$\underline{A}$nnual $\underline{P}$hosphorus $\underline{L}$oss $\underline{E}$stimator

User's Manual
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Model Description

APLE is a Microsoft Excel spreadsheet model that runs on an annual time step. The model simulates dissolved and sediment bound phosphorus (P) loss in surface runoff only. It does not consider subsurface loss of P through leaching or artificial drainage. It is intended to estimate edge-of-field P loss for uniform fields of several hectares in size, or smaller. **APLE** does not simulate P loss through grassed waterways or buffers that may occur beyond the field edge. The model will consider all kinds of animal manure (beef, dairy, poultry, swine), applied either by machine or by grazing beef or dairy cattle, but consider only highly soluble commercial fertilizers such as superphosphate, triple superphosphate, or mono- and di-ammonium phosphate.

APLE is intended to be user-friendly and does not require extensive input data to operate. All data are input into directly into the first worksheet labeled ***Data Entry and Results***. User-input data include:

- Soil property data, including depth of the top two soil layers, Mehlich-3 soil test P, soil clay content, and soil organic matter content
- The area of the field (ha)
- The annual rain, runoff, and erosion amounts
- The total annual crop P uptake
- When grazing animals are present, the total number of animal days in the field, including beef cattle and calves, dairy lactating and dry cows, and dairy heifers and calves.
- For manure applications, the manure amount applied, manure % solids, manure total P_2O_5 content, % of manure total P that is water extractable P, the % of manure that is incorporated, and the depth of incorporation.
- For fertilizer applications, the mass of fertilizer P applied, the % of fertilizer that is incorporated, and the depth of incorporation.

Data Input and Description

The model runs in a Microsoft Excel spreadsheet. All data required for the model to operate are input directly into the spreadsheet on the ***Data Entry and Results*** page. The following describes the input variables needed.

Variable Name	Definition

Soil Properties

Depth of Soil layers	The model is intended to simulate processes in only the topsoil, but can simulate two layers in the topsoil. This is intended to estimate P stratification (i.e., significantly different P concentrations in different soil layers) in soils with no or limited tillage. This would be important for pastures or no-till soils where more P might accumulate in the top 1 inch of soil than deeper in the topsoil. The depth in inches to the bottom of each of the two layers in the topsoil should be entered. The first layer could be a depth such as 1 or 2 inches, while the second layer depth could be 6 or 8 inches. APLE will return error messages if

the top layer is less than 1 inch or the bottom layer is not deeper than than the top layer.

If only one topsoil layer is to be simulated, the depth of the first layer should be set to the entire thickness of the layer desired (e.g., 0-6 inches). The bottom layer should be set to a similar thickness (e.g., 6-12 inches.

Mehlich 3 Soil P	This is the soil test P content in ppm for the two simulated soil layers. The model is currently designed based on Mehlich 3 soil extraction data. Other soil test data should be converted to a Mehlich 3 equivalent. For these modeling purposes, it can be assumed that Mehlich 3 P is equal to Bray-1 P, and twice as much as Mehlich-1 P, Olsen P, Fe-oxide strip extractable P, and anion exchange resin extractable P.
Soil Clay	This is the clay content in % of the two soil layers. These data are used to estimate the PSP value that controls soil P transformations. It is therefore important to have accurate soil clay data. However, testing of the model has shown some inaccurate soil P predictions for low clay soils (<10%) that still have significant P sorption capacity, such as sandy soils with significant amounts of iron or aluminum. In these cases, soil clay should be set at about 10% to make sure the model still accounts for adequate P sorption.
Soil OM	This is the organic matter content in % of the two soil layers. These data are used to estimate the PSP value that controls soil P transformations. It is therefore important to have accurate soil organic matter data.
Field Area	This is the area in acres of the field being simulated. Field area is only used when calculating manure application from grazing animals. If no grazing animals are present, the value entered is not critical. However, the cell should not be left blank or set to 0 because that will cause errors in calculations.

Transport

Rain	Enter the total annual precipitation (rain, snow, and irrigation) in inches.
Runoff	Enter the total annual surface runoff in inches. The user has to estimate this value. For poorly drained soils, annual runoff may be 30-40% of total annual precipitation. For well drained soils, annual runoff may be only 5-10% of annual precipitation.

Sediment Loss   Enter the total annual erosion rate in ton/acre. The user has to estimate
                             this value. Well established pastures may lose only 0.1 ton/acre of
                             soil, while highly erosive soils may lose 7-8 tons/acre of soil per year.

Annual Crop P

Crop P Export   Enter the total annual crop P export in lb/acre. This is P that is
                             actually removed from the field in harvested products. For typical row
                             crops with high yields, this value may be 25 lb/acre. For double crops,
                             the value may be greater, while for poorly yielding crops or pastures,
                             the value may be only 5-10 lb/acre.

Grazing Animals   Enter the total number of grazing animal days in each category. For
                             example, if 50 lactating cows grazed for 20 days, the value entered
                             should be 1000 (50x20).

Manure Applications

The following information is for both solid manure applications and liquid manure applications.
Manure application information should be entered in the appropriate season. This is important
because applications in the fall affect P loss estimates in the following year. ***For this model, solid
manures are defined as manures with 15% solids or greater. Liquid manure applications with less
than 15% solids should not be entered into the solid manure category because the model calculates
P loss in runoff differently for the two manure forms***.

Manure Applied   Enter the application rate in wet ton/acre for solid manures and
                             gallons/acre for liquid manures. For liquid manures, the rate of
                             application will determine how much of the manure P infiltrates into
                             soil at application. This will reduce the amount of manure P that will
                             be lost in runoff, so it is important to enter an accurate value.

Manure Solids   Enter the solids content of the manure. This value is used only to
                             determine if the manure has enough liquid that will cause significant
                             immediate infiltration of manure P into the soil. For values less than
                             15% solids, the model assumes that a portion of the manure P applied
                             immediately infiltrates into the soil. This will reduce the amount of
                             manure P that will be lost in runoff, so it is important to enter an
                             accurate value.

Manure P_2O_5 Enter the total P_2O_5 content of the manure applied in either lbs/wet
                             ton for solid manures or lbs/1000 gallons for liquid manures. Be sure
                             to enter P_2O_5 content and not P content. Total P is typically measured
                             by digestion of a manure sample, such as Kjeldahl digestion. If
                             measured data are not available, typical manure total P contents can
                             be taken from literature sources such as Kleinman et al. (2005).

Manure WEP/TP   This is the % of manure total P that is in a water-extractable form
                             (WEP). For this model, manure WEP can be measured by shaking

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fresh manure with de-ionized water at a dry weight equivalent, water to manure solids ratio of 250:1 for 1 h, filtering extracts through 0.45-um filters, and measuring P in filtrates colorimetrically. Manure water extraction data are becoming more common (Bundy et al., 2004; (Kleinman et al., 2005; Vadas and Kleinman, 2006), but most extractions will not use the procedure required for our model, particularly the 250:1 extraction ratio. However, data from any extraction ratio can be extrapolated to estimate manure P at a 250:1 ratio using regression figures relating extraction ratio to extractable P in Vadas et al. (2005). Default values can be used, including 50%, for dairy and beef manure, 20% for poultry manure, 35% for swine manure, and 10% for manures amended to reduce soluble P (such as poultry litter amended with alum).

Manure Injection — Enter either 1 or 2 to indicate if liquid manure is injected without tillage. APLE determines how much of the manure P actually enters the soil based on application rate, with the idea that liquid manures cannot be effectively injected at high rates (e.g., 25000 gallons per acre) and the manure P essentially remains in the soil surface.

Manure Incorporated — Enter the % of total manure applied that is incorporated into the soil either by tillage. Table 1 at the end of the document lists values for common tillage equipment.

Depth of Incorporation — Enter the depth in inches to which manure is directly injected or tilled into the soil. Enter the deeper depth if injection and tillage both occur, although this is unlikely.

Fertilizer Applications

Fertilizer P_2O_5 Applied — Enter the total amount of commercial fertilizer P_2O_5 applied in lb/acre. Be careful to enter the amount of P_2O_5 applied and not the amount of P applied (P is 44% of P_2O_5) or the amount of fertilizer mass applied.

Fertilizer Incorporated — Enter the % of fertilizer incorporated into the soil either by injection or by tillage. Table 1 at the end of the document lists values for common tillage equipment.

Depth of Incorporation — Enter the depth in inches to which fertilizer is directly injected or tilled into the soil.

Degree of Soil Mixing — This variable determines how much the two soil layers are mixed together each year, either by tillage or by natural processes, and also how much P added in fertilizer or manure gets mixed into the second soil layer. For pastures or no-till soils, there is still soil mixing even though no tillage occurs. A value such as 10-15% should be entered for such soils. For tilled soils, Table 1 lists values for common tillage

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equipment. If multiple tillage implements are used in a year, a value should be entered for the tillage operation that causes the most mixing. If the deepest depth of tillage is less than the depth of the first soil layer, than a value that is appropriate for no-till soils should be entered. Practically, this value should never be 0.

Model Output

The table at the bottom of the ***Data Entry and Results*** worksheet displays annual output results in lb/ac for eroded sediment P loss; soil, manure, and fertilizer dissolved P loss; and total dissolved and total P loss. Values are given for each of the ten years simulated. Values are also given for soil test P (Mehlich-3) at the end of the year for both topsoil layers and the entire topsoil with both layers combined. On the ***Output Graphs*** worksheet, two graphs visually depict the same output data described above.

References

Bundy, L.G., J.S. Studnicka, and, J.M. Powell. 2004. Manure handling and extraction procedure effects on determination of water-extractable phosphorus in manures. *In* 2004 Agronomy Abstracts. ASA, Madison, WI.

Kleinman, P.J.A., A.M. Wolf, A.N. Sharpley, D.B. Beegle, L.S. Saporito. 2005. Survey of water-extractable phosphorus in livestock manures. Soil Sci. Soc. Am. J. 69:701-708.

Vadas, P.A., P.J.A. Kleinman. 2006. Effect of methodology in estimating and interpreting water-extractable phosohorus in animal manures. J. Environ. Qual. 35:1151-1159.

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Table 1. Tillage implement, incorporation efficiency, and mixing efficiency of common tillage implements.

Implement	Incorporation Efficiency	Mixing Efficiency
Anhydrous ammonia applicator	0.05	0.05
Bedder-lister	0.95	0.05
Burn	0.00	0.00
Chisel	0.10	0.05
Cultivator-field (Hoeme)	0.10	0.10
Cultivator--row	0.10	0.10
Digger--peanut	0.05	0.05
Digger--potato	0.15	0.05
Disk harrow-offset	0.85	0.60
Disk harrow--tandem	0.75	0.50
Disk hiller	0.30	0.05
Disk plow	0.80	0.40
Disk plow -- one way	0.50	0.50
Do-all	0.10	0.25
Drill--deep furrow (dempster)	0.30	0.05
Drill--small grain	0.05	0.05
Harrow--spike tooth	0.05	0.05
Harrow--spring tooth	0.05	0.05
Moldboard plow	1.00	0.25
Paraplow	0.05	0.05
Planter--in-row chisel	0.05	0.05
Planter--knife, disk, sweep	0.05	0.00