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Editorial

Flow Hydrodynamic in Open Channels: A Constantly Evolving Topic

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1. Introduction

Streams and riverbeds are subject to considerable hydromorphological alterations due to the interaction of their flow with natural or man-made structures found throughout them, i.e., natural vegetation, grade control structures, piers and abutments, discharge/suction systems, seepage, and movable/fixed boundaries. Flow interactions with natural or artificial obstacles lead to the development of complex hydrodynamic structures, which require further studies in order to fully understand them. Thanks to advances in technological devices (i.e., sensors and software), the measurements and numerical modeling of turbulent flows become both easier to conduct and more accurate, giving rise to a better understanding of complex flow dynamics. The significant number of studies conducted on open channel flows certainly helps readers to understand the turbulent flow involved in open channels, as well as to apply this understanding to the design and practice of hydraulic engineering and river management.

Many previous studies have extensively investigated flow dynamics in open channels and their interactions with cross-sectional features. Some, for example, focused on the vegetation effects on flow structures (e.g., [1–9]), characterizing the flow evolution process in vegetated channels. Several studies focused on how to predict the flow discharge in open channels of different cross-sectional shapes (e.g., [10–14]). Others have dealt with estuaries, the interconnection dynamics between rivers and seas, and the relative transport processes of sediment, pollutants, nutrients, and many other substances (e.g., [15–20]). The presence of natural or man-made structures on riverbeds, i.e., natural vegetation, riverbed debris, sills, weirs, sluice gates, spillways, spur dikes, bridge piers, abutments, etc., produce additional complex effects on the flow hydrodynamic characteristics, affecting riverbed evolution and causing scouring processes. Many studies have been conducted on this topic, especially on scour development at hydraulic structures (e.g., [21–28]). Many other studies (e.g., [29–36]) have looked at flow hydrodynamic structures in open channels, i.e., current distributions, turbulence properties, vortex structures, shear/boundary layer development, hydraulic jumps, discharge of turbulent jets and mixing processes, etc.

Despite the numerous studies that have been conducted in recent decades on open channel flows, many aspects still need to be improved. The availability of sophisticated experimental tools, theoretical methods, large data storage, and the high capacity of computers has added many new dimensions to the study of open channel flows. To summarize the results of several previous studies, to improve or propose new and more accurate predictors of many characteristic parameters, and to encourage the development of further knowledge in the field of open channel flows, this Special Issue (SI) has been proposed.

The SI, entitled "Flow Hydrodynamic in Open Channels: Interaction with Natural or Man-Made Structures", comprises eleven original articles [37–47] and two reviews [48,49] on flow hydrodynamic structures in open channel flows.

The next section presents a short descriptive summary of each manuscript.

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2. Short Descriptive Summary of the Different Manuscripts

In [37], the authors dealt with understanding the hydraulic characteristics of lateral deflectors with different geometries in gentle-slope free-surface tunnels. Indicating their great importance for many engineering applications, such as in gentle-slope tunnels of high dams, in this study, the authors analyzed the results of both experimental and numerical modeling of two new deflector geometries. The hydraulic characteristics of the newly designed deflectors and the traditional triangular deflector were analyzed and compared. Particular attention was focused on the flow pattern improvement and the energy dissipation characteristics of the three deflectors.

Estuaries are one of the most important interconnections between land and sea; they are often important areas for leisure and economic activities. Estuaries are also ecosystems which are highly vulnerable to human impacts and environmental change; thus, they must be adequately preserved. In [38], the authors attempted to comprehend the hydrodynamic impact of waves on a river estuary in a case study of the Oued Sebou on Morocco's north Atlantic coast. Specifically, the study focused on the dredging effect (caused by sand extraction) on the wave motion and its impact on the estuary environment. Different scenarios of wave-propagation simulations were carried out, using different significant wave heights and considering bathymetry both before and after two dredging cases of 2 and 4 m depths.

In [39], the authors carried out field measurements in a river estuary, a case study of the Kampar River estuary in Indonesia, to determine the real-time properties of tidal bore generation, hydraulic jump, and transport mechanisms. Using a least-square-based tidal model, the tidal harmonic and its range were analyzed. The tidal bore's hydraulic jump properties were determined using survey datasets of the height and flow velocities of the tidal bore in the estuary. In addition, an acoustic-based approach was employed to quantify the suspended sediment concentration and flux during the passage of the tidal bore.

In [40], the authors were interested in the impact of long waves on hydraulic structures, such as bridge piers. An experimental study was carried out on the propagation of two different long waves, released on a steady current, and their interactions with a bottom-mounted rigid emergent cylinder. The flow velocity fields around the emergent cylinder were measured using a Particle Image Velocimetry (PIV) system, and the flow turbulence structures were analyzed. The measured data were also used to verify analytical theories or to approximate the methods that best predicted the flow properties generated by the wave–cylinder interaction.

In [41], the authors sought to solve the scouring problem at hydraulic structures. They specifically proposed a methodology to estimate the scour hazard, considering both the scour–fill interaction and the Monte Carlo simulation method. The general extreme value probability distribution was used to characterize the intensity of the scouring events. The lognormal distribution was used to characterize the sedimentation process (fill), and a homogeneous Poisson process was employed to forecast the occurrence of both the sedimentation and scouring events. Based on this approach, several histories of scour–fill depths were performed and used to develop time-dependent scour hazard curves. In this study, the authors proposed several hazard curves associated with different time intervals for a bridge located in Oaxaca, Mexico. The presented approach takes into account both missing data and outliers.

In [42], the authors aimed to experimentally investigate the effects of bed sediments on flow in a vegetated channel. Since in previous laboratory studies, most of the experiments were conducted in vegetated channels with smooth beds, the effect of bed sediment was certainly neglected. In this study, the authors focused on the bed roughness impact on the flow turbulence characteristics. A large experimental series was carried out in a vegetated channel composed of randomly arranged rigid emergent vegetation and beds with different sizes of uniform bed sediments. Based on flow velocity measurements, using an Acoustic Doppler Velocimeter (ADV) profiler, a refined analysis of the bed sediment impact on flow turbulence structures within vegetation arrays was performed.

In [43], the authors raised the problem of the complex mechanism of head loss in open channel flow and its accurate prediction. Unlike classic methods such as the Darcy–Weisbach equation, in this study, the authors proposed a new theoretical friction coefficient equation based on the entropy concept and hydraulic properties. The proposed equation was determined using different cross-section shapes of open channels, i.e., rectangular, trapezoidal, parabolic, round-bottomed triangle, and parabolic-bottomed triangle. To validate the proposed equation, the estimated values of friction coefficients were compared with the measured values for both the smooth and rough flow conditions. The author claimed that this new equation was able to calculate friction coefficients with very high accuracy, without the use of energy slopes.

In [44], the authors performed laboratory experiments and numerical simulations to investigate the flow-field structures in a curved channel. In a channel with a U-shaped cross-section and 180-degree curvature, extensive velocity measurements were carried out using an ADV at different cross-sections along the channel. The bed roughness effect was also considered, using sediment particles with different grain sizes. The primary current, turbulent kinetic energy, and turbulent bursting were analyzed in depth. Flow numerical simulations were also conducted using the Renormalization-Group (RNG) turbulence model in the FLOW-3D software. The bed roughness effects on the secondary current distribution were also provided.

Flow turbulence properties and secondary currents strongly affect the sediment transport processes, and, in turn, suspended particle motion influences flow turbulence, such as Reynolds shear stress and velocities. Since most previous studies on scouring processes did not consider secondary currents, in [45], the authors attempted to investigate the generation and turbulence properties of secondary currents across a scour hole under equilibrium conditions. Based on comprehensive measurements of flow velocities, using an ADV, the development of secondary current cells was proven in a clear water equilibrium scour downstream of a grade control structure, in a channel with non-cohesive sediments. A detailed analysis of the turbulence intensities and Reynolds shear stresses was implemented and compared with previous studies. The results showed that the anisotropy term of normal stresses has exhibited significant magnitudes, dominating the other terms in the mean streamwise vorticity equation, which may reflect its potential effect in generating the secondary current motion in straight non-circular channel flows.

In [46], the authors presented the results of flume experiments conducted to investigate flow velocity and concentration distributions within debris bodies, using high-resolution images. The data analysis showed that the concentration and mobility of sediment grains vary according to depth. A linear law to interpret the grain concentration distribution, starting from the knowledge of the packing concentration and the surface concentration, Cs, was established. Based on this finding (linear law), the authors proposed modified expressions of Bagnold's number and velocity in stony-type debris flows. The use of these expressions led to the identification of three motion regimes along the depth, and the velocity profile within the debris body was determined as a function of the parameter Cs. The comparison of the predicted velocity profiles, determined using the modified equation, with measured profiles from the literature confirmed the credibility of the proposed approach.

In [47], the authors attempted to understand the erosion and deposition behaviors in meandering watercourses. A series of experiments were conducted in a sinuous channel in order to investigate both the bed morphological changes and the flow hydrodynamic structures. High-order velocity fluctuation moments were analyzed at the outer and inner banks to explain the morphological variations of the bed. The magnitude values of the flow velocity fluctuation moment, in both the outer and inner bend regions, were determined and related to the erosion rate. The authors claimed that the higher-order moments, in association with the morphological changes of the bed, contributed to a new approach that helped them to understand the flow turbulent characteristics of a meandering channel.

Recently, possibly due to climate change, extreme rainfall events have become more frequent, causing floods. These floods threaten the stability of many hydraulic structures due to significant scouring effects. Predicting scour dimensions of hydraulic structures continues to be a concern for engineers and researchers. In [48], the authors provided a comprehensive and relevant review of scour prediction at bridge piers. Several empirical methods from previous studies for predicting scour at bridge piers were reviewed and analyzed. A summary of relevant scour predictors was provided, which will be useful for practitioners. A discussion on future research directions that could contribute to the field was also proposed. Some recommendations for future research to improve the knowledge in this field were also proposed.

Finally, in [49], the authors provided an interesting review on the topic of vegetated channel flows. They particularly focused on the different methodologies and approaches used in previous studies to evaluate the resistance to flow caused by the presence of vegetation in open channels. Different expressions of the drag coefficient and Manning/Chézy coefficient were reviewed and analyzed for submerged and emergent, rigid, and flexible vegetation. Furthermore, new developments in the field of 3D numerical methods, currently used for the evaluation of the turbulence characteristics and the transport of sediments and pollutants, were also briefly reviewed. The authors also proposed several recommendations for future research to improve many aspects related to the characterization of hydrodynamic structures in vegetated channel flows.

3. Conclusions

This Special Issue consists of thirteen manuscripts relating to the topic of flow hydrodynamics in open channels. Various arguments are addressed herein, including flow interaction with hydraulic structures [37,40–42,45,48], flow dynamic in estuaries [38,39], flow–vegetation interactions [42,49], bed sediment effects on flow structures [42,43,45,46], and the effect of channel curvature on flow behaviors and sediment transport [44,47]. This Special Issue represents a significant contribution to the state of the art of the open channel flow fields, extending our knowledge and providing useful references for hydraulic engineers, experts, and those interested in the environment.

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