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NUMERICAL MODELING OF TRANSPORT OF THERMAL POLLUTION IN A RIVER – CASE STUDY

Monika B. Kalinowska¹, Paweł M. Rowiński² and Artur Magnuszewski³

The paper proposes a modeling technique for the simulation of an anticipated heated water jet that is planned to be continuously released in the lowland, urban part of the Vistula River in Poland after an existing thermal-electric power plant is reconstructed. Given reach of the Vistula River has semi natural braided channel geometry and is protected by Nature 2000 protocol. The cooling water discharges and particularly their localization are being designed to minimize the anticipated heat effects on local fish communities and the proposed model is supposed to aid this designing strategy. Since the created thermal pollution may eventually cause a thermal shock, changes in dissolved oxygen, and consequently the redistribution of organisms in the local community, methods to minimize those environmental threats are of crucial importance.

Different variants of warm water release with constant intensity of 9 m³/s have been analyzed. The temperature of discharge water was 8 °C higher than the temperature of ambient river water but did not exceed the temperature of 35 °C (the limit imposed by Polish law). Since we must take into account the extreme conditions, the computations have been done for the mean low-flows of the river $Q = 200 \text{ m}^3/\text{s}$. Additionally the calculations have been performed for the lowest possible value of the flow $Q = 100 \text{ m}^3/\text{s}$. The values have been determined on the basis on the longstanding observations. The results of the computed temperature distributions, for the selected case for the summer period (average temperature of natural water in summer in the analyzed region of the river is 22.7 °C) have been presented in Fig. 1. The used two-dimensional computational models are based upon Reynolds-averaged Navier-Stokes equations for simulations of the velocity field (CCHE2D model) and the depth-averaged heat transport equation in which a non-diagonal dispersion tensor with four dispersion coefficients is taken into account (RivMix model). This method is aimed to arrive at a quantitative prediction of the thermal plume properties in the so-called mid-field region, i.e. until the heated and ambient water are fully mixed within a cross-section. The RivMix (River Mixing Model) – the two-dimensional numerical model – has been developed at the Institute of Geophysics of the Polish Academy of Sciences (Kalinowska & Rowiński, 2007, 2008). The CCHE2D, developed by NCCHE – National Center for Computational Hydrosience and Engineering is the two-dimensional depth-averaged, unsteady turbulent open channel flow model (Altinakar et al., 2005; Ye & McCorquodale, 1997; Jia & Wang, 2001).

The proposed methodology appears to be reasonably accurate and robust but still bringing numerous problems particularly due to insufficient measuring data. Problems begin when defining the geometry of the river, other problems arise from the limitations of the models used (even the best models are only approximations of reality). It is not easy to determine all the relevant coefficients appearing in the solved equations, such as e.g. dispersion coefficients, therefore the used simplifications are another source of errors. Those problems, influencing both the resulting

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velocity field and water temperature distributions are crucial in the presented study. Numerical diffusion and numerical dispersion, instability and the limitations of computation time have been also under investigation.

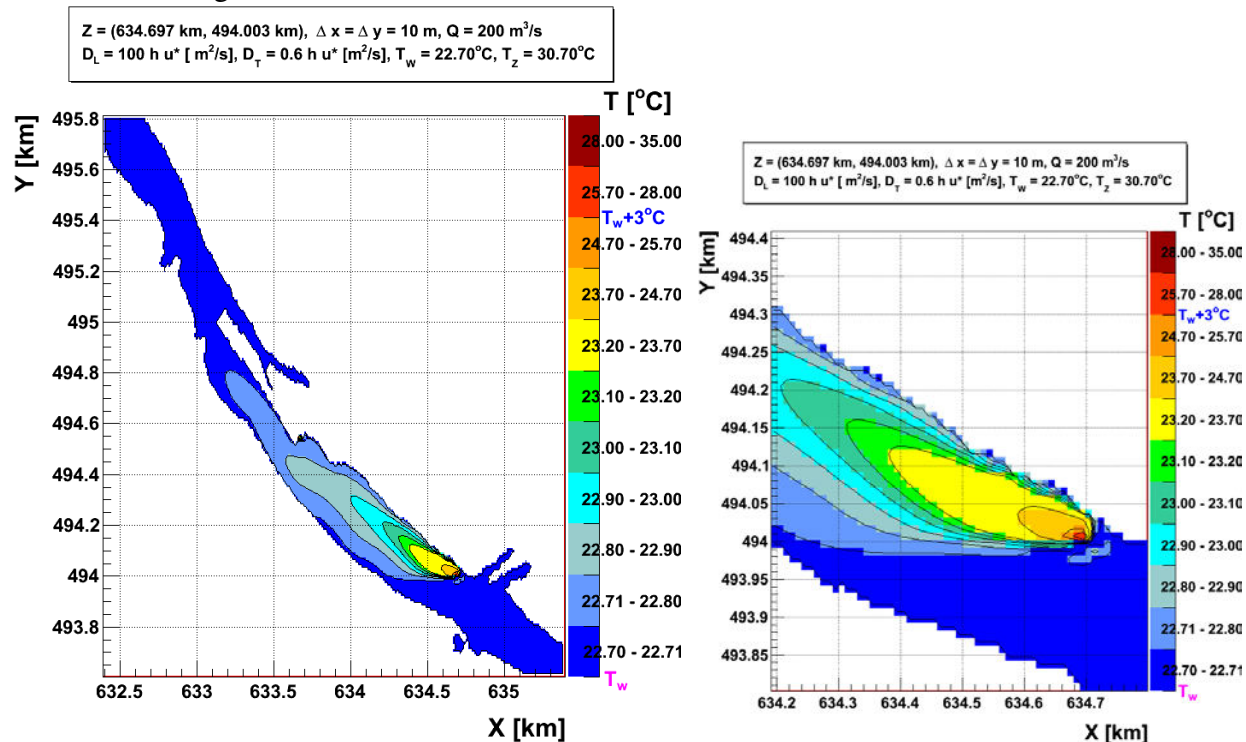


Figure 1 Predicted two-dimensional temperature distribution in case of continuous discharge of 9 m³/s of warm water at point $Z = (634.697 \text{ km}, 494.003 \text{ km})$ in the summer time for the average ambient water temperature $T_w = 22.7^\circ\text{C}$ and $Q = 200 \text{ m}^3/\text{s}$. Left plot – the whole considered reach of Vistula River; right plot – the zoomed discharge area. T_Z denotes the water temperature at discharge point Z , h is the water depth, u^* is the shear velocity, D_L and D_T are longitudinal and transverse dispersion coefficients, Δx and Δy denote the computational grid spacing.

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