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LES Study of Meandering Flow in Streams Exhibiting Downstream Variation in Curvature

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Abstract

This paper presents a Large Eddy Simulation (LES)-based study of meandering flow. In agreement with the conditions present in natural streams, the channel centerline is idealized as a sine-generated curve, characterized by a downstream variation in curvature, and the stream width-to-depth ratio is large.

A typical feature of meandering streams is that their bed deforms by developing large-scale, laterally adjacent erosion pools and deposition bars (pool-bar complexes), which grow in amplitude until the equilibrium state is achieved. From laboratory and field studies, it has become clear that the location in flow plan of the pool-bar complexes, as well as their detailed geometry, strongly depend on the sinuosity of the stream as well as its width-to-depth ratio. Furthermore, the existing data, even if limited, strongly suggests that the geometry acquired by the bed can be largely explained on the basis of characteristics of the flow at the initial stages of bed development, when the bed is still nearly flat. That is, it seems that the "information" needed for a flow to subsequently generate its equilibrium deformed bed surface is already locked in the structure of the flow at its initial stage when the bed is still flat. Yet, very few studies have focused on the flow at initial stages of bed development and the studies that did so almost invariably considered the case of bends with constant radius of curvature and small width to-depth ratio.

Based on these considerations, in this paper LES is used to investigate the flow dynamics over the flat bed, representing the flow at the very early stages of the bed development. As study cases, we model the flow in two sine-generated channels having initial deflection angles of 45 and 95 degrees, respectively, and a width-to-depth ratio equal to 15. To capture the dynamics of the energetic eddies in flow a low-pass filter is applied to the velocity field to filter out the small scales of turbulence whose effect on the resolved field is parameterized through the use of a sub-grid scale (SGS) model. The LES algorithm uses a semi-implicit fractional step, accurate to second order both in time and space.

Analysis of the numerical results is carried out on the basis of both instantaneous and time-averaged velocity fields. In addition to providing an accurate description of the mean flow, this work enables the characterization of the cross-circulatory motion and the internal turbulence structure of the flows.

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