$$V_L = \left(gL_s / 2\pi\right)^{1/2} \tag{4.169}$$

$$V_L = \left(gh\right)^{1/2} \tag{4.170}$$

The minimum value should be applied in further calculations.

3 **Actual speed, V_s**

The actual speed of the vessel, V_s (m/s), is evaluated as a factor of the limit speed V_L (see Equation 4.171):

$$V_s = f_v V_L \tag{4.171}$$

where f_v = 0.9 for unloaded ships and f_v = 0.75 for loaded ships.

For loaded push-tow units and conventional motor freighters the actual speed can also be determined from Equation 4.172.

$$V_s = 2.4\sqrt{\frac{A_c}{b_w}}\exp\left(-2.9\frac{A_m}{A_c}\right) \tag{4.172}$$

Note: Equation 4.172 is derived by implicitly assuming that ships sail with a speed of 0.9 times V_L (f_v = 0.9).

4 **Mean water level depression, Δh and mean return flow, U_r**

The mean water level depression, Δh (m), is calculated by Equation 4.173.

$$\Delta h = \frac{V_s^2}{2g}\left[\alpha_s\left(A_c / A_c^*\right)^2 - 1\right] \tag{4.173}$$

where:

α_s = factor to express the effect of the sailing speed V_s relative to its maximum (-), α_s = 1.4 - 0.4V_s/V_L

A_c^* = cross-sectional area of the fairway next to the ship (m²), $A_c^* = b_b (h - \Delta h) + \cot\alpha (h - \Delta h)^2 - A_m$

A_c = cross-sectional area of the fairway in the undisturbed situation (m²), $A_c = b_b h + h^2\cot\alpha$

α = slope angle of the bank (-).

The mean return flow velocity, U_r (m/s), is calculated by Equation 4.174.

$$U_r = V_s\left(A_c / A_c^* - 1\right) \tag{4.174}$$

5 **Maximum water level depression, $\Delta\hat{h}$ and return flow, $\hat{U}_r$**

The maximum water level depression, $\Delta\hat{h}$ (m/s) can be calculated by Equation 4.175:

$$\Delta\hat{h} / \Delta h = \begin{cases} 1 + 2A_w^* & \text{for} \quad b_w / L_s < 1.5 \\ 1 + 4A_w^* & \text{for} \quad b_w / L_s \geq 1.5 \end{cases} \tag{4.175}$$

where $A_w^* = y\, h/A_c$ (-).

For ratios of A_c/A_m smaller than about 5 (ie comparable with b_w/B_s < 10) the flow field induced by sailing ships might be considered as one-dimensional. For these situations Equation 4.176 is applicable.

$$\hat{U}_r / U_r = \begin{cases} 1 + A_w^* & \text{for} \quad b_w / L_s < 1.5 \\ 1 + 3A_w^* & \text{for} \quad b_w / L_s \geq 1.5 \end{cases} \tag{4.176}$$

For larger ratios, ie A_c/A_m > 5 or b_w/B_s > 10, the flow field is two-dimensional. Then, the gradient in the return current and the water level depression between the ship and the bank should be taken into account. In the computer program DIPRO these formulae are incorporated.