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Preliminary study on icebreaking operation on the Middle and Lower Odra River

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The Odra-Vistula Flood Management Project (OVFMP) is implemented with the assistance of international financial institutions, including the International Bank for Reconstruction and Development and the Council of Europe Development Bank, as well as with the support of funding from the Cohesion Fund and the state budget. Aside from others, the objective of the OVFMP is to increase flood protection for people living in selected areas of the Odra and Upper Vistula basins. The Odra-Vistula Flood Management Project consists of 5 components. In this paper the Component 1, Flood protection of the Middle and Lower Odra River will be discussed.
This component aims to enhance protection against summer floods and winter floods to the cities and smaller towns located along the Odra River. The activities will include, among others, the (re)construction of dikes and other bank protective works, dredging of the Odra riverbed and its channels, river training works, and the reconstruction of spur dikes. All mentioned works will be carried out to ensure the safety of icebreaking operation which requires sufficient depth over the entire river course. Five bridges also need to be raised to facilitate safe passage of icebreakers.
Within Lower and Middle Odra River the most significant flood risk is posed, in winter conditions, by ice jams created when flowing ice is stopped by existing obstacles such as shallow areas in the riverbed, narrowing of the riverbed and other obstacles caused by a result of sudden changes of the river current, backwater from sea waters and northern winds, which contribute to creation of ice jams (Lower Odra River runs a typically meridional course). This in turn causes damming of water and flooding of adjacent areas. The main aim of proposed tasks is to reduce possibility of creation of ice jams and to enable icebreaking which is the most efficient tool for minimizing risks of winter floods. These tasks will ensure safe passage of ice down the river and at the same time reduction of flood risk to adjacent areas.

1. Introduction

Ensuring and improving flood protection is one of the most important factors determining sustainable and stable social and economic development of regions and countries. Odra-Vistula Flood Management Project (OVFMP) assumes the implementation of the most urgent tasks in the field of flood protection within selected parts of river basins of the two largest Polish rivers, the Vistula River and the Odra River (Sweco 2017)

The project includes various activities carried out within the vast section of the Odra River with total length of approx. 440 km (within: Lower and Middle Odra River). All the work necessary for implementation are: (1) flood protection of areas in Zachodniopomorskie Voivodeship, (2) Flood protection on the Middle and Lower Odra, and (3) Flood protection of Słubice city (PCU 2015). The first and last tasks are mainly focusing on construction and modernization of existing embankments of the river, in order to increase security of adjacent areas, as well as works aimed at improving flow conditions for flood waters in the area between the embankments. Works planned for implementation in second task will result in improvement river conveyance for water and ice runoff during the spring or mid-winter breakup to reduce the ice jam flood risk. It is mainly focused on enabling operation of icebreakers on a long section of the river, which required ensuring of the river depth to the class III of the regional waterway which will allow navigation of the vessels with maximum draught 1,6-2,0 m (UNCE 2012). In addition, five bridges need to be raised to facilitate safe passage of the icebreakers underneath including but not limited to bridges shown on Figure 1(a) (Kreft, 2011).

2. Ice condition on the Odra River

The channel of the Oder River was regulated in early 19th century with corrections made in 1924-1941. River engineering works mainly concerned the use of a system of spurs located on both river banks for the so called low water level, however the efforts have never been completed. Currently the crowns, heads and main bodies of the structures are damaged to a varying extent, and a number of erosion potholes are found between the spurs (Kreft, Parzonka 2007). Despite significant alterations made to the riverbed, resulting from adjusting Odra River to the function of a waterway in the last centuries, the Valley maintained typical features of a large lowland river. The river source is in the Sudety Mountains and the mouth of the Odra is at the Baltic Sea, via Dąbie Lake and Szczecin Bay (Figure 1).

Ice phenomena on the Odra River are observed every season with some exceptions. Typically the first ice occur on Lake Dąbie, where static cover is formed during the due to low water velocity. If condition are suitable, frazil ice will be formed in the Odra River, which travels downstream and accumulate on the existing cover on Dąbie Lake. Thermal simulation of the ice cover formation on lake Dąbie have been proceeded to show the possible extend of the static ice cover. Air temperature recorded in February and March 2018 was used for the simulation. Water discharge is not observed on the East Odra or Regalica River (main inflow to the Lake Dabie – see Figure 1a) therefore typical flow conditions were used (low flow Q = 300 m^3/s and average flow Q = 575 m^3/s – data from Kundzewicz at al. 1999). Simulation results shown, that the static ice covers nearly entire lake. It leads to conclusion that for regular winter season ice cover will initiate at the Lake Dąbie and it will progress upstream through the accumulation of incoming surface ice. The progress of the dynamic ice cover is imitated by the stability conditions at the leading edge of the cover. In last decades, the maximum extend of equilibrium cover rarely reached Kostrzyń (Warta River outlet – Figure 1) or Słubice.

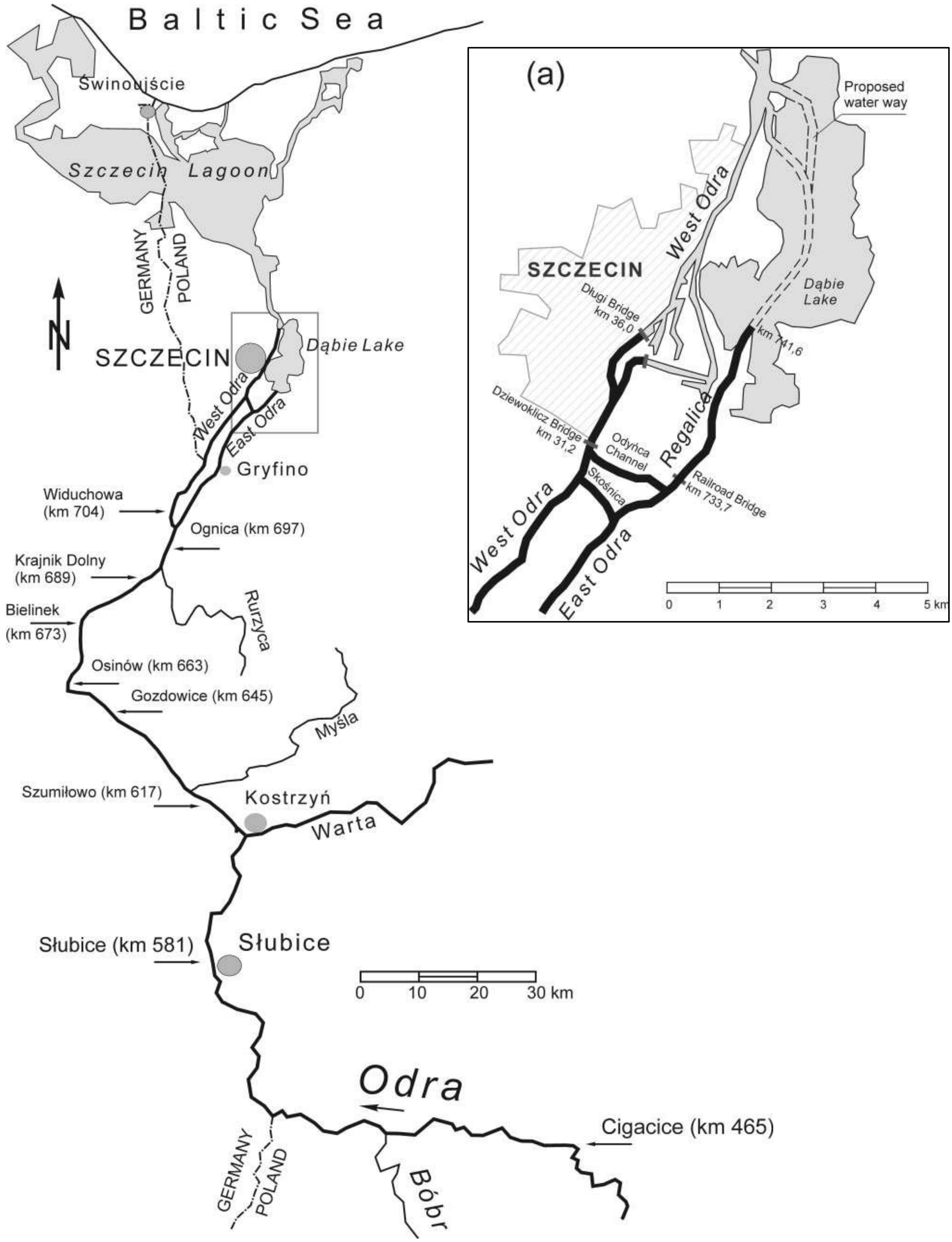

Fig. 1. Odra River in its lower and Middle section, (arrows indicate ice jam prone locations with river millage) together with a detail of the Szczecin Water Junction and lake Dąbie (a).

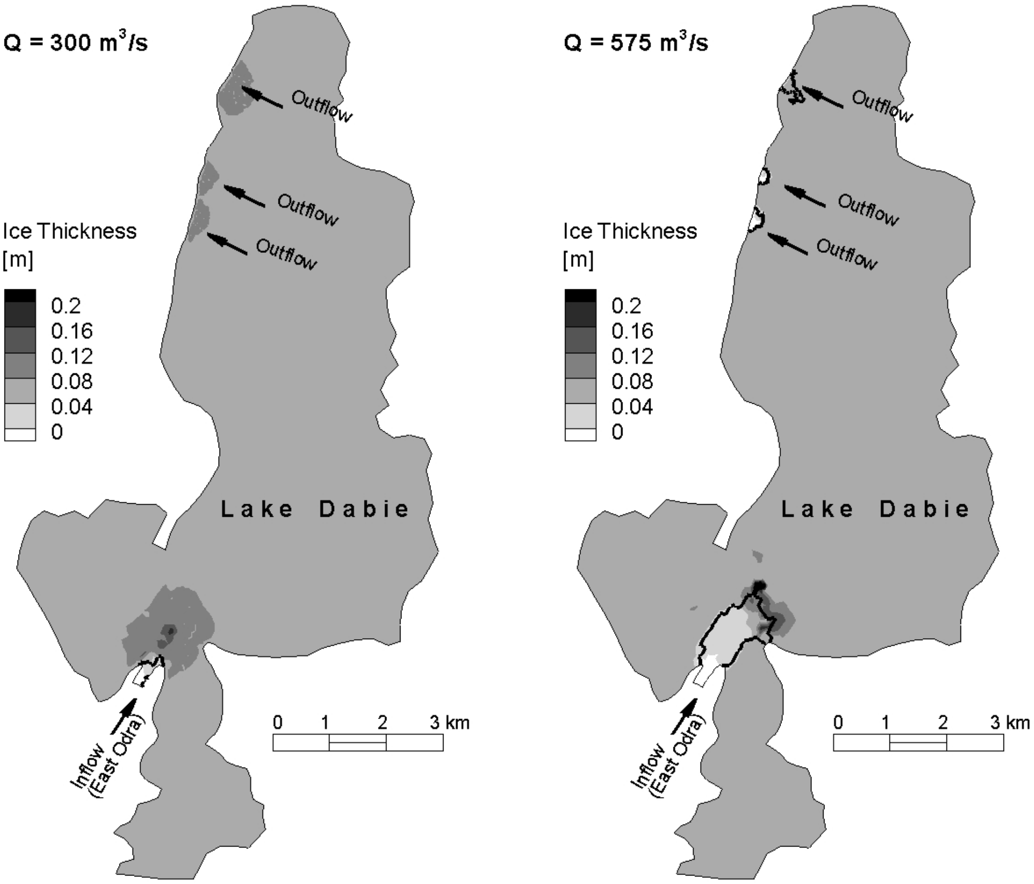

Fig. 2. Ice cover extend (black line) and thickness for air temperature data from February- Mach 2018, and variable water discharge

Ice formation and breakup on the Odra River may lead to severe jamming situations, which results for instance from the bad technical condition of river engineering structures and from years of neglect in water management. The situation is further amplified by hydraulic characteristic of the flow in the Lower Odra River which is strongly affected by hi water level on the Baltic Sea. Sea water set up together with northern wind is causing extensive backwater with effect observed up to Warta outlet (about 200 km). Locations of ice jam prone sections of the river were indicated on the map presented on Figure 1. In the paper two ice jam prone locations are analyzed: the border river section (km 571-586) in the vicinity of the Słubice and the sharp band on the Middle Odra near Cigacice (km 466-468).

2. Icebreaking operation

Numbers of possible ice breaking operations are available, however from technical and economical point of view the most reliable on the Odra River is to use specially designed vessels called icebreakers. To allow safe icebreaking operation the ship's power must be sufficient and the hull must have specific shape and be strengthened to withstand the ice load. Currently, there is a joint effort from German and Polish sides to relief winter flood risk by using 20 icebreakers.

Majority of the vessels are old and even though the fleet was recently updated by 4 new ships the average age of Polish icebreakers is 27 years and German is 44 years. Icebreaking operation is completed nearly every season, starting from lake Dąbie and continue upstream to release all ice jams on the Lower and Middle river sections. For the estuarine section of the East Odra, the ice could be additionally melted by using warm water, a coolant in the thermal power plant Grifice. The main obstacles for icebreakers in the Lower Odra are the bridges which in many cases have not enough clearance. In case of increased water level due to the ice jam the vertical clearance is too little for icebreakers to pass it safety. On the Middle Odra the biggest issue hampering the safe operation are the river depths, which may not exceed 1,0 m. To operate efficiently in Odra the icebreaker must have draught of about 1,8 m which is related to its horsepower required to break ice cover of thickness up to 30 cm (single floes) and exceeding 2 in case of ice jam.
Part of the project was proceeded to evaluate a "zero action" approach for the Odra, and to analyze the flood safety as a consequence of rejection of any further river engineering works. Those who support the continuation of the Odra River modernization maintain that building a river walls, longitudinal dykes with crosspieces on concave curves and in the passages between the curves, and spurs on convex banks is the best solution to the problem however not permanent. Opponents of the idea point to the fact that Western countries have ceased building dams and river engineering structures on lowland rivers. They claim that construction of other engineering structures would destroy naturally valuable areas, reserves, and Natura 2000 sites of conservation. Therefore it was desirable to recognize the ice condition in Lower and Middle Odra River in current state of the river bathymetry, and pointed out the possible problems related to winter water management and icebreaking operation.

3. Ice transport in the Słubice region (Lower Odra, km 571-586, Poland-Germany border)

Among others, the Lower River section in the vicinity of Słubice – Frankfurt is under constant surveillance due to its high risk of possible ice jam and flooding both cites in consequence. The main reason for hampering the ice flow is a bridge and longitudinal dyke narrowing the river to about 50% of its regular width. This leads to ice contraction and possible stoppage which may occur in case of high concentration of incoming ice. To check the ice condition in the vicinity of Słubice-Frankfurt bridge, mathematical model of 5 km of Odra River was build up to simulate ice run in the typical winter conditions. DynaRICE model was used as the most reliable and allowing simulation of dynamic balance between ice dynamics and river hydrodynamics (Shen 2010). The model was widely tested and successfully applied to number of domains including St. Clair River (Kolerski and Shen 2015) or Vistula River (Kolerski 2014). Boundary conditions for river hydrodynamics were set to represent flow conditions observed during core winter months. The data from Słubice gauging station were analyzed where daily water surface elevation is recorded. The station has also some ice thickness observations; however is mostly quantitative information of ice type. Detailed river bathymetry and the shoreline data were also used for the study. Simulation results for low flow condition and ice inflow of concentration 0,4 and initial thickness of 0,2 m were presented on Figure 3 in form of counter plot of ice thickness. Simulated results showed very fast process of ice accumulation and jamming which initiate at the bridge cross section and developed quickly upstream reaching the domain boundary after 24 hours.

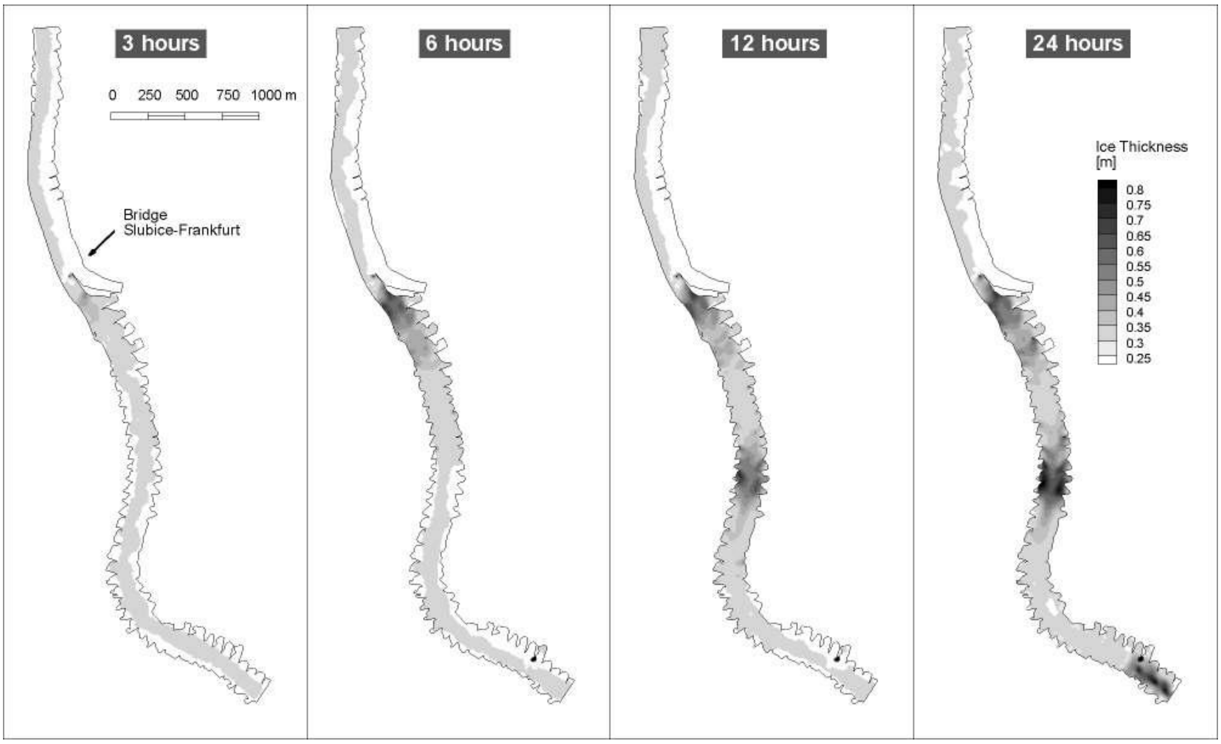

Fig. 3. Simulated ice thickness distribution in the Lower Odra River in the vicinity of the Słubice-Frankfurt bridge (km 551-586)

The simulated results were representative to the situation observed during the freeze-up as well as breakup operation. Mechanical breakup is proceeded in such way that icebreakers forming the ice free channel to release ice and water stored in the jams. Next the channel should be cleaned and widen to allow any additional ice to pass downstream without stoppage. Since the cross section near Słubice is significant river narrowing the ice could naturally accumulated there, which was confirmed by the numerical simulation. The model results shown that the process of ice accumulation will be very fast and if not released will lead to nearly 1,0 m jam. This ice formation if created downstream form operating icebreaker may be severe obstacle causing dangerous situation. To release ice jam with thickness up to 1 m and the range of about 3 km will require using icebreakers with significant horsepower. Since the horsepower of the icebreaker is related to its hull shape and draught, the river must have parameters allowing the large ship to operate safe. It leads to conclusion that to satisfy safety requirement on the Lower Odra, it modernization is needed. It could also be concluded to make use of those existing structures which are in a good condition to the extent possible.

4. Ice transport on the Middle Odra (Cigacice case, km 466-468)

The next simulation was proceed in the sharp river band on the Middle Odra where spur dikes on both river banks exists. The spurs as river training structures were built to enhance navigation and protect erodible banks but they origin form first river regulation (mid of the XIX century) and are in bad shape mostly. Existence of these structures affects intense vortex action which is set up at the streamward end of a spur dike. Intermittent vortices of lesser strength occur along both upstream and downstream face of the dike. This turbulence causes the bed material to be suspended causing scour hole that develops around the spur dike with extend determined by the

bed material's angle of response. Analyzing bed bathymetry extensive souring is visible on the concave bank of the bank and the river depth varies significantly along the thalweg.
Mathematical model was set up on the 2 km section of the river upstream of the gauging station Cigacice. For hydrodynamic boundary condition water discharge representing low flow condition was set up ($Q = 84\ m^3/s$). In addition western wind with velocity of 10 m/s was simulated to study the effect of ice drifting towards the left, shallow bank of the river. Ice was supply at the model upstream with concentration of 0,3 and initial thickness of 0,2 m.
Simulation results showed that ice has tend to move close to nose of the spur dikes on the concave bank, where depths varies significantly (0,5 – 4,0 m) due to erosion and accumulation caused by the river training structures. In some locations ice settle on the river bottom causing anchored jam. Due to the western wind action, ice is pushed towards left bank, where is stopped on extensive shoals.
Icebreaking operation on The Middle Odra River must proceed continuously along both river banks. In case of ice stopped at the shallow part of the river its release may be impossible due to insufficient depth for the ships. In order to satisfy flood prevention during winter season Middle Odra must be regulated to satisfy required depth of about 2 m.

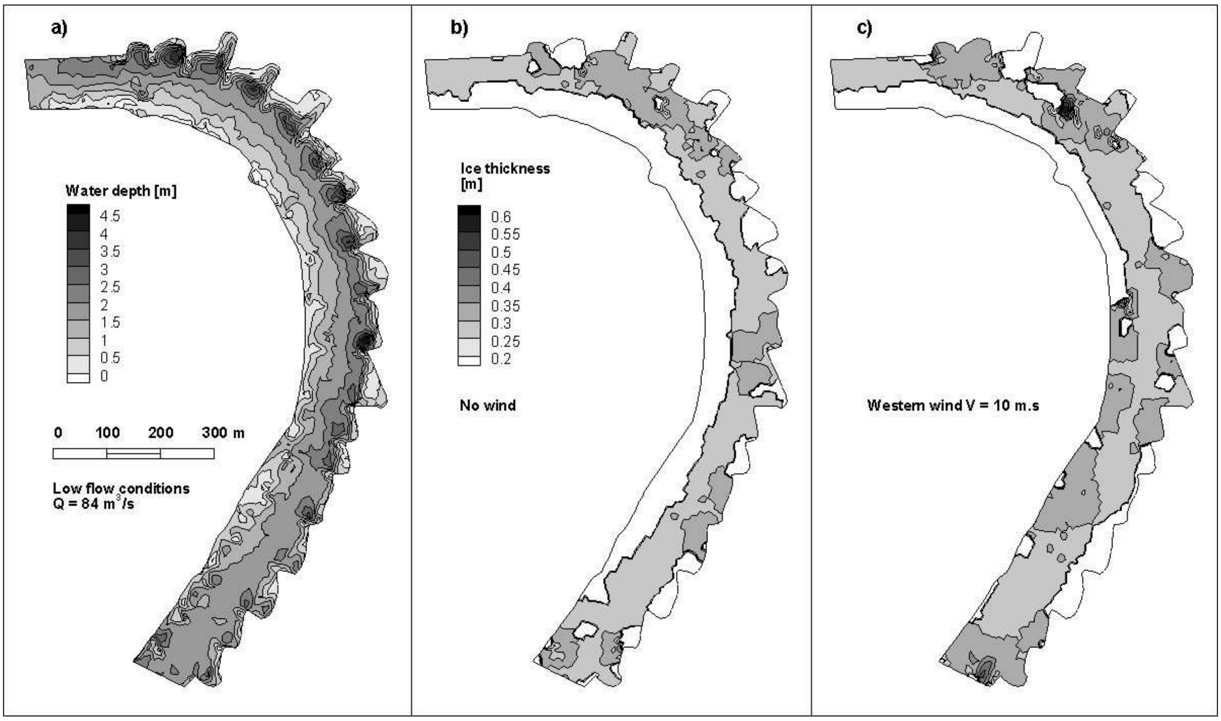

Fig. 3. Simulated water depth (a) ice thickness distribution (b) and ice thicnkess distributin with western wind (c) in the Middle Odra River near the Cigacice gauging station (km 466-468), for low flow conditions

Sumary

Concluding the practical experience of employees Water Resources Board in Szczecin (Kreft, 2011), and quantitative results of mathematical modeling presented above it must be said that icebreakers in the Odra River facing harsh ice conditions. It means that their power must be adequate and the design draught may not be less than 1,8 m. Opponents of river regulation claimed that similar to Danube or Elbe river vessels may be used in Odra, however on mentioned rivers ice jams occur occasionally and the thickness and range of historical jams were relatively small. It must be emphasized that ice conditions and parameters are side specific and cannot be directly transferred from other climatic zones to Polish rivers. It is important to study and describe qualitatively and quantitatively local ice condition on the Odra River. It could be done by implementation both, empirical and analytical approaches which must be well referred to historical observations. Based on results received from the ice research on the Odra River adequate technical solutions may be proposed. Results of above study confirmed the technical parameters of icebreakers to be used in the Odra River.

Acknowledgments
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