BUNDESANSTALT FÜR WASSERBAU
Karlsruhe · Hamburg · Ilmenau

Federal Waterways Engineering
and Research Institute

The Tidal Elbe

Natural Development

Sediment Management (Physical Basics)

Climate Change

Tidal Elbe - Natural Development Sediment Management (Physical Basics) and Climate Change

1. German tidal areas (focus on Tidal Elbe)
2. How-to estimate development of the estuary ?
3. Tools for optimization of estuary systems
4. Asymmetry – A physical process based view
5. Minimize effects of fairway deepening
6. Climate Change – Sediment dynamics in the future
7. Conclusion

Prologue

The natural development of Tidal Elbe is interfered by man-made measures.

The shape (component geometry) is modified by hydraulic structures (fairways, groins, ..)

Shape alterations cause alterations of tidal processes
(energy of tidal waves, tidal range, tidal currents, symmetry and asymmetry of tidal processes).

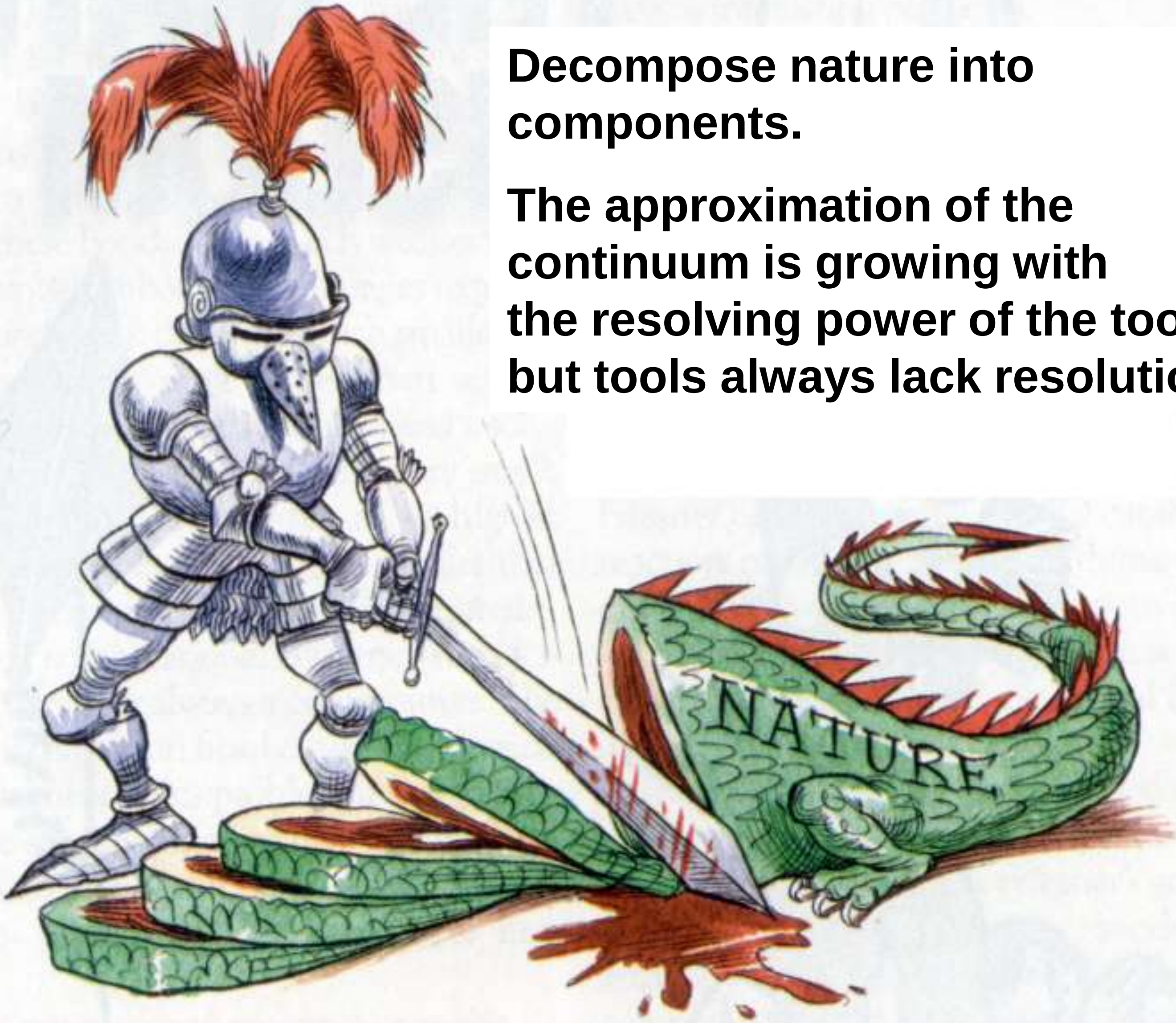
Alteration of tidal dynamics can lead to unwanted sediment transports.

Tools are needed to improve the predictability of the processes and sediment management strategies.

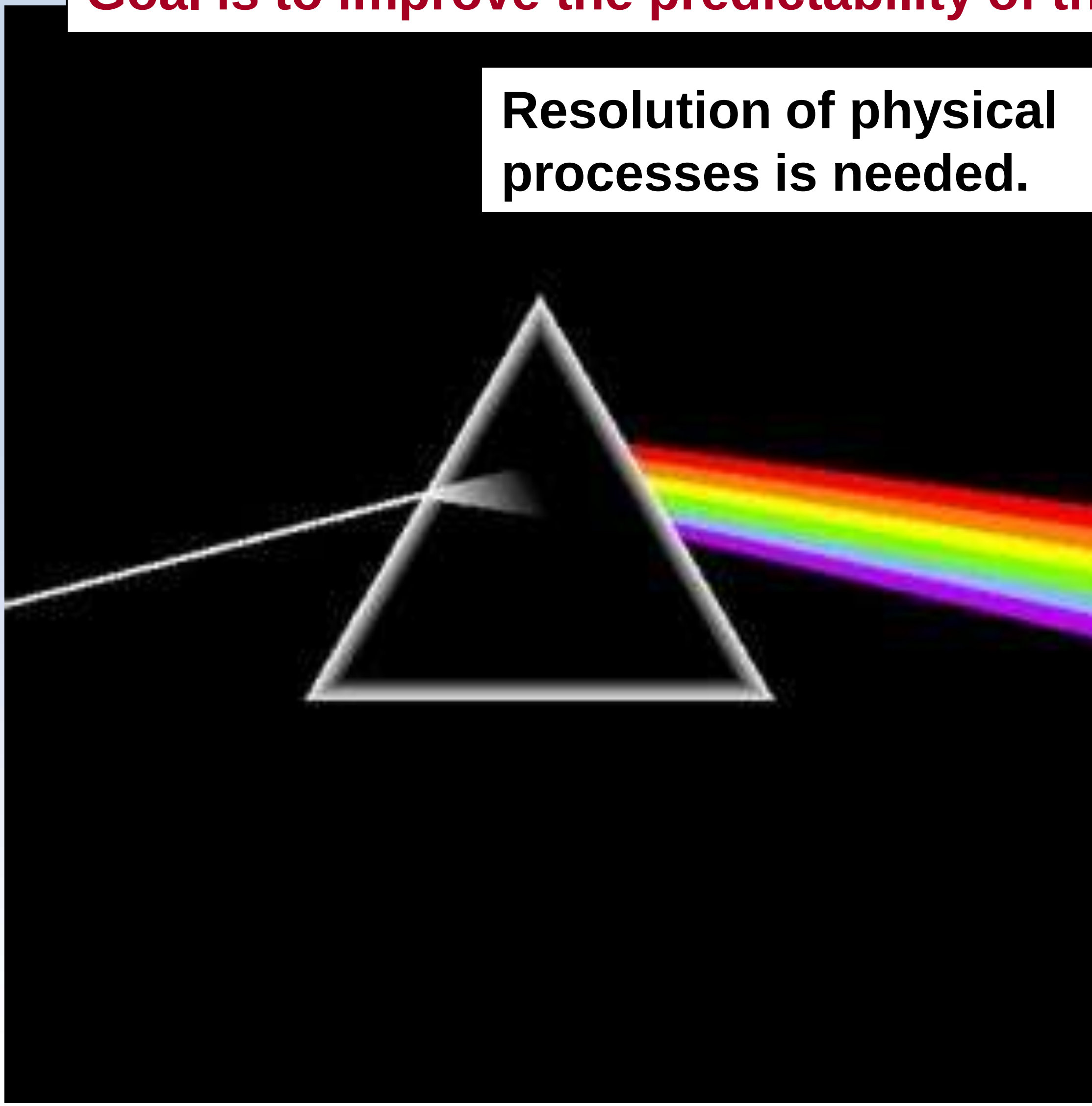
Goal is to improve the predictability of the processes.

Decompose nature into components.

The approximation of the continuum is growing with the resolving power of the tools – but tools always lack resolution.

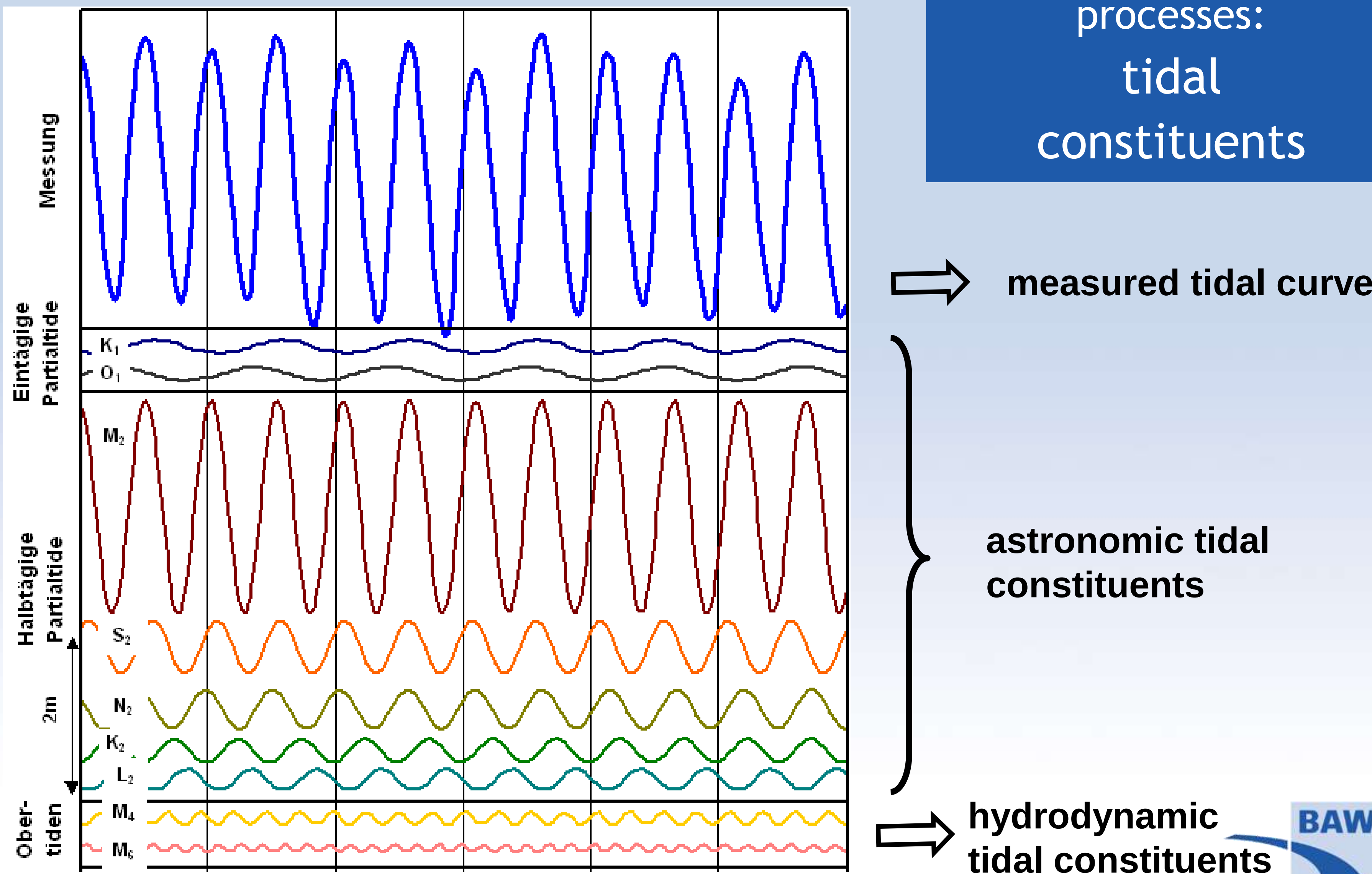


Goal is to improve the predictability of the processes.



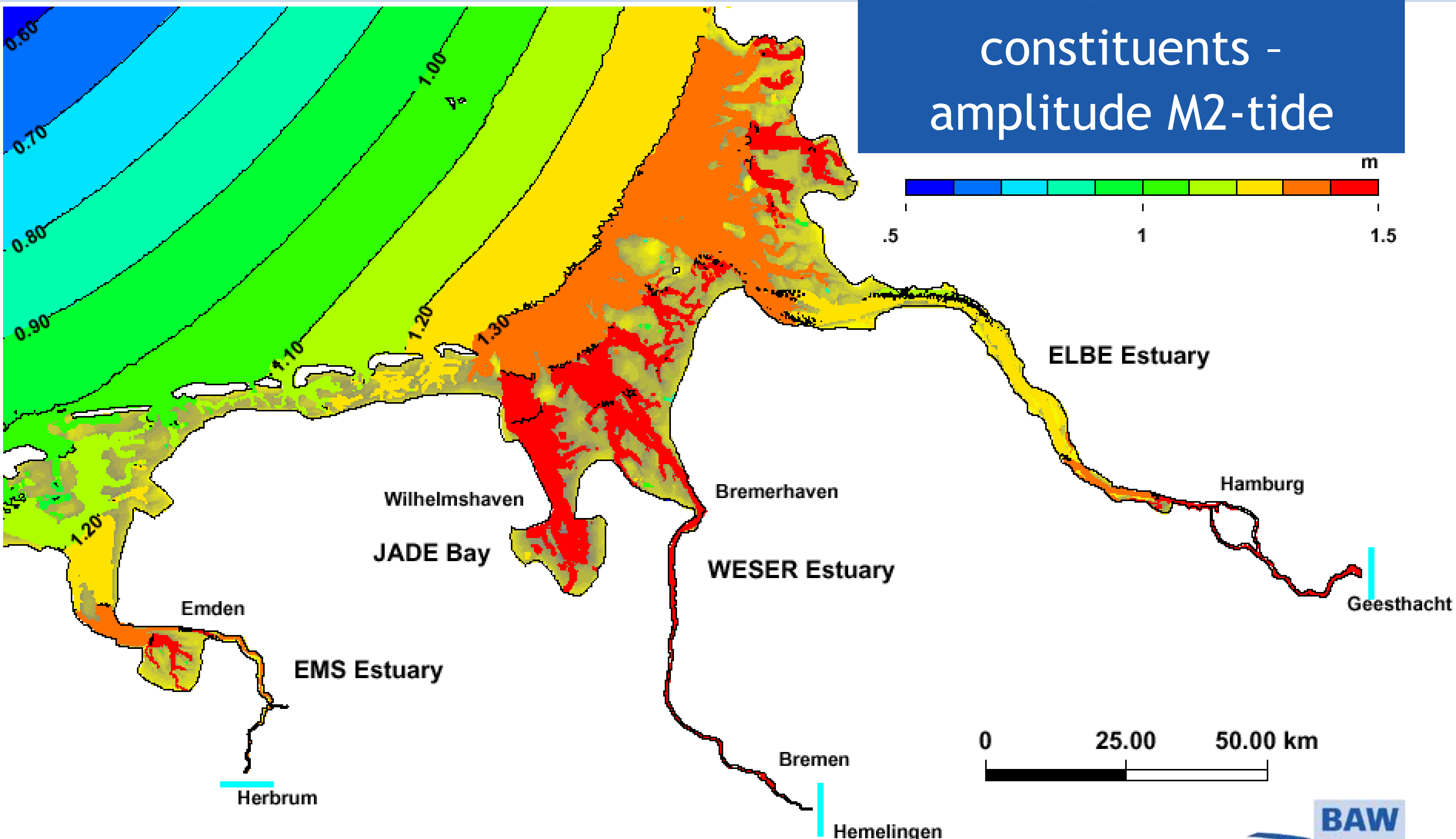
Resolution of physical processes is needed.

Resolution of physical processes: tidal constituents



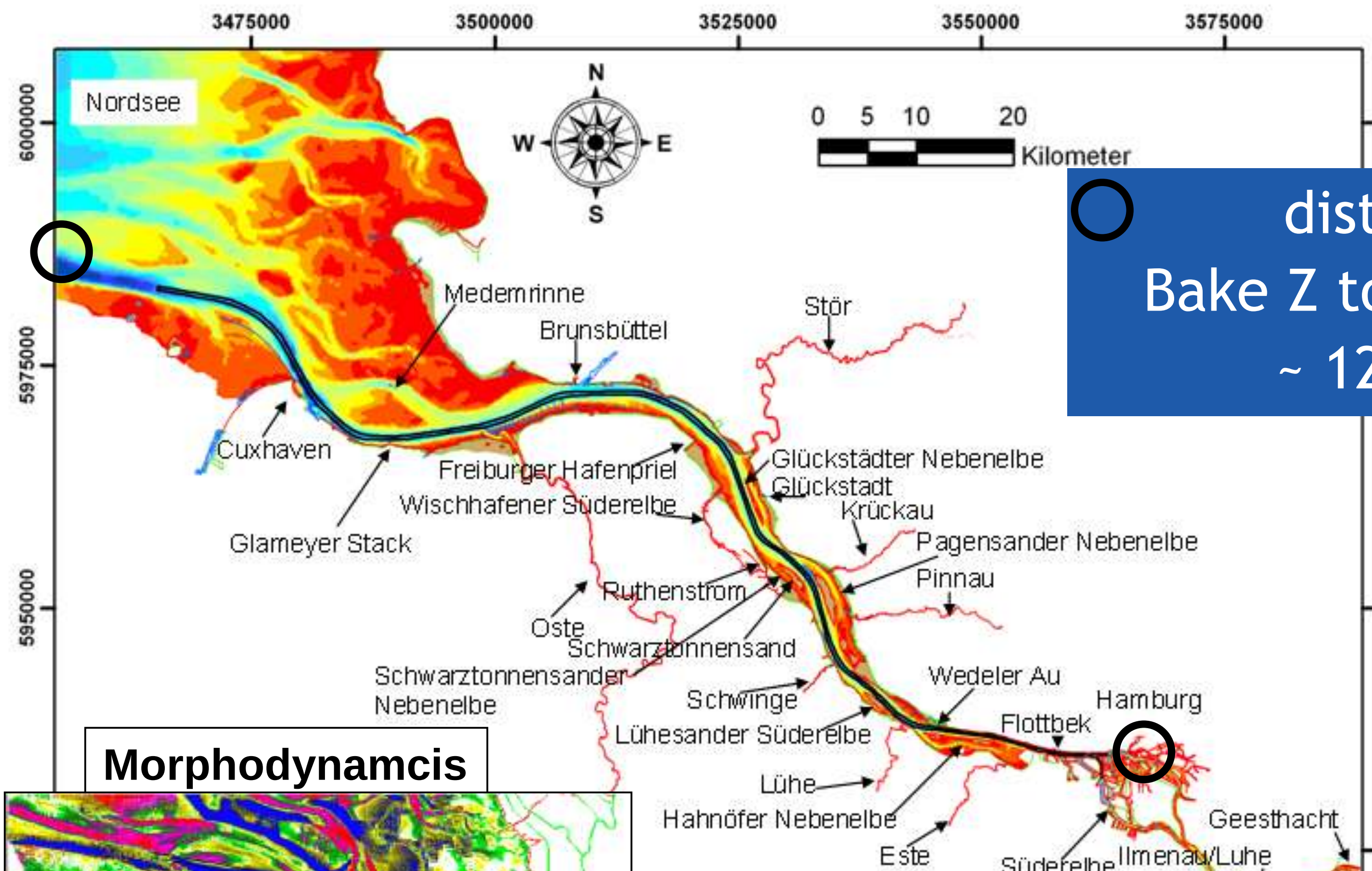
German Tidal Areas

tidal constituents – amplitude M2-tide



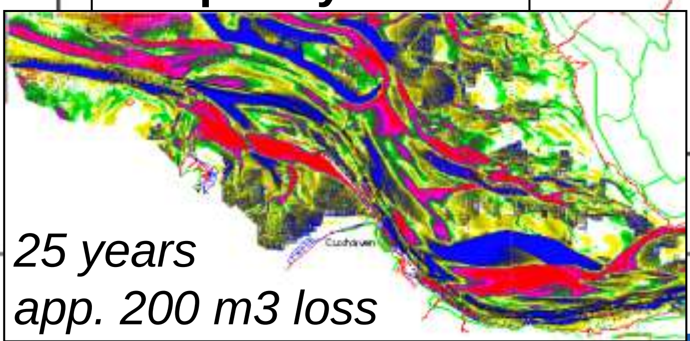
BAW

Tidal Elbe



distance
Bake Z to Hamburg
~ 120 km

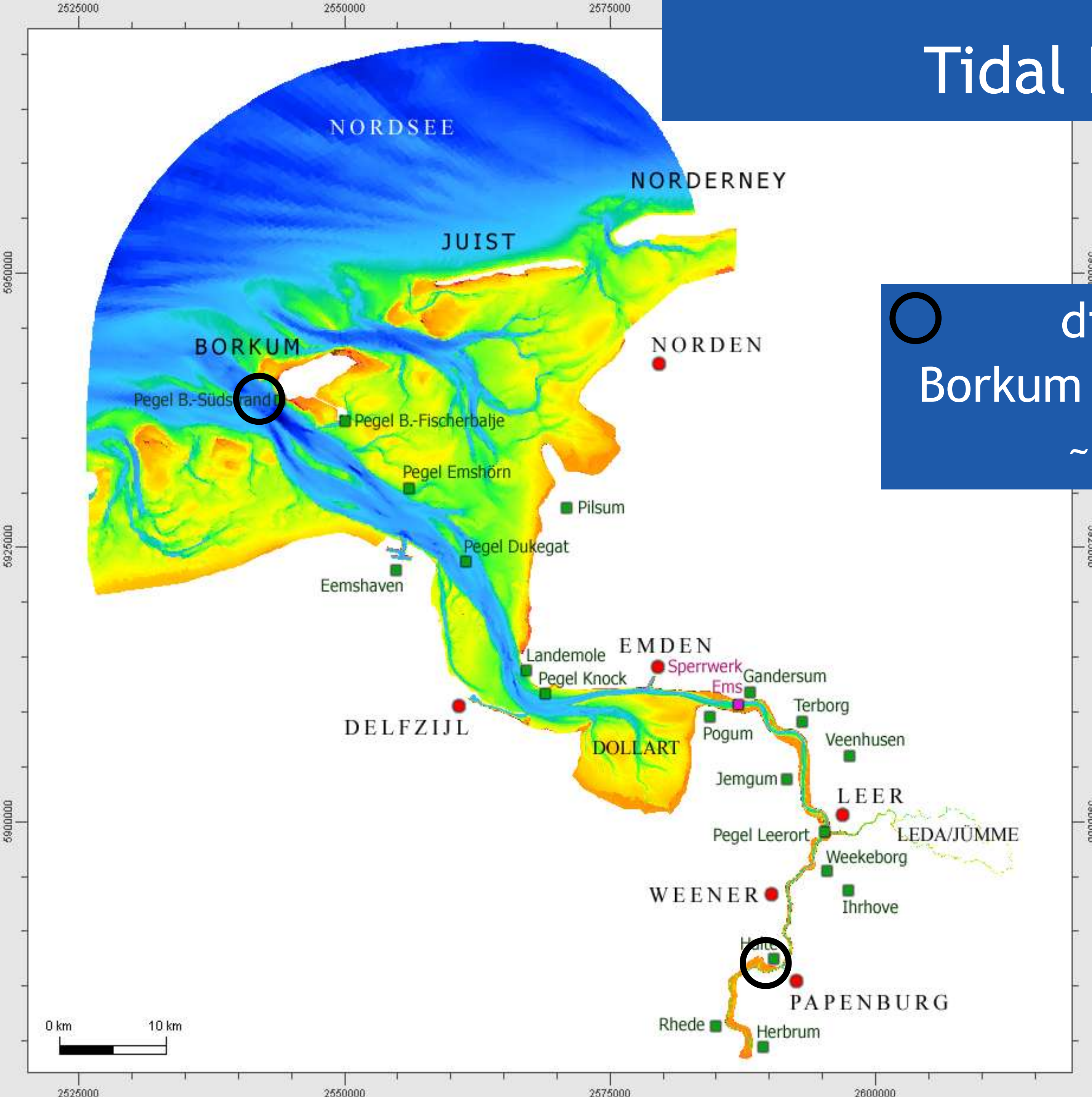
Morphodynamcis



25 years
app. 200 m3 loss

BAW

Tidal Ems



distance
Borkum to Papenburg
~ 90 km

BAW

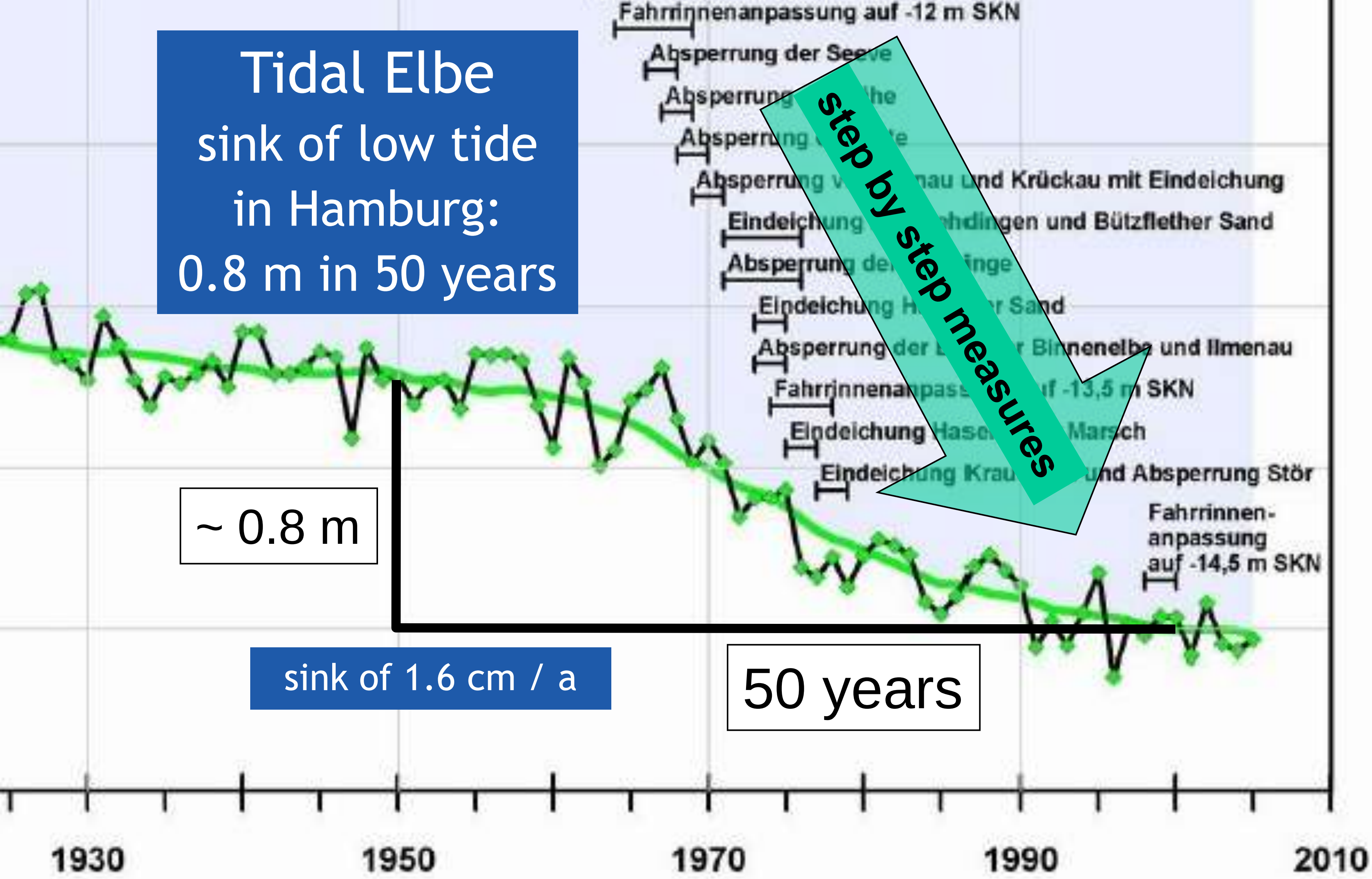
How-to estimate Development of the German Estuaries

What can be the leading (tidal) parameter for an assessment of ongoing development of tidal processes?

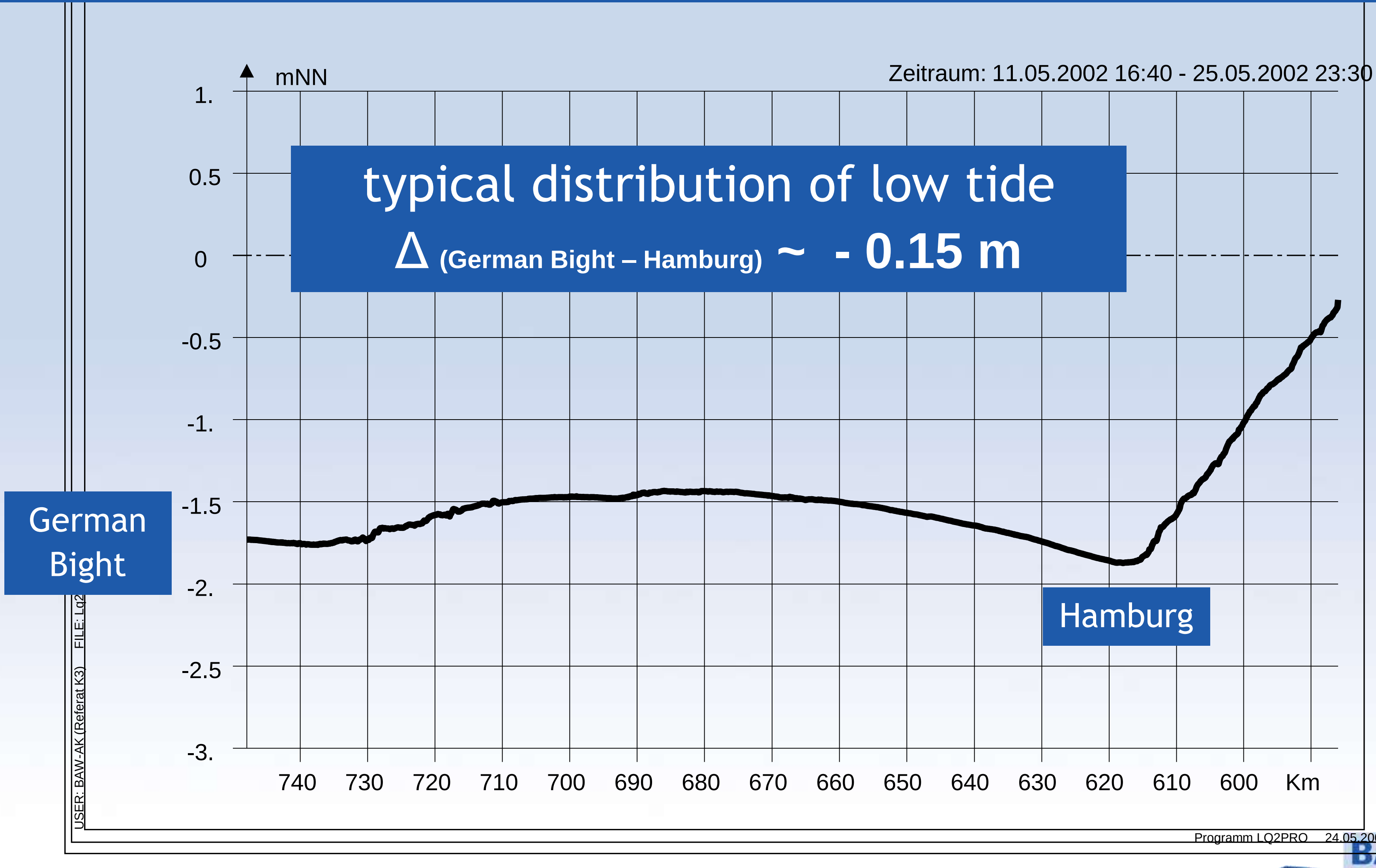
How-to estimate Development of the German Estuaries

What can be the leading (tidal) parameter for an assessment of ongoing development of tidal processes?

- **chronology of low tide development in the upper estuary region**
- **gradients of the water level during incoming tidal wave**


Tidal Elbe
sink of low tide
in Hamburg:
0.8 m in 50 years
Fahrrinnenanpassung auf -12 m SKN
step by step measures
Fahrrinnen-
anpassung
auf -14,5 m SKN
~ 0.8 m
sink of 1.6 cm / a
50 years
1930
1950
1970
1990
2010

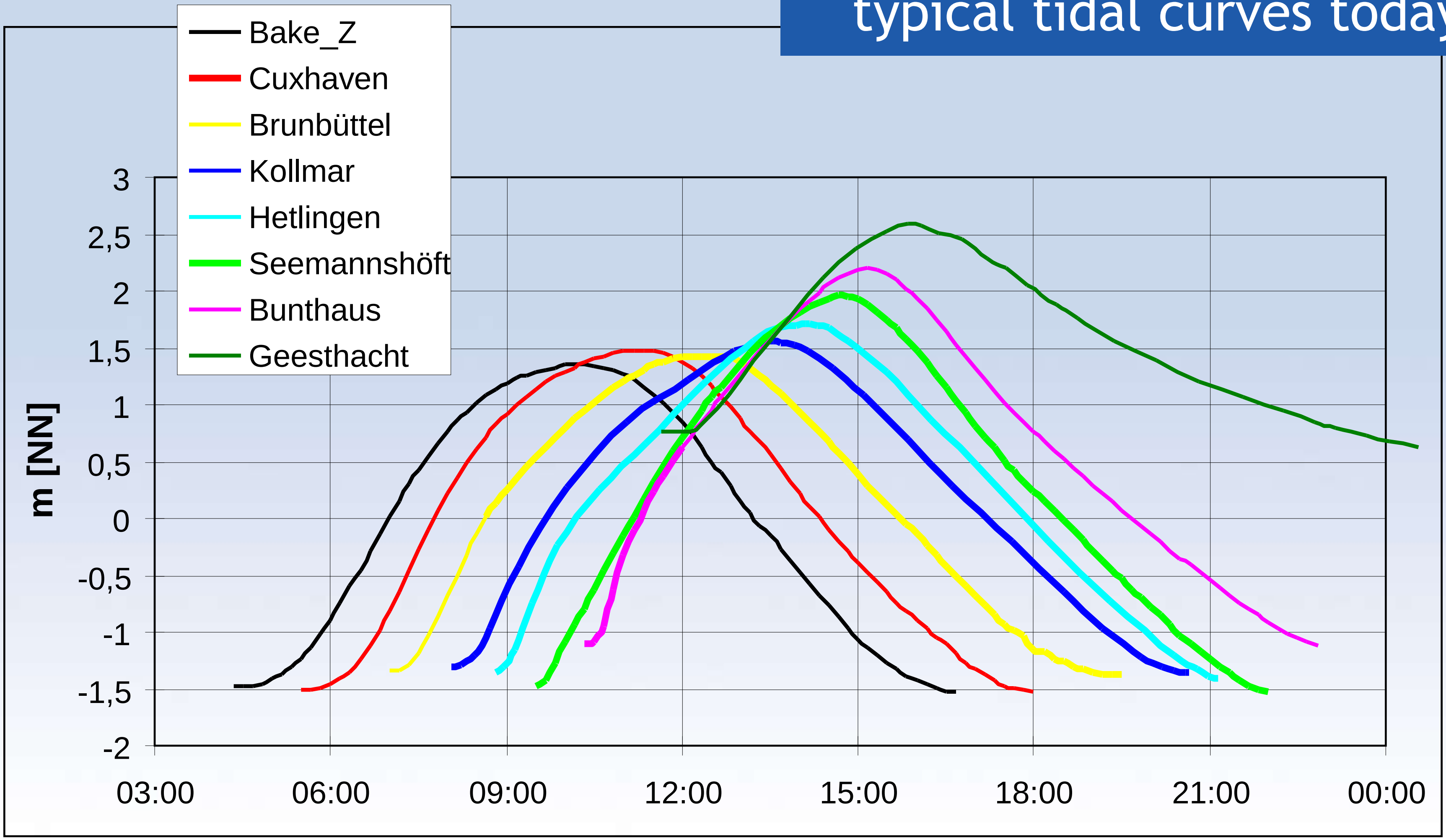
Tidal Elbe



mNN
Zeitraum: 11.05.2002 16:40 - 25.05.2002 23:30
1.
0.5
0
-0.5
-1.
-1.5
-2.
-2.5
-3.
740 730 720 710 700 690 680 670 660 650 640 630 620 610 600 Km
typical distribution of low tide
Δ (German Bight – Hamburg) ~ - 0.15 m
German Bight
Hamburg
USER: BAW-AK (Referat K3) FILE: Lq2
Programm LQ2PRO 24.05.2006

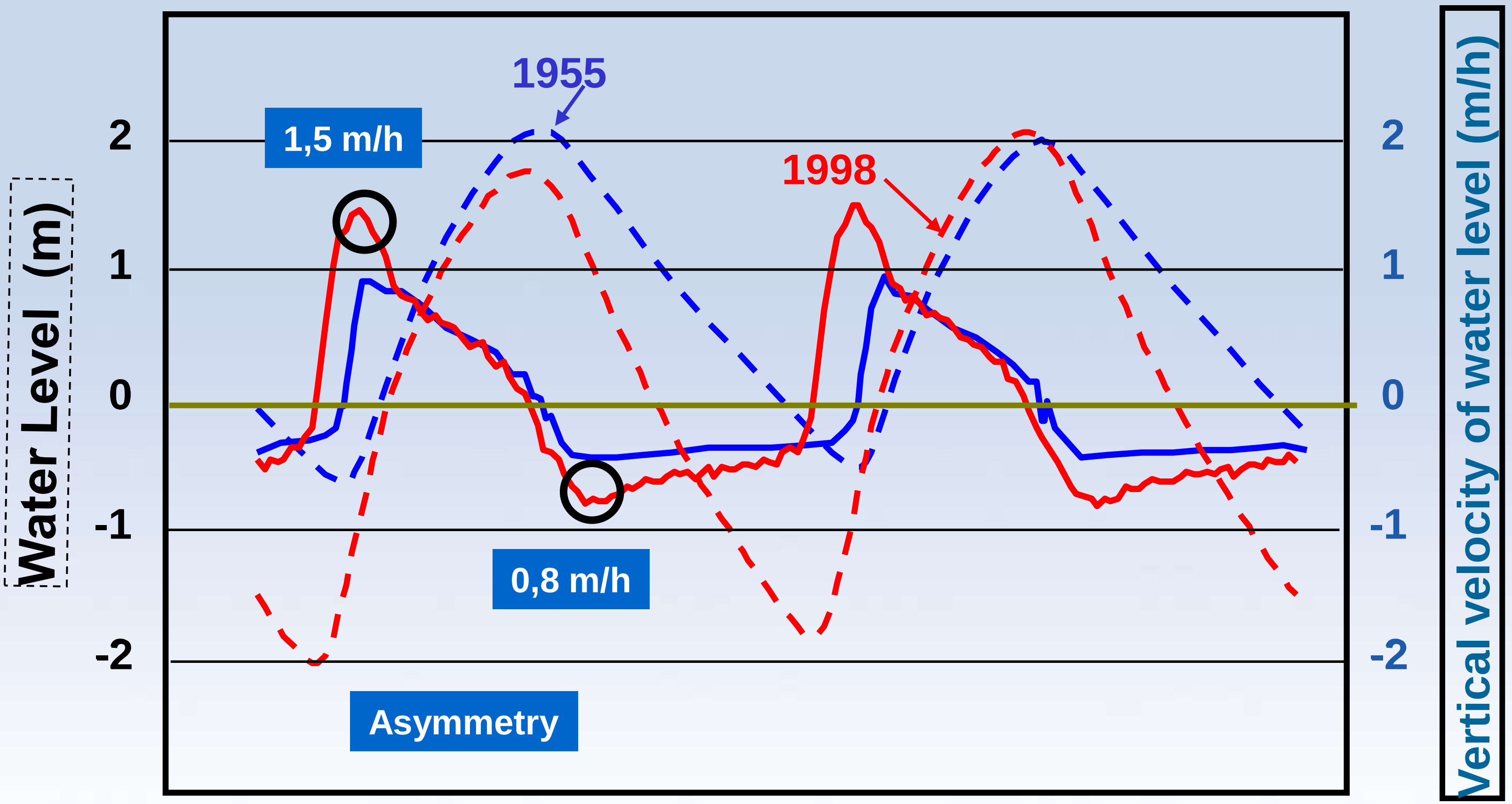
Tidal Elbe

typical tidal curves today

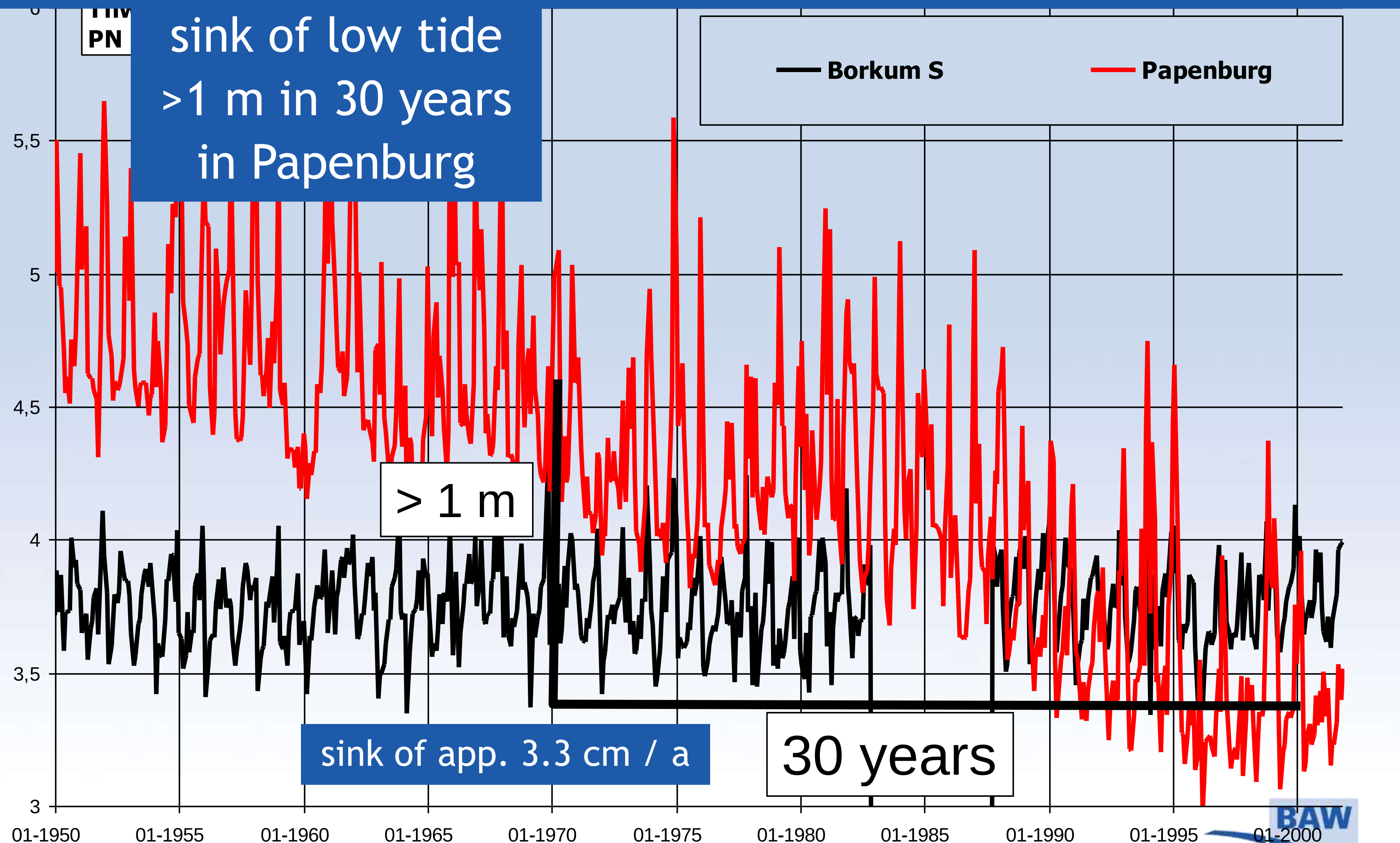


Tidal Elbe – speed of local water variation

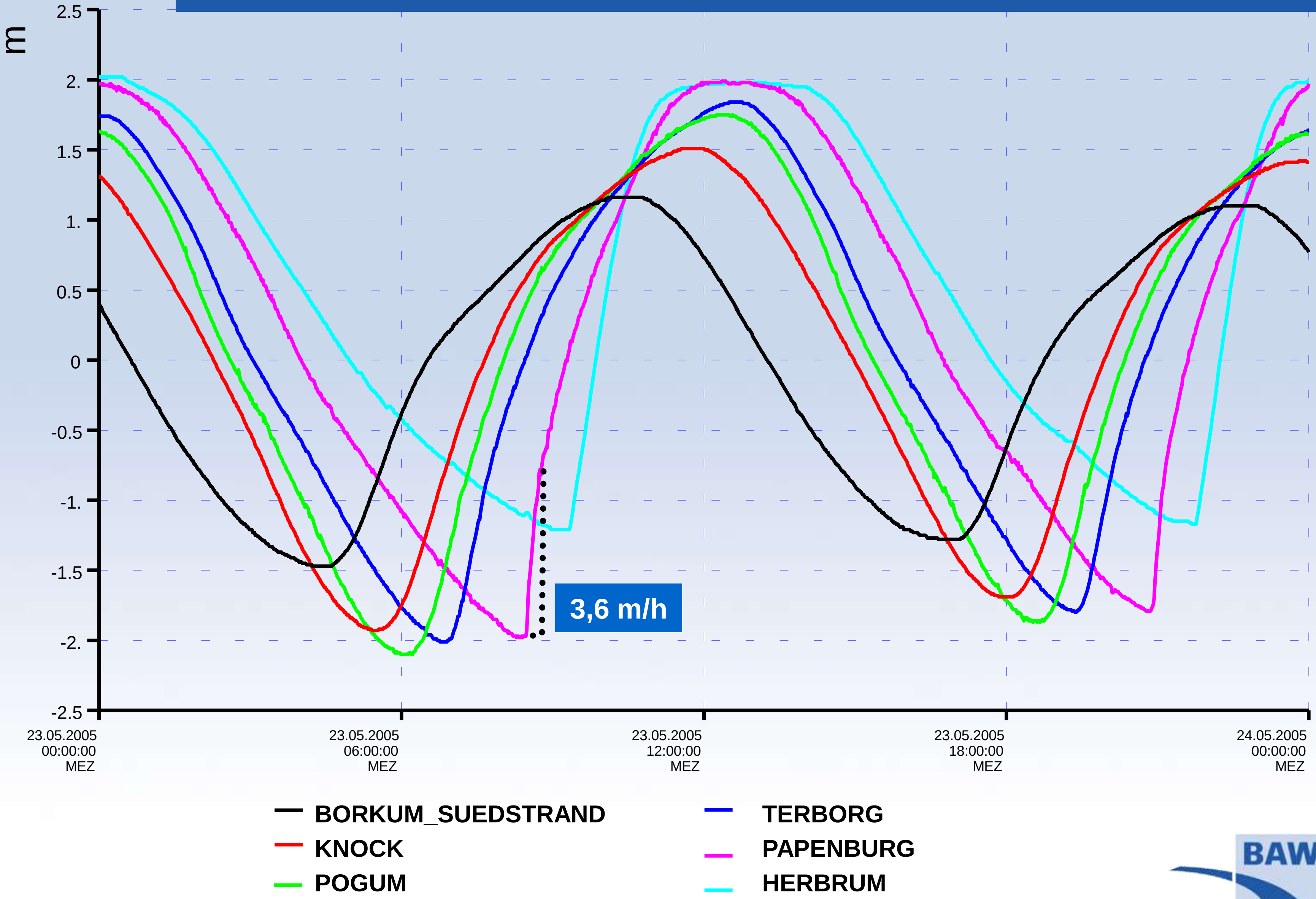
gauge Hamburg St. Pauli



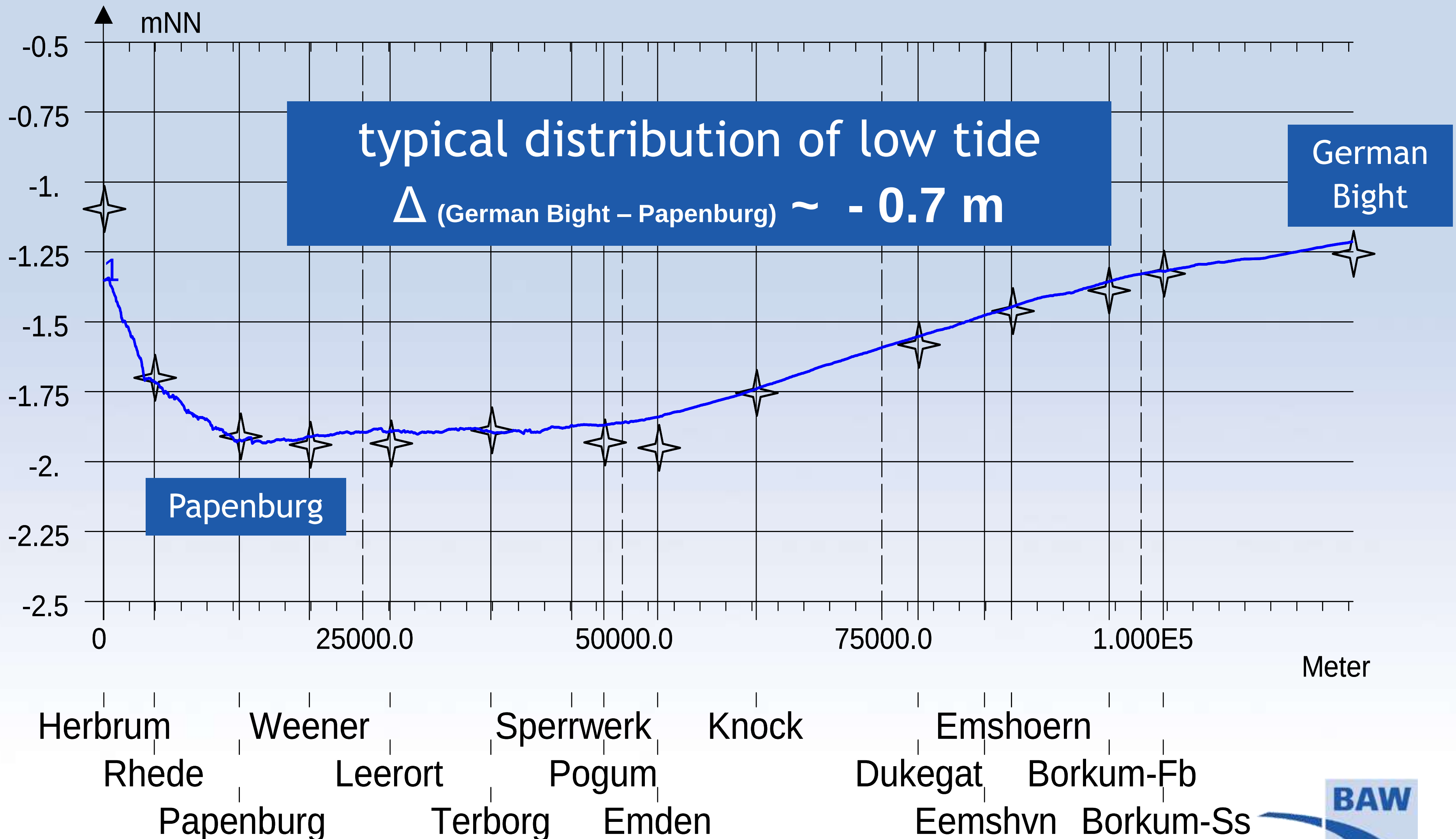
As a rule we can say: an increasing climbing speed goes on with increasing flow velocities.
The largest speeds occur during the fist flood phase.


PN
sink of low tide
>1 m in 30 years
in Papenburg
Borkum S
Papenburg
> 1 m
30 years
sink of app. 3.3 cm / a
5,5
5
4,5
4
3,5
3
01-1950
01-1955
01-1960
01-1965
01-1970
01-1975
01-1980
01-1985
01-1990
01-1995
01-2000

Tidal Ems: Water-Level Gauges (2005)



Tidal Ems



mNN
-0.5
-0.75
-1.
-1.25
-1.5
-1.75
-2.
-2.25
-2.5
typical distribution of low tide
Δ (German Bight – Papenburg) ~ - 0.7 m
German Bight
Papenburg
1
0
25000.0
50000.0
75000.0
1.000E5
Meter
Herbrum
Rhede
Papenburg
Weener
Leerort
Terborg
Sperrwerk
Pogum
Emden
Knock
Dukegat
Emshoern
Eemshvn
Borkum-Fb
Borkum-Ss

Tools for Optimization of Estuary Systems

Estimating the development of the system, data of water level measurements are very important to get an idea of asymmetry.

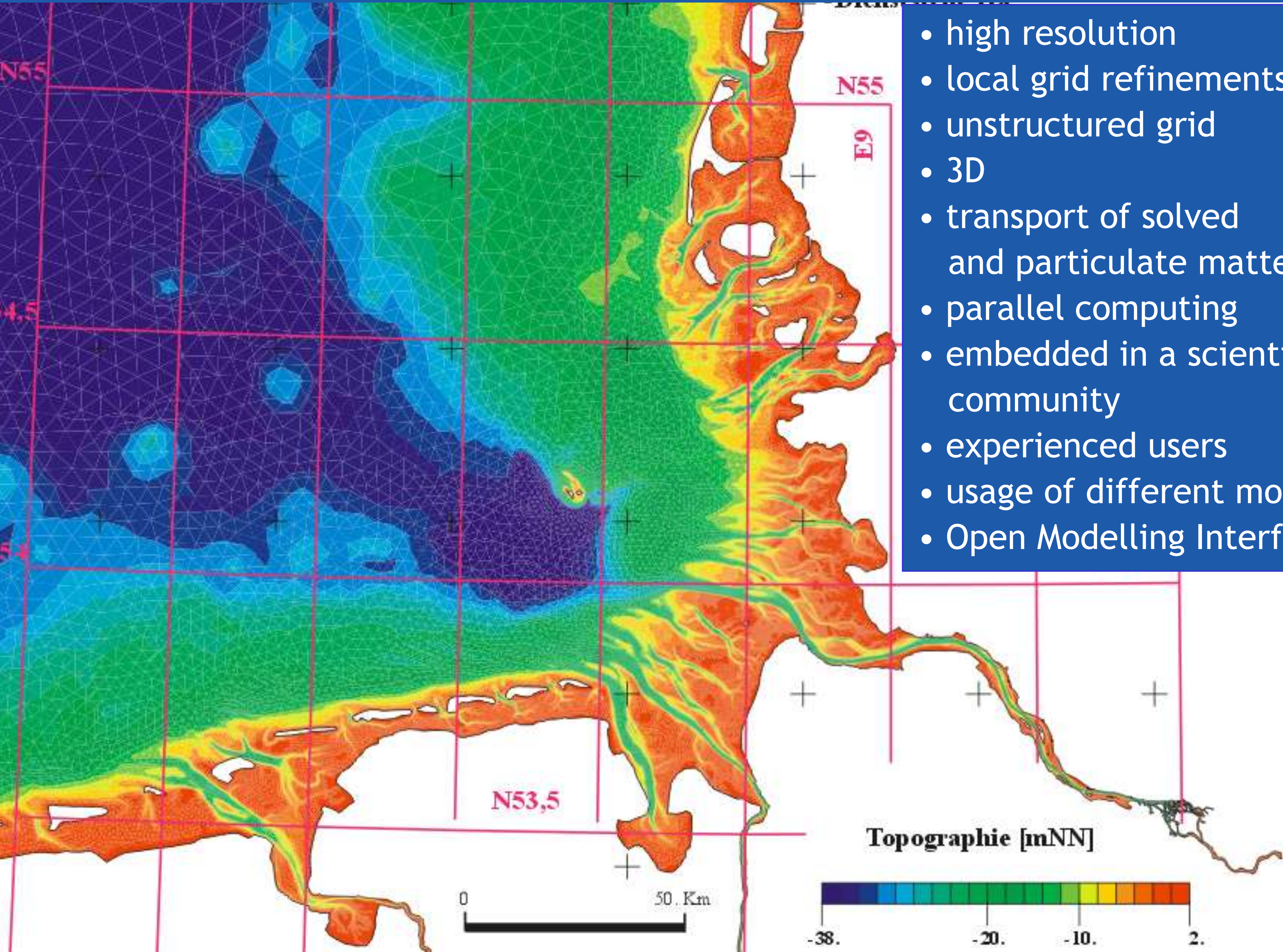
To become more insights into the operating principles of asymmetric tidal processes we need additional tools .

This can only be achieved with the *best mathematical models*.

The term *best mathematical model* means:
- realize any possible improvement of the model code
- never give up to achieve better model validations.

We need organizations with money and staff for that task.

Detail of German Bight Model at BAW



- high resolution
- local grid refinements
- unstructured grid
- 3D
- transport of solved and particulate matter
- parallel computing
- embedded in a scientific community
- experienced users
- usage of different models
- Open Modelling Interface

Asymmetry – A Physical Process based View in Terms of Sediment Management

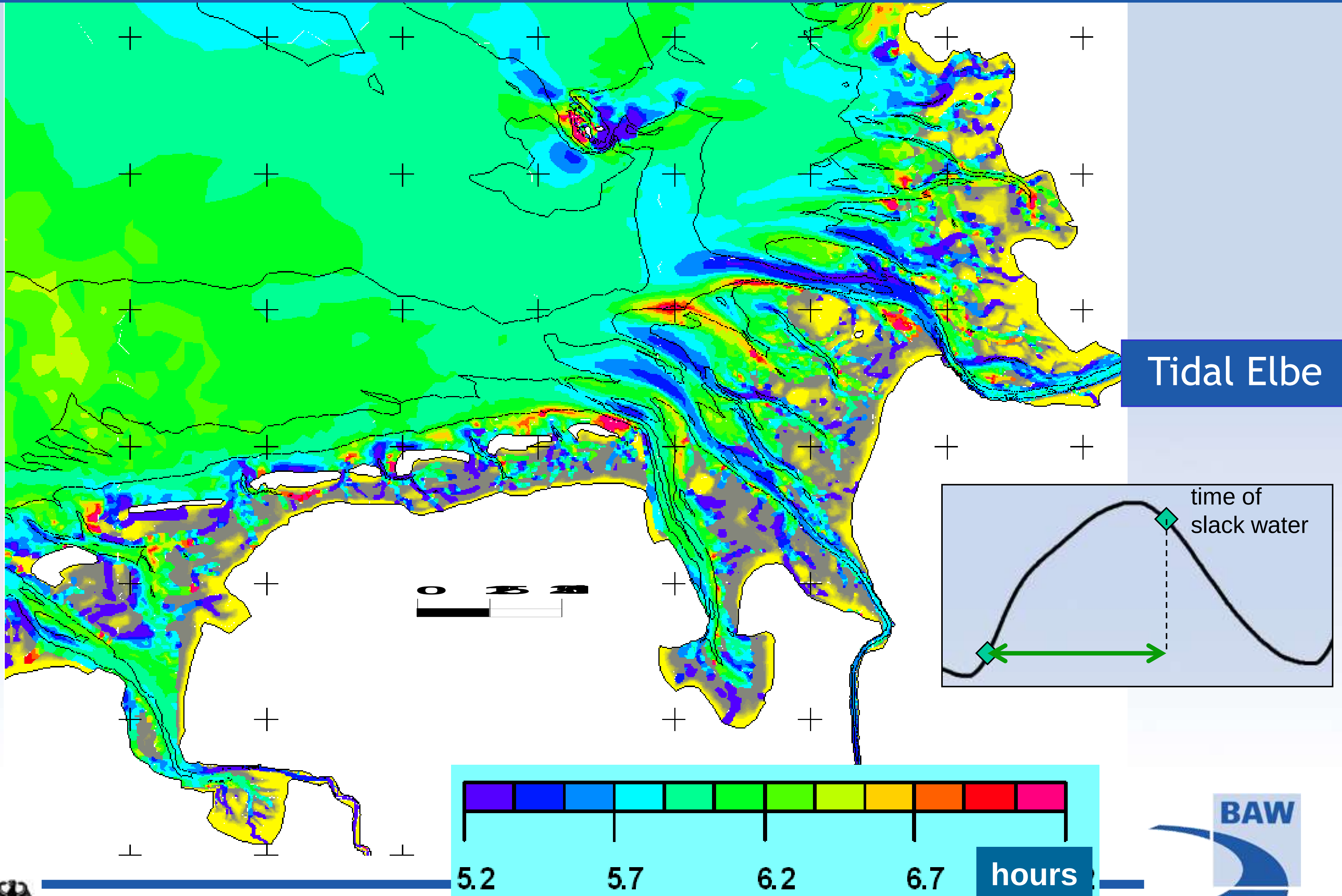
The shape of tidal curve indicates the amount of asymmetry.

But a lot of other features in tidal processes are driving the long term sediment transport in distinct directions.

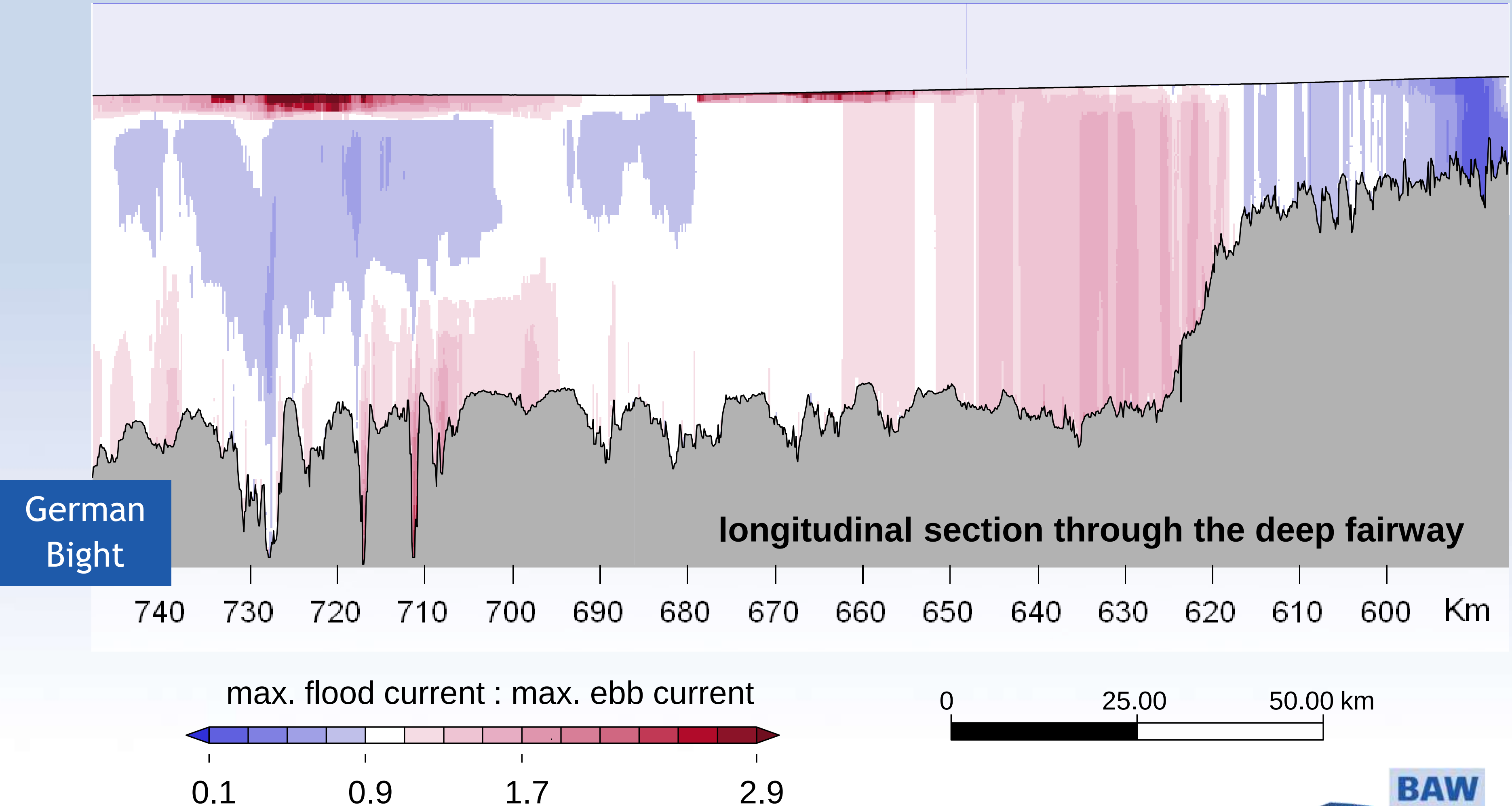
➔ Analysis of more tidal parameters on the basis of model results.

A sediment manager should have knowledge about basic correlations of factors driving the system.

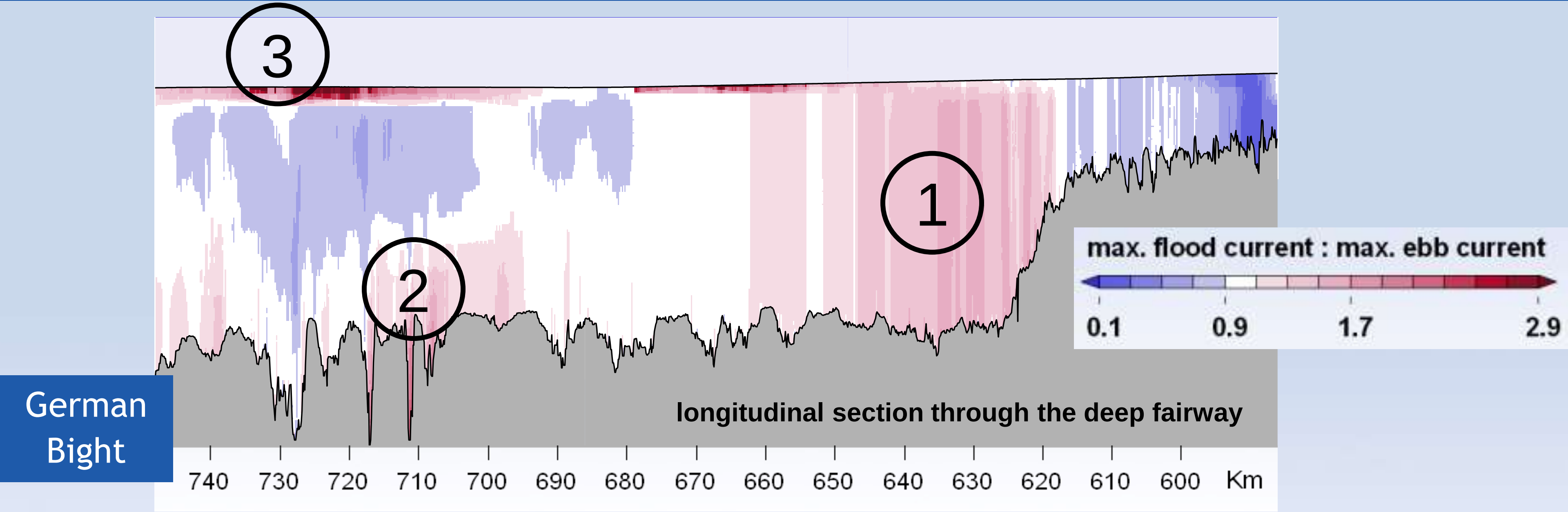
computed mean duration of flood current



Tidal Elbe: computed ratio of max. flood current to max ebb current



Tidal Elbe: computed ratio of max. flood current to max ebb current



Mechanisms responsible for upstream transport

1. **Asymmetry of tidal curve in upper part of the estuary**
2. **Near river bed density driven transport**
3. **Flood currents acting after high tide until slack water (mainly in the outer part of the Tidal Elbe)**

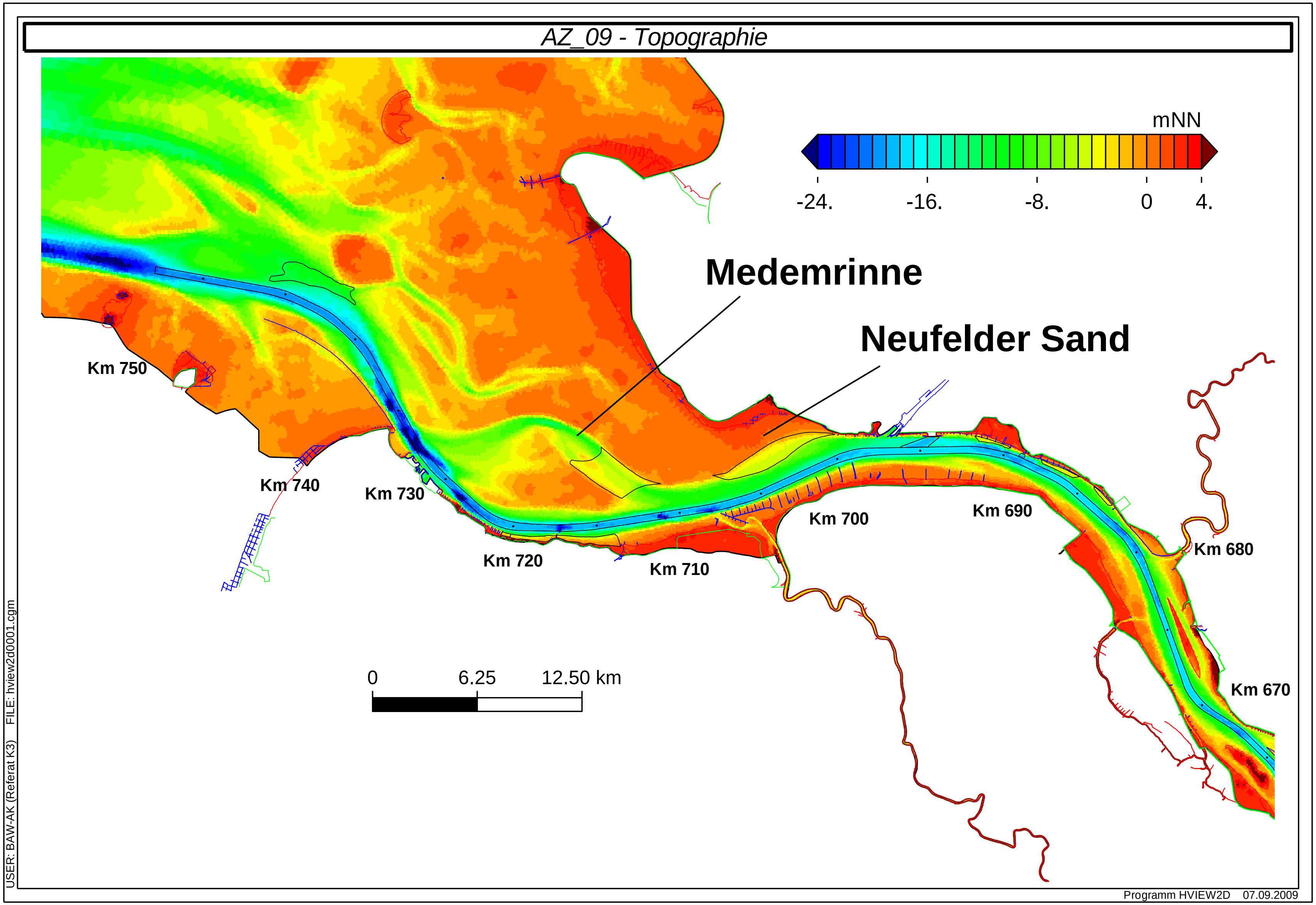
How-to minimize effects of fairway deepening?

A next fairway deepening of Tidal Elbe is on the agenda.

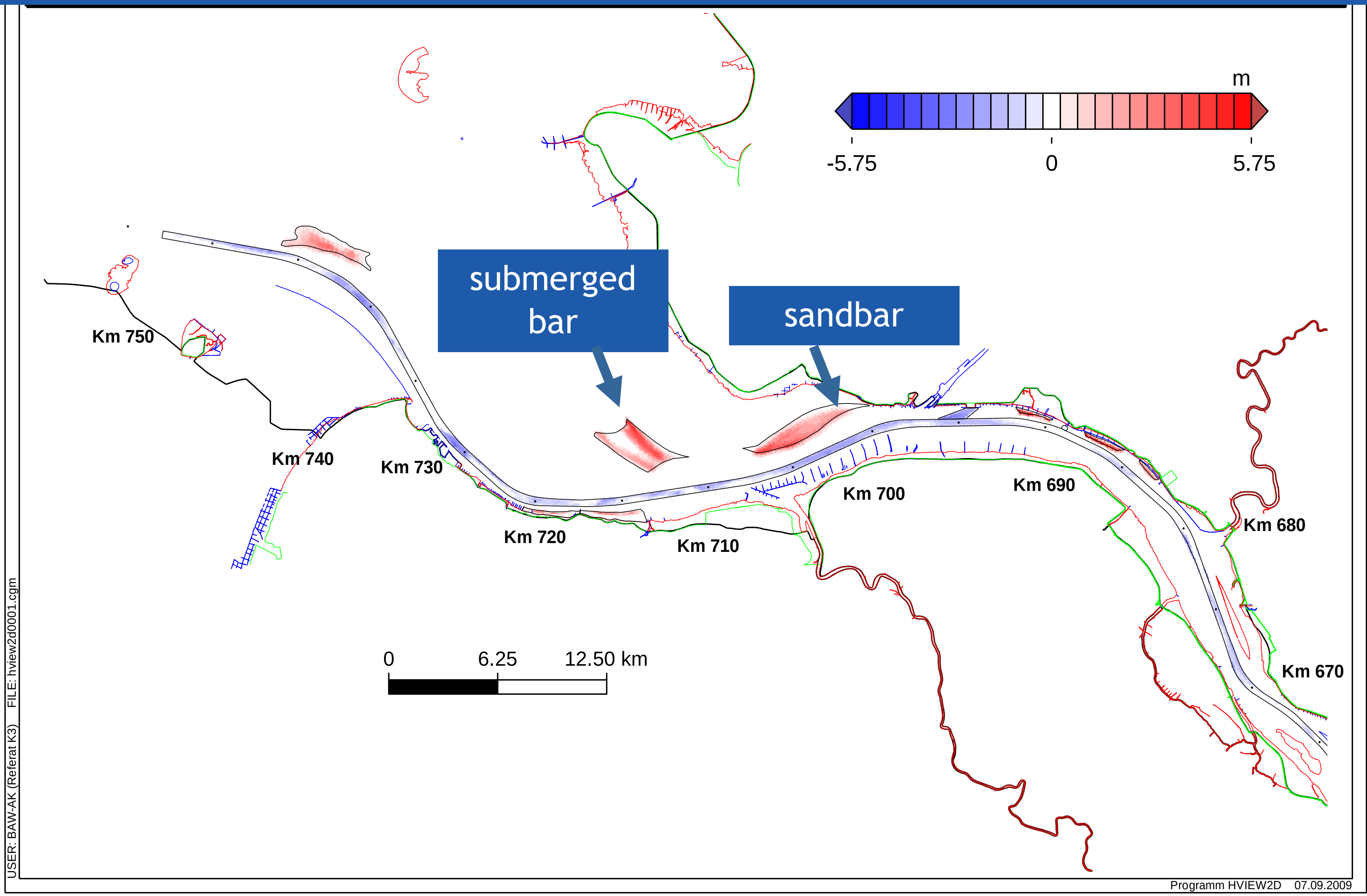
Measures against further decline of low water levels in Hamburg are necessary.

For deepening a total volume of 34 Mio. m^3 should be excavated.

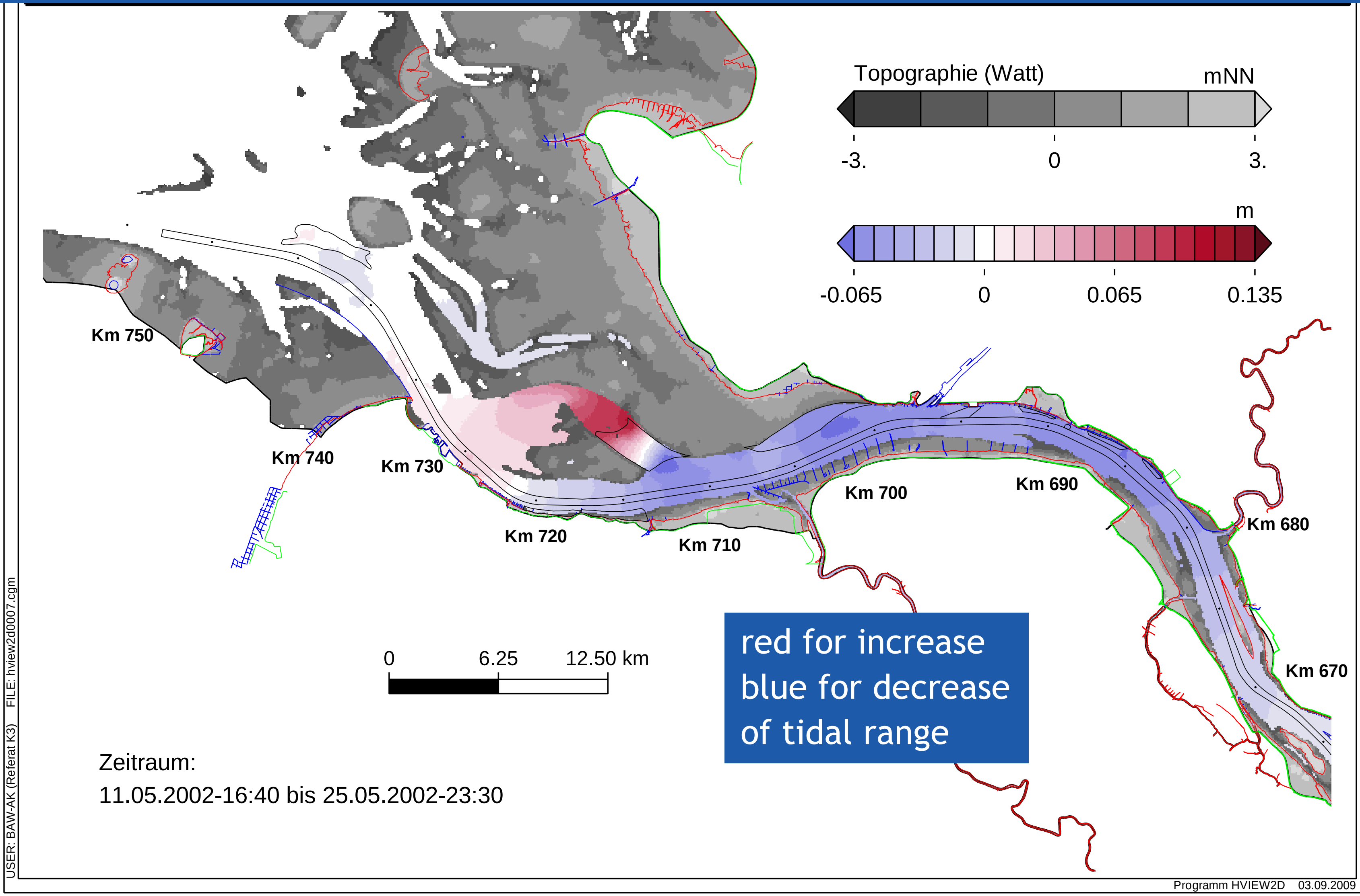
About 60 % of this volume could be used for two hydraulic structures (submerged bar / sand bar) for which maintenance procedures are required.


AZ_09 - Topographie
mNN
-24.
-16.
-8.
0
4.
Medemrinne
Neufelder Sand
Km 750
Km 740
Km 730
Km 720
Km 710
Km 700
Km 690
Km 680
Km 670
0
6.25
12.50 km
USER: BAW-AK (Referat K3)   FILE: hview2d0001.cgm
Programm HVIEW2D   07.09.2009

Fairway deepening – use of dredged material

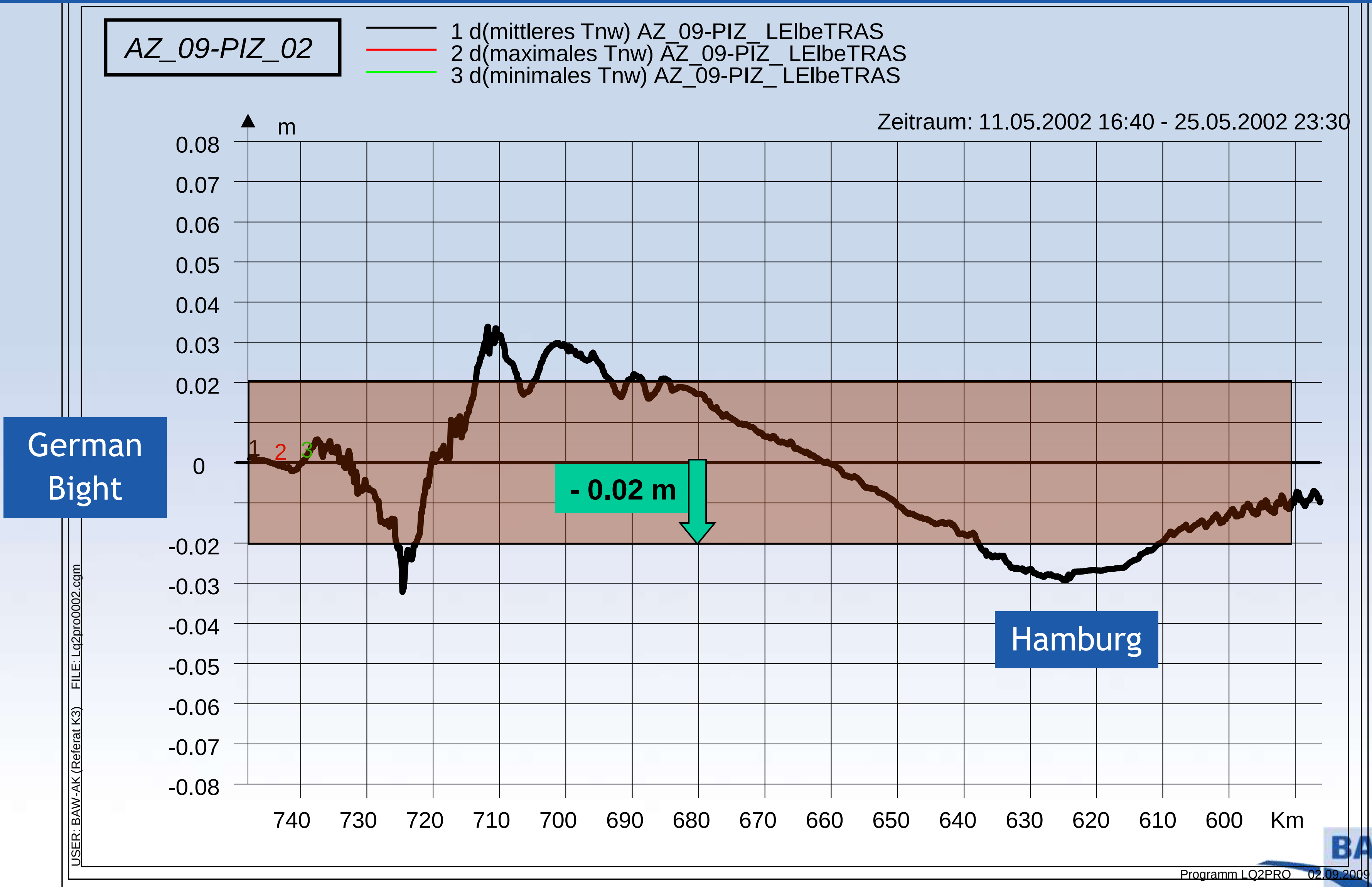


Fairway deepening – change of tidal range



red for increase
blue for decrease
of tidal range

Fairway deepening – change of low tide

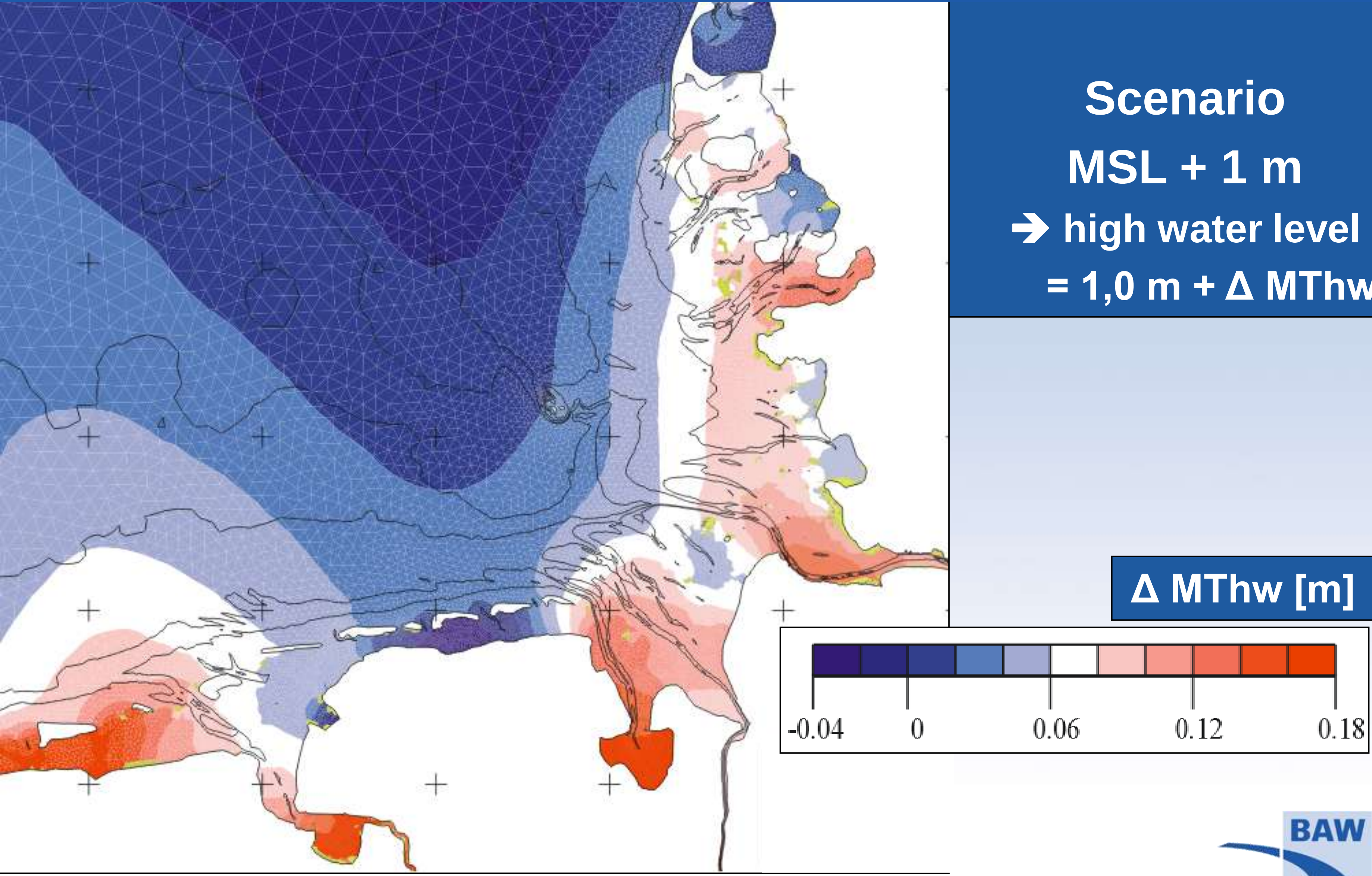


Climate Change
Sediment Dynamics in the Future ?

What can be the outcome of sea level rise in the North Sea with respect to sediment transport processes ?

If we assume a certain amount of sea level rise
e.g. 0.6 m or even 1.0 m
we can predict the outcome with a detailed model,
including North Sea, German Bight and Estuaries.

Development of mean high tide after sea level rise



Scenario

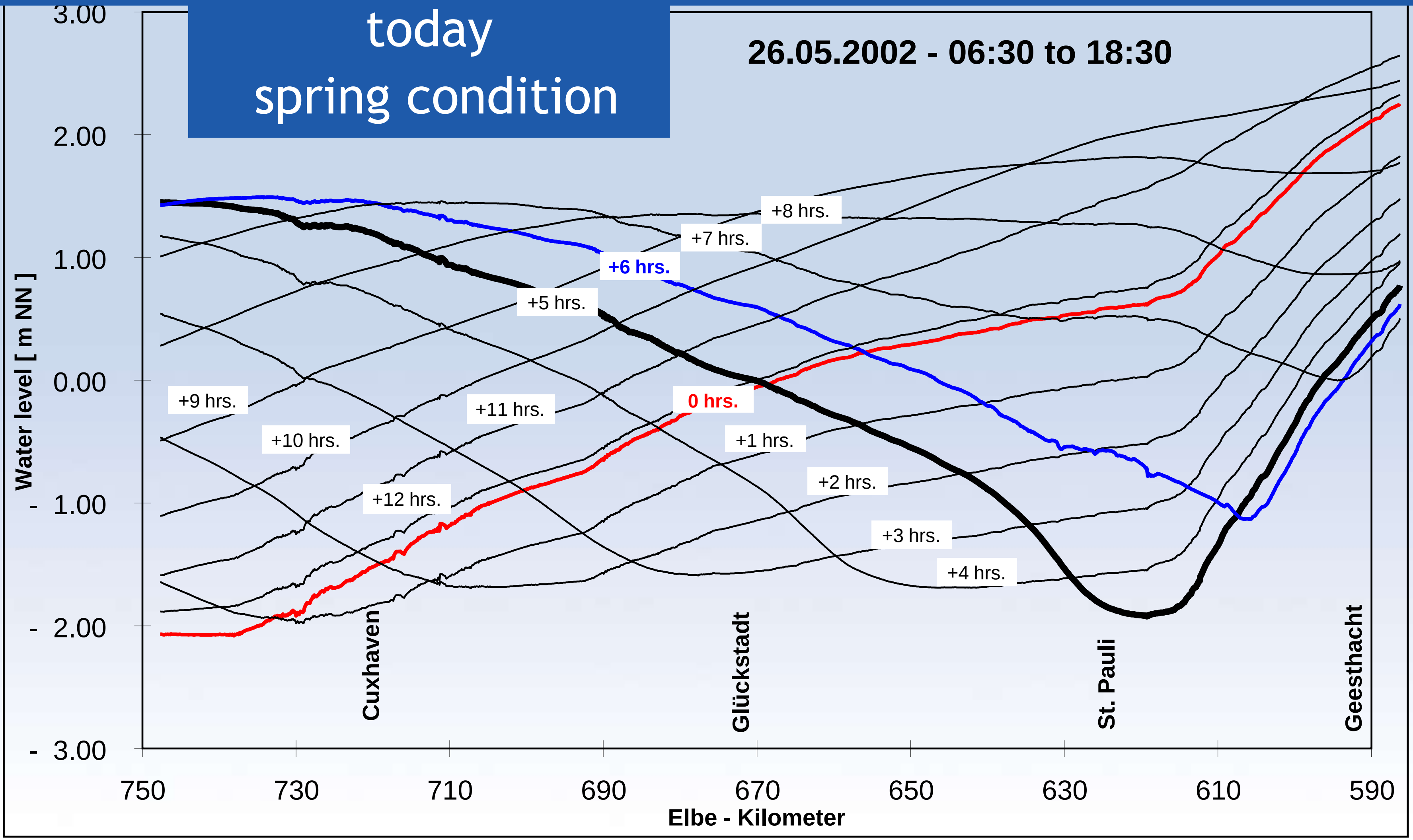
MSL + 1 m

➔ high water level

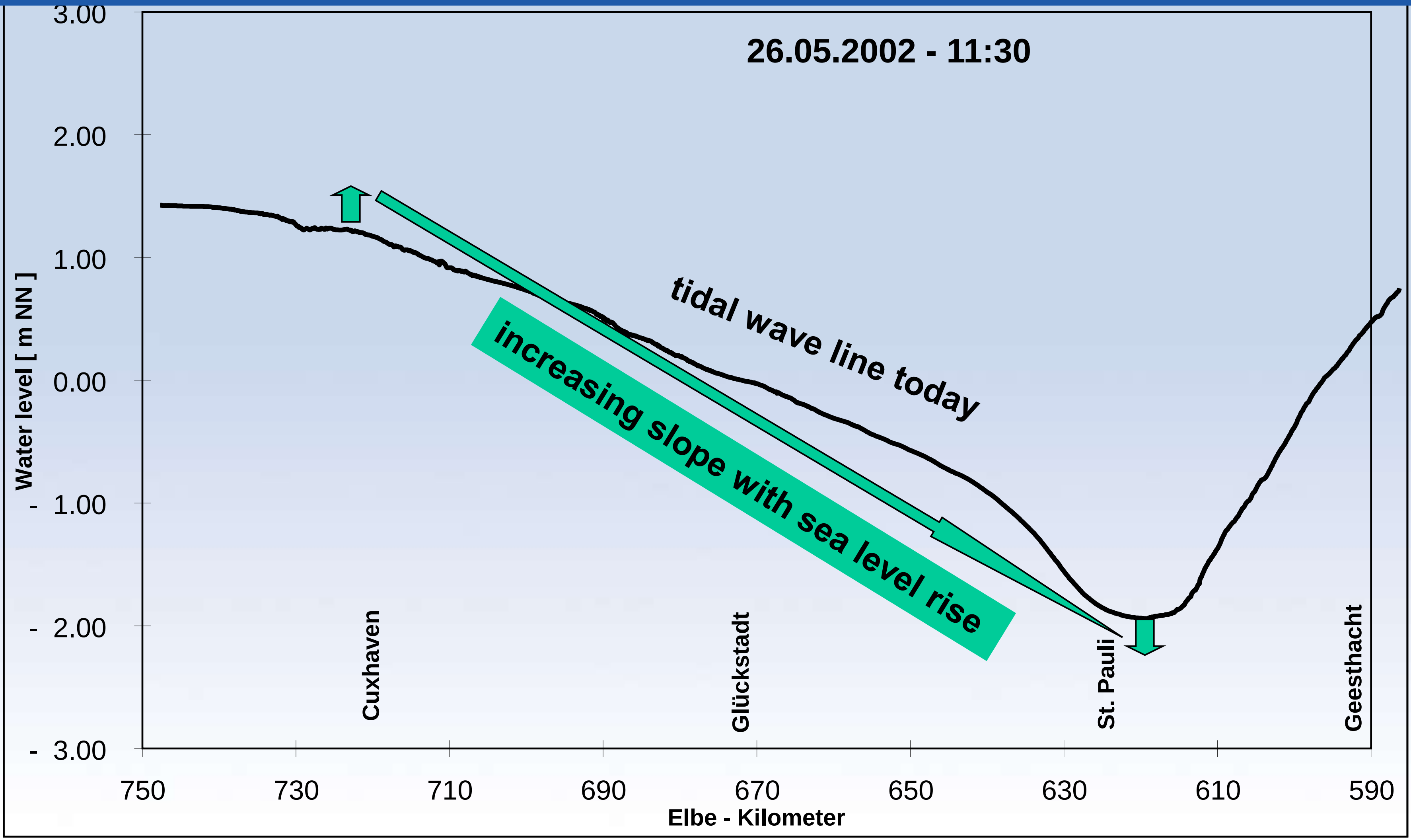
= 1,0 m + Δ MThw

Δ MThw [m]

tidal wave lines today spring condition

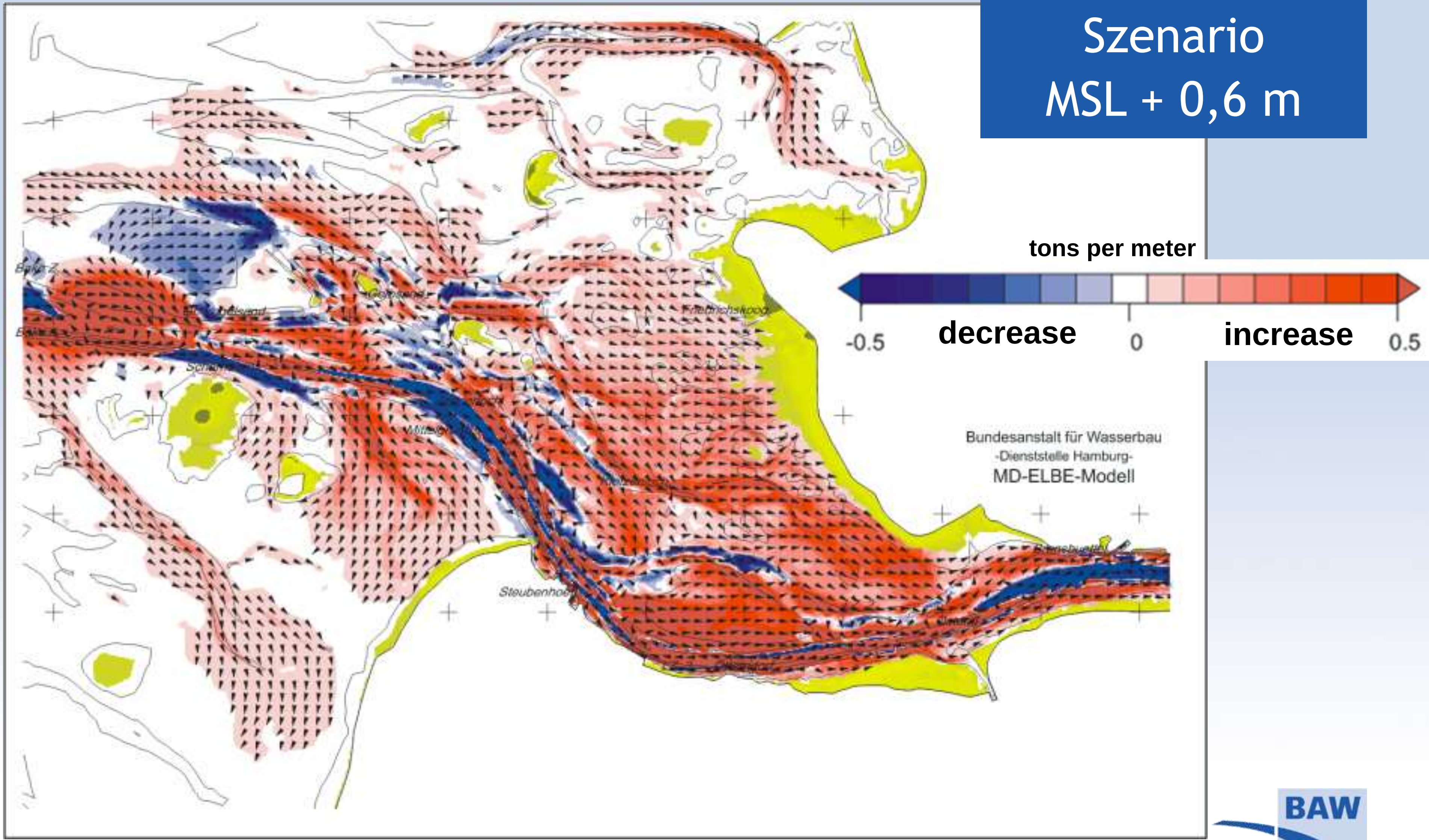


Tidal Elbe


26.05.2002 - 11:30
tidal wave line today
increasing slope with sea level rise
Water level [m NN]
3.00
2.00
1.00
0.00
- 1.00
- 2.00
- 3.00
Cuxhaven
Glückstadt
St. Pauli
Geesthacht
750
730
710
690
670
650
630
610
590
Elbe - Kilometer

Change of Net-Sediment Transport

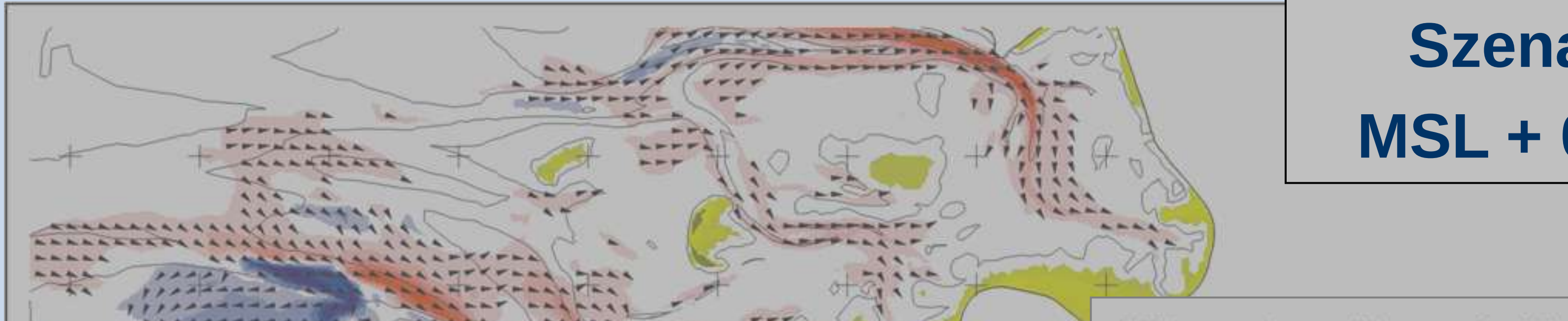
Szenario MSL + 0,6 m



Sediment Dynamics in the Future ?

Szenario

MSL + 0,6 m



Finding: Sea level rise leads to increased sediment transports within Elbe Estuary.

More net-sediment transport is mainly directed into the Tidal Elbe.

The sediment sources are nourished by local erosions.

As a consequence, the tidal range in Hamburg will increase further more due to

- **climate change and**
- **further sediment losses in the outer Elbe river.**

Conclusion

Sediment Management is directly combined with the history and future of characteristic tidal parameters.

Leading parameters for the German estuaries are low tide values and water level gradients of incoming tides.

Models are today usable tools for analysis, diagnosis and forecast of estuary systems especially for sediment movements but further improvements are necessary.

With respect to climate change sediment managers should look into the future.