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

$$(CH_2O)_n \longrightarrow CO_2$$

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*.

Synthesis $CO_2 \rightarrow CH_2O$

Photosynthesis
Chemosynthesis

$\updownarrow$

Respiration $CO_2 \leftarrow CH_2O$

Aerobic Respiration
Anaerobic Respiration
Fermentation

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^-

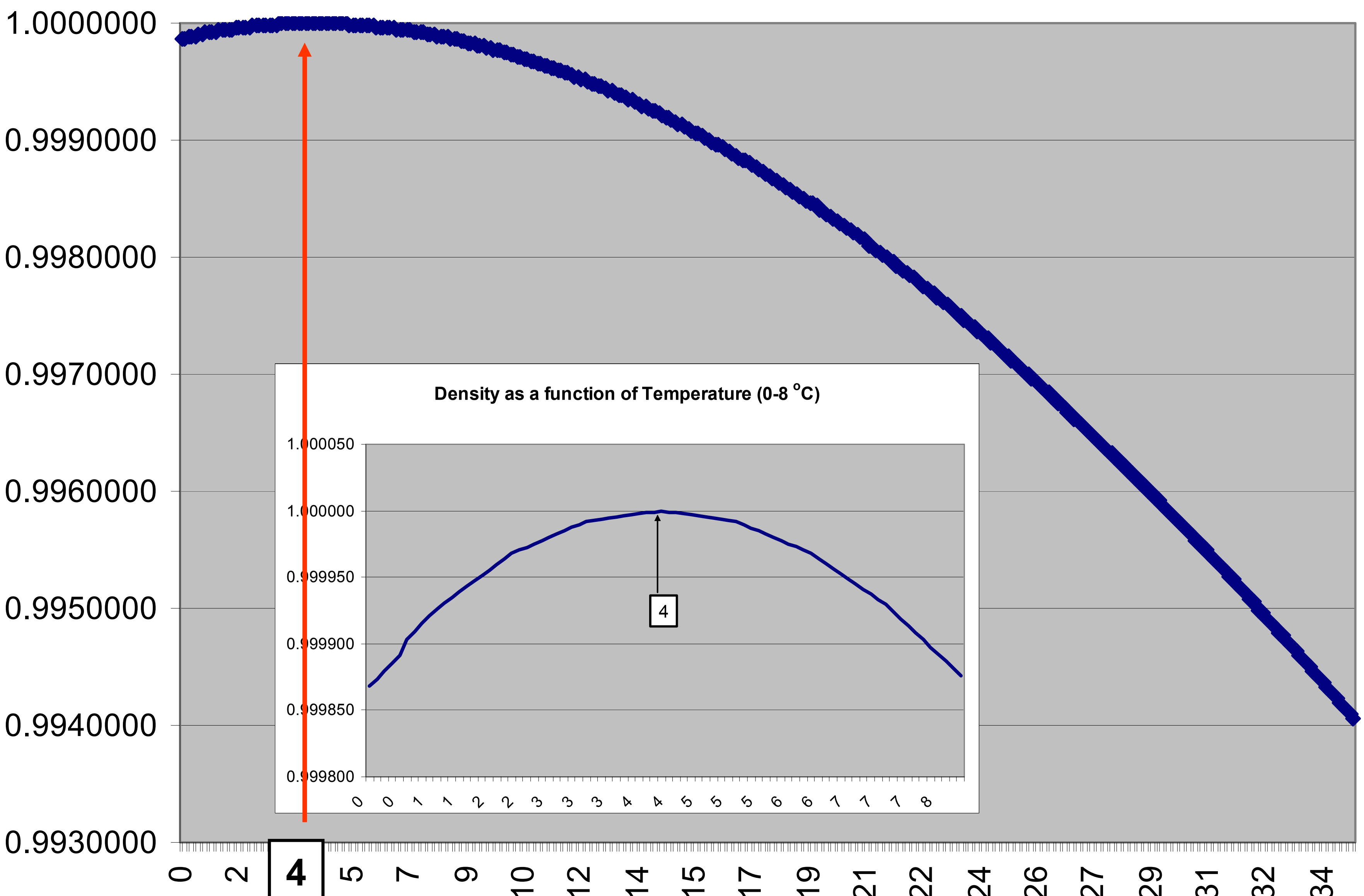
$NO_3 \longrightarrow N_2$

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

$S^o \longrightarrow H_2S^=$

Anaerobic Respiration

Density as a function of Temperature (°C)



RTRM

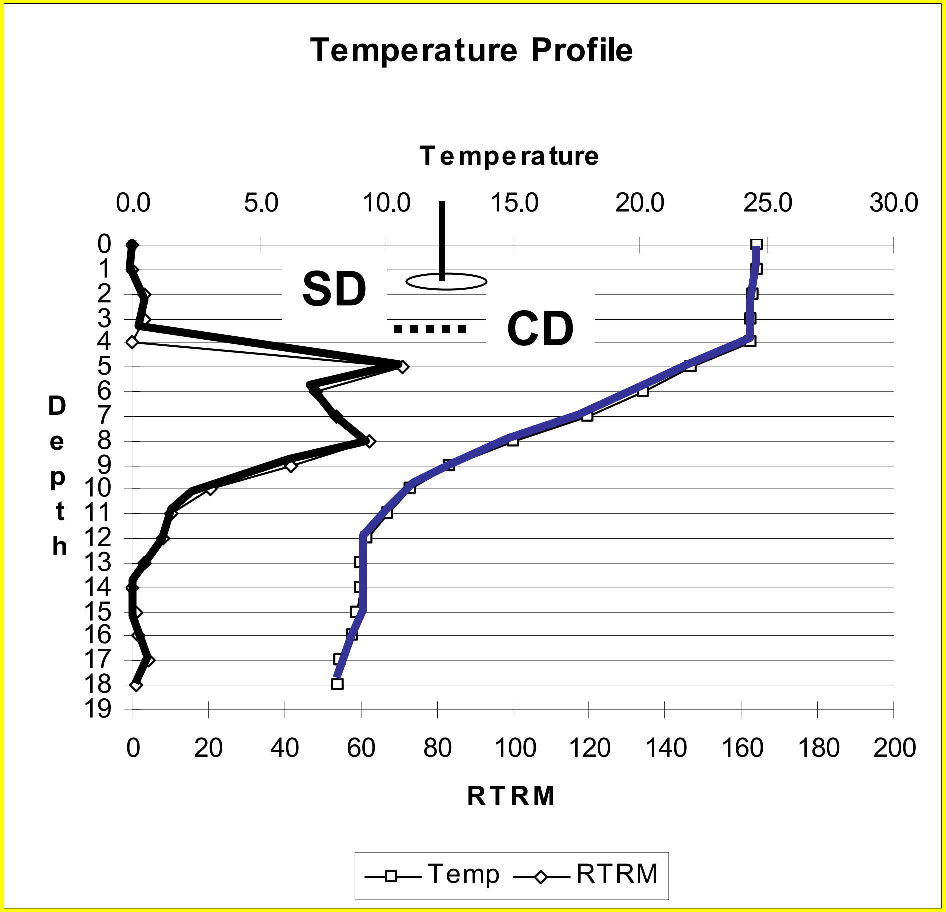
Relative Thermal Resistance to Mixing

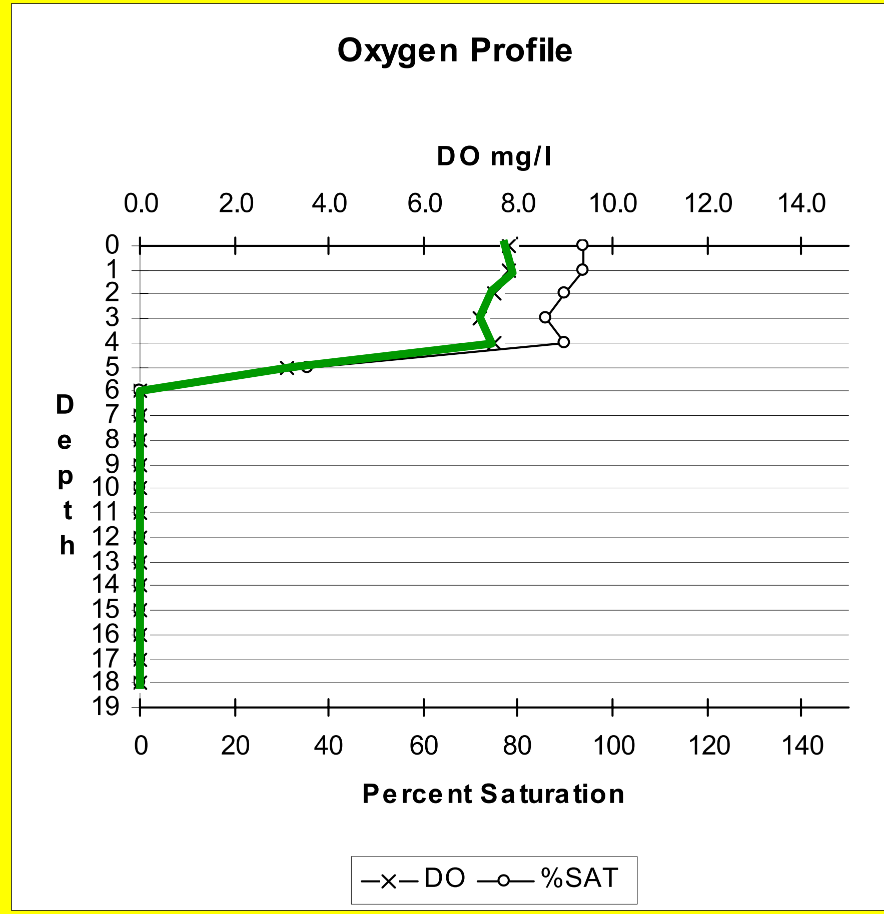
$$\text{RTRM} = \frac{\text{Density of Upper Layer} - \text{Density of Lower Layer}}{\text{Density at } 5^{o}\text{ C} - \text{Density at } 4^{o}\text{ C}}$$

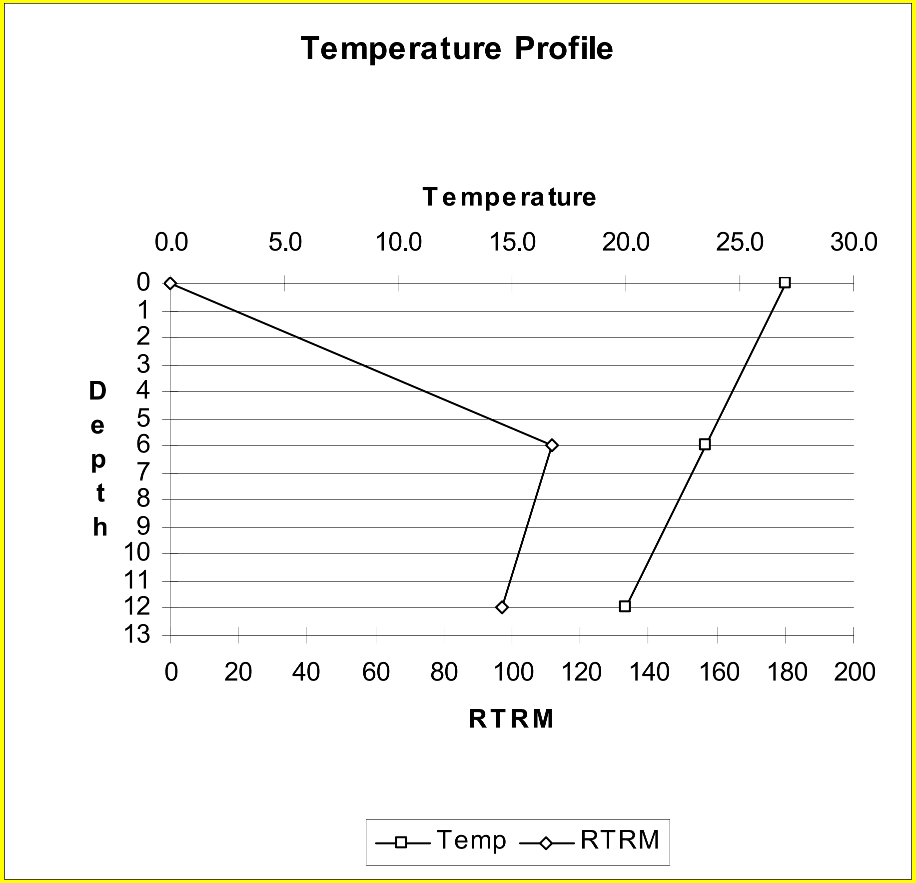
RTRM

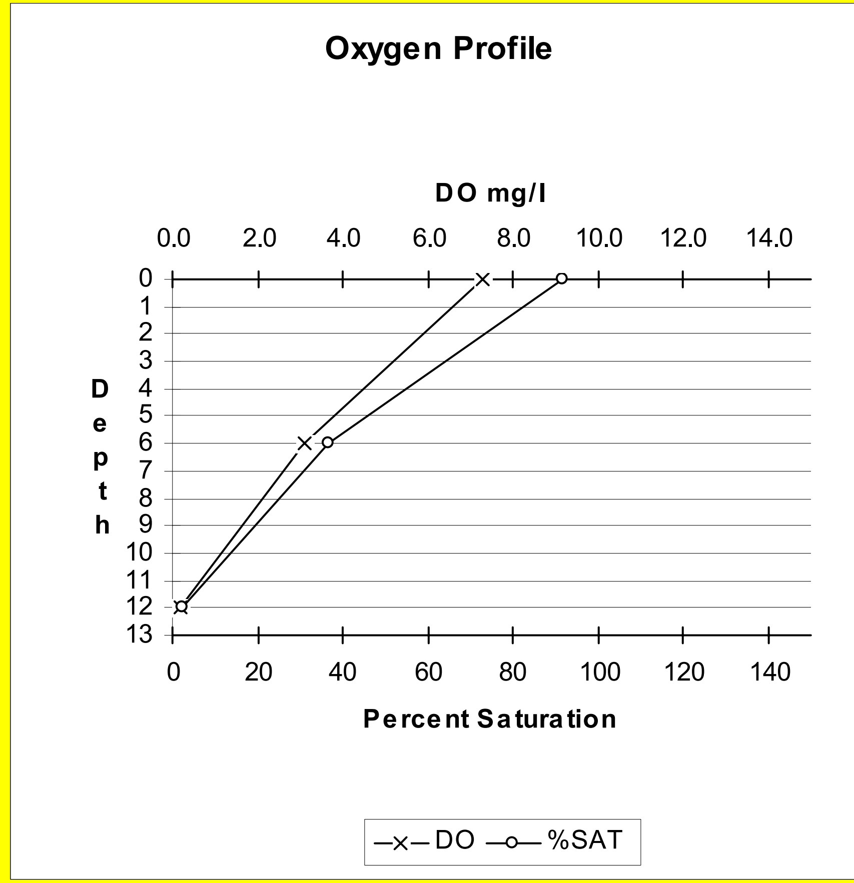
- …is a relative, non-dimensional, value which quantifies stratification as a function of temperature differential.
- …is independent of the units of depth used.
- …is additive (RTRMsum indicates total stratification intensity).
- …the Peak RTRM identifies the location and intensity of the thermocline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

“Typical Stratification”



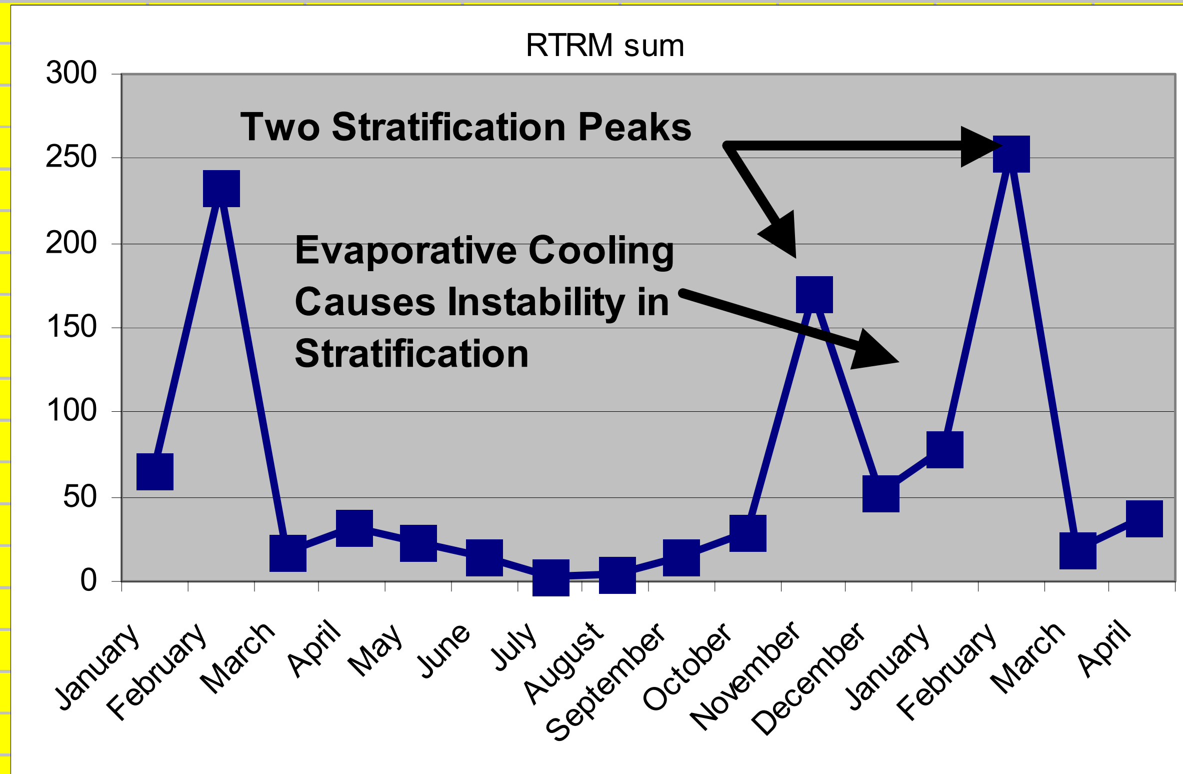






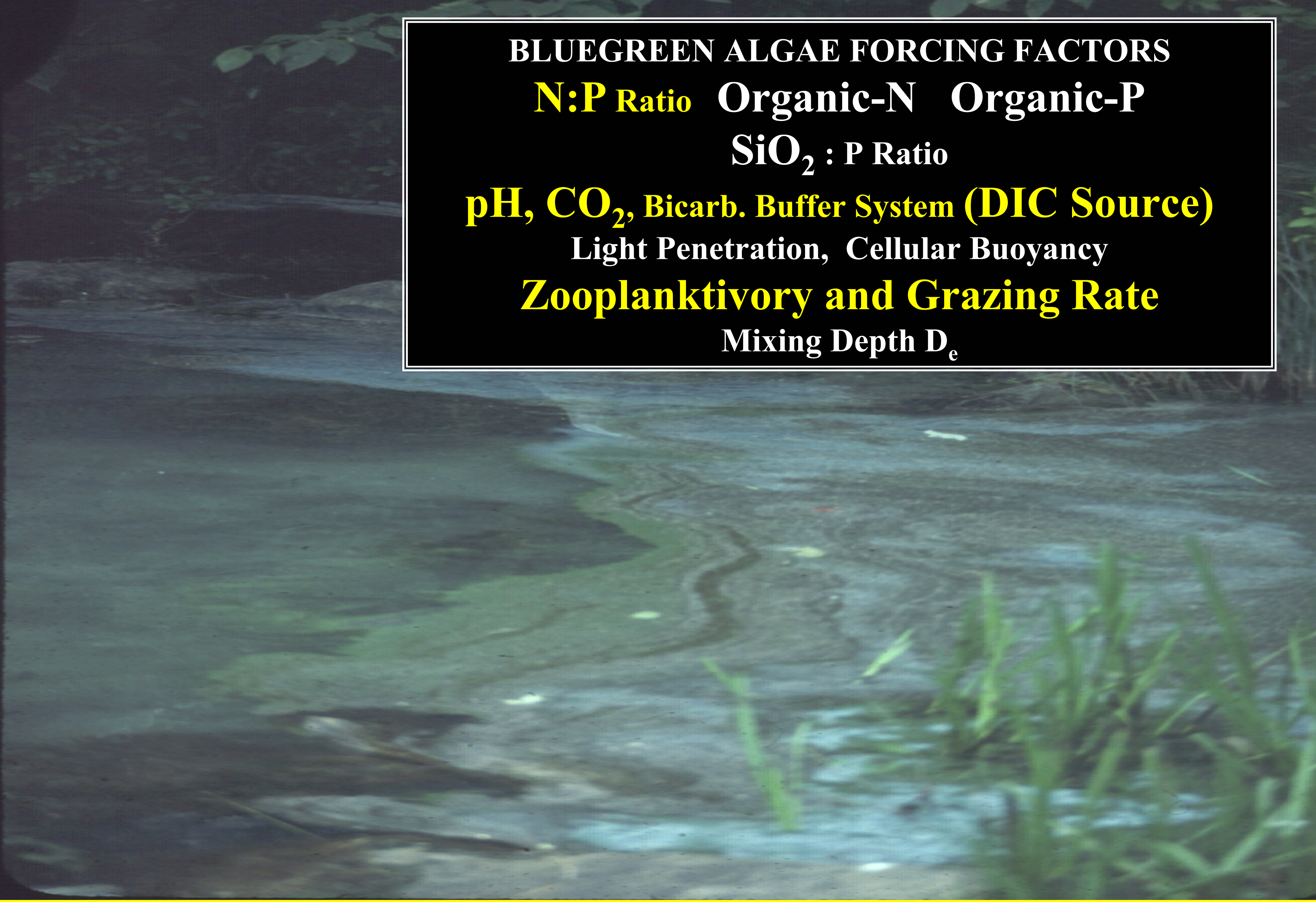
December 1993 (their summer)
Rio Grande Reservoir, Sao Paulo, Brazil
Depth in Meters   RTRMsum= 209 RTRM Units

	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

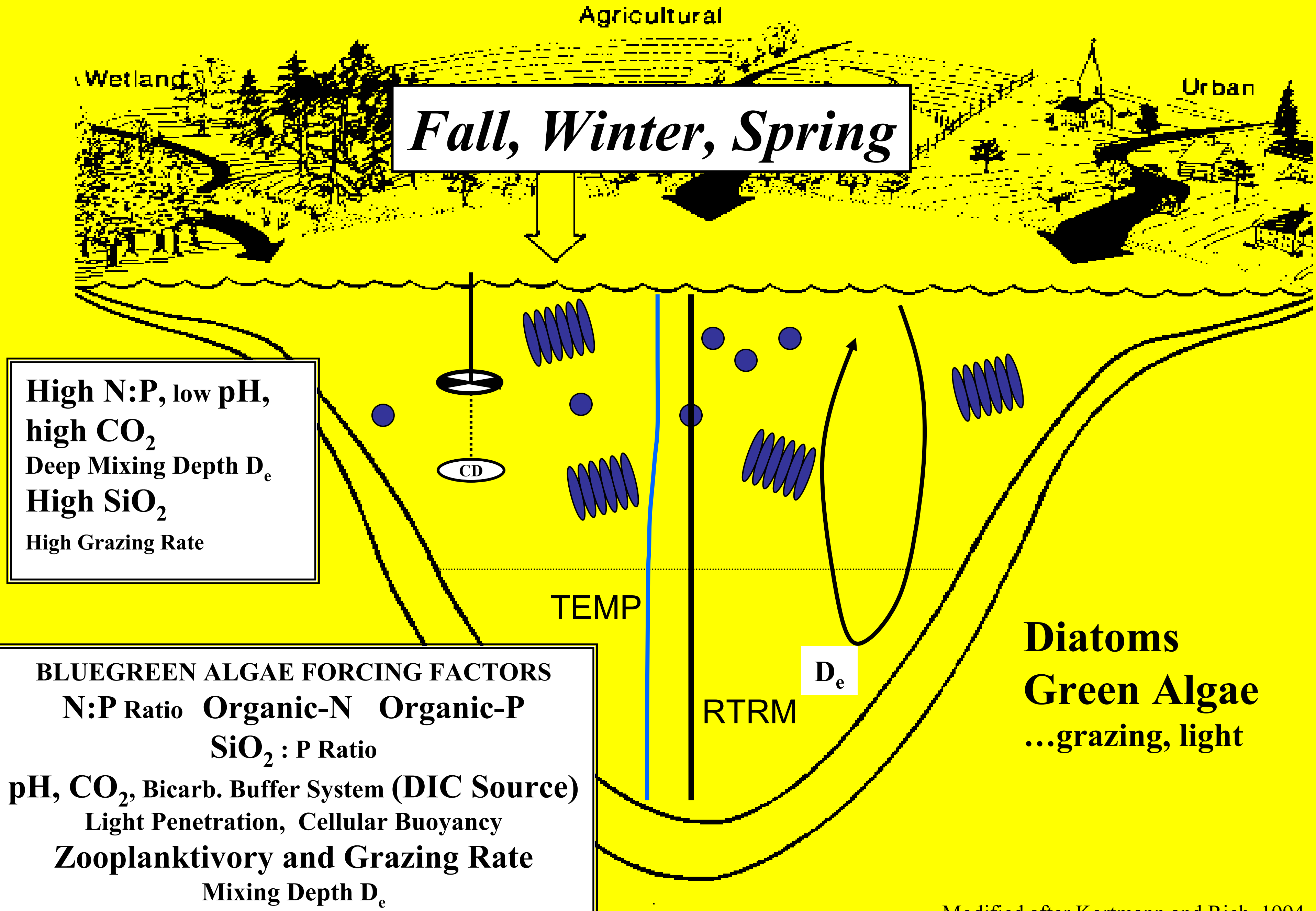


Guarapiranga Reservoir, Sao Paulo, Brazil

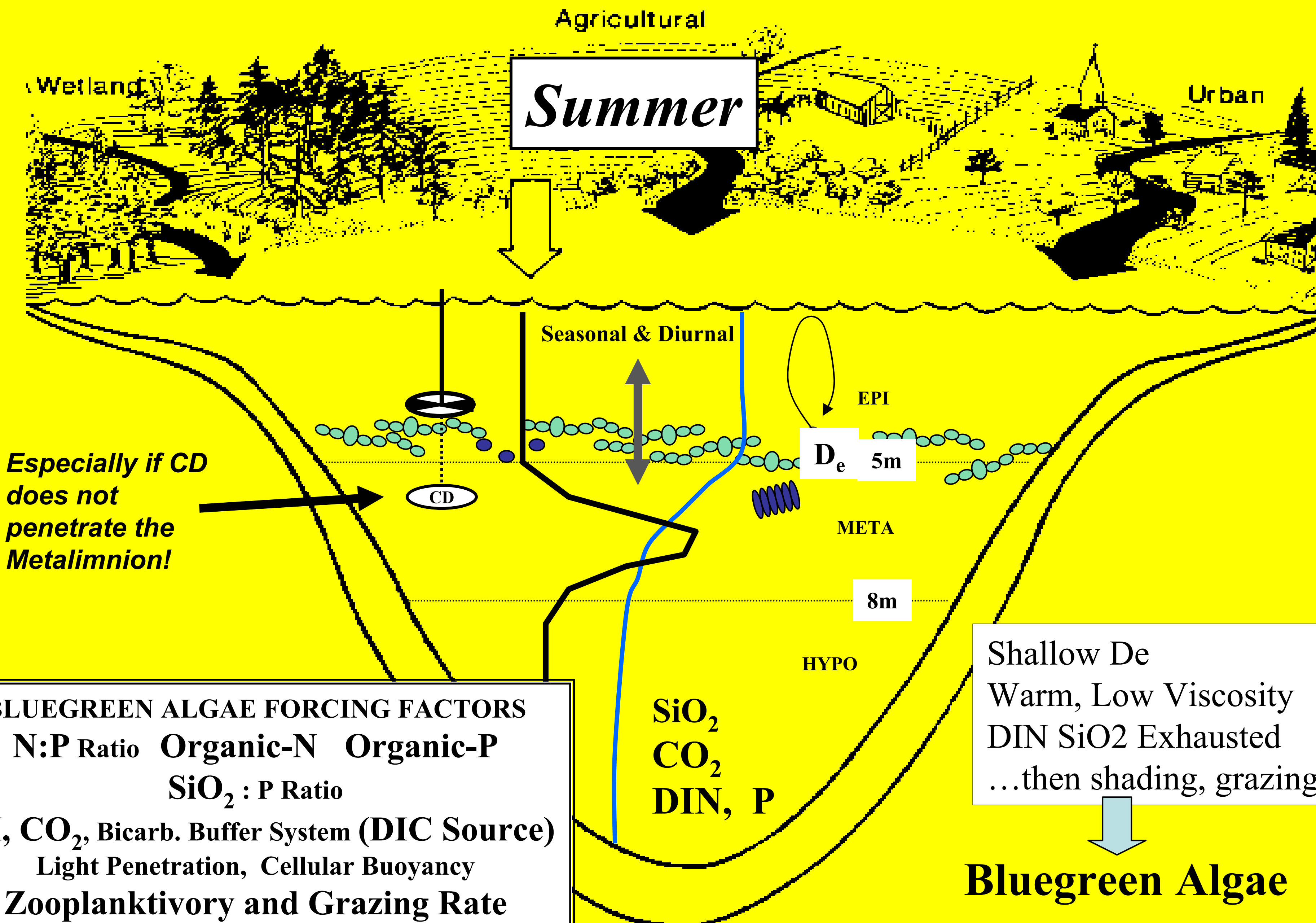
During the summer, two stratification peaks are observed (and result in two anoxia seasons, separated by a mixing episode). The evaporative cooling during mid-summer represents enough temperature change (hence density change at the warm lake temperatures) To cause instability in stratification. The RTRM 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)



Modified after Kortmann and Rich, 1994

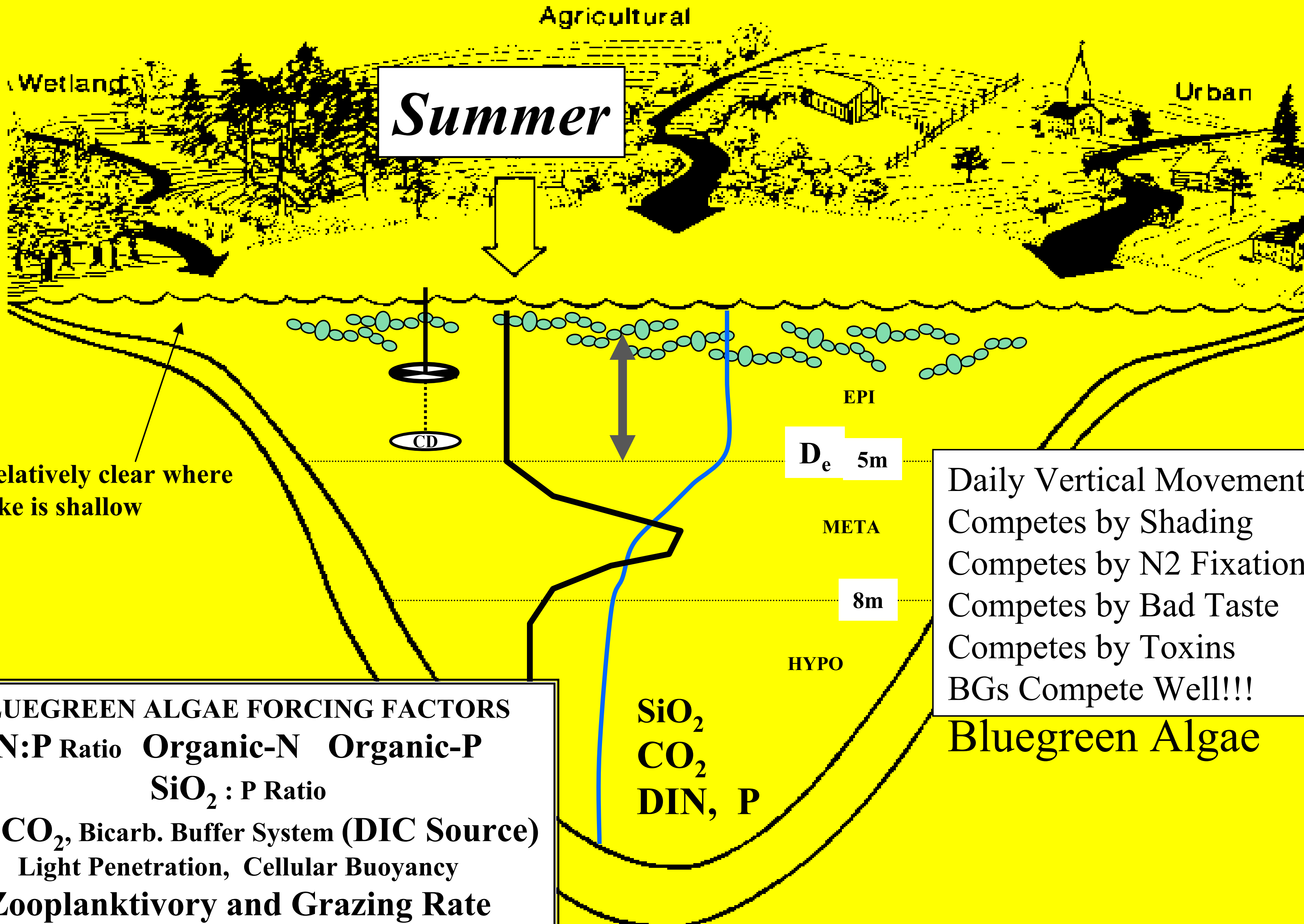


BLUEGREEN ALGAE FORCING FACTORS
N:P Ratio Organic-N Organic-P
SiO_2 : P Ratio
pH, CO_2, Bicarb. Buffer System (DIC Source)
Light Penetration, Cellular Buoyancy
Zooplanktivory and Grazing Rate
Mixing Depth D_e

Shallow De
Warm, Low Viscosity
DIN SiO2 Exhausted
…then shading, grazing

Bluegreen Algae

Modified after Kortmann and Rich, 1994



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

Daily Vertical Movement
Competes by Shading
Competes by N2 Fixation
Competes by Bad Taste
Competes by Toxins
BGs Compete Well!!!

Bluegreen Algae

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

Raw Water Quality Relationships:

Anaerobic Respiration Products- Fe, Mn, S=; NTU, Filter Runs

Alkalinity, Buffering Capacity

Relates to Coagulation Flocculation/Dosing, Enhanced Coag.

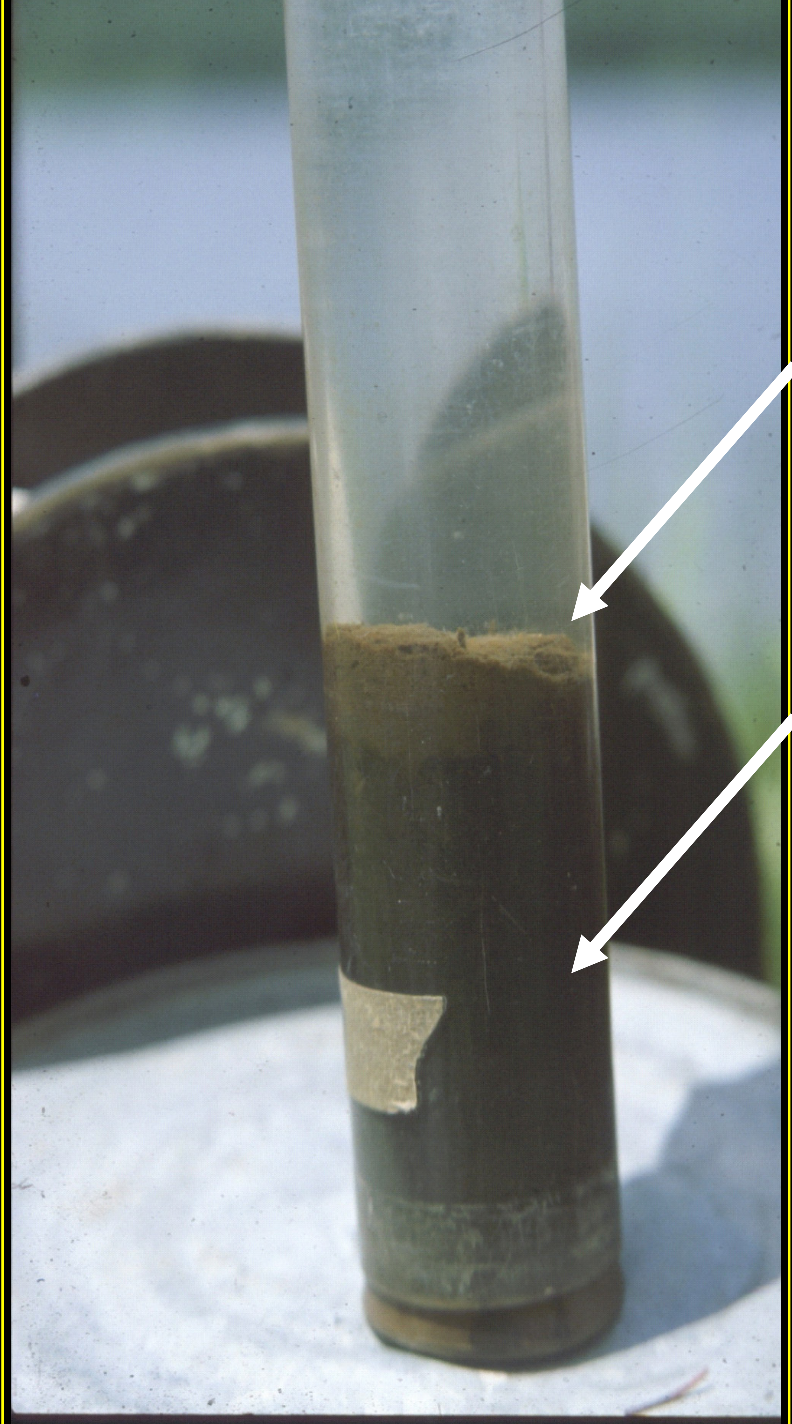
Temperature Swings- Disruption of Settling Processes

Disinfection Byproducts and Precursors- THMs and HAAs

Where to place the first Disinfection Step

Taste and Odor- Geosmin and MIB – Phytoplankton vs Epibenthic Algae

"Nutrient" Source Management – Internal vs. External



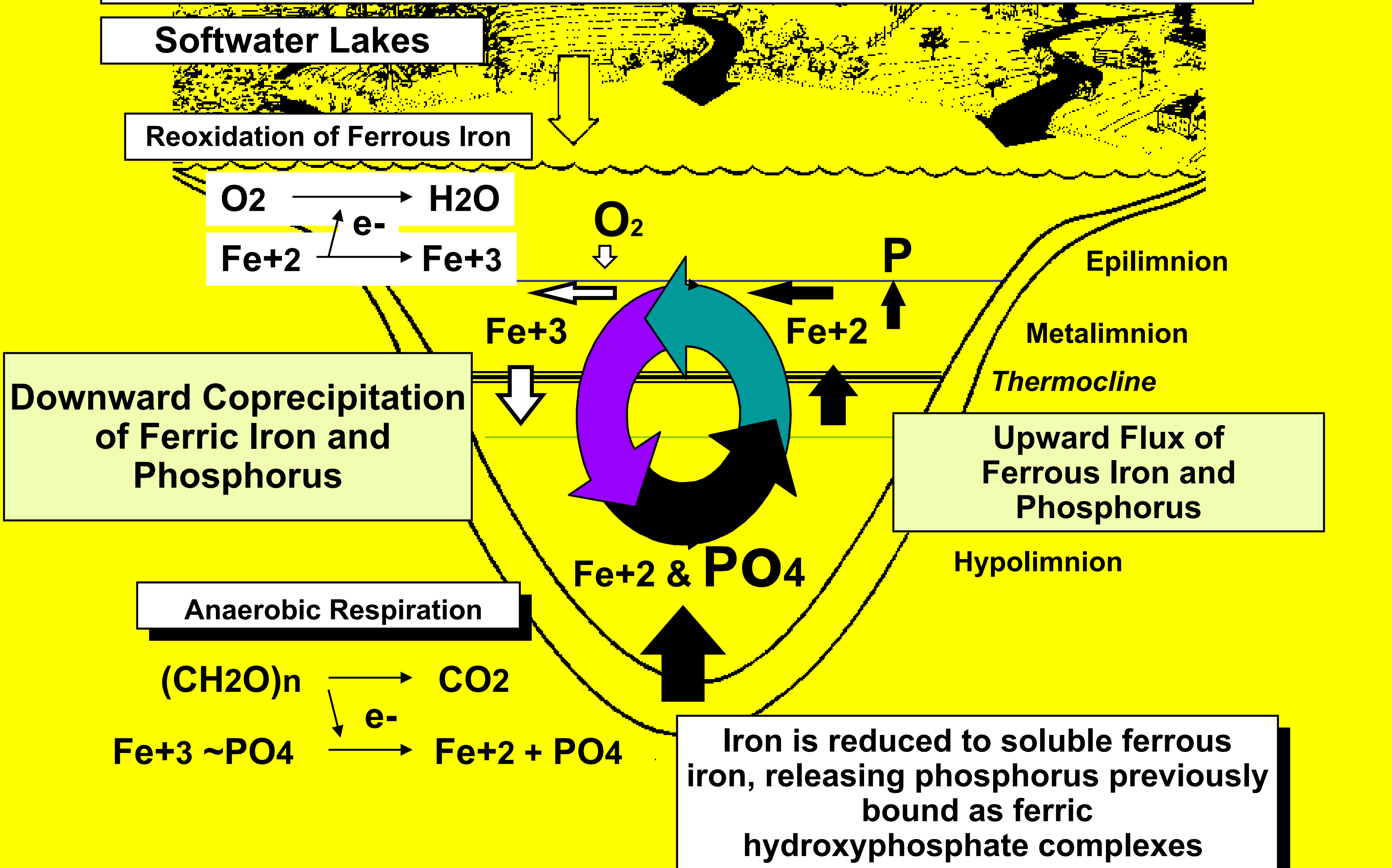
In Fe-dominated systems:

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

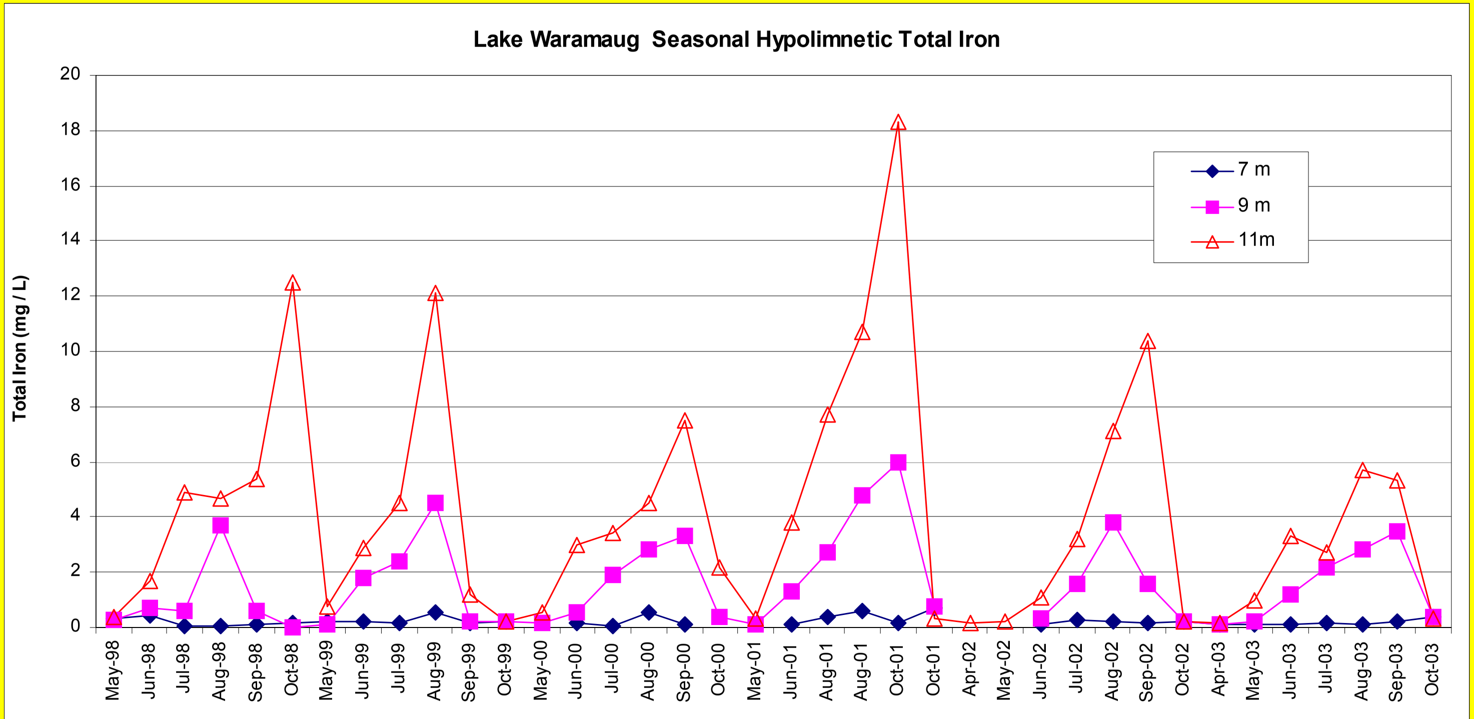
Deep Anaerobic Sediments
(with Ferr***ous*** Sulf***ide*** solids;
Note: both the iron and
sulfur are chemically
reduced and do not
participate in biotic redox or
P-binding any longer!)

(Re: Roger Doyle, 1968)

The Ferrous Wheel

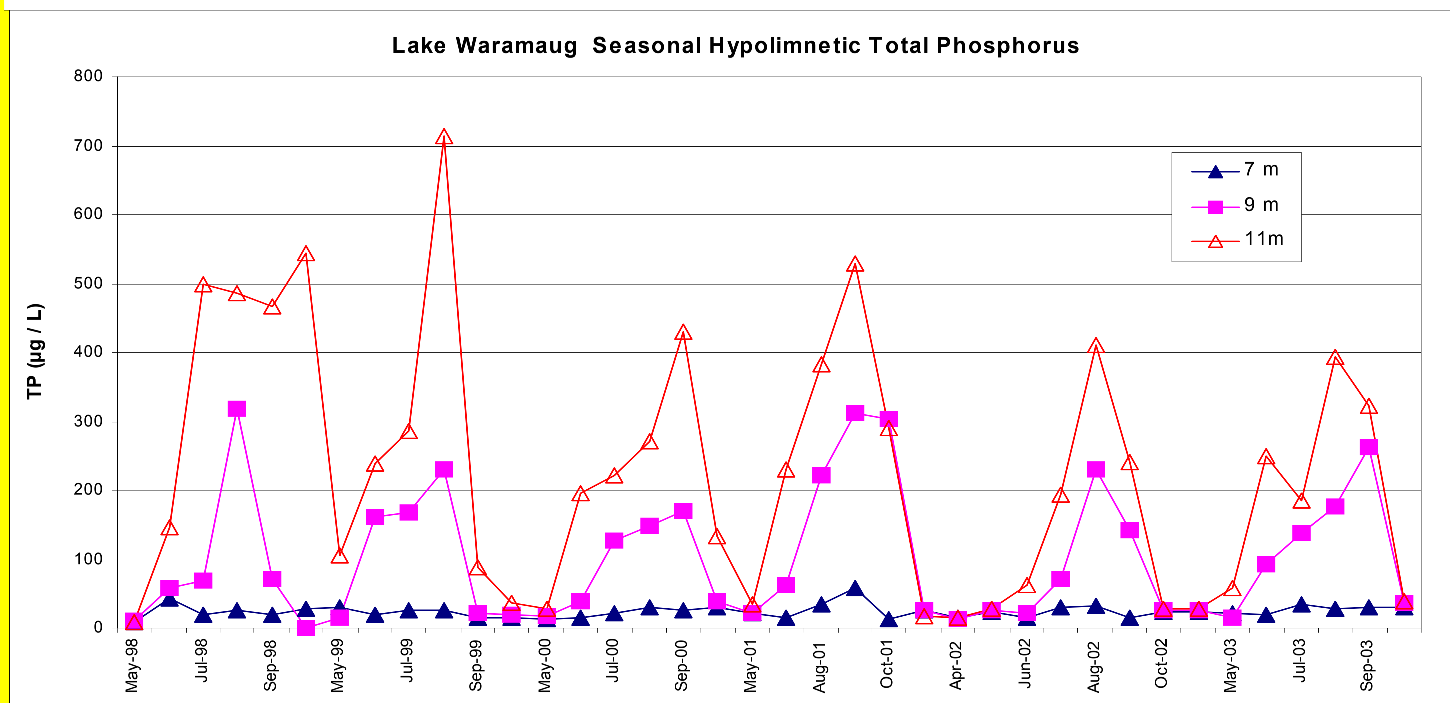


Fe



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



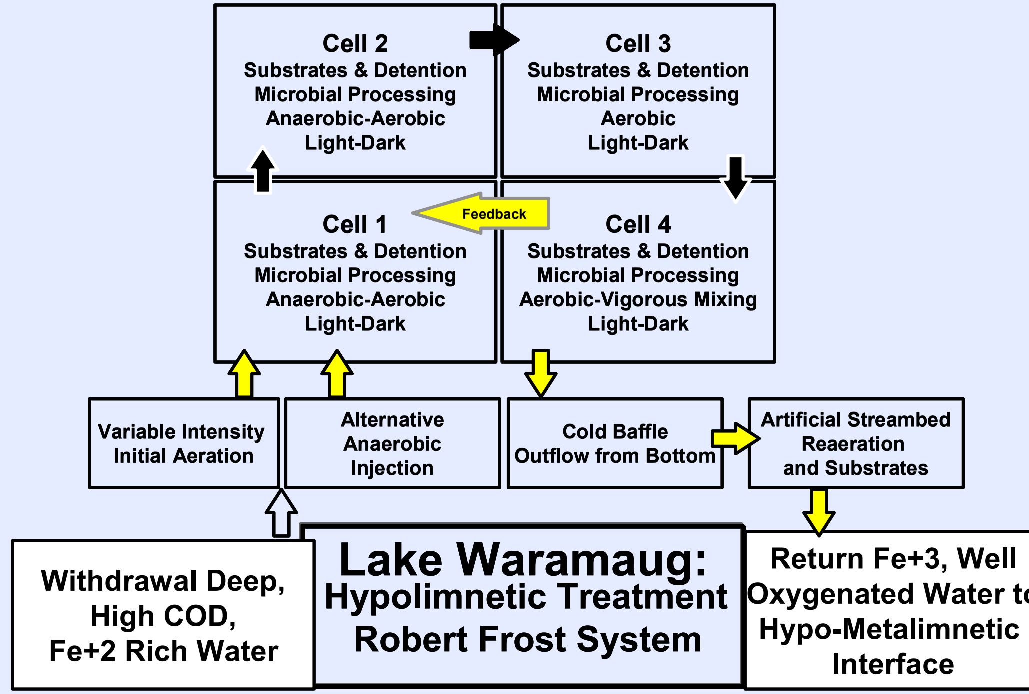
Lake Waramaug Seasonal Hypolimnetic Total Phosphorus
TP (µg / L)
800
700
600
500
400
300
200
100
0
7 m
9 m
11m
May-98
Jul-98
Sep-98
May-99
Jul-99
Sep-99
May-00
Jul-00
Sep-00
May-01
Aug-01
Oct-01
Apr-02
Jun-02
Aug-02
Oct-02
May-03
Jul-03
Sep-03

Lake Waramaug

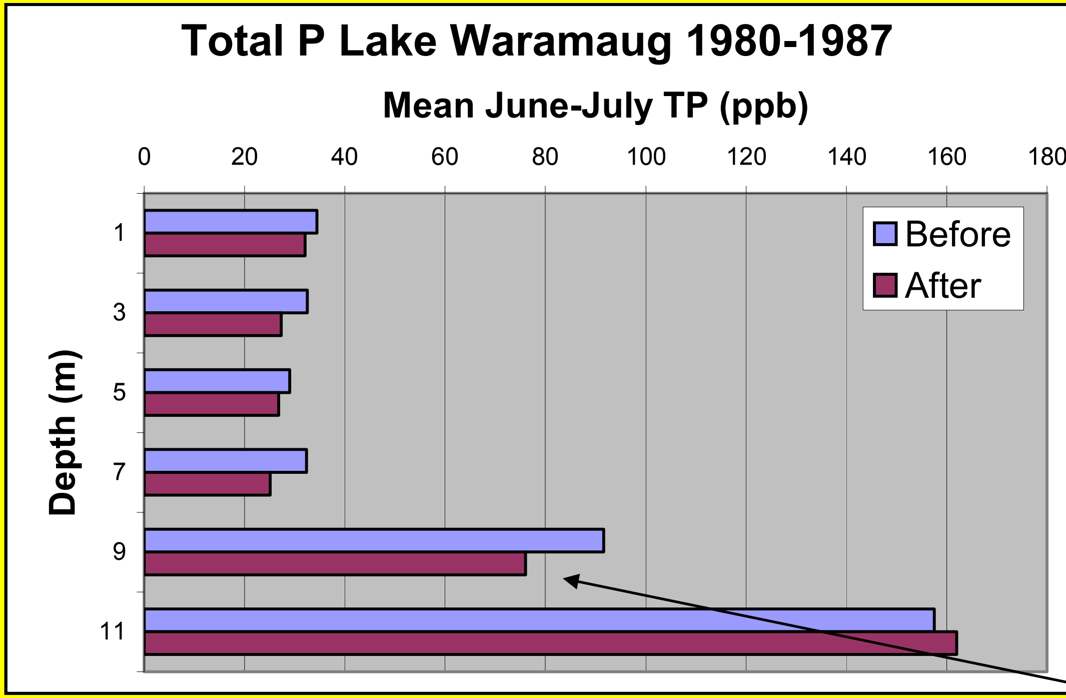
(Fe still carries Anaerobic Respiration)

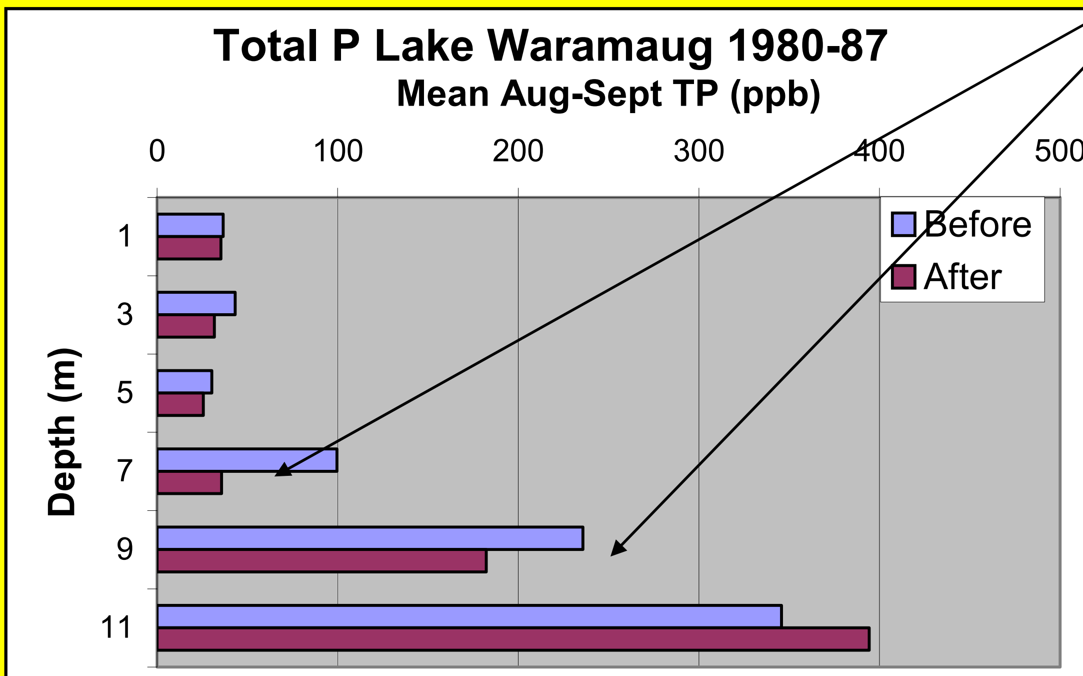
Iron, generated by anaerobic respiration, is used as a coagulant to remove P from lake water.

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



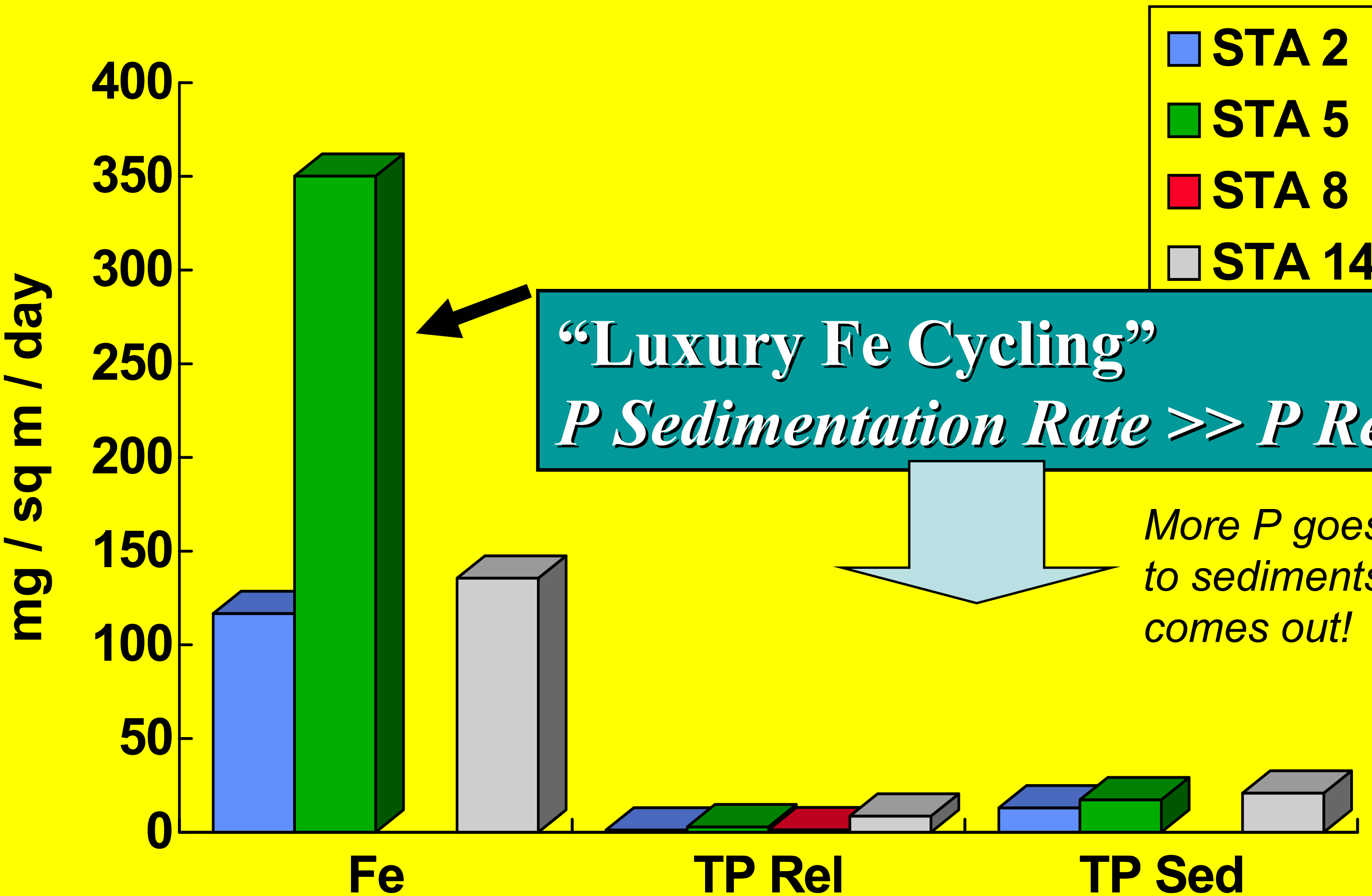
In-lake treatment focused on the "nature of the iron cycle"; ferrous iron generated deep in the hypolimnion was oxidized and "rained back down through the hypolimnion", taking P with it.





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

TP Fe Sedimentation 1994

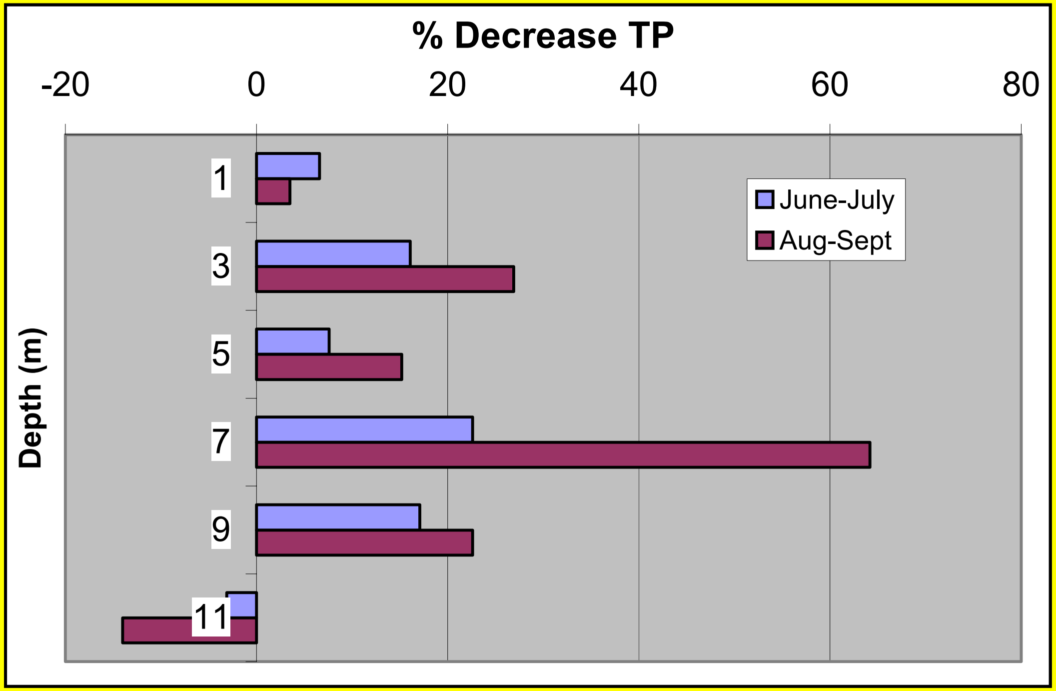


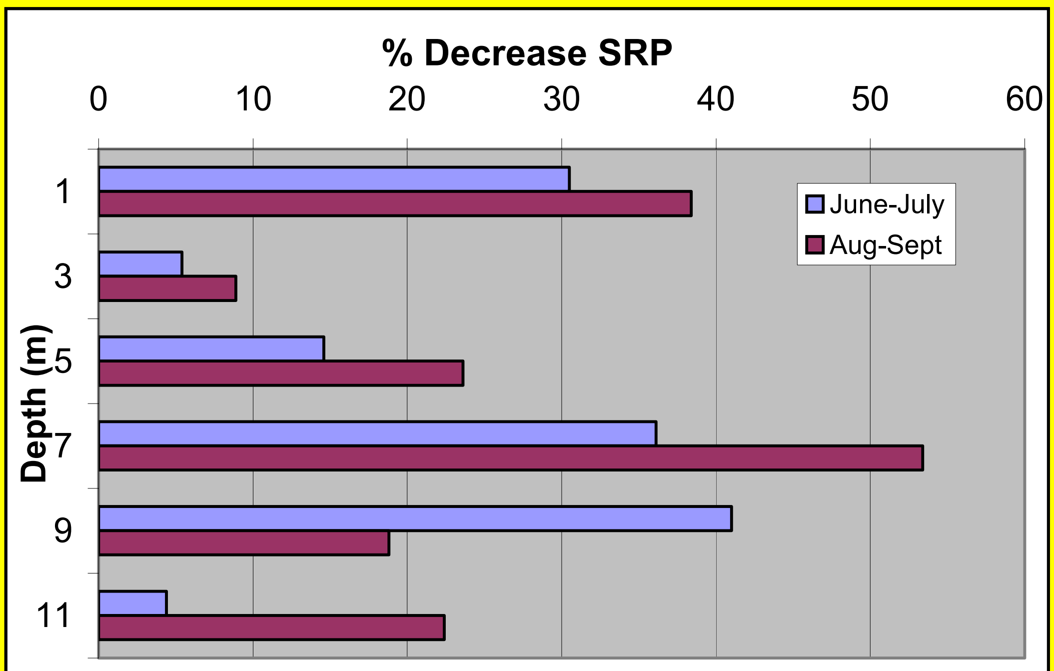
"Luxury Fe Cycling"

P Sedimentation Rate >> P Release

More P goes back to sediments than comes out!

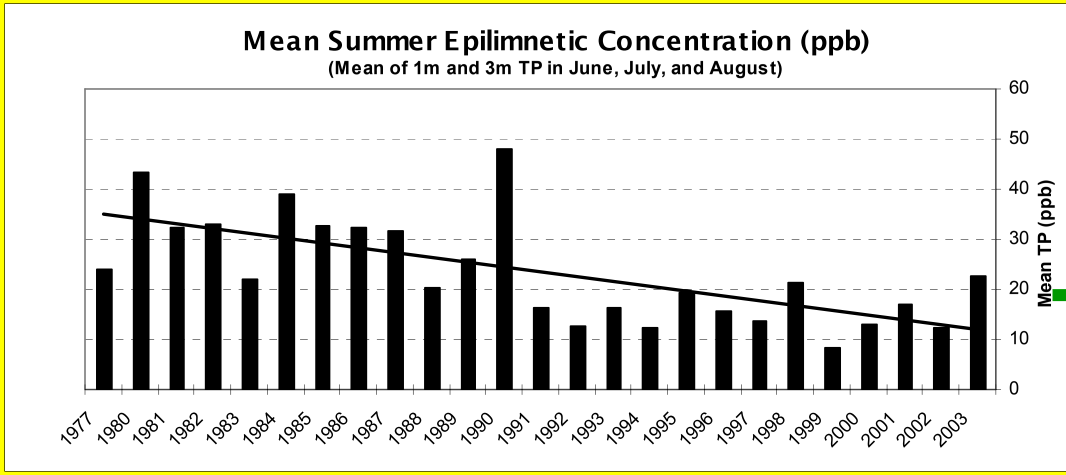
% Decrease in TP and SRP at Lake Waramaug





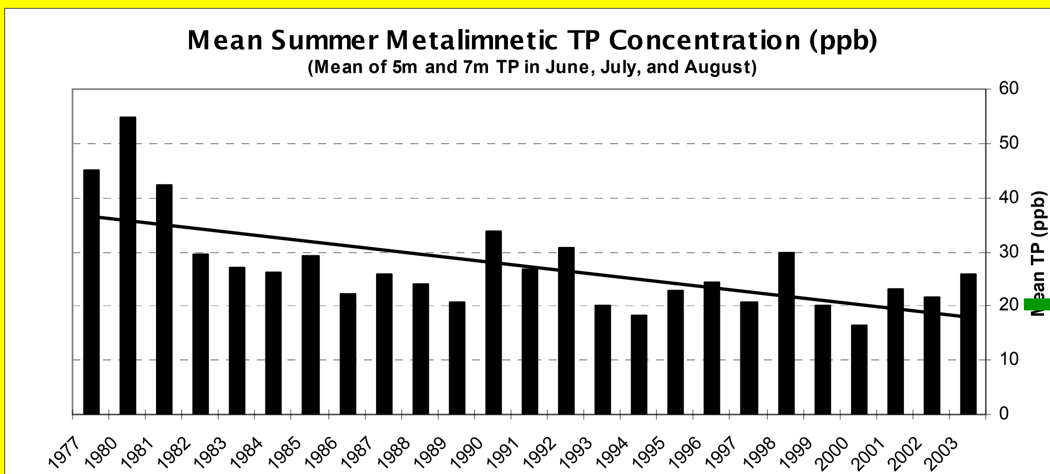
In addition to decreased TP concentrations in the upper hypolimnion, *much less of the TP was readily assimilable SRP*.

LAKE WARAMAUG Mean Summer TP Concentrations



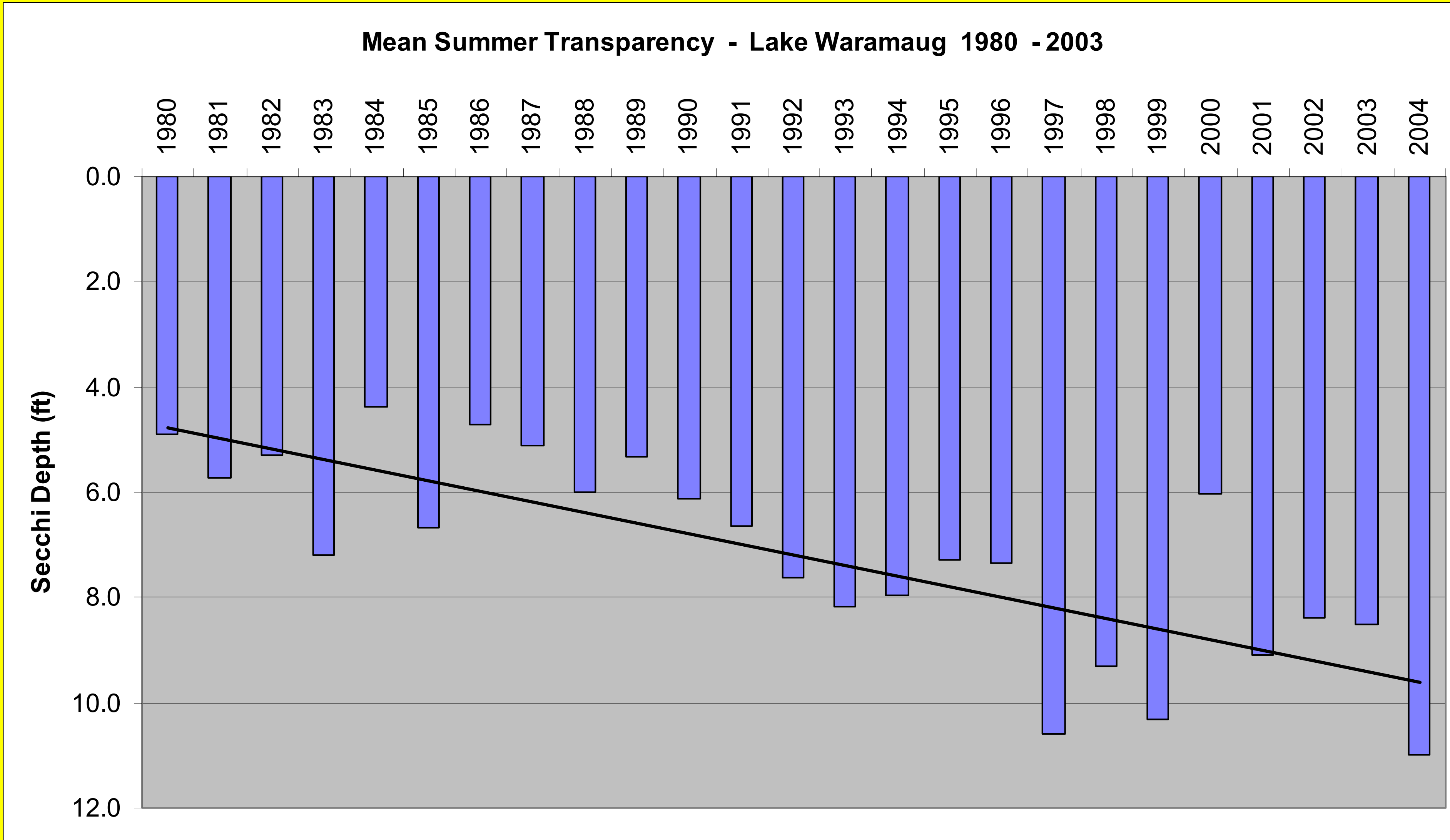
Surface Water

20 ppb



Mid-Depth Water

20 ppb



Mean Summer Transparency - Lake Waramaug 1980 - 2003
Secchi Depth (ft)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
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

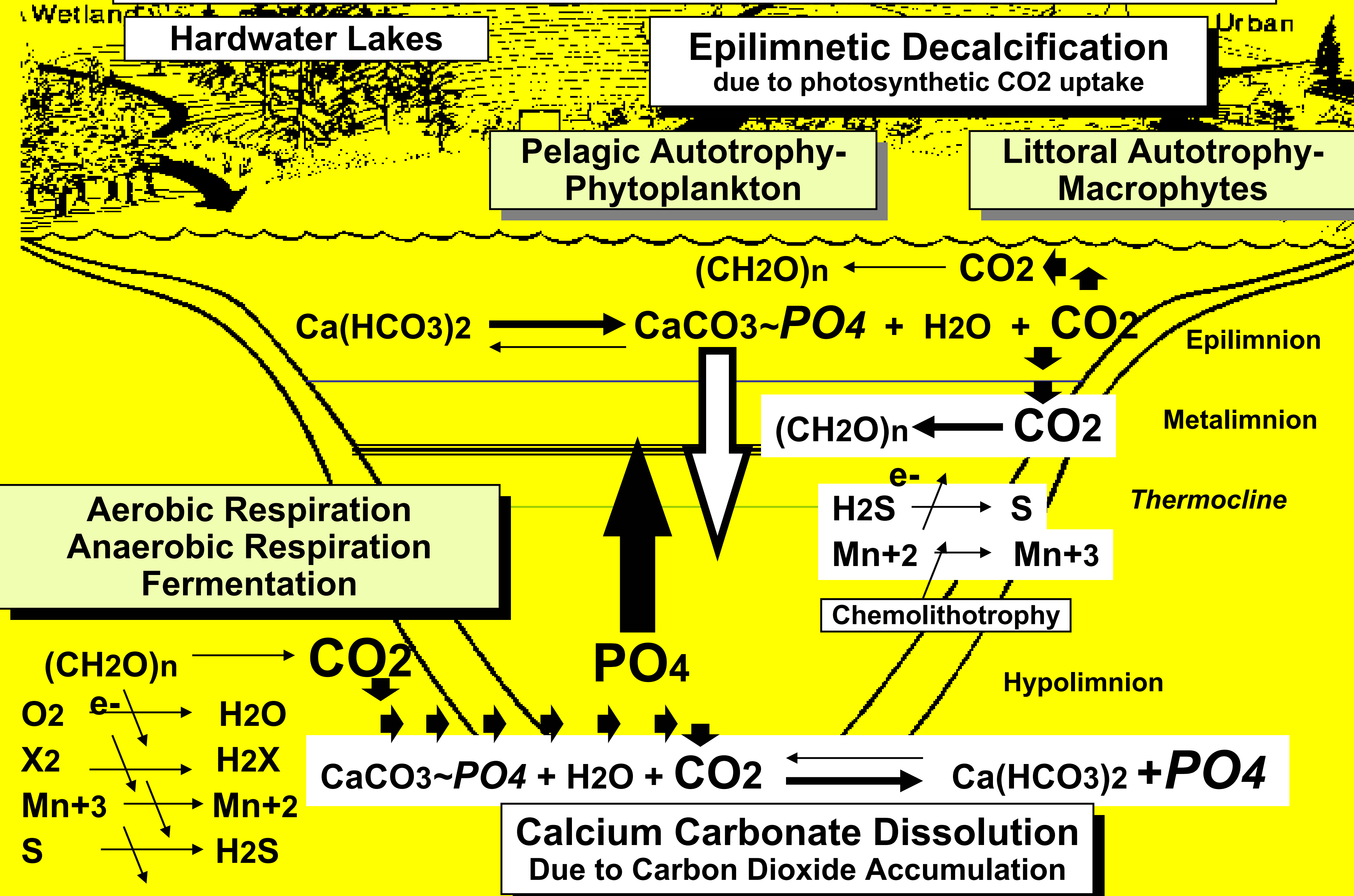
Robert Frost Hypolimnetic Treatment System

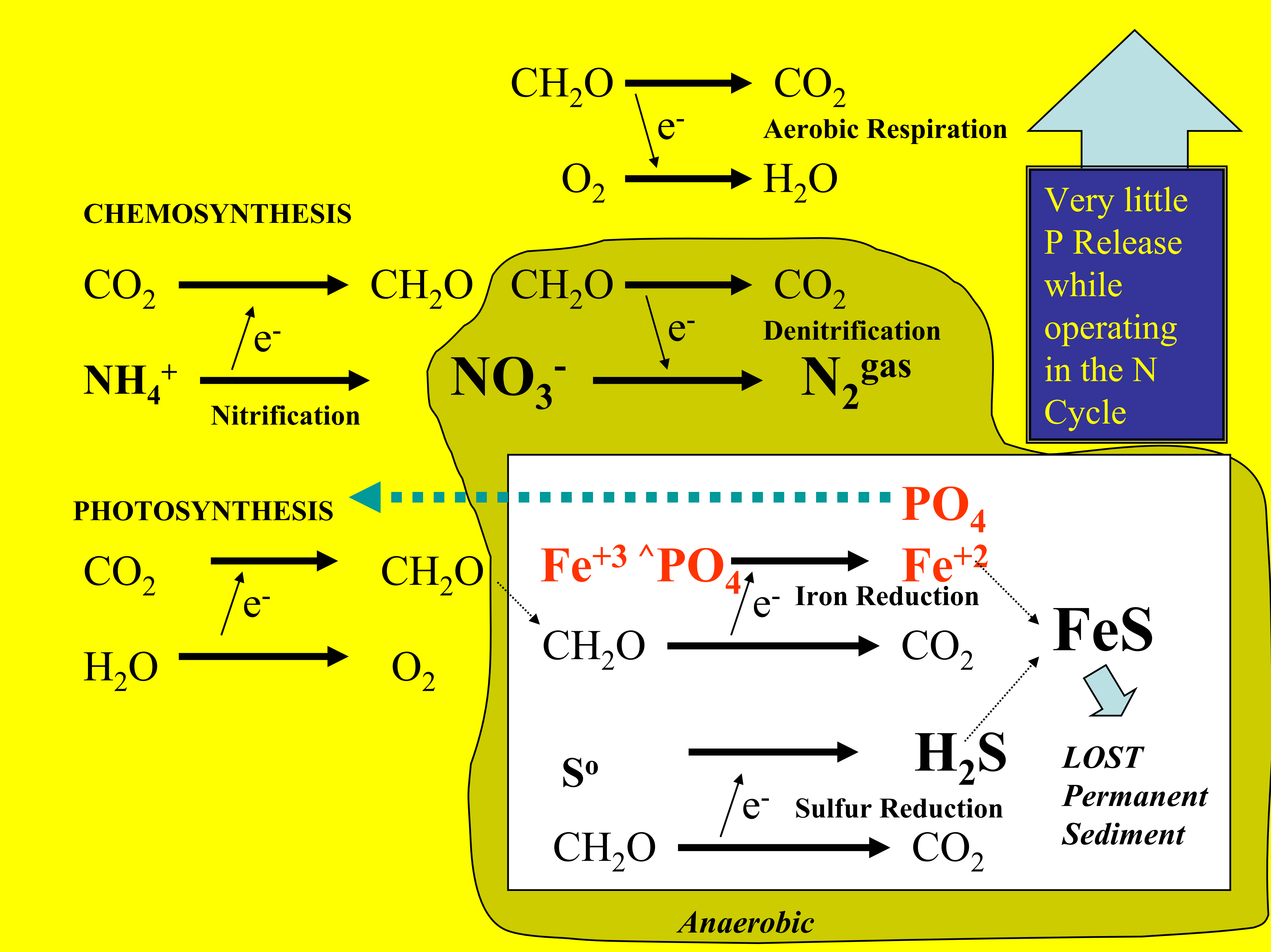
"Uses iron generated by the lake to remove P from the lake."

Layer Aeration System

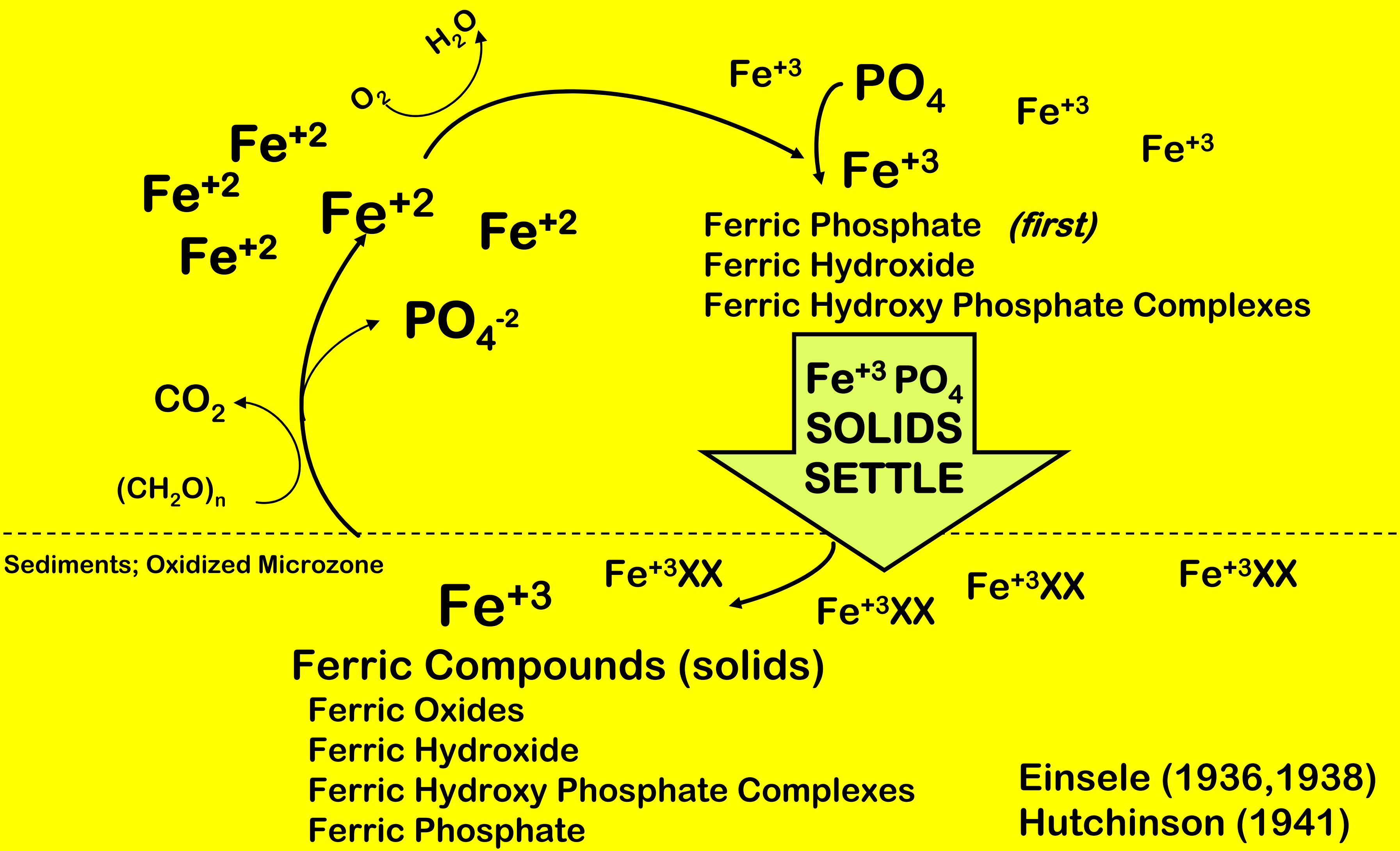
"Uses oxygen produced by plants and algae to aerate deeper waters."

Carbonate System P Dynamics



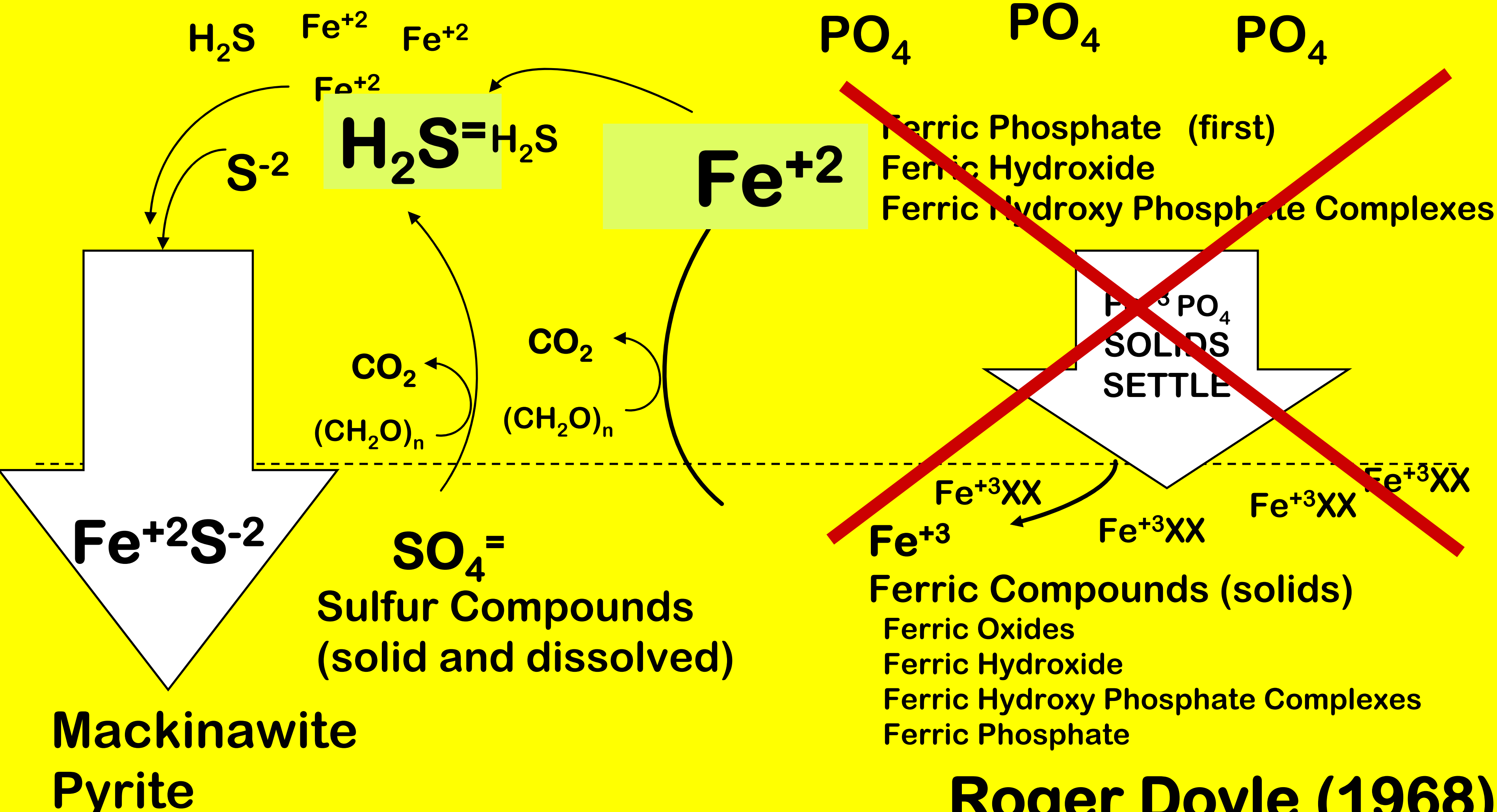

CH2O → CO2
e-
O2 → H2O
Aerobic Respiration
Very little P Release while operating in the N Cycle
CHEMOSYNTHESIS
CO2 → CH2O
e-
NH4+ → Nitrification
CH2O → CO2
e-
Denitrification
NO3- → N2 gas
PHOTOSYNTHESIS
CO2 → CH2O
e-
H2O → O2
PO4
Fe+3 ^PO4 → Fe+2
e- Iron Reduction
CH2O → CO2
FeS
LOST
Permanent
Sediment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

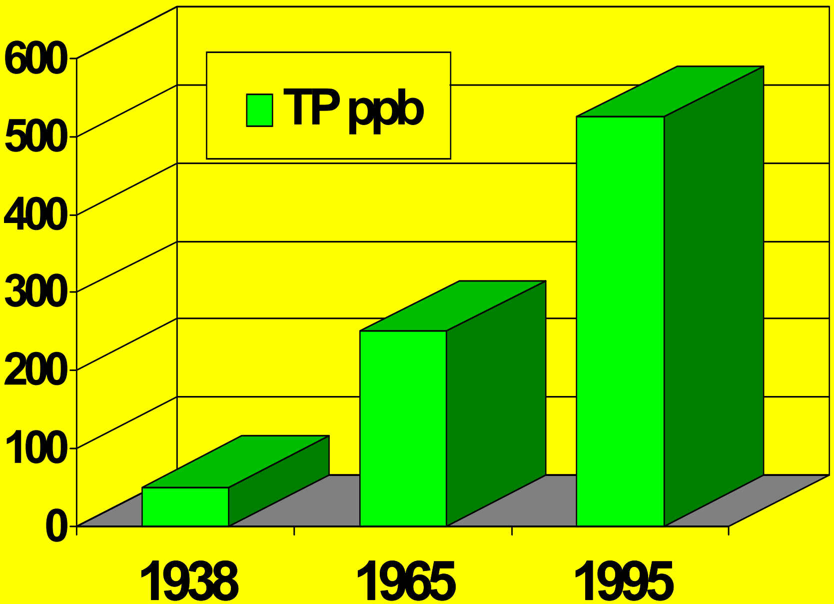
- *Iron no longer participates in anaerobic respiration (it is permanently deposited as ferrous sulfide).*
- *Iron no longer cycles between the sediments and the water column.*
- *Iron no longer removes phosphorus from the water column, (phosphorus is left behind in the water).*
- *More Hydrogen Sulfide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



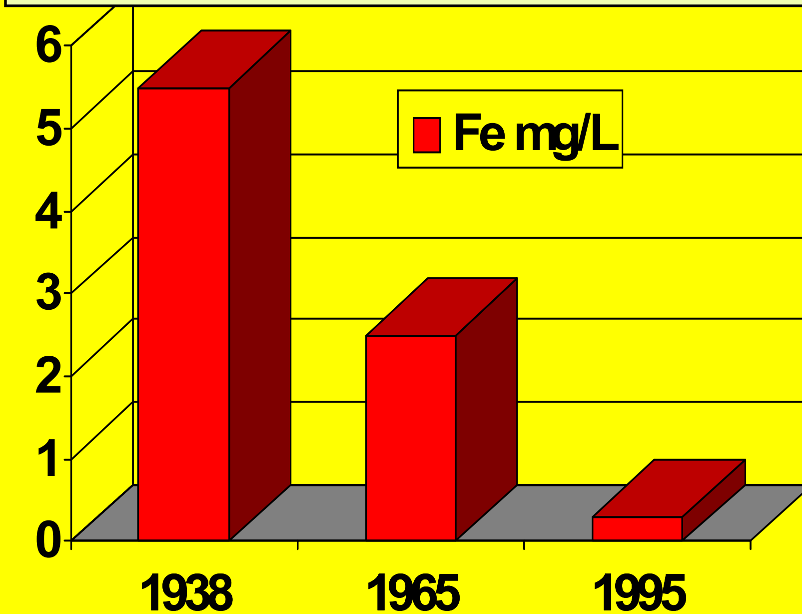
Roger Doyle (1968)

- *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



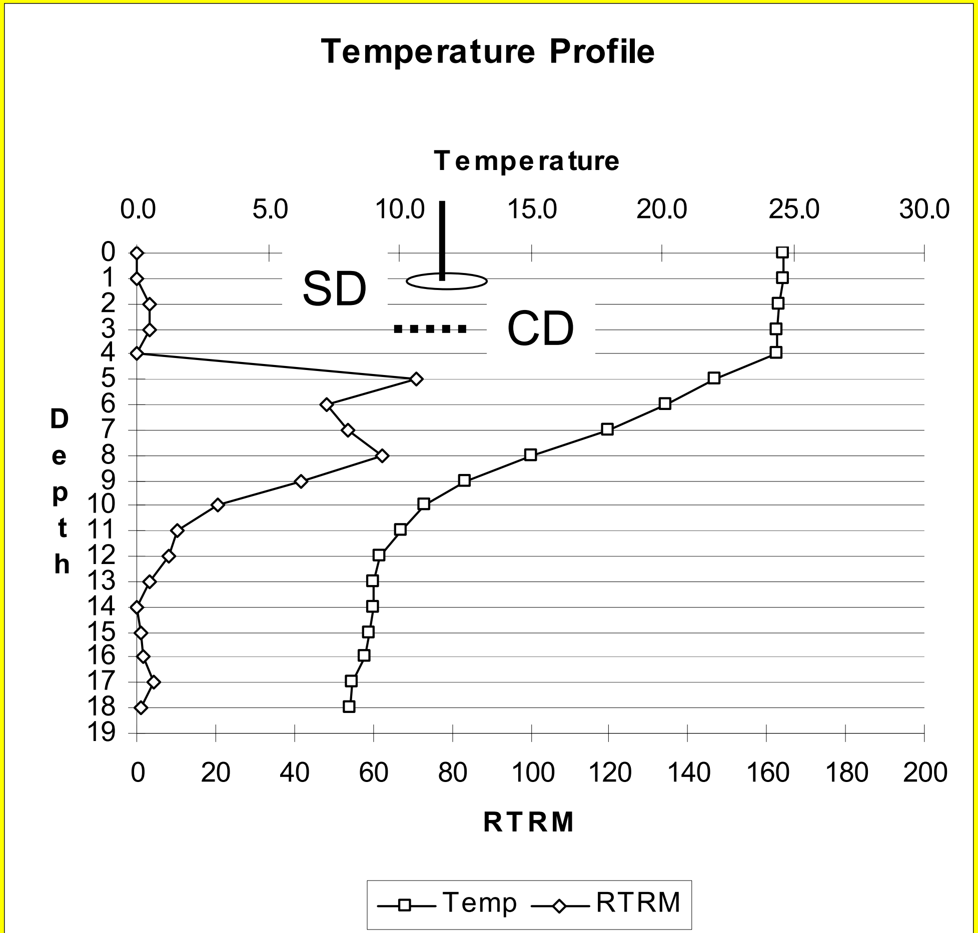
Sulfur Cycle Became Dominant

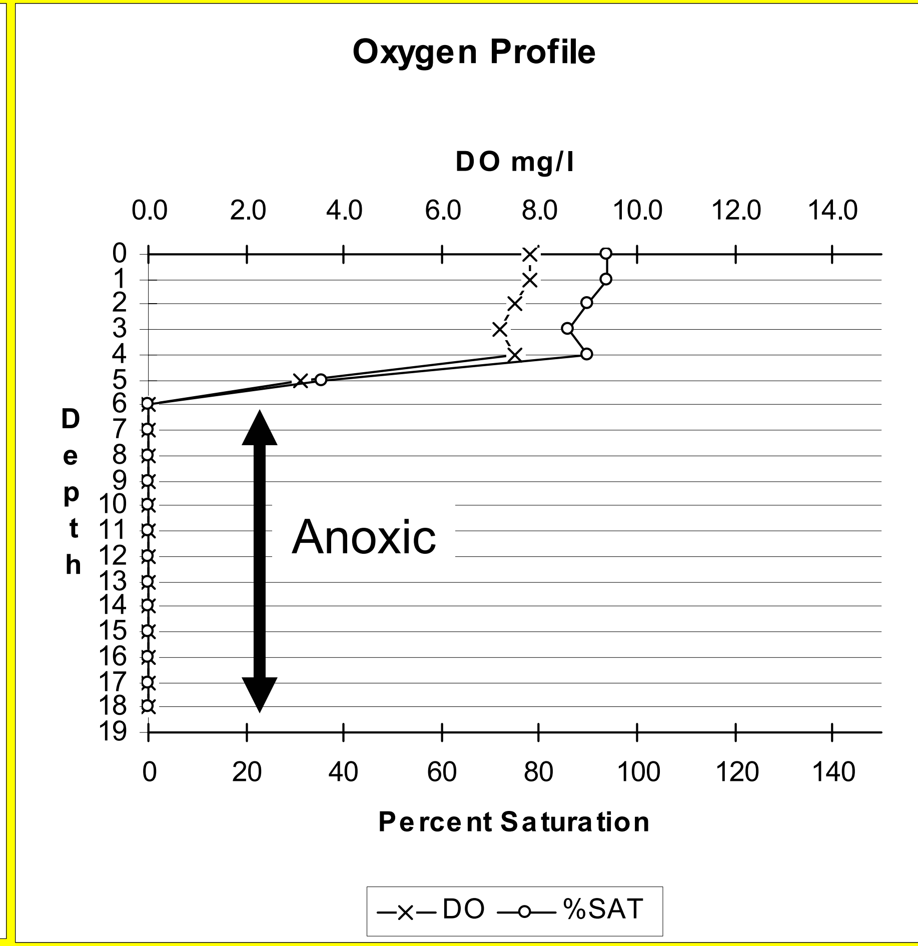


Increasing Eutrophication,
Increasing Organic Supply (Autoth. And Allochth.),
Increasing Carbonaceous Oxygen Demand
Increasing demand for ATEAs…more S= production which permanently removes Fe.

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

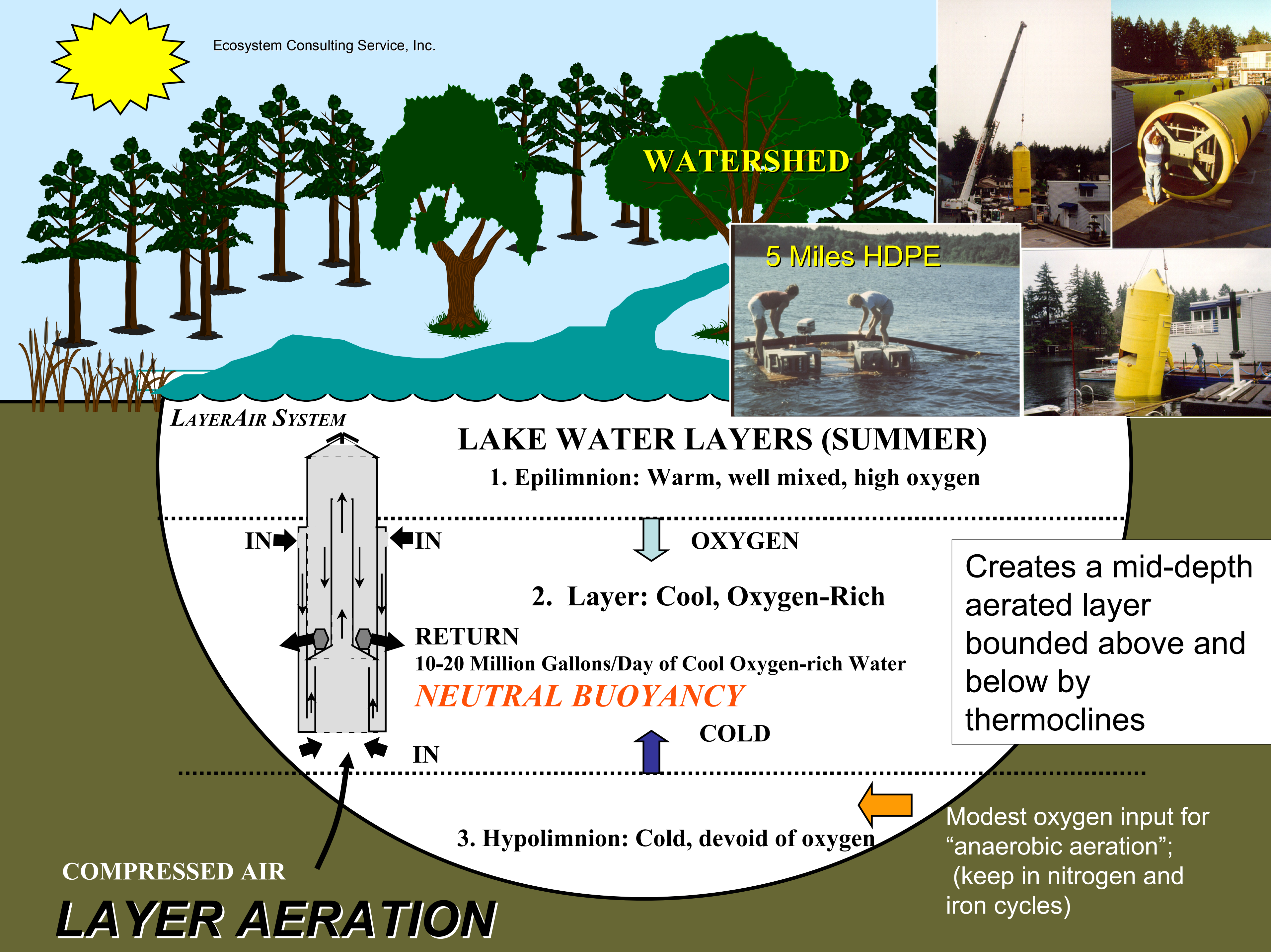
Loss of a "Functional Iron Cycle" is a *consequence of Eutrophication, and leads to more intense eutrophic conditions.*





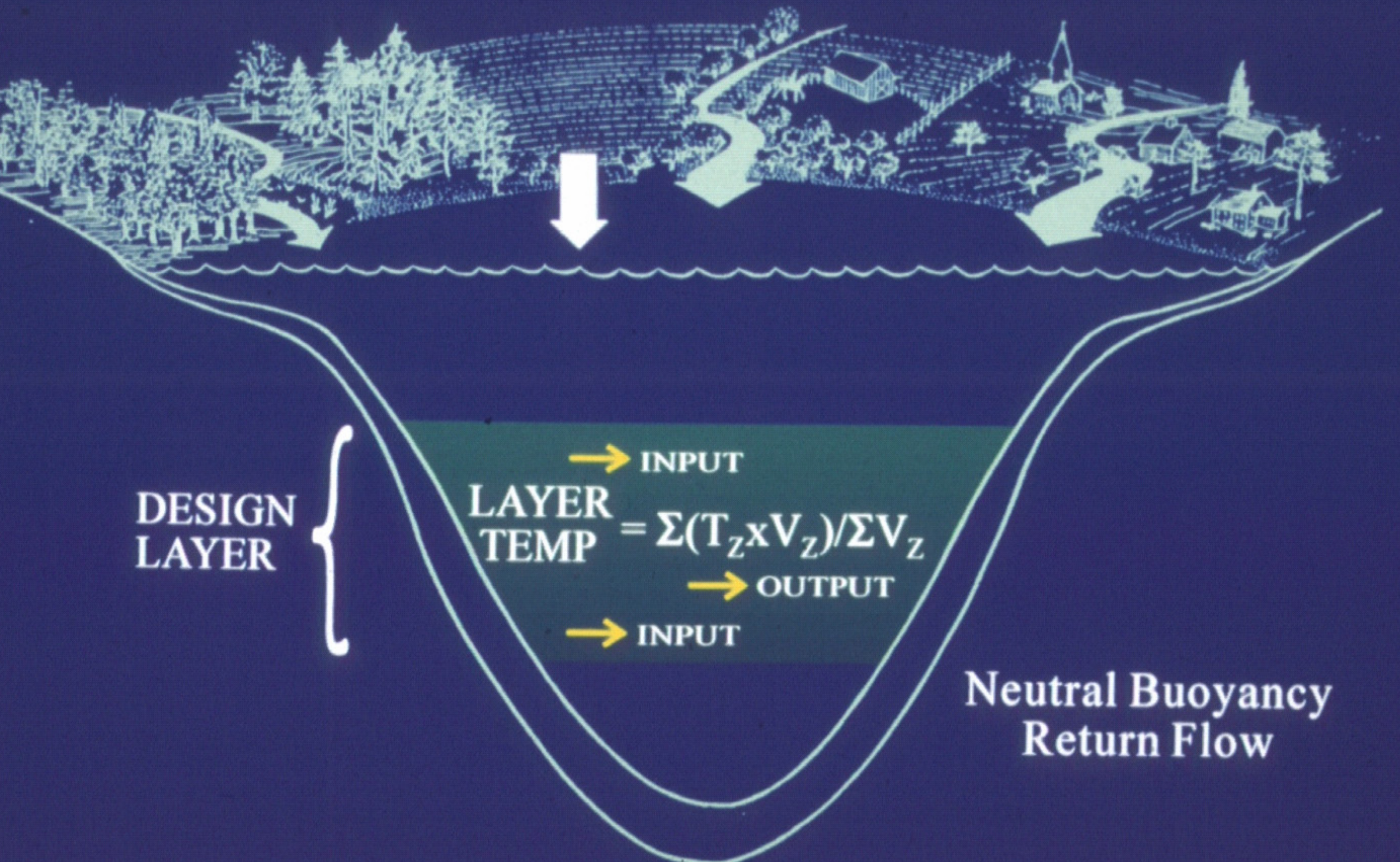
Lake Shenipsit 8/19/1985 (Before Multiple Layer Aeration)

SD= 1.5 m   RTRMsum= 333 RTRM Units



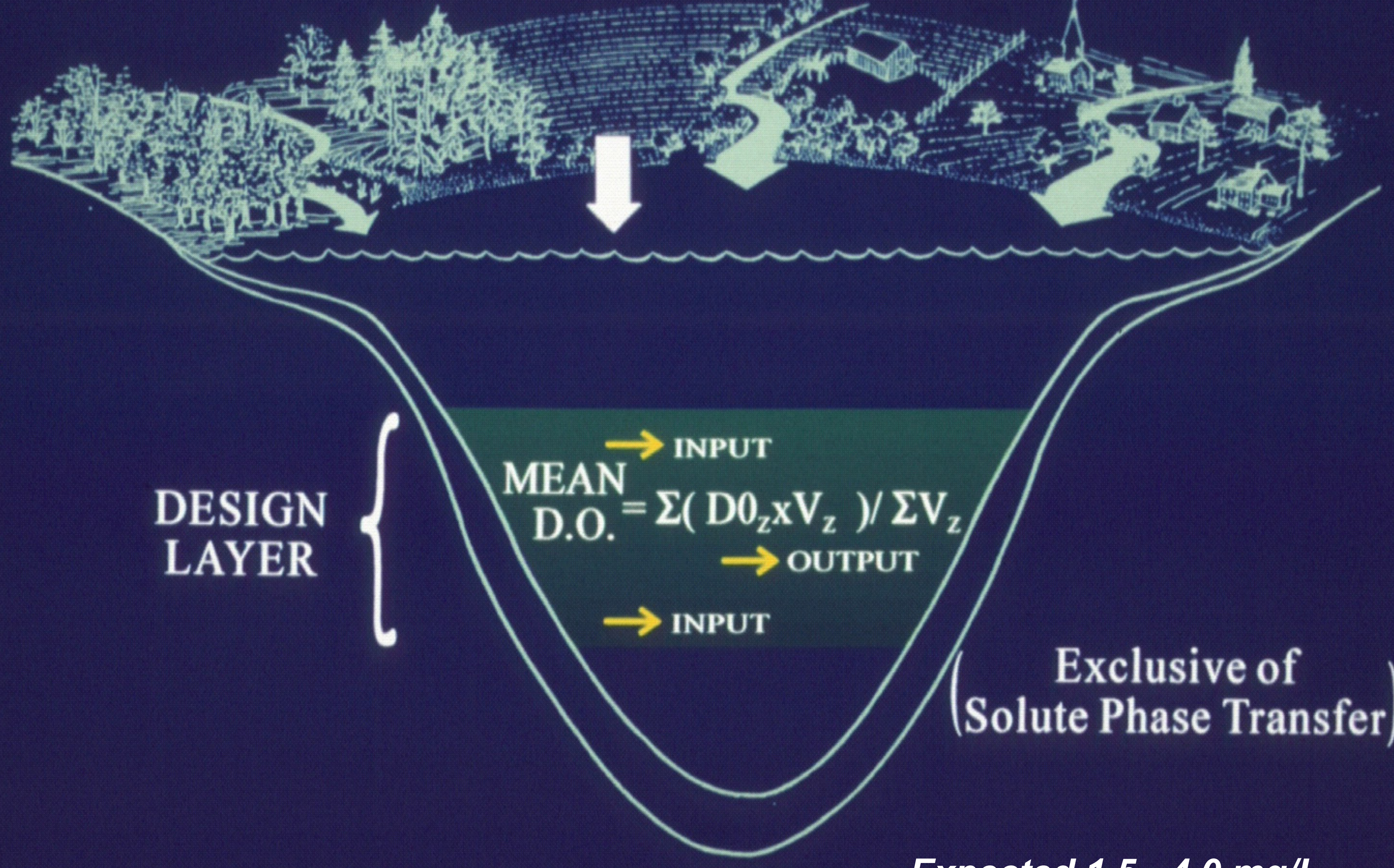
Ecosystem Consulting Service, Inc.
WATERSHED
5 Miles HDPE
LAYERAIR SYSTEM
LAKE WATER LAYERS (SUMMER)
1. Epilimnion: Warm, well mixed, high oxygen
IN
IN
OXYGEN
2. Layer: Cool, Oxygen-Rich
RETURN
10-20 Million Gallons/Day of Cool Oxygen-rich Water
NEUTRAL BUOYANCY
COLD
IN
3. Hypolimnion: Cold, devoid of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

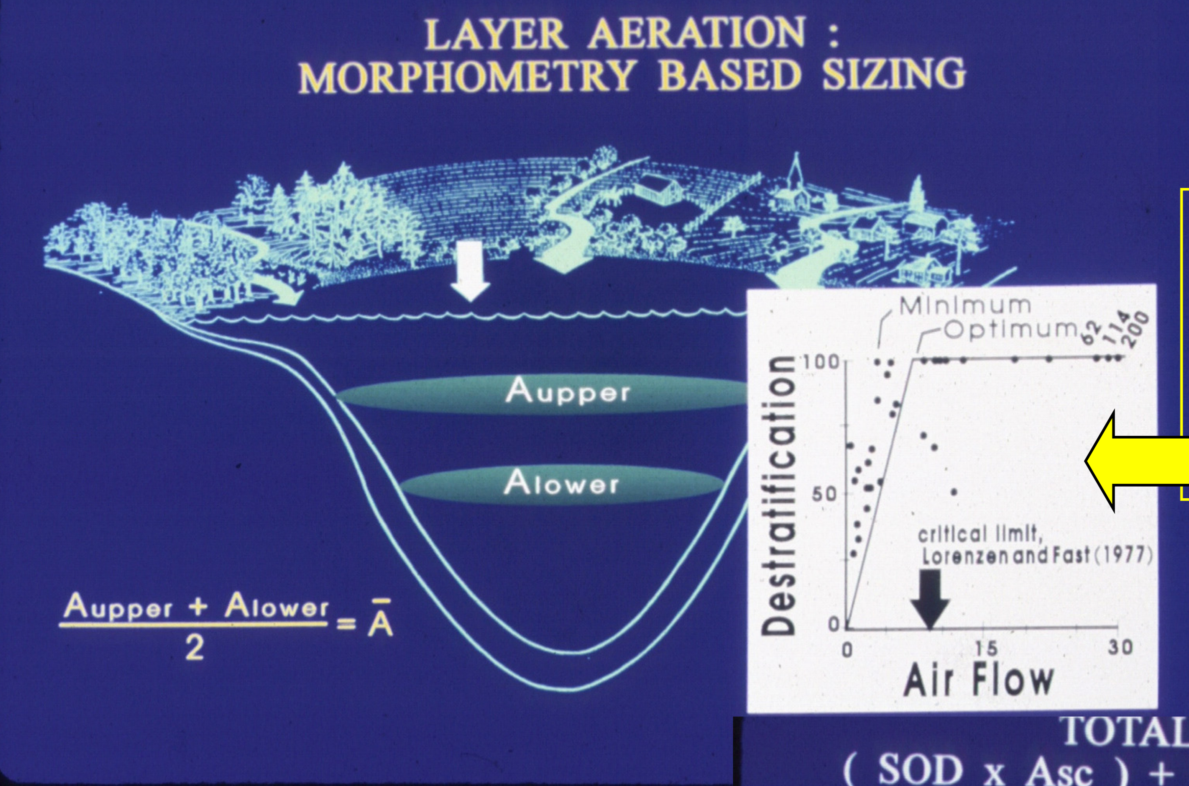
MEAN LAYER TEMPERATURE



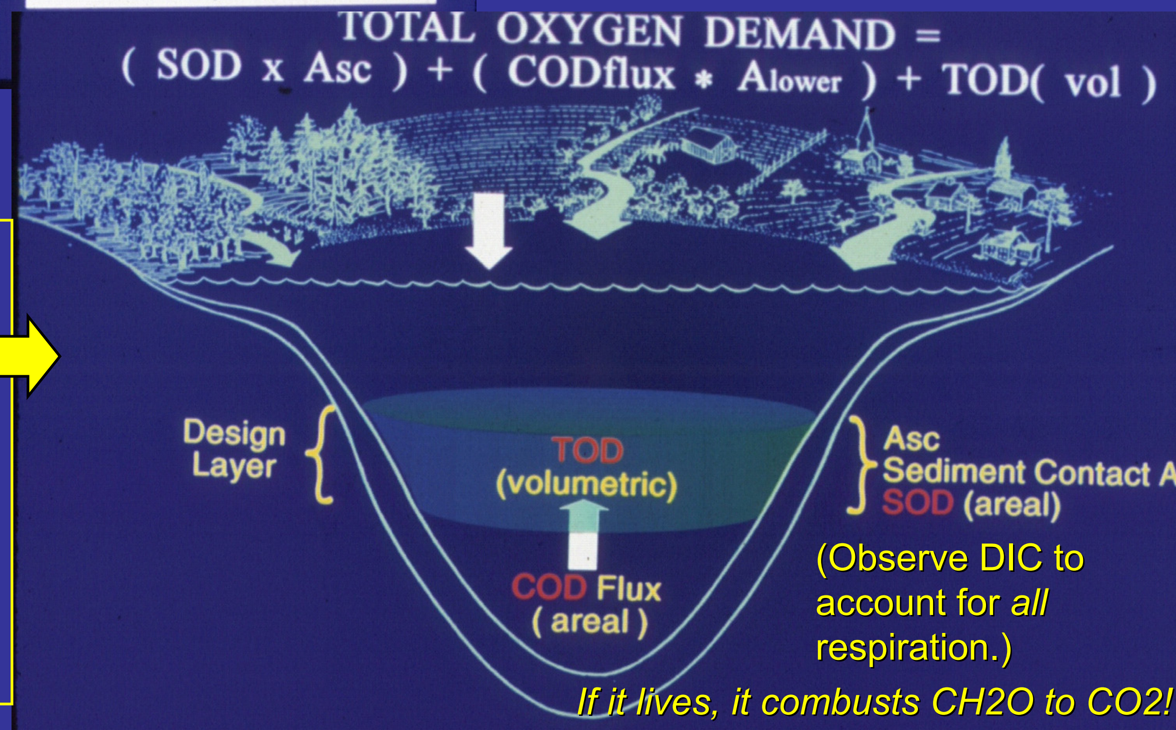
Expected 12-14°C

MEAN LAYER DISSOLVED OXYGEN





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

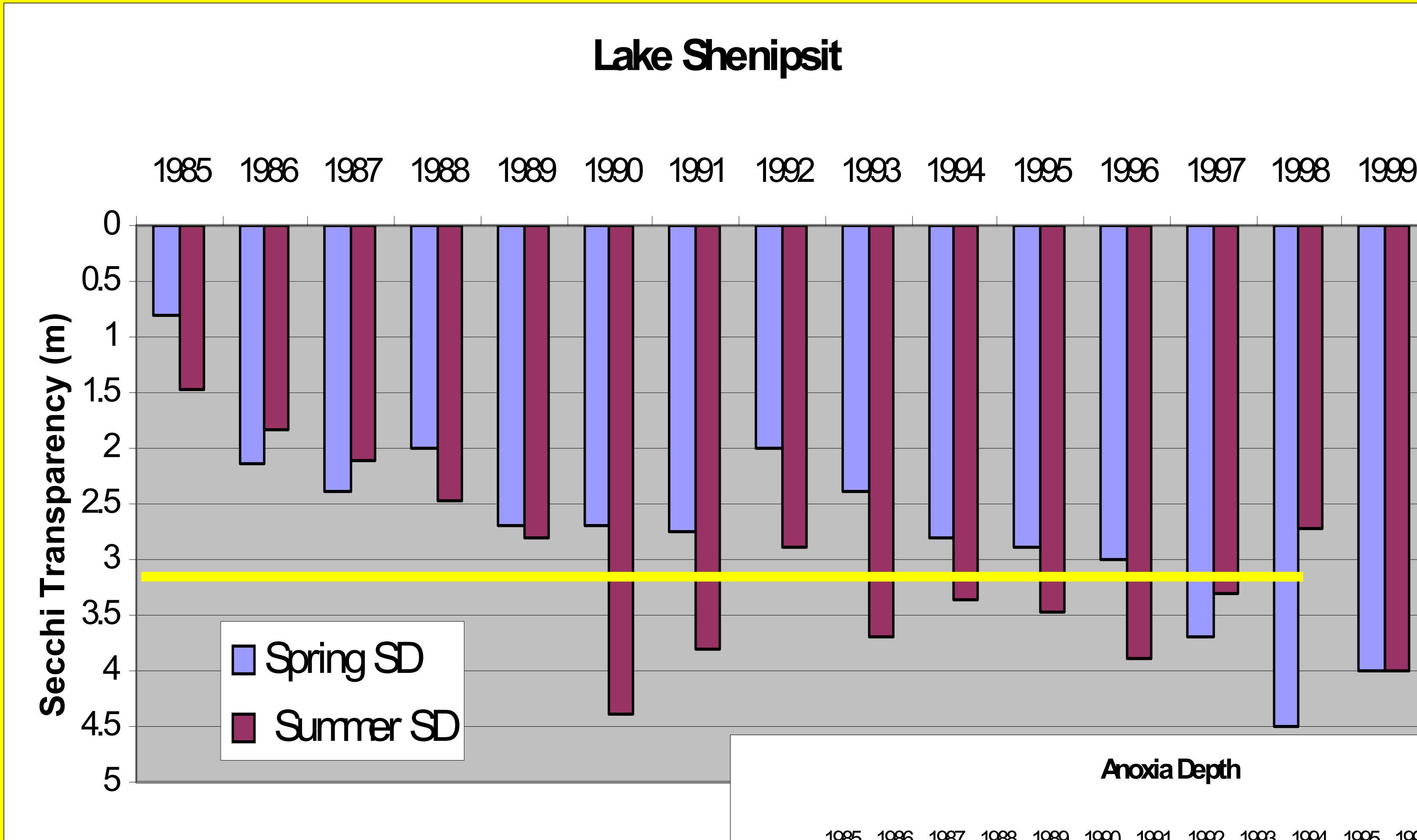


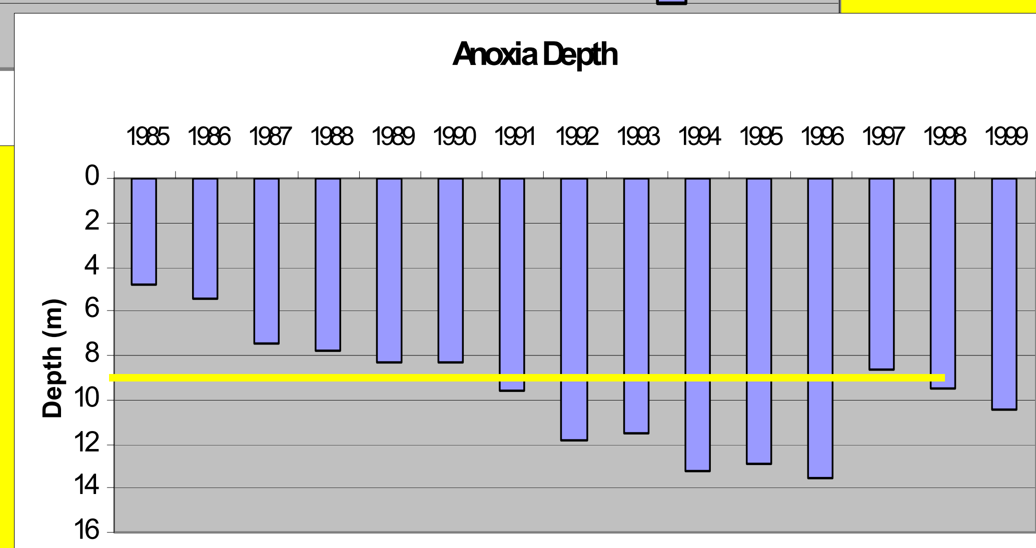
(Observe DIC to account for *all* respiration.)

If it lives, it combusts CH2O to CO2!

How much more DO needs to enter solute phase?

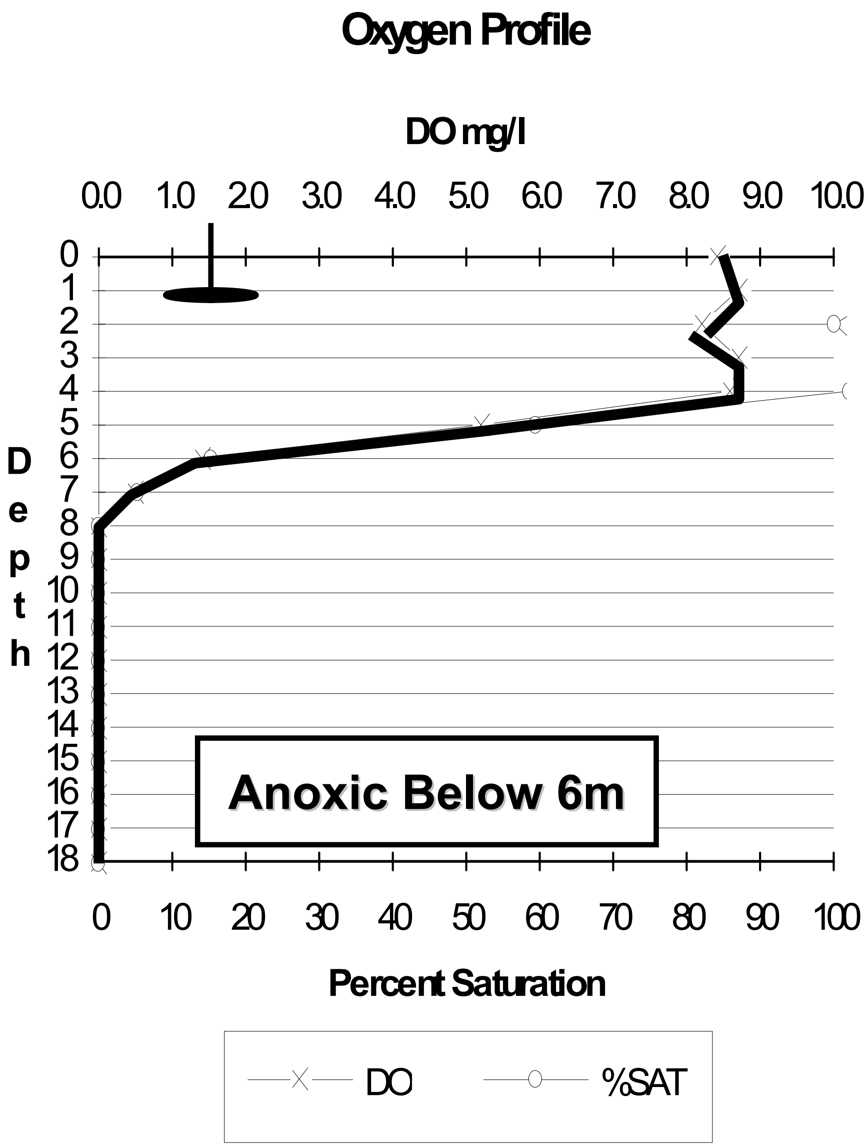
Volumetric Oxygen Demand
Sediment Oxygen Demand
COD Flux Rates
Nitrogenous Oxygen Demand


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

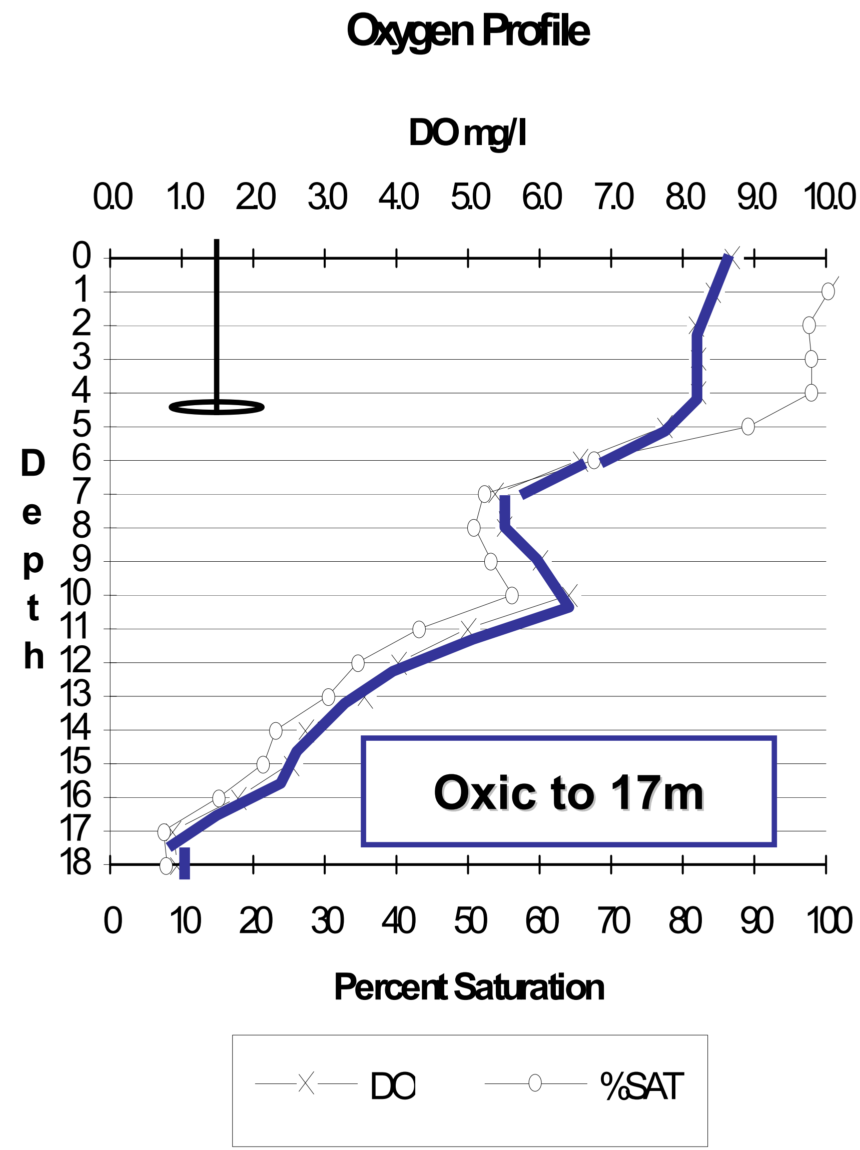

Anoxia Depth
Depth (m)
0
2
4
6
8
10
12
14
16
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

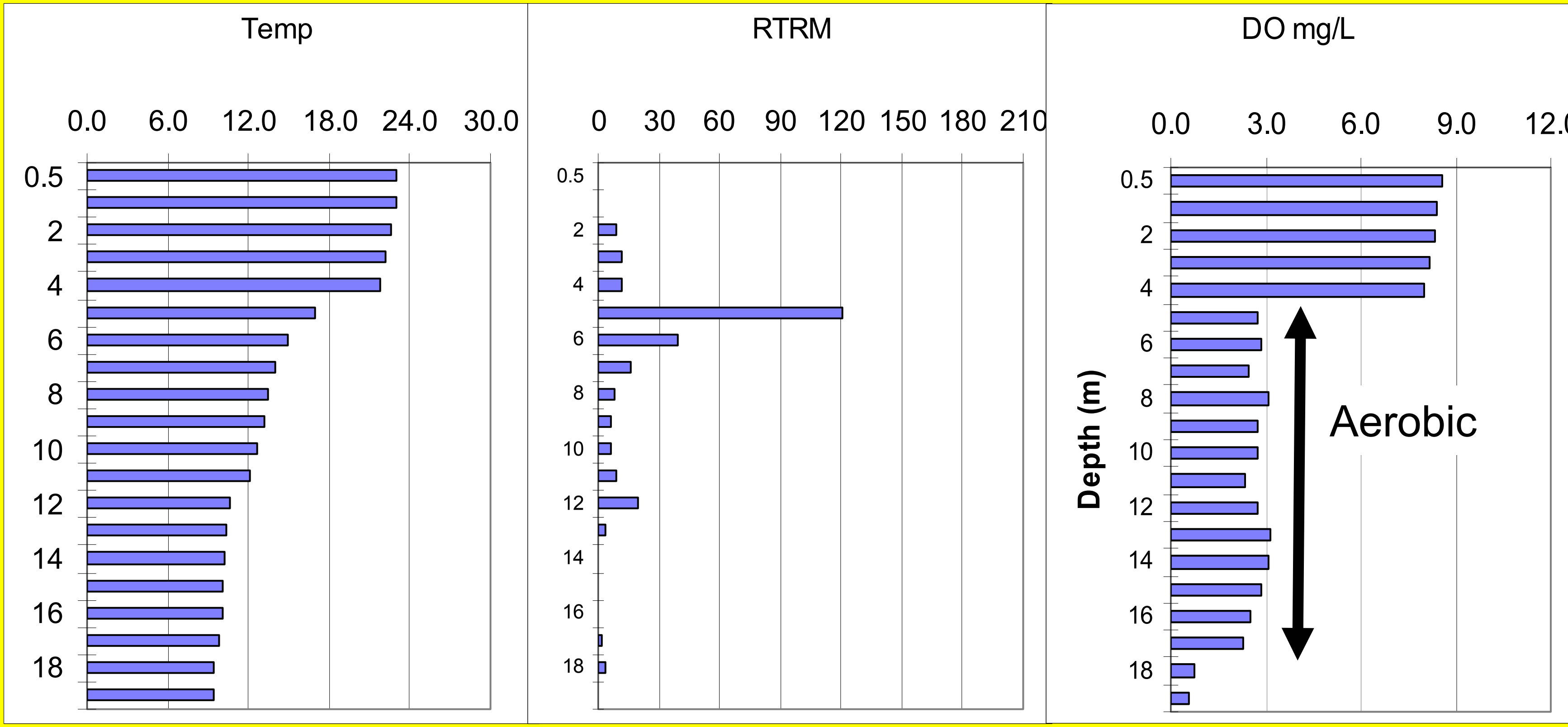
Layer / Hypolimnetic Aeration – Effect of Dissolved Oxygen Distribution

July 22,1985 **Secchi= 1.3m**

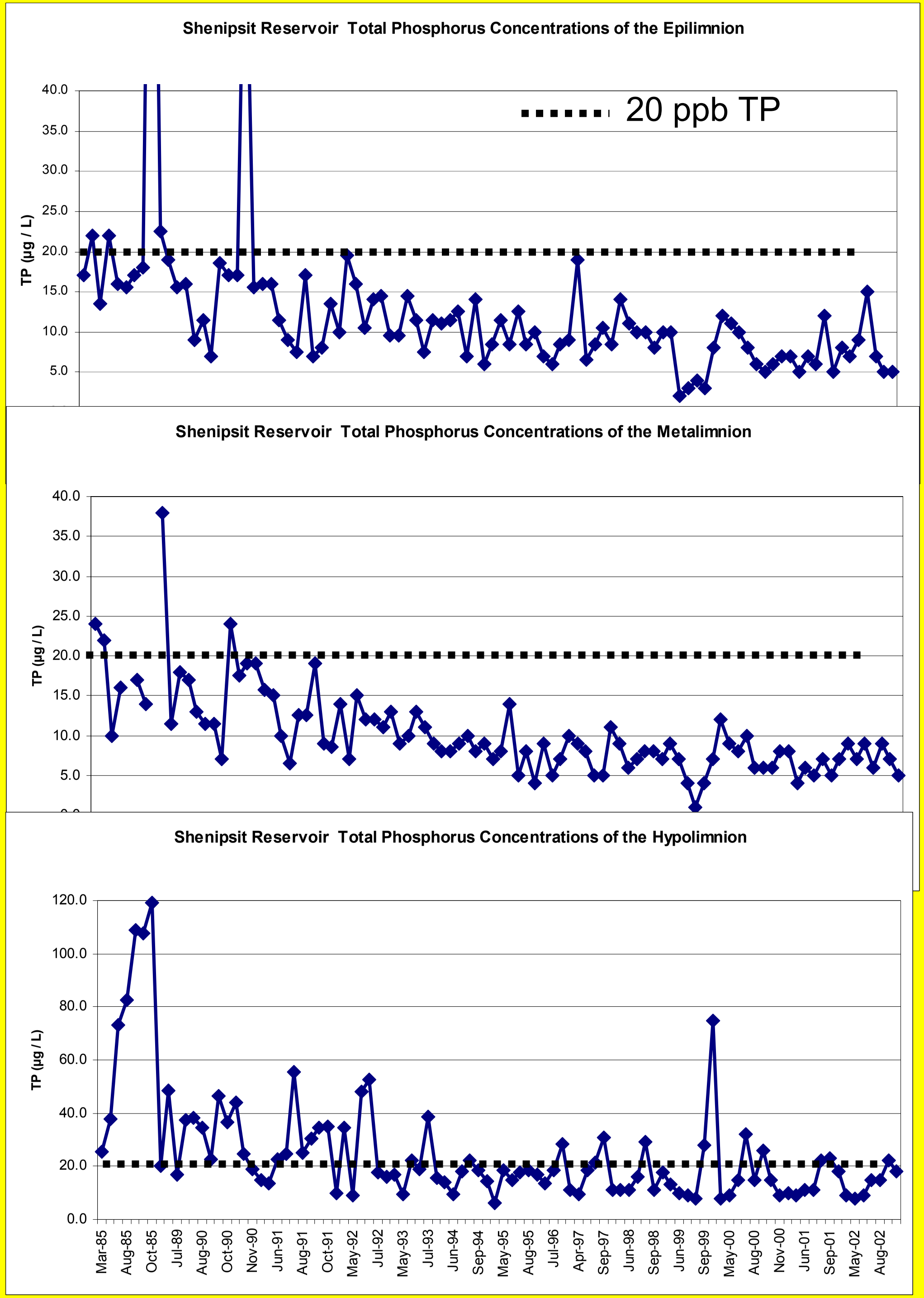


July 22,1993 **Secchi= 4.0m**





Lake Shenipsit 2000 (During Multiple Layer Aeration)



TP Epilimnion

TP Metalimnion
(Aerated Layer)

1985

2002

TP Hypolimnion
(“Anaerobic Aeration”)

Lake Shenipsit: Additional Effects on Ecosystem Structure and Function:

- ***3000+ 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***

ECOSYSTEM
Consulting Service, Inc.

BTMUA Reservoir
Aeration Management System

BTMUA Reservoir (1988)

Supply Intakes

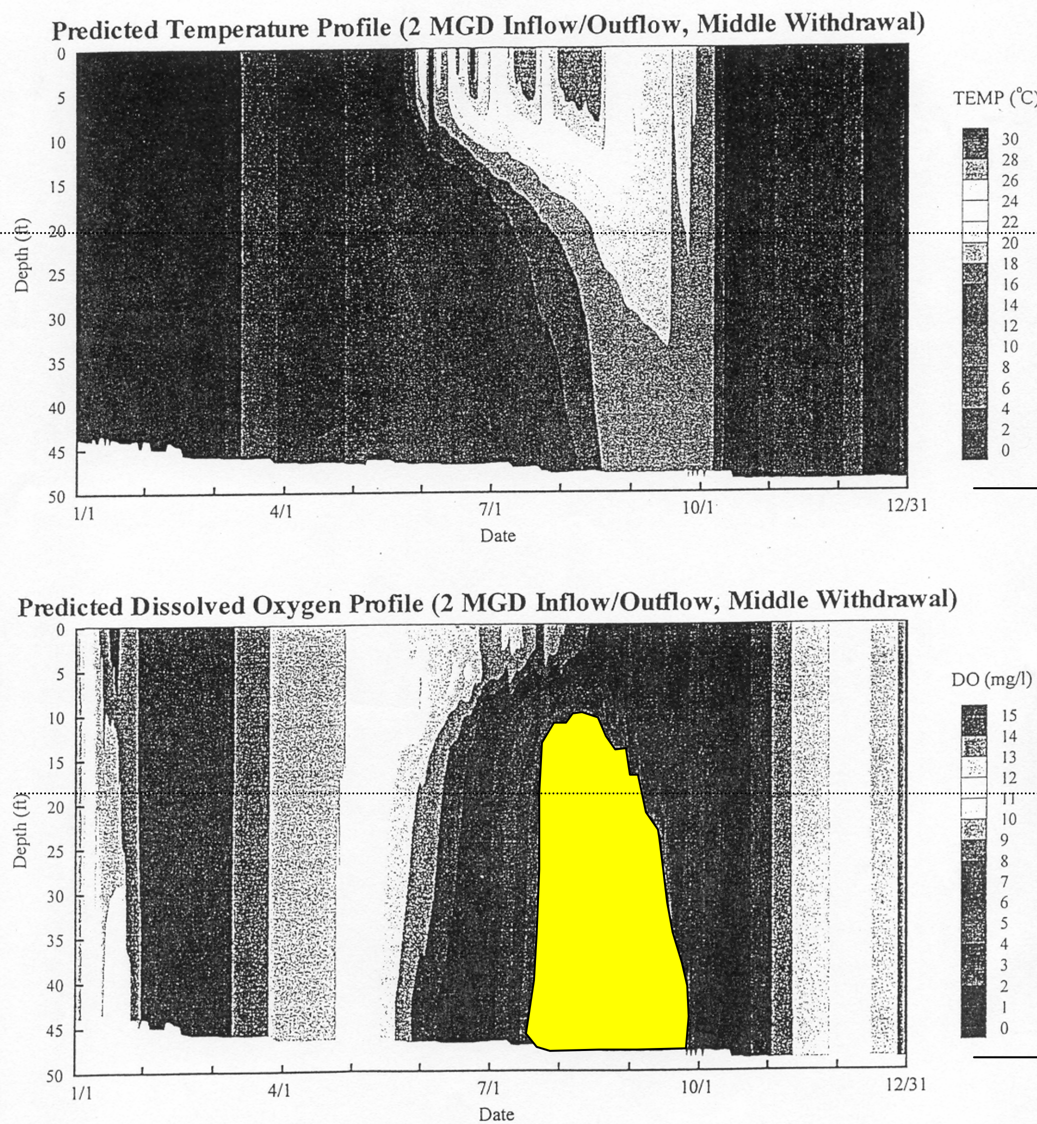
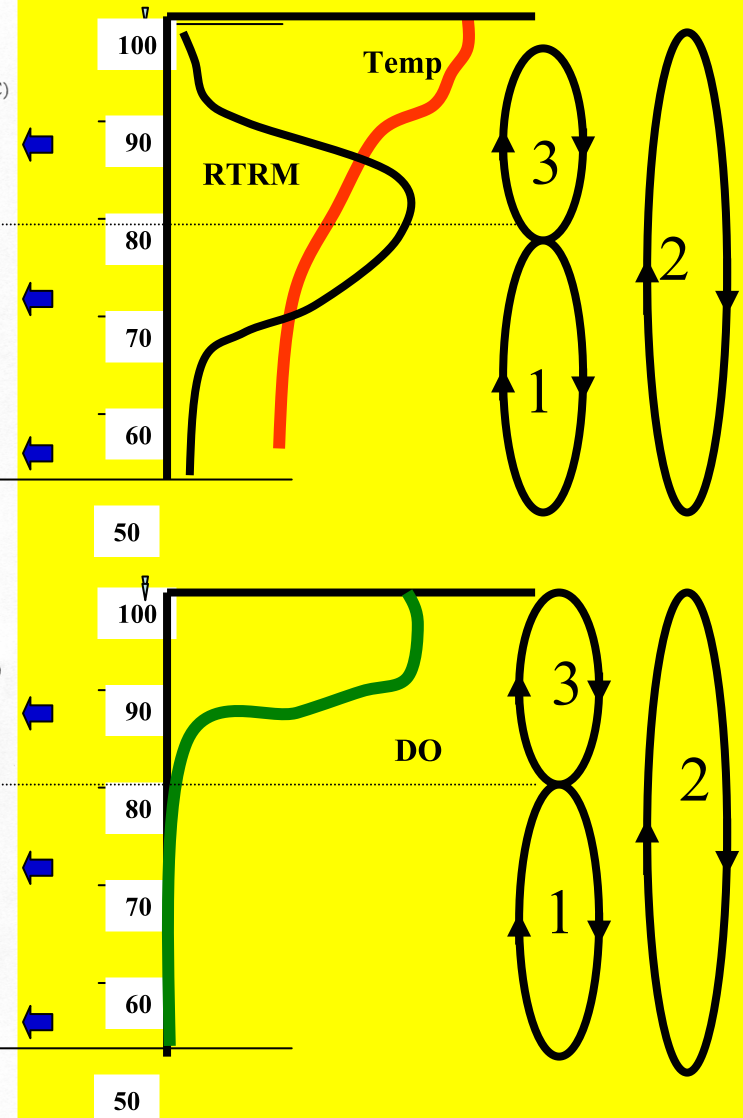
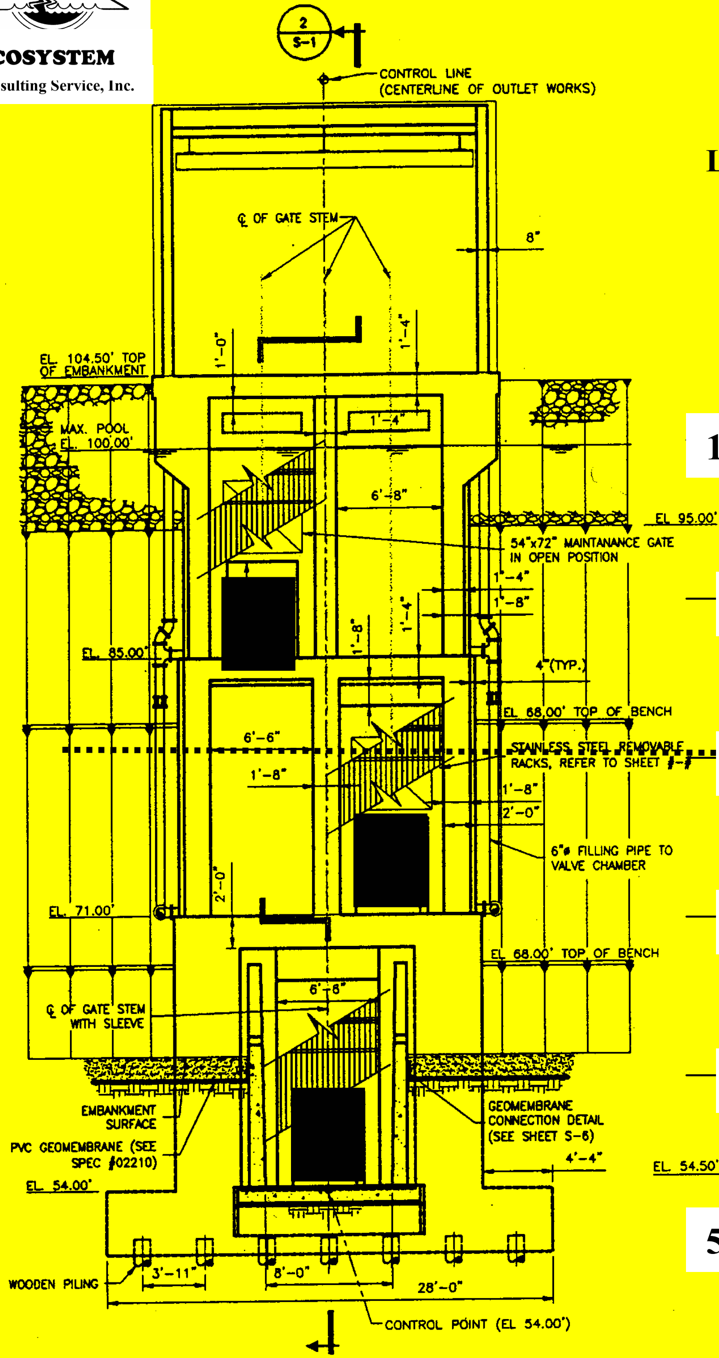


Figure 12



ECOSYSTEM
Consulting Service, Inc.

Process Schematic – BTMUA Storage Reservoir Management / Treatment System

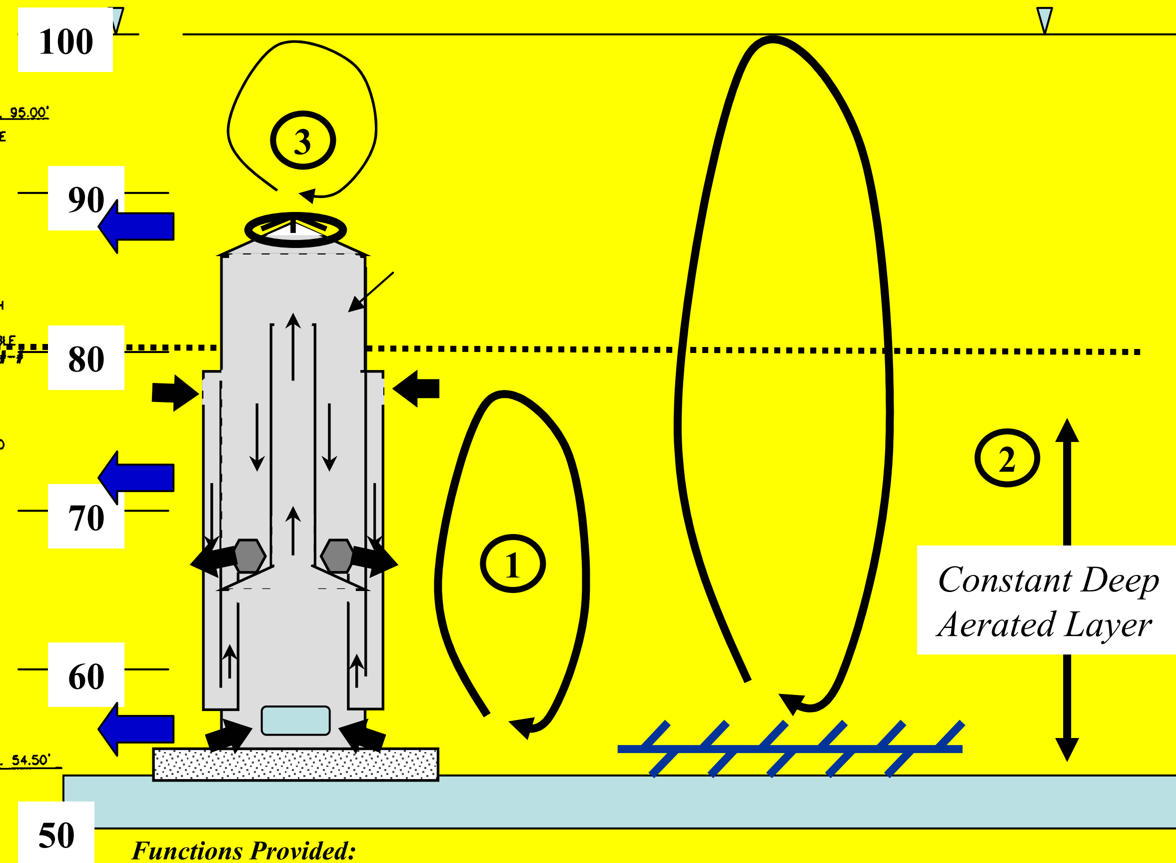


Layer Aeration (Partial Lift)

Add a ChemFeed
Manifold to the
diffused vent release

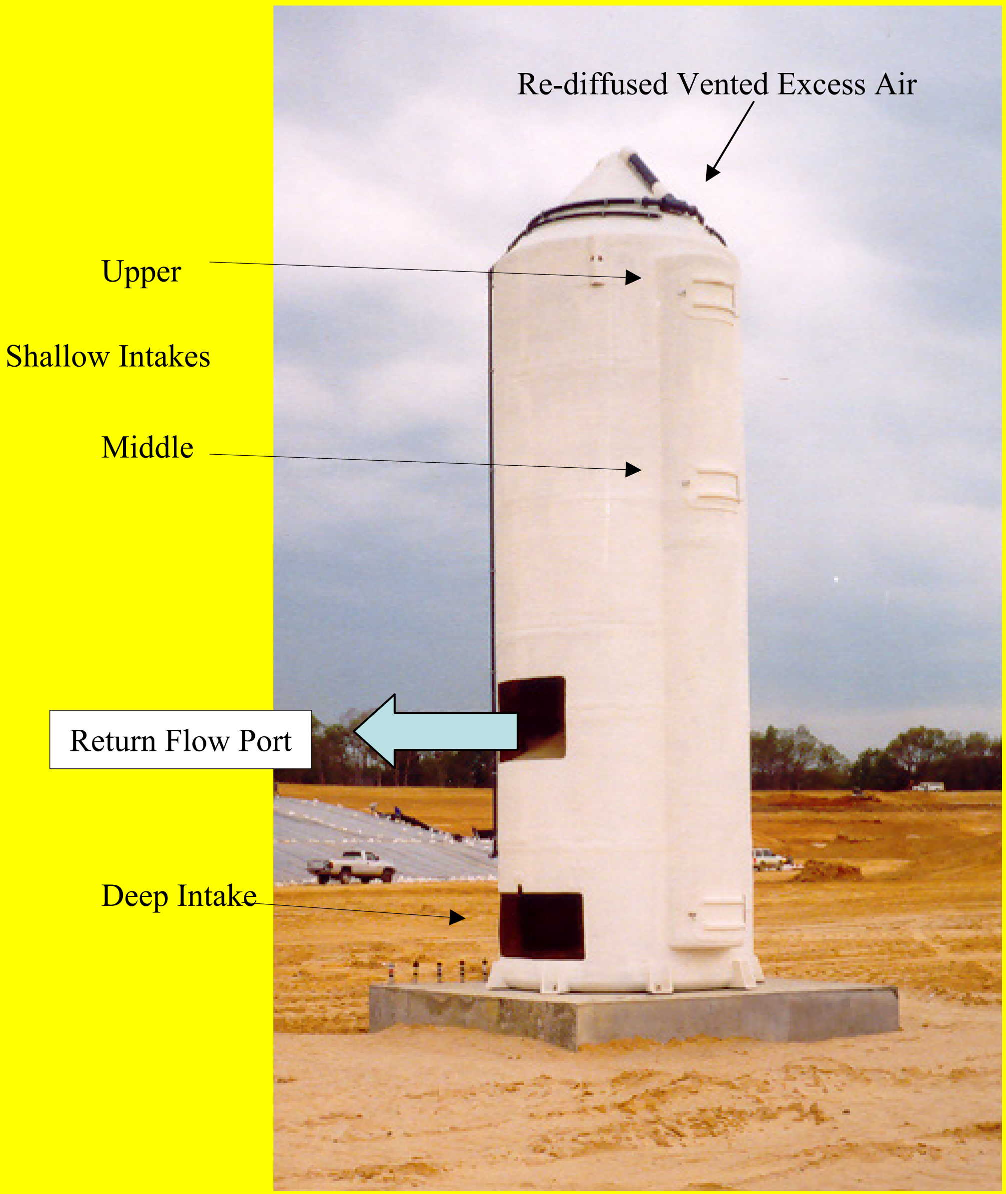
Artificial Circulation

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

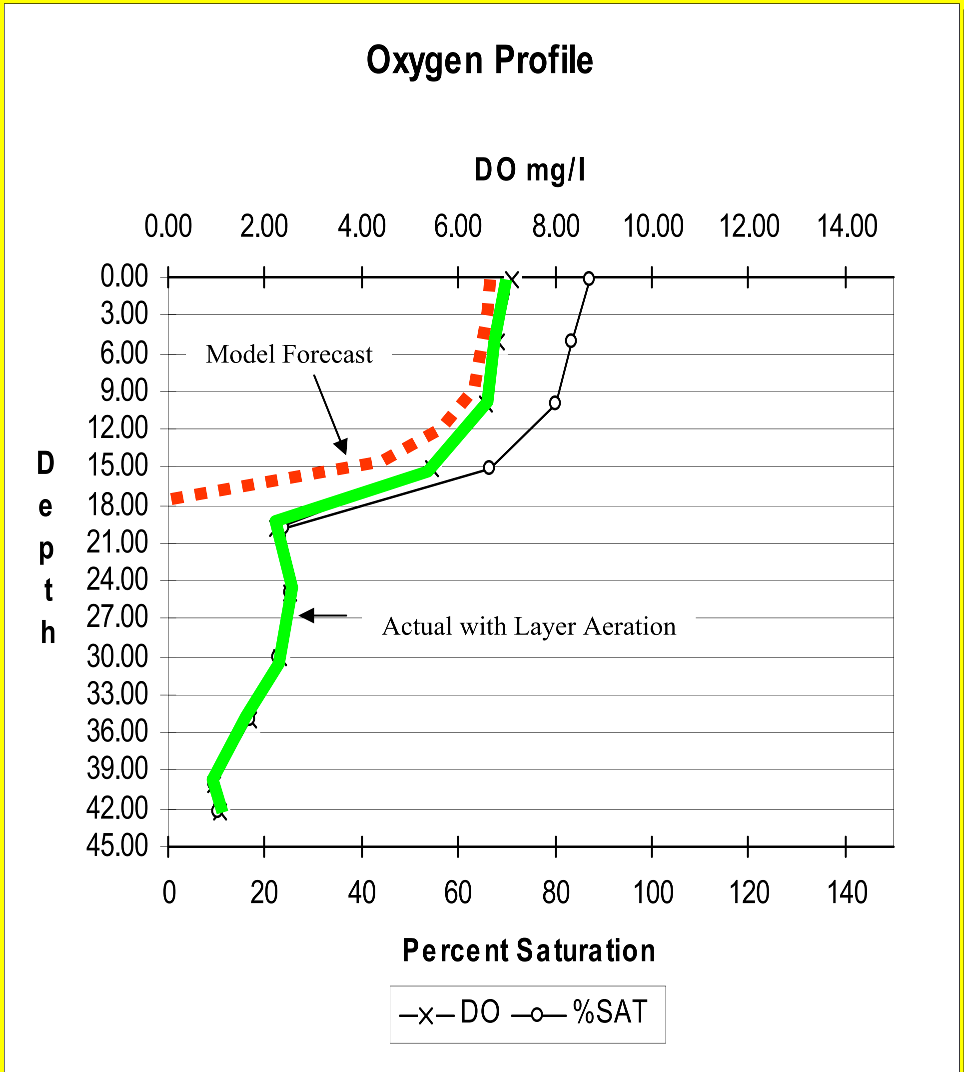
Three shallow intakes are available to establish the thickness of the aerated layer. The deep intake is always used. The initial set-up has the upper shallow intake port open (other two are closed). As lake data is collected, the upper intake could be closed and the middle intake opened which will focus 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.

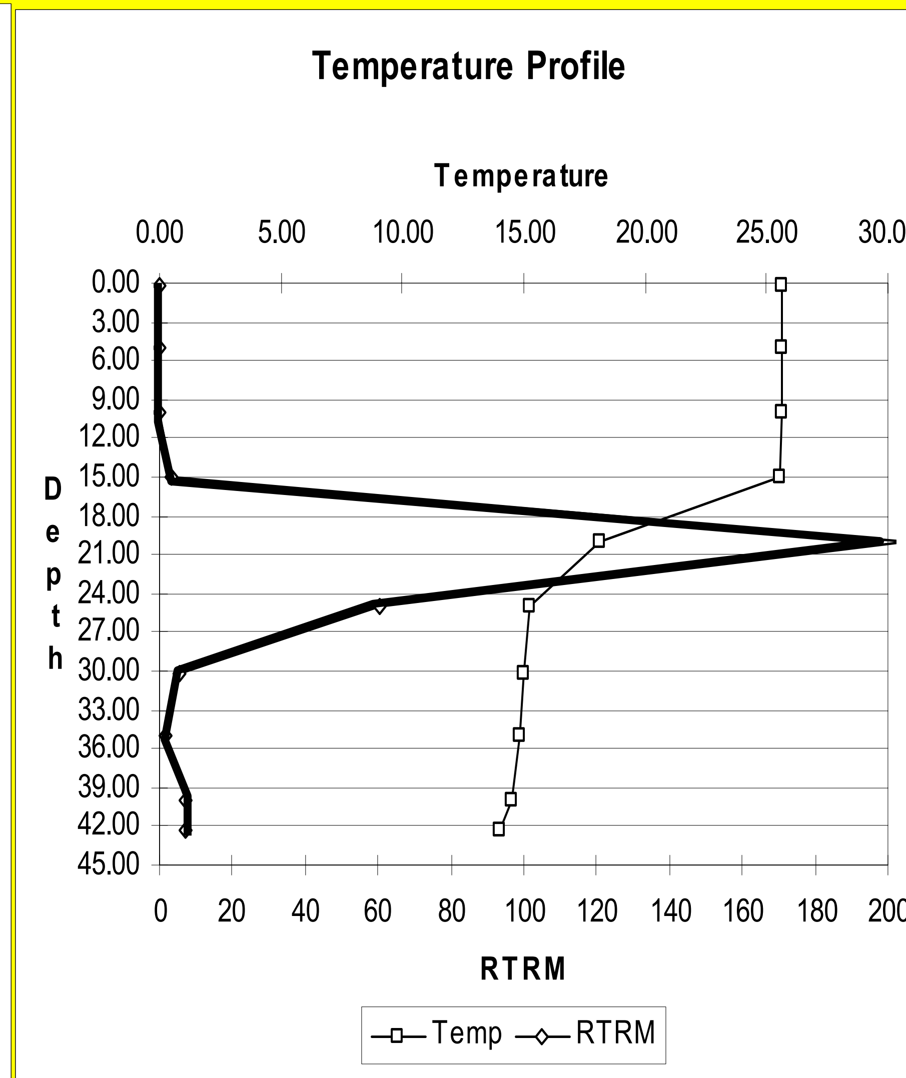
Chemical Feed Options

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.

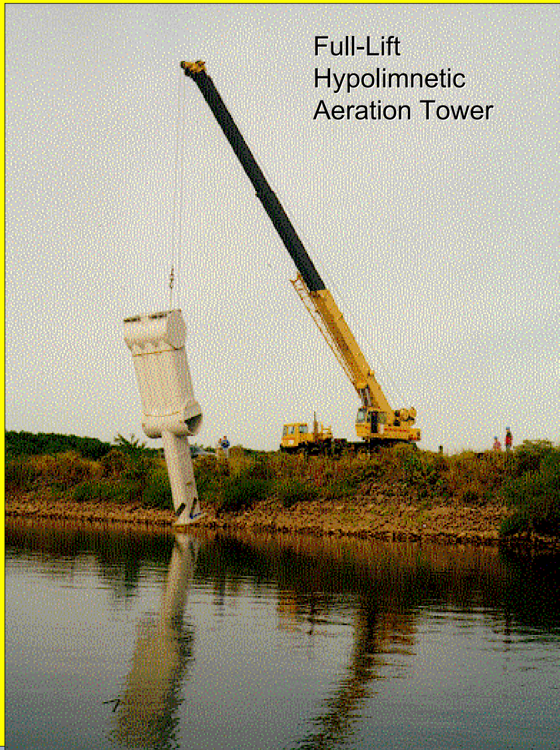
BTMUA Reservoir R-8 8/6/2004



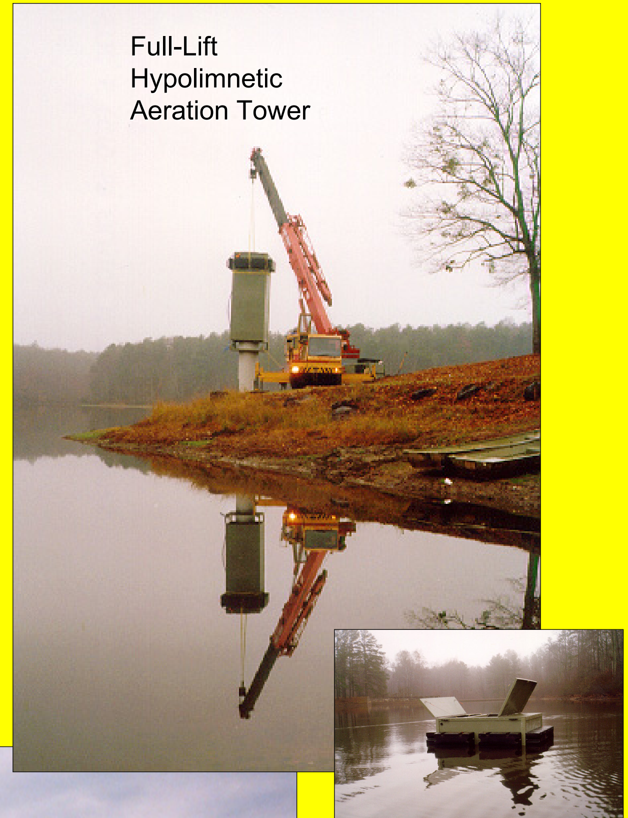


Remained Aerobic; would have been anoxic below 21 ft without aeration.

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



Full-Lift
Hypolimnetic
Aeration Tower

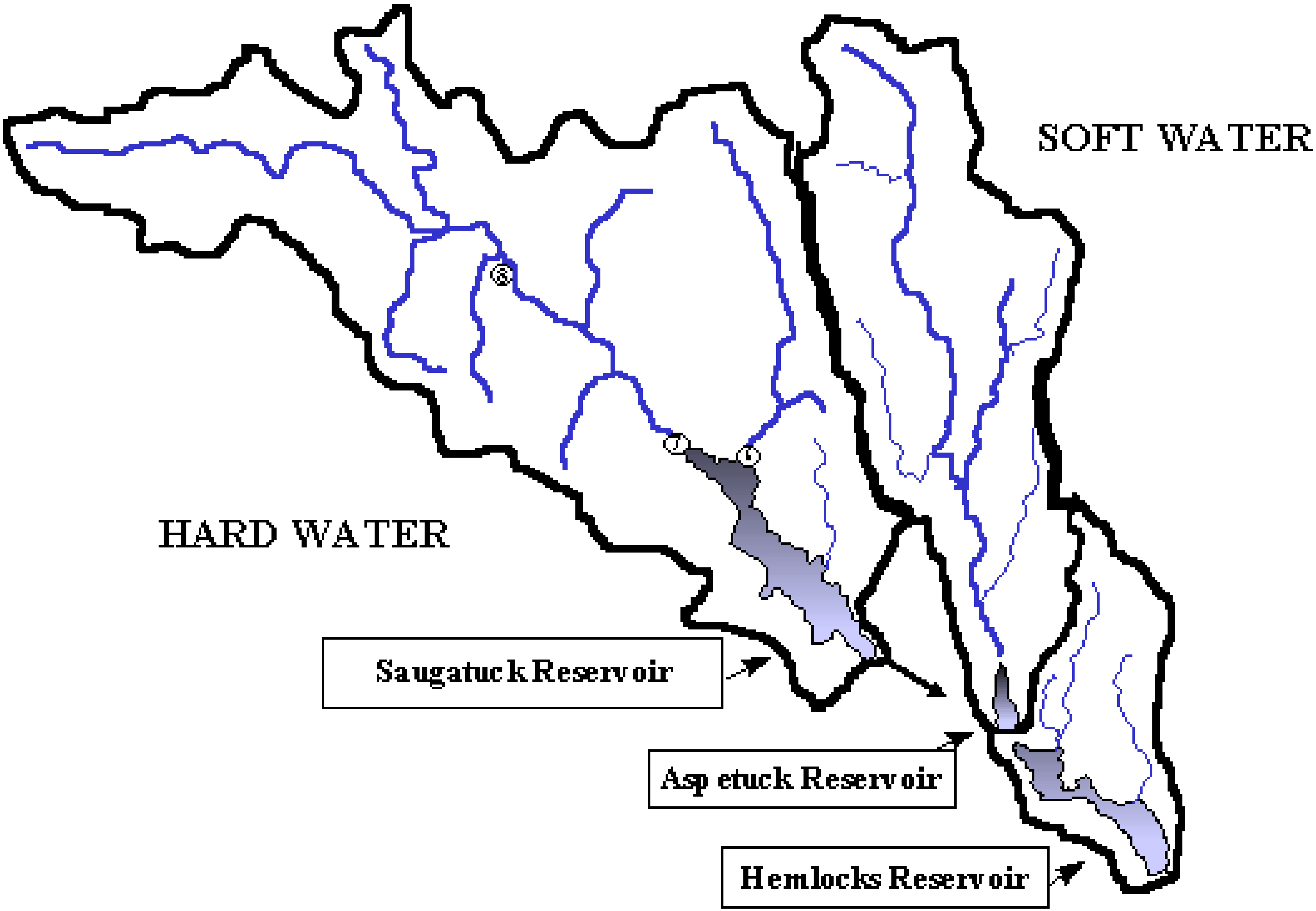


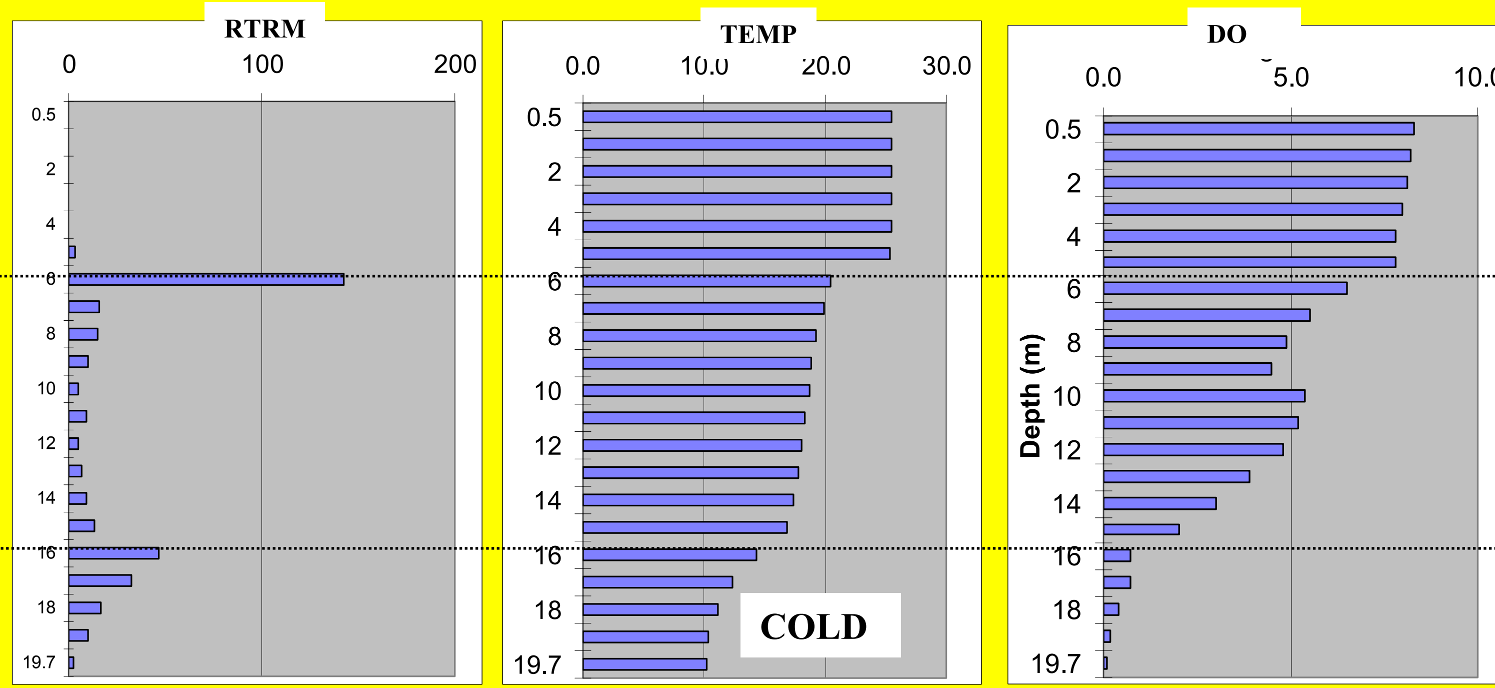
Full-Lift
Hypolimnetic
Aeration Tower

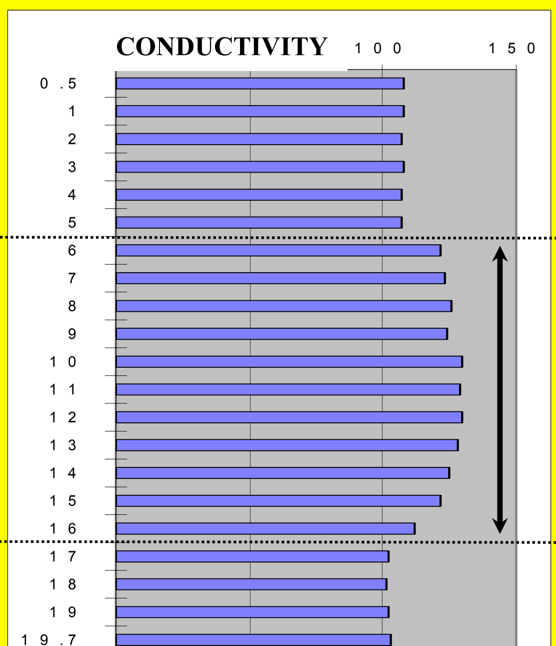
Partial-Lift (submerged)
Layer Aeration Tower

Partial-Lift (submerged)
Layer Aeration Tower
Installed during
construction of a new off-line storage reservoir

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


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.

Seasonal Source System Optimization – Hemlocks System
(Based on Water Quality – Quantity needs balancing)

"Season 1"
Winter

Approx. December 15 to March 15
- Use the Aspetuck River source to maintain/refill Hemlocks Reservoir;
- Winter Drawdown of Hemlocks for Milfoil Control (option)
- Winter Circulation for Alewife Control (option)
- Allow Refill of Saugatuck Reservoir Storage

Utilize Aspetuck River during Higher Flow/Water Quality Season
(while refilling Saugatuck Storage Volume)

"Season 2"
Spring

Approx. March 15 to May 15
- Close the Aspetuck Reservoir Gate;
- Consume Hemlocks Reservoir Storage;
- Allow Aspetuck Dam Overflow
- Allow Refill of Saugatuck Reservoir Storage

Minimize Spring Nutrient Input to Hemlocks Reservoir

"Season 3"
Summer

Approx. May 15 to October 15
- Open the Aspetuck Reservoir Gate to Hemlocks Reservoir;
- Divert from Saugatuck Reservoir Storage at 50 ft;
- Layer Aeration and Interflow to/thru Hemlocks Reservoir

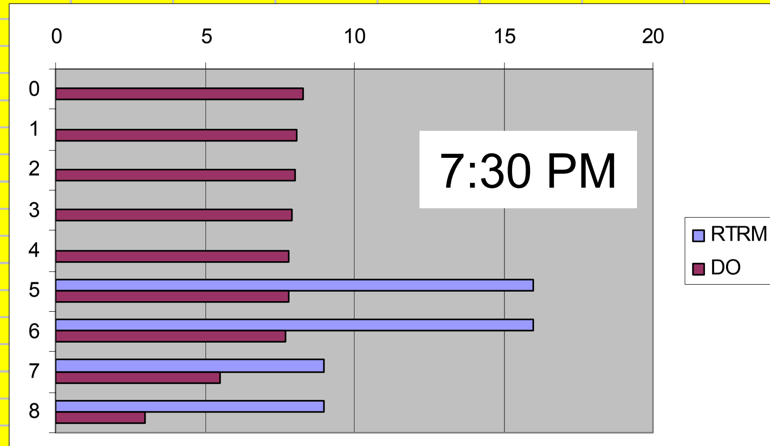
Maximize use of Saugatuck Reservoir Water

"Season 4"
Autumn

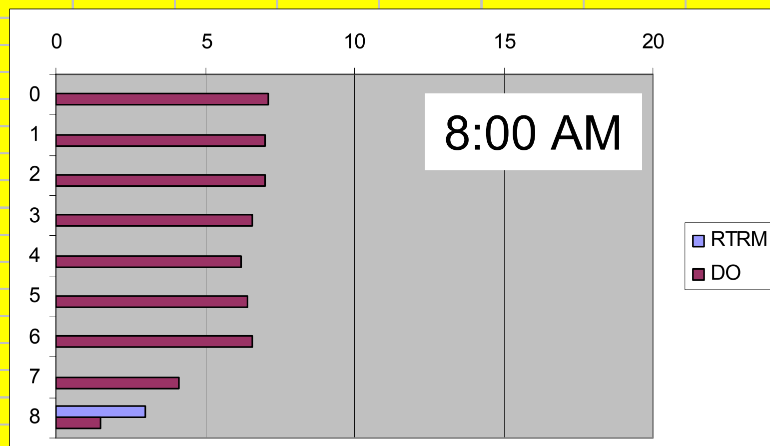
Approx. October 15 to December 15
(From the beginning of leaf-fall)
- Consume Hemlocks Storage
- Close the Aspetuck Reservoir Gate;
- Close the diversion from Saugatuck Reservoir;
- Allow refill of Saugatuck Storage

Avoid High Color, TOC/DOC, in Aspetuck River

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

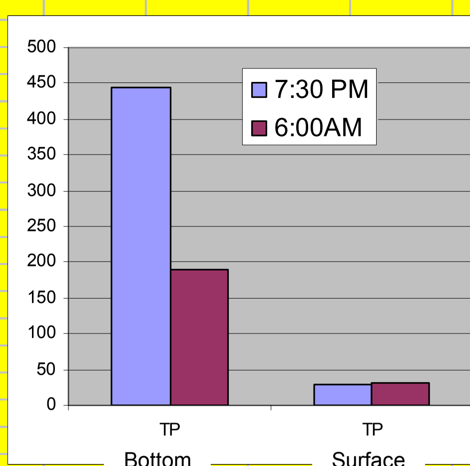


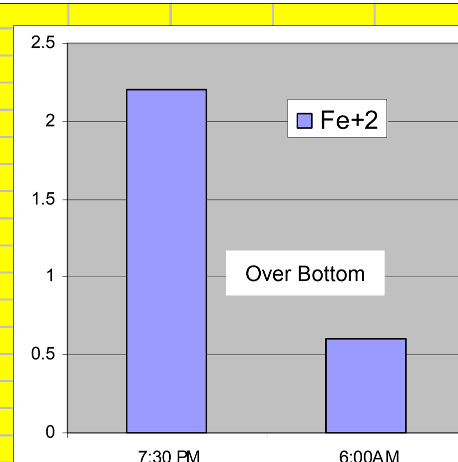
8/26/83	6:00 AM		
Depth (ft)			
	RTRM	DO	TEMP
0	0	7.1	24.5
1	0	7	24.5
2	0	7	24.5
3	0	6.6	24.5
4	0	6.2	24.5
5	0	6.4	24.5
6	0	6.6	24.5
7	0	4.1	24.5
8	3	1.5	24.4



	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



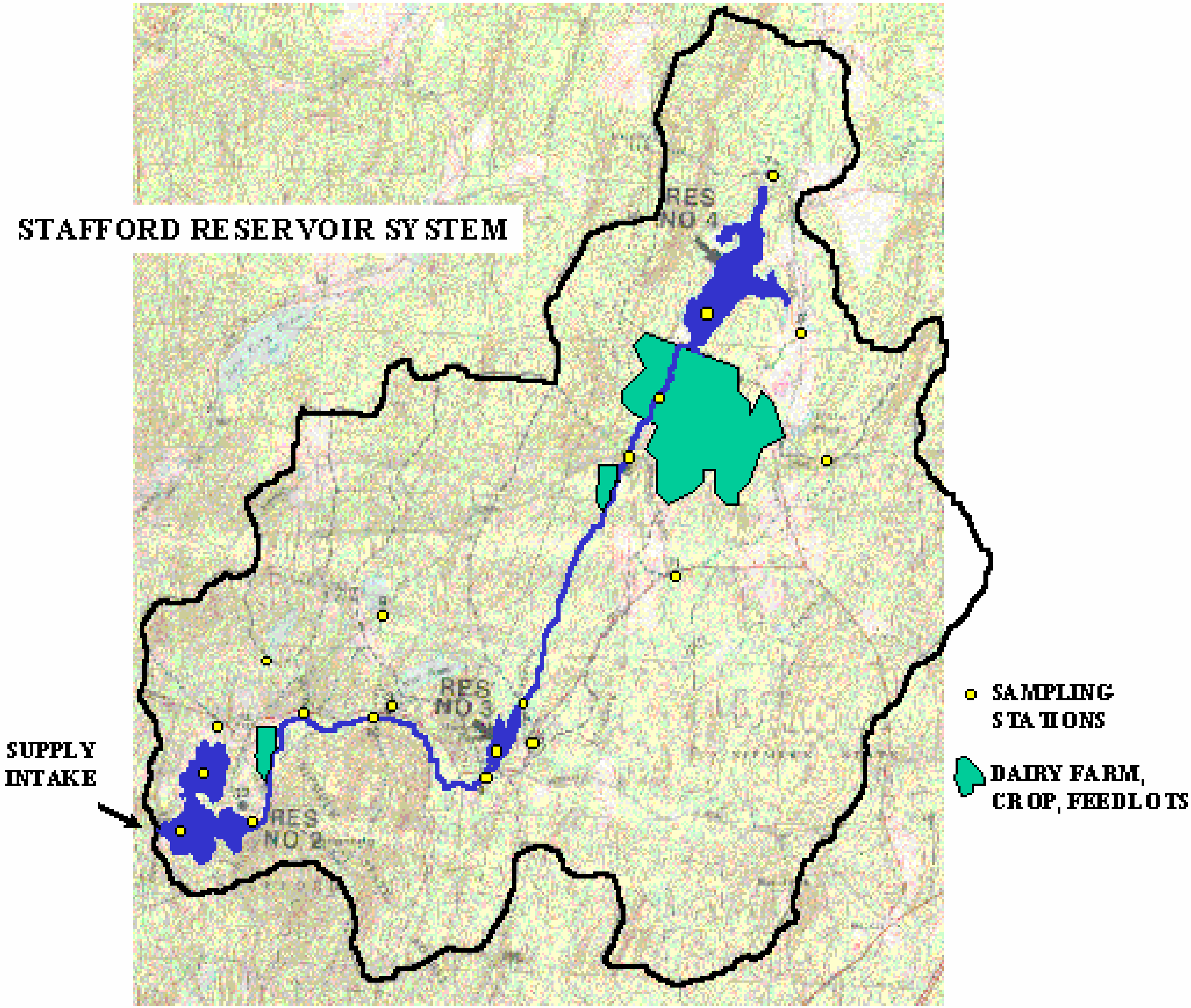


When is oxygen loss most intense, during day or night?

Is there a difference during night vs. day?

What would be expected?

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

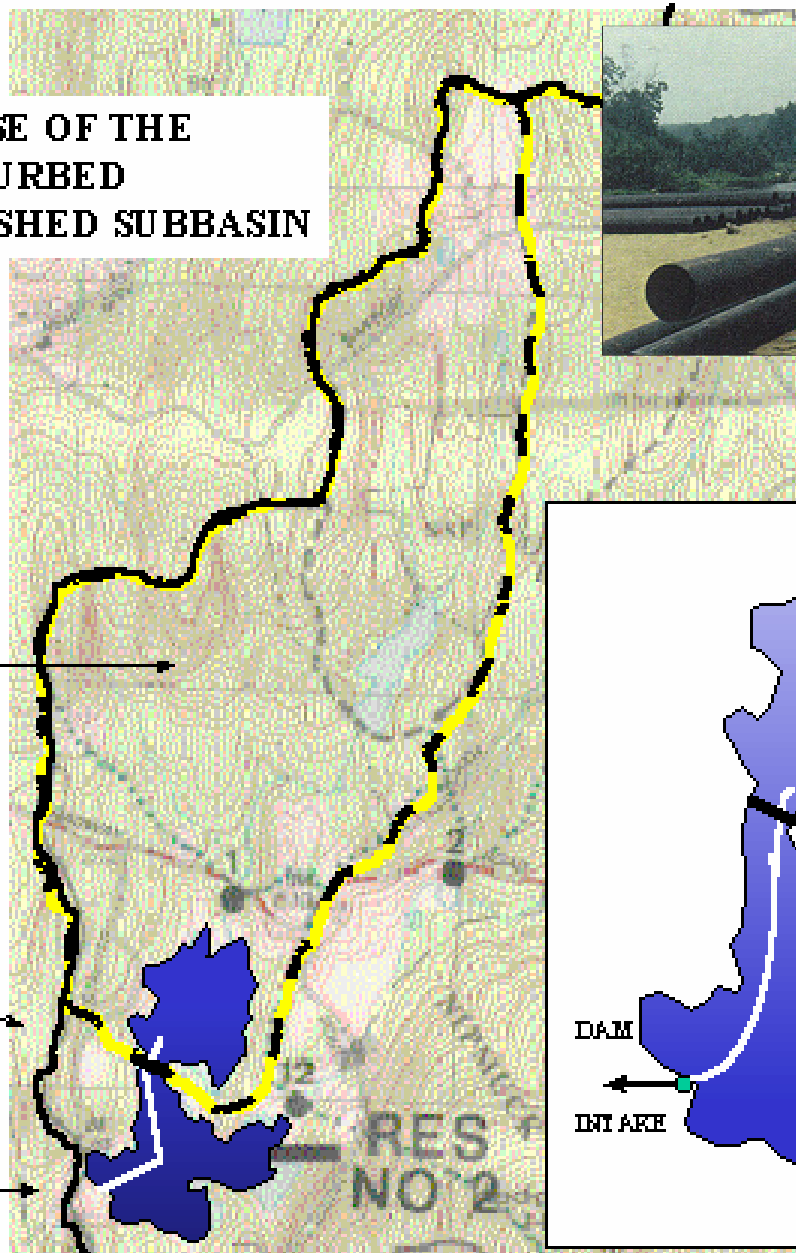

STAFFORD RESERVOIR SYSTEM
RES NO 4
RES NO 3
RES NO 2
SUPPLY INTAKE
SAMPLING STATIONS
DAIRY FARM, CROP, FEEDLOTS

MAXIMIZE THE USE OF THE TOTALLY UNDISTURBED WOODED WATERSHED SUBBASIN

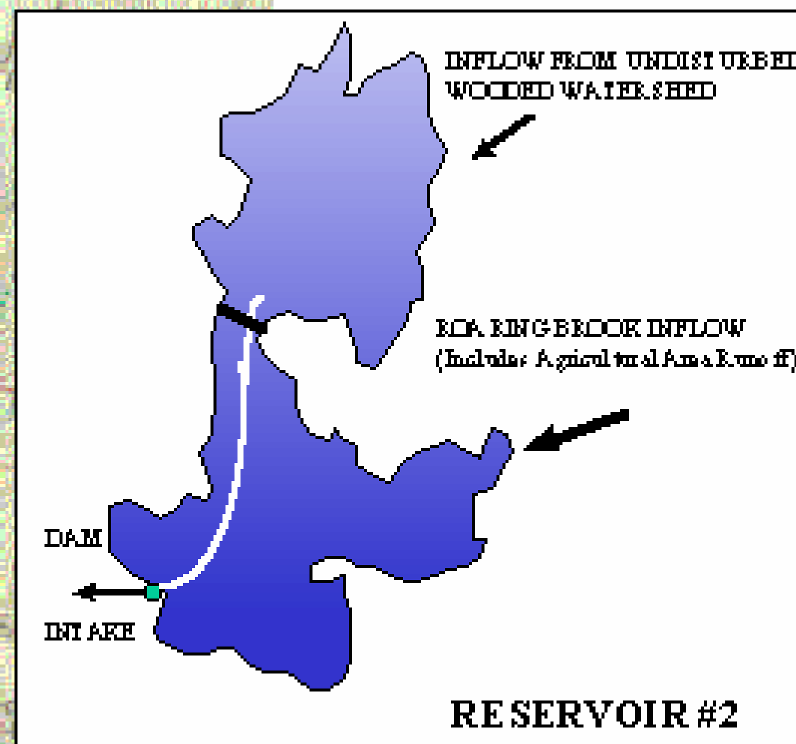
Watershed Area Draining Directly to the Northern Bay of the Reservoir

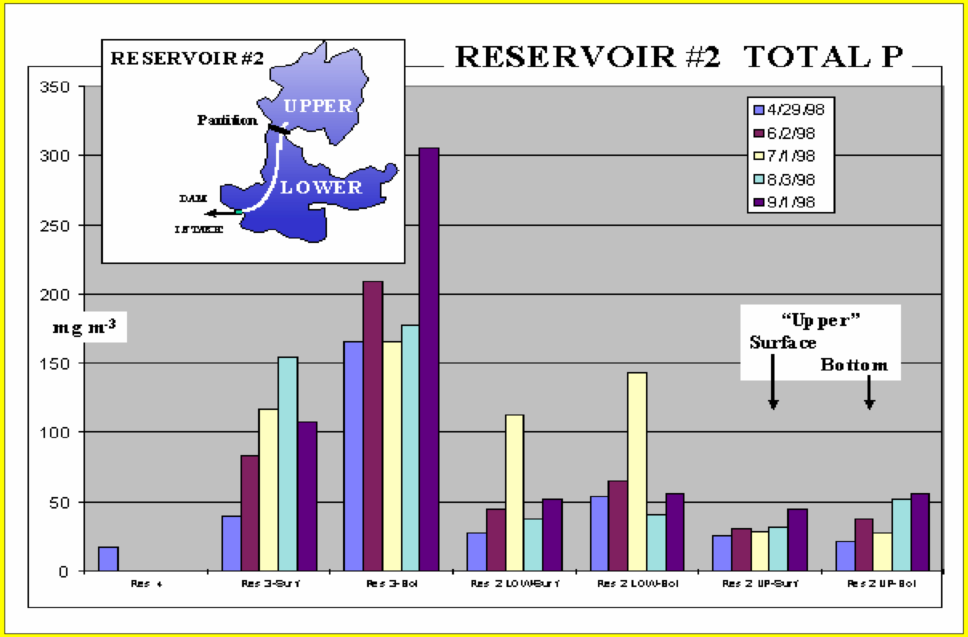
"PARTITION CURTAIN"

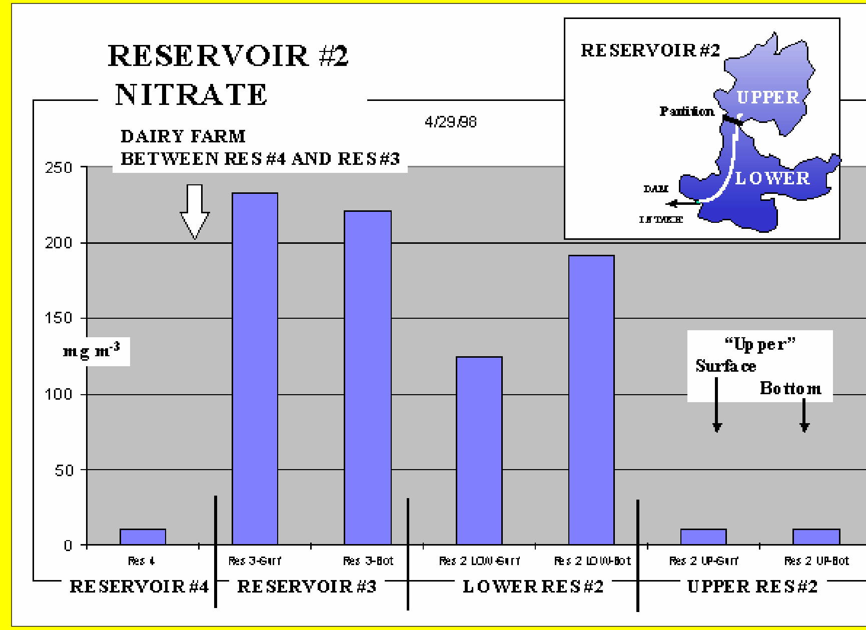
INTAKE EXTENSION

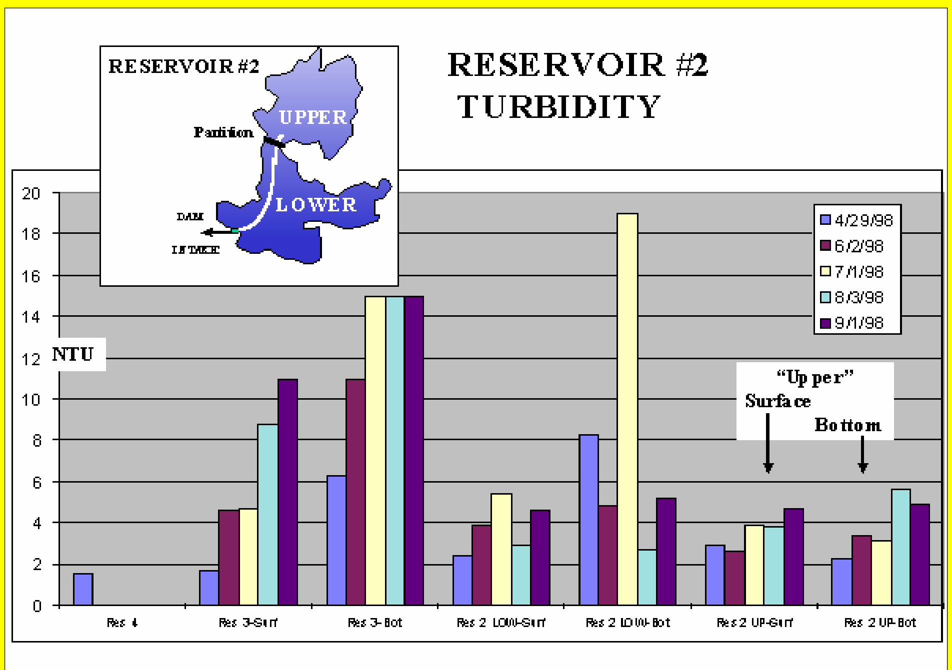


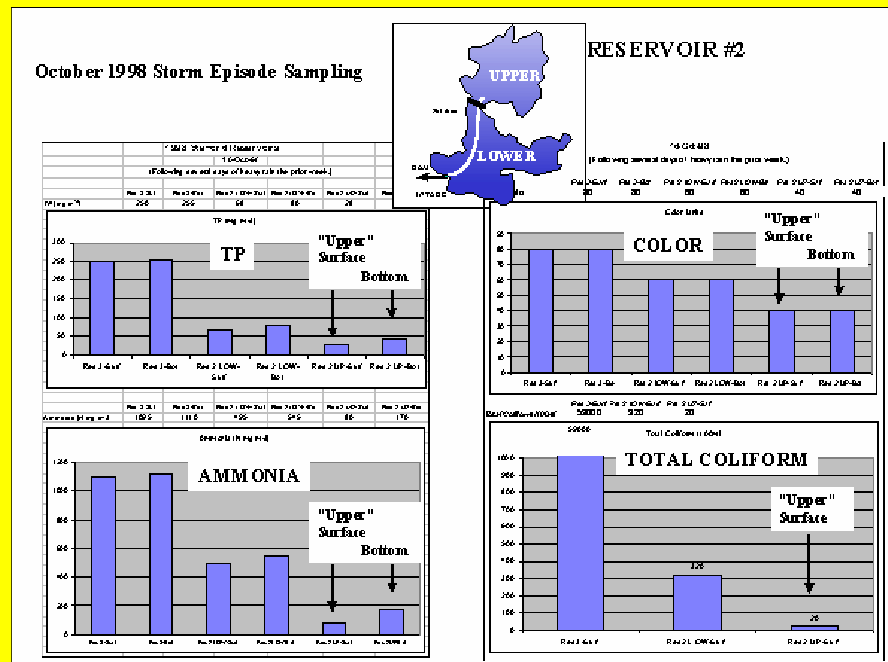
RESERVOIR PARTITIONING
INTAKE ISOLATION




RESERVOIR #2 TOTAL P
RESERVOIR #2
UPPER
Partition
LOWER
DAM
INTAKE
mg m-3
4/29/98
6/2/98
7/1/98
8/3/98
9/1/98
"Upper"
Surface
Bottom
Res 4
Res 3-Surf
Res 3-Bot
Res 2 LOW-Surf
Res 2 LOW-Bot
Res 2 UP-Surf
Res 2 UP-Bot


RESERVOIR #2
NITRATE
4/29/98
DAIRY FARM
BETWEEN RES #4 AND RES #3
mg m-3
"Upper"
Surface
Bottom
Res 4
Res 3-Surf
Res 3-Bot
Res 2 LOW-Surf
Res 2 LOW-Bot
Res 2 UP-Surf
Res 2 UP-Bot
RESERVOIR #4
RESERVOIR #3
LOWER RES #2
UPPER RES #2


RESERVOIR #2
TURBIDITY
RESERVOIR #2
UPPER
Partition
LOWER
DAM
INTAKE
NTU
4/29/98
6/2/98
7/1/98
8/3/98
9/1/98
"Upper"
Surface
Bottom
Res 4
Res 3-Surf
Res 3-Bot
Res 2 LOW-Surf
Res 2 LOW-Bot
Res 2 UP-Surf
Res 2 UP-Bot


October 1998 Storm Episode Sampling
RESERVOIR #2
UPPER
LOWER
TP
"Upper"
Surface
Bottom
AMMONIA
COLOR
TOTAL COLIFORM

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}		

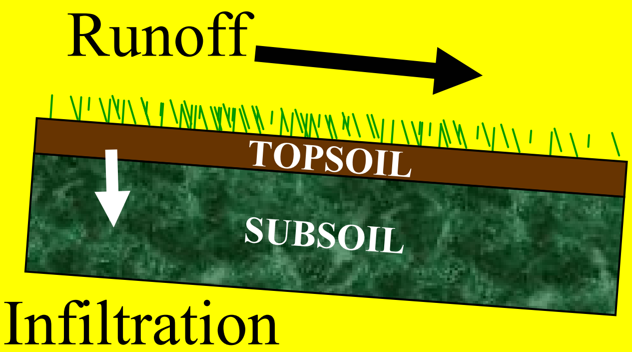
Existing Single Family Residential Use: **No BMP Credits**

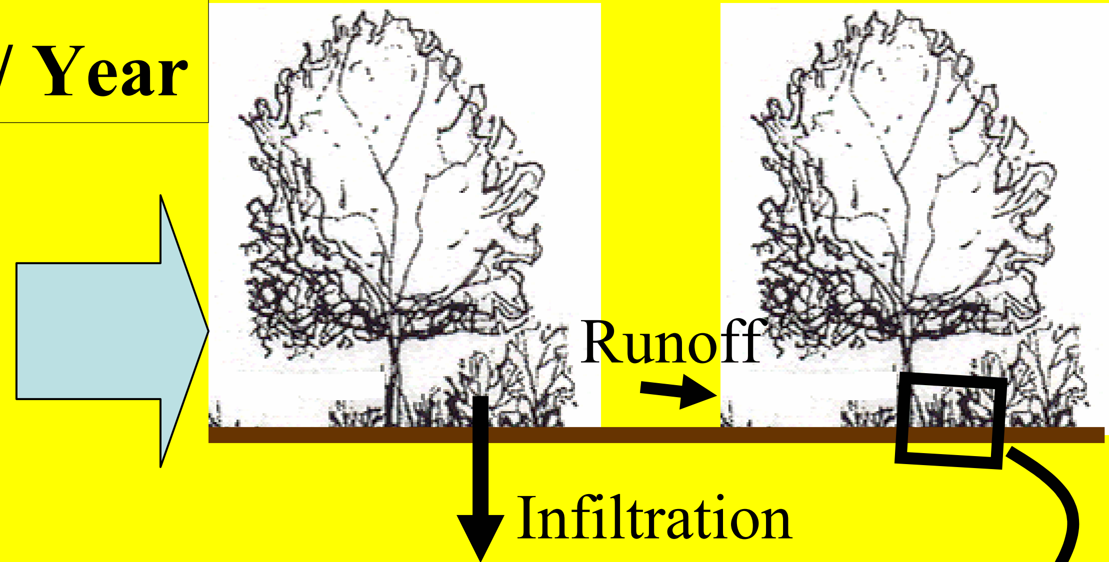
	sq ft	Est P Load (lb P / acre / yr)	LOAD
Roof	1860	1.5	0.06405
Driveway	1530	1.5	0.052686
Lawn	7000	1.25	0.200872
Woodland	43120	0.09	0.089091
Pond Surface	13975	0.75	0.240616
TOTAL	67485		**0.647315**

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



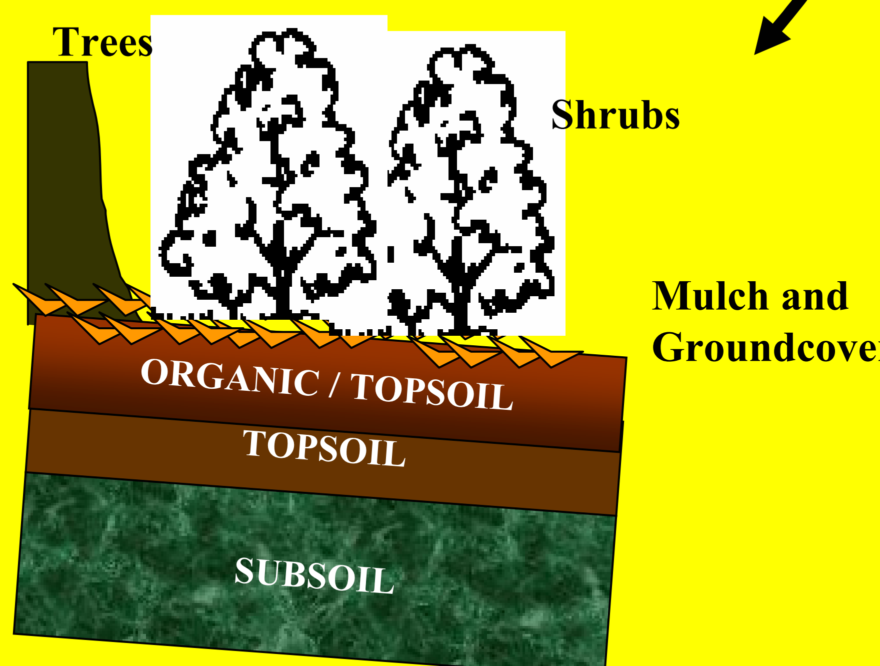


Convert Semi-Pervious to "Simulated Woodland"

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

Example: Convert a Lawn

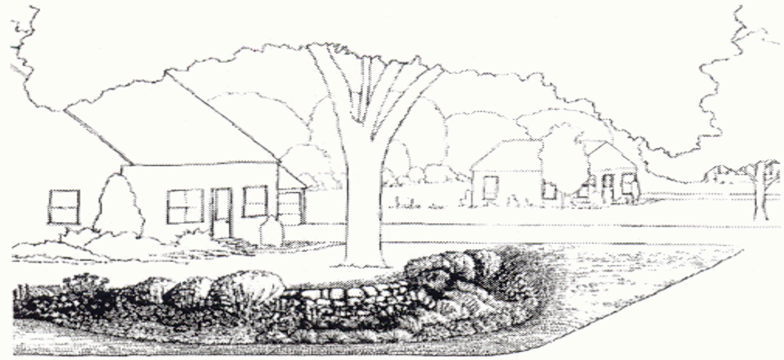
1. **Spread 3" of Peat Moss over the area**
2. **Rototill to > 6 inches**
3. **Cover with Mulch**
4. **Plant Groundcover**
5. **Plant Shrubs (50% cover when grown)**
6. **Plant Tree Saplings (> 1"DBH; 30' On-Center Spacing)**

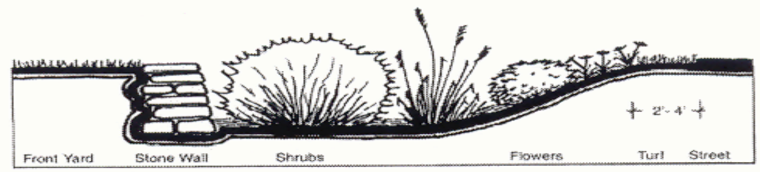


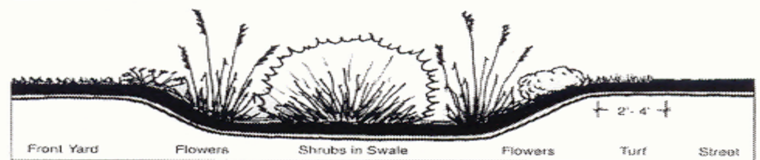
First ½ Inch
0.40 lb P / Acre / Year
First 1 Inch
0.20 lb P / Acre / Year

Figure 4-6. Residential Rain Gardens

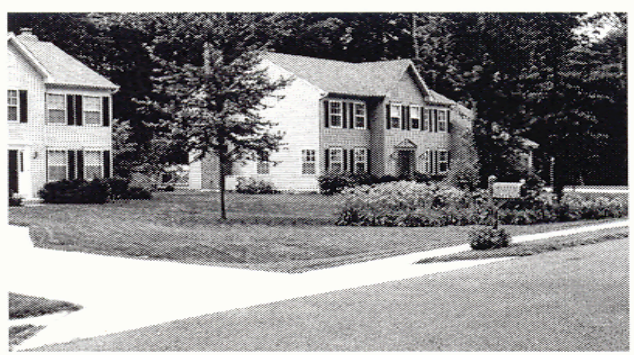
Typical Residential Rain Garden (With and Without Masonry Wall)





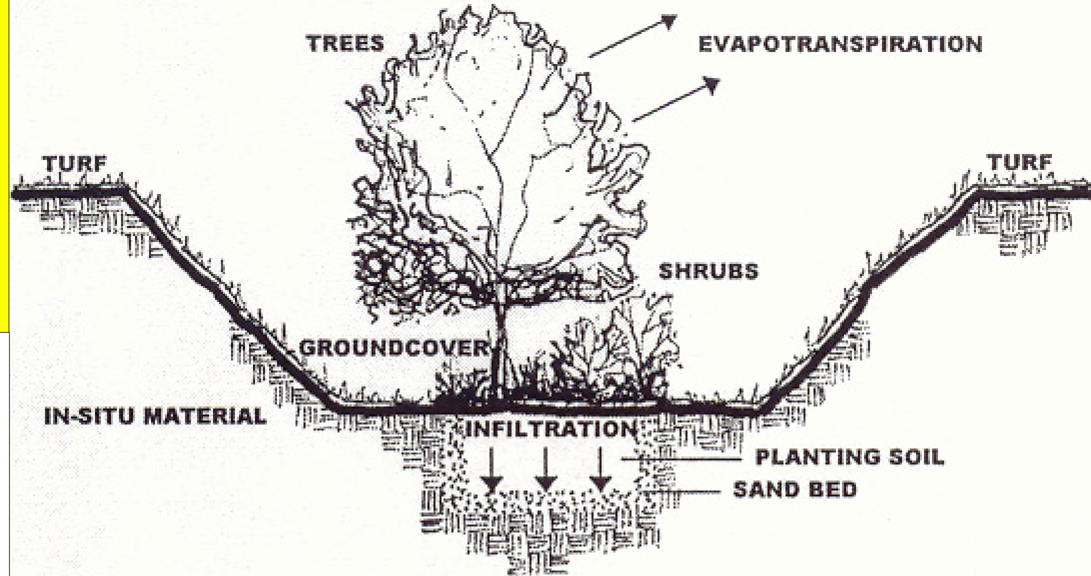


Examples of Residential Rain Gardens

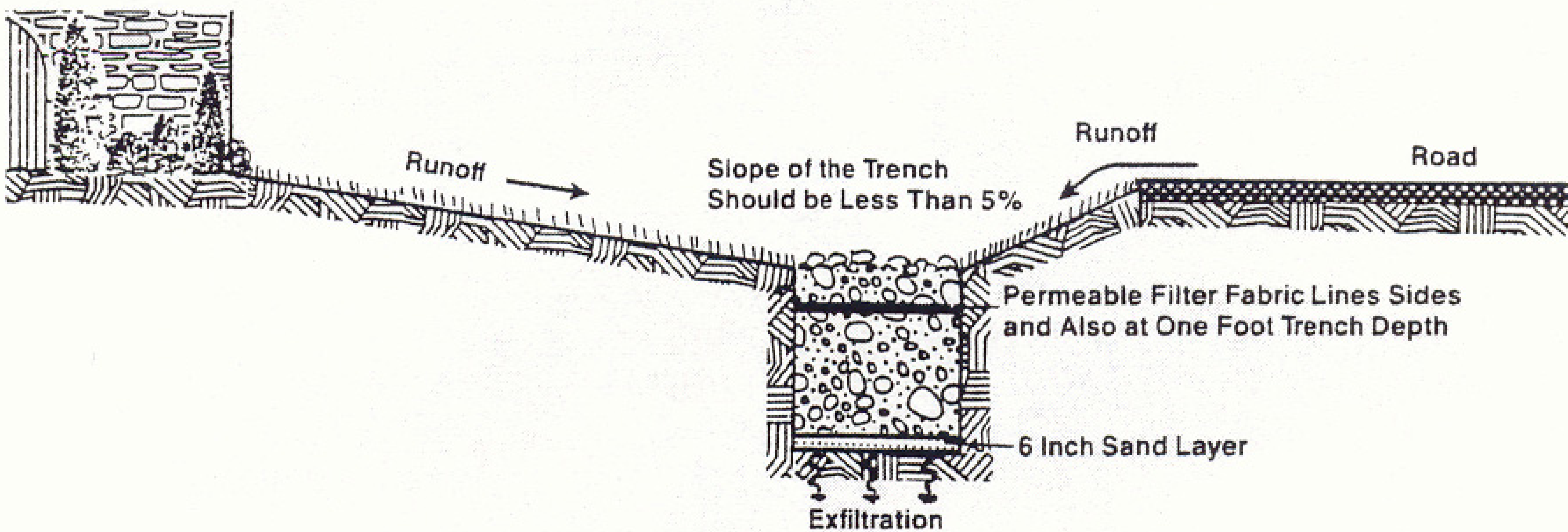


Source: Metropolitan Council, 2001 (Adapted from Nassauer et al., 1997) and Low Impact Development Center (www.lowimpactdevelopment.org), 2001.

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



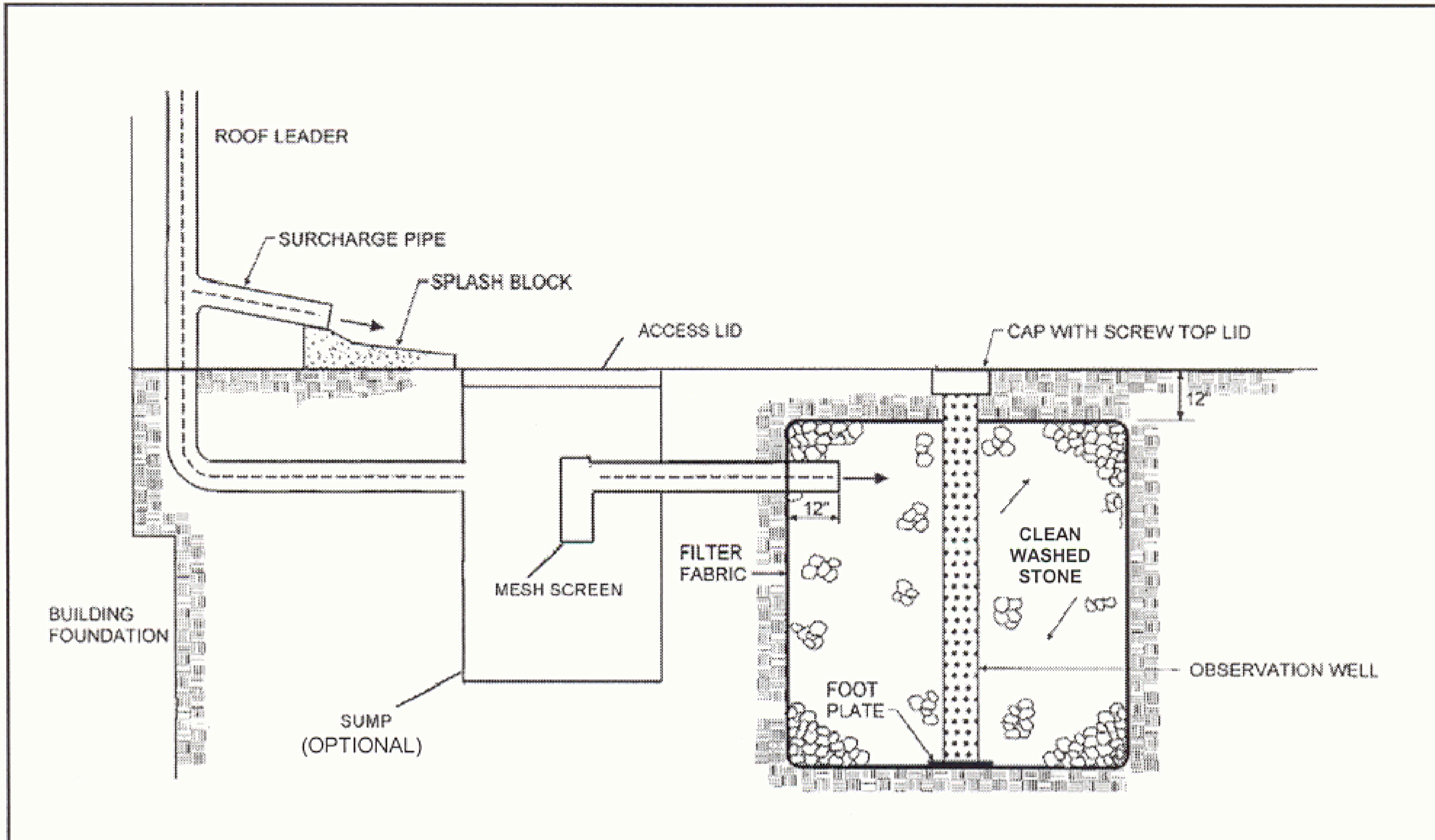
Bioretention Basin



Enhanced Swale

ADAPTED FROM SCHUELER

Figure 4-7. Schematic of Typical Dry Well

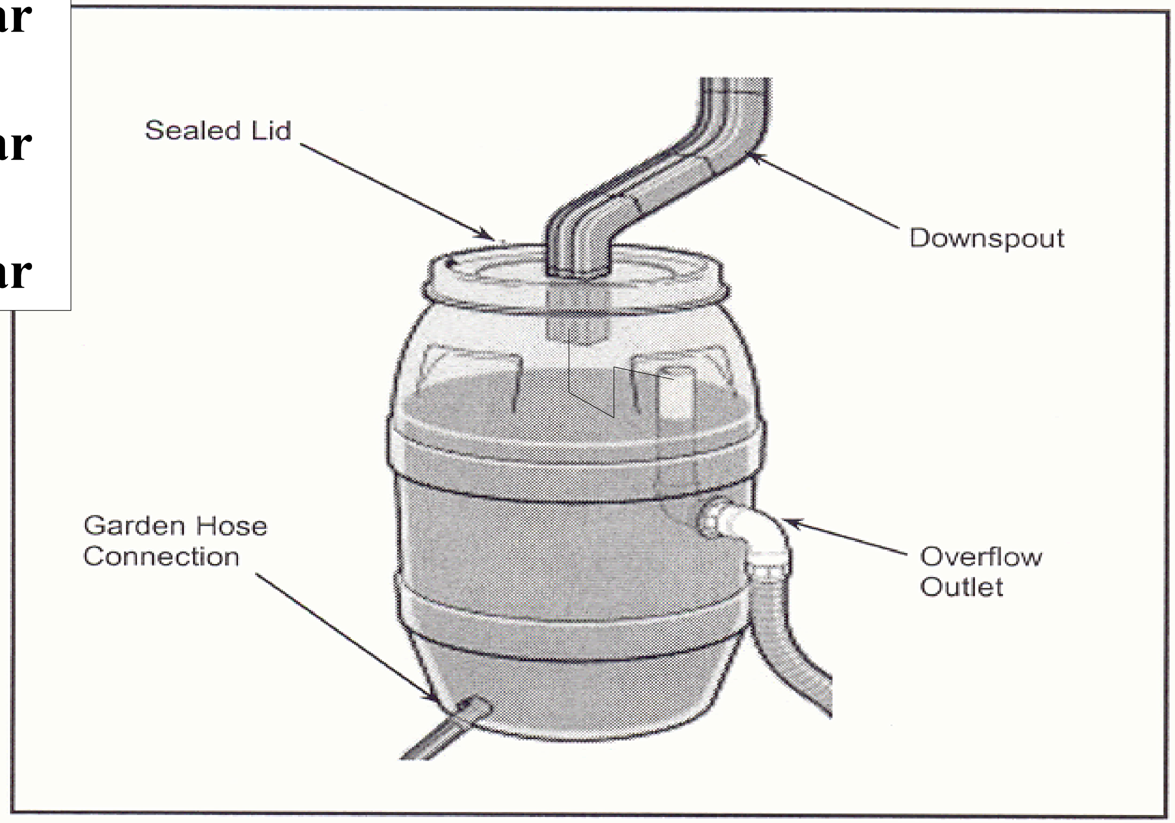


Source: Adapted from NYDEC, 2001.

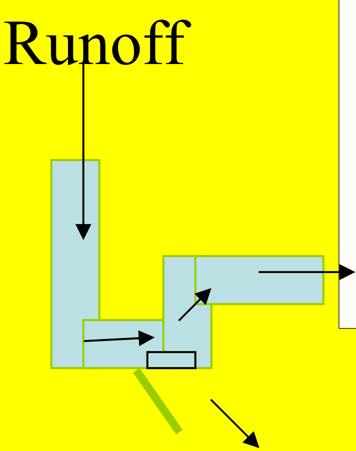
First ½ Inch
0.40 lb P / Acre / Year
First 1 Inch
0.20 lb P / Acre / Year

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).



First Flush Fills Barrel


The End
Questions?
Remember…you are what you …*DRINK!*