

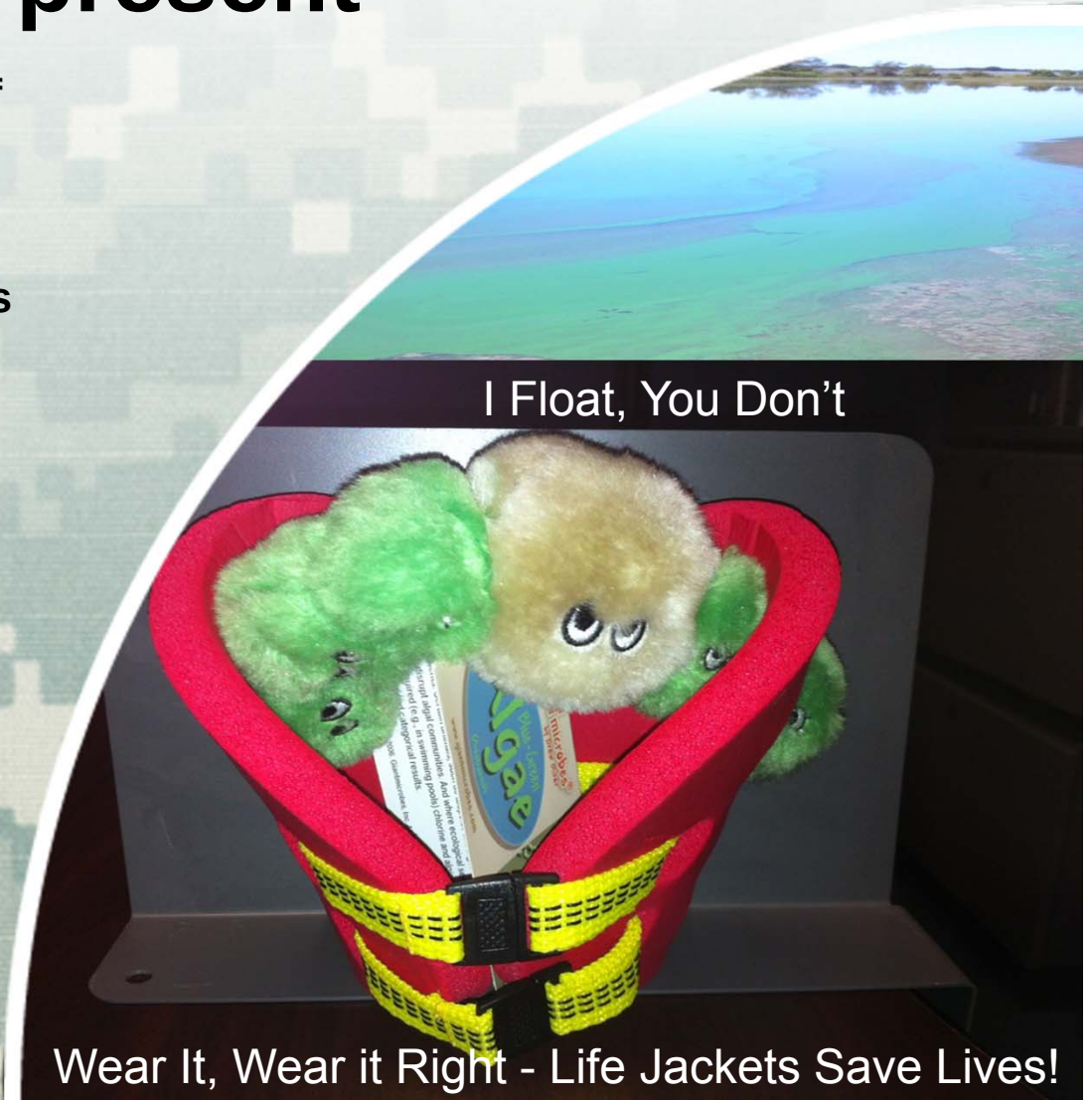
Historical Overview of Cyanobacterial Blooms in Oklahoma 1996 – present

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Oklahoma Clean Lakes and Watersheds
Association

April 2, 2014



Summary Table of WHO , OK, KS, and TX Guidelines for Cyanobacteria Levels in Water

		WHO	OK	KS	TX
Risk of adverse health effects	Level	Recommended Action	Recommended Action	Recommended Action	
LOW	20,000 cells/mL or 10ug/L chl a during blue green Dominance; 4ug/L MYC	At this level, the WHO states that providing information to bathers is considered sufficient.	No Action	Post ADVISORY discouraging swimming, wading, skiing, and jet skiing. Keep pets and livestock out of water. Children and animals may get sick. Signage posted.	No Guidance at the present time
MODERATE	100,000 cells/mL or 50ug/L chl a during blue green dominance; ≤ 4 ug/l MYC ≥ 20 ug/L	The WHO states that interventions such as restricting bathing at beaches and public education campaigns may be appropriate when cyanobacterial counts are at this level.	Issue ADVISORY when cell Densities are $\geq 100,000$ cells/ml AND MYC ≥ 20 ug/l Only signage permitted directs individuals to OTRD website.	Post WARNING prohibiting swimming, wading, skiing, and jet skiing. Keep children, pets, and livestock out of water. Children and animals may get sick. Signage posted.	
HIGH	Presence of cyanobacterial scum at bathing areas; MYC ≥ 20 ug/l	The WHO reports that animal poisonings and human illnesses related to cyanobacteria are usually accompanied by the presence of scum material at the water surface, and that ongoing observation of bathing beaches is necessary to assess the existence of high-risk exposures. INDIVIDUALS SHOULD RESPECT PUBLIC BEACH CLOSURES AS THEY INDICATE A SIGNIFICANT HEALTH RISK.	Post ADVISORY when cell Densities are $\geq 100,000$ cells/ml AND MYC ≥ 20 ug/l Only signage permitted directs individuals to OTRD website. USACE posts on site signage Blue-green Algae Alert Level	Extreme blooms with significant toxin production CLOSURE of lake is coordinated with KDWP&T, KDHE, and stakeholders/Federal and local entities.	

Components of SB 259 incorporated into Tulsa District CyanoHAB Procedures

- Advisories issued by OTRD for cyanoHAB's at reservoirs managed by the Tulsa District when:
 - ▶ $\geq 100,000$ cells/ml total cyanobacteria AND
 - ▶ ≥ 20 ug/l microcystin
- Advisories lifted by OTRD for cyanoHAB's at reservoirs managed by the Tulsa District when:
 - ▶ $\leq 100,000$ cells/ml total cyanobacteria AND
 - ▶ ≤ 20 ug/l microcystin
 - ▶ SB 259 available from the Oklahoma Secretary of State at:
<https://www.sos.ok.gov/documents/legislation/53rd/2012/2R/SB/259.pdf>
- Data provided to OTRD. OTRD responsible for notifying the public via www.checkmyoklake.com
- On site Advisory/Warning signage no longer posted by USACE. General informational flyer posted throughout the recreation season on site.
 - ▶ USACE will close beaches and post signage under extreme bloom conditions (e.g., scum formation, excessive toxin production).



Blue-green Algae Awareness Level

Elevated Risk of Adverse Health Effects

BLUE-GREEN ALGAE BLOOMS ARE PRESENT

**For Your Safety, The U.S. Army Corps of Engineers, Tulsa District
Recommends the Following:**

- **Children and pets are more likely to get sick because of blue-green algae.**
- **Use caution when swimming, water skiing and coming into contact with water.**
- **DO NOT drink untreated lake water.**
- **Keep pets/livestock off of the beach and out of the water.**
- **Avoid areas with visible algae accumulation.**

Symptoms from exposure may include nausea, vomiting, diarrhea, skin rash, eye irritation, respiratory problems or other unexplained illness.

For more information go to:



**www.TravelOK.com/checkmyoklake
or
www.swt.usace.army.mil**

**To Report Illness Due to Exposure, Please Contact Your Doctor or
the Oklahoma Poison Control Hotline at: 1-800-222-1222**

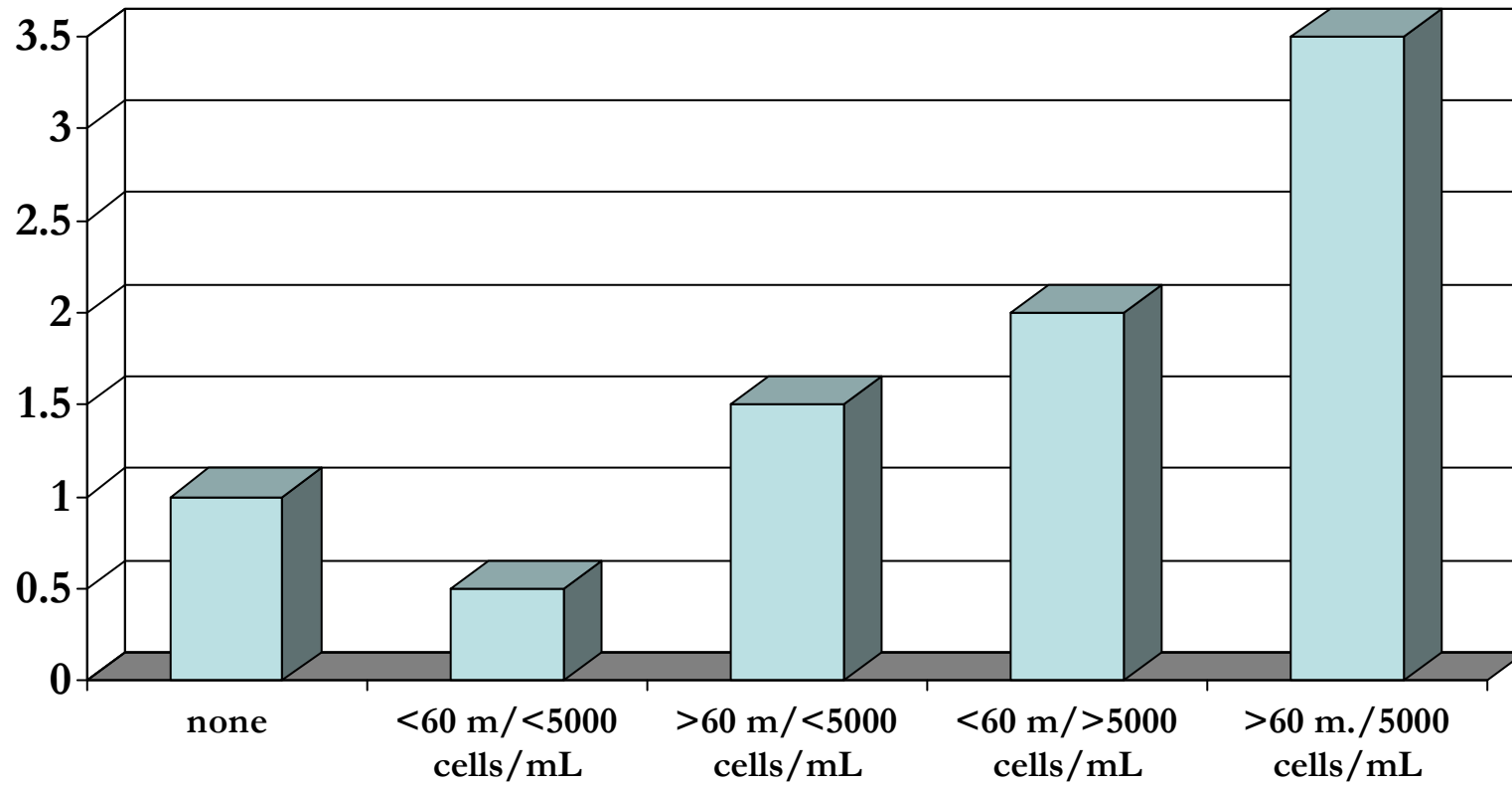


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Australian Swimming Study

Occurrence of Symptoms in Swimmers

(Pilotto *et al.* 1997. Australian and New Zealand Journal of Public Health)



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1996-1997
1999-2001

Lake Texoma, OK-TX – Aug 96 –Sep 97 (501 – 200,748 cells/ml); Mar 99 – Nov 01 (501 – 200,748 cells/ml)

2002

Tenkiller Reservoir, OK – Jun-Sep (0-130,000 cells/ml historic data)

2003

Marion Reservoir, KS June-July
Skiatook Reservoir, OK Aug-Sep (0-58,000 historic data)
Fort Gibson Reservoir, OK (up to 115,000 cells/ml)

2004

Marion Reservoir, KS June-July (up to 24,000,000 cells/ml)
Prymnesium parvum HAB, Lake Texoma, January 2004
Winter T&O reports, Big Hill Lake, KS
Skiatook Reservoir, OK (up to 25,000 cells/ml)

2005

Marion Reservoir, KS June-July
Winter T&O reports, Big Hill Lake, KS
Preliminary assessment of cyanotoxin production

2006

Marion Reservoir, KS June-July
Kerr Reservoir, OK
Winter T&O reports, Big Hill Lake, KS
Dog Death, Lake Texoma, June 26
USGS-USACE cyanotoxin study Marion Reservoir, KS
Isolated *P. parvum* bloom, Lebanon Pool, Lake Texoma, OK
Marion Reservoir, KS June-July (multiple dog deaths)
Winter T&O reports, Big Hill Lake, KS
Present of historic USACE WQ data to Gov. Water Conf.
Isolated *P. parvum* bloom, Lebanon Pool, Lake Texoma, OK
Three dog deaths Marion Reservoir, July 12

2007

2008

Marion Reservoir, KS June-July
Winter T&O reports, Big Hill Lake, KS

2009

Marion Reservoir, KS June-July
Winter T&O reports, Big Hill Lake, KS

Marion Reservoir, KS June-July
KDHE HAB policy development and implementation

CyanoHAB blooms: 12 Reservoirs

Grand Lake, OK June-July – SWT consulted by DEQ and GRDA

Marion Reservoir, KS – Jul-Aug (>100,000)

Big Hill Reservoir, KS – Jul (>20,000)

Keystone Reservoir, OK – Jul-Sep (20,000- >100,000)

Skiatook Reservoir, OK – Jul-Sep (< 100,000)

Waurika Reservoir, OK – Aug-Nov (>20,000 - > 1,000,000)

Eufaula Reservoir, OK – Aug-Sep (11,608 – 153,936)

Lake Texoma, OK – Aug-Dec (<20,000 – 500,000)

Fort Gibson Reservoir, OK – Jul-Sep (> 20,000)

Tenkiller Reservoir, OK – Jul-Sep (>100,000)

Lake Hefner, OK – Summer (max 474,500)

Lake Overholser – Summer (max 1,564,900)

Suspected dog death Eufaula Lake

2010

2011



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CyanoHAB blooms: 26 Reservoirs

Marion Reservoir, KS – Jun-Aug (20,000 – 22,000,000) 40-5000 ug/l MYC 28 Jun; <0.15ug/l – 5000ug/l Jun-Aug

22 Cattle deaths in late May 2012. Veterinary Diagnostic Lab at KSU confirmed BGA probable cause of deaths

Keystone Reservoir, OK – Jun-current (50,000 - >100,000)

Skiatook Reservoir, OK – Jun-Sep (0-60,000)

Waurika Reservoir, OK – May-current (11,000 – 600,000) < 0.15 ug/l MYC

Eufaula Reservoir, OK – Jun-Sep (0-900,000)

Lake Texoma, OK – Jan-Mar & May-Sep (3,000-2,500,000) ND – 0.2 ug/l MYC; ND-0.5 ug/l CYN; ND STX; ND ANT-X-A

Fort Gibson Reservoir, OK – May-Sep (12,000 – 1,300,000)

Tenkiller Reservoir, OK – May-Sep (12,000 – 580,000)

Copan Reservoir, OK – Aug-Sep (3,000 – 56,000,000) < 0.15 – 3455 ug/l MYC

Hugo Reservoir, OK – May & Aug (< 20,000)

Oologah Reservoir, OK – Jun & Aug (3,800 – 37,900)

MKARNS-Verdigris River, OK – Aug (122,000) 0.18ug/l MYC; ND CYN

R.S. Kerr Reservoir, OK – Aug-Sep (26,000 – 480,000) < 0.15 ug/l MYC

Wister Reservoir, OK – Aug-Sep (183,000 – 210,000)

Lake Arbuckle, OK – Summer (max 192,000)

Clear Creek Lake, OK – Summer (max 611,000)

Duncan City Lake, OK – Summer (max 75,000)

Fort Cobb Lake, OK – Summer (max 361,000*)

Foss Lake, OK – Summer (max 24,600,000*)

Lake Fuqua, OK – Summer (max 51,800)

Lake Hefner, OK – Summer (max 54,700*)

Lake Humphries, OK – Summer (max 91,300)

Lake Charlotte, OK – Summer (max 150,000**)

Lake Overholser, OK – Summer (max 64,780)

Lake Lawtonka, OK – Spring (max 232,000*)

Wes Watkins Lake, OK – (max 11,200)

Two dog deaths at Lake Ellsworth, May 17, 2012

* Microcystin detected, below 20 ug/l

** Microcystin detected, below 20ug/l;
saxatoxin detected (no guidance value in
Oklahoma)

SB 259 signed by Gov. Mary Fallin May 24, 2012

2012



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CyanoHAB blooms: 18 Reservoirs

Copan Lake – Aug 2013 (107,544 cells/ml) < 0.15 ug/l MYC

El Dorado Lake – Apr-Sep (37,000 – 502,654 cells/ml) ND – 0.961 ug/l MYC

Eufaula Lake – May-Dec (26,000 – 685,792 cells/ml) ND – 0.345 ug/l MYC

Fort Gibson Lake – May-Sep (12,000 – 463,000 cells/ml) ND – 0.176 ug/l MYC

Heyburn Lake – May-Sep (16,000 – 539,000 cells/ml) ND – 0.24 ug/l MYC

Hulah Lake – Bloom reported in Jul, no data

Keystone Lake – Apr-Sep (4,000 – 700,000 cells/ml) ND – 0.53 ug/l MYC

Marion Lake – Jun-Jul (2,000 – 195,930,000 cells/ml) 1100ug/l MYC

Pat Mayes Lake – May-Sep (50,000 – 1,000,000 cells/ml) ND - < 0.15 ug/l MYC; ND CYN

Skiatook Lake - Jun-Aug (24,000 – 222,687 cells/ml) < 0.15 ug/l MYC

Tenkiller Lake – May-Sep (40,000 – 1,076,000 cells/ml) ND – 0.25 ug/l MYC

Lake Texoma – Apr-Sep (11,000 – 915,000 cell/ml) ND-0.25 ug/l MYC;

Waurika Lake – May-Oct (68,000 – 1,000,000 cells/ml) < 0.15 – 0.174 ug/l MYC

Wister Lake – Mar-Dec (0 – 637,000 cells/ml) ND – 0.24 ug/l MYC

Lake Altus-Lugert – Summer (max 55,200 cells/ml)

Lake Hiwassee – Summer (max 78,000 cells/ml)

Frederick Lake – Summer (max 15,700,000 cells/ml)

Reported cattle death(s) in Tillman County, OK. No information available on final toxicity results

Lake Lawtonka – Summer (max 13,500 cells/ml)

2013



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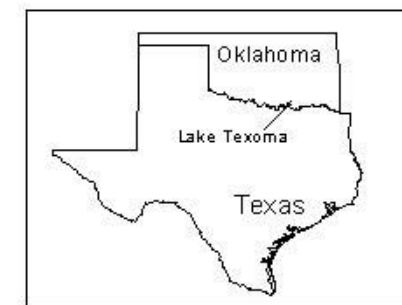
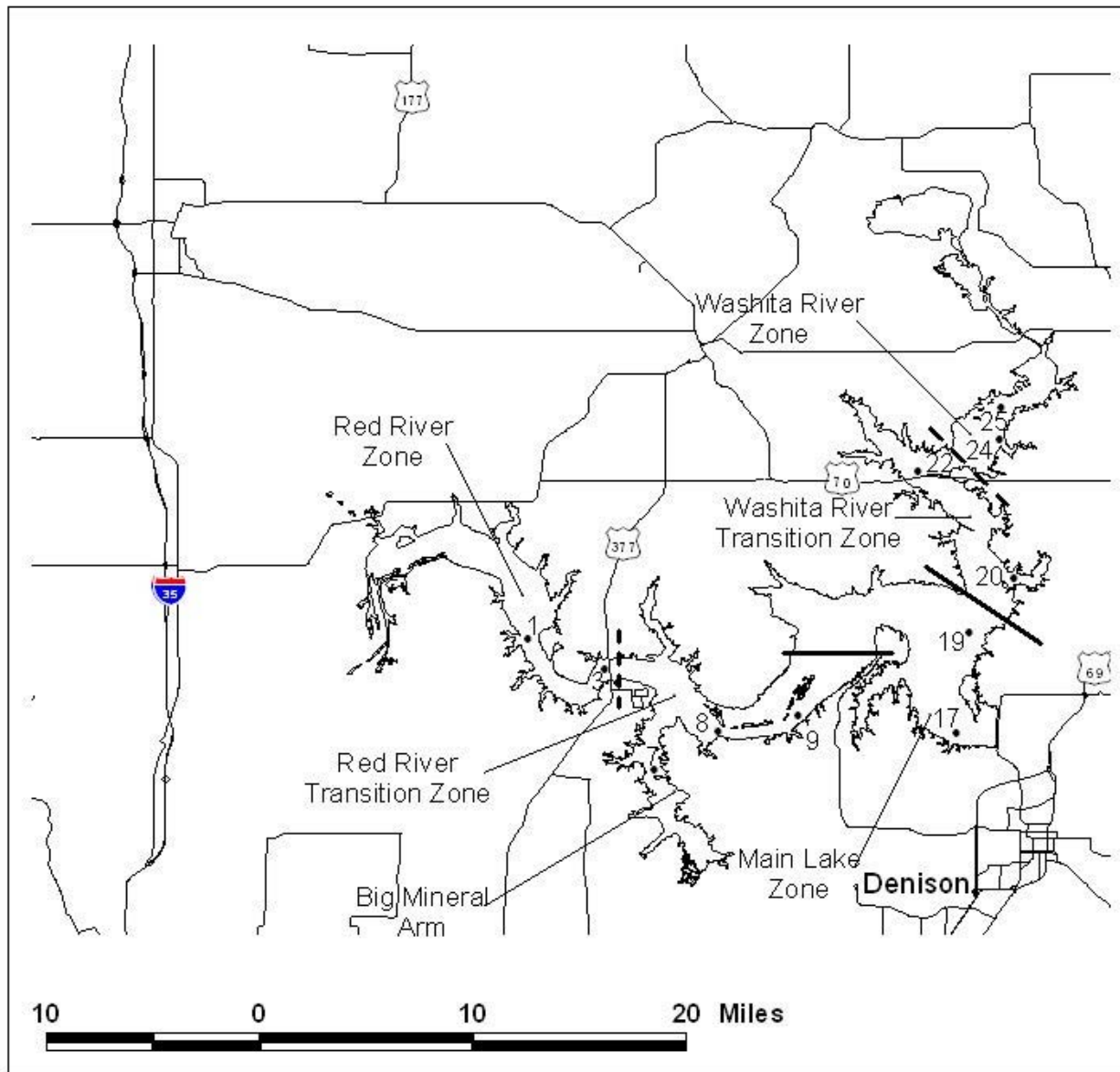
CyanoHAB blooms: ?? Reservoirs

Wister Lake, OK – Jan – present (6,199 – 73,644 cells/ml) < 0.15 ug/l MYC

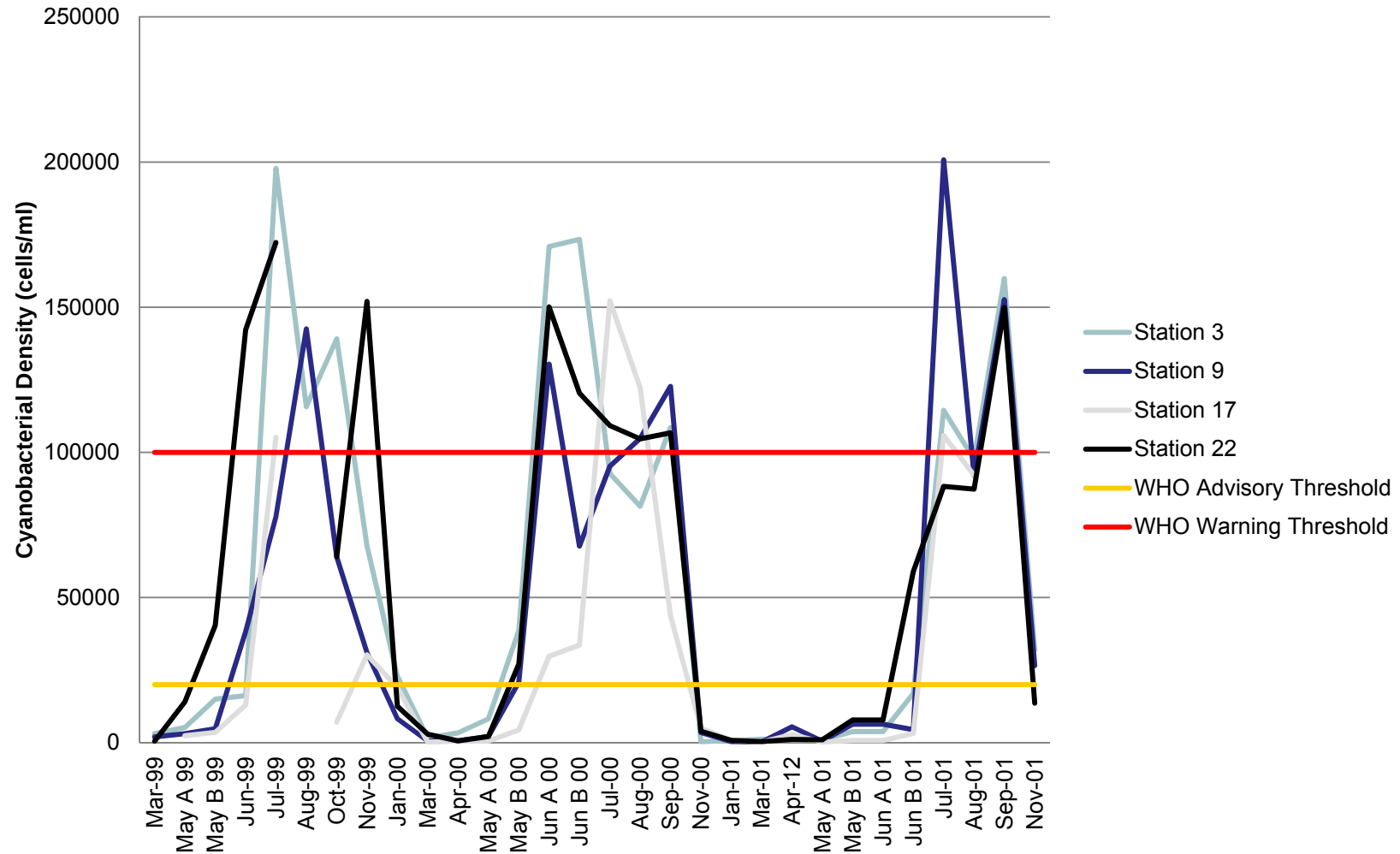
2014



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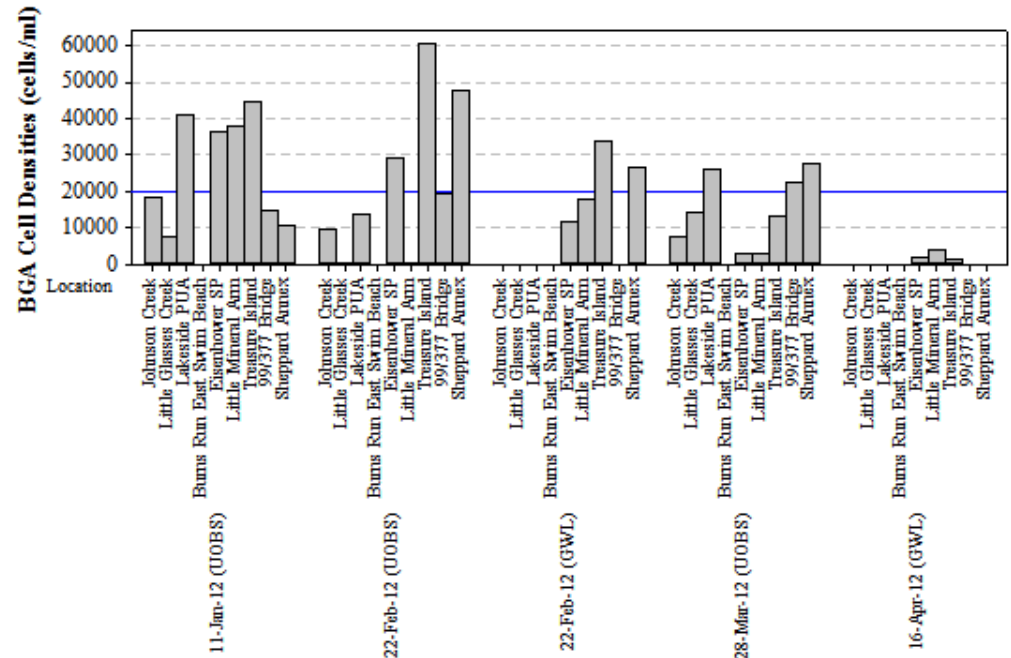
Cyanobacterial cell densities in Lake Texoma at various locations from March 1999 through November 2001





August 20, 2012

- Blooms continued through much of the winter of 2011-2012
 - ▶ Advisories lifted in April 2012
- Blooms returned in May 2012
 - ▶ Cell densities ranged from:
 - 27,811 – 42,545 cells/ml in May
 - 3,058 – 408,759 cells/ml in June
 - 571,415 – 909,172 cells/ml in July
 - 629,289 – 1,334,902 cells/ml in Aug
- Cyanotoxin production remains minimal
 - ▶ Microcystin documented from <0.15 to 3.2 ug/l; sporadic occurrence
 - ▶ Saxatoxin present on one date, 0.027
 - ▶ Cylindrospermopsin from 0.05 to 0.5 ug/l; continuously present
 - ▶ Multiple analytical methods/analysts: LC/MS/MS; ELISA



Courtesy Univ. of Oklahoma, Grayson County Health Department

Lake Texoma,
Oklahoma-Texas



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Marion Reservoir, KS



Date	Cell Densities (cells/ml)	Microcystin (ug/l)
6-18-12	493 – 14,458	<0.5 – 2.0
6-25-12	241,290 – 22,648,500	40.0 – 5,000
7-16-12	28,980 – 262,521	10.0 – 18.0
7-23-12	0 – 12,604	2 – 3
6-10-13	25,190 – 195,930,000	<0.5 – 1,100
6-24-13	34,946 - 254,543	<0.5 – 6.0
7-01-13	39,054 – 696,732	2-120
7-08-13	25,844 – 102,048	4.0 – 12.0
7-22-13	1,890 – 13,222	<0.5 – 1.0

Courtesy KDHE



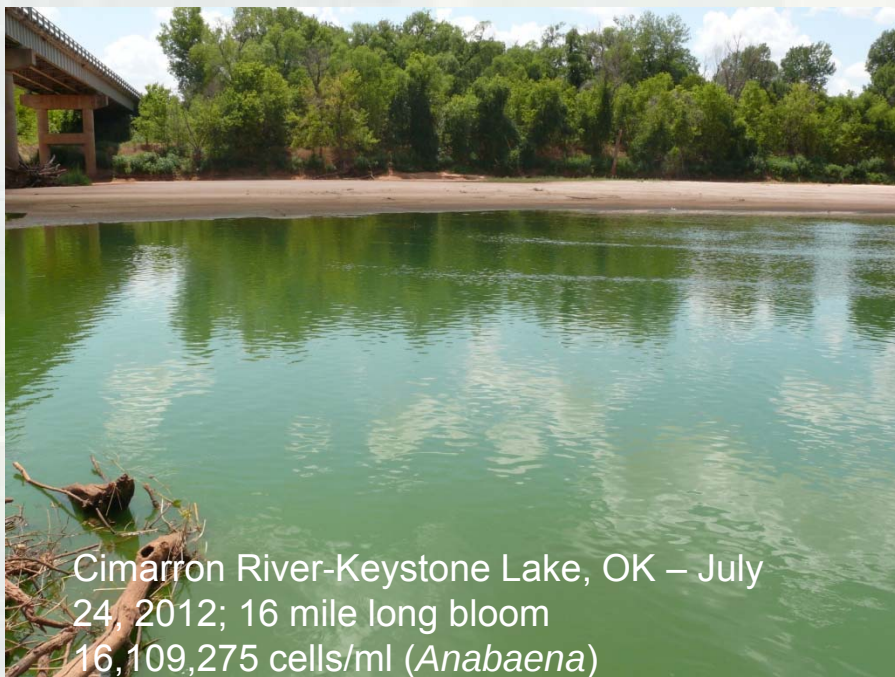
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Copan Lake, OK - 2012

- Bloom reported in on August 7, 2012
 - ▶ Copan Point Swim Beach: 1,442,397 cells/ml
- Bloom reported on August 21, 2012 (*Microcystis*)
 - ▶ Copan Point Swim Beach: 78,134 cells/ml; 6.99 ug/l microcystin
 - ▶ Post Oak Camp Ground: 66,968 - 56,811,116 cells/ml; 10.38 – 3,455 ug/l
 - ▶ Re-sampled on September 18, 2012
 - ▶ Copan Point Swim Beach: 4,693 cells/ml; 0.26 ug/l microcystin
 - ▶ Post Oak Camp Ground: 25,790 cells/ml; <0.15 ug/l microcystin
- Closed signs were posted at Post Oak Camp Ground in accordance with OK State Law, USACE signage posted at Copan Swim Beach



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Cimarron River-Keystone Lake, OK – July
24, 2012; 16 mile long bloom
16,109,275 cells/ml (*Anabaena*)



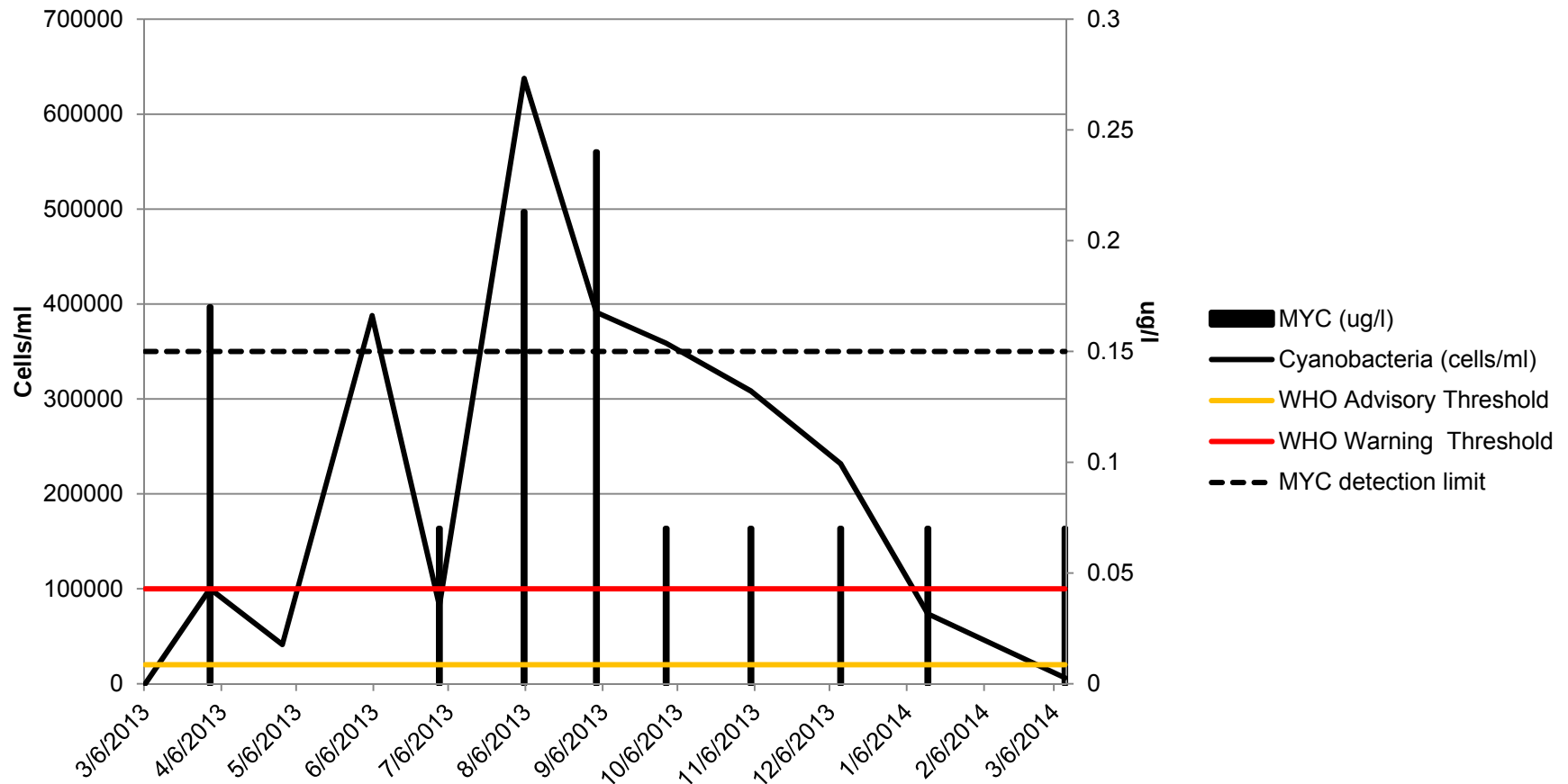
Hulah Lake, OK – August 29, 2012
No samples collected



R.S. Kerr Lake, OK – August 29, 2012
482,144 cells/ml

Wister Lake, OK

March 2013 – March 2014



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Historical USACE CyanoHAB Activities

Table 3. HAB occurrence and impact summary table.

District	HAB Occurrence	HAB Impact
Louisville	Blooms occur at multiple Corps projects every summer, late in the season. Blue-green algae blooms have become a larger issue in the Louisville District in the past three years, most often in Indiana lakes, but also in Ohio and Kentucky bodies of water. Associated factors are thought to include eutrophication, oxygen depletion, high temperatures, and drought conditions.	Multiple projects have reported fish kills. Anecdotal reports of dogs that died after jumping into/drinking water high in algal toxins. Blooms have necessitated an increase in filtration and application of carbon to remove taste and toxins in the water supply. Beaches have been closed down due to blooms, and some people have reported skin rashes.
Norfolk	Large bloom occurred at the Craney Island Dredged Material Management Area in the summer of 2005.	Algal toxin effects are negligible, as the toxins dissipate in the wide mixing area of Norfolk Harbor and recreational activities do not take place in the region.
Buffalo	The Buffalo District manages and maintains many harbors along the south shore of Lake Erie, which currently faces multiple problems and concerns with algal blooms. Blooms have occurred on Lake Erie every summer, with a peak of 2-3 weeks, for at least the past 5 years.	No documented human health impacts have resulted thus far. Beaches have been closed as a precautionary measure.
Portland	Most of the Portland District projects have experienced algal blooms at one time or another. Blooms begin in June and last through the summer. In 2005, large blooms occurred at three of the 17 district projects; typically up to two-thirds of the district's projects experience a large bloom in a given year.	Despite bloom prevalence, health and property impacts were not specified.
Jacksonville	Blooms occurred at several of the district's biggest projects in 2005. Blooms seem to be associated with heavy rainfall periods.	Anecdotal reports of dead manatees. Many human health concerns, especially relating to potable water. Concerns will likely impact the design of a costly project where a downstream water quality treatment installation could increase costs.
Tulsa	Blooms occurred at six of the district's 36 projects in 2005. Marion Reservoir in Kansas blooms annually.	A dog is thought to have gotten sick from Microcystin at Marion Reservoir, Kansas. A golden algae bloom at Lake Texoma in January 2004 killed 25-30,000 fish. Golden algae threaten the striped bass fishery on the lake, which is a \$40 million/year economic asset as reported by Paul Mauk, Oklahoma Department of Wildlife Conservation.

Table 5. HAB monitoring summary table.

District	HAB Monitoring
Louisville	The Louisville District collects data from each of their reservoir projects, from the inflows and from the tail waters. At Harsha Lake the District conducted a modeling study, collecting data on a weekly basis through the summer of 2005. Sampling included five locations within the lake every four weeks at different depths. Measurements included metals, nutrients, phytoplankton, chlorophyll, and physical parameters. However, the budget only contains enough money to monitor other locations once a year (in August or September). The Corps collects water for analysis from different depths at tail waters, dam sites, and major tributaries. Special circumstances may warrant a closer look at other places. Other agencies, such as the Division of Water, Fish & Wildlife, and USGS, also collect data in Kentucky, as well as many Indiana agencies.
Norfolk	The Norfolk District has recently measured chlorophyll A levels at Craney Island. USACE noticed these levels increasing over the summer of 2005. Levels started fairly low (i.e. levels the previous winter were around 1-2 ug/L, but levels in the spring and summer were 15-20 ug/L). USACE does not have past summer background measurements and has not done testing until the last few years.
Buffalo	The Buffalo District does not collect data related to algal blooms.
Portland	For the past ten years, the Portland District has taken comprehensive measurements at three projects: the Willow Creek Reservoir (which often experiences algal blooms), Lost Creek Lake, and Applegate Dam. Sample analysis consists of organism ID, cell counts, cell density, and biovolume, as well as environmental factors (including temperature, pH, turbidity, dissolved oxygen, dissolved solids, etc.). Samples are generally 500 mL to 1 L, taken from the top layer of water. Due to budget constraints, samples are not taken regularly at other projects and often include analysis for fewer factors. The interviewee estimated that monitoring all projects on a weekly basis would take over \$100,000 per year, which is much larger than the District's entire water quality budget.
Jacksonville	Rather than USACE, the Florida DEP and South Florida Water Management District often sample for algal blooms. The Jacksonville District has, however, collected data about cyanobacteria at sites connected with the Aquifer Storage & Recovery Project. These data are taken from four sites (Lake Okeechobee, Kissimmee River, Hillsboro Canal, Caloosahatchee River), quarterly for one year. Sampling is expensive.
Tulsa	In 2005, the Tulsa District took measurements at the Marion and Fort Gibson reservoirs. Microcystin levels ranged from 2.9 to 9.6 ppb at Marion (June 8th to July 13th, samples taken every two weeks, possibly 60 or 70 samples); 2.8 to 3.6 ppb at Fort Gibson (July 6th, possibly 40 samples). Samples were also taken at Tenkiller Reservoir in 2005, and Skiatook Lake samples were taken on a day at peak of cylindrospermopsin bloom near a swim beach. All told, approximately 360 samples were taken during the year. Data include nutrient levels, total phosphorous, nitrate/nitrite, ammonia, organic carbon, chloride, and total calcium in some lakes, as well as vertical profiles of turbidity, oxygen, pH, conductivity, temperature, chlorophyll, and some light data. Most samples are surface samples; others are a half meter below surface or a meter above the bottom, taken in 1-L amber bottles, split between microcystin and cylindrospermopsin analysis. Historically, the District has had chlorophyll data, but now Dr. Bob Lynch at OU is doing phytoplankton analysis for them.

Excerpted from ERDC/TN ANSRP09-1, The Impact of Harmful Algae Blooms on USACE Operations:

<http://el.ercd.usace.army.mil/elpubs/pdf/ansrp09-1.pdf>



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FY14 HAB ACTIVITIES

- Update Tulsa District BGA policy and SOP to reflect reorganization of OD and PE/RPEC.
- Continue collaboration with others
 - ▶ OTRD, ODEQ, TCEQ, KDHE, USGS, LRDOR, LRL, LRH, LRP, NWP, NWK, ERDC, HQ-USACE WQ Committee
- Participate in USACE HAB Technical Workshop to update the 2009 Technical Note.
- Bloom conditions outside of past experience not anticipated
 - ▶ Nutrient inputs during drought minimal
 - ▶ No major flooding over Fall/Winter 2013
 - ▶ Major flooding in Spring/Summer 2014 could influence intensity and impact of blooms



Conclusion-Discussion

- Nationally, the intensity and frequency of cyanoHAB's at USACE managed reservoirs is increasing
- Currently, the USACE is responding to cyanoHAB's specifically, and HAB's generally, within a local regional context
 - ▶ Individual local/county and state policies, procedures, and statutes
 - ▶ Lack of national guidelines/policies with regard to HAB's
 - ▶ Stakeholders in different jurisdictions within any given USACE District/Division Office AOR are not provided consistent environmental health risk assessments and information to make informed decisions for themselves and their families
 - The USACE manages 422 lakes in 43 states
 - > 90% of USACE recreation areas are within 50 miles of a major metropolitan center
 - 55,000 miles of shoreline; 4,500 miles of trails; 90,000 campsites; 3,400 boat ramps
 - The USACE provides PWS storage capacity of 329.2 million ac-ft
- The scope of the USACE recreation and water storage missions necessitates a national approach to cyanoHAB guidance

