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Mixing length to be used in salt dilution gauging of turbulent flows in rough open channels

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Salt dilution gauging is a technique frequently used for small, rough streams, where it is difficult to work with velocity probes (e.g. propeller meters). Salt dilution gauging can handle geometrically irregular boundaries well and permits discharge to be measured also in streams with roughness elements of the size of the flow depth. The technique is usually applied in the form of either a continuous injection or an instantaneous slug release of the salt dissolved in water. Although quite practical, the instantaneous injection requires some decisions to be made prior to the actual release of the salt solution, which may be more difficult to take in the transient case as compared to the steady state one. This contribution reports on the results of research on one such issue, the question of how long a (longitudinal) distance between the respective points of injection and measurement is needed to avoid bias by incomplete transverse mixing.

Transverse mixing theory in rivers and streams seems established well enough to answer the above question in an adequate manner. Assuming vertical mixing not to be the key limiting process in this regard (a valid assumption in the vast majority of rough, small, comparatively high-gradient streams), the mixing distance necessary can be written in the form:

$$L = \alpha \cdot \frac{B^2}{h} \tag{1}$$

with L denoting transverse mixing length, B the channel width and h the flow depth. α acts as a coefficient of proportionality typically related to the percentage of transverse mixing desired. The above equation and the 'percentage of full transverse mixing', have, however, been derived from solutions of a diffusion model subject to steady state injection instead of an instantaneous slug release. Thus, the concept of the 'percentage of full mixing' has no precise meaning in the transient case treated here. It is not straightforward to say which percentage of transverse mixing in the (corresponding) steady state case is needed for the measured zeroth temporal moment of the breakthrough curve (n_0) to become accurate enough for a reliable estimate of flow rate to be obtained from the following equations:

$$n_0 = \int_0^{+\infty} \left[C\left(t\right) - C_0 \right] dt \tag{2}$$

$$Q = \frac{M_0}{n_0} \tag{3}$$

with Q the flow rate, C the tracer concentration, C_0 the background, M_0 the tracer mass injected and n_0 the zeroth moment given above.

There is ample literature available on what is needed for the 1D advection-diffusion (dispersion) model to apply, but those studies refer to a (more or less) complete breakthrough curve, which, mathematically, is equivalent to 'all' (or at least three or four) temporal moments of the function being good enough. In contrast, the instantaneous form of dilution gauging places demands only on one temporal moment, the zeroth. It is, therefore, to be expected that in this context α can be chosen distinctly smaller than in full dispersion or transient storage modelling. And, indeed, evaluation of experiments made by the authors strongly indicate that a choice of

$$\alpha = 1.0 \tag{4}$$

will be adequate in the context of salt dilution gauging by instantaneous centreline injection.