

PHOSPHORUS IN LAWNS, LANDSCAPES, AND LAKES



An Informative Guide on Phosphorus
August 1, 2004

Phosphorus in Lawns, Landscapes and Lakes

Most professionals working in the lawn and landscape industry are aware of the essential role phosphorus plays as a plant nutrient. An increasing number of professionals are also aware of the detrimental impact that phosphorus can have on lakes and rivers. Increased amounts of phosphorus entering surface waters can simulate excessive algae growth, which brings with it such associated water quality problems as decreased water clarity, disagreeable odor, habitat loss, and fish kills.

Through educational outreach and the recent Minnesota phosphorus lawn fertilizer law, the general public has become aware of the impact of phosphorus on water resources, and frequently come to professionals with questions on lawn fertilization and yard care management.

The purpose of *Phosphorus in Lawns, Landscapes and Lakes*, is to provide lawn and landscape professionals with a better understanding of phosphorus as a needed plant nutrient and potential water pollutant. It is hoped that this guide will provide a better understanding of issues surrounding the nutrient phosphorus, and assist in making informed decisions on phosphorus management.

Contributing Authors:

Minnesota Department of Agriculture

Jerry Spetzman

Minnesota Office of Environmental Assistance

Ginny Black

Colleen Hetzel

Kevin McDonald

Minnesota Pollution Control Agency

Steve Heiskary

University of Minnesota Extension Service

Brian Horgan

Bob Mugaas

Carl Rosen

Ron Struss

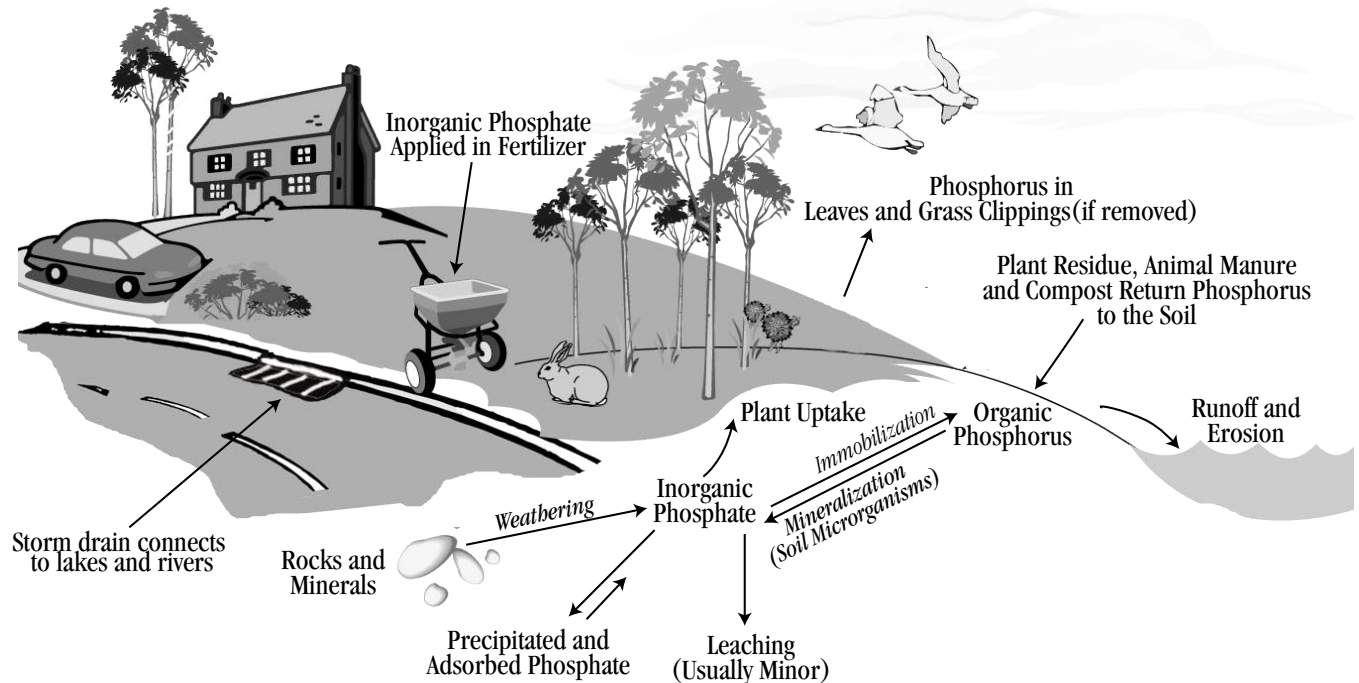
BACKGROUND

Phosphorus (P) as a natural element

- Although phosphorus is widely distributed, (existing in soils and minerals, living organisms, wind-blown dust and water), it is not found in its elemental form in nature. Rather, elemental P, which is extremely reactive, readily forms compounds with oxygen, aluminum, and calcium.
- In natural systems like soil and water, P exists as **phosphate**, a chemical form in which each P atom is surrounded by 4 oxygen (O) atoms. **Orthophosphate**, the simplest phosphate, has the chemical formula PO_4^{-3} .
- Nearly all of the phosphorus absorbed by plants is taken up as two ions, molecules with either a positive (+) or negative (-) charge. The HPO_4^{-2} ion dominates in calcareous soils and is the form of phosphorus absorbed when plants are grown on these soils. The $\text{H}_2\text{PO}_4^{-1}$ ion dominates in acid soils and is the ion absorbed when the soil pH is less than 7.0. Since these compounds are not combined with the element carbon they are known as **inorganic** phosphate forms.
- When P is found in combination with carbon it is said to be in the **organic** form. P is not absorbed by the plant in an organic form so organic matter must be broken down to release P anions for uptake by plants. Some organic forms are usually quite water soluble and can be easily carried in runoff.

Phosphorus as a plant nutrient

- Phosphorus, along with nitrogen (N) and potassium (K) are the three major plant nutrients taken up by plant roots from the soil.
- While phosphorus is needed by plants in smaller quantities than nitrogen and potassium, it is vitally important to the plant's energy and reproductive systems.
- Soil phosphorus is essential for the successful early establishment of vegetables, flowers and lawn grasses. For that reason, "starter" fertilizers, relatively high in phosphorus, are often used to ensure adequate phosphorus levels at the time of planting.
- Once plants become established and there exists sufficient soil phosphorus reserves to sustain healthy growth, additional phosphorus fertilization is usually unnecessary.
- In most outdoor garden and landscape plantings, phosphorus deficiency is rarely encountered. However, some indicators that your plants may need additional phosphorus include slow growth, undersized foliage, flowers and fruit, and poor flower and fruit development. In lawn grasses, some of the grass blades may exhibit a purpling of the foliage. This symptom is also typical for phosphorus deficiency in corn. Since other growing conditions can cause similar symptoms, it is always best to have your soil tested before applying additional phosphorus fertilizer.



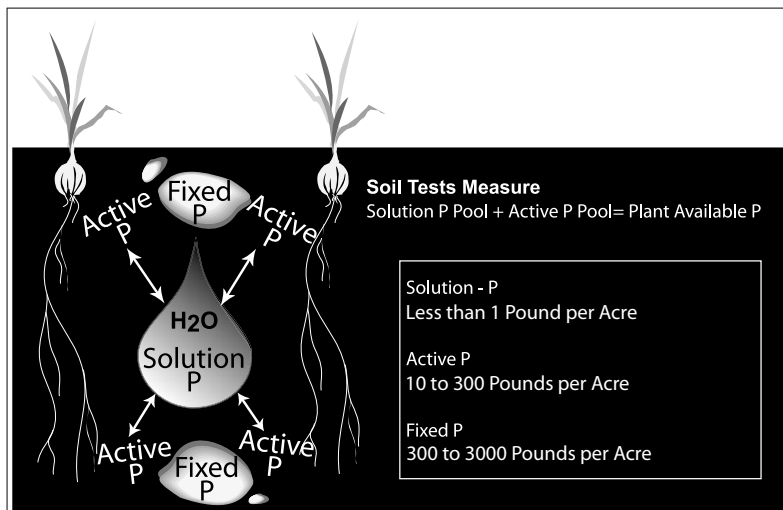
The phosphorus cycle

- The phosphorus cycle is complex in nature. The diagram above shows some of the key components.
- Plants take up inorganic phosphate from the soil. Birds and other animals may then eat the plants.
- When plant residues, animal droppings/manure, or compost are returned or applied to the soil, organic phosphate will slowly be released as inorganic phosphate or be incorporated into more stable organic materials and become part of soil organic matter.
- The release of inorganic phosphate is called **mineralization** and is controlled by soil microorganisms breaking down organic compounds. The process is most rapid when soils are warm and moist but well drained.
- Incorporation of phosphate into more stable soil organic matter is called **immobilization** and is also controlled by microorganisms.
- Phosphate can interact with soil particles and become **adsorbed** (held) onto mineral surfaces, clays, iron and aluminum oxides, and calcium carbonate. Phosphate can also be **precipitated**, forming relatively insoluble iron, aluminum, and calcium phosphates. Adsorbed and precipitated phosphate can be slowly released through desorption and dissolution processes.
- Soluble phosphate can move downward through the soil in a process called **leaching**. But, because of adsorption and precipitation processes, leaching losses are considered to be of minor importance in most soils.
- Sources of inorganic phosphorus include rocks and minerals. Phosphorus is released through a slow process called **weathering**.
- Fertilizers containing phosphorus applied to the soil are a source of phosphorus for plant growth.
- Lawn clippings contain about 0.13 pounds of phosphorus (0.3 lbs P_2O_5) per 1000 feet² during the growing season.
- If clippings or tree leaves are removed from the site, this will also remove phosphorus from the system and soil phosphorus will eventually be depleted.
- Recycling clippings will help to maintain soil phosphorus levels.
- the soil.
- Cement and asphalt surfaces reduce the area for soil infiltration and can enhance loading of sediment and phosphorus from decaying organic material or misapplied fertilizers into lakes, rivers, and streams.

PHOSPHORUS IN SOILS AND FERTILIZER

Phosphorus in the soil

- Even though many different forms of phosphorus exist in the soil, in practical terms, phosphorus can be thought of existing in three “pools”: **solution P**, **active P** and **fixed P**.
- While the **solution P** pool is very small (less than one pound per acre) it is important because it is the pool from which plants take up phosphorus and is the only pool that has any measurable mobility. The solution P pool consists of orthophosphate (plant available phosphorus) and some organic phosphorus (plant unavailable phosphorus, at least initially).
- The **active P** pool is P in the solid phase attached to soil particles and is relatively easily released to the soil solution, that is, the water surrounding soil particles. As plants take up phosphate, the concentration of phosphate in solution is decreased and some phosphate from the active P pool is released to the solution pool. Thus, the main source of **plant available P** for plants is derived from the active P pool. The ability of the active P pool to replenish the soil solution P pool in a soil is what makes a soil **fertile** with respect to phosphate.
- Most of the phosphorus taken up by plants during a growing season will have moved an inch or less through the soil to the roots. As actively growing plants deplete the solution P pool the pool is replenished by phosphorus moving out of the active P pool.
- As plant roots grow they are exposed to higher reserves of phosphorus in the soil. In addition, plants have developed mechanisms to increase root surface area to explore greater volumes of soil and access larger reserves of soil P.
- The **fixed P** pool contains inorganic phosphate compounds that are very insoluble and organic compounds that are resistant to mineralization by soil microorganisms. Fixed phosphate may remain in soils for years without being available to plants and may have very little impact on soil fertility.
- The amount of P in the solution P pool is generally less than 1 pound per acre.
- The amount of P in the active P pool is generally between 10 and 300 pounds per acre.
- The amount of P in the fixed P pool can range from 300 to 3000 pounds per acre.
- Soil tests measure the amount of solution P plus active P. This represents the amount of P available to plants.



Measuring soil phosphorus levels

- Determining the amount of phosphorus available for plant growth is accomplished by having soil tested. In the laboratory, soil samples are subjected to various methods that extract phosphorus from the sample. The amount extracted over a specified length of time is considered plant available phosphorus and includes both the soluble and active pools of P.
- The University of Minnesota soil testing lab measures what research has determined to be plant available phosphorus and not the total amount of phosphorus present in the soil. These results provide the basis for recommending or not recommending additional phosphorus containing fertilizer.
- Soil test results are reported in parts per million (ppm) along with the extraction method that was used to make that determination. For soils with a pH of 7.4 or less, the Bray extraction method is used. For soils with a pH of higher than 7.4, the Olsen extraction method is used. When soil samples are analyzed by both methods, research indicates that fertilizer recommendations should be based on the higher value.

- The University of Minnesota recommends phosphorus be applied to an **established lawn or turfgrass area** as follows:

PHOSPHORUS LEVEL MEASURED by SOIL TEST		AMOUNT of PHOSPHATE (P ₂ O ₅) RECOMMENDED to APPLY
parts per million (ppm)		pounds phosphate
Bray-P1	Olsen-P	per 1000 square feet
0 – 10	0 – 7	1
11 – 25	8 – 18	0.5
over 25	over 18	0

- The University of Minnesota recommends phosphorus be applied to a **new lawn or turfgrass area** before seeding or sodding as follows:

PHOSPHORUS SOIL TEST LEVEL		AMOUNT of PHOSPHATE (P ₂ O ₅) to APPLY
parts per million (ppm)		pounds phosphate
Bray-P1	Olsen-P	per 1000 square feet
0 – 10	0 – 7	5
11 – 25	8 – 18	2
over 25	over 18	1

- The University of Minnesota recommends phosphorus be applied to **vegetable and flower gardens** as follows:

PHOSPHORUS SOIL TEST LEVEL		AMOUNT of PHOSPHATE (P ₂ O ₅) to APPLY	
parts per million (ppm)		pounds phosphate	
Bray-P1	Olsen-P	per 100 square feet	per 1000 square feet
0 – 5	0 – 3	0.4	4
6 – 10	4 – 7	0.3	3
11 – 15	8 – 11	0.2	2
16 – 25	12 – 18	0.1	1
over 25	over 18	0.0	0

Phosphorus in fertilizer

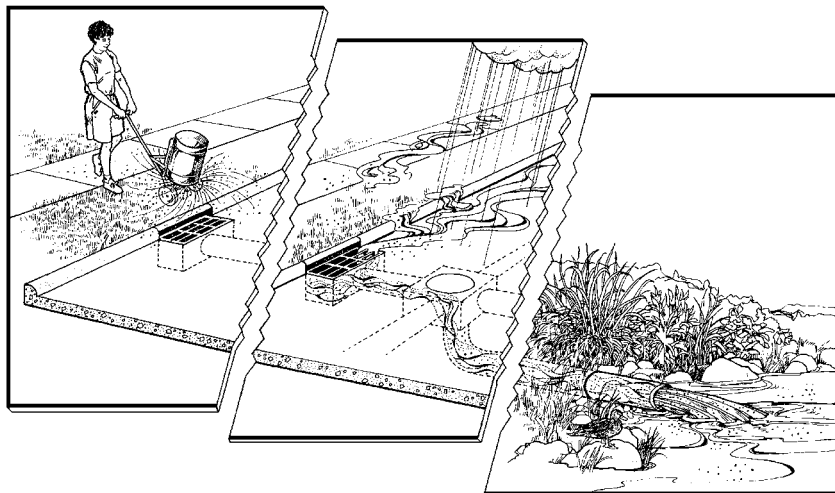
- The word phosphorus or P refers to the element but is also used as a general term when a particular chemical form of P is not being designated. For example, the total P content of a soil or plant material is usually expressed as percent P.
- Fertilizer phosphorus can be derived from natural organic sources such as animal manures, composts or other animal by-products or manufactured through a process that begins with reacting mined rock phosphate with phosphoric acid or heat. Fertilizers that derive their phosphorus from natural sources are often termed **organic** sources while those manufactured from rock phosphate are known as **inorganic** sources. Rock phosphate itself is an inorganic compound. However, it is sometimes referred to as a **natural** form of phosphate since it is a naturally occurring source.
- Seventy-five percent of the rock phosphate used in the United States is surface mined in Florida.
- In the case of fertilizers, the term **organic** usually refers to those plant nutrients chemically bonded together with the element carbon. These organic compounds usually require microbial action in the soil to release their nutrients for the plant to use. On the other hand most manufactured, inorganic sources of nutrients are available immediately for the plant to take-up and use upon being watered into the soil.
- The phosphorus (P) content of fertilizer is measured as phosphate (P_2O_5). The phosphorus content of phosphate is 43%. By law, phosphate content of fertilizer is always the second number on fertilizer bags. The first number is nitrogen and the third number is potash (K_2O).
- Since lawn fertilizer application rates are based on the amount of nitrogen applied per 1000 square feet, a fertilizer with a high nitrogen content (e.g. 25-3-10) will cover more area than one with a low nitrogen content (e.g., 5-3-1) applied at the same rate. However, since the phosphate content is the same in both of these fertilizer examples, five times more phosphate would be applied with the lower nitrogen fertilizer than the high nitrogen fertilizer assuming 1 pound of actual nitrogen was applied per 1000 square feet of lawn area, a typically recommended rate.

	25-3-10	5-3-1
Area	5000 square feet	5000 square feet
Rate	1 pound N per 1000 square feet	1 pound N per 1000 square feet
Pounds fertilizer	20 pounds	100 pounds
Pounds N	5 pounds	5 pounds
Pounds P_2O_5	0.6 pounds	3 pounds
Pounds K_2O	2 pounds	1 pound

WATERSHEDS AND URBAN RUNOFF

What is a watershed?

- A watershed is the surrounding land area that drains into a lake, stream, or river. It includes natural and artificial drainage systems, such as ditches and storm sewers. Even if a home is not next to a lake, stream, or river, it is still in a watershed. Every waterbody has a watershed that surrounds it. Everyone lives in a watershed and shares in the responsibility of protecting water quality.
- If we pollute the watershed surrounding a lake, stream, or river, we are directly affecting the water quality in that lake, stream, or river. Everything we do in a watershed, from caring for our lawns and gardens to picking up our leaves, affects the local water body. Caring for our watersheds is caring for our local lake or stream.
- In a natural watershed, rain falls on vegetated areas. Vegetation allows the soil to soak up most of the rain that falls. In an urban watershed, much of the rain falls on hard surfaces such as streets, driveways, and rooftops. The rain water runs quickly over these hard surfaces and is not soaked up. This moving water is called **stormwater runoff**.
- Stormwater not only comes from hard surfaces, but also from lawns that can't absorb irrigation, rain, snowmelt, or runoff from hard surfaces as fast as it arrives. Compacted soils and steep slopes increase the rate of stormwater runoff from vegetated areas.
- Stormwater runoff is a result of rainfall and melting snow. As this water flows to storm sewers, it picks up pollutants from the land. Pollutants in storm water runoff include sediment (eroded soil and street dirt); nutrients from grass clippings, tree leaves and seeds, pet waste and fertilizer; bacteria from pet and wildlife waste; road salt; pesticides; and materials from illegal disposal.
- The loss of vegetated areas due to urbanization and development dramatically increases the volume of storm water runoff. Urbanization also increases the amount of pollutants available to be picked up by storm water.
- Stormwater runoff is carried directly to lakes and streams through **storm sewers**. Storm sewers are designed to prevent flooding, but also provide direct routes for pollutants to lakes and streams. By controlling the pollutants in stormwater runoff, we can control the amount of pollution entering our lakes and streams.



Fate of phosphorus fertilizer applied to soil

- In the case of inorganic fertilizers, phosphate in fertilizers is initially soluble and available . However, when fertilizer phosphorus comes in contact with the soil, various reactions begin that make the phosphate less soluble and less available. These reactions depend on soil conditions related to pH, moisture content, temperature and the minerals already in the soil.
- Once in contact with the soil, moisture from the soil will begin dissolving a fertilizer particle. This increases the phosphate in the solution P pool around the fertilizer particle and allows the dissolved phosphate to move a short distance away from the fertilizer particle. This movement is slow but may be increased by rainfall or irrigation water flowing through the soil.
- As phosphate ions in solution slowly migrate away from the fertilizer particle, most of the phosphate will react with the minerals within the soil. Phosphate ions generally react by attaching to soil particles, a process known as **adsorption**. These ions may also combine with cations (positively charged ions) in the soil such as calcium (Ca) or magnesium (Mg) in alkaline soils or aluminum (Al) and iron (Fe) in acidic soils to form insoluble compounds. At this point, the adsorbed phosphate and the newly formed compounds are relatively available to meet plant growth needs. Maintaining soil pH between 6 and 7 will generally result in the most efficient use of phosphate.
- Gradually, reactions occur in which the adsorbed phosphate and the easily dissolved compounds of phosphate form more insoluble compounds that cause the phosphate to become fixed and unavailable. Over time this, along with plant harvesting and removal, results in a decrease in soil test P and may require additional phosphorus fertilizer to meet plant requirements.

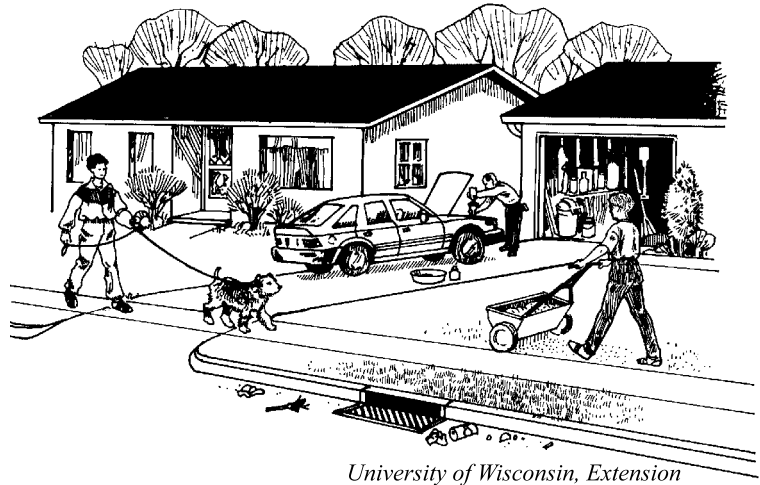
Phosphorus loss from soils and landscapes and potential impacts on water quality

- Phosphorus in soils is almost entirely associated with soil particles. When soil particles are carried to a river or lake, P will likely be contained in the sediment. When the sediment reaches a body of water it can either bind or release soluble P. In either case, sediment can be a potential source of P release into the aquatic system causing increased algae growth and deterioration in water quality.
- The majority of P added to soils will be retained by soils provided there is phosphate contact with the soil particles.
- Soil phosphate is associated more with fine particles than coarse particles. When soil erosion occurs, more fine particles are removed than coarse particles, causing sediment leaving a soil through erosion to be enriched in P. Thus, fine textured soils (i.e., soils high in clay and silt content) have a high potential to supply P to surface water bodies if erosion occurs and the soil particles are not kept on the landscape.
- However, increasing the amount of soil phosphate results in increasing levels of (dissolved phosphorus DP) in the solution P pool. This generates small but potentially important increases in the amounts of phosphate that could be lost in water that passes over or through soils.
- Although small in relative amount, phosphorus dissolved in water and not attached to soil particles can be a significant source of phosphorus runoff. In this process, P is extracted from the soil and dead plant material or debris and dissolved in runoff water. This occurs especially during spring snow melt, when phosphorus contained in the plant tissue is released due to breakdown of plant cells by freezing and thawing.
- As soil phosphorus is relatively immobile, P loss through movement of water down through the soil (i.e., leaching) is relatively small compared to its potential to be carried in runoff water. Thus, accelerated degradation of surface waters by P is mostly associated with inputs from surface flow rather than leaching.

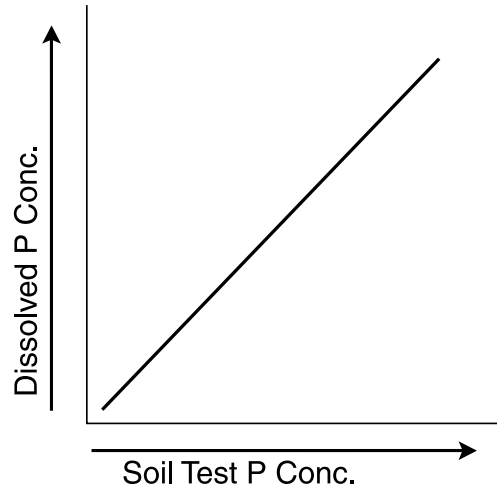
- A soil cannot continue to hold increasing amounts of P in the solid form without also increasing soil solution phosphate. Increased amounts of phosphate in solution will potentially cause phosphate to be lost to water running over the soil surface. Thus, additional loading of soils already high in phosphate will generally not hurt the plants but may result in increased phosphate movement to nearby bodies of water.

Urban landscape sources of phosphorus

- In modern developed landscapes, phosphorus runoff can occur from pervious and impervious surfaces. Pervious surfaces include lawns, flower beds, vegetable gardens, mulched surfaces, wooded areas, and prairie gardens. Impervious surfaces include features such as sidewalks, roofs, driveways, and streets.
- Yearly, these surfaces receive varying levels of phosphorus inputs from tree leaves, flowers and seeds, grass clippings, animal and pet waste, fertilizers, bird droppings, soil, rainfall and airborne dust.
- While these sources of phosphorus may land on each surface indiscriminately, material landing on pervious surfaces may move into the soil with water infiltration, may readily decompose into organic matter, or may be carried away in stormwater runoff.
- Material landing on impervious surfaces has a greater likelihood of moving with runoff into nearby lakes and rivers.
- Although often open for less than a season, exposed soils on construction sites can experience high rates of soil erosion. Phosphorus attached to sediment leaving construction sites is a major source of stormwater phosphorus in urban and urbanizing areas.
- Runoff volume and concentration of nutrients vary significantly during the year and is a function of site specific plant-soil-water interactions. Runoff water is the primary means of phosphorus loss from an urban landscape.
- Thick, dense lawns slow the speed of water runoff and potentially decrease the amount of runoff. Dense lawns and the resultant organic layer of thatch create conditions that promote infiltration of water and a reduction of dissolved or suspended chemicals.
- Factors that may potentially increase phosphorus loss in runoff from lawns and landscapes include:
 - a. steepness of slope to surface water bodies or impervious surfaces;
 - b. soils compacted from construction;
 - c. water saturated soils; or
 - d. poor or low density of grass and other plants as affected by shade, fertility, moisture and mowing practices.

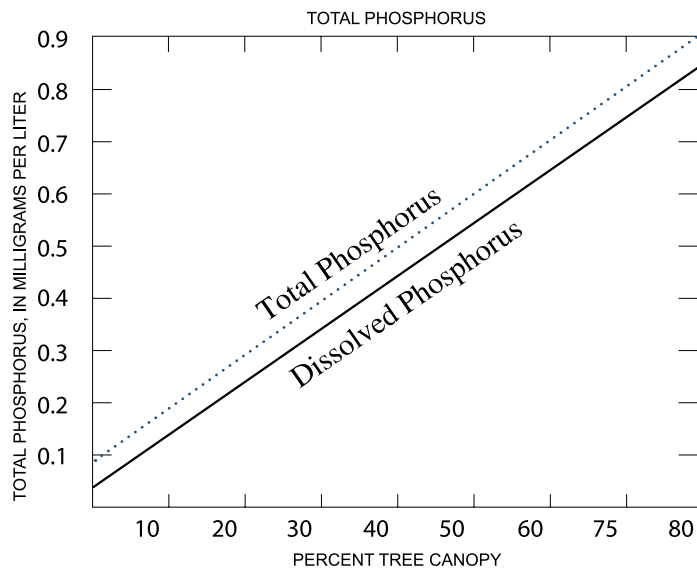


- Infiltration and thus runoff characteristics are more uniform in undisturbed landscapes than they are in areas subjected to compaction.



Bussman et.al.1998

- As soil test phosphorus levels increase in bare soil, the concentration of phosphorus in runoff increases.



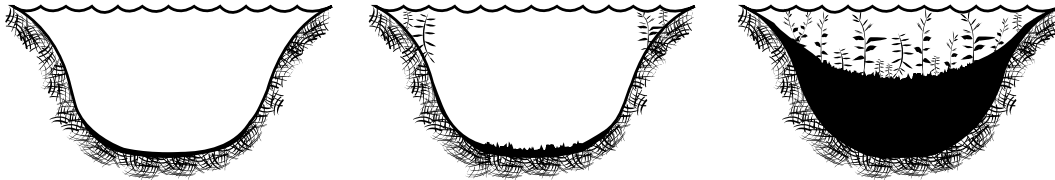
Washbush, selbis, and Bannerman, 1994

- As the amount of tree canopy increases, there are more leaves and therefore the amount of dissolved and total phosphorus in street runoff increases.

LAKE RESPONSE TO PHOSPHORUS

Eutrophication - the aging of lakes

- **Eutrophication** is a natural process where lakes become increasingly enriched with nutrients. Lakes start out with clear water and few aquatic plants and over time become more enriched with nutrients and vegetation until they “disappear” as a lake and become a marsh or bog.



OLIGOTROPHIC

- Clear water, low productivity
- Very desirable fishery of large game fish

MESOTROPHIC

- Increased production
- Accumulated organic matter
- Occasional algal bloom
- Good fishery

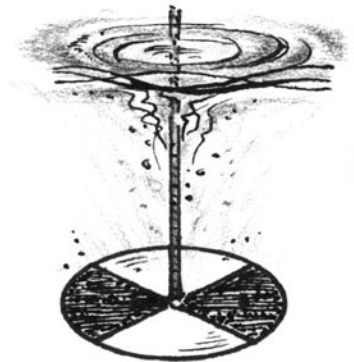
EUTROPHIC

- Very productive
- May experience oxygen depletion
- Rough fish common

- The natural process of eutrophication takes thousands of years. However, human activities can speed up this process significantly so a lake can become “old” within decades often referred to as cultural eutrophication. Over the past 60 to 70 years, lakes that were clear and open have become green with algae and choked with aquatic plants.
- For detailed information on lake eutrophication check out the Citizen’s Guide to Lake Protection provided by the Minnesota Pollution Control Agency at www.pca.state.mn.us/water/lakeprotection.

Phosphorus – what drives eutrophication

- The main nutrient that drives eutrophication in most surface waters is phosphorus. Other nutrients, such as nitrogen and potassium, are needed for aquatic plant growth, but they usually are found in adequate levels in lakes. In many surface waters phosphorus is the primary nutrient that may limit the growth of algae and small amounts of phosphorus entering a lake can go a long way to stimulate growth of algae and other aquatic plants.
- In some instances, nitrogen can be the limiting nutrient. However, bluegreen algae have the ability to fix nitrogen from the atmosphere if inadequate amounts of nitrogen are not available in the water. When blue-green and other algae die they provide nitrogen and phosphorus that can contribute to further algae or plant growth.



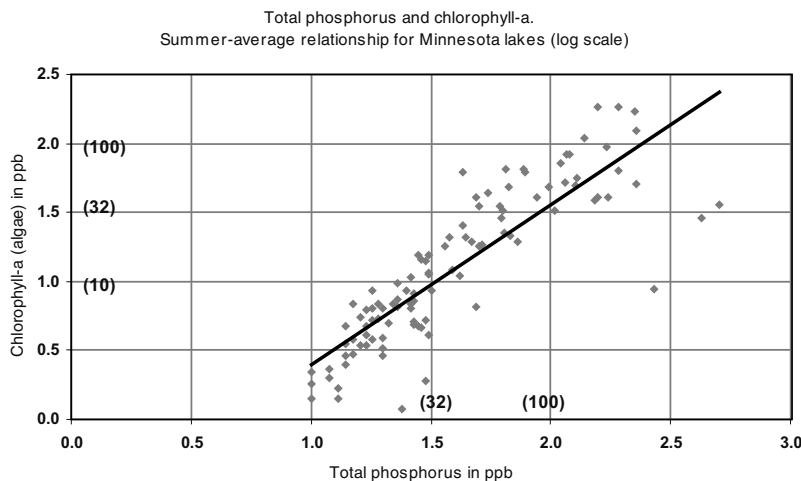
secchi disk

- Phosphorus levels in soils are measured in parts per million (ppm). In lakes and rivers, phosphorus levels are measured in parts per billion (ppb) – a unit 1,000 times smaller. This gives an indication how sensitive lakes and rivers are to additional inputs of phosphorus. Where it takes 25 ppm of soil phosphorus to grow healthy turf, 25 ppb – a quantity 1,000 times smaller can promote excessive algae growth in lakes.
- When used to measure quantities of substances in water one microgram per liter (ug/l) is equivalent to one part per billion (ppb) and one milligram per liter (mg/l) is equivalent to one part per million (ppm).
- It takes about 300 ppb phosphorus in soil solution P pool for healthy plant growth. To obtain 300 ppb in solution the soil needs to have about 25 ppm of plant available P.

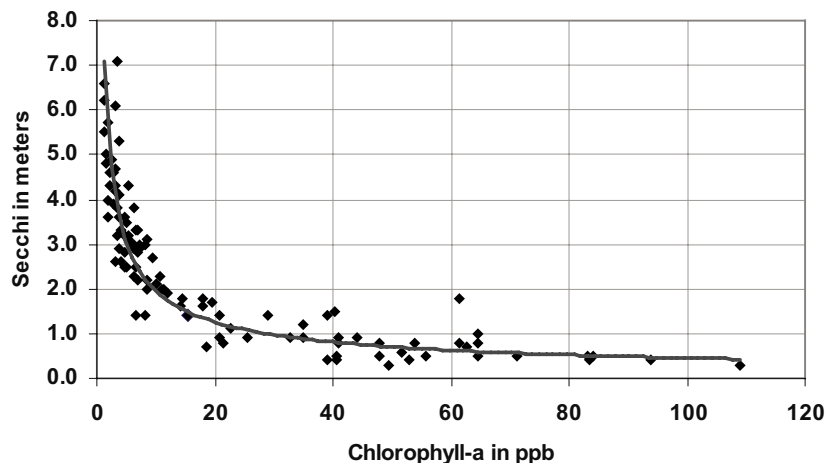
Phosphorus in Lawns, Landscapes and Lakes

- This sensitivity of lakes and rivers to phosphorus means even small sources of phosphorus in runoff, that by themselves may seem inconsequential, can result in water quality problems when combined with other similar sources across a watershed.
- Humans can increase the amount of phosphorus entering lakes through **point sources** of water pollution, such as factories and wastewater treatment plants. We can also increase phosphorus through **non-point sources** of water pollution, the pollution that occurs when rain and melting snow move nutrients, sediment and other pollutants from the landscape. Nonpoint source water pollution is also known as **runoff pollution** or **stormwater** pollution because it is connected to stormwater runoff. Runoff of phosphorus from urban yards is one type of nonpoint source water pollution.
- The relationship between phosphorus levels in lake water and lake clarity is well established. Phosphorus, algae (typically measured in terms of chlorophyll-a – a pigment found in all algae), and transparency (as measured by a Secchi disk) are closely interrelated based on studies conducted throughout the world.
- For example, using summer average data from Minnesota lakes the Minnesota Pollution Control Agency provides the following relationships:

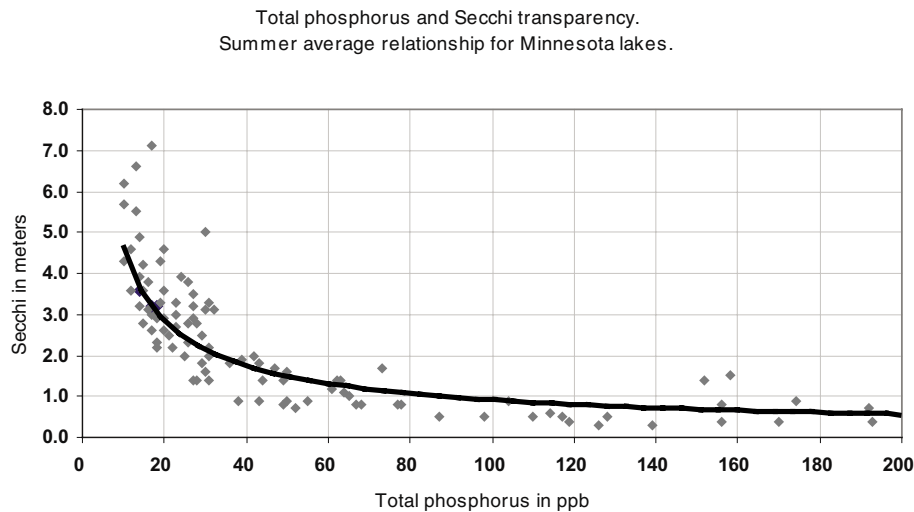
As the total amount of phosphorus in the water increases, the amount of algae in the water increases.



As the amount of algae in the water increases, the clarity of the water decreases.



As the amount of total phosphorus in the water increases, the clarity decreases.



- These interrelationships have been brought together in an index, referred to as Carlson's Trophic State Index that is routinely used in Minnesota to describe the trophic state of lakes.
- As the amount of phosphorus in the water increases, the clarity decreases, and the values of lakeshore property decreases.

Behavior of phosphorus in lakes

- Phosphorus is involved in complex cycles in lakes. Soluble phosphorus is quickly taken up by plants and converted into non-soluble organic forms. As plants are consumed by animals, or die and decay, non-soluble phosphorus is once again made soluble and quickly taken up by other plants.
- Phosphorus can also form insoluble compounds with calcium, iron, and aluminum. Lakes with high levels of calcium or iron are less sensitive to phosphorus because it quickly forms precipitates (particles) with these chemicals and settles out to the bottom. However, various processes in the lake may allow this phosphorus to become soluble and available for plant growth. Aluminum is not found in high levels in lakes naturally, but often is added to eutrophic lakes or stormwater as an alum (aluminum chloride and aluminum sulfate) treatment to precipitate and settle out phosphorus.
- Lakes may vary in their sensitivity to excess phosphorus. Shallow lakes (small volume) may respond dramatically to small inputs (loads) of phosphorus, resulting in excessive algae and plant growth. Whereas deeper lakes (large volume) that more efficiently settle out incoming soil and nutrients may be able to assimilate greater loadings of phosphorus before exhibiting water quality problems.
- Phosphorus concentrations as low as 20-30 parts per billion can already begin to promote blooms of algae. Significant and frequent blooms are noted as concentrations rise to 50-70 parts per billion (see Carlson TSI graph).
- Reservoirs (impoundments) and rivers may also be impacted by excess phosphorus loads, however their response, in terms of algal blooms, may vary somewhat from that of natural lakes because of various physical factors such as flow.

Carlson's Trophic State Index (TSI)
R.E. Carlson

TSI < 30 Classic Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.

TSI 30 - 40 Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.

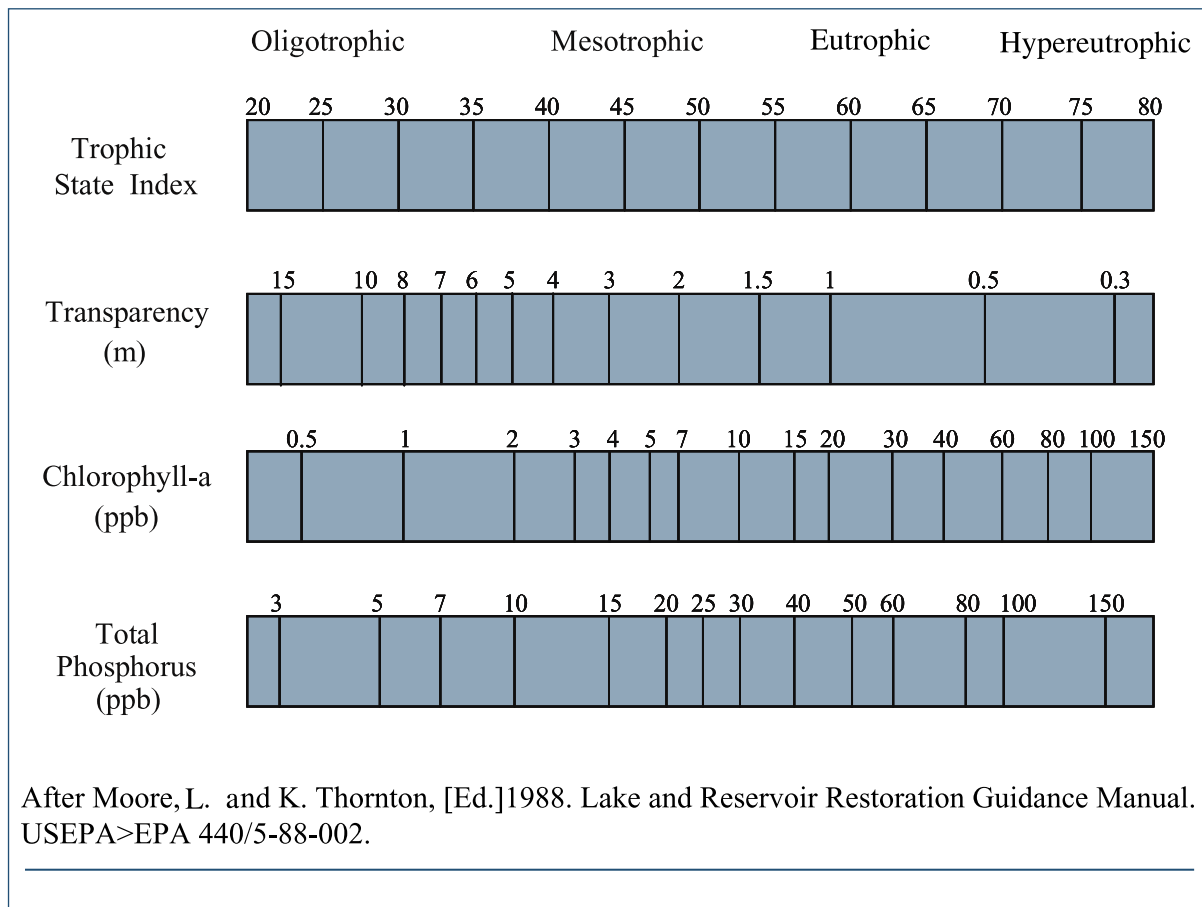
TSI 40 - 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

TSI 50 - 60 Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimni during the summer, macrophyte problems evident, warm-water fisheries only.

TSI 60 - 70 Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.

TSI 70 - 80 Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.

TSI > 80 Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



For more complete information on the relationships between phosphorus, algae and water clarity check out Lake Water Quality Assessment on the Minnesota Pollution Control Agency web site at www.pca.state.mn.us/water/lakequality.html.

Measuring phosphorus in lakes

- One measure of phosphorus in lakes is **soluble phosphorus** (or soluble reactive phosphorus). However, since this form of phosphorus is so fleeting in lake systems – being quickly taken up by plants and converted to non-soluble forms – the measure of **total phosphorus** best reflects the level of phosphorus in lake water. Total phosphorus is a measure of both the soluble and non-soluble organic phosphorus.
- Various units may be used to measure phosphorus concentrations in lakes. Parts per billion (ppb) and micrograms per liter (ug/l) are most frequently used. Because the metric system uses water as a basis of measure, these two units of measurement are equivalent when concentration is being measured in water, that is, 1 ppb = 1 ug/l.
- The range in concentrations for most lakes across Minnesota fall between 10-150 ppb. Common concentrations in northern Minnesota are 10-30 ppb. Common concentrations in central Minnesota are 20-60 ppb. Common concentrations in southern Minnesota are 50-150 ppb.

WHAT CAN BE DONE TO PROTECT WATER QUALITY?

Fertilizers, leaves, grass clippings, eroded soil, and animal waste are all sources of phosphorus. When they are swept or washed into the nearest street or storm drain, they end up in a local lake or river. People can do their part to protect water quality by doing the following:

- Keep leaves, tree seeds and lawn clippings out of gutters, streets, and ditches.
- Never wash or blow soil or grass clippings into the street.
- Pick up pet waste promptly. Pet waste can contain harmful bacteria as well as nutrients. Never drop pet waste in the street or ditches.
- Control soil erosion around homes. When left bare, soil is easily washed away with rain, carrying phosphorus with it. Soil erosion can be prevented by keeping soil covered with vegetation or mulch.

Follow Minnesota's phosphorus lawn fertilizer law

- Except as noted below starting January 1, 2005, **fertilizers containing phosphorus cannot be used on lawns in Minnesota**. Look for the middle number on a bag of fertilizer, it should be zero (0).
- **Keep fertilizer off paved surfaces:** It's illegal to spread any fertilizer on hard surfaces such as streets, sidewalks and driveways. Rain can wash the fertilizer into a nearby lake or river. Fertilizer accidentally spilled or spread on a hard surface needs to be cleaned up immediately.
- **Exemptions:** Fertilizers containing phosphorus may be used on lawns if a soil test indicates that it is needed or if a new lawn is being established. These restrictions do not apply to fertilizers used for agricultural crops, flowers and vegetable gardening, or on golf courses by trained staff.
- More information on Minnesota's new Phosphorus Lawn Fertilizer Law can be found at the Minnesota Department of Agriculture web site at www.mda.state.mn.us. From the home page, click on "Water and Land", then click on "Lawn Care and Water Quality".

Find out what is needed: Test the soil

- A soil test is a good idea, especially when concerned that a lawn may need phosphorus.
- Instructions on soil testing are available through the University of Minnesota Extension Service's INFO-U by calling 612-624-2200 (metro) or 1-800-525-8636 and requesting message 468.
- Soil testing information can also be obtained through the internet by visiting www.extension.umn.edu and searching for "Lawn Soil Testing".
- A list of laboratories certified for soil testing by the Minnesota Department of Agriculture can be found at www.mda.state.mn.us/appd/soilabs.htm.

FOR MORE INFORMATION

- The Yard & Garden Line is the University of Minnesota Extension Service's one-stop link to information about plants and insects in the home landscape. Call 612-624-4771 or go to the website at: www.extension.umn.edu/projects/yardandgarden
- University of Minnesota Extension Service's web site: www.extension.umn.edu. From the home page click on "Garden" then on "Lawn".
- University of Minnesota Extension Service - Sustainable Urban Landscape Information Series (SULIS): www.sustland.umn.edu. From the home page, click on "Maintenance" then on "Lawn Care".
- Minnesota Department of Agriculture: www.mda.state.mn.us. From the home page, click on "Water & Land", then on "Lawn Care & Water Quality".
- Minnesota Pollution Control Agency: www.pca.state.mn.us. From the home page, click on "Water".

REFERENCES

- Busman, L., J. Lamb, G. Randall, G. Rehm, and M. Schmitt. 1998. The nature of phosphorus in soils. University of Minnesota Extension Service, FO-6795-GO.
- Daniel, W. and R. Freeborg. 1979. Turf Managers' Handbook. Harvest Publishing Company, p. 222.
- Minnich, J. and M. Hunt. 1979. The Rodale Guide to Composting. Rodale Press, Inc., Emmaus, PA pp. 149-154.
- Randall, G., D. Mulla, G. Rehm, L. Busman, J. Lamb, and M. Schmitt. 1998. Phosphorus transport to and availability in surface waters. University of Minnesota Extension Service, FO-6796-GO.
- Rehm, G. M. Schmitt, J. Lamb, G. Randall, L. Busman. 1998. Understanding phosphorus fertilizers. University of Minnesota Extension Service, FO-6288-GO.
- Rehm, G. and M. Schmitt. 1993. Understanding phosphorus in Minnesota soils. University of Minnesota Extension Service, FO-0792-GO.
- Rosen, C., T. Halbach, and R. Mugaas. 2000. Composting and mulching – a guide to managing organic yard wastes. University of Minnesota Extension Service – BU-3296-F.
- Rosen, C. and D. White. 1999. Preventing pollution problems from lawn and garden fertilizers. University of Minnesota Extension Service – FO-2923-GO.
- Rosen, C., P. Bierman, and R. Eliason. 1998. Soil test interpretations and fertilizer management for lawns, turf, gardens and landscape plants. BU-1731-F.
- Waschbusch, S. and R. Bannerman. 1999. Sources of phosphorus in stormwater and street dirt from two urban residential basins in Madison, Wisconsin, 1994-95. U. S. Geological Survey, Water Resources Investigations Report 99-4021.

For additional copies of this publication, contact the Minnesota Department of Agriculture at 651-296-6121.

In accordance with the Americans With Disabilities Act, an alternative form of communication is available upon request.
TTY: 1-800-651-627-3529
The Minnesota Department of Agriculture is an Equal
Opportunity Employer

NOTES



MINNESOTA DEPARTMENT OF
AGRICULTURE
FROM THE FARM TO YOUR FAMILY



**Minnesota
Pollution
Control
Agency**

UNIVERSITY OF MINNESOTA
Extension
SERVICE



**Minnesota
Office of
Environmental
Assistance**