**Supplementary information**

2D representations of flow velocity

‘Cross-channel’

This method defines that the cross-stream flow and the downstream flow are the flow normal and parallel to the channel margins respectively (Corney et al., 2006; Islam and Imran, 2008; Parsons et al., 2010; Sumner et al., 2014). The transects in this work were designed to be normal to the channel axis (Figure S2). Therefore, velocity components that are parallel to the surveyed transects represent the cross-channel circulation, and the velocity components that are perpendicular to them correspond to the downstream circulation.

The baseline calculations above provide velocities parallel and perpendicular to each transect and therefore, no further calculations are required to obtain the cross-channel velocities according to this method (Figure S2).

‘Rozovskii’

This method is commonly used in river studies and states that the cross-stream flow is the circulation normal to the flow direction. The flow direction is calculated for each vertical flow profile as the averaged direction of the flow that permits a zero net circulation. Thus, the sum of the flow velocities towards the outer bend equals the sum of the flow velocities towards the inner bend in the vertical profile (Rozovskii, 1957; Parsons et al., 2007). The averaged direction of the flow is obtained from the mean of the components of the velocities at each measured depth. These components of the velocities include both measured velocities and interpolated velocities in the SLIA. The ‘*Rozovskii’* cross-stream flow is the circulation normal to the flow direction in each profile (Figure S2).

‘Zero net flow’

Similarly to the previous method, the cross-stream flow is defined as the circulation normal to the flow direction. However, in this case, the flow direction is calculated as the averaged direction of the flow that permits a zero net circulation in the whole cross-stream transect (Figure S2; Dietrich and Smith, 1983).

ADCP operation and side lobe interference area

The ADCP used in this study was a 600 kHz Teledyne 4-beam ADCP mounted on an autonomous underwater vehicle that was set up to follow nine cross-channel transects (Figure 1). The acoustic technology of ADCPs allows the computation of flow velocities based on the difference of the acoustic waves, which are emitted by the ADCP at a fixed frequency, that are reflected back towards the instrument (Oberg and Mueller, 2007; Teledyne, 2011). Instruments are set up to listen to acoustic signals in layers or bins, whose size is also fixed. The ADCP provides the averaged velocity of each bin in three components (Vparallel to the AUV axis, Vnormal to the AUV axis and Vvertical). The bin size of the ADCP in this study was 1 m.

One crucial limitation of ADCPs is their performance in the near-bed region. Acoustic waves are emitted in narrow beams that form an angle to the vertical. The outside edge of the acoustic beam reflects from the seafloor earlier than the axial beam and, as a consequence, the echoed wave interferes with the measurement from the axial beam that gets acoustically contaminated in the near-bed region (Sumner et al., 2013; Teledyne, 2011). This area where measurements are not reliable is called side lobe interference area (SLIA) and its size depends on the axial beam aperture to the vertical (20° in this study) and the elevation of the ADCP over the seafloor (elevation of the AUV over the seafloor in this study). The size of the SLIA in this study is shown in Figure S1. It is important to note that bins that were partially within the SLIA have been fully removed from the analysis.

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