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CONSERVATION PLANNING FOR WATER QUALITY CONCERNS, PHOSPHORUS LOADING

The purpose of this Technical Note is to provide consultants and experienced planners with a tool to assess the potential of phosphorus (P) movement into surface water from a manure application site, identify appropriate BMPs, and identify critical factors that impact P loss. Degradation of surface water quality from (P) in runoff and sediment is an increasing water quality concern. Excessive P in surface water can result in excessive algae and plant growth causing a depletion of oxygen for fisheries. This Technical Note is based on the original P-index developed by Lemunyon and Gilbert (1993) and is based on the major factors affecting P loss.

This tool can also be used to compare the relative risk of P loss of one site versus another. When individual factors that impact P loss are analyzed, it is apparent that individual factors such as soil erosion and soil P test impacts P loss disproportionately. Factors such as P soil test levels, P management practices (rate, timing and method of application), runoff, soil erosion, and other factors impact the potential for P loss. Reducing runoff and erosion is also important to maximize nutrients available for crops. Appropriate best management practices (BMPs) to reduce the risk of P loss can be identified after determining the most critical factors that impact P loss. Practices and management measures identified through the use of this tool need to be incorporated into Comprehensive Nutrient Management Plans (CNMPs).

Conservation Planning for Water Quality Concerns, Phosphorus Loading

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This tool can also be used to compare the relative risk of P loss of one site versus another. When individual factors that impact P loss are analyzed, it is apparent that individual factors such as soil erosion and soil P test impacts P loss disproportionately. Factors such as P soil test levels, P management practices (rate, timing and method of application), runoff, soil erosion, and other factors impact the potential for P loss. Reducing runoff and erosion is also important to maximize nutrients available for crops. Appropriate best management practices (BMPs) to reduce the risk of P loss can be identified after determining the most critical factors that impact P loss.

Factors Affecting P Loss

Phosphorus is transported from manure application sites by runoff. Phosphorus in runoff is made up of sediment P, water soluble P and organic P (manure/residue/organic matter). Sediment P lost by water erosion normally accounts for most 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 applied 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 transports 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. Erosion induced by irrigation systems also increases the potential of P loss.

Procedures for Making an Assessment

Site characteristics/factors impacting P loss have been placed in categories and assigned a weight factor based on relative impact on P movement from the site. Instructions are provided for each category, and only categories that apply to the manure application site are to be used. Each category's weight factor is multiplied by its risk value to get a weighted risk factor for each category. All categories are rated and the overall risk rating for the site is the sum of all values (see Table 3, Phosphorus Index for Assessing Vulnerability of the Site).

Phosphorus Loss Categories with Weight Factors (numbers in parentheses):

- Soil Erosion (1.5)
- Furrow Irrigation Erosion (1.5)
- Sprinkler Erosion/Runoff (0.5)
- Runoff Class (based on slope and soils) (1.5)
- Soil Test (surface) Bray P1 or Olson Soil P Test (1.0)
- Commercial P Fertilizer Application Method (0.5)
- Commercial P Fertilizer Application Rate (0.5)
- Manure/Organic P Application Method (1.0)
- Manure/Organic P Application Rate (1.0)
- Distance to Concentrated Surface Water Flow (1.0)

Risk Ratings for Each Category:

- None = 0 (Not applicable = NA)
- Low = 1
- Medium = 2
- High = 4
- Very High = 8

Category Instructions

Individual sections from Table 3 are included at the beginning of instructions for each category to assist in determining the weighted risk factor for each category. After reviewing instructions for each category, up to three sites can be rated for P loss risk utilizing Table 3.

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 tons/ac/yr	5-8 tons/ac/yr	9-12 tons/ac/yr	>12 tons/ac/yr		X 1.5	

Soil erosion is the movement of soil from the site due to runoff. This category is given in tons per acre per year (ton/ac/yr). Soil erosion can be predicted using the Revised Universal Soil Loss Equation found in the Natural Resources Conservation Service (NRCS) Field Office Technical Guide. Erosion estimates are based on rainfall intensity, soil characteristics, percent and length of slope, crop rotation, tillage system (no-till, mulch till, etc.), and other practices such as terraces and contouring. If erosion estimates from NRCS are available, use them, if not, use Table 1 to estimate annual water erosion.

Table 1. Soil Erosion Categories (Cropland only)

BMP Category	None/NA	Low	Medium	High	Very High
With BMPs 1/	Non-sandy soils on 0-3% slope, sandy soils 0-5% slope	Non-sandy soils on 3-5% slope, sandy soils 5-8% slope	Non-sandy soils on 5-8% slope, sandy soils >15% slope	Non-sandy soils on 8-15% slope	
Without BMPs		Non-sandy soils on 0-3% slope, sandy soils on 3-8% slope	Non-sandy soils on 3-5% slope, sandy soils 8-15% slope	Non-sandy soils on 5-8% slope, sandy soils on >15% slope	Non-sandy soils on >8% slope
Regardless of BMPs	Sandy soils on 0-5% slope				Non-sandy soils on >15% slope

1/ "With BMPs" means all crops are no-till planted, or the site/field is terraced with 20 percent or more ground cover at planting, or greater than 50 percent of the crop rotation is perennial grasses and/or legumes, or a combination of these practices. Sandy soils are coarse textured soils that include fine and very fine sandy loam, loamy fine sand, loam and very fine sand textures. Non-sandy soils include silt, silt loam, silty clay, clay and clay loam textures.

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	QS >6 for very erodible soils		X 1.5	

Sediment-borne P and other nutrients may be lost due to erosive flows within the furrow, high furrow flow rates in gallons per minute (gpm), soil texture, and furrow slope. Tailwater recovery means that irrigation runoff is captured in a tailwater recovery pit and is re-used for irrigation. Furrow flow rate and slope are accounted for as follows where Q = gpm per furrow and S = slope in percent:

QS Value	=	Furrow Flow Rate (gpm)	X	Furrow Slope (percent)		
Example (QS)	=	20	X	.50	=	10

Soils are separated into three surface texture categories based on susceptibility to erosion due to furrow irrigation. Refer to the County Soil Survey Manual if you don't know the soil texture. The three surface texture categories are:

- Very Erodible Soils…Soils with silt, fine and very fine sandy loam, loamy fine sand, loam and very find sand textures.
- Erodible Soils… Silt loam soils.
- Erosion-Resistant Soils…Soils with silty clay, clay and clay loam textures.

Sprinkler Irrigation Erosion

Sprinkler irrigation water runoff from a site is based on NRCS intake families, percent slope and wetted diameter of the spray nozzle. Intake families, broken into permeability classes for specific soils, can be found in the soil series description in the County Soil Survey Manual.

Sprinkler Irrigation Table (Kranz and Fairbanks, 1997)

Spray Nozzle Wetted Diameter (feet)	Soil Texture or Permeability Class in top 3 foot of soil (refer to County Soil Survey manual)																			
	Sand & Fine Sand (Very rapid, >20 in/hr)				Sandy Loam & Loam (Moderately rapid, 2 - 6 in/hr. or rapid, 6 – 20 in/hr)				Silt Loam (Moderately slow, 0.2 – 0.6 in/hr or moderate, 0.6 – 2 in/hr)				Silty Clay Loam (Slow, 0.06 – 0.2 in/hr)				Silty Clay & Clay Loam (Very slow, <0.06 in/hr)			
% Slope→	0-4	4-8	8-12	>12	0-4	4-8	8-12	>12	0-4	4-8	8-12	>12	0-4	4-8	8-12	>12	0-4	4-8	8-12	>12
- feet -	----------rating (multiply value times 0.5 weight factor)----------																			
< 10	1	4	8	8	2	6	8	8	4	7	8	8	5	8	8	8	5	8	8	8
10-30	0	0	2	4	0	1	2	4	1	4	6	8	3	5	6	8	4	7	8	8
30-50	0	0	0	2	0	0	0	2	0	2	4	6	1	3	4	5	3	6	7	8
> 50 (volume gun)	0	0	0	0	0	0	0	1	0	0	1	2	0	1	3	4	0	2	4	6
If site evaluation indicates little or no runoff, use a rating of 0.																				

As an alternative, knowledge of soil texture can provide a reasonable approximation of permeability class (USDA, 2000). Multiply the value taken from the table below times a weighting factor of 0.5.

Alternative (Simplified) Sprinkler Runoff Table

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 Erosion	All sites 0-3% slope, all sandy sites, or site evaluation indicates little or no runoff., large spray on silts 3-8% slopes	Medium spray on silty soils 3-15% slopes, large sprays on silty soils 8-15% slope, low spray on silt soils 3-8%, large spray on clay soils 3-15% slopes	Medium spray on clay soils 3-8% slopes, large spray clay soils >15% slope, medium spray on silt soils >15% slope	Medium spray on clay soils >8 slope, low spray on clay soils 3-8% slopes, low spray on silty soils >15% slope	Low spray on clay soils >8% slope		X 0.5	

This category rates the potential for erosion due to irrigation runoff from sprinklers. Spray type, soil texture and percent of slope impact erosion due to sprinkler irrigation runoff. When a comprehensive evaluation of irrigation runoff potential indicates little or no runoff will occur, this category is not applicable (NA) and is given a rating of None (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 manure application site being evaluated

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

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 1.5	

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 your County Soil Survey Manual. Slope and soil permeability class must be determined, then runoff class can be determined (Table 2).

Table 2. Runoff Class

Slope %	Soil Permeability Class				
	Very Rapid (>20.00 in/hr)	Moderately Rapid (6.00-20 in/hr)and Rapid (2.00-6.00 in/hr)	Moderate (0.60-2.00 in/hr) and Moderately Slow (0.20-0.60 in/hr)	Slow (0.06-0.20 in/hr)	Very Slow (<0.06 in/hr)
	Runoff Class				
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

Soil Phosphorus Tests (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
Bray P1 Soil P Test	---	<30 ppm	30-60 ppm	60-120 ppm	>120 ppm		X 1.0	
Olson Soil P Test	---	<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 2-3 inches for continuous no-till cropland, hayland and pastures, and from the top 8 inches or less for tilled cropland.

Commercial Phosphorus 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	Surface applied >3 months before crop		X 0.5	

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, incorporation, and crop utilization.

Commercial Phosphorus 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 P_2O_5 lbs/ac	31-90 P_2O_5 lbs/ac	91-150 P_2O_5 lbs/ac	>150 P_2O_5 lbs/ac		X 0.5	

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).

Manure/Organic Phosphorus 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
Manure/ Organic P Source Application Method	None Applied	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 planting	Surface applied to pasture or >3 months before crop		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 phosphorus 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.

Manure/Organic Phosphorus 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
Manure/Organic P application Rate	None Applied	<30 P_2O_5 lbs/ac	31-90 P_2O_5 lbs/ac	91-150 P_2O_5 lbs/ac	>150 P_2O_5 lbs/ac		X 1.0	

The organic phosphorus source application rate is the amount, in pounds per acre (lbs/ac), of phosphate (P_2O_5) contained in manure, litter, or process wastewater that is applied. The amount of phosphate applied is based on tons per acre or gallons per acre applied and nutrient content can be estimated from manure, litter, and process wastewater tests or book values.

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	Runoff and sediment can not exit the site	>200 feet or functioning grassed waterways, or tile outlet terraces or sediment basins in concentrated surface water flow areas, or functioning grassed filter strips that are at least 100 feet wide	100-200 feet or functioning grass filter strips that are at least 35 feet wide that filter runoff from the field	<100 feet	0 feet (occurs on-site), or applications directly into concentrated surface water flow areas that occur within the application site		X 1.0	

This category is an estimate of distance between the application site and the point where runoff water concentrates, which includes natural and man-made conveyances within the application site that direct runoff into intermittent or perennial streams, lakes or other water bodies. Use zero for distance, if manure, litter, process wastewater, or fertilizer phosphorus is applied directly in concentrated flow areas that runoff directly into intermittent or perennial streams, lakes or other 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, tile outlet terraces, or sediment basins within concentrated flow areas that occur within the application site will reduce the risk of sediment-phosphorus loss due to concentrated water flow. Application setbacks from concentrated flow areas will reduce the risk of total phosphorus loss due to sheet flow. Grass filter strips are effective at reducing risk of sediment-phosphorus from sheet flow but do not effectively reduce the risk of loss of sediment-phosphorus in concentrated runoff.

Completing Risk Ratings

Each category-weighting factor in Table 3 is multiplied by the site risk rating to get a weighted value. All categories are rated (according to individual category instructions), and the overall risk rating is the sum of all values. After individual manure application sites/fields are rated (up to three sites), record the sites in the appropriate vulnerability-rating category in Table 4. Tables 3 and 4 are available in spreadsheet form on the internet at on eFOTG http://efotg.nrcs.usda.gov/efotg_locator.aspx?map=NE, found under Section IV under the Nutrient Management 590 standard.

Table 3. Phosphorus Index for Assessing Vulnerability of the Site (three sites can be evaluated on this form)

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		
Manure Application Site/Field No.												
Soil Erosion (1.5)	N/A	<5 tons/ac/yr	5-8 tons/ac/yr	9-12 tons/ac/yr	>12 tons/ac/yr				X 1.5			
Furrow Irrigation Erosion (1.5)	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	QS >6 for very erodible soils				X 1.5			
Sprinkler Erosion/Runoff (0.5) (Refer to Agronomy Tech Note 104 for more specific values and breakdowns on this category)	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 sprays on silty soils 8-15% slope, low spray on silt soils 3-8%, large spray on clay soils 3-15% slopes	Medium spray on clay soils 3-8% slopes, large spray clay soils >15% slope, medium spray on silt soils >15% slope	Medium spray on clay soils >8 slope, low spray on clay soils 3-8% , low spray on silty soils >15% slope	Low spray on clay soils >8% slope				X 0.5			
Runoff Class (1.5)	Negligible	Very Low or Low	Medium	High	Very High				X 1.5			
Bray P1 Soil P Test Olson Soil P Test (1.0)	---	<30 ppm Bray <20 ppm Olson	30-60 ppm Bray 20-40 ppm Olson	60-120 ppm Bray 40-80 ppm Olson	>120 ppm Bray >80 ppm Olson				X 1.0			
Commercial P Fertilizer Application Method (0.5)	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	Surface applied >3 months before crop				X 0.5			
Commercial P Fertilizer Application Rate (0.5)	None Applied	<30 P_2O_5 lbs/ac	31-90 P_2O_5 lbs/ac	91-150 P_2O_5 lbs/ac	>150 P_2O_5 lbs/ac				X 0.5			
Manure/ Organic P Source Application Method (1.0)	None Applied	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 planting	Surface applied to pasture or >3 months before crop				X 1.0			
Manure/ Organic P Application Rate (1.0)	None Applied	<30 P_2O_5 lbs/ac	31-90 P_2O_5 lbs/ac	91-150 P_2O_5 lbs/ac	>150 P_2O_5 lbs/ac				X 1.0			
Distance to concentrated surface water flow	Runoff and sediment can not exit the site	>200 feet or functioning grassed waterways, or tile outlet terraces or sediment basins in concentrated surface water flow areas, or functioning grassed filter strips that are at least 100 feet wide	100-200 feet or functioning grass filter strips that are at least 35 feet wide that filter runoff from the field	<100 feet	0 feet (occurs on-site), or applications directly into concentrated surface water flow areas that occur within the application site				X 1.0			
Site/Field Vulnerability Total (LOW <14; MEDIUM 14 – 27.5; HIGH 28 – 55.5; VERY HIGH > 55.5)												

Interpreting Results of Site Vulnerability Ratings and BMP Recommendations

After multiplying the weighting factor by the risk factor for each site category and totaling all values in Table 3, record the manure application sites in the appropriate vulnerability-rating category in Table 4.

Table 4. Site/Field Vulnerability to Phosphorus Loss

Total of Weighted Values	Site Vulnerability	Site/Field Number(s)
<14	LOW	
14 – 27.5	MEDIUM	
28 – 55.5	HIGH	
>55.5	VERY HIGH	

BMP Guidelines and Site Vulnerability Definitions

- LOW – This site has a LOW potential for 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 water resources.
- MEDIUM – This site has a MEDIUM potential for phosphorus movement from the site. There is a greater probability for an adverse impact to surface water resources than from a LOW rated site. Some remedial action such as using phosphorus management measures (i.e. filter strips, grassed waterways, application setbacks, injection or incorporation) should be taken to lessen the probability of phosphorus movement.
- HIGH – This site has a HIGH potential for phosphorus 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 phosphorus management measures (i.e., P-based manure application rates) should be taken to reduce the risk of phosphorus movement and probable water quality degradation.
- VERY HIGH – This site has a VERY HIGH potential for phosphorus 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 phosphorus movement. Soil and water conservation practices and a phosphorus management plan are needed to reduce the potential of water quality degradation.

Best management practices utilized to reduce phosphorus loss can vary from one site to the next. Site categories that have the highest weighted risk rating are the most critical factors impacting phosphorus loss. BMPs that reduce the risk rating of these factors are the most effective.

BMPs can include phosphorus management measures such as: planting high phosphorus-use crops; rotating manure application sites; reduced manure application rates; manure application setbacks from areas where runoff concentrates; application method (injection and 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.

OTHER CONSIDERATIONS

If the site is prone to flooding the potential of surface water degradation increases. Sites that frequently flood (more than once in two years) should be avoided as manure application sites. Most phosphorus loss occurs shortly after manure application when runoff occurs due to heavy rainfall. Phosphorus loss is significantly reduced if adequate time passes before runoff occurs. Grassed waterways are effective at removing sediment-borne phosphorus in concentrated surface water flow and filter strips are effective in reducing sediment-borne phosphorus in sheet flow.

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