Nitrogen and Phosphorus Pollution and Harmful Algal Blooms in Lakes

Watershed Academy Webcast

Wednesday January 26, 2011
1:00–3:00 Eastern

Instructors:
Joe Piotrowski, Senior Advisor, US EPA, Office of Wetlands, Oceans and Watersheds
Ken Wagner, Water Resource Manager, Water Resources LLC, Wilbraham, MA
Russ Gibson, Nonpoint Source Program Manager, Ohio Environmental Protection Agency

Guide to Our Webcasts – For Technical Support Click the "Help" Button

- **To Ask a Question** – Type your question in the text box located in the lower left-hand corner of your screen and click on the "Submit Question" button.
- **To Answer Poll Question** – Click on the radio button to the left of your choice and click submit. Do not type your answer in the "Ask a Question" box.
- **To See Closed Captioning** – Turn your pop-up blocker off and click on the "closed captioning" button.
- **To Complete the Survey** –Fill out the survey in the window
- **To Obtain a Certificate** – Watch 1.5 hours of the webcast and then click "Download Certificate." If you are in a room with multiple attendees please wait until the last slide to obtain the URL to customize your own certificates.

Topics for Today's Webcast

- Overview of N and P pollution and the need for action
- N and P pollution and harmful algal blooms
- Case study: Grand Lake St. Marys (OH)
- Case study: Lake Waco (TX)

Nutrients and Harmful Algal Blooms: A National Overview and Need for Action

Joe Piotrowski, Senior Advisor U.S. EPA Office of Wetlands, Oceans, and Watersheds

Extent of the Nitrogen and Phosphorus Problem: Key NITG Findings

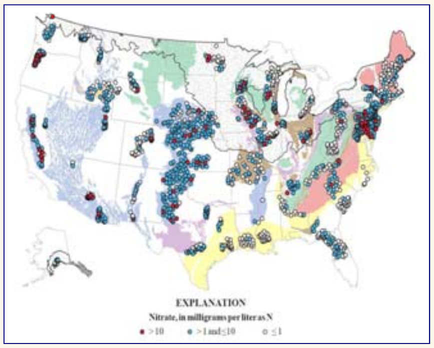
- Nutrient-related pollution significantly impacts drinking water supplies, aquatic life, and recreational water quality
- Knowledge, collaboration, and incentives will fail absent joint accountability
- Current CWA tools underused; additional tools rarely used
- Current regs disproportionately address certain sources to the exclusion of others
- Parts of state Nonpoint Source Programs highly successful, but broader application undercut by absence of a common multi-state framework of mandatory point and nonpoint source accountability

National Scope of Nitrogen and Phosphorus Pollution: EPA database information

- 14,000 Nutrient-related impairment listings in 49 states
  - 2.5 million acres of lakes and reservoirs
  - 80,000 miles of rivers and streams
  - And this is an underestimate . . .
- Over 47% of streams have medium-to-high levels of P and over 53% have medium-to-high levels of N
- 78% of assessed continental U.S. coastal waters exhibit eutrophication, many with harmful algal blooms
- Nutrient impacts reflect doubling of U.S. population over past 50 years
  - Increased construction, wastewater, and food production

National Drinking Water Impacts

Public Health Risks:



(MCL of 10 mg/l exceeded as N in 4.4 percent of the wells)

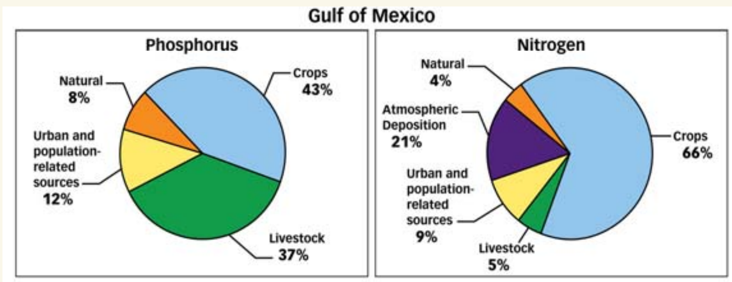
- Nitrate MCLG exceeded in 7% of 2,400 drinking water wells sampled
- Disinfectant by-products; significant and costly
- Rate of nitrate violations in community water systems has doubled over past seven years
- Harmful algal blooms and increased treatment costs
- In agricultural areas, more than one in five shallow, private wells contained nitrate at levels above the EPA drinking water standard (USGS, Circular 1350)

Science and Analysis to Date

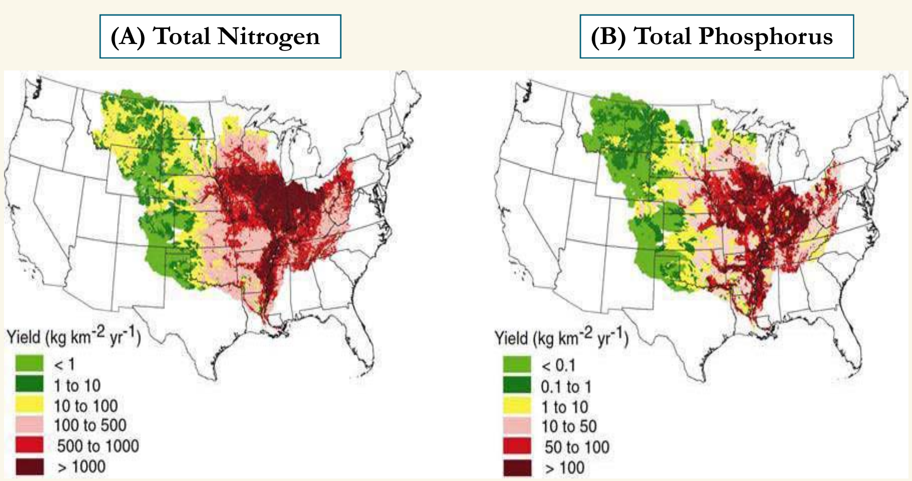
- National Oceanic and Atmospheric Administration
  - Effects of Nutrient Enrichment in the Nation’s Estuaries (Bricker et al. 2007)
- National Research Council
  - Mississippi River Water Quality – Challenges and Opportunities (NRC 2008)
  - Urban Stormwater Management (NRC 2008)
  - Improving MARB Water Quality (NRC 2010)
- EPA Science Advisory Board
  - Reactive Nitrogen in the U.S. (USEPA 2009)
  - Hypoxia in the Northern Gulf of Mexico (USEPA 2007)
- U.S. EPA
  - National Lakes Assessment (USEPA 2010)
  - National Coastal Condition Report III (USEPA 2008)
  - Wadeable Streams Assessment (USEPA 2006)
- United States Geological Survey
  - Nutrients in the Nation's Streams and Groundwater (2010)
- Numerous articles, state reports, and university studies

Agriculture is the leading contributor of nutrients in the MARB

- Influenced primarily by agricultural runoff from the MARB
- Two-thirds of N loadings and almost one-half of the P loadings to the Gulf are attributed to row crop agriculture, which is not regulated under the Clean Water Act
- A little over one-third of the P that enters the Gulf is due to livestock production, some but not all of which is subject to Clean Water Act regulation



Nutrient Loading Model: SPARROW (USGS)



Alexander, et al, *Environ. Sci. Tech.*, 2008

Conclusion

- Nitrogen and phosphorus pollution are of a pervasive nature and have detrimental effects on our all of our nation's waterbodies
- Today's webcast focuses on the effects of nutrient pollution on lakes and this is the first in a series of webcasts on the topic of nitrogen and phosphorus pollution. We look forward to discussing a variety of topics related to the challenges of nutrient pollution throughout the country.

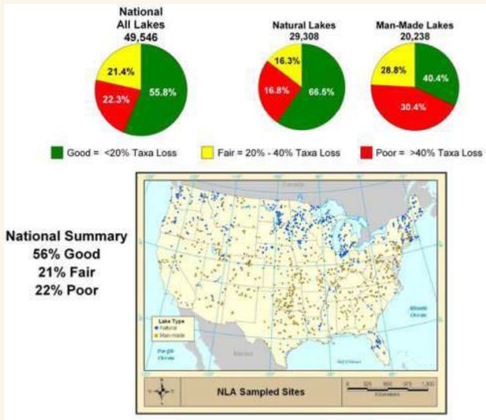
Nutrients and Harmful Algal Blooms: Effects on Lakes and Lake Users

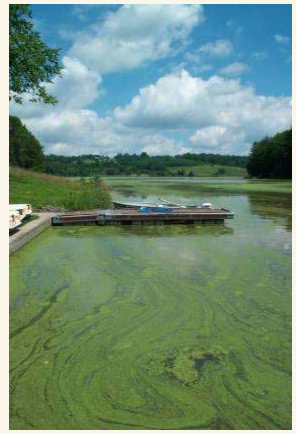
Ken Wagner, Ph.D, CLM

Water Resource Services

WRS

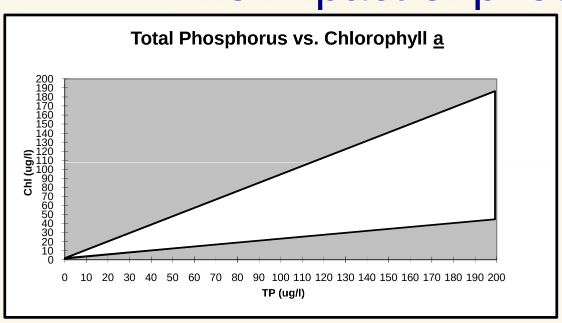
Why are nutrients a concern?

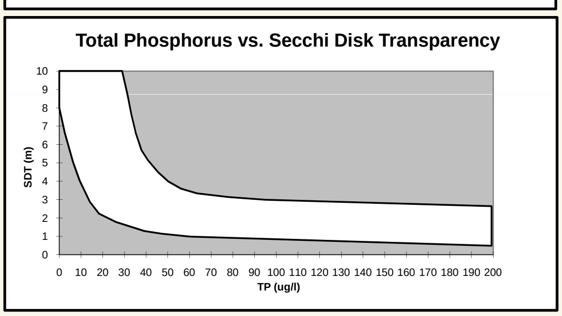




According to the NLAP study, almost half of our nation's lakes are in less than good shape as a consequence of nutrient pollution. Nutrients have a positive connotation in health, but overabundance of nutrients can lead to overfertility in lakes (i.e., "fat" lakes).

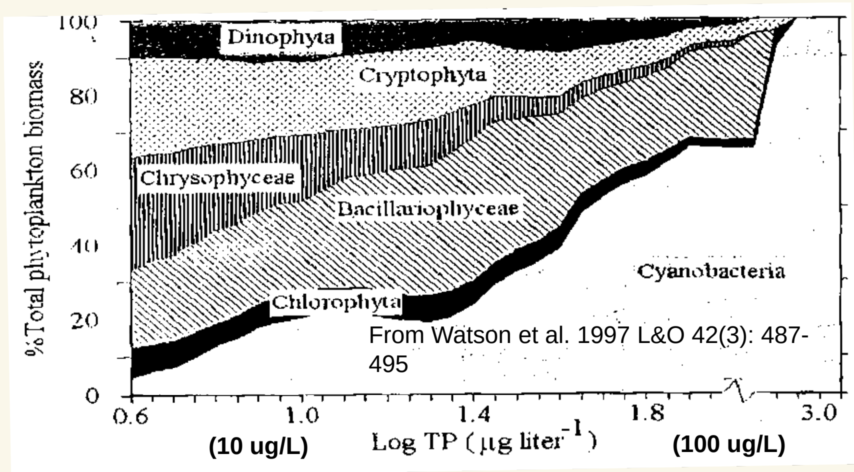
The impact of phosphorus





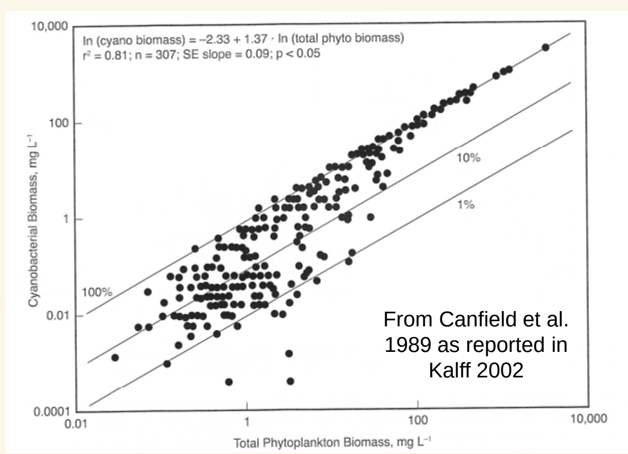
- Based on decades of study, more P leads to more algae
- More algae leads to lower water clarity, but in a non-linear pattern

The impact of phosphorus



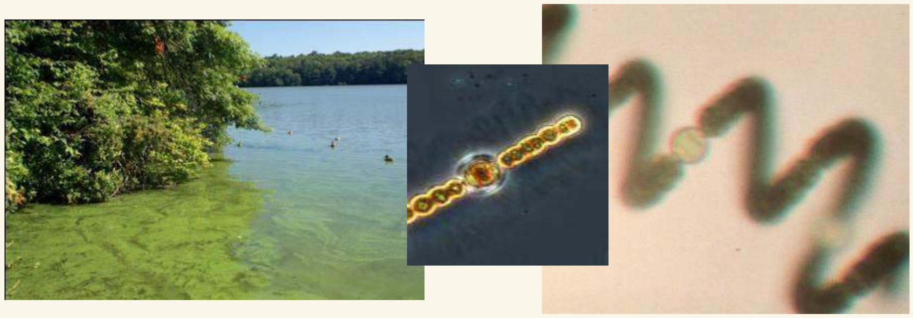
High P also leads to more cyanobacteria, from considerable empirical research. Key transition range is between 10 and 100 ug/L

The impact of phosphorus



As algal biomass rises, a greater % of that biomass is cyanobacteria. So more P = more algae = more cyanobacteria.

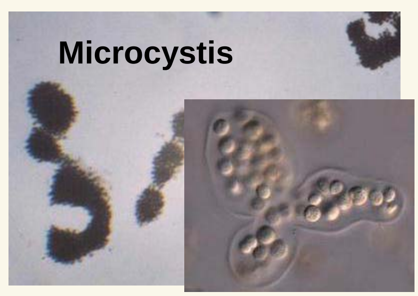
Don’t ignore nitrogen!

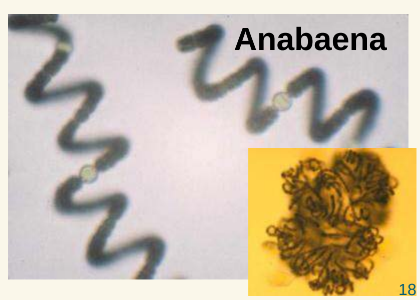


- N and P tend to co-vary, so increased N also results in increased algal abundance
- N:P ratio often determines which algae are dominant; lower N:P leads to more cyanobacteria, as many cyanobacteria can use dissolved N gas, unique to this group

Cyanotoxins

- May be liver, nerve or skin toxins
- Selectively produced by many genera, but not very predictable
- Widely distributed, but not often at acutely toxic levels





Cyanotoxins

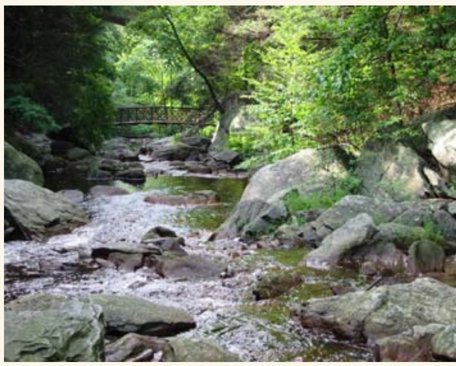
- Some other algae produce toxins - Prymnesium, or golden blossom, can kill fish; marine dinoflagellates, or red tides, can be toxic to many animals and humans.
- Cyanobacteria are the primary toxin threats to people from freshwater; acute toxicity is rare, but chronic effects may be significant and are difficult to detect.
- Research (e.g., 3 papers in Lake and Reservoir Management in September 2009) indicates widespread occurrence of toxins but highly variable concentrations, even within lakes.
- Water treatment in typical supply facilities is adequate to minimize risk; the greatest risk is from substandard treatment systems and direct recreational contact.

Sources of Nutrients

- Natural background: P that falls from the sky, dissociates from soil or is released from decaying vegetation, also P in manure from wild animals
- Fecal material: Inadequately treated human or domestic/farm animal wastes
- Fertilizers: Improperly applied or poorly retained agricultural or residential growth enhancing materials
- Stormwater runoff: Not an actual source, but conveyance linked to impervious surfaces and inadequate buffer zones
- Internal recycling: “The ghost of loadings past”, nutrients that come back out of the sediments by multiple mechanisms and become available again.

Magnitude of Nutrient Loads

- Very desirable TP: <10 ug/L; Poor: >100 ug/L
- Background P concentrations = 5-50 ug/L typical, variation with geography and related soils and water chemistry




Magnitude of Nutrient Loads

- Urban runoff P concentrations: 50 to 5000 ug/L, median between 370 and 470 ug/L
- Agricultural runoff P concentrations: 30 to 4000 ug/L for crops, feedlots normally exceed 4000 ug/L (can be >100,000 ug/L)

Magnitude of Nutrient Loads

- Wastewater treatment effluent P: Very best treatment achieves 20 to 50 ug/L; few WWTF achieve better than 1000 ug/L, some as high as 12,000 ug/L

The impact of development

Lake George, NY: 5% developed watershed contributes same P load as remaining undeveloped 95%

Watershops Pond, MA: 75% developed watershed, input P averages 193 ug/L.

The impact of agriculture

Missouri reservoirs in areas with mean crop cover of 25% have mean TP of 58 ug/L (Jones et al. 2009)

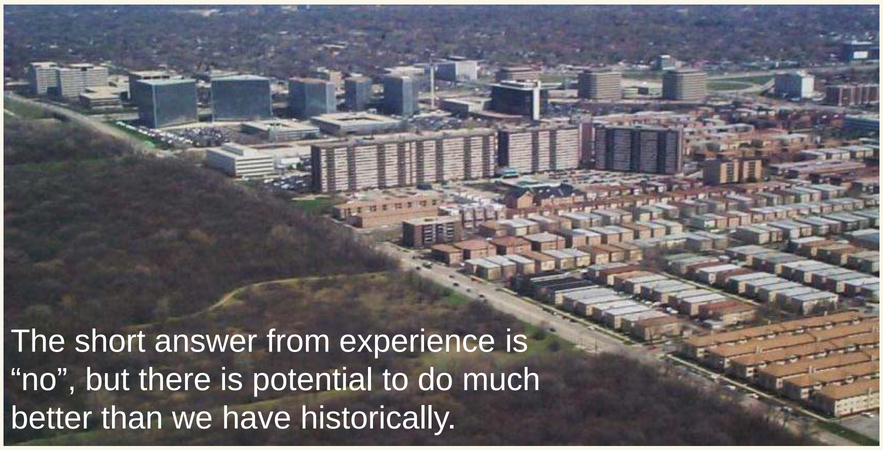
Lake Waco watershed in TX has 5% of land in dairy farms, contributing 26% of TP to inlet concentration of 140 ug/L, and over 50% of available P (Wagner 2010)

How do we address nutrient loading?

- Source and Activity Controls – Eliminate or reduce sources which generate pollutants
- Transport Reduction – Capture and remove or convert pollutants before they enter target resource
- Instream/Inlake Treatments – enhancing internal processes for pollutant inactivation
- **Ecosystem Rehabilitation – Repair damage to resources when controls fail**

Doing the math on watershed controls

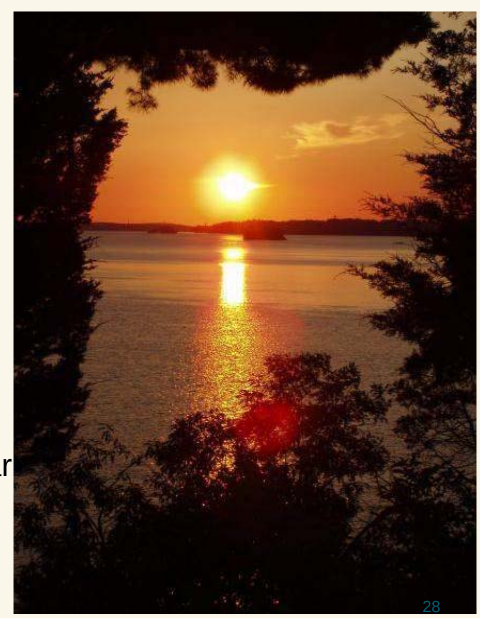
Can we get the land on the right
to act like it is land on the left?



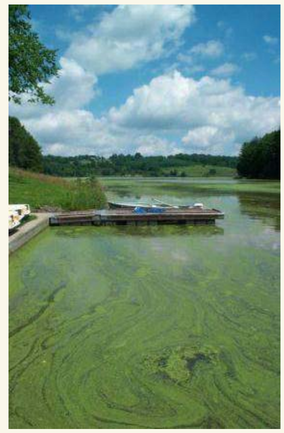
The short answer from experience is "no", but there is potential to do much better than we have historically.

Conclusions

- Increased nutrient loading supports more algal growth with a greater portion of cyanobacteria
- Abundant algae can impair uses, but abundant cyanobacteria represent a distinct health threat as well
- Nutrient loads induced by human activities (development, agriculture, wastewater discharge) are far in excess of natural background levels in most areas



Questions?

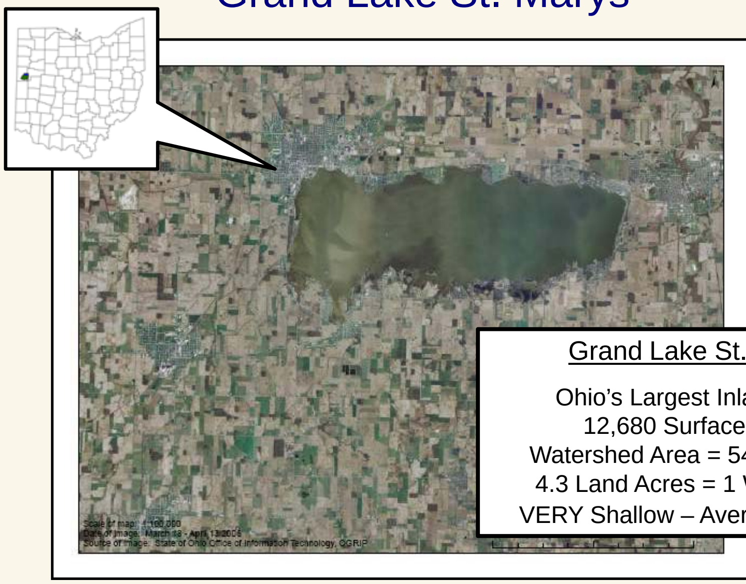


Ken Wagner
Water Resource Manager,
Water Resource Services LLC

Grand Lake St. Marys

Russ Gibson, NPS Program Manager
Ohio Environmental Protection Agency
Division of Surface Water

Grand Lake St. Marys



Grand Lake St. Marys

Ohio's Largest Inland Lake
12,680 Surface Acres
Watershed Area = 54,000 acres
4.3 Land Acres = 1 Water Acre
VERY Shallow – Average 5-7 feet

Land Use in the Watershed

Cropland	**73%**
Developed	**14%**
Pasture	**9%**
Forest	**3%**
Wetlands	**<1%**

Population

Mercer County:	40,666
Auglaize County:	46,576

Importance of Grand Lake to the Community

Public drinking water supply.

Hosts more than 100 fishing tournaments per year.

Lake-based recreation and tourism accounts for up to $150 million annually.

Grand Lake State Park enjoyed by more than 700,000 visitors each year.

Extensive lakeshore residential development.

A focal point for community and fellowship with many festivals and events each year.

Houston …

We have a Problem!

Algae – it's more than just ugly!

Environmental Impacts

- Horrible Odor
- Multiple Fish Kills
- Waterfowl and Pet Deaths
- Severe Dissolved Oxygen (DO) Swings

Public Health Impacts

- 23 Suspected Illnesses
- Recreation and Boating Advisory
- Fish Consumption Advisory

Economic Impacts

- $150 Million Tourism Industry Decimated
- Regatta Cancelled = @$600,000 Lost
- Park Revenues down >$250,000/yr
- 5 Lakeside Businesses Closed

Harmful Algae Blooms

Algae toxins (microcystin) as high as 2,000 ppb recorded in GLSM during 2010

Other Algae Toxins Present during 2010 in Grand Lake St. Marys

Anatoxin-a

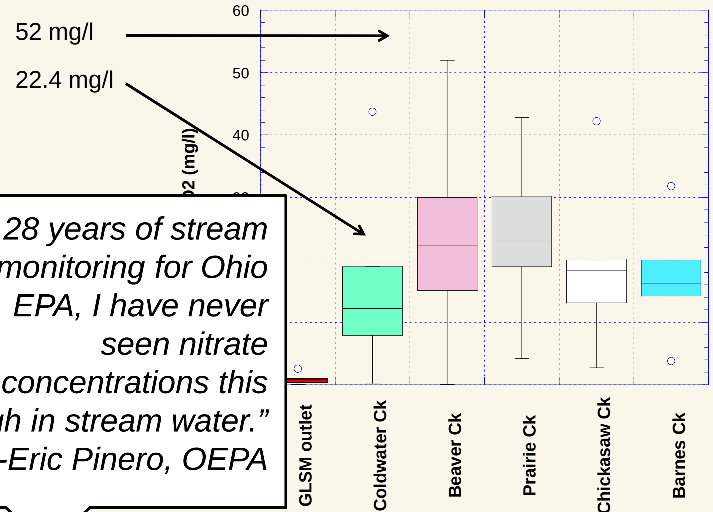
Cylindrospermopsin

Saxotoxin

Toxic algae advisories have severely diminished local recreation and tourist economic activities.

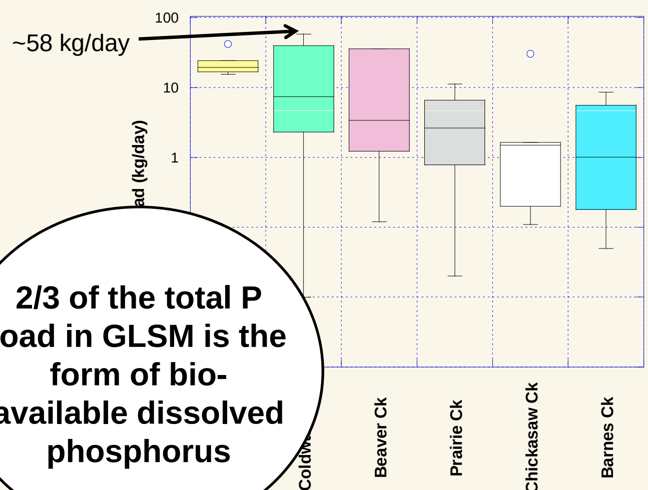
So … what's feeding the algae?

Nitrate + Nitrite Concentration (mg/l)



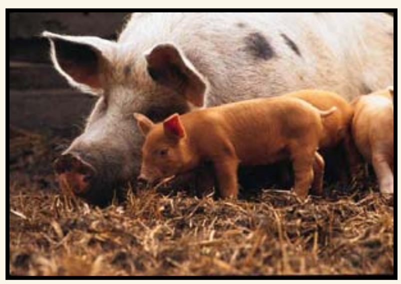
"In 28 years of stream monitoring for Ohio EPA, I have never seen nitrate concentrations this high in stream water."
-Eric Pinero, OEPA

Total Phosphorus Load (kg/day)



2/3 of the total P load in GLSM is the form of bio-available dissolved phosphorus

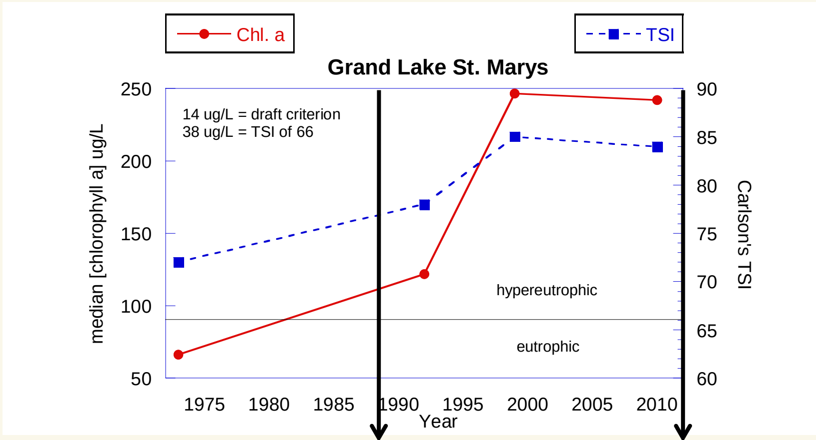
So … what has changed in the GLSM watershed?



"Lake water quality problems related to nutrient and algae control appear better resolved through reduction of nutrient loads to the lake and in particular control of agricultural and livestock waste sources."

Louisville District Corps of Engineers
Department of the Army
August, 1981

Historical levels of chlorophyll-a and trophic state index



1987 GLSM Livestock Population	2007 GLSM Livestock Population
45,000 cows	79,000 cows
123,000 hogs	273,000 hogs
3.9 million chickens	9.3 million chickens

Urgency Prompts New Approach

Extreme impacts to the community require us to first focus on what is needed to fix the lake NOW!!!

- **Reduce harmful algae blooms**
- **Insure safe water-based recreation**
- **Reduce fish kills**
- **Protect public drinking water supply**
- **Reduce external and internal nutrient loads**

Considerations

- Algae blooms are being fueled by internal nutrient cycling as well as external loads.
- In-lake management effectiveness is directly affected by watershed nutrient loads.
- Substantial watershed based nutrient reduction actions will likely require several years.

We know that …

1. **INTERNAL P-loads need to be reduced from 200µg/L to between 25-50µg/L.**
2. **EXTERNAL P-loads need to be reduced by 80% and this will take some time.**
3. **TRIBUTARY treatment of nutrients will be necessary to reduce loads entering the lake.**

Grand Lake St. Marys
Recommended Management Actions

Aluminum sulphate treatment

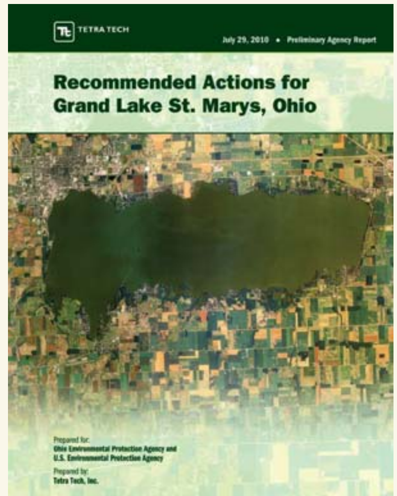
Strategic dredging

Wetland treatment trains

Site specific aeration

Lake shoreline stabilization

Agricultural BMPs

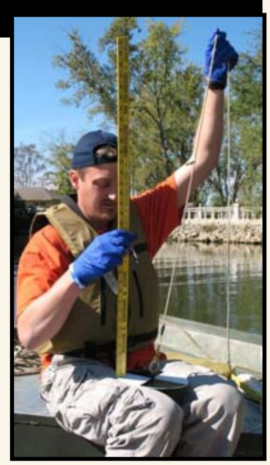


GRAND LAKE ST. MARY'S
Recommended Actions & Timeline

Year 1 Actions	Year 2 & 3 Actions	Year 4 - 5 Actions
Alum Demonstration Project	Install 2 Wetland Treatment Trains	2 additional Wetland Treatment Trains
Install 3 Sediment Collectors	Whole Lake Alum Treatment*	Continue Land Treatment Effort
Strategic Aeration	Strategic Aeration	Lake Shoreline Stabilization BMPs
Accelerate Land Treatment Implementation	Install 3 Sediment Collectors	
	Continue Land Treatment Effort	

Alum Treatment Demonstration Project for Grand Lake St. Marys

What are the goals for this demonstration project?



To reduce GLSM internal phosphorus levels by 60-85%.

To sustain P-reductions through the first phase of degradation.

To refine dosing requirements for a potential whole-lake treatment.

Initial Results

(48 hours after treatment)

Harmon Channel—Total Phosphorus reduced 92%

Otterbein Channel—Total Phosphorus reduced 42%

West Bank Marina—Total Phosphorus reduced 89%

Final Results

(6 weeks after treatment)

Harmon Channel—Total Phosphorus reduced 52%

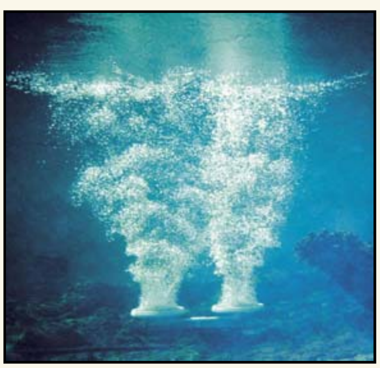
Otterbein Channel—Total Phosphorus reduced 57%

West Bank Marina—Reduction not sustained

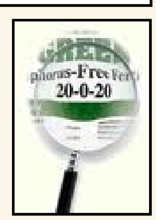
Tributary Treatment Trains

- A variation of this plan will be installed at the mouths of each of the six south shore tributary streams.
- During high flows, runoff will be diverted through wetland areas prior to discharging into GLSM.
- Strategic dredging will occur in areas where sediment deposition are highest.
- Sediment collectors may operate in conjunction with in-stream alum dosing units upstream from wetland treatment areas.

Grand Lake St. Mary's—Restoration Plan
Lakefront Landowners Strategies



Lakefront homeowners are being encouraged to use ZERO P fertilizers. Workshops are planned to help with this effort.



Strategically placed aerators in private channels will reduce odors and fish kills.

Small floating wetland kits (right) may help take up nutrients in channels.

Specific efforts to reduce agricultural nutrients

"Distressed Watershed" Rule

Prohibition of Winter Manure Application

Nutrient Management Planning

Mandatory Soil Testing

Community Anaerobic Digester (proposed)

Refining the P-Index (proposed)

Continued expansion of special EQIP

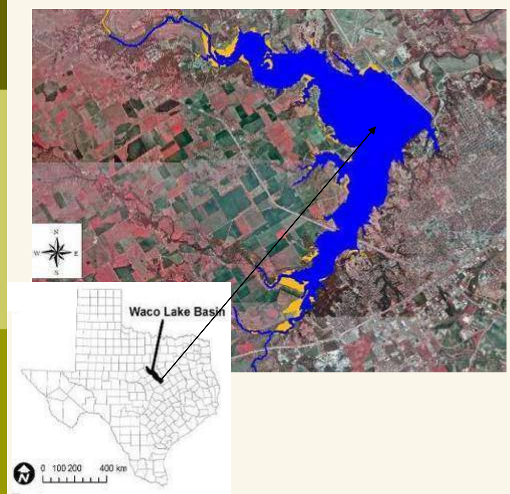
Ongoing Challenges

- Future funding
- Agency action & coordination
- Community pressure
- Timing of in-lake measures
- Owning the load issues
- Local economic impacts


Questions?
Ohio Environmental Protection Agency
Russ Gibson, NPS Program Manager
Ohio EPA-Division of Surface Water
59

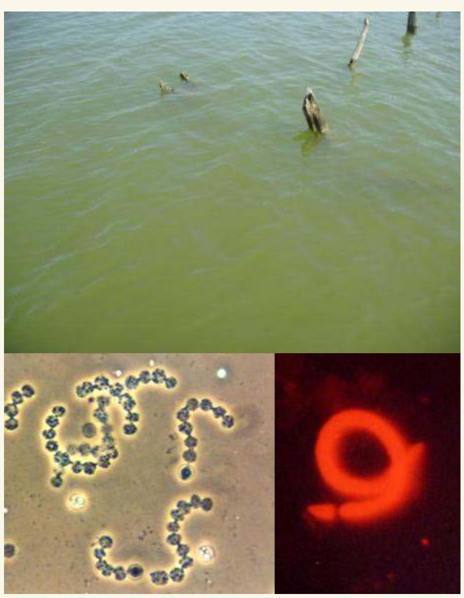

NUTRIENT LOADING TO LAKE WACO
Ken Wagner, Ph.D, CLM,
Water Resource Services
WRS
60

Location and Historic Perspective



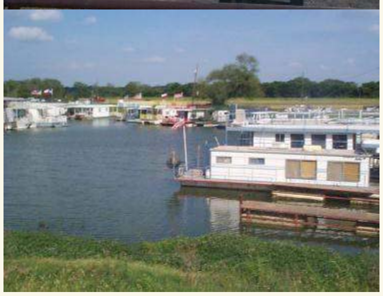
- Lake Waco initially constructed in 1929
- Largely filled in by late 1950s
- New dam enlarged Lake Waco in 1965
- Water quality decline and increasing bloom frequency in the 1990s
- Pool raised in 2003

Algal Bloom Impacts



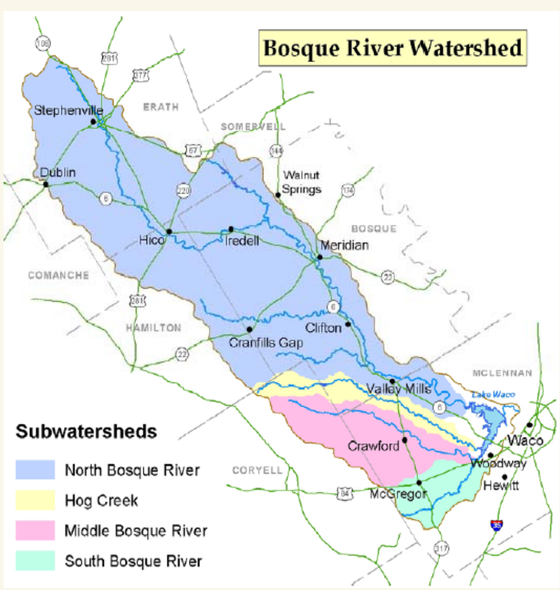
- Lake Waco is the primary drinking water reservoir for the area
- Cyanobacterial blooms create taste and odor that impair water supply, possible toxicity
- Expensive water treatment facility upgrade to protect consumers

Algal Bloom Impacts

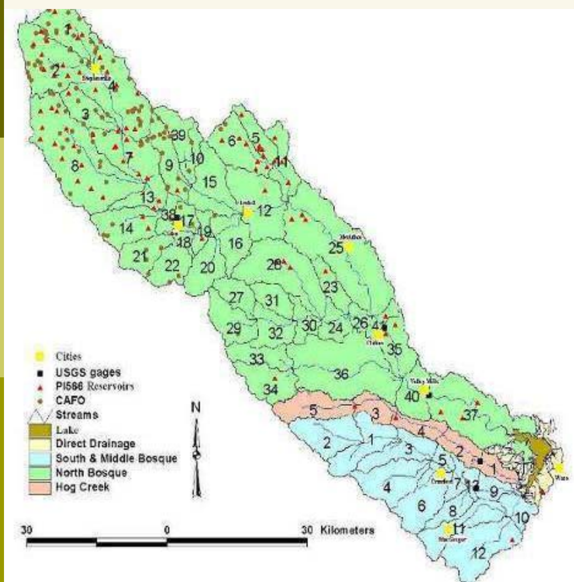
- Lake Waco is also a popular recreation facility, managed by the US Army Corps of Engineers
- Lake Waco is a regional “economic engine”
- Aesthetics and risks from direct exposure must be considered

Watershed Drainage



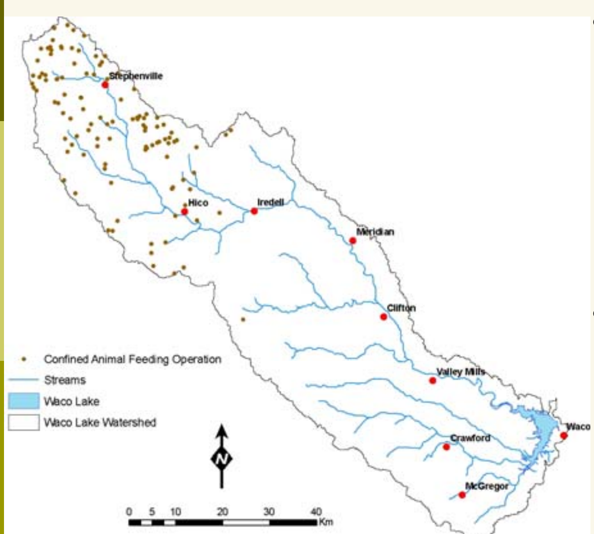
- Watershed >100 times lake area
- Four tributaries feed Lake Waco from a 1 million acre watershed
- The North Bosque River is the largest, draining 75% of the watershed

PL566 and Dairy Distribution



- PL566 reservoirs constructed in the 1960s for multi-purpose use
- Dairy operations established in the 1980s, rise through the 1990s, all in the upper NBR

Wastewater Discharges

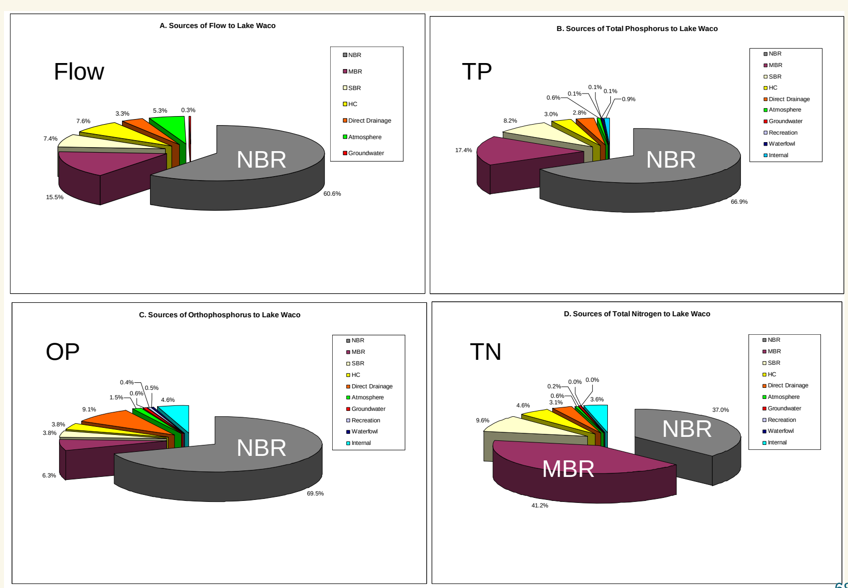


- 8 WWTF associated with towns in the watershed upstream of Lake Waco
- 1st and 3rd largest WWTF have enhanced P removal, one has no discharge

Sources to Lake Waco
Partitioning the load by drainage area and direct sources

Source	% of Total Area	% of Total Flow	% of Total P Load	% of Ortho P Load	% of Total N Load	TN:TP Load Ratio
NBR	74.8	60.8	66.9	69.5	37.0	5.4
MBR	12.1	15.5	17.4	6.3	41.2	23.3
SBR	5.3	7.4	8.2	3.8	9.6	11.6
HC	5.0	7.6	3.0	3.8	4.6	15.0
Direct Drainage	2.2	3.3	2.8	9.1	3.1	11.1
Atmosphere	0.7	5.3	0.6	1.5	0.6	10.0
Groundwater	0.1	0.3	0.1	0.6	0.2	19.4
Recreation	0.7	0.0	0.1	0.4	0.0	3.1
Waterfowl	0.7	0.0	0.1	0.5	0.0	4.8
Internal	0.7	0.0	0.9	4.6	3.6	39.7
Total	100	100	100	100	100	9.8

Sources to Lake Waco



Sources to Lake Waco

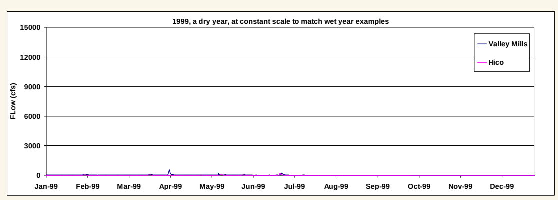
Partitioning the P load by source type

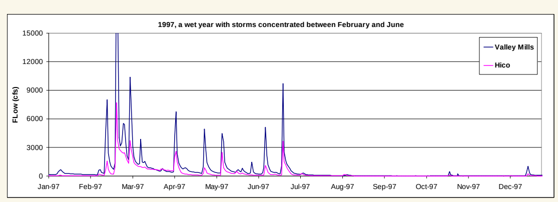
	% of Contribution to Lake Waco			
Source Type	**TP**	**OP**	**Available P**	**TN**
Woodland and rangeland (natural)	28	5	3	22
Urban runoff	10	15	12	5
Wastewater discharges	4	9	8	1
Cropland (row and cover crops)	19	15	10	51
Pasture (non-dairy animals)	13	15	12	17
Dairy operations (CAFOs and WAFs)	26	41	55	5

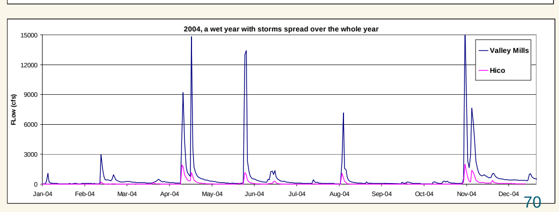
- Natural land is the largest TP contributor, but represents 63% of watershed land.
- Dairy operations provide >50% of the available P and represent <5% of the land.
- Crops provide >50% of TN and represent 15% of the land.

Wet Weather Drives Loading

- Minimal loading occurred in dry 1999
- High loading in the wet first half of 1997 produced summer blooms in the dry second half
- High loading in 2004 was counteracted by continued flushing throughout the year





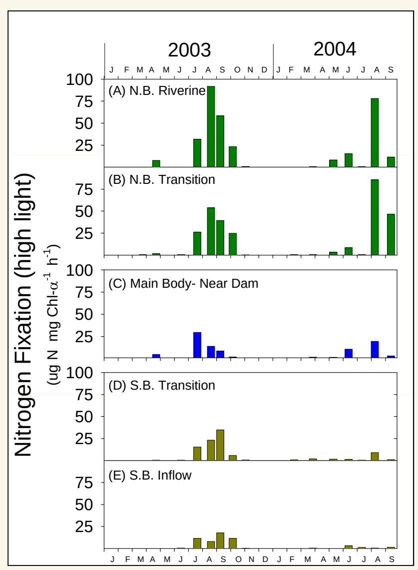


Dairy Waste Application Fields

- Manure spread on fields
- P binding capacity exhausted over time
- Large storms move P into streams, NBR and Lake Waco
- Low N:P ratio during these pulsed events

Nitrogen Fixation

- N fixation increases during summer and is higher in the NBR arm of Lake Waco
- Performed by certain cyanobacteria which have become common
- Matches pattern of increasing flow dominance by low N:P NBR water in summer, warmer water, increasing cyanobacteria
- 4% of TN load, but 27% of summer N load



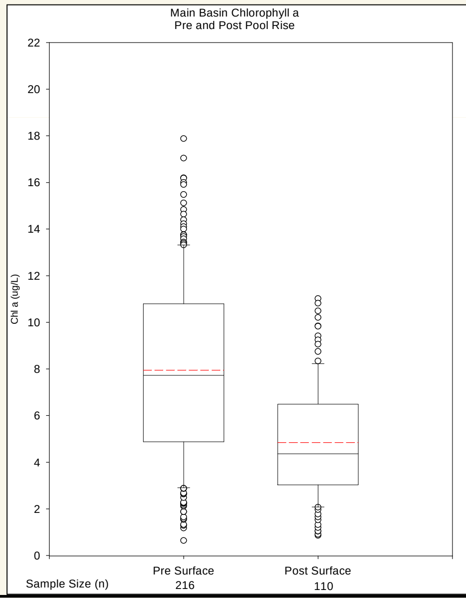
Lake Loading Issues

- Pulsed loads of nutrients, sediment, bacteria and other contaminants with wet weather
- Dairy operations represent a very large P source
- Urban activities have increased and are a significant source of contaminants
- Soils are not conducive to absorbing runoff and associated contaminants
- Travel time to lake during storms can be short
- PL 566 reservoirs provide valuable detention, but not enough and for how long?
- N shortages in Lake Waco favor N-fixing cyanobacteria

Managing Dairy Influence

- Nutrient management plans are to be implemented on all dairy farms
- Approximately half of the collectable manure to be hauled out of the Lake Waco watershed for disposal
- No application of manure to fields with insufficient P binding capacity

Post-manure Management Conditions



- No significant change in dissolved N forms in Lake Waco between pre- and post-management
- Decrease in TKN, TP, OP and Chl a
- Increase in clarity
- Yet changes in nutrients and clarity are not large in a management context

Limits to Benefits of Recent Improvements

- Some changes counter each other
  - Wetter weather and a bigger lake
  - Reduced inputs but faster delivery with storms
- Continued loading from dairy operations
  - It may take years for residual P to be reduced
  - Collectable manure is only 38% of total
  - Funding for manure haul out has now ended
- Some changes seem larger than they may be
  - Manure not necessarily removed from watershed (3rd party applicators)
  - Reductions at WWTFs are minor overall

To Sum Up

- Weather drives lake condition, with the vast majority of inputs during storms
- P loads are high and N:P ratios are low as a function of NBR inputs
- Dairy operations account for over half the available P input and foster low N:P ratio
- As some cyanobacteria can use dissolved, gaseous N, periodic blooms are expected when mixing or flushing is low after pulsed inputs, especially with high temperatures
- Management to date shows some improvement, but more action needed

Speaker Contact Information

Ken Wagner
Water Resource Manager, Water Resource Services LLC
144 Crane Hill Road, Wilbraham, MA 01095
413-219-8071
kjwagner@charter.net

Russ Gibson
Nonpoint Source Program Manager
Ohio EPA
614-644-2020
russ.gibson@epa.gov.state.oh.us

Joe Piotrowski
Senior Advisor
US EPA, Office of Wetlands, Oceans and Watersheds
piotrowski.joe@epa.gov

Next Watershed Academy Webcast:

Mitigating Climate Change with
Water and Energy Efficiency

March 2011
1:00–3:00pm Eastern

www.epa.gov/watershedwebcasts

Participation Certificate

If you would like to obtain participation certificates for multiple attendees, type the link below into your browser:

http://water.epa.gov/learn/training/wacademy/upload/2011_1_26_certificate.pdf

You can type in each of the attendee's names and print the certificates.