"Eutrophication" means there is more of this (because there is more organic fuel produced in, or washed into, the lake).

$$\mathbf{(CH_2O)_n \longrightarrow CO_2}$$

If it lives…it performs respiration!

All living organisms "combust" organic fuel to carbon dioxide. We often measure the rate of oxygen loss in a lake hypolimnion. That measures *aerobic respiration*. We rarely measure the rate of increase in dissolved inorganic carbon (CO_2) which would account for *all respiration* of *all living organisms*.

Autochthonous *and* Allochthonous

Synthesis

$CO_2 \longrightarrow CH_2O$

Photosynthesis

Chemosynthesis

Respiration

$CO_2 \longleftarrow CH_2O$

Aerobic Respiration

Anaerobic Respiration

Fermentation

Photosynthesis | **Aerobic Respiration**

Photosynthesis

$$CO_2 \longrightarrow (CH_2O)_n$$

$$e^-$$

$$H_2O \longrightarrow O_2$$

Aerobic Respiration

$$(CH_2O)_n \longrightarrow CO_2$$

$$e^-$$

$$O_2 \longrightarrow H_2O$$

In Order

(ATEAs)

$$(CH_2O)_n \longrightarrow CO_2$$

$$e^-$$

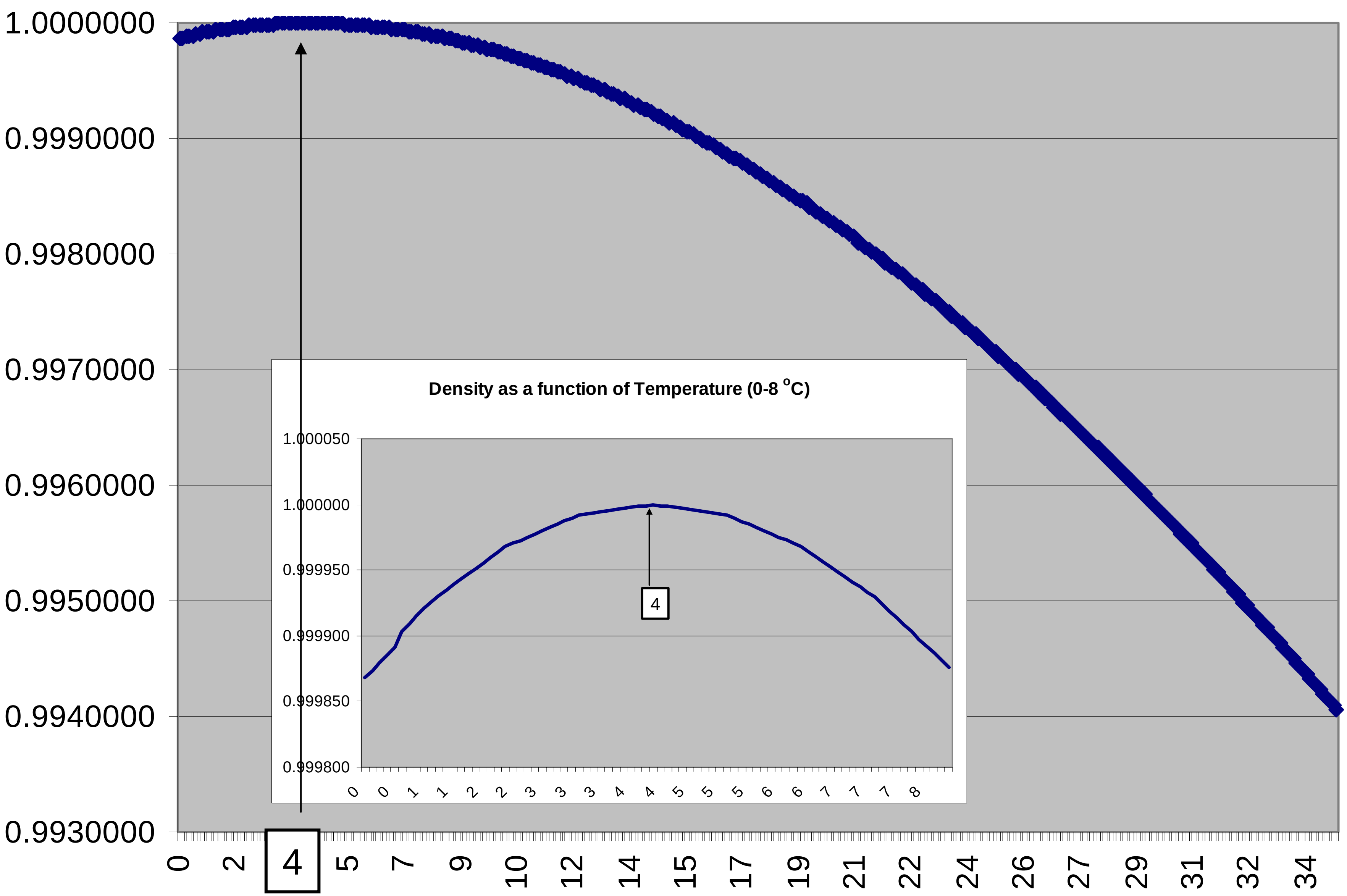
$$NO_3 \longrightarrow N_2$$

$$\boxed{Fe{+}3\text{-}PO_4} \longrightarrow Fe{+}2 \; + PO_4$$

$$S^o \longrightarrow \boxed{H_2S^=}$$

Anaerobic Respiration

Density as a function of Temperature (^{o}C)



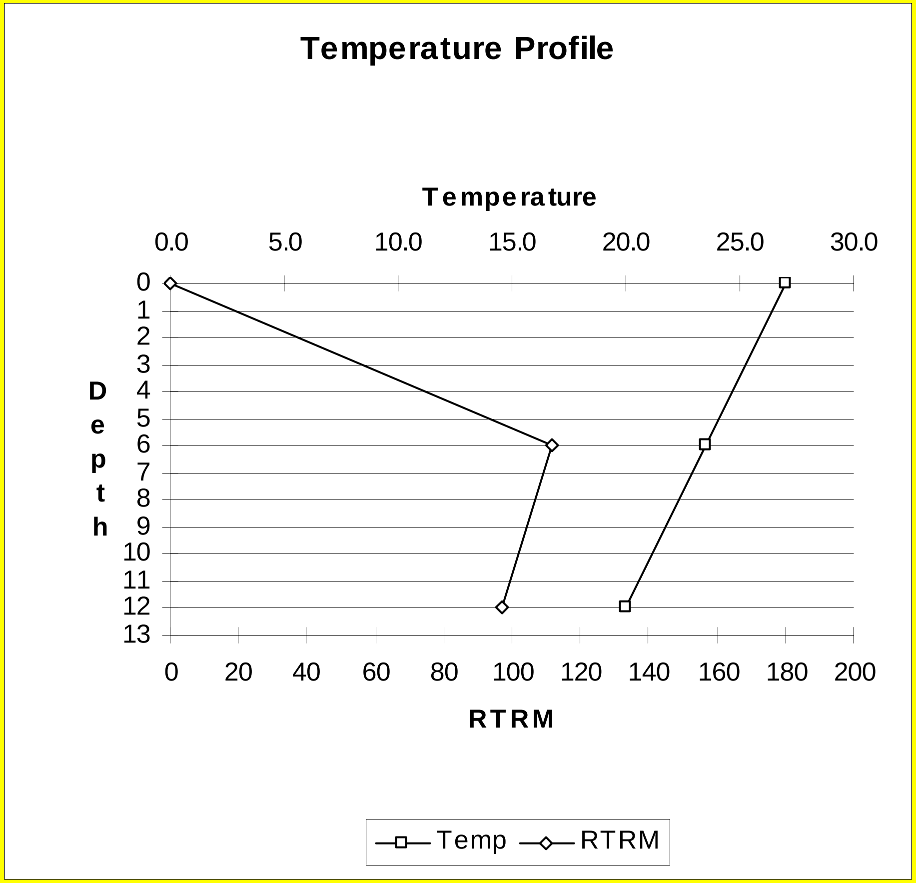
RTRM

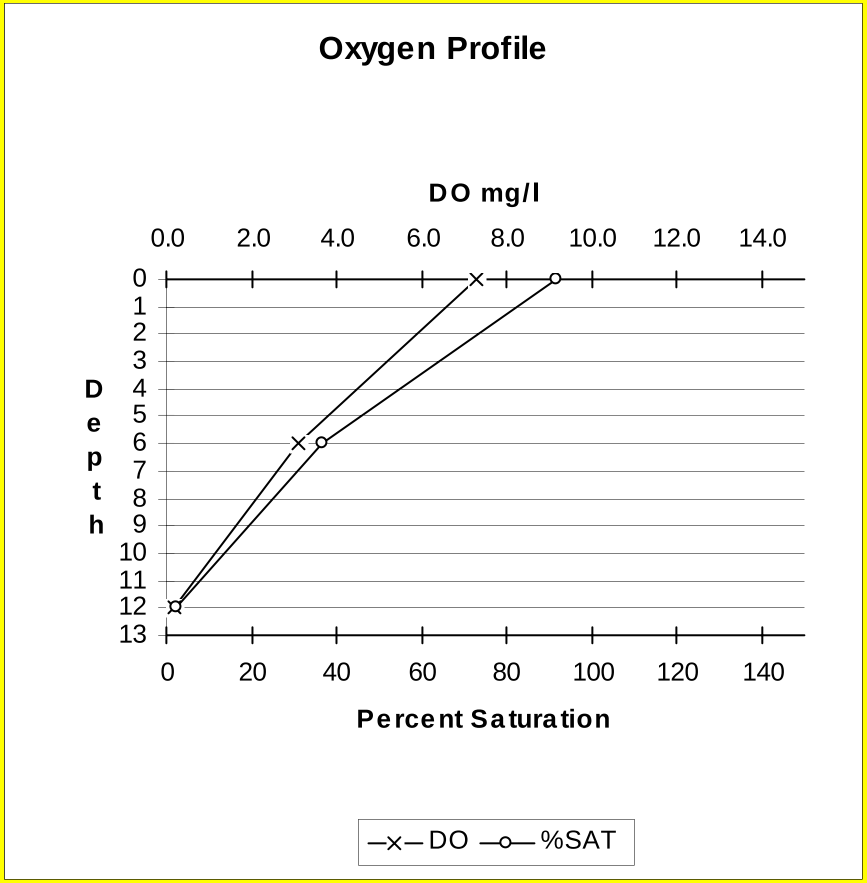
Relative Thermal Resistance to Mixing

$$\textbf{RTRM} = \frac{\textbf{Density of Upper Layer} - \textbf{Density of Lower Layer}}{\textbf{Density at } 5^{o}\textbf{ C} - \textbf{Density at } 4^{o}\textbf{ C}}$$

RTRM

- …is a relative, non-dimensional, value which quantifies
- stratification as a function of temperature differential.
- …is independent of the units of depth used.
- …is additive (RTRMsum indicates total stratification intensity).
- …the Peak RTRM identifies the location and intensity
- of the thermocline (steepest density gradient).



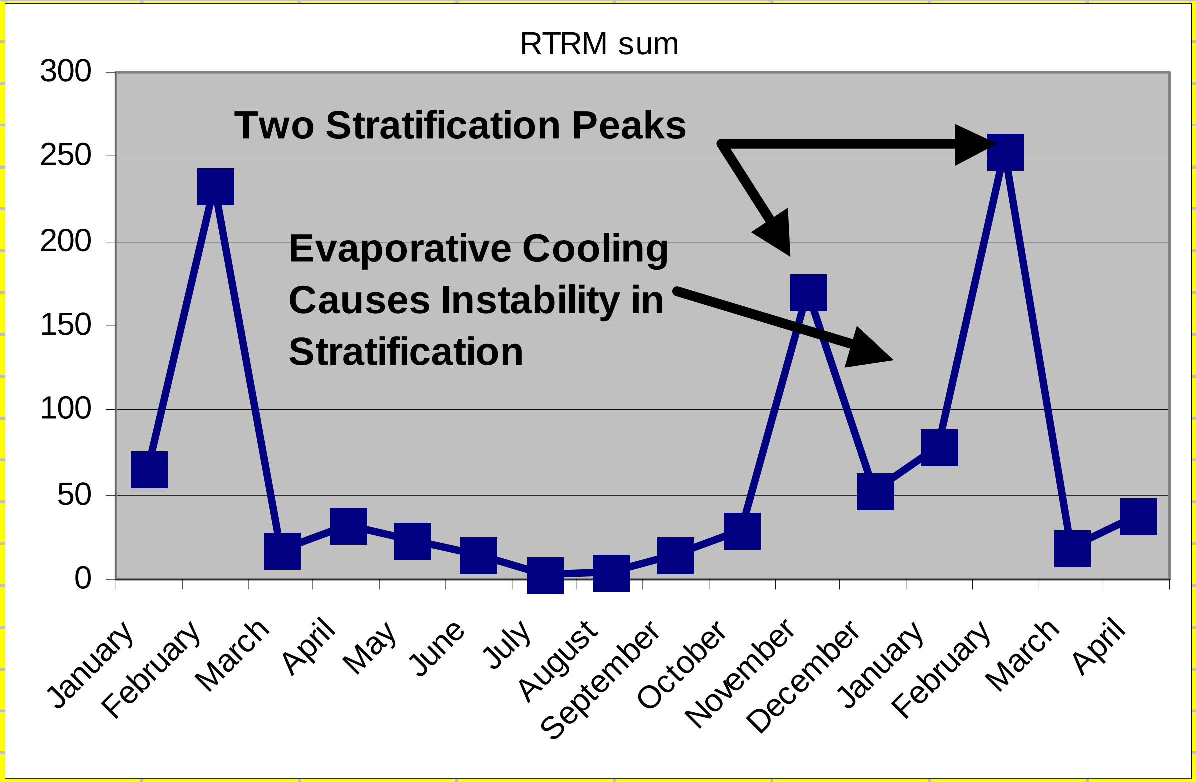


December 1993 (their summer)

Rio Grande Reservoir, Sao Paulo, Brazil

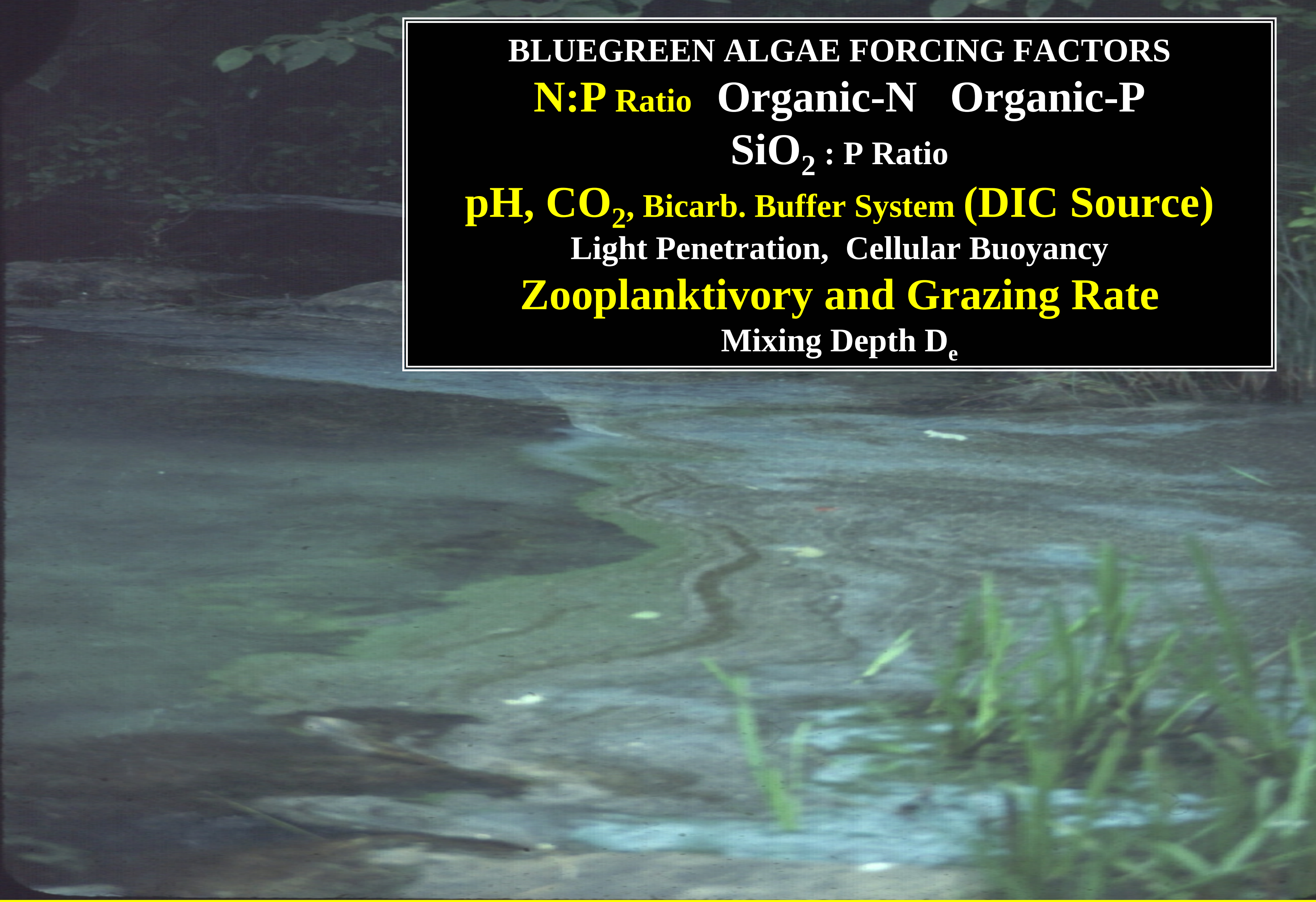
Depth in Meters RTRMsum= 209 RTRM Units

	RTRM sum
January	65
February	233
March	17
April	32
May	23
June	15
July	3
August	5
September	15
October	29
November	171
December	53
January	79
February	253
March	19
April	38

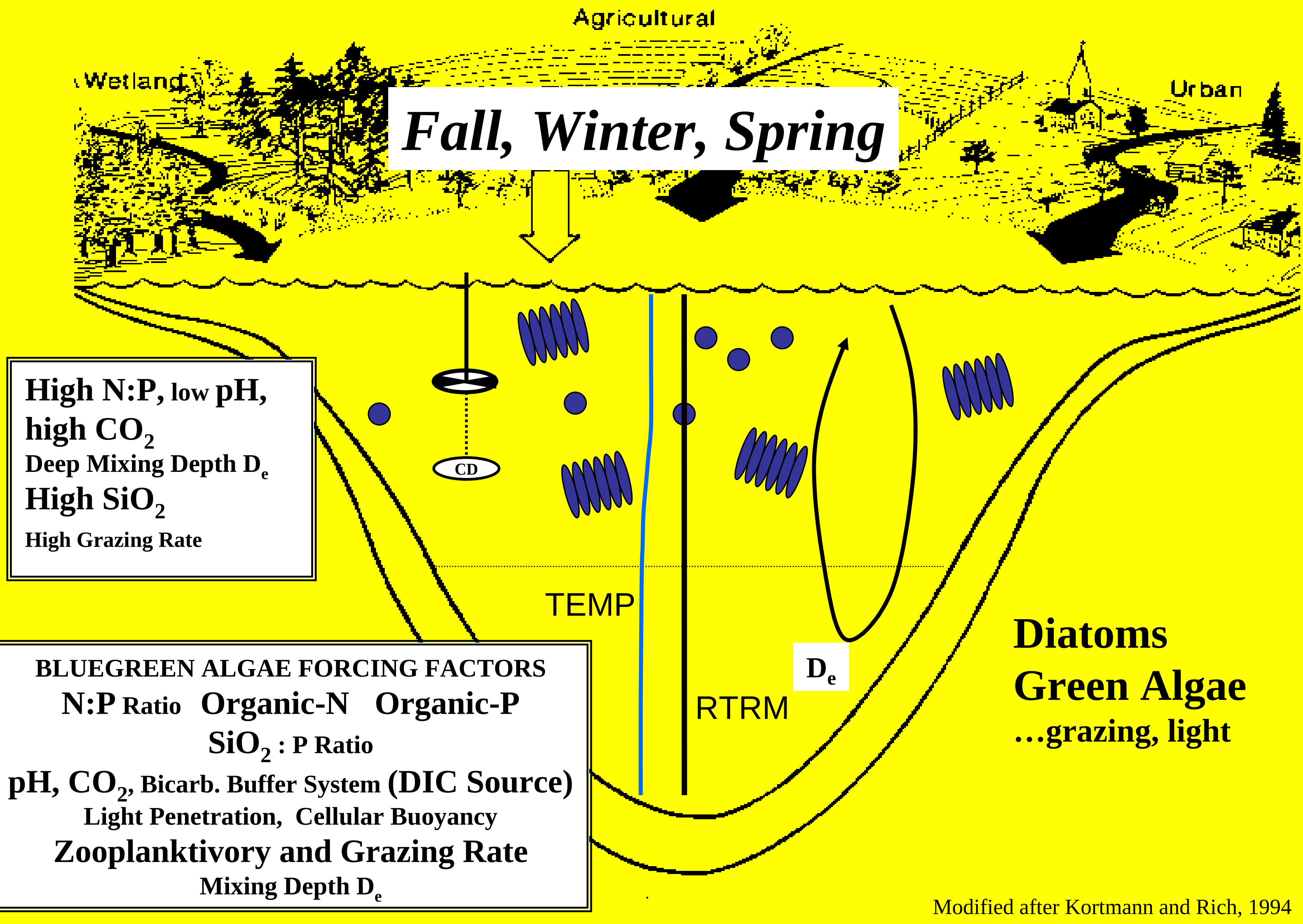


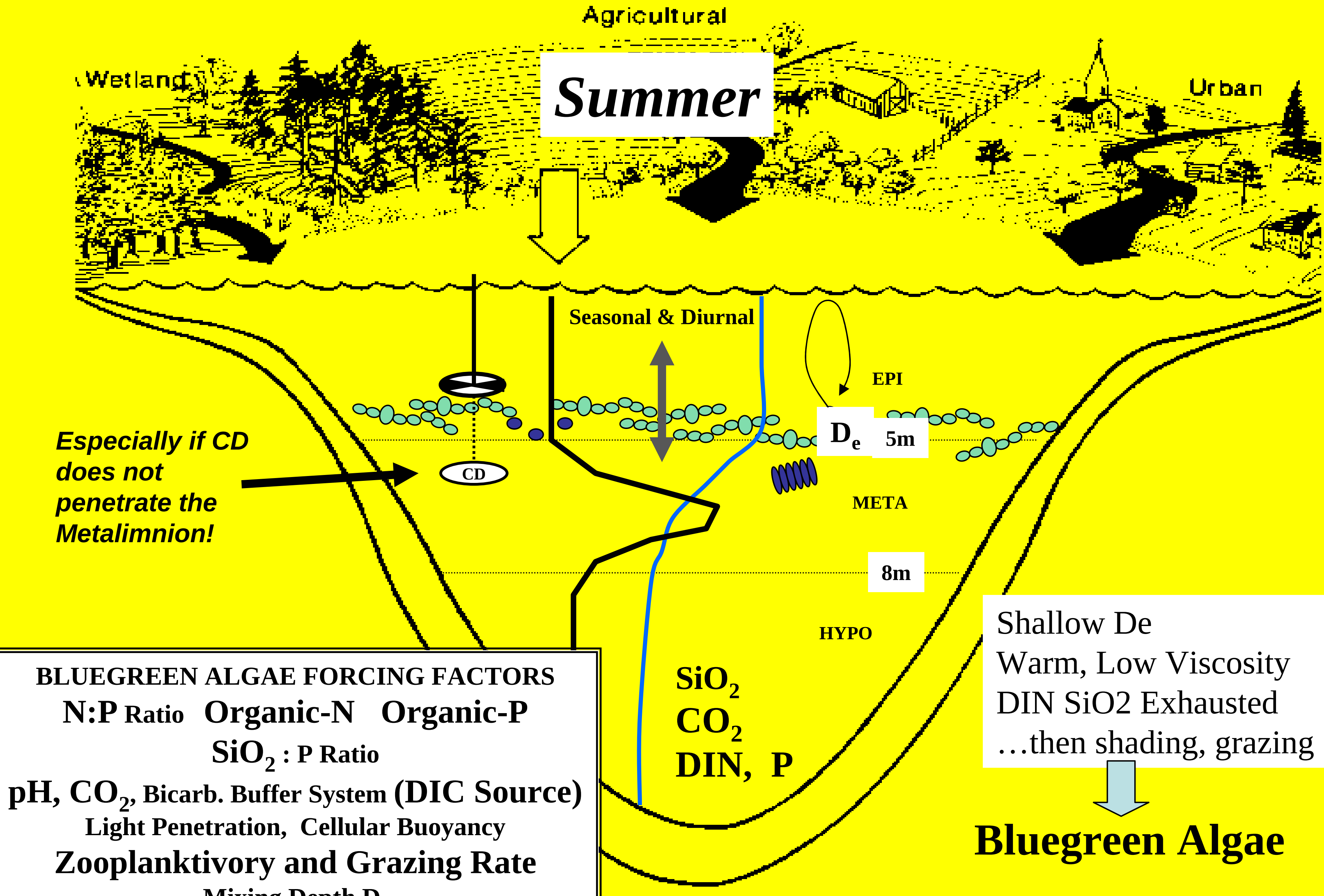
Guarapiranga Reservoir, Sao Paulo, Brazil

During the summer, two stratification peaks are observed (and result in two anoxia seasons, separated by a mixing episodes). The evaporative cooling during mid-summer represents enough temperature change (hence density change at the warm lake temperatures) To cause instability in stratification. The RTRM peaks during February and March are typically Stronger because overall temperatures are higher (remember the higher the temperature, the stronger The resistance to mixing per degree difference). The reservoir typically exhibits bluegreen algae Blooms in January-April.

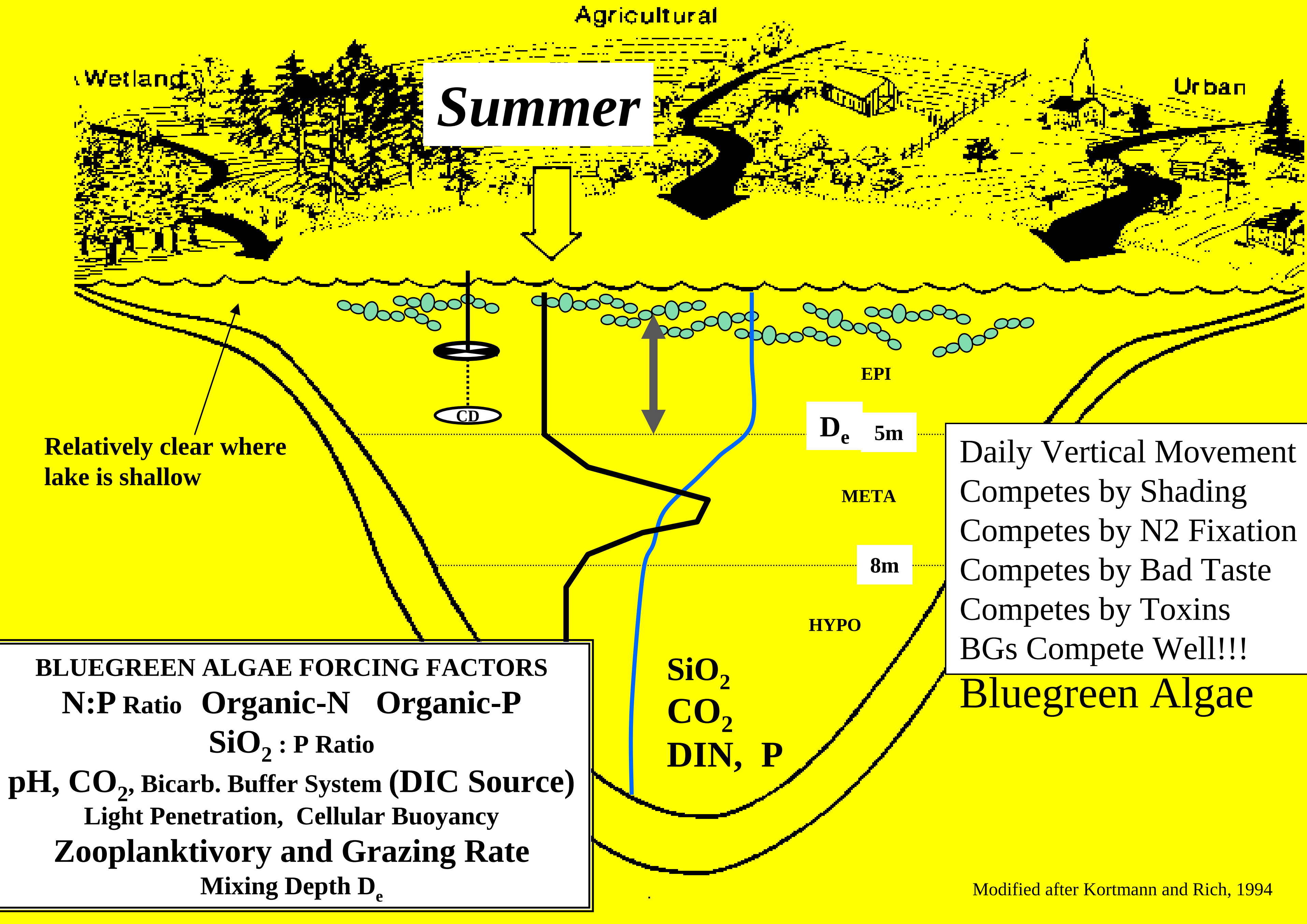


Bluegreen Algae (Cyanobacteria, prokaryotic cells)


Agricultural
Wetland
Urban
Fall, Winter, Spring
CD
TEMP
RTRM
D_e
High N:P, low pH, high CO_2
Deep Mixing Depth D_e
High SiO_2
High Grazing Rate
BLUEGREEN ALGAE FORCING FACTORS
N:P Ratio Organic-N Organic-P
SiO_2 : P Ratio
pH, CO_2, Bicarb. Buffer System (DIC Source)
Light Penetration, Cellular Buoyancy
Zooplanktivory and Grazing Rate
Mixing Depth D_e
Diatoms
Green Algae
…grazing, light
Modified after Kortmann and Rich, 1994



Modified after Kortmann and Rich, 1994


Agricultural
Wetland
Urban
Summer
CD
EPI
D_e
5m
META
8m
HYPO
Relatively clear where lake is shallow
Daily Vertical Movement
Competes by Shading
Competes by N2 Fixation
Competes by Bad Taste
Competes by Toxins
BGs Compete Well!!!
Bluegreen Algae
SiO_2
CO_2
DIN, P
BLUEGREEN ALGAE FORCING FACTORS
N:P Ratio Organic-N Organic-P
SiO_2 : P Ratio
pH, CO_2, Bicarb. Buffer System (DIC Source)
Light Penetration, Cellular Buoyancy
Zooplanktivory and Grazing Rate
Mixing Depth D_e
Modified after Kortmann and Rich, 1994

Now for a "closer look" …

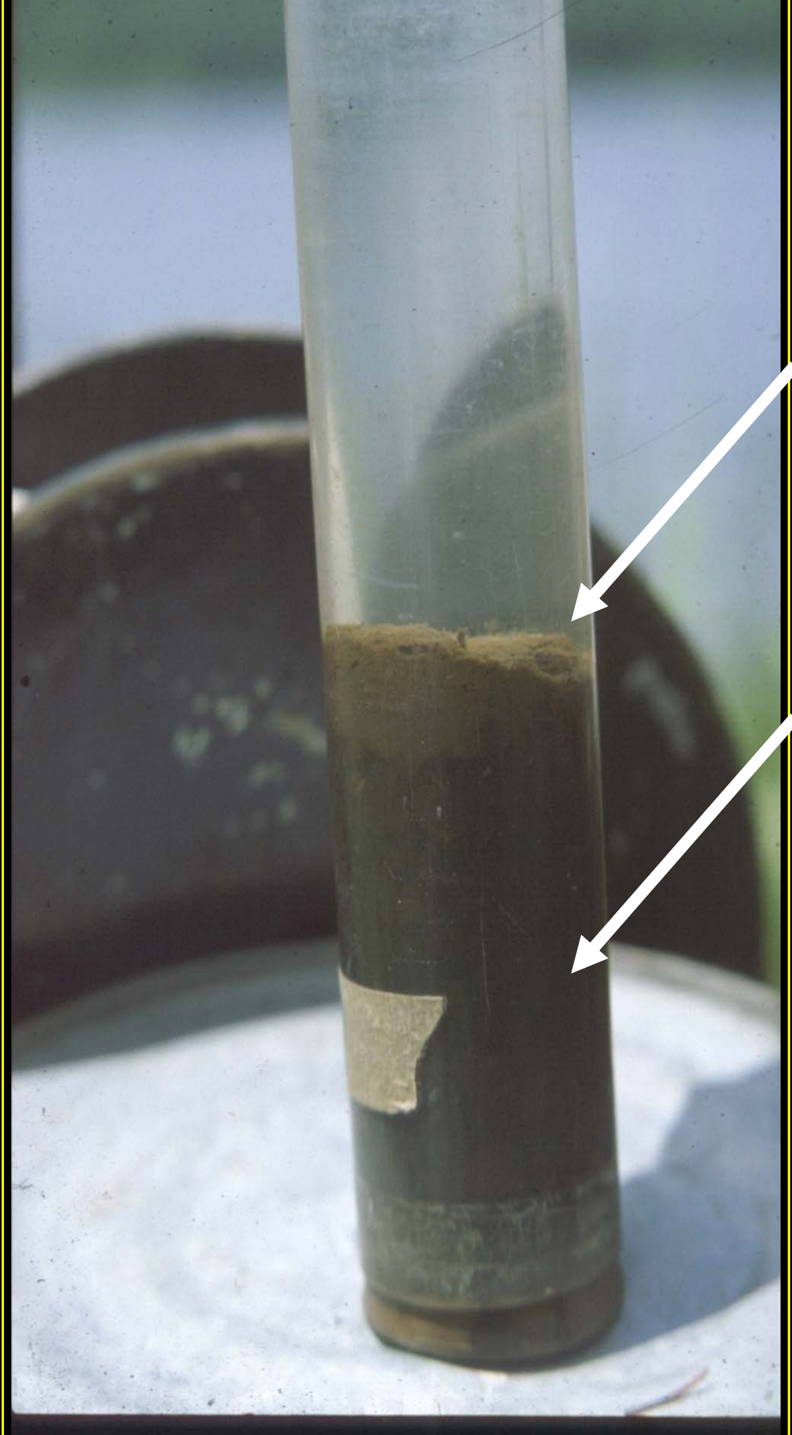
… with diagnostic and management implications.

Synthesis – Respiration: Anaerobic Pathways

Physical Limnology: Managing the Heat Budget and Stratification Dynamics

Food Web Dynamics: Productivity vs. Biomass

In Fe-dominated systems:

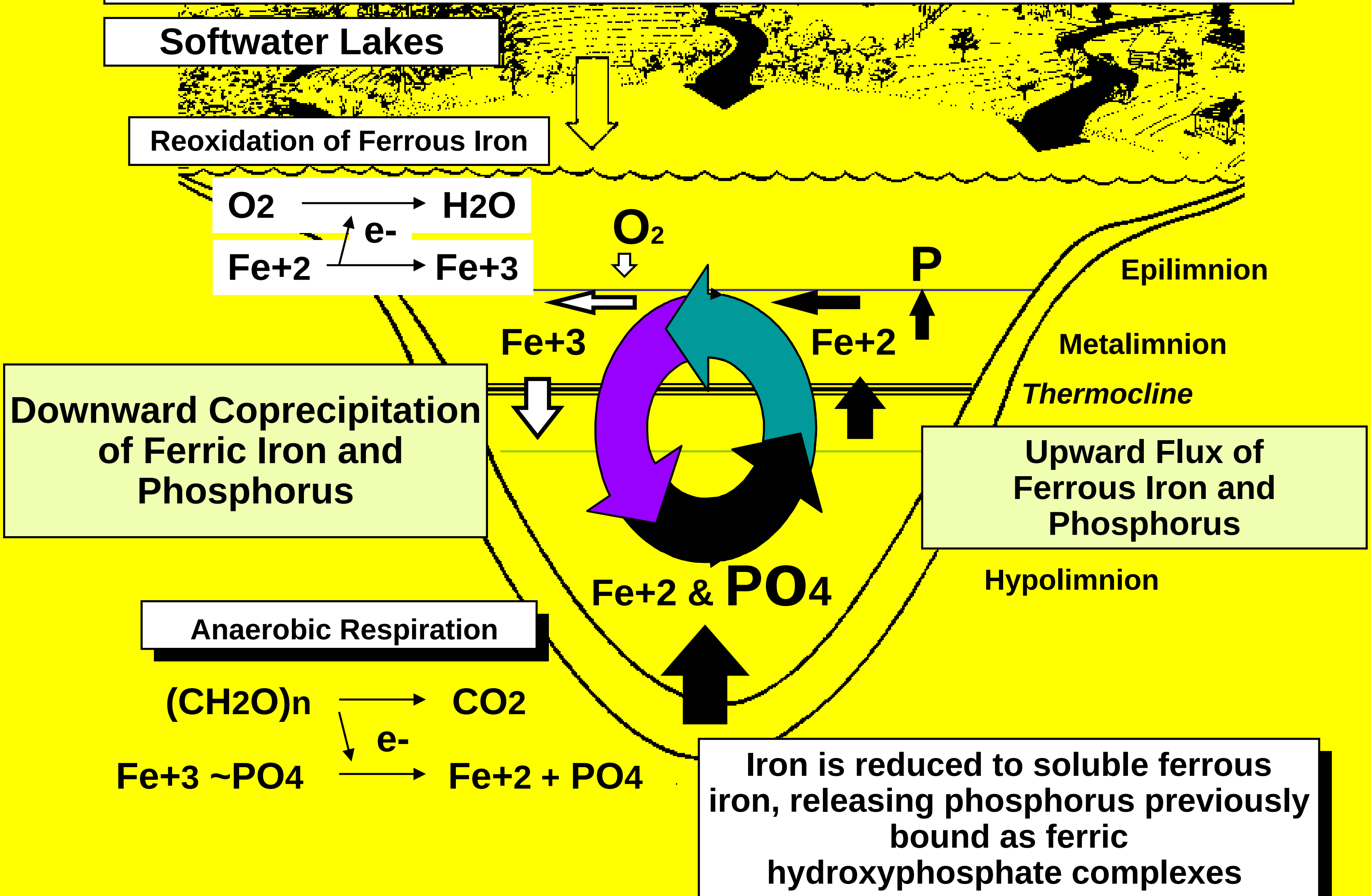


Oxidized Microzone
Ferric Iron Complexes
(*Some* of the Fe binds P)

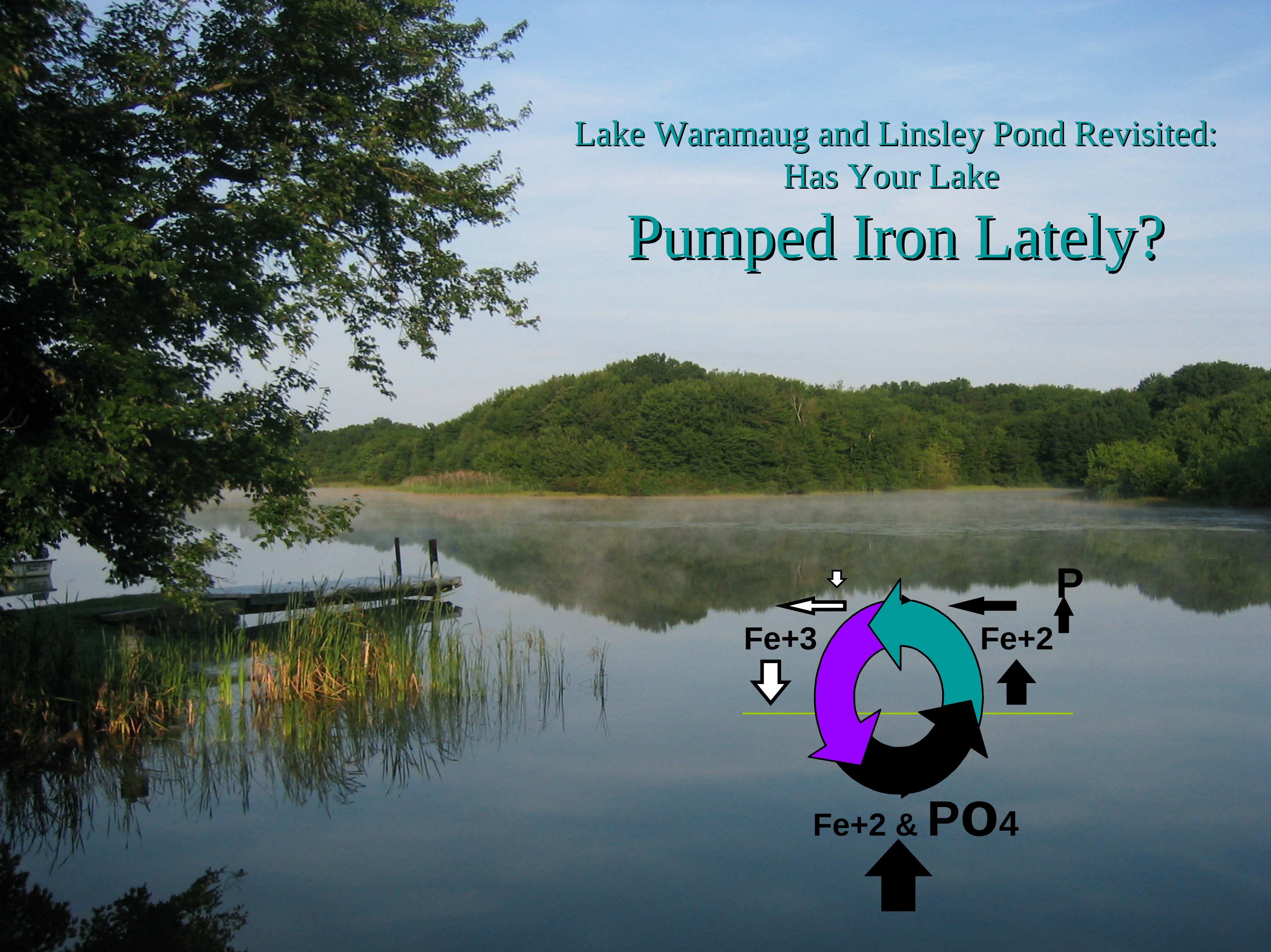
Deep Anaerobic Sediments
(with Ferr***ous*** Sulf***ide*** solids;
Note: both the iron and
sulfur are chemically
reduced and do not
participate in biotic redox or
P-binding any longer!)

(Re: Roger Doyle, 1968)

The Ferrous Wheel

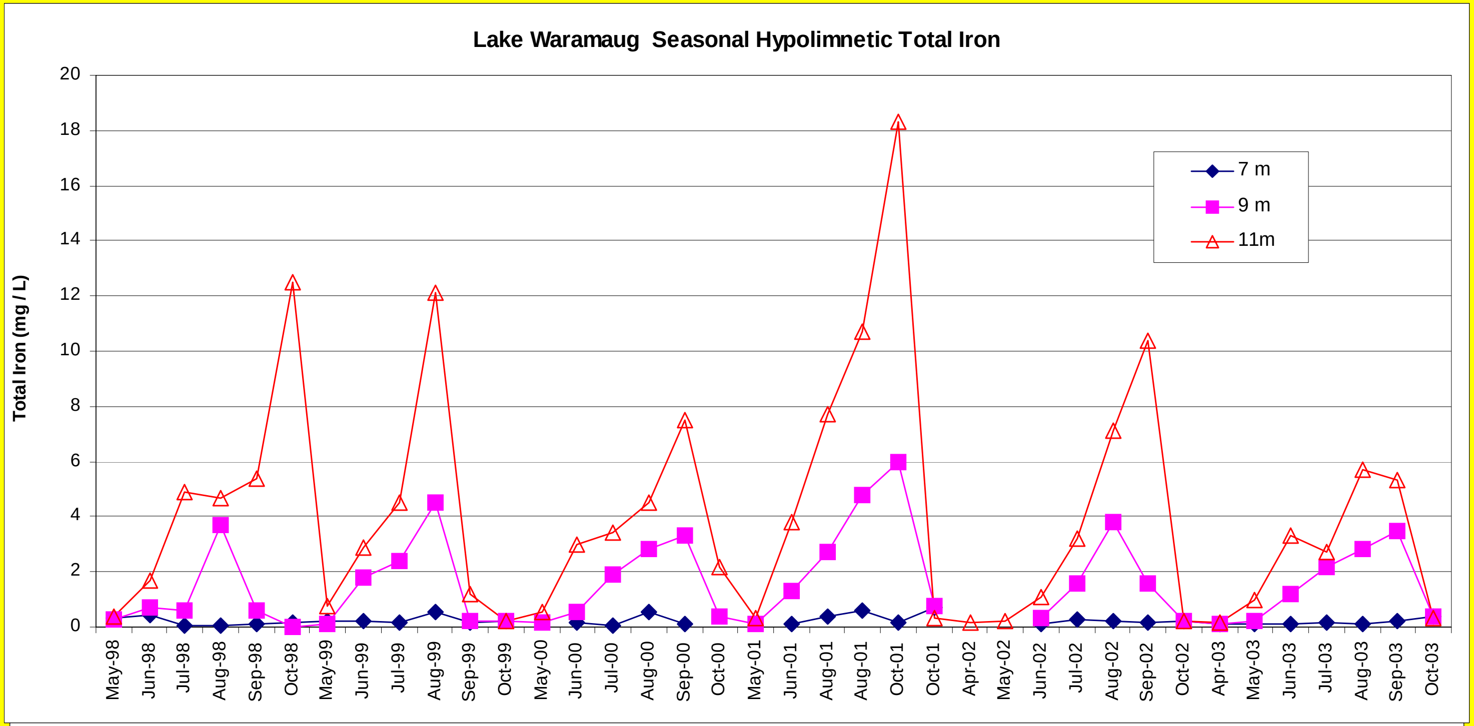


Lake Waramaug and Linsley Pond Revisited: Has Your Lake Pumped Iron Lately?

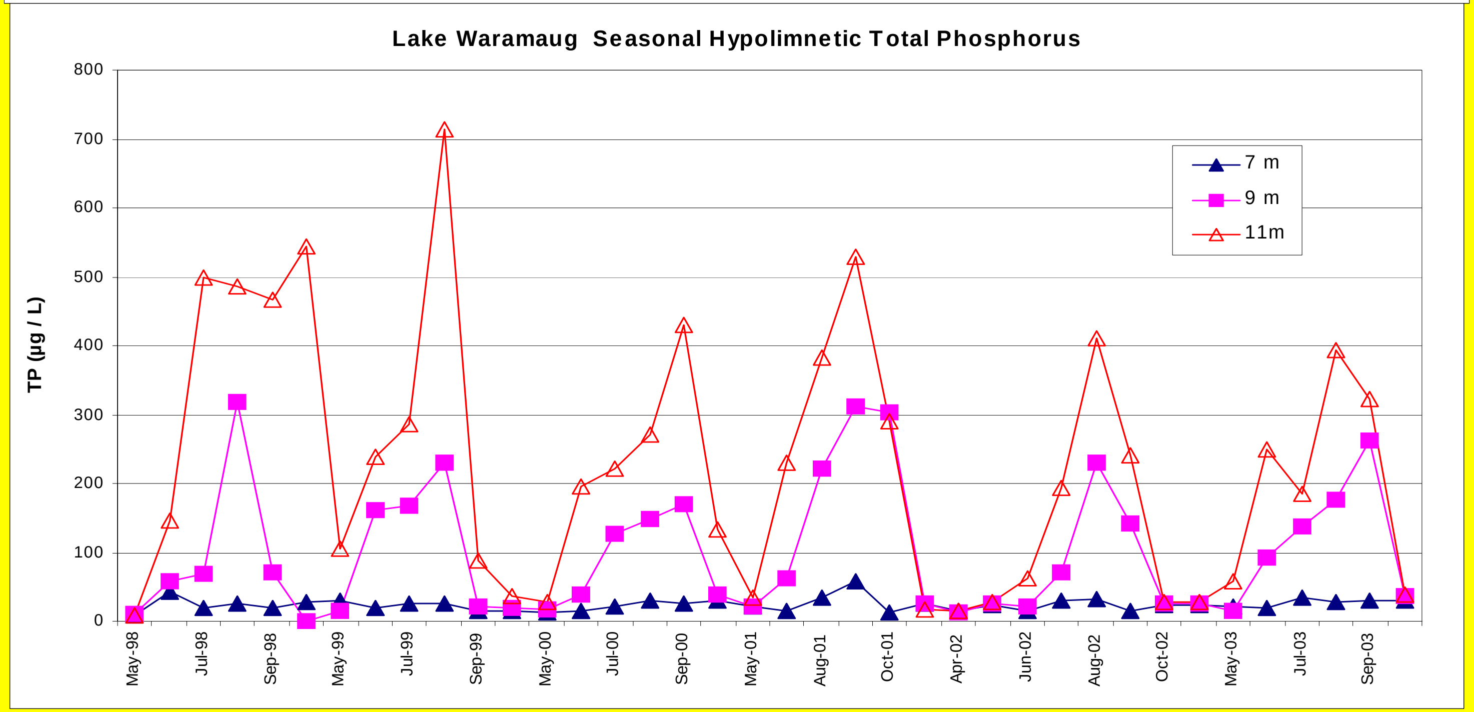


Lake Waramaug (Algonquin for “place of good fishing”) began to experience intense BG blooms in the late 1970’s.

Fe


Lake Waramaug Seasonal Hypolimnetic Total Iron
Total Iron (mg / L)
20
18
16
14
12
10
8
6
4
2
0
7 m
9 m
11m
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Oct-98
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
May-01
Jun-01
Aug-01
Aug-01
Oct-01
Oct-01
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03

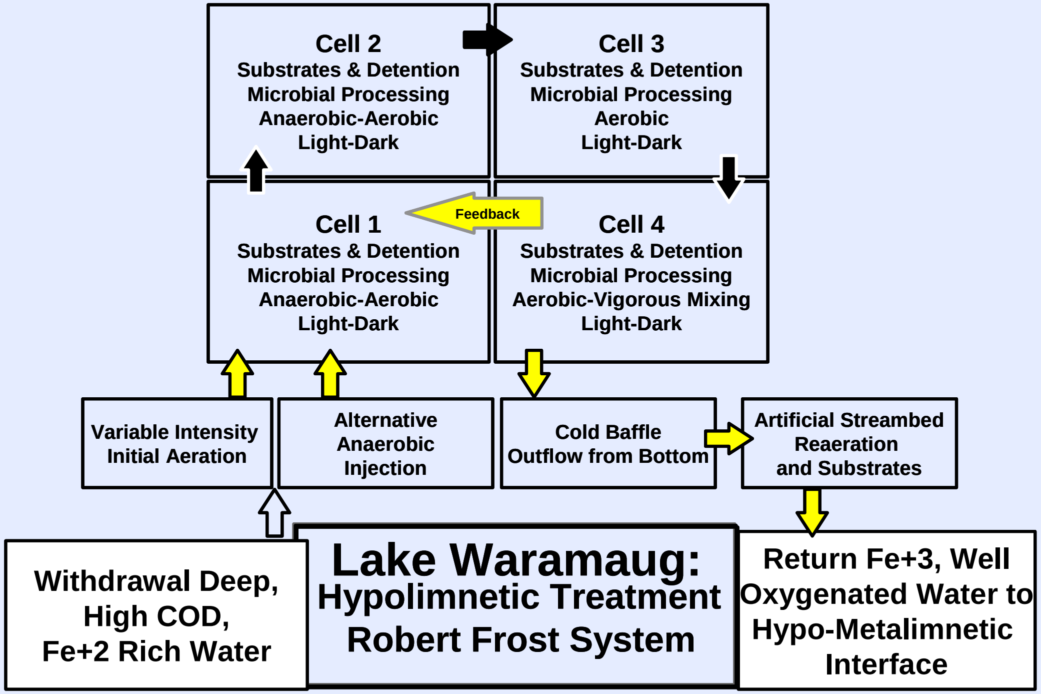
TP


Lake Waramaug Seasonal Hypolimnetic Total Phosphorus
TP (µg / L)
800
700
600
500
400
300
200
100
0
7 m
9 m
11m
May-98
Jul-98
Sep-98
May-99
Jul-99
Sep-99
May-00
Jul-00
Sep-00
May-01
Aug-01
Oct-01
Apr-02
Jun-02
Aug-02
Oct-02
May-03
Jul-03
Sep-03

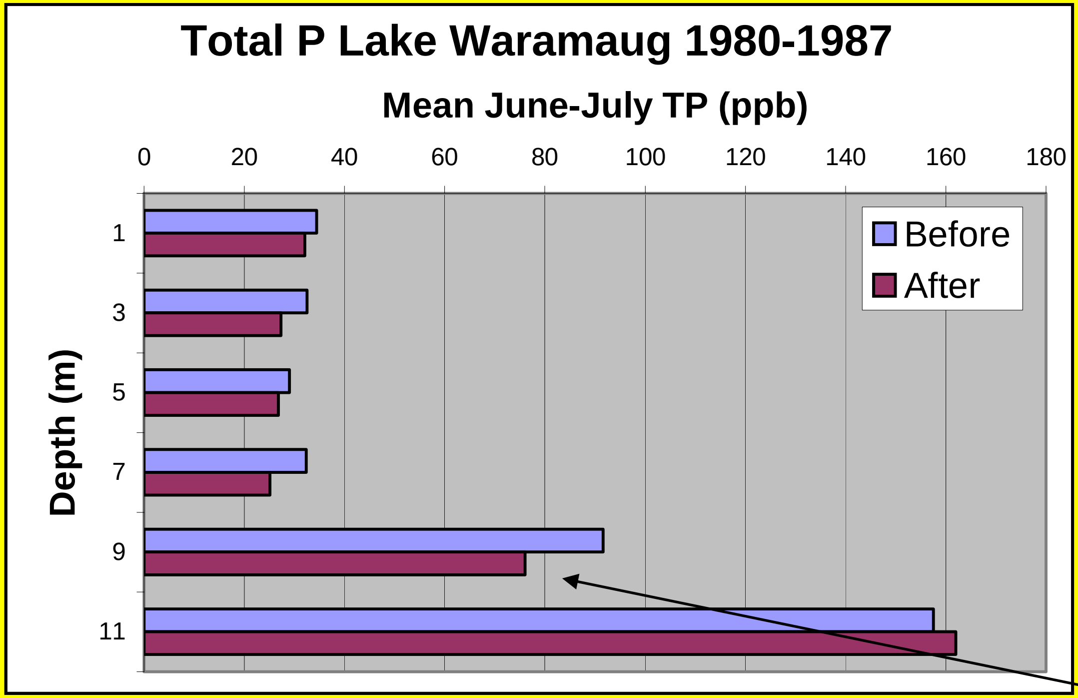
Lake Waramaug
(Fe still carries Anaerobic Respiration)

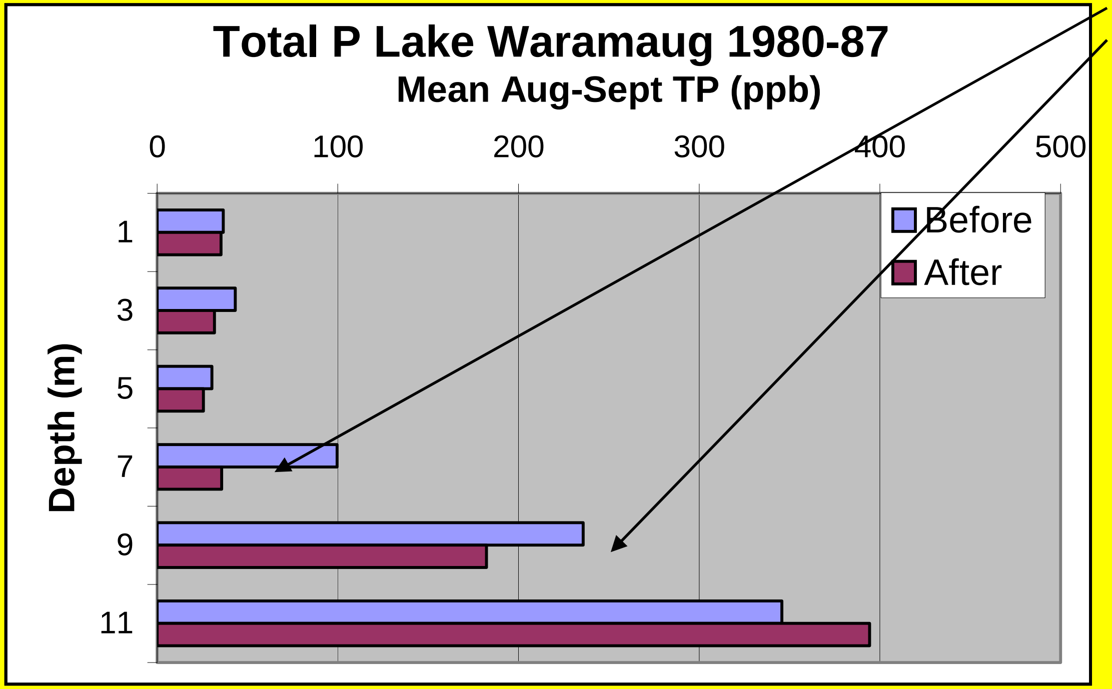
Iron, generated by anaerobic respiration, is used as a coagulant to remove P from lake water.

(Akin to an *annual* alum treatment without adding any chemicals.)



In-lake treatment focused on the "nature of the iron cycle"; ferrous iron generated deep in the hypolimnion was oxidized and "rained back down through the hypolimnion", taking P with it.

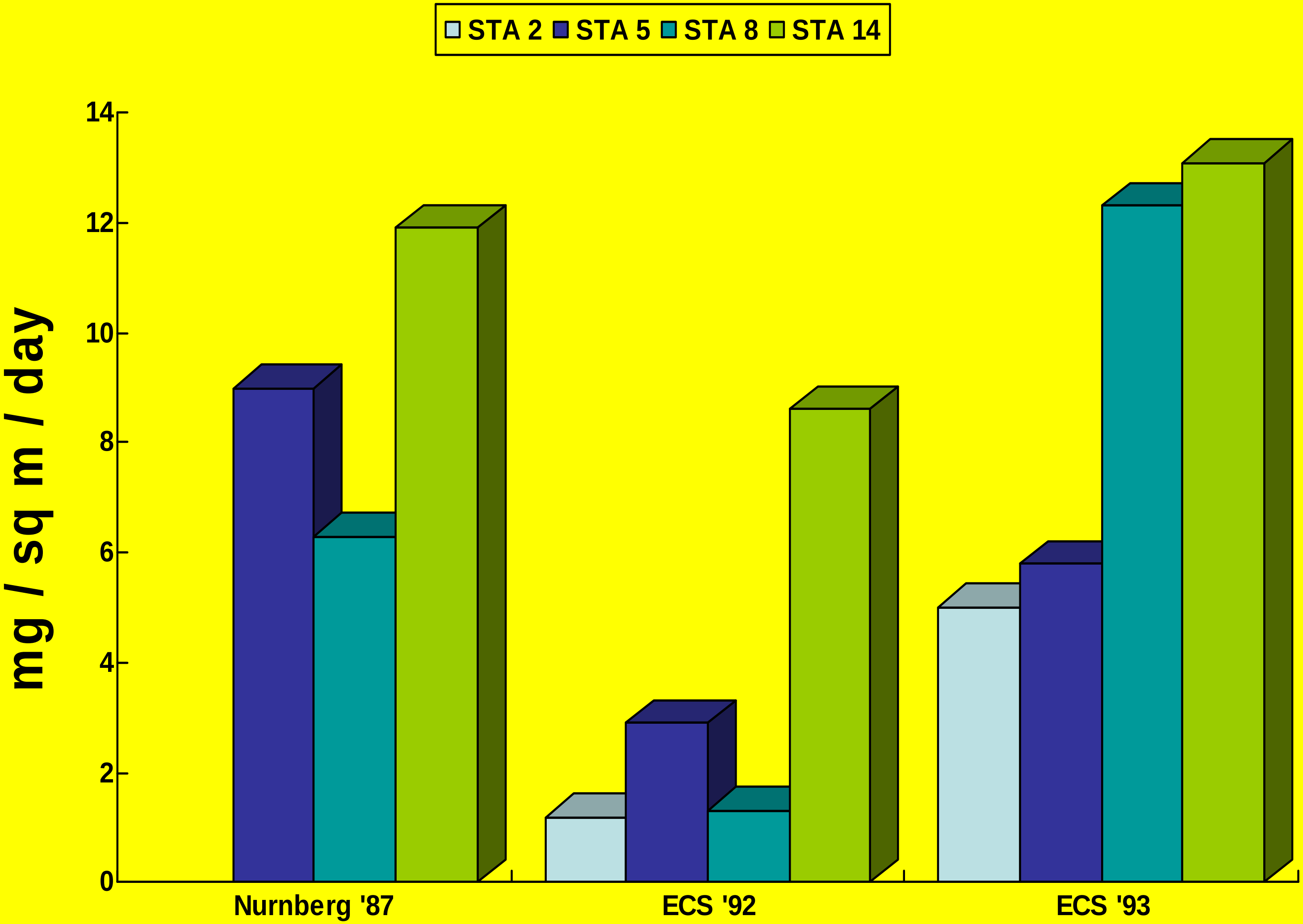




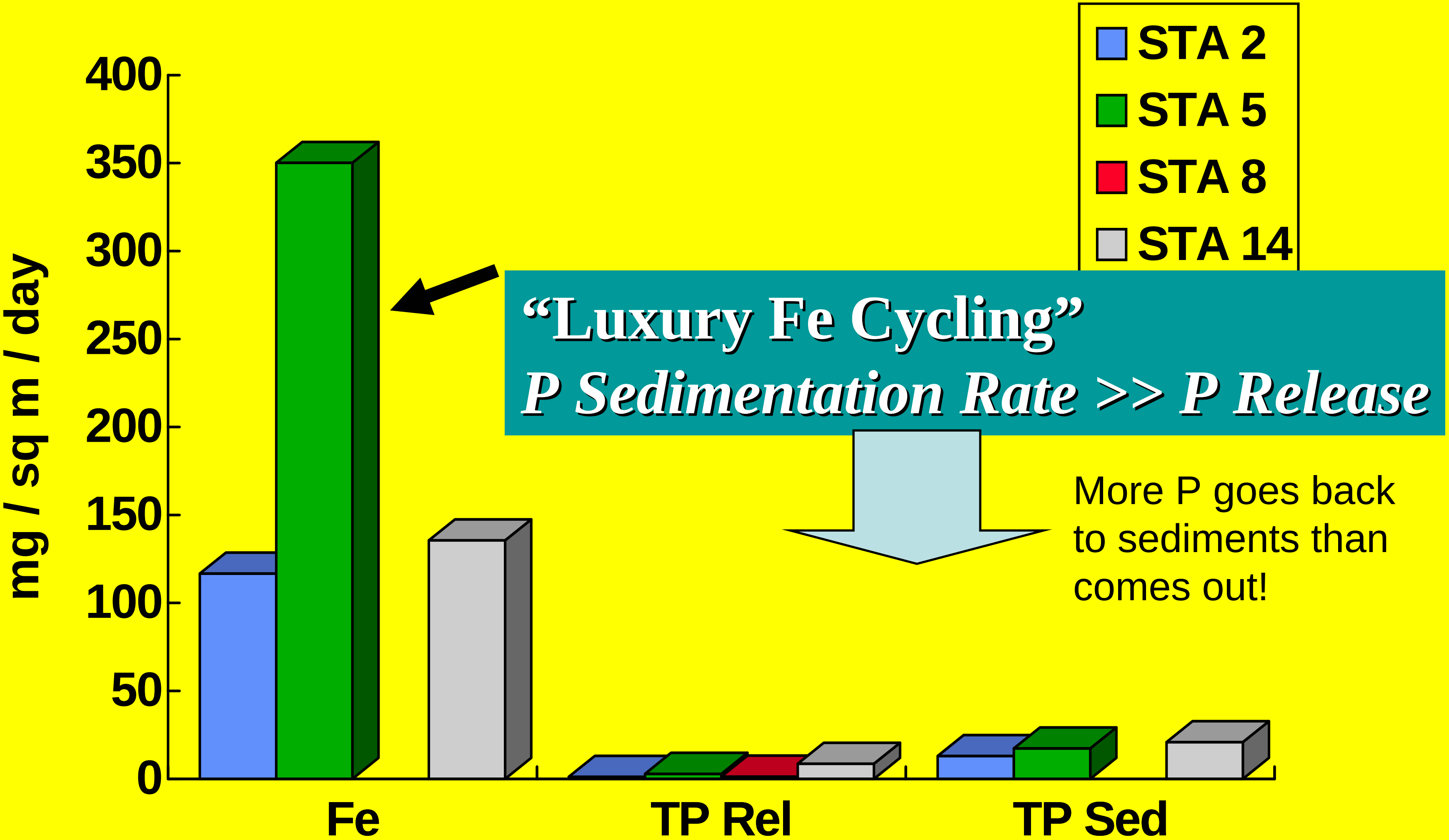
During the initial years of "treatment", TP concentrations decreased, *especially in the upper hypolimnion.*

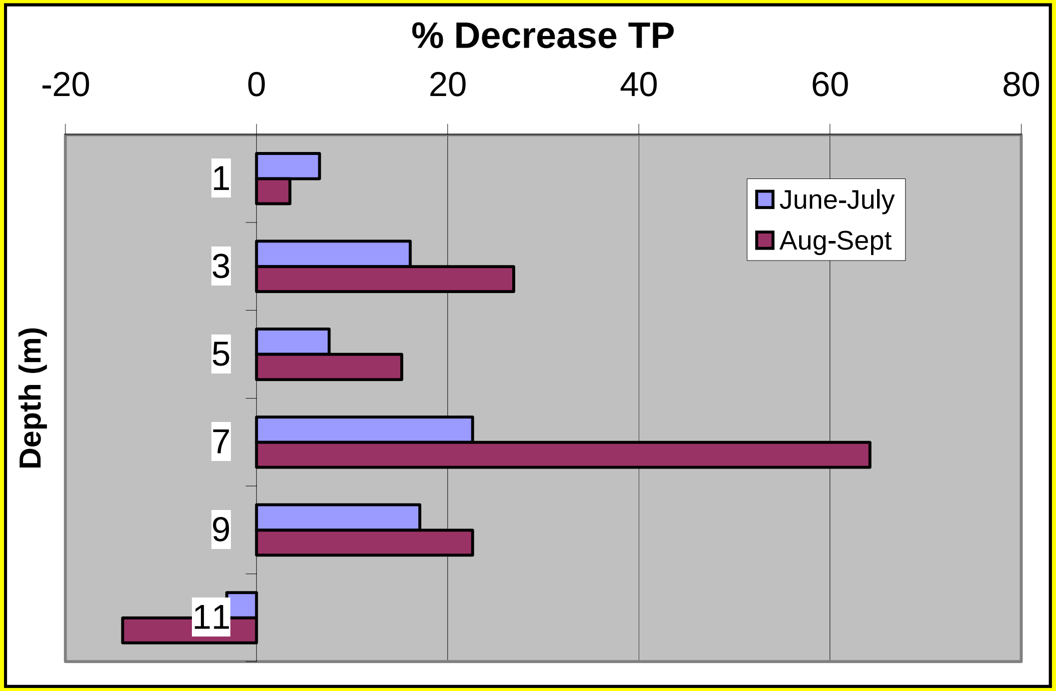
Lake Waramaug

Mean Summer Sediment TP Release Rates

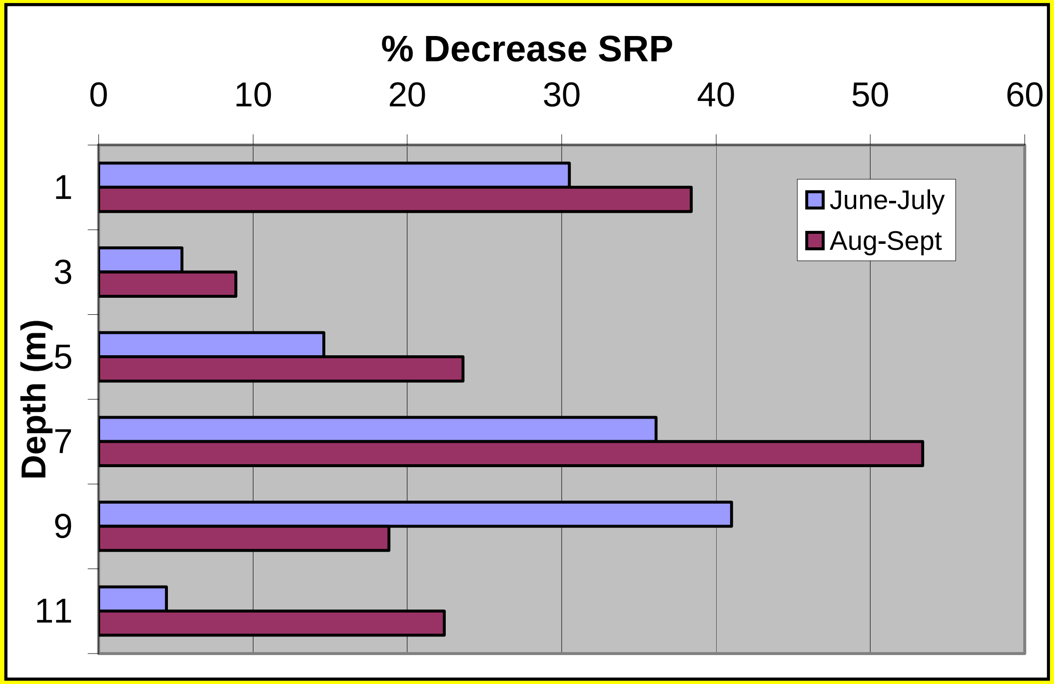


TP Fe Sedimentation 1994





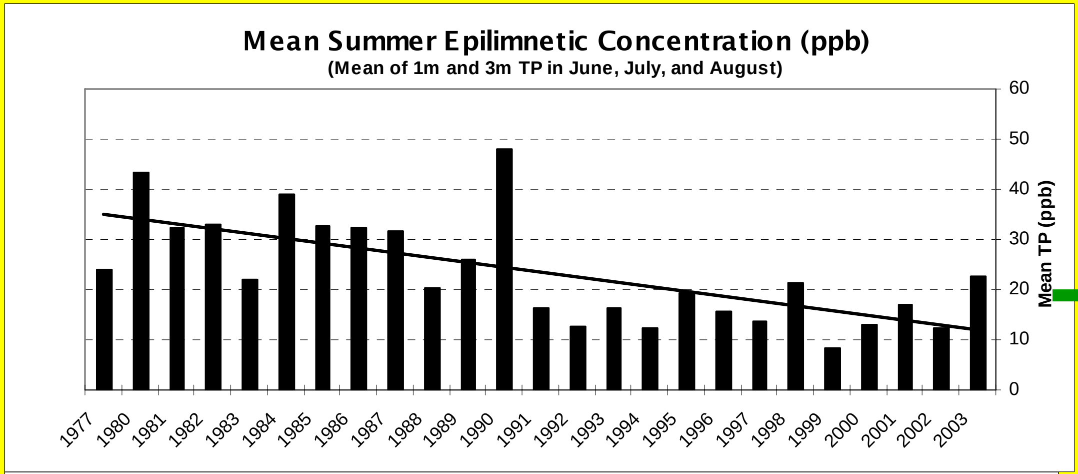
% Decrease in TP and SRP at Lake Waramaug



In addition to decreased TP concentrations in the upper hypolimnion, *much less of the TP was readily assimilable SRP*.

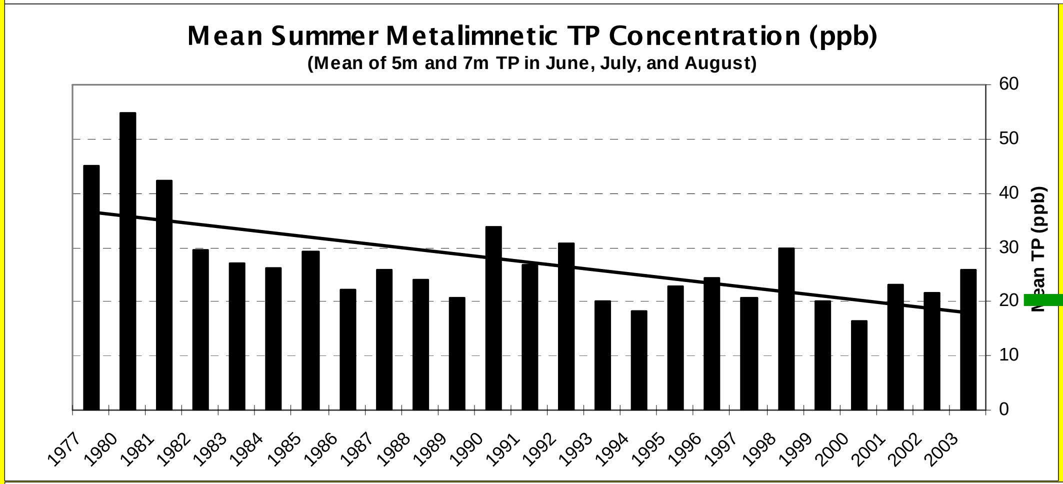
LAKE WARAMAUG
Mean Summer
TP Concentrations

Surface Water



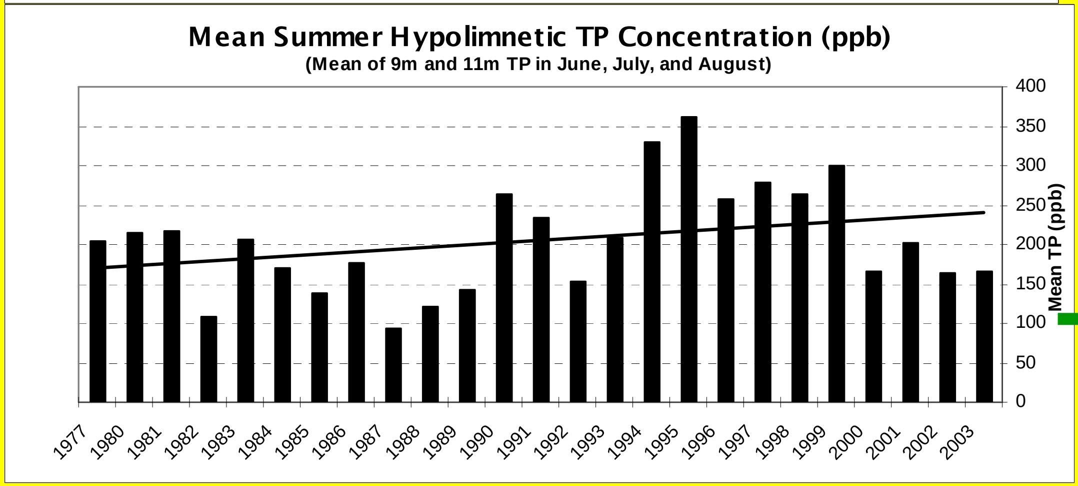
20 ppb

Mid-Depth Water



20 ppb

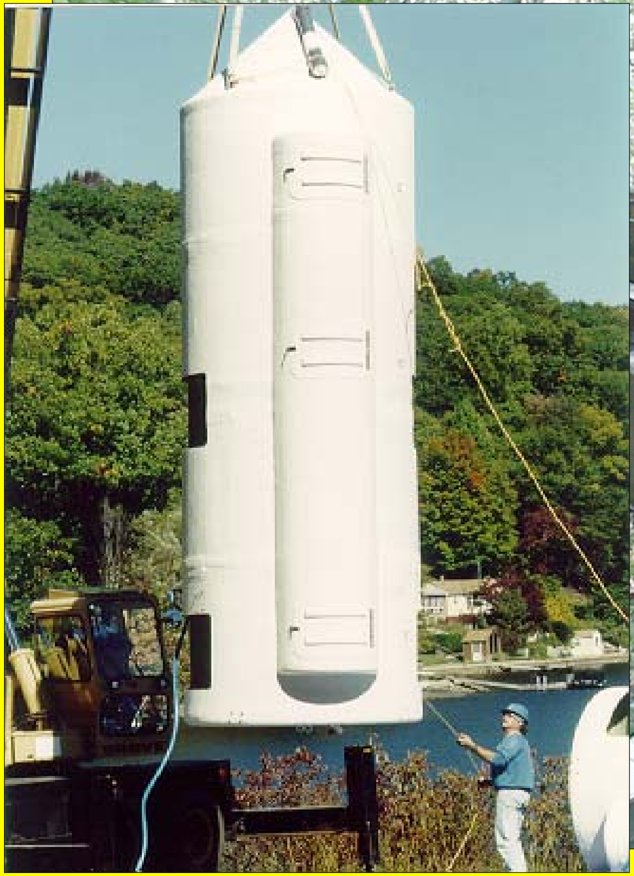
Deep Water



100 ppb

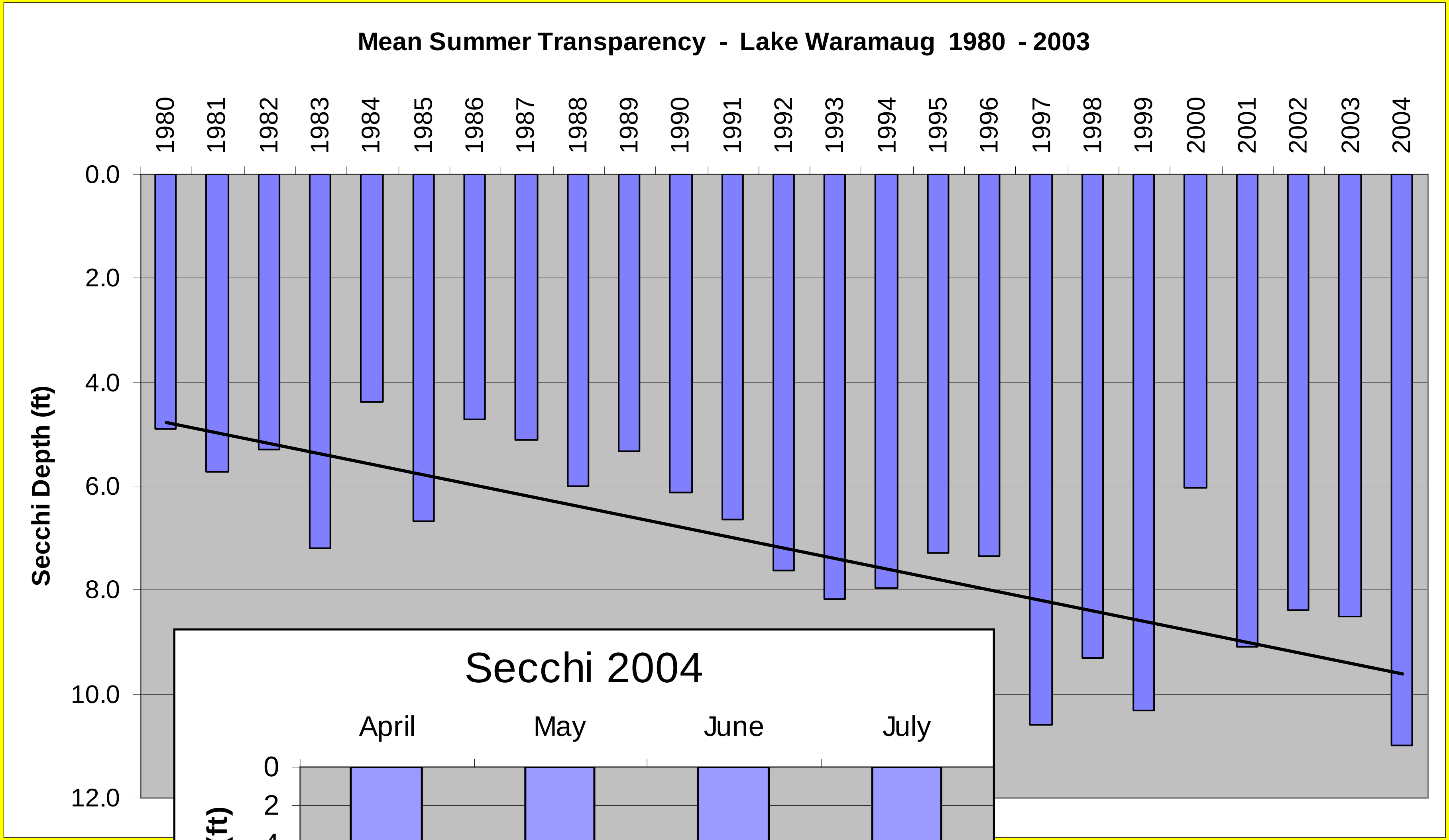
Robert Frost Hypolimnetic Treatment System

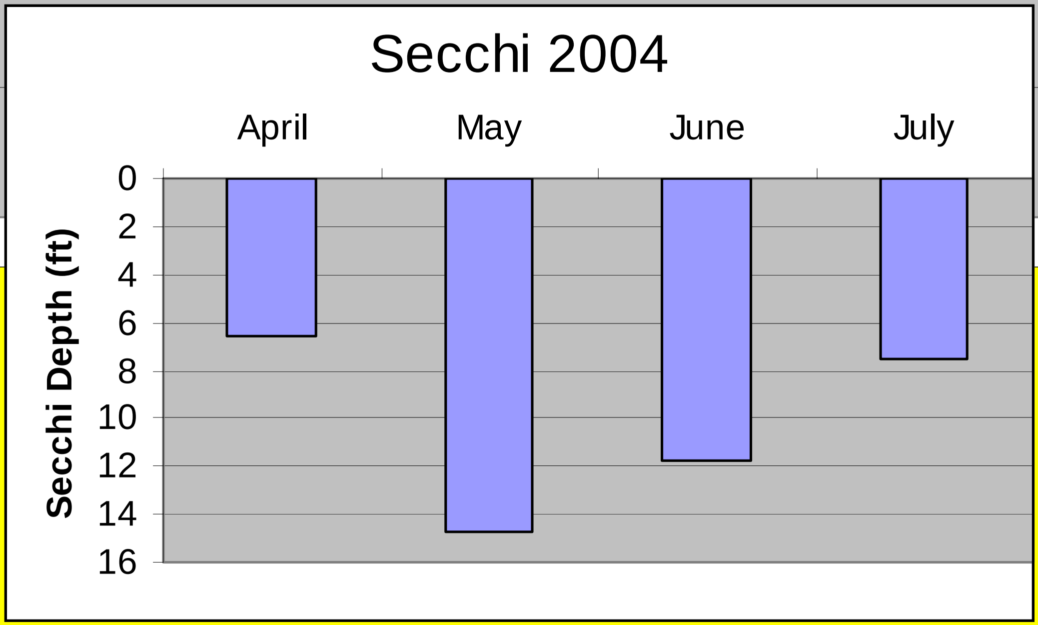
"Uses iron generated by the lake to remove P from the lake."



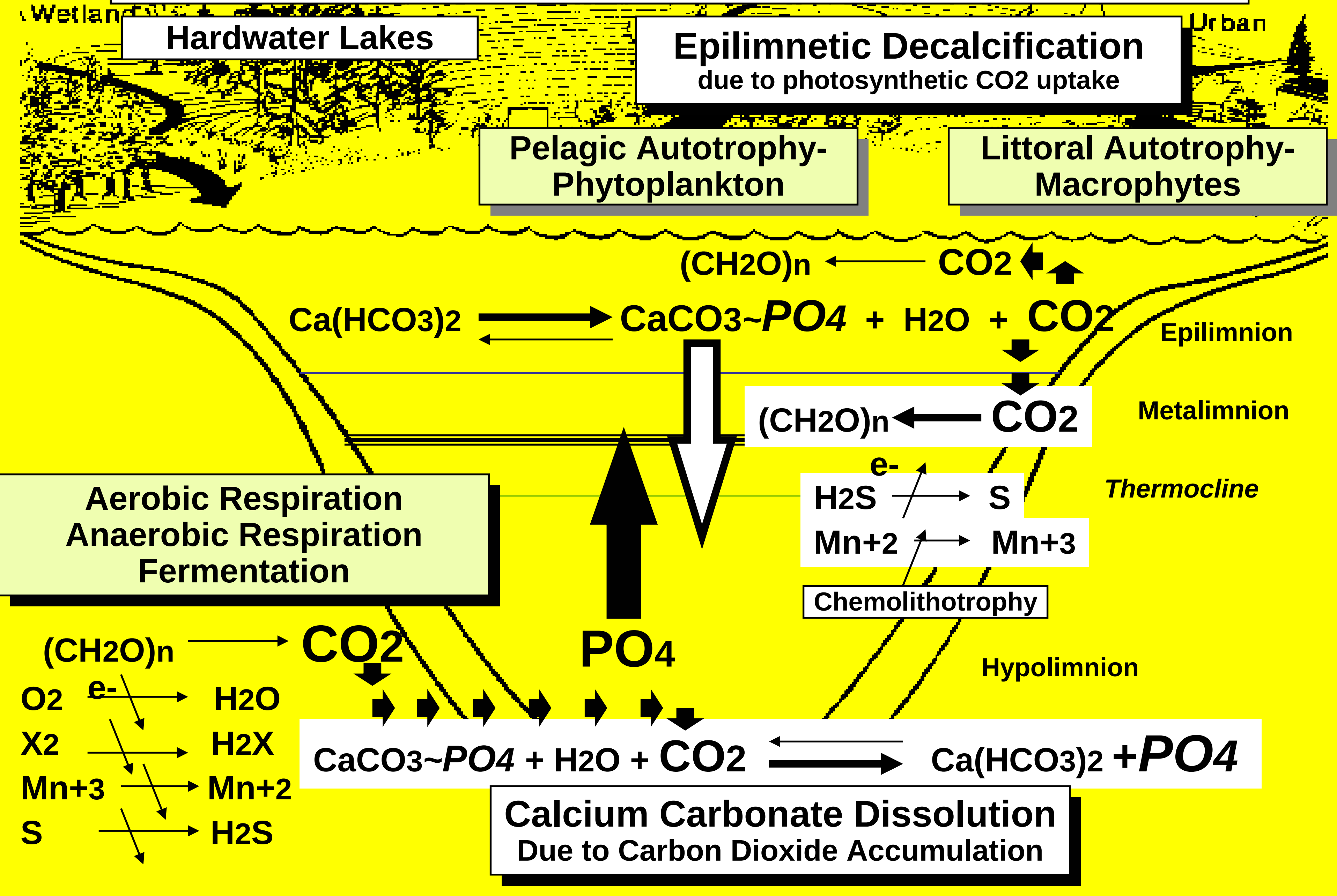
Layer Aeration System

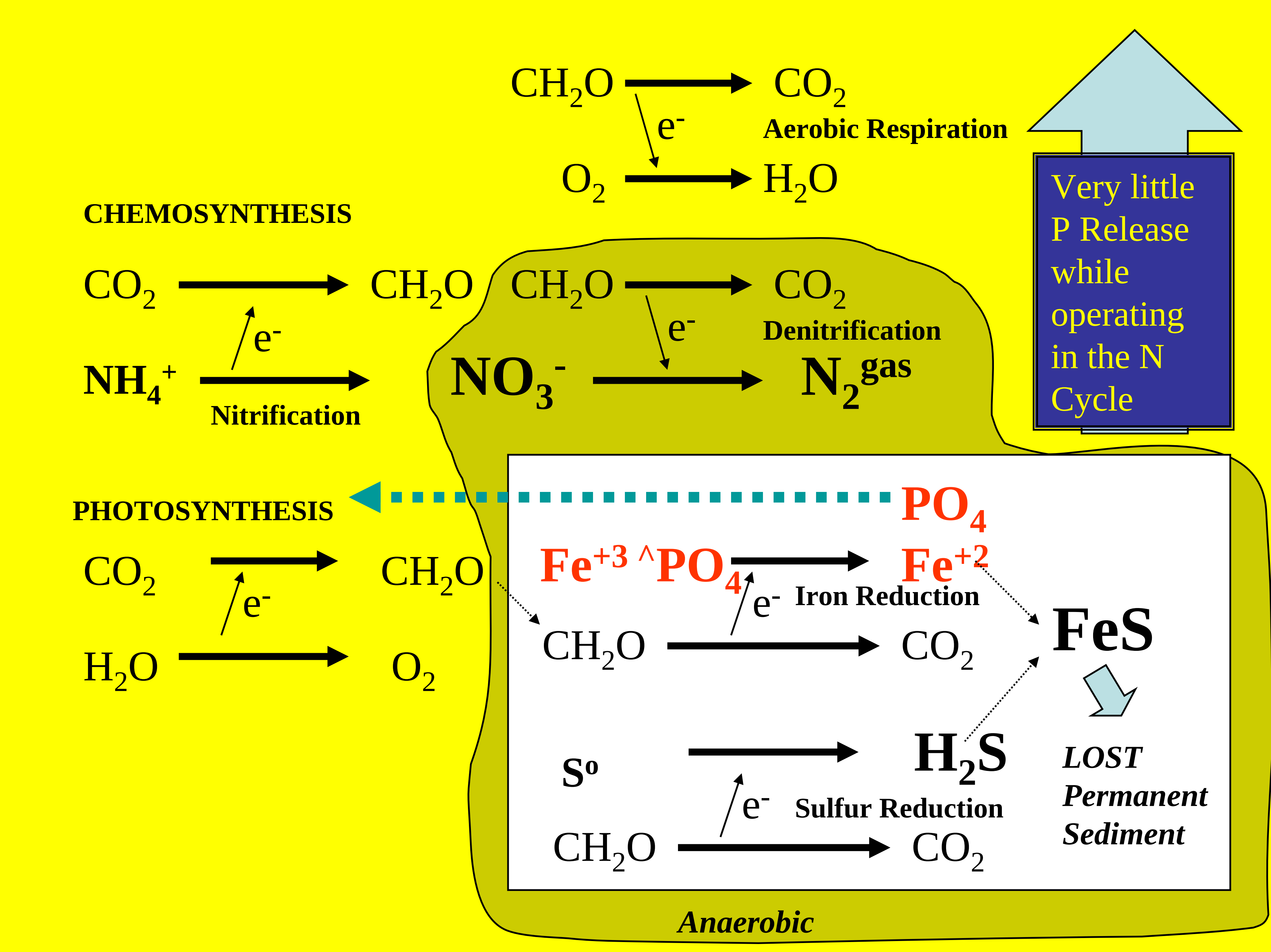
"Uses oxygen produced by plants and algae to aerate deeper waters."


Mean Summer Transparency - Lake Waramaug 1980 - 2003
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
0.0
2.0
4.0
6.0
8.0
10.0
12.0
Secchi Depth (ft)


Secchi 2004
April
May
June
July
0
2
4
6
8
10
12
14
16
Secchi Depth (ft)

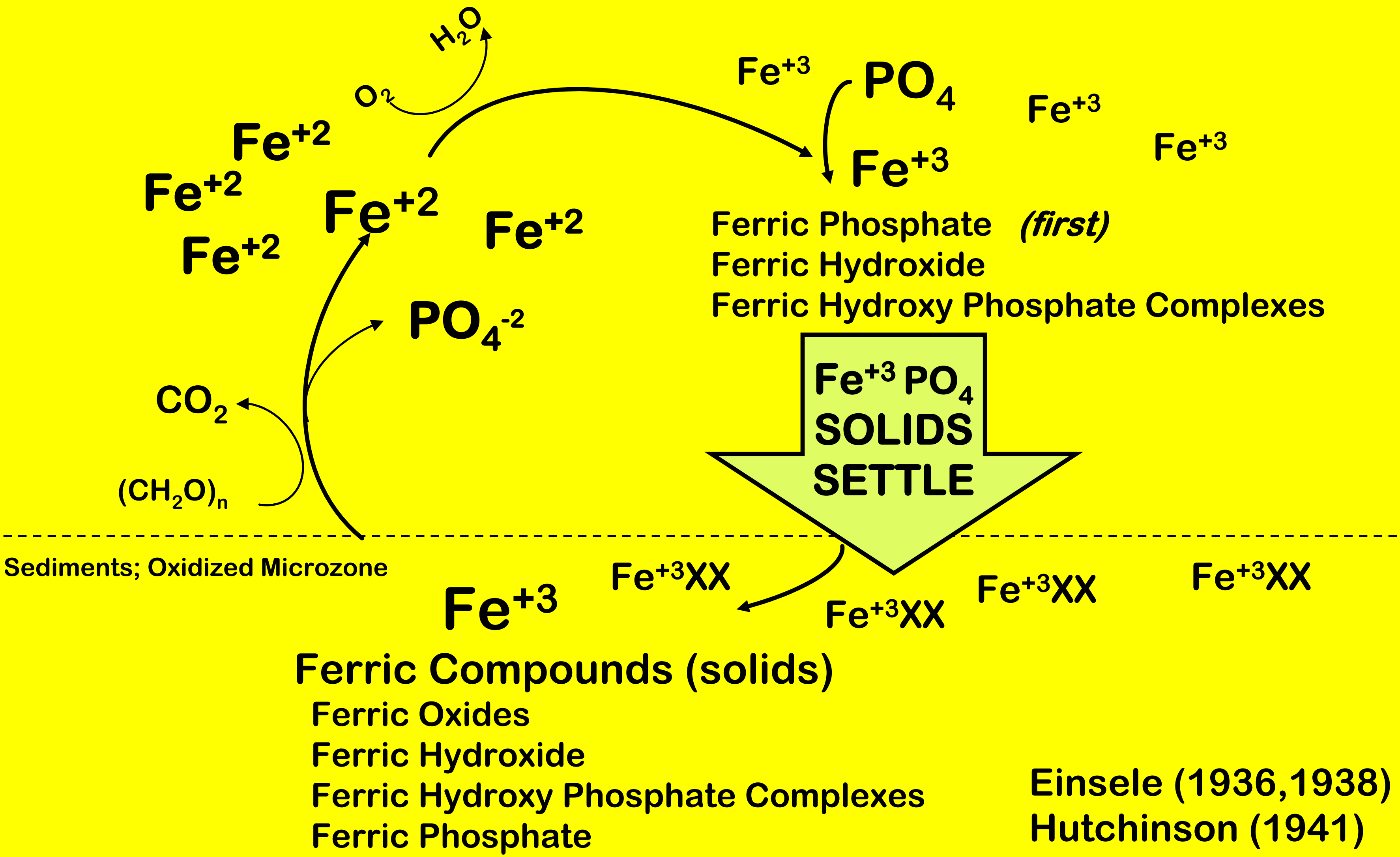
Carbonate System P Dynamics





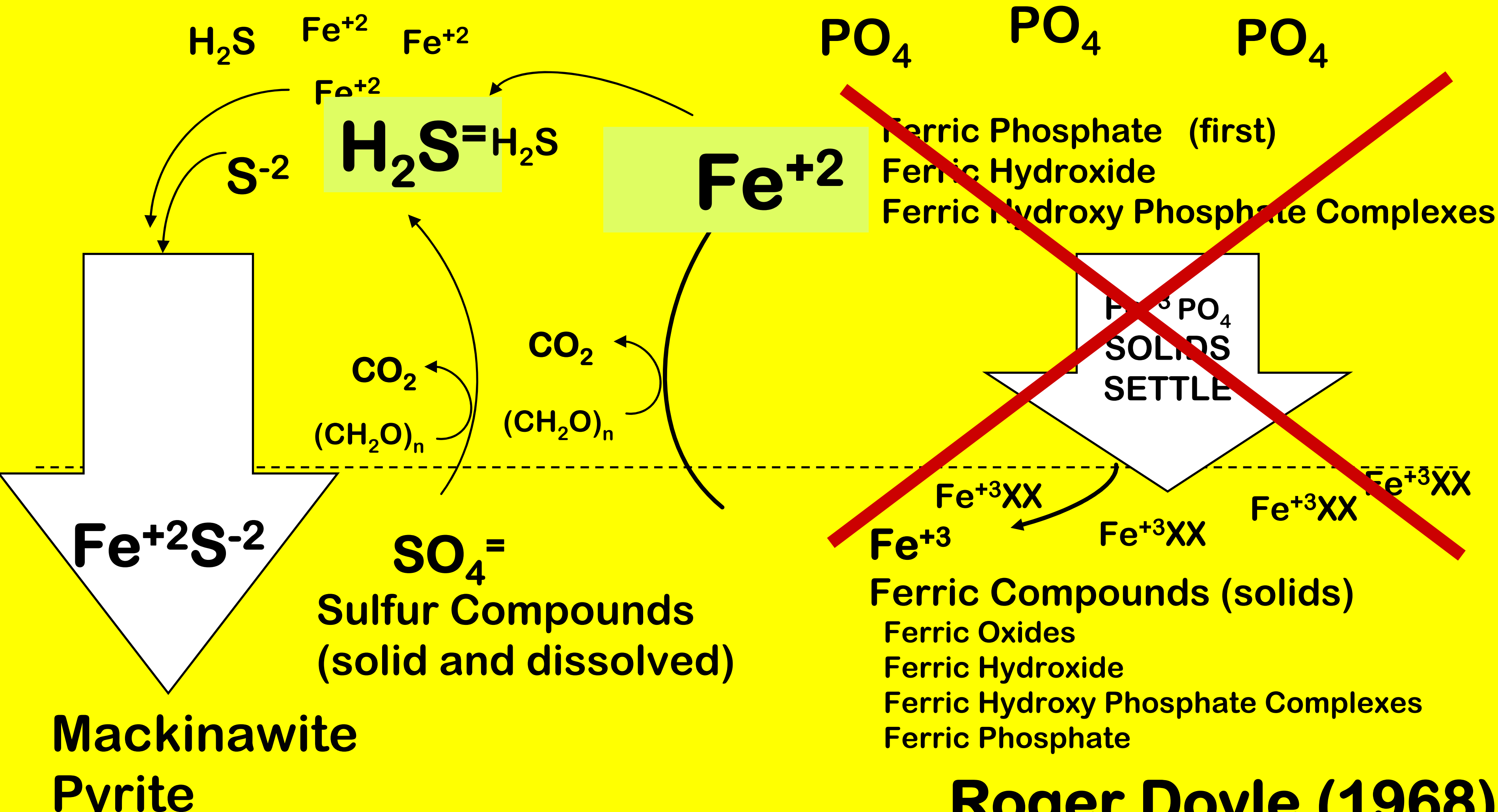
CH2O → CO2
e-
O2 → H2O
Aerobic Respiration
Very little P Release while operating in the N Cycle
CHEMOSYNTHESIS
CO2 → CH2O
e-
NH4+ →
Nitrification
CH2O → CO2
e-
Denitrification
NO3- → N2 gas
PHOTOSYNTHESIS
CO2 → CH2O
e-
H2O → O2
PO4
Fe+3 ^PO4 → Fe+2
e-
Iron Reduction
CH2O → CO2
FeS
So → H2S
e-
Sulfur Reduction
CH2O → CO2
LOST
Permanent
Sediment
Anaerobic

- *Ferrous Iron is typically in excess compared to phosphorus.*
- *Iron is precipitated as phosphate before hydroxide is formed.*



- *Ferric Iron gives sediments a "Phosphorus Binding Capacity".*

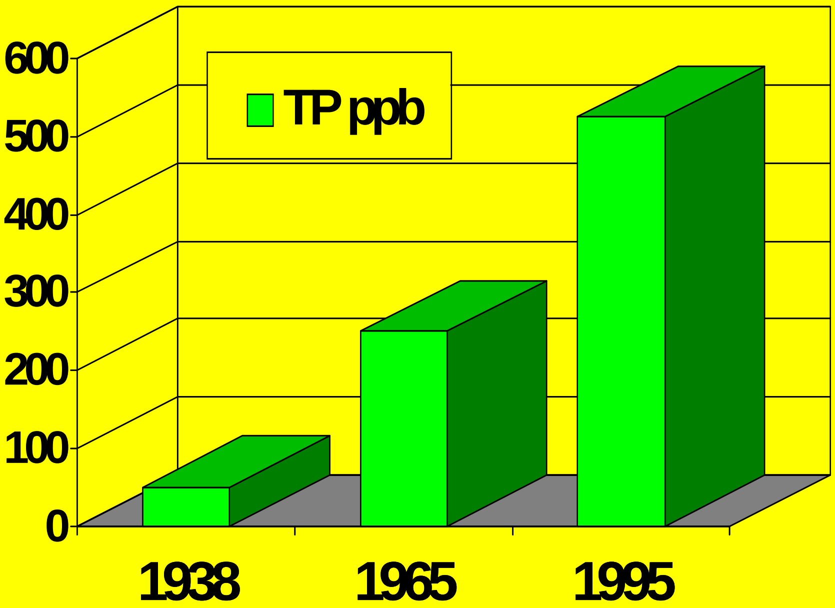
- *Iron no longer participates in anaerobic respiration (it is permanently deposited as ferrous sulfide).*
- *Iron no longer cycles between the sediments and the water column.*
- *Iron no longer removes phosphorus from the water column, (phosphorus is left behind in the water).*
- *More Hydrogen Sulfide production occurs to replace the respiration role previously filled by iron.*



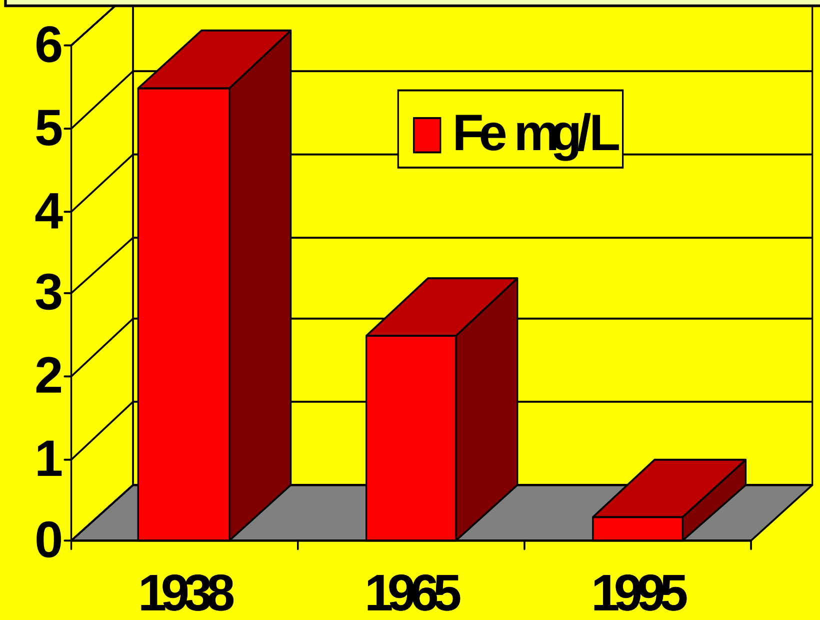
Roger Doyle (1968)

- *The Phosphorus Binding Capacity of sediments is lost.*
- *$AlSO_4$ = ALUM, Might the sulfate load have an adverse impact?*

Linsley Pond 13m Fe TP Concentrations



Sulfur Cycle Became Dominant



Increasing Eutrophication,
Increasing Organic Supply (Autoth. And Allochth.),
Increasing Carbonaceous Oxygen Demand
Increasing demand for ATEAs…more S= production which permanently removes Fe.

It is "*iron*ic" that this was observed at Roger Doyle's study lake.

Loss of a "Functional Iron Cycle" is a *consequence of Eutrophication, and leads to more intense eutrophic conditions.*

Questions

Given The TP – Fe Relationship observed in the hypolimnion of Lindsley Pond:

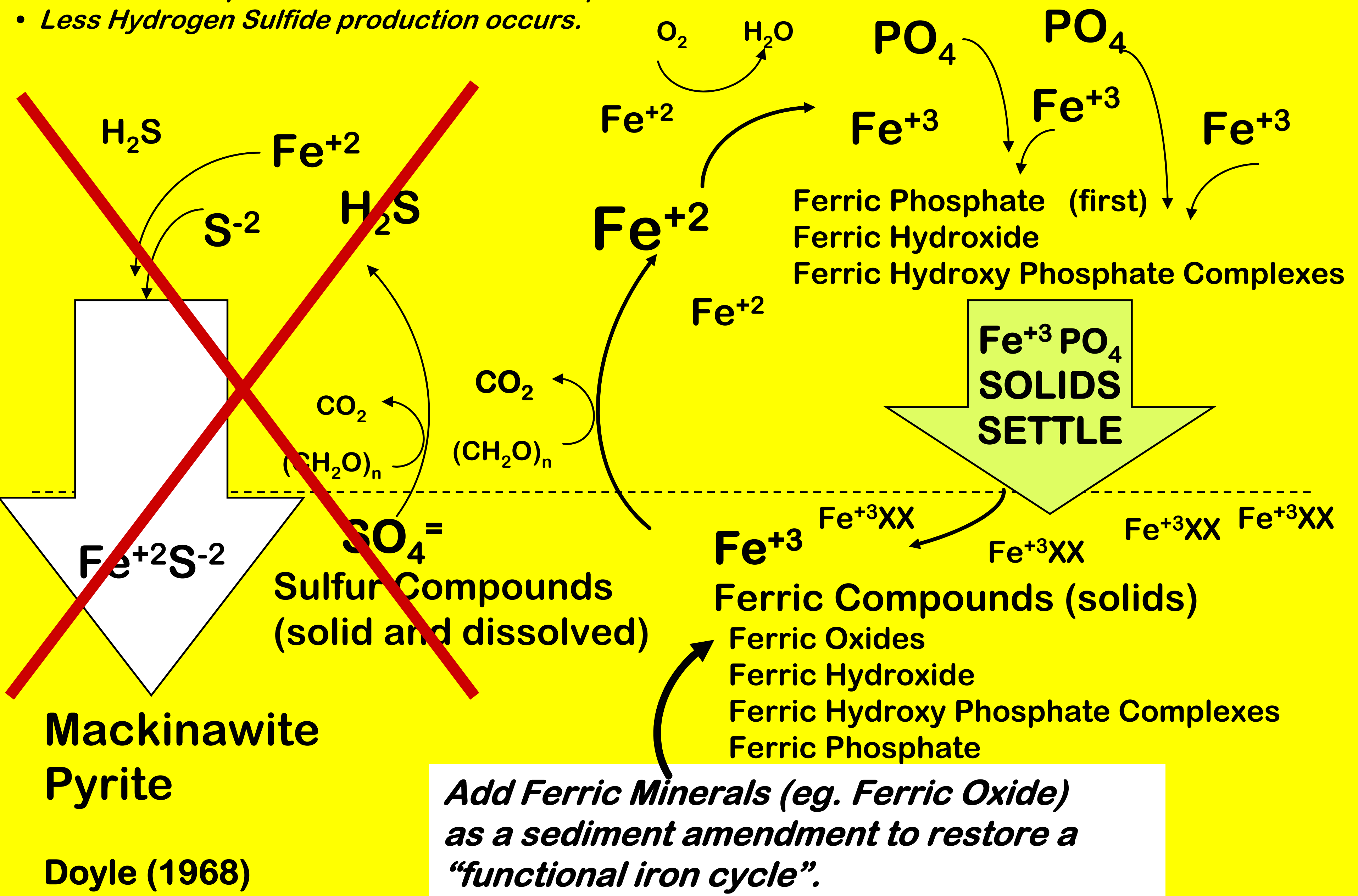
***   Would hypolimnetic aeration control internal P loading by maintaining an oxidized state of iron?**

***   Might hypo aeration be useful via other functions?**

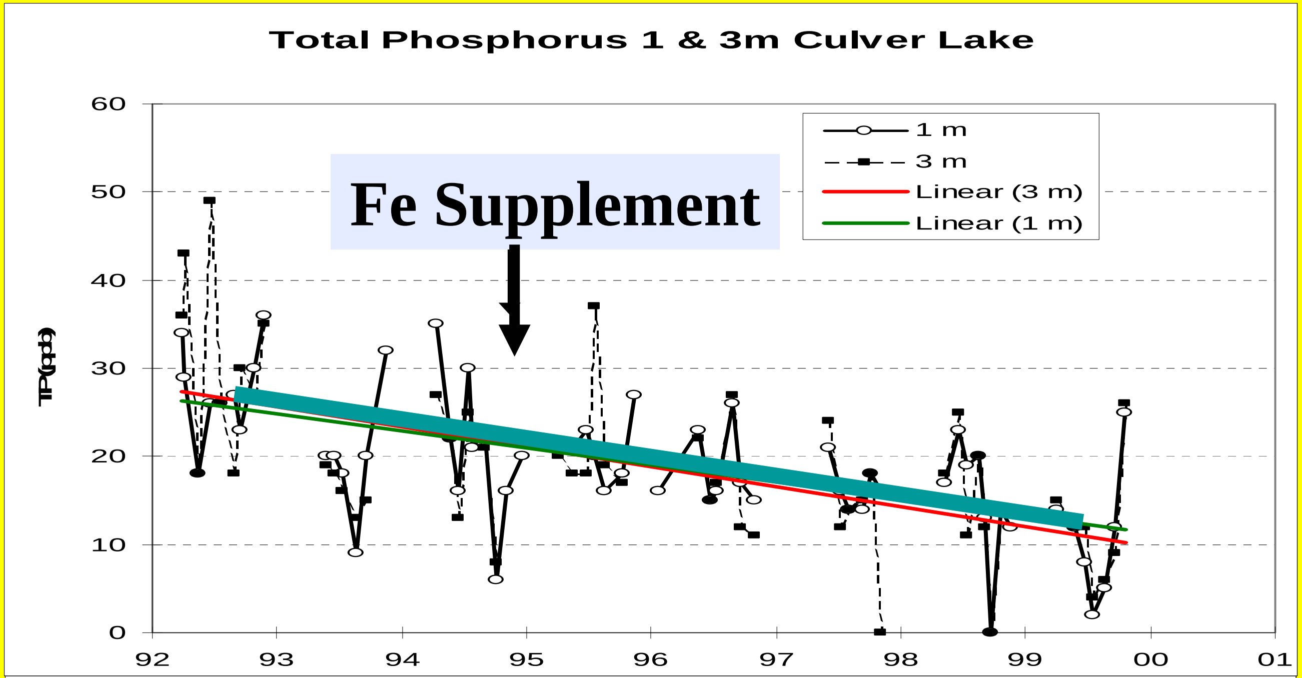
(What functions????)

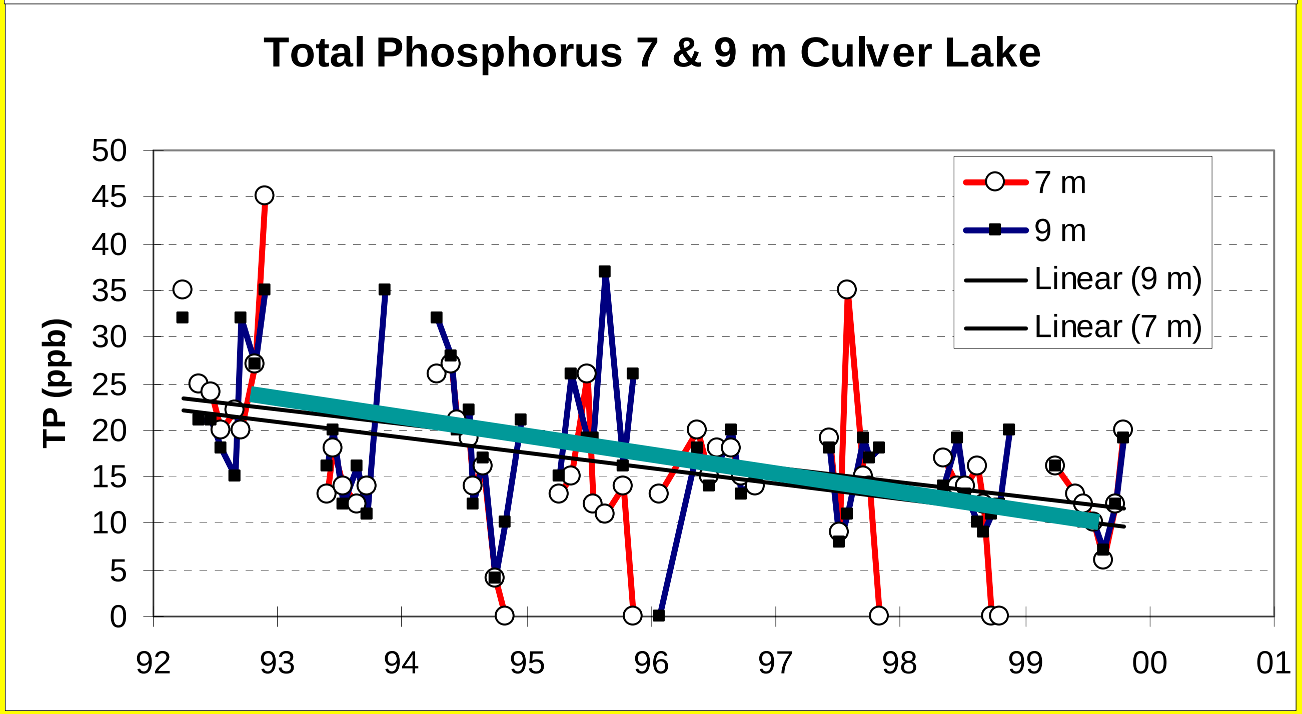
***   Could a “functional iron cycle” be restored in such a lake?**

- *Iron again participates in anaerobic respiration.*
- *Iron is again in excess to P, and precipitates out Ferric Phosphate Compounds.*
- *Iron is used to perform most anaerobic respiration.*
- *Less Hydrogen Sulfide production occurs.*



Doyle (1968)


Total Phosphorus 1 & 3m Culver Lake
Fe Supplement
1 m
3 m
Linear (3 m)
Linear (1 m)
TP(ppb)
60
50
40
30
20
10
0
92
93
94
95
96
97
98
99
00
01


Total Phosphorus 7 & 9 m Culver Lake
7 m
9 m
Linear (9 m)
Linear (7 m)
TP (ppb)
50
45
40
35
30
25
20
15
10
5
0
92
93
94
95
96
97
98
99
00
01

Questions?

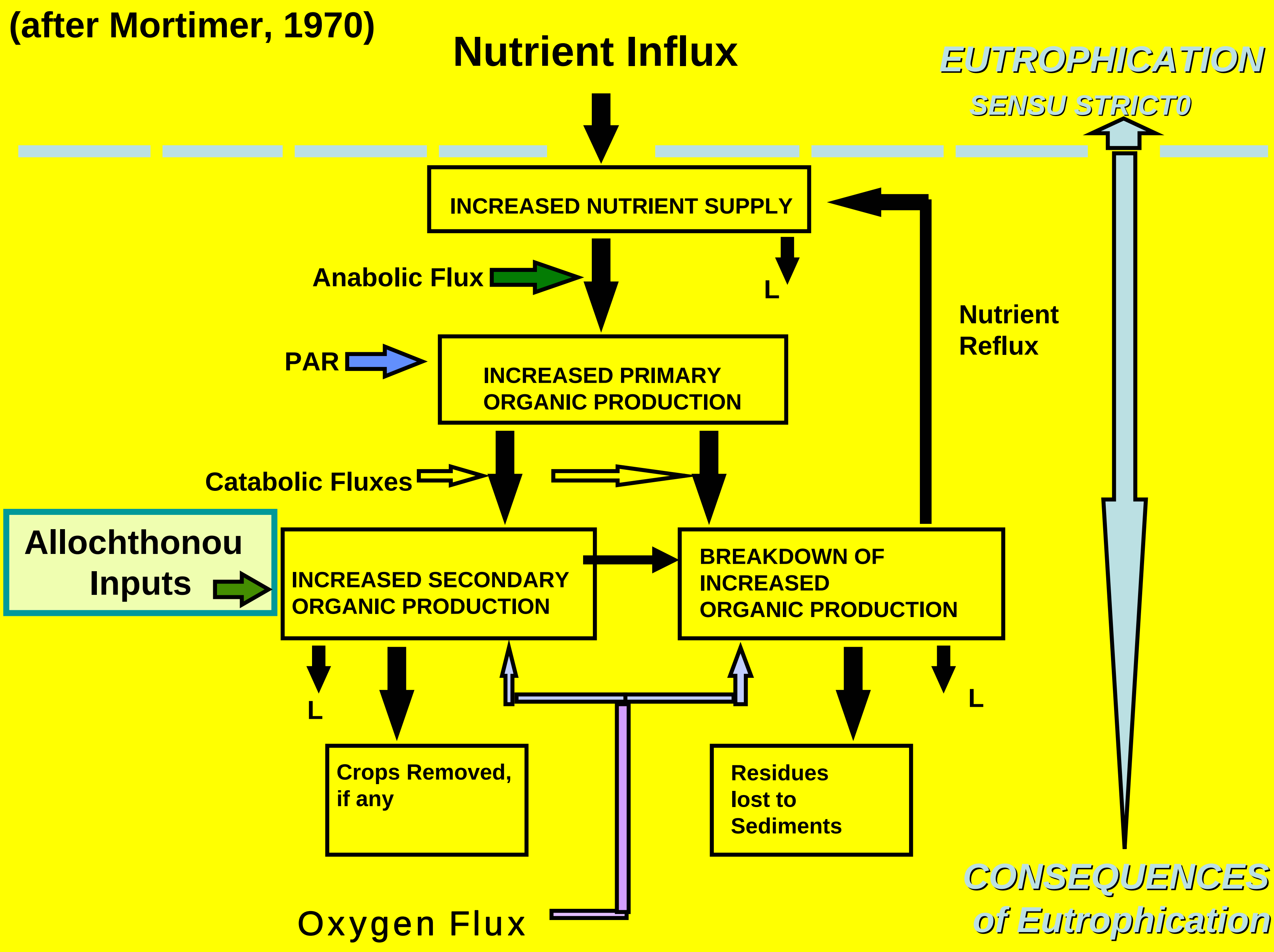
Or I'll address these if you wish:

• What are the different "functions" of internal P cycling in Soft Water (Fe-generating) vs Hard Water (S= generating) Lakes?

• Are both systems driven by respiration? …by respiratory demand for ATEAs?

• How do those differences influence whether "aeration" will successfully manage phytoplankton blooms (via nutrient control)?

• Does long-term eutrophic productivity impact anaerobic respiration pathways and internal P cycling?

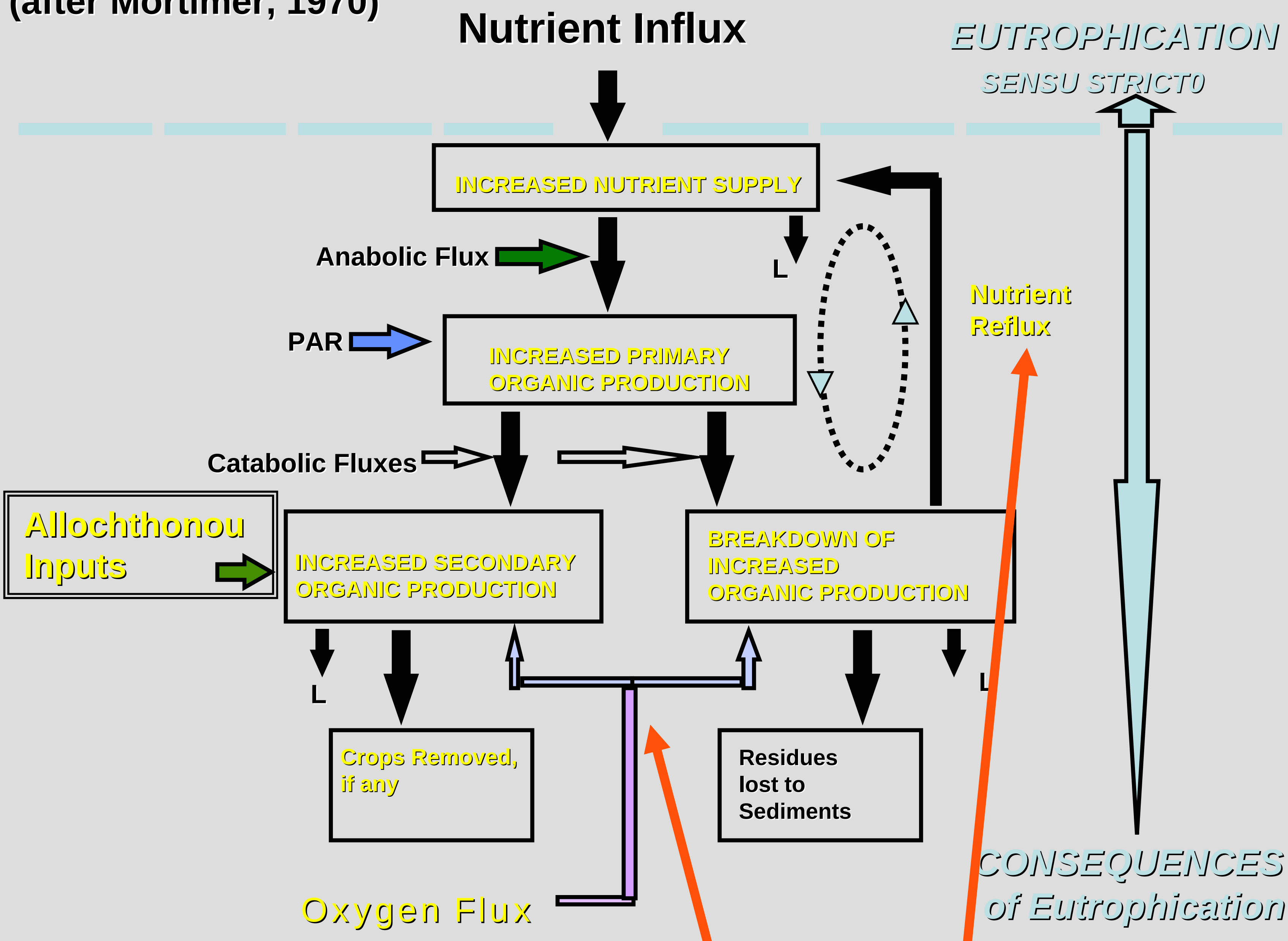


(after Mortimer, 1970)
Nutrient Influx
EUTROPHICATION
SENSU STRICT0
INCREASED NUTRIENT SUPPLY
Anabolic Flux
L
Nutrient
Reflux
PAR
INCREASED PRIMARY
ORGANIC PRODUCTION
Catabolic Fluxes
Allochthonou
Inputs
INCREASED SECONDARY
ORGANIC PRODUCTION
BREAKDOWN OF
INCREASED
ORGANIC PRODUCTION
L
L
Crops Removed,
if any
Residues
lost to
Sediments
Oxygen Flux
CONSEQUENCES
of Eutrophication

Photosynthesis Happens in the Watershed too.

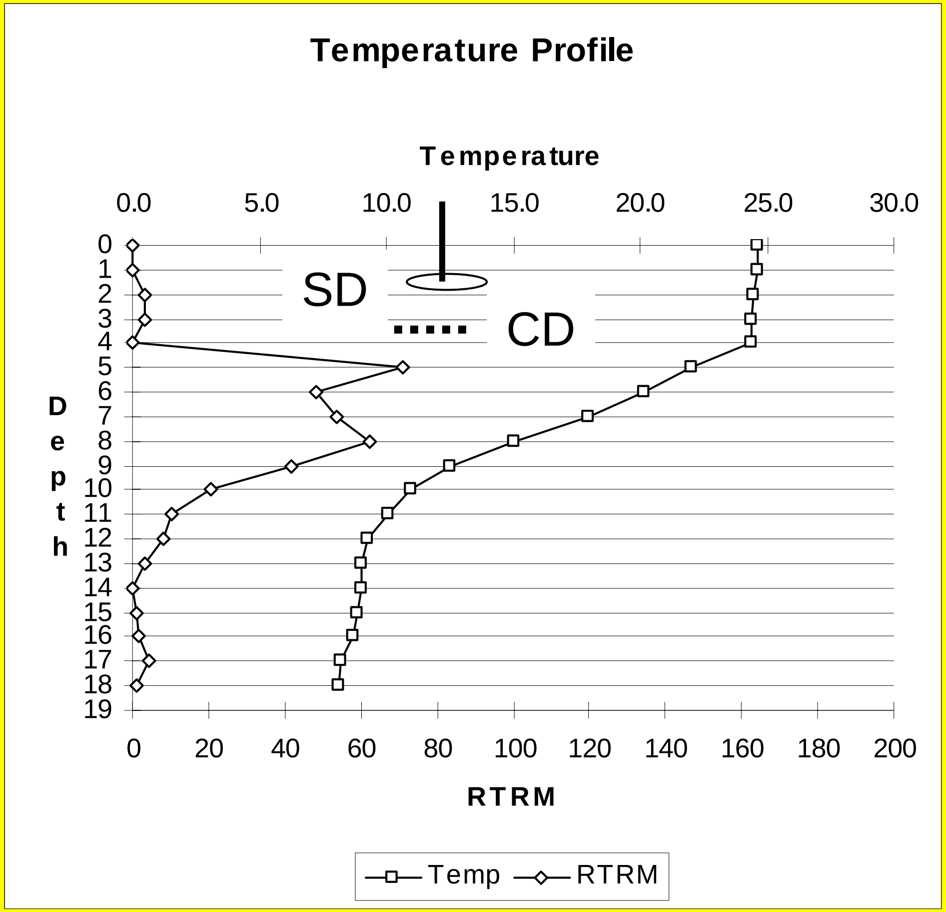
(ALLOCHTHONOUS LOADING)

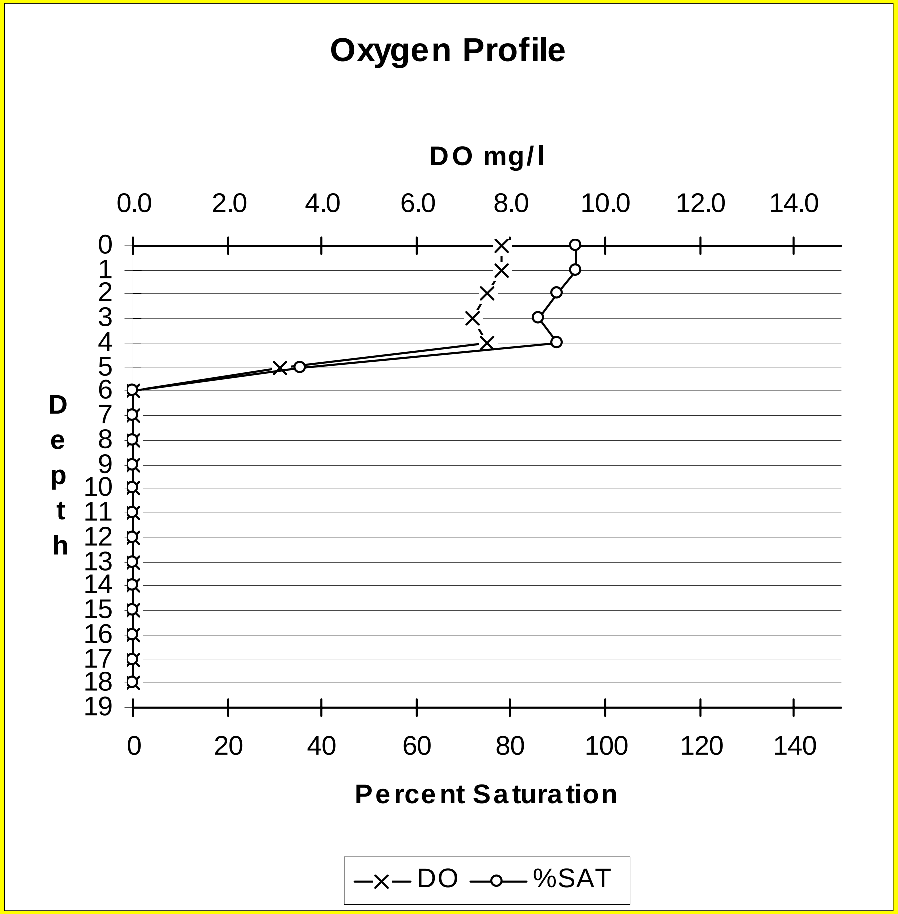
(after Mortimer, 1970)



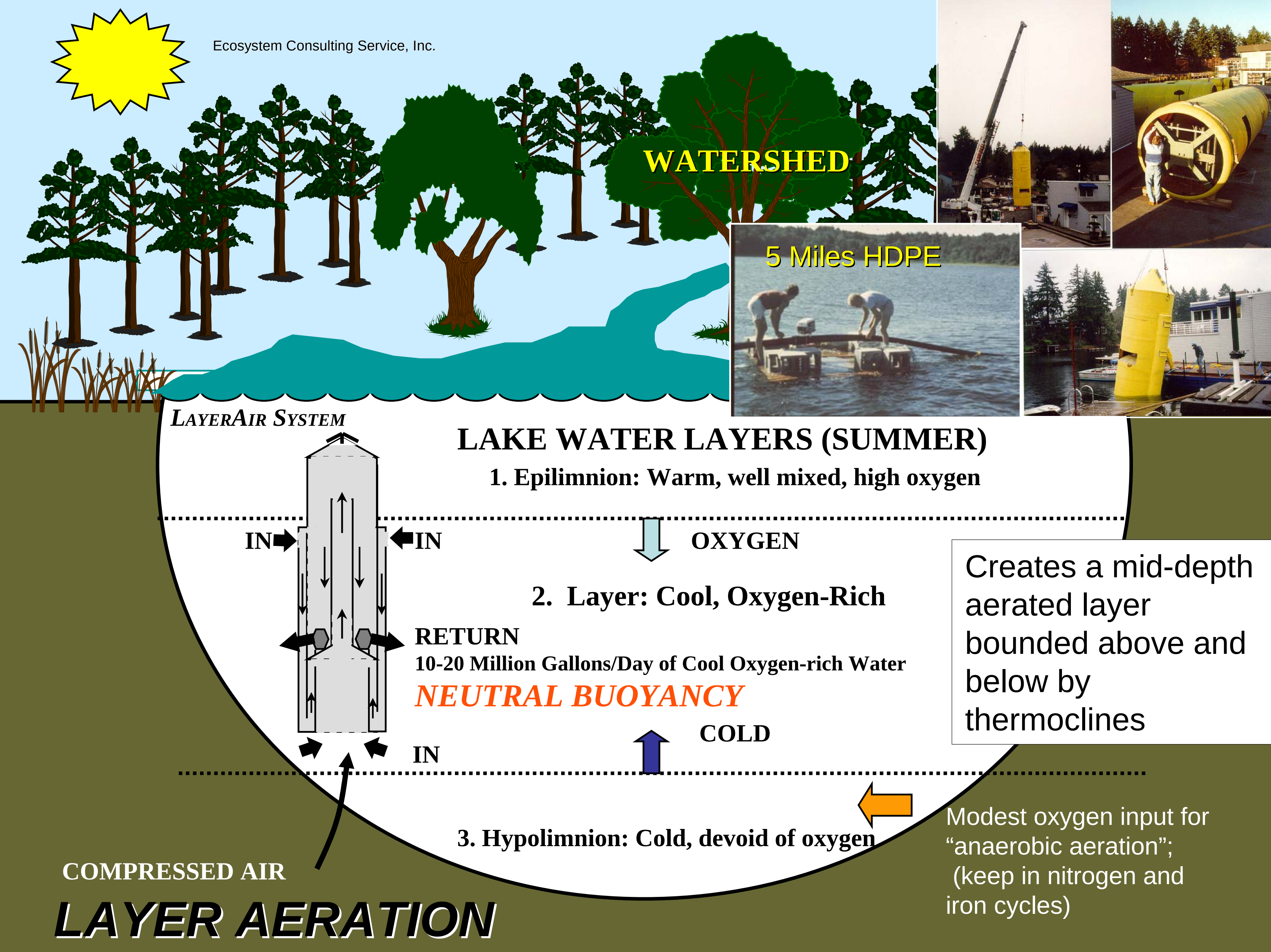
Influence of Aeration Approaches on Aquatic Ecosystem Functions/Processes

Is Detritus Productive?

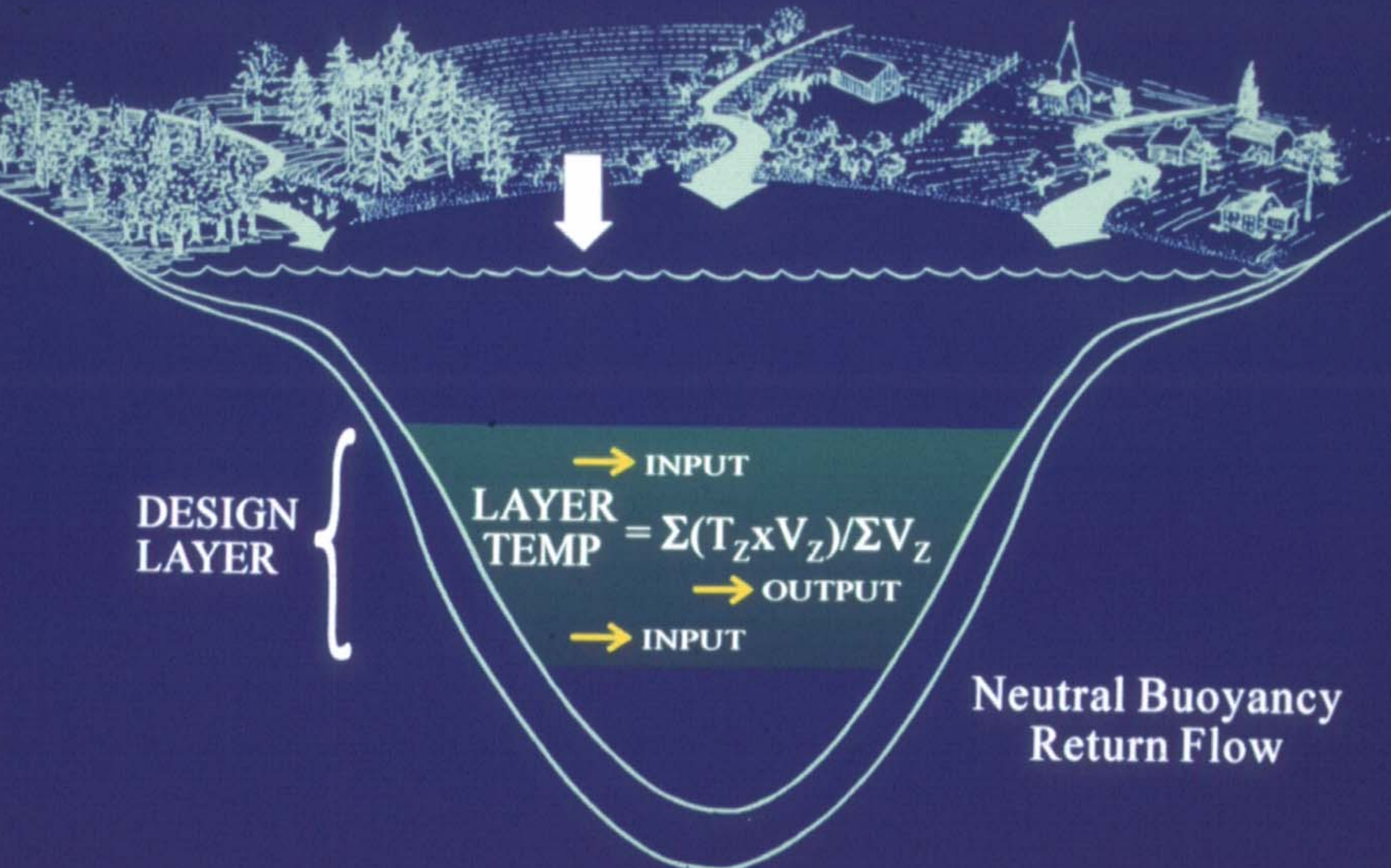




Lake Shenipsit 8/19/1985 (Before Multiple Layer Aeration)
SD= 1.5 m RTRMsum= 333 RTRM Units

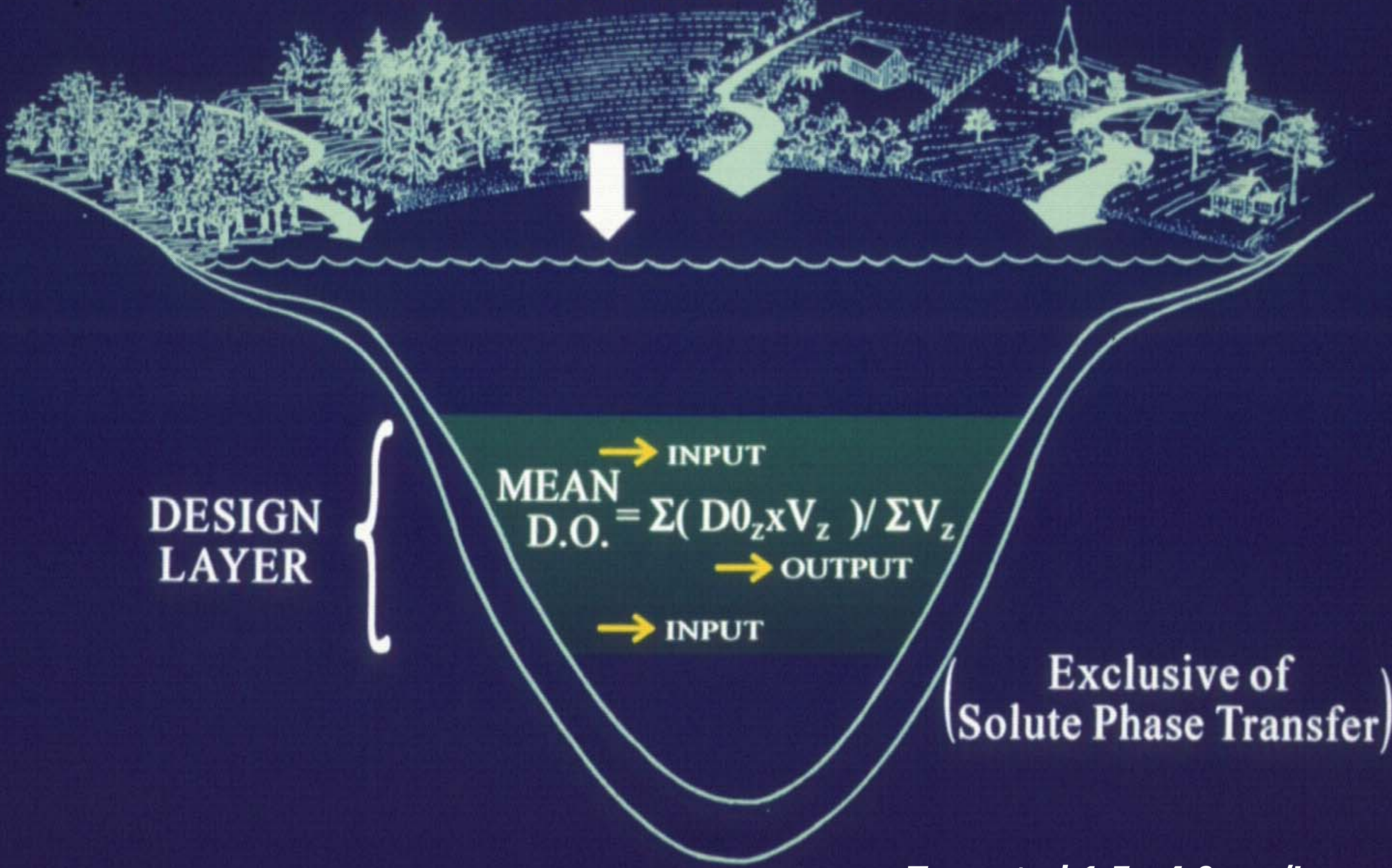

Ecosystem Consulting Service, Inc.
WATERSHED
5 Miles HDPE
LAYERAIR SYSTEM
LAKE WATER LAYERS (SUMMER)
1. Epilimnion: Warm, well mixed, high oxygen
IN
IN
OXYGEN
2. Layer: Cool, Oxygen-Rich
RETURN
10-20 Million Gallons/Day of Cool Oxygen-rich Water
NEUTRAL BUOYANCY
COLD
IN
3. Hypolimnion: Cold, devoid of oxygen
COMPRESSED AIR
LAYER AERATION
Creates a mid-depth aerated layer bounded above and below by thermoclines
Modest oxygen input for "anaerobic aeration"; (keep in nitrogen and iron cycles)

MEAN LAYER TEMPERATURE

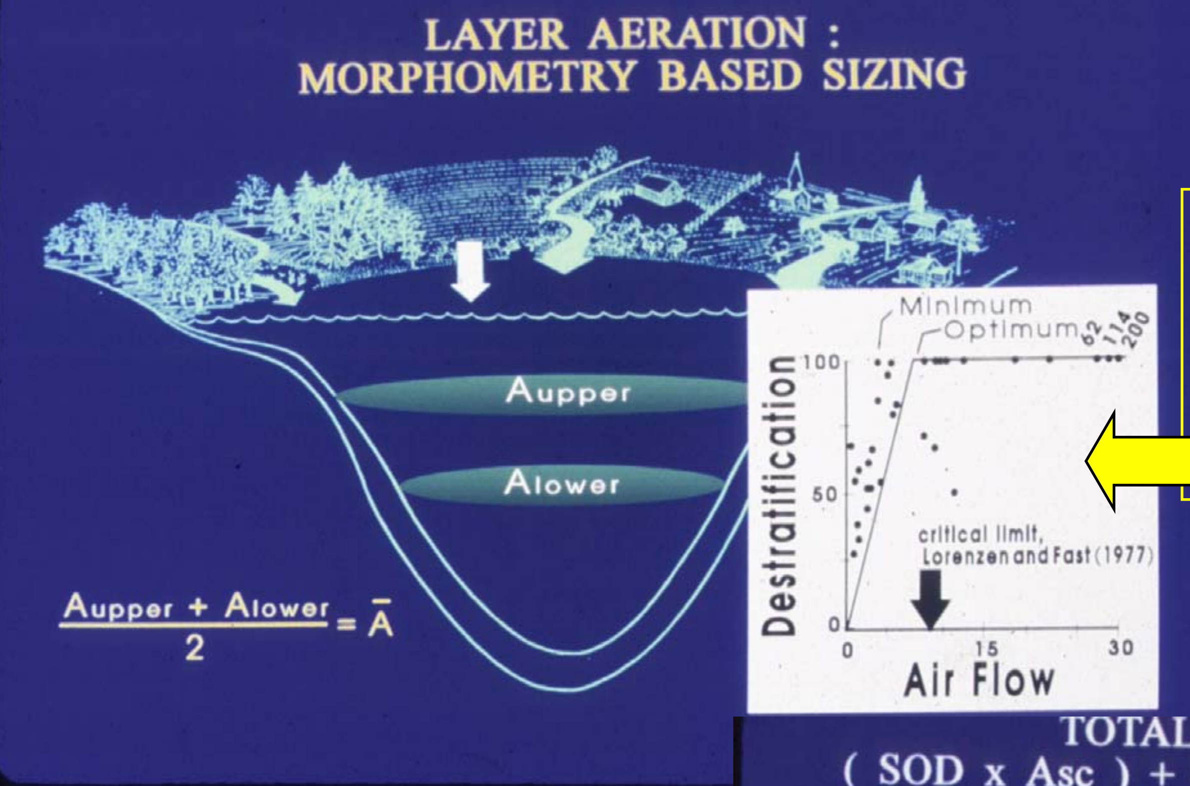


Expected 12-14^{o}C

MEAN LAYER DISSOLVED OXYGEN



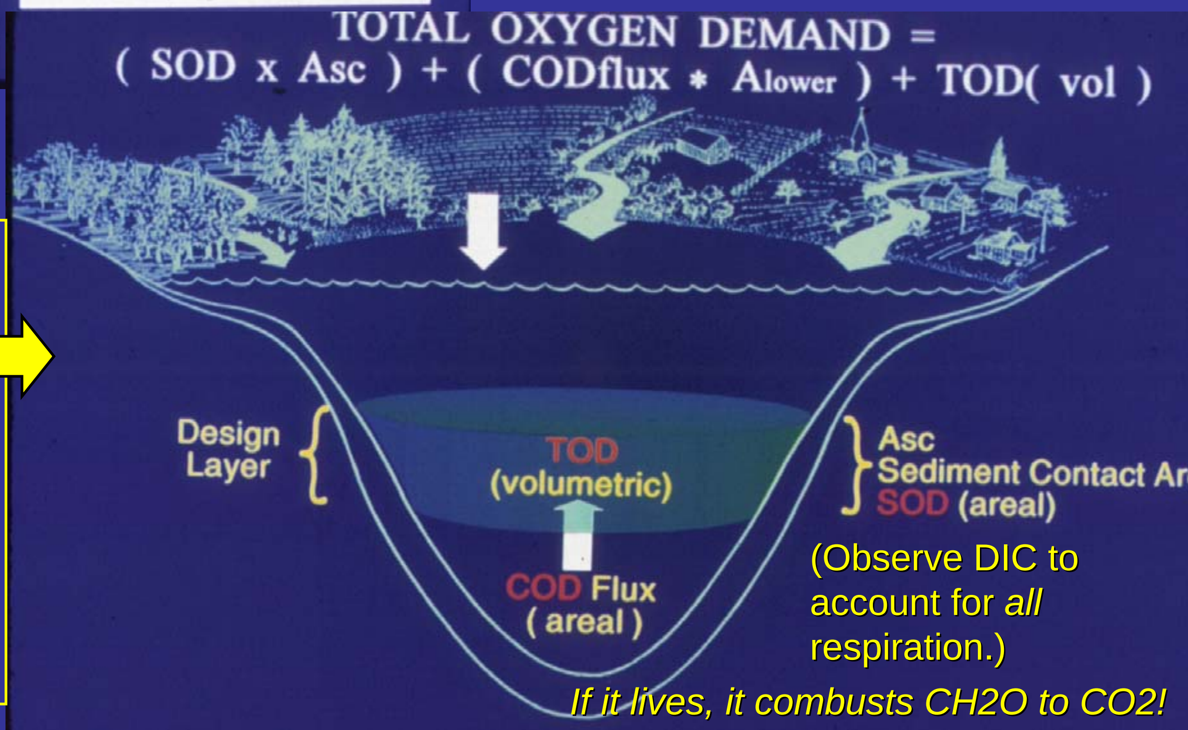
Expected 1.5 - 4.0 mg/L



Depth-Discrete Circulation Capacity estimated from empirical artificial circulation case results; using area of the layer.

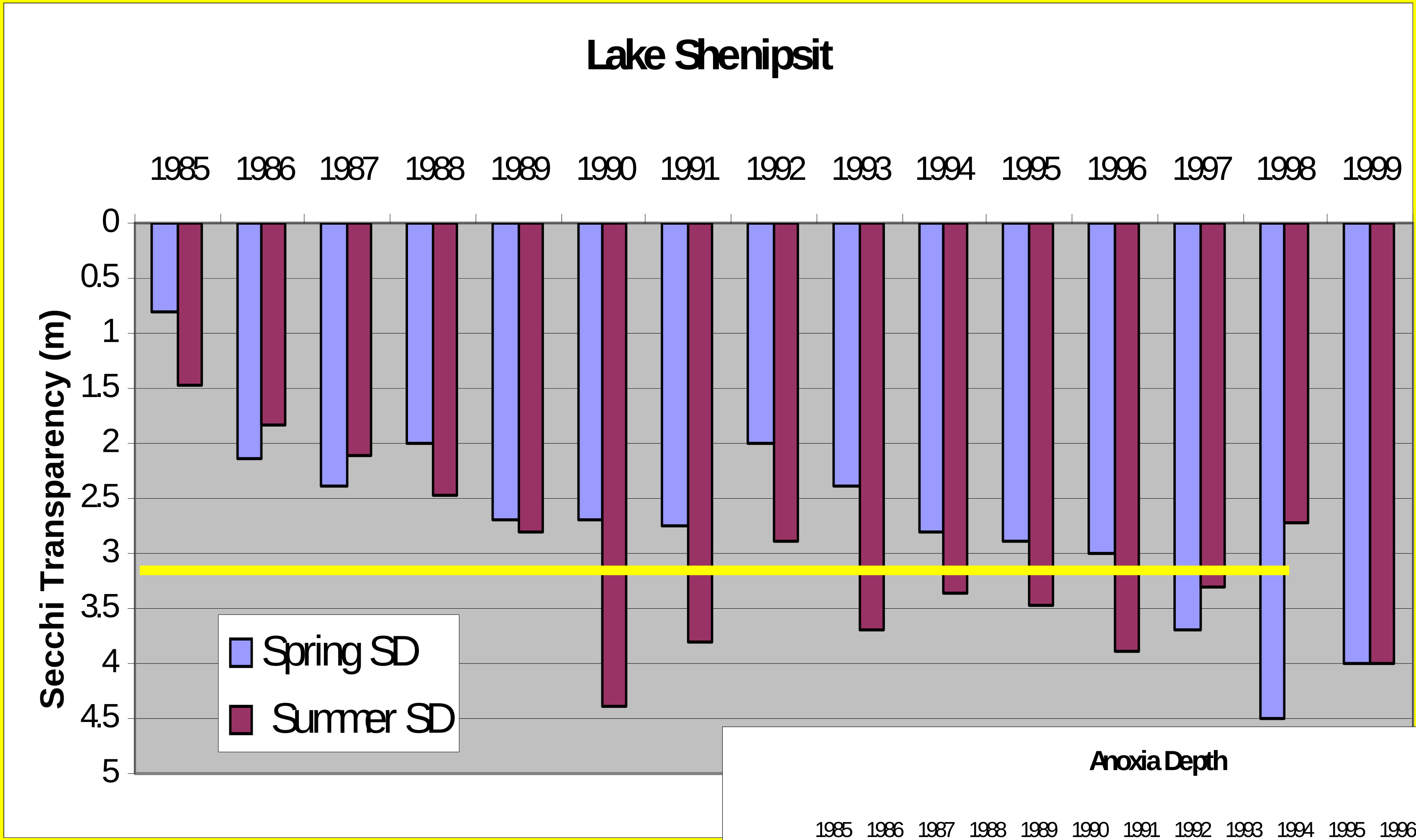
How much more DO needs to enter solute phase?

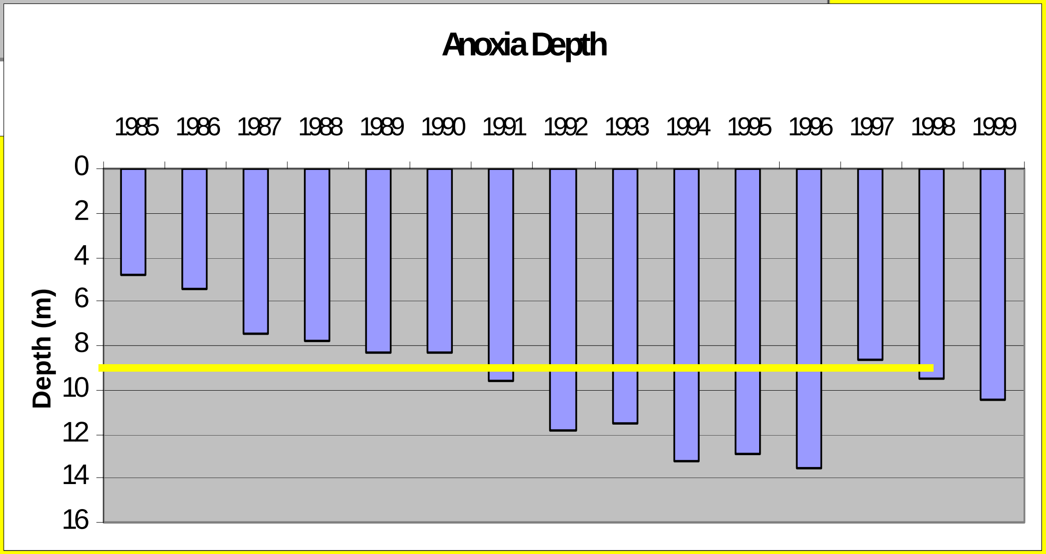
Volumetric Oxygen Demand
Sediment Oxygen Demand
COD Flux Rates
Nitrogenous Oxygen Demand

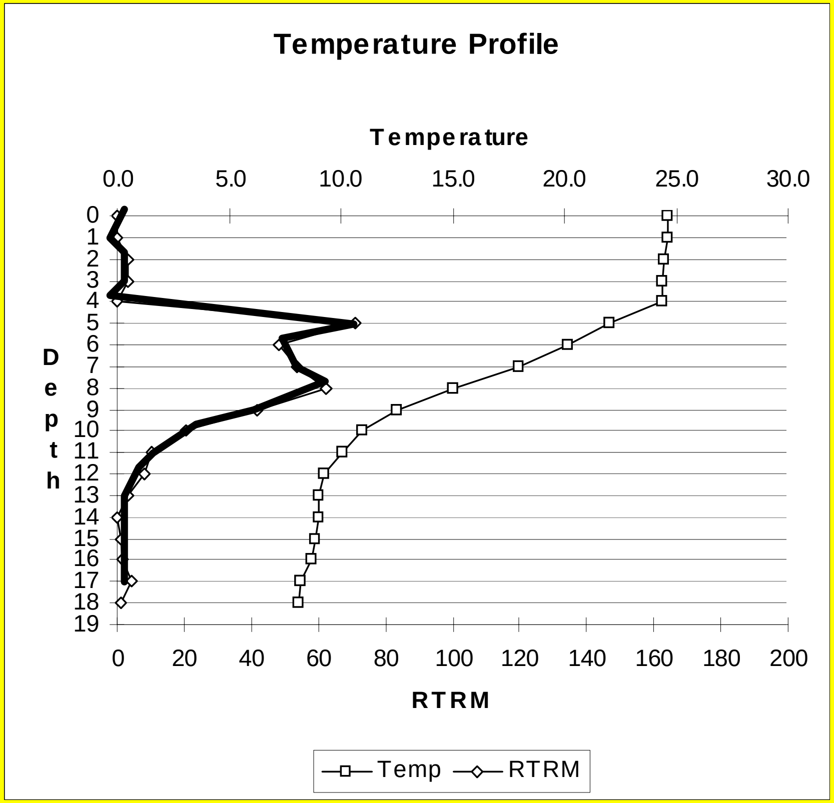


(Observe DIC to account for *all* respiration.)

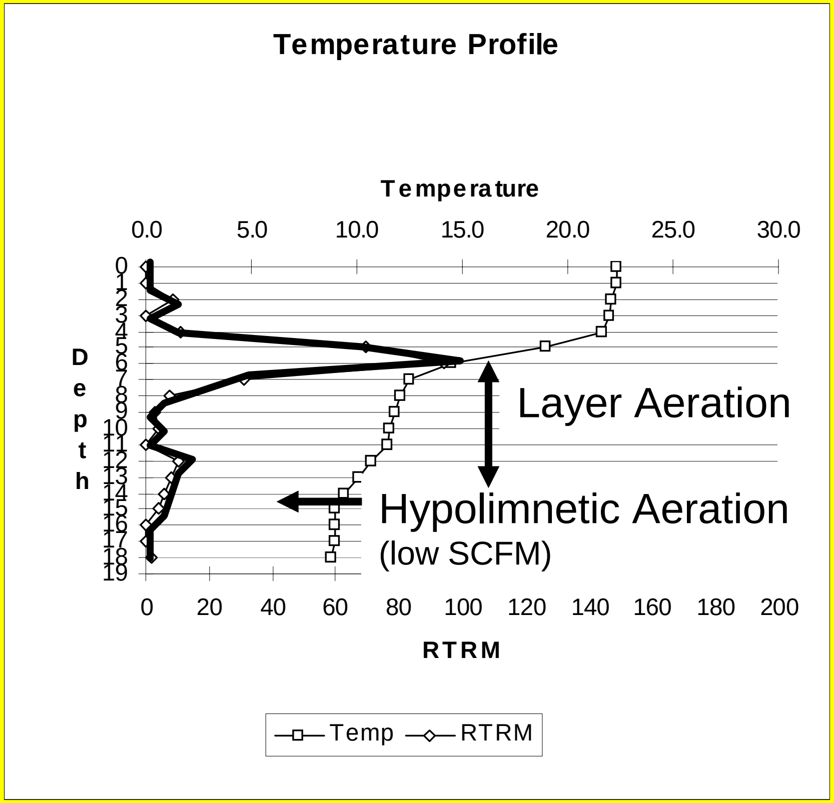
If it lives, it combusts CH2O to CO2!


Lake Shenipsit
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
Secchi Transparency (m)
Spring SD
Summer SD


Anoxia Depth
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
0 2 4 6 8 10 12 14 16
Depth (m)



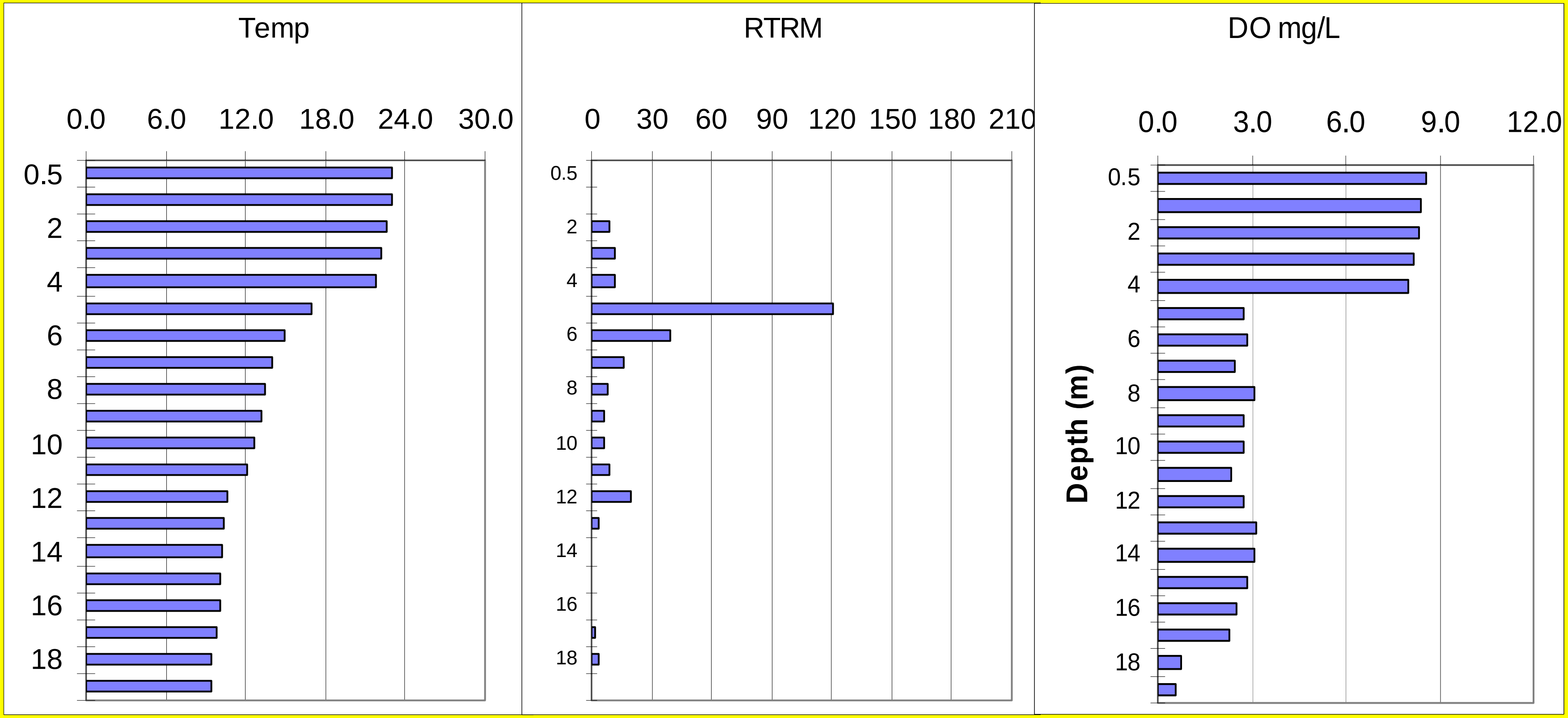
August 19, 1985



August 2, 2000

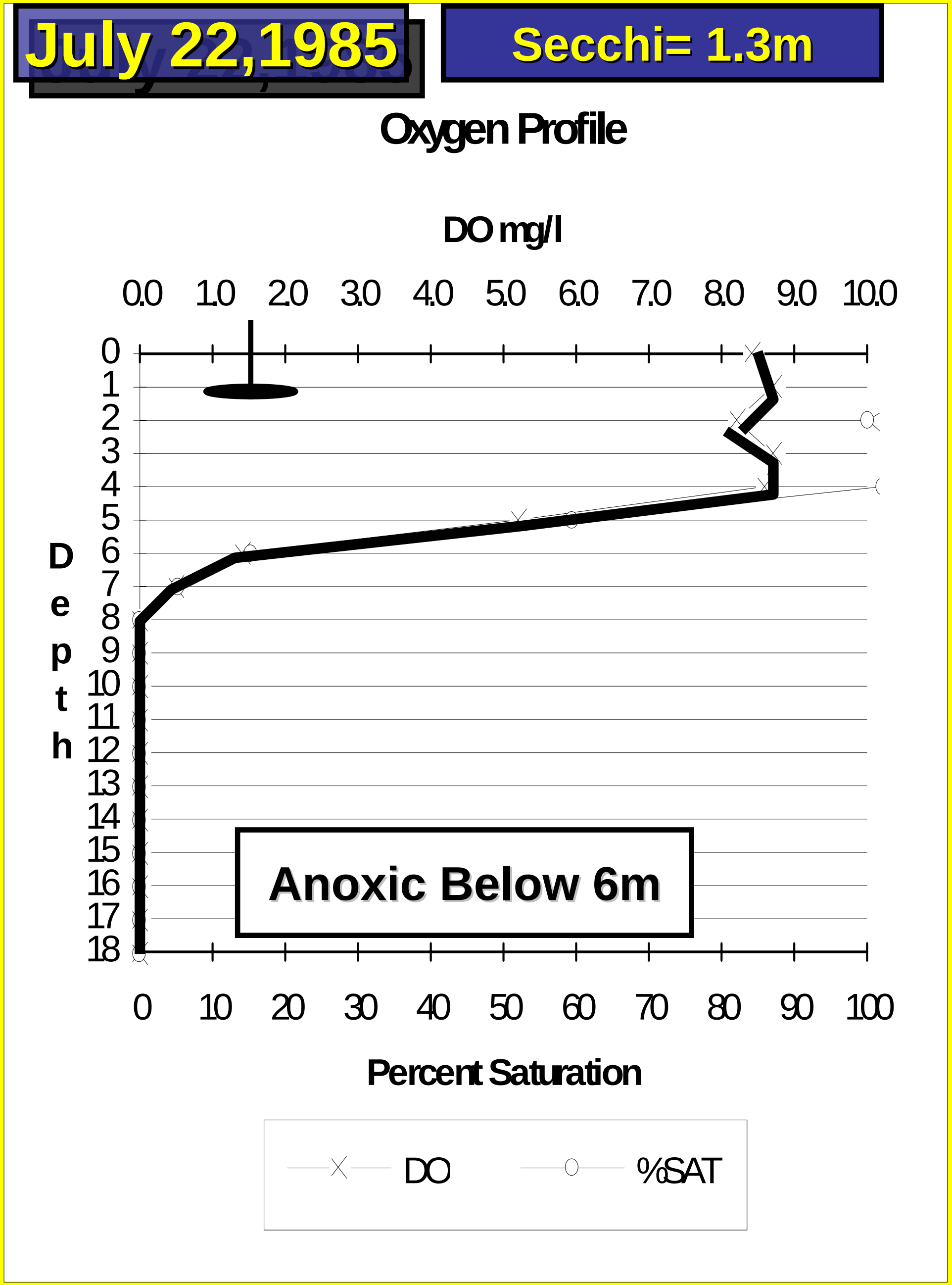
RTRM Profiles (Before and During Layer Aeration)

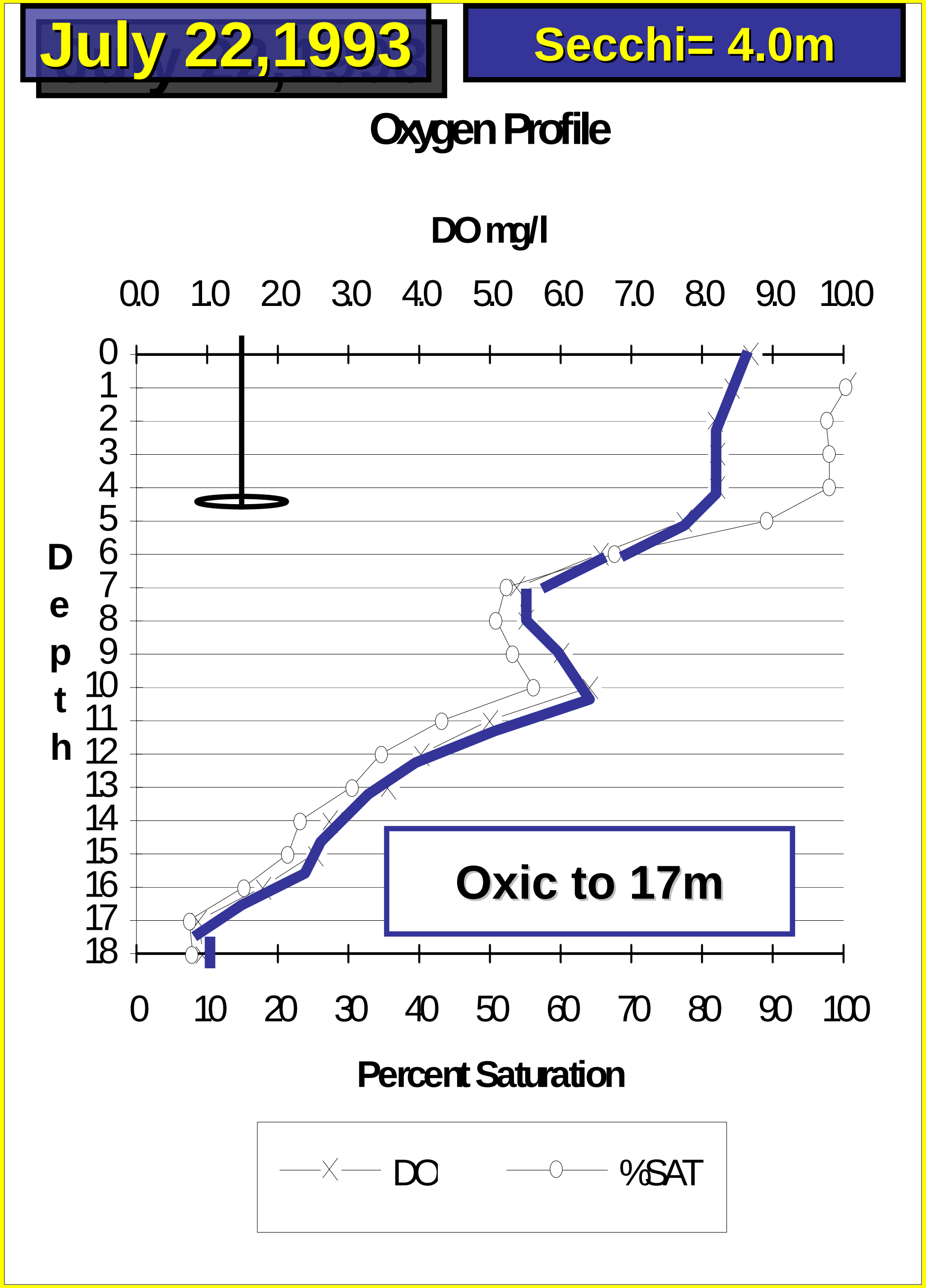
Layer Aeration divides the natural “thermocline” into two functional thermoclines with a cool, aerobic layer between. The deepest hypolimnetic layer volume and area is reduced and can be aerated more efficiently



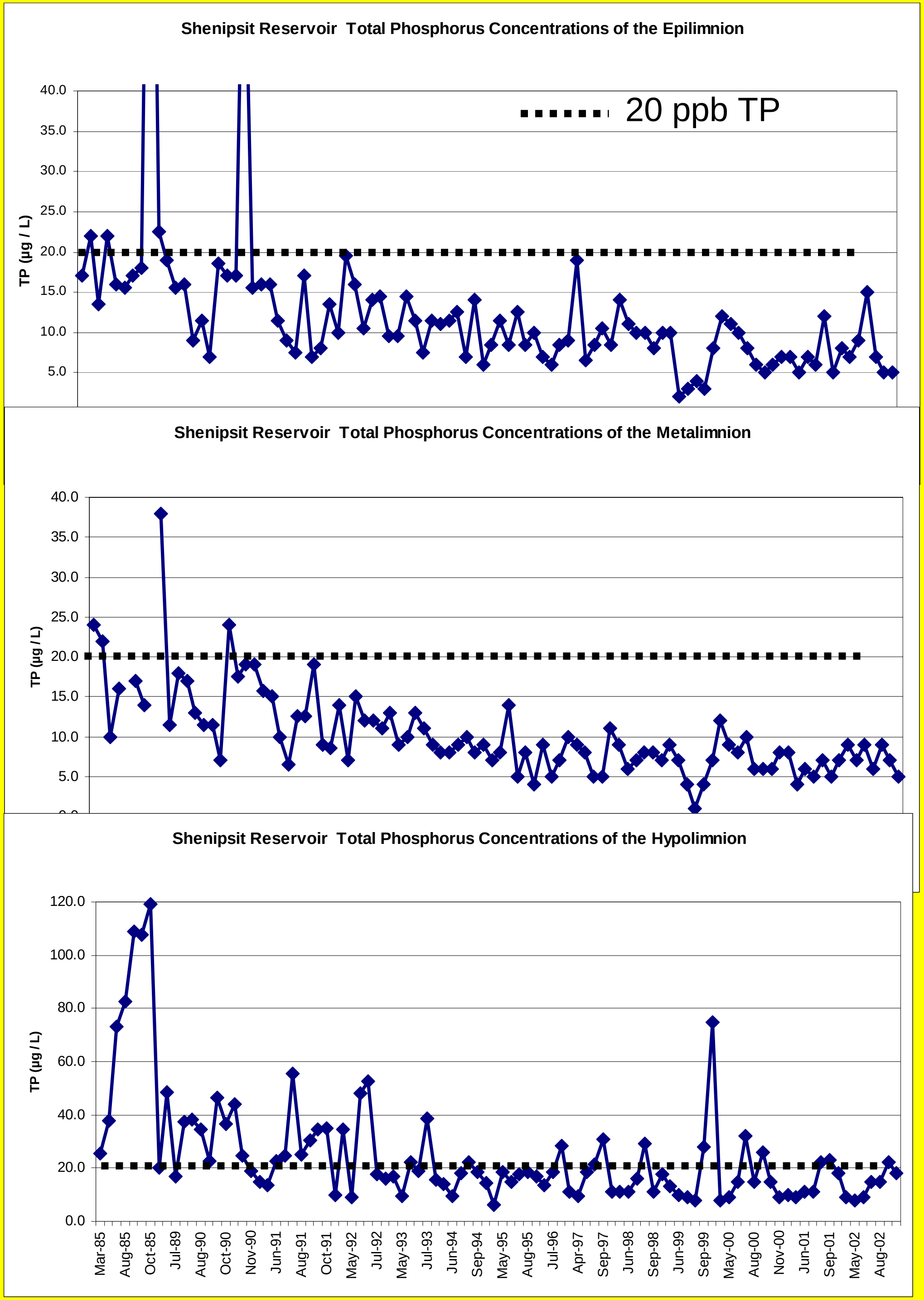
Lake Shenipsit 2000 (During Multiple Layer Aeration)

Layer / Hypolimnetic Aeration – Effect of Dissolved Oxygen Distribution





1985



TP Epilimnion

TP Metalimnion
(Aerated Layer)

TP Hypolimnion
(“Anaerobic Aeration”)

2002

Lake Shenipsit: Additional Effects on Ecosystem Structure and Function:

- ***2000+ acre-ft of CW Habitat Restored***
    - ***Fish (piscivory, zooplanktivory)***
    - ***Herbivorous Zooplankton Refuge***
- ***Increased Nitrification (less Ammonia-N)***
- ***Lower TOC, lower pH peaks***
- ***Deepened SD and CD***

Nutrient Inactivation?

Iron Replenishment or Alum?

Al Sulfate or Al Nitrate? (Alum Surrogates)

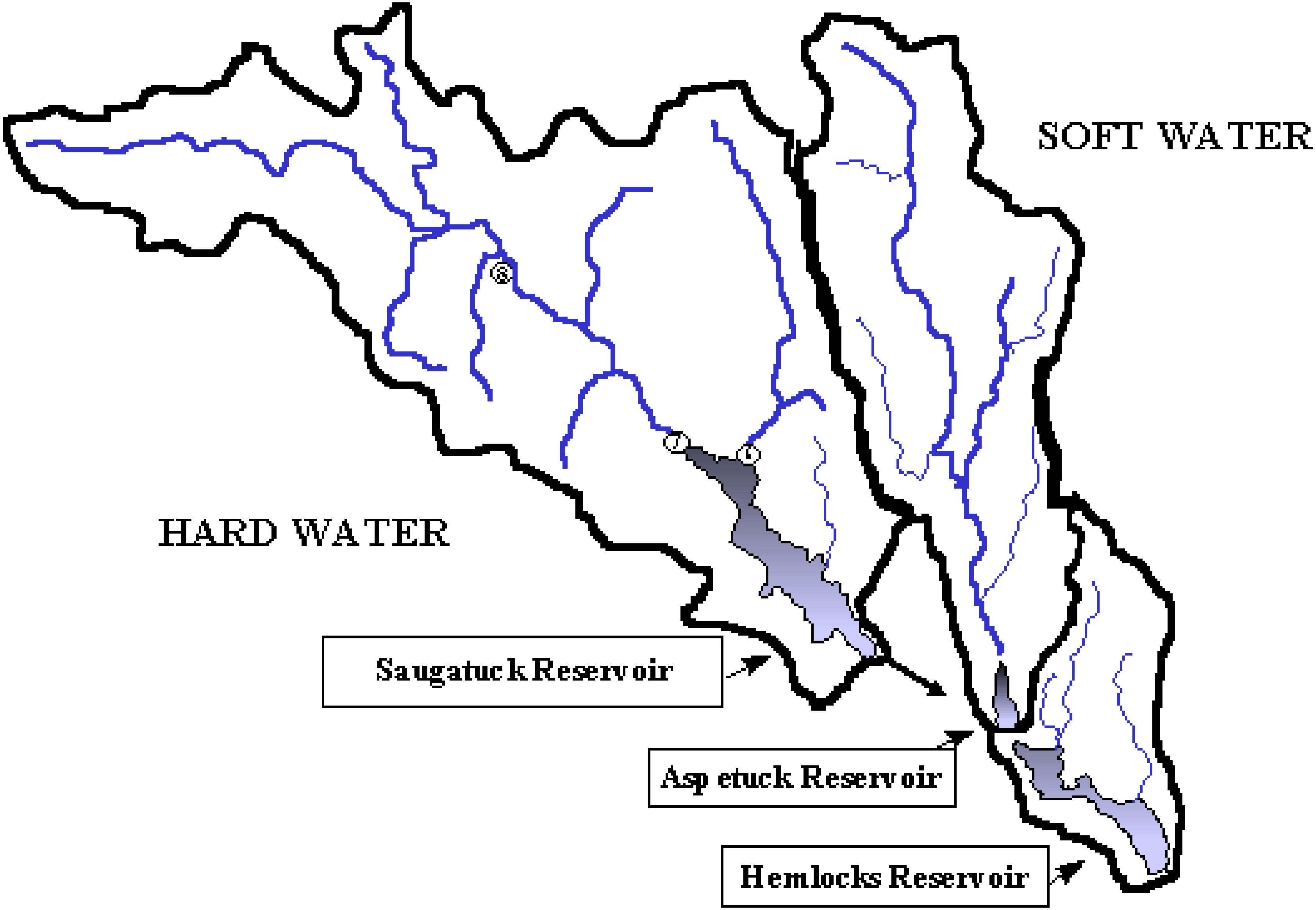
Aeration?

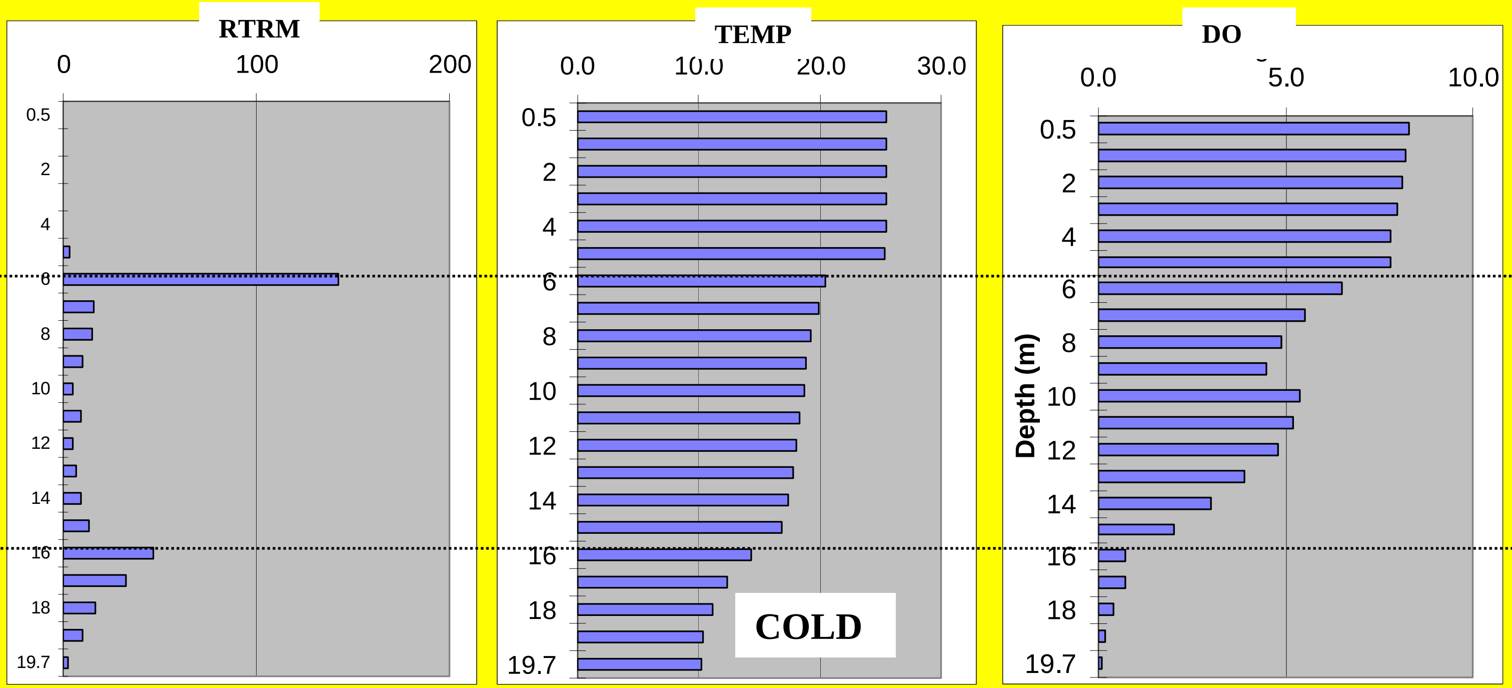
Iron or Sulfide Generating?

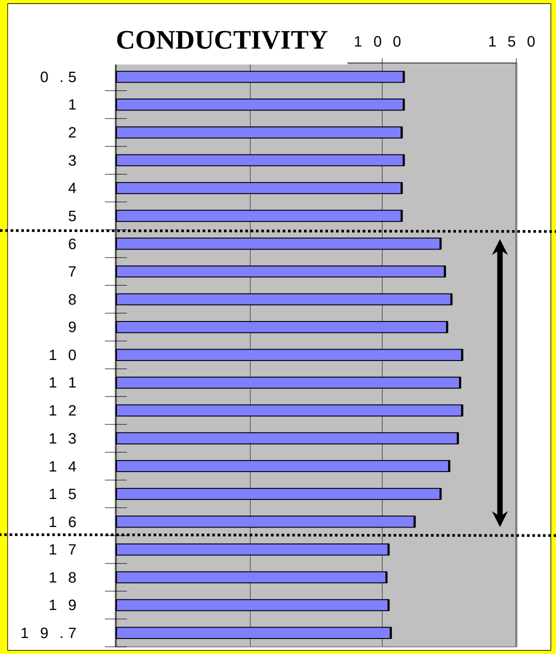
Hard or Soft?

Decalcification Intensity?

Questions (VERY rarely asked)


SOFT WATER
HARD WATER
Saugatuck Reservoir
Aspetuck Reservoir
Hemlocks Reservoir

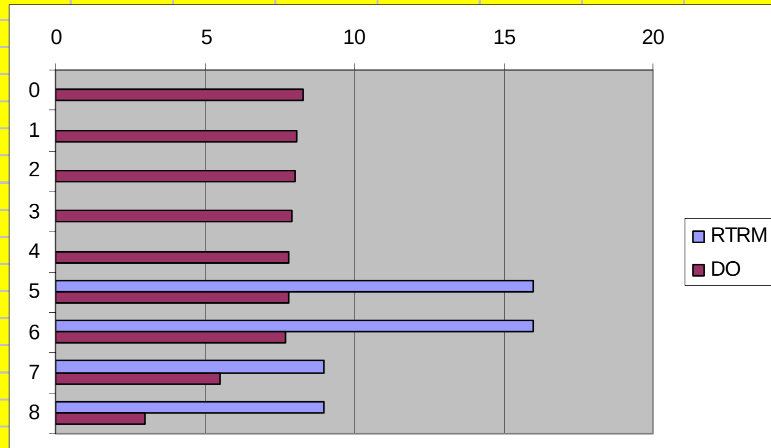




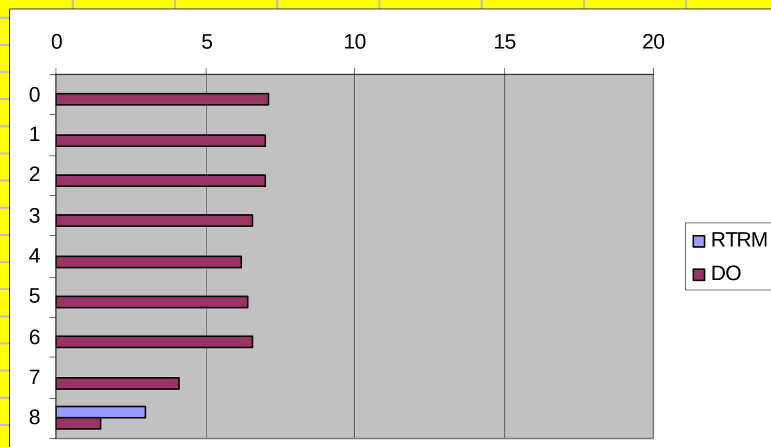
Hemlocks Reservoir August 19, 1998

Saugatuck Reservoir water, released from about 50 feet deep, flows through Aspetuck Reservoir as an "Underflow", and then it flows through Hemlocks Reservoir as an "Interflow" between thermoclines at 6 and 16 meters deep.

8/25/83	7:30 PM		
Depth (ft)			
	RTRM	DO	TEMP
0	0	8.3	26
1	0	8.1	26
2	0	8	26
3	0	7.9	26
4	0	7.8	26
5	16	7.8	25.5
6	16	7.7	25
7	9	5.5	24.7
8	9	3	24.4

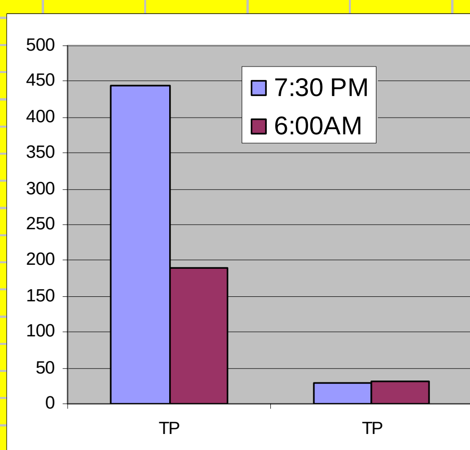


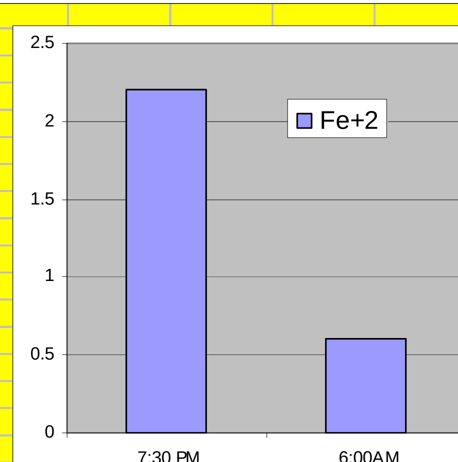
8/26/83	6:00 AM		
Depth (ft)			
	RTRM	DO	TEMP
0	0	7.1	24.5
1	0	7	24.5
2	0	7	24.5
3	0	6.6	24.5
4	0	6.2	24.5
5	0	6.4	24.5
6	0	6.6	24.5
7	0	4.1	24.5
8	3	1.5	24.4



	Over Bottom	Surface
	TP	TP
7:30 PM	445	29
6:00AM	190	31

	Over Bottom
	Fe+2
7:30 PM	2.2
6:00AM	0.6





Is there a difference during night and day?

What would you expect?

USE GOOD SCIENCE! Don’t put too much weight on “theoretical expectations”!

Develop a hypothesis…
…Test it…
… and USE THE DATA!

EXAMPLE

Example
Watershed Management Plan

- Designation of Lake Protection Areas
- Septic System Mgmt Approaches
    1. Pump Out Reporting Ordinance
    2. Effluent Filters - “Consider for Use”
    3. P Removal Minimums for Sand Fill
    4. Leaching Field Geometry
    5. “Ban” Septic System Additives
    6. Innovative Septic Designs- P Removal

- “Ban” on High-P Fertilizers
- Standard Conditions/Policies PZC, IW
- Nutrient Allocation Evaluation
- Road / Drainage Maint. Schedule
- Wetland Restoration - Erdoni Basin

EXAMPLE

Nutrient Allocation - Land Use Worksheet

Watershed Areal P Export Allocation= 0.32 lb P Acre^{-1} Year^{-1}

Base Loading Areal TP Allocations:

Undisturbed Woodlands=	*0.09*	lb P Acre^{-1} Year^{-1}
Impervious Area=	*1.5*	lb P Acre^{-1} Year^{-1}
Semi-Pervious Area=	*1.25*	lb P Acre^{-1} Year^{-1}

Parcel Area=	67485 sq ft	1.549242 Acres	67485	Sq. Feet
Parcel Allocation=		**0.495758** lb P Year^{-1}		
		0.495758 lb P Year^{-1}		

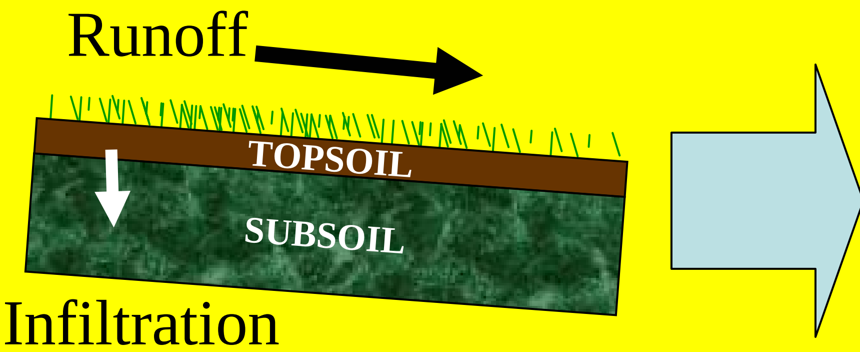
Existing Single Family Residential Use: No BMP Credits

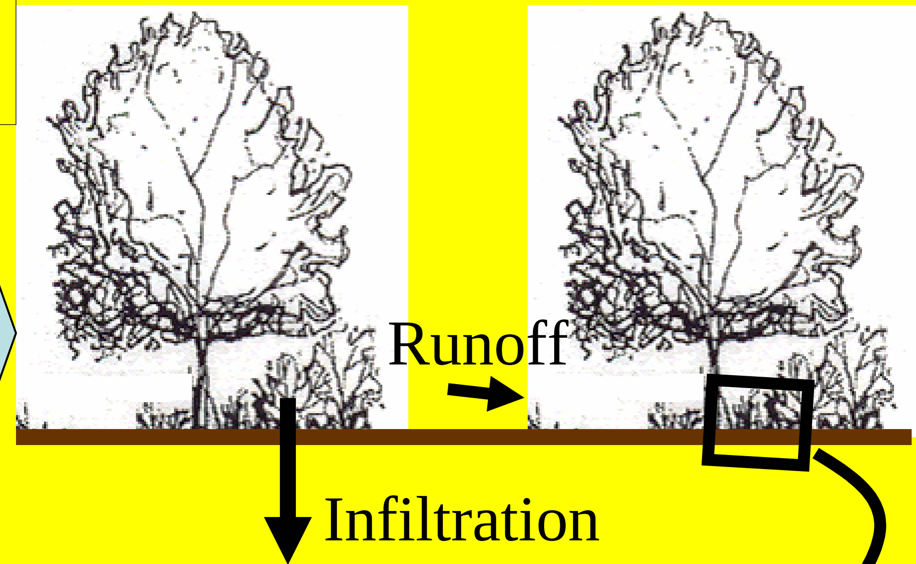
	sq ft	Est P Load (lb P / acre / yr)	LOAD
Roof	1860	1.5	0.06405
Driveway	1530	1.5	0.052686
Lawn	7000	1.25	0.200872
Woodland	43120	0.09	0.089091
Pond Surface	13975	0.75	0.240616
TOTAL	67485		**0.647315**

Compare:
Does not meet allocation.

Need to apply Best Management Practices to comply with the Total Phosphorus Allocation:
Reduce disturbed area, reduce impervious areas, increase retained woodland,
Rain Gardens, Roof Water Harvesting / Rain Barrels, "Simple" Infiltrators,

0.20 lb
P / Acre / Year



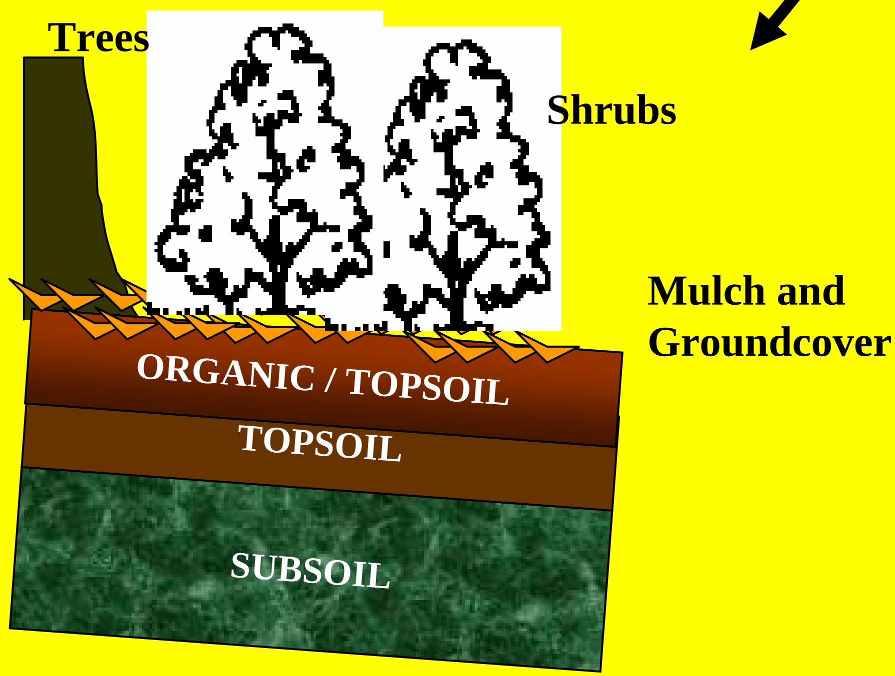


Convert Semi-Pervious to "Simulated Woodland"

- **Mimic the Function of Woodlands**
- **Ornamental Landscaping**

Example: Convert a Lawn

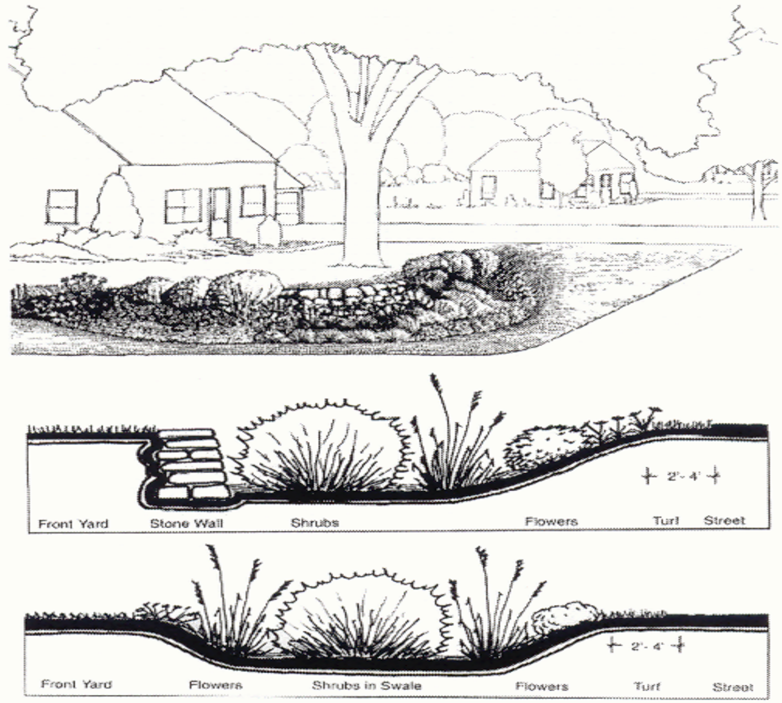
1. **Spread 3" of Peat Moss over the area**
2. **Rototill to > 6 inches**
3. **Cover with Mulch**
4. **Plant Groundcover**
5. **Plant Shrubs (50% cover when grown)**
6. **Plant Tree Saplings (> 1"DBH; 30' On-Center Spacing)**



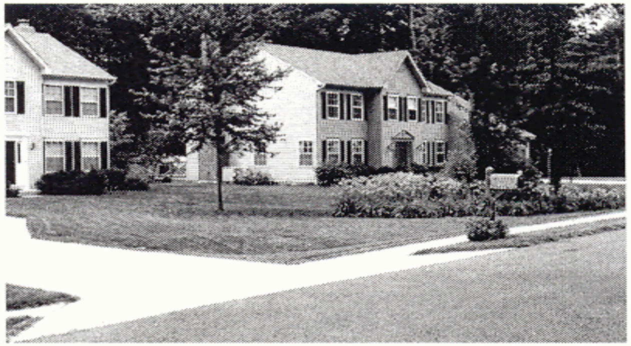
First ½ Inch
0.40 lb P / Acre / Year
First 1 Inch
0.20 lb P / Acre / Year

Figure 4-6. Residential Rain Gardens

Typical Residential Rain Garden (With and Without Masonry Wall)

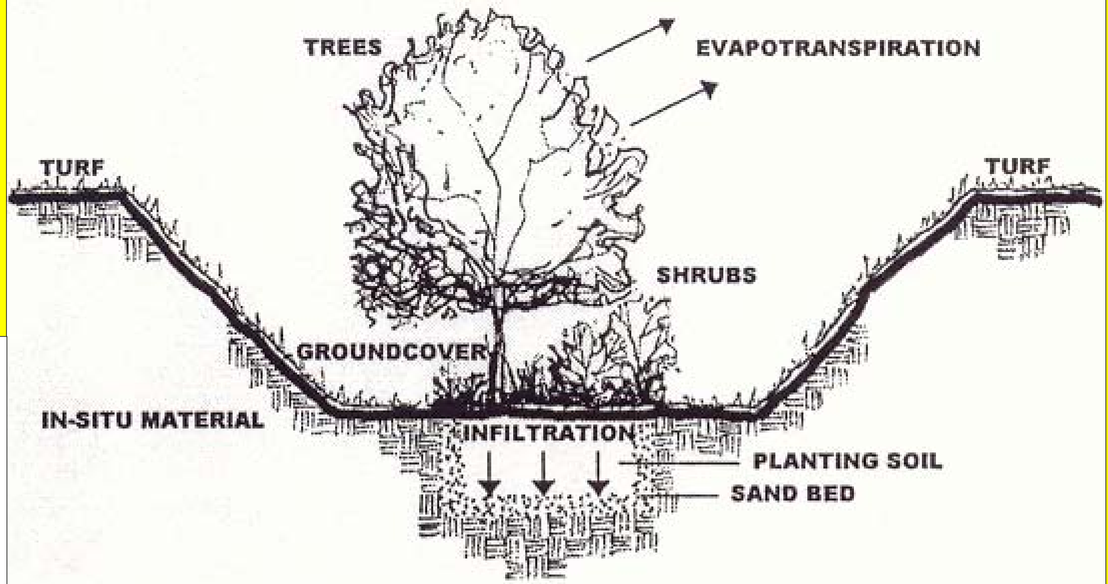


Examples of Residential Rain Gardens

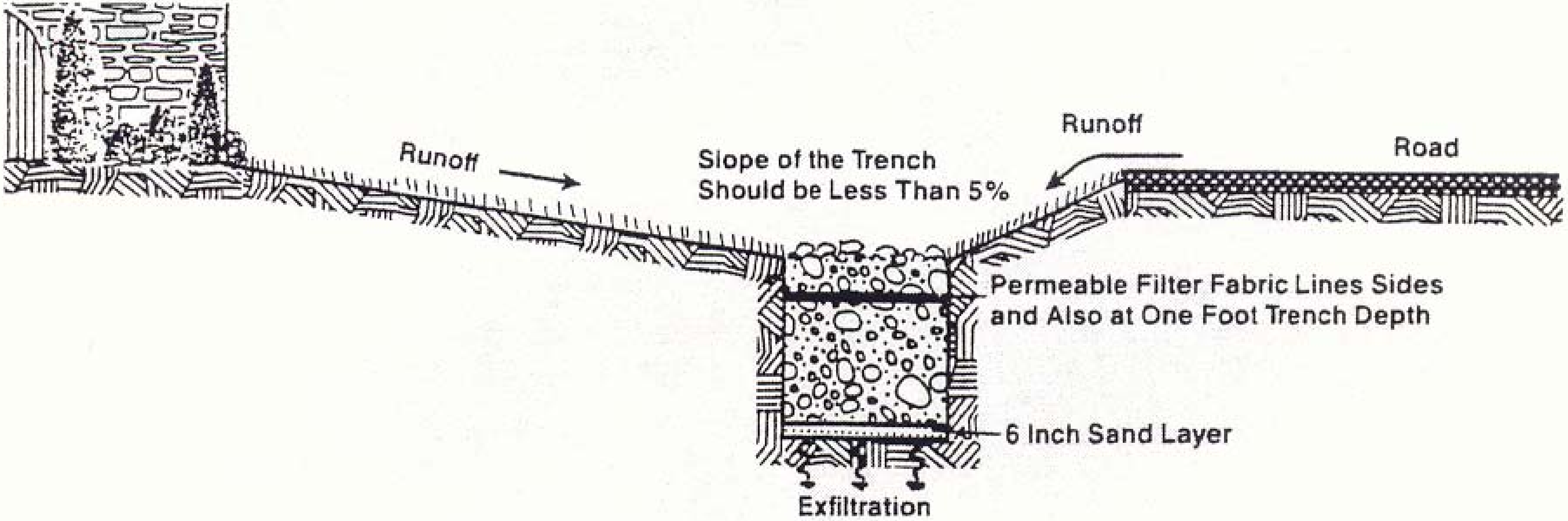


Source: Metropolitan Council, 2001 (Adapted from Nassauer et al., 1997) and Low Impact Development Center (www.lowimpactdevelopment.org), 2001.

First ½ Inch
0.40 lb P / Acre / Year
First 1 Inch
0.20 lb P / Acre / Year



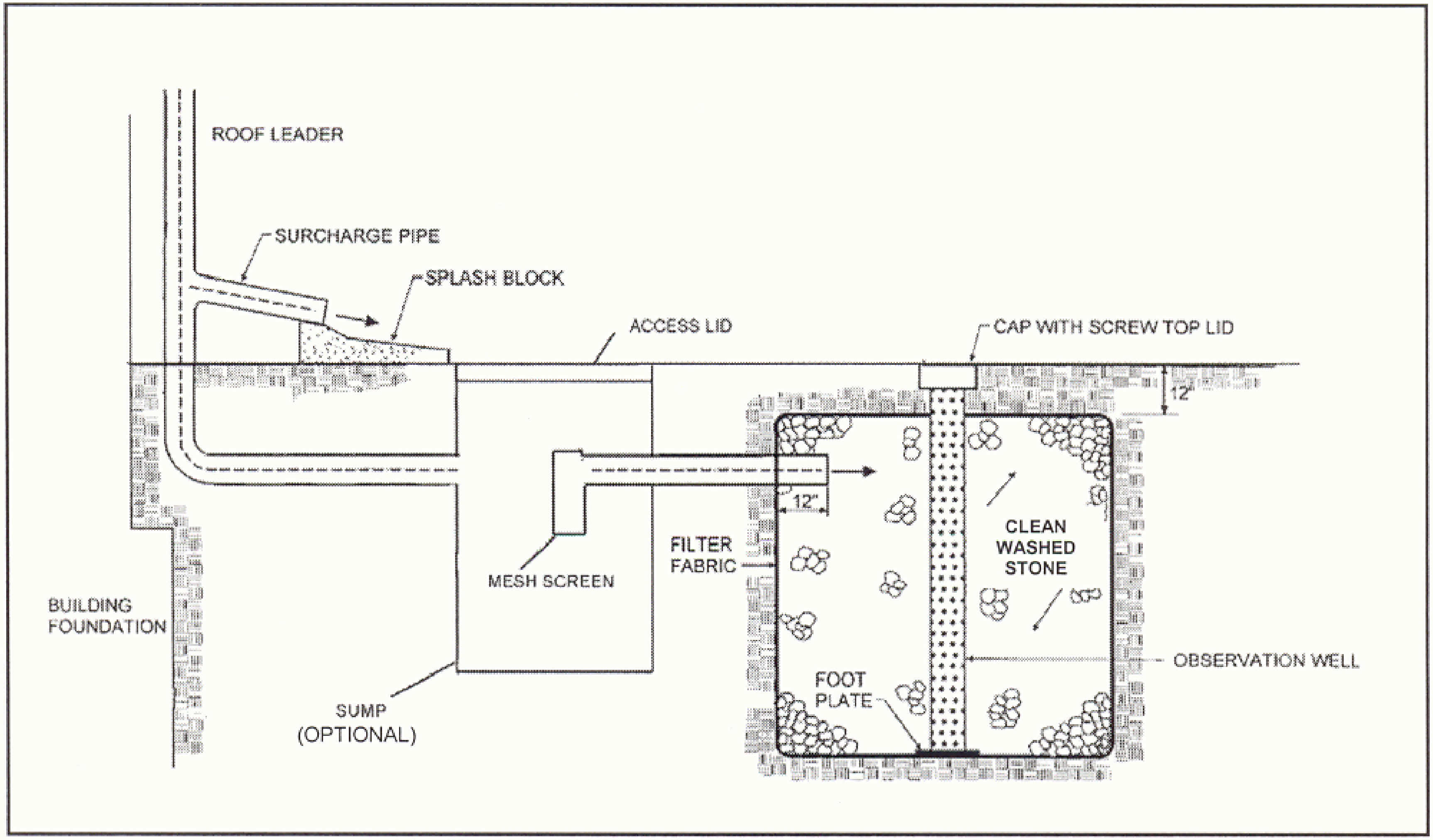
Bioretention Basin



Enhanced Swale

ADAPTED FROM SCHUELER

Figure 4-7. Schematic of Typical Dry Well

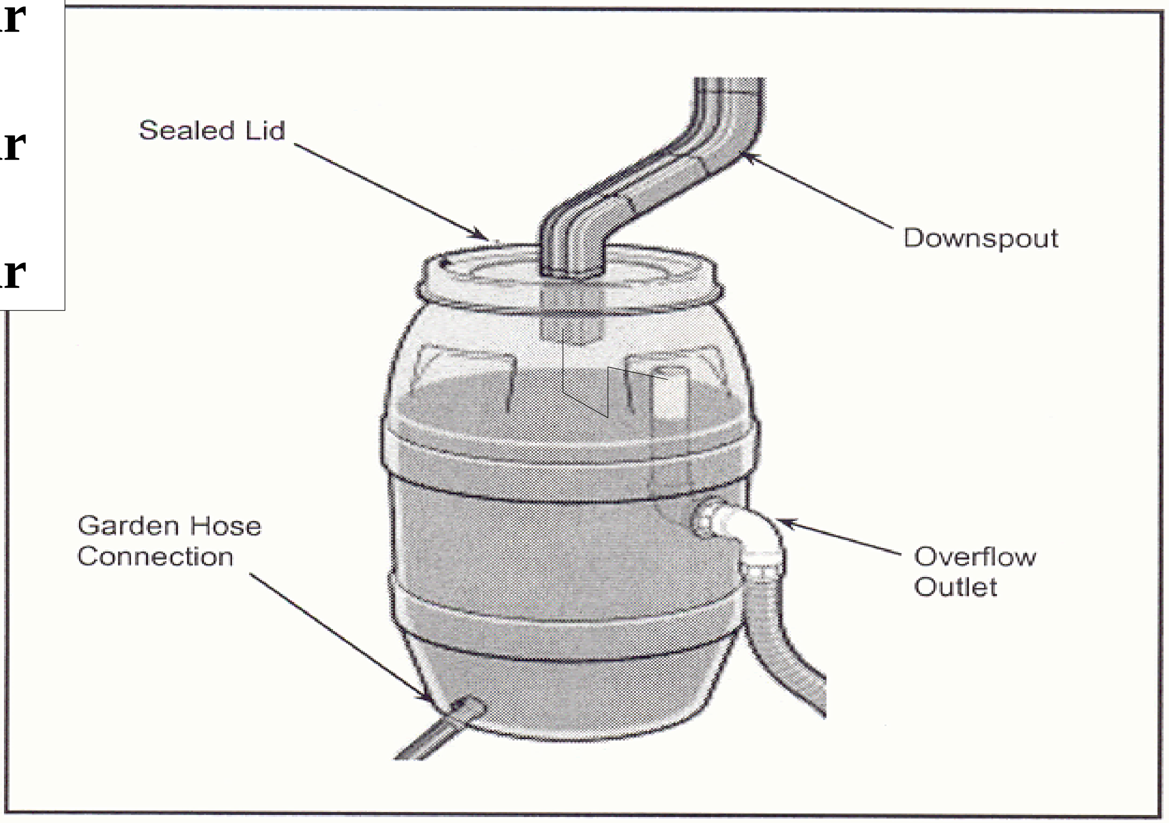


Source: Adapted from NYDEC, 2001.

First ½ Inch
0.40 lb P / Acre / Year
First 1 Inch
0.20 lb P / Acre / Year

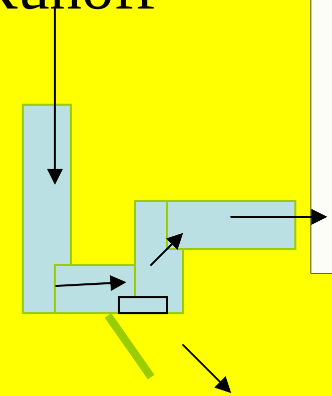
First ¼ Inch
0.60 lb P / Acre / Year
First ½ Inch
0.40 lb P / Acre / Year
First 1 Inch
0.20 lb P / Acre / Year

Figure 4-8. Typical Rain Barrel



Source: Adapted from urbangardencenter.com (D&P Industries, Inc., 2001).

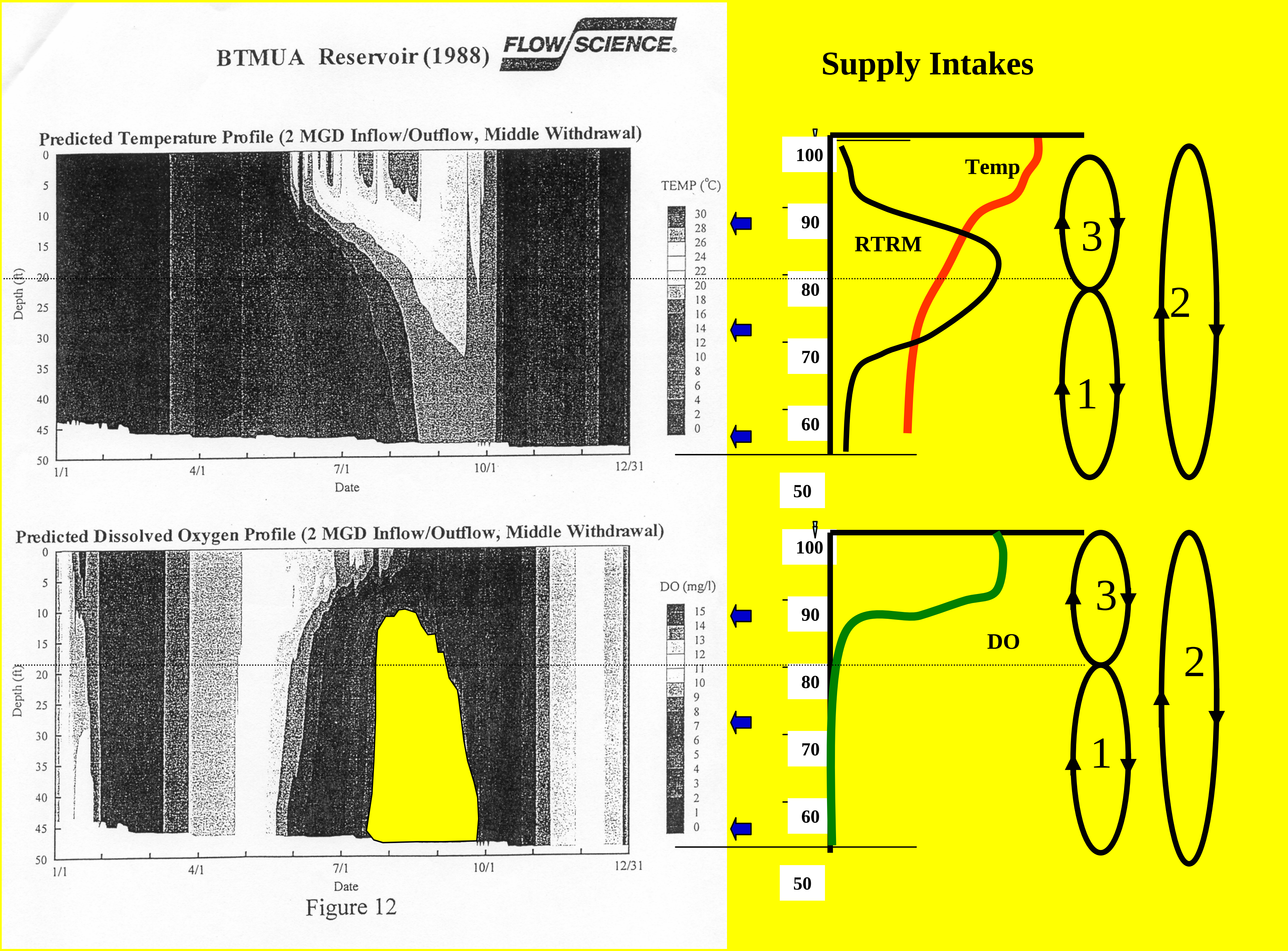
Runoff



Bypass After Full

First Flush Fills Barrel

BTMUA Reservoir
Aeration Management System

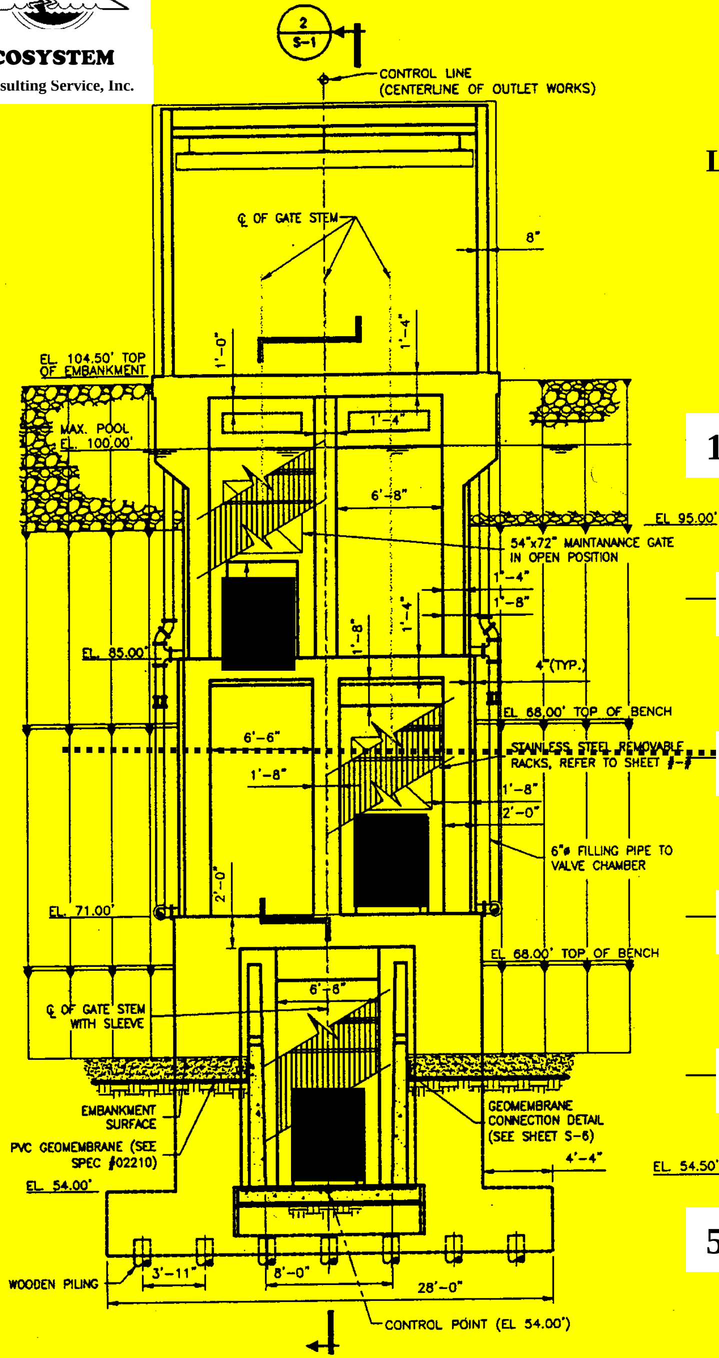


BTMUA Reservoir (1988)
FLOW SCIENCE
Supply Intakes
Predicted Temperature Profile (2 MGD Inflow/Outflow, Middle Withdrawal)
Depth (ft)
Date
1/1
4/1
7/1
10/1
12/31
TEMP (°C)
Temp
RTRM
100
90
80
70
60
50
Predicted Dissolved Oxygen Profile (2 MGD Inflow/Outflow, Middle Withdrawal)
DO (mg/l)
DO
3
2
1

Figure 12

Ecosystem
Consulting Service, Inc.

Process Schematic – BTMUA Storage Reservoir Management / Treatment System

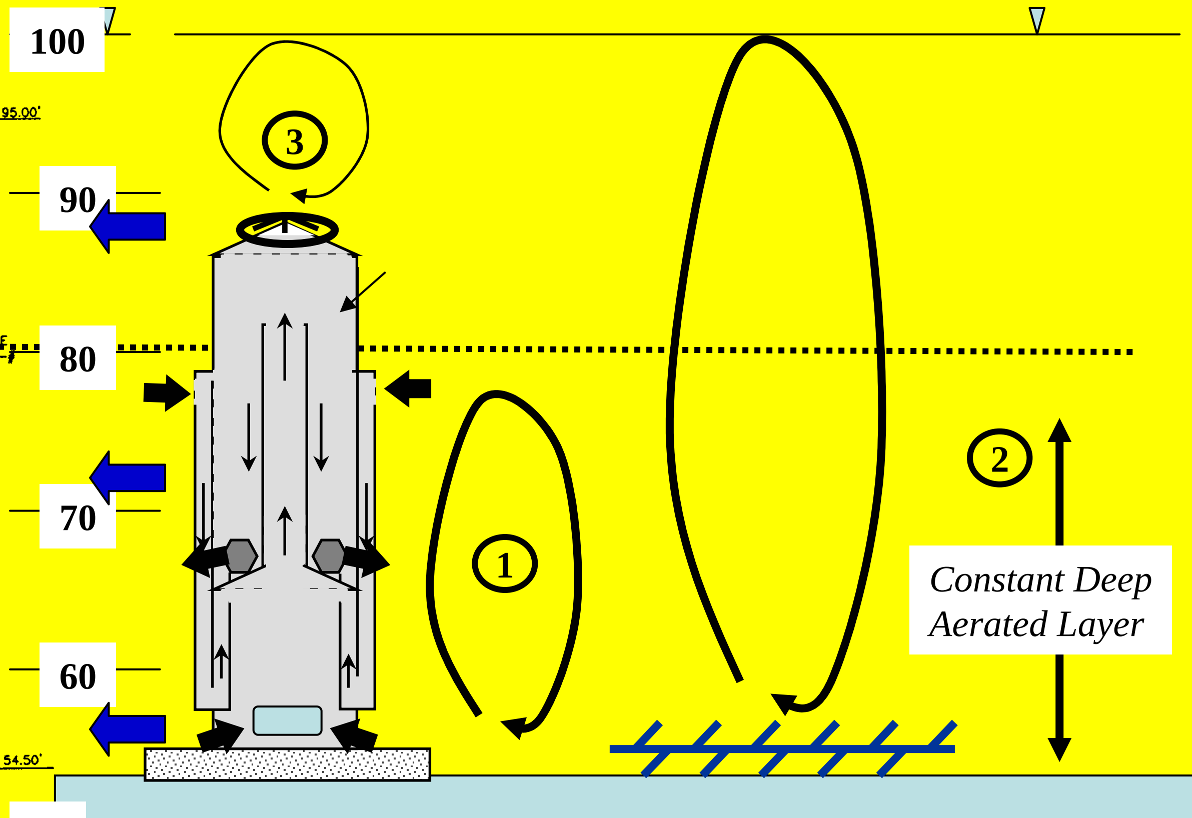


Layer Aeration (Partial Lift)

Add a ChemFeed Manifold to the diffused vent release

Artificial Circulation

Full Artificial Circulation Diffuser Module with Dual Chem Feed Installed at each Layer Aerator Slab



Functions Provided:

1. Layer Aeration below elev. 78ft with Dual ChemFeed
2. Complete Artificial Circulation down to elev. 50 ft with Dual Chem Feed
3. Enhanced Epilimnetic Circulation down to elev. 80ft (using vented air)

LayerAir PIP8 Layer Aerator

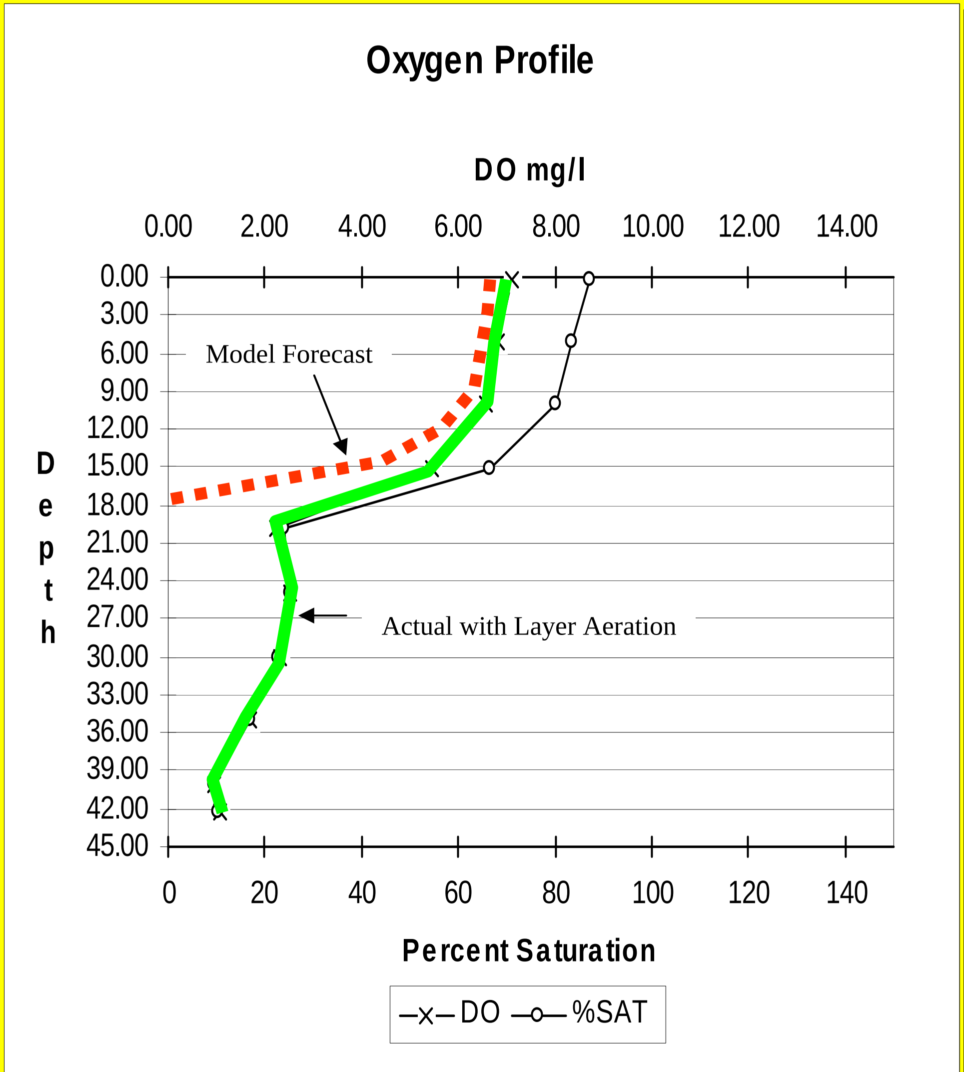
Three shallow intakes are available to establish the thickness of the aerated layer. The deep intake is always used. The initial set-up has the upper shallow intake port open (other two are closed). As lake data is collected, the upper intake could be closed and the middle intake opened which will focus aeration on a more narrow water layer. Opening only the lower shallow intake (or closing all three intakes) turns the aerator function into a “Hypolimnetic” mode of operation.

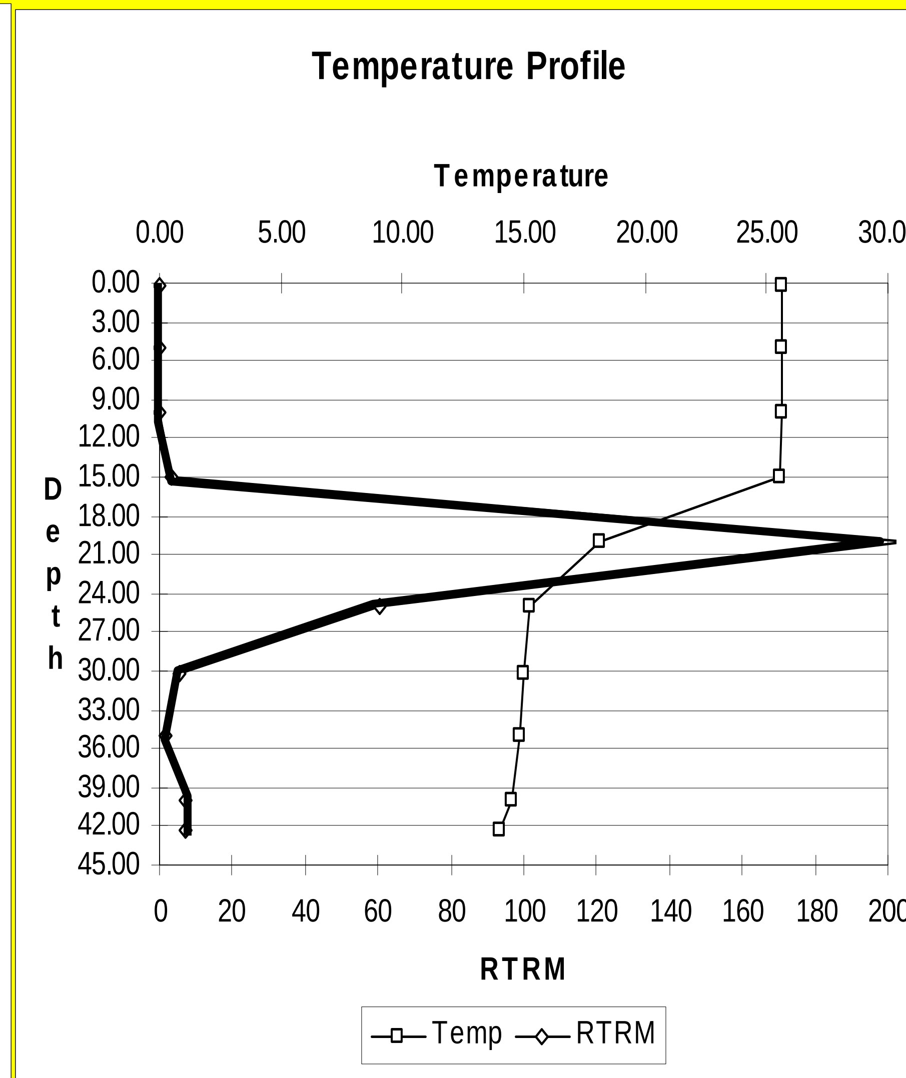
Chemical Feed Options

1. Into the Layer Aeration Tower (to treat the deep layer),
2. Into the re-diffused vent air plume (to treat the surface layer),
3. Into the Full Artificial Circulation Diffuser Module (to mix and treat the entire water column).

All operational modifications and treatments can be performed from the land-based compressor facility.

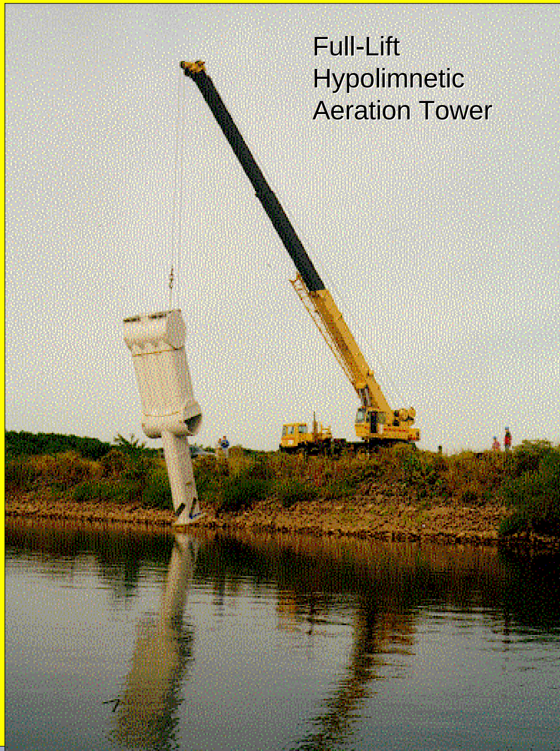
BTMUA Reservoir R-8 8/6/2004

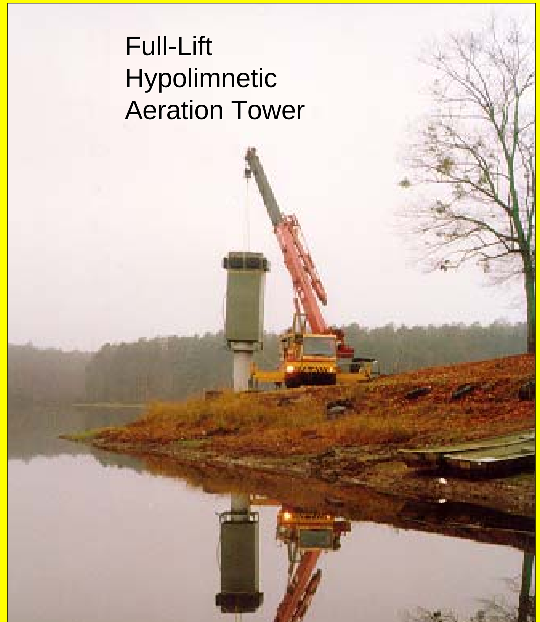




Remained Aerobic; would have been anoxic below 21 ft without aeration.

Very Strong Thermocline @ 21 ft; Good circulation of surface and deep layers.





Partial-Lift (submerged)
Layer Aeration Tower

A few Examples of Aeration Towers for Layer Aeration or Hypolimnetic Aeration.

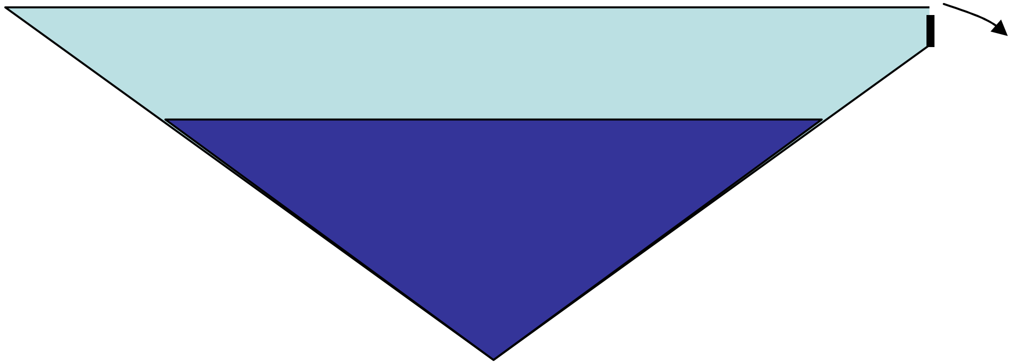
Assignment due ________

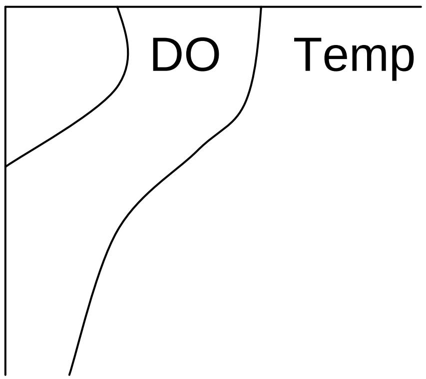
Name____________________

You may only use this piece of paper, front and back, for your answer(s).

Diagnostic Observations:

Pond has max depth of 12 ft, mean depth of 6 ft.
Outlet is a spillway with flashboards which extend from full surface down 2 ft. The pond doesn't have a "weed problem"; does occasionally have a lot of duckweed and "floating scums", and has green-turbid BG algae problems.
Very large drainage area relative to volume; flushing rate is 38 times/year; outflow is continuous all year.
Anoxia consumes all waters > 6 ft deep; during summer TP at surface = 25ppb; deep water = 65ppb;
Average Secchi= 2 ft; Spring TP=15 ppb Fall TP= 35ppb.





Pond Management – What alternatives would you suggest be evaluated?
(Unfortunately watershed management is not an option because of "ownership issues".)
NOTE: You will only "Ace this assignment" **IF** you can devise a management scheme that is low cost to implement, requires no ongoing power cost, and requires no chemical additions!