10th International SedNet Conference "Sediments on the move" 14-17 June 2017, Genoa, Italy

Assessment of Vistula delta cone development under sediment deficit conditions (Poland)

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OBJECTIVE

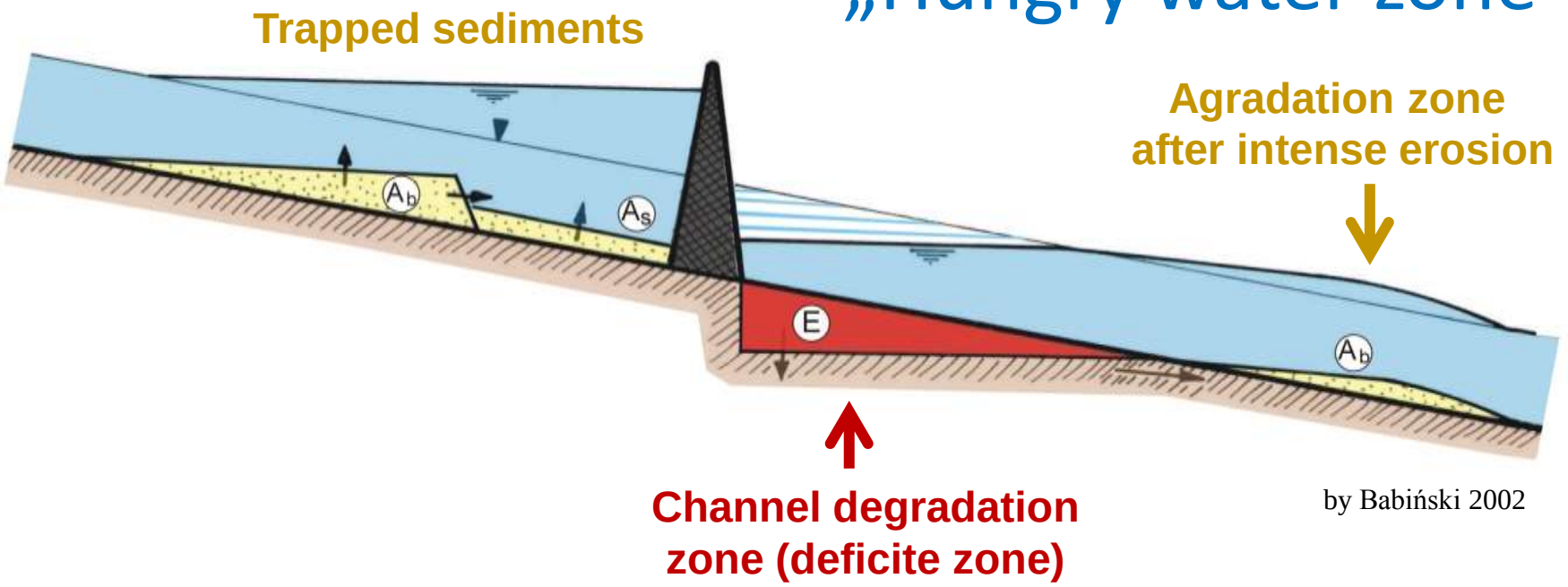
The Vistula delta cone is important habitat for rare protected animal species. Objective of this paper is assessment of this delta cone development under clastic sediment deficit condition:

Estimating the rate erosion zone shifting downstream of the Wloclawek dam and reservoir and prediction when will reach the mouth section of the Vistula,

Evaluating the amount of transport of bed load on different channel sections below the dam with using of morphological methods,

Forecast of change on delta cone morphology under clastic sediment deficit condition.

„Hungry water zone”



by Babiński 2002

Model of channel processes in an alluvial/lowland river under the influence of a single dam

Explanation: A_b – bed load deposition zone, A_s – suspended load deposition zone, E – erosion zone; vectors indicate the directions of channel processes development.

Flash sed. progradation after decommisioned Glines Canyon dam and Elwha dam on the Elwha river, (Washington)

Flash development of delta cone !

STUDY AREA - Vistula river

STUDY AREA - Vistula river (lower reach)

Location of the Vistula reach under study.

Explanation:

1 – unregulated channel
2 – reservoir
3 – erosion zone
4 – regulated channel
5 – estuary reach.

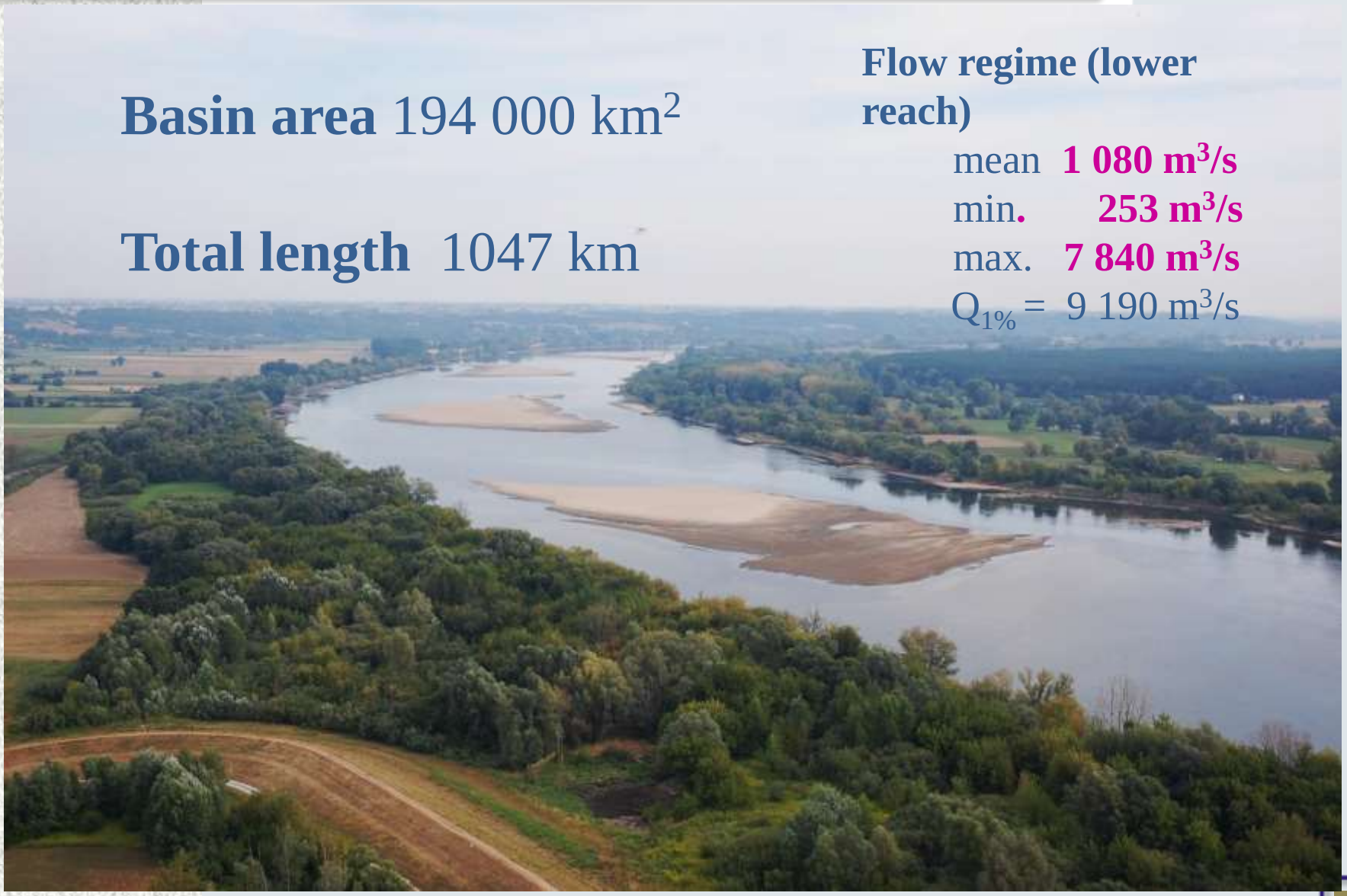
STUDY AREA - Vistula river (lower reach)

Basin area 194 000 km^2

Total length 1047 km

Flow regime (lower reach)

mean **1 080 m^3/s**
min. **253 m^3/s**
max. **7 840 m^3/s**
$Q_{1\%}$ = 9 190 m^3/s



braided – anastomosing river type

[Phot. Oct. 15th 2015]

Middle reach of Vistula, no-regulated channel near Warsaw during low water level

STUDY AREA

Middle reach of Vistula, no-regulated channel near Warsaw during low water level

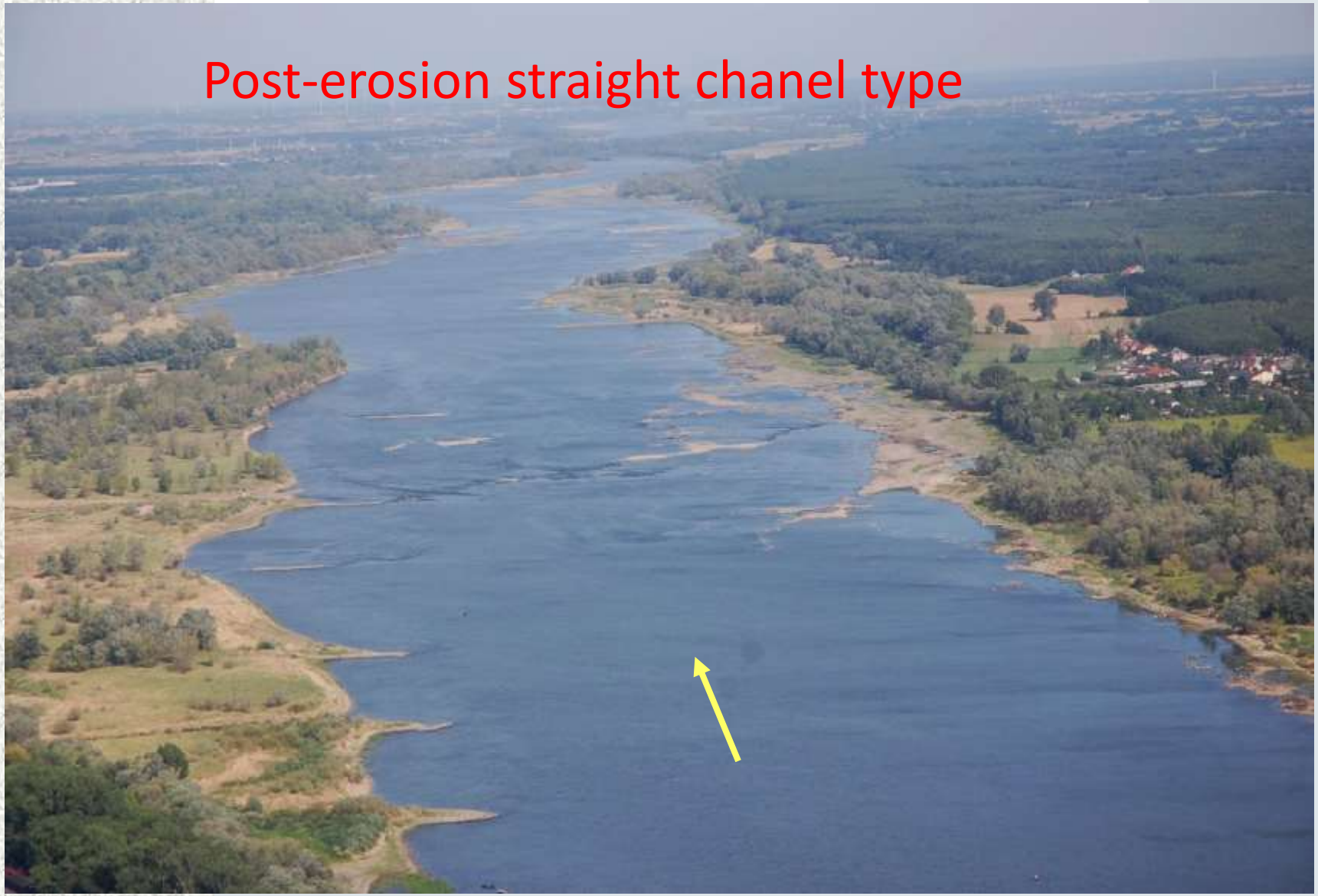
STUDY AREA

Lower of Vistula in the backwater of Wloclawek reservoir, no-regulated channel

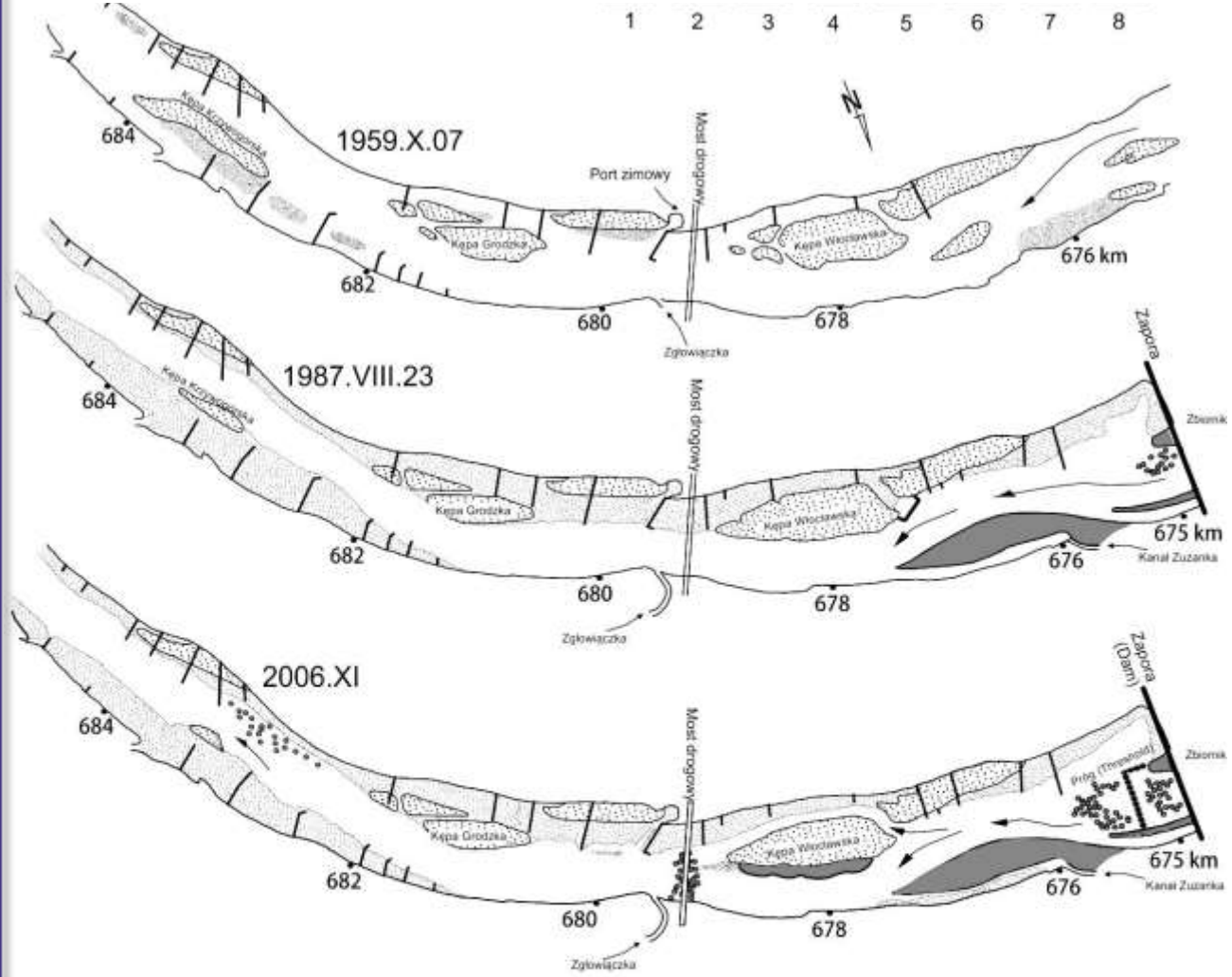
STUDY AREA - WLOCLAWEK DAM and RESERVOIR

Wloclawek dam and reservoir [Phot. July 8th 2008]

STUDY AREA - erosion reach below dam



Horizontal channel changes of the Vistula channel below dam

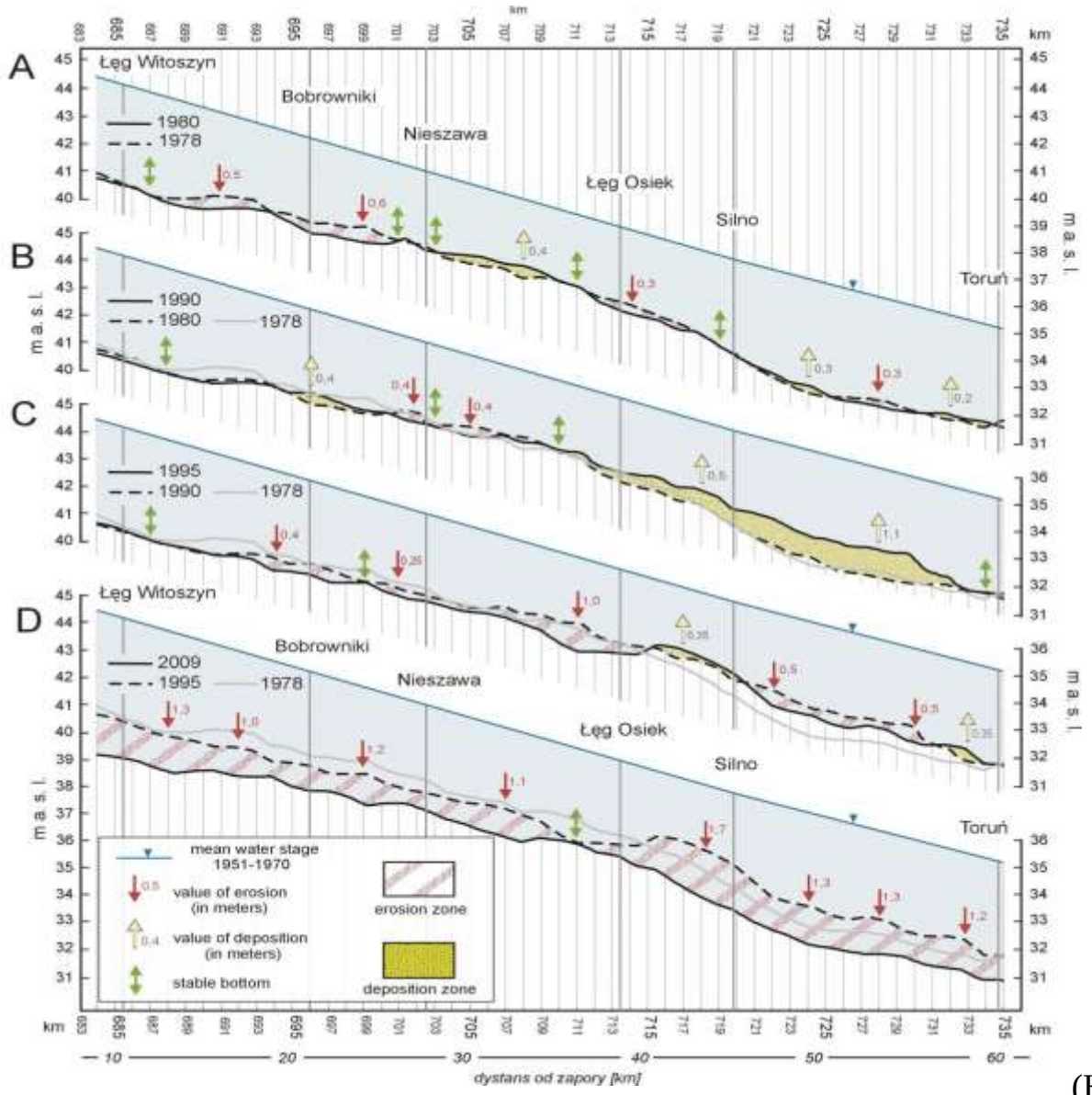


(Babiński&Habel 2013)

Morphometric facts for 10 km below:

Reduction in channel width on 34%; with intensity 8.8 m per year (1967 – 2010)

STUDY AREA

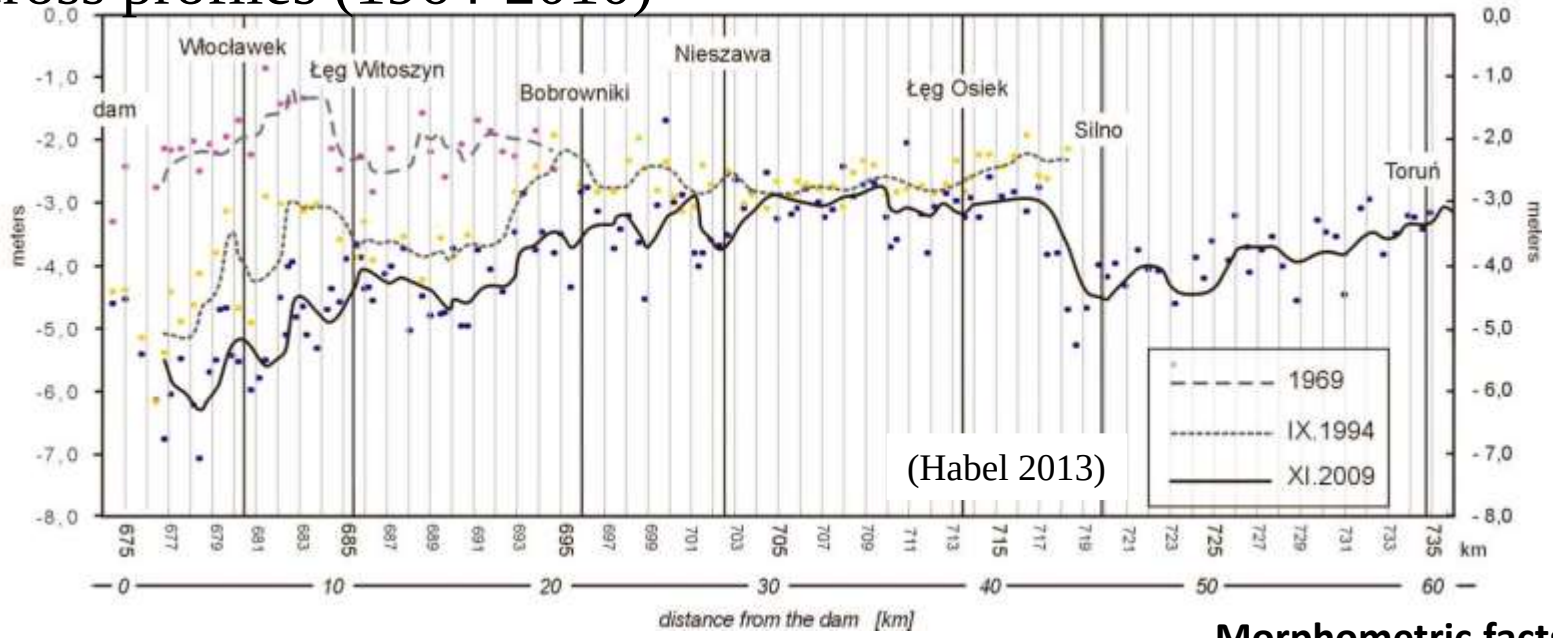


The rate of erosion zone shifting downstream of the Wloclawek dam:

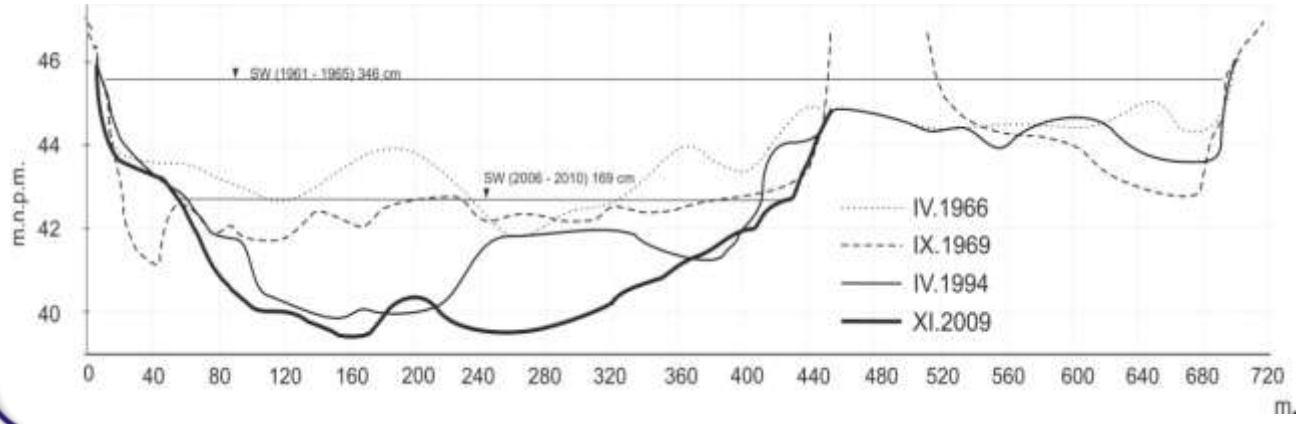
- **unregulated reach 1.1 km per year**
- **regulated reach 5.2 km per year**

(Habel 2013)

Changes in time of hydraulic mean channel depths in controlled cross profiles (1964-2010)



(Habel 2013)



Morphometric facts :

Lowering the bottom

in 10 km below

avarege 2.75 m (1967-2006)

Intensity of erosion

0.33 mln m^3/y (1967-2006)

0.08 mln m^3/y (1994-2006)

STUDY AREA - erosion reach below dam

Sed. transport deficit effects
(5 km below dam)

river bank zone 5 km below dam

STUDY AREA - erosion reach below dam


Regulated reach - 200 km straight (artificial) channel

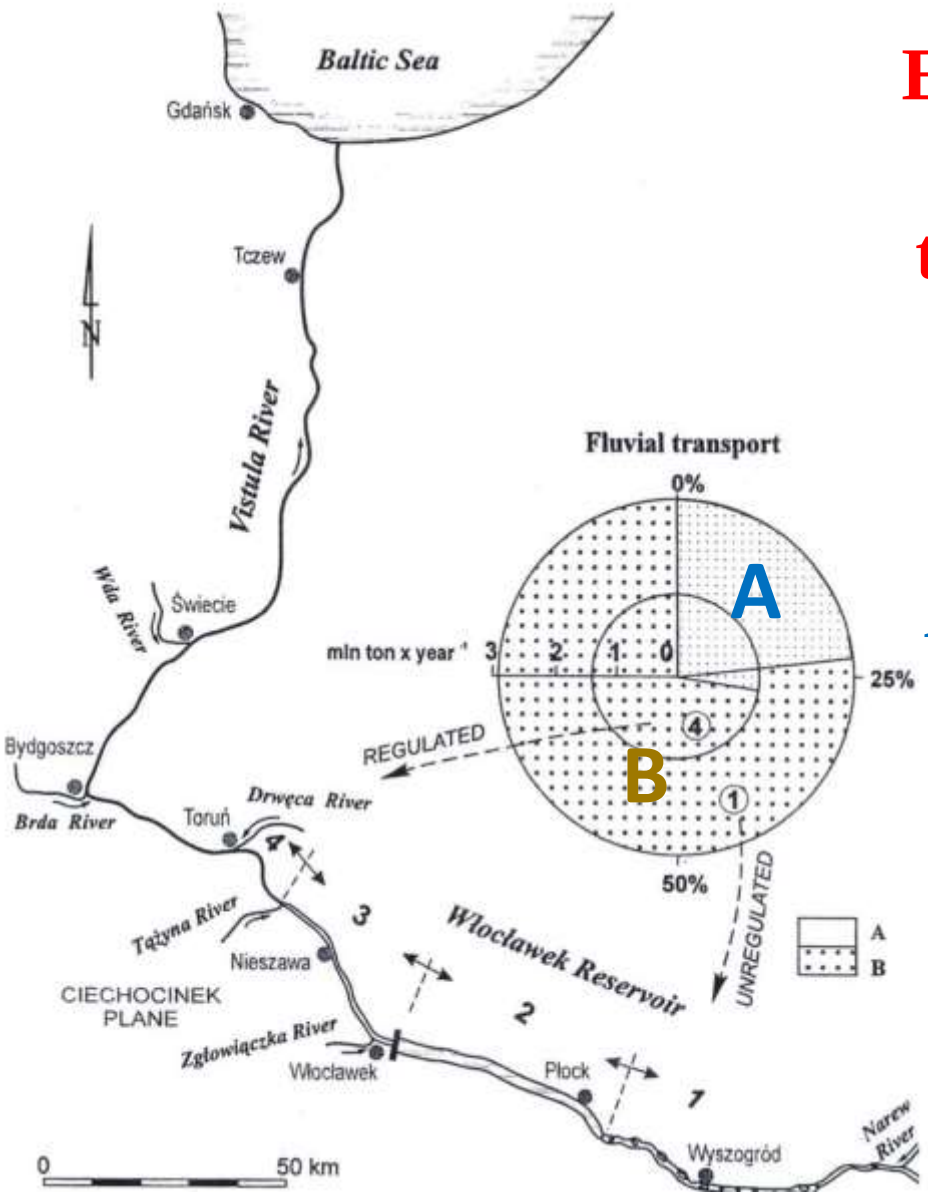
STUDY AREA


Arificial dig channel – outlet of Vistula river

STUDY AREA

SPA PLH220044 „Natura2000”

STUDY AREA - Vistula river (lower reach)

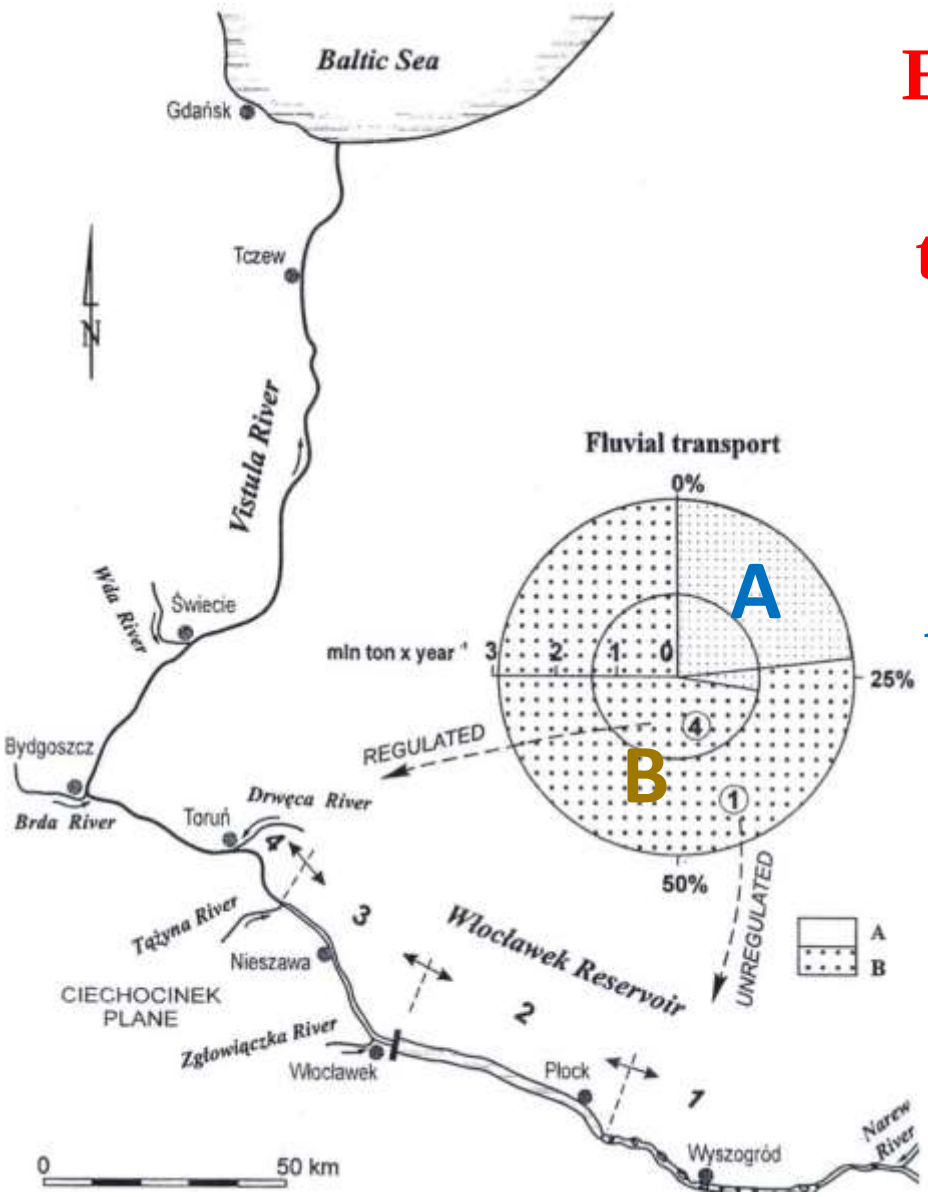


Estimated relation bed load to suspended load transport in total sediment yield for lower Vistula by Babiński (2005):

A – suspended load aprox. 23%

B - bed load aprox. 77%

STUDY AREA - Vistula river (lower reach)



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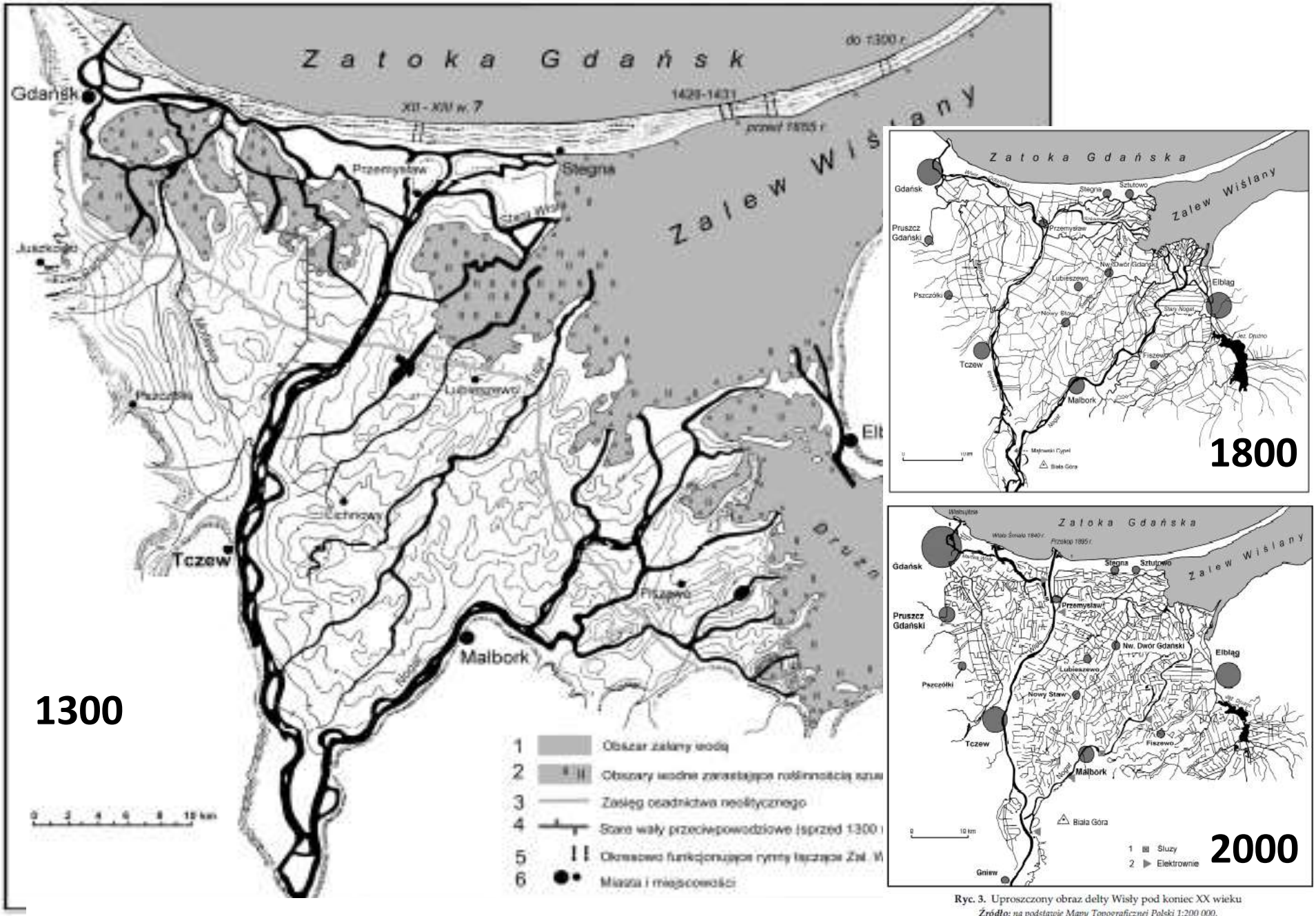
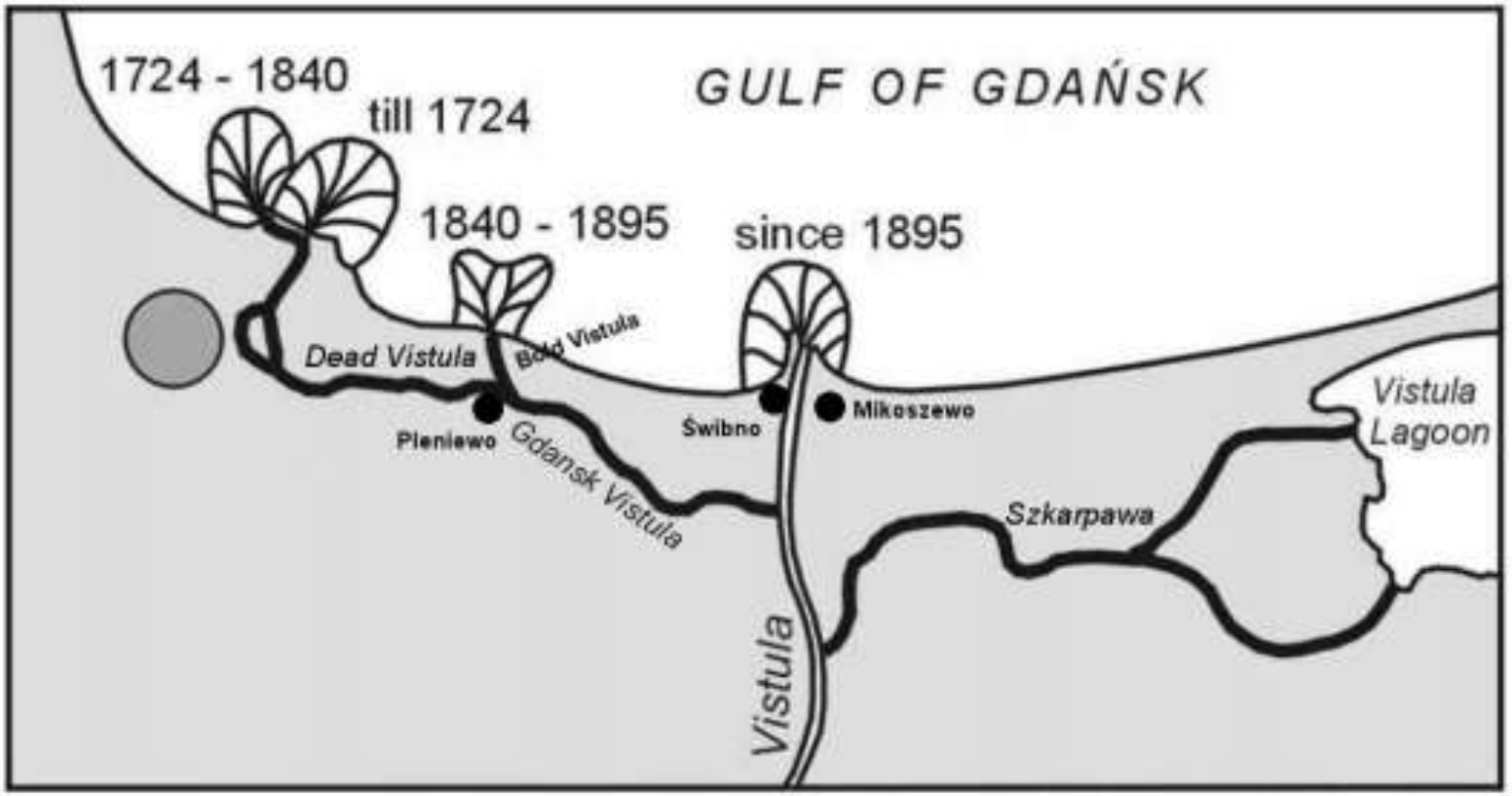


Ryc. 3. Uproszczony obraz delty Wisły pod koniec XX wieku
Źródło: na podstawie Mapy Topograficznej Polski 1:200 000.

The Vistula Delta reconstruction by Bertram et al. (1924)

STUDY AREA – delta cone history



Changes of the location of the Vistula mouth until 1724, in 1724 – 1840, 1840 – 1895 and after 1895, after Uścinowicz et al. (2001) with amendments by Cyberski

The development of the settlement on Vistula's delta caused the problem of flood hazard.

1840 r.

1895

Einlage

Einlage

Neue Binnennehrung

Gemarkung

Schiewenhorst

Schiewenhorst

Bodenablagerung

Alte Binnennehrung

Gemarkung Schönbaum

Gemarkung

Nickelswalde

Nickelswalde

Königliche

Nehrunger

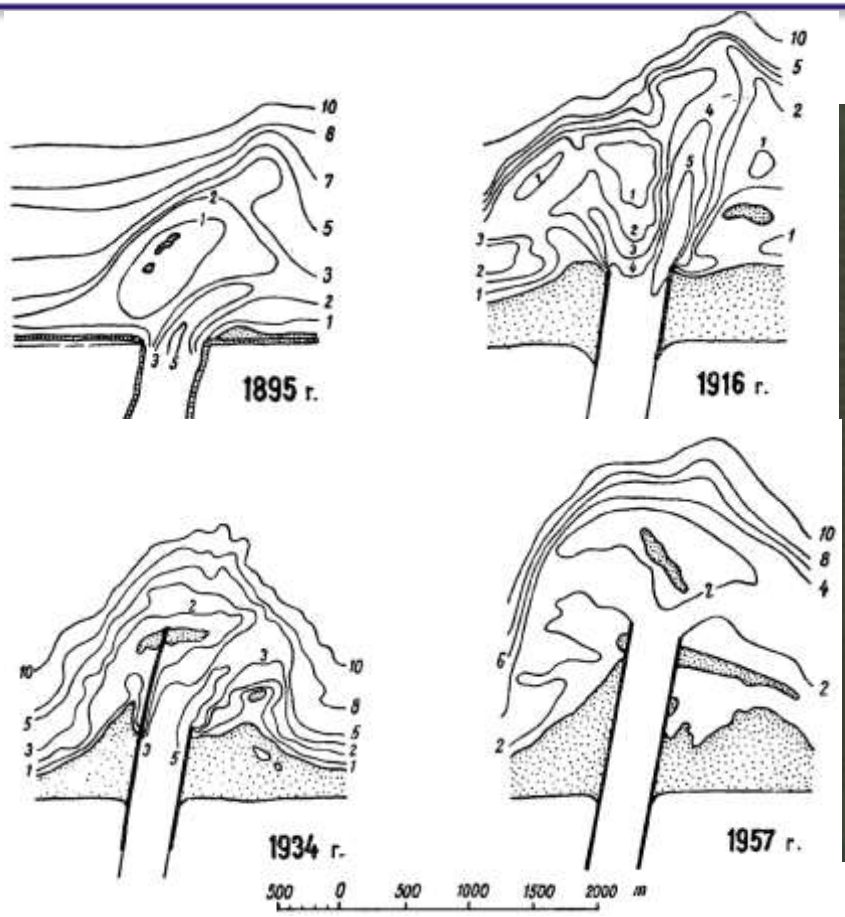
Forst

OSTSEE

STUDY AREA – delta cone history

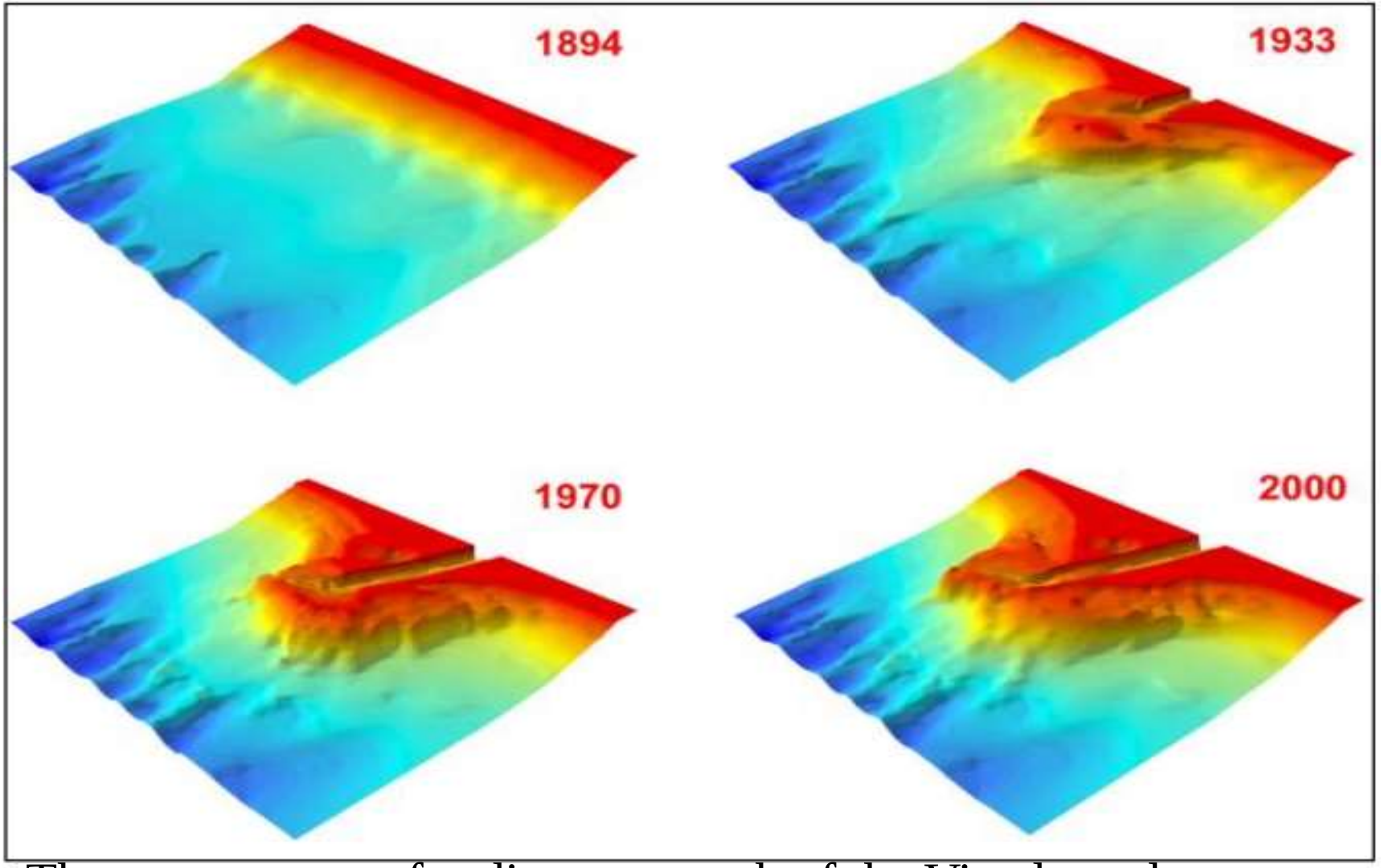
Hiorizontal changes. The rate of accretion of on shore part of the Vistula outlet cone (Graniczny et. al., 2004) = **2.96 ha per year** (1985-2000).

STUDY AREA – delta cone history



Total bed load accumulation on the delta cone was 0.8 mln tons per year (total clastic sediments 2.0 mln tons/year) between 1895 – 1957 by Łomniewski, 1960.

STUDY AREA – delta cone history



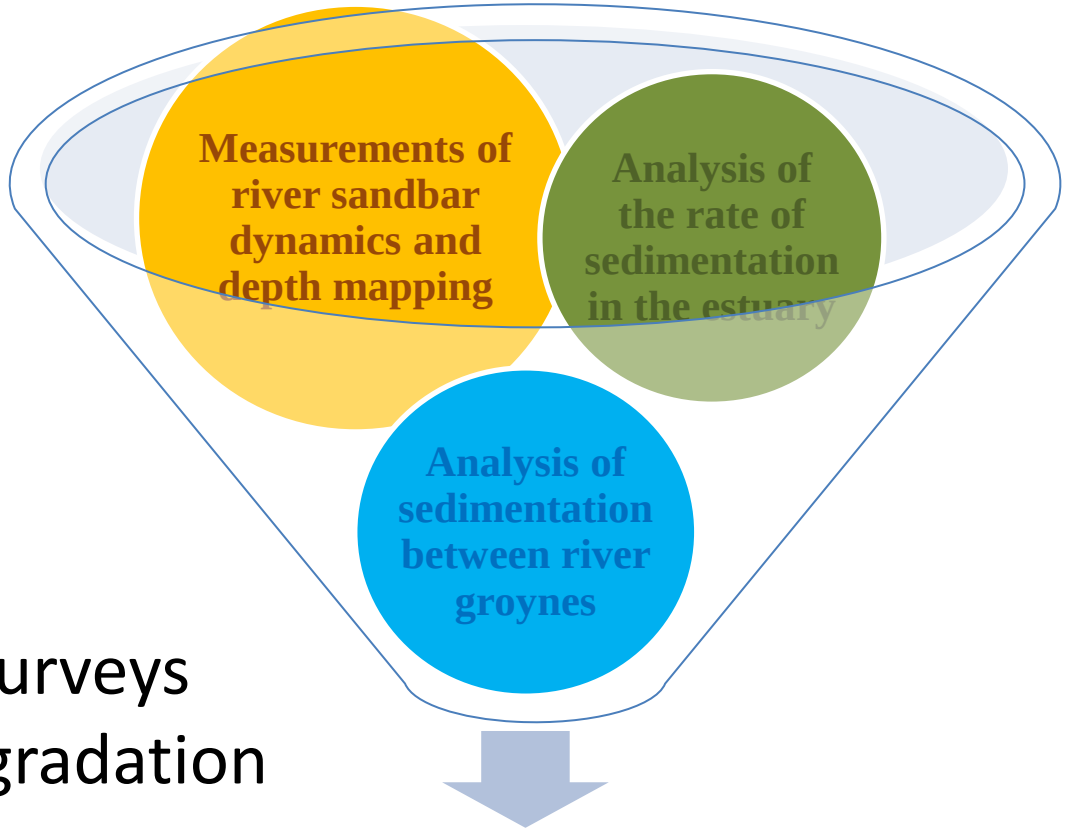
The average rate of sediment growth of the Vistula outlet cone (Graniczny et. al., 2004) = **1,27 mln m^3 per year** (1985-2000)

Morphological methods:

a. Bedform surveys (sandbars)

b. Channel surveys (bathymetry mapping)

c. Sedimentation-zone surveys (present delta cone progradation mapping)



METHODS

Location of the Vistula reach under study. Explanation:

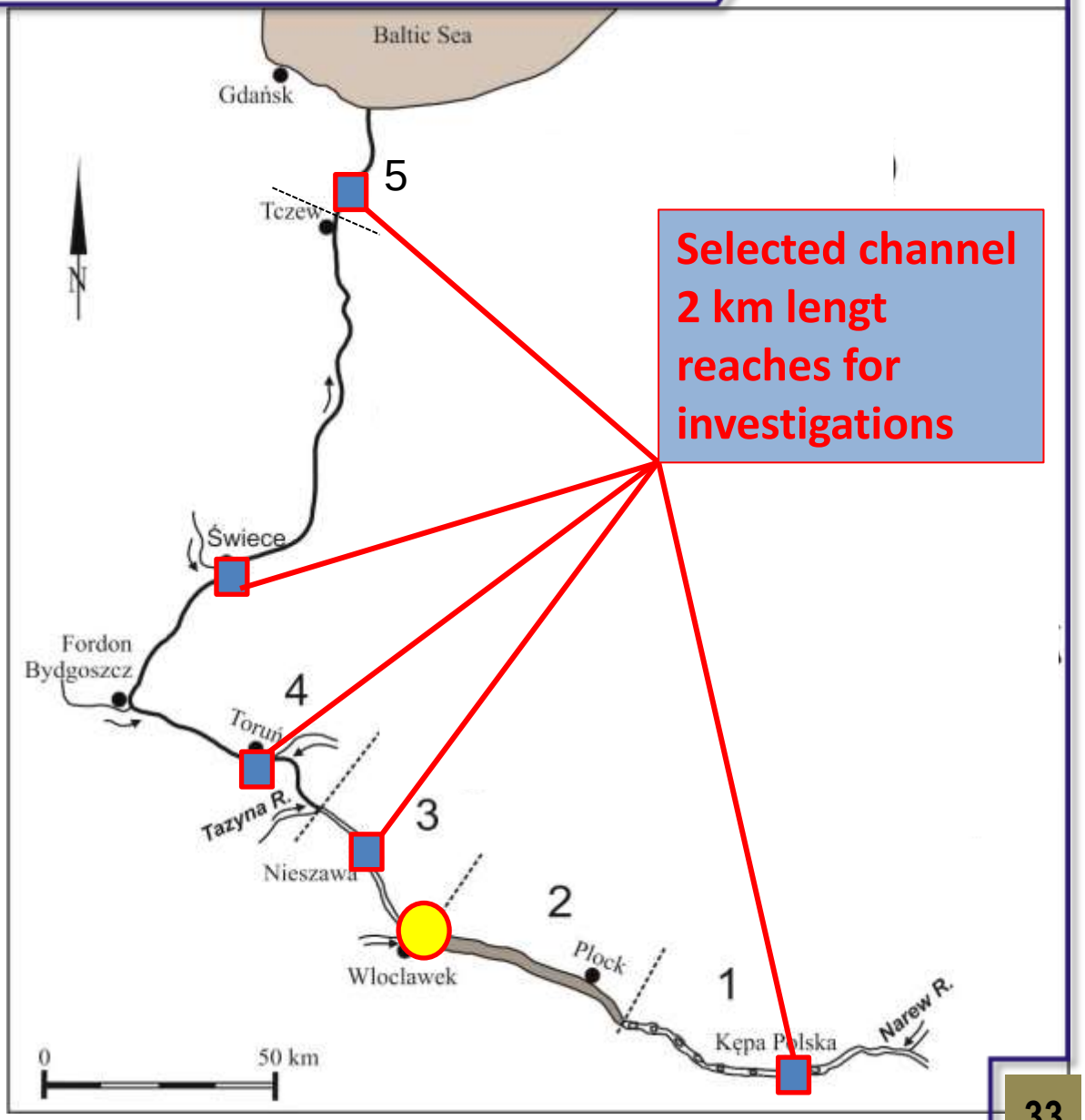
1 – unregulated channel, braided-anastomosing reach;

2 – reservoir;

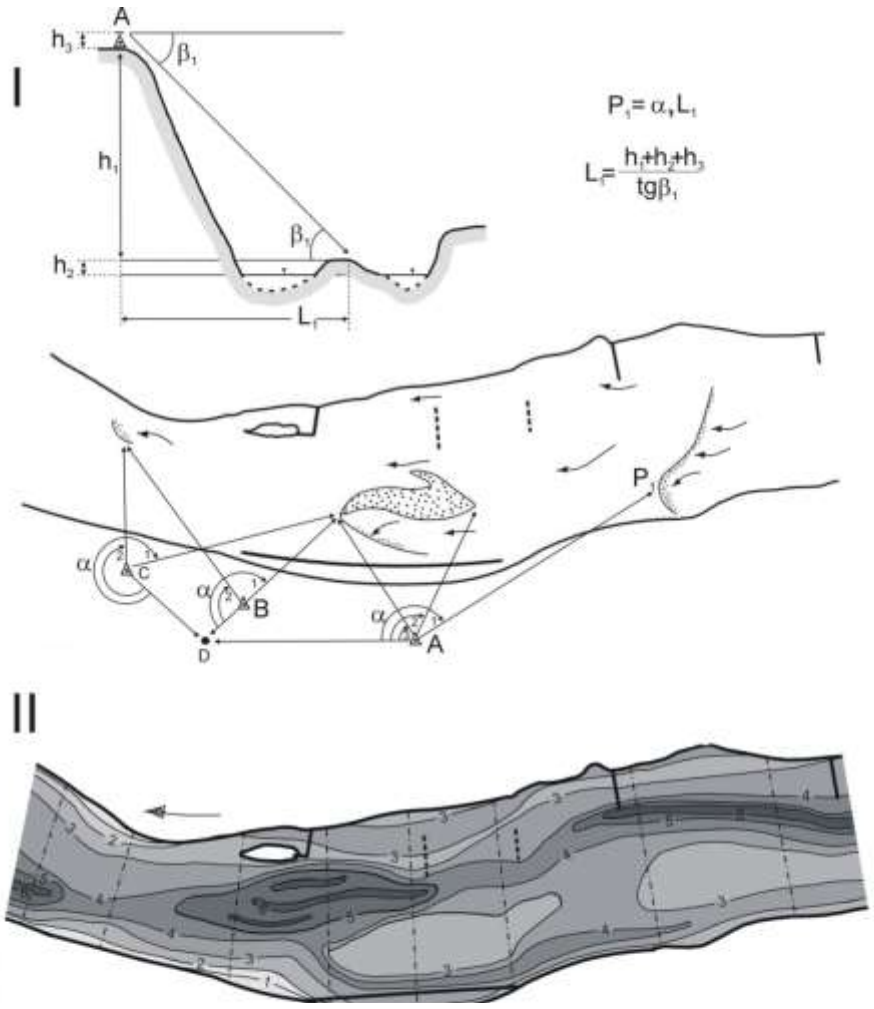
3 – erosion zone below dam;

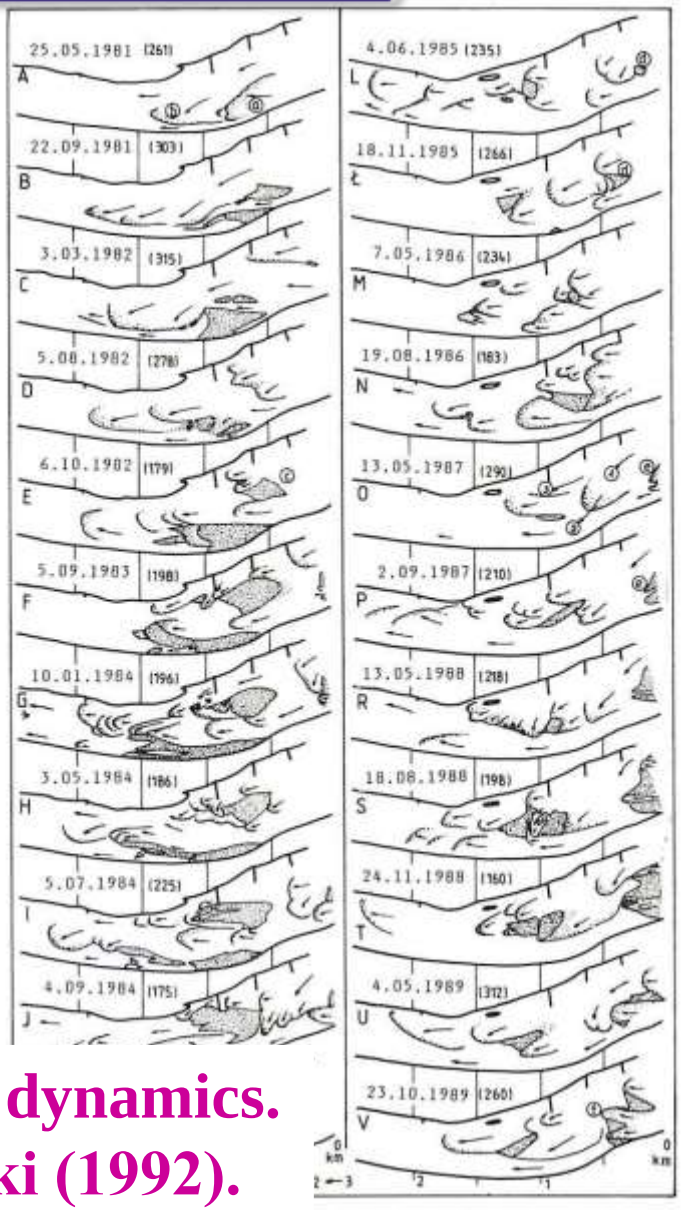
4 – regulated channel with mid-chanel transverse sandbars;

5 – estuary reach.



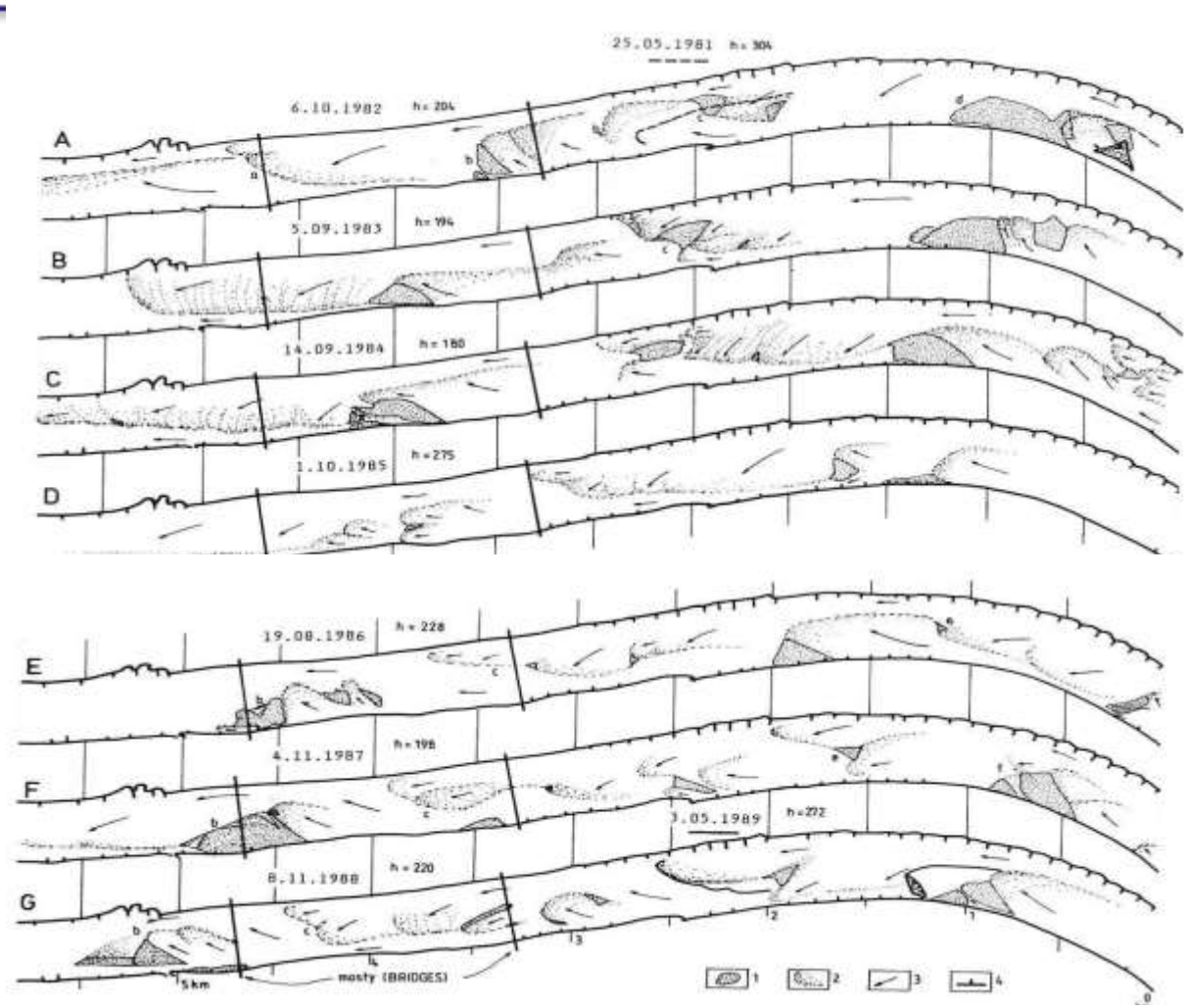
METHODS





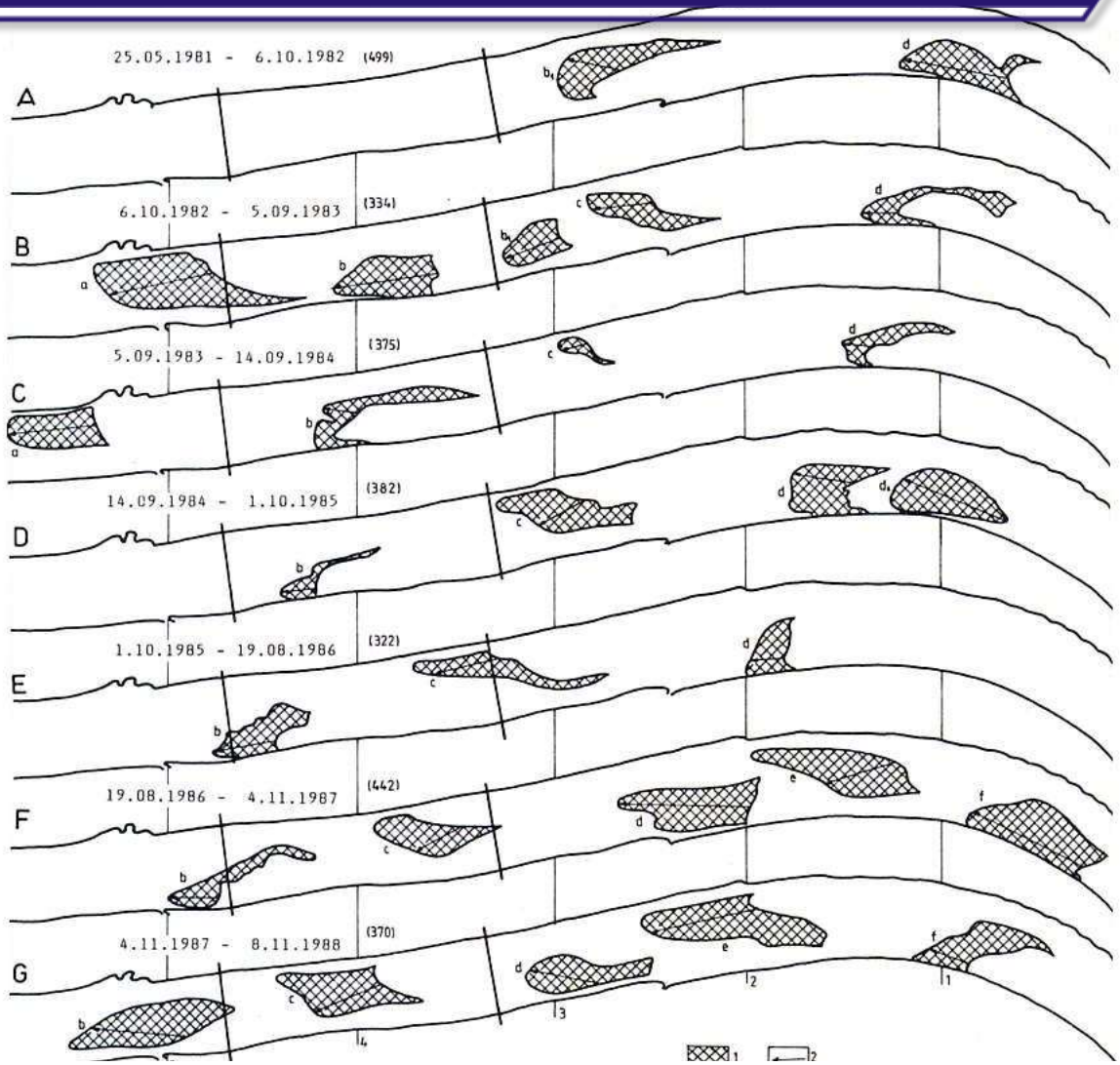
Physical observation of river sandbar dynamics. Russian method developed by Babiński (1992).

METHODS



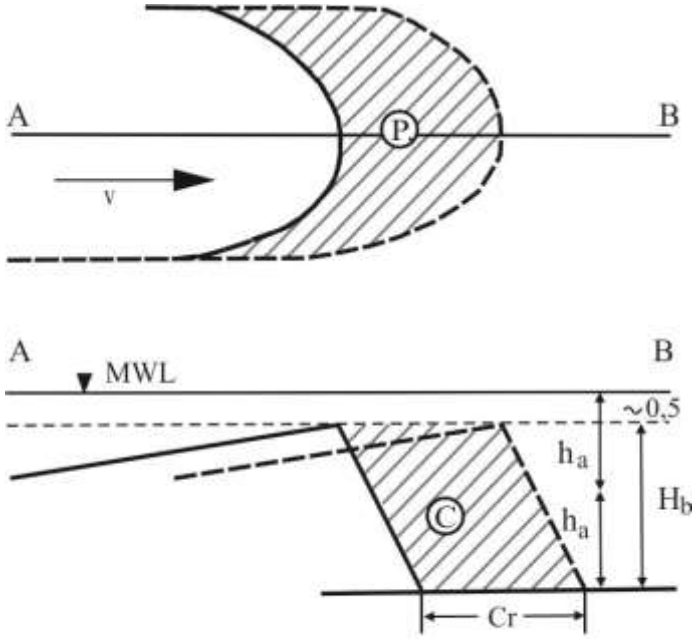
Physical observation of river sandbar dynamics
Morphological situations emarged and submarged bars

METHODS



Physical observation of river sandbar dynamics

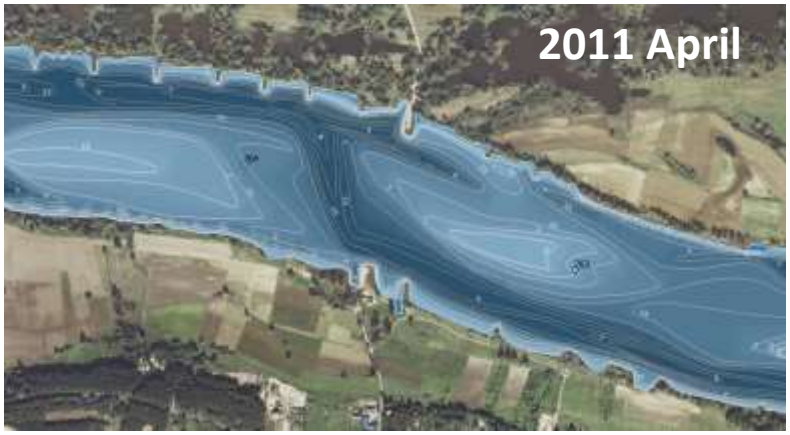
Surface and vector dymamic of sand barsmovement

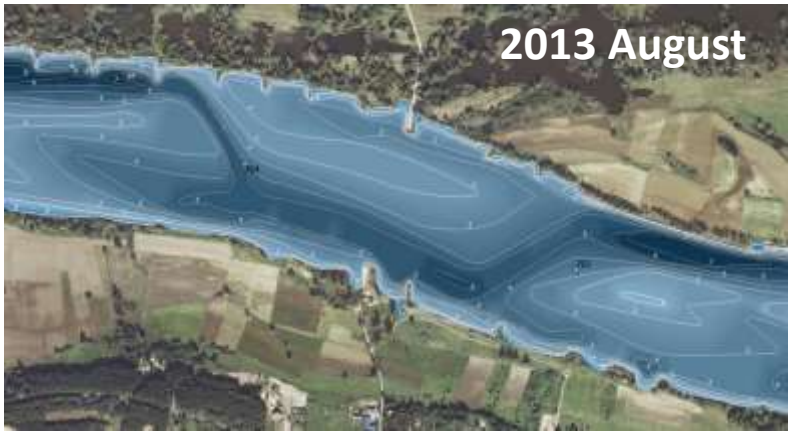


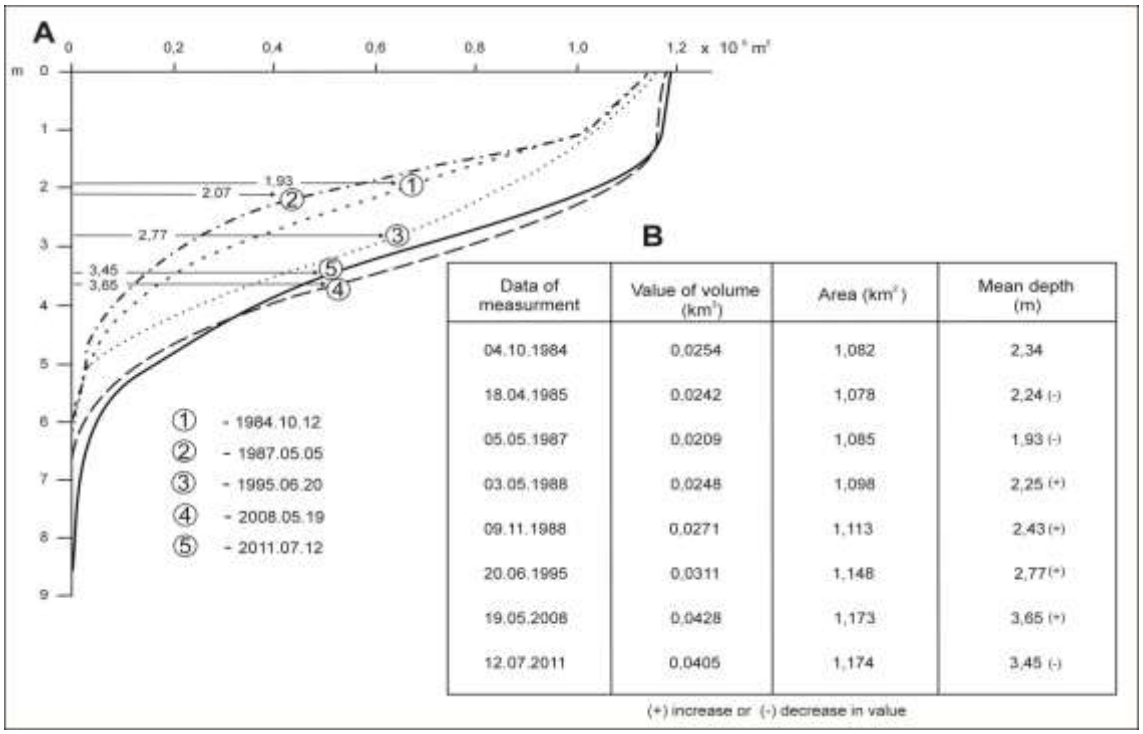
$$T = P \cdot H_b = P\,(2h_a - 0{,}5)$$

Ideogram of bed load transport value (T) based on measurements of transverse sand bars dynamics at the regulated Vistula reach. Explanations: Hb – average thickness of sandbar, Cr – velocity of movement, P – surface rate of movement.

METHODS







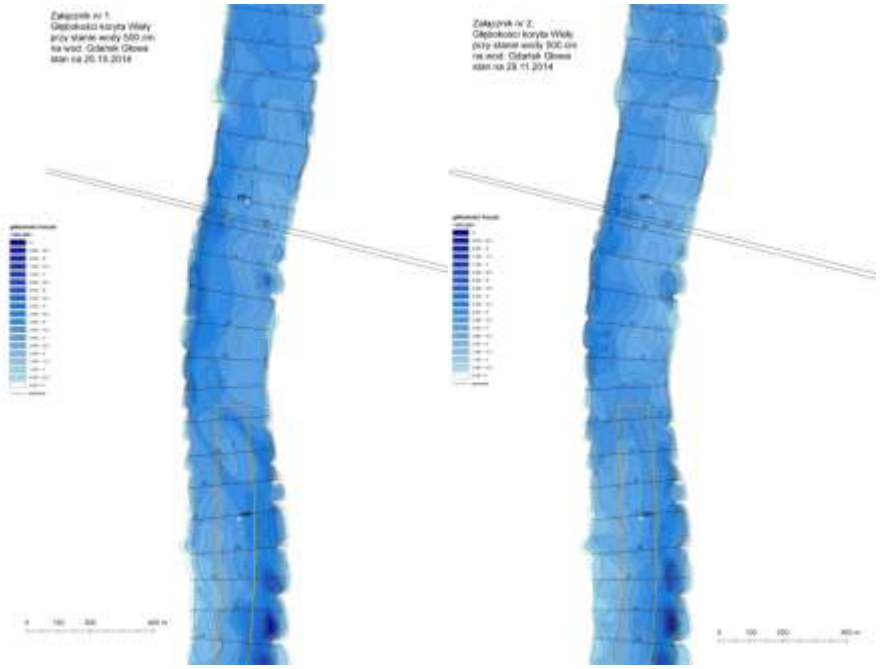
B

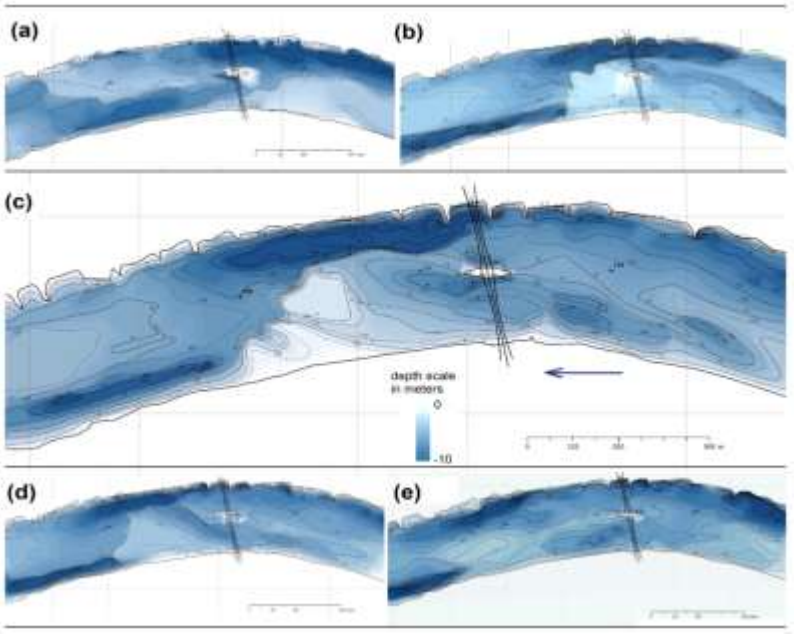
Data of measurment	Value of volume (km^3)	Area (km^2)	Mean depth (m)
04.10.1984	0.0254	1,082	2,34
18.04.1985	0.0242	1,078	2,24 (-)
05.05.1987	0.0209	1,085	1,93 (-)
03.05.1988	0.0248	1,098	2,25 (+)
09.11.1988	0.0271	1,113	2,43 (+)
20.06.1995	0.0311	1,148	2,77 (+)
19.05.2008	0.0428	1,173	3,65 (+)
12.07.2011	0.0405	1,174	3,45 (-)

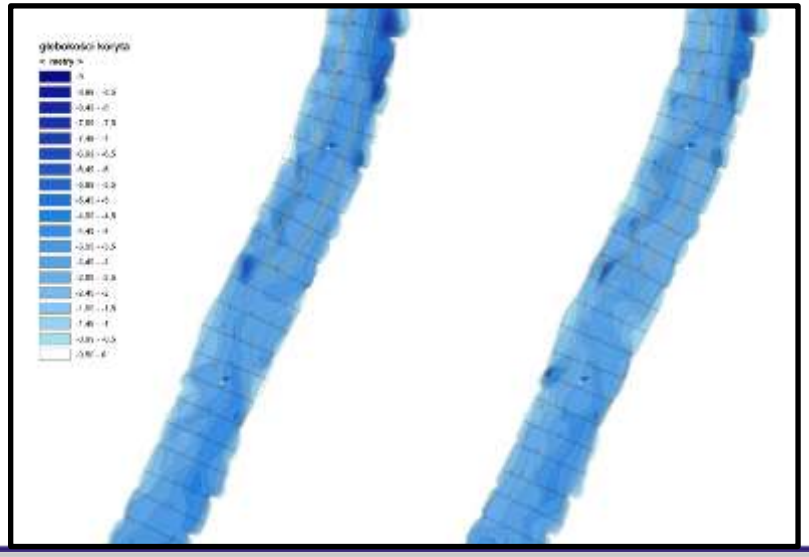
(+) increase or (-) decrease in value

Channel dept mapping and bathymetric curves analysis
(Vistula river km 762.0-765.0)

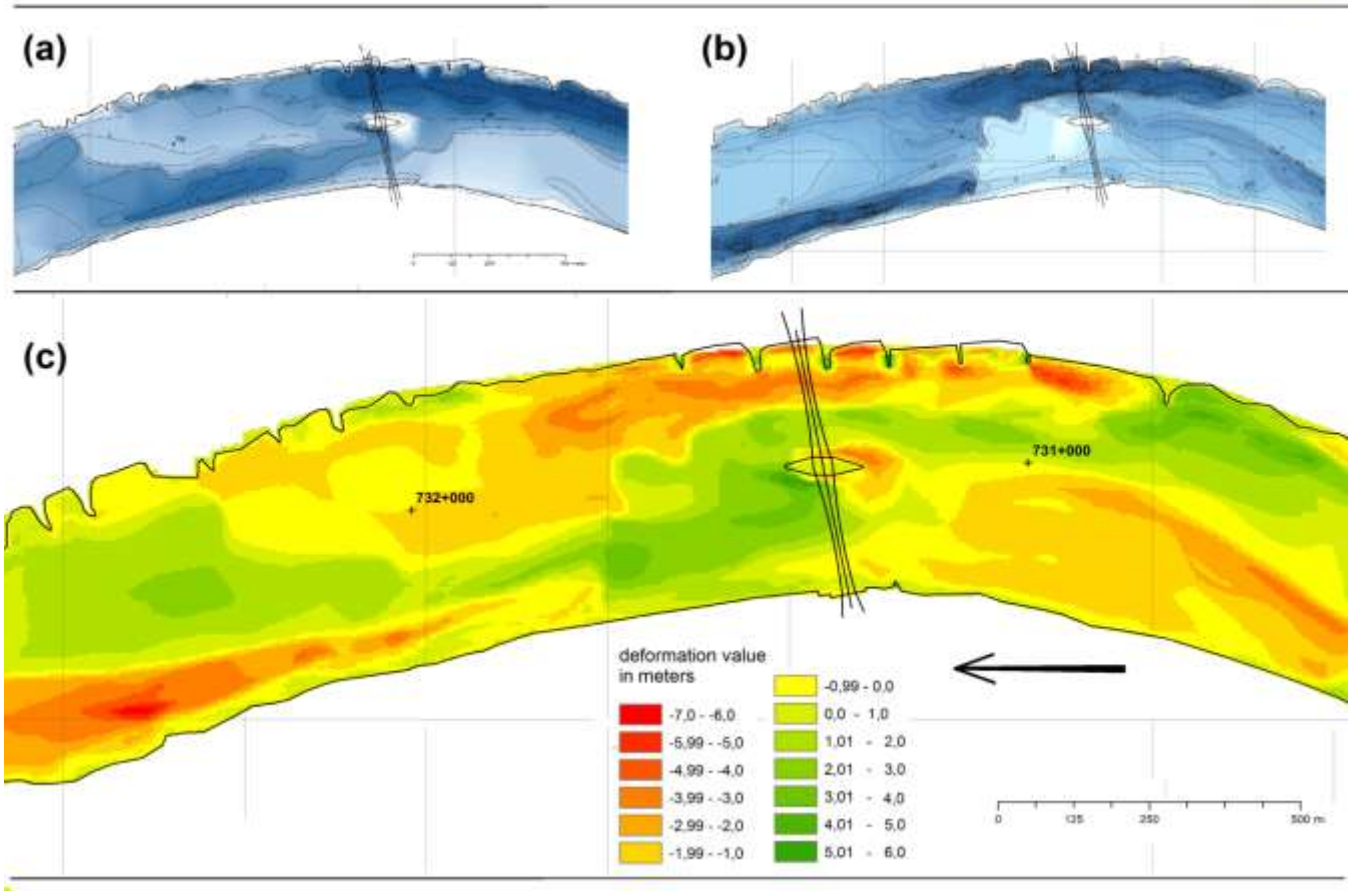
METHODS



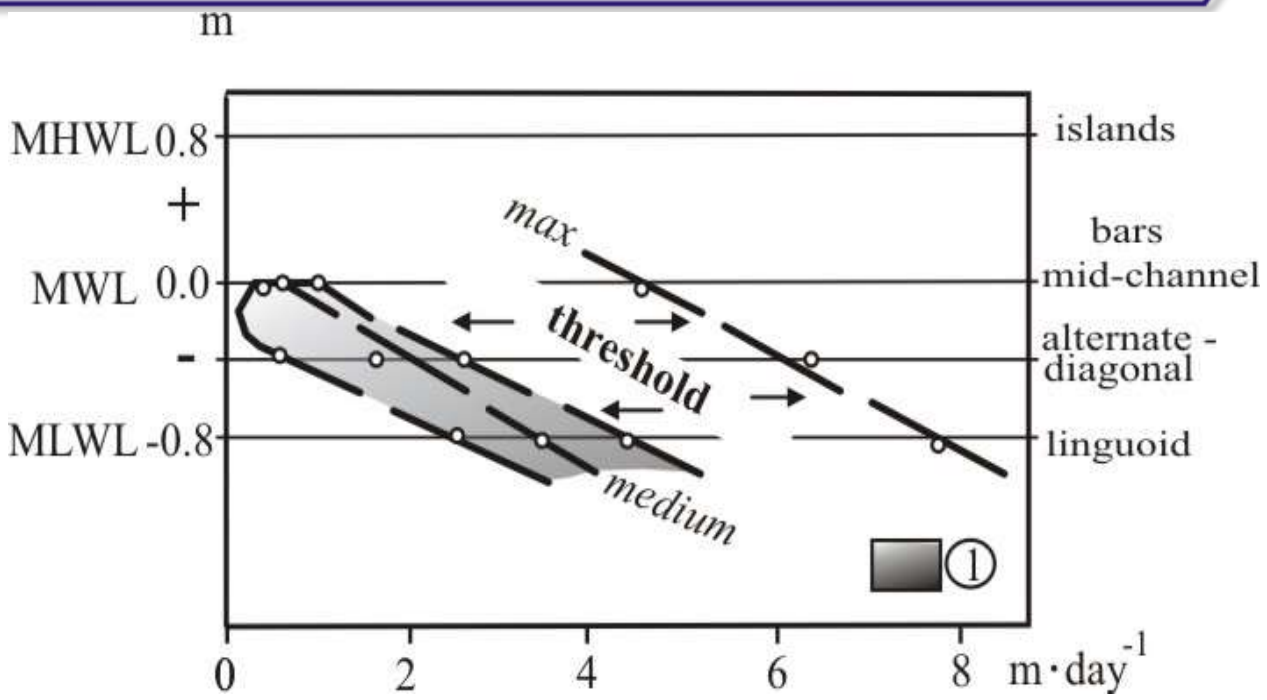

(a)
(b)
(c)
depth scale
in meters
0
-10
(d)
(e)


głębokości koryta


11.08.2011
I
II
III
29.04.2013
I
II
III
IV

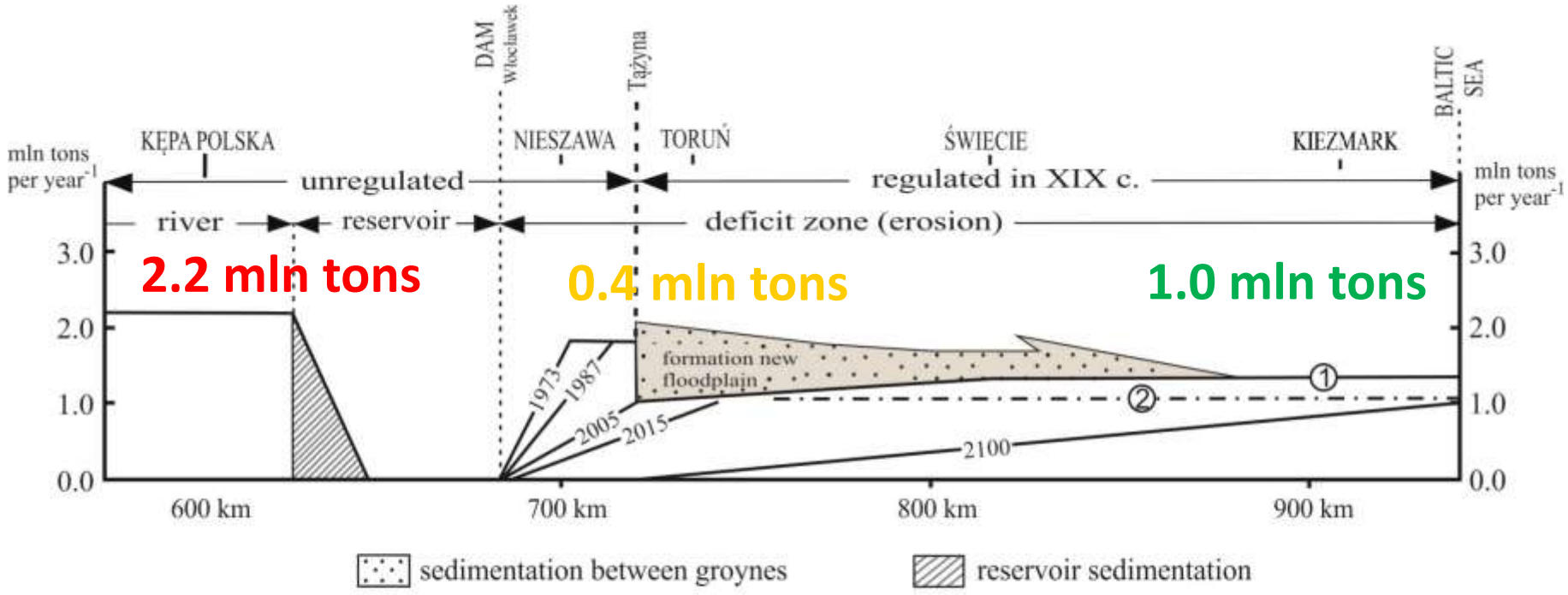


A 18th month bottom deformation model – Vistula channel in Torun (c) created on the basis of two bathymetric maps in the form of a DEM: (a) 2013-07-18 and (b) 2014-12-16.



Mean diurnal rate of sandbars shifting at the unregulated and regulated sections of the Vistula: 1 — zone of average velocities of bar shifting, MHWL — average high water stage, MWL — average water stage, MLWL — average low water stage (Babiński 1992)

RESULTS and DISCUSSION



Changes in bed load transport in the lower Vistula resulting from construction of the Wloclawek dam.

Explanation: 1 - bed-load transport of regulated channel after 1950; 2 - line represents a border value of bed-load transport between erosion and accumulation.

SUMMARY

- The study on morphological methods:the dynamics of sandbars and bathymetry mapping indicates that bed load transport at the already regulated reach of the lower Vistula ranges from approx. 1.0 million tons per annum in the profile from 60km below dam and 210 km from estuary, up to 1.2 million tons per annum at the mouth to the sea. In result of regulation Vistula lost approx. 50% of load.

- After the construction of the Wloclawek dam we observed below dam deficit zone in sediments transport (100% of bed load is trapped in the reservoir). 25 km below dam Vistula transported 0.4 million tons of sand and gravel, 60 km below approx. 1.0 million tons per annum = renewal of fluvial transport.

- We estimated that the erosion zone stretching below the dam (rate 2.2 km/per year) and it will reach the mouth section of the Vistula by the year 2100.

- Deficit in delivery bed load within delta cone will result in the diminishing of the underwater part of the cone, the disappearance of the sand bars and the erosion and destruction of regulatory structures.


10th International SedNet Conference “Sediments on the move” 14-17 June 2017, Genoa, Italy
Thank you for your attention!
Michal J. HABEL
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