Use of principal component analysis in conjunction with soft computing methods for investigating total sediment load transferability from laboratory to field scale

APPENDIX I: DEFINITION OF DIMENSIONLESS PARAMETERS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h$</td>
<td>dimensionless flow depth</td>
</tr>
<tr>
<td>$u_m h$</td>
<td>Reynolds number related to average flow velocity</td>
</tr>
<tr>
<td>$u_d$</td>
<td>Reynolds number related to particle size</td>
</tr>
<tr>
<td>$u_h$</td>
<td>Reynolds number related to shear velocity</td>
</tr>
<tr>
<td>$\tau_s = \frac{h s}{(G_s - 1)d_{50}}$</td>
<td>dimensionless shear stress</td>
</tr>
<tr>
<td>$\frac{q}{\sqrt{gh}}$</td>
<td>Froude number</td>
</tr>
<tr>
<td>$q_{u, d_{50}}$</td>
<td>dimensionless flow unit discharge</td>
</tr>
<tr>
<td>$B$</td>
<td>dimensionless width</td>
</tr>
<tr>
<td>$\frac{v u_s}{g(G_s - 1)d_{50}}$</td>
<td>dimensionless shear velocity</td>
</tr>
<tr>
<td>$\frac{1}{d_s^2} = \frac{v^2}{g(G_s - 1)d_{50}^2}$</td>
<td>dimensionless particle size</td>
</tr>
<tr>
<td>$\frac{q}{\sqrt{gh}}$</td>
<td>dimensionless flow unit discharge</td>
</tr>
<tr>
<td>$\frac{\rho_s u^2}{g(G_s - 1)d_{50}^2}$</td>
<td>mobility number related to particle size</td>
</tr>
<tr>
<td>$\frac{u_m}{\sqrt{g(G_s - 1)d_{50}}}$</td>
<td>Froude number related to particle size</td>
</tr>
</tbody>
</table>

APPENDIX II: EMPIRICAL METHODS

Bagnold method

Bagnold (1966) developed sediment transport function using the stream power concept which is based on energy balance concept. He considered the total load as the sum of suspended and bed load.

Bed load formula:

$$q_{b,c} = \frac{e_b \tau_b \bar{u}}{(\rho_s - \rho) g \cos \beta (\tan \phi - \tan \beta)}$$

Suspended load formula:

$$q_{s,c} = \frac{e_s (1 - e_b) \tau_b \bar{u}}{(\rho_s - \rho) g \cos \beta (|\bar{w}_s/\bar{u}| - \tan \beta)}$$

Total load formula:

$$q_t = \frac{\gamma}{(\gamma_s - \gamma)} \tau \left( \frac{e_b}{\tan \alpha} + 0.01 \frac{\bar{u}}{\bar{w}_s} \right)$$

where:

- $q_{b,c}$ = volumetric bed load transport (L²T⁻¹)
- $q_{s,c}$ = volumetric current related suspended load (L²T⁻¹)
- $\tau_b$ = overall bed shear stress (ML⁻¹T⁻²)
- $\bar{u}$ = depth-averaged velocity (LT⁻¹)
- $e_b$ = efficiency factor (0.1–0.2)
- $e_s$ = efficiency factor related to suspended load (0.01–0.02)
- $\bar{w}_s$ = fall velocity of sediment (LT⁻¹)
- $\tan \varphi$ = dynamic friction coefficient
- $\tan \beta$ = bed slope
- $\tan \alpha$ = ratio of tangential to normal shear factor

Ackers and White method

Based on the study of Bagnold (1966), Ackers & White (1973) applied dimensional analysis to develop a sediment transport model. They assumed that total shear stress is effective in the mobility of sediment.

The general sediment transportation function is expressed as:

$$F_{gr} = U^n \left[ gd \left( \frac{G_s}{\gamma_s} - 1 \right) \right]^{-1/2} \left[ \frac{V}{\sqrt{32 \log(aD/d)}} \right]^{1-n}$$

$$d_{gr} = a \left[ \frac{g(\gamma_s/\gamma - 1)}{v^2} \right]^{-1/3}$$
\[ G_{sp} = f(F_{sp}, d_{sp}) \]

\[ G_{sp} = \frac{XD}{d(\gamma_s/\gamma)} \left( \frac{U^*}{V} \right)^n \]

\( X \) = rate of sediment transport in terms of mean flow per unit mass flow rate
\( U^* \) = shear velocity (LT\(^{-1}\))
\( n \) = transition exponent, depending on sediment size
\( \alpha \) = coefficient in rough turbulent equation
\( D \) = water depth (L)

**Van Rijn method**

Van Rijn (1984a, b) postulated that hydrodynamic fluid forces and gravity forces are effective in the movement of sediment particles. The character of jumping motion is obtained by the solution of the motion equation for an individual bed particle. According to Van Rijn (1984b), suspension of a particle occurs when the value of bed shear velocity exceeds the particle fall velocity.

For bed load:

\[ q_b = 0.1(s - 1)^0.5 d_{50}^{1.5} D_s^{-0.3} T^{2.1} T \geq 5 \]

For suspended load:

\[ q_s = \text{Füh} C_a \]

\( q_b \) = volumetric bed load transport rate (L\(^2\)T\(^{-1}\))
\( T \) = dimensionless bed-shear parameter
\( D_s \) = dimensionless particle parameter
\( F \) = shape factor
\( \bar{u} \) = depth average velocity (LT\(^{-1}\))
\( C_a \) = reference concentration

**REFERENCES**


