

# **Satellite Multispectral & Planktonic Evidence of Freshwater Harmful Algal Bloom (FHAB) Suppression through Solar-Powered Circulation (SPC)**

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# Overview

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

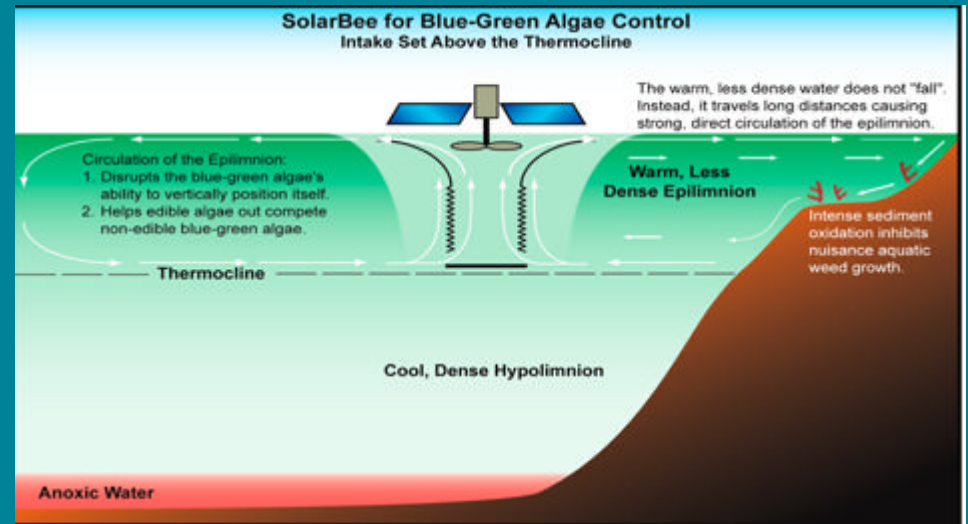
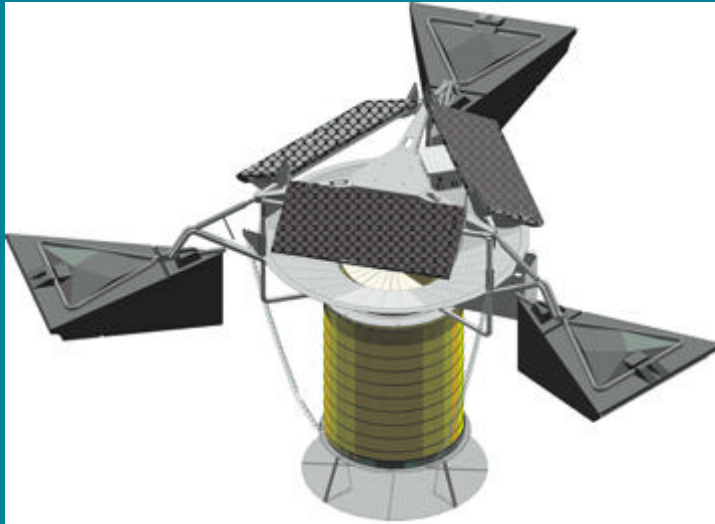
Material from: Hudnell *et al.* (in press). Freshwater Harmful Algal Bloom (FHAB) Suppression with Solar Powered Circulation (SPC). Harmful Algae, 2010.

# Ecological Approaches to FHAB Suppression

- **Factors that stimulate FHABs**
  - **Sunlight**
    - Shading reduces photosynthesis
  - **Temperatures, increasing w/ Global Climate Change**
    - No near-term solutions
  - **Nutrient inputs, increasing w/ Global Climate Change**
    - Imperative to reduce non-point runoff
    - Should recapture & recycle nutrients, particularly P
    - Long-term approach to FHAB control
  - **Quiescent or Stagnant waters, increasing w/ GCC**
    - Artificial circulation, a near-term, interim solution
      - **Solar-Powered Circulation**

# SPC Units

## Only the Epilimnion is Circulated for FHAB Control



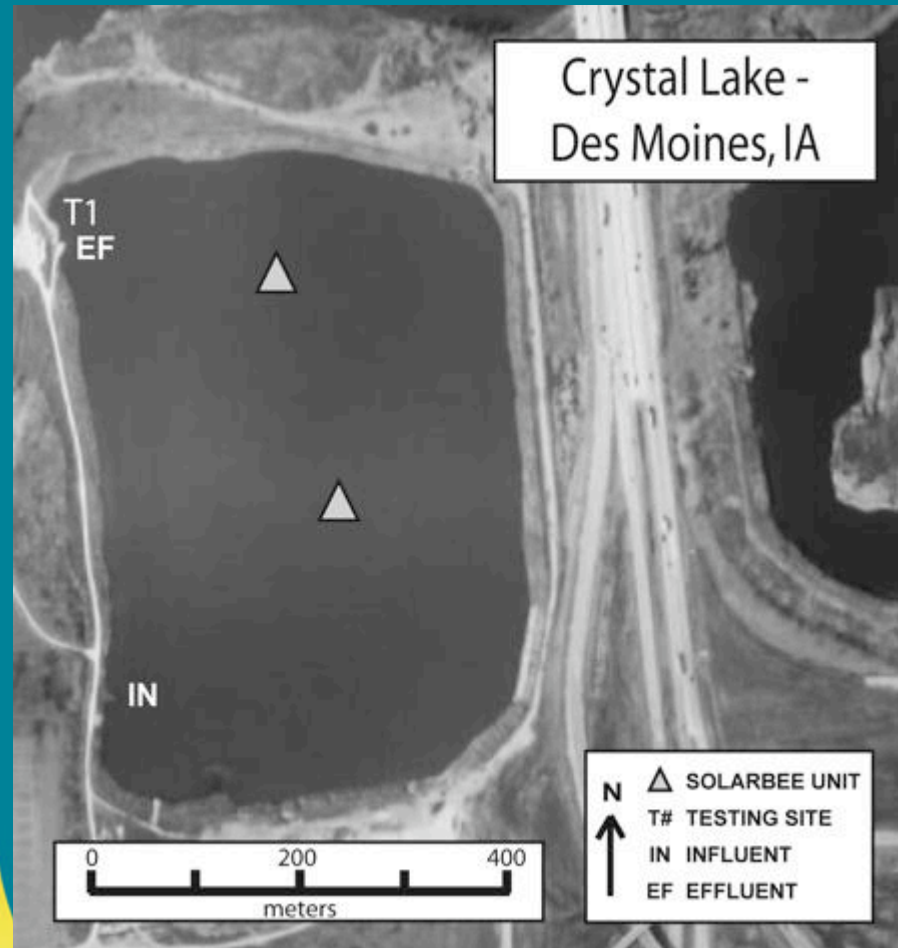
**Three 80 watt solar panels; 18 Volt direct-drive motor & battery;  
Continuous day/night operation at 80 RPM; Near-laminar radial inflow; Non-turbulent outflow at surface; 10,000 GPM upflow, 35 acre spacing**

# Site Selection

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

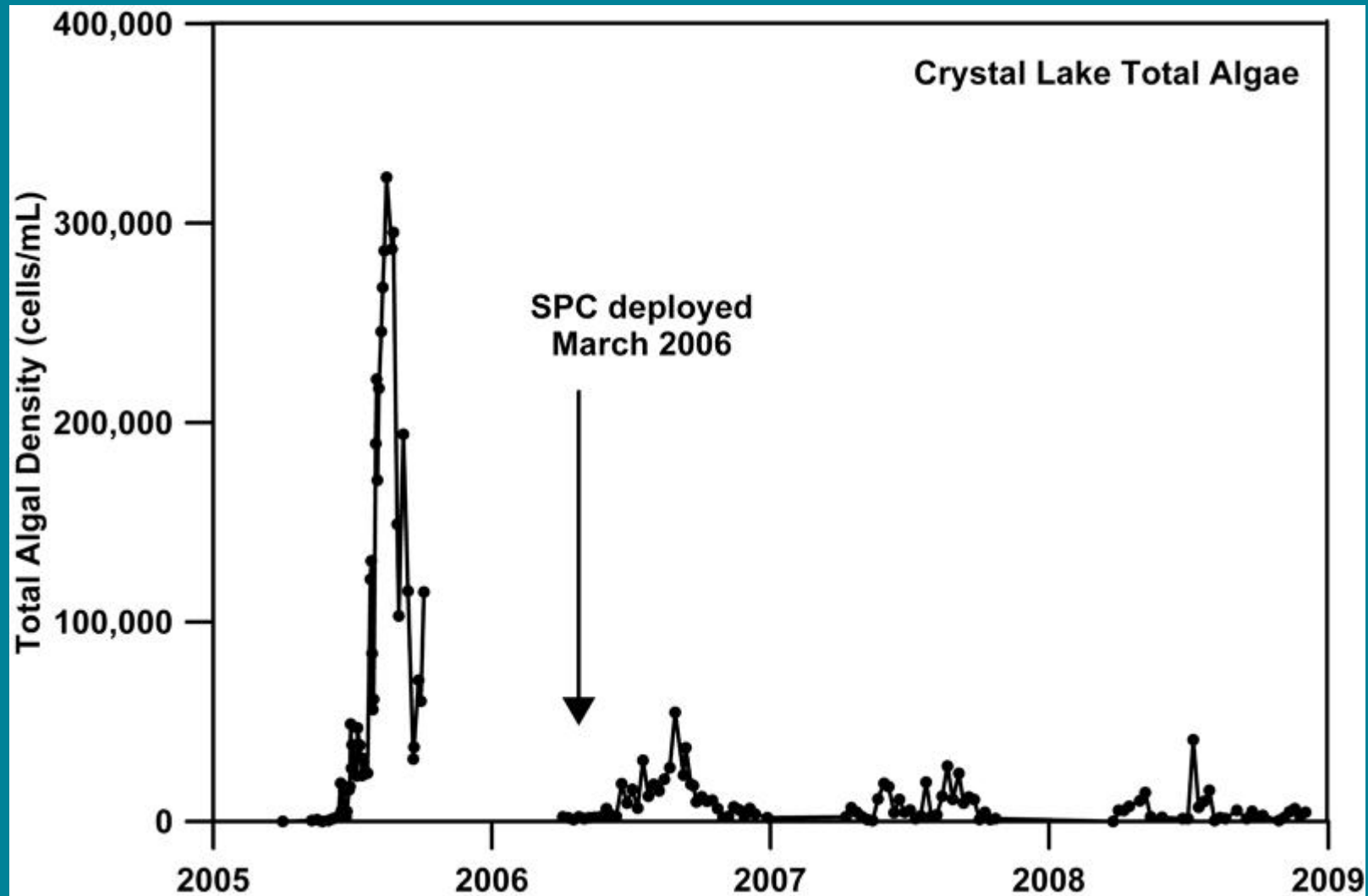
- SPC was deployed for epilimnetic circulation to suppress FHABs
- The whole water body was treated (surface area/SPC unit <16 ha)
- Water body personnel systematically assessed phytoplanktonic density
- Internal analytical methods were validated, standardized and consistent
- Densities of total plankton, 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

# Crystal Lake

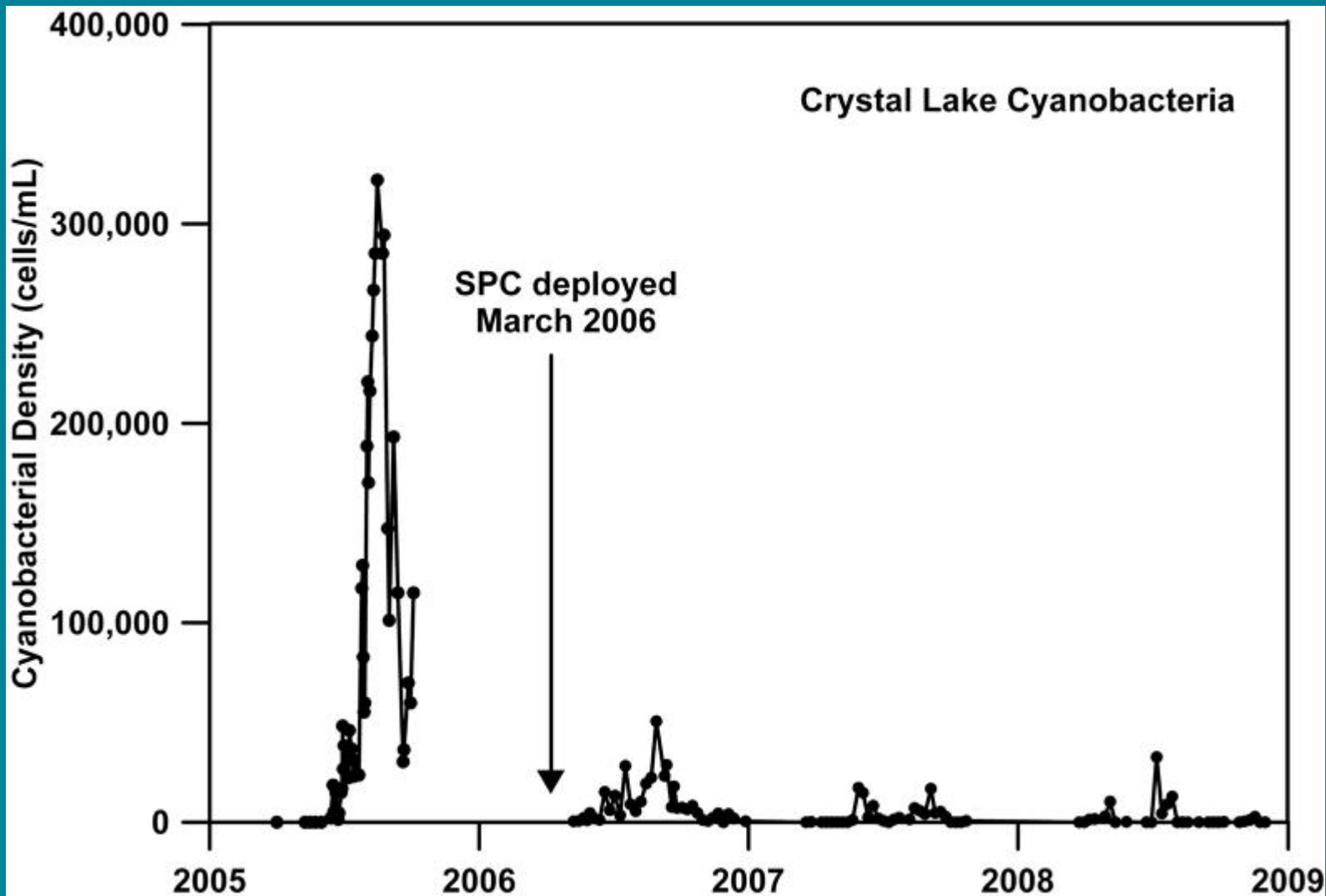


- 63 ac source water
- 25 maximum depth
- 10 ft mean depth
- 7.9 ft SPC mean intake depth
- 5 MGD mean input from Raccoon River
- 40 day mean residence time
- Total N reaches 18 mg/L
- Total P reaches 8 mg/L
- River seeds lake with FHAB cells
- Taste & odor problems
- **Algaecides never used**

# Crystal Lake Total Algal Densities

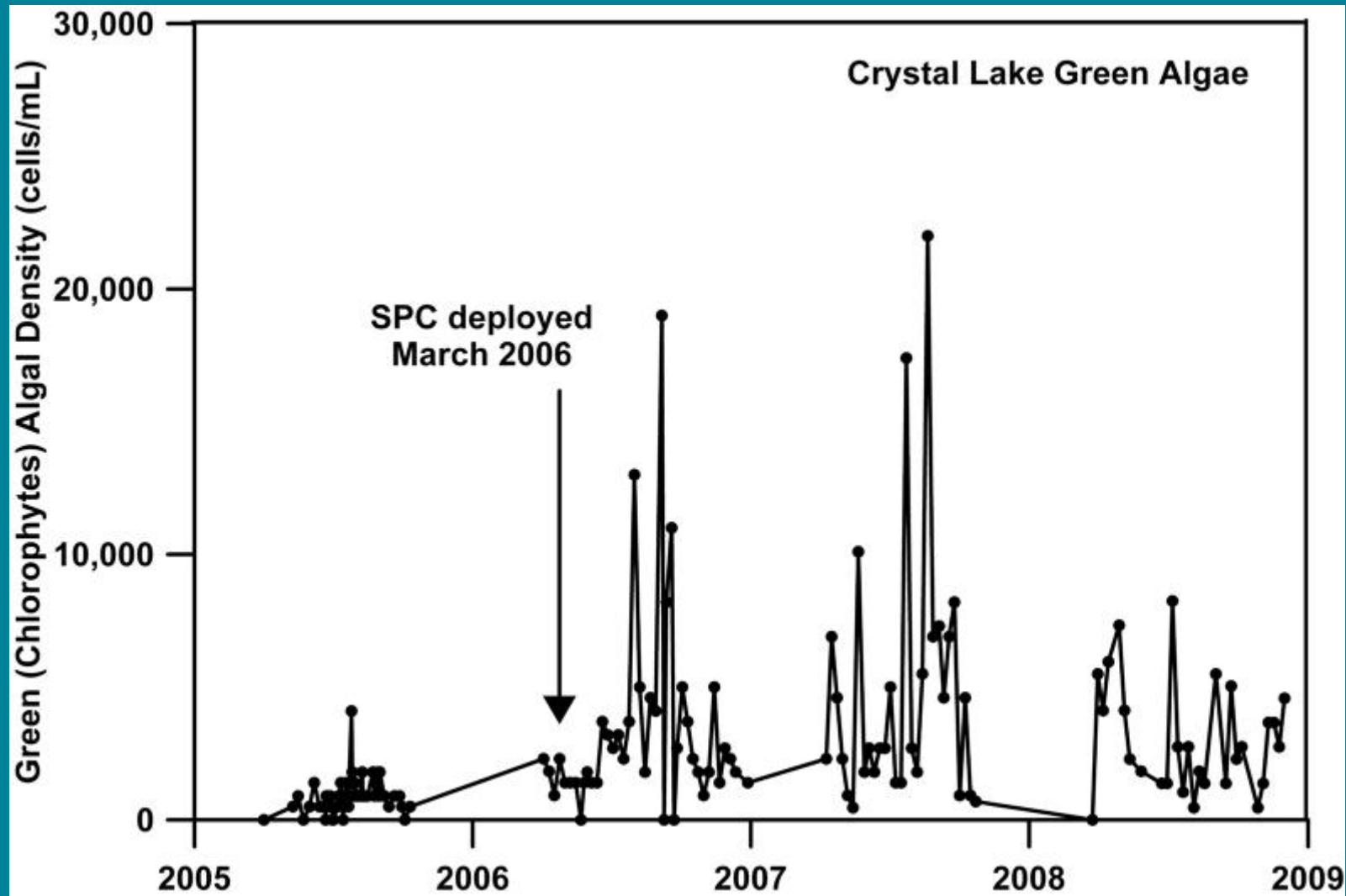


# Crystal Lake Cyanobacterial Density



Algaecides never used

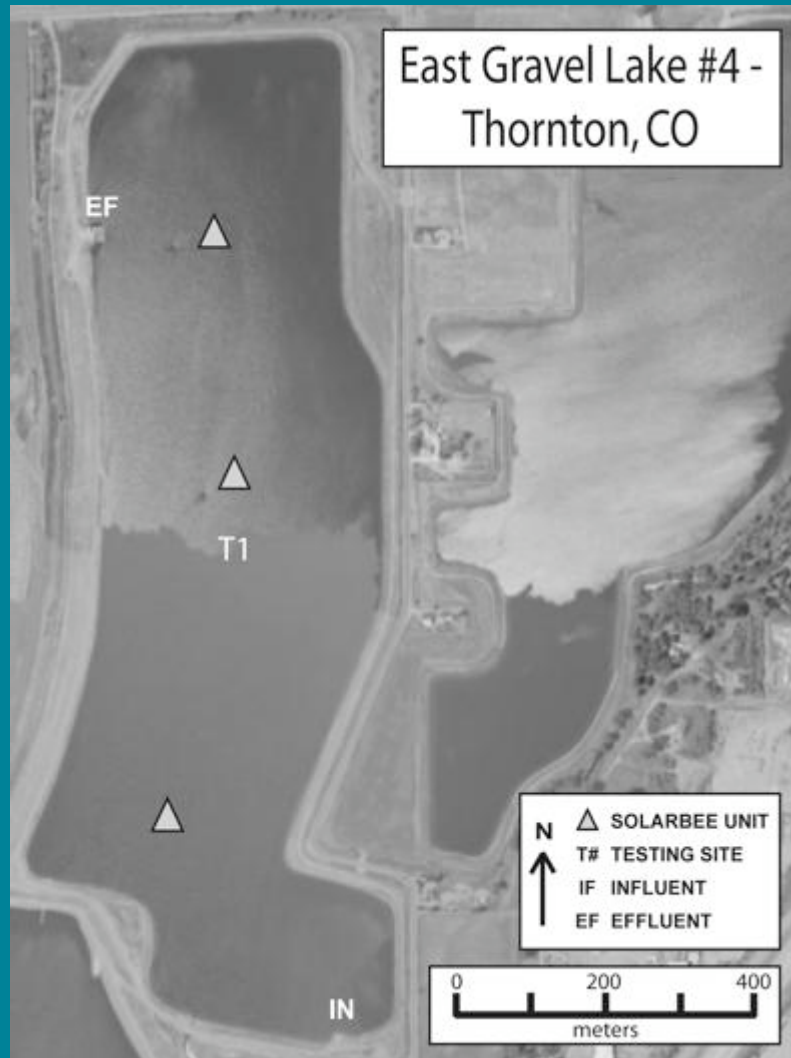
# Crystal Lake Green Algal Densities



# Crystal Lake Data Summary

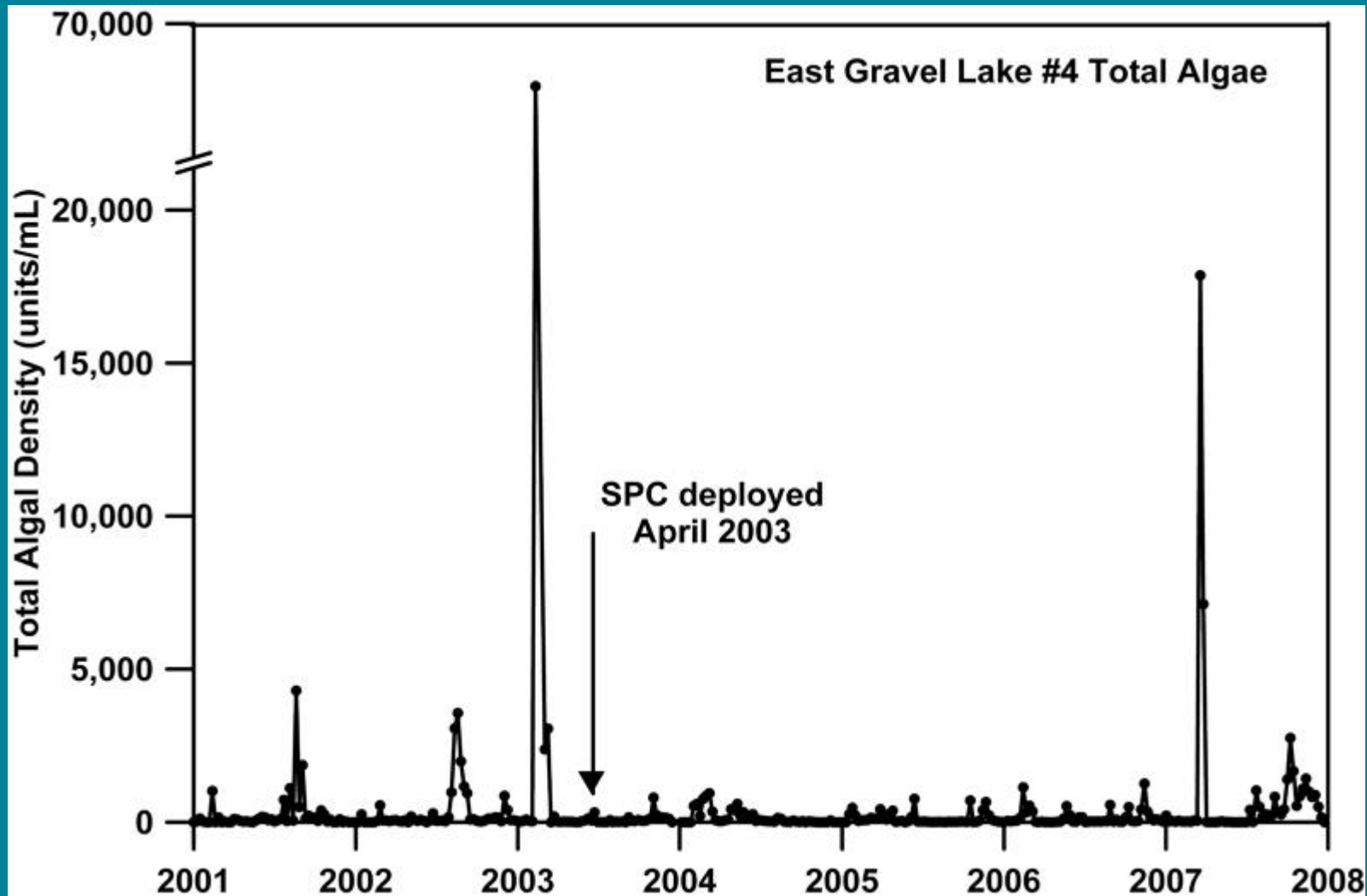
- High densities of total algae were dominated by cyanobacteria prior to SPC
- Total algal & cyanobacterial densities decreased significantly during SPC
  - Indication that FHAB suppression strengthened over time
- Green algal densities increased significantly during SPC

# East Gravel Lake 4 (EGL 4)

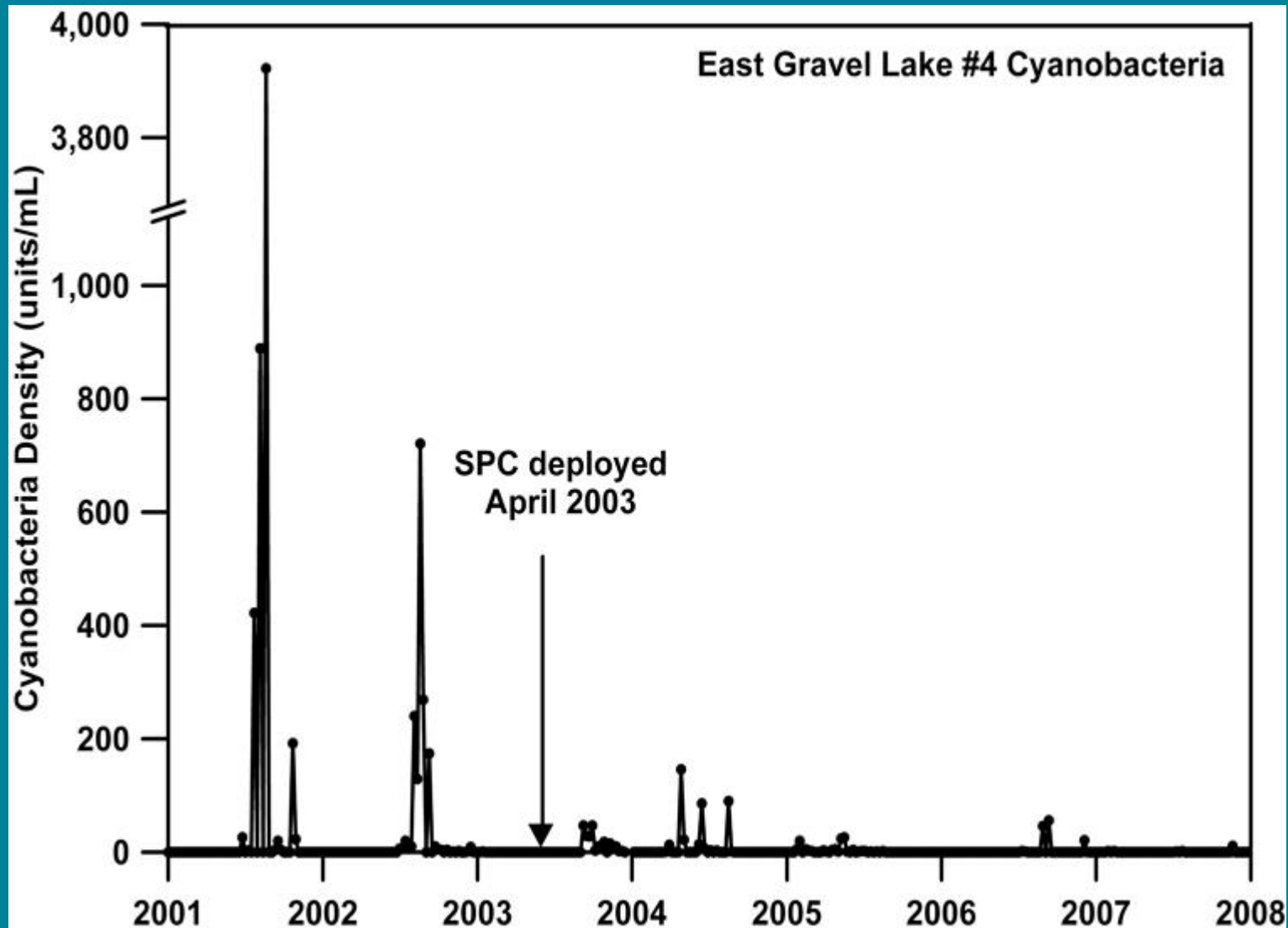


- 115 ac source water
- 35 maximum depth
- 25 ft mean depth
- 22-14.1 ft mean SPC intake depth
- 3.4 MGD mean input from Burlington Ditch (carries Denver effluent)
- 270 day mean residence time
- Nitrate reaches 10 mg/L
- Total P reaches 1.3 mg/L
- Ditch seeds lake with FHAB cells
- Taste & odor problems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

# EGL 4 Total Algal Densities

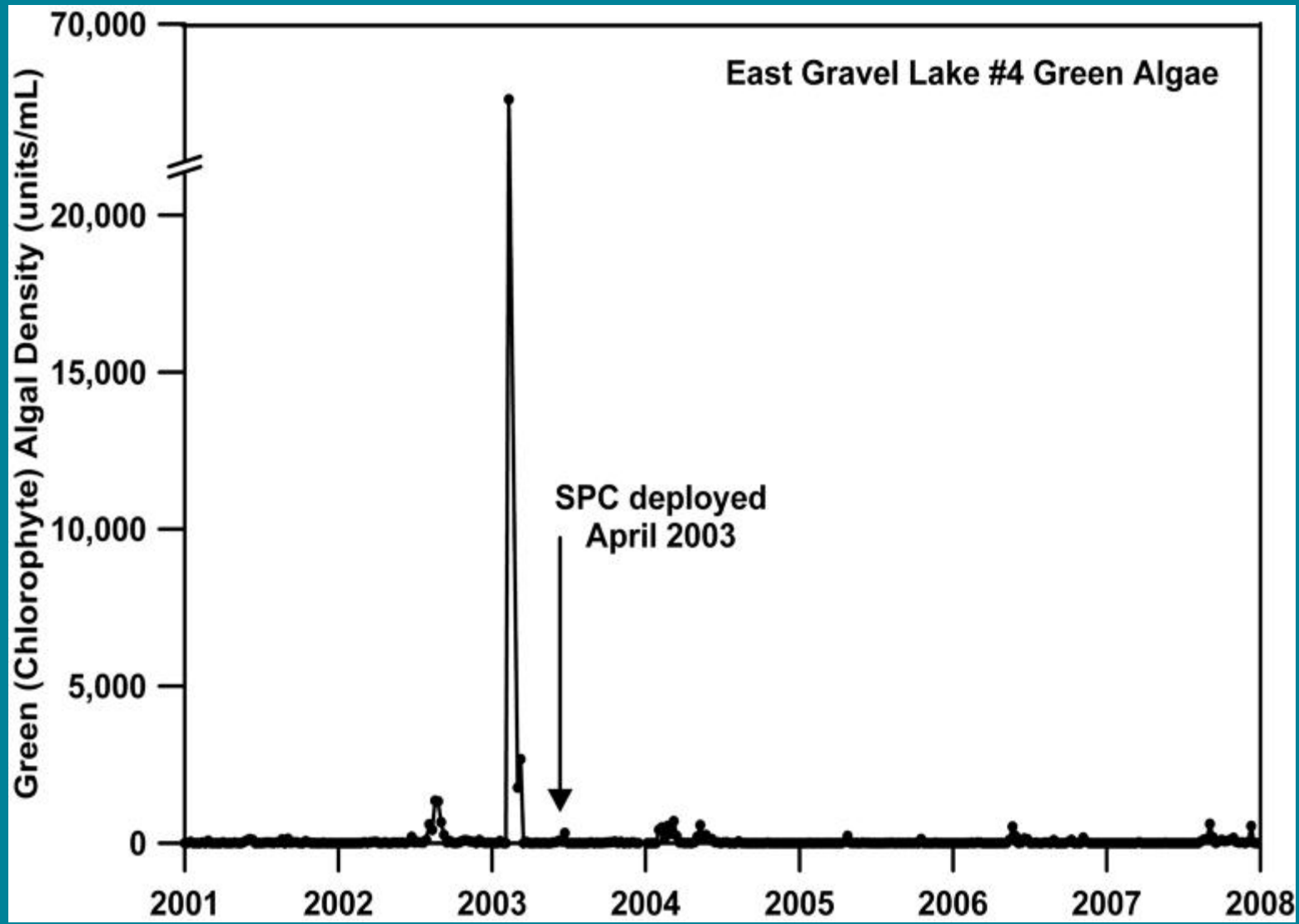


# EGL 4 Cyanobacterial Densities

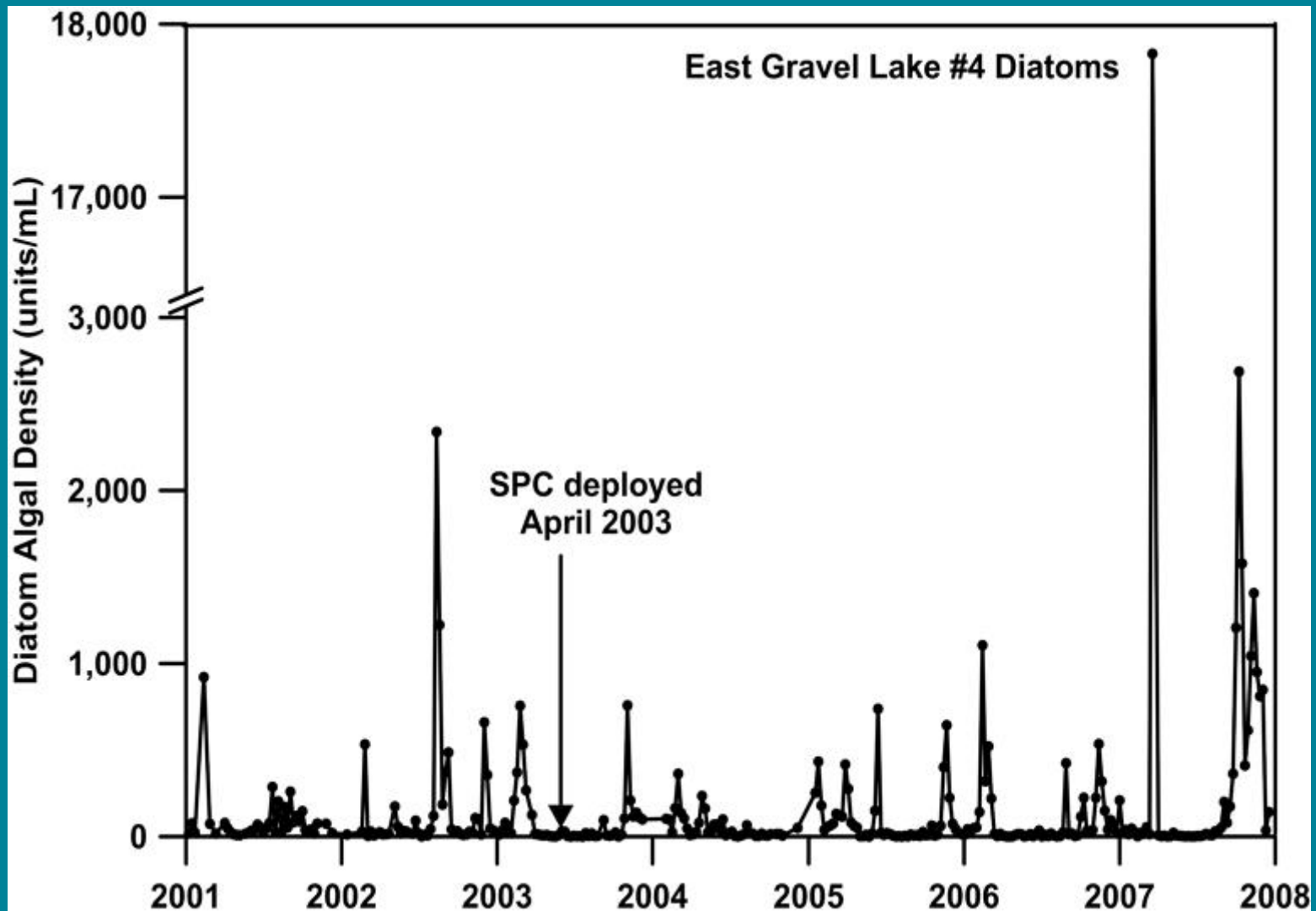


Algaecide usage: 1-2/mth pre- to 1-2/yr during-SPC

# EGL 4 Green Algal Densities



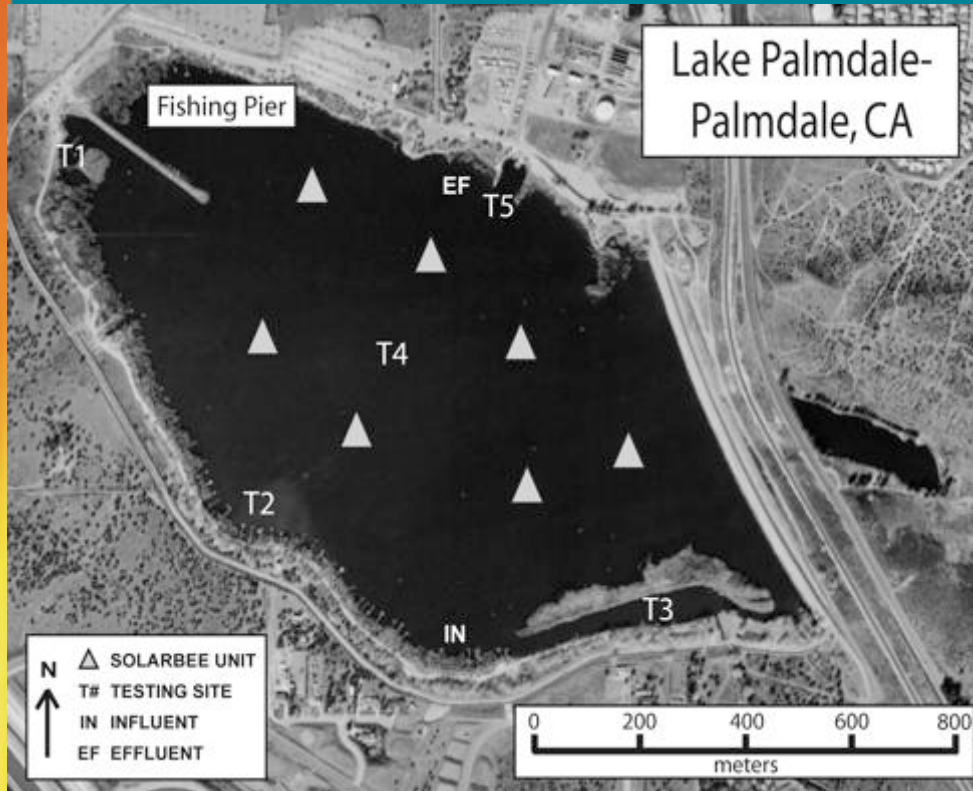
# EGL 4 Diatom Densities



# EGL 4 Data Summary

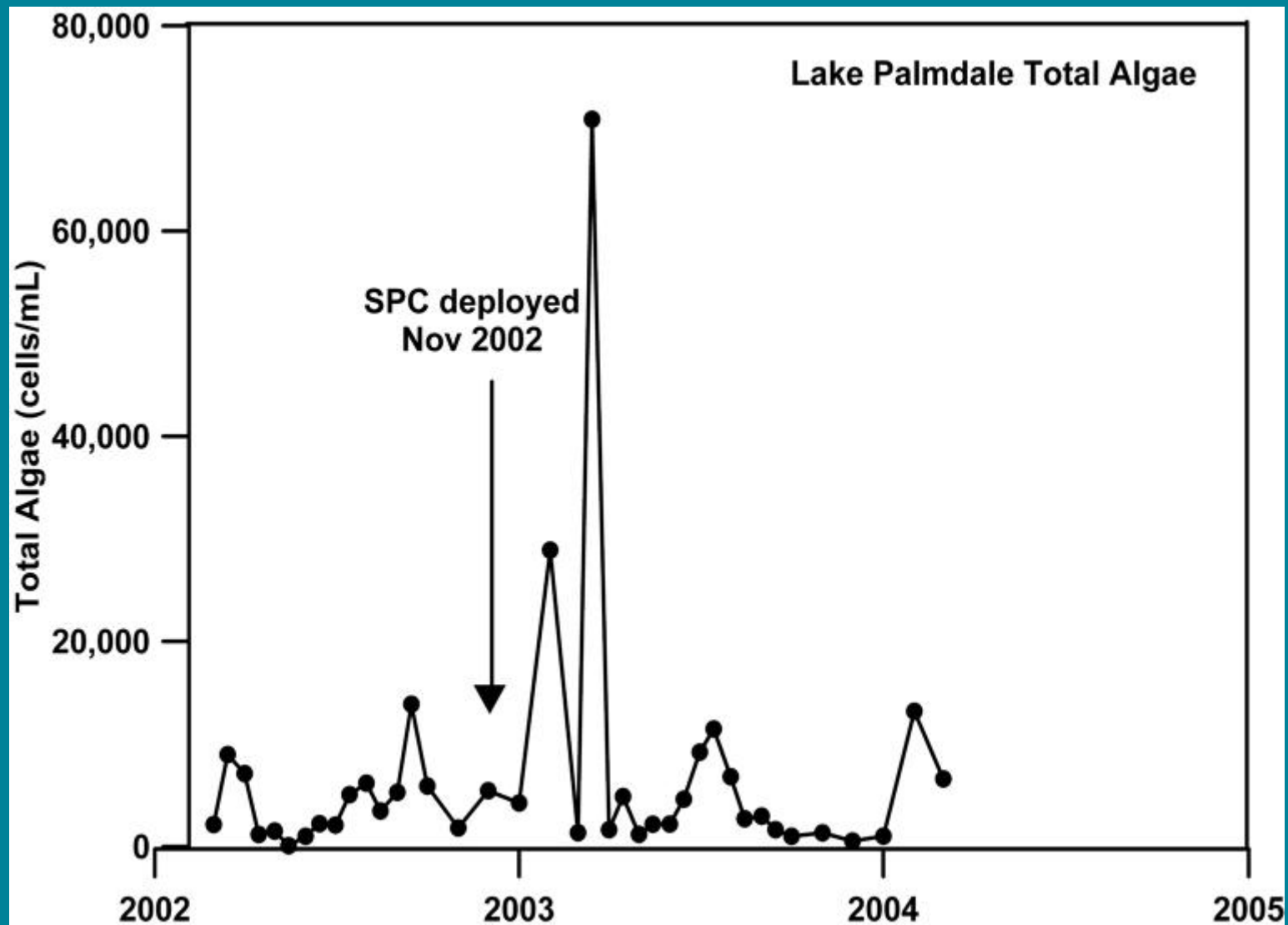
- High densities of total algae were dominated by cyanobacteria prior to SPC
- Total algal & cyanobacterial densities decreased significantly during SPC
  - Indication that FHAB suppression strengthened over time
- Large spike in green algal density just before SPC responsible for significant decrease during SPC
- Diatom densities increased significantly during SPC
- Algaecide applications declined from 1-2/mth to 1-2/yr during SPC

# Lake Palmdale

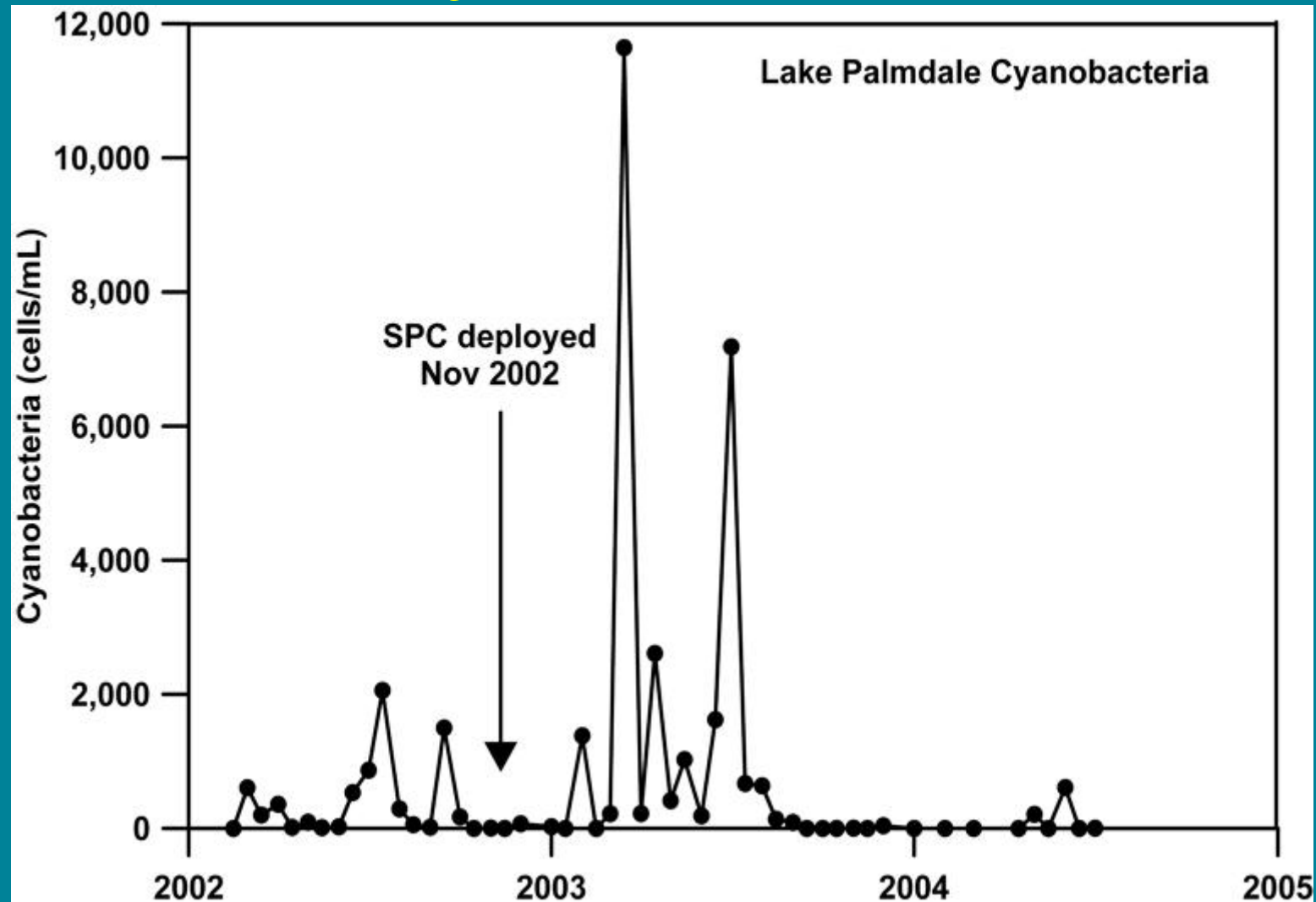


- 234 ac source water
- 25 maximum depth
- 18 ft mean depth
- 15.1 ft mean SPC intake depth
- 14.2 MGD mean input from California Aqueduct
- 270 day mean residence time
- Nitrate reaches 6 mg/L
- Total P reaches ? mg/L
- Aqueduct seeds lake with FHAB cells
- Taste & odor problems
- **Algaecides used**

# Lake Palmdale Total Algal Densities

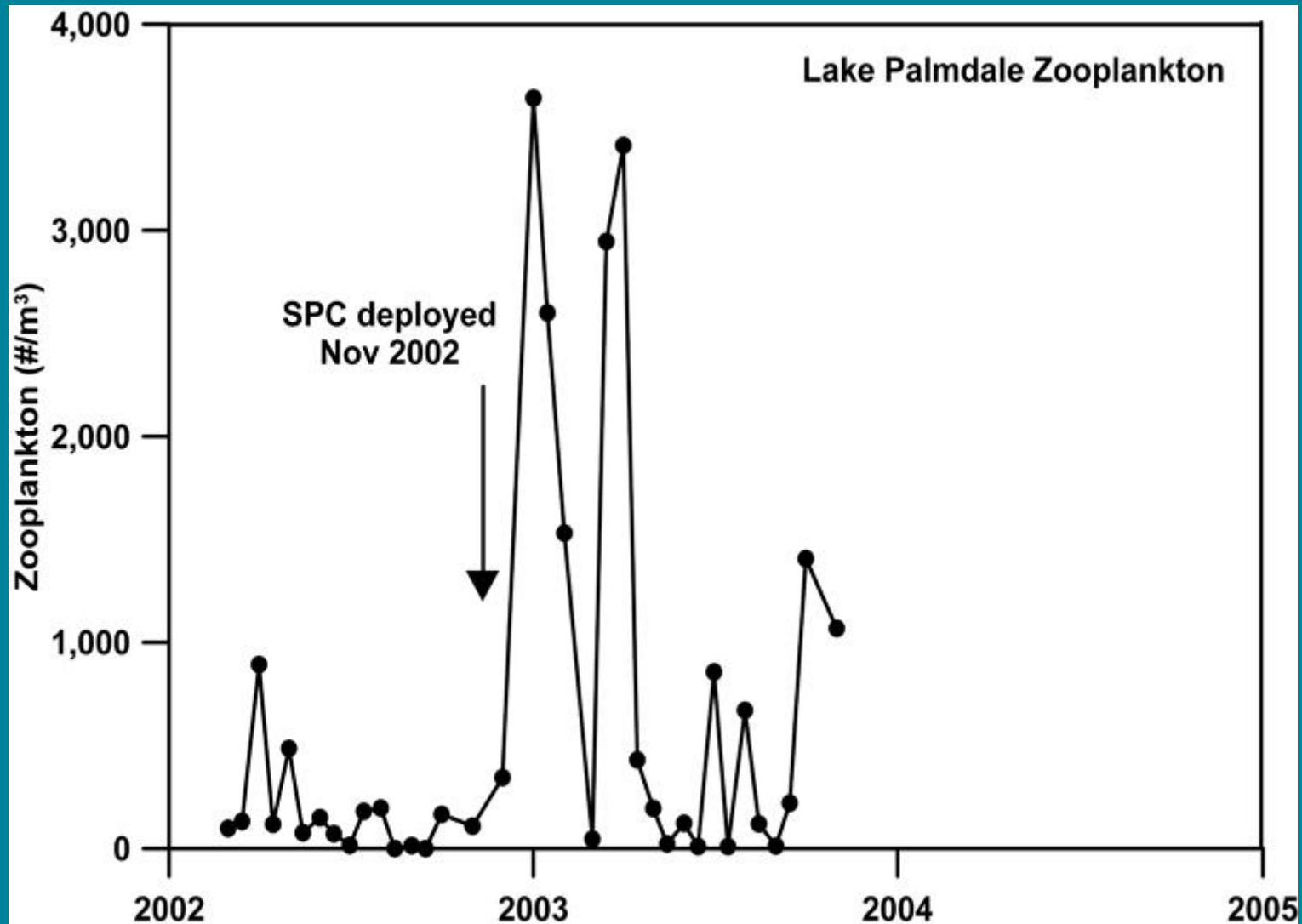


# L Palmdale Cyanobacterial Densities



Algaecide usage (lbs/yr): 2002-57,490; 2003-8,647; 2004-8,274; approximately an 85% decrease

# Lake Palmdale Zooplankton Density



# Lake Palmdale Data Summary

- Total algal mean density significantly higher during SPC
- Large FHAB during 1<sup>st</sup> year of SPC, cyanobacterial density significantly lower in year 2 than pre-SPC
- No significant change in green algal or diatom densities during SPC
- Zooplankton densities increased significantly during SPC
- Algaecide usage declined by approximately 85% during SPC

# 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

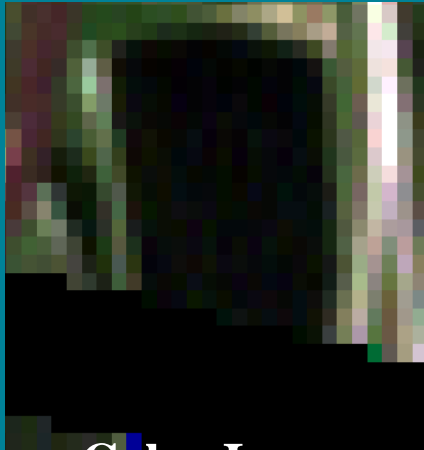
Bolded values are statistically significant at  $p \leq 0.05$ ; Between-site comparisons are inappropriate

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

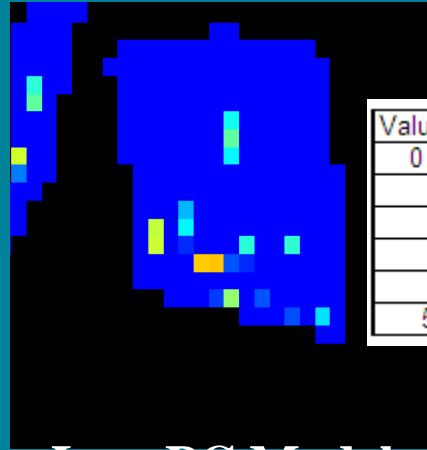
**SPC provides an Ecological Approach to FHAB Suppression**

# Satellite Multispectral Signals

Crystal Lake; 9-7-07; 4,600 cells/mL; Phycocyanin (PC) level unknown

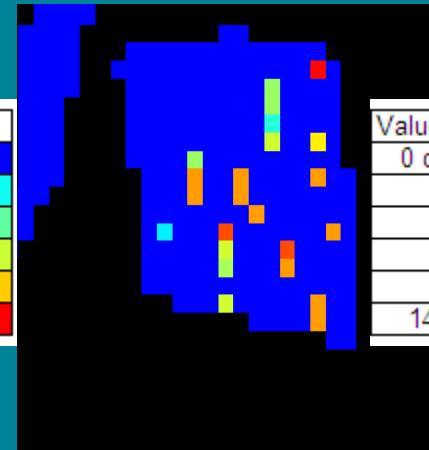


Color Image



Low PC Model

Values (PPB)	Color
0 or >30	Blue
1.6	Cyan
2.3	Light Green
3.1	Yellow-Green
3.75	Yellow
5 - 30	Red



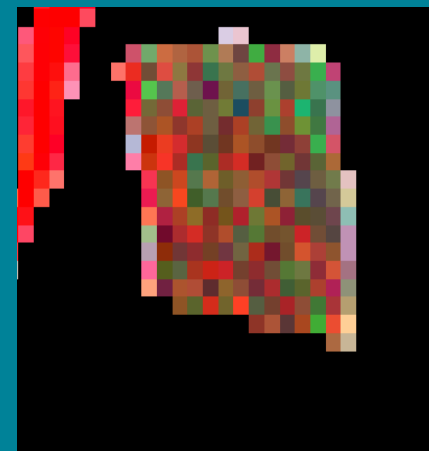
High PC Model

Values (PPB)	Color
0 or >145	Blue
45	Cyan
76	Light Green
97	Yellow
112	Orange
140-145	Red

- 30 x 30 m resolution; 2 LANDSAT units - 5 & 7;
- Unit 7 has venetian blind effect; Both units on 14 day cycle – image same site each 7 days;
- Cloud cover on about 1/2 passes

Blue Water Satellite, Inc.

- Initially developed for early warning – detect low PC levels. Now higher level detection ability



PC Enhancement Model

Promising technology in development

# **Thank You!**

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

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

# 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