RIVERS AND STREAMS

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1. Flow:

River parameters are:

S = slope of river bed = $\frac{\text{vertical drop}}{\text{downstream distance}}$
A = cross-sectional area of flowing water
P = wetted perimeter = bottom contour length from shoreline to opposite shoreline
W = river width = surface distance from shoreline to opposite shoreline
H = average water depth = $\frac{A}{W}$
g = gravitational acceleration = 9.81 m/s^2
ρ = water density = 1000 kg/m^3

From these parameters, determine:

R_h = hydraulic radius = $\frac{A}{P}$
u_* = turbulent (friction) velocity = $\sqrt{gR_hS}$
$\bar{u}$ = average velocity = Cu_* = $C\sqrt{gR_hS}$ (Chézy formula)
For a wide and shallow river, R_h is nearly equal to H, and H can be substituted for R_h in the formulas.

Manning's formula:

$$C\sqrt{g} \;=\; \frac{R_h^{1/6}}{n} ,$$

with R_h in meters and C dimensionless. Typical values for n range from 0.012 for a very smooth channel to 0.150 for a very rough and meandering river bed.

If a value of n is not specified, take $n = 0.035$.

2. Manning's factor:

Channel type		n
Cement	smooth slabs	0.012
	finished	0.014
	unfinished	0.014
	bottom sand ripples	0.018
	very rough	0.020
Asphalt		0.016
Excavated channel	clay loam	0.018
	gravel	0.025
	weeds	0.030
	cobbles	0.030
	stones	0.035
Natural channel	cobblestone bed	0.030
	irregular edges	0.035
	major rivers	0.035
	rocky edges	0.040
	sluggish, pools	0.040
	variable section	0.040
	irregular, rocks	0.045
	very irregular, trees	0.060
Flood plains	pasture, farmland	0.035
	light brush	0.050
	floodway channel	0.125
	trees, obstructions	0.150

3. Mixing:

Vertical diffusivity (top to bottom mixing):

$$D_{\text{vertical}} = 0.067 u_* H$$

Transverse diffusivity (left to right mixing):

$$D_{\text{transverse}} = 0.15 u_* H$$

Longitudinal diffusivity (downstream mixing):

$$D_{\text{longitudinal}} = 0.0197 \ \frac{\bar{u}^2 H}{u_*}$$

or

$$D_{\text{longitudinal}} = 0.011 \frac{\bar{u}^2 W^2}{u_* H}$$

whichever is largest.
Time for vertical homogenization (if discharge is placed at mid-depth):

$$t_{\text{vertical}} = 0.134 \frac{H^2}{D_{\text{vertical}}} = 2.0 \frac{H}{u_*}$$

Quadruple this value if the discharge occurs on the surface or bottom.
Distance for vertical homogenization (if discharge is placed at mid-depth):

$$x_{\text{vertical}} = \bar{u} t_{\text{vertical}} = 2.0 \frac{\bar{u} H}{u_*}$$

Time for transverse homogenization (if discharge is placed along the side):

$$t_{\text{transverse}} = 0.536 \frac{W^2}{D_{\text{transverse}}} = 3.6 \frac{W^2}{u_* H}$$

Distance for transverse homogenization:

$$x_{\text{transverse}} = \bar{u} t_{\text{transverse}} = 3.6 \frac{\bar{u} W^2}{u_* H}$$

4. Re-aeration:

4a) The exchange coefficient of oxygen across the air-sea interface (= vertical transfer velocity, the so-called 'piston velocity') is:

$$k_{O2}(\text{at } 20^\circ\text{C}) \;=\; 3.9 \sqrt{\frac{\bar{u}}{H}} \; ,$$

where $\bar{u}$ is in m/s, H is in m, and k_{O2} is in m/day.

4b) Temperature correction:

$$k_{O2}(T) \;=\; k_{O2}(20^\circ\text{C}) \; (1.024)^{T-20} \; ,$$

where T is the ambient temperature in °C.

4c) Re-aeration rate:

$$K_{O2}(T) \;=\; \frac{k_{O2}}{H} \;=\; \frac{3.9}{H}\sqrt{\frac{\bar{u}}{H}} \; (1.024)^{T-20},$$

in 1/day, with $\bar{u}$ in m/s, H in m, and T in °C.

5. Biodegradation rates:

- Raw sewage: K_{BOD} = 0.35 to 0.70 /day at 20°C
- Treated sewage: K_{BOD} = 0.12 to 0.23 /day at 20°C
- Various chemicals: See Masters' book, Table 2-3, page 55

Temperature correction:

$$K_{BOD}(T) \;=\; K_{BOD}(20^\circ\text{C}) \; (1.047)^{T-20} \; ,$$

where T is the ambient temperature in °C.