Evolution of Phosphorus Criteria for Lakes and Reservoirs

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Acknowledgements

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• Paul Cunningham
• Scott Van Egeren
Phosphorus from many Point and Nonpoint Sources
Recreational Impairments

- Discourage beach use
- Aesthetics of near-shore lake use
- Swimming impairments
Fish and Aquatic Life Impairments

Dissolved Oxygen

![Graph showing dissolved oxygen levels from 8/9 to 8/15 with varying levels of oxygen between 0 to 16.]

![Image of a green algae-covered stream with a wooden railing on the right side.]
Human Health Concerns
Where Algal Toxins Were Found in High Levels

Occurrence of Toxic Blue-Green Algae in Wisconsin Waters
Data are based on a 1986 survey for toxins in 86 lakes (Repavich et al. 1988) and DNR monitoring for Cylindrospermopsis and algal toxins in 2003-2006.

200,000 plus acres of lakes have had at least one toxic algae event.

Among the largest lakes affected:  
Menomin Lake 1405 acres  
Tainter Lake 1752 acres  
Beaver Dam Lake 6542 acres  
Eau Pleine Reservoir 6830 acres  
Lake Wisconsin 9000 acres  
Lake Castle Rock 13955 acres  
Lake Petenwell 23040 acres  
Lake Winnebago 137708 acres

“Phosphorus Rule”

• S. NR 102.06 – phosphorus water quality standards criteria for streams, lakes and Great Lakes

• Ch. NR 151 – additional nonpoint source performance standards and prohibitions - phosphorus index for farm fields

• Subch. III, NR 217 - water quality based effluent limits
Status

• NR 102 and NR 217 changes became effective December 1, 2010

• EPA approved NR 102 changes on December 30, 2010

• NR 151 changes became effective January 1, 2011

• Guidance being developed on a number of topics
Why Develop the Criteria?

• Obvious water quality problems in state caused by excess nutrient loading

• Numeric goals for protecting or restoring Recreational and Fish and Aquatic Life Uses

• EPA requirement
How Are Criteria Used?

- Goal for lake and stream management
- Used as a factor to determine impaired waters (or not impaired)
- Target for TMDLs
- Basis for water quality based effluent limits for point sources
Chapter NR 102 - P Criteria

- Rivers - 100 ug/l
- Streams - 75 ug/l
- Lakes and Reservoirs - 15 - 40 ug/l
- Lake Michigan - 7 ug/l
- Lake Superior - 5 ug/l
- No ephemeral streams, wetlands, LAL waters
Does not apply to:

- Lakes less than 5 acres in size
- Wetlands
- Waters impounded that don’t have sufficient water residence time to be considered as a reservoir (e.g. millpond)
Specific Lake Criteria

- 2-story fishery lakes - 15 ug/l
- Stratified seepage lakes - 20 ug/l
- Stratified drainage lakes - 30 ug/l
- Stratified reservoirs - 30 ug/l
- Non-stratified lakes - 40 ug/l
- Non-stratified reservoirs - 40 ug/l
Definitions

- Seepage vs drainage
- Stratified vs non-stratified
- Two story fishery
- Reservoir vs lake
- Reservoir vs impounded water
LANDSCAPE POSITION

- PRECIPITATION-DOMINATED
- SEEPAGE LAKES (Isolated)
- HEADWATER DRAINAGE LAKES (connected)
- LOWLAND DRAINAGE LAKES (connected)
- GROUNDWATER & SURFACE WATER-DOMINATED

Water Table
- Groundwater Flow
- Surface Water Flow
LAKE DEPTH MATTERS

Deep Lake

Shallow Lake

Temperature

Stratification

Continuous P Recycling
Deep = Stratified/pelagic

Shallow = Mixed/littoral

Defined by lake surface area to maximum depth ratio
# Natural Lake “Communities”

<table>
<thead>
<tr>
<th>Natural Community</th>
<th>Stratification Status</th>
<th>Hydrology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakes less than 10 acres</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>Variable</td>
<td>Any Hydrology</td>
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</table>

<table>
<thead>
<tr>
<th>Lakes 10 acres or greater</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow Seepage</td>
<td>Mixed</td>
<td>Seepage</td>
</tr>
<tr>
<td>Shallow Headwater</td>
<td>Mixed</td>
<td>Headwater Drainage</td>
</tr>
<tr>
<td>Shallow Lowland</td>
<td>Mixed</td>
<td>Lowland Drainage</td>
</tr>
<tr>
<td>Deep Seepage</td>
<td>Stratified</td>
<td>Seepage</td>
</tr>
<tr>
<td>Deep Headwater</td>
<td>Stratified</td>
<td>Headwater Drainage</td>
</tr>
<tr>
<td>Deep Lowland</td>
<td>Stratified</td>
<td>Lowland Drainage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Classifications (any size)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring Ponds</td>
<td>Variable</td>
<td>Spring Hydrology</td>
</tr>
<tr>
<td>Two-Story Lakes</td>
<td>Stratified</td>
<td>Any Hydrology</td>
</tr>
<tr>
<td>Impounded Flowing Waters</td>
<td>Variable</td>
<td>Headwater or Lowland Drainage</td>
</tr>
</tbody>
</table>
Paleolimnology

- Indicator of previous ecological state
- Pre-settlement
- Undeveloped lakes
- Minimally impacted lakes
- Top/bottom (Tier 1) or full core (Tier II)
“Stratified two-story fishery lake” means a stratified lake which has supported a cold water fishery in its lower depths within the last 50 years.

(from Sharma et al. 2011)
Reservoirs vs. Impounded Flowing Waters

- Both are waterbodies created or augmented by a dam, with at least half the depth due to the presence of the dam (otherwise it is a lake)
- Reservoirs have > 14 day residence time, so are subject to lake criteria
- Impounded flowing waters (< 14 day residence time) are subject to river/stream criteria
Basis for Lake Criteria

- Minimize risk of nuisance algal blooms -
  - 5% chance of 20 ug/l chl. a bloom
  - 1% chance of 30 ug/l chl. a bloom

- Prevent shift in shallow lakes from macrophytes to algal domination

- Protect sport fisheries

- Maintain dissolved oxygen in hypolimnion of 2-story lakes

- Protect and provide margin of safety for deep seepage lakes
Preventing nuisance algal blooms

![Graph showing the relationship between mean TP (μg/L) and nuisance algal frequency for Deep Drainage and Deep Seepage.](image-url)
Stable States in Shallow Lakes

Clear State
- clear water
- low algal biomass
- high macrophyte biomass

Turbid State
- murky water
- high algal biomass
- sparse macrophytes
40 ug/L prevents “forward switch” to algal dominance in shallow lakes
Protecting Fish and Aquatic Life

Cool water species

Warm water species

Why are two-story lakes 15 μg/L?

Deep seepage lakes protected

- Long residence time
- Sensitive to P inputs
- Difficult to clean up once polluted
Phosphorus trends using lake bottom sediment core data

Summer Mean Phosphorus

Source: Paul Garrison
Phosphorus Assessment

- Guidance in Wisconsin Consolidated Assessment and Listing Methodology (WisCALM)
- Data may be contributed by the public (period just ended for 2014 cycle).
- Data collected by Citizen Lake Monitors and entered into SWIMS are automatically used in assessments

http://dnr.wi.gov/topic/surfacewater/assessments.html
Data Requirements

• 6 samples collected over a minimum of two years
• June 1 - September 15
• Surface grab or integrated samples from top 2 m
• Chemical analysis by state-certified laboratory
Confidence Intervals

We can be 90% confident that the true mean concentration falls within the confidence interval.
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Confidence Intervals

![Graph showing TP (μg/L) with confidence intervals for 'Clearly Meets', 'May Meet', 'May Exceed', and 'Clearly Exceeds'.]
Site-specific Criteria

- Code “mentions” process for developing site-specific criterion
  - Must have scientific rationale
  - Must be adopted on a case-by-case basis by administrative rule
  - Must be approved by EPA

- Could be more or less restrictive than “default” criteria

- Chlorophyll a concentrations can be used as “biological confirmation” of a phosphorus impairment.
Site-specific Criteria Examples

- Preventing phosphorus increases in oligotrophic lakes
- Naturally high phosphorus concentrations in some lakes
- Short residence time in some reservoirs may allow for higher criteria
Site Specific Criteria

![Graph showing the relationship between Total Phosphorus (μg/L) and Chlorophyll a (μg/L) with data points classified as Stratified, Mixed (WRT > 120 days), and Mixed (WRT < 120 days).]
Site-Specific Criteria

![Graph showing the relationship between nuisance algal frequency and mean TP (µg/L) for Deep Drainage and Deep Seepage.](image-url)
Site-Specific Criteria

Nuisance algal frequency vs. Mean TP (μg/L)
Adaptive Management

Why do it?

• Phosphorus standards require reductions in P loading from permitted facilities.
• In some cases, it may be less expensive to reduce nonpoint sources of P than to upgrade wastewater treatment systems.

http://dnr.wi.gov/topic/surfacewater/adaptivemanagement.html
Which facilities are eligible?

- The receiving water is exceeding the applicable P criteria.
- Filtration or equivalent technology would be required to meet the proposed phosphorus limit.
- Nonpoint sources contribute at least 50% of the total phosphorus entering the receiving water.

http://dnr.wi.gov/topic/surfacewater/adaptivemanagement.html
Roles of citizens

- Monitor phosphorus concentrations to document water quality problems.
- Encourage your water utility board to consider the option.
- Monitor phosphorus concentrations to document water quality improvements.

Feature Name: Lake Geneva
WBIC: 758300
TP Criterion: 20 ug/L
Surface Area: 5401 acres
Watershed Area: 73.87 sq km
Water Residence Time: 23 yr
Agriculture: 23%  
Click here for more information.
Thank You!
What about these?

TP:CHL a relationships in WI lakes

Are these lakes impaired?

Source: Matt Diebel, WDNR
What about these?

Are these lakes impaired?

Data from Matt Diebel
## FAL and Recreation Thresholds

<table>
<thead>
<tr>
<th></th>
<th>Shallow</th>
<th>Deep</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Headwater Drainage</td>
<td>Lowland Drainage</td>
</tr>
<tr>
<td><strong>TOTAL PHOSPHORUS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REC</td>
<td>≥ 40 ug/l</td>
<td>≥ 40 ug/l</td>
</tr>
<tr>
<td>FAL</td>
<td>≥ 100 ug/l</td>
<td>≥ 100 ug/l</td>
</tr>
<tr>
<td><strong>CHLOROPHYLL A</strong></td>
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<td></td>
</tr>
<tr>
<td>REC*</td>
<td>≥ 25 ug/l</td>
<td>≥ 25 ug/l</td>
</tr>
<tr>
<td>FAL</td>
<td>≥ 60 ug/l</td>
<td>≥ 60 ug/l</td>
</tr>
</tbody>
</table>

*Chl a Recreation Thresholds should only be used as loose guidance.
What data do we use to determine whether TP criteria are exceeded?

<table>
<thead>
<tr>
<th>Minimum data requirements</th>
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<tbody>
<tr>
<td><strong>Years</strong></td>
</tr>
<tr>
<td><strong>Stations</strong></td>
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<tr>
<td><strong>Season</strong></td>
</tr>
<tr>
<td><strong>Timing</strong></td>
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<tr>
<td><strong>Frequency</strong></td>
</tr>
<tr>
<td><strong>Exceedance Flag</strong></td>
</tr>
</tbody>
</table>
Phosphorus Assessment Method for Lakes and Reservoirs

• Current Method (2012 WisCALM)
  – TP criteria in Sec. NR 102.06(4) Wis. Adm. Code
  – Five year assessment period (Jun 1- Sep 15)
  – Minimum of 3 samples in each of two years
  – Deep Hole station, or representative site (multiple stations can be averaged)
  – Two annual average values must exceed
  – Biological impairment must be observed to list as an impaired water
Ecoregions

Total Phosphorus (µg/L)

Chlorophyll a (µg/L)

N Lakes & Forests
N Central Hardwood Forests
SE Wisc Till Plains
Driftless Area

N = 602
2012 Impaired Waters List
Addressing the Cause – Reducing Nutrients in the Watershed

- Impaired waters 303 (d)
- TMDLs
- Point and non-point source reduction
- Grants

The WDNR is actively developing several large-scale basin-wide TMDLs – many of these are in basins with chronic severe algal blooms and measured toxins
Proposed 2012 List Updates

• **32 new water listings**
  – 20 streams and lakes (total phosphorus)
  – 6 lakes (mercury in fish tissue)
  – 5 beaches (E. coli)
  – 1 stream (copper and zinc)

• **25 water delistings**
  – 21 beaches (E. coli)
  – 3 streams (degraded habitat)
  – 1 lake (aquatic toxicity)
Top Five Pollutants on 2012 Impaired Waters List

- Mercury: 26%
- Sediment: 25%
- TP: 21%
- PCB: 11%
- Other: 11%
- Bacteria: 6%