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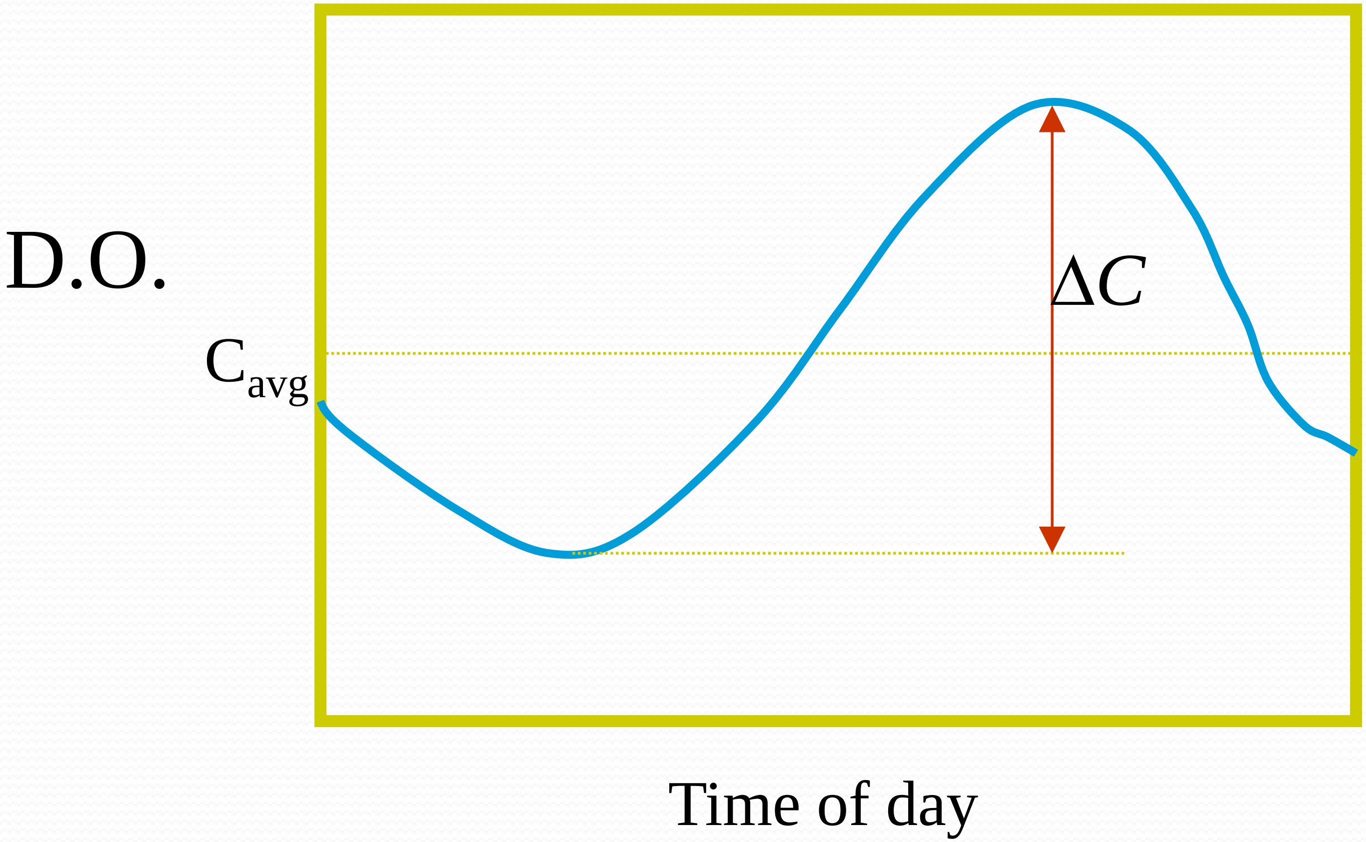
CEE 577: Surface Water Quality Modeling

Lecture #21

Qual2E/K: Algae &Basic Formulation cont.; Heat Balance

(Chapra, L24 & L26)

Measurement of Diurnal DO Range, "The Delta Method"



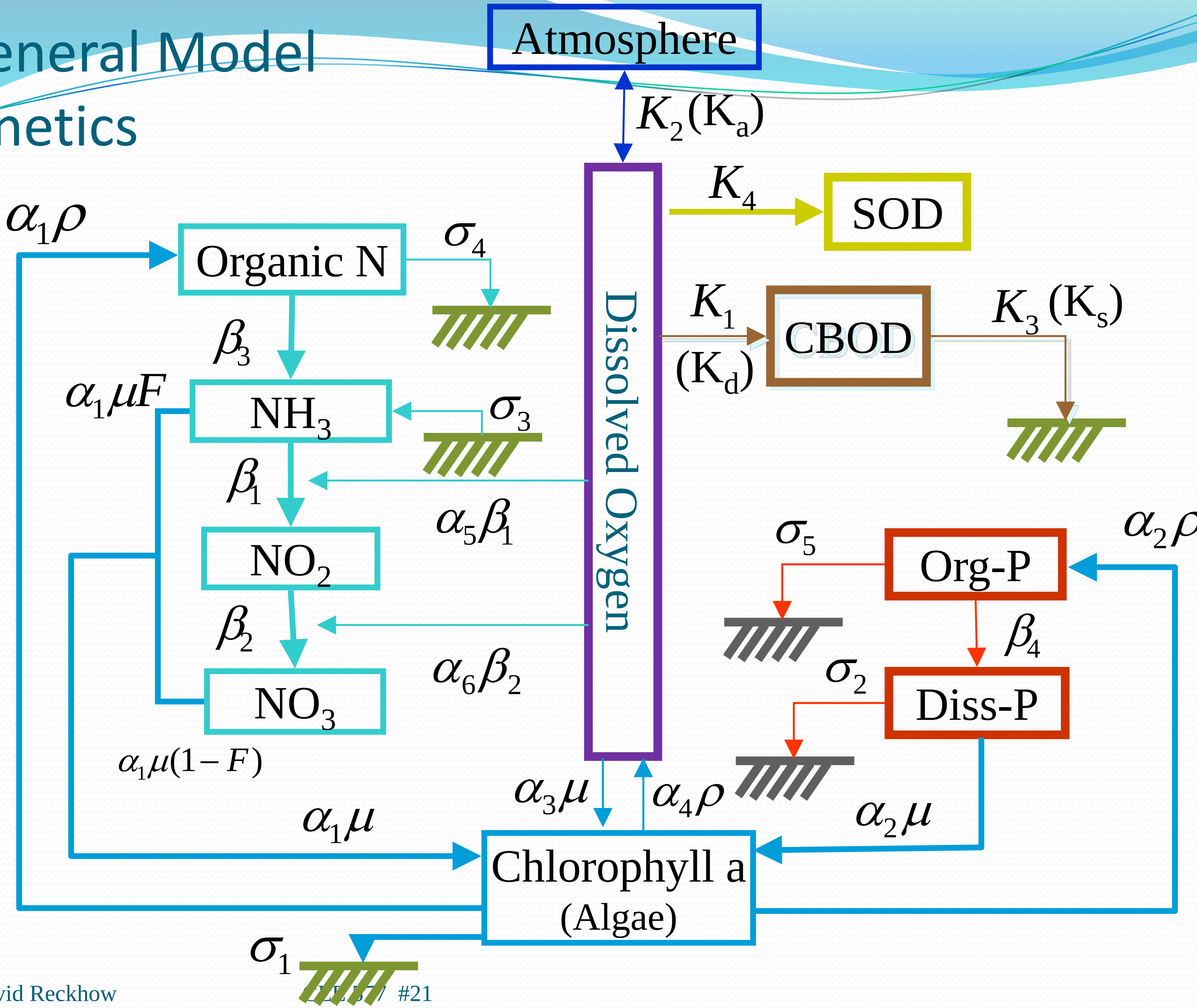
- Streeter-Phelps:

DiToro method (1975)

$$P = \left\{ \frac{0.5k_a\left[1 - e^{-k_a}\right]}{\left(1 - e^{-0.5k_a}\right)^2} \right\} \Delta C$$

$$R = P + k_a \overline{D}$$

General Model Kinetics



Algal growth model

- General mass balance

$$\frac{dA}{dt} = \mu A - \rho A - \frac{\sigma_1}{z} A$$

- Algal specific growth rate
  - multiplicative model
  - limiting nutrient model
  - inverse additive model

$$\mu = \mu_{max}(FL)(FN)(FP)$$

Algal growth model

- General mass balance

Respiration rate (d^{-1})

Algal settling rate (ft/d)

$$\frac{dA}{dt} = \mu A - \rho A - \frac{\sigma_1}{z} A$$

- How do we calculate μ ?

Specific growth rate (d^{-1})

Algal growth model

- Algal specific growth rate
  - multiplicative model

$$\mu = \mu_{max}(FL)(FN)(FP)$$

All based on algal growth limitation factors: numbers between 0 and 1

  - limiting nutrient model
    - if N is limiting $\mu = \mu_{max}(FL)(FN)$
    - if P is limiting $\mu = \mu_{max}(FL)(FP)$
  - inverse additive model

$$\mu = \mu_{max}(FL)\left[\frac{2}{1/FN + 1/FP}\right]$$

Algal growth model

- Algal growth limitation factors
  - Nitrogen

$$FN = \frac{N_e}{N_e + K_N}$$

    - where the half velocity constant for N is K_N
      - and the available nitrogen is: $N_e = NH_3\text{-}N + NO_3\text{-}N$
  - Phosphorus

$$FP = \frac{P_2}{P_2 + K_P}$$

    - and the half velocity constant for P is K_P
      - and the available phosphorus (P_2) is dissolved-P

Algal light functions

- Types
  - Half saturation
  - Smith's function
  - Steel's equation
- Light-depth function

$$FL_z = \frac{I_z}{I_z + K_L}$$

$$FL_z = \frac{I_z}{\sqrt{I_z^{\,2} + K_L^{\,2}}}$$

$$FL_z = \frac{I_z}{K_L} \exp\left(1 - \frac{I_z}{K_L}\right)$$

Extinction coefficient (ft^{-1})

$$I_z = I_o e^{-\lambda z}$$

The light attenuation factor

$$\phi_l = \frac{2.718 f}{k_e H}\left(e^{-\alpha_1} - e^{-\alpha_0}\right)$$

Where:

$$\alpha_1 = \frac{I_a}{I_s} e^{-k_e H}$$

$$\alpha_0 = \frac{I_a}{I_s}$$

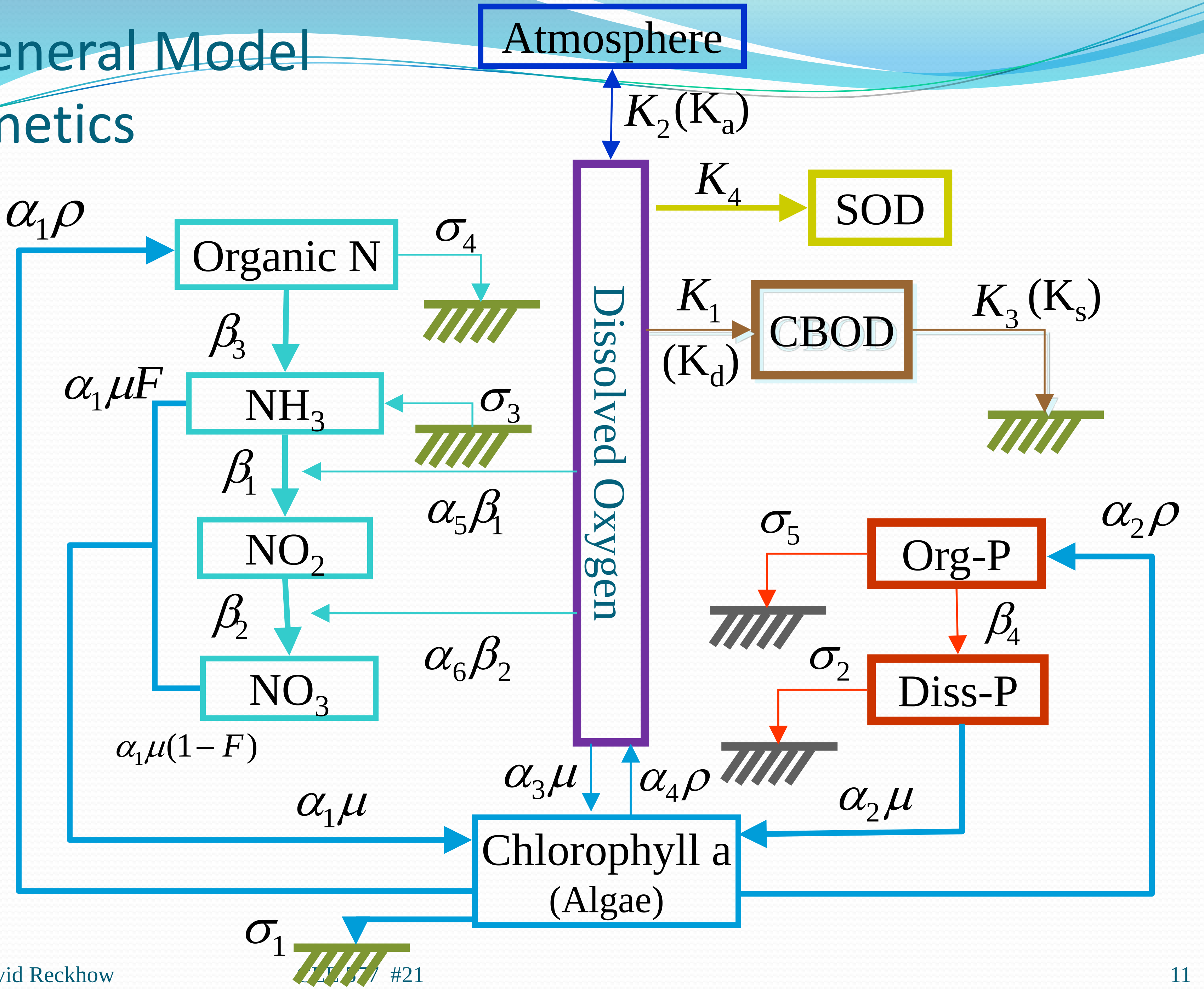
And: $k_e = \frac{1.8}{SD}$

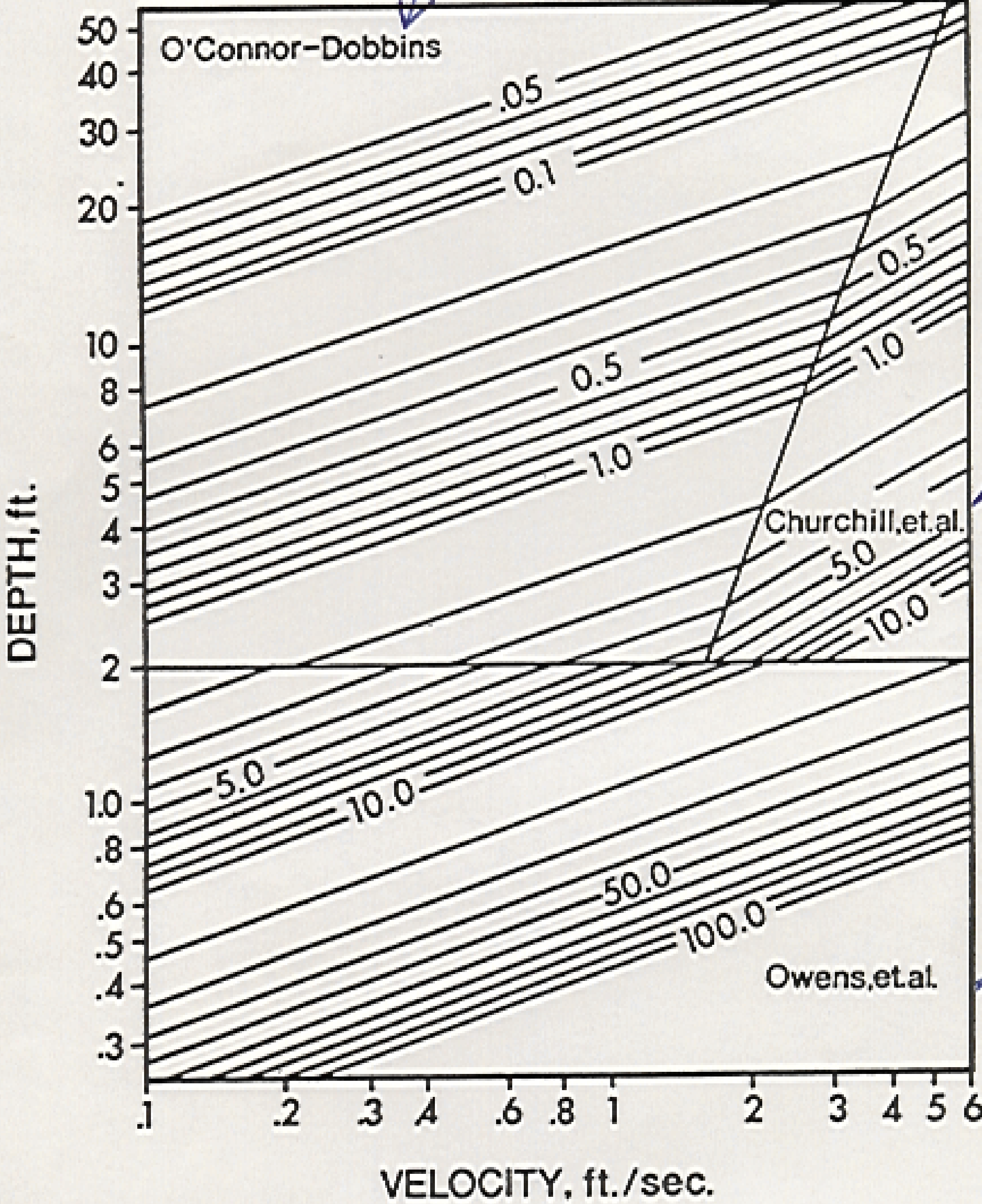
Extinction coefficient (m^{-1})

Avg.daylight intensity

Optimal intensity for plant growth (250-500 ly/d)

General Model Kinetics





The method of Covar (1976)

Values for k_a are in units of d^{-1}

Reaeration

- Eight Options in QUAL2E
  - 1 = specify value
  - 2 = Churchill Formula
  - 3 = O'Connor Dobbins Formula
  - 4 = Owens Formula
  - 5 = Thackston & Krenkel
    - developed for TVA's narrow streams with low DO, requires "n", generally good equation
      - froude number
      - shear velocity

$$k_a = 11.6 \frac{U}{H^{1.67}}$$

$$k_a = 12.9 \frac{U^{0.5}}{H^{1.5}}$$

$$k_a = 21.6 \frac{U^{0.67}}{H^{1.85}}$$

$$k = 25\left(1 + F^{0.5}\right)\left(U^* / z\right)$$

$$F = \frac{U^*}{\sqrt{gz}}$$

$$U^* = \frac{Un\sqrt{g}}{1.49z^{1.167}}$$

Reaeration

- Eight options cont.
  - 6 = Langbien & Durum
    - for z>2ft (synthesis of others)
  - 7 = Power Function of Flow
  - 8 = Tsivoglou & Wallace
    - requires escape coefficient
      - c=0.054 ft^{-1} for Q=15-3000 cfs
      - c=0.110 ft^{-1} for Q=1-15 cfs

$$k = 7.62\frac{U}{z^{1.33}}$$

$$k = aQ^b$$

$$k = 38{,}900n^2\frac{U^3}{z^{1.333}}c$$

Waste Loading

- Point Sources
  - Municipal WW
  - Industrial WW
  - Tributaries
- Non-point Sources
  - Agricultural
  - Silvicultural
  - Atmospheric
  - Urban & Suburban Runoff

Loading Calculations

Point Sources - General Concepts

$$W(t) = Q(t) \bullet c(t)$$

lb/d or kg/d

ft³/s or L/d

mg/L

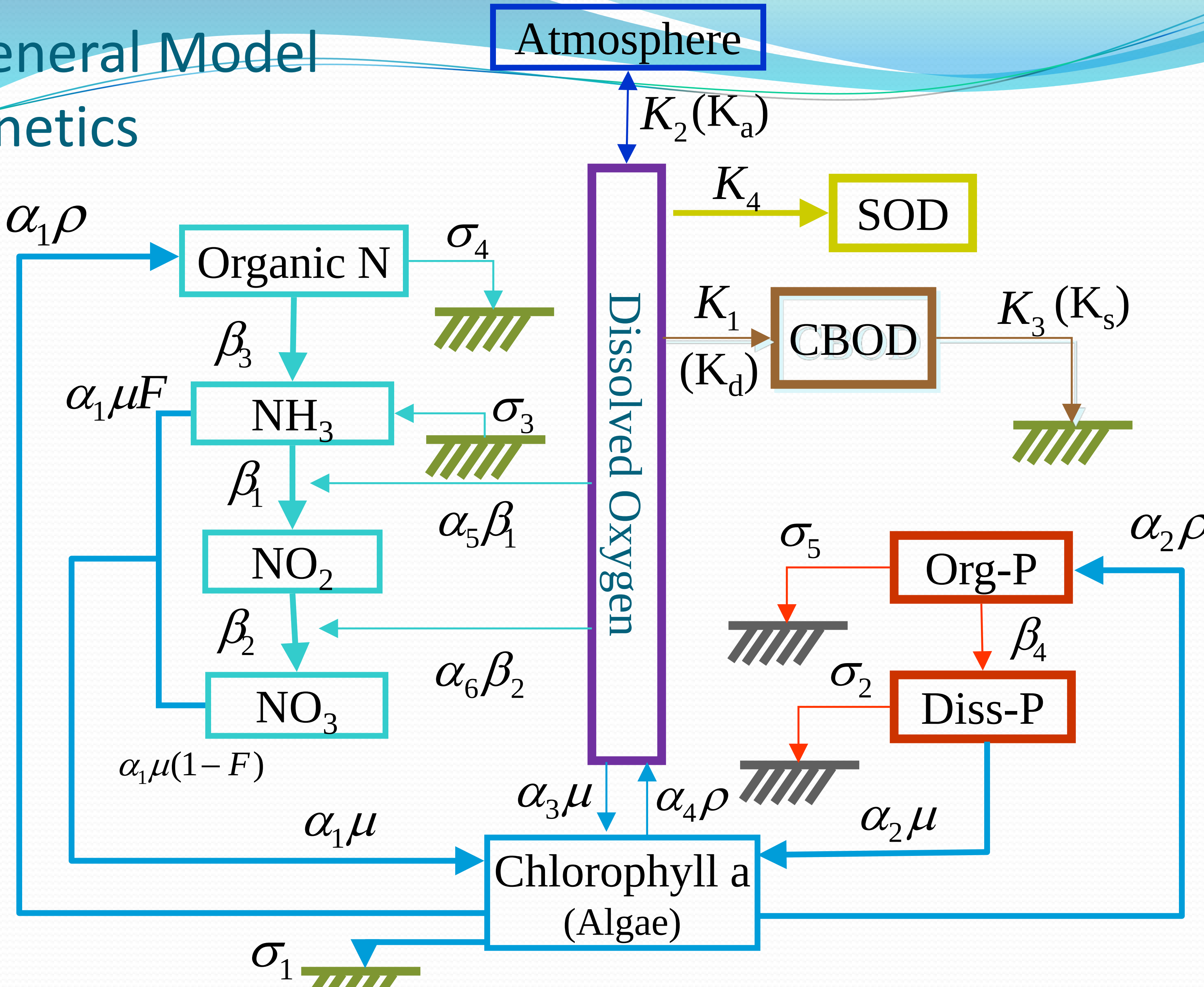
Important Conversion Factors:

$$8.34 \frac{lb \bullet liters}{mg \bullet MG}$$

$$5.39 \frac{lb \bullet liters \bullet \sec}{mg \bullet ft^3 \bullet day}$$

$$2.45 \frac{Kg \bullet liters \bullet \sec}{mg \bullet ft^3 \bullet day}$$

General Model Kinetics



- To next lecture