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Stormwater Design for Urban Lakes

Presented at:
Stormwater Design to Protection Watersheds
Coeur d'Alene, Idaho
March 6, 2002
Presented by:

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Stormwater Design for Urban Lakes

In this presentation…

- Impact of land development on lakes
- Phosphorus loading in urban lakes
- Crafting a lake protection ordinance
- 8 tools of watershed protection for lakes

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Impacts of Land Development on Lakes

- Decrease in population and diversity of shoreline vegetation and wildlife.
- Decrease in littoral zone species richness and abundance.
- Increased eutrophication.
- Introduction of invasive species.
- Increased sediment from shoreline erosion.
- Increase in pollutants that threaten drinking water.
- Impacts to lake residents and users.

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Source: University of Wisconsin

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Eutrophication

- Cultural eutrophication is the premature change in trophic state, or productivity level, of a lake due to input of excess nutrients from human activities
- Excess phosphorus loading is most often the reason for eutrophication because lake productivity is limited by the amount of phosphorus present
- Half of all lakes in the U.S. are eutrophic or hyper-eutrophic (NALMS, 2001)
- A eutrophic lake has excess nutrients, high chlorophyll a, algal blooms, low dissolved oxygen and low secchi depth

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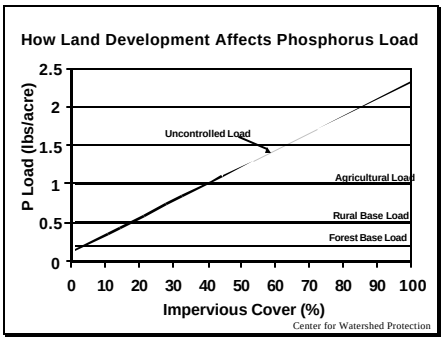

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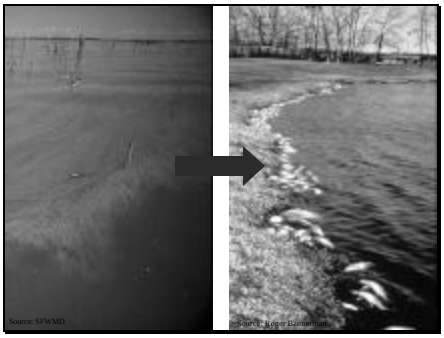

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Impacts of Eutrophication on Lake and Reservoir Quality

- Nuisance algal blooms
- Reduced dissolved oxygen in lake bottom
- Fish kills due to low dissolved oxygen
- Taste and odor problems with drinking water
- Formation of disinfection byproducts in water supplies
- Increased drinking water costs

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Impacts of Eutrophication on Lake and Reservoir Quality (continued)

- Reduced water clarity
- Decline in fish community
- Blockage of intake screens by algal mats
- Reduced quality of recreational experience
- Decline in lakefront property values
- Floating algal mats/decaying algal clumps
- Increased density of aquatic weeds in shallow areas

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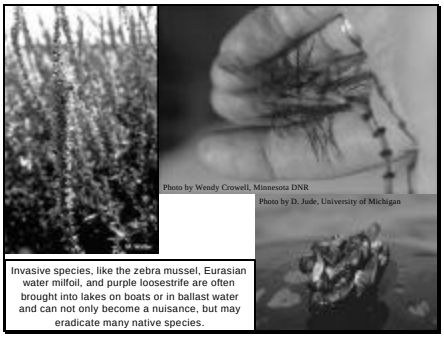

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Sources of Turbidity in Urban Watersheds

Source	Turbidity Level (NTU)
Stormwater Runoff	100 to 200
Construction Sites	400 to 500
Construction Sites with ESC	200 to 300
Channel Enlargement	200 to 1000
Drinking Water Standard	**1**

Source: Kitchell, 2001 Center for Watershed Protection

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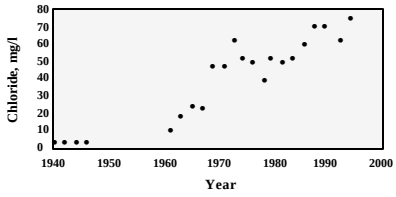
Average Annual Chloride Levels in Lake Wingra: 1940-1995



Source: Roger Bannerman

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Impacts of Development on Lake Residents and Users

- Decrease in lakefront property values
- Shoreline erosion
- Decreased quality of recreational experience
- Noise from boating

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Urban Lake Nuisances

- Trash
- Overgrowth of weeds
- Harmful algae
- Bacteria
  - Swimming beaches and recreational contact impaired in many urban watersheds
  - Stormwater concentrations exceed standards by factor of 20 to 50

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Phosphorus Loading in Urban Lakes

- Sources of Phosphorus
  - Primary Sources
  - Secondary Sources
  - Internal Sources
- Phosphorus Budget

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Primary Sources of Phosphorus

- Residential land
- Commercial land
- Roadways
- Industrial land
- Rural land
- Forest land
- Agricultural land

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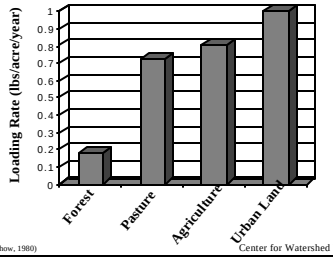
Phosphorus Loads from Various Land Uses



Source: Reckhow, 1980)

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Phosphorus Loads Associated With Different Urban Land Uses

Land Use Category	% Impervious Cover	P Load (lbs/acre/year)
Open urban land	8.6%	0.31
2 acre lots	10.6%	0.36
1 acre lots	14.3%	0.44
½ acre lots	21.2%	0.59
¼ acre lots	27.8%	0.74
1/8 acre lots	32.6%	0.84
Townhomes	40.9%	1.03
Multifamily	44.4%	1.10
Institutional	34.4%	0.88
Light industrial	53.4%	1.30
Commercial	72.2%	1.72

For 40 inches of rainfall/year, impervious data from Cappiella and Brown, 2001, assumed total P concentration of 0.3 mg/L (Source: Caraco, 2000)

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Secondary Sources of Phosphorus

- Wastewater discharges
- Combined sewer overflows
- Sanitary sewer overflows
- Illicit connections
- Septic systems
- Hobby Farms/livestock
- Marinas
- Road sanding
- Concentrated Animal Feeding Operations (CAFOs)
- Managed turf

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Internal Sources

- Boat sewage (10 mg/l)
- Sediment release (up to 50 lbs/lake acre/year)
- Waterfowl (25 to 34% of total P budget)
- Open water
- Atmospheric deposition (0.5 lbs/lake acre/year)

Source: Caraco and Brown, 2001

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Source: Lake Access

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Source: State of Connecticut Municipal Public Access Initiative

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Phosphorus Budget

- A phosphorus budget is an assessment of the amount of phosphorus entering, leaving and residing in a lake ecosystem.
- Primary sources of phosphorus to a lake can be estimated using export coefficients for different land uses
- Secondary and internal sources can be estimated using various assumptions and equations (Caraco, 2001)
- Can be used to predict future loads and load reductions

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Crafting a Lake Protection Ordinance

- Why lakefront development is unique
- The four zones of lake protection
- Incentives and flexibility

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Why Lakefront Development Is Unique

Source: University of Wisconsin

- The ring around the lake
- Incremental development over time
- Water views and lake access
- Accessory structures
- Waterfront premium
- Density in otherwise rural areas
- Seasonal use/second homes

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Source: the Brostad home website

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The Four Zones of Lake Protection

a. Shoreline
b. Shoreline buffer
c. Shoreland protection area
d. Contributing watershed

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The Four Zones of Lake Protection

- The four zone approach to lake protection is most restrictive at the shoreline, and is more flexible as one progresses further up the watershed
- The key criteria should be adapted to account for lake size, uses, water supply, trophic state, and existing development

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Zone 1: Shoreline

- Point where high water mark meets the land
- Littoral area is important habitat and vulnerable to alteration
- No disturbance of natural state without permit

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Shoreline: Permits

- Require a permit for any alteration or clearing along shoreline
- Avoid bulkheads, riprap and retaining walls, unless imminently needed for bank erosion protection
- Promote bio-engineering as an alternative
- Expansion of pre-existing structures

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Shoreline: Use Restrictions

- One stairway for water access
- One pier or dock per frontage lot
- Limits on area and extension into lake
- Boathouse setbacks
- No tree clearing
- No stormwater outfalls

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Source: Rob Mitchell

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Source: Lake RipRap

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Shoreline: Regulating Lake Uses

- Designate recreational use areas in lake
- Limit boat speeds to reduce wakes
- Prohibit motorized boats to reduce noise and avoid pollution potential (hydrocarbons)
- Role of lake association in arranging covenants for existing property

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Zone 2: Shoreline Buffer

- Extends landward from high water mark (75 to 300 feet)
- Expanded to include steep slopes, wetlands, and sensitive areas
- Vegetative target is mature forest or native vegetation

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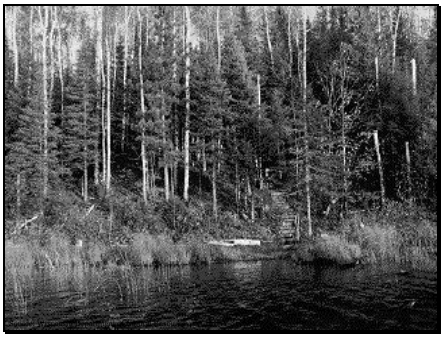

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Shoreline Buffer: Width

- Recommended minimum base width is 75 feet.
- Expand width to 150 feet for pristine or lightly developed lakes.
- Expand width up to 300 feet if lake is a drinking water supply.
- Measured from "full pond" for reservoirs.

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Shoreline Buffer: The View Corridor

- One corridor per lot.
- No more than 25% of frontage.
- No opening more than 250 square feet in canopy.
- Permit for thinning or pruning.
- No clearing, but a winding trail is okay.

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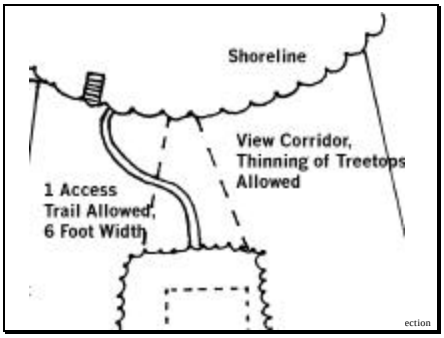

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Shoreline Buffer:
Stormwater Strategy

- No stormwater practices located within the buffer.
- No new pipes or channels can convey stormwater across buffer.
- Outer boundary of buffer graded to accept sheetflow.

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Shoreline Buffer:
Allowable Uses

- Shoreline access path.
- Limited view corridors.
- Boathouses (25' ft setback).
- Existing structures.
- Public boat ramps and beaches.

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Shoreline Buffer:
Restricted Uses

- Septic systems.
- Paved surfaces or primary structures.
- Mowing or clearing.
- Grading or soil disturbance.
- Motorized vehicles.
- Pesticide or fertilizer application.
- Livestock or grazing.

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Shoreline Buffer: Vegetation

- Vegetative target: mature forest or native vegetation.
- Restrict clearing to the minimum amount for access.
- Encourage planting with native vegetation or trees.
- Provide specific guidelines for tree thinning.

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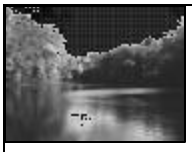

Benefits of Shoreline Vegetation

- Provides habitat for wildlife and fish
- Reduces erosion
- Reduces runoff and pollutant loads
- Increases aesthetic value
- Increases property values
- Provides shade, leaf litter, woody debris in littoral zone

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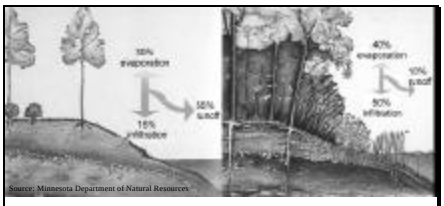

Source: Minnesota Department of Natural Resources

Water quickly runs off a shoreline cleared of natural vegetation, washing nutrients and pesticides into the water. A natural shoreline holds rainfall, which soaks into the soil; less water, soil and chemicals run into the lake or river. Shoreline and aquatic plants anchor shoreline areas, helping to protect them from erosion due to runoff and waves (Source: MN DNR).

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Key Features of Buffer Management

- Mark buffer boundaries.
- Educate land owners and contractors.
- Ensure that new owners are fully informed about uses/limits when property is sold.
- Key role of lake associations in education and enforcement.
- Integrate with other lake education efforts.

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Zone 3: Shoreland Protection Area

- Special overlay zone for residential development
- Extends 250 to 1000 feet from high water mark
- Regulates development within at least two lot lengths from the lake
- Includes shoreline buffer

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Shoreland Protection Area: Non-Conforming Uses

- Livestock operations.
- Facilities that handle hazmats.
- Landfills/junkyards.
- Industrial or commercial zones.
- Above and below ground storage tanks.
- Stormwater hotspots and golf courses.
- Non-residential roads.

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Shoreland Protection Area: Stormwater and Septic Systems

- Structural practices often not feasible in the shoreland protection area
- Use of Better Site Design on lot development as substitute
- Septic systems may be setback beyond the shoreline buffer

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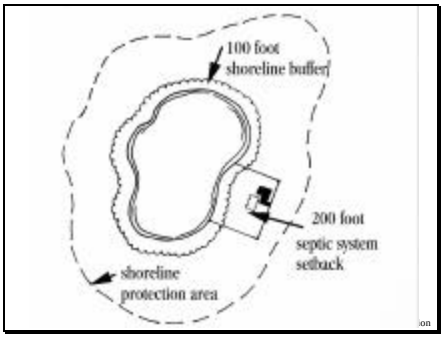

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Better Site Design for Lakefront Lots

- Minimum lot sizes
- Minimum shoreline frontages
- Maximum impervious cover limit of 10%
- Site fingerprinting
- Grading limits
- Rooftop disconnection
- Limits on keyhole or backlot development
- Use of natural conveyance methods
- Permeable pavement
- Tree conservation

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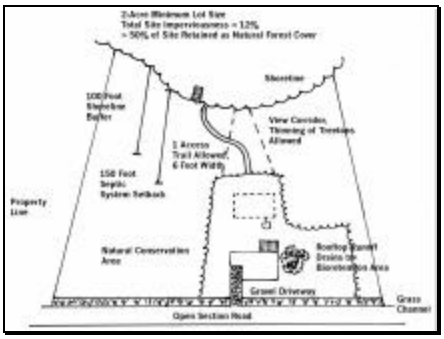

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Keyhole or Backlot Development

- Allows off-water lots to share a narrow strip of waterfront land that provides access to the water.
- May result in over-development of the lakeshore
- Zoning techniques to prevent over-development:
  - Prohibit the development of shore lots with more than 1 owner
  - Establish limits on the number of off-water lots served by one access lot
  - Set minimum lot sizes for off-water lots by extending the width of the shoreland protection area further from the lake

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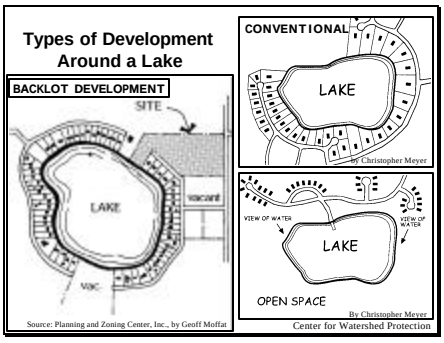

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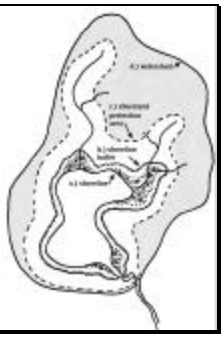
Zone 4: The Contributing Watershed

8 Tools of Watershed Protection:

- Watershed zoning and planning
- Land conservation
- Aquatic buffers
- Better Site Design
- Erosion and sediment control
- Stormwater treatment practices
- Non-stormwater discharges
- Watershed stewardship



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A Lake Watershed

A lake watershed consists of the lake and all of the surrounding land which drains toward the lake.

Source: Northeastern Illinois Planning Commission

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Incentives and Flexibility

- By-right open space development
- Density compensation
- Stormwater credits
- Buffer averaging
- Property tax credit
- Density bonus
- Transferable development rights
- Off-site mitigation

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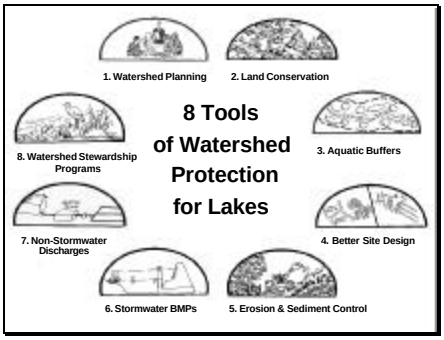

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Tool 1: Watershed Planning

- Develop current and future phosphorus budgets and set goals for trophic state
- Evaluate effect of stormwater treatment practices
- Assess current and future impervious cover
- Land use planning options
  - Large lot zoning
  - Land use exclusion
  - No extension of sewer

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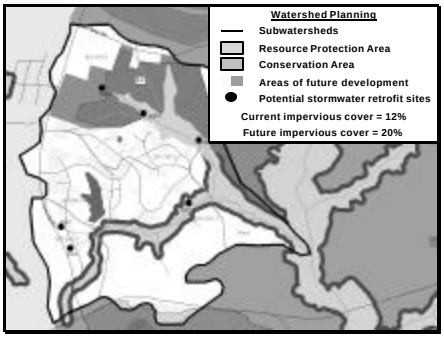

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Tool 2: Land Conservation

- Land acquisition and easements
- Key areas:
  - Shoreline
  - Shoreline buffer
  - Tributary streams
  - Wetlands
  - Public access areas
  - Forest

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Tool 3: Aquatic Buffers

- Useful for all contributing streams in the lake watershed
- Improves subsurface phosphorus removal
- Design is different than for shorelines
- Distance to intake may be a factor
- See model ordinance at:
  www. stormwatercenter.net

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Tool 4: Better Site Design

- Better Site Design does not have to be applied only at the individual lot level
  - Street design
  - Cluster development
- Using Better Site Design and stormwater treatment practices, phosphorus loads from primary sources can be reduced by 44 to 58% (Caraco, 2001)

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Tool 5: Erosion and Sediment Control

- Construction sites are a major source of sediment to surface waters
- Erosion and sediment control practices can reduce the amount of sediment leaving the site in stormwater runoff
- Regulation of practices is important

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Tool 6: Stormwater Management Practices

- Choose and design practices to maximize phosphorus (P) removal.
- Establish explicit P removal goals.
- Compute pre and post development P loads.
- Developer pays with a watershed offset or fee if goal is not met.

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Typical STP Phosphorus Removal Efficiencies

Practice Group	Total P (%)	Soluble P (%)
Dry Ponds	19	-6
Wet Ponds	51	66
Wetlands	49	35
Infiltration*	70	85
Filtering Systems	59	3
Water Quality Swales	34	38

Source: Winer, 2000

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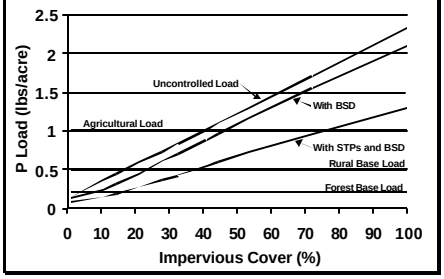
The Best We Can Do



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Tool 7: Non-Stormwater Discharges

Three options for wastewater treatment:

- Reliance on septic systems
- Limited sewer relief
- Reliance on sewer
  - Pump out from watershed
  - High phosphorus treatment at wastewater treatment plant in watershed

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Septic System Criteria for Lake Watersheds

- Designate areas of concern in the watershed
- Setbacks of at least 150 feet
- Separation distances
- Reserve fields
- Alternative technology
- Innovative technology
- Creation of septic management districts or enforceable maintenance agreements
- Minimum lot size
- Inspections and certification
- Allow shared systems

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Phosphorus Concentrations in Wastewater

Pollutant Source	Total P Concentration
Untreated wastewater	20 to 25 mg/l
Septic tank effluent	13 to 15 mg/l
Septic plumes	1 to 5 mg/l
Hydraulic failure	5 mg/l ?
Subsurface failure	1 mg/l ?
Treatment failure	0 mg/l ?

Source: Swann, 2001

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Source: Houston/Galveston Area Council

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Tool 8: Watershed Stewardship

- Education and outreach
- Enforcement
- Role of lake association
- Lake restoration techniques

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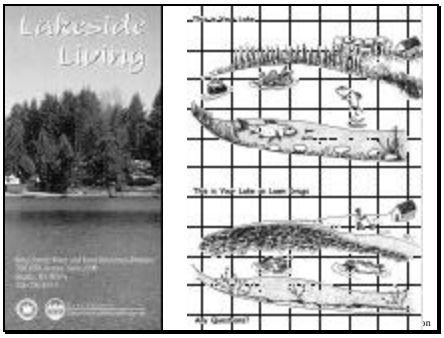

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In-Lake Restoration Techniques

Lake restoration should be based on a long-term comprehensive management plan that reduces pollutant source reduction. When necessary, in-lake restoration techniques can be used:

- Aquatic plant harvesting
- Dredging
- Aeration of hypolimnion
- Alum treatment
- Sediment covers
- Water level drawdown
- Hypolimnetic withdrawal
- Biological controls

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Lake Resources

- North American Lake Management Society: http://www.nalms.org
- American Society of Limnology and Oceanography: http://www.aslo.org
- EPA Clean Lakes Program: http://www.epa.gov/OWOW/LAKES
- Northern Temperate Lakes Long-Term Ecological Research: http://limnosun.limnology.wisc.edu
- University of Minnesota Limnological Research Center: http://lrc.geo.umn.edu
- University of Wisconsin Center for Limnology: http://limnology.wisc.edu
- Adirondack Aquatic Institute: http://www.paulsmiths.edu/aai
- LakeAccess: http://lakeaccess.org
- Wisconsin Lakes Partnership: http://www.uwsp.edu/cnr/uwexlakes

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Glossary

Algal bloom: Excessive growth of algae in a water body due to increased input of nutrients during warm summer months when productivity is high

Better Site Design: A series of model development principles that reduce impervious cover, conserve natural areas, and prevent stormwater pollution from new development

Chlorophyll a: A type of chlorophyll present in all types of algae, sometimes in direct proportion to the biomass of algae

Disinfection by-products: Possible carcinogens that form in water with high concentrations of organic matter when chlorine or bromine is used to treat the water

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Glossary

Eutrophication: The process of physical, chemical, and biological changes associated with nutrient enrichment of a water body. If the process is accelerated by man-made influences, it is termed cultural eutrophication

Export coefficient: A pollutant loading rate typically associated with a particular land use

Impervious cover: Surfaces such as roads, driveways, sidewalks, parking lots, and rooftops that do not allow for infiltration of stormwater runoff.

Invasive species: Non-native plant or animal species that outcompete native species

Littoral zone: The relatively shallow areas around a lake's shoreline

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Glossary

Phosphorus loading: The amount of phosphorus input to a water body

Productivity: The mass of new organic material formed over a period of time, plus any losses during that period. A lake's productivity is then the rate of production divided by a period of time

Secchi depth: A measure of transparency of water obtained by lowering an 8-inch diameter disk (Secchi disk) into water until it is no longer visible

Stormwater hotspots: Land uses or activity that generate highly contaminated runoff

Trophic state: The degree of productivity of a lake. Transparency, chlorophyll a levels, phosphorus concentrations, macrophytes and dissolved oxygen can be used to assess state

Turbidity: Degree to which light is blocked because water is cloudy or muddy

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