Environmental Transport and Fate

Chapter 6

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Wetlands

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Definition

According to the EPA (http://www.epa.gov/wetlands/), wetlands are those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.

Wetlands generally include swamps, marshes, bogs and similar areas.

Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance.

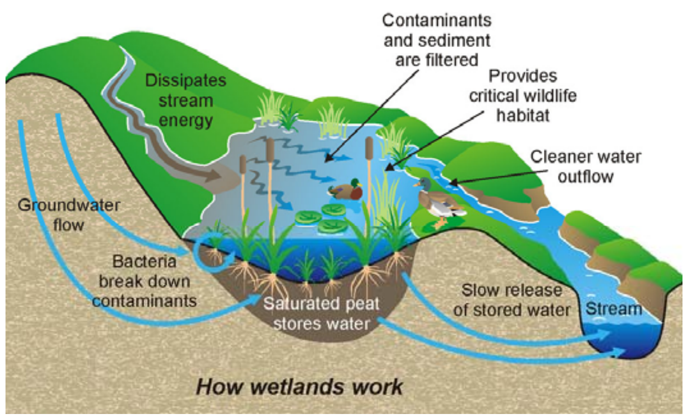
Wetlands are found from the tundra to the tropics and on every continent except Antarctica.

Environmental value of wetlands:

- They filter and purify water;
- They allow time for bacteria to break down contaminants;
- They reduce or eliminate floods by impounding water;
- They recharge groundwater;
- They provide habitats for wildlife.

Often called “nurseries of life,” wetlands provide habitat for thousands of species of aquatic and terrestrial plants and animals. Migrating birds use wetlands to rest and feed during their cross-continental journeys and as nesting sites when they are at home. As a result, wetland loss has a serious impact on these species.

Wetland hydrology

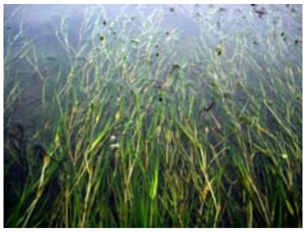


Freshwater wetlands with open water come in two varieties:

1. Wetland with emerging vegetation

Water flow is slow causing high residence time with ample cleaning and settling time.

2. Wetland with submerged vegetation



Faster water flow above vegetation and slower flow below amidst vegetation.

Velocity shear between the two flows causes instability and overturning, causing good exchange rates between both flows.

Two-box model

(Ghisalberti & Nepf, 2005)

Figure 6. Evidence of the lateral heterogeneity in vegetated shear flows. The flow is divided laterally into (in this case, two) subchannels of the vortex width ($\approx t_{ml}/2$). In the left-hand picture, the dye in the vortex street nearer the camera is swept into the canopy simultaneously to the vortex street in the neighboring subchannel ejecting dye above the canopy. In the right-hand picture, taken half a vortex period ($\frac{1}{2f_v}$) later, the reverse is true.

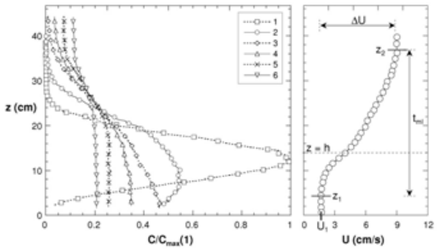


Figure 5. Steady-state concentration profiles and velocity profile (taken from Ghisalberti and Nepf [11]) of Run I. All concentration data have been normalized by the maximum value at measurement location 1. The velocity shear and, subsequently, the bed result in a concentration profile that is asymmetric about the injection point ($z = h$). The markers are used simply to identify each profile; the true vertical resolution of the concentration data is approximately 1 mm. The estimated uncertainty in each data point is roughly 10%.

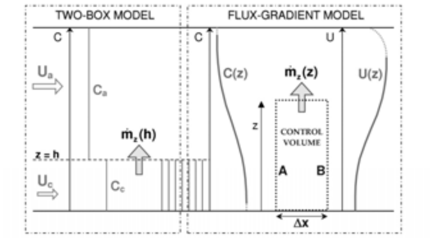


Figure 8. Definitive diagram of the two-box and flux-gradient models used to describe vertical transport. In the two-box model, concentration and velocity are considered uniform in both the upper ($h < z < H$) and lower boxes ($0 < z < h$). Extrapolation of the experimental concentration and velocity profiles was required at the outer edges of the flow. These extrapolations are represented with dotted lines.

Two-box model (cont'd)

Budget in upper flow (above vegetation):

$$(H-h)U_a \frac{dC_a}{dx} = k\,(C_c - C_a) \quad (1)$$

with k = exchange coefficient (units: length/time, like a velocity)

Budget in lower flow (amidst vegetation):

$$hU_c \frac{dC_c}{dx} = -k\,(C_c - C_a) \quad (2)$$

Define $\Delta C = C_c - C_a$, the concentration difference, and subtract Eqn. (2) from Eqn. (1):

$$\frac{d}{dx}\Delta C = -\left(\frac{k}{hU_c} + \frac{k}{(H-h)U_a}\right)\Delta C$$

Define:

$$\lambda = \frac{k}{hU_c} + \frac{k}{(H-h)U_a}$$

Solution:

$$\Delta C(x) = \Delta C(0)\exp(-\lambda x)$$

Back to C_c in lower flow, for which Eqn. (2) can be rewritten as:

$$hU_c \frac{dC_c}{dx} = -k\,\Delta C$$

$$\frac{dC_c}{dx} = -\frac{k}{hU_c}\,\Delta C(0)\exp(-\lambda x)$$

Solution is:

$$C_c(x) = C_c(\infty) + \frac{k}{\lambda h U_c}\Delta C(0)\exp(-\lambda x)$$

$$= C_c(\infty) + \frac{(H-h)U_a}{(H-h)U_a + hU_c}\Delta C(0)\exp(-\lambda x)$$

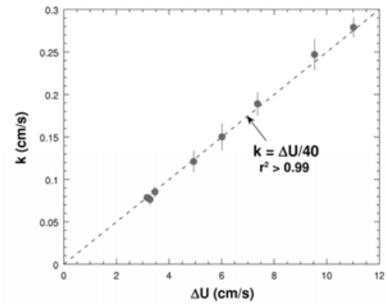


Figure 10. The direct proportionality between the exchange velocity, k, and the total shear, ΔU. The vertical bars represent the 90% confidence intervals of each point, based on the uncertainty of the exponential fit through each data set.

Laboratory experiments suggest:

$$k = \frac{\Delta U}{40}$$

where $\Delta U = |U_a - U_c|$

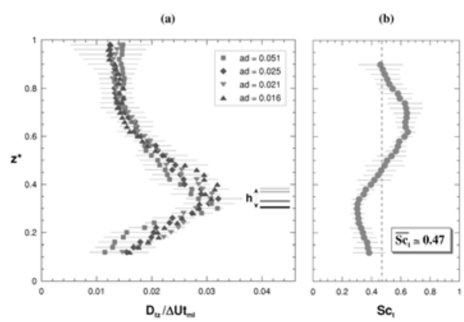


Figure 11. (a) The collapse of D_{tz}, when normalized by $\Delta U t_{ml}$, across the range of plant densities. Data of equal plant density have been grouped, with horizontal bars representing the inter-run variability in each point. The vertical axis ($z^* = (z - z_1)/t_{ml}$) represents the dimensionless height above the shear layer bottom. The thick grey bars show the average location of canopy height in z^* space for each plant density; the greater the density, the darker the bar. For each density, the turbulent diffusivity peaks near the top of the canopy. (b) The vertical profile of the turbulent Schmidt number ($\mathrm{Sc}_t = \nu_{tz}/D_{tz}$) in the shear layer. Sc_t has an average value of approximately 0.47 in the shear layer and reaches a minimum just below the top of the canopy.