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ECOLOGICAL SCIENCES—AGRONOMY TECHNICAL NOTE

PHOSPHORUS INDEX ASSESSMENT FOR MONTANA

Richard A. Fasching, State Agronomist

Phosphorus Concerns in the Environment

Phosphorus (P) is an essential nutrient for plant and animal growth and its use has been long recognized as necessary to maintain profitable crop and animal production. However, phosphorus can also increase the biological productivity of surface waters by accelerating eutrophication, the natural aging process of lakes and streams brought on by nutrient enrichment. Human activity can greatly accelerate the eutrophication process through activities that increase nutrient loading to water.

The U.S. Environmental Protection Agency (1996) identified eutrophication as the main cause of impaired surface water quality in the United States. Eutrophication restricts water use for fisheries, recreation, industry, and drinking due to the increased growth of undesirable algae and aquatic weeds and to oxygen shortages caused by their death and decomposition. Associated periodic surface blooms of blue-green algae can occur in drinking water supplies and may pose a serious health hazard to animals and humans.

Eutrophication of most fresh water is accelerated by P inputs. Although exchangeable atmosphere and water sources of nitrogen and carbon are also essential to the growth of aquatic biota they are difficult to control. Thus, P is considered the most limiting element, and its control is of prime importance in protecting and improving Montana surface waters.

Surface water concentrations of P above 0.02 ppm generally accelerate eutrophication. These values are an order of magnitude lower than P concentrations in soil solution critical for plant growth (0.2 to 0.3 ppm), emphasizing the disparity between critical lake and soil P concentrations and the importance of controlling P losses to limit eutrophication.

P Index Concept

Nonpoint source P pollution of surface waters is a complex set of processes that involves P application, build up in soils, and transport to surface waters. High P application in the form of P fertilizer or manure can increase the risk of P transport to surface waters. However, unless there is loss in runoff (solution or adsorbtion), risk in minimal. Extremely high soil test P also increases the risk of P enrichment, but there must be dissolution and transport of P before there is an environmental concern.

The P Index is a field-level assessment tool that ranks the relative potential for off-site movement of phosphorus from the landscape. The purpose of the phosphorus index is to provide field staffs, watershed planners, and land users with a tool to assess the various land forms and management practices for potential risk of phosphorus movement toward water bodies. The ranking of the Phosphorus Index identifies sites where the risk of phosphorus movement may be relatively higher than from other sites. The P Index can also be used to develop planning considerations that can be provided to the land user. From these planning considerations alternatives are provided to the producer to minimize the potential phosphorus movement from the landscape.

Factors Affecting P Loss

Phosphorus is transported from manure application sites by runoff water. Phosphorus in runoff is made up of adsorbed P (P attached to soil particles), water soluble P and organic P (found in manure/residue/organic matter). Adsorbed P transported by water erosion normally accounts for a large portion of P lost from a site. However, when P soil test levels increase, the amount of water-soluble P in runoff increases.

Reducing rates of manure or fertilizer P decreases the risk of P loss. Applying fertilizer P and manure closer to crop uptake, and injecting or incorporating manure reduces the risk of P loss. Concentrated surface water runoff is largely responsible for transporting most P lost from the manure application site and can enter directly into streams and lakes. When manure is applied farther away from areas where surface water runoff concentrates, the potential for P loss decreases. Additionally, when buffers are used to protect down slope areas the potential for P loss to surface water is reduced. Irrigation induced erosion also substantially increases the potential for P loss.

The P Index uses ten specific field characteristics and management practices to obtain a rating for each field. Not all field features and management practices have the same influence on potential P loss. Research has shown that relative differences exist in the importance of each field feature to P loss. Thus, site characteristics have been placed in categories and assigned a weight factor based on relative impact on P movement from the site. Instructions and definitions are provided for each factor. Each category's weight factor is multiplied by its risk value to get a weighted risk factor for each specific category. All categories are rated and the overall risk rating for the site is the sum of all values (refer to TABLE 3). TABLE 3 is available as a .pdf worksheet on the Montana NRCS home page address: *http//www.mt.nrcs.usda.gov/*

TABLE 1. PHOSPHORUS LOSS CATEGORIES AND WEIGHT FACTORS

FIELD FEATURE/MANAGEMENT PRACTICE	WEIGHTED FACTOR
Soil Erosion	1.5
Furrow Irrigation Erosion	1.5
Sprinkler Irr. Erosion/runoff	0.5
Runoff class	0.5
Soil test P (Bray P1 or Olson)	1.0
Commercial P fertilizer application rate	1.0
Commercial P fertilizer application method	1.0
Manure/organic P application rate	1.0
Manure/organic P application method	1.0
Distance to concentrated surface water flow	1.0

The risk rating for each category is as follows:

- None = 0 (not applicable – N/A)
- Low = 1
- Medium = 2
- High = 4
- Very High = 8

Category Descriptions and Instructions

Individual sections from TABLE 3 are provided here to assist in determining the weighted risk factor for each category. After reviewing the descriptions and instructions for each category, assign a risk value and calculate the weighted risk factor using the Phosphorus Index Rating worksheet.

1. Soil Erosion

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Soil Erosion	N/A	<5 ton/ac/yr	5-10 tons/ac/yr	10-15 tons/ac/yr	>15 tons/ac/yr		X 1.5	

Soil erosion is the movement of soil from the site due to runoff. This category is quantified in tons/acre/year. Water erosion can be predicted using the Revised Universal Soil Loss Equation (RUSLE) found in the Natural Resources Conservation Service (NRCS) Field Office Technical Guide (FOTG). Erosion predictions are calculated based on precipitation, rainfall intensity, soil characteristics, slope gradient and slope length, cropping system, and supporting practices including terraces, contour farming, etc.

2. Furrow Irrigation Erosion

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Furrow Irrigation Erosion	N/A	Tailwater recovery, QS >6 very erodible soils, or QS >10 other soils	QS >10 for erosion resistant soils	QS >10 for erodible soils	QA >6 for very erodible soils		X 1.5	

Adsorbed P and other nutrients can be lost due to erosive flows within the furrow. QS value is determined by furrow flow rate (gallons per minute - gpm), soil texture, and furrow slope. Tailwater recovery means that a system is in place that captures irrigation runoff (e.g. pit) and is re-used again for irrigation after sediment has settled out. Furrow flow rate and slope are accounted for as follows:

QS value = Furrow Flow Rate (gpm) X Furrow Slope (%)

Example: QS = 20 gpm X 0.5% = 10.

Soils are broken down into three surface texture categories based on susceptibility to furrow irrigation induced erosion. Refer to published soil survey data for soil texture classifications.

- Very erodible Soils - soils with silt, fine and very fine sandy loam, loamy fine sand, and loamy very fine sand textures.
- Erodible soils - silt loam and loam soils.
- Erosion-resistant soils - soils with silty clay, clay, and clay loam textures.

3. Sprinkler Irrigation Erosion

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Sprinkler Irrigation Erosion	All sites 0-3% slope, all sandy sites, or site evaluation indicates little or no runoff, large spray on silts 3-8%	Medium spray on silty soils 3-15% slopes, large spray on silty soils 8-15% slope, low spray on silt soils 3-8%,large spray on clay soil 3-15% slope	Medium spray on clay soils 3-8% slopes, large spray on clay soils >15% slope, medium spray on silt soil >15% slope	Medium spray on clay soils >8% slope, low spray on clay soil 3-8% slope, low spray on silty soils >15% slopes	Low spray on clay soils >8% slopes.		X 0.5	

This category rates the potential for sprinkler irrigation induced erosion. Spray type, soil texture and soil gradient impact sprinkler irrigation induced erosion. When a comprehensive evaluation of irrigation induced runoff indicates little or no runoff will occur, this category is not applicable (N/A) and is given a rating of (0).

Spray type

- Large spray = nozzle wetted diameter is > 50 feet.
- Medium spray = nozzle wetted diameter is 20-50 feet.
- Low spray = nozzle wetted diameter is < 20 feet.

Slope

- Percent of slope on the application site being evaluated.

Texture

- Sandy textured (fine and very fine sandy loam, loamy fine sand, and loamy very fine sand).
- Silt (silt, silt loam, loam).
- Clay (silty clay, silty clay loam, clay and clay loam).

4. Runoff Class

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Runoff Class	Negligible	Very Low or low	Medium	High	Very High		X 0.5	

The runoff class of a site is based on the least permeable soil layer in the top three feet. Permeability classes for specific soils can be found in the soil series description in the published soil survey manual or in NASIS. Slope and soil permeability class must be determined, then runoff class can be determined (refer to TABLE 2).

TABLE 2. RUNOFF CLASS

SLOPE %	Soil Permeability Class				
	VERY RAPID (>20.0 in/hr)	MODERATELY RAPID (2.0–6.0 in/hr and RAPID (6.0–20.0 in/hr)	MODERATE (0.60–2.0 in/hr) AND MODERATELY SLOW (0.20–0.60 in/hr)	SLOW (0.06–0.20 in/hr)	VERY SLOW (<0.06 in/hr)
Depressions	Negligible	Negligible	Negligible	Negligible	Negligible
0-1%	Negligible	Negligible	Negligible	Low	Low
1-5%	Negligible	Very Low	Low	Medium	High
5-10%	Very Low	Low	Medium	High	Very High
10-20%	Very Low	Low	Medium	High	Very High
>20%	Low	Medium	High	Very High	Very High

5. Soil Test Phosphorus (use only one soil test category)

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Olson Soil Test P	---	<20 ppm	20-40 ppm	40-80 ppm	>80 ppm		X 1.0	

Bray P1 soil tests are typically used on soils with a pH of 7.0 or less, while Olson (sodium bicarbonate) soil tests are utilized on soils with a pH greater than 7.0 and contain calcium carbonate. Phosphorus soil tests should be taken from the top 6" of the soil. In Montana, the Bray test should not be used.

6. Commercial P Fertilizer Application Method

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Commercial P Fertilizer Application Method	None Applied	Placed with planter or injected deeper than 2 inches.	Incorporated <3 months prior to planting or surface applied during the growing season.	Incorporated >3 months before crop or surface applied <3 months before crop emerges.	Surface applied >3 months before crop emerges.		X 1.0	

The manner in which P fertilizer is applied to the soil and the time that fertilizer is exposed on the soil surface impacts potential P loss. Incorporation implies that fertilizer P is incorporated into the soil a minimum of two inches. The categories of increasing severity, LOW to VERY HIGH, depict the longer surface exposure time between fertilizer application and crop utilization.

7. Commercial P Fertilizer Application Rate

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Commercial P Fertilizer Application Rate	None Applied	<30 lbs/ac P_2O_5	31–90 lbs/ac P_2O_5	91–150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5		X 1.0	

Commercial P fertilizer application rate is the amount, in pounds per acre (lbs/ac), of phosphate fertilizer (P_2O_5) that is applied. This does not include phosphorus from organic sources (manure).

8. Manure/Organic P Source Application Method

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Organic P Source Application Method	None Applied	Injected deeper than 2 inches	Incorporated <3 months prior to planting or surface applied during growing season.	Incorporated >3 months before crop or surface applied < 3 months before crop emerges.	Surface applied to pasture or applied >3 months before crop emerges.		X 1.0	

The manner in which manure is applied to the soil and the time it is exposed on the soil surface impacts potential P loss. Incorporation implies that manure is incorporated into the soil a minimum of two inches. The categories of increasing severity, LOW to VERY HIGH, depict the longer surface exposure time between manure application, incorporation, and crop utilization

9. Manure/Organic P Source Application Rate

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Organic P Application Rate	None Applied	<30 lbs/ac P_2O_5	31–90 lbs/ac P_2O_5	91–150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5		X 1.0	

10. Distance to Concentrated Surface Water Flow

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Distance to Concentrated Surface Water Flow	>1,000 feet	200–1000 feet, or functioning grasses waterways in concentrated surface water	100–200 feet	<100 feet	0 feet or applications are directly into concentrated surface water flow areas.		X 1.0	

This category is an estimate of distance between the application site, and the point where runoff water concentrates. Use zero for distance if manure or fertilizer P is applied directly in concentrated flow areas (eg. drainage course, ditch) that delivers runoff water into intermittent or perennial streams, lakes or water bodies. If concentrated flow areas do not deliver runoff directly into a stream or other water body (concentrated flow

spreads prior to entering the stream or other water body), use the distance from where runoff exits the application site to the point where it enters a stream or other water body. Installation of grassed waterways in concentrated flow areas will reduce the risk of sediment-P loss due to concentrated water flow.

Completing Risk Ratings

Each site category's weighting factor in TABLE 3 is multiplied by the site risk rating (value) to get a weighted risk value. All categories are rated (according to individual category instructions), and the overall rating is the sum of all values. After individual sites/fields are rated, refer to the appropriate vulnerability rating in TABLE 4.

TABLE 3. PHOSPHORUS INDEX ASSESSMENT

SITE CATEGORY FACTOR	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Soil Erosion	N/A	<5 ton/ac/yr	5-10 tons/ac/yr	10-15 tons/ac/yr	>15 tons/ac/yr		X 1.5	
Furrow Irrigation Erosion	N/A	Tailwater recovery, QS >6 very erodible soils, or QS >10 other soils	QS >10 for erosdion resistant soils	QS >10 for erodible soils	QA >6 for very erodible soils		X 1.5	
Sprinkler Irrigation Erosion	All sites 0-3% slope, all sandy sites, or site evaluation indicates little or no runoff, large spray on silts 3-8%	Medium spray on silty soils 3-15% slopes, large spray on silty soils 8-15% slope, low spray on silt soils 3-8%,large spray on clay soil 3-15% slope	Medium spray on clay soils 3-8% slopes, large spray on clay soils >15% slope, medium spray on silt soil >15% slope	Medium spray on clay soils >8% slope, low spray on clay soil 3-8% slope, low spray on silty soils >15% slopes	Low spray on clay soils >8% slopes.		X 0.5	
Runoff Class	Negligible	Very Low or low	Medium	High	Very High		X 0.5	
Olson Soil Test P	---	<20 ppm	20-40 ppm	40-80 ppm	>80 ppm		X 1.0	
Commercial P Fertilizer Application Method	None Applied	Placed with planter or injected deeper than 2 inches.	Incorporated <3 months prior to planting or surface applied during the growing season.	Incorporated >3 months before crop or surface applied <3 months before crop emerges.	Surface applied >3 months before crop emerges.		X 1.0	
Commercial P Fertilizer Application Rate	None Applied	<30 lbs/ac P_2O_5	31–90 lbs/ac P_2O_5	91–150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5		X 1.0	
Organic P Source Application Method	None Applied	Injected deeper than 2 inches	Incorporated <3 months prior to planting or surface applied during growing season.	Incorporated >3 months before crop or surface applied < 3 months before crop emerges.	Surface applied to pasture or >3 months before crop emerges.		X 1.0	
Organic P Application Rate	None Applied	<30 lbs/ac P_2O_5	31–90 lbs/ac P_2O_5	91–150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5		X 1.0	
Distance to Concentrated Surface Water Flow	>1,000 feet	200–1000 feet, or functioning grasses waterways in concentrated surface water	100–200 feet	<100 feet	0 feet or applications are directly into concentrated surface water flow areas.		X 1.0	
Site/Field Total Phosphorus Index Value								

Interpreting Results of Site Vulnerability Ratings

After multiplying the weighting factor by the risk value for each category and totaling all values in TABLE 3, assign the overall site/field vulnerability to phosphorus loss from TABLE 4.

TABLE 4. SITE/FIELD VULNERABILITY TO PHOSPHORUS LOSS

Total of Weighted Risk Values	Site Vulnerability	Site/Field Number(s)
<11	LOW	
11-21	MEDIUM	
22-43	HIGH	
> 43	VERY HIGH	

Vulnerability Definitions

LOW – This site has a low potential for P movement from the site. If farming practices are maintained at the current level there should be a low probability of an adverse impact to surface resources.

MEDIUM – This site has a medium potential for P movement from the site. There is a greater probability of an adverse impact to surface water resources than from a low rated site. Some remedial action such as using P management measures (i.e. filter strips, grassed waterways, application setbacks, manure injection or incorporation) should be taken to lessen the probability of P movement.

HIGH – This site has a high potential for P movement from the site. There is a higher probability of an adverse impact to surface water than medium sites unless remedial action is taken. Soil and water conservation (refer to soil erosion category for conservation options) as well as P management measures (i.e. P based manure application rates) should be taken to reduce the risk of P movement and probable water quality degradation

VERY HIGH – This site has a very high potential for P movement from the site. There is a very high probability for an adverse impact to surface water. Remedial action should be taken to reduce the risk of P movement. Soil and water conservation practices and a phosphorus management plan are needed to reduce the potential of water quality degradation.

Practices utilized to reduce P loss can vary from one site to the next. Site categories that have the highest weighted risk value are the most critical factors impacting P loss. Practices that reduce the risk value of these categories are the most effective.

Effective practices can include: P management measures such as planting high P-use crops, rotating manure application sites, reduced manure application rates, manure application set-backs from areas where runoff concentrates, application method (injection or incorporation versus broadcast), timing (growing season, spring and split applications versus fall or applications to frozen/snow covered ground), and soil and water conservation practices such as residue management, terraces, contouring, grassed waterways, filter strips, etc.

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