THE EFFECTS OF GEOMETRICAL FEATURES OF PUMPING STATIONS ON THE DOWNSTREAM DESIGN OF BED PROTECTION

Pumping stations fulfill an important function in the context of the Dutch water management system, as they are able to pump water from low level areas to higher areas. When a pumping station discharges in the adjacent water, large currents originate, inducing stresses near the bed. In Dutch waters, where the bed contains mainly sandy and clayey material, these stresses are likely to cause erosion of the bed material. In order to move the erosion away from the structure, a bed protection is often deployed downstream of the pumping station. The design of the dimensional characteristics of a bed protection is done with rather conservative design rules. These design rules are applicable on all hydraulic structures in waterways and do not explicitly take into account the individual effects of geometrical and hydraulic features of structures.

During an expert study, experts in the field of hydraulic engineering were asked to identify the geometrical and/or hydraulic features of pumping stations, which they think have a significant effect on the required bed protection dimensions. It can be concluded that the effects of (1) the angle of the valve preventing backflow and (2) the presence of multiple outlets are not clear to experts and need further investigation. In this context three case studies were done, carrying out measurements (using Acoustic Doppler Current Profiler equipment) and model studies (using Computational Fluid Dynamics) at three pumping stations. The measurements were mainly used for validation of the models. The best performing model was used to perform a sensitivity analysis, investigating the effect of the valve angle and the presence of multiple outlets.

The results of the sensitivity analysis show that the valve angle affects the maximum near bed velocity downstream of the structure, its location with respect to the outlet and the deceleration rate of the near bed velocity when moving away from the structure, significantly. When the valve angle is smaller (i.e. it is closing), the maximum velocity magnitude is higher, is located closer to the structure and decreases faster when moving away from the structure. This means a heavier sorting is needed close to the structure, although it can be deployed at a smaller distance behind the outlet. The effect of an additional outlet on the required bed protection dimensions is relatively small. During the research a required lengthening of the bed protection was found of approximately 20% with respect to a single outlet situation.

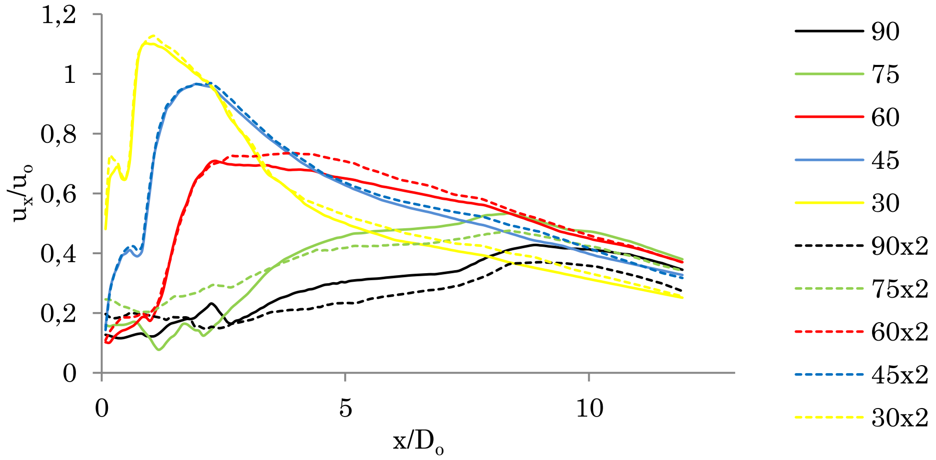

Figure 1: The dimensionless velocity profile downstream of the structure at different valve angles (90, 75, 60, 45 and 30) and different numbers of outlets (1 or 2). The dimensionless quantity u_x/u_o represents the velocity at a certain distance x from the structure with respect to the outlet velocity. x/D_o represents the distance with respect to the diameter of the outlet.

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