XL International School of Hydraulics
23-26 May 2023, Kąty Rybackie, Poland

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What if it was possible to fully open the lock in the Nowy Świat canal?

Modeling the hydrodynamics of the Vistula Lagoon and the potential water exchange through the ditch in Vistula Spit

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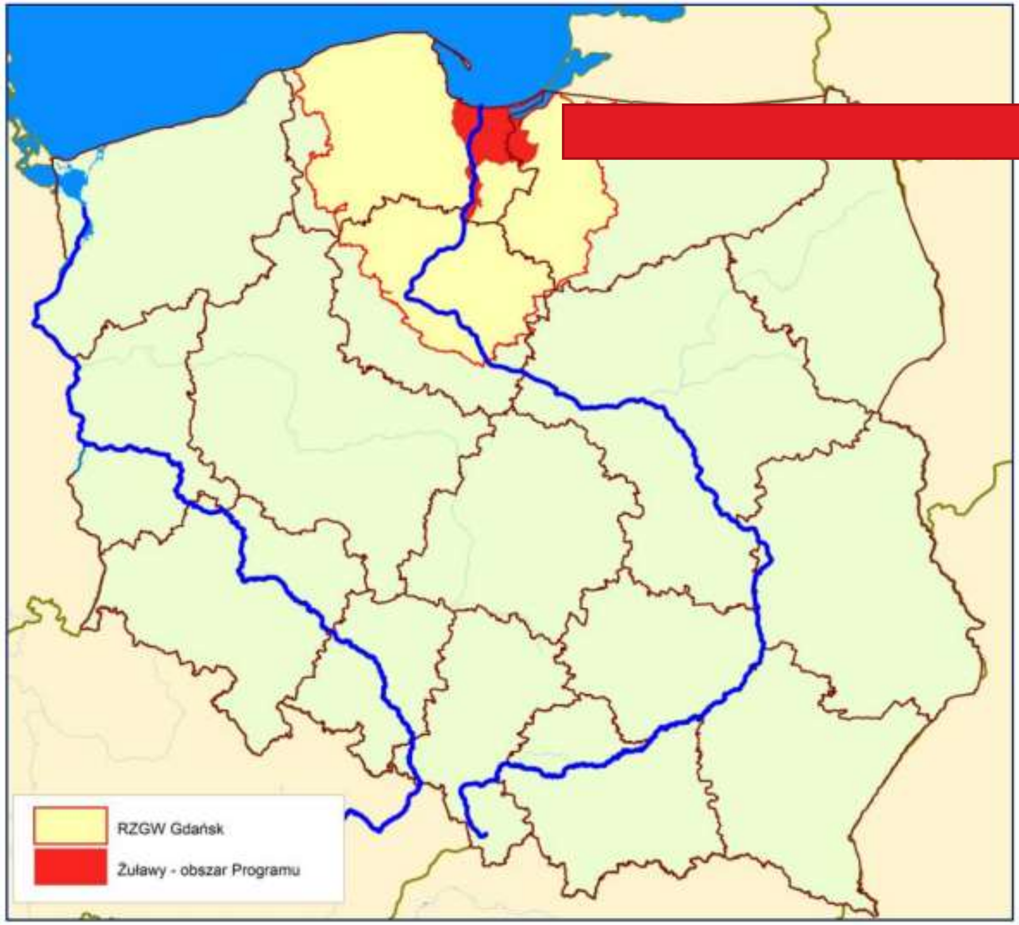
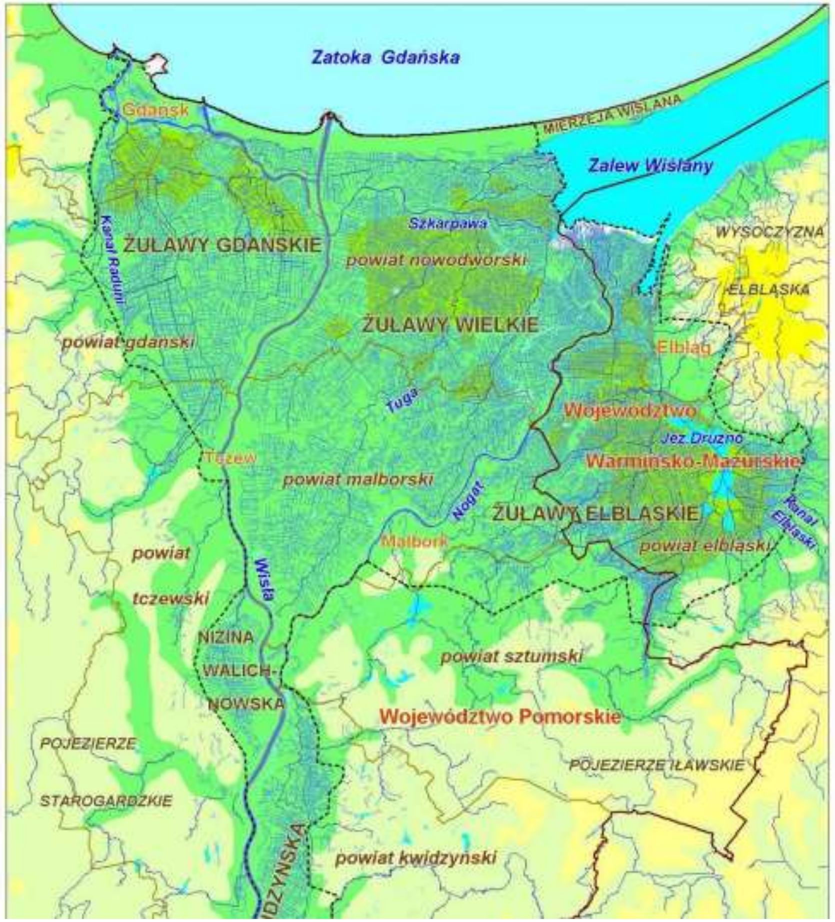
Where we are? Żuławy (lowland)





Historical estuary of the Vistula river

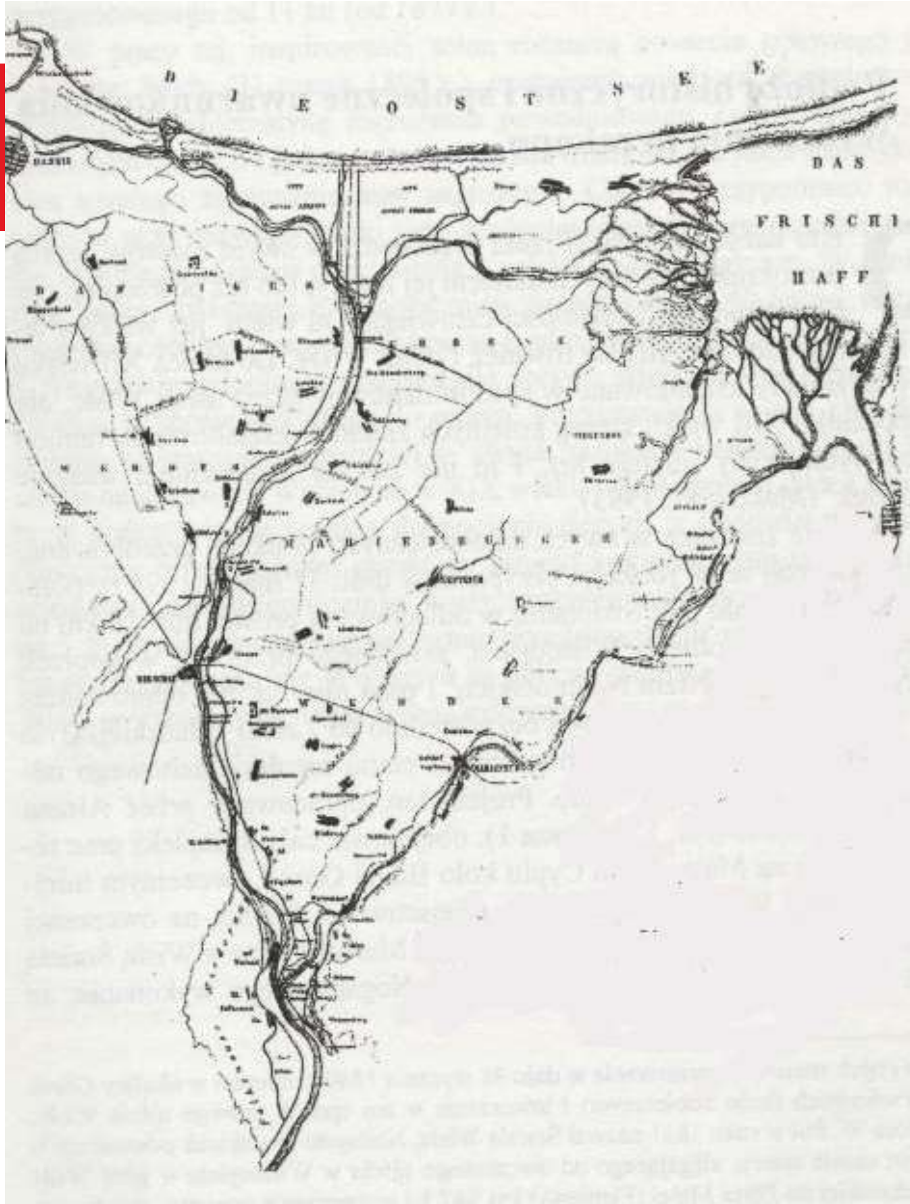
- Vistula lagoon 13th century

Historical estuary of the Vistula river

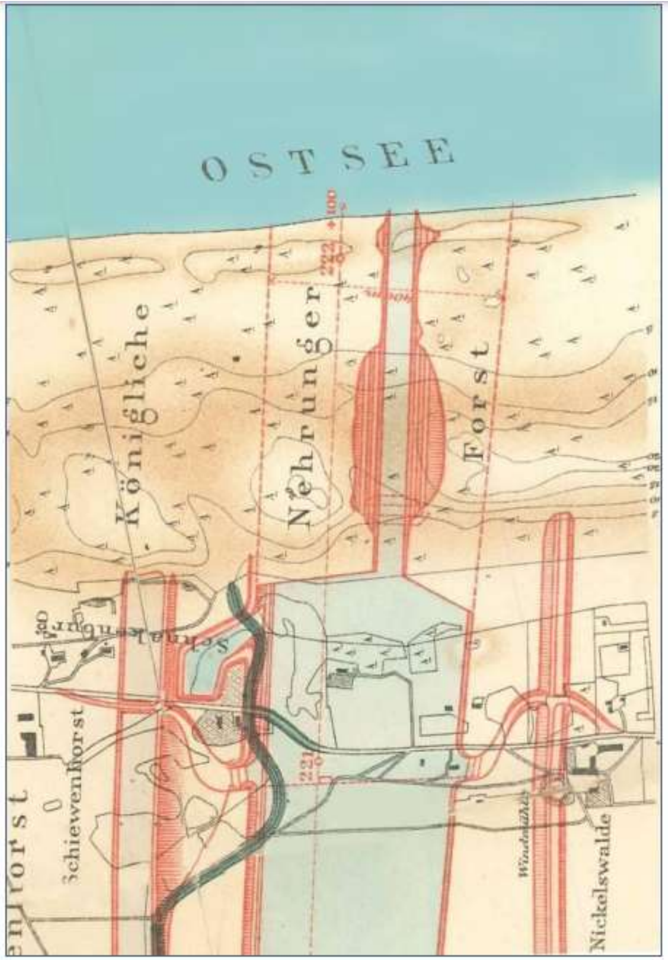
- Vistula lagoon 18th century

Historical estuary of the Vistula river

- Permanent flood risk (ice jam flooding)
- 1768 – first approach for flood prevention: cutting Nogat from the Vistula, all flow will go directly to Baltic sea
- 19th century – repeatable flooding of the City of Gdansk (25 events)
- 1891 – decision to build the cutoff channel according to Alsen and Fahl project



Historical estuary of the Vistula river



- **Opening of the channel - March 31st 1895, 3:15 pm**

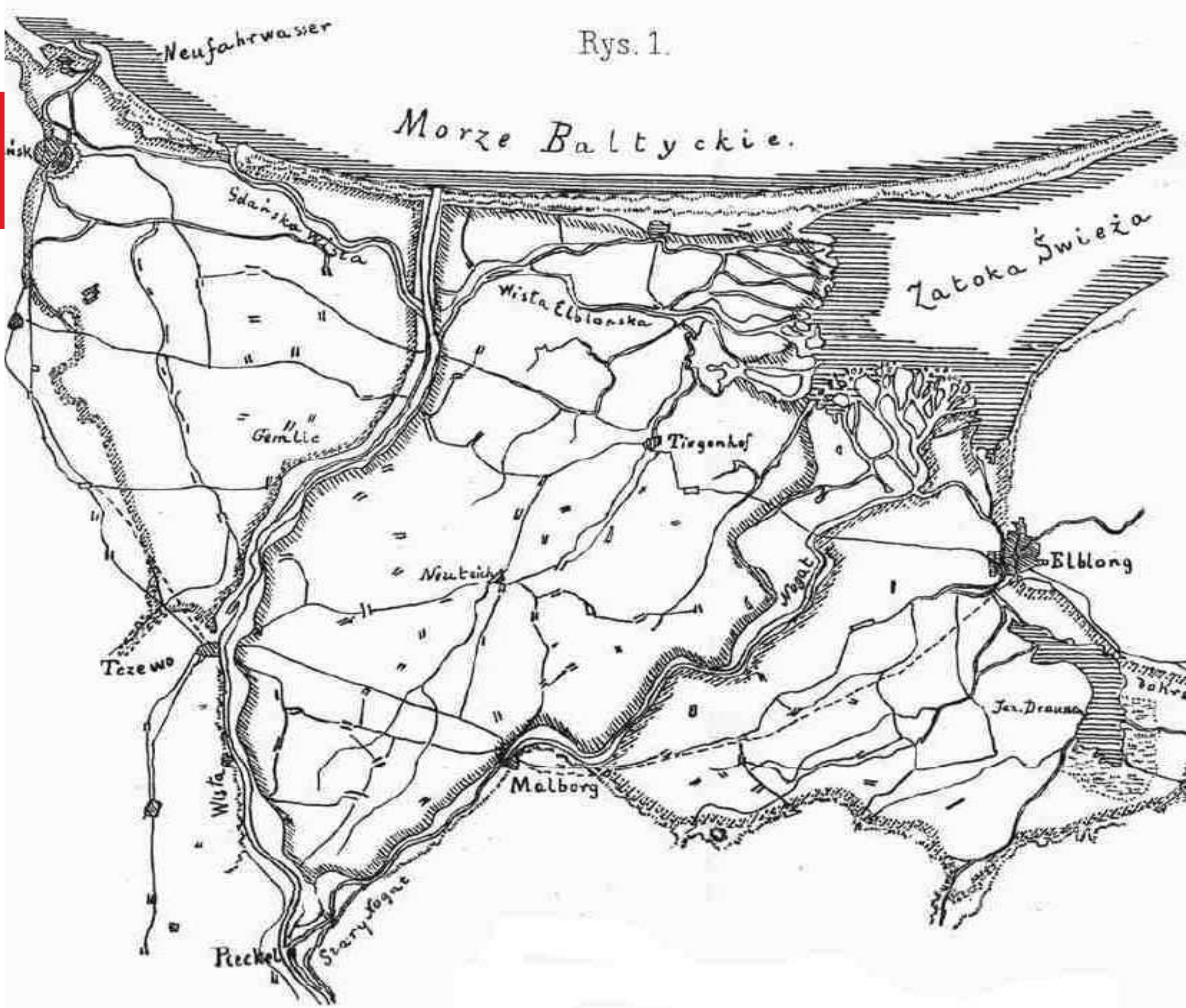
Vornahme des Weichseldurchstiches am 31. März 1895, 15 Uhr 45 Min.

Artificial channel km 932.6 – 939.7

- **Cutting off rivers**
  - Vistula
  - Szkarpawa
  - Nogat

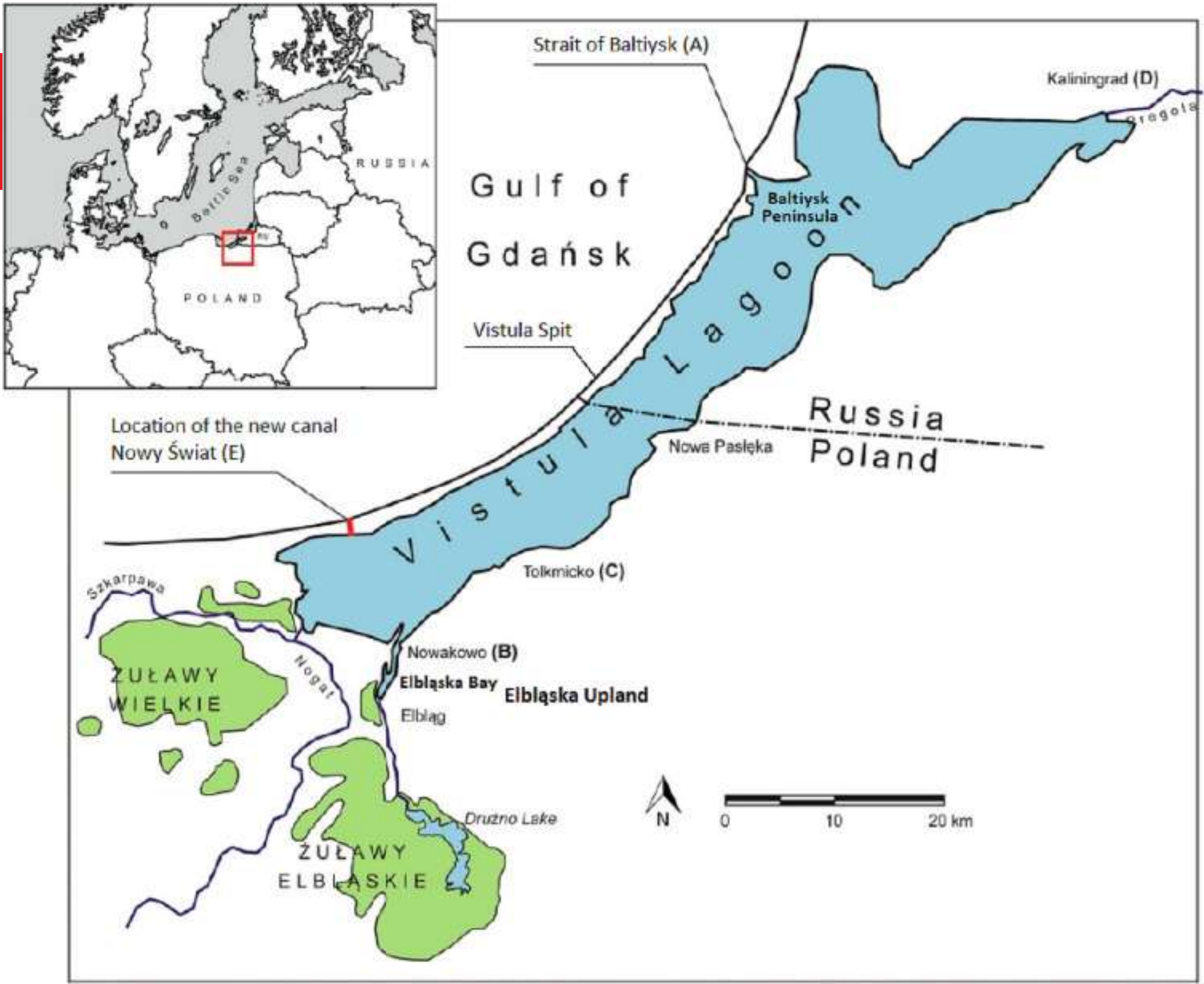
- **Locks in**
  - Przegalina
  - Gdańska Glowa
  - Biała Góra

- **Embankments**



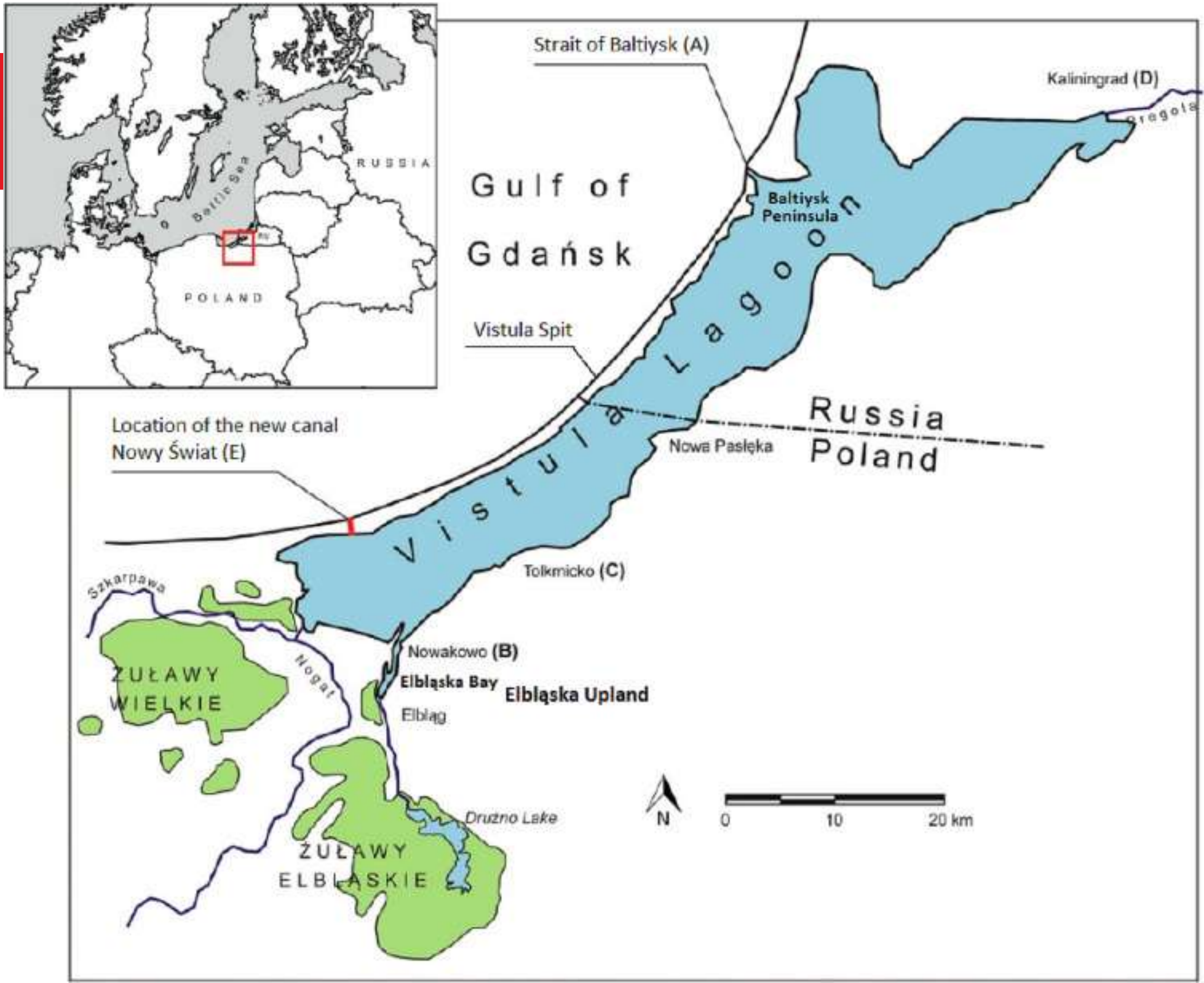
Location of the Vistula Lagoon

- **The length of the lagoon is 90.7 km and its width varies from almost 6 km up to 13 km.**
- **The lagoon is a shallow basin with a mean depth of about 2.75 m.**
- **It is separated from the Gulf of Gdańsk by the Vistula Spit. The length of the spit is 65 km.**
- **Till 2022, the only connection between the Vistula Lagoon and the Baltic Sea was through the Strait of Baltiysk (Russia).**

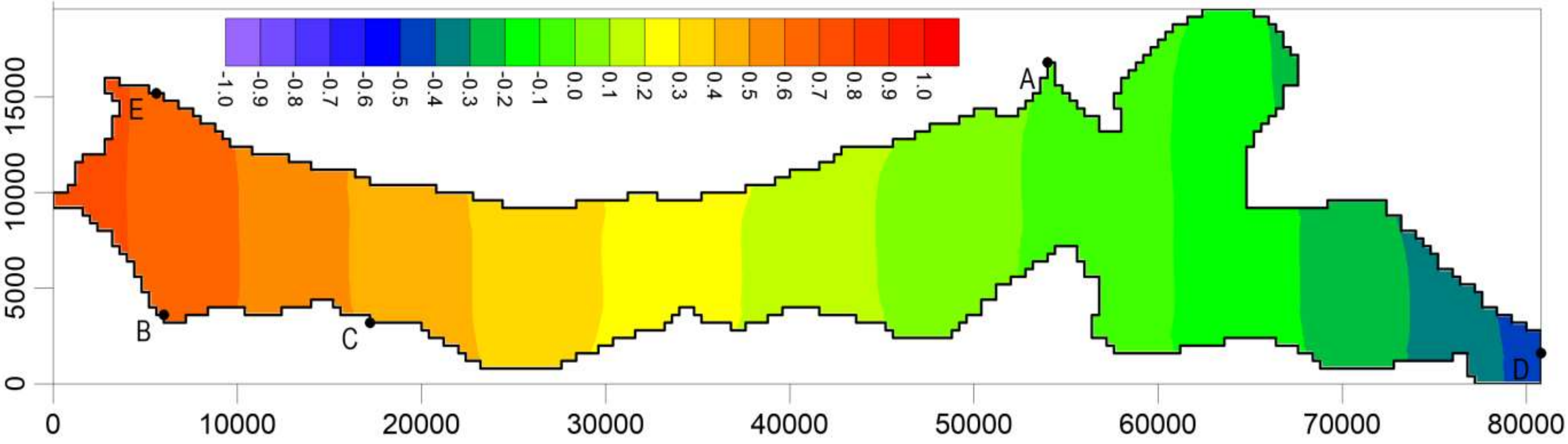


Location of the Vistula Lagoon

- **Hydraulic conditions in the Vistula Lagoon are usually the result of variations in the sea level in the Gulf of Gdańsk and the wind action on the water surface of the lagoon.**
- **The long-lasting rising of water in the southern part of the lagoon can be a cause of flood risk for the lowland areas of Żuławy Elbląskie.**
- **Currently, the project of a new strait connecting the Baltic Sea with the Vistula Lagoon was completed.**

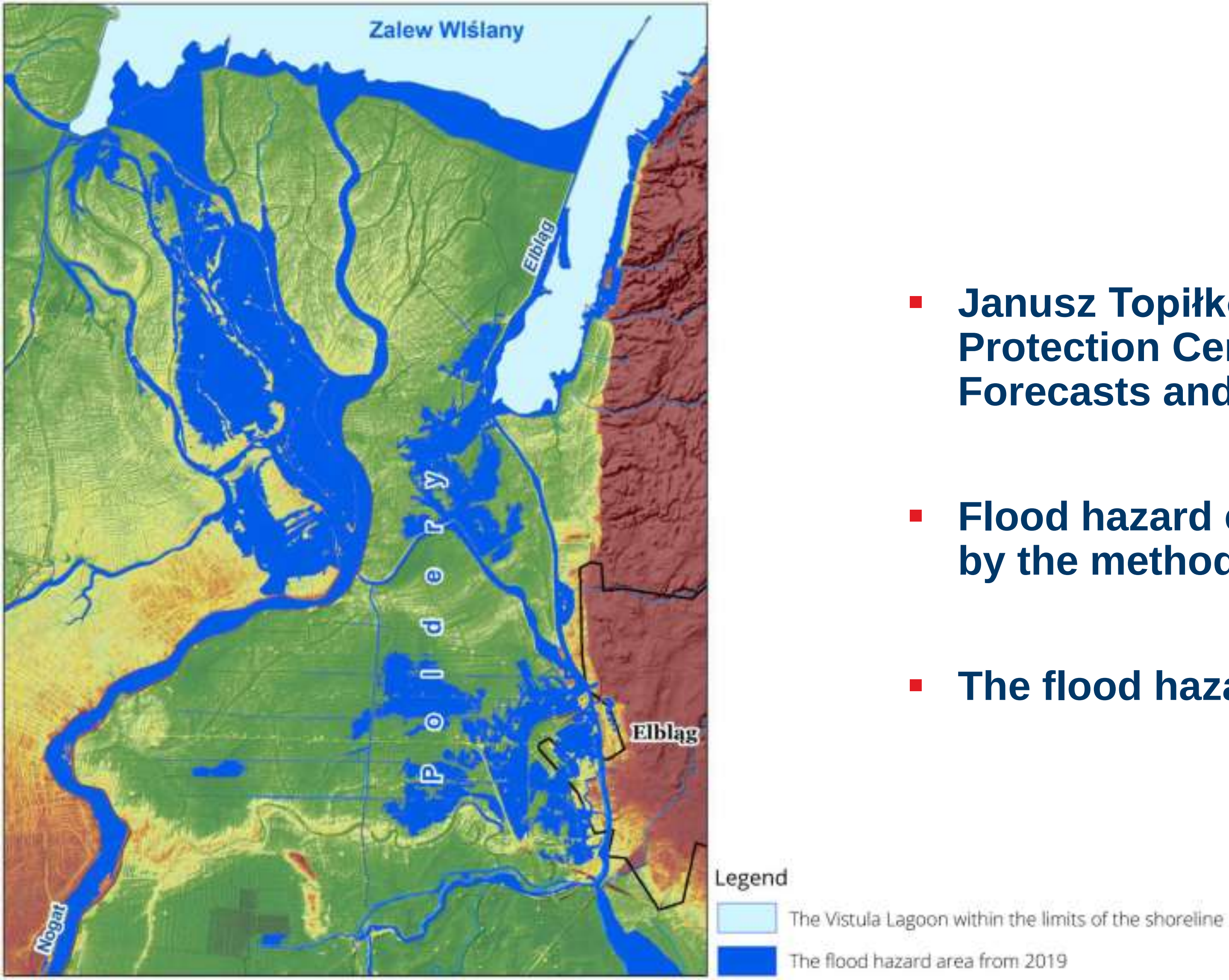


Water surface elevation after 12 hours of a NE wind at a speed of 12 m/s



- A significant increase of the water level is observed in the SW part of the lagoon exceeding 0.8 m a.s.l. near points B and E, which makes flooding in the Żuławy Elbląskie polder area possible.

Modeling storm surge floods – case study Żuławy Elbląskie



- Janusz Topiłko, IMGW-PIB/National Hydrological Protection Centre, Department of Hydrological Forecasts and Studies in Gdynia
- Flood hazard extent p = 1% from the Vistula Lagoon by the methodology from 2019
- The flood hazard area was approximately 28.2 km^2

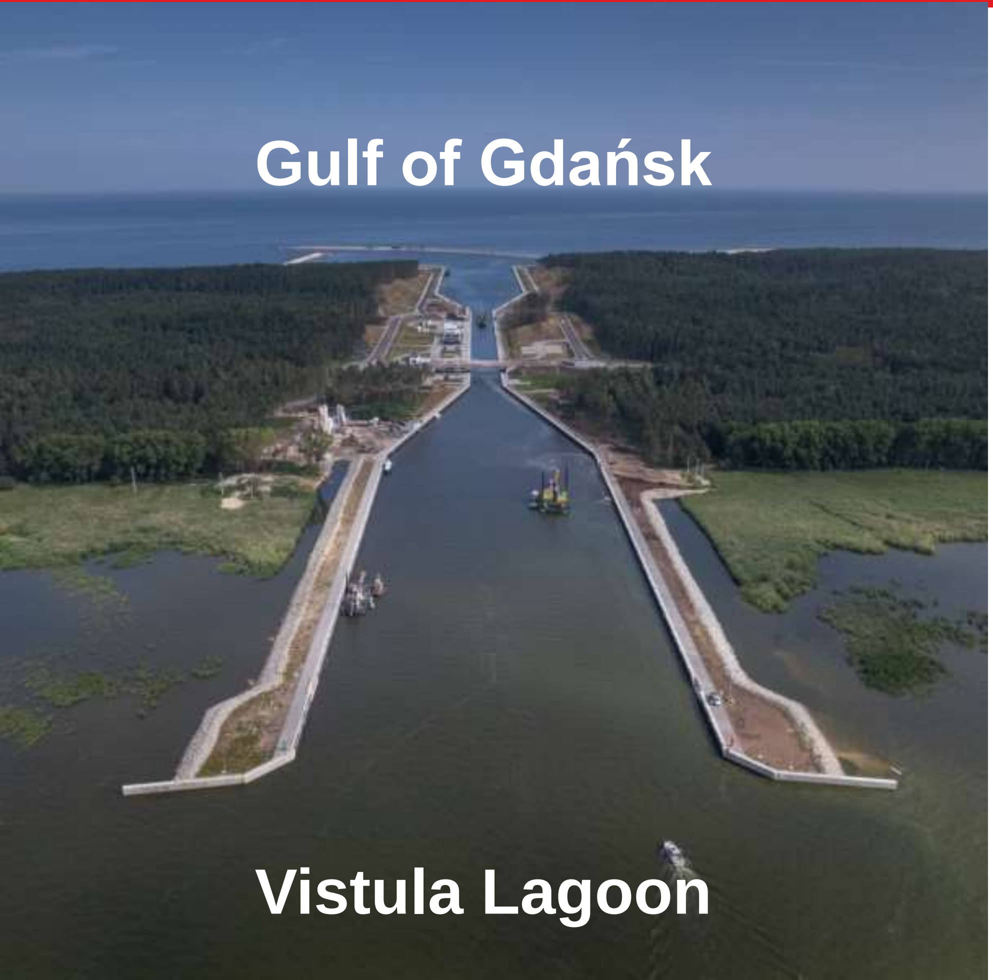
Flood conditions – Elbląg, January 2019

Flood conditions – Elbląg, January 2019

Ship canal Nowy Świat trough the Vistula Split

- The final decision to build this hydrotechnical facility was made in 2017
- Nowy Świat has been chosen as the location of the new navigable canal
- The aim of the project is to shorten the waterway from the port of Elbląg to the Baltic Sea
- The new navigable waterway was opened on September 17, 2022

Ship canal Nowy Świat trough the Vistula Split



- The length of the canal from the northern shoreline to the end of the southern breakwaters is 1515 m
- The canal has a basic width of 90 m and is narrowing to 25 m in the area of the lock (length 420 m)
- The bottom of the canal and the port is located at the ordinate of -5.0 m above sea level.

Mathematical model of lagoon and ship canal hydrodynamics

- **A two-dimensional shallow water equation model was adapted to simulate free surface water flow in the lagoon driven by the wind and storm surges.**

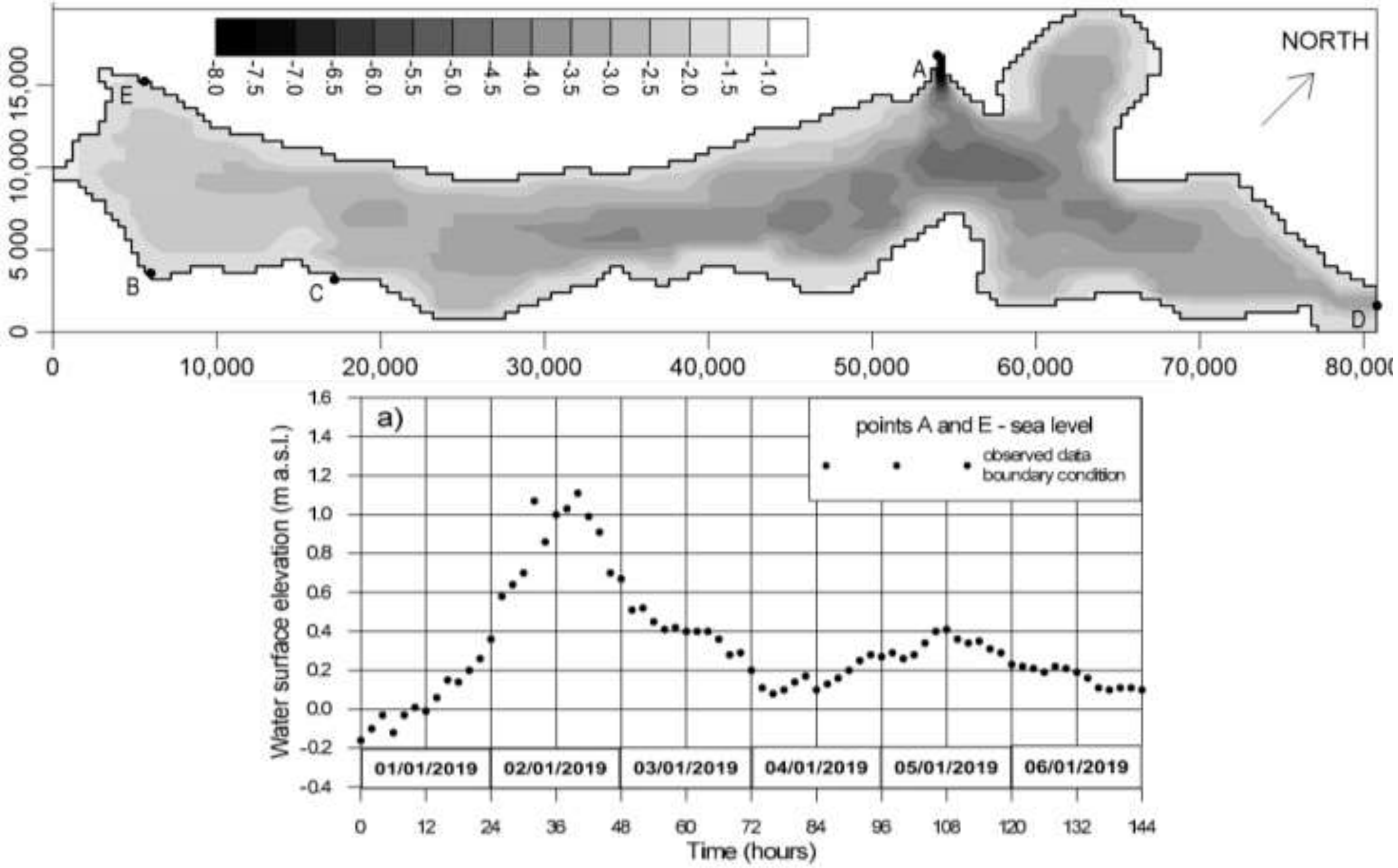
$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}+g\frac{\partial h}{\partial x}+\frac{gn^2}{H^{4/3}}U|W|-\nu_o\left(\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}\right)-\frac{T_x}{H}=0$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}+g\frac{\partial h}{\partial y}+\frac{gn^2}{H^{4/3}}V|W|-\nu_o\left(\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}\right)-\frac{T_y}{H}=0$$

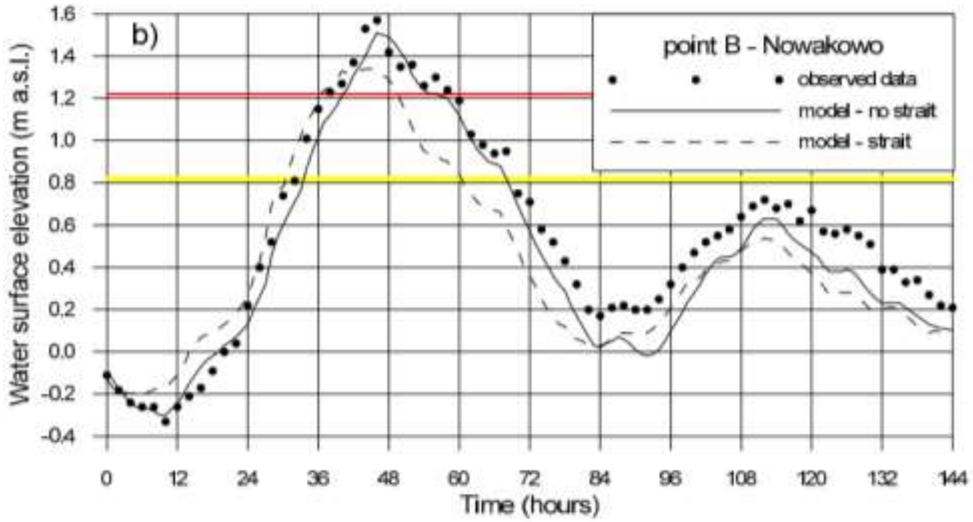
$$\frac{\partial h}{\partial t}+\frac{\partial (UH)}{\partial x}+\frac{\partial (VH)}{\partial y}=0$$

- where: x, y – spatial coordinates; t – time; U, V – depth-averaged components of velocity in x and y direction;
- $|W|=(U2+V2)^{0.5}$ – modulus of the velocity vector; h – water surface elevation; H – water depth;
- g – acceleration due to gravity; n – Manning roughness coefficient; v_0 - coefficient of turbulent viscosity;
- T_x – wind stresses in x direction; T_y – wind stresses in y direction.

The impact of the Nowy Świat lock opening on the water levels in the Vistula Lagoon



period 1-6/01/2019



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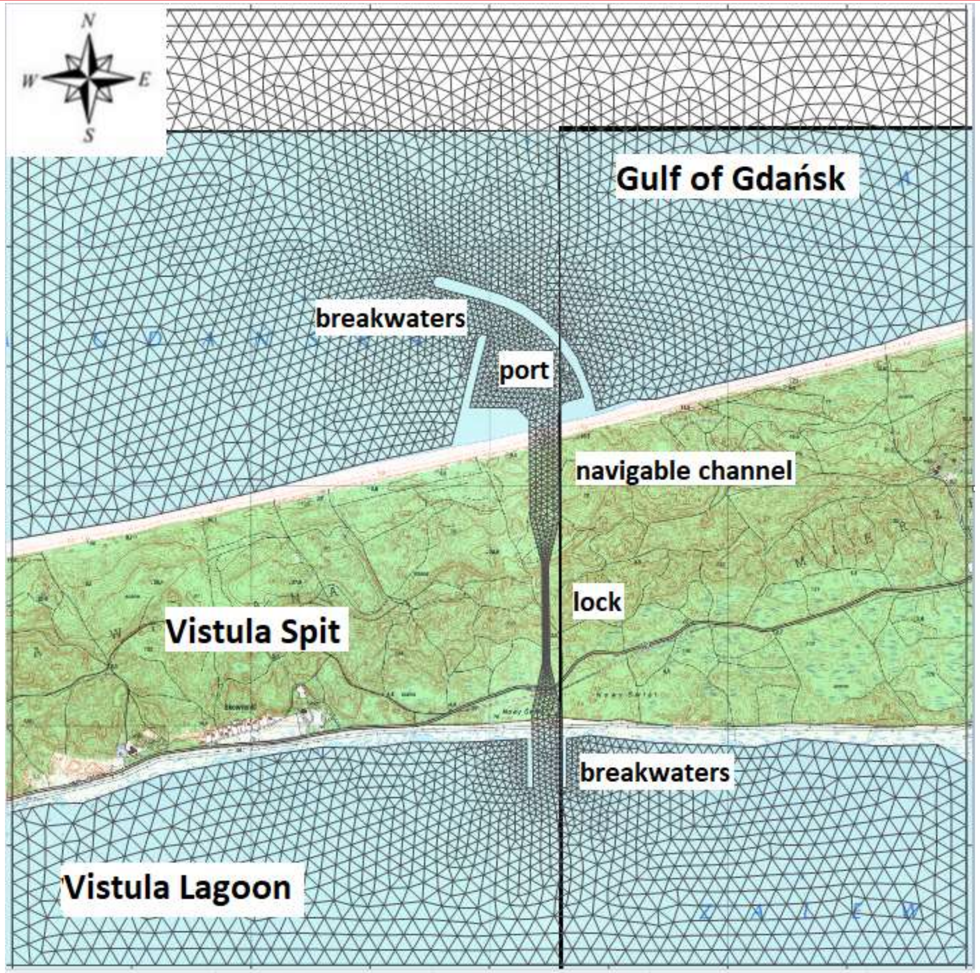
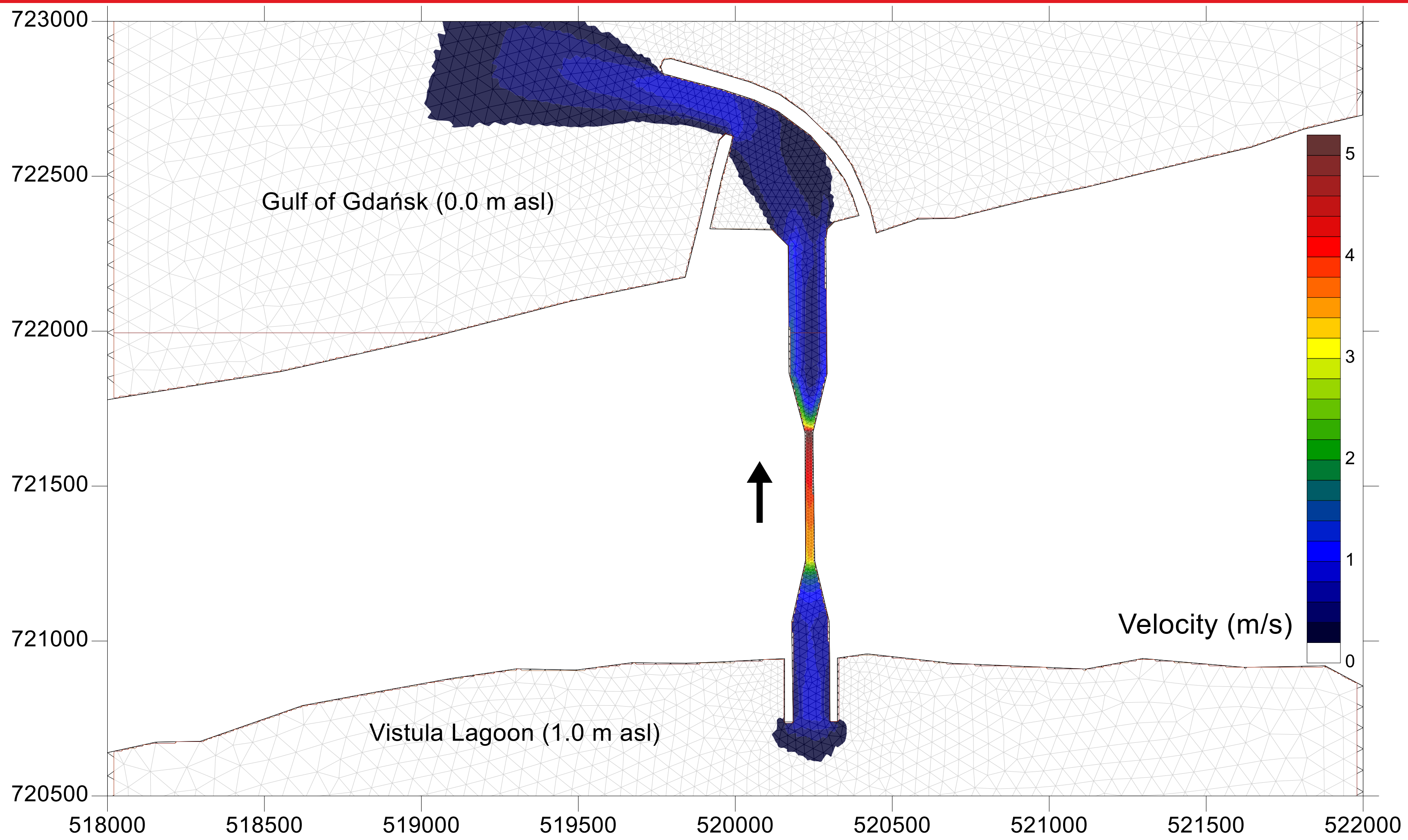
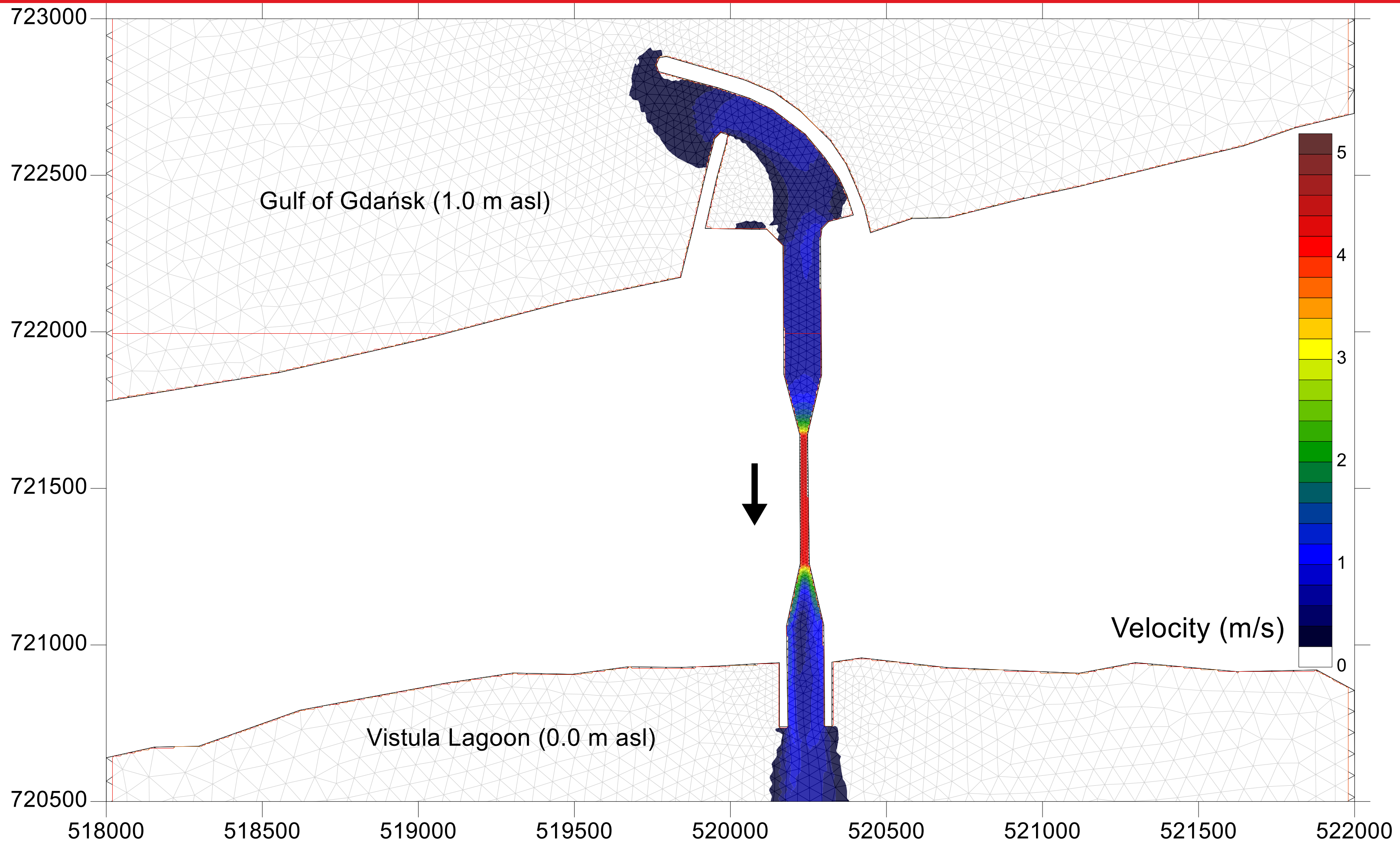
Hydraulic characteristics of the navigation channel through the Vistula Spit



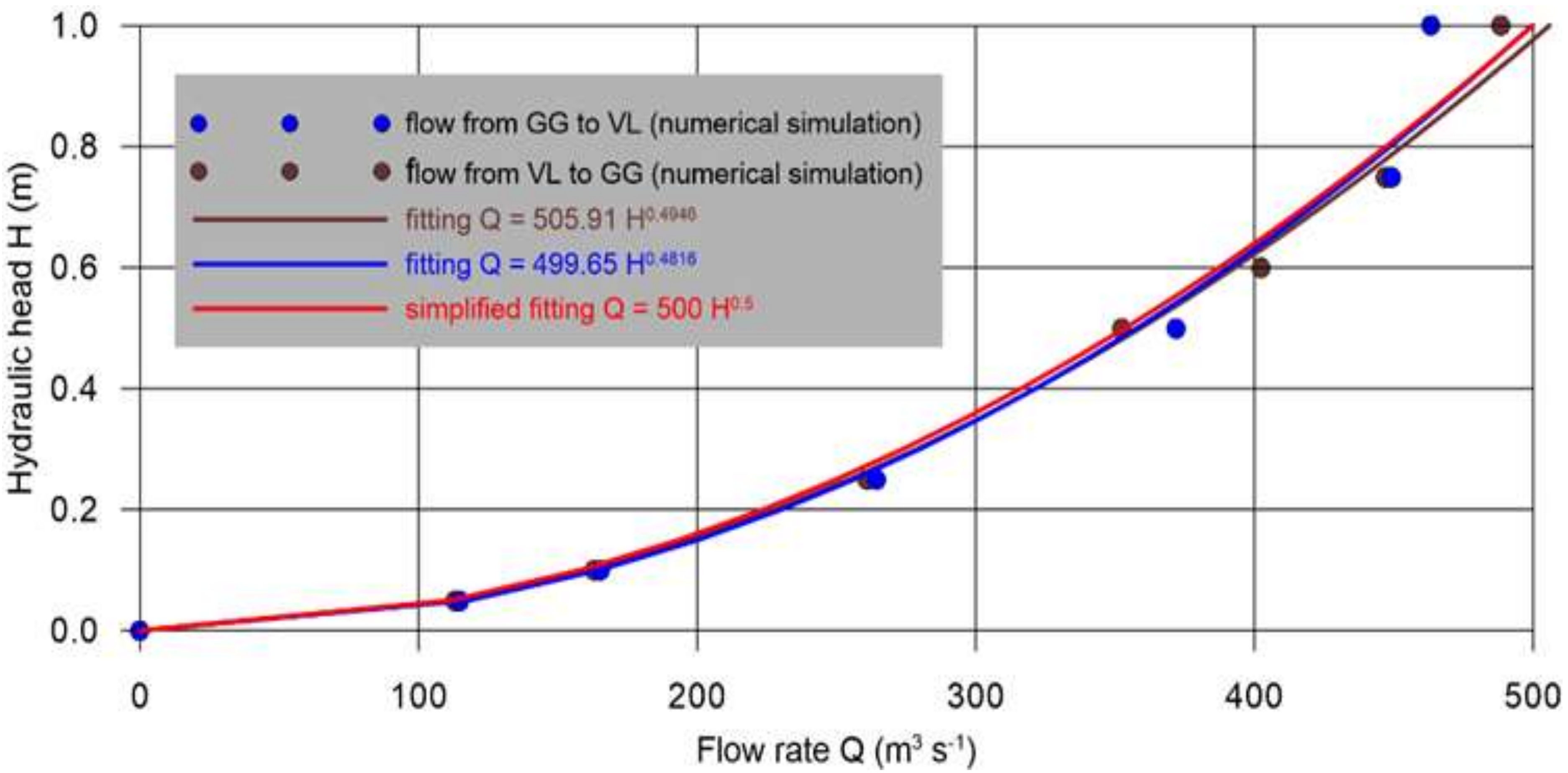
Numerical modeling results Lagoon→ Sea



Numerical modeling results Sea → Lagoon



Rating curve of the canal with open lock



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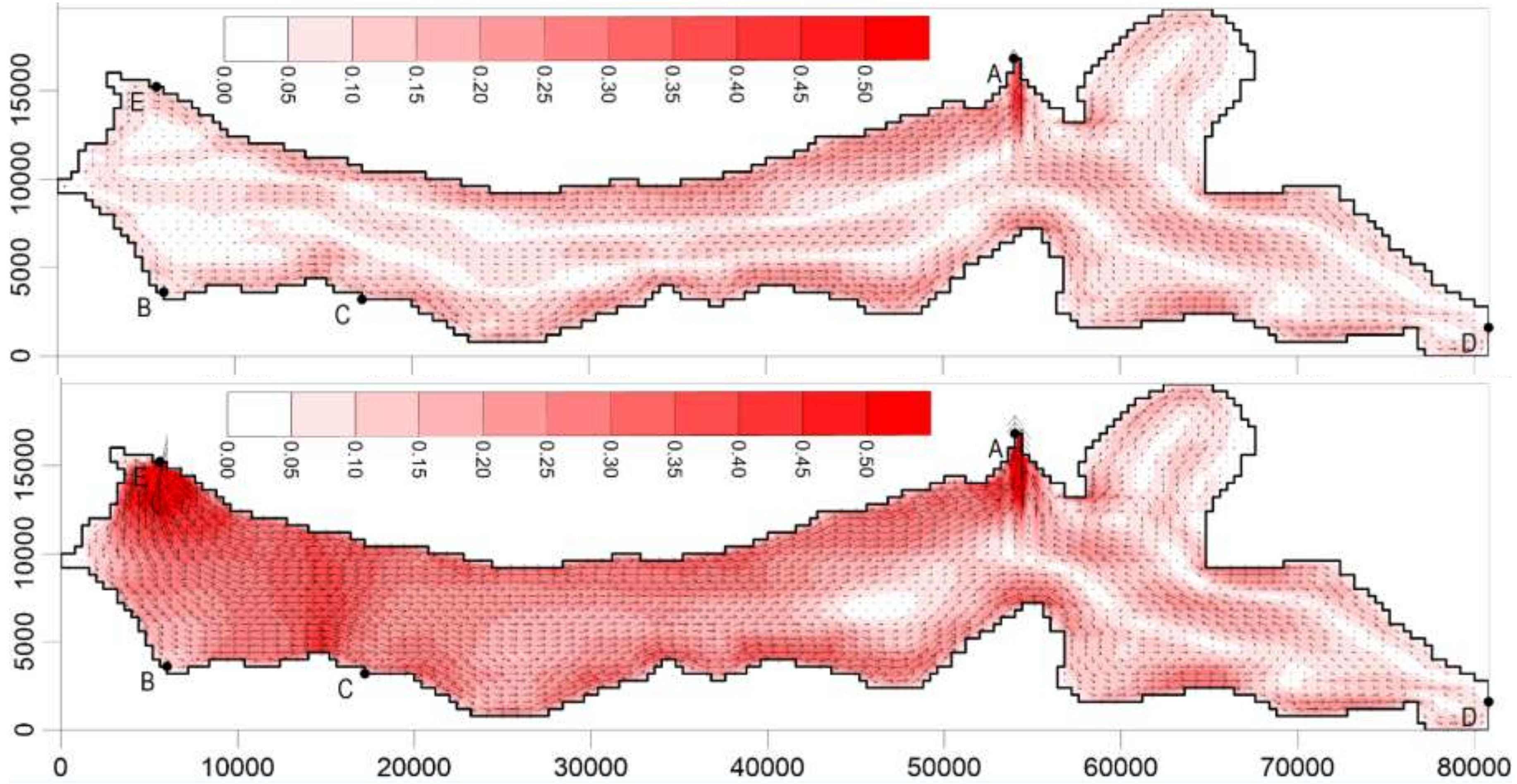
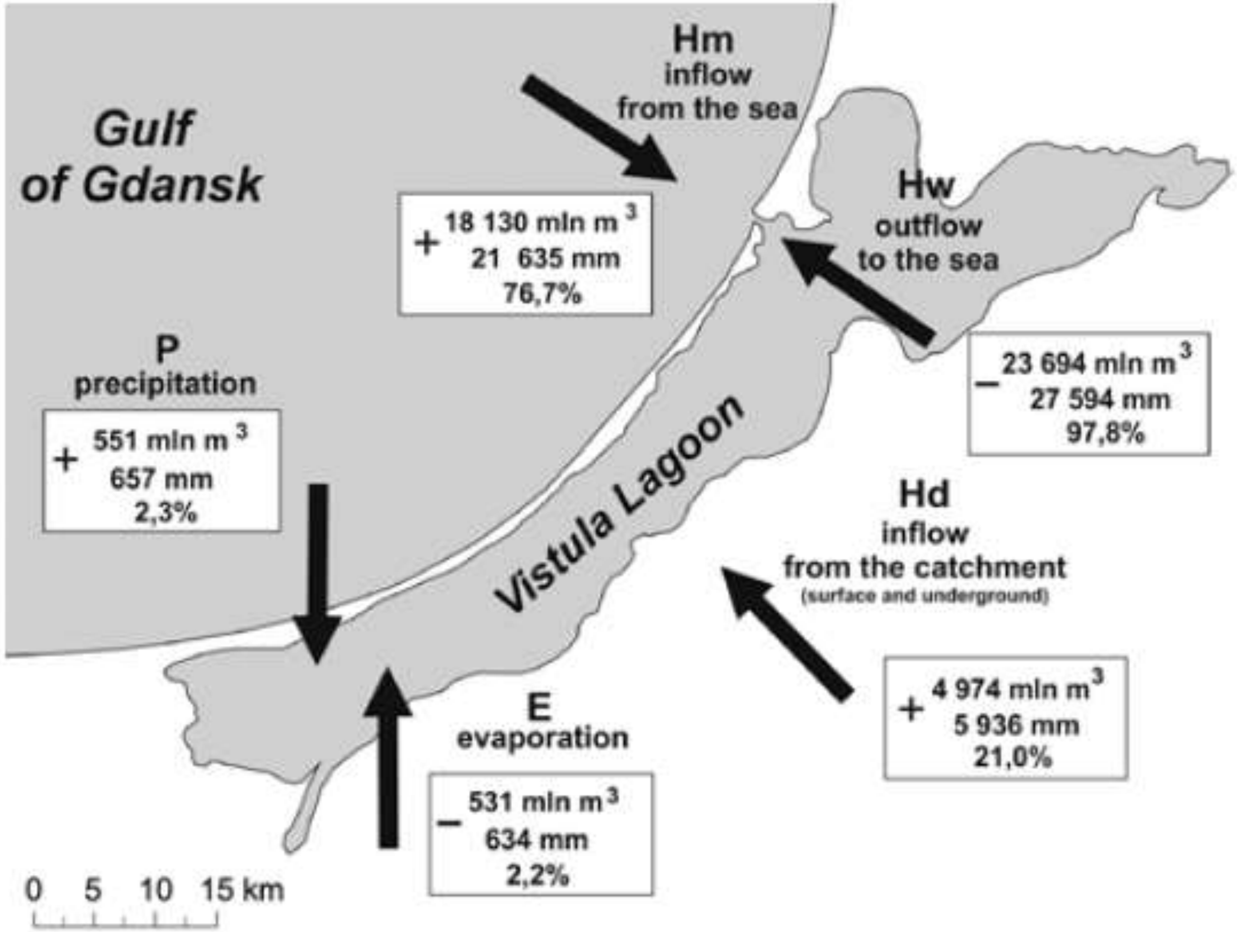
Intensification of water exchange (example for SW wind)



Water budget of the Vistula Lagoon

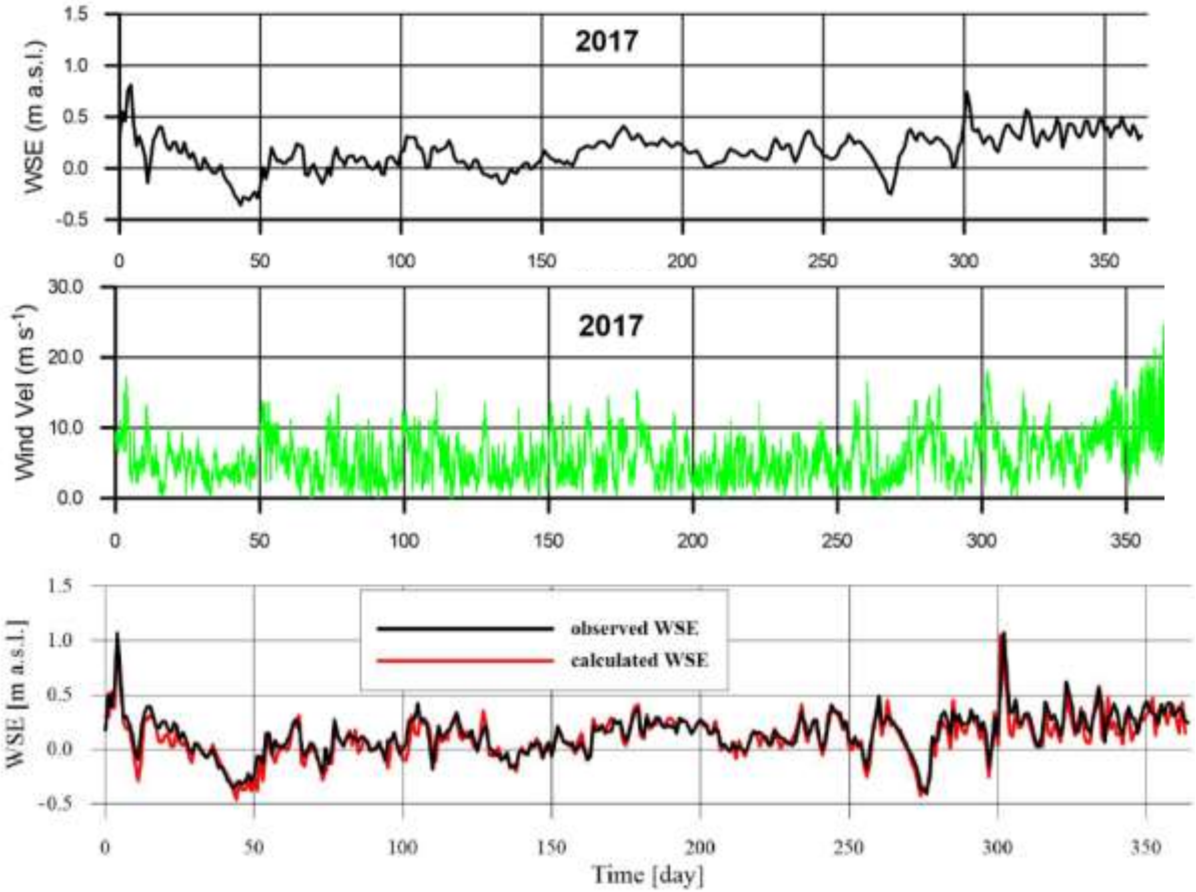
- The hydraulic conditions in the Vistula Lagoon are mainly the result of sea level changes in the Gulf of Gdańsk and the action of the wind on the water surface of the Lagoon
- The Vistula Lagoon budget depends on the inflow of sea water (15-18 km^3 per year)
- Freshwater: catchment runoff (4.97 km^3 / year), rainfall (0.55 km^3 / year), evaporation (0.53 km^3 / year loss)
- The total outflow from the Vistula Lagoon to the sea is estimated at 23.69 km^3 per year
- The balance is completed by the flow of groundwater

Water budget of the Vistula Lagoon



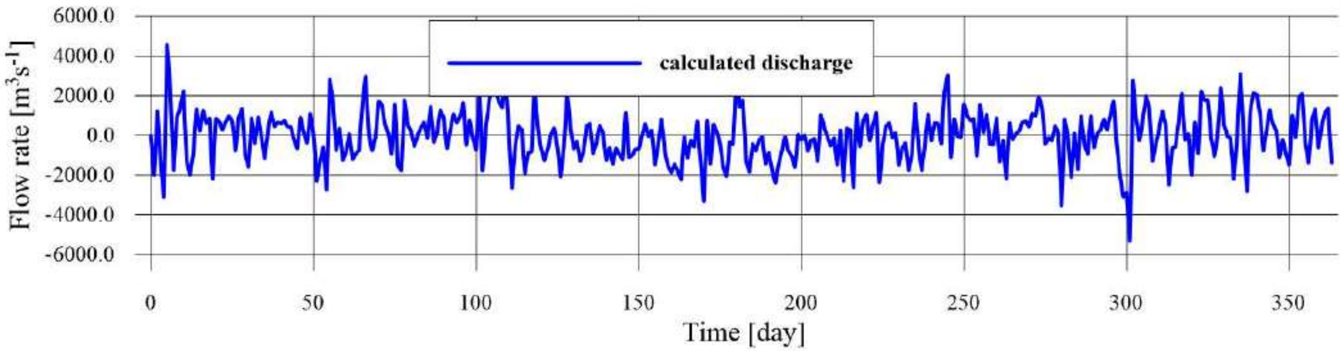
- Cieśliński R, Chlost I (2017) Water balance characteristics of the Vistula Lagoon coastal area along the southern Baltic Sea. Baltica 30 (2), 107-117
- doi: 10.5200/baltica.2017.30.12

Numerical estimation of water exchange through the Strait of Baltyjsk



The hydrodynamic model was used to estimate the average annual balance of water exchanged between the Bay of Gdańsk and the Vistula Lagoon

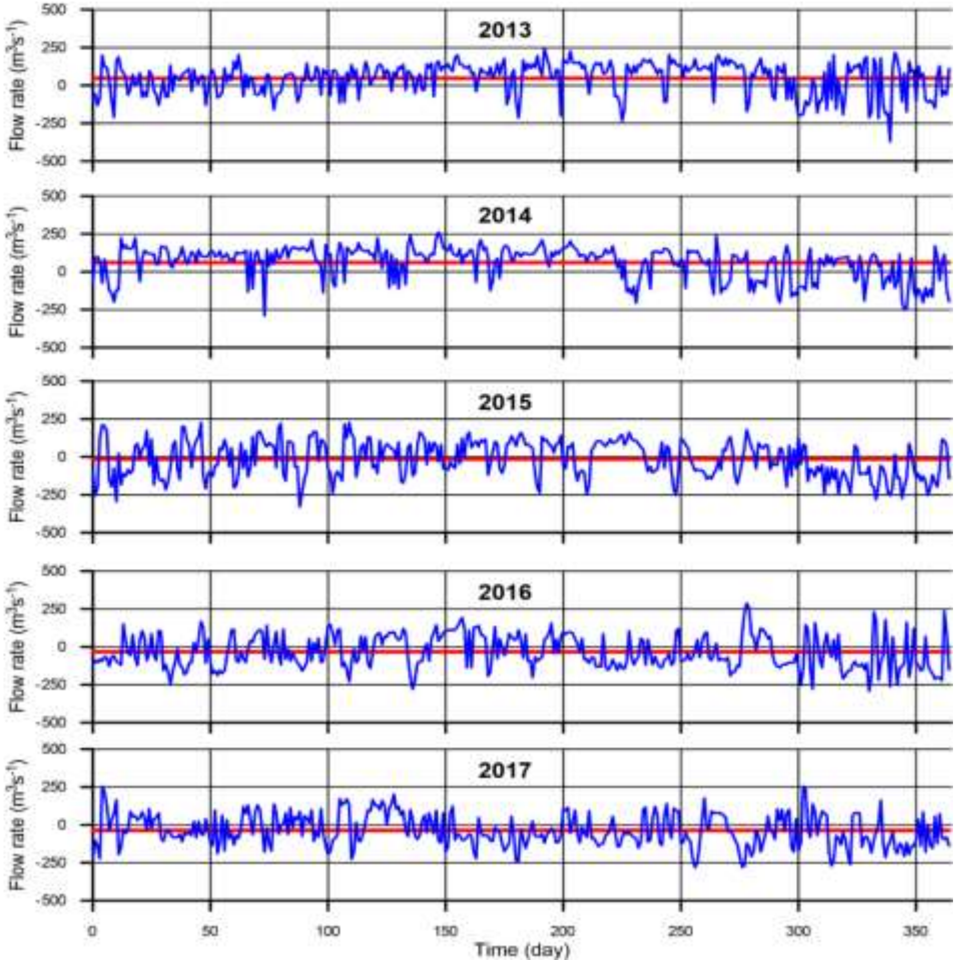
Numerical estimation of water exchange through the Strait of Baltyjsk



Value/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Annual accumulative inflow (km^3)	17.78	15.40	15.76	16.23	16.35	15.42	14.31	16.50	15.18	15.73
Annual accumulative outflow (km^3)	17.60	15.66	15.68	15.95	15.97	15.57	14.43	16.75	15.38	15.94

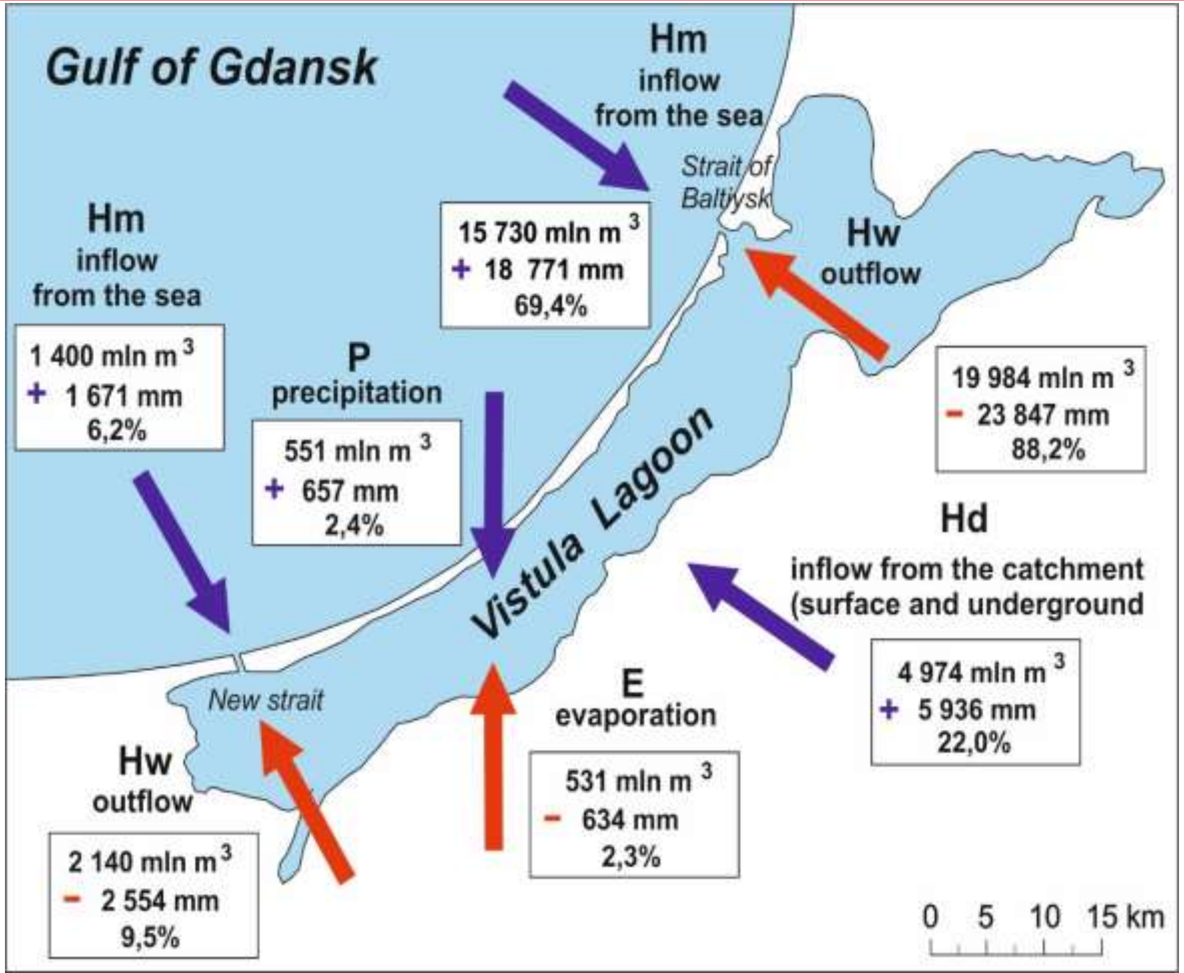
- The total annual (2017) inflow to the lagoon was 15.73 km^3
- The total annual runoff from the lagoon with a volume of 15.94 km^3

Numerical estimation of water exchange through the Nowy Świat ship canal with open lock



- **Relation ($Q = 500\ H^{0.5}$) was assumed to calculate the flow rate in the navigable channel for both flow directions.**
- **It was found that if the Nowy Świat canal is fully open, annual water inflow from the sea via this canal for the period 2008-2017 would be approximately equal to 1.4 km^3, while outflow to the sea would be equal 2.14 km^3.**

Improved water budget of the Vistula Lagoon



- **Cieśliński R, Chlost I, Szydłowski M (2024) Impact of new, navigable channel through the Vistula Spit on the hydrologic balance of the Vistula Lagoon (Baltic Sea)**
- **Journal of Marine Systems**
- **https://doi.org/10.1016/j.jmarsys.2023.103908**

Presentation based on reserach in period 2018-2022

- **Szydłowski M**, Kolerski T, Zima P (2019) Impact of the Artificial Strait in the Vistula Spit on the Hydrodynamics of the Vistula Lagoon (Baltic Sea), Water, 11 (5), 990, doi: 10.3390/w11050990
- **Szydłowski M**, Kolerski T (2020) Hydrodynamic model of the new waterway through the Vistula Spit, Polish Maritime Research, 27, 159-167. doi: 10.2478/pomr-2020-0057
- **Szydłowski M** (2020) Numerical Simulation of Annual Sea Water Exchange in the Vistula Lagoon through the Strait of Baltiysk (Baltic Sea) in: Proceedings of 6th IAHR Europe Congress the Hydro-environment research and engineering - no frames, no borders, Warsaw, Poland. Polish Academy of Sciences, 672–673
- **Szydłowski M**, Artichowicz W, Zima P (2021) Analysis of the Water Level Variation in the Polish Part of the Vistula Lagoon (Baltic Sea) and Estimation of Water Inflow and Outflow Transport through the Strait of Baltiysk in the Years 2008–2017, Water, 13 (10), 1328, doi: 10.3390/w13101328
- Cieśliński R, Chlost I, **Szydłowski M** (2024) Impact of new, navigable channel through the Vistula Spit on the hydrologic balance of the Vistula Lagoon (Baltic Sea), Journal of Marine Systems, 241, 2024, 103908, doi: 10.1016/j.jmarsys.2023.103908

What if it was possible to fully open the lock in the Nowy Świat canal?

The fully open canal could reduce the water level in Polish part of lagoon up to 0.3 m during the floods in Żuławy Elbląskie lowland.

Annual water inflow from the sea via this canal would be approximately equal to 1.4 km^3, while outflow to the sea would be equal 2.14 km^3.

Results showed that the new canal would not significantly change the water balance of the Vistula Lagoon, even if it is fully opened.

New canal could reduce water stagnation in the southern part of the reservoir.

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HISTORY IS WISDOM
FUTURE IS CHALLENGE