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THE NEBRASKA PHOSPHORUS INDEX: BACKGROUND AND USERS GUIDE

The purpose of this Technical Note is to provide consultants and experienced planners with a tool to aide in determining land treatment needs and manure management measures on land application sites. The P Index (http://cnmp.unl.edu/cnmpsoftware2.html) to be used has been developed as a spreadsheet. This tool is also available on eFOTG under Section IV, Tools, Phosphorus_Index_2006. This tool will assess the relative risk of phosphorus (P) movement into surface water from a manure application site, identify appropriate best management practices (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 the Background Paper and Users Guide developed in conjunction with the new P-Index. The new P-Index is an adaptation of the multiplicative Iowa P-Index.

This tool can also be used to compare the relative risk of P loss of one site versus another. Factors such as P soil test levels, P management practices (rate, timing and method of application), runoff, soil erosion, sediment delivery and other factors impact the potential for P loss. Reducing runoff and erosion is also important to maximize nutrients available for crops. Appropriate 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).

THE NEBRASKA PHOSPHORUS INDEX (2005): BACKGROUND AND USERS GUIDE

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This publication provides the basis and procedure for use of phosphorus (P) index to assess risk of P delivery from agricultural land to surface waters. The P Index is intended for planning as well as regulatory and educational purposes.

Phosphorus is an essential nutrient for crop growth and for the growth of aquatic vegetation. Phosphorus, either in inorganic form such as with fertilizer or in organic form as with animal manures, often needs to be applied to the land for optimal crop growth. An important by-product of animal feeding is manure that contains P. Land application of manure can be beneficial to crop production but can result in increased risk of P loss to surface waters. Phosphorus indexes are tools for the assessment of the potential for P delivery from agricultural lands to surface waters. Effective January 1, 2007, operators of large concentrated animal feeding operations (CAFOs) in Nebraska need to assess the risk of P delivery to surface waters from each field receiving manure. This assessment needs to be done once every five years.

The Nebraska P Index (2005) is a tool for risk assessment, land management planning, education of factors contributing to P loss, and regulation of P application to agricultural land. The Nebraska P Index (2005) was developed through the integration of concepts from an earlier Nebraska P Index (Kucera, 2000; revised in 2004); (http://www.ne.nrcs.usda.gov/technical/CNMP/NE_CNMP_Livestock.html), an index developed for Iowa (Iowa NRCS, 2004); (http://www.ia.nrcs.usda.gov/technical/Phosphorus/phosphorusstandard.html); and recent research findings.

The P Index considers source and transport factors to estimate P loss to surface waters. The source factors allow assessment of the quantity and forms of P present at the site (Table 1). The transport factors allow assessment of the potential for transport of P from the site to a water body.

The P Index was designed to be used on the basis of a whole field or management units within a field. In many fields, risk of P loss is often considerably greater for part of a field than for the whole field and it may be economically and environmentally advantageous to do the P loss risk assessment by zones within fields.

The Structure of the Nebraska P Index (2005)

The worksheets

The P index (http://cnmp.unl.edu/cnmpsoftware2.html) is developed as a spreadsheet to ease calculations. Tabs to these worksheets are found at the bottom of the screen.

1. **Nebraska P-Index** is the worksheet of greatest concern to the user. All data is entered here and the results are presented.
2. **Summary** contains the summarized results of P index evaluations for up to six fields. The records are numbered one to six and coincide with the run number at the top of the Nebraska P-Index worksheet.
3. **Ephemeral** contains two tools for estimating sediment loss due to ephemeral gully (3- to 18-inch depth) erosion. The first tool calculates an estimate of ephemeral gully erosion

after entering values for total length of all ephemeral gullies in the field and their average width and depth. The second tool automatically estimates ephemeral erosion based on the rate of sheet and rill erosion location, location in the state, and conservation practices. The user can access this from the **Nebraska P-Index** worksheet by clicking on the word **Estimate** next to the cell for Ephemeral Erosion in the spreadsheet.

4. **Landform Regions** contains a list and map of Nebraska showing the regions. The user can access this from the **Nebraska P-Index** worksheet.
5. **Code 393** is the NRCS standard for filter strips. The user can access this from the **Nebraska P-Index** worksheet.

The components

The P index has erosion and runoff components which integrate source and transport factors to give component risk values. The irrigation and manure components modify the risk values for the erosion and runoff components. An estimate of sheet and rill erosion is calculated once data entry for a field is completed. The sum of the risk value of both the erosion and runoff components is the P index score. It is shown in the lower right part of the **Nebraska P-Index** worksheet in the red box.

The **erosion component** (potential delivery of sediment P to surface water) gives an approximate estimate of the P delivered in sediment (lb P/ac/yr) which will eventually be available for use by aquatic vegetation (Mallarino et al., 2002). It assumes that 70% of sediment P will become bio-available to aquatic vegetation over a long period of time. The erosion component is a function of 6 factors.

1. Rate of sheet and rill erosion is estimated in tons per acre per year (t/ac/yr). This value can be determined by one of the two methods:
    a. This erosion rate may be best estimated with RUSLE2 but other means of estimating erosion, such as the Universal Soil Loss Equation or RUSLE1, may be acceptable.
    b. The Nebraska P-Index (2005) does calculate an estimate of sheet & rill erosion as a function of county precipitation, cropping system, tillage practices, conservation practices and irrigation. This estimate is accurate enough for most fields.
2. Ephemeral gully and classic gully erosion (t/ac/yr) are estimated and prorated over the whole field or management unit. The P index provides two tools for estimation of ephemeral gully erosion; see the section on the **Ephemeral** worksheet.
3. The sediment delivery ratio is estimated in consideration of land form and mean distance from the center of the slopes feeding runoff water to a water body or perennial or intermittent stream lying adjacent to or in the field, or to the nearest road ditch or other man-made conveyance lying outside the field that directs runoff water into intermittent or perennial streams, lakes or other water bodies.
4. Use of conservation practices is indicated by selection from a drop-down list and credit is given to their sediment trap efficiency.
5. Phosphorus enrichment of runoff is estimated considering tillage, surface cover, and buffer strip width.
6. Soil test P (STP; Bray-P1, Mehlich 3, or Olsen) is used to estimate total soil P (TP). The equations for medium and fine textured soils are TP = 400 + (2.5 x STP) when using the Bray-P1 or Mehlich-3 soil test and TP = 400 + (3.6 x STP) when using the Olsen test. For sandy soils, TP = 250 + (2 x STP) with the Bray-P1 or Mehlich-3 and TP = 250 + (3 x STP) with the Olsen test.

The **runoff (water loss) component** estimates the amount of dissolved P (orthophosphate P and other dissolved P) delivered with runoff water (Mallarino et al., 2002). It is a function of:

1. Mean county precipitation and percent of rainfall events that are greater than 0.75 inch;
2. Runoff curve numbers which are calculated from soil property information, land use, and management practices;
3. An estimate of dissolved soil P (DP) estimated from soil test P where DP = 0.05 + (STP x 0.005); and,
4. P application rate, time and method.

The **irrigation component** considers sprinkler and furrow irrigation. The runoff P risk factor is increased by 10% with sprinkler irrigation due to increased runoff potential should a heavy rainfall event occur when the soil is wet following irrigation. Risk with furrow irrigation is primarily due to increased erosion potential and the irrigation erosion factor is determined considering soil erodibility, rate of water flow (gal/min/furrow), furrow slope, use of polyacrylamide (PAM), and the presence of a re-use pit for recycling of irrigation water (Table 2).

The erosion and runoff components are adjusted by the **manure component** which accounts for beneficial effects on soil properties due to previous applications of manure. The values for the erosion and runoff components are reduced by 2% per ton of the mean annual rate of manure application on a dry weight basis.

Interpretation of the P loss ratings

The P index risk value is the sum of the erosion and runoff components. The risk scores fall into four risk levels: Low, Medium, High and Very High.

P-Index Risk		Water Quality Concerns	Manure Application Rates
Scores	**Levels**		
0-2	Low	❖ Low water quality impairment due to Agricultural P pollution with current practices.	➢ Can be applied at rates sufficient to meet crop N needs.
2-5	Medium	❖ Delivery of agricultural P may cause some water quality impairment. ❖ Consideration should be given to alternative conservation and P management practices.	➢ Can be applied at rates sufficient to meet crop N needs.
5-15	High	❖ Phosphorus loss from the field causes much water quality impairment. ❖ Remedial action, such as alternative conservation measures or P management practices, is required.	➢ Can be applied, but P applied should not exceed crop P removal. ➢ Can be applied to meet a crops N need but total P applied in one or more applications during a five-year period, but P applied should not exceed crop removal during that five-year period.
>15	Very High	❖ Impairment of water quality is extreme and remedial action is urgently recommended.	➢ P application should be discontinued. ➢ Improved conservation measures should be implemented.

Using the Nebraska P Index (2005)

Information is needed for each field or management unit within a field in order to calculate a P index value. Table 3 or a equivalent form can be used for collecting the necessary information. The information may be obtained from the client, records, reports, and observations. The information is entered into the white cells of the **Nebraska P-Index** and **Ephemeral** worksheets. Values in yellow boxes are calculated based on information entered in the white boxes or selected from drop-down lists. The phosphorus index value will appear in the red box. Throughout the **Nebraska P-Index** worksheet are **Notes** which give further explanation; move the cursor over the red triangle (upper right of word **Note**) and a message will open.

1. At the top of the Nebraska P-Index worksheet, enter appropriate information, including field name; option if one or more assessments are done for a field such as to evaluate alternative management practices; person using the P index; and the client. The run number (1-6) is normally assigned automatically. It can be specified, for example, to revise the record of a previous assessed field.
2. Select the **County** in which the field is located from a dropdown list. The P index then accesses relevant rainfall and soils information.
3. From the **Soil Type** dropdown list, select the predominant soil unit, including the correct slope class, for the field.
4. **Gross Erosion** is determined next.
    a. Give an estimate of mean annual loss of soil to **Sheet & Rill Erosion** for this field/management unit. The estimate might be determined using RUSLE 2 (*http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm*) or by other means, or obtained from the local NRCS office. The P Index has an erosion calculator which produces an estimate once all other information for the field has been entered. To use this option, leave the sheet and rill estimate blank until other data has been entered, and then click on “Use estimate” next to the erosion estimate found on the right side of the **Nebraska P-Index** worksheet.
    b. Give estimates for **Ephemeral and Gully Erosion** for the full management unit and the number of acres in the management unit. Clicking on **Estimate** next to **Ephemeral** provides guidance & two options for estimating ephemeral erosion.
    c. An estimate for **Classic Gully** erosion can be given. If such a gully exists in the field and has not been well stabilized, e.g. with perennial vegetation, seek assistance to estimate the mean annual rate of erosion due to cutting the gully wider, deeper and/or longer. Select a relevant **Conservation Practice** such as terraces from the dropdown list.
5. Select a relevant **Conservation Practice** such as terraces from the dropdown list.
6. For Landform Region, select the correct part of Nebraska by clicking View Map and Choose. Click on a digit of the white number on the map for the correct landform region, and you will be returned to the main worksheet.
7. Enter the average distance in feet for the drainage basin lying in a management unit to the nearest intermittent or perennial stream, canal or road ditch, or to another surface water body nearer than the channelized flow. More details are provided in the associated **Note**.
8. Select the **Grassed Filter Strip Width** from the dropdown list. A **Note** as well as a **hot link** to the NRCS 393 Standard provides information on filter strips.
9. Move to the top of central part of the **Nebraska P-Index** worksheet.
10. There are three dropdown lists for **Tillage and Cropping System**. In the **Tillage 1** dropdown list, select to indicate if the field is tilled, no-tilled, or in perennial vegetation.

This choice affects the options offered in the **Tillage 2** and **Cropping System** dropdown lists. The **Notes** further define tillage and cropping system choices.

11. For soil test P, select **Phosphorus Test** method (Bray-P1, Mehlich 3, or Olsen) from the dropdown list and enter the P test result for the 0-8" depth.
12. Enter the mean annual **Application Rate** for Phosphate in fertilizer and organic materials, e.g. manure, compost, and bio-solids. Select the application time and method from the dropdown list.
13. Select **Type of Irrigation** from the dropdown list. If furrow is selected, enter **flow rate** in gallons per minute per furrow and **furrow slope**.
14. Enter a value for **Manure Component**. It is explained in the associated **Note** that this is the mean annual rate of application on a dry weight basis (tons per acre per year, dry weight) and an example calculation is given.
15. The calculated partial P index values are given in yellow boxes for the **Erosion Component** and **Runoff Component**.
16. Upon filling the white boxes on the P index spreadsheet, view the **Erosion Estimator Value**. If you wish to use this as your sheet and rill erosion value, click on the "use estimate" gray box. If using the Option #2 for the Ephemeral Estimate, go to Operation #2 in the **Ephemeral** worksheet and click on the "Transfer" button to receive the value in the **Nebraska P-Index** worksheet.
17. The overall **P Index Value** is given in the red box on the lower right side of the worksheet. If you have used the Erosion Estimator for Sheet & Rill Erosion & the P Index value borders on a risk class, e.g. between 14 to 16, you will received a message indicating that actual RUSLE2 values should be used for a more accurate erosion estimate.
18. Click on the **Summary** button to create a summary report. Click the Summary worksheet tab to go to this worksheet in order to view, save and pint one or more summaries.

Repeated scenarios can be run for a field, changing management practices to assess the effectiveness of various management practices and combinations of practices. Each scenario is given a name and the data from the previous scenario can be carried forward so that only the variable or variables that are changed for the new scenario need to be entered. Detailed outputs for these scenarios are tabulated in a worksheet that can be saved and printed for further study.

Using the P Index to Compare Management Scenarios: An Example

Consider the information presented in Table 3 for a hypothetical field to create a base scenario. For the information given, the P index score is 5.36 with a risk rating of High. Let's consider the effects of several alternatives on the base scenario; after each change, return to the base scenario before making another change.

1. If manure application continues, and Bray P is increased to 160 ppm, the P index score is 5 with a risk rating of *High*.
2. If the land has tile inlet terraces, the P index score is 0.88 with a risk rating of *Low*.
3. If 25 ft buffer strips are established between this field and concentrated water flow or the surface water body, the P index score is 4.62 with a risk rating of *Medium.*
4. If the manure is incorporated within 24 hours of application and assuming no increase in erosion, the P index score is 5.34 with a risk rating of *High*.
5. If distance from the middle of the sub-field to concentrated water flow is reduced from 600 to 150 ft, the P index score is 7.41 with a risk rating of *High*.

Table 1. Source and Transport Factors That Contribute to the Potential for P Loss from Agricultural Lands to Surface Waters.

Site & Management Factors	**Transport Factors[1]**
Soil P level P application practices including time, rate and method of application Field management practices such as tillage practices and use of cover crops	Runoff volume Erosion from rainfall and snowmelt events and from irrigation events Distance from P source to concentrated water flow or a water body

[1] Other possible transport factors that are not considered in the Nebraska P index include: surface and sub-surface drainage; percolation and under-ground movement of P to seepage areas; and atmospheric deposition that may be associated with wind erosion. These are relatively minor transport factors, as compared to runoff volume and erosion, for P delivery from fields to surface waters in Nebraska.

Table 2. Factor Values for Erosion Risk with Furrow Irrigation.

Furrow Flow Rate / **Furrow Slope**	**Soil Erodibility**											
	Very Erodible Soil[1]				**Erodible Soil[2]**				**Erosion Resistant Soil[3]**			
	<0.5 %	0.5-1.0%	1.0 - 1.5%	>1.5%	<0.5 %	0.5-1.0%	1.0 - 1.5%	>1.5 %	<0.5 %	0.5-1.0 %	1.0 - 1.5%	>1.5%
Gallons/min	----------rating----------											
<5	1.5	1.5	12.0	12.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
10	1.5	12.0	12.0	12.0	1.5	1.5	6.0	6.0	1.5	1.5	3.0	3.0
15	12.0	12.0	12.0	12.0	1.5	6.0	6.0	6.0	1.5	3.0	3.0	3.0
>20	12.0	12.0	12.0	12.0	6.0	6.0	6.0	6.0	1.5	3.0	3.0	3.0
If irrigated field includes tail water pit with total recapture, use a rating of 0. If polyacrylamide (PAM) is used, use a rating of 1.5												

[1]Very erodible soils (silt, fine and very fine sandy loam, loamy fine sand, loam, and very fine sand soils)
[2]Erodible soils (silt loam soils)
[3]Erosion resistant soils (silty clay, clay, and clay loam soils)

Table 3. Data Form with Required Variables for P Index. Assessment May Be Whole Field Basis or Management Zones in Fields.

Field Name	Run	County	Soil Type & Slope	[1]Sheet & Rill Value (T/ac/yr)		Field Area (ac)	[2]Ephemeral Erosion (ft)			[3]Conserv. Practice	Distance to Water or Conc. Flow (ft)	Filter Strip Width (ft)
				RUSLE-2	EE		Length	Width	Depth			
W 1/4	*1*	*Colfax*	*Nora si cl l 6-11 %*			*40*	*200'*	*1.0'*	*0.5'*	*none*	*600*	*7*

[1]Sheet & Rill Value – Use either RUSLE2 or Erosion Estimator (EE) calculations. If P-Index value is border line risk categories, then use RUSLE2 calculations
[2]Ephemeral Erosion – Complete if using actual field measurements.
[3]Conservation Practices – Grade stab. Full flow; level terrace; pond & grad stab; tile inlet terraces; water & sediment control basin; grass waterway.

Tillage	Crops	Soil P		Mean P Application		Sprinkler Irrigation	[4]Furrow Irrigation				[6]Mean Manure Application Dry wt. (T/Yr)
		Test	ppm	(lbs P_2O_5)	Method		Rate (gpm)	Furrow Slope	[5]PAM	Reuse Pit	
Tillage	*Corn/Bean*	*Bray1*	*95*	*100*	*Surf. app.*	*No*	*NA*	*NA*	*NA*	*NA*	*10*

[4]Furrow Irrigation – Enter flow rate in gallons per minute per furrow.
[5]PAM – polyacrylamide
[6]Mean Manure Application Dry Wt. (T/yr) = Example: If 80 Ton Manure Applied in 4 years at 50% Dry Matter Basis (from manure analysis), then = (80 T x 0.5)/4 yr = 10 T/yr