Freshwater Harmful Algal Blooms in California: Recent Events and Impacts

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TMDL Task Force Meeting March 22, 2017

Unprecedented Years for Freshwater HABs and Cyanotoxins

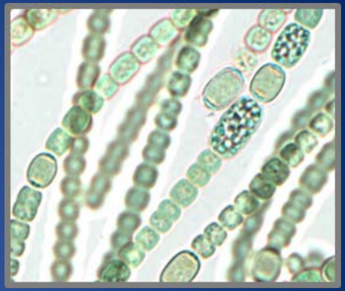
- **New record high concentrations of toxins**
  - Multiple toxins detected simultaneously

- **Many impacts and effects**
  - Record number of lakes closed for recreation
  - Annual dog deaths attributed to cyanotoxins
  - Wildlife mortality events
- **New situations and HAB organisms**
  - New HAB organism, golden algae, *Pyrmnesium parvum*
  - Ubiquitous and year round toxins
  - Toxins detected in marine shellfish and outflows to marine waters

Types of Freshwater HABs

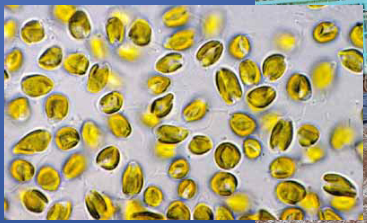
Cyanobacteria

- >3 billion years old
- Occur in most waterbodies (fresh, brackish, marine)
- Can form dense blooms
- Some produce toxins - Cyanotoxins
  - >90 described
  - Common toxins include microcystins, anatoxin-a, cylindrospermopsin, saxitoxin
  - Bioaccumulate



Golden Algae

- *Prymnesium parvum*
  - Fish kills; no human health concerns



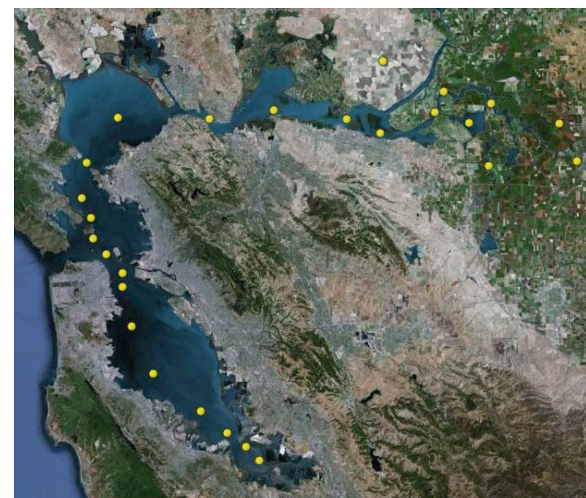
A Tour of California Hotspots

Lake Elsinore

- 4 toxins detected simultaneously
- 2 or more toxins exceeded health thresholds
- Highest toxin in Southern CA

Pinto Lake

- 2nd most toxic lake in the world
- Year round toxins

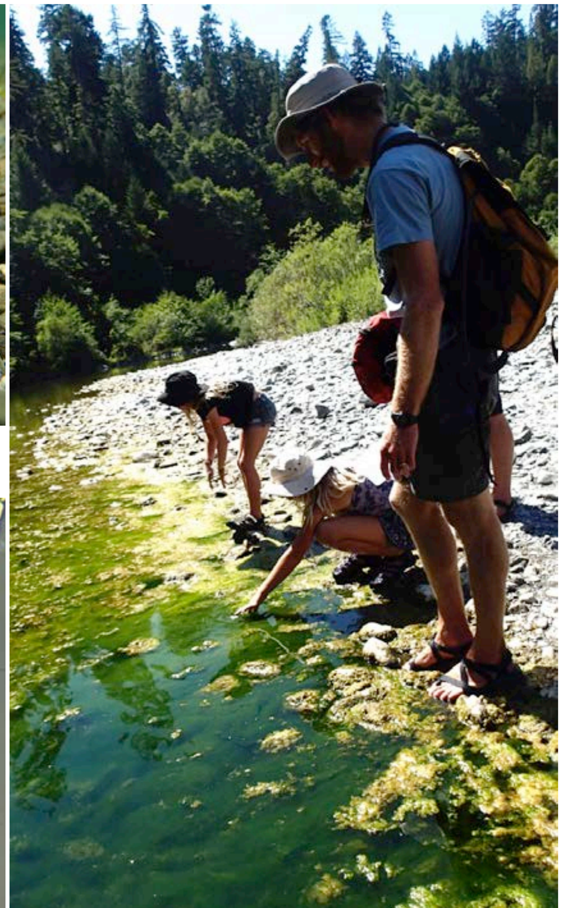


San Joaquin Marsh

San Francisco Bay

- Ubiquitous and year round toxins
- The Bay acts as a mixing bowl for both freshwater and marine toxins

A Tour of California Hotspots



Wadeable Streams:

Microcystin—33%

Lyngbyatoxin—21%

Saxitoxin—7%

Anatoxin-a—3%

Eel River algal mats:

Anatoxin-a—42%

Microcystins—15%

Both—5%

ATX ~ 10x > MCY

Globally, Cyanobacteria Blooms are Increasing in Frequency, Extent and Duration

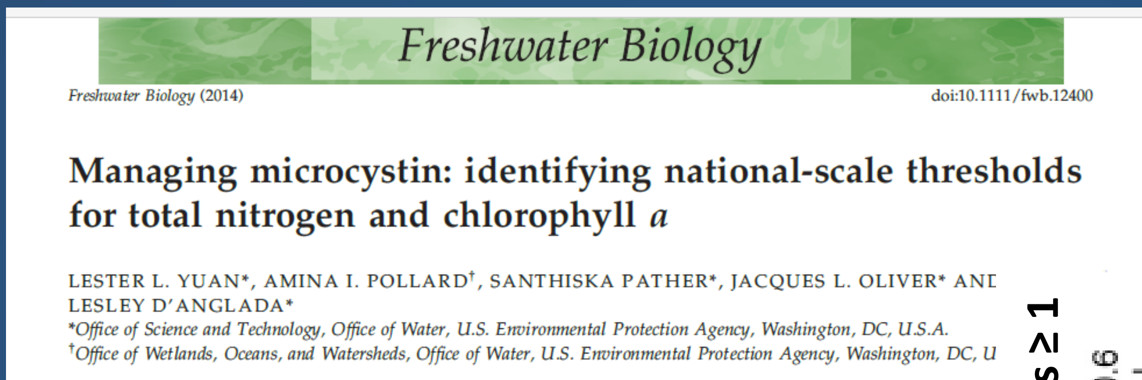
Environmental Drivers:

- Climate change and warm temperatures
  - Fundamental driver of the rate of growth
- Increased anthropogenic nutrient inputs
- Hydrologic modification and water use

& SLOW!

Paerl et al. 2009

How Do Local Nutrients Impact HABs?


Freshwater Biology

Freshwater Biology (2014) doi:10.1111/fwb.12400

Managing microcystin: identifying national-scale thresholds for total nitrogen and chlorophyll *a*

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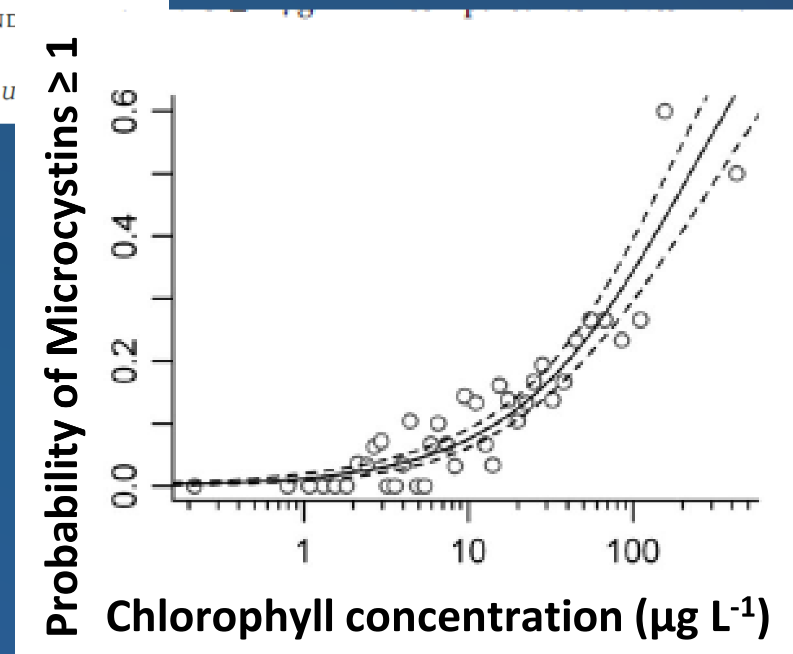
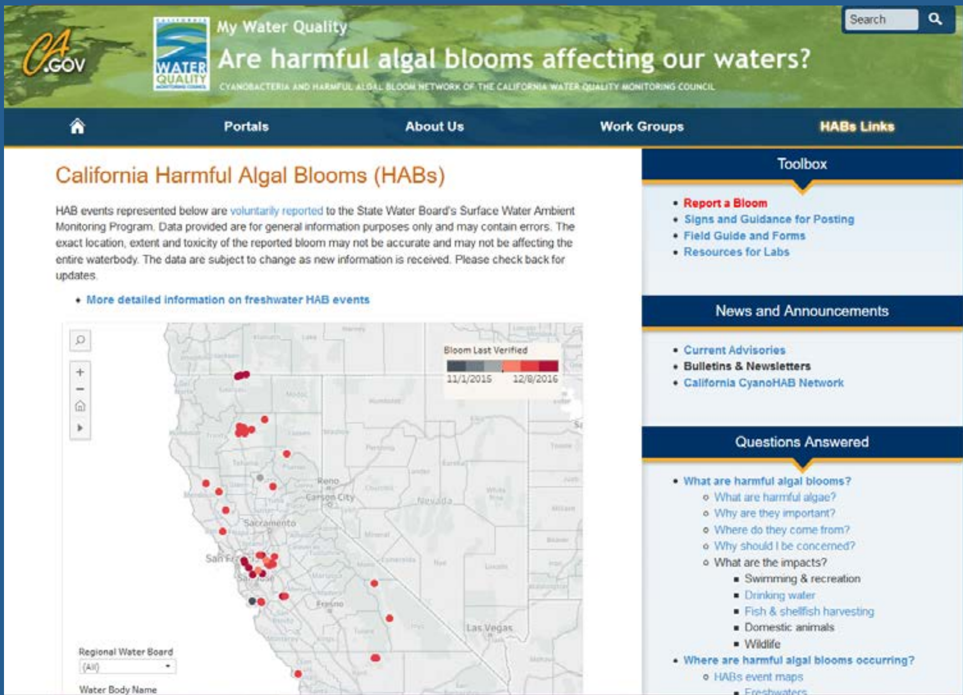
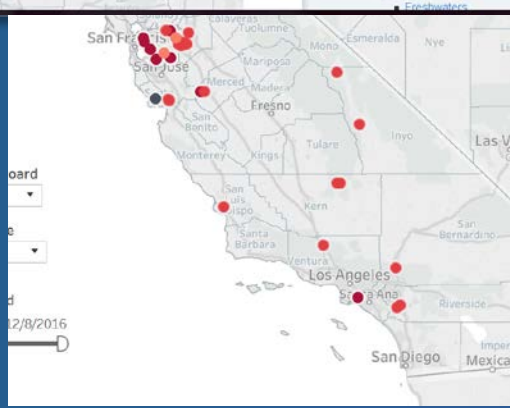
- Nutrients cause increase in biomass (chlorophyll-a)
- Risk of HABs increases with increasing chlorophyll-a



- Cyanotoxins will likely be a supporting indicator used to set nutrient (biostimulatory) objectives established by State

What Is California Doing To Manage HABs?





- **Before Heading Out. . .**
  - Health and Safety Guide
  - Site Reconnaissance Guide
- **Making Observations and Measurements in the Field**
  - Field Sheet and Chain-of-Custody Forms
  - Visual Guide to Observing Blooms
  - Field Microscopes SOP
  - Field Fluorometry SOP
  - Field Toxin Detection Test Kits SOP
- **Collecting Samples for Laboratory Analysis**
  - Toxin Sample Collection SOP
  - Microscopy Sample Collection SOP
  - Fluorometry Sample Collection SOP
  - Laboratories for Analysis Guide
- **Interpreting the Data & Posting Advisories**
  - Cyanobacteria and Known Toxins Chart
  - Guide to Interpreting the Lab Report
  - HAB Incident Response and Posting Advisories Guide
  - Submitting Data to State Water Board
- **Incidents of Toxin Exposure**
- **Glossary**
- **Contacts**

Health Based Advisory Thresholds for Cyanotoxins

- Health impacts and mortality to humans, pets, wildlife, livestock
- Impede beneficial uses
- EPA for drinking water and recreation waters (draft)
  - Microcystins: 4 µg/L (ppb)
  - Cylindrospermopsin: 8 µg/L (ppb)

	Caution Action Trigger	Warning TIER I	Danger TIER II
Primary Triggers [a]			
Total Microcystins [b]	0.8 µg/L EPA	6 µg/L	20 µg/L
Anatoxin-a	Detection [c]	20 µg/L	90 µg/L
Cylindrospermopsin	1 µg/L	4 µg/L EPA	17 µg/L

Exposure Pathways

Ingestion of contaminated shellfish and fish

Inhalation of water and dermal contact from recreational activities

Drinking Water

Recreational exposure to microcystins during algal blooms in two California lakes

Lorraine C. Backer[a,*], Sandra V. McNeel[b], Terry Barber[c], Barbara Kirkpatrick[d], Christopher Williams[e], Mitch Irvin[f], Yue Zhou[f], Trisha B. Johnson[g], Kate Nierenberg[d], Mark Aubel[e], Rebecca LePrell[a], Andrew Chapman[e], Amanda Foss[e], Susan Corum[h], Vincent R. Hill[g], Stephanie M. Kieszak[a], Yung-Sung Cheng[f]

Irrigation

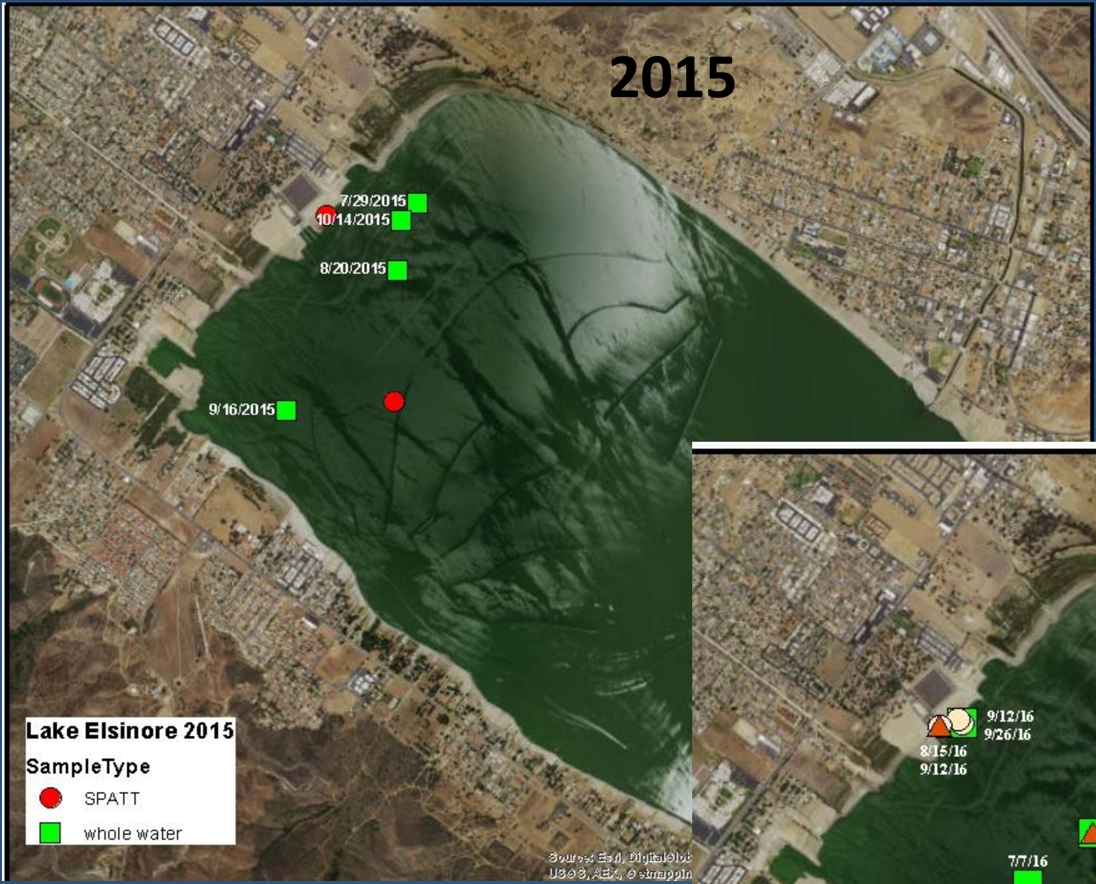
Inhalation of aerosolized toxins

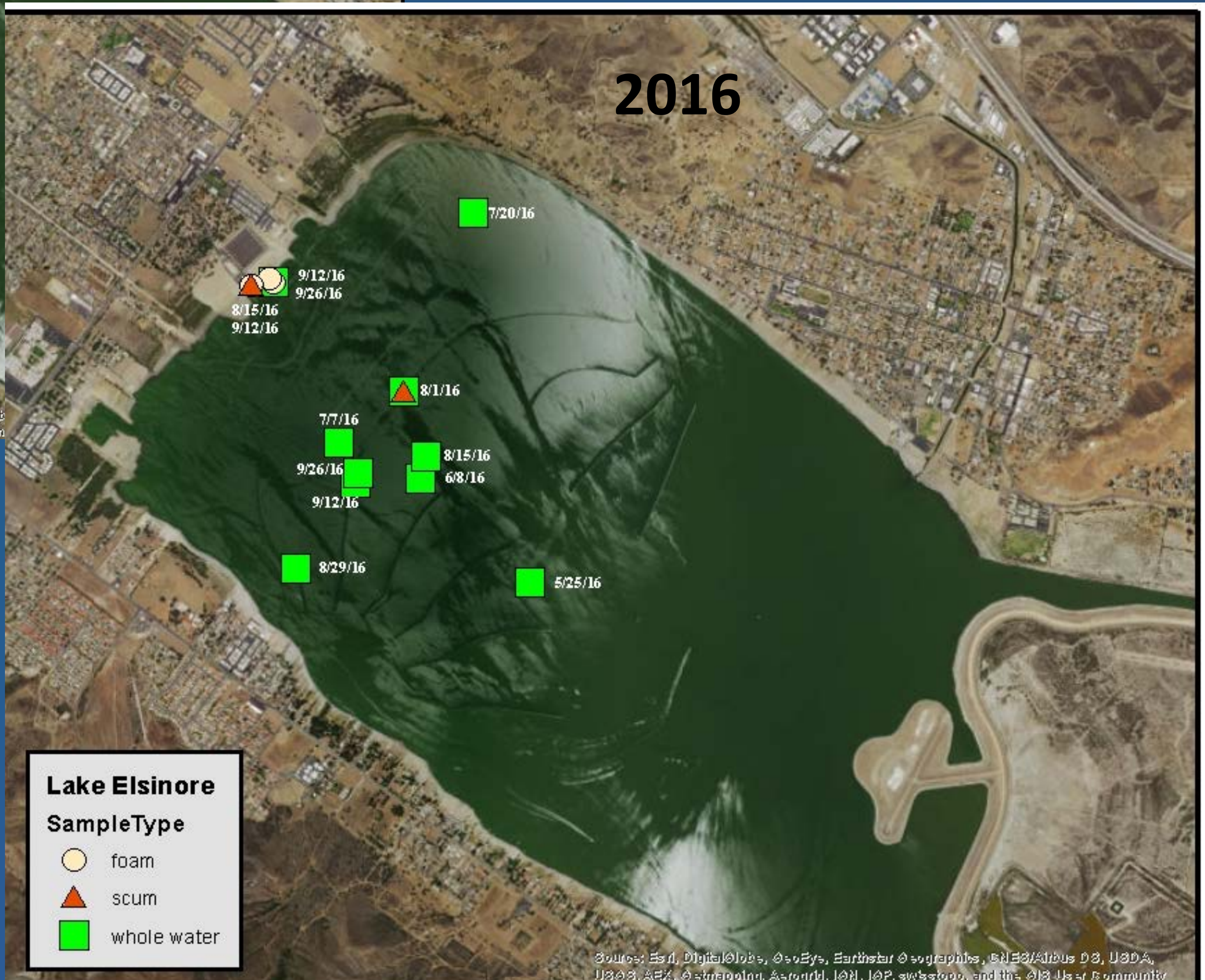
Goals of the Lake Elsinore and Canyon Lake HAB Assessment Study

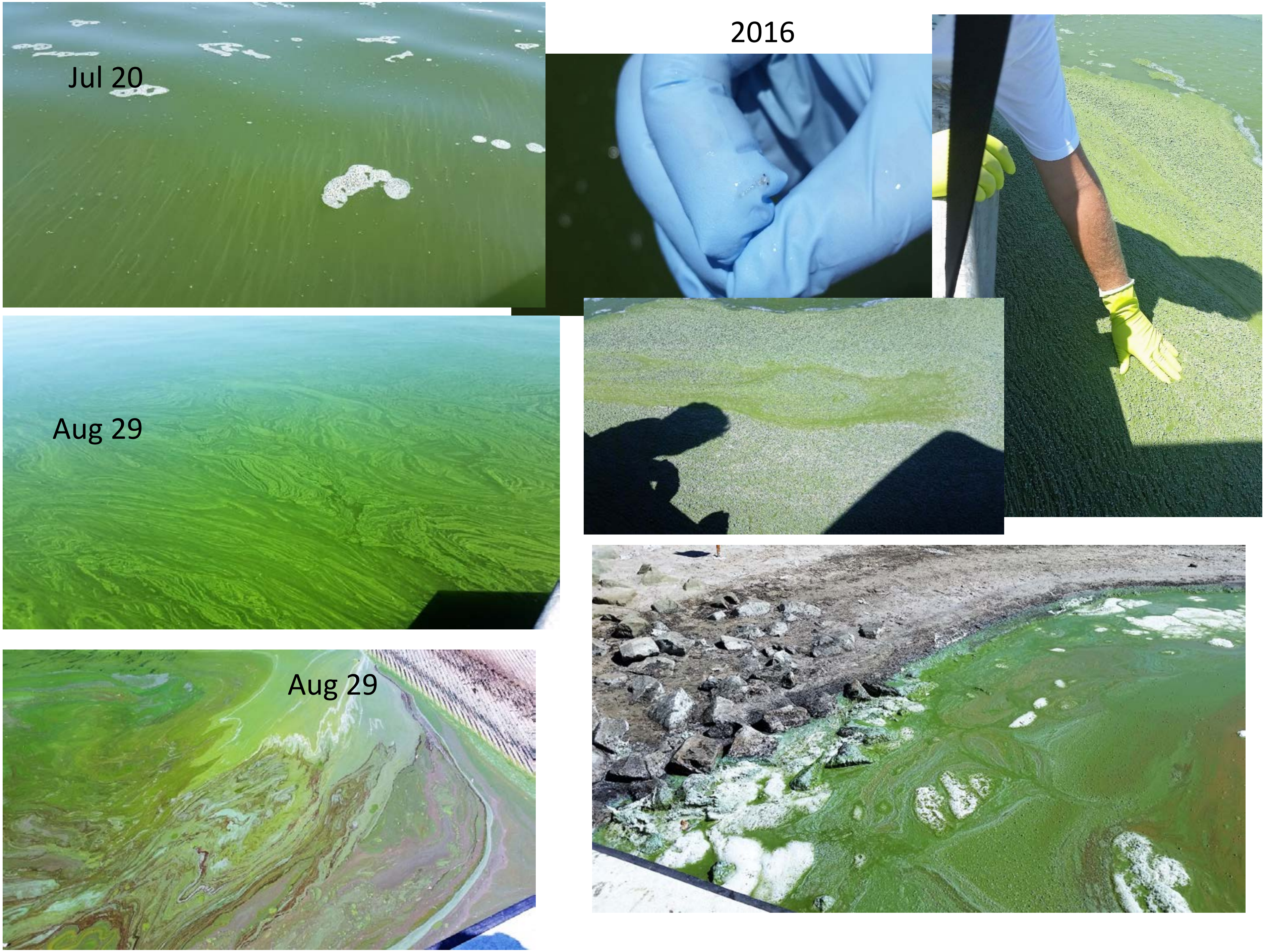
- Determine if HAB toxins are present
  - If present, determine if concentrations exceed health advisory thresholds
- Determine the potential toxin producing cyanobacteria routinely present
- Determine if long-term monitoring programs should be established in these systems

Lakes Study Design: Sample Collection

- Criteria for sample collection location:
  - Determine the area of the lake with the highest risk for human health
    - Within or close to recreational areas
  - Determine where surface accumulations are located (usually dependent on wind)
  - Use a sonde to determine high biomass areas


2015
7/29/2015
10/14/2015
8/20/2015
9/16/2015
Lake Elsinore 2015
SampleType
SPATT
whole water

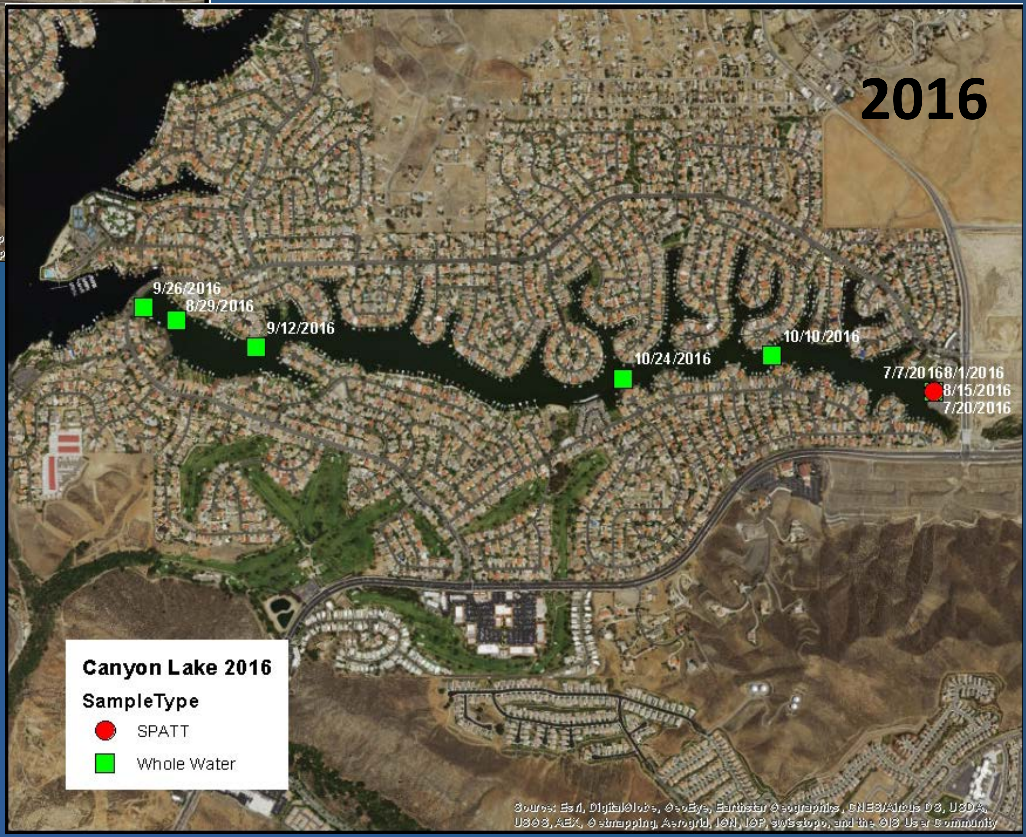

2016
7/20/16
9/12/16
9/26/16
8/15/16
9/12/16
8/1/16
7/7/16
8/15/16
6/8/16
9/26/16
9/12/16
8/29/16
5/25/16
Lake Elsinore
SampleType
foam
scum
whole water



2016
Jul 20
Aug 29
Aug 29


2015
7/29/2015
9/16/2015
8/20/2015
10/14/2015
Canyon Lake 2015
SampleType
SPATT
Whole Water


Google earth


2016
9/26/2016
8/29/2016
9/12/2016
10/24/2016
10/10/2016
7/7/20168/1/2016
8/15/2016
7/20/2016
Canyon Lake 2016
SampleType
SPATT
Whole Water

Lakes Study Design: Sample Collection

Timing of Sample Collection:

- 4X in 2015 (monthly July – Oct)
- 13X in 2016 (May-Oct)
- 2X in 2017 (TBD)

Measurements:

- Toxin samples
  - Whole water; foam and scum when present
- Chlorophyll *a*
- Passive Samplers - SPATT

Newly Developed Monitoring Tool for Toxins: SPATT

Solid Phase Adsorption Toxin Tracking (SPATT)

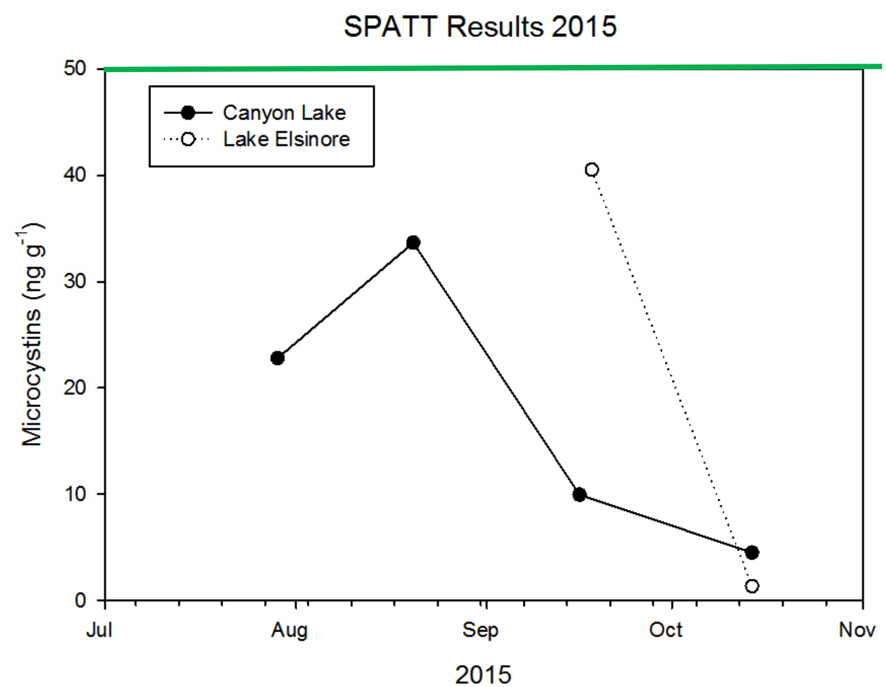
- Passive Sampler that is time-integrative
- Provides continuous toxin detection to capture ephemeral events
- Applicable to both marine and freshwater toxins
- Determines the prevalence and persistence of toxins

Study Design: Sample Analysis

- Tiered design to sample analysis to conserve resources
  - Analyze SPATT and taxonomy samples immediately
  - Use this information to determine if grab toxin samples need to be analyzed
- Did not work!
  - Taxonomy samples ***always*** had potentially toxin producing cyanobacteria
  - Toxin detected from most SPATT samples

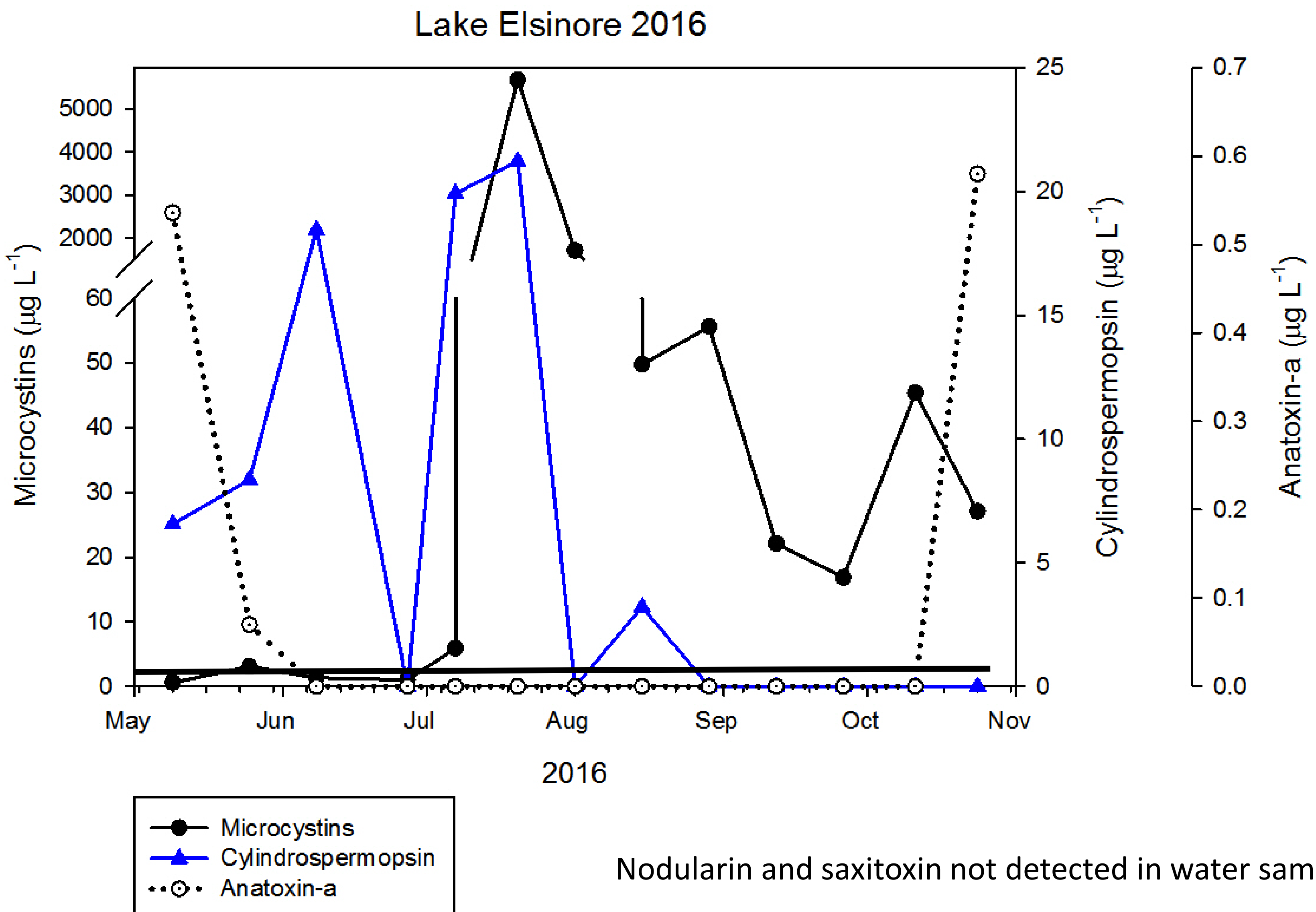
2015: Low Chronic Microcystin Concentrations

- No toxin exceedances above health thresholds
- Microcystins, Anatoxin-a, Cylindrospermopsin not detected in water samples
    - Low saxitoxin detected <2 ug/L
        - Canyon Lake July and Sept
        - Lake Elsinore Sept
- **100% of SPATT samples positive for MCY**
    - Low chronic concentrations
    - Corresponding MCY concentration < 1 ug/L



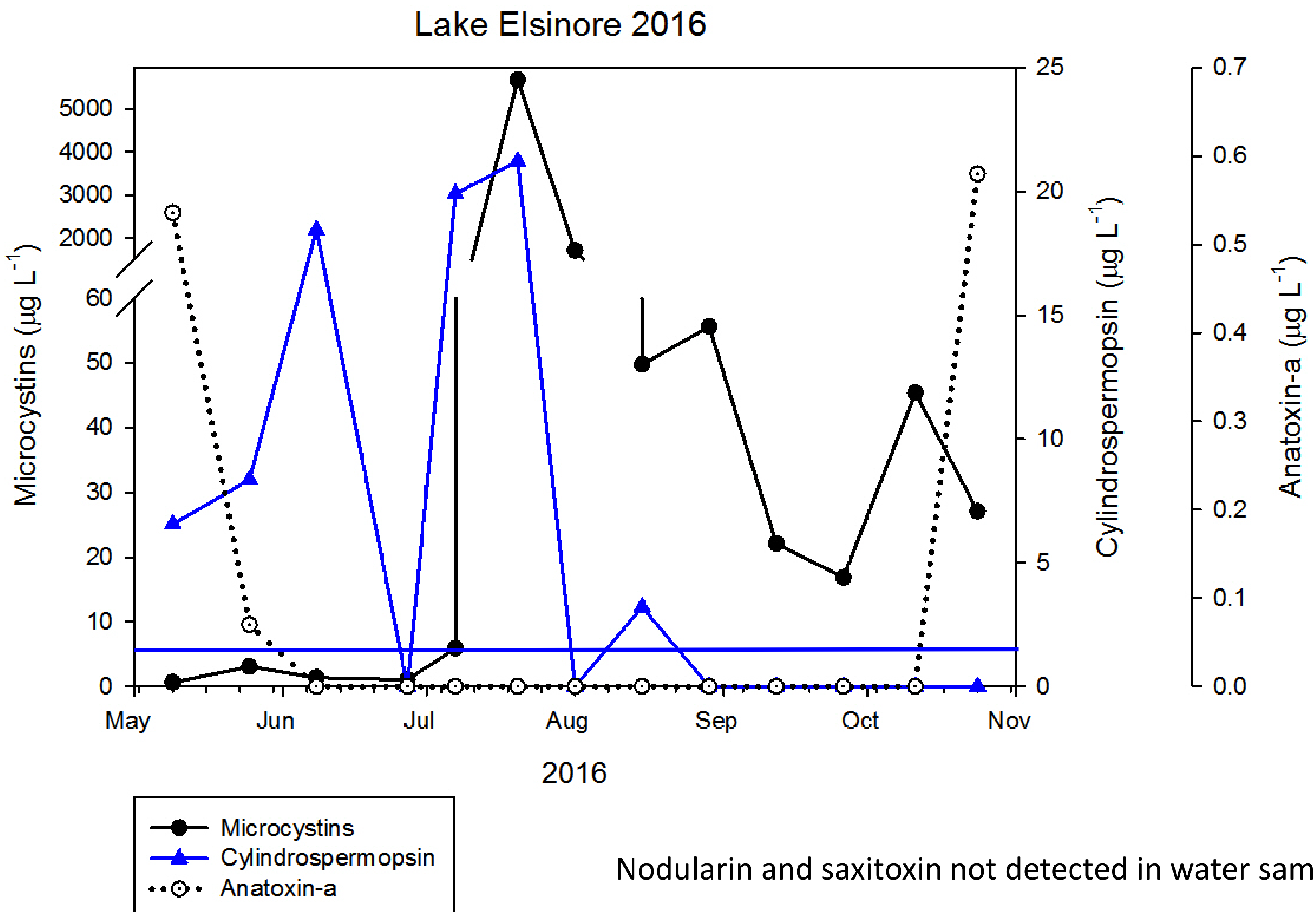
Microcystin Grab Sample (ppb)	SPATT (ng/g)
Non-Detect	5-13
< 1 ppb	20-50
1< x < 10 ppb	50-200
> 10 ppb	175-275

2016: Multiple Cyanotoxins Detected Simultaneously



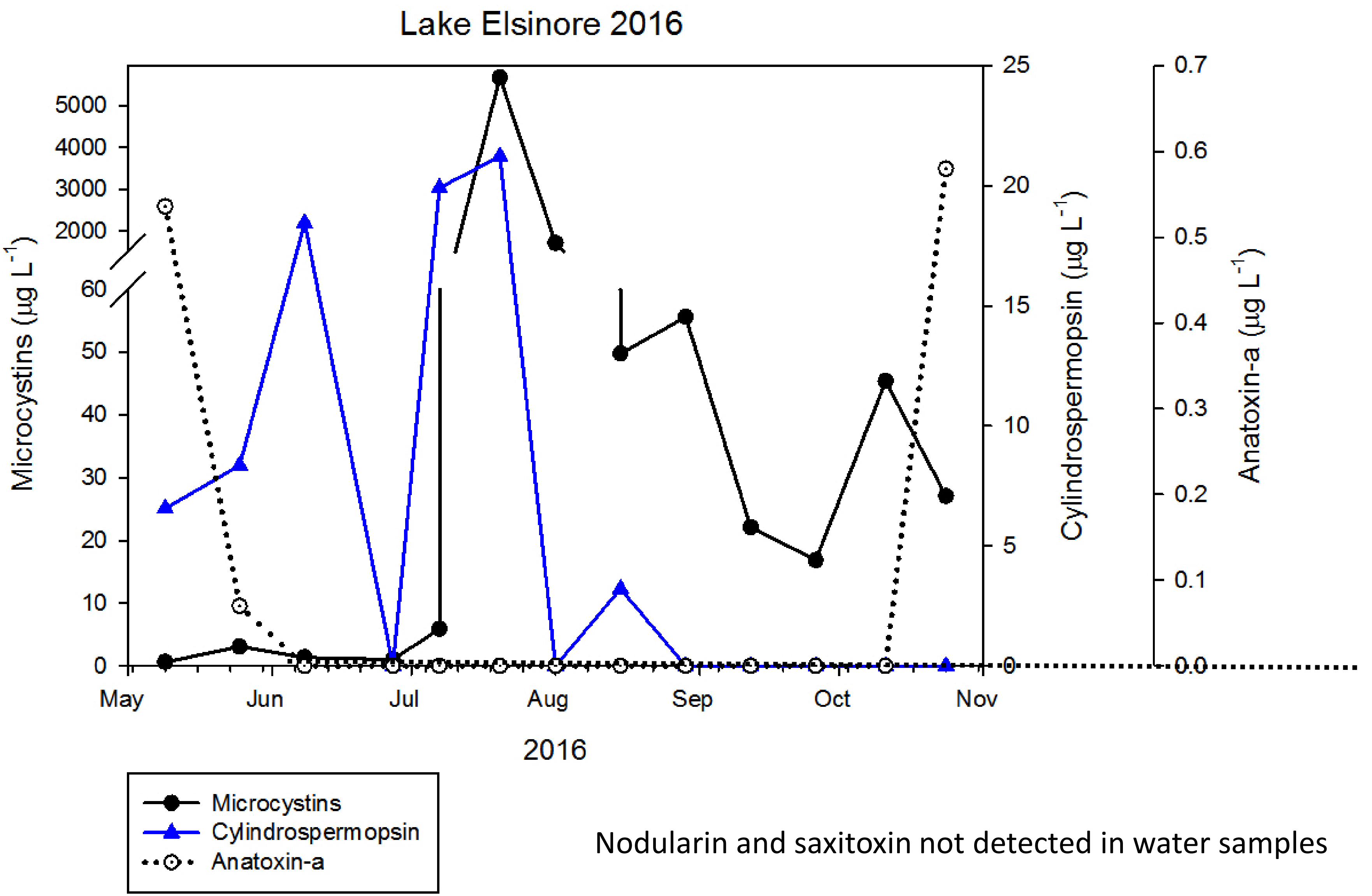
Nodularin and saxitoxin not detected in water samples

2016: Multiple Cyanotoxins Detected Simultaneously



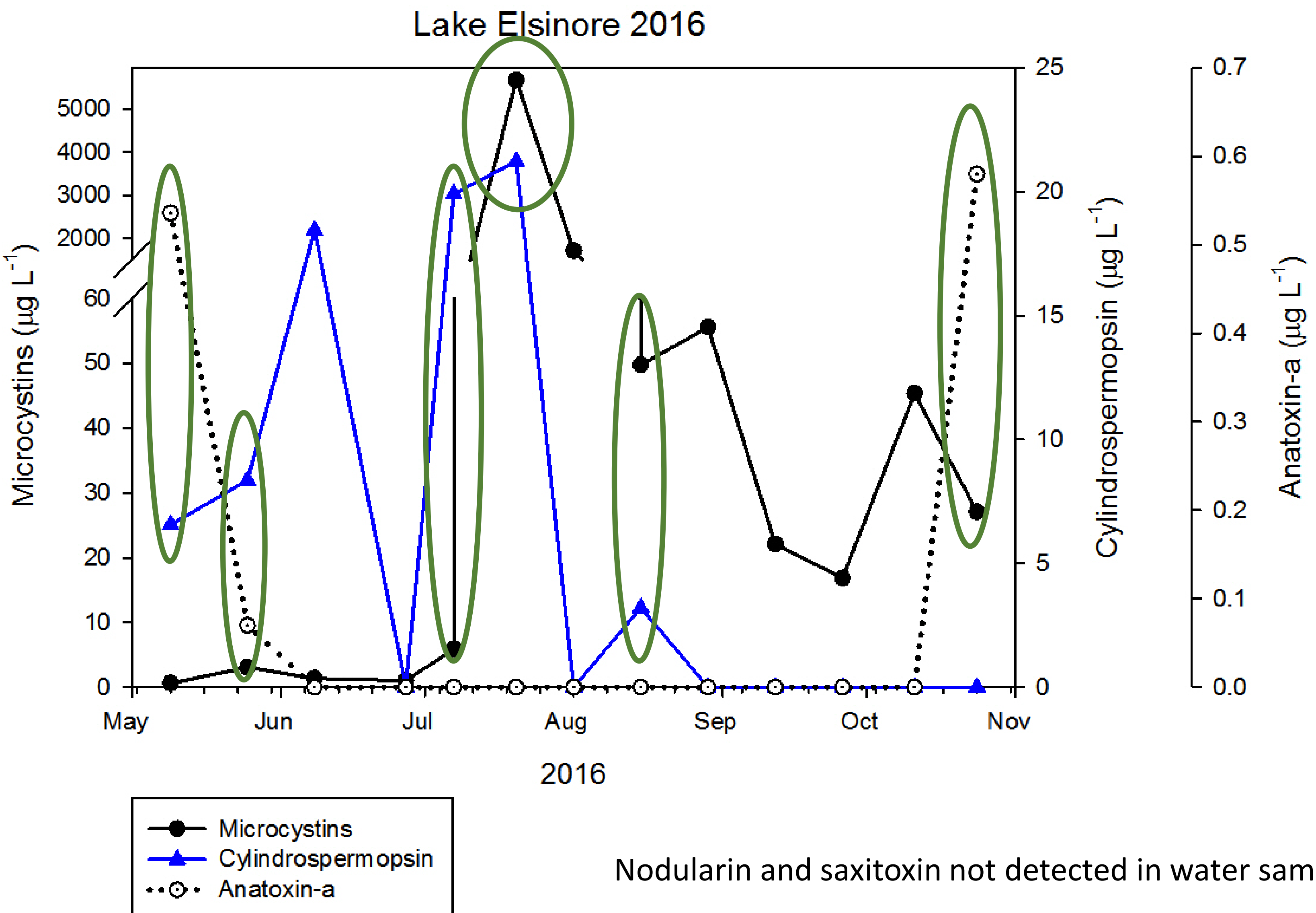
Nodularin and saxitoxin not detected in water samples

2016: Multiple Cyanotoxins Detected Simultaneously



Nodularin and saxitoxin not detected in water samples

Synergistic Stressors: Multiple Cyanotoxins Detected Simultaneously



Nodularin and saxitoxin not detected in water samples

2016: Summary Lake Elsinore Toxin Results

84% of the time, 2 or more toxins present
AND exceeded health thresholds

Microcystins
- Detected in **100%** of all samples!
  - 92% samples exceeded health thresholds
- Detected in **100%** of SPATT

Cylindrospermopsin
- Detected in **57%** of grab samples
  - 46% samples exceeded health thresholds
- Detected in **72%** of SPATT

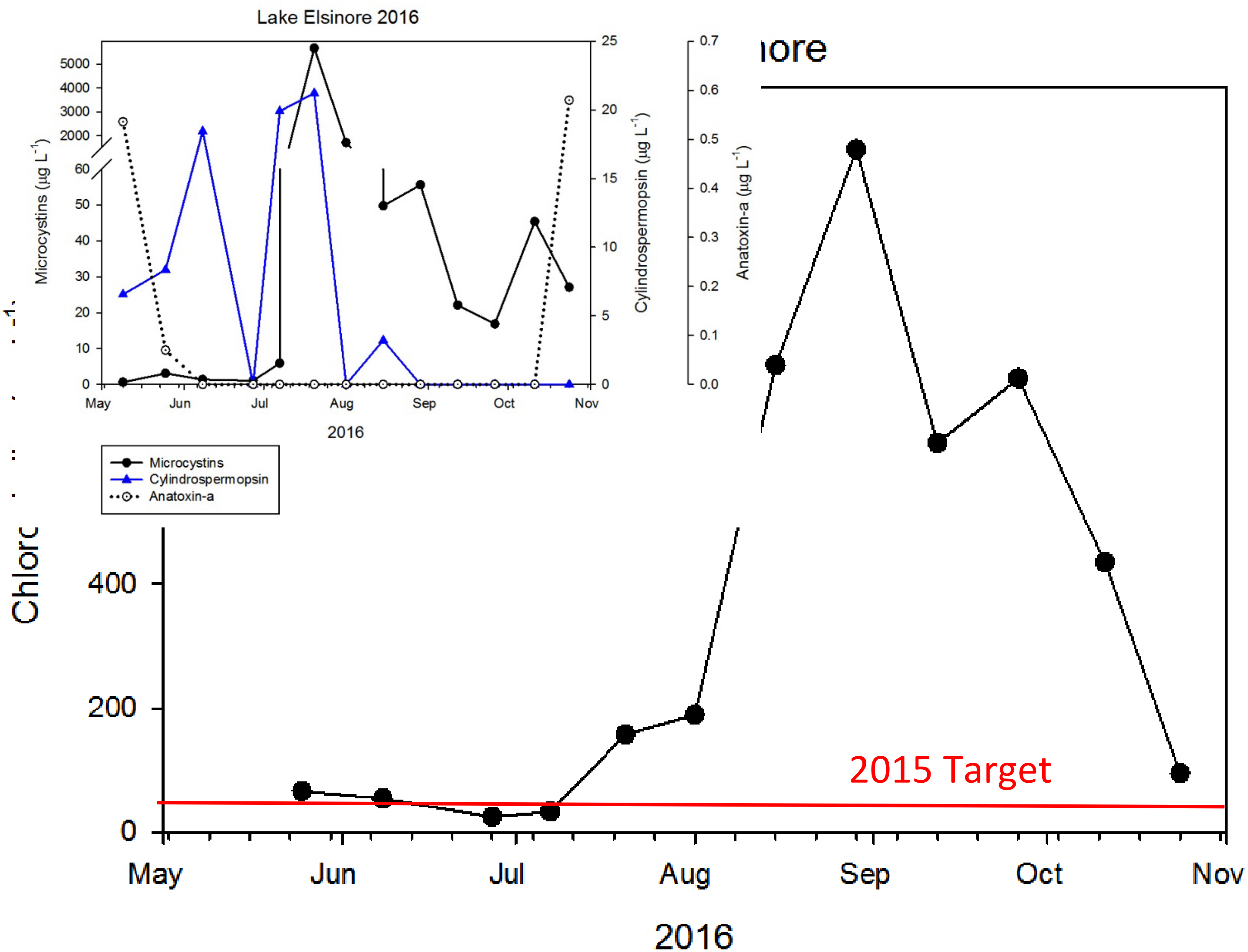
Anatoxin-a
- Detected in **30%** of grab samples
  - **All** exceeded health thresholds
- Detected in **18%** of SPATT

Saxitoxin
- Below detection limit May through Aug

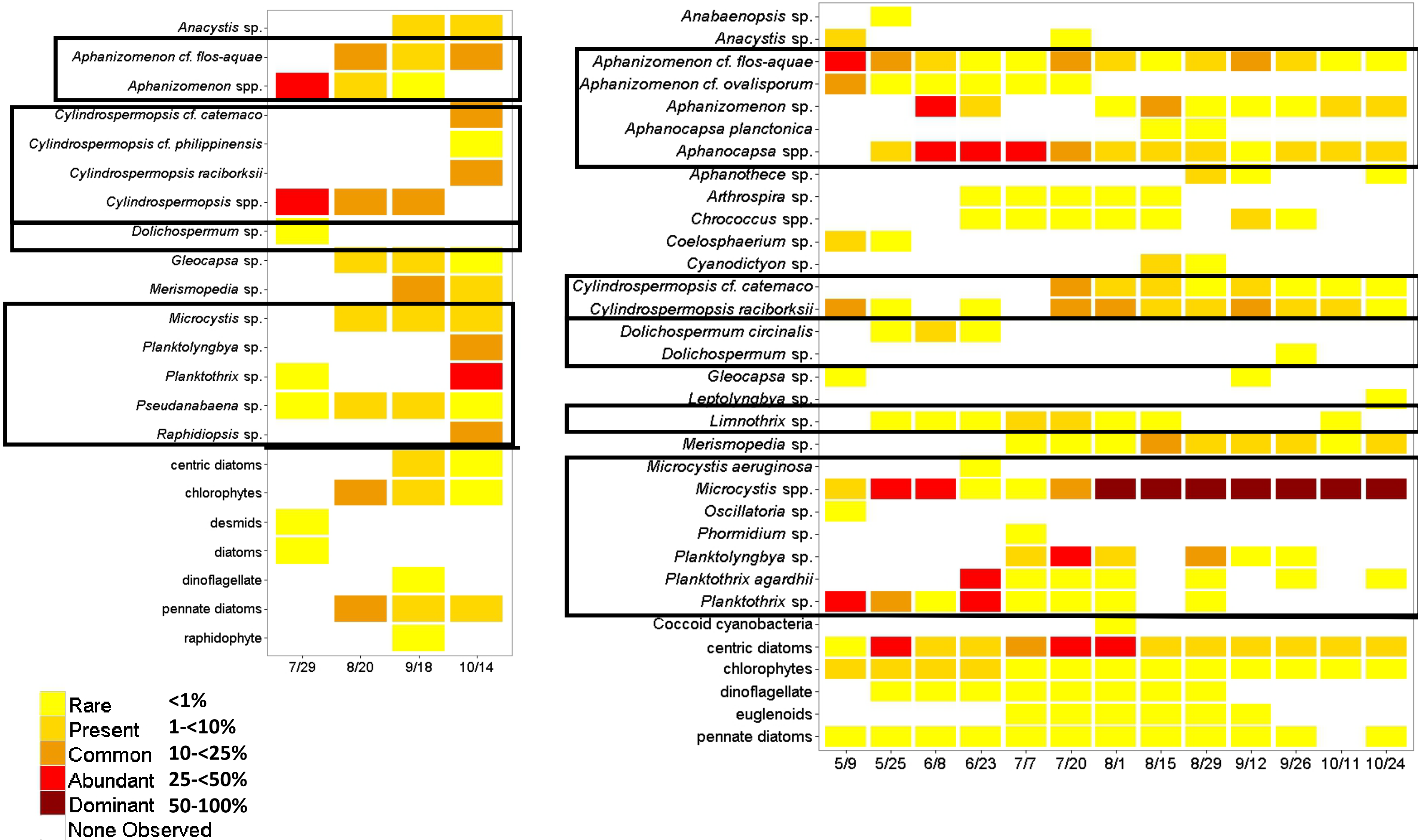
Nodularin
- Below detection limit in water
- Detected in foam and scum samples

Stats include foam and scum samples

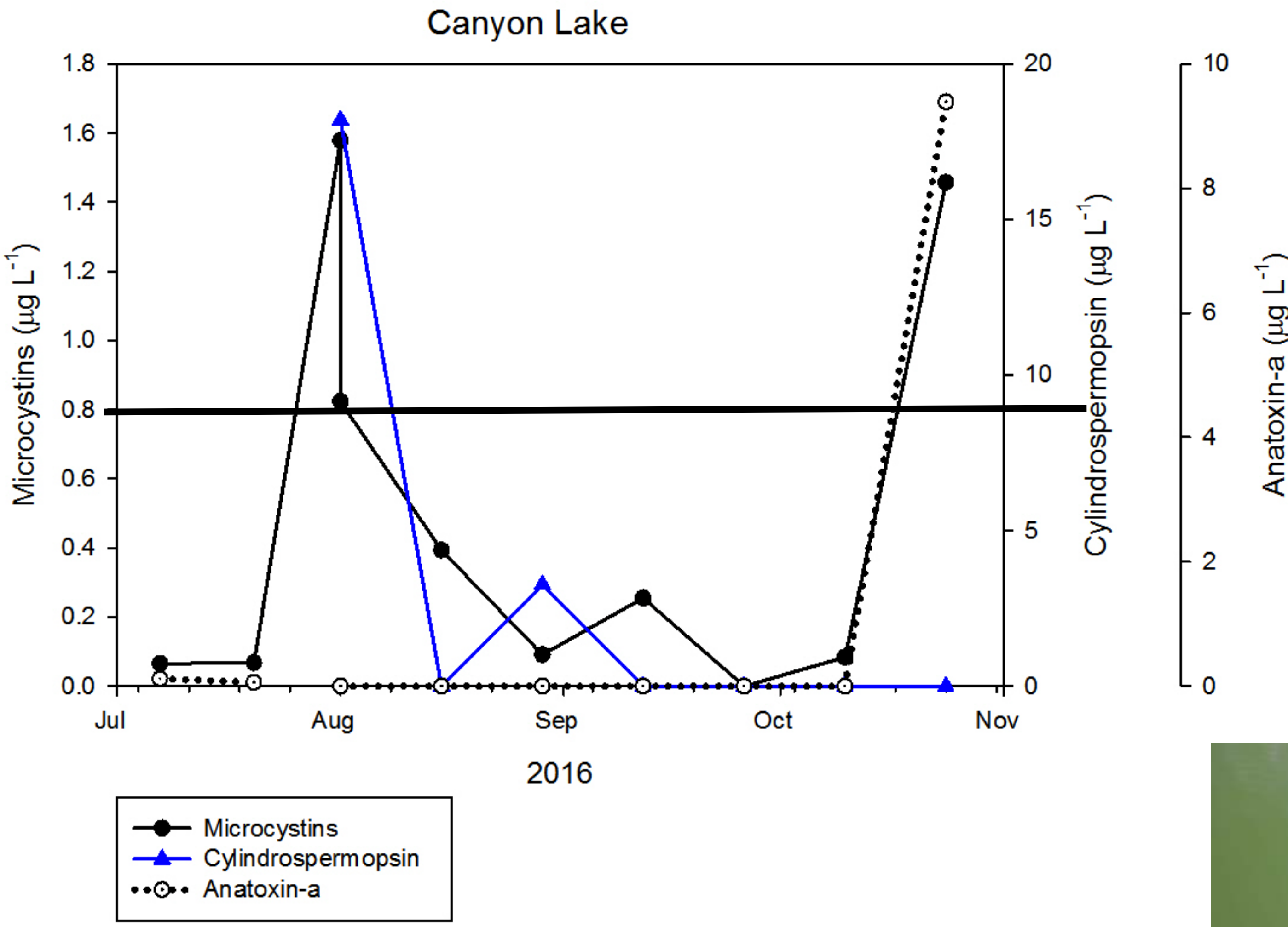
Chlorophyll not a good indicator of cyanotoxins



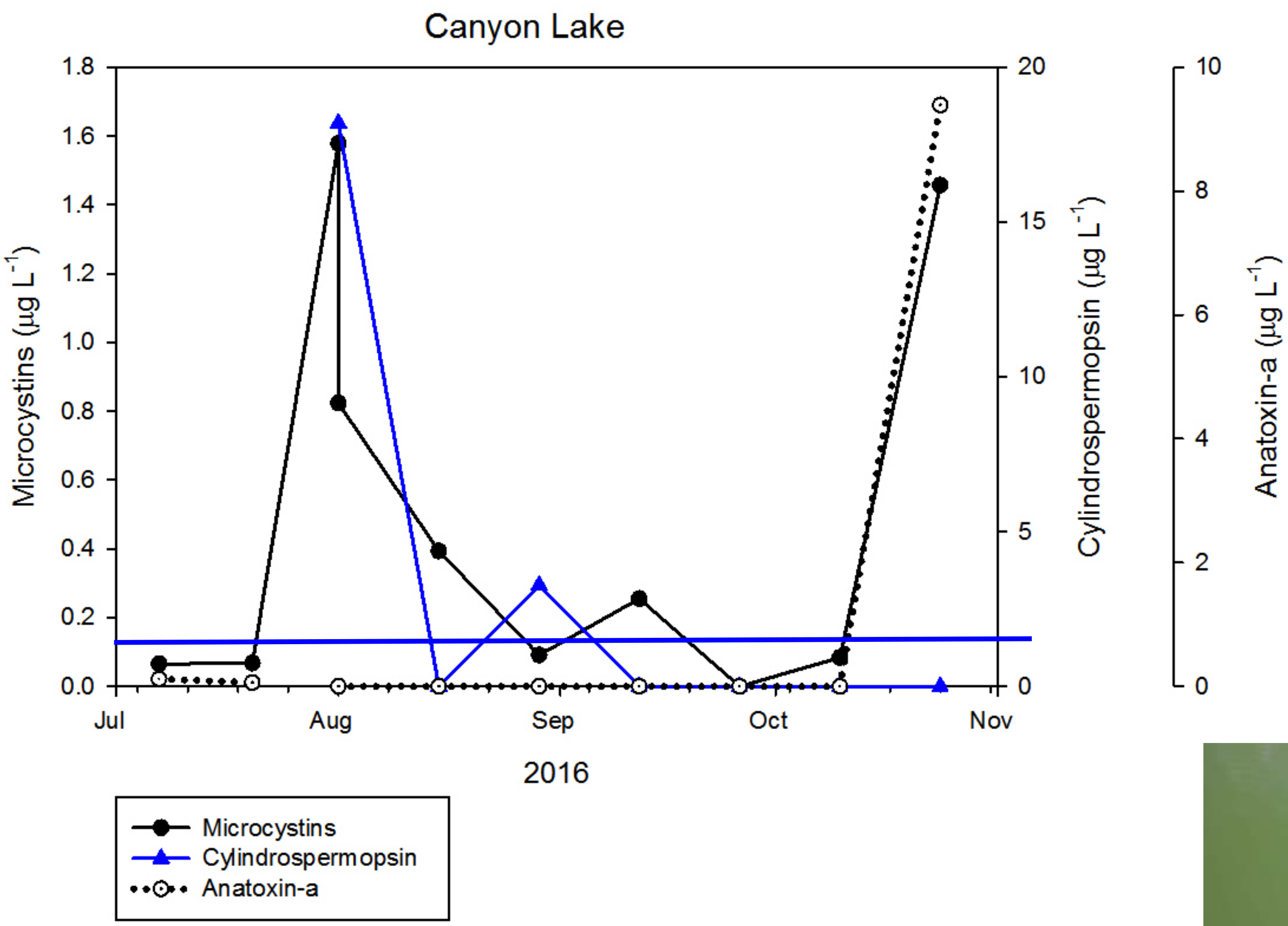
Lake Elsinore: Relative Abundance and Taxonomy



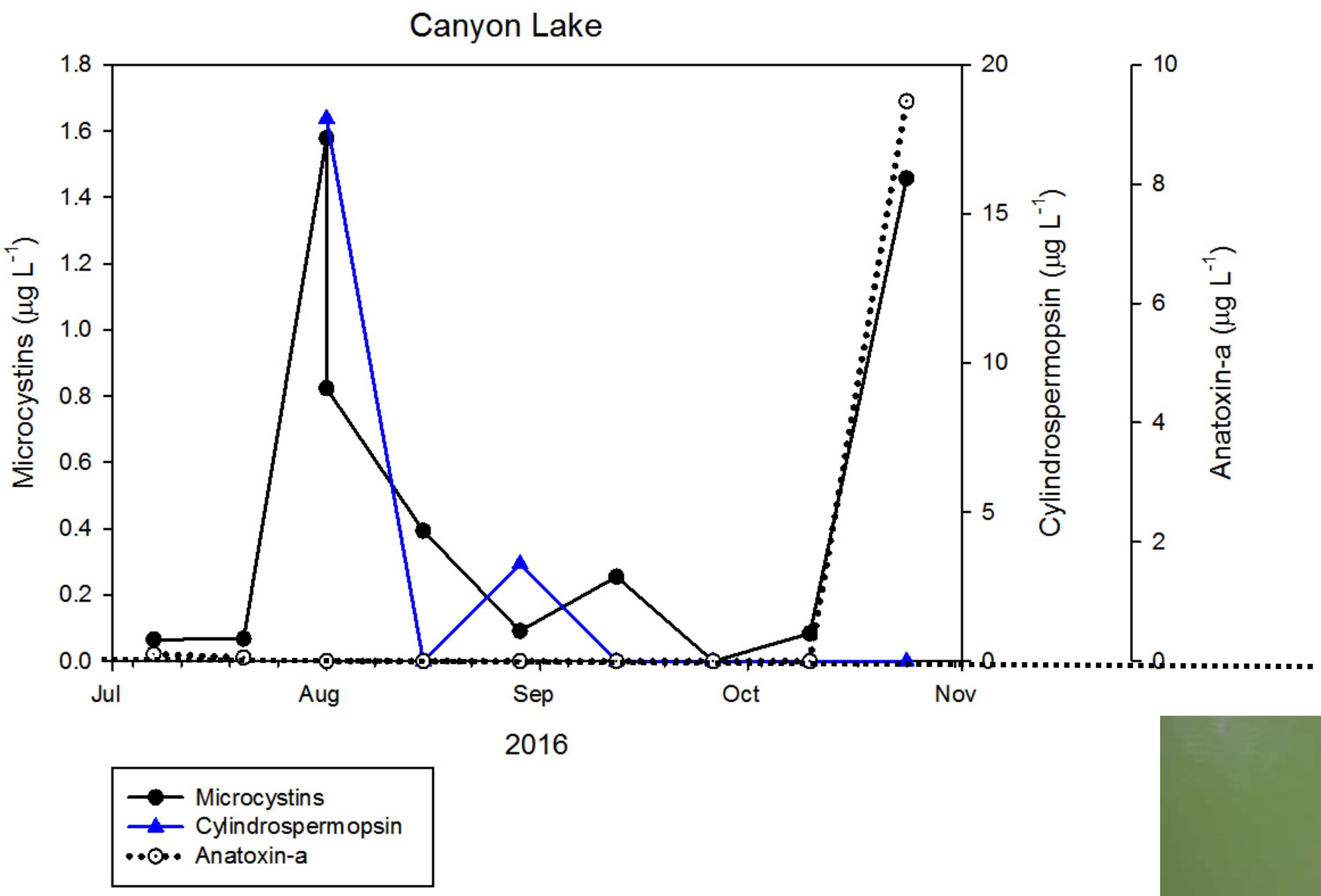
2016: Canyon Lake Toxin Results



2016: Canyon Lake Toxin Results



2016: Canyon Lake Toxin Results



Summary of Canyon Lake 2016

Microcystins
- Detected in **90%** of grab samples
  - Low chronic detection
  - ~30% exceeded health thresholds
- Detected in **36%** SPATT samples

Cylindrospermopsin
- Detected in **25%** grab samples
  - All exceeded health thresholds
- Detected in **63%** of SPATT samples

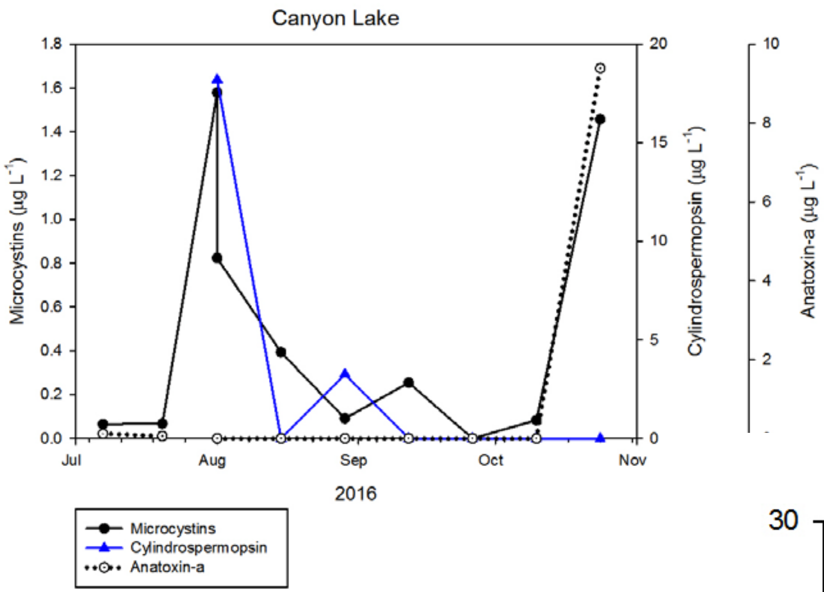
Anatoxin-a
- **27%** grab samples positive
  - All exceeded health thresholds
- **18%** of SPATT samples positive

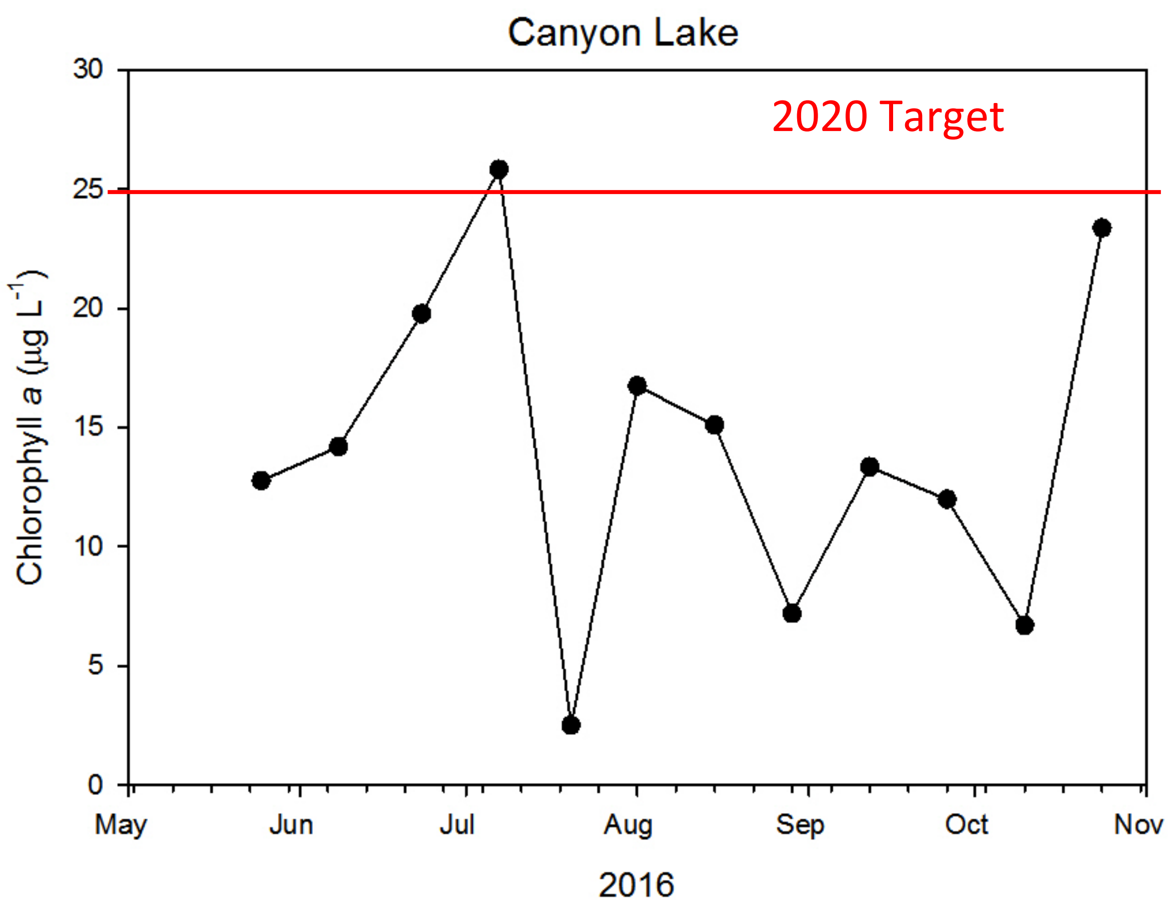
Saxitoxin
- Not detected in July and Aug

Nodularin
- Not detected

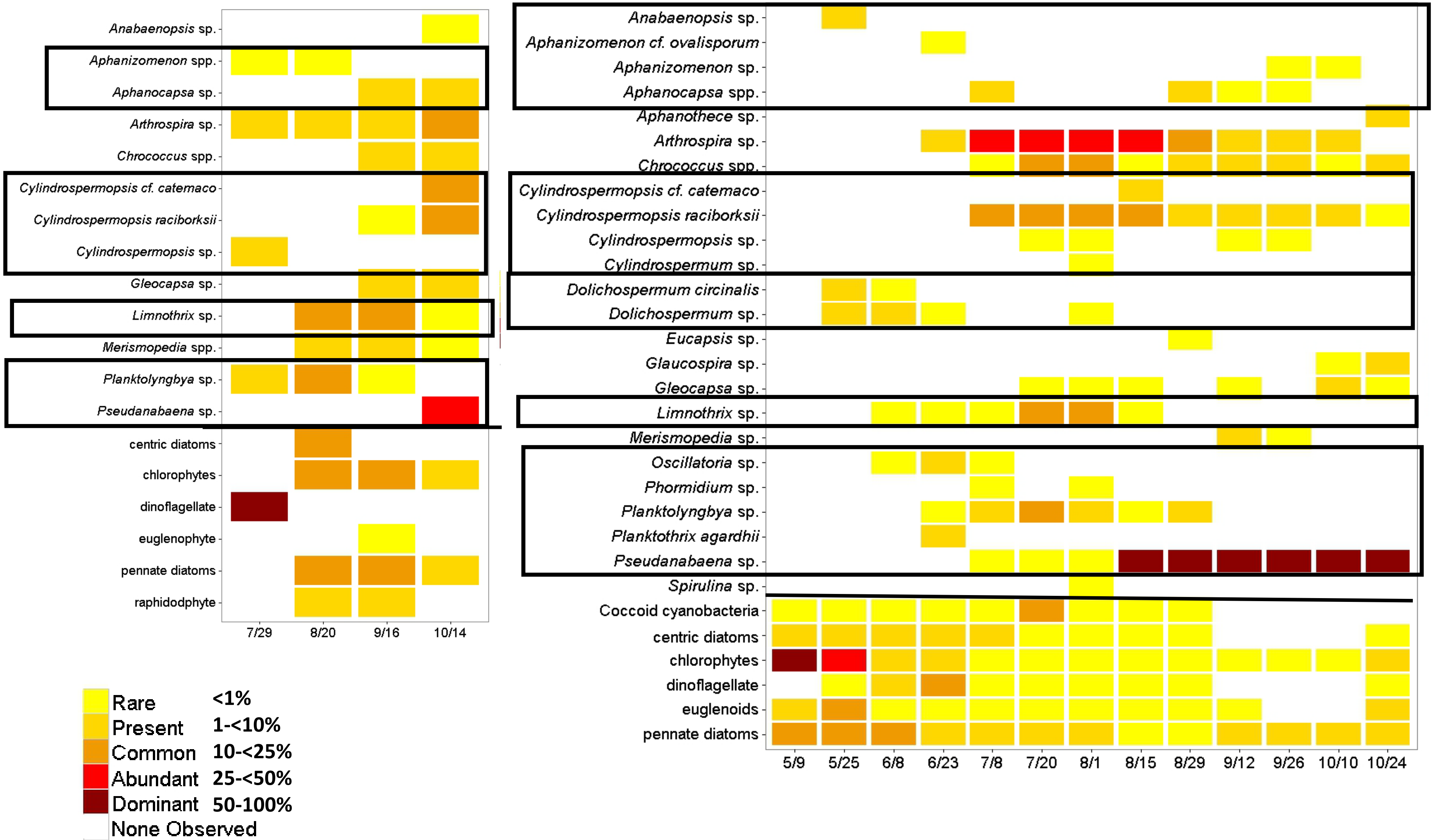
Low chronic concentrations of microcystins and cylindrospermopsin

Chlorophyll at 2020 Target





Canyon Lake:
Relative Abundance and Taxonomy



Final Thoughts and Conclusions

- Recent sampling of Canyon Lake and Lake Elsinore revealed:
  - Simultaneous detection of multiple toxins
  - Chronic (months) persistence of toxins
- Multiple potential toxin producing cyanobacteria routinely present in both lakes
  - Other toxins potentially present: Lyngbyatoxin, BMAA, homoanatoxin, neosaxitoxins

Next steps

- Identify which organisms are producing toxins
- Establish routine monitoring program to protect public health

Opportunity to Learn More

HABs Webinar and Meeting in April

Webinar: April 5th

- Overview of HABs in drinking and recreational waters
  - Human and animal impacts, surveillance reporting, monitoring technologies, EPA regulatory guidelines, and nutrient dynamics that effect blooms.

Meeting: April 25 – 27th at SCCWRP

- Remote participation will be available

- Day 1
  - ½ day focused on marine HABs
    - Remote sensing and forecasting systems for HABs, HAB modeling, impacts to fish and shellfish and relevant HAB issues in estuarine and marine waters
- Days 2 and 3
  - Focus on freshwater HAB issues in recreational and drinking waters
    - Monitoring tools, other State's experiences and lessons learned, mitigation and management strategies

Collaborators and Acknowledgements

Santa Ana Regional Water Quality Control Board

Heather Boyd, Mark Smythe

University of Southern California

David Caron, Avery Tatters

University of California, Santa Cruz

Raphael M. Kudela, Kendra Hayashi

AMEC Foster Wheeler

Chris Stransky, John Rudolph

City of Lake Elsinore,

Canyon Lake Property Owners Association

Questions?

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Revision of the Lake Elsinore & Canyon Lake Nutrient TMDL

CDM Smith Team & Risk Sciences

Load Reductions from Existing Control Programs

March 22, 2017

Lake Elsinore/Canyon Lake Task Force Meeting

RISK SCIENCES

CDM Smith

Presentation Outline

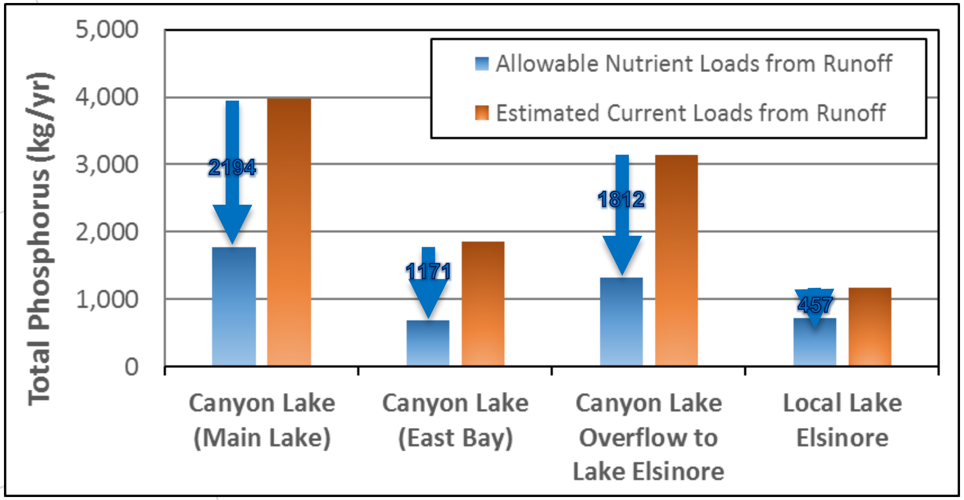
- Load Reductions for TMDL Compliance
- Watershed BMPs
  - CNRP
  - AgNMP
- In-Lake Nutrient Management

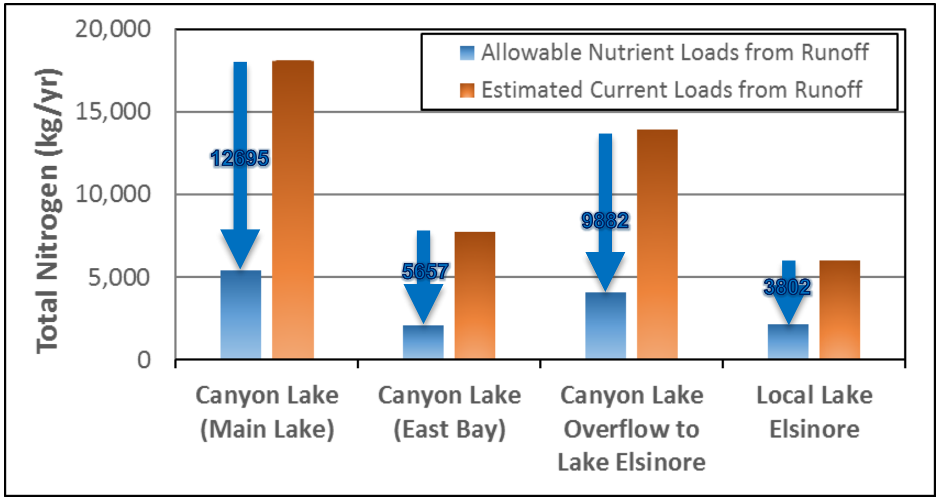
Load Reductions for TMDL Compliance

CDM Smith

Load Reduction by TMDL Lake Segment

- Required load reduction = estimated current load minus allowable load (i.e. incremental load above reference condition)





CDM Smith

Source Assessment by Jurisdiction

- MS4s: 54.8%
- Federal: 27.5%
- Ag CWAD: 7.3%
- State, Caltrans: 6.8%
- Tribal: 1.7%
- Ag-Small: 1.0%
- CAFO: 0.5%
- March JPA: 0.5%

Responsible Agency	Canyon Lake Main Lake		Canyon Lake East Bay		Local Lake Elsinore		Canyon Lake Overflow to Lake Elsinore	
	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)
Ag-CWAD	610	1,343	331	714	2	5	507	1,108
Ag-Small	110	244	73	157	6	11	98	215
BANNING	1	5	-	-	-	-	0	3
BEAUMONT	5	28	-	-	-	-	3	15
CAFO	18.4	36.8	3.2	6.5	2	1	12	23
California Dept. Fish and Wildlife	57	175	-	-	-	-	31	94
Caltrans	31	390	9	118	14	157	22	274
CANYON LAKE	34	195	51	315	20	117	46	275
Federal - DOD	61	523	-	-	-	-	33	282
Federal - National Forest	113	348	2	5	122	376	62	190
Federal - Other	43	132	8	23	-	-	27	83
Federal - Wilderness	22	67	-	-	-	-	12	36
HEMET	11	67	156	830	-	-	90	483
LAKE ELSINORE	40	204	9	48	540	2,932	26	135
March Joint Powers Authority	47	230	-	-	-	-	25	124
MENIFEE	168	859	768	4,040	14	59	504	2,638
MORENO VALLEY	932	5,648	-	-	-	-	502	3,041
MURRIETA	-	-	20	125	-	-	11	67
PERRIS	468	2,746	1	2	-	-	252	1,480
RIVERSIDE	33	201	-	-	-	-	18	108
Riverside County	1,073	4,365	422	1,363	236	1,151	805	3,084
SAN JACINTO	20	105	1	5	-	-	11	59
State Land	55	171	-	-	-	-	30	92
Tribal Reservations	6	22	-	-	-	-	3	12
Western RivCo Conservation Authority	10	31	4	12	-	-	8	23
WILDOMAR	-	-	0	0	216	1,1832	0	0
Total Existing Watershed Load	3,969	18,132	1,858	7,763	1,171	5,992	3,137	13,944

Allocations by Jurisdiction

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	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)
Ag-CWAD	180	552	80	246	0	1	140	429
Ag-Small	27	81	14	43	1	4	22	67
BANNING	0	1	-	-	-	-	0	0
BEAUMONT	3	9	-	-	-	-	2	5
CAFO	5.9	18.0	1.9	6	0	0	4	13
California Dept. Fish and Wildlife	54	165	-	-	-	-	29	89
Caltrans	12	37	4	12	6	17	9	26
CANYON LAKE	12	36	14	44	7	23	14	43
Federal - DOD	26	79	-	-	-	-	14	43
Federal - National Forest	107	327	2	5	121	371	58	179
Federal - Other	42	129	7	21	-	-	26	81
Federal - Wilderness	21	64	-	-	-	-	11	34
HEMET	3	8	48	147	-	-	27	84
LAKE ELSINORE	15	44	6	19	317	971	11	34
March Joint Powers Authority	28	87	-	-	-	-	15	47
MENIFEE	74	227	279	854	10	30	190	582
MORENO VALLEY	278	852	-	-	-	-	150	459
MURRIETA	-	-	5	16	-	-	3	9
PERRIS	198	607	1	2	-	-	107	328
RIVERSIDE	6	18	-	-	-	-	3	9
Riverside County	615	1,885	220	674	139	427	450	1,378
SAN JACINTO	8	26	1	2	-	-	5	15
State Land	46	141	-	-	-	-	25	76
Tribal Reservations	6	18	-	-	-	-	3	10
Western RivCo Conservation Authority	9	27	4	13	-	-	7	21
WILDOMAR	-	-	0	0	113	345	0	0
Total Allowable Watershed Load	1,774	5,438	687	2,106	715	2,190	1,325	4,062

CDM Smith

Load Reduction by Jurisdiction

- MS4s: 54.8%
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- March JPA: 0.5%

Responsible Agency	Canyon Lake Main Lake		Canyon Lake East Bay		Local Lake Elsinore		Canyon Lake Overflow to Lake Elsinore	
	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)
Ag-CWAD	430	791	251	469	2	4	367	679
Ag-Small	84	162	59	114	4	7	77	149
BANNING	1	4	-	-	-	-	0	2
BEAUMONT	2	19	-	-	-	-	1	19
CAFO	13	19	1	1	0	1	7	11
California Dept. Fish and Wildlife	3	10	-	-	-	-	2	5
Caltrans	20	353	5	106	9	141	13	248
CANYON LAKE	23	159	37	271	13	94	32	231
Federal - DOD	35	444	-	-	-	-	19	239
Federal - National Forest	6	21	(0)	(0)	1	5	3	11
Federal - Other	1	3	1	1	-	-	1	2
Federal - Wilderness	1	4	-	-	-	-	1	2
HEMET	9	58	108	683	-	-	63	399
LAKE ELSINORE	25	159	2	28	224	1,961	15	101
March Joint Powers Authority	19	143	-	-	-	-	10	77
MENIFEE	94	631	489	3,186	4	29	314	2,055
MORENO VALLEY	654	4,795	-	-	-	-	352	2,582
MURRIETA	-	-	15	109	-	-	8	59
PERRIS	269	2,139	0	0	-	-	145	1,152
RIVERSIDE	27	183	-	-	-	-	15	99
Riverside County	458	2,480	20	688	96	724	355	1,706
SAN JACINTO	11	79	0	2	-	-	6	44
State Land	9	30	-	-	-	-	5	16
Tribal Reservations	1	4	-	-	-	-	0	2
Western RivCo Conservation Authority	2	4	(0)	(1)	-	-	1	2
WILDOMAR	-	-	0	0	103	837	0	0
Total Load Reduction	2,194	12,695	1,171	5,657	457	3,802	1,812	9,882

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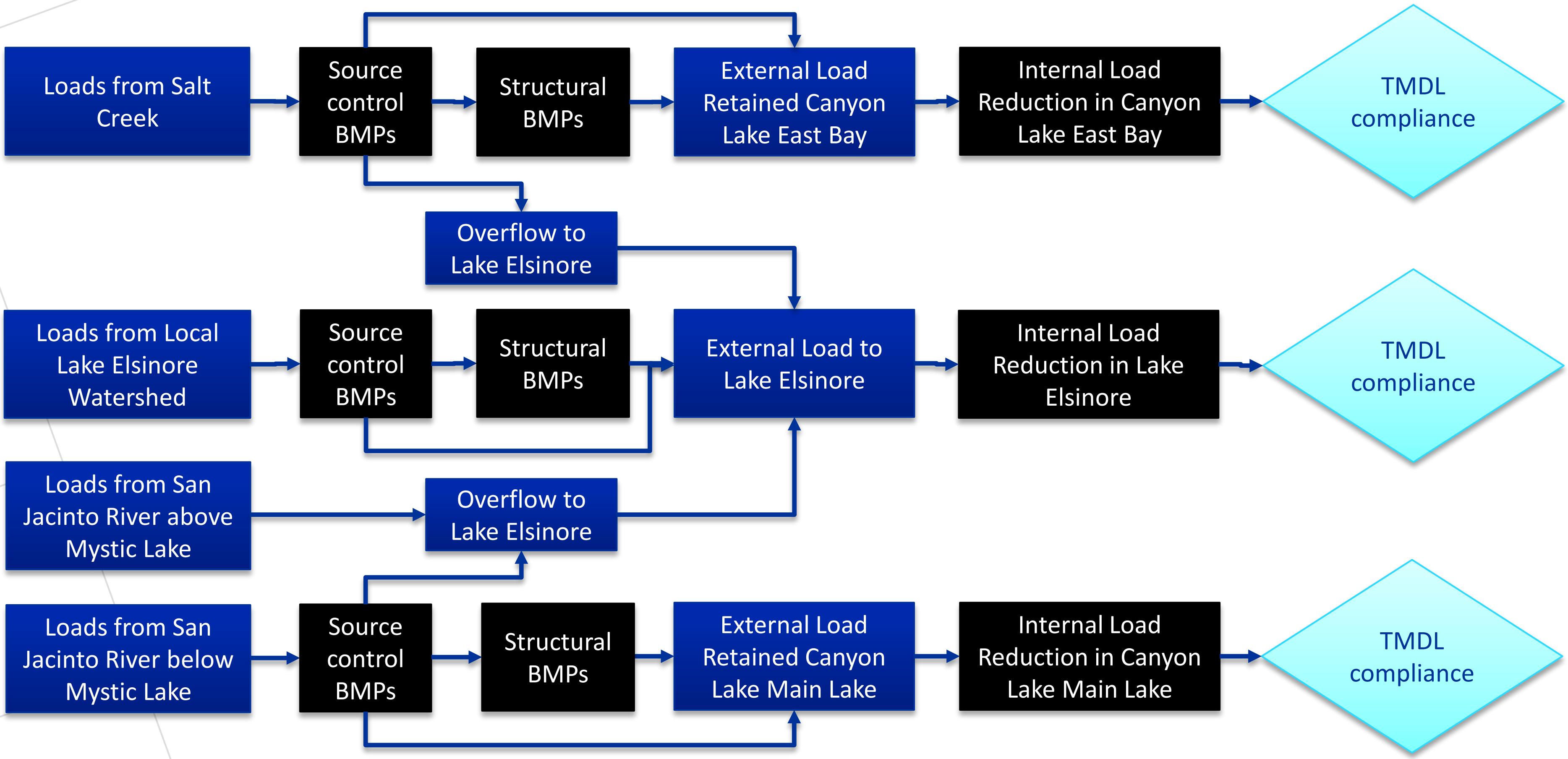
Treatment Train

- Source control to reduce washoff from watershed subareas
  - Street sweeping and drainage system debris removal
  - Agricultural field winter crop buffers
  - Septic system management
- Structural BMPs to capture runoff for infiltration or treatment
  - WQMP projects for new development/re-development
  - Diversions to recharge basins
- Retention in upstream lakes, including Canyon Lake

Load Reduction Demonstration



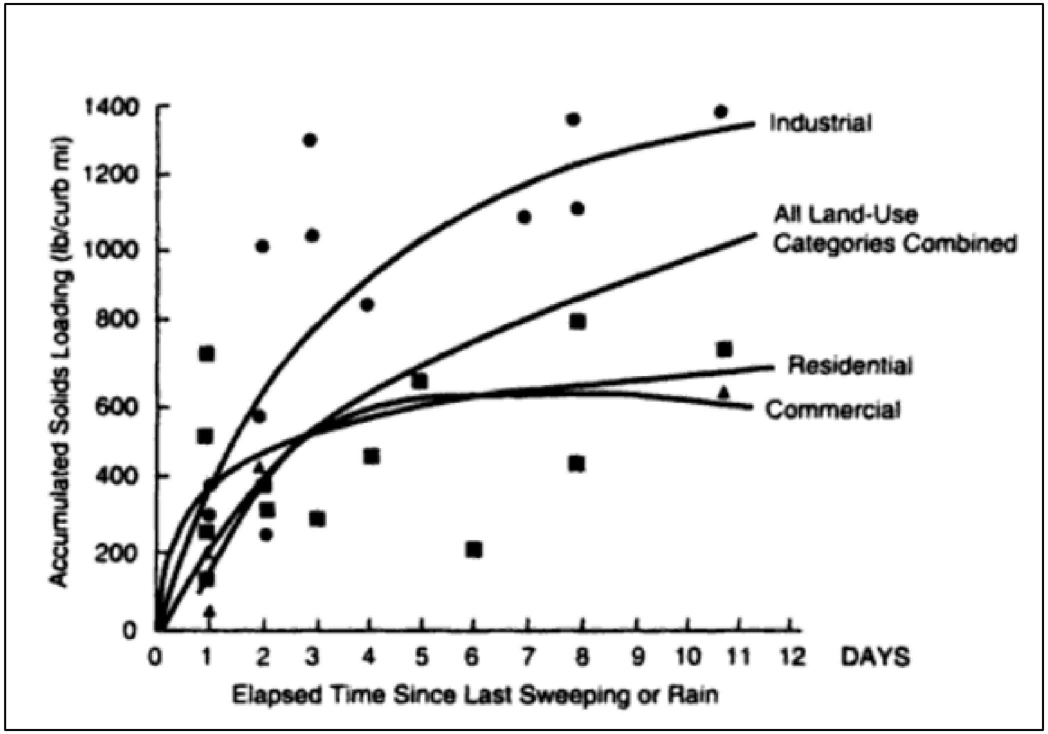
Watershed BMP Load Reductions

Watershed BMPs

- Watershed BMP deployments reported for urban and ag sources
- Review methodology for nutrient reduction credit estimation
  - CNRP
  - AgNMP
- Present watershed-wide load reductions achieved

Street Sweeping and Debris Removal

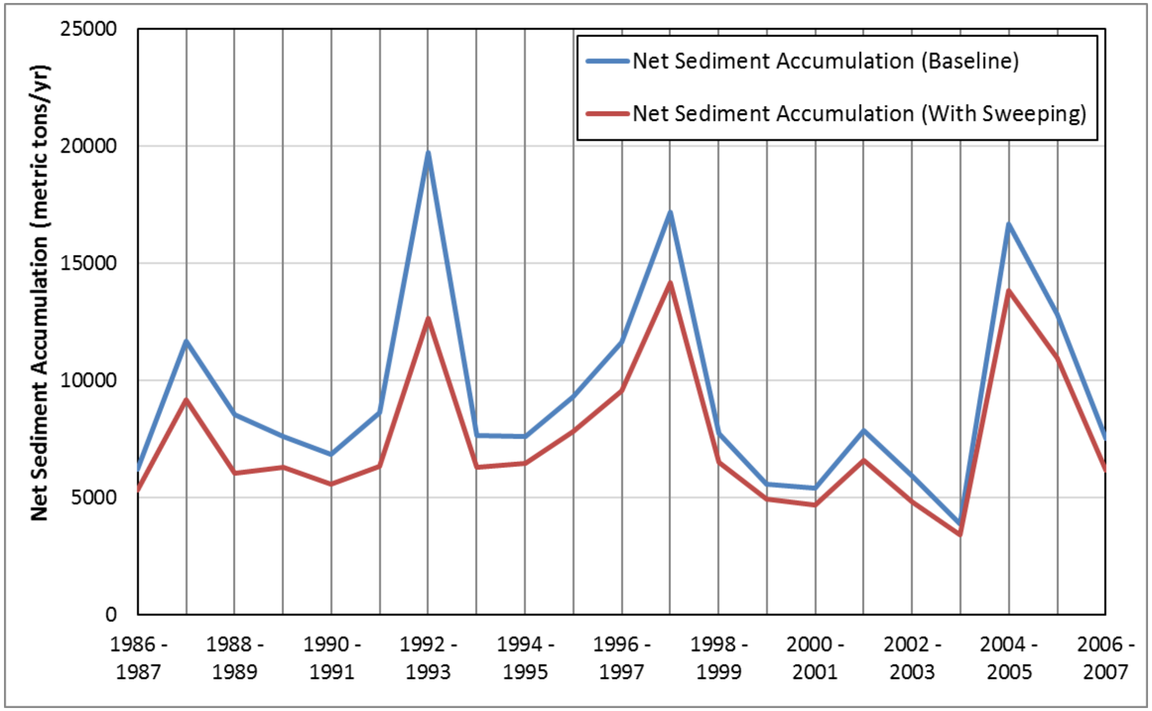
- Exponential buildup/washoff method developed after Sartor and Boyd, 1972
- Historical rainfall data analysis from Lake Elsinore stations for two key inputs:
  - Dry days prior to rains (for buildup model)
  - Depth of runoff (for washoff model)



From Sartor and Boyd, 1972. Water Pollution Aspects of Street Surface Contaminants, EPA R2-72-081.

Street Sweeping and Debris Removal

- Buildup model for street sediment
- Exponential buildup as function of dry days - sediment carrying capacity reach after 20 days
- Assumes annual swept material is achieved uniformly over the year for historical hydrology



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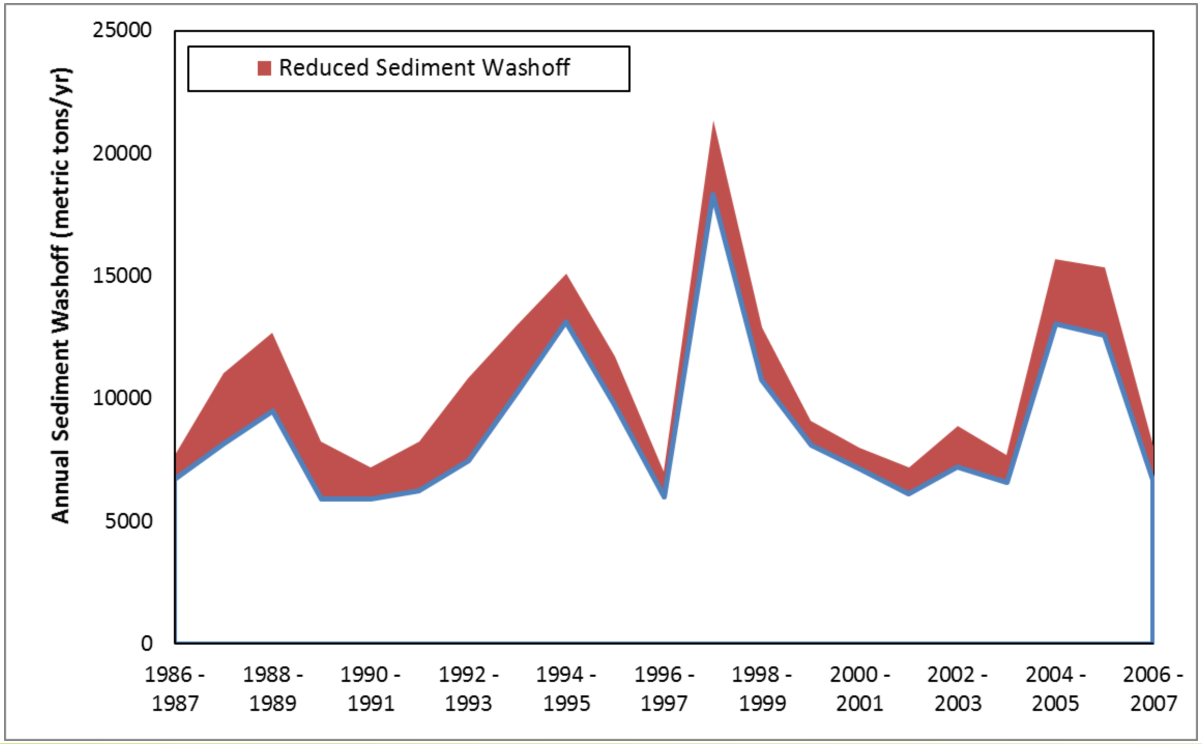
Street Sweeping and Debris Removal

- Washoff model for street sediment
- Exponential washoff as a function of runoff depth - assume 0.5 inch runoff washes off 90 percent of sediment



Street Sweeping and Debris Removal

- Annual Nutrient Reduction Credits

Sediment Analysis	Baseline	With Sweeping
Street Sweeping (metric tons/yr)	0	5,200
Sediment Washoff (metric tons/yr)	10,789	8,384
Average Annual Reduction in Sediment Washoff (tons/yr)	0	2,406
Average Annual Reduction in Sediment Washoff (%)	0%	46%

Nutrient Reduction Analysis	TP	TN
Concentration in Sediment (kg/metric ton)[1]	0.3	1.1
Reduced Loading (kg/swept ton/yr)	0.15	0.5
Total Reduction (kg/yr)	794	2598

1) Estimated from City of San Diego Targeted Aggressive Street Sweeping Study

Nutrients within Erodible Watershed Soil, Sediment

- Street surface sediment
- Debris in drainage systems
- Agricultural field soils
- Natural hillside soils

Source	Urban		Agriculture		Natural	
	TP (mg/g)	TN (mg/g)	TP (mg/g)	TN (mg/g)	TP (mg/g)	TN (mg/g)
LE/CL TMDL revision [1]	0.3	1.1	0.5 – 1.2	0.9 – 1.6	Under investigation	
Range of reference values [2,3]	0.2 - 1.0	0.5 - 2.0	0.4 – 1.1	1.0		

1) Data for urban street sediment presented in CNRP compliance analysis. Data for agricultural lands presented in Klang, 2017.
2) Refernce values for urban street sediment ranges from Sartor and Boyd, 1972; Walch, 2006, Baker et. Al., 2014; San Diego, 2011; Sansalone et. Al., 2011.
3) Agriculture values from F. Fang et. al., 2002; Knisel, 1979.

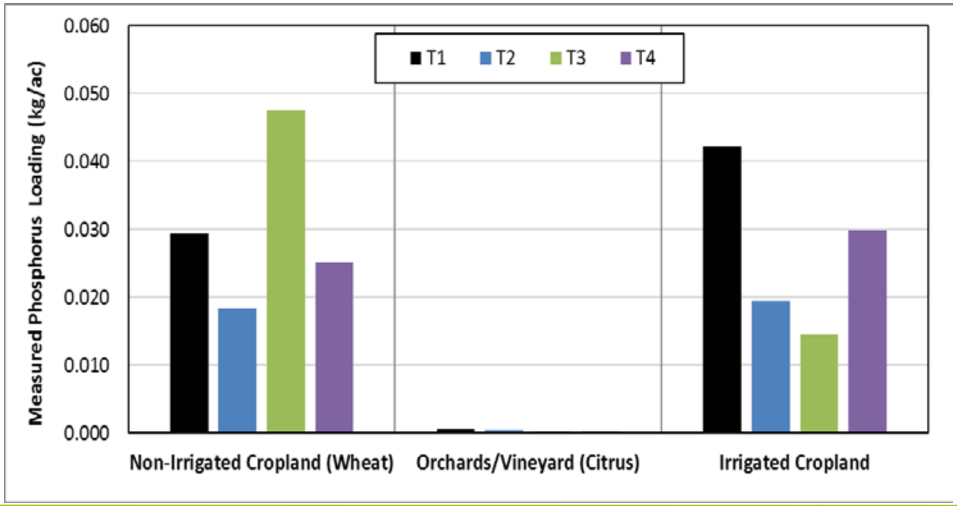
Cropping Practices to Reduce Erosion

- AgNMP based reductions on experiments by UC Riverside

Treatment Matrix	Non-irrigated Cropland	Orchards / Vineyards	Irrigated Cropland
T1	Control	Control	Control
T2	Incorporated manure	Cover Crop	Incorporated manure
T3	Spread manure	PAM	PAM
T4	Vegetated buffers	Mulch	Vegetated buffers

- Compliance analysis

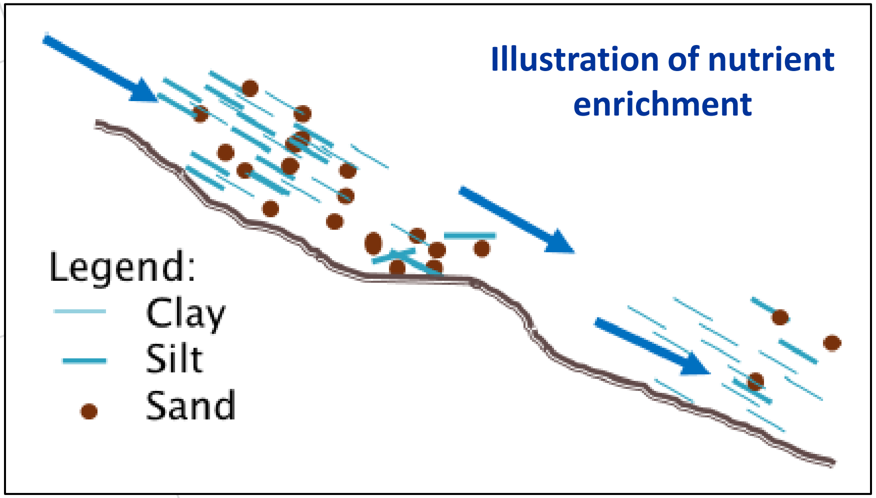
Land Use	Reduced TP (kg/yr)	Reduced TN (kg/yr)
Irrigated Cropland	174	55
Non-irrigated Cropland	89	202
Orchards / Vineyards	3	3



Cropping Practices to Reduce Erosion

- New soil health study by WRCAC
  - Will improve load reduction estimates from agricultural land BMPs
- Samples analyzed for N and P

From Rolfes, T. 2017. NRCS Work on Soil Health Presented at the NRCS and CDFA Summit: Building Partnerships on Healthy Soil. January 11, 2017

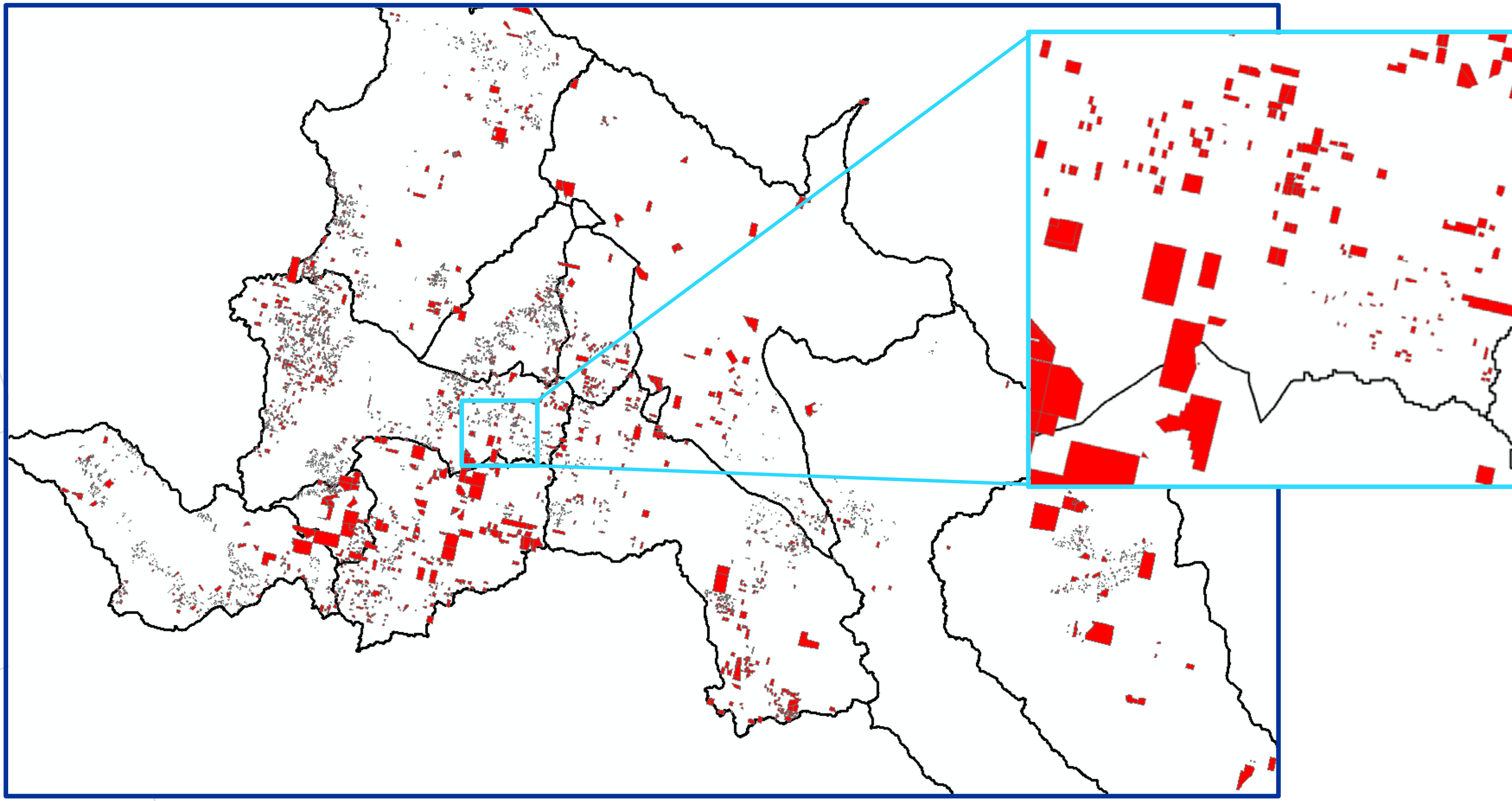


- Scope expanded to develop expert estimates of edge of field erosion

from Klang, 2017. Agricultural Phosphorus and Nitrogen Non-point Source Loading Estimates, Technical Memorandum, Feb 22, 2017.

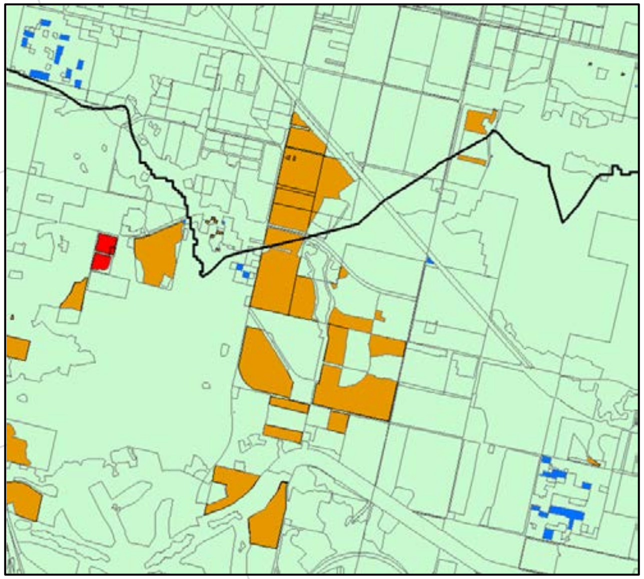
Septic System Management

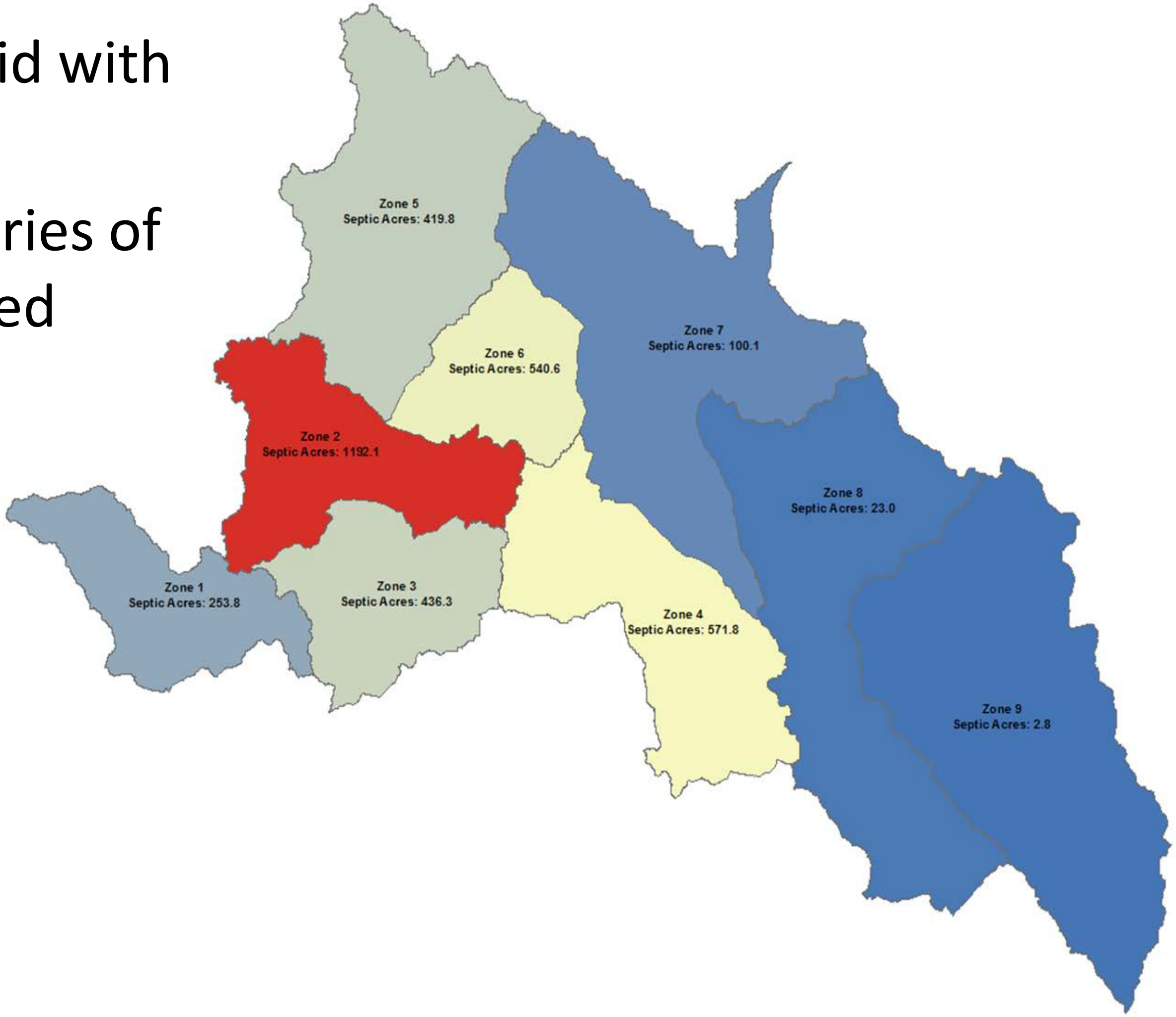
- Septic parcel areas from Riverside County



Septic System Management

- Septic parcels overlaid with residential land use
- New land use categories of sewered or unsewered residential





Septic System Management

- Incremental difference in sewered and unswered EMCs is attributed to septic source

Septic system elimination	**TP**	**TN**
EMCs for Unsewered Residential	0.59	5.30
EMCs for Sewered Residential	0.48	2.93
DeltaEMC (Sewered - unsewered)	0.11	2.37
Runoff (in/yr)	1.00	1.00
Load Reduction (kg/ac/yr)	0.01	0.24

Watershed loading model

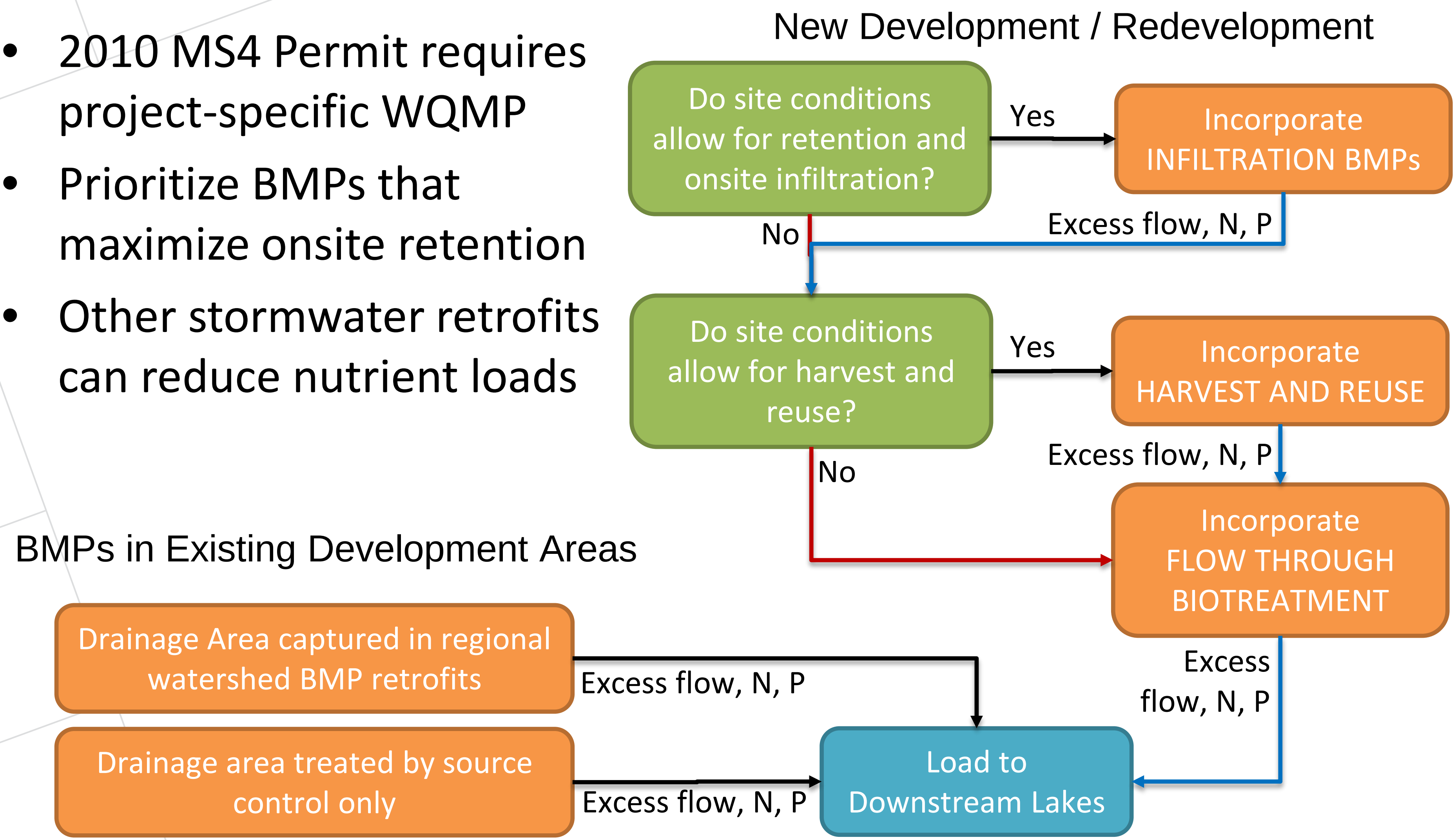
Septic System Management

- Septic parcels overlaid with residential land use to develop land use categories of sewered or unsewered

Zone	Septic Acres	Sewer Acres	% Septic	Potential TP Reduction (kg/yr)	Potential TN Reduction (kg/yr)
1	254	6,652	3.7%	2.9	61.8
2	1,192	9,009	11.7%	13.5	290.1
3	436	9,536	4.4%	4.9	106.1
4	572	7,914	6.7%	6.5	139.2
5	420	16,407	2.5%	4.7	102.2
6	541	2,456	18.0%	6.1	131.6
7	100	7,757	1.3%	1.1	24.3
8	23	2,370	1.0%	0.3	5.6
9	3	15	16.1%	0.0	0.7
10	322	3,609	8.2%	3.6	78.4
Total	3,863	65,726	5.6%	43.7	940.0

Structural BMPs

- 2010 MS4 Permit requires project-specific WQMP
- Prioritize BMPs that maximize onsite retention
- Other stormwater retrofits can reduce nutrient loads



Structural BMPs

Jurisdiction	Infiltration	Extended Detention	Separators	Vegetated Swale	Media Filter
	Effectiveness (% TP Removal for TP, TN) approximated from International BMP Database				
	100, 100	75, 24	33, 13	47, 0	69, 0
	Drainage Area to BMP Treatment (acres)				
Caltrans		46		47	
Hemet	73	44		17	
Lake Elsinore	24	1,142	35	40	100
March ARB	496		1,001	1	
March JPA	45	34		6	
Menifee	39	730	65	290	30
Moreno Valley	264	1,248	208	109	389
Murrieta	14	236			
Perris	614	773	819	114	18
Riverside		511			
Riverside County		25			
Subtotal (below Mystic Lake)	1,569	4,789	2,128	624	537

Structural BMPs

- Baseline estimated nutrient loads averaged for urbanized land use types
  - TP: 0.05 kg/ac/yr; TN: 0.44 kg/ac/yr
- Estimate of deployment levels that would meet WLA without other source control or in-lake controls

BMP Type	TP Load Reduction (kg/ac/yr)	TN Load Reduction (kg/ac/yr)	Drainage Area Treated to achieve LE/CL WLAs for MS4s	
			TP	TN
Infiltration / Bioretention	0.04	0.35	71,744	8,083
Extended Detention / Bioretention with drains	0.03	0.09	95,659	33,678
Hydrodynamic Separator	0.01	0.05	217,407	62,175
Vegetated Swale	0.02	0.00	152,648	n/a
Media Filter	0.03	0.00	103,977	n/a

Structural BMPs

- Estimated nutrient reduction achieved in structural BMPs implemented since 2005

BMP Type	To Canyon Lake	To Lake Elsinore
Infiltration/Bioretention w/o Underdrain	1,545	24
Extended Detention	3,647	1142
Hydrodynamic Separator	2,093	35
Vegetated Swale	584	40
Media/Sand Filter	437	100
TP Reduction (kg/yr)	222	39
TN Reduction (kg/yr)	948	107

In-Lake Nutrient Management

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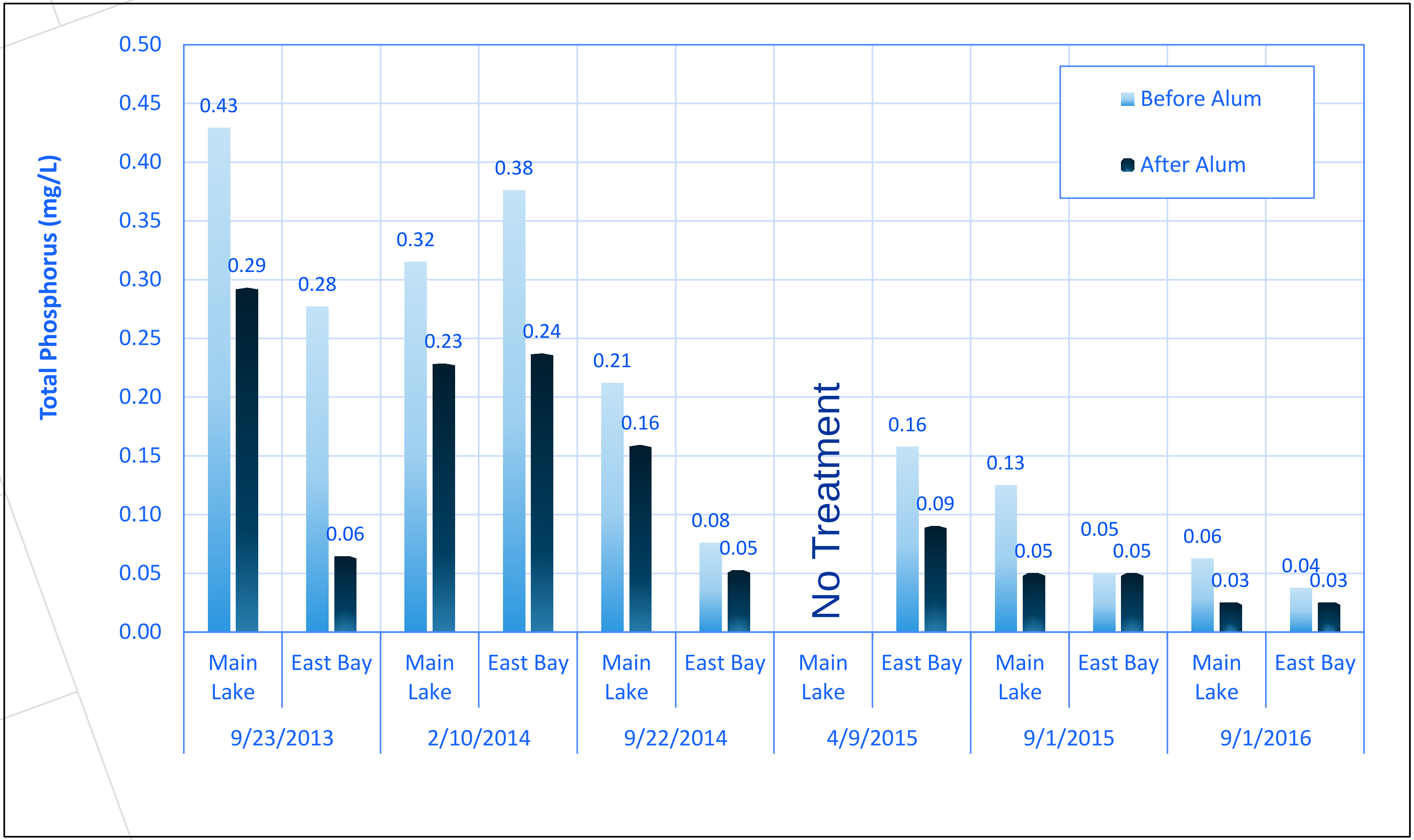
Alum Effectiveness Monitoring

- Monitor water column phosphorus before/after additions
- Efficiency estimated from ratio of alum applied to water column P removed
- Lower Alum:P ratio means treatment more effective for water column stripping
- Six alum treatments evaluated:
  - 9/23/2013
  - 2/10/2014
  - 9/22/2014
  - 4/9/2015
  - 9/2015
  - 9/2016

Phosphorus Reduction



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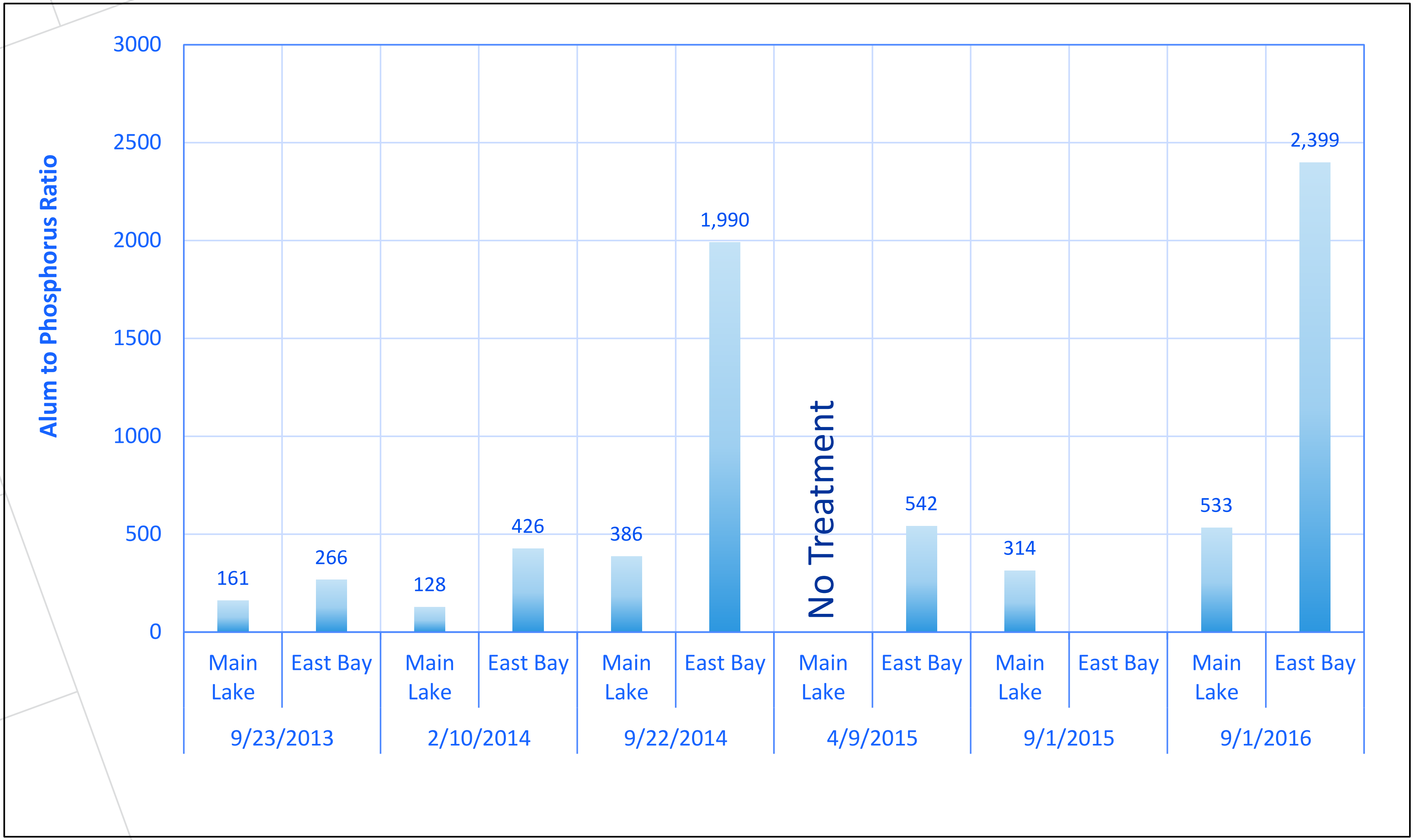
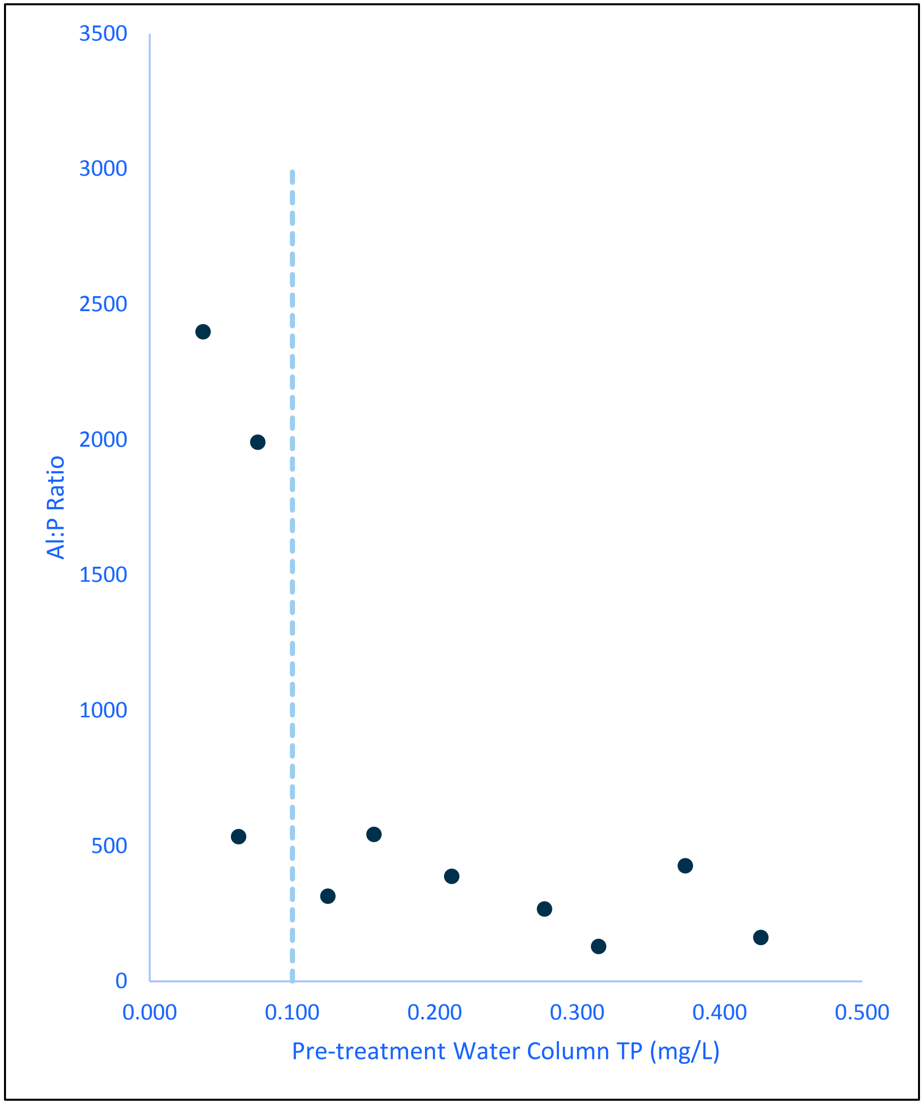
Alum to Phosphorus Ratio



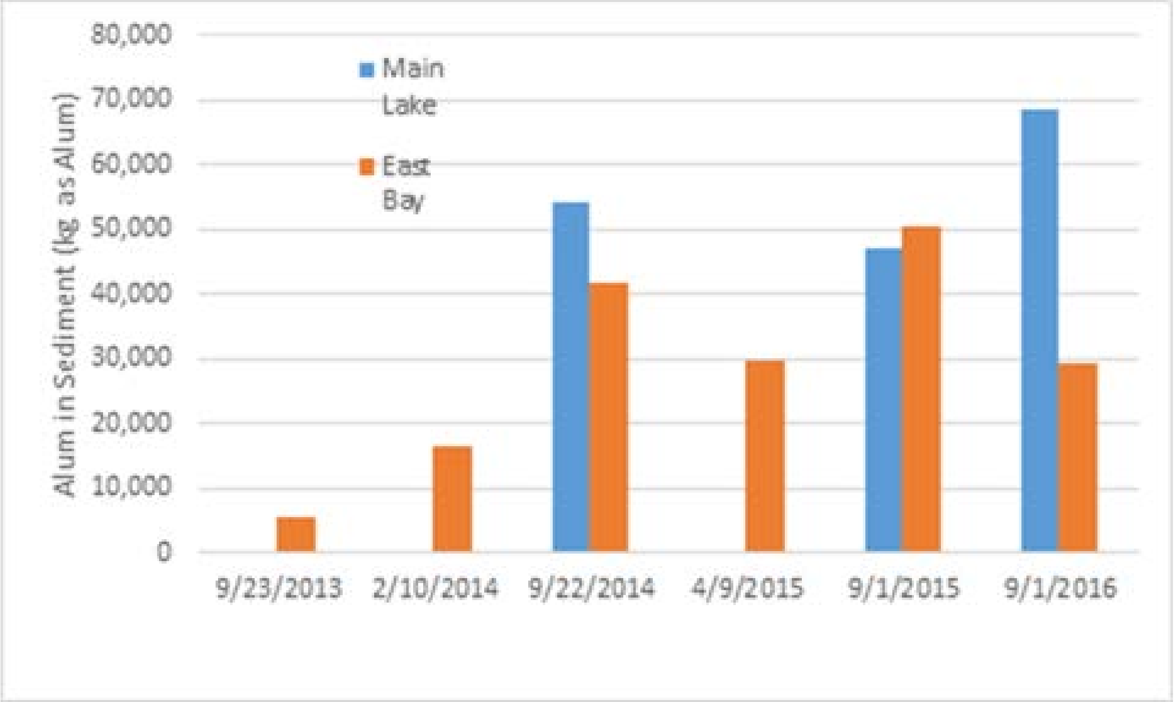
Alum to Phosphorus Ratio

- Al:P ratio from water column measurements is variable
- Al:P ratio typically high for pre-treatment TP < 0.1 mg/L
- Increasing water column stripping efficacy at high pre-alum TP concentrations



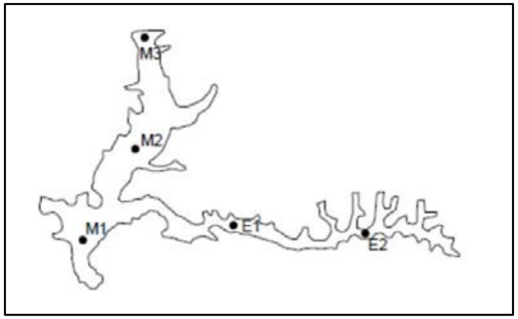
Unused Alum: Where does it go?

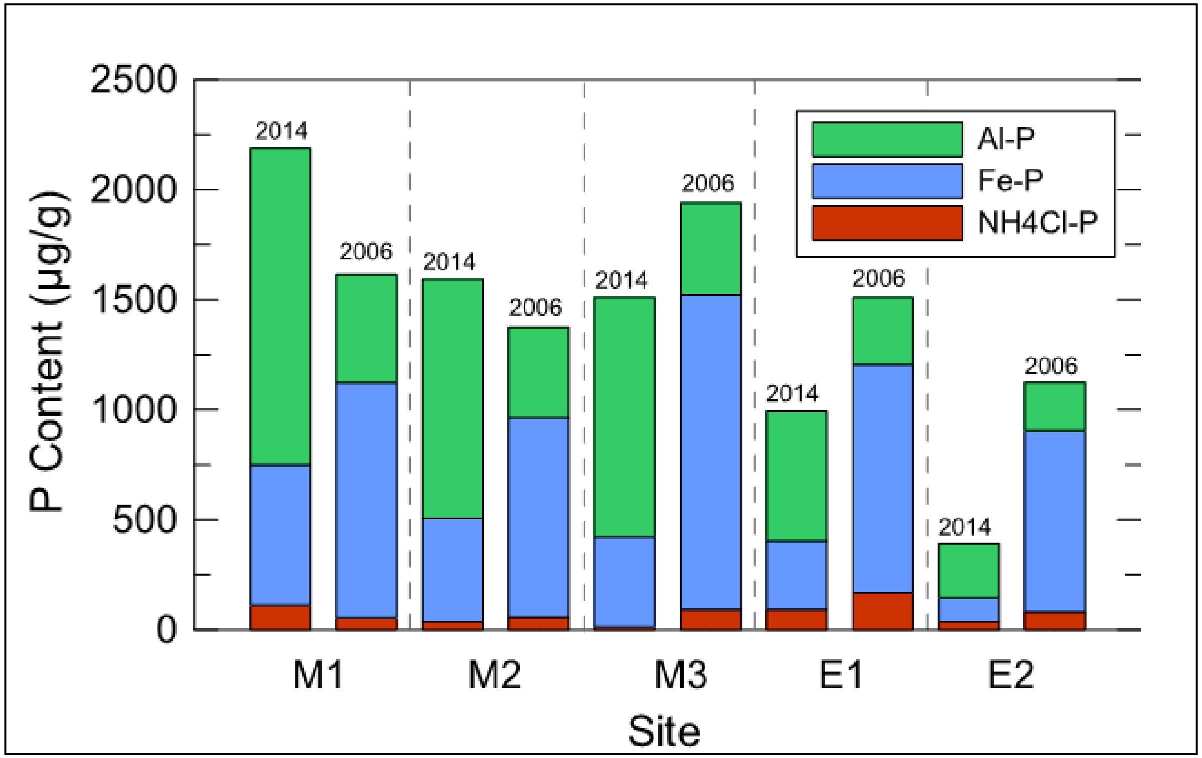
- Reduce pH forming aluminate precipitate (gibbsite)
- Settles to bottom as aluminum hydroxide and serves to permanently bind mobile P in sediments



Evidence of Aluminum in Sediments

- Iron-bound P levels reduced since 2006
- Aluminum-bound P levels increased since 2006
- Suggests alum applications are having an effect on sediment P





Source: Anderson (2016), Technical Memorandum, Task 2.4: Mobile-P and Internal Phosphorus Recycling Rates in Canyon Lake

Summary of Current Controls in Canyon Lake

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Change in Implementation Planning – Canyon Lake

CNRP and AgNMP

LSPC washoff rates based on land use and jurisdiction

↓

Reduced loading to Canyon Lake with watershed BMPs

↓

DYRESM-CAEDYM estimates alum addition that would achieve Chl-a response target

TMDL Revision

Load reduction estimated by jurisdiction/lake segement

↓

Reduced loading to Canyon Lake with watershed BMPs

↓

Remaining load reduction achieved with alum (alum to P-removed of 220:1)

↓

ELCOM-CAEDYM computes expected in-lake water quality for reference watershed

Summary of Current Nutrient Reductions for Canyon Lake

- Update compliance analysis with new source assessment and BMP deployment data
- Collectively, BMPs have achieved more than 75 percent of the required TP reduction (assuming ongoing implementation)

Nutrient Control Strategy	TP Reduction (kg/yr)	TN Reduction (kg/yr)
Source Control by MS4s	866	2888
Structural BMPs by MS4s	222	948
Alum Addition	1500	n/a
Total	2,588	3,836
Remaining Reduction to be Met	777	14,516

Current Nutrient Reductions for Lake Elsinore

- Still being developed

Development of Load Reduction Credit Tracking Tool

- Data input by agencies through straightforward GUI