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University of Maryland Phosphorus Management Tool: Technical Users Guide

The Phosphorus Index Concept

In 1990, a national cooperative workgroup of scientists from numerous universities and the United States Department of Agriculture (USDA) was organized to develop a procedure that could identify soils, farm management practices, and specific locations within a farm where phosphorus (P) losses in field drainage water may pose the potential for negative environmental impacts on nearby surface waters. The goals of this national work group were:

- To develop an easily used field rating system that rates farm fields according to the potential for P loss to surface water (the Phosphorus Index).
- To relate the P Index to the sensitivity of receiving surface waters to eutrophication and degradation resulting from nonpoint source P enrichment.
- To facilitate adaptation and modification of the P Index to regional and site-specific conditions.
- To develop agricultural management practices that will minimize the buildup of soil P to excessive levels and the transport of P from soils to sensitive water bodies.

The Objective of the University of Maryland Phosphorus Management Tool

Our objective was to develop a phosphorus site index (PSI) that uses readily available information to evaluate the relative risk of P transport from agricultural fields, including vegetable and row crop production and pasture based systems where P may be applied either as inorganic or organic fertilizer. Furthermore, the PSI should be applicable within all physiographic provinces present in Maryland. Phosphorus transport is controlled by site characteristics (e.g. hydrology and slope), climate, and P sources (e.g. manure, inorganic fertilizer, and soil P). The revised PSI, or the University of Maryland – Phosphorus Management Tool (UM-PMT), seeks to include new science relative to site and source factors and highlight management decisions so that the learning opportunities associated with performing a P index are more pronounced. The overall objective is to identify critical areas where there is a high P loss potential due to both a high transport potential and a large source of P, and also to encourage the use of management practices in those critical source areas that protect water quality.

Development of the University of Maryland – Phosphorus Management Tool

In 1994, we began the development of a P Index tool specifically tailored to Maryland's soils, agricultural management practices, climate, topography, hydrology, and surface water characteristics. The Maryland PSI was originally based on the generalized national model published in 1993 by the USDA's Natural Resources Conservation Service, but it has undergone many substantive changes and modifications during its development to more accurately reflect Maryland conditions.

An Overview of How the University of Maryland – Phosphorus Management Tool Works

Equation 1 presents the generalized equation for the new University of Maryland Phosphorus Management Tool (UM-PMT), which replaces the 2005 Maryland PSI. The UM-PMT calculates the risk of P transport through surface runoff (RUNOFF), subsurface discharge (SUBSURFACE), and particulate bound P (PARTICULATE). In Eq. 1, DBF represents the combined distance and buffer factors; DPR_r and DPR_{sub} are the dissolved P source risk factors for runoff and subsurface losses, respectively; SD is the subsurface drainage transport factor; SR is the surface runoff transport factor; and SED is the sediment transport factor derived from RUSLE or RUSLE2. The construction of each of these factors is discussed in detail below. In general, the new arithmetic construction captures the intent of the original P index. It still identifies the areas where high transport potential and high source are present, but it does so separately for each of the three major P transport pathways.

Equation 1. General equation for the University of Maryland – Phosphorus Management Tool.

$$
\begin{gathered}
UMPMT = 0.1 * (SUBSURFACE + RUNOFF + PARTICULATE) \\
Where \\
SUBSURFACE = SD * DPR_{sub} \\
RUNOFF = DBF * SR * DPR_r \\
PARTICULATE = DBF * SED * FIV
\end{gathered}
$$

Interpretation of the Final Scores

The final P loss ratings are divided into three interpretative categories: low, medium, and high. Fields that score less than or equal to 50 are considered to present a low potential for P movement from the site. However, since according to current Maryland state regulations, all fields evaluated by the UM-PMT have soil test P greater than 150 FIV, which is considered excessive by agronomic standards, some risk exists relative to potential build-up of soil P concentrations due to application of P in excess of crop needs. Therefore, it is recommended that total P applied in a three year period not exceed the anticipated three year crop removal rate for P based on realistic yield goals and published crop removal rates. The intent is to prevent further buildup of soil P and therefore increase risk.

Fields that score from 51 – 100 present a medium potential for P movement from the site. They likely have intermediate soil P concentrations and soil P saturation, combined with moderate transport potential in one or more transport categories. Therefore, the recommendation is to limit P application within a single year to a one year crop removal rate of P based on realistic yield goals and published crop removal rates. The intent is to prevent further buildup of soil P and also protect against incidental transfer of organic or inorganic nutrients associated with higher application rates.

Finally, fields scoring greater than 100 are considered to have a high potential for P movement. They likely have high soil P concentrations and soil P saturation combined with high transport potential. No P should be applied to these sites and active remediation techniques (e.g. crop drawdown of soil P, dissolved P filters, or drainage management) should be implemented in order to reduce the potential for P movement from the site.

Gathering All Appropriate Information

The following is a list of information needed to determine the UM-PMT, as well as the source from which to obtain the information.

Information Source #1: Farm Operator

- Soil-test P converted to Maryland Fertility Index Value (FIV) units from soil-test report
- Degree of P saturation (DPS_{M3}) predicted by Mehlich 3 from soil test report
- Amount, analysis and type of P fertilizer applied
- Application method and timing of P fertilizer application
- Amount and type of manure, compost or biosolids applied
- Application method and timing for manure, compost, or biosolids application
- Manure, compost, or biosolids analysis
- Type and width of vegetated field buffers
- Crop rotation sequence
- Tillage rotation sequence
- Conservation practices such as strip or contour cropping, buffer strips, etc.
- Artificial drainage areas (drainage ditches, tile drains, or mole drains)

Information Source #2: Web Soil Survey

- Predominant soil mapping unit in the field
- Soil permeability class
- Soil drainage class
- Hydrology soil group

Information Source #3: Field Visit

- Distance from edge of the field to the nearest down gradient surface water (feet)
- Slope of field (length and steepness)

Information Source #4: RUSLE or RUSLE2 Calculation Capability

- RUSLE "P" practices: ridge height, furrow grade, cover management condition, number of crop strips across RUSLE slope, width of crop and/or buffer strips

Supplies Necessary for Data Collection

The following is a list of supplies and equipment that are necessary for collecting P Site Index data:

- UM-PMT Technical Users Guide
- Maryland Nutrient Management Training Manual
- Web Soil Survey
- Clinometer or similar slope measuring device
- Measuring wheel or measuring tape

Calculating the UM-PMT

On the following pages are detailed instructions on how to calculate the three components of the UM-PMT and determine the final score.

Calculating the University of Maryland Phosphorus Management Tool

Combined Distance and Buffer Factor

Equation 2. Combined distance buffer factor calculation.

$$DBF = DF * BF$$

Equation 2 presents the calculation for the combined Distance-Buffer Factor (DBF). The DBF accounts for management and land cover of the intervening area between the managed field and surface water receiving runoff. The user should select the Distance Factor (DF) from Table 1 based on the distance from the edge of the field to the nearest body of surface water that receives surface discharge from the field. The user should also select the appropriate Buffer Factor (BF) from Table 2. The Distance-Buffer Factor (DBF) is applied to the transport components for dissolved P and particulate P in runoff, presented as RUNOFF and PARTICULATE in Eq. 1, respectively. The DBF will NOT be applied to subsurface transport (SUBSURFACE, Eq. 1), since subsurface transport of P is not controlled to the same extent by distance from water or intervening land cover as surface transported P.

Table 1. Distance from edge of field to surface water† and resulting distance factor.

Distance from Surface Water	Distance Factor (DF)
>500 feet	0.2
350 to 500 feet	0.4
200 to 349 feet	0.6
100 to 199 feet	0.8
<100 feet	1.0

†Surface water includes any permanent, continuous, physical conduit for transporting surface water, including permanent streams and ditches even if they only flow intermittently during the course of the year.

Table 2. Types of buffers† and resulting buffer factors that will modify the Distance Risk Factor to yield the combined Distance Buffer Factor.

Type of Buffer	Buffer Factor (BF)
>50 feet Permanent Vegetated Buffer Meeting USDA-NRCS Standards	0.8
>35 feet Permanent Vegetated Buffer	0.9
<35 feet Vegetated Buffer or No Buffer	1.0

†Permanent vegetated buffers do not receive any phosphorus applications.

Source Risk Factors for Dissolved Phosphorus

The RUNOFF and SUBSURFACE components from Eq. 1 describe the transport of dissolved P, which can originate from desorbable soil P or soluble P in organic or inorganic amendments. The UM-PMT includes separate dissolved P risk factors for the surface runoff (DPR_r) and subsurface discharge components (DPR_{sub}). The generalized form for both is presented in Equation 3.

Equation 3. Subsurface and runoff dissolved P source risk factor calculation.

$$DPR = WSP_{app} + (2 * DPS_{M3})$$

The subsurface and runoff dissolved P source risk factor (DPR_{sub} & DPR_r represent the combination of soluble P applied, the method it is applied by, and the amount of soluble P already in the soil (Eq. 5). DPR_r and DPR_{sub} are calculated by summing the water soluble P application factor (WSP_{app}) and two times the degree of P saturation (DPS_{M3}) predicted by Mehlich 3 extractable P, Fe, and Al as per Sims et al. (2002). The same value for DPS_{M3} should be used for both DPR_r and DPR_{sub}; however, WSP_{app} will be different for DPR_r and DPR_{sub}. Equation 4 describes the water soluble P application factor (WSP_{app}) that is used to represent the risk posed by the total amount of soluble P applied and the method used to apply it.

Equation 4. Water soluble phosphorus application factor for subsurface and runoff dissolved P source risk factor.

$$\sum_0^n WSP_{app-sub} = \sum_0^n PSC * TP * AM_{sub}$$
$$\sum_0^n WSP_{app-r} = \sum_0^n PSC * TP * AM_r$$

The WSP_{app} is calculated by multiplying the P source coefficient (PSC) for each source by the planned total P application rate (TP) for that source and the application method factor (AM_{sub} or AM_r). The AM represents the risk posed by the application method and is taken from Table 3 for DPR_{sub} and Table 4 for DPR_r. The WSP_{app} should be calculated separately for each planned P application (e.g. starter fertilizer, biosolids, manure) and then the separate WSP_{app} factors should be summed. This will account for the cumulative risk posed by the application of P at multiple times to both surface and subsurface discharge. The PSC's account for the varying solubility of different sources of P and are provided in Table 5 or the PSC can be determined individually by analyzing the amendment for WEP_{100} and using Eq. 5. If laboratory data is not available and an amendment is not listed in Table 5 then a standard PSC of 0.6 should be used. If calculating the actual PSC of an amendment using Eq. 5, the method described by Elliott et al. (2006) should be used, where WEP_{100} is the water-extractable P in the amendment (g kg^{-1}) determined in the laboratory using the method of Kleinman et al. (2007).

Equation 5. Phosphorus source coefficient calculation using water-extractable phosphorus concentration (Elliott et al., 2006).

$$PSC = 0.117 * WEP_{100}$$

Table 3. Phosphorus application method factor for subsurface transport component (AM_{sub}).

Application Method	Value
None Applied	0
Incorporated within 5 days with soil mixing (precludes straight aerator) March - Nov.	0.32
Incorporated within 5 days with soil mixing (precludes straight aerator) Dec. - Feb.	0.4
Surface applied and subsurface placement without soil mixing (includes banded fertilizer and injection without soil mixing) March - Nov.	0.64
Surface applied and subsurface placement without soil mixing (includes banded fertilizer) Dec. - Feb.	0.8

Table 4. Phosphorus application method factor for surface transport component (AM_r).

Application Method	Value
None Applied	0
Subsurface placement or immediate full incorporation (>90% residue)	0.2
Incorporated within 5 days of application (≥50% residue)	0.4
Surface applied March - Nov. OR incorporated after 5 days OR <50% residue	0.6
Surface applied or incorporated after 5 days Dec. - Feb.	0.8

Table 5. Standard phosphorus source coefficients for organic and inorganic amendments.

Organic P Source	PSC
Default	0.6
Inorganic P fertilizer	0.6
Swine manure	0.6
Other manures (beef, dairy, poultry, horse, etc.)	0.5
BPR & BNR biosolids	0.5
Alum-treated manures	0.3
Biosolids (all except BPR & BNR biosolids)	0.2

Subsurface Dissolved Phosphorus Discharge Component

The subsurface discharge component of the UM-PMT is presented as SUBSURFACE in Eq. 1 and represents the risk of dissolved P being transported to surface water through subsurface pathways. The calculation for this component is given in Eq. 6 below. If artificial drainage (e.g. ditches, tile drains) is present, then SUBSURFACE should be calculated. If artificial drainage is not present, then SUBSURFACE has a value of zero. SUBSURFACE is calculated by multiplying the subsurface drainage transport factor (SD) by the DPRsub (described above). The SD should be taken from Table 6, which is calculated by a matrix of the risk factors associated with soil drainage class and the hydrologic soil group. The user should select the hydrologic soil group and soil drainage class for the dominant soil type in the field and then determine the SD where the two intersect using Table 6.

Equation 6. Subsurface dissolved phosphorus discharge calculation.

$$SUBSURFACE = SD * DPR_{sub}$$

Table 6. The subsurface drainage transport factor (SD) is calculated as a function of hydrologic soil group and soil drainage class of the dominant soil type in the field.

		Hydrologic Soil Group			
		A	B	C	D
Soil Drainage Class	Risk Factor	**1**	**1.2**	**1.2**	**1**
Very Poorly Drained	**8**	8.0	6.7	6.7	8.0
Poorly Drained	**7**	7.0	5.8	5.8	7.0
Somewhat Poorly Drained	**6**	6.0	5.0	5.0	6.0
Moderately Well Drained	**5**	5.0	4.2	4.2	5.0
Well Drained	**6**	6.0	5.0	5.0	6.0
Somewhat Excessively Drained	**7**	7.0	5.8	5.8	7.0
Excessively Drained	**8**	8.0	6.7	6.7	8.0

Runoff Dissolved Phosphorus Component

The risk of dissolved P transport in overland flow is represented by the RUNOFF component of Eq. 1 and presented below in Eq. 7. It includes the DBF and the DPR_r, both described previously (Eqs. 2 and 3, respectively), which are then multiplied by the surface runoff transport risk factor (SR). The appropriate value for SR is where soil permeability class and slope of the dominate runoff generating area of the field intersect on Table 7.

Equation 7. Calculation for the runoff dissolved phosphorus component.

$$RUNOFF = DBF * SR * DPR_r$$

Table 7. Surface runoff transport risk factor (SR) based on field slope and soil permeability class.

	Soil Permeability Class† (inches/hour)				
Slope (%)	Very Rapid (> 20)	Moderately Rapid *and* Rapid (2.0 to 20)	Moderately Slow *and* Moderate (0.2 to 2.0)	Slow (0.06 to 0.2)	Very Slow (< 0.06)
Concave‡	0.10	0.10	0.10	0.10	0.10
< 1	1.20	1.40	1.60	1.80	2.00
1 – 5	4.20	4.90	5.60	6.30	7.00
6 – 10	4.80	5.60	6.40	7.20	8.00
11 – 20	5.40	6.30	7.20	8.10	9.00
> 20	6.00	7.00	8.00	9.00	10.00

†Permeability class of the least permeable layer within the upper 39 inches of the soil profile. Permeability classes can be obtained from Web Soil Survey.
‡Area from which no or very little water escapes by overland flow.

Particulate Phosphorus Component

Equation 8 presents the calculation for the particulate P component (PARTICULATE) of the UM-PMT. It is calculated as the product of the University of Maryland soil P Fertility Index Value (FIV), the combined distance-buffer factor (DBF, Eq. 2), and the Sediment Transport Factor (SED) value.

Equation 8. Particulate phosphorus transport component calculation.

$$PARTICULATE = DBF * SED * FIV$$

The Sediment Transport Factor (SED) value is determined by risk categories assigned to RUSLE or RUSLE2 scores and presented in Table 8. NRCS has moved to the use of RUSLE2 as their supported tool for predicting potential sediment loss from fields. However, in the interim as users learn RUSLE2, either RUSLE calculated within NuMan Pro software or the annual soil loss calculated by RUSLE2 for a field may be used in calculating UM-PMT.

Table 8. Distribution of RUSLE scores into risk based categories.

RUSLE or RUSLE2† "A" Value	SED Value
<1	2
1 – 2	4
2 – 3	6
3 – 4	8
>4	10

†Either RUSLE or RUSLE2 annual soil loss value in tons acre^{-1} may be used.

Interpretation of the Final Score

After calculating each individual part of the UM-PMT as described above, the three components should be summed and that sum multiplied by a scaling factor of 0.1 as described in Eq. 1. Table 9 should be used to determine the farm management implications of the final P loss rating. Users are encouraged to run the UM-PMT multiple times with different management strategies to arrive at an implementable management strategy providing the lowest possible P loss risk. It is important to understand that the P loss rating does not have a numeric, quantitative interpretation. The P loss rating conveys only a relative meaning. Those fields in the “Low” category are predicted to have a relatively lower potential for P losses than the fields in the “Medium” category and the fields in the “Medium” category are predicted to have a relatively lower potential for P losses than the fields in the “High” category.

Table 9. Interpretation of final UM-PMT score.

P Loss Rating	Generalized Interpretation of P Loss Rating
0-50	**LOW** potential for P movement from this site given current management practices and site characteristics. Soil P levels and P loss potential may increase in the future due to continued nitrogen-based nutrient management. Total phosphorus applications should be limited to no more than a three-year crop P removal rate applied over a three year period.
51-100	**MEDIUM** potential for P movement from this site given current management practices and site characteristics. Practices should be implemented to reduce P losses by surface runoff, subsurface flow, and erosion. Phosphorus applications should be limited to the amount of P expected to be removed from the field by the crop harvest immediately following P application or soil-test based P application recommendations.
> 100	**HIGH** potential for P movement from this site given current management practices and site characteristics. No phosphorus should be applied to this site. Active remediation techniques should be implemented in an effort to reduce the P loss potential from this site.

<u>University of Maryland Phosphorus Management Tool Worksheet</u>

Part 1. Combined distance-buffer factor used for surface runoff and particulate bound P components.

1.1	Distance Factor (DF)	Select the appropriate distance factor from Table 1 based on the distance from the edge of field to the nearest receiving body of water.	
1.2	Buffer Factor (BF)	Select the appropriate buffer factor from Table 2 describing the type of buffer on the down gradient edge of the field (nearest the surface water used for 1.1).	
1.3	**Combined Distance-Buffer Factor (DBF)**	**Multiply value from 1.1 by value from 1.2 and enter the product to the right.**	

Part 2. Particulate phosphorus component.

2.1	Combined distance-buffer factor (DBF)	Enter the value for DBF from box 1.3 to the right	
2.2	Phosphorus fertility index value (FIV)	Enter the soil test phosphorus value from the soil test report in University of Maryland Fertility Index Value (FIV) units	
2.3	Sediment transport factor (SED)	Use RUSLE in NuMan Pro or RUSLE2 to calculate the annual soil loss for the field in tons/acre. Using Table 8 enter the corresponding sediment transport risk value.	
2.4	**Particulate phosphorus risk component (PARTICULATE)**	**Multiply DBF (2.1) times FIV (2.2) times SED (2.3) and enter the product to the right**	

Part 3. Surface dissolved phosphorus source factor. Complete for each planned application and then sum. Add additional applications as needed. All P applications for the upcoming crop year should be included in the total.

3.1.a	PSC - First application	Enter the PSC from the Table 5 or calculate the PSC as described in Eq. 5	
3.1.b	Total P application - First application	Enter the total P application rate in lbs-P_2O_5/acre.	
3.1.c	Runoff application method (AM_r)	Enter the value from Table 4 that corresponds to the application method for this P application.	
3.1	**First P application factor**	**Multiply 3.1.a times 3.1.b times 3.1.c and enter the result**	
3.2.a	PSC - Second application	Enter the PSC from the Table 5 or calculate the PSC as described in Eq. 5	
3.2.b	Total P application - Second application	Enter the total P application rate in lbs-P_2O_5/acre.	
3.2.c	Runoff application method (AM_r)	Enter the value from Table 4 that corresponds to the application method for this P application.	
3.2	**Second P application factor**	**Multiply 3.2.a times 3.2.b times 3.2.c and enter the result**	
3.3	**Total P application factor (WSP_{app-r})**	**Sum 3.1 and 3.2 and any other application factors that were completed on separate sheets and enter the value in the space to the right**	
3.4	Degree of P saturation (DPS_{M3})	Enter the DPS_{M3} value from your soil test report.	
3.5	**Surface dissolved P source risk factor (DPR_r)**	**Multiply the DPS_{M3} value from box 3.4 by 2 and add the product to the WSP_{app-r} value in box 3.3**	

Part 4. Surface runoff dissolved phosphorus transport component.

4.1	Combined distance-buffer factor (DBF)	Enter the value for DBF from box 1.3 to the right	
4.2	Surface dissolved P source risk factor (DPRr)	Enter the value from box 3.5 to the right	
4.3.a	Soil permeability class	Using Web Soil Survey, enter the soil permeability class of the dominant soil type in the field	
4.3.b	Slope	Enter the percent slope of the dominate runoff generating area of the field in the box to the right. The slope should have been measured during the site visit.	
4.3	Surface runoff transport risk factor (SR)	Using the matrix in Table 7, enter the value that corresponds to the soil permeability class (4.3.a) and slope (4.3.b) for the dominate runoff generating area of the field	
4.4	**Runoff dissolved phosphorus risk component (RUNOFF)**	**Multiply the DBF (4.1) times the DPR_r (4.2) times the SR (4.3) and enter the product to the right**	

Part 5. Subsurface dissolved phosphorus source factor. Complete for each planned application and then sum. Add additional applications as needed. All P applications for the upcoming crop year should be included in the total.

5.1.a	PSC - First application	Enter the PSC from the Table 5 or calculate the PSC as described in Eq. 5	
5.1.b	Total P application - First application	Enter the total P application rate in lbs-P_2O_5/acre.	
5.1.c	Subsurface transport application method - First application (AM_{sub})	Enter the value from Table 3 that corresponds to the application method for this P application.	
5.1	**First P application factor**	**Multiply 5.1.a times 5.1.b times 5.1.c and enter the result**	
5.2.a	PSC - Second application	Enter the PSC from the Table 5 or calculate the PSC as described in Eq. 5	
5.2.b	Total P application - Second application	Enter the total P application rate in lbs-P_2O_5/acre.	
5.2.c	Subsurface transport application method - Second application (AM_{sub})	Enter the value from Table 3 that corresponds to the application method for this P application.	
5.2	**Second P application factor**	**Multiply 5.2.a times 5.2.b times 5.2.c and enter the result**	
5.3	**Total P application factor ($WSP_{app\text{-}sub}$)**	**Sum 5.1 and 5.2 and any other application factors that were completed on separate sheets and enter the value in the space to the right**	
5.4	Degree of P saturation (DPS_{M3})	Enter the DPS_{M3} value from your soil test report.	
5.5	**Subsurface dissolved P source risk factor (DPR_{sub})**	**Multiply the DPS_{M3} value from box 5.4 by 2 and add the product to the $WSP_{app\text{-}sub}$ value in box 5.3**	

Part 6: Subsurface dissolved phosphorus transport component.

6.1.a	Soil Drainage Class	Select the soil drainage class from the dominant map unit from Web Soil Survey and enter the appropriate risk factor from Table 6.	
6.1.b	Hydrologic Soil Group	Select the hydrologic soil group from the dominant map unit from Web Soil Survey and enter the appropriate risk Factor from Table 6.	
6.1	Subsurface drainage transport factor (SD)	Use the Soil Drainage Class (4.1.a) and Hydrologic Soil Group (4.1.b) risk factors entered above to find the appropriate Subsurface Drainage Transport Factor from Table 6.	
6.2	Subsurface dissolved P source risk factor (DPR_{sub})	Enter the value from box 5.5 to the right.	
6.3	**Subsurface dissolved P transport risk component (SUBSURFACE)**	**Multiply the value in box 6.1 (SD) times the value in box 6.2 (DPR_{sub}) and enter the product to the right**	

Part 7. Final University of Maryland Phosphorus Management Tool (UMPMT) calculation.

7.1	PARTICULATE	Enter the value from box 2.4	
7.2	RUNOFF	Enter the value from box 4.4	
7.3	SUBSURFACE	Enter the value from box 6.3	
7.4	**Final UM-PMT Score**	**Sum the values in boxes 7.1 - 7.3 and multiply the sum by 0.1. This is the final UM-PMT score. Use Table 9 to determine the final interpretative rating from this score.**	

References

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