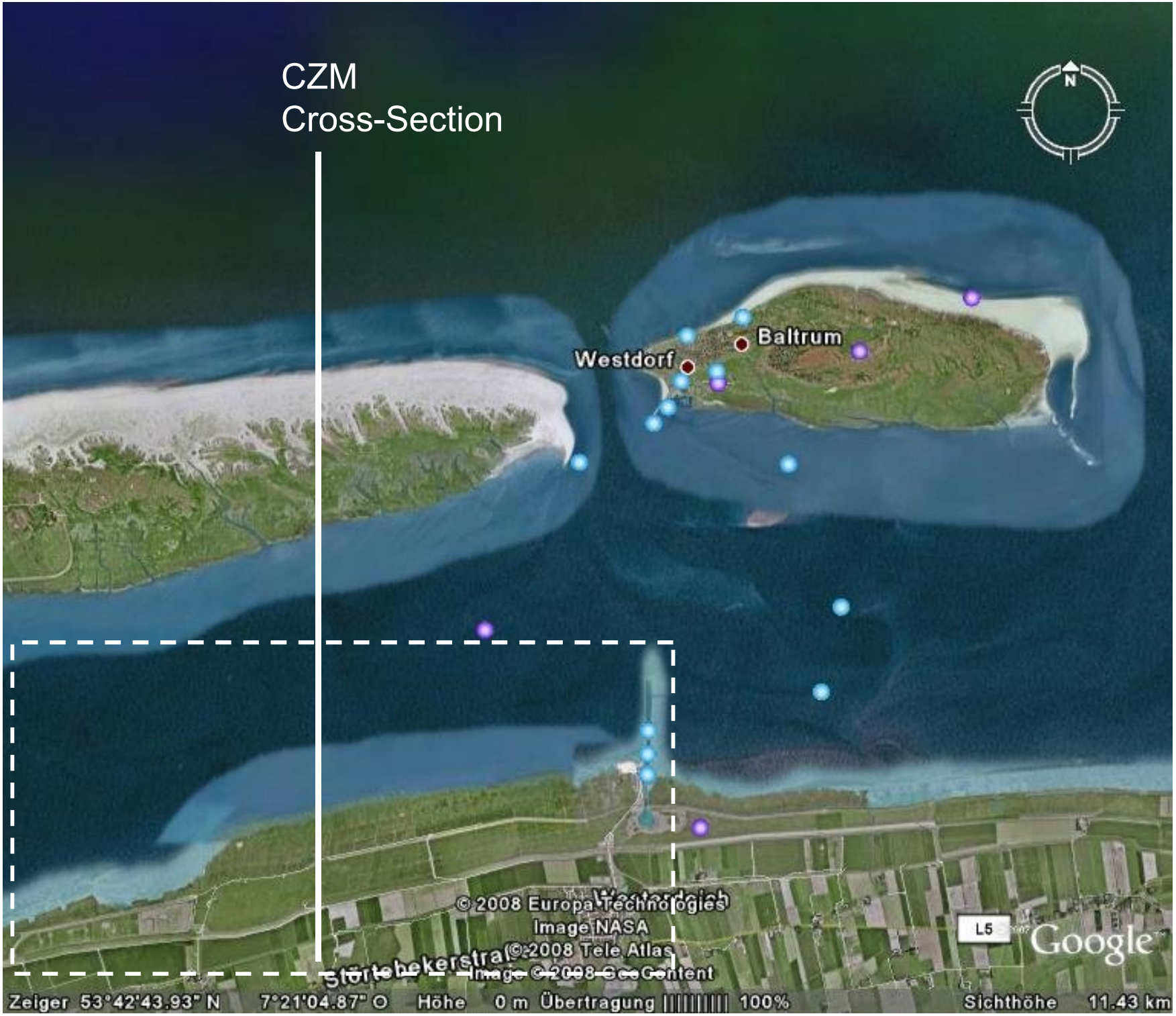
Case studies: Impact of natural conditions, coastal engineering reponses and interactions

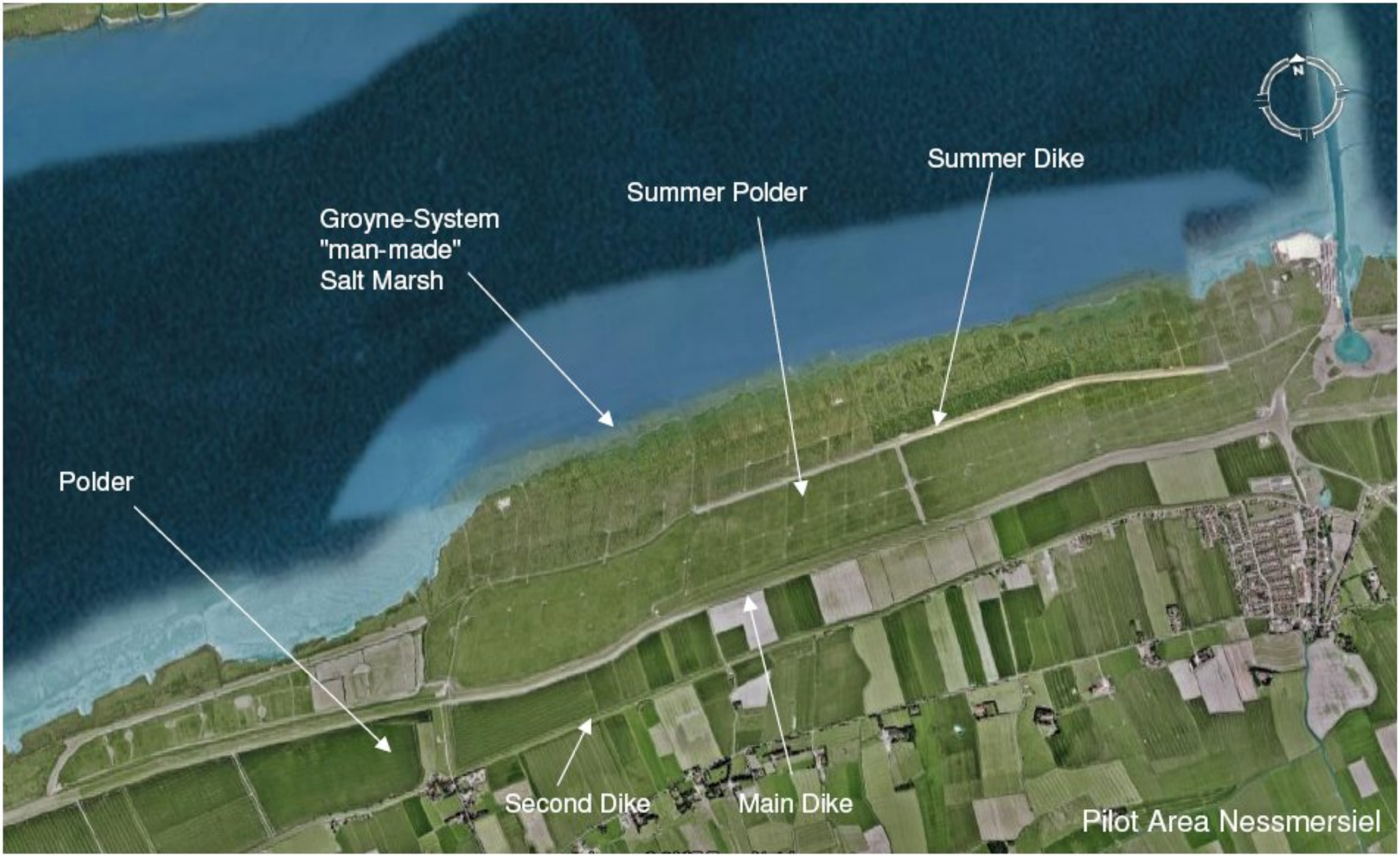


Change in Surface Height of Tidal Flats (Lagoon) (Erosion/Sedimentation) – example catchment area Juist from 1958 to 1998

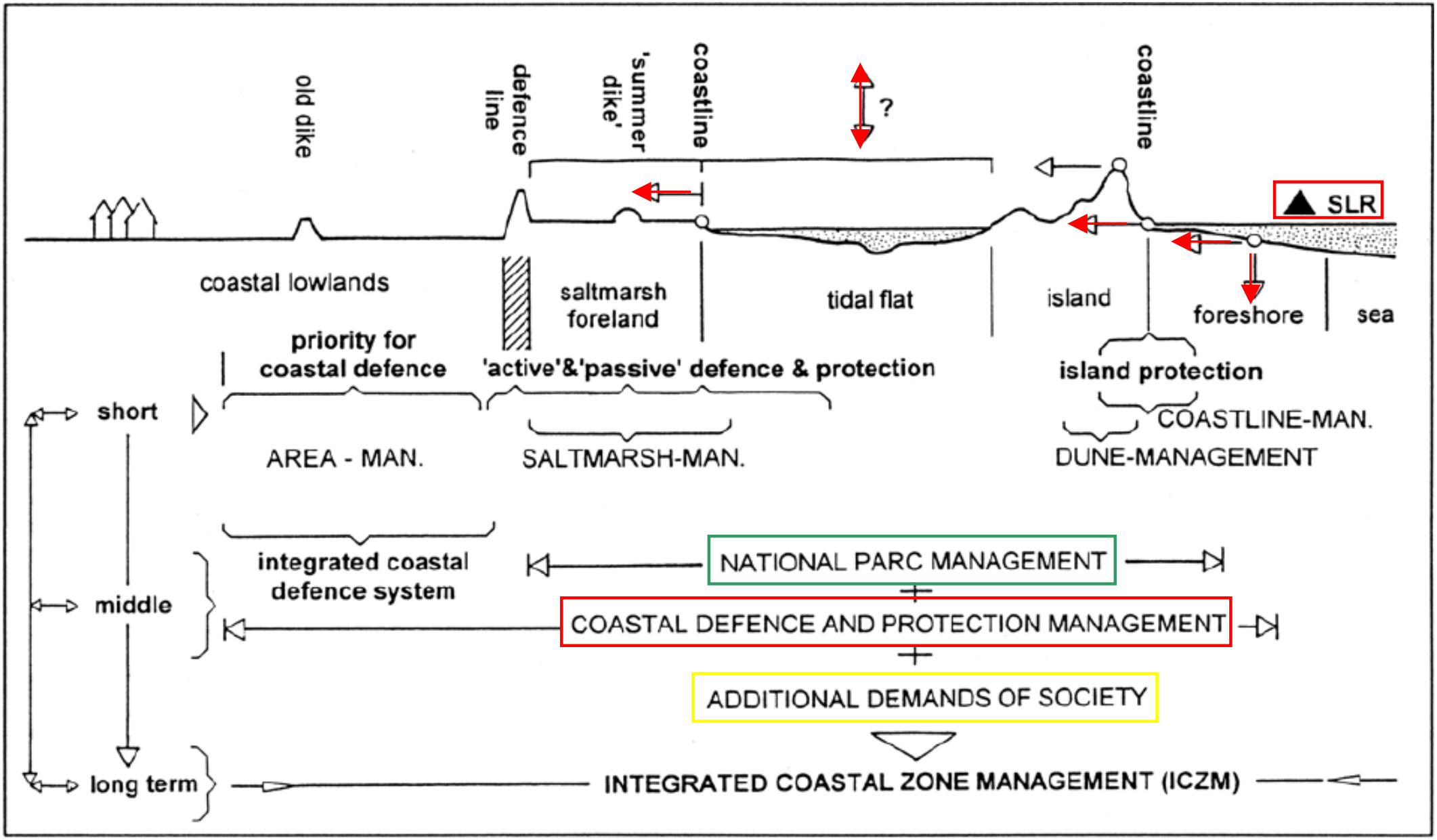



Norderneyer Seegat
(2.2.83 2:22 - 2:32)
NN +3,35m
H_S
4,0m
3,5m
3,0m
2,5m
2,0m
1,5m
1,0m
0,5m
40
25
15
5
10
N

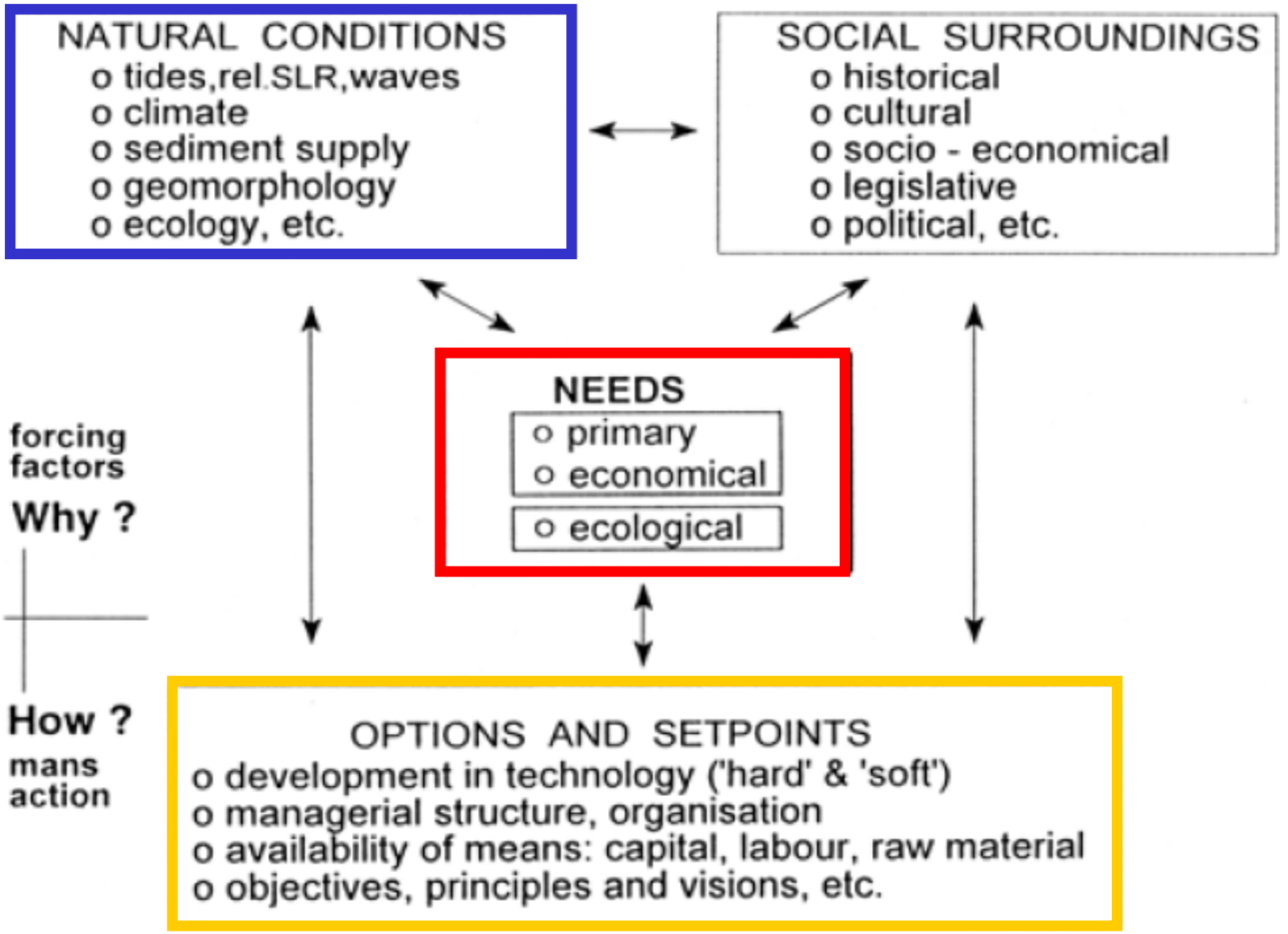

CZM
Cross-Section
N
Baltrum
Westdorf
© 2008 Europa Technologies
Image NASA
© 2008 Tele Atlas
Image © 2008 GeoContent
L5
Google
Zeiger 53°42'43.93" N 7°21'04.87" O Höhe 0 m Übertragung 100%
Sichthöhe 11.43 km


Summer Dike
Summer Polder
Groyne-System
"man-made"
Salt Marsh
Polder
Second Dike
Main Dike
Pilot Area Nessmersiel

Steps towards an Integration of Coastal Protection into Coastal Zone Management (ICZM)
Principle Sketch demonstrated by a cross-section for the East Frisian Coast

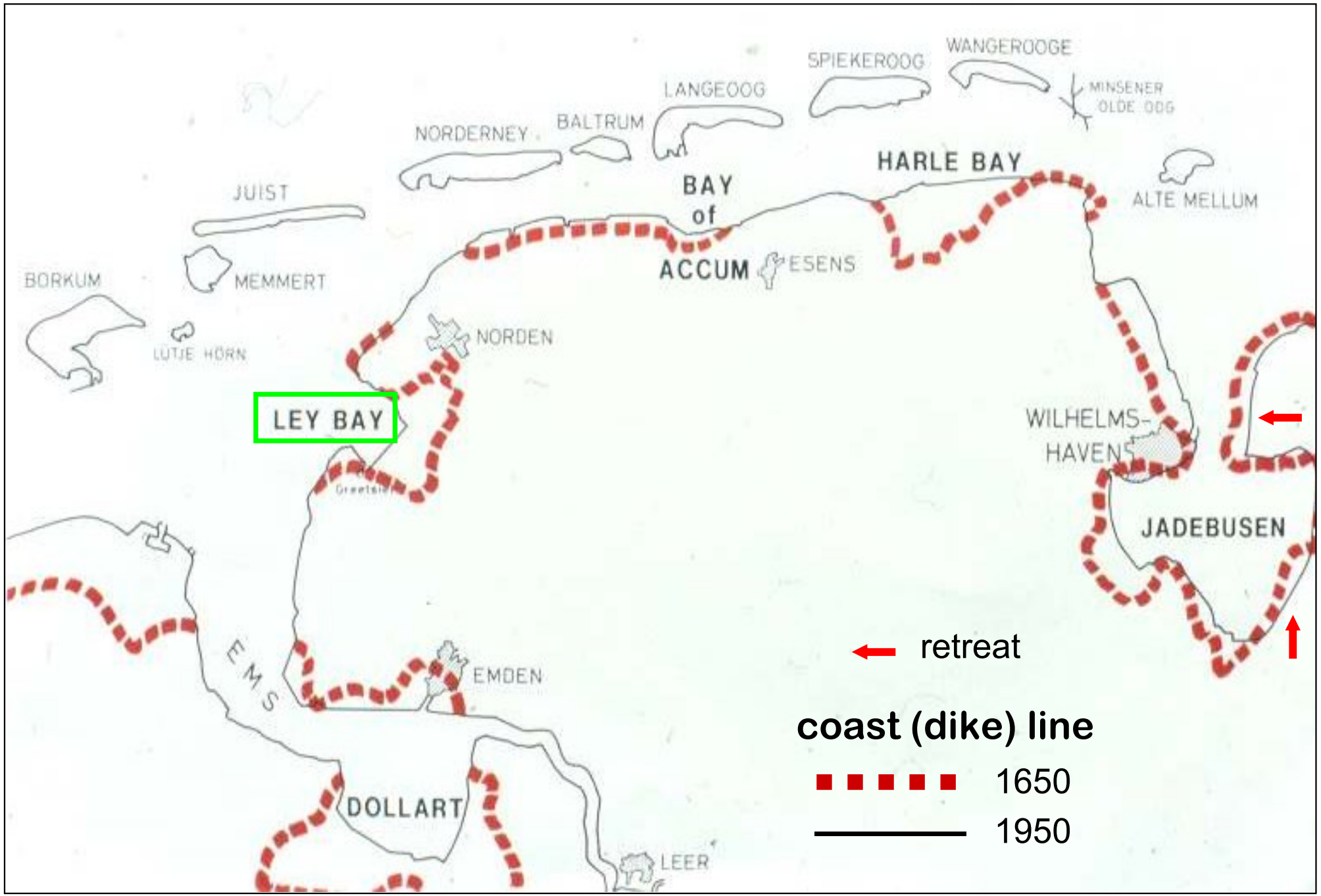


Scheme of combined key factors for coastal zone management

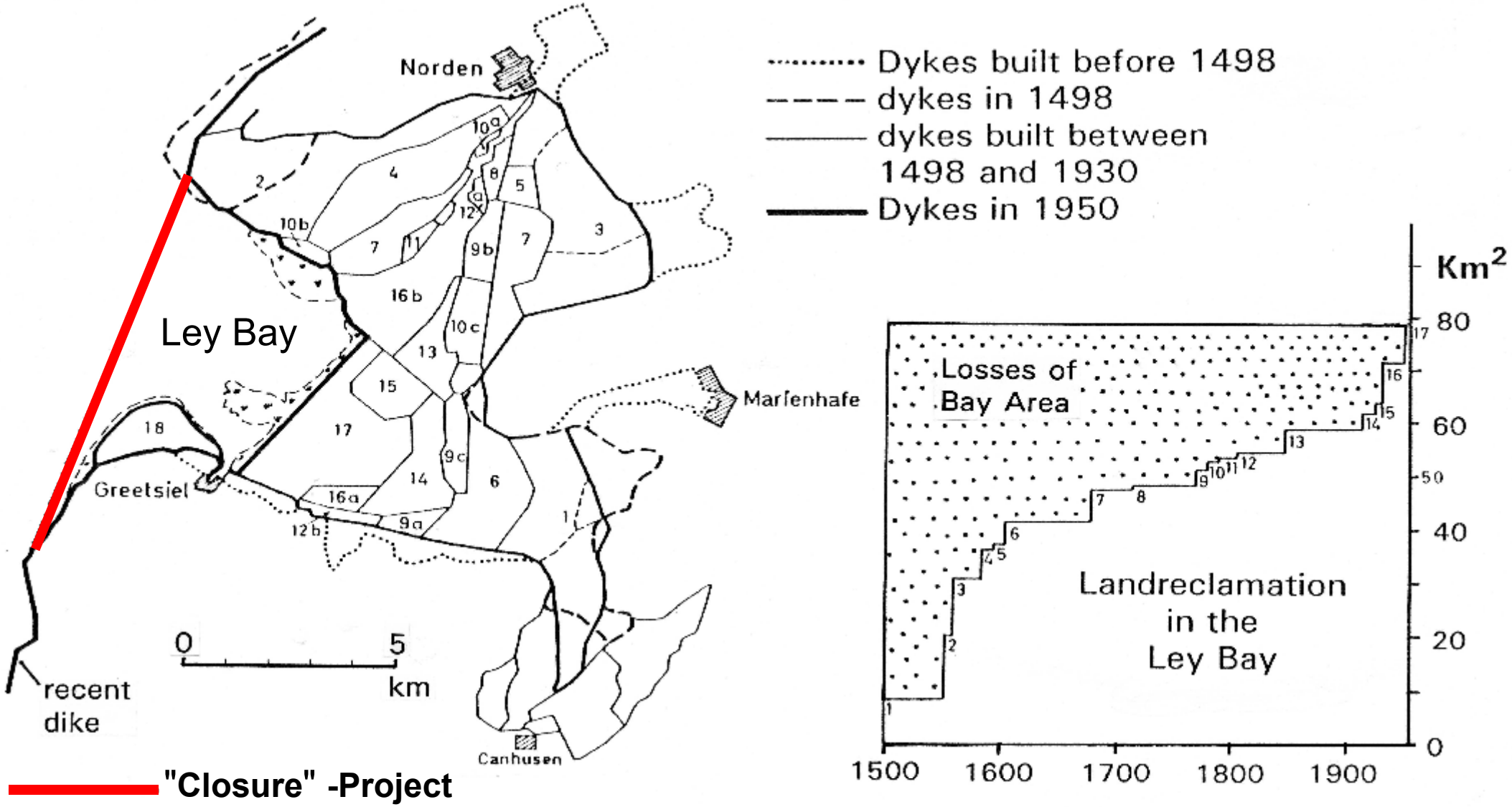


Focus: Interaction between Natural Conditions and Protection Responses
Case Studies German Bight, East Frisian Coast, North Sea

Advancement of the Dike Line from 1650 to 1950



Ley-Bay:
Natural Conditions: Silting up towards a "morphological equilibrium" after the land losses during medieval storm floods → problems with access to the sea (drainage, shipping) → diking associated with land reclamation follows the natural conditions until 1930 → seaward directed diking in 1950 → closure project (single defence line concept) rejected with respect to the key-factor "social needs"



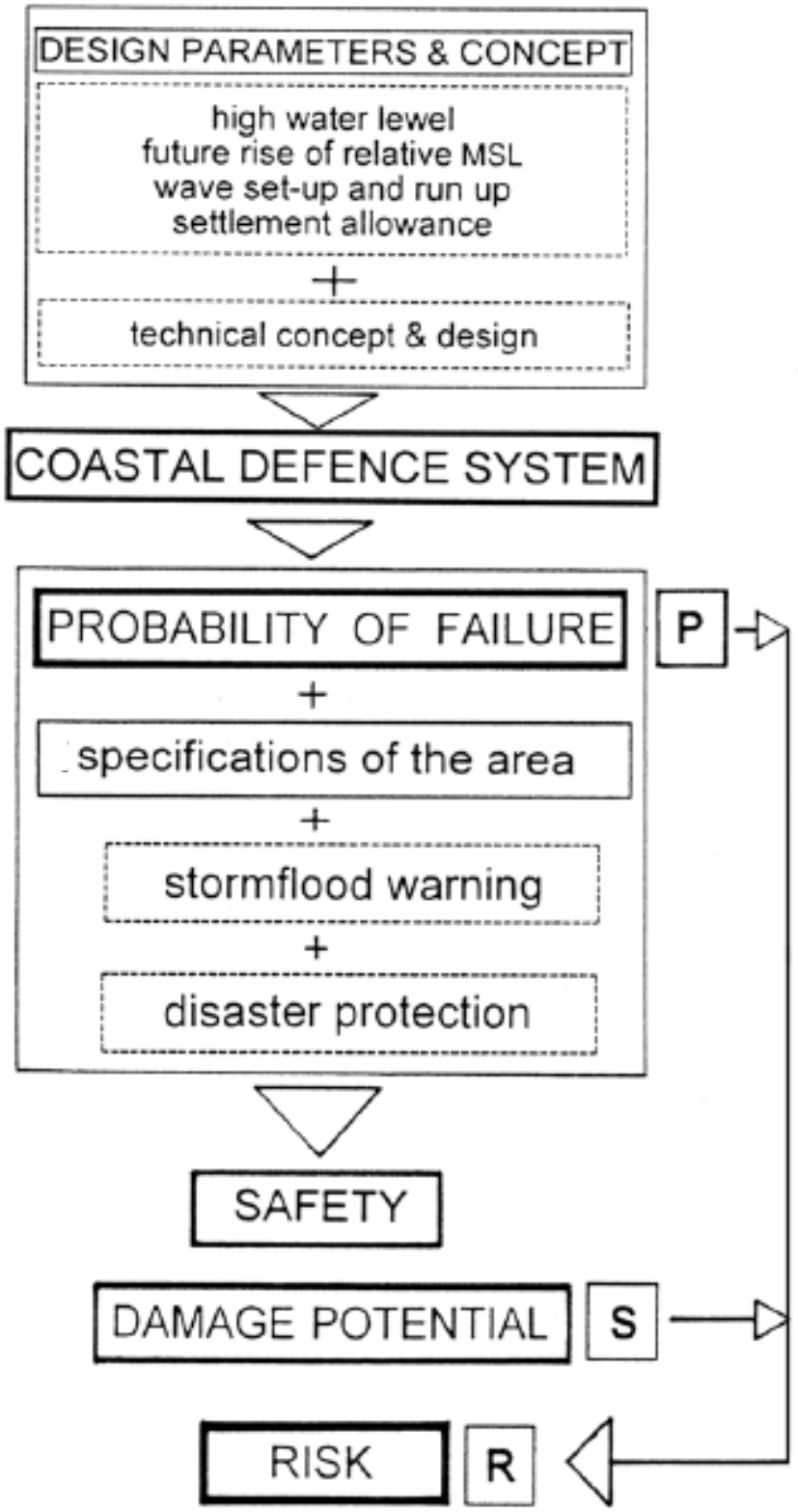
"Leyhörn" as an example for Coastal Zone Management

Ecological needs

keep Ley Bay open

Primary & Economical needs

access to deep water for drainage and shipping shorten the dike line



stochastic input data

combined probability of occurence

no

tolerable?

yes

acceptable? no

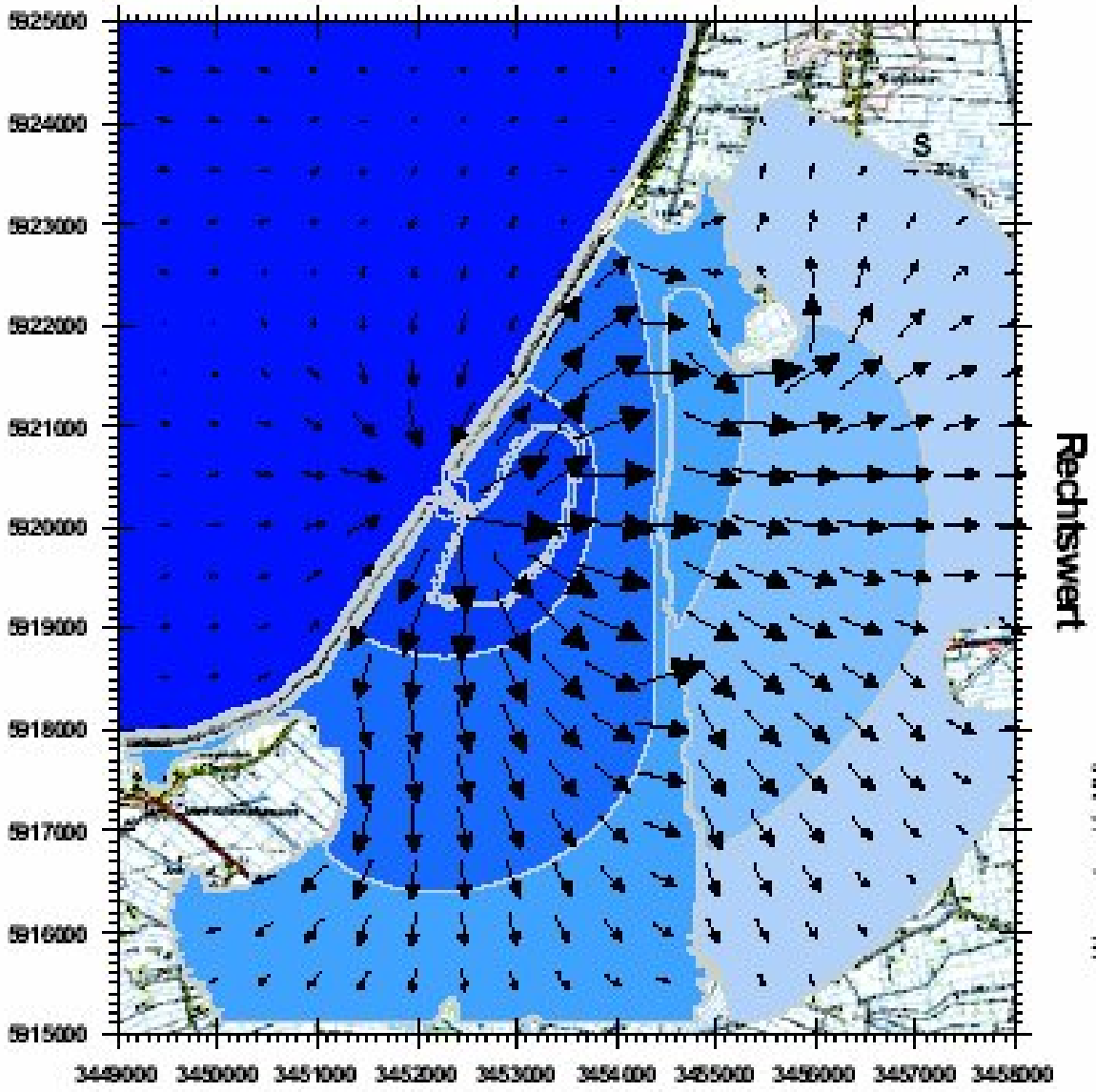
From deterministic Coastal Defence to probabilistic Risk Management

Visualisation of Spatial Coastal Protection Concepts (Example Overtopping Embankment)

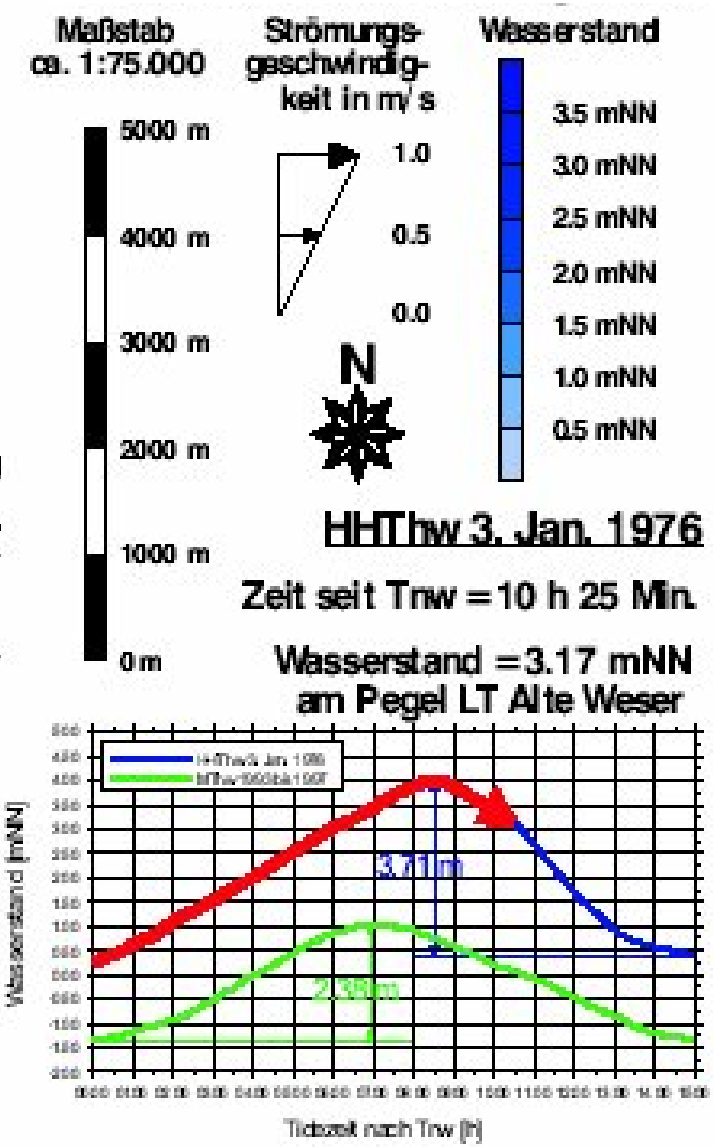
Failure of the Main Dike during the February Storm Flood in 1962

Flooding caused by Failure of a Dike
Numerical Simulation of Water Level and Currents

Flooding process as result of dike failure

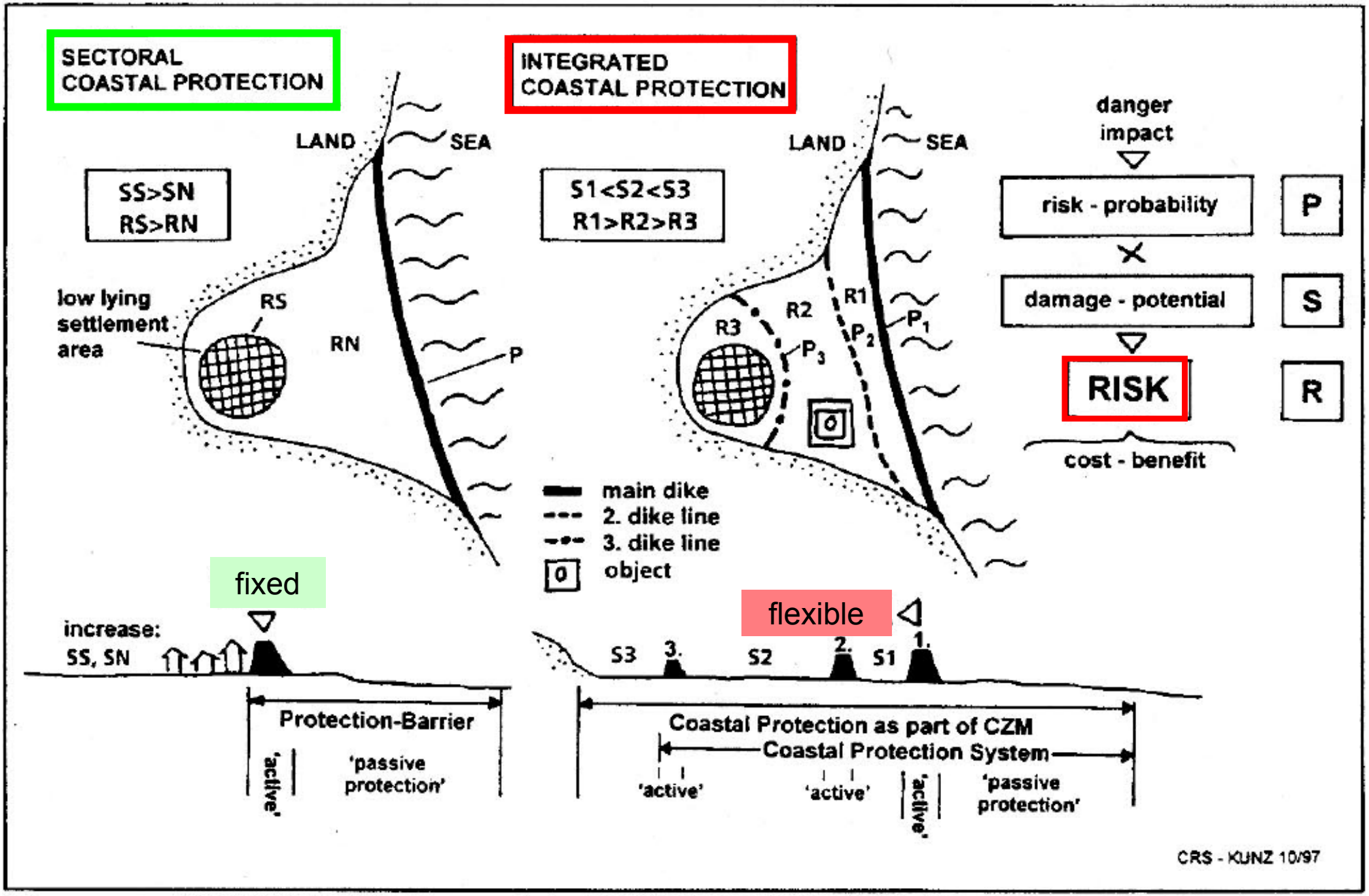


Failure Schweiburger Siel

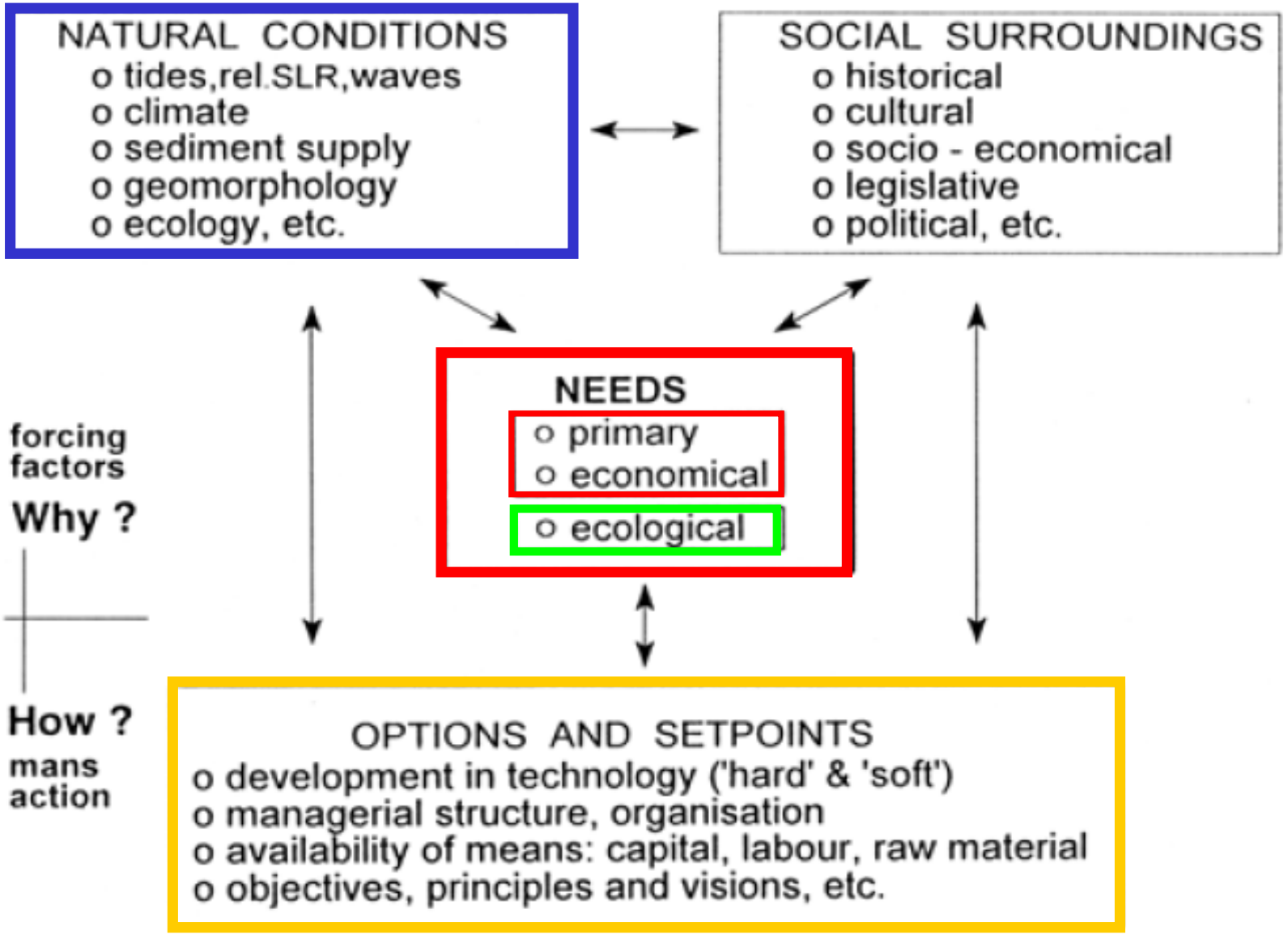


Concepts for Coastal Protection

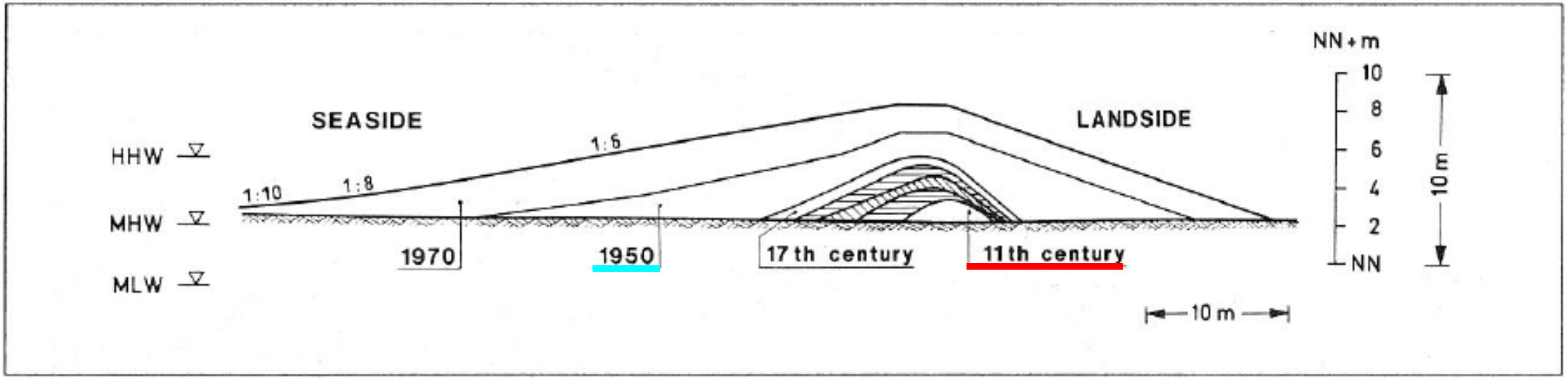
Single Line (Flood Defence) versus Spatial (Flood & Risk Management)



Combined Key-Factors for Coastal Zone Management (CZM)



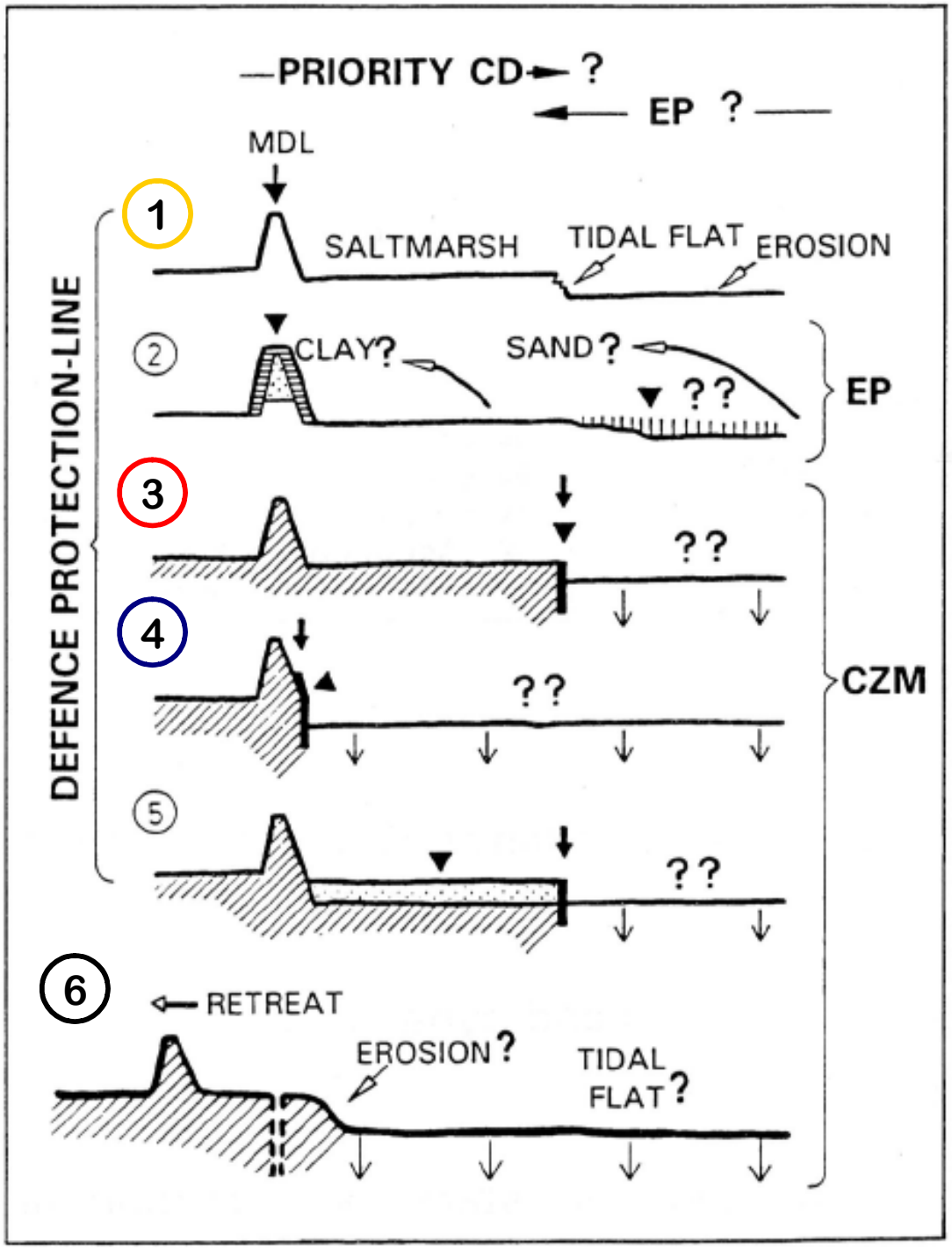
Development of dike-profiles - German North Sea coast



From 11th century to the storm flood disasters in 1953 (Dutch Flood) and 1962 (February Flood, Germany):
reactive strategy → height raised according to experiences gained by catastrophic failures of dikes

After 1953/1962 → design criteria, precaution concerning expected future hydro-morphological developments (100years) → response to environmental targets ("ecological" needs) → adapting to the "principle of sustainability"

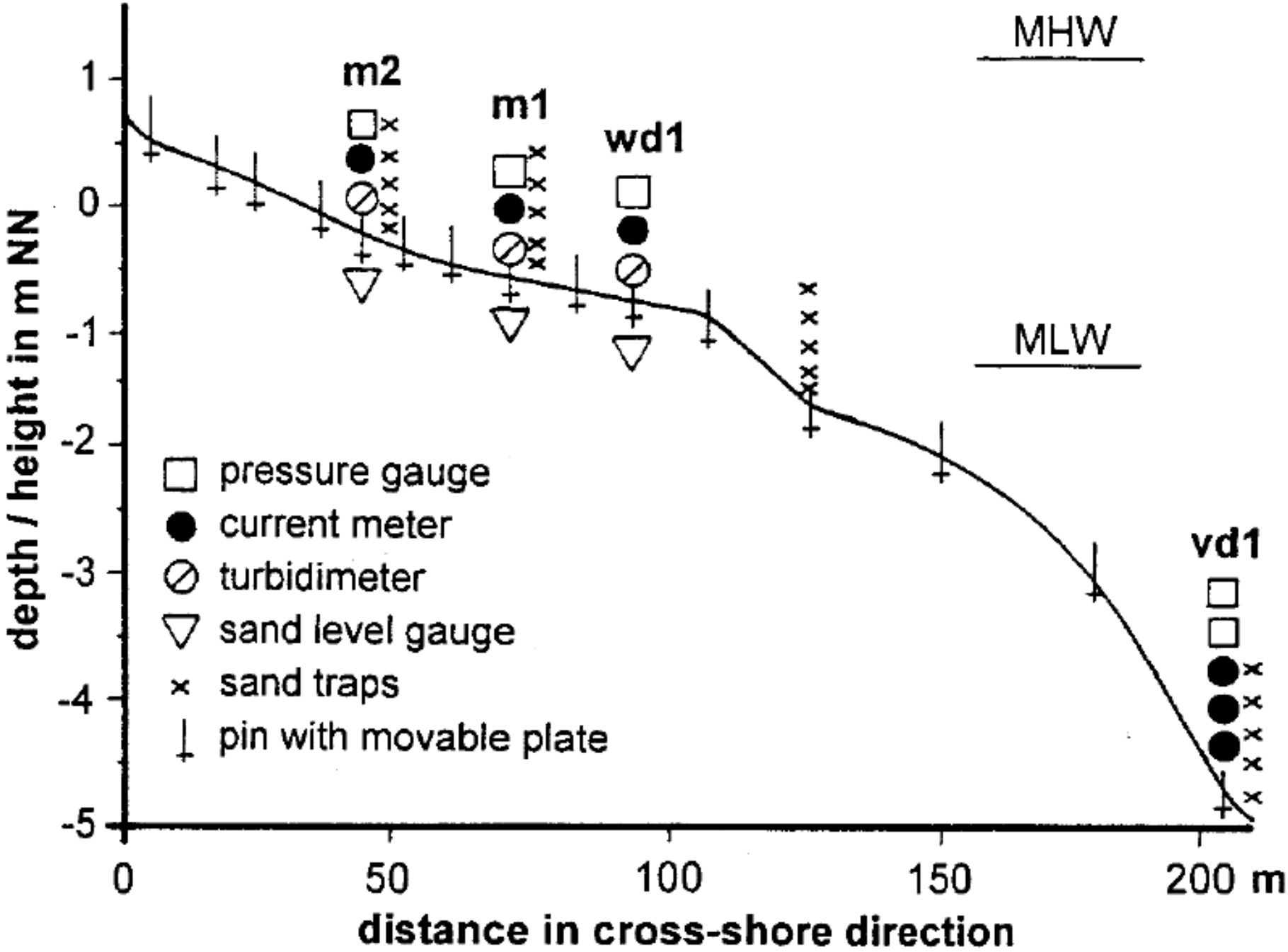
Coastal Protection Strategies – Dike with Fore Land

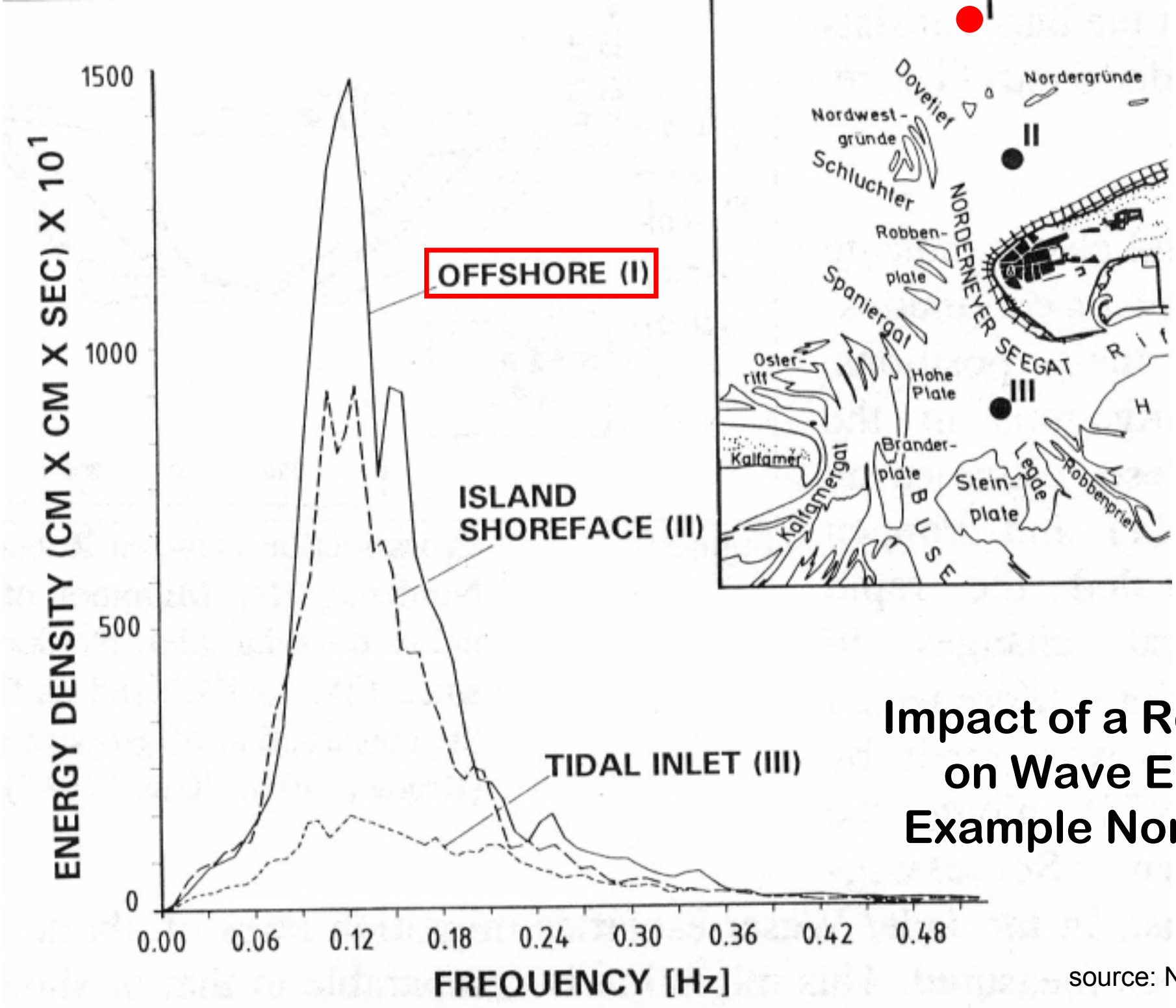


CD	Coastal Defence (Protection)
EP	Environmental Problems (preservation of nature)
MDL	Main Dyke (Defence Line)
▼	no retreat allowable
▼	technique avaible
▌	solid construction
? ?	impact of RSLR, tides, waves, surges, currents

Coastal Protection Strategy depends on: water-level, wave-run-up, development of tidal flat and saltmarsh, subsoil, security-targets

German–Russian Field-Experience on Norderney (East Frisian Island) – Cross-section with devices

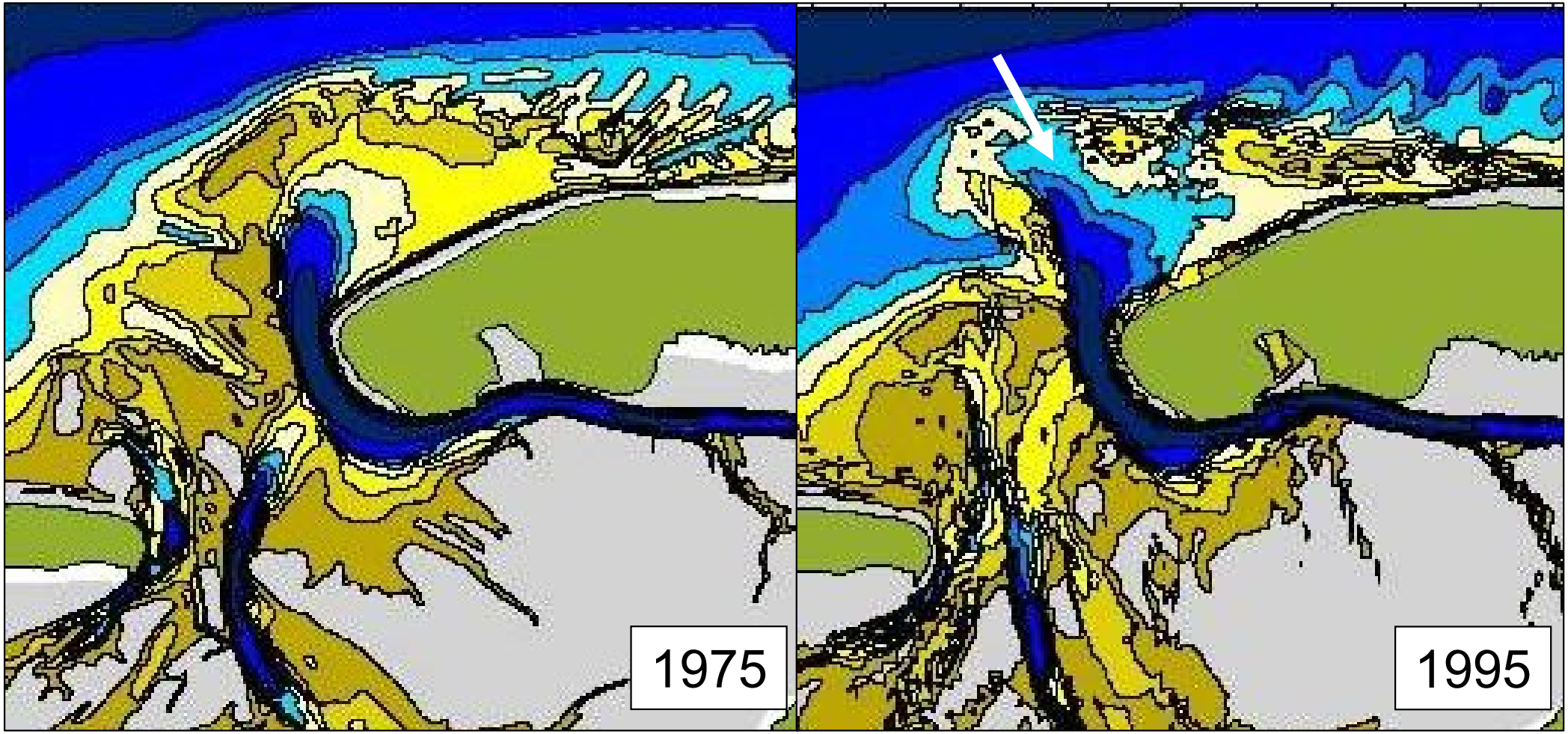




Impact of a Reef Bow on Wave Energy Example Norderney

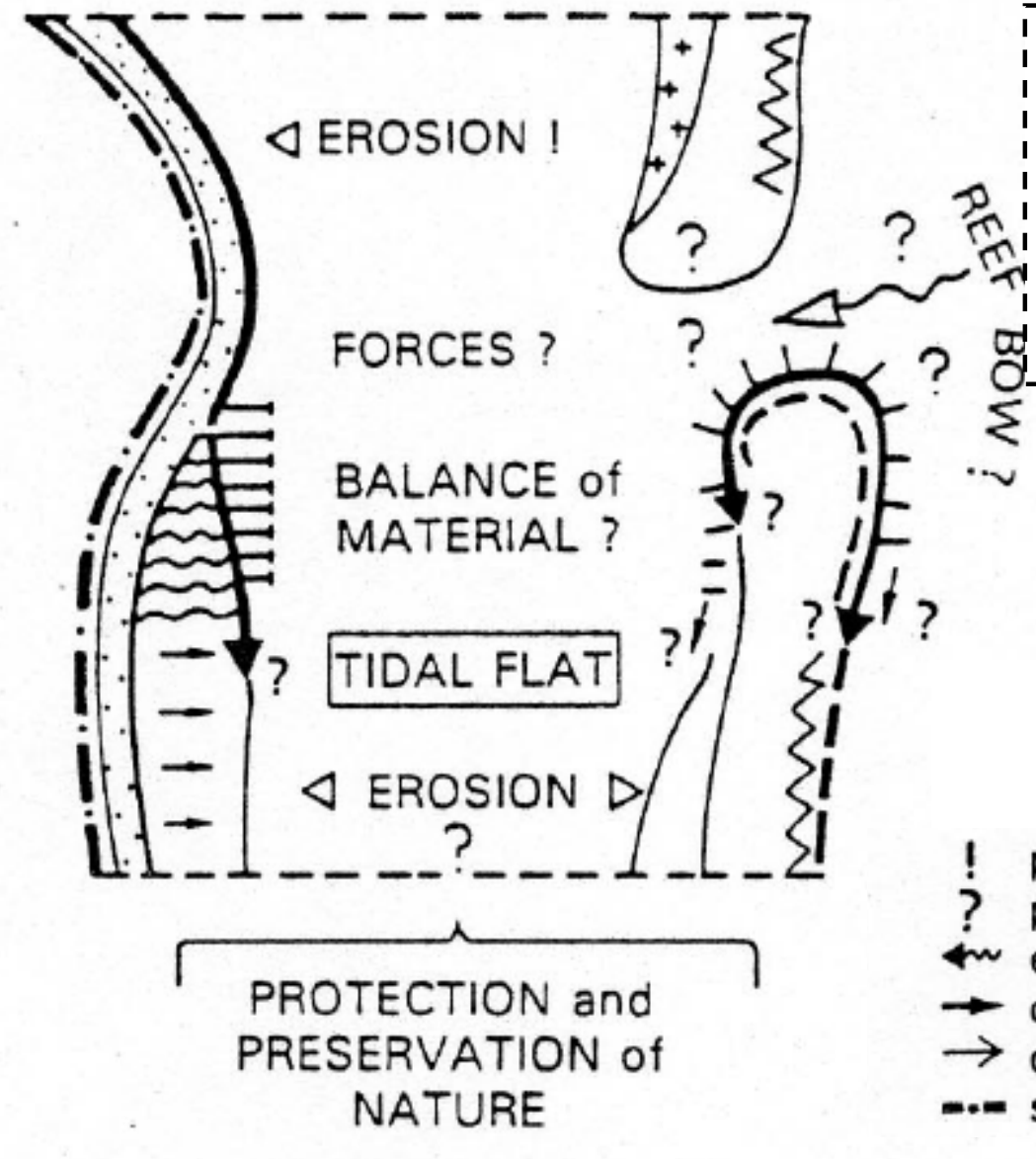
source: Niemeyer/FSK

Change "Reef Bow" (Ebb-Delta shoals) of the "Norderneyer Seegat" from 1975 to 1995



Future Development of Impacts and Reactions

Reactions



Impacts (uncertainties)

water level/SLR
waves
sediment supply

Impact of the Leyhörn-project on the morphology of the Ley Bay
Erosion/sedimentation during the time-period 1983-1996