# How to translate Surface-water Velocities into a Mean-vertical or mean-channel Velocity

Regardless of the method (LSPIV or velocity radars) used to measure surface-water velocities, computing a discharge requires:

- Mean-channel velocity
- Cross-sectional area

This post offers methods for translating surface-water velocities into a mean-vertical ($u_{\text{vertical}}$) or mean-channel ($u_{avg}$) velocity either directly (USGS Surface-water Method, Probability Concept) or indirectly (Index Velocity Rating). Future posts will address steps for (1) assessing the quality of surface-waters scatterers, (2) correcting for wind drift, which can bias measurements and alter surface-water velocities, (3) schemes for filtering instantaneous velocity measurements, (4) computing area, and (5) computing real-time discharge.

It is important that when reporting $u_{avg}$, the method should account for the velocity distribution that exists at the transect or cross-section-of-interest. For example, if the maximum velocity occurs at the water surface, a logarithmic or or power law can be assumed; however, if the maximum velocity occurs below the water surface, a non-standard velocity distribution equation (e.g., Chiu velocity equation) should be used.

Direct Measurement:

### *USGS Surface-water Method for estimating the mean-vertical velocity*

If surface-water velocities ($u_D$) are measured directly (LSPIV or velocity radars) and at multiple stations (25-30) from the left edge of water (LEW) to the right edge of water (REW), $u_{vertical}$ at a station can be computed using equation 1:

- $u_{vertical} = u_D$ *x coefficient (typically ranging from .84 to .90)* *Eq. 1*

This assumes the vertical-velocity profile can be characterized by a logarithmic or 1/6th or 1/7th power law (Mueller, 2013). Rantz et al. (1982) and Turnipseed and Sauer (2010) recommend a coefficient is necessary to convert a surface-water velocity to a $u_{vertical}$; however, these coef-ficients are generally difficult to determine reliably because they may vary with stage, depth, and position in the measur-ing cross section. Experience has shown that the coefficients generally range from about 0.84 to about 0.90, depending on the shape of the vertical-velocity curve and the proximity of the vertical to channel walls, where secondary currents may develop causing the maximum velocity to occur below the water surface. During these conditions, the coefficient can exceed unity (1.0). Larger coefficients are generally associated with smooth streambeds and normally shaped vertical-velocity curves; whereas, smaller coefficients are associated with irregular streambeds and irregular vertical-velocity curves.

In many instances, the velocity distribution is non-standard or the maximum velocity occurs below the water surface. In these cases, an alternative velocity distribution equation is needed to translate a surface-water velocity into a $u_{avg}$ (Chiu, 1989; Chiu and Tung, 2002; Fulton and Ostrowski, 2008) or $u_{vertical}$ (Guo and Julien, 2008; Jarrett, 1991; Kundu and Ghoshal, 2012; Wiberg and Smith, 1991; Yang et al., 2006).

### *Probability Concept Method for estimating the mean-channel velocity*

The Probability Concept was pioneered Chiu (1989) and offers an efficient platform for computing $u_{avg}$ at a cross-section-of-interest. Two parameters,  and the maximum-instream velocity ($u_{max}$), are needed to compute $u_{avg}$. The variable  is derived by measuring point velocities along a very important and single vertical as a function of depth beginning at the channel bottom and concluding at the water surface or by collecting pairs of $u_{avg}$ and $u_{max}$ for a variety of flow conditions. The vertical is called the "y-axis" and all data collection efforts should focus on that station, which is that vertical that contains the maximum information content (minimum velocity, maximum velocity, and depth) to derive the parameters $u_{max}$, , $h/D$ used to compute $u_{avg}$ (equations 2 and 3). Research suggests (Chiu et al., 2001; Fulton and Ostrowski, 2008; Fulton et al., in preparation) the location or stationing of the y-axis is generally stable for a given transect and does not vary with changing hydraulic conditions including variations in stage, velocity, flow,  flow, channel geometry, bed form and material, slope, or alignment; however, field verification of these parameters must be conducted periodically and a stage-area rating must be maintained. The y-axis rarely coincides with the thalweg in open or engineered channels. Computing  is accomplished through a Python or R-script (**will provide link**); $u_{max}$ can be computed or measured directly using LSPIV or velocity radars.

- $u_D = u_{max}/M \times \ln [1+ (e^{M}-1) \times 1/(1-h/D) \times \exp(1- 1/(1- h/D)]$ *Eq. 2*

- $= u_{avg} / u_{max}$ *Eq. 3*

*Where  = function of M (2 to 5.6) and generally ranges from* ***.58 to .82*** *and*

$u_{max}$ *= maximum in-stream velocity*

$u_{avg}$ = *mean-channel velocity*

$M$ = *entropy parameter and is related to* $= e^{M} / (e^{M}-1) -1/M$

$u_D$ = *surface-water velocity*

$h/D$ = *location of* $u_{max}$ *below the water surface at the y-axis/water depth at the y-axis*

## Indirect Measurement:

### ***Index Velocity Rating for estimating the mean-channel velocity***

The protocol for establishing index velocity ratings are described by Levesque and Oberg (2012) where an index such as $u_D$ can be paired to a measured discharge for a variety of flow conditions.

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