LES SIMULATION OF CONTAMINANT REMOVAL FROM THE EMBAYMENT AREA BETWEEN TWO VERTICAL GROYNES IN A CHANNEL

ANDREW MCCOY[1], GEORGE CONSTANTINESCU[2] and LARRY WEBER[3]

[1] Civil & Environmental Engineering, IIHR-Hydroscience and Engineering,
The University of Iowa, Stanley Hydraulics Laboratory, Iowa City, IA 52242
(Tel: +319-335-5597, Fax: +319-335-5238, e-mail: andrew-mccoy@uiowa.edu)
[2] Civil & Environmental Engineering, IIHR-Hydroscience and Engineering,
The University of Iowa, Stanley Hydraulics Laboratory, Iowa City, IA 52242
(Tel: +319-335-5597, Fax: +319-335-5238, e-mail: sconstan@engineering.uiowa.edu)
[3] Civil & Environmental Engineering, Director, IIHR-Hydroscience and Engineering,
The University of Iowa, Stanley Hydraulics Laboratory, Iowa City, IA 52242
(Tel: +319-335-5597, Fax: +319-335-5238, e-mail: larry-weber@uiowa.edu)

The flow around two spanwise vertical obstructions in an open channel mounted on one of the lateral channel walls is investigated using Large Eddy Simulation. The upstream flow is fully turbulent and the obstructed area represents 17% of the total channel section. The focus of the present paper is to examine the mass transfer between the pollutant situated initially in the groyne area (embayment) and the main channel. A more compete description of the simulation setup is included in previous work [1] that also focused on the description of the horseshoe vortex system that forms at the base of the upstream obstruction. There is substantial experimental evidence [2,3] that the detached shear layer and its interaction with eddies inside the embayment is controlling the mass exchange between the groyne area and the main channel. The mass transfer is simulated using a passive (conserved) scalar transport equation. The evolution of the concentration field in time illustrates the dispersion process of the pollutant cloud as it is convected downstream of the groyne area. The vortical structures that populate the detached shear layer and their interaction with the recirculation eddies inside the embayment area and with eddies originating at the tip of the downstream obstruction that entrain fluid from the region downstream of the second groyne inside the embayment are shown to play an important role in the pollutant entrainment from the groyne area into the main channel. The LES simulation also allowed a detailed quantification of the non-uniformity of the exchange process over the depth of the embayment. The analysis of the variation of the pollutant fluxes in the top, middle and bottom layers inside the embayment region allowed to better understand how the pollutant exits the groyne area. The decay of pollutant within the embayment was quantified enabling calculation of a global 1D exchange coefficient, k, based on dead-zone theory. It was found that the exchange process is not characterized by a unique value of the exchange coefficient. Rather two distinct phases of the decay process were identified. In the initial phase of decay over which about 68% of the total mass of pollutant leaves the embayment, the exchange coefficient was found to be about twice the value recorded for the final phase.

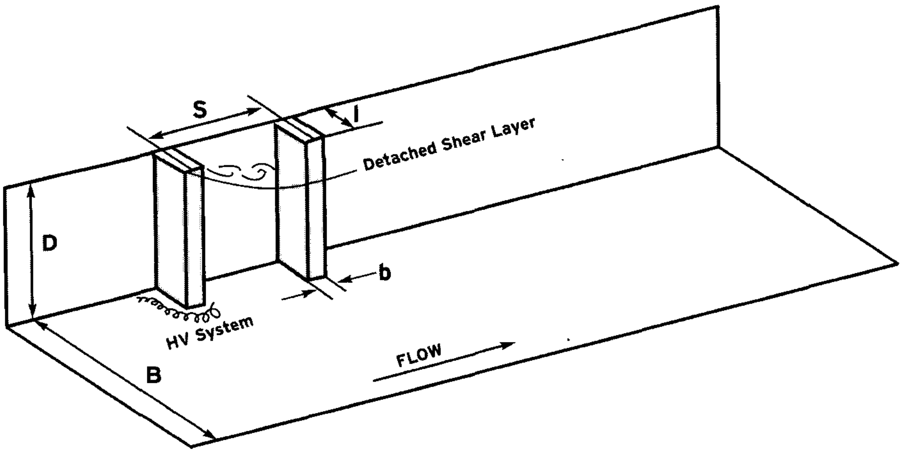

Fig. 1 General sketch of flow in a channel with two lateral obstructions

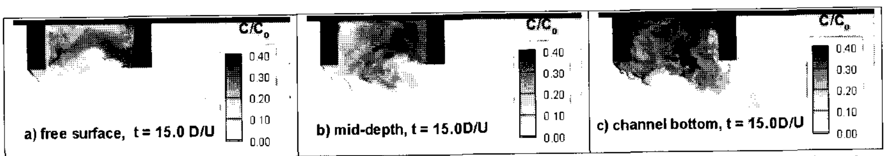

Fig. 2 Instantaneous contours of passive scalar concentration at different levels in embayment and channel at t=15D/U; a) free surface (h/D = 1.0); b) mid-depth (h/D = 0.5); c) close to channel bottom (h/D = 0.1).

REFERENCES

McCoy, A., Constantinescu, S.G., and Weber, L., 2004, Coherent Structures and Mass Exchange Processes in Channel Flow with Spanwise Obstructions, Proceedings of ETMM6 Ercoftac Conference

Weitbrecht, V., Uijttewaal, W. and Jirka, G.H., 2003, 2D Particle Tracking to Determine Transport Characteristics in Rivers with Dead Zones, Proceedings Int. Symp. Shallow Flows, Delft, The Netherlánds, 2,pp. 103-110.

Uijttewaal, W., Lehmann, D., van Mazijk, A.,2001, Exchange Processes Between a River and Its Groyne Fields: Model Experiments, Journal of Hydraulic Engineering, 127:11, pp. 928-936