

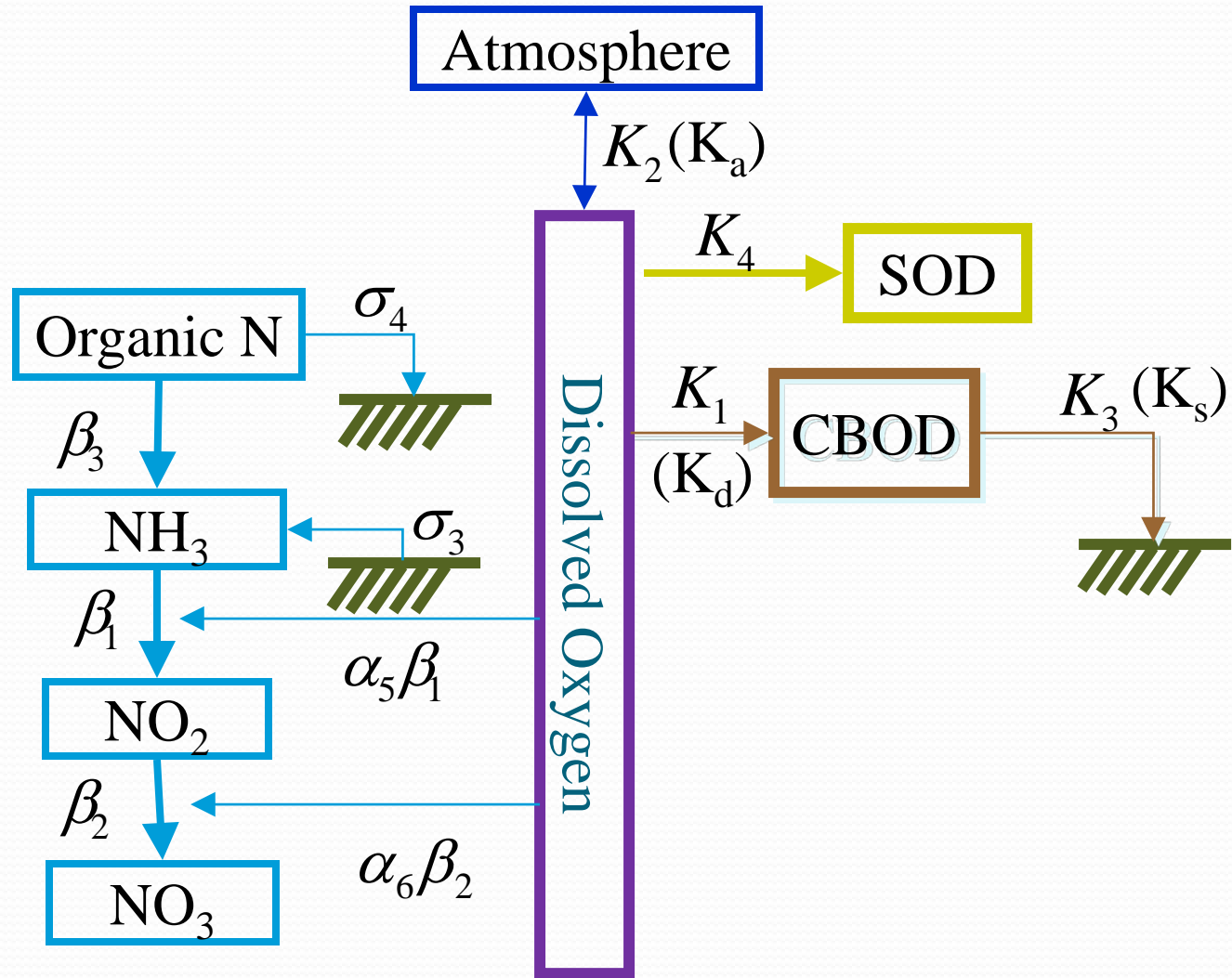
# CEE 577: Surface Water Quality Modeling

Lecture #20

Streeter-Phelps: Photosynthesis/Respiration  
(Chapra, L24)

# General Model

## Kinetics



# Modeling procedures

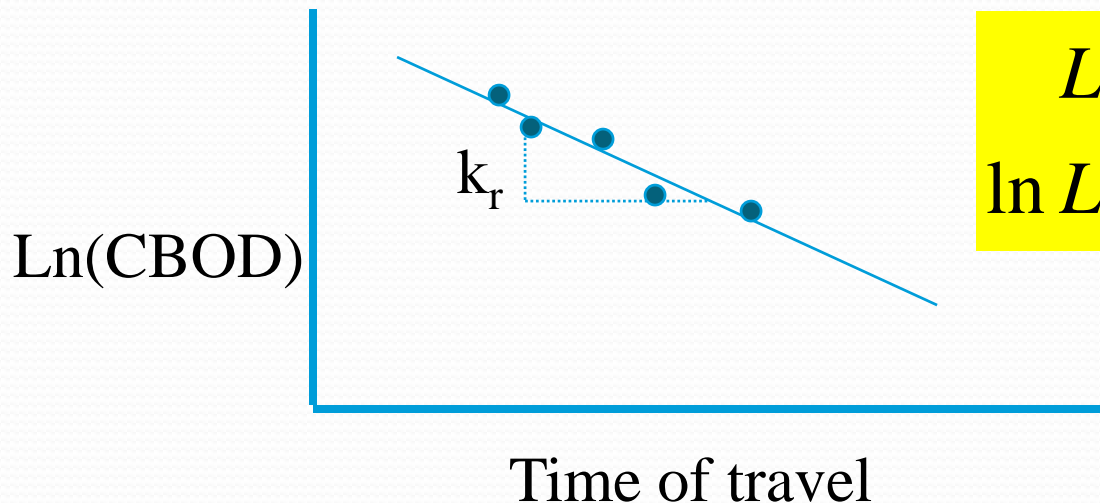
- Verify model calculations
  - using a simplified example, check computer vs. analytical
- Identify inputs (loads, rate coefficients, transport)
  - reaction coefficients - general
    - all rate constants must be uniform in space and time unless variations are linked to system characteristics
    - rates and formulations should fall within the range reported in the literature (e.g., Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling, Bowie et al., US EPA, Athens Environmental Research Laboratory, EPA/600/3-85/040, June 1985., see: <http://www.epa.gov/ORD/WebPubs/surfaceH20/surface.html>) or course [website](#)

# Identifying inputs (cont.)

- $k_d, k_r$ 
  - simplified method:
  - in-stream assessment

$$k_d = 0.3 \left( \frac{H}{8} \right)^{-0.434} \text{ d}^{-1}; \text{ for } H < 8 \text{ ft}$$

$$k_d = 0.3 \text{ d}^{-1} \quad \text{for } H > 8 \text{ ft}$$



$$L = L_o e^{-k_r t}$$
$$\ln L = \ln L_o - k_r t$$

# Identifying inputs (cont.)

## ■ $k_d$ , $k_r$ (cont.)

### ■ Tierney & Young correction for bottle rates

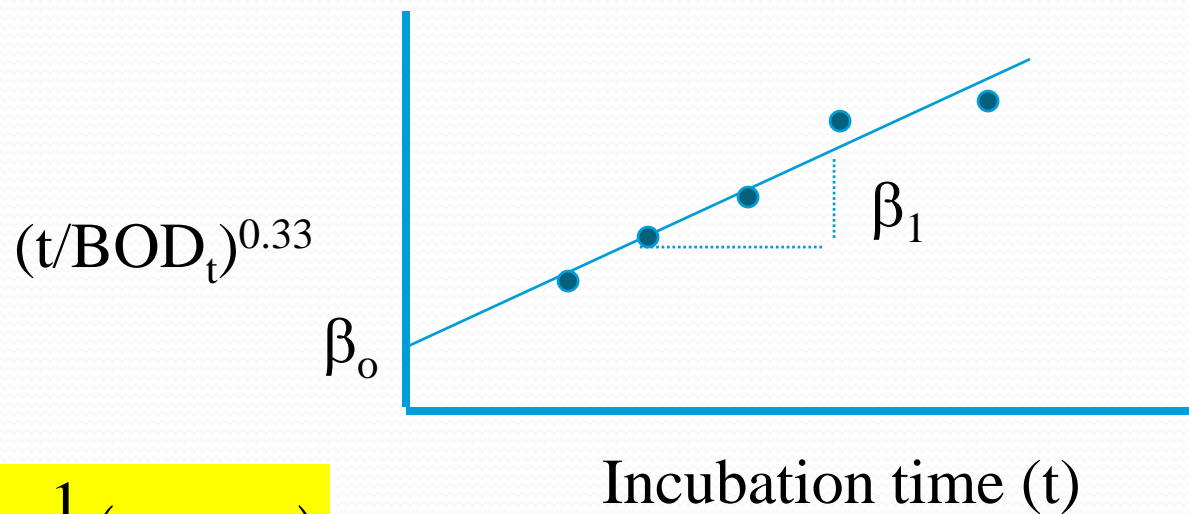
<b>Stream slope (ft/mile)</b>	<b>N</b>
<b>2.5</b>	<b>0.1</b>
<b>5</b>	<b>0.15</b>
<b>10</b>	<b>0.25</b>
<b>25</b>	<b>0.4</b>
<b>50</b>	<b>0.6</b>

$$k_d = k_b + \frac{nU}{z}$$

Annotations:  $nU$  is labeled ft/s, and  $z$  is labeled ft.

# Identifying inputs (cont.)

- Determining bottle rates from Lab data
  - Thomas Method



$$L_o \cong \frac{1}{6} (\beta_1^{-1} \beta_0^{-2})$$
$$k_b \cong L_o^{-1} \beta_0^{-3}$$

# Identifying inputs (cont.)

- Photosynthesis/Respiration (Chapra L24)

- chemistry



- two important issues

- long term effect: net of P & R
- short term effect: extent of DO drop during night

- Three common methods

- Light and Dark bottle method

- expose aquatic biota to natural light conditions, with “control” in the dark

- Estimation from Observed Chlorophyll levels

- Measurement of Diurnal DO Range

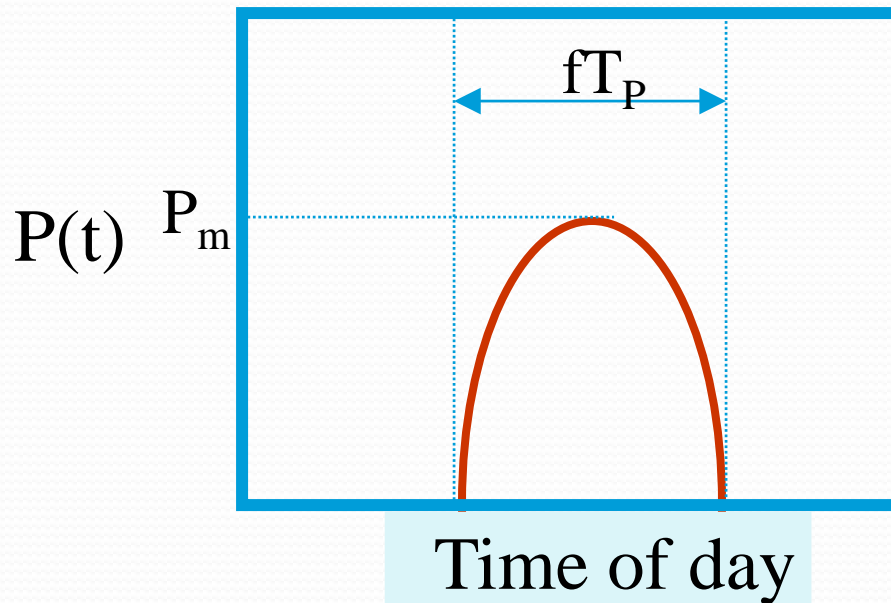
# Additional notes on WLA (cont.)

- Algal modeling
  - Level I
    - measure P-R: diurnal swings in D.O.
  - Level II
    - measure chlorophyll a, light, light extinction, nutrients “in-situ”
    - calculate P-R
  - Level III
    - assess nutrient loadings, light extinction
    - model nutrient conc., chlorophyll a, P-R



# Time variability of Photosynthesis

- Assumed to be proportional to light intensity



$$P = \frac{\int_0^{T_P} P(t) dt}{T_P} = P_m \frac{2f}{\pi}$$

# Light and dark bottle method

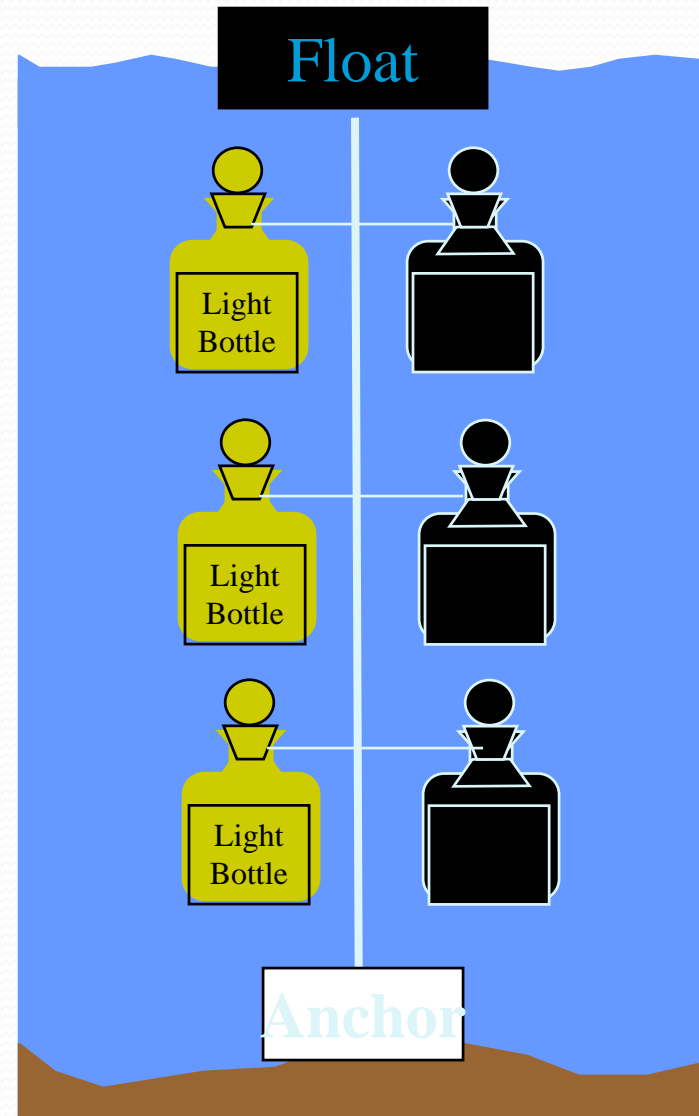
- Expose aquatic plants to natural light conditions
- “control” in the dark bottle

$$P_{net} = \frac{DO_{lf} - DO_{li}}{t}$$

$$R_{cm} = \frac{DO_{di} - DO_{df}}{t}$$

$$R_b = R_{cm} - k_d L_{of}$$

$$P_b = P_{net} - R_{cm}$$



# Estimation from observed chlorophyll levels

- Under conditions where algal metabolism is not limited

Light attenuation factor

$$P = r_{oa} G_{\max} 1.066^{T-20} a \phi_l \approx 0.25a$$

Oxygen generated per unit biomass produced (0.1-0.3 mg-O<sub>2</sub>/μg-chla)

Maximum plant growth rate for optimal conditions (1.5-3.0 d<sup>-1</sup>)

Concentration of plant biomass (μg-chla/L)

# P-R method

- Respiration is from rates and stoichiometry
  - Need chlorophyll level

$$R = r_{oa} k_{ra} 1.08^{T-20} a$$
$$\approx 0.025a$$

Plant  
respiration  
rate (0.05-  
0.25 d<sup>-1</sup>)

- To next lecture