

# **Freshwater Harmful Algal Bloom Suppression: Solar-Powered Circulation and Current U.S. Policy**

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# Overview

## ➤ Background

- Freshwater Harmful Algal Blooms (FHABs)
- US Policy & Legislation
- Within Water-Body Management

## ➤ FHAB Suppression: Solar Powered Circulation (SPC)

- Planktonic Densities Before & During SPC
  - Crystal Lake, Des Moines, IA
  - East Gravel Lake 4, Thornton, CO
  - Lake Palmdale, Palmdale, CA

## ➤ Hypothesized SPC mechanisms of FHAB Suppression

## ➤ Problematic Applications or Learning Experiences

# Background



1

## Freshwater Harmful Algal Blooms (FHABs)



2

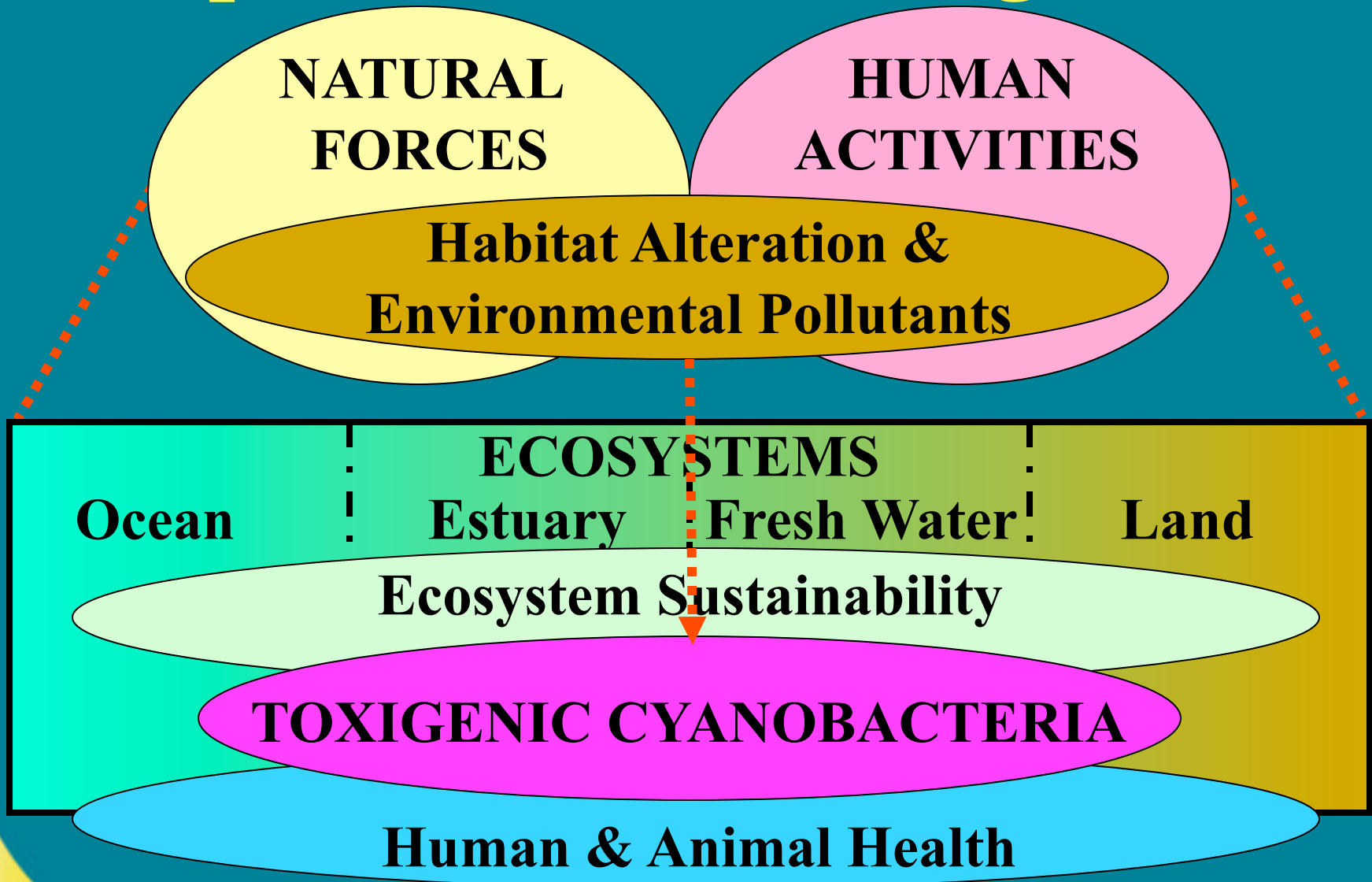
The Interagency, International Symposium on Cyanobacterial HABs: ISOC-HAB



1 Hudnell HK [Ed.], 2008. *Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs*. Advances in Experimental Medicine and Biology, Vol. 619, 959 pp

2 Lopez CB, Jewett EB, Dortch Q, Walton BT, Hudnell HK, 2007. *Scientific Assessment of Freshwater Harmful Algal Blooms*. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

# Eutrophic → Harmful Algal Blooms



# U. S. FHAB Policy & Legislation

No U.S. FHAB guidelines, regulations or policy

- HABHRCA mandates EPA start a FHAB Research & Control Program
    - Passed House, no Senate vote yet
- See <http://www.freshwaterHABlegislation.com/>



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Review

The state of U.S. freshwater harmful algal blooms assessments, policy and legislation

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# Systems Approach: FHAB Risk Management



Ken Hudnell  
ISOC-HAB Ch. 1

# Will We Have a Sustainable Supply of Usable Freshwater?

Watershed Management (4 Decades) & Soil Conservation (7 Decades) > \$5 Billion/yr FED each



Clean Techn Environ Policy (2010) 12:205–207  
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GUEST COLUMN

**Within water-body management: a needed but neglected complement to watershed management**

**H. Kenneth Hudnell**

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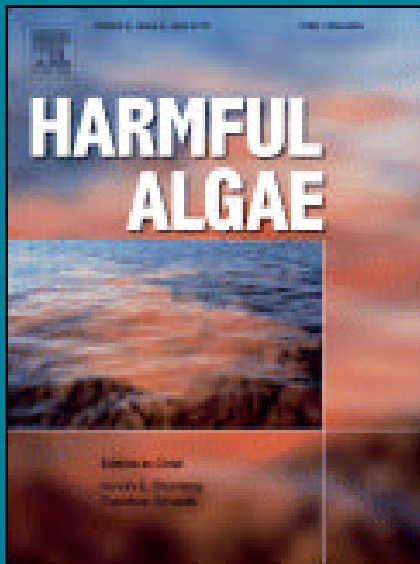
# Will We Have a Sustainable Supply of Usable Freshwater?

- 44% of river & stream miles, & 64% of lake & reservoir acres are impaired pursuant to section 305(b) of the U.S. Clean Water Act (EPA, 2009)
  - Flux of nutrients, toxic substances & pathogens to receiving waters
- 1972, 1<sup>st</sup> EPA Eutrophication Survey: 10-20% of all U.S. lakes & reservoirs eutrophic (Gakstatter & Malone, 1975)
- 2009, EPA Eutrophication Survey: 50+% of all U.S. lakes & reservoirs eutrophic/hypereutrophic (EPA, 2009)

# Solar Powered Circulation, an Ecological Approach to FHAB Suppression

## Targeting a FHAB Stimulatory Factor

- Sunlight
- Temperature
- Nutrients
- Quiescent, stagnant water



### Freshwater harmful algal bloom (FHAB) suppression with solar powered circulation (SPC)

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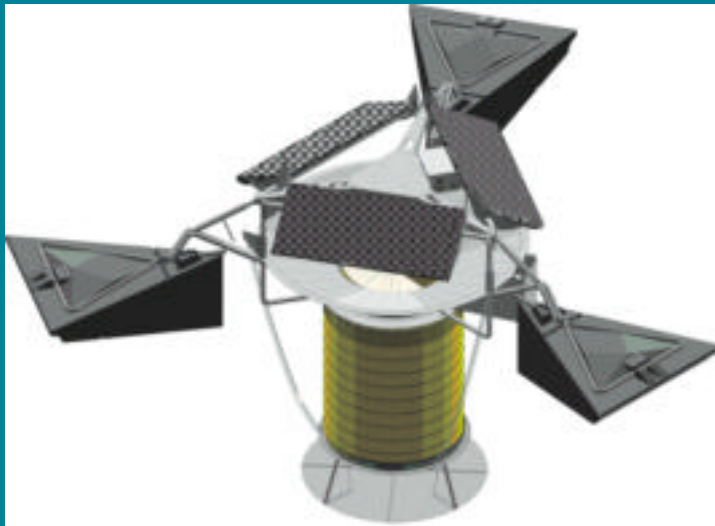
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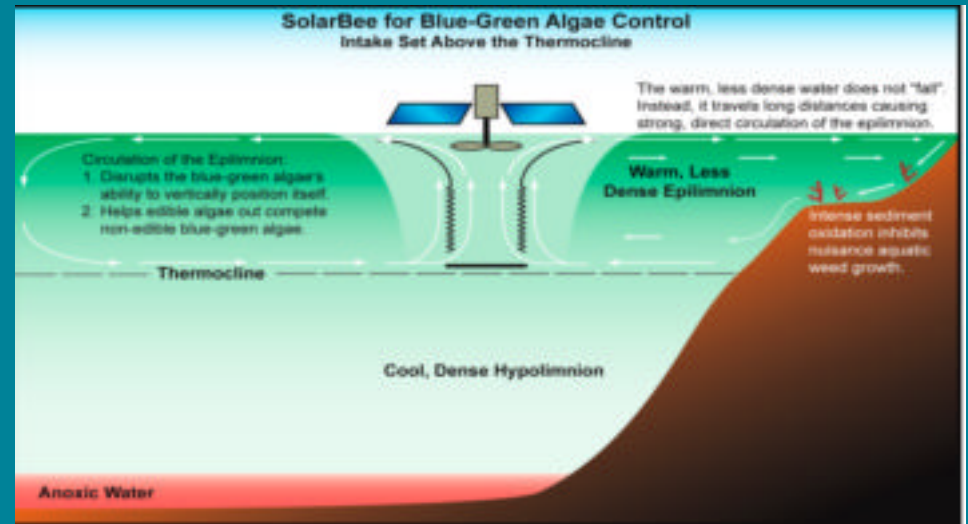
<sup>e</sup> City of Thornton, Thornton, CO 80229, USA

# Solar Powered Circulation An Ecological Solution

## Only Epilimnion Circulated for FHAB Control



### SPC Unit



Three 80 watt solar panels & battery; 18 Volt direct-drive motor; Continuous day/night operation at 80 RPM; Near-laminar radial inflow; 10,000 GPM upflow, Non-turbulent outflow at surface; 0.14 km<sup>2</sup> (35 acre) spacing

## Long Distance Circulation

# Site Selection

## ➤ March 2007, Survey sent to 1<sup>st</sup> 121 SPC users - 121/83/64: 50 FHAB control, Epilimnetic SPC

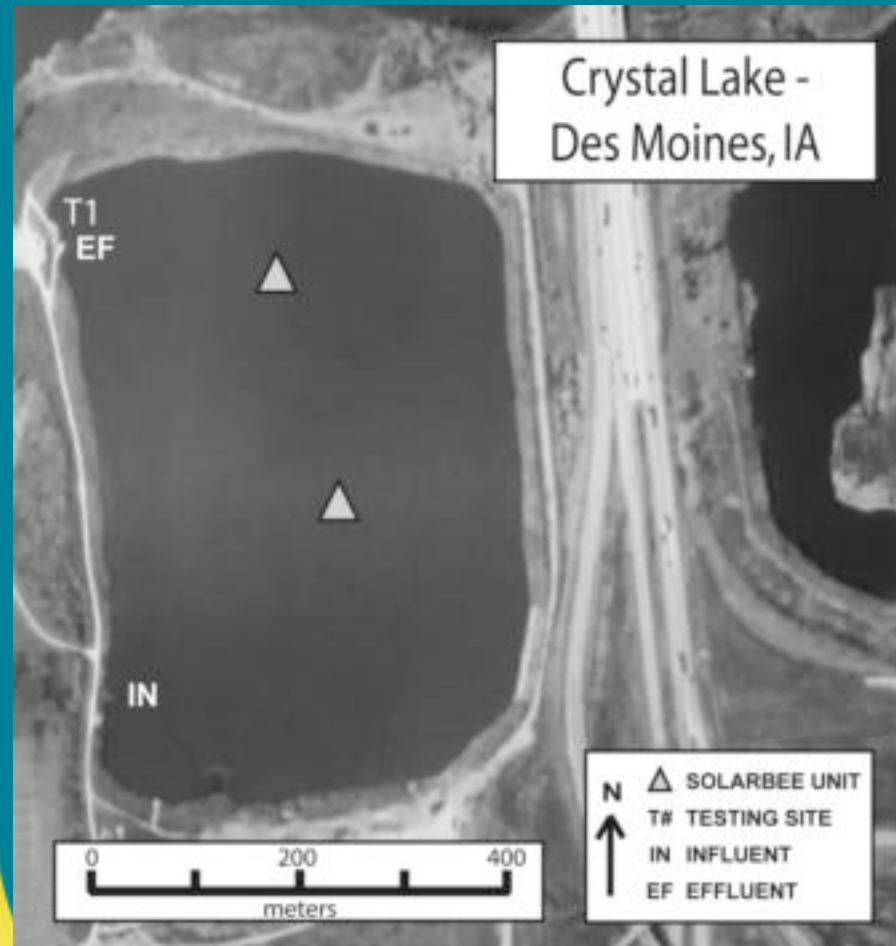
- SPC was deployed for epilimnetic circulation to suppress FHABs
- The whole water body was treated (surface area/SPC unit <16 ha)
- Water body personnel systematically assessed phytoplanktonic density
- Internal analytical methods were validated, standardized and consistent
- Densities of total plankton, cyanobacteria and green algae were available
- Phytoplankton data were available  $\geq$  one spring-fall season pre-SPC
- Phytoplankton data were available  $\geq$  one spring-fall season during SPC

**3 Sites qualified for the study**

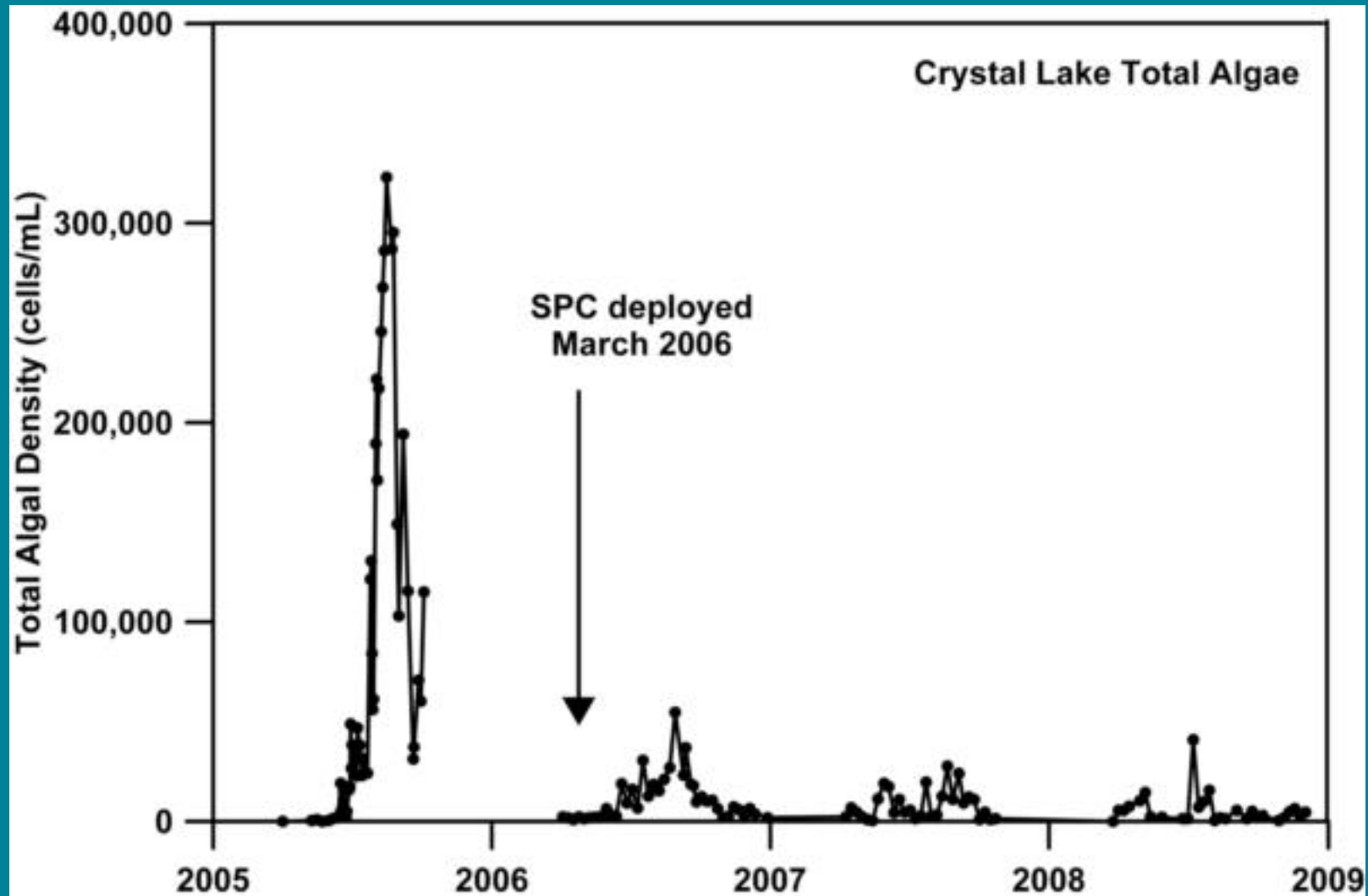
# Crystal Lake

➤ 0.25 km<sup>2</sup> (63 ac) source water

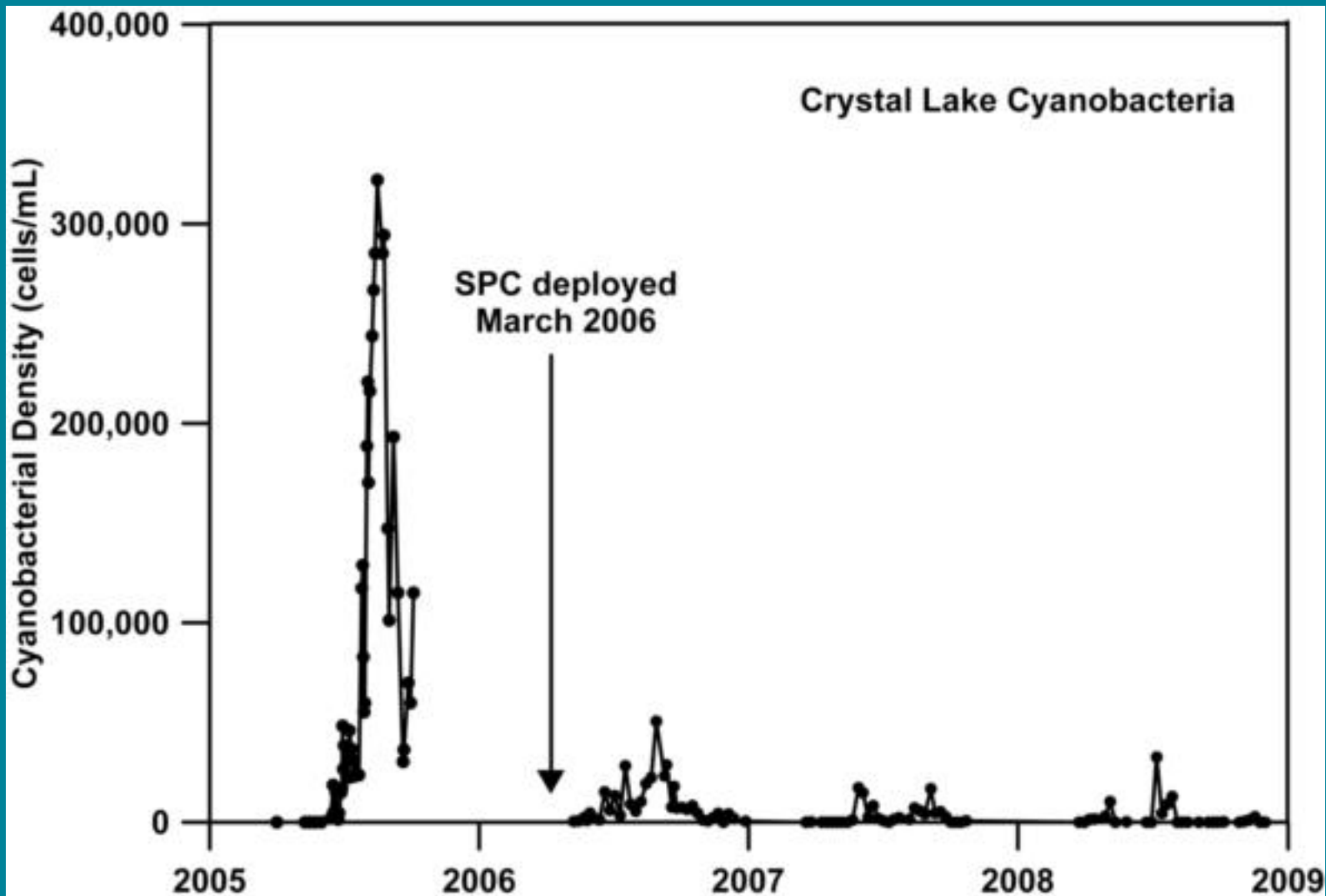
- 25 maximum depth
- 10 ft mean depth
- 7.9 ft SPC mean intake depth
- 5 MGD mean input from Raccoon River
- 40 day mean residence time
- Total N reaches 18 mg/L
- Total P reaches 8 mg/L
- River seeds lake with FHAB cells
- Taste & odor problems
- **Algaecides never used**



# Crystal Lake Total Algal Densities

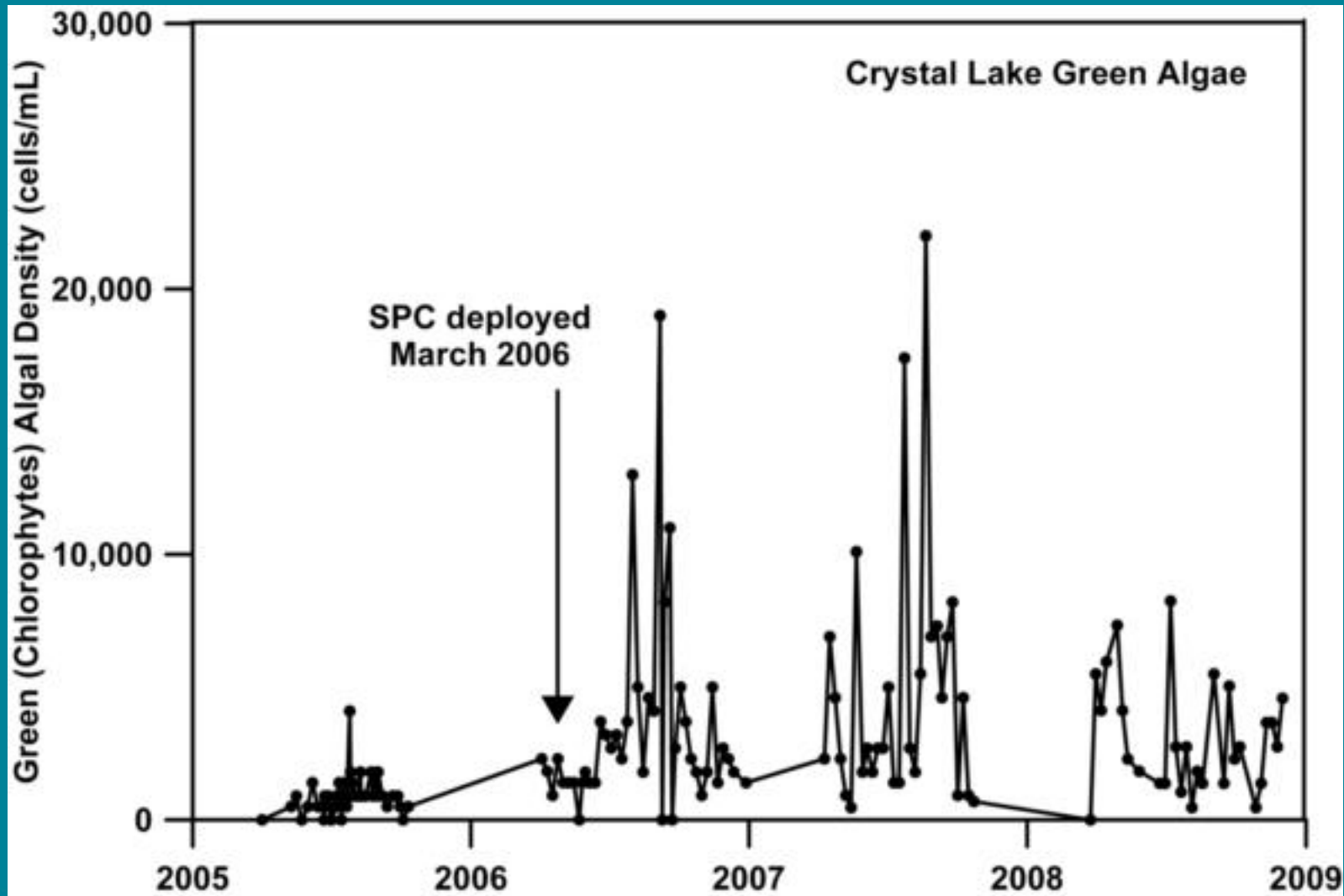


# Crystal Lake Cyanobacterial Density



Algaecides never used

# Crystal Lake Green Algal Densities



# Crystal Lake Data Summary & Conclusions

- High densities of total algae were dominated by cyanobacteria prior to SPC
- Total algal & cyanobacterial densities decreased significantly during SPC
  - Indication that FHAB suppression strengthened over time
- Green algal densities increased significantly during SPC, enabling nutrients to be moved up trophic levels of the food web, creating an exceptional fishery

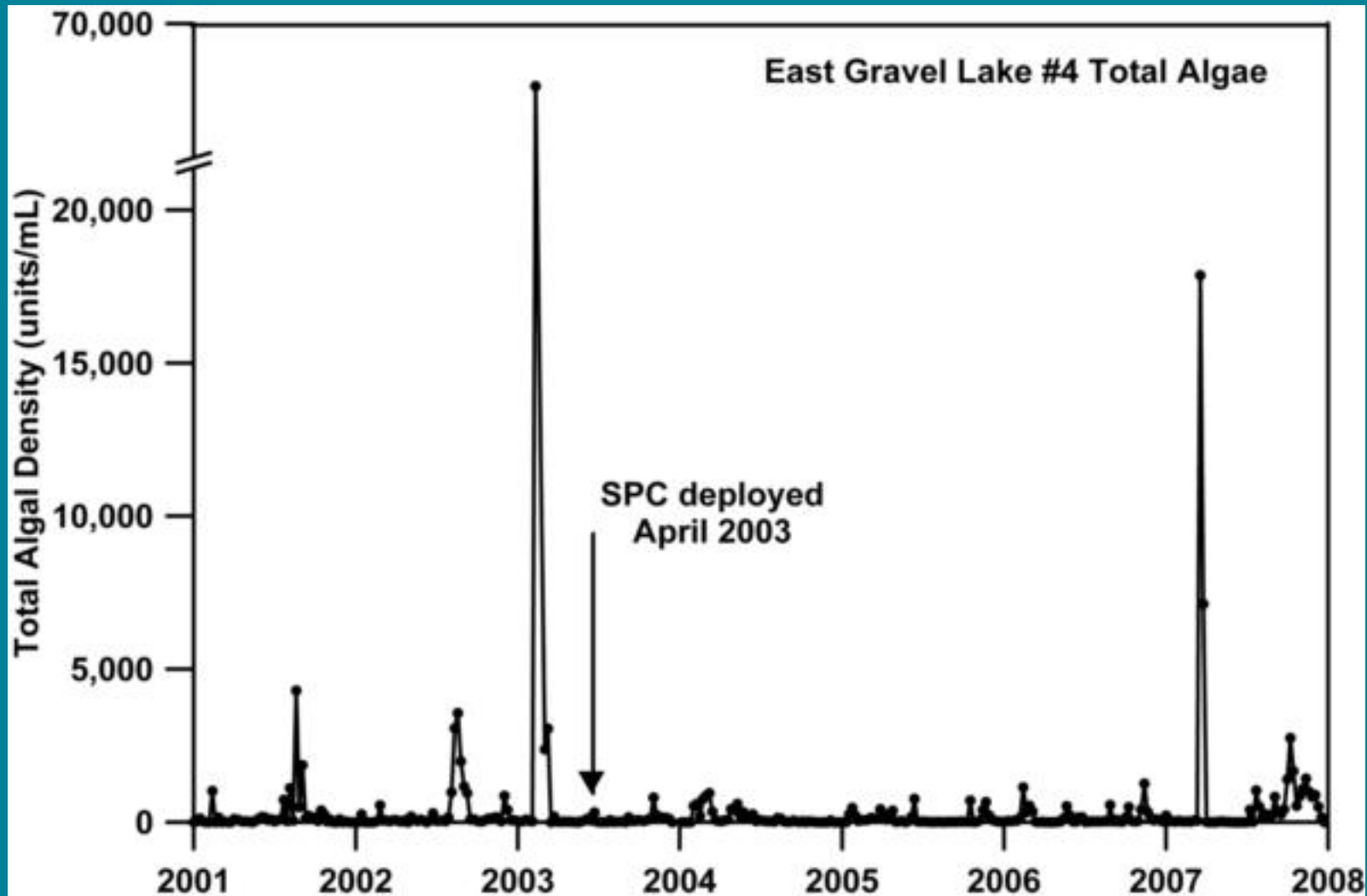
# East Gravel Lake 4 (EGL 4)

➤ 0.47 km<sup>2</sup> (115 ac) source water

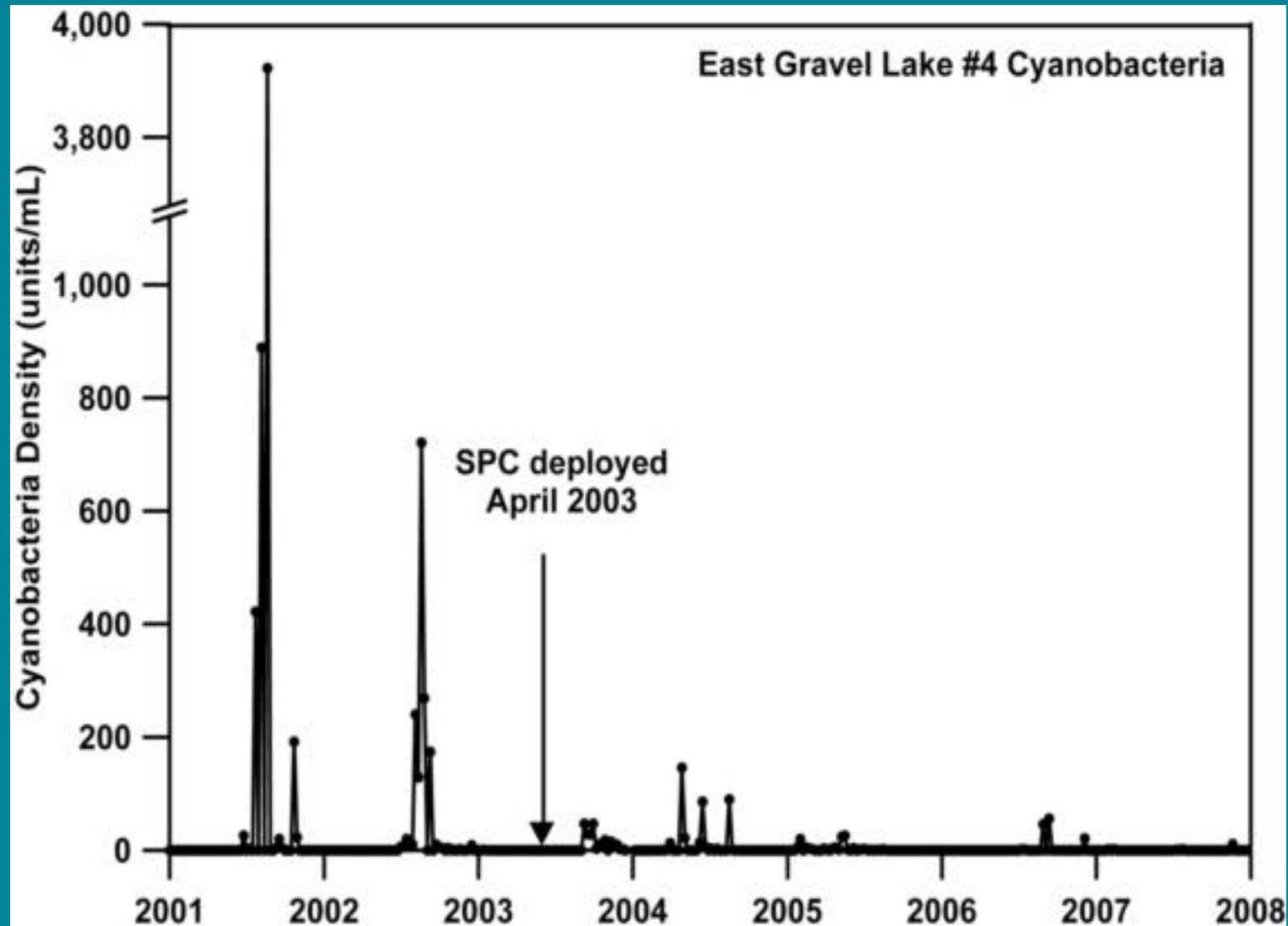


- 35 maximum depth
- 25 ft mean depth
- 22-14.1 ft mean SPC intake depth
- 3.4 MGD mean input from Burlington Ditch (carries Denver effluent)
- 270 day mean residence time
- Nitrate reaches 10 mg/L
- Total P reaches 1.3 mg/L
- Burlington ditch seeds lake with FHAB cells
- Taste & odor problems
- **Algaecides used**

# EGL 4 Total Algal Densities

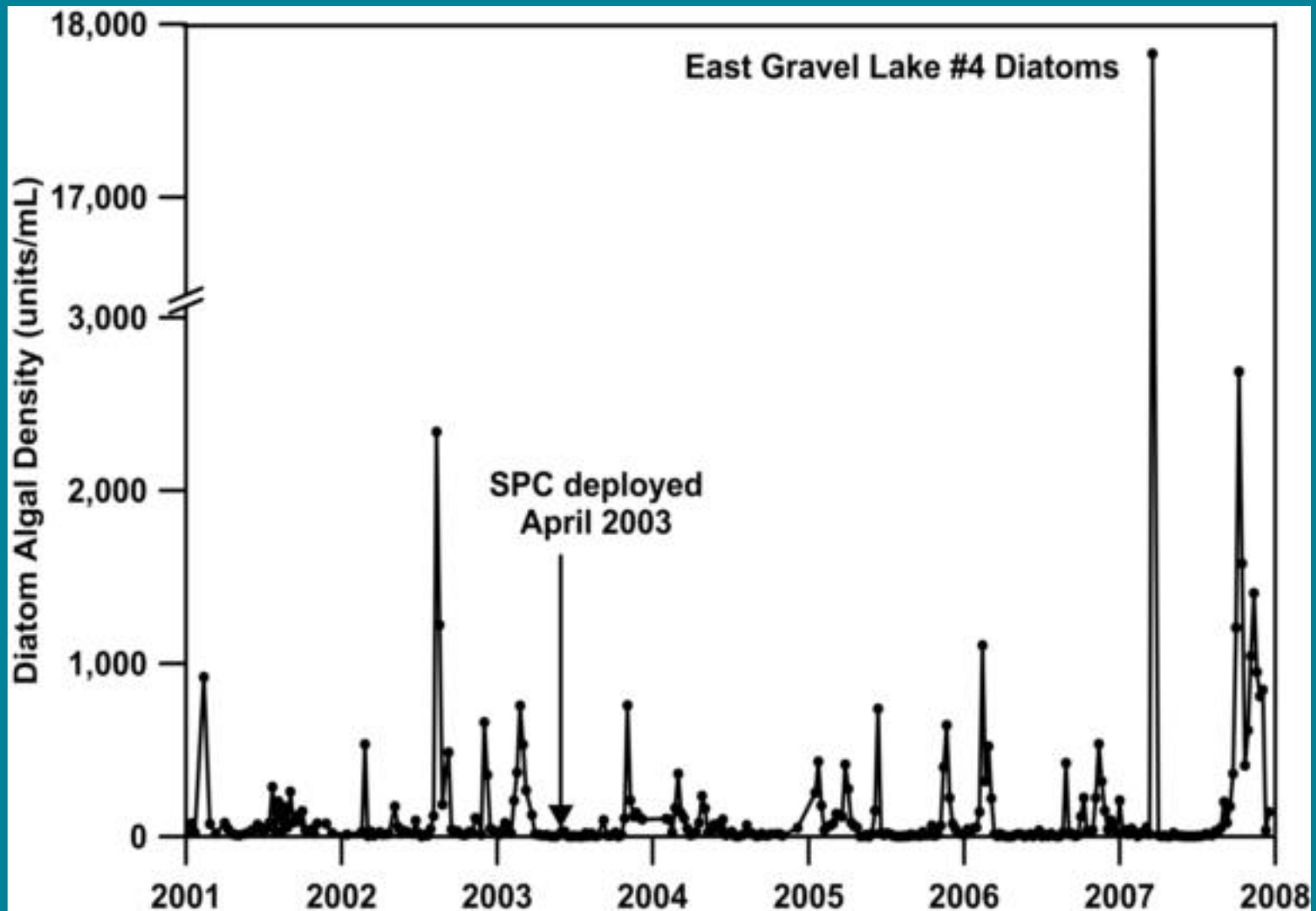


# EGL 4 Cyanobacterial Densities



Algaecide usage: 1-2/mth pre- to 1-2/yr during-SPC

# EGL 4 Diatom Densities



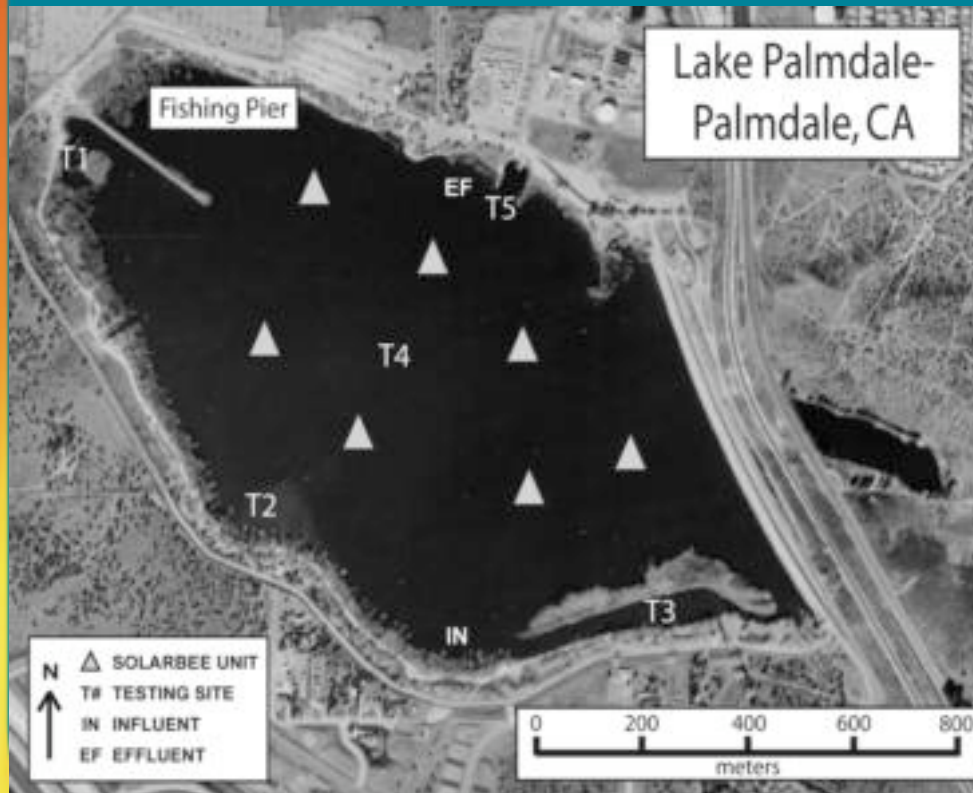
# EGL 4 Data Summary & Conclusions

- High densities of total algae were dominated by cyanobacteria prior to SPC
- Total algal & cyanobacterial densities decreased significantly during SPC
  - Indication that FHAB suppression strengthened over time
- Diatom densities increased significantly during SPC, enabling nutrients to be moved up trophic levels of the food web, creating an exceptional fishery
  - Green algae density increase not significant
- **Algaecide applications declined by 92%**

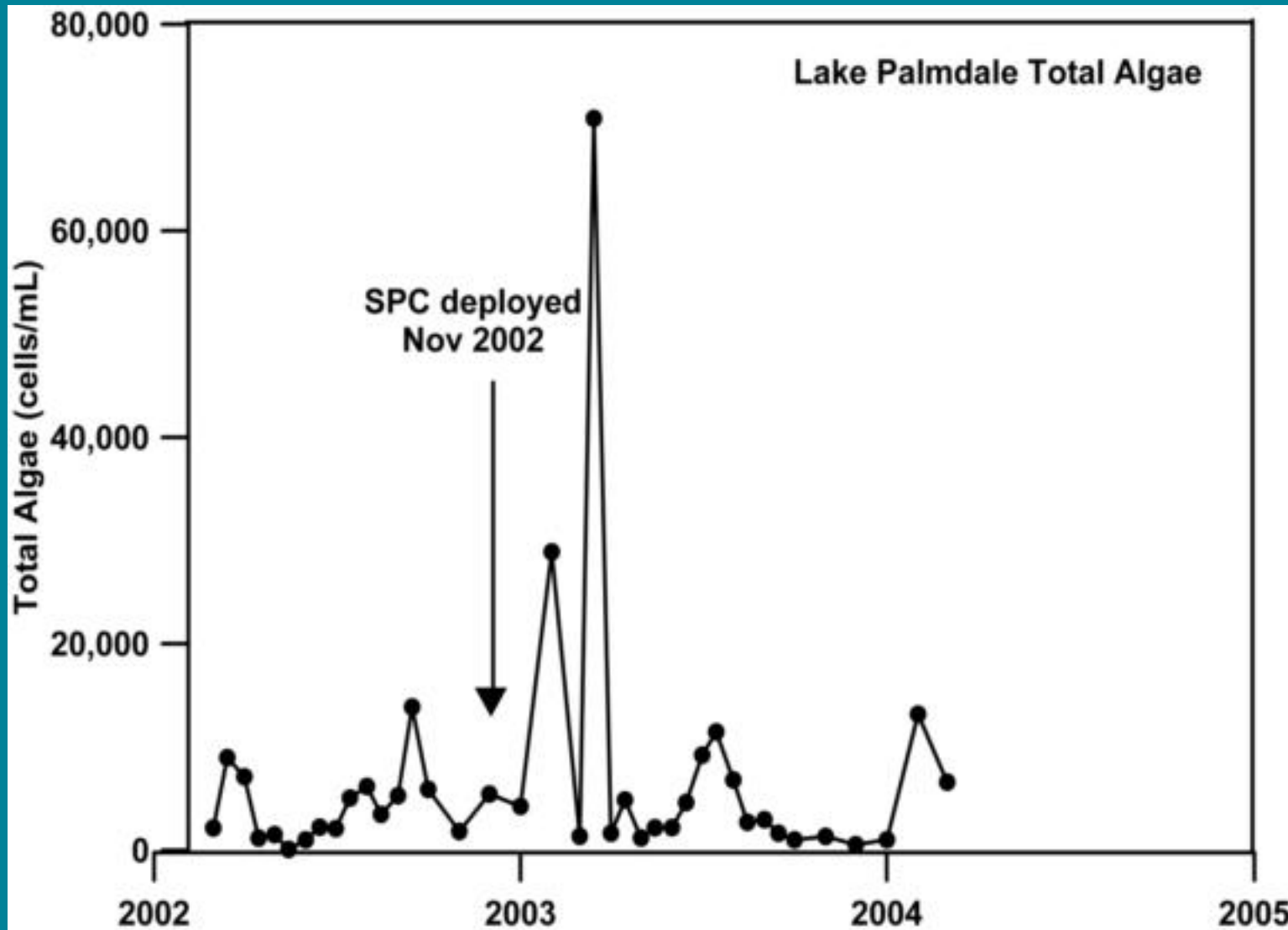
# Lake Palmdale

➤ 0.95 km<sup>2</sup> (234 ac) source water

- 25 maximum depth
- 18 ft mean depth
- 15.1 ft mean SPC intake depth
- 14.2 MGD mean input from California Aqueduct
- 270 day mean residence time
- Nitrate reaches 6 mg/L
- Total P reaches 0.22 mg/L
- California aqueduct seeds lake with FHAB cells
- Taste & odor problems
- **Algaecides used**



# Lake Palmdale Total Algal Densities



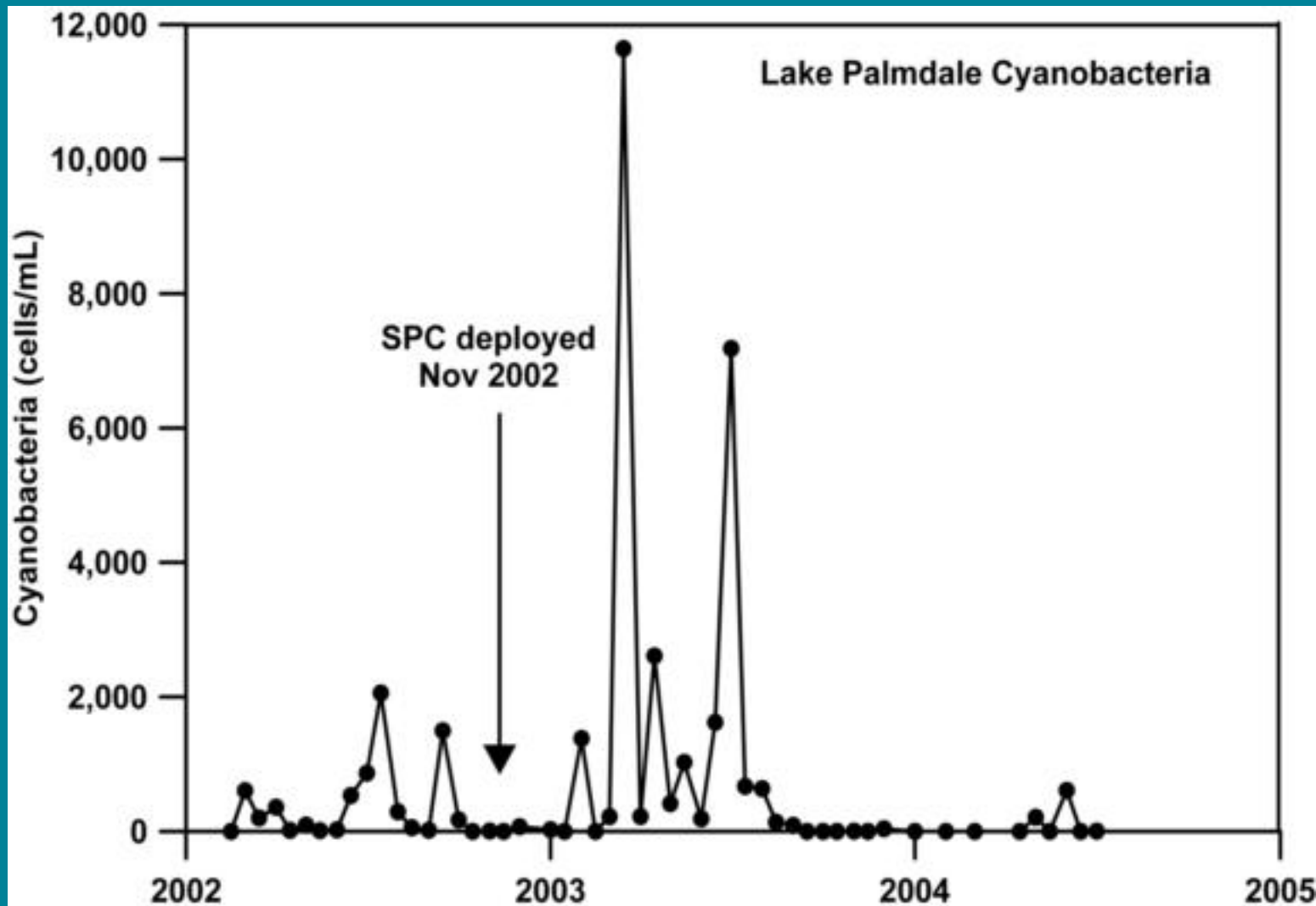
26,070 kg

3,922 kg

3,753 kg

CuSO<sub>4</sub>

# L Palmdale Cyanobacterial Densities



26,070 kg

3,922 kg

3,753 kg

CuSO<sub>4</sub>



# Lake Palmdale Data Summary & Conclusions

- Total algal mean density significantly higher during SPC
- Large FHAB during 1<sup>st</sup> year of SPC, cyanobacterial density significantly lower in 2<sup>nd</sup> year than pre-SPC
- No significant change in green algal or diatom densities during SPC
- Zooplankton densities increased significantly during SPC, indicating that nutrients were being moved up trophic levels of the food web
- **Algaecide usage declined by approximately 85% during SPC**

# Possible Mechanisms

- **Disruption of cyanobacterial buoyancy control**
  - **Non-optimal positioning for light & nutrients**
- **Distribution of non-motile cyanobacterial pathogens**
  - **Cyanophage (viruses), cell lysing bacteria, fungi**
- **Distribution of non-motile beneficial algae & bacteria**
  - **Higher reproduction rates, limit available nutrients**
- **Enhance iron oxidation rate, making it less available**
  - **Cyanobacteria require much iron more than others**
- **Promote zooplankton & grazing**

**May be multifactorial or vary with conditions**

# Problematic Applications or Learning Experiences

- **Small, shallow (< 1 m) aquaculture ponds**
  - High fish density & nutrient levels, low zooplankton density
- **Other small, shallow ponds, particularly when adjacent to wetlands that seed cyanobacteria**
- **Lakes with residence time < 5 days and frequent seeding from inflows**
- **Some partial-lake applications**
  - High nutrient & seeding rate, leeward side of prevailing wind, photic zone beyond thermocline

# **SPC is an Ecologically-based, Sustainable Approach to FHAB Suppression**

## **Thank You!**

**Please Consider Joining the Informal Coalition for Improved FHAB Federal Research & Control Legislation (FHAB ACT)**

**Now Folded into the HABHRCRA Reauthorization**

**<http://www.FreshwaterHABlegislation.com>**

**Need Integrated National Water Policy**

**<http://www.CleanWaterAmericaAlliance.org/index.php>**

# Reservoirs & Treatment

	Crystal Lake	EGL 4	Lake Palmdale
Algaecides Used	No	Yes	Yes
Surface Area (km <sup>2</sup> )	0.26	0.47	0.89
Max Depth (m)	7.6	10.7	7.6
Mean Depth (m)	3.0	7.6	5.5
Water Volume (km <sup>3</sup> )	7.65x10 <sup>-4</sup>	3.53x10 <sup>-3</sup>	4.90x10 <sup>-3</sup>
Water Mean Residence Time (days)	40	270	91
Data Collection Period	March-December 2005-2008	January-December 2001-2007	January-December 2002-2004
SPC Initiation Date	March 2006	April 2003	November 2002
# SPC Units	2	3	6-7 <sup>a</sup>
Surface Area km <sup>2</sup> /SPC unit	0.13	0.16	0.15-0.13 <sup>a</sup>
Mean Intake Depth (m)	2.4	6.7-4.3 <sup>b</sup>	4.6
Water Volume Circulated (km <sup>3</sup> )	6.1x10 <sup>-4</sup>	3.1x10 <sup>-3</sup> -2.0x10 <sup>-3b</sup>	4.1x10 <sup>-3</sup>
Water km <sup>3</sup> Circulated/SPC unit	3.05x10 <sup>-4</sup>	1.04x10 <sup>-3</sup> -6.67x10 <sup>-47b</sup>	6.82x10 <sup>-4</sup> -5.85x10 <sup>-4a</sup>
SPC Circulation Rate (km <sup>3</sup> /day)	5.5x10 <sup>-2</sup>	5.5x10 <sup>-2</sup>	5.5x10 <sup>-2</sup>
Total Circulation Rate (km <sup>3</sup> /day)	0.11	0.17	0.33-0.39 <sup>a</sup>
Turnover Duration (days) <sup>c</sup>	5.6	19.0-12.2 <sup>b</sup>	12.4-10.6 <sup>a</sup>

<sup>a</sup> A seventh SPC unit was installed in June 2003

<sup>b</sup> Water intake depths were varied as the reservoir surface elevation and water clarity varied over time

<sup>c</sup> The duration required for the SPC units to circulate all the water between the surface and mean intake depths one time

# Pre- v During-SPC Data Summary

	Total Algae	Cyanobacteria	Green Algae	Diatoms	Zooplankton
Crystal Pre	86,302 <sub>+13,834</sub>	85,447 <sub>+13,799</sub>	871 <sub>+90</sub>	NA	NA
Crystal Post	8,668 <sub>+972</sub>	5,161 <sub>+524</sub>	3,665 <sub>+380</sub>	NA	NA
EGL 4 Pre	1,796 <sub>+862</sub>	72 <sub>+41</sub>	1,534 <sub>+850</sub>	135 <sub>+30</sub>	NA
EGL 4 Post	306 <sub>+87</sub>	3.9 <sub>+1</sub>	45 <sub>+8</sub>	232 <sub>+86</sub>	NA
Palmdale Pre	4,228 <sub>+848</sub>	426 <sub>+148</sub>	1,528 <sub>+423</sub>	2,216 <sub>+769</sub>	<b>169<sub>+56</sub></b>
Palmdale Post	7,977 <sub>+2,449</sub>	967 <sub>+446</sub>	888 <sub>+214</sub>	4,436 <sub>+2,211</sub>	<b>984<sub>+272</sub></b>

Numbers are means  $\pm$  standard errors of the means; NA = not available

Units are cell/mL at Crystal and Palmdale, and units/mL at EGL 4

Bolded values are statistically significant at  $p \leq 0.05$ ; Between-site comparisons are inappropriate

Algaecides were never used at Crystal, whereas copper sulfate usage declined by 85% at Palmdale and from 1-2/mth to 1-2/yr at EGL 4 after SPC initiation

**SPC provides an Ecological Approach to FHAB Suppression**