Potential Benefits of Solar-powered Circulation for Lake Cochituate, with an Emphasis on Controlling Eurasian Watermilfoil

Presentation for:

The Cochituate State Park Advisory Committee (CSPAC)
Protect Our Water Resources (POWR)
Mass. Congress of Lakes and Ponds (COLAP)

March 23, 2006

Christopher F. Knud-Hansen, Ph.D., CLM
Limnologist & Certified Lake Manager
SolarBee - Pump Systems, Inc.
Email: chris@solarbee.com; www.solarbee.com

SolarBee®
Solar-Powered Reservoir Circulator
"Quality Water, Naturally"

Presentation Outline

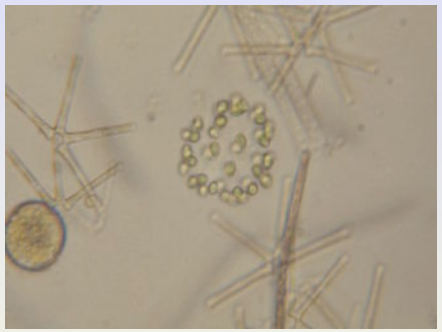
- Basic biological and physical lake properties
- Benefits of circulation for lake management
  - Blue-green algae bloom control
  - Invasive aquatic weed control
  - Reducing inorganic chemical release from sediments
  - Fisheries improvement
- Examples:
  - Raw water reservoir (Thornton, CO)
  - Raw water reservoir (Palmdale, CA)
  - City park lake (Duck Lake, Denver, CO)
- Conclusions on ecological benefits
- Discussion of Lake Cochituate
  - Why sediments are not disturbed

Natural Food Production in Lakes

Primary Production:

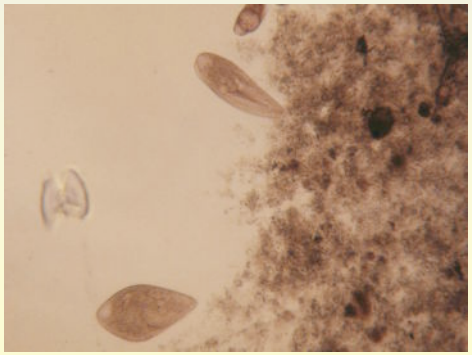
+ nutrients

Algae + H_20 + CO_2 → New Plant Matter + O_2



Consumption & Decomposition

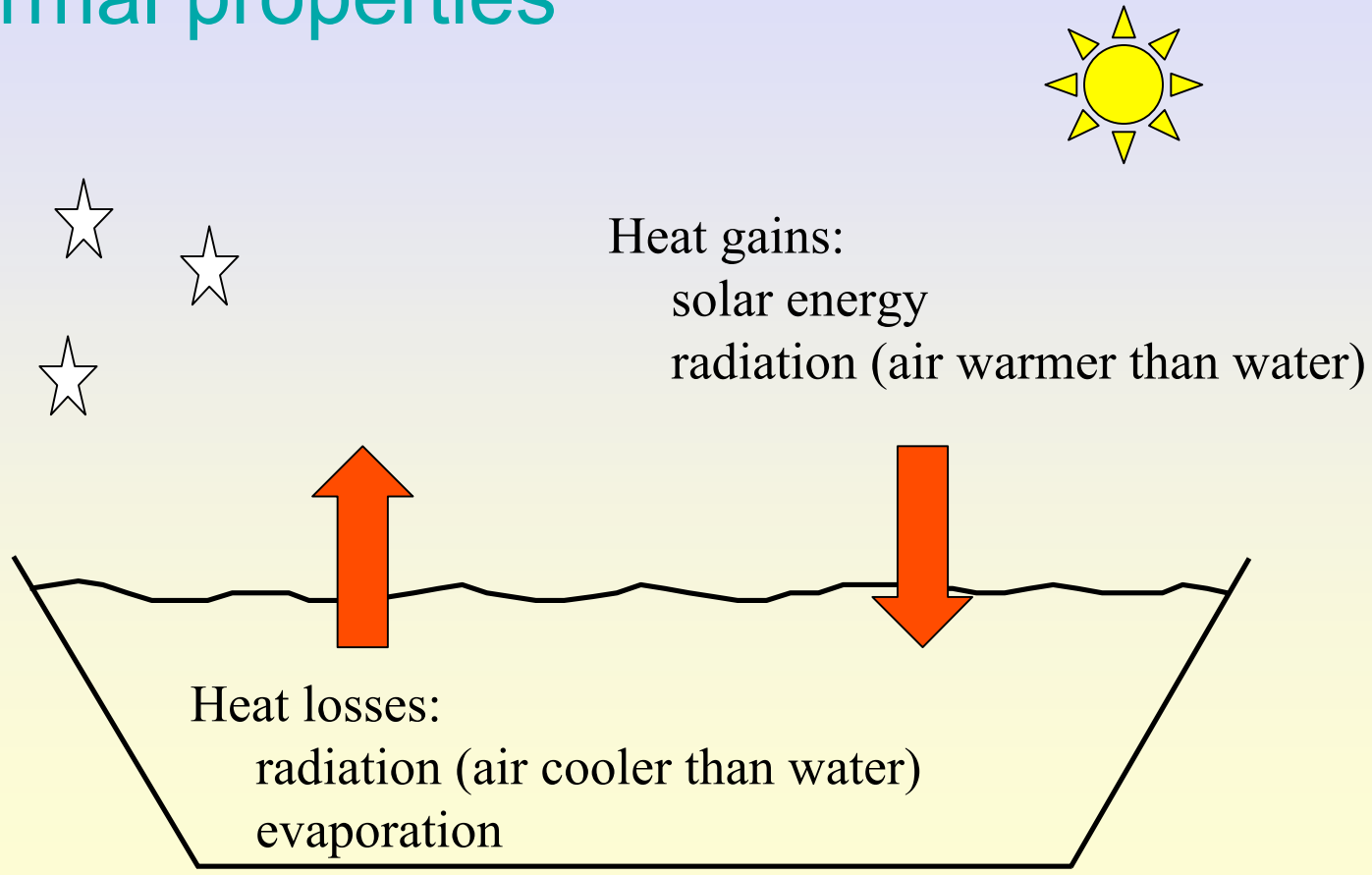
Secondary Production:



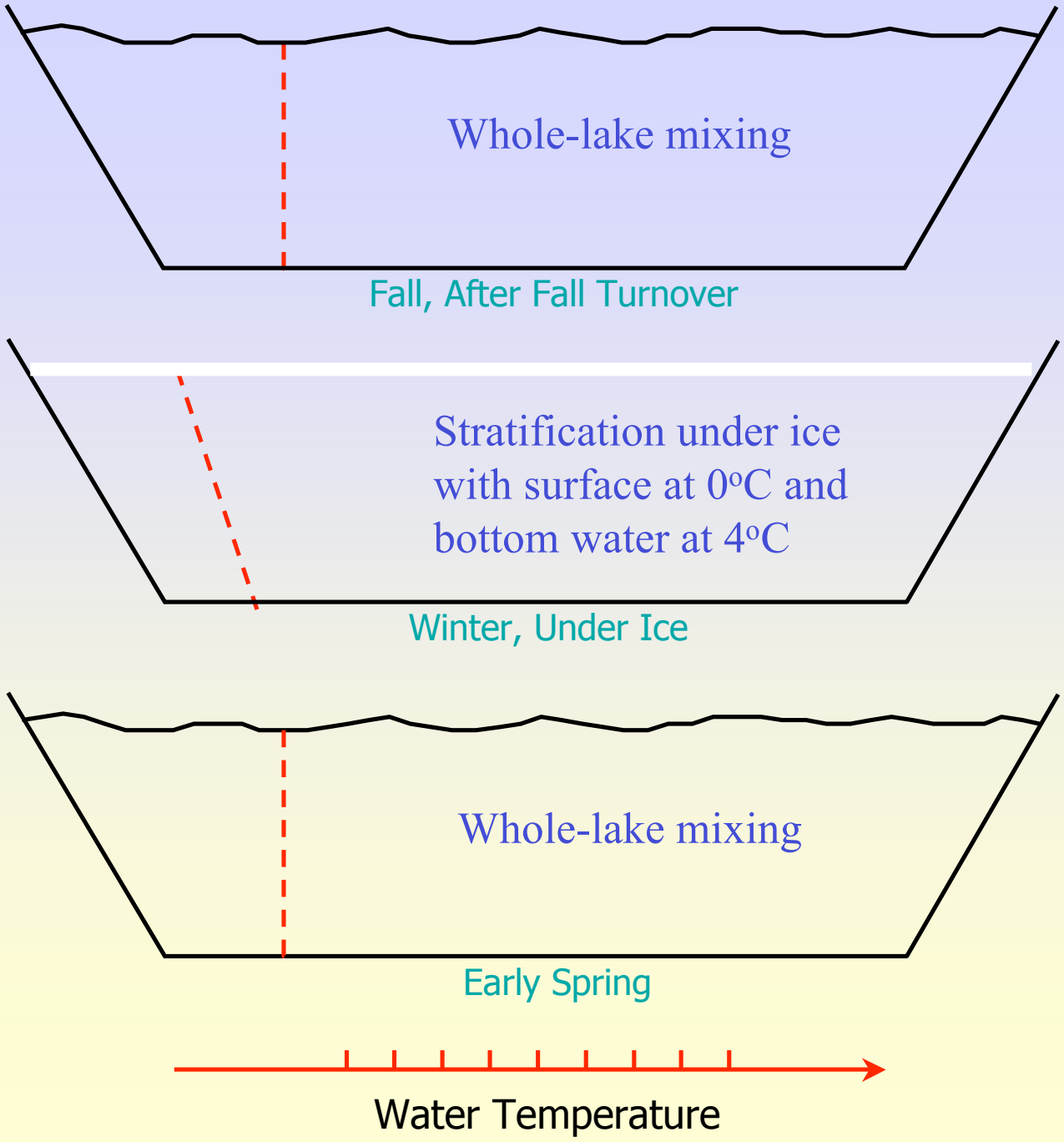
Organic Matter + O_2 → H_2O + CO_2

Lake Physical Properties

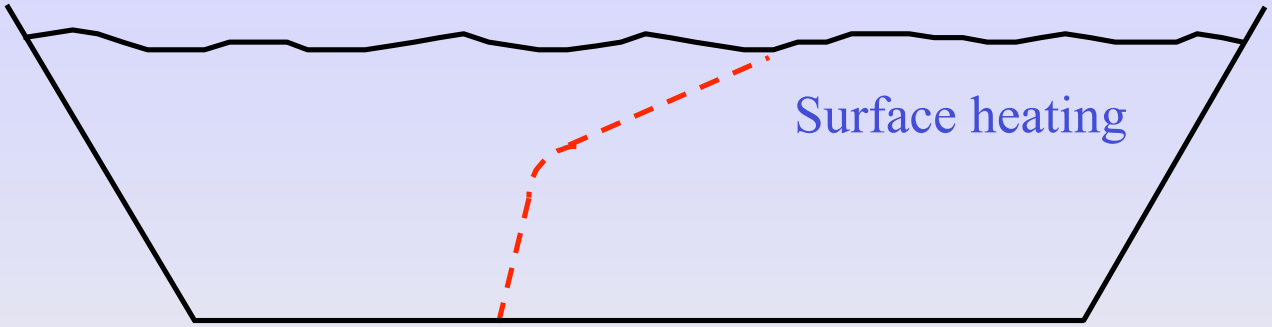
Thermal properties



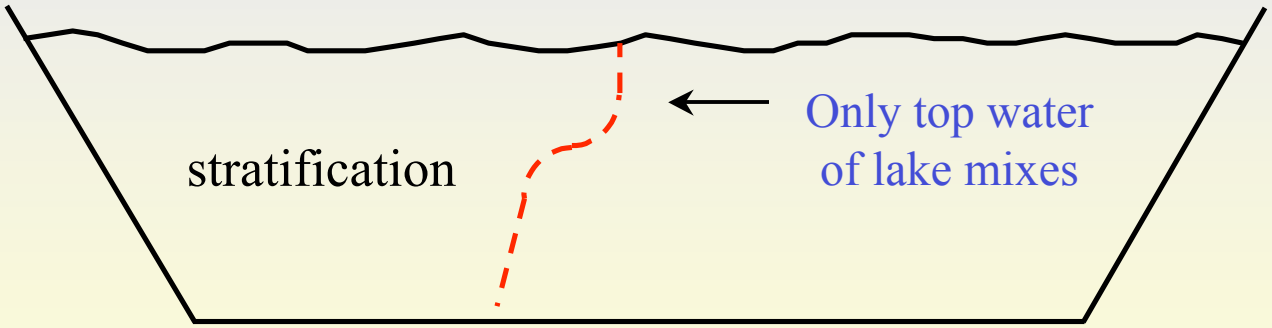
Seasonal Mixing Patterns



Seasonal Mixing Patterns, cont.



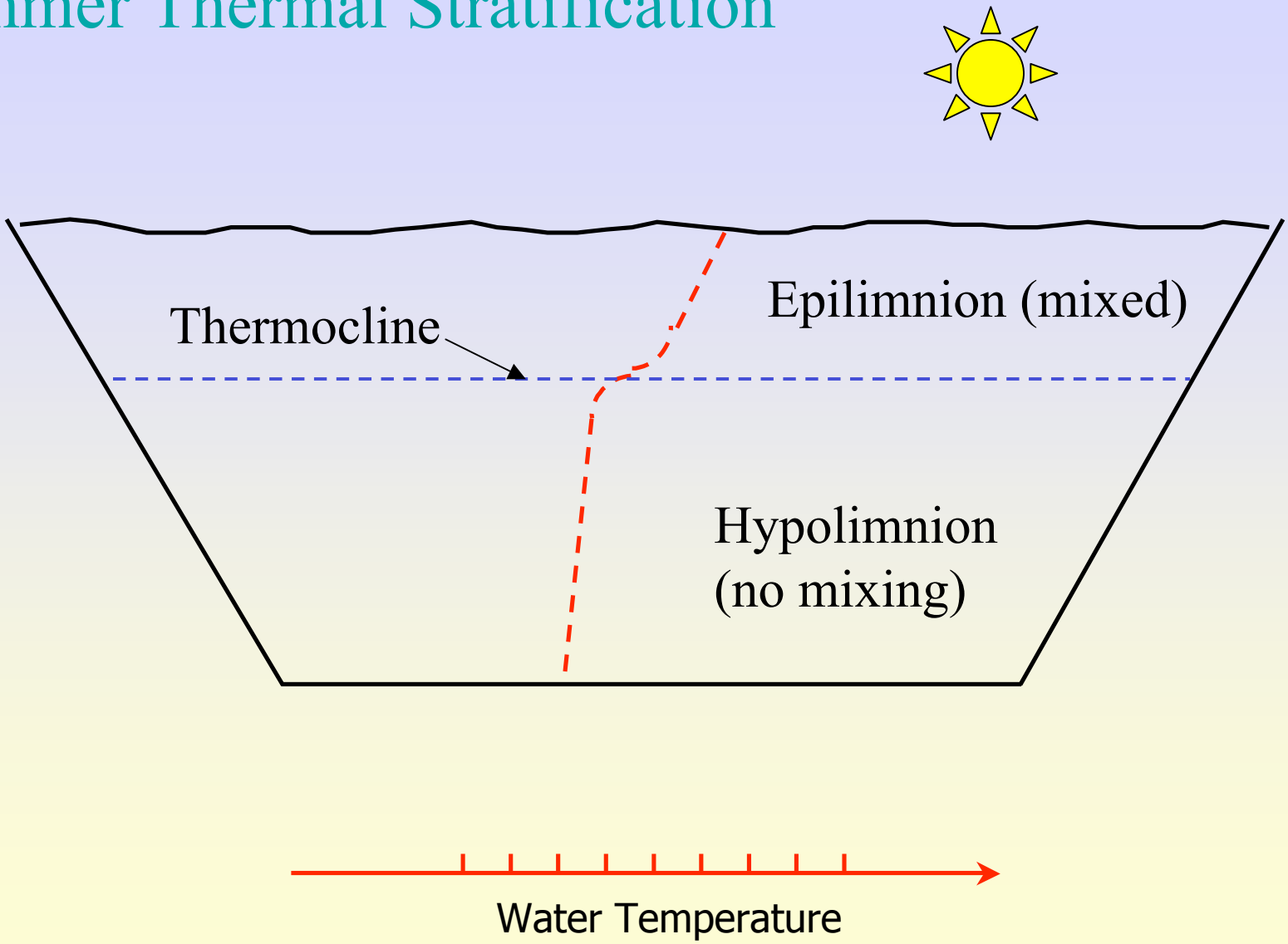
Late Spring – Early Summer



Summer - Until Fall Turnover

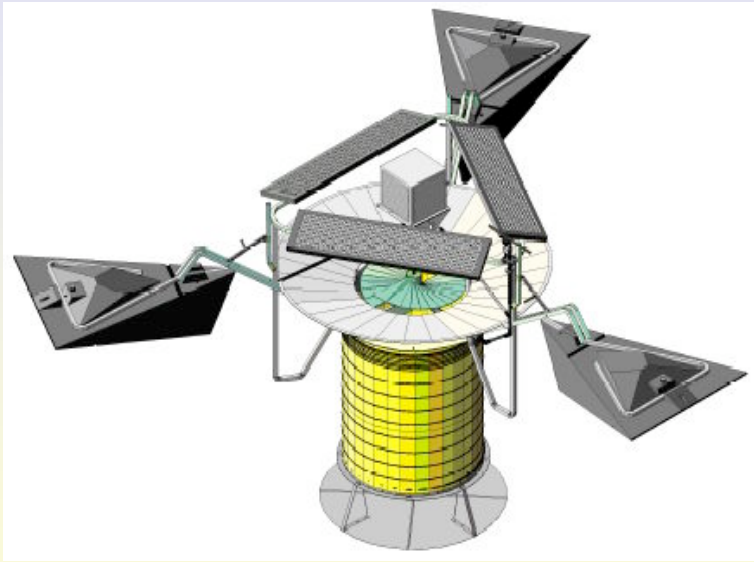
Water Temperature

Summer Thermal Stratification



The SolarBee® creates long-distance, radial flow circulation

- **900+ machines installed worldwide since 1998**
  - *4 models: 1250, 2500, 5000, & 10000 gpm*
    - *2 patents + 69 features patent pending*
  - *Applications:*
    - lake & reservoir management
    - potable water, wastewater

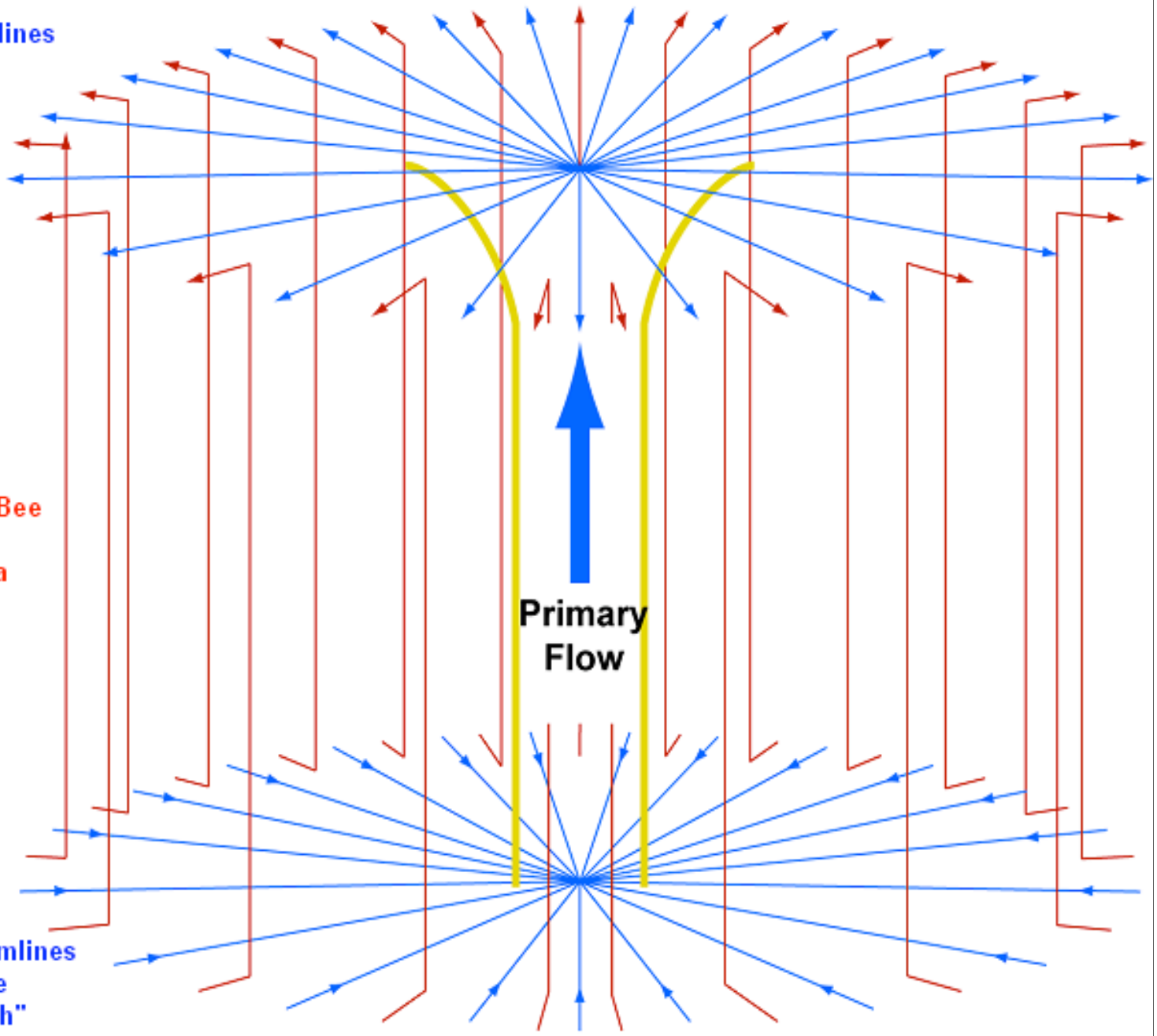


Manufactured by Pump Systems, Inc., Dickinson, ND
(in the pump business since 1978)

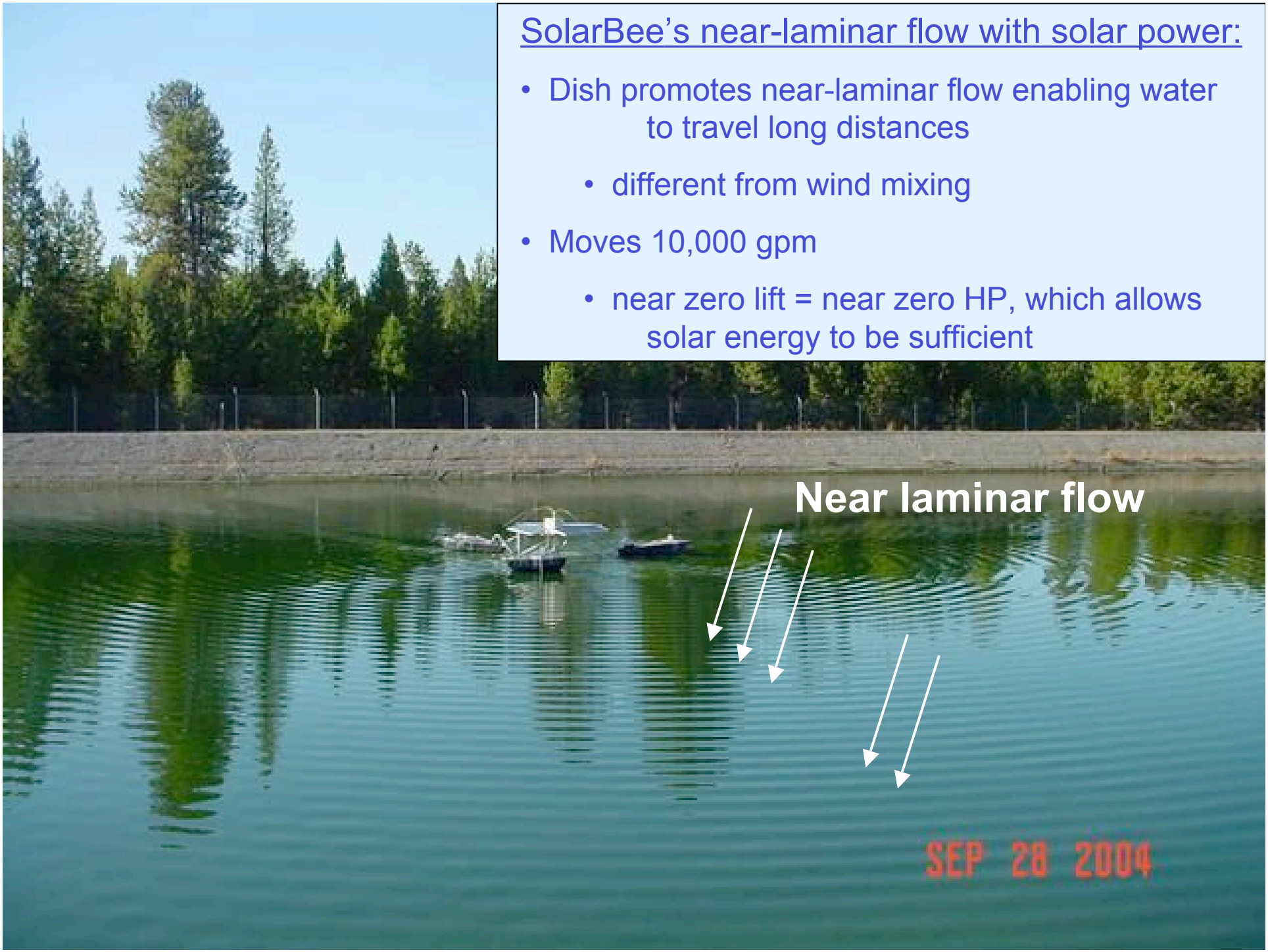
SolarBee radial flow causes both horizontal and vertical mixing.

Horizontal diverging streamlines at the surface create voids and upward "pull"

Vertical flow is caused by diverging horizontal flow at the surface & converging horizontal flow at the SolarBee intake. This vertical flow extends thoughtout the 20ha (50acres) or more area of influence



Horizontal converging streamlines atthe SolarBee intake create compression & upward "push"



SolarBee's near-laminar flow with solar power:

- Dish promotes near-laminar flow enabling water to travel long distances
  - different from wind mixing
- Moves 10,000 gpm
  - near zero lift = near zero HP, which allows solar energy to be sufficient

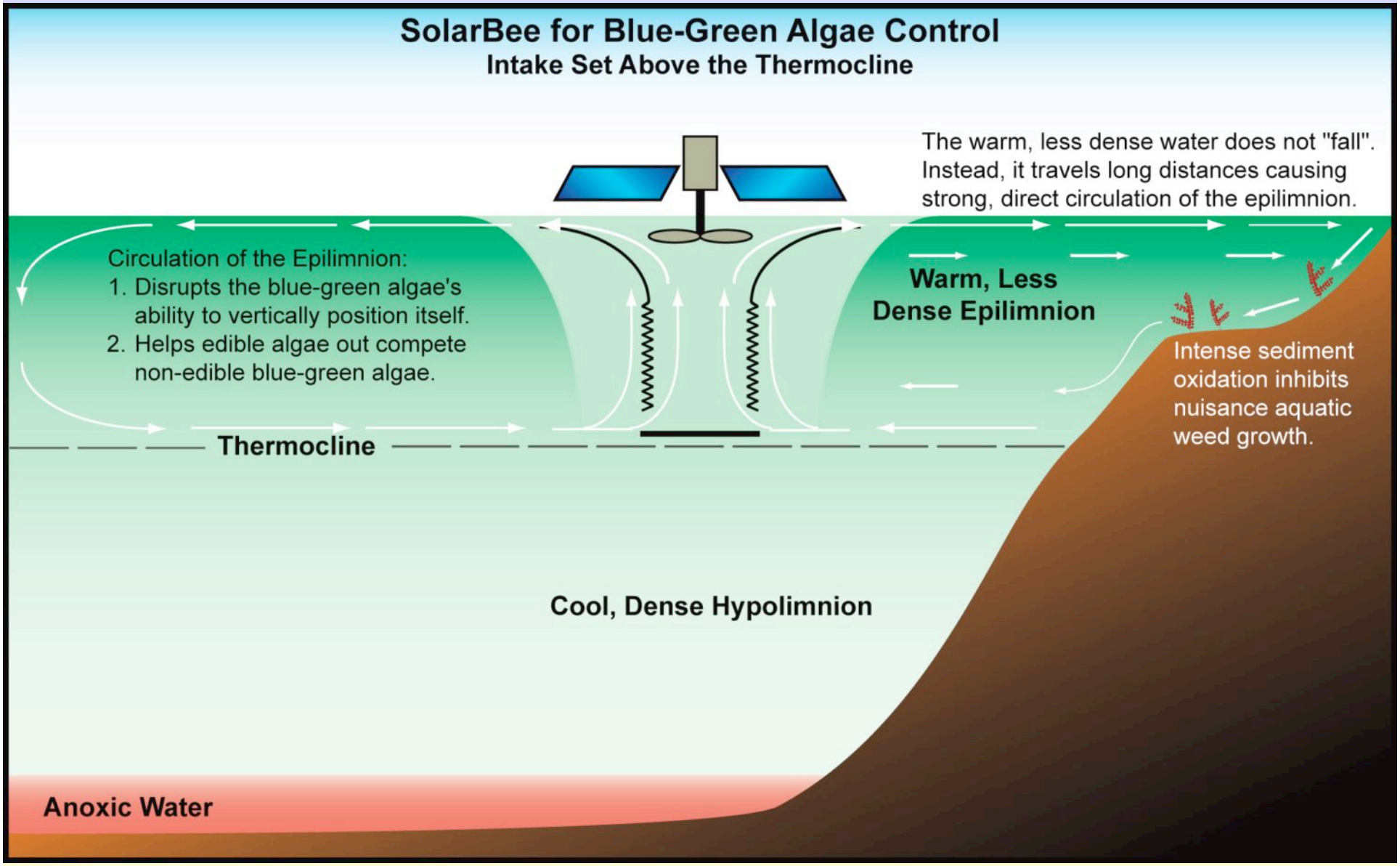
Major requirements for Blue-green Algae Blooms

1. Nutrients (e.g., N & P)
2. Suitable temperatures (typically warm)
3. Sufficient light for photosynthesis
4. Quiescent, stagnant waters

Blue-green Algae Competitive Advantages

Blue-green algae (cyanobacteria) have evolved competitive advantages to ensure their success:

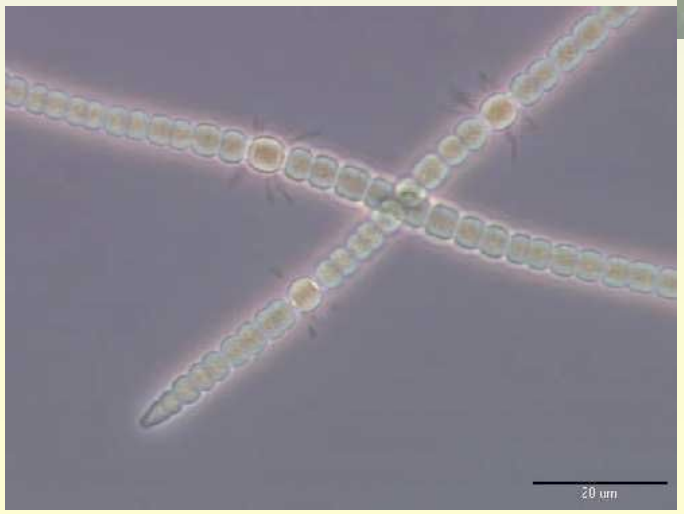
1. *Gas vesicles that allow them to regulate their buoyancy*
   - Move up during day for sunlight, down at night for nutrients
   - Competitive advantage for light and carbon dioxide
2. *Some species can "fix" atmospheric nitrogen*
3. *Many species contain nasty toxins*
   - Makes blue-green algae inedible for zooplankton and fish
   - Reduces diversity of non-blue-green algae

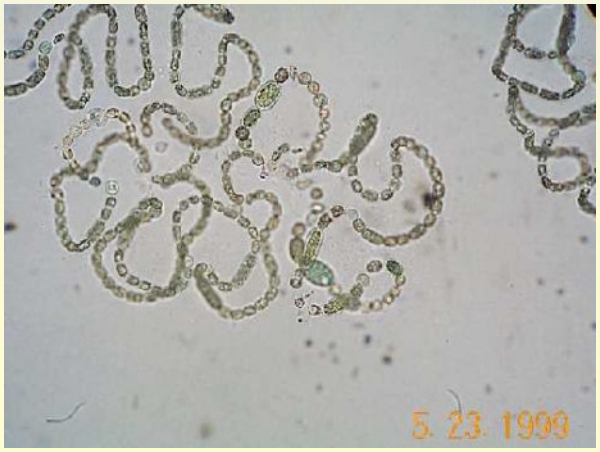

SolarBee for Blue-Green Algae Control
Intake Set Above the Thermocline
The warm, less dense water does not "fall". Instead, it travels long distances causing strong, direct circulation of the epilimnion.
Circulation of the Epilimnion:
1. Disrupts the blue-green algae's ability to vertically position itself.
2. Helps edible algae out compete non-edible blue-green algae.
Warm, Less Dense Epilimnion
Intense sediment oxidation inhibits nuisance aquatic weed growth.
Thermocline
Cool, Dense Hypolimnion
Anoxic Water

Control of blue-green algae through long-distance circulation

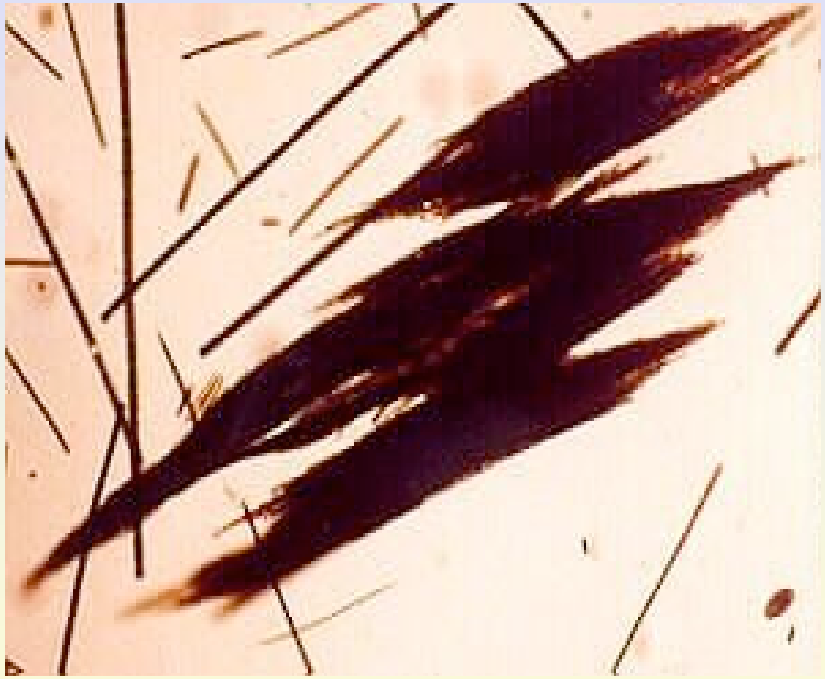
- **Both horizontal and vertical circulation**
  - disrupts the BGA's favored environment of stagnant warm water
  - disrupts BGA's ability to regulate their buoyancy
- **Physically transports BGA out of the surface waters**
- **Allows "good", edible algae (i.e., greens, diatoms, etc.) to out compete blue-greens for soluble P & N**
  - enhances the lake's food web while improving water clarity

Blue-Green Algae: *Anabaena* sp.

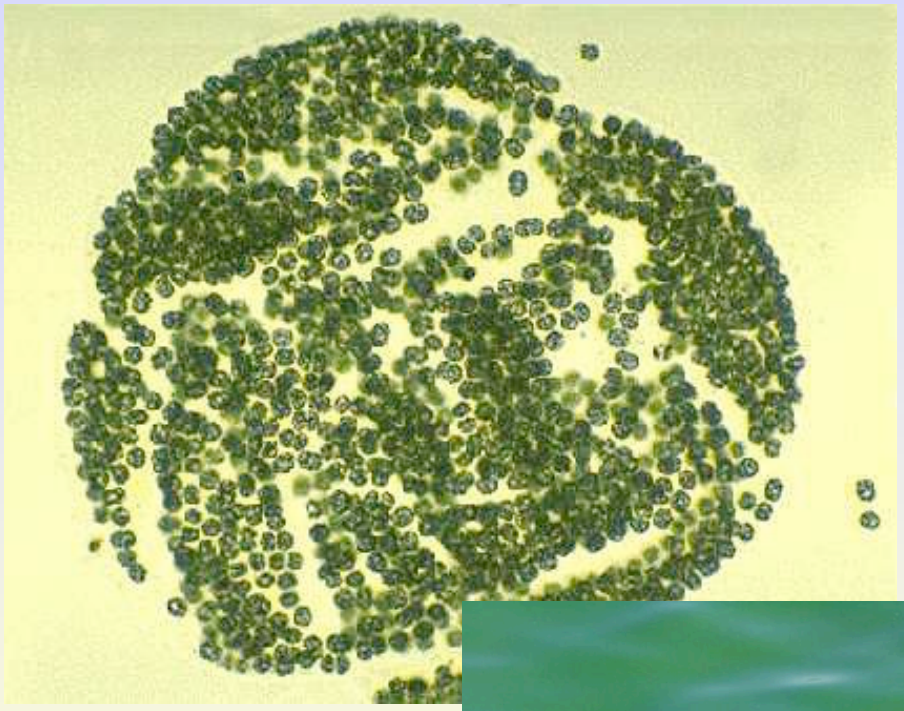


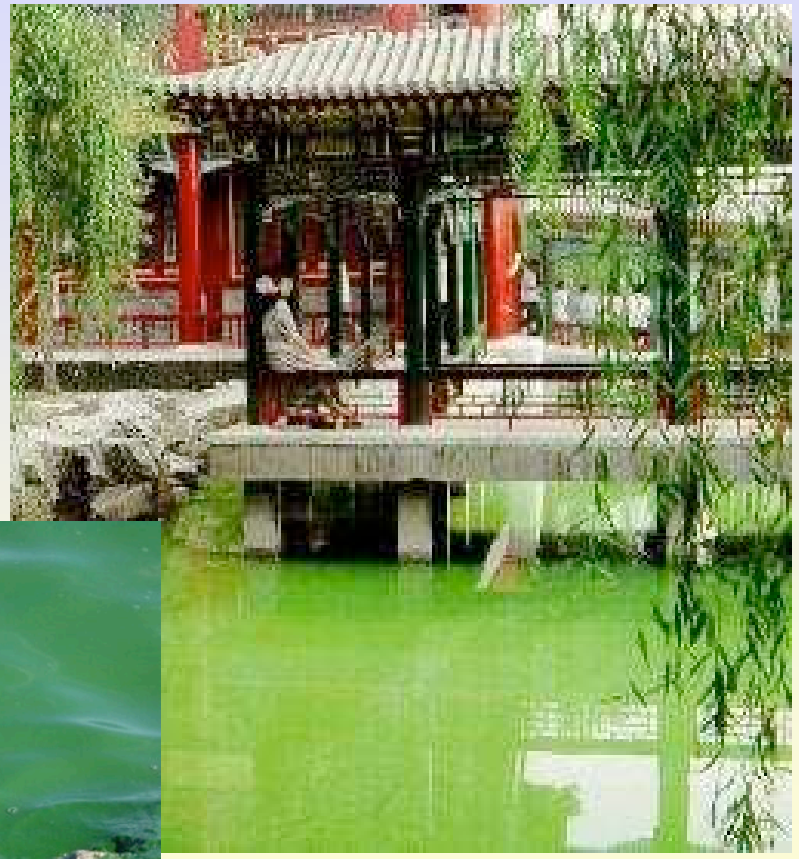


Blue-Green Algae: *Aphanizomenon* sp.



Blue-Green Algae: *Microcystis* sp.





Symbiotic Relationship between Blue-green Algae & Aquatic Macrophytes

Blue-green algae are often associated with aquatic macrophytes:

- macrophytes provide quiescent waters for blue-greens
- blue-greens' settling and decomposition provides NH_4-N for aquatic macrophytes

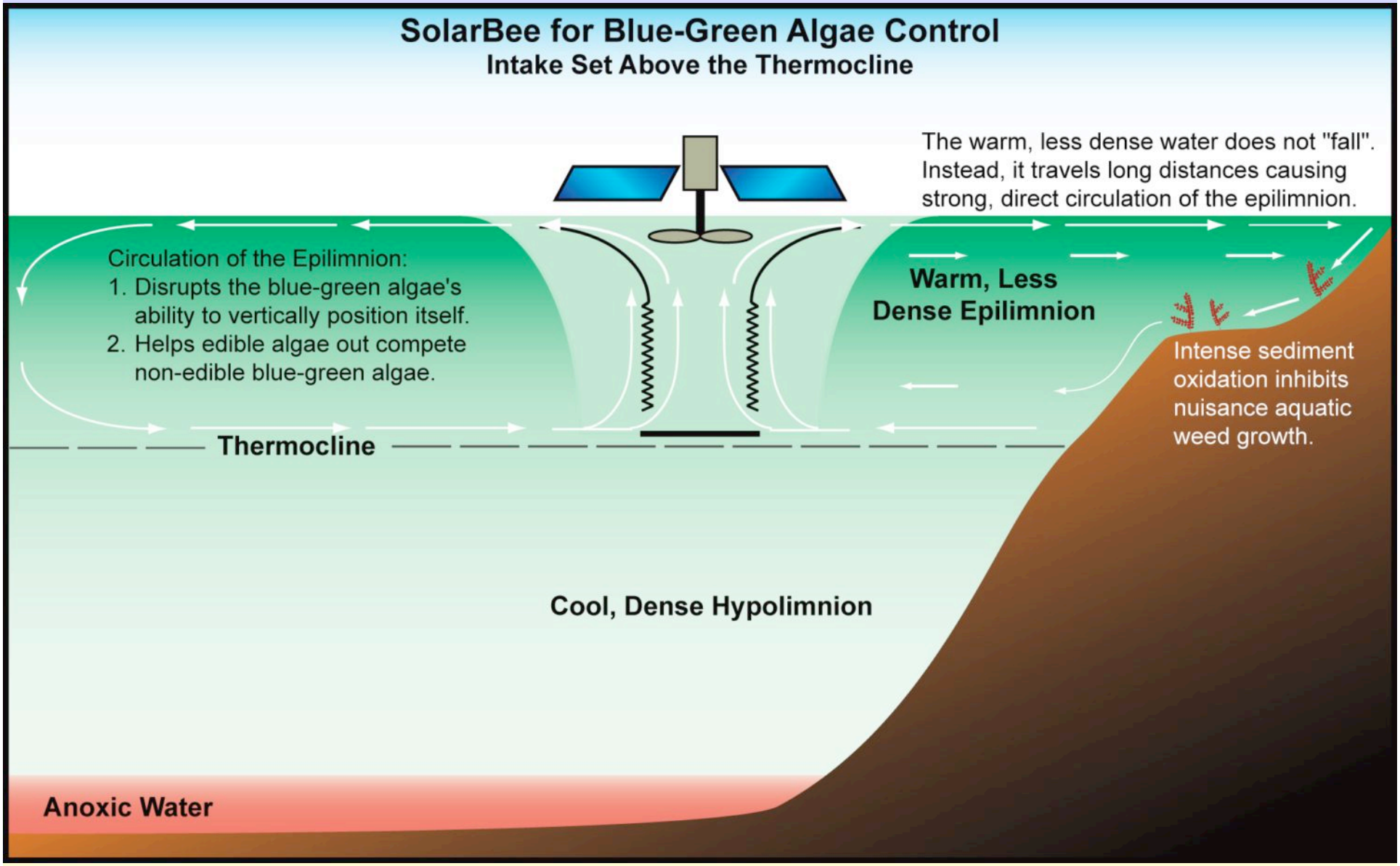
Invasive Aquatic Weed Control

Because many invasive aquatic weeds only use ammonia (NH_4) instead of nitrate (NO_3), SolarBee circulation likely[1] promotes N-limitation of aquatic weeds by:

1. *SolarBee's near-laminar return flow of oxygen-rich water back to the machine:*
   - oxidizes NH_4^+ to NO_3^- in the sediments, and

2. *Eliminating blue-green algae blooms:*
   - reduces N inputs to (and NH_4^+ generation in) the sediments.

[1] Eurasian watermilfoil problem solved in several lakes - with few remaining plants often yellowish & sickly, typical of nitrogen deficiency. Collaborative research with US Army Engineer Waterways Experiment Station, Vicksburg, MS, and Eau Galle Aquatic Ecology Laboratory, Spring Valley, WI, is planned for 2007.


SolarBee for Blue-Green Algae Control
Intake Set Above the Thermocline
The warm, less dense water does not "fall". Instead, it travels long distances causing strong, direct circulation of the epilimnion.
Circulation of the Epilimnion:
1. Disrupts the blue-green algae's ability to vertically position itself.
2. Helps edible algae out compete non-edible blue-green algae.
Warm, Less Dense Epilimnion
Intense sediment oxidation inhibits nuisance aquatic weed growth.
Thermocline
Cool, Dense Hypolimnion
Anoxic Water

Evidence of Effective Aquatic Weed Control by Sediment Oxidation of Ammonia

Empirical relationship between sediment ammonia-N concentrations and the presence of EWM in lakes,

Support of ammonia-N limitation hypothesis by leading aquatic weed scientists at the Army Corps of Engineers,

Effective aquatic weed reduction (as a secondary benefit) with SolarBees in about a dozen lakes:

- NY, CA, MI, WI, SD, and Canada
- current testing in CA, VT, WI

In the 130+ lakes and reservoirs where SolarBees have significantly improved water clarity, EWM has ***never*** moved in, and

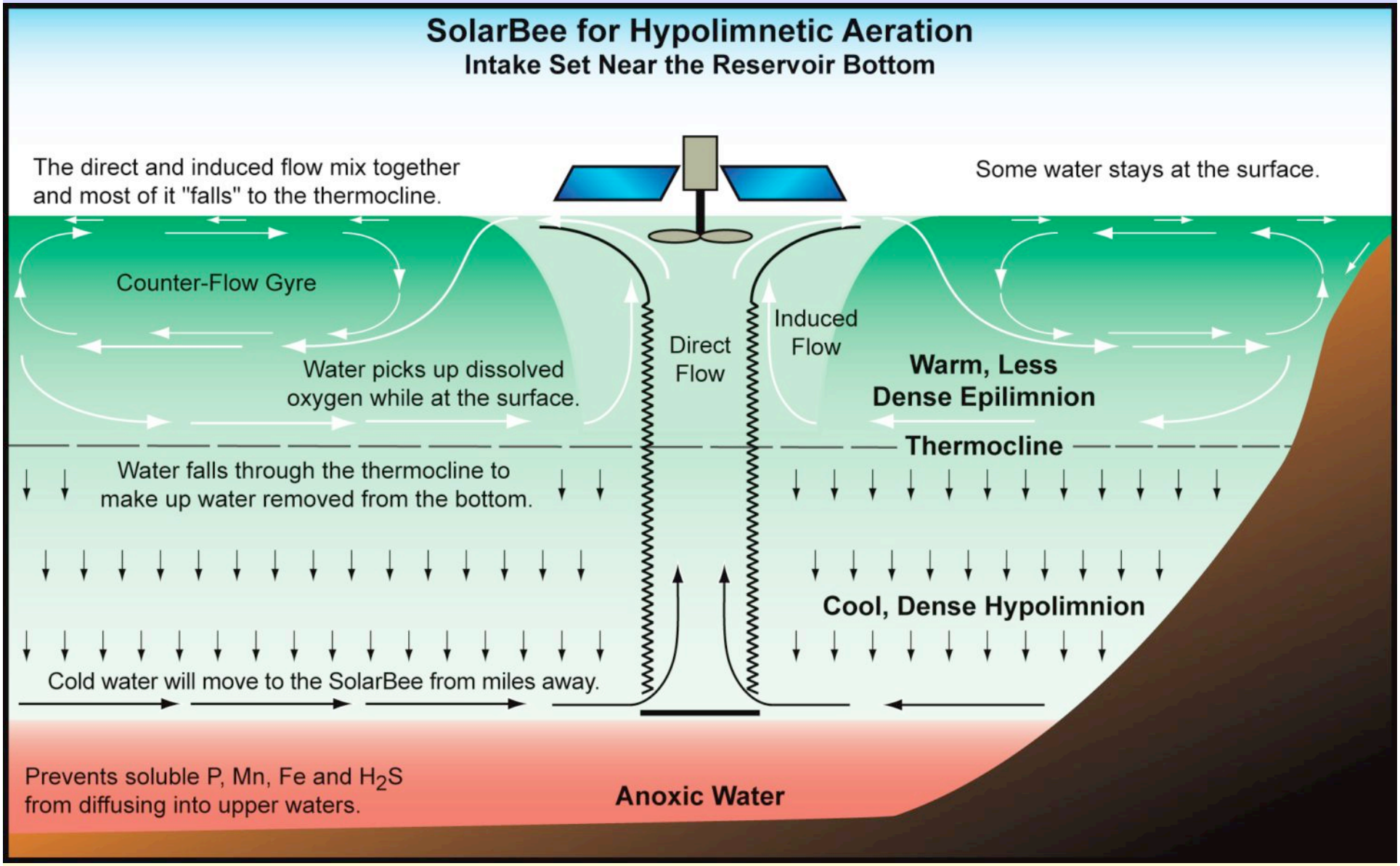
A Canadian company sells an up-flow, wind-powered circulator that has effectively eliminated EWM in 20-30 lakes and ponds (but with a small area affected per machine)

Evidence of ammonia-N limitation of EWM

Inorganic Chemical Release Prevention

When the SolarBee intake hose is set off the bottom, the near-laminar return flow of oxygen- water back to the machine “seals” the sediments, minimizing the release into the water column of:

- *soluble phosphorus*
- *iron*
- *manganese*
- *hydrogen sulfide*

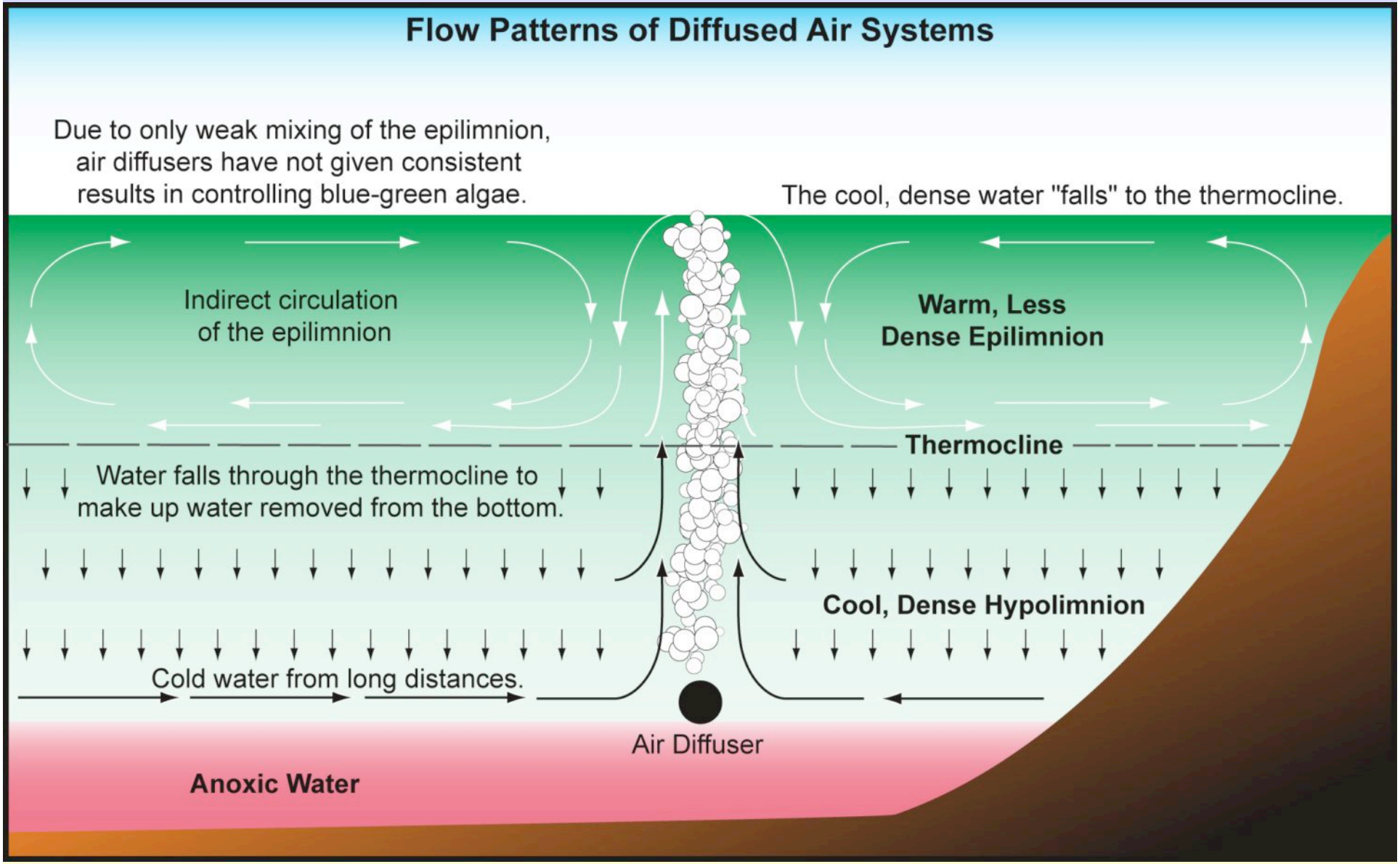

SolarBee for Hypolimnetic Aeration
Intake Set Near the Reservoir Bottom
The direct and induced flow mix together and most of it "falls" to the thermocline.
Some water stays at the surface.
Counter-Flow Gyre
Direct Flow
Induced Flow
Water picks up dissolved oxygen while at the surface.
Warm, Less Dense Epilimnion
Thermocline
Water falls through the thermocline to make up water removed from the bottom.
Cool, Dense Hypolimnion
Cold water will move to the SolarBee from miles away.
Prevents soluble P, Mn, Fe and H_2S from diffusing into upper waters.
Anoxic Water

Fishery Benefits

Fisheries are benefited because SolarBee circulation:

- provides higher DO throughout the water column,
- prevents seasonal fish kills,
- keeps littoral sediments oxidized for better spawning habitat,
- enhances food web by eliminating blue-green algae blooms, and
- lowers both pH and unionized ammonia concentrations.

Comparison with Aeration Systems



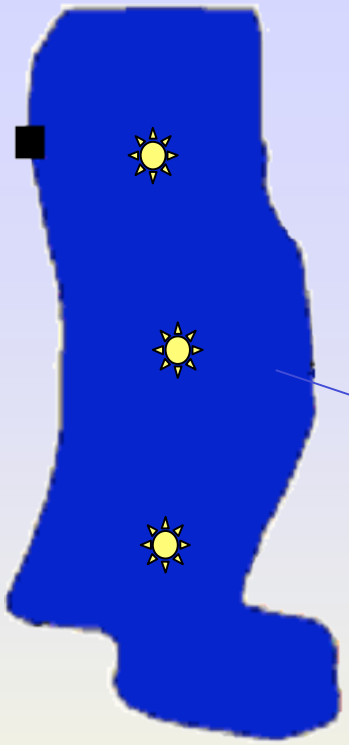
Although theoretically possible, Aeration has not been effective in preventing blue-green algae blooms in large lakes or reservoirs because:

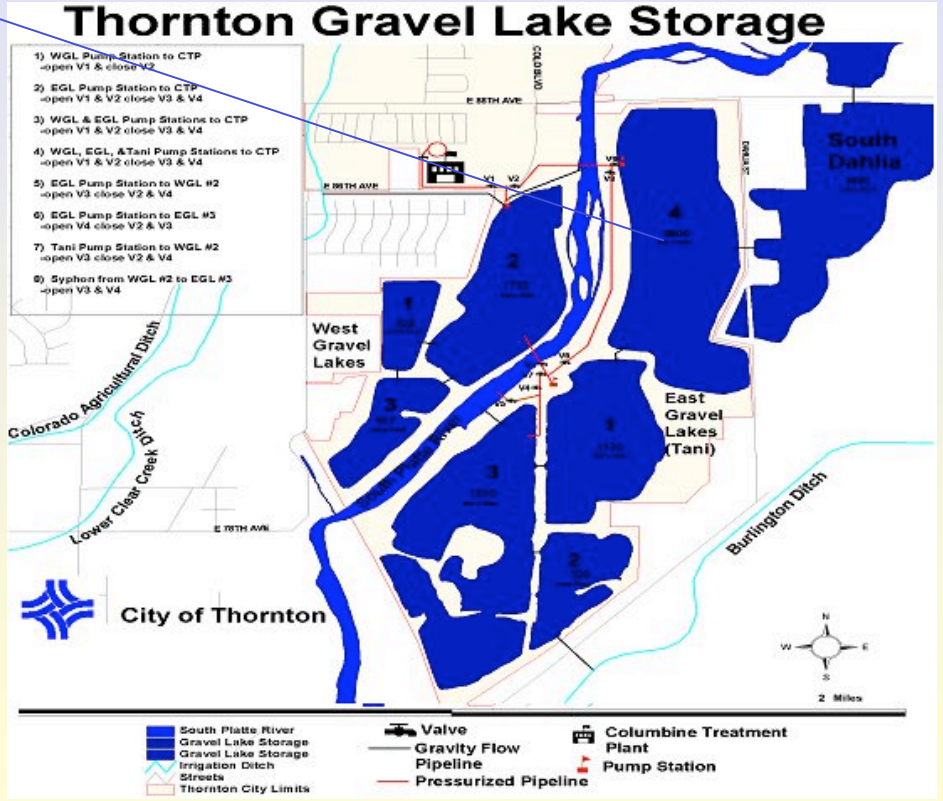
- incomplete coverage (blue-green blooms typically begin in shallow waters unaffected by deep water aerators)
- incomplete mixing (cold water sinks before sufficiently mixing surface waters)
- does not seal sediments (air bubbles go up in the water column, not down into sediments)
- can transport soluble N and P upward from sediments
- economics (expensive capital, maintenance and energy costs to do it right)

East Gravel lake, Thornton, CO

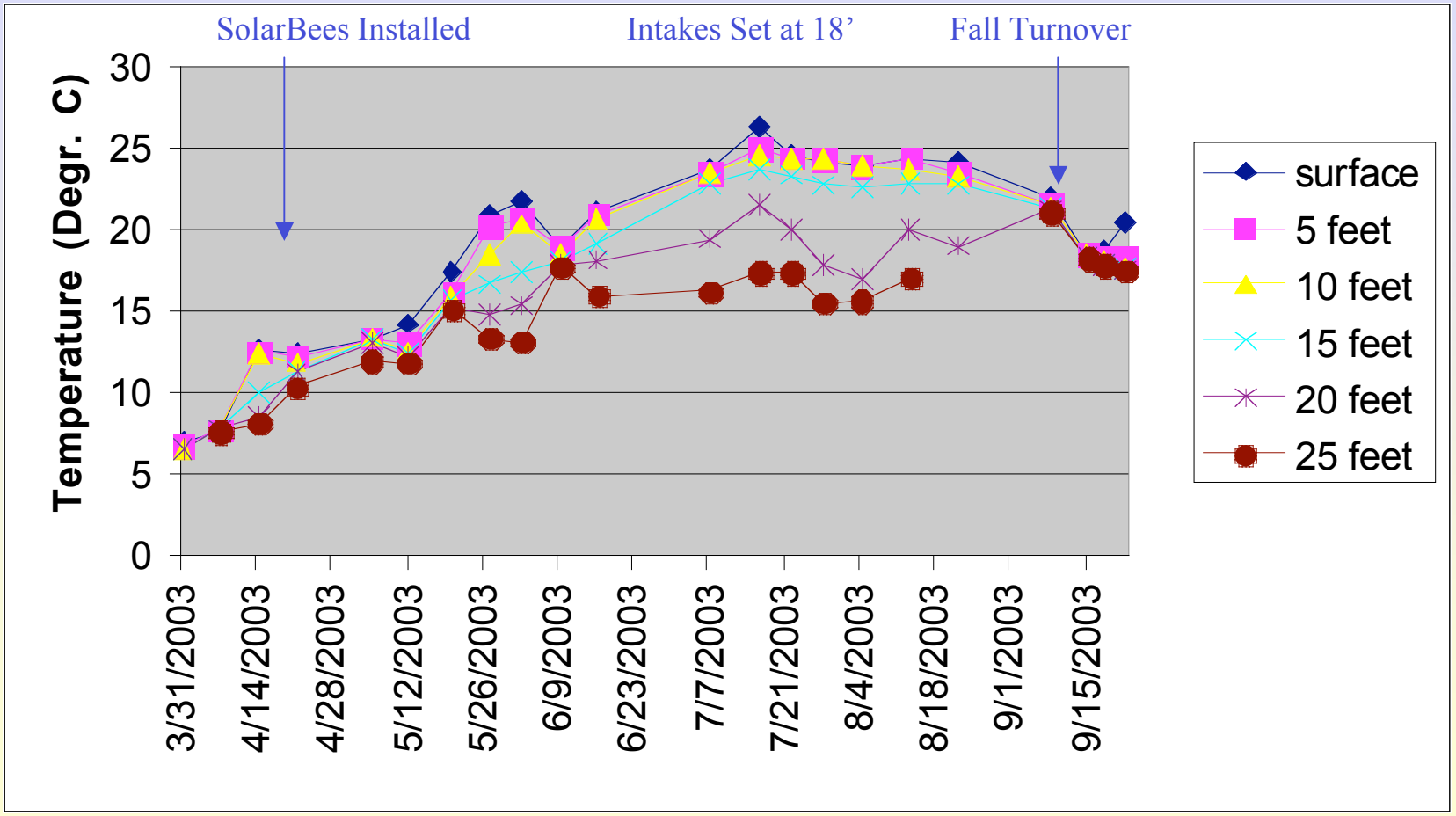
Surface area: 115 acres

- **Depth max.: ~ 30 ft**

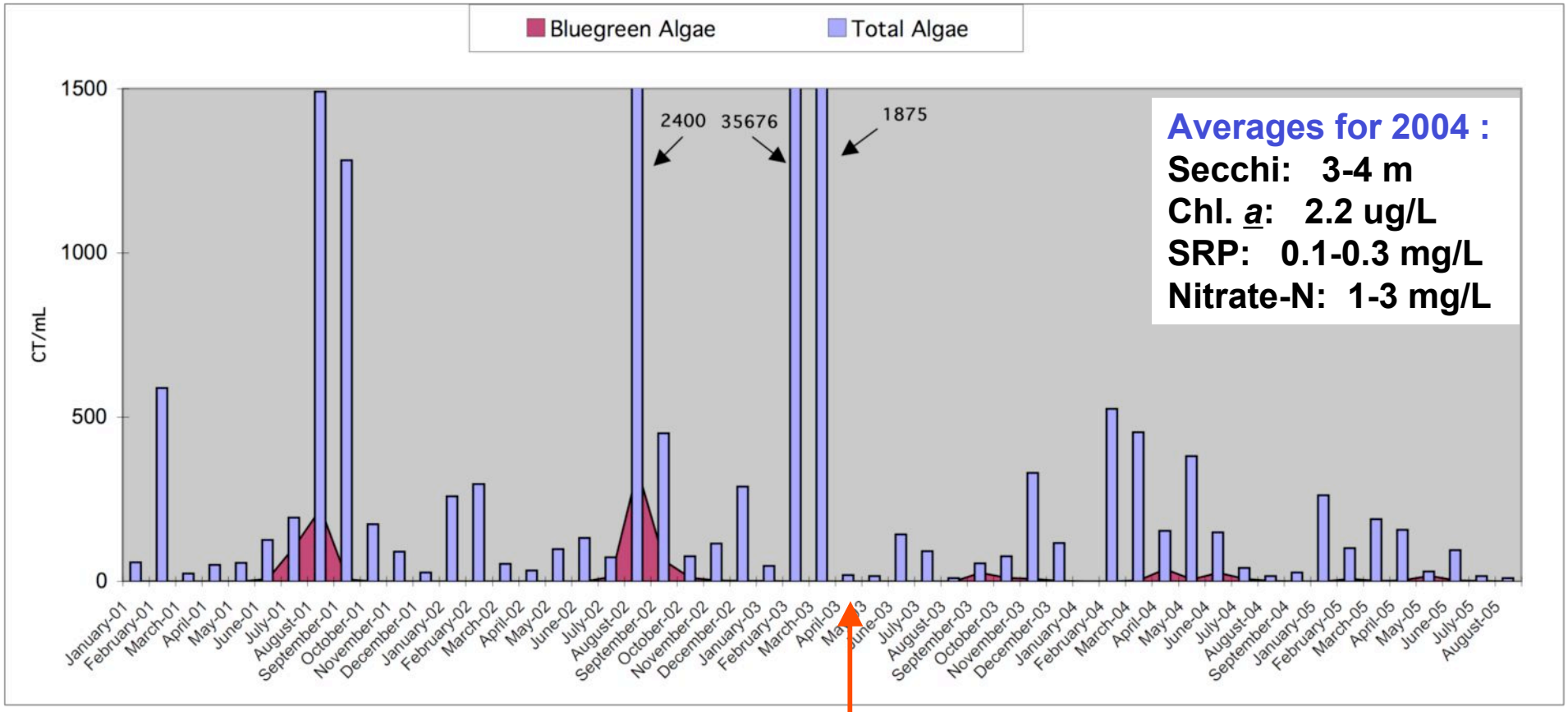




East Gravel Lake 4
2003 Temperature Profiles



Total algae & blue-green algae in East Gravel Lake 4
2001 – 2005 monthly averages



SolarBee Installation April 2003

Lake Palmdale, California

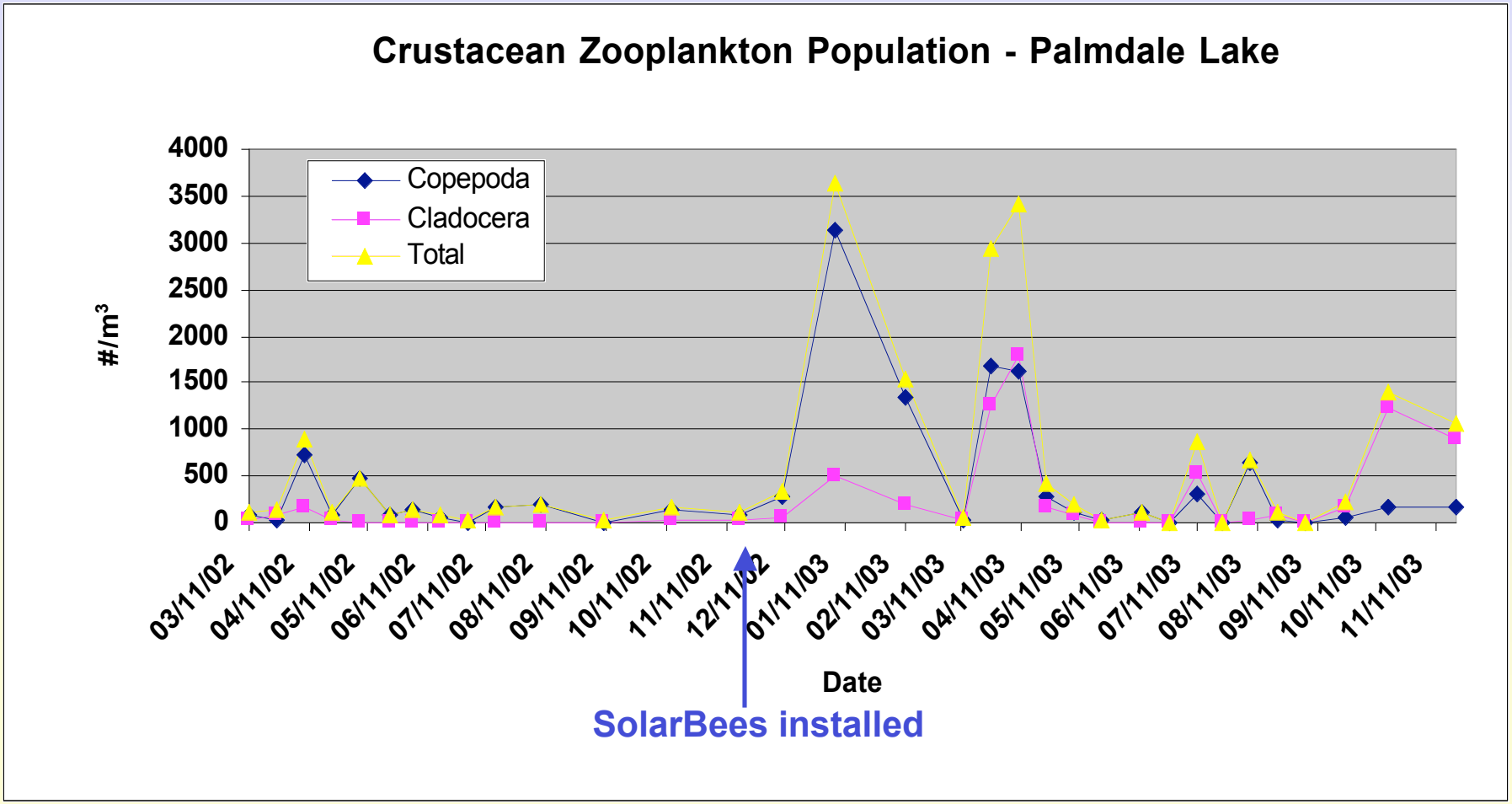
- Surface area: 234 acres
- Depth max. ~ 25 ft

- Blue-green algae (BGA)
- Taste and odor associated to BGA
- High chemical treatment costs

7 SolarBees installed in November 2003

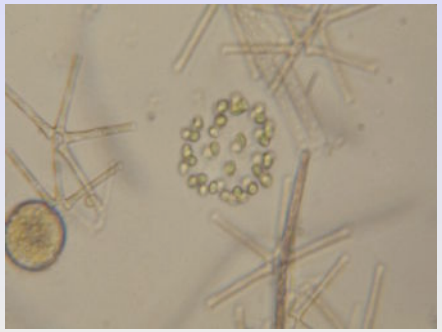

Palmdale Lake, CA
Area = 234 acres
Volume = 4129 AF
Max. depth = 25 ft.
12 4:03PM

Palmdale Lake
Zooplankton (2002-3)

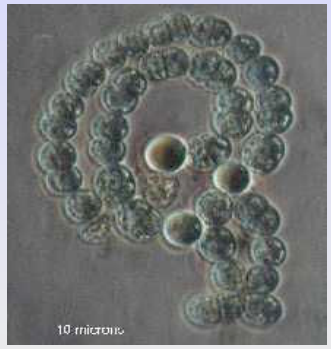


Consumption vs. Decomposition Algal Pathways

N + P +  + warm temp.



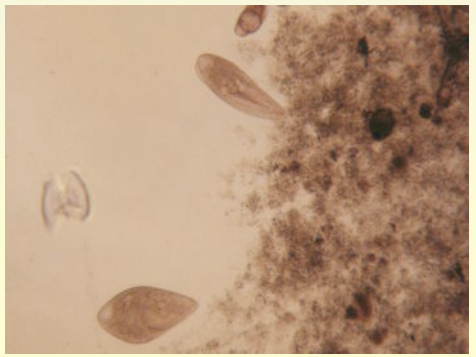
Edible algae (e.g., diatoms, greens, etc.)



Non-edible blue-greens

Consumption

Decomposition



Fishermen at Lake Palmdale, CA

Palmdale Lake: Data Summary

	Average	Minimum	Maximum
2002 – No lake circulation			
pH	**8.79**	**8.24**	**9.12**
Temperature ^{o}C	**19.1**	**12.6**	**24.8**
Turbidity, NTU	**6.66**	**2.7**	**9.3**
Chlorophyll a	**13.5**	**5.3**	**24.9**
TSI (Chl a)	**56**	**47**	**62**
Trophic State	**Eutrophic**	**Mesotrophic**	**Eutrophic**
Secchi depth, ft	**3**	**3**	**4**
2003 – Lake circulation with SolarBees			
pH	**8.46**	**8.13**	**8.97**
Temperature ^{o}C	**20.3**	**13.6**	**25.6**
Turbidity, NTU	**5.21**	**0.7**	**12**
Chlorophyll a	**6.6**	**2**	**20.1**
TSI (Chl a)	**49**	**37**	**60**
Trophic State	**Mesotrophic**	**Oligotrophic**	**Eutrophic**
Secchi depth, ft	**6**	**3**	**14**

Palmdale Lake: Data Summary

	Average	Minimum	Maximum
2002 – No lake circulation			
pH	8.79	8.24	9.12
Temperature ^{o}C	19.1	12.6	24.8
Turbidity, NTU	6.66	2.7	9.3
Chlorophyll a	13.5	5.3	24.9
TSI (Chl a)	56	47	62
Trophic State	Eutrophic	Mesotrophic	Eutrophic
Secchi depth, ft	3	3	4
2003 – Lake circulation with SolarBees			
pH	8.46	8.13	8.97
Temperature ^{o}C	20.3	13.6	25.6
Turbidity, NTU	5.21	0.7	12
Chlorophyll a	6.6	2	20.1
TSI (Chl a)	49	37	60
Trophic State	Mesotrophic	Oligotrophic	Eutrophic
Secchi depth, ft	6	3	14

Note: 2005 chlorophyll *a* concentrations remained about 3 ug/L

Palmdale Lake: Data Summary

	Average	Minimum	Maximum
2002 – No lake circulation			
pH	8.79	8.24	9.12
Temperature °C	19.1	12.6	24.8
Turbidity, NTU	6.66	2.7	9.3
Chlorophyll a	13.5	5.3	24.9
TSI (Chl a)	56	47	62
Trophic State	Eutrophic	Mesotrophic	Eutrophic
Secchi depth, ft	3	3	4
2003 – Lake circulation with SolarBees			
pH	8.46	8.13	8.97
Temperature °C	20.3	13.6	25.6
Turbidity, NTU	5.21	0.7	12
Chlorophyll a	6.6	2	20.1
TSI (Chl a)	49	37	60
Trophic State	Mesotrophic	Oligotrophic	Eutrophic
Secchi depth, ft	6	3	14

Palmdale Lake: Data Summary

	Average	Minimum	Maximum
2002 – No lake circulation			
pH	8.79	8.24	9.12
Temperature ^{o}C	19.1	12.6	24.8
Turbidity, NTU	6.66	2.7	9.3
Chlorophyll a	13.5	5.3	24.9
TSI (Chl a)	56	47	62
Trophic State	Eutrophic	Mesotrophic	Eutrophic
Secchi depth, ft	3	3	4
2003 – Lake circulation with SolarBees			
pH	8.46	8.13	8.97
Temperature ^{o}C	20.3	13.6	25.6
Turbidity, NTU	5.21	0.7	12
Chlorophyll a	6.6	2	20.1
TSI (Chl a)	49	37	60
Trophic State	Mesotrophic	Oligotrophic	Eutrophic
Secchi depth, ft	6	3	14

Duck Lake (Denver, CO) May 27, 2005

No ducks swimming,
only a few dead ducks floating

Stagnant water, high surface tension,
no fish visible,
lake has unhealthy atmosphere

Duck Lake (Denver, CO) June 9, 2005

Ducks & geese, young & old,
swimming and bathing in lake

No stagnant water,
schools of little fish swimming,
lake has a healthy atmosphere

Duck Lake (Denver, CO) June 9, 2005

Composite Lake Management Benefits

The application of SolarBees in freshwater lakes and reservoirs have consistently given the following general results:

- Controlled the incidence of summer blue-green algal blooms,
- Substantially less chemicals were used to treat the lakes, resulting in significant savings,
- Secchi disk transparency, DO, and pH all improved,
- Zooplankton populations increased, helping reduce chlorophyll *a* concentrations,
- Fish spawning improved, and seasonal fish kills eliminated,
- Eurasian watermilfoil dramatically reduced under and around units, with remaining plants often yellowish and sickly.

Without SolarBees

Red = detrimental
Blue = beneficial

N & P Input

+

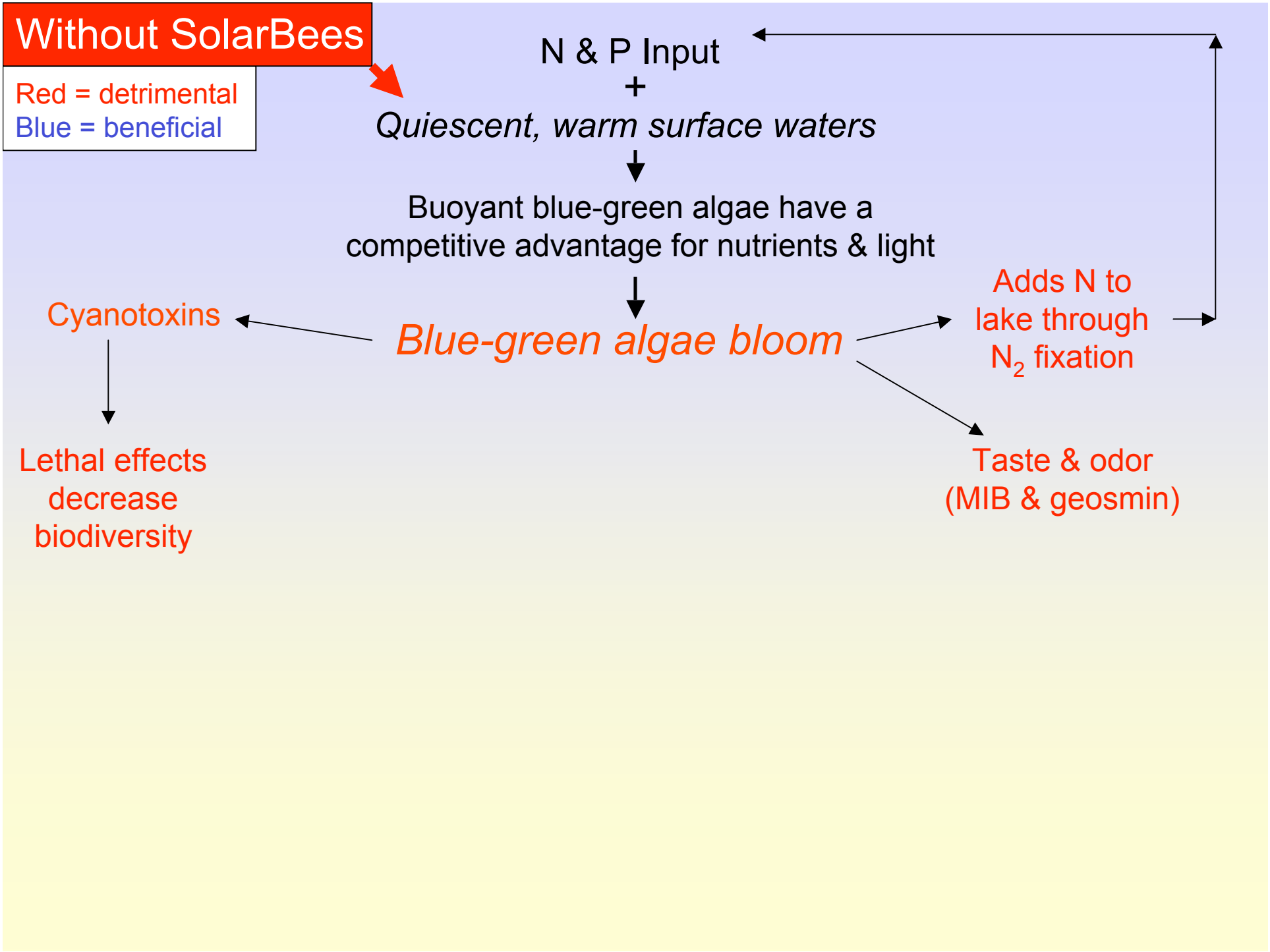
Quiescent, warm surface waters

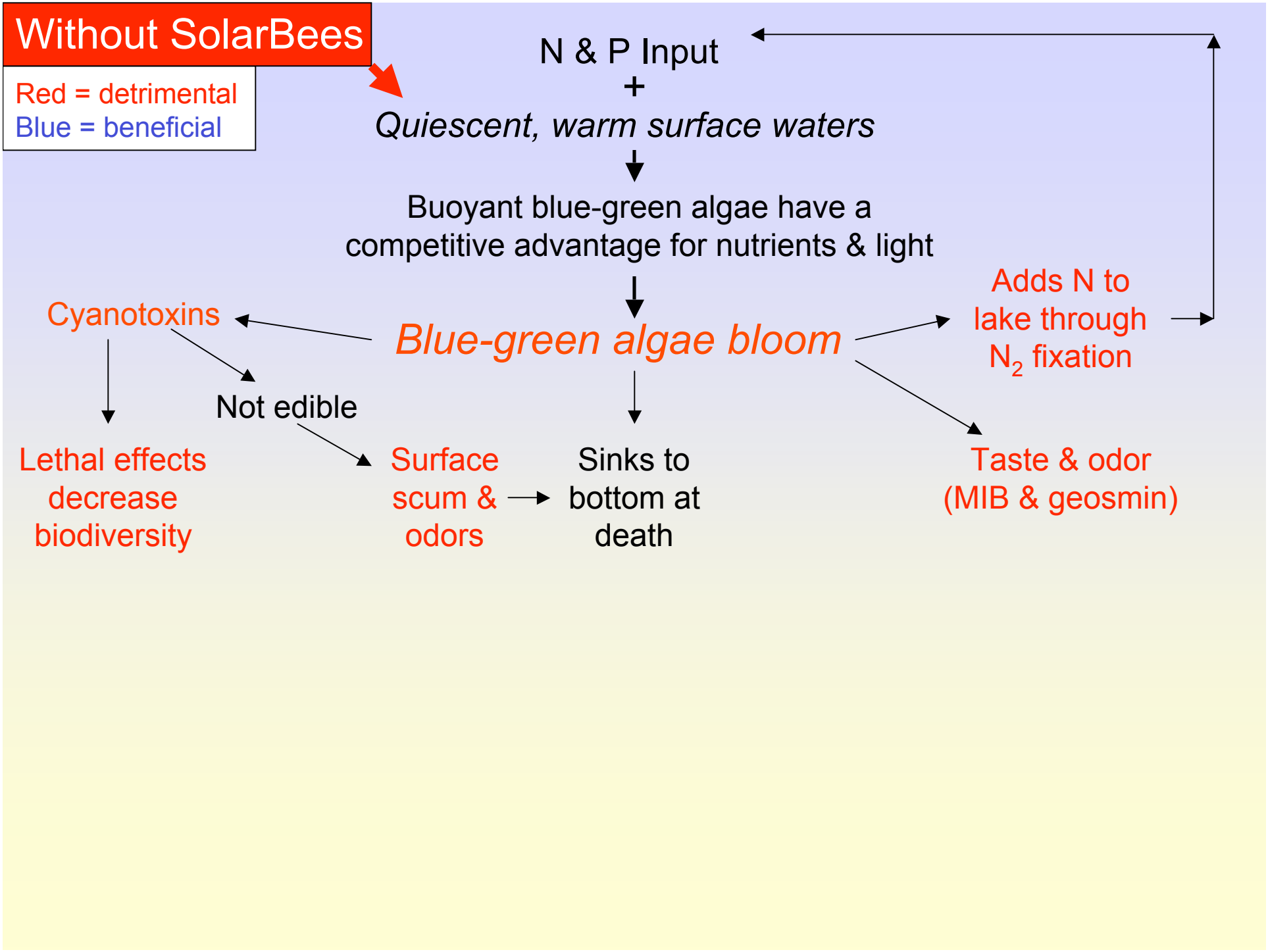
↓

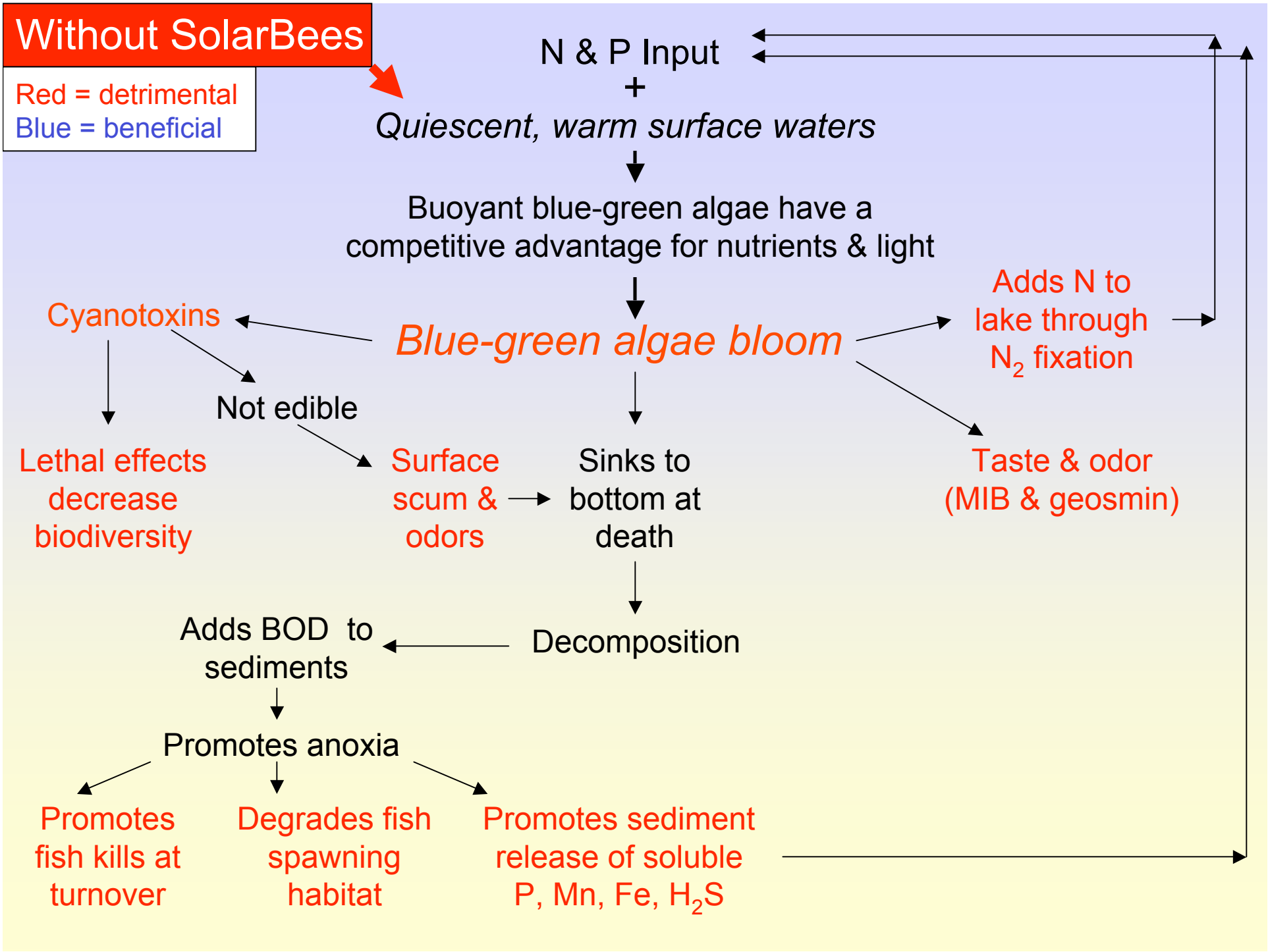
Buoyant blue-green algae have a competitive advantage for nutrients & light

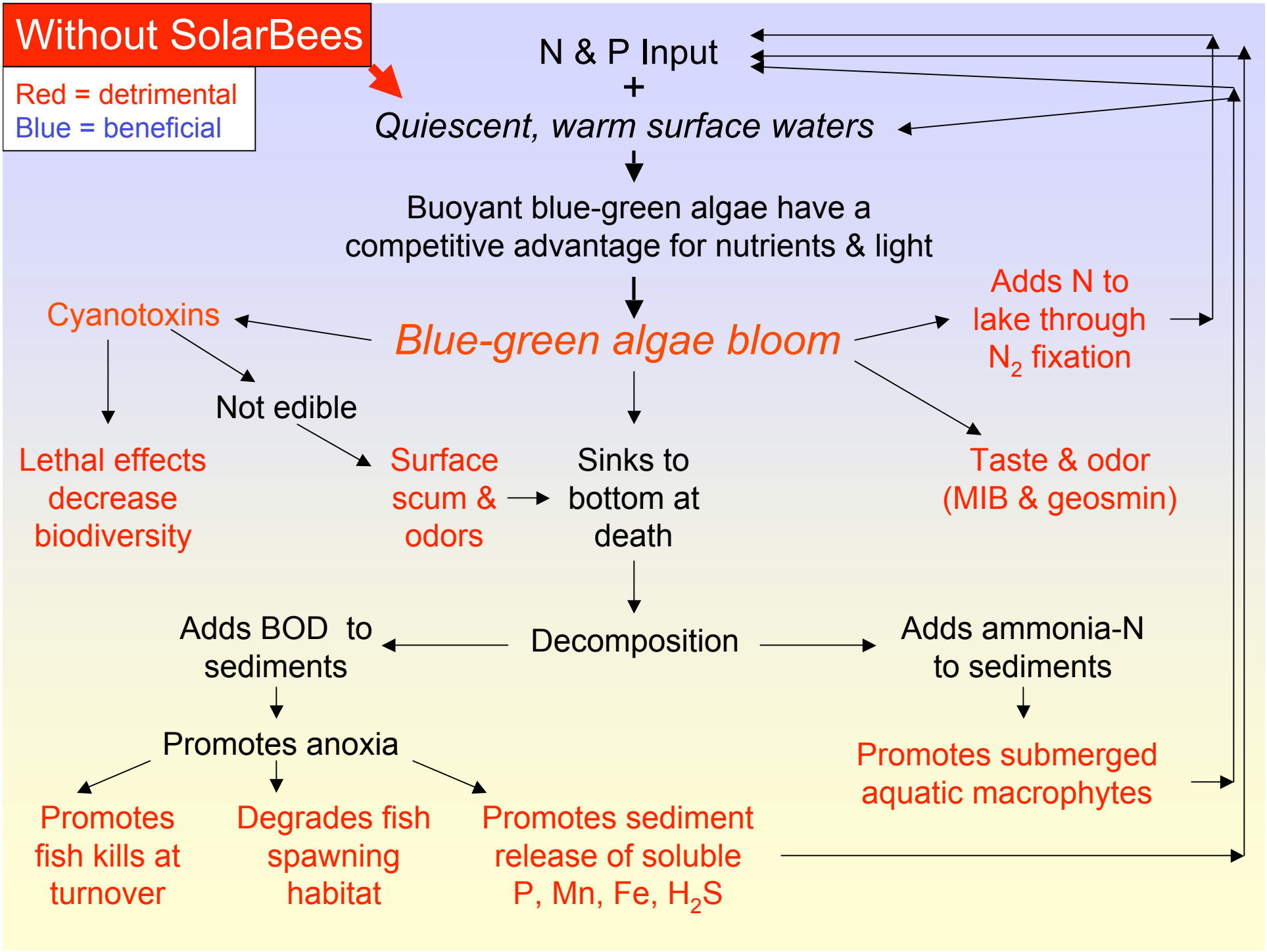
↓

Blue-green algae bloom


Without SolarBees
Red = detrimental
Blue = beneficial
N & P Input
+
Quiescent, warm surface waters
Buoyant blue-green algae have a competitive advantage for nutrients & light
Blue-green algae bloom
Cyanotoxins
Lethal effects decrease biodiversity
Adds N to lake through N_2 fixation
Taste & odor (MIB & geosmin)


Without SolarBees
Red = detrimental
Blue = beneficial
N & P Input
+
Quiescent, warm surface waters
Buoyant blue-green algae have a competitive advantage for nutrients & light
Blue-green algae bloom
Cyanotoxins
Not edible
Lethal effects decrease biodiversity
Surface scum & odors
Sinks to bottom at death
Adds N to lake through N_2 fixation
Taste & odor (MIB & geosmin)


Without SolarBees
Red = detrimental
Blue = beneficial
N & P Input
+
Quiescent, warm surface waters
Buoyant blue-green algae have a competitive advantage for nutrients & light
Blue-green algae bloom
Cyanotoxins
Not edible
Lethal effects decrease biodiversity
Surface scum & odors
Sinks to bottom at death
Adds N to lake through N_2 fixation
Taste & odor (MIB & geosmin)
Decomposition
Adds BOD to sediments
Promotes anoxia
Promotes fish kills at turnover
Degrades fish spawning habitat
Promotes sediment release of soluble P, Mn, Fe, H_2S


Without SolarBees
Red = detrimental
Blue = beneficial
N & P Input
+
Quiescent, warm surface waters
Buoyant blue-green algae have a competitive advantage for nutrients & light
Blue-green algae bloom
Cyanotoxins
Not edible
Lethal effects decrease biodiversity
Surface scum & odors
Sinks to bottom at death
Adds N to lake through N_2 fixation
Taste & odor (MIB & geosmin)
Decomposition
Adds BOD to sediments
Promotes anoxia
Promotes fish kills at turnover
Degrades fish spawning habitat
Promotes sediment release of soluble P, Mn, Fe, H_2S
Adds ammonia-N to sediments
Promotes submerged aquatic macrophytes

With SolarBees

Red = detrimental
Blue = beneficial

N & P Input

+

Horizontally & vertically circulating epilimnetic (surface) waters

Disrupts blue-greens' habitat
(eliminates competitive advantage)

↓

Prevents ***blue-green blooms***

With SolarBees

Red = detrimental
Blue = beneficial

N & P Input
+
Horizontally & vertically circulating epilimnetic (surface) waters

Disrupts blue-greens' habitat
(eliminates competitive advantage)

↓

Prevents ***blue-green blooms***

↓

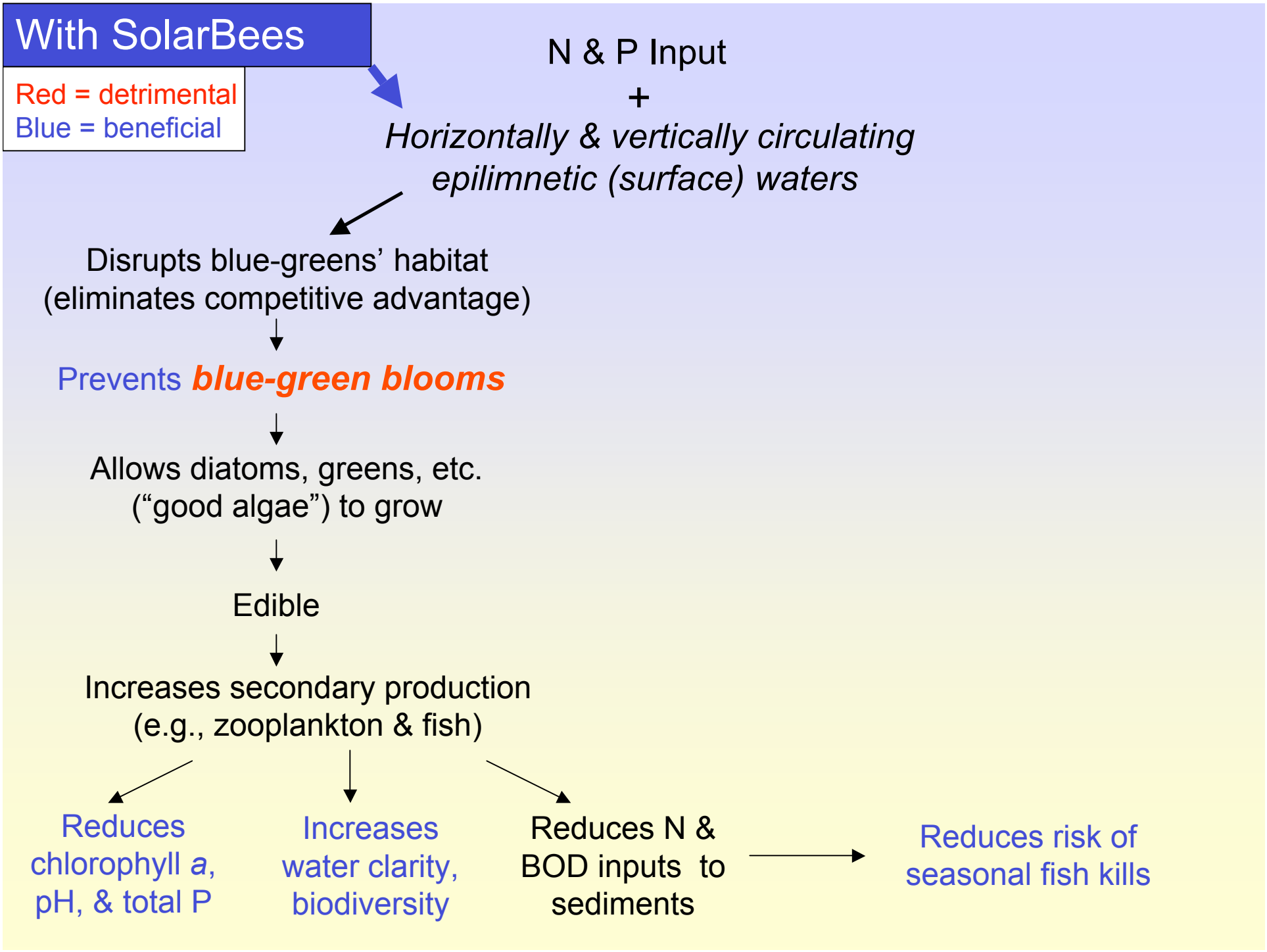
Allows diatoms, greens, etc.
("good algae") to grow

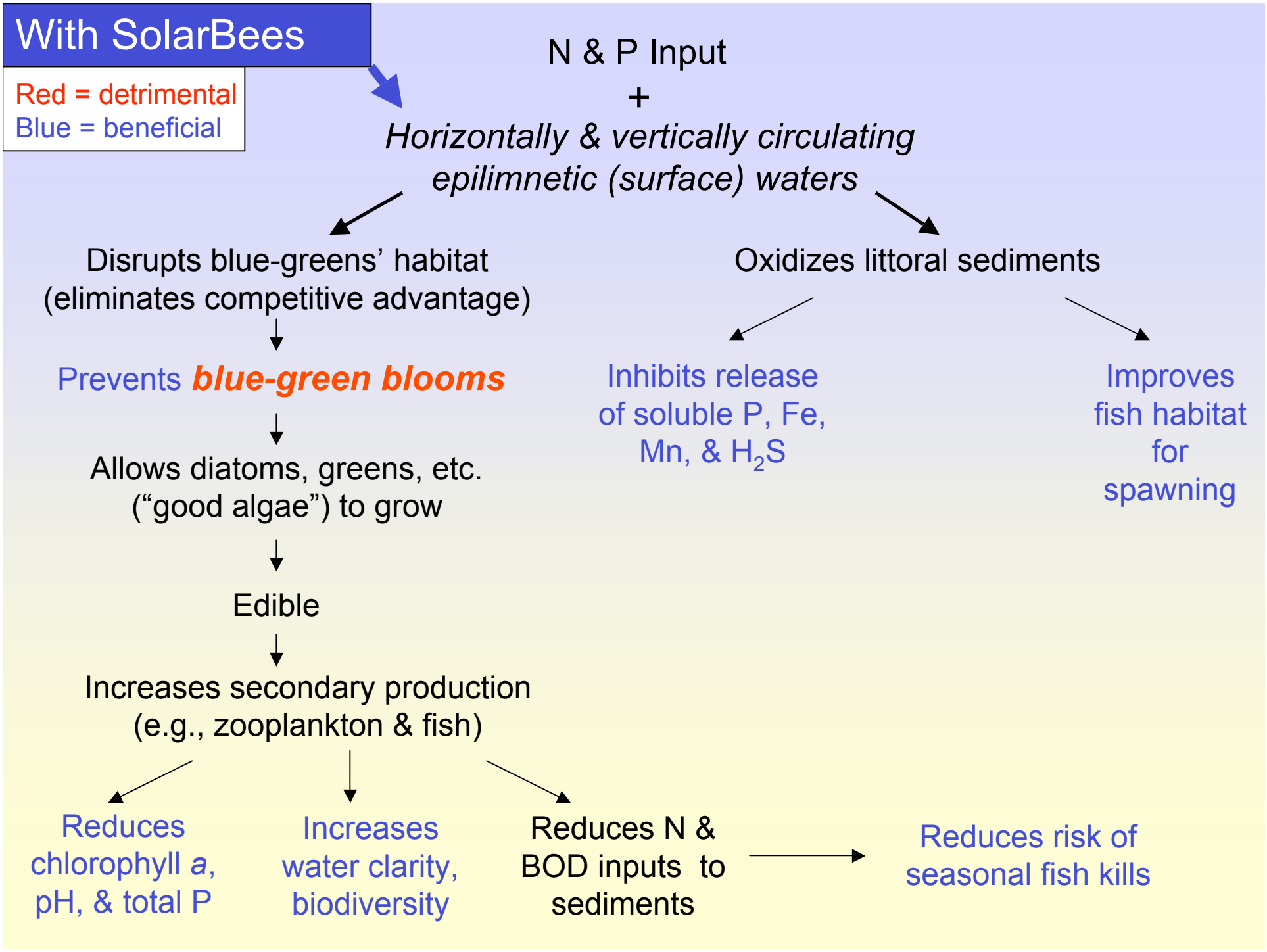
↓

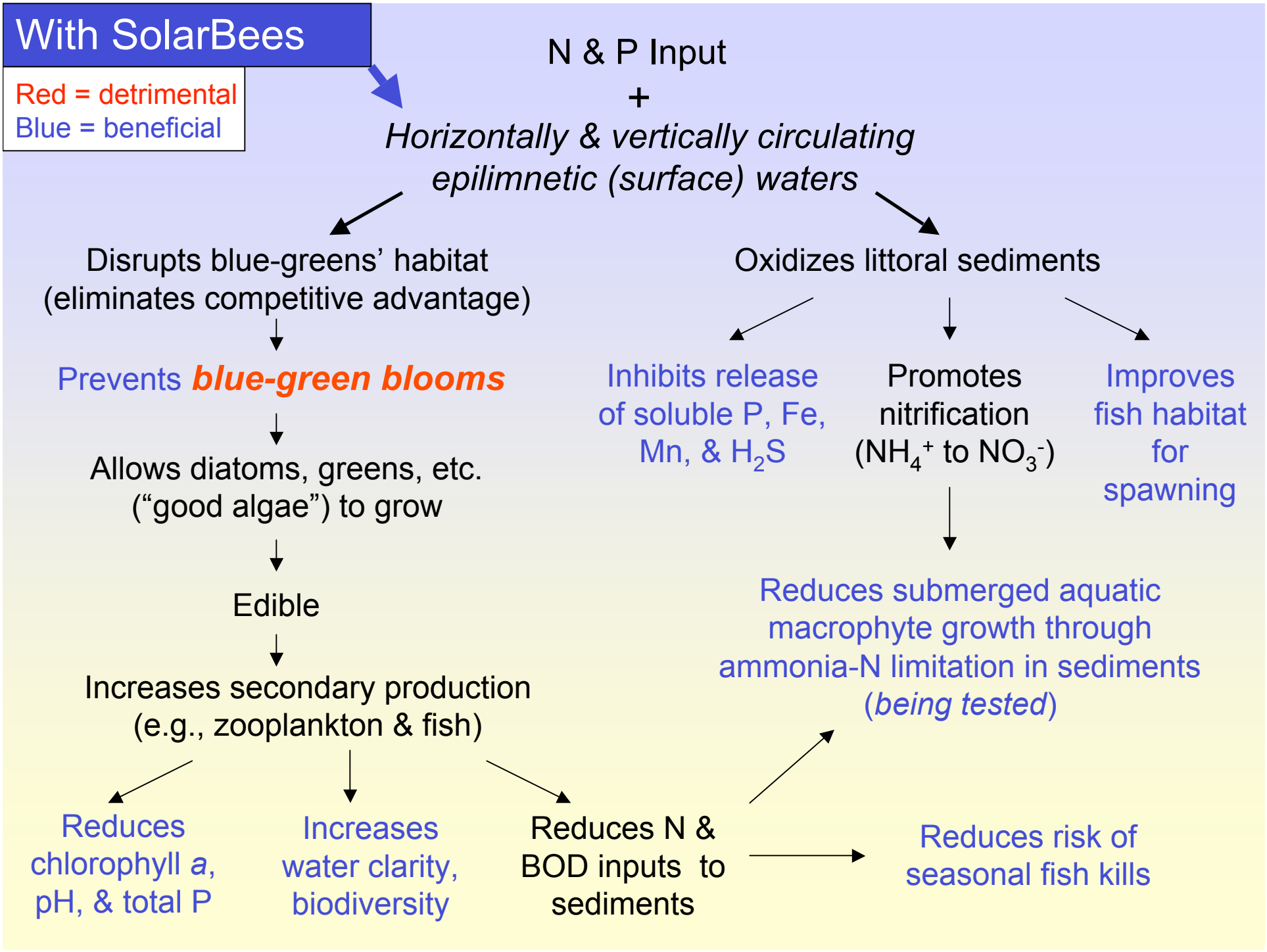
Edible

↓

Increases secondary production
(e.g., zooplankton & fish)


With SolarBees
Red = detrimental
Blue = beneficial
N & P Input
+
Horizontally & vertically circulating epilimnetic (surface) waters
Disrupts blue-greens' habitat (eliminates competitive advantage)
Prevents blue-green blooms
Allows diatoms, greens, etc. ("good algae") to grow
Edible
Increases secondary production (e.g., zooplankton & fish)
Reduces chlorophyll a, pH, & total P
Increases water clarity, biodiversity
Reduces N & BOD inputs to sediments
Reduces risk of seasonal fish kills


With SolarBees
Red = detrimental
Blue = beneficial
N & P Input
+
Horizontally & vertically circulating epilimnetic (surface) waters
Disrupts blue-greens' habitat (eliminates competitive advantage)
Prevents blue-green blooms
Allows diatoms, greens, etc. ("good algae") to grow
Edible
Increases secondary production (e.g., zooplankton & fish)
Reduces chlorophyll a, pH, & total P
Increases water clarity, biodiversity
Reduces N & BOD inputs to sediments
Reduces risk of seasonal fish kills
Oxidizes littoral sediments
Inhibits release of soluble P, Fe, Mn, & H_2S
Improves fish habitat for spawning


With SolarBees
Red = detrimental
Blue = beneficial
N & P Input
+
Horizontally & vertically circulating epilimnetic (surface) waters
Disrupts blue-greens' habitat (eliminates competitive advantage)
Prevents blue-green blooms
Allows diatoms, greens, etc. ("good algae") to grow
Edible
Increases secondary production (e.g., zooplankton & fish)
Reduces chlorophyll a, pH, & total P
Increases water clarity, biodiversity
Reduces N & BOD inputs to sediments
Oxidizes littoral sediments
Inhibits release of soluble P, Fe, Mn, & H_2S
Promotes nitrification (NH_4^+ to NO_3^-)
Improves fish habitat for spawning
Reduces submerged aquatic macrophyte growth through ammonia-N limitation in sediments (being tested)
Reduces risk of seasonal fish kills

Additional Lake Management Benefits of SolarBee Circulation

Public health

- Eliminates toxic blue-green algae blooms,
- Enhanced exposure to direct solar radiation reduces pathogens and harmful bacteria in surface waters,
- Disrupts surface tension to reduce habitat for mosquito breeding,
- Eliminates stagnant areas of a lake.

Economic

- Solar-powered 24/7, so no need for land-based power source,
- Minimizes need for chemicals or mechanical harvesting,
- Usually less than10% the cost of chemicals over a 25-year period

Pump Systems, Inc

- ***In water moving business since 1978***
- ***Designed SolarBee in 1998; over 900+ installations since 2000***
- ***Factory and Corporate Headquarters, Dickinson, ND***
  - 55 employees, over 80% of business is in the SolarBee Division
  - 7 engineers, 3 biologists,
  - 7 installation crews
- ***Regional Offices in CO, CA, DE, FL, MN, & WA***
  - Hockessin, DE: Bruce Richards, PhD, Northeast Regional Manager
  - Denver, CO: Chris Knud-Hansen, PhD, Limnologist & Certified Lake Manager
- ***SolarBee Division of Pump Systems is committed to being the world leader in improving water quality with solar energy***

SolarBee-induced circulation has been effective in over 100 lakes and reservoirs since 2000

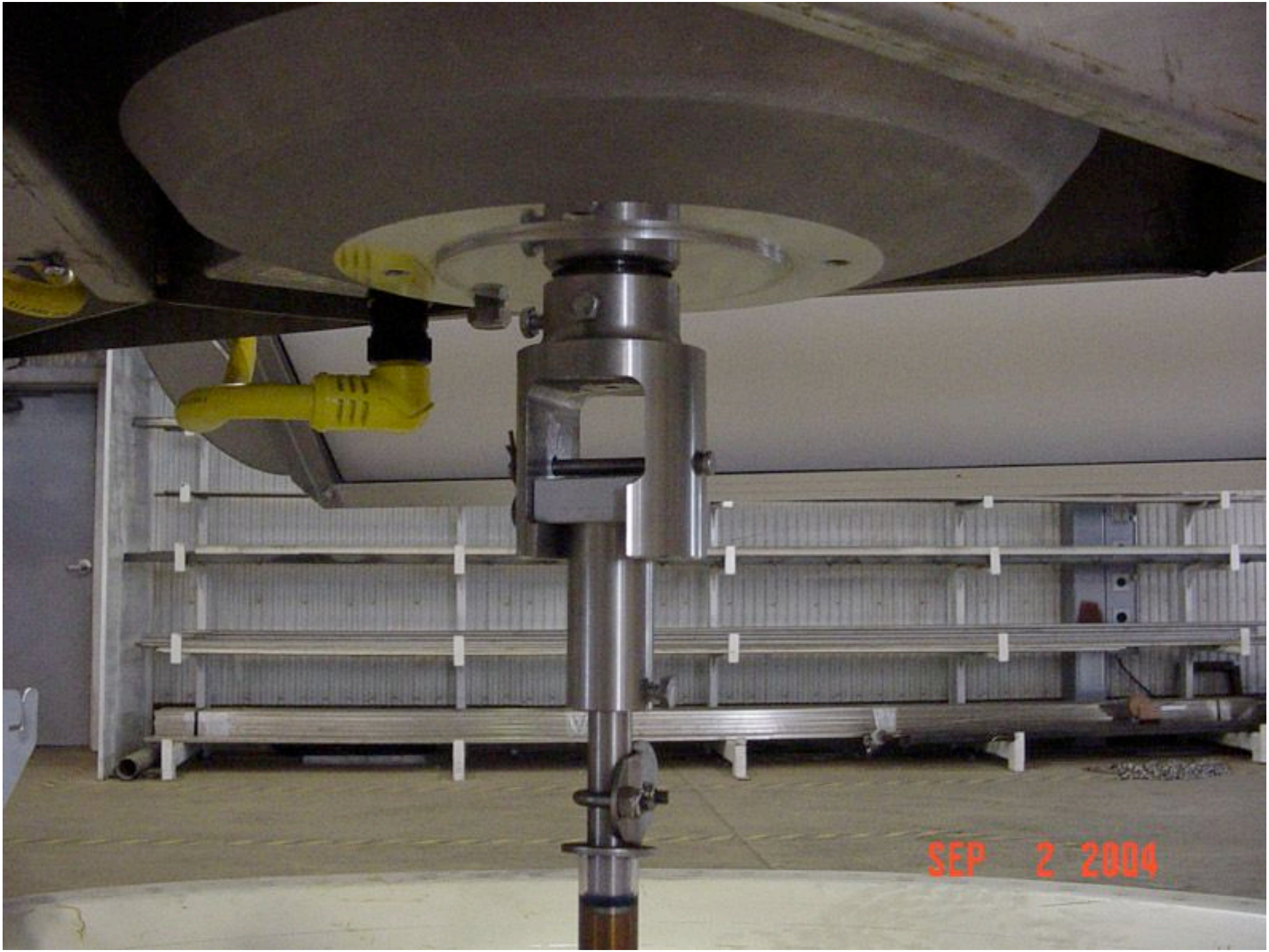
Freshwater Locations: Types of Lakes

	Number of Lakes
• Raw water storage reservoirs	41
• Private lakes	21
• City park lakes	8
• Irrigation ponds	6
• Marinas and coves	6
• Power plant cooling lakes	4
• Catfish ponds (one location)	4
• Effluent storage ponds	2
• Percolation ponds	2
• Treated potable water reservoirs	2
• Evaporation ponds	1
• Fish hatcheries	1

SolarBee-related Independent Studies

- ***OHIO EPA 104G PERSONNEL Dye Test***
- ***US BUREAU OF RECLAMATION Evaporation Study at Salton Sea***
- ***SAN FRANCISCO P.U.C. Potable Water Mixer Study***
- ***CPUC Wastewater Optimization Program***
- ***SMUD Customer Advanced Technology Program for homeowners' lake in Elk Grove***
- ***California Energy Commissions Peak Load Reduction Program***
- ***Minnesota Alum Application Test for P Removal in wastewater.***
- ***U. of Delaware (on-going mosquito test)***
- ***U. of North Carolina (2006 blue-green algae control)***
- **Army Corps of Engineers (2007 aquatic macrophyte control study)**
- **Army Corps of Engineers, Chicago (due dilligence)**
- **Detroit Beach (2006 coliform study)**


16
17
15


SEP 2 2004

Electronic Controller located onboard the SolarBee

Plastic NEMA 4X Enclosure

Approximate Dimensions: 12" Height X 10" Width X 7" Depth

Inputs/Outputs: Photovoltaic (PV) modules (input only), battery lead, brushless motor lead, and optional onshore power box lead.

Bottom circuit board (charge controller) - primary function is to monitor and direct power to and from the battery. Also supplies power to the top circuit board.

Top circuit board (motor controller) - primary function is to communicate with the brushless motor and control its operation.


SolarBee
Reservoir and Pond Circulators
"Cleaner Water at Less Cost"
www.solarbee.com
1-866-437-8076
AUG 17 2004


MAY 28 2004

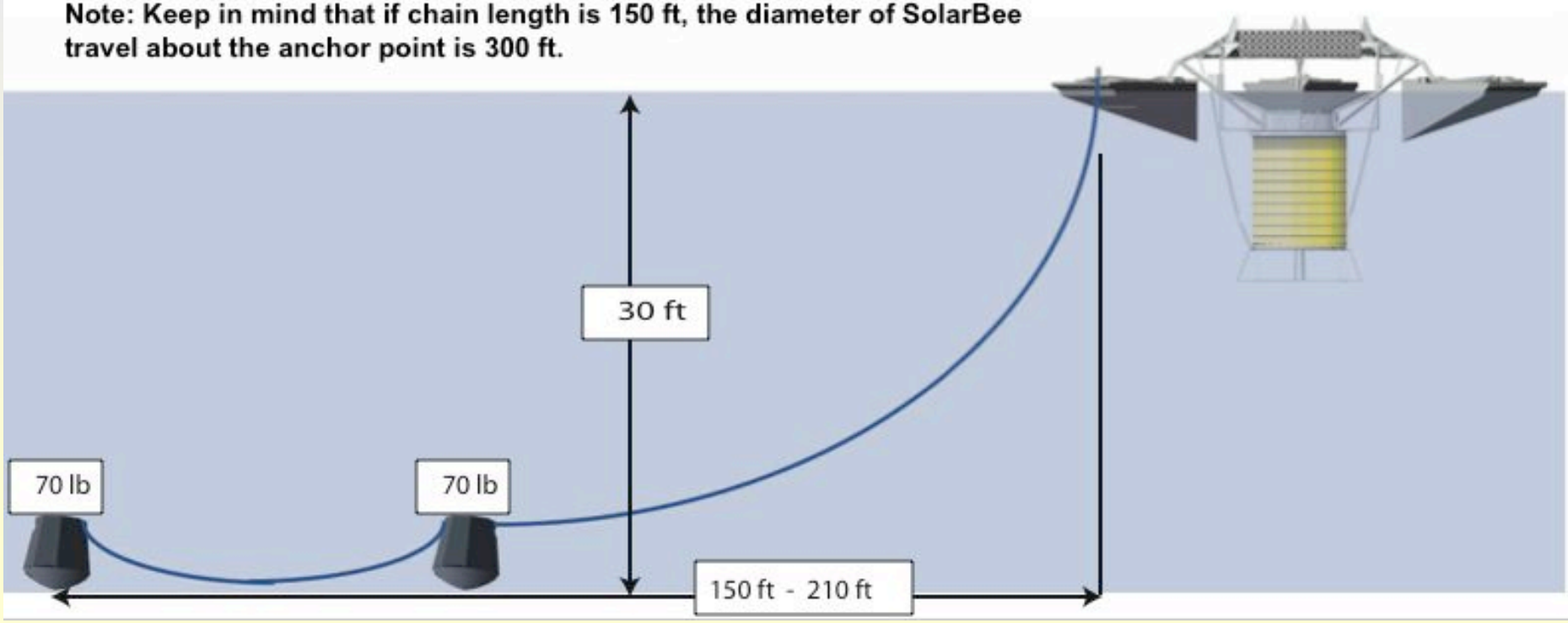
MOORING BLOCK ANCHORING SYSTEM

SolarBee®
Solar-Powered Reservoir Circulator
"Quality Water, Naturally"
http://www.solarbee.com (866) 437-8076

7:1 (Chain Length to Water Depth) Ratio should be used when possible. Some conditions may not allow this ratio, and it may need to be decreased to a 5:1 ratio or less.

Conditions can be but are not limited to the following:
1) Small surface area to depth ratio (20:1 or less, flat bottom reservoir)
2) Very deep reservoirs (50 ft +), chain gets too heavy
3) Steep bottom slopes or bottom rises near SolarBee location

Note: Keep in mind that if chain length is 150 ft, the diameter of SolarBee travel about the anchor point is 300 ft.




Lake Palmdale Spacing:
~ 750’ from shore,
~ 1500’ (0.28 miles)
apart from each other
Installed 11/2/2002
12 4:03PM

SolarBee Standard Safety Features:

- Warning Sign
- Visibility Kit
- Solar Beacon

Since the first SolarBee lake installation in 2000, there has been only 1 minor incident - a fisherman fishing next to a unit started his boat motor without looking.

SolarBee Features and Testing

- ***SB10000v12 Features:***
  - solar powered high flow circulator; 10,000 gpm total flow leaving the machine in full sunlight,
  - 25-year life brush-less electric motor design that provides day and night operation with an energy storage system,
  - 3 each 80 watt solar panels,
  - stainless steel and non-corrosion polymer construction, 36” diameter x 20’ maximum length (per segment) intake hose,
  - bird deterrent and anchoring system,
  - Solar beacon and increased visibility kit optional.
- ***Testing:***

  As part of our standard installation procedure, the SolarBee crew will identify test points with GPS coordinates, measure Secchi depths, and use a YSI meter/submersible probe to determine vertical profiles of dissolved oxygen, pH, temperature and conductivity.

Management Issues for Lake Cochituate

1. Excessive and uncontrolled growth of submerged aquatic plants, particularly Eurasian watermilfoil
2. Swim beach: potential blue-green algae blooms, colilforms
3. Need to keep bottom sediments both oxidized and undisturbed

Invasive Aquatic Weed Control

Because many invasive aquatic weeds only use ammonia (NH_4) instead of nitrate (NO_3), SolarBee circulation likely[1] promotes N-limitation of aquatic weeds by:

1. *SolarBee's near-laminar return flow of oxygen-rich water back to the machine:*
   - oxidizes NH_4^+ to NO_3^- in the sediments, and

2. *Eliminating blue-green algae blooms:*
   - reduces N inputs to (and NH_4^+ generation in) the sediments.

Issue 1. How sustainable are the benefits when the approach does work?

Toxic Herbicides:

- ecologically, about 4 weeks or more
- economically, never-ending expense

SolarBee Circulation:

- ecologically, decades or longer
- economically, one-time purchase, minimal after-purchase costs over 25-yr period

Issue 2. What are the secondary consequences?

Toxic Herbicides:

- anoxic sediments due to oxygen demand from plant decomposition
- blue-green algae blooms from the release of soluble N and P from plant decomposition
- death of non-target native invertebrates and plants
- bio-accumulation of toxic chemicals up the food chain (including shore birds and amphibians)
- water use restrictions for protecting public health

Issue 2. What are the secondary consequences?

SolarBee Circulation:

- improved fish spawning habitats (sediments oxygenated with return flows to machine)
- improved zooplankton and fish productivity
- lower chlorophyll *a* and TP concentrations
- improved water clarity and elimination of stagnation
- reduced mosquito breeding and coliform survival
- no need for toxic chemicals or land-based energy requirements

Issue 3. What response can you reasonably expect if the selected approach does not “work”?

Toxic Herbicides:

- likely recommendations for:
  - higher doses
  - more powerful chemicals, and/or
  - broader areas of application

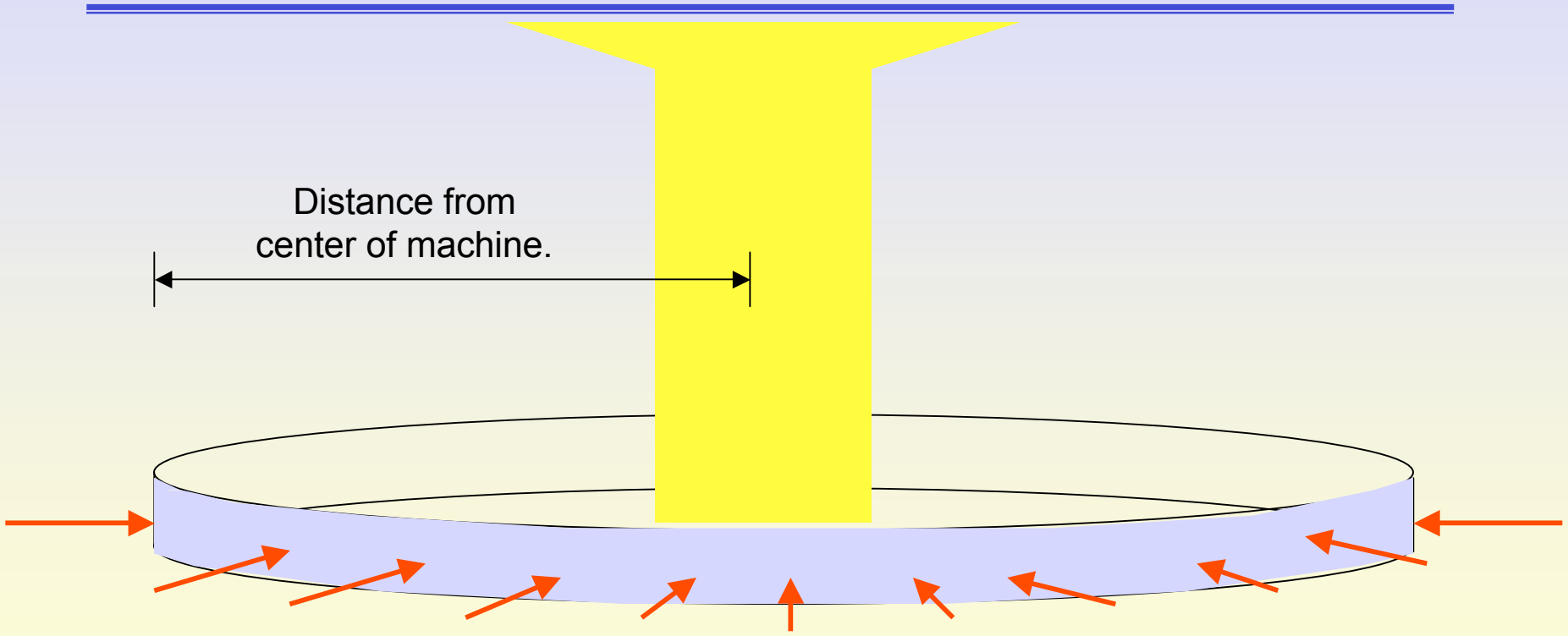
SolarBee Circulation:

- adjust hose intake depths, unit locations, unit size, etc. until the problem is solved
- if they are not working for you, they are not working for us either

The Solarbee Approach: Economics

- One SolarBee (SB10000v12) covers about 40 acres at approximately $40,000 per unit (installed) =
  - $1,000 per acre/year initial cost
  - $0 cost per acre/year next 24 years
  - Over a 25-year period = $40/acre/year, total cost = $40,000
- Aeration, Chemicals, or Alum: $100 to $500/acre/year
  - Over a 25-year period, total cost for 40 acres = *$100,000 - $500,000*

Intake flow velocity can be determined at any distance from the SolarBee intake hose. It is not enough to re-suspend sediments.



Flow moves toward SolarBee as a 1 ft. tall layer, at an equal velocity in all 360 degrees around the 1 ft. tall opening between the bottom of the hose and flat intake plate. The intake plate is typically 2-3 ft above the sediment. The flow velocity is slower at long distances, faster at shorter distances.

Intake water flow velocity at various distances from center of SolarBee. (Note: 10 ft/sec. is used in pumps to purposely suspend solids).

Distance from center of machine, Radius, ft	Diameter of flow pattern, ft	Area, acres	Lineal length of flow, Circumference, ft	Height of the flow pattern, ft	Area of flow, length x height, sq ft	Velocity of the flow, ft/sec	Velocity of the flow, ft/min	Velocity of the flow, ft/hour
8	16	0.0046	50.3	1	50	0.133	8.0	479
50	100	0.1803	314	1	314	0.021	1.3	77
100	200	0.721	628	1	628	0.011	0.6	38
200	400	2.885	1257	1	1257	0.005	0.3	19
300	600	6.491	1885	1	1885	0.0035	0.2	13
400	800	11.5	2513	1	2513	0.0027	0.16	10
500	1000	18.0	3142	1	3142	0.0021	0.13	8
600	1200	26.0	3770	1	3770	0.0018	0.11	6
800	1600	46.2	5027	1	5027	0.0013	0.08	5

SolarBee circulation gentle enough to allow minnows to swim around impeller without being affected

SolarBees do not Resuspend Sediments

1. Bottom plate promotes horizontal, near-laminar flow back to the SolarBee,
2. Maintain intakes off the lake bottom,
3. Salton Sea and CA Fish & Game “no significant impact” evaluation for desert pupfish,
4. Wisconsin DNR evaluation of no sediment resuspension at Monona Bay (Madison, WI),
5. City of San Francisco testing in potable water tanks
6. CA testing at Lake Tahoe (Tahoe Keys Marina) showing reduction of total suspended solids in water,
7. Monitoring data from Lake Palmdale (CA) showing reduction of total suspended solids in water.

Lake Cochituate, MA

urrent Mode ?

View Purchase

nage Info ?

Resolution:	4 Meter
Lat:	42.2872959
Long:	-71.36455619
mage Size:	2,000 m x 2,000 m
Provider:	DigitalGlobe
Nearest City:	NATICK, MA
Date:	3/21/2004
Best Res:	0.6096 Meter
Scale:	1 Inch = 288 m

verlays ?

Set Overlays Toggle Overlays

ther

- Help
- Price List
- Other Imagery Options
- Weather

Image Navigation ?

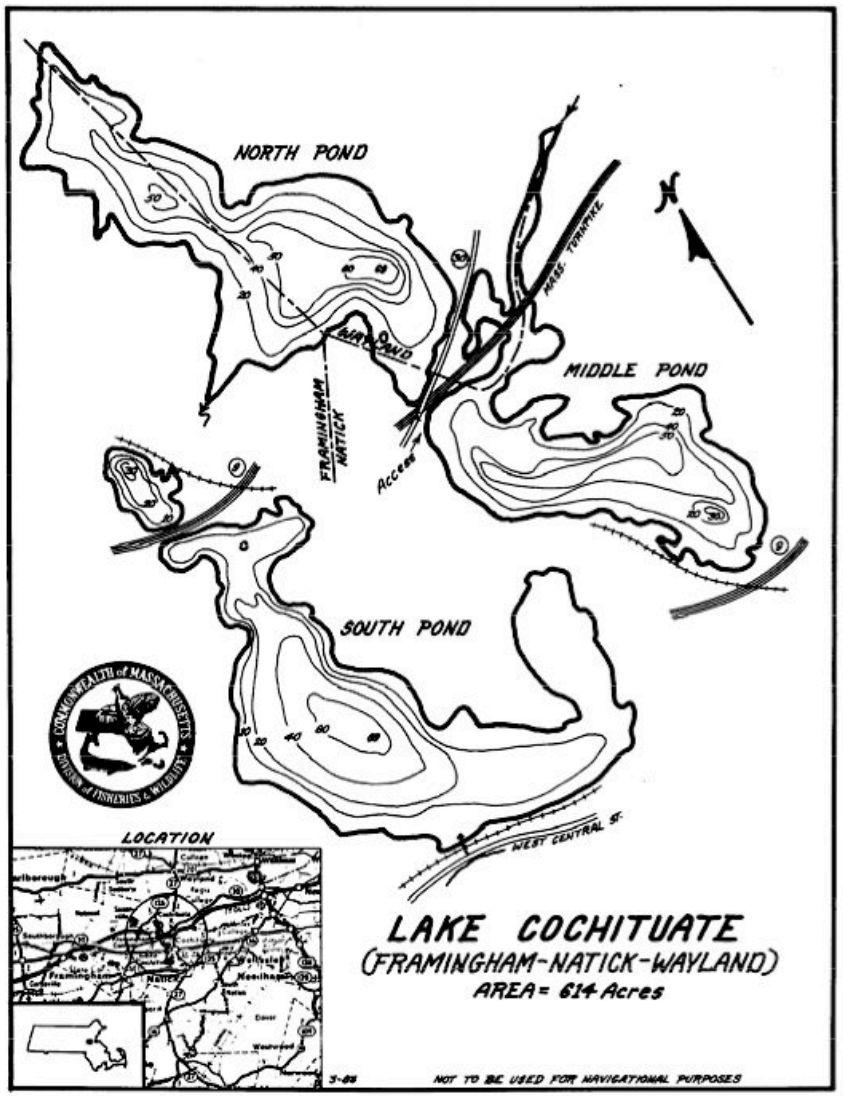
Pan Zoom In
Magnify Measure

Zoom In/Out

Quick Zoom

Quick Pan

Lake Cochituate, MA



Pegan Cove, Lake Cochituate

Current Mode

View Purchase

Image Info

Resolution:	2 Meter
Lat:	42.28555767
Long:	-71.35238753
Image Size:	1,000 m x 1,000 m
Provider:	DigitalGlobe
Nearest City:	NATICK, MA
Date:	3/21/2004
Best Res:	0.6096 Meter
Scale:	1 Inch = 144 m

Overlays

Set Overlays Toggle Overlays

Other

- Help
- Price List
- Other Imagery Options
- Weather

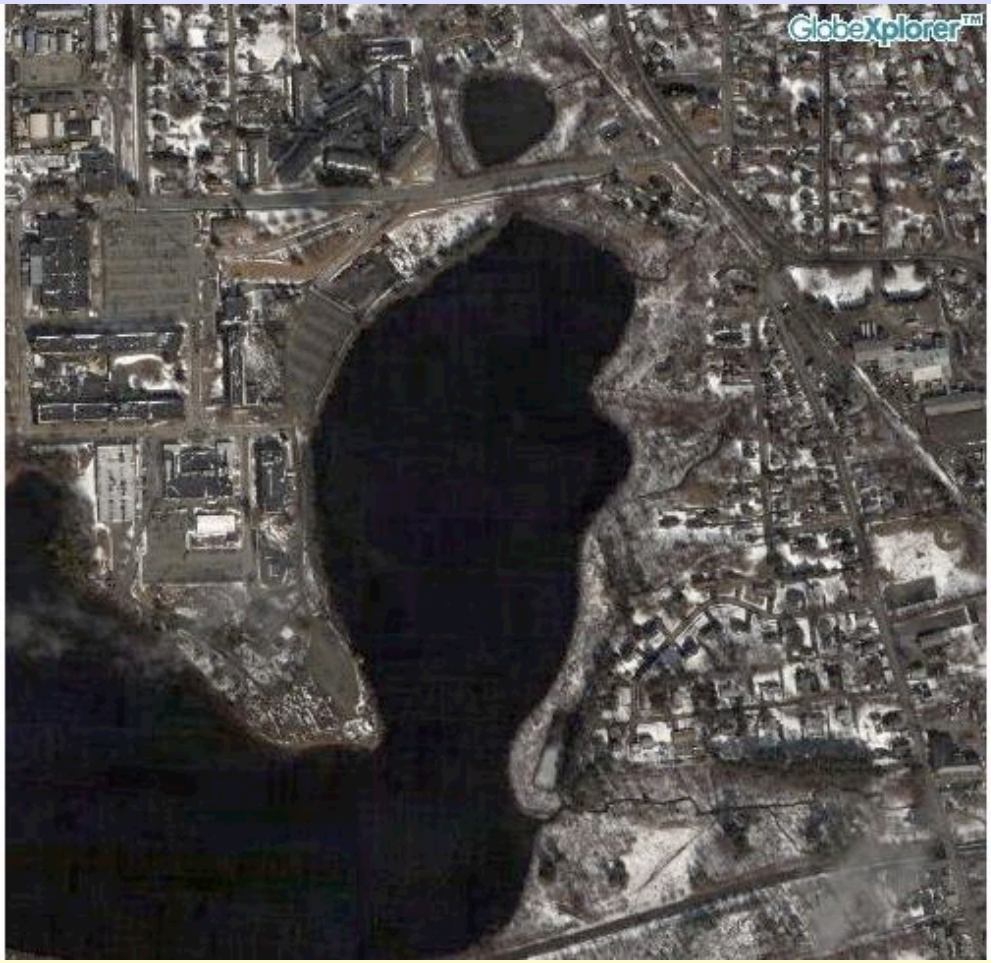


Image Navigation

Pan Zoom In
Magnify Measure

Distance: **Area:**

Points: 18

Area: 31.4347697

Acres

Clear Area

Calculate Area