# The Pennsylvania Phosphorus Index: Version 1

# User Documentation

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## Introduction to the PA P Index

Phosphorus (P) has been of concern to farmers and other water quality stakeholders for some time. Excess nutrients, particularly phosphorus in freshwater, increases biological activity in water systems, thereby speeding up the process called eutrophication. Eutrophication is the most common reason for impairment of surface waters for fishing, recreation, industrial and domestic water uses.

While concerns about eutrophication, and the potential environmental impact of P, have existed and been part of management recommendations for some time, concerns with nitrogen (N) have received more attention. As scientific evidence clarifying the importance of phosphorus in water quality protection grew and concerns about impaired uses of surface water increased, public policy makers turned more attention to phosphorus management.

In early 2003, the USEPA adopted new regulations for Concentrated Animal Feeding Operations (CAFOs) that require nutrient management plans to address both N and P. Regulations to implement these federal requirements are currently being developed for Pennsylvania. Also, in 2003, PA NRCS implemented the 590 Standard for Nutrient Management, consistent with the NRCS national standard for nutrient management. This national standard requires nutrient management plans that address both N and P farmers receiving financial or technical assistance from USDA. In 2004, the Pennsylvania State Conservation Commission (SCC) proposed revised regulations for the Pennsylvania Nutrient Management Act (Act 6) that would include a phosphorus component. Also, in May 2004 the SCC adopted an interim policy that requires all nutrient management plans to include a P component. All of these programs currently or will require that P be included in nutrient management planning. The approach that is used in all of these programs in Pennsylvania is the Phosphorus Index (P Index).

### The Phosphorus Index

The P Index is a field evaluation tool that was developed to identify areas that have a high vulnerability or risk of phosphorus loss to surface water bodies. The Pennsylvania P Index was developed by scientists at the USDA-ARS Pasture Systems and Watershed Management Research Unit at University Park, PA and Penn State University College of Agricultural Sciences. It is the outcome of a major state and regional effort as part of an international research and development endeavor to produce a management approach that protects water quality from phosphorus pollution and enables sustainable, economic animal agricultural production.

This tool combines indicators of P sources and of P transport. The P source factors used in the Pennsylvania P Index are the Mehlich-3 soil test P, P fertilizer application rate and method, and manure P application rate, method, and P availability. The transport factors used are soil erosion, runoff potential, subsurface drainage, distance to a water body, and an evaluation of management practices that impact how phosphorus is potentially lost from a field. These factors are combined in a simple calculation to arrive at a P Index value for the field. The P Index value indicates whether the manure application rate may be limited and/or other management practices may be required to address phosphorus concerns. Other management practices may include installation of best management practices to reduce transport potential, such as common erosion control

practices or buffers. Alternatively, changes in the time or method of manure application may reduce the risk of P loss to the point where manure can be applied.

The P Index is an effective method of addressing phosphorus in manure applications because it addresses P loss from croplands by focusing on the critical factors found to impact P loss. The P Index identifies those fields that are likely to affect water quality by the loss of soluble and insoluble P and limits application rates or directs the implementation of other management practices, as the situation warrants.

**Where to Get a Copy of the P Index**

The P Index is available as a factsheet, *Pennsylvania Phosphorus Index: Version 1* from Penn State Cooperative Extension and on the web at: http://pubs.cas.psu.edu/freepubs/pdfs/UC180.pdf A P Index Microsoft Excel Spreadsheet is also available for download from the Pennsylvania Nutrient Management Program Web site at: http://panutrientmgmt.cas.psu.edu/pdf/phosphorus_index_spreadsheet.XLS

**Using the P Index**

A nutrient management plan that addresses both N and P, using the P Index, generally begins with the evaluation of a N based nutrient management plan. It does not require starting from scratch. The starting point for using the P Index is to develop a N-based nutrient management plan for the farm. This is the same plan that has been required in the past for the programs listed above. The P Index is then used to evaluate the N based plan to determine if this plan represents significant risk of P loss to the environment. The information in the P Index can then be used to select management alternatives to address these concerns. For more information, refer to the example on page 12.

**Overview of Information Required for the P Index for each Crop Management Unit**

Table 1 below provides a list of the information required for each crop management unit to run the P Index. A significant amount of this information comes directly from the N based plan and the rest comes from existing sources that should be available for each farm. Details on these items are given in following sections of this document.

Table 1. Information required for the PA Phosphorus Index

| Information | Source of information |
|---|---|
| Field Map of the land for the plan | Taken directly from the N based plan |
| Mehlich 3 P Soil Test values (ppm) | Taken directly from the soil test reports every three years |
| Distance to water | Estimated from maps or measured in the field |
| Fertilizer P to be applied (lb $P_2O_5$ /A) | Taken directly from the N based plan |
| Method of fertilizer P application | Taken directly from the N based plan |
| Manure P to be applied (lb $P_2O_5$ /A) | Taken directly from the N based plan |
| Method of manure P application | Taken directly from the N based plan |
| Manure P source availability coefficient | Table 1 in P Index Factsheet |
| Erosion (ton soil loss/A) | Taken from farm conservation plan or calculated using the Revised Universal Soil Loss Equation (RUSLE) |
| Runoff Potential | Based on soil type determined from the County Soil Survey and PA USDA-NRCS Surface Index Runoff Classes tables |
| Subsurface Drainage | Determined from the farmer interview or farm conservation plan |
| Modified Connectivity | Determined from the farmer interview and/or field inspection |

## Crop Management Units

A critical issue in using the P Index is determining what area of land can be included in each crop management unit in the plan. In nutrient management plans that only address N, it has been a common practice to combine fields with similar management histories into crop management groups. The actual location of the fields was not critical as long as they had similar histories and would be managed the same in the nutrient management plan. However, location and topography of a field are important in the P Index as other factors such as: distance to water, erosion, runoff potential, and modified connectivity may be very different for fields within an N based crop management group. When using the P Index, combining fields requires that it can be shown that all of the factors in the P Index are the same for the individual fields and the crop management unit. If the crop management unit is divided, all of the individual fields must have the same P Index inputs as the aggregate crop management unit. **If the P Index factors are not all the same for a proposed crop management group, then the worst case scenario must be used for the whole group.** For example, if one field in a group is close to water and has a high erosion potential then **all** of the fields in that group would have to be considered to be close to water and have a high erosion potential in the P Index regardless of their actual properties. Therefore, it is best in a using the P Index to collect the information on a field-by-field basis and then determine if the factors used in the P Index would be all the same for a group of fields.

Often there is considerable variability within fields, thus the same approach is used within a field. Part of a field may be a high risk for P loss while another part of the field may be a low risk. For the P Index, you must use the worst case part of the field to determine the P Index. There may be situations where it would be advantageous to split a field into subfields for P management. For example, a field may have a relatively small steep sloping area near to a stream. For the P Index, the whole field would be considered to be steep sloping and near to the stream. Splitting off this small area and deciding to manage it differently (e.g. applying less manure or applying manure at a different time or in a different way in this area, etc.) may remove P based restriction on the rest of the field.

## Frequency of P Index Evaluation

Most nutrient management plans are written for multiple years. For example, Act 6 nutrient management plans are written for a three year period. The P Index can be applied to a multiple year period as long as all of the factors in the P Index stay the same for all years. If any changes in management will occur during the plan cycle, it must be determined if this will impact the P Index. For example, if the crop changes in a field, the N based manure rate or method of application may change which could in-turn change the P Index. Thus for a given field, the plan may require several P Index evaluations and may required different management in certain years during the plan. Fortunately, many of the factors in the P Index are constant ie. distance to water, runoff potential, subsurface drainage, modified connectivity and even erosion unless major changes are made in BMPs. Soils tests are required in Act 6 on the same frequency as planning (every three years), thus there is no need to change the soil test value within a

planning cycle. Therefore, doing the evaluation for individual years is simply a matter of changing the fertilizer and/or manure P application information.

***Following is a detailed description of each factor in the PA P Index. At the beginning of each section in the shaded box is the relevant section from the P Index.***

## Part A: Screening Tool

The screening tool uses the soil test level (Mehlich-3 ppm P) and the contributing distance of field to assess if a more complete evaluation using Part B is needed.

**PART A: Screening Tool**

User's Note: If a field has a soil test level greater than 200 ppm Mehlich-3 P or is within 150 feet of a water body, then continue with Part B.

| | | |
|---|---|---|
| Field ID | | |
| Soil Test Mehlich-3 P | Greater than 200 ppm P | |
| Contributing Distance | Less than 150 ft. | |

The evaluation criteria are as follows:

> If a field has a Mehlich-3 soil test P level greater than 200 ppm P or is less than 150 ft. from a receiving body of water, then the field must be evaluated using Part B of the P Index.
>
> If the field has a Mehlich-3 soil test P level less than 200 ppm P and is not within 150 ft of a receiving body of water, the nitrogen-based management is recommended for this field.
>
> See *Soil Test Mehlich 3 P* and *Contributing Distance* sections for further guidance in using Part A.

The use of the screening tool is not appropriate for all fields. The approach in Part A of the P Index is to use the soil test, which reflects P management history, as an indicator of current management assuming a relatively stable management system. However, when the current planned practices do not match with the historical practices this assumption is not valid. The most common reason that soil test P levels do not reflect current manure P application is that there has been a change in management made on the farm. Usually this means that manure applications in the plan being evaluated are significantly higher than historical rates. The types of management changes that would result in this discrepancy are generally obvious and often include addition of new lands to or expansion of the agricultural operation. An additional reason for this type of discrepancy is that the soil test P level is close to, but does not exceed the 200 ppm Mehlich-3 threshold. In this case, if the current P application rate is maintained, the soil test threshold of 200 ppm Mehlich-3 P will most likely be reached by the next soil sampling.

## Part B: Source Factors

### Soil Test

| Soil Test | Soil Test P (ppm Mehlich-3 P) | |
|---|---|---|
| Soil Test Rating = 0.20 x Soil Test P (ppm Mehlich-3 P) | | |

*Soil Test*

The soil test level is the Mehlich 3 extractable phosphorus in parts per million (ppm). This is taken directly from the soil test report.

Penn State Soil Test Report P Results

| SOIL NUTRIENT LEVELS | | | Below Optimum | Optimum | Above Optimum |
|---|---|---|---|---|---|
| [1]Soil pH | 6.3 | | | | |
| [1]Phosphorus (P) | 20 | ppm | | | |
| [1]Potassium (K) | 80 | ppm | | | |
| [2]Magnesium (Mg) | 60 | ppm | | | |

All commercial labs that do business in Pennsylvania offer the Mehlich 3 soil test as their standard test or as an alternative test on request and report the soil test P value in mg/kg. However, if needed, the following factors can be to convert Mehlich 3 results in other units to Mehlich 3 results in ppm:

mg P/kg = ppm P
lb P/A ÷ 2 = ppm P
lb $P_2O_5$ /A ÷ 4.6 = ppm P

*Soil Test Rating*

The Mehlich 3 soil test P value in ppm is multiplied by 0.2 to get the Soil Test P Rating in the P Index. This calculation adjusts the soil test value to give it the appropriate weighting in the P Index relative to the other source factors.

### Fertilizer

| Fertilizer Rate | Fertilizer P (lb $P_2O_5$/acre) | | | | | |
|---|---|---|---|---|---|---|
| Fertilizer Application Method | 0.2<br>Placed or injected 2" or more deep | 0.4<br>Incorporated in less than 1 week | 0.6<br>Incorporated after 1 week or not incorporated April to October | 0.8<br>Incorporated after 1 week or not incorporated November to March | 1.0<br>Surface applied during frozen or snow-covered conditions | |
| Fertilizer Rating = Fertilizer Rate x Fertilizer Application Method | | | | | | |

*Fertilizer Rate*

This is the rate in pounds per acre $P_2O_5$ of fertilizer phosphorus that will be applied to the field. This can be determined directly or by multiplying the fertilizer P analysis as a fraction time the amount of fertilizer that will be applied. For example: If a farmer applies 150 lb/A of a 10-20-10 starter fertilizer, the calculation would be as follows:

150 lb/A x 20% $P_2O_5$ = 30 lb $P_2O_5$ /A

For a liquid fertilizer such as 5 gal per acre of 10-34-0 liquid fertilizer as a starter, the calculation must also include a volume (gallons) to weight (pounds) conversion. To do this conversion the weight per gallon of the fertilizer must be known. Fertilizer dealers should be able to provide this information. Thus for this example with 10-34-0 fertilizer which weighs 11.68 lb/gal., the calculation would be as follows:

5 gal/A x 11.68 lb/gal x 34% $P_2O_5$ = 20 lb $P_2O_5$ /A

Information on P fertilizer application rate should be available directly from the N based plan.

*Fertilizer Application Method*

Select the category that is closest to the planned fertilizer application method from the list in the P Index and enter the factor for that category:

FERTILIZER APPLICATION METHOD

| 0.2 | 0.4 | 0.6 | 0.8 | 1.0 |
|---|---|---|---|---|
| Placed or injected 2" or more deep | Incorporated <1 week following application | Incorporated > 1 week or not incorporated following application in April - October | Incorporated >1 week or not incorporated following application in Nov. - March | Surface applied to frozen or snow covered soil |

Following is additional information on these categories:

| | | |
|---|---|---|
| Placed or injected 2" or more deep | – | The most common example of this would be starter fertilizer P that is placed several inches deep in the soil with the planter. This category only applies with immediate injection. Application followed by mechanical incorporation would fall in the next category. |
| Incorporated <1 week following application | – | This would be mechanical incorporation of the fertilizer with primary or secondary tillage within 1 week following application. This does not include incorporation by rainfall. |
| Incorporated > 1 week or not incorporated following application in April – October | – | Choose this category if mechanical incorporation is done more than 1 week following application or if there is no incorporation of fertilizer applied in April to October. |
| Incorporated >1 week or not incorporated following application in Nov. – March | – | This category is similar to the previous category except it applies for application in November through March. |
| Surface applied to frozen or snow covered soil | – | Choose this category if the fertilizer is applied on frozen or snow covered soil. |

*Fertilizer Rating*

The fertilizer rating is calculated by multiplying the *Fertilizer rate* times the *Fertilizer Application Method Factor.*

If more than one fertilizer application is made on a given field, calculate the *Fertilizer Rating* with the rate and method for each individual fertilizer application and then add these together to arrive at the final *Fertilizer Rating* for the field.

## Manure

| Manure Rate | Manure P (lb $P_2O_5$/acre) | | | | | |
|---|---|---|---|---|---|---|
| Manure Application Method | 0.2 Placed or injected 2" or more deep | 0.4 Incorporated in less than 1 week | 0.6 Incorporated after 1 week or not incorporated April to October | 0.8 Incorporated after 1 week or not incorporated November to March | 1.0 Surface applied during frozen or snow-covered conditions | |
| Manure P Availability | Refer to Table 1: Organic Phosphorus Source Availability Coefficients | | | | | |
| Manure Rating = Manure Rate x Manure Application Method x Manure P Availability | | | | | | |

*Manure Rate*

This is the rate of manure phosphorus that will be applied to the field in pounds per acre $P_2O_5$. This can be determined by multiplying the manure P analysis, directly from the manure analysis report times the amount of manure that will be applied. Typically, this will be the actual planned manure rate based on balancing N. Because manure analyses are reported in different units by different labs, be careful with units. The most common units for manure analysis are lb/1000 gal, lb/100 gal, and lb/ton, all on an as sampled basis.

For example: If a farmer applies 7000 gal per acre of dairy manure with an analysis of 13 lb $P_2O_5$ /1000 gal, the calculation would be as follows:

7000 gal/A x 13 lb $P_2O_5$ /1000 gal = 91 lb $P_2O_5$ /A

Information on manure P application should be available directly from the N based plan or can be calculated as shown above from information in the N based plan and the manure analysis.

*Manure Application Method*

This is the same as the methods for fertilizer application. Select the category that is closest to the planned manure application method from the list in the P Index and enter the factor for that category:

MANURE APPLICATION METHOD

| 0.2 Placed or injected 2" or more deep | 0.4 Incorporated <1 week following application | 0.6 Incorporated > 1 week or not incorporated following application in April - October | 0.8 Incorporated >1 week or not incorporated following application in Nov. - March | 1.0 Surface applied to frozen or snow covered soil |
|---|---|---|---|---|

Following is additional information on these categories:

| | | |
|---|---|---|
| Placed or injected 2" or more deep | – | This category would only apply to directly injected manure such as with a chisel or disk injector. Application of manure followed by mechanical incorporation would fall in the next category. |
| Incorporated <1 week following application | – | This would be mechanical incorporation of the manure with primary or secondary tillage within 1 week following application. This does not include incorporation by rainfall. |
| Incorporated > 1 week or not incorporated following application in April – October | – | Choose this category if mechanical incorporation is done more than 1 week following application or if there is no incorporation of fertilizer applied in April to October. |
| Incorporated >1 week or not incorporated following application in Nov. – March | – | This category is similar to the previous category except it applies for application in November through March. |
| Surface applied to frozen or snow covered soil | – | Choose this category if the fertilizer is applied on frozen or snow covered soil. |

*Manure P Availability*

The manure P availability factor accounts for the availability of P to be lost directly from the manure to runoff. It is not related to manure P crop availability. The appropriate availability factor is select based on the type of manure from Table 1 in the P Index or below. For other types of manure not listed in the table a default value of 1.0 should be used. This table will likely be updated over time. Please check for updates at: panutrientmgmt.cas.psu.edu.

Organic Phosphorus source availability coefficients

| | |
|---|---|
| Swine | |
| Swine slurry | 1.0 |
| Poultry | |
| Broiler | 0.8 |
| Layer | 0.9 |
| Turkey | 0.9 |
| Duck | 0.9 |
| Dairy | |
| Liquid | 0.9 |
| Bedded pack | 0.8 |
| Beef | 0.8 |
| Alum treated manure | 0.5 |
| Biosolids | |
| Biological nutrient removal | 0.8 |
| Alkaline stabilized | 0.4 |
| Conventionally stabilized | 0.3 |
| Composted | 0.3 |
| Heat-dried | 0.2 |
| Advanced-alkaline stabilized | 0.2 |

*Manure Rating*

The manure rating is calculated by multiplying the *Manure P rate* x *Manure Application Method Factor* x *Manure P Availability.*

If more than one manure application is made on a given field, calculate the *Manure Rating* with the rate, method and availability for each individual manure application and then add these together to arrive at the final *Manure Rating* for the field.

## Source Factor


The overall source factor is calculated by adding the *Soil Test Rating* + *Fertilizer Rating* + *Manure Rating*. These are the shaded lines in the P Index.

## Part B: Transport Factors

### Erosion

| Erosion | Soil Loss (ton/acre/year) | |
|---|---|---|

The erosion rate estimates soil loss based on crop management, tillage practices, regional location, and best management practices. The erosion value for the P Index is calculated using the Revised Universal Soil Loss Equation (RUSLE) and is reported in tons/acre/year by Pennsylvania USDA-NRCS as a part of the conservation plan development process. For the P Index, the actual (A) erosion value should be used and not the tolerable (T) soil loss value. If the A value is not a part of the current and implemented farm conservation plan, contact your regional nutrient management coordinator (see Contacts for Additional Information).

### Runoff Potential

| Runoff Potential | 0<br>Very Low | 2<br>Low | 4<br>Medium | 6<br>High | 8<br>Very High | |
|---|---|---|---|---|---|---|

Surface runoff potential is based on the USDA-NRCS Index Surface Runoff Class. The Index Surface Runoff Class values are classified into Very Low, Low, Medium, High, and Very High using a combination of soil properties. To facilitate the incorporation of this factor into the P Index, the Pennsylvania USDA-NRCS has developed Runoff Class tables for each county. These tables are available at: http://panutrientmgmt.cas.psu.edu/rp_runnoff_tables.htm

When determining the appropriate Surface Runoff Potential category for a field, first determine the predominate soil type in the field. Then use the surface index runoff class table for the county in which you are working, find the predominate soil type, and determine the surface index runoff class value. Finally, choose the corresponding category in the P Index. If soil is listed with two different surface index runoff class values, select the more restrictive of the two values. For example, if a Low and Medium class are listed, select the Medium value for use in the P Index evaluation.

### Subsurface Drainage

| Subsurface Drainage | 0<br>None | | 1<br>Random | | 2**<br>Patterned | |
|---|---|---|---|---|---|---|

**Or a rapidly permeable soil near a stream

Subsurface drainage accounts for the presence of artificial drainage in a field. There are three options provided in the P Index: None, Random, and Patterned. None refers to a field that has no artificial drainage. Random applies to fields with one or more isolated drains that address wet conditions in a section(s) of a field. Patterned applies to fields that have multiple connected drains designed to address conditions across an entire field. The patterned drainage will not commonly be found in areas outside of northwest Pennsylvania.

In determining the appropriate category, the type of subsurface drainage needs to be determined using farm maps, farm records, or information from the farmer interview. The appropriate P Index category can then be selected.

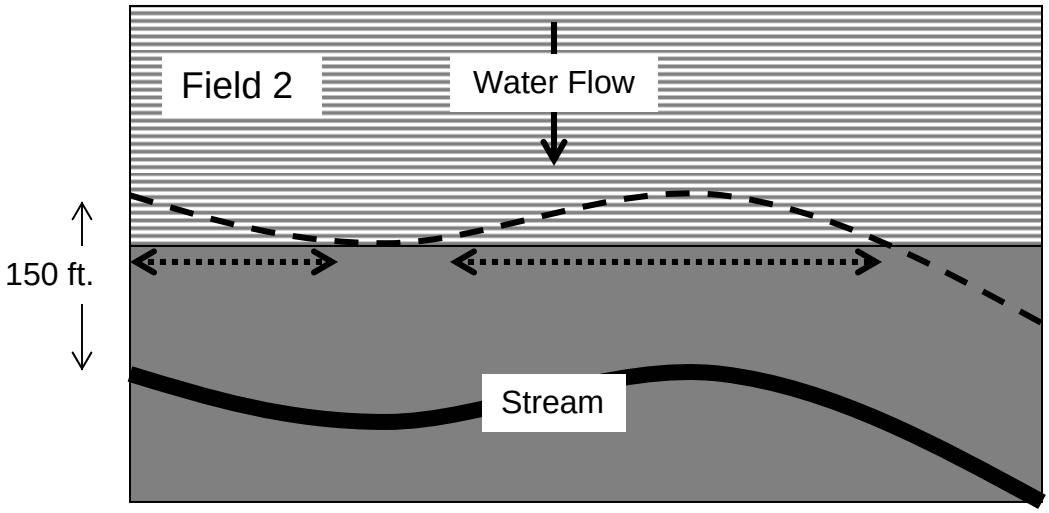
An additional consideration for subsurface drainage is whether or not a rapidly permeable soil exists near a receiving body of water. If this type of soil exists, the appropriate category to select is Patterned. Soils in this category must be: 1) identified as such in the soil survey and 2) be within 150 ft. of the receiving body of water. These soils are most commonly found in the northeastern region of Pennsylvania.

**Contributing Distance**

| Contributing Distance | 0<br>> 500 ft. | 2<br>500 to 350 ft. | 4<br>350 to 250 ft. | 6<br>150 to 250 ft. | 8<br>< 150 ft. | |
|---|---|---|---|---|---|---|

Contributing distance determines how far a field is from a receiving body of water. The distance categories were developed using landscape properties in combination with the potential occurrence of storms with varying intensities. The closer a field is to a receiving body of water, the more likely it is that P leaving the field will reach the body of water.

To determine the contributing distance for a field, the lower edge of the field boundary is used. It is necessary to determine how the P Index distance categories correspond with the farm field boundaries. This is most easily done by plotting distance lines at 150, 250, 350, and 500 ft. on a farm map with field boundaries and receiving bodies of water delineated. Then determine which distance category accounts for a majority (50% or more) of the lower edge of the field in the direction of water flow. In the example below, more than 50% of the lower boundary of Field 2 (dotted arrows) is within the 150 ft. line thus this field would be in the <150 ft category in the P Index.



This is the same evaluation criteria used in Part A and distance determinations must be consistent in Parts A and B. Therefore, a field designated within 150 ft. in Part A must also be within 150 ft. in Part B.
In this determination a receiving body of water can include: ponds, lakes, and streams with channels (bed and bank). Other conveyances such as ditches are accounted for in the Modified Connectivity section of the P Index.

## Transport Sum

| Transport Sum = Erosion + Runoff Potential + Subsurface Drainage + Contributing Distance | |
|---|---|

The *Erosion, Surface Runoff Potential, Subsurface Drainage, and Contributing Distance* factors are summed. This is represented by a shaded line in the P Index.

## Modified Connectivity

| Modified Connectivity | 0.7 Riparian Buffer *Applies to distances < 150 ft.* | | 1.0 Grassed Waterway OR None | | 1.1 Direct Connection *Applies to distances > 150 ft.* | |
|---|---|---|---|---|---|---|

The previous transport factors account for the landscape or inherent properties of field that influence P transport and with the exception of erosion cannot be changed. However, the modified connectivity factor accounts for management practices that can change, inhibiting or facilitating, how P moves from the field to the receiving body of water.

If a field is within 150 ft. of the receiving water body, it is necessary to determine if a riparian buffer designed to meet Pennsylvania USDA-NRCS Practice Standards 390 (Herbaceous Riparian Cover), 391(Forested Riparian Buffer), or 393 (Filter Strip) is present. If a buffer has not been designed by Pennsylvania USDA-NRCS, but appears to be functioning as if it were, it must be certified by Pennsylvania USDA-NRCS to receive credit in the P Index.

If a field is outside of 150 ft. of the receiving water body, it is necessary to evaluate whether there is a direct connection that takes the runoff and erosion leaving a field and artificially places into or near the receiving body of water. These direct connections can include: ditches (without channels) and pipe outlets. Additionally, the location of the pipe or ditch outlet is important. If the outlet is into a grassed or area covered with vegetation, it is not a direct connection. However, if the outlet is directly into the receiving body of water or an area with no vegetation, it is a direct connection.

**In considering this factor, it is important to remember that buffers apply to fields within 150 ft. of a receiving body of water and direct connections apply to fields at distances greater than 150 ft.**

A grass waterway is considered as a special case of a direct connection. Even though it is a form of a direct connection, if properly designed and maintained, a grass waterway should reduce sediment and P transport thus it is not counted as a direct connection in the P Index.

## Transport Factor


The *Transport Sum* is multiplied by the *Modified Connectivity* value and this product is divided by 22. Twenty-two is the maximum *Transport Sum* value and dividing by this value allows the Transport Factor to vary generally between 0 and 1. One is the point at which the full (100%) field transport potential is reached. Any other value would represent a percentage of the field's full transport potential. The transport factor only exceeds 1 when erosion losses are exceptionally high. This is represented by a shaded line in the P Index.

## P Index Calculation and Interpretation


The final P Index for a field is calculated by multiplying the *Source Factor* x *Transport Factor* x *2.* The factor of 2 is simply used to put the P Index values on a scale from 0 being "Very Low" to anything over 100 being "Very High". The P Index rate is a relative rating of the vulnerability or risk of P loss to surface water bodies. The calculated P Index value can then be interpreted using Table 2 from the Pennsylvania P Index (See below).

**Table 2. Phosphorus index management guidance. (From Pennsylvania Phosphorus Index: Version 1).**

| Value | Rating | Management Guidance |
|---|---|---|
| 0 to 59 | Low | **Nutrients can be applied to meet the Nitrogen crop requirement.** *Low* potential for P loss. Maintenance of current farming practices is recommended to minimize the risk of adverse impacts on surface waters. |
| 60 to 79 | Medium | **Nutrients can be applied to meet the Nitrogen crop requirement.** *Medium* potential for P loss. The chance for adverse impacts on surface waters exists. An assessment of current farm nutrient management and conservation practices is recommended to minimize the risk of future P losses. |
| 80 to 99 | High | **Nutrients can be applied to meet the Phosphorus crop removal.** *High* potential for P loss and adverse impacts on surface waters. Soil and water conservation measures and P-based management plans are needed to minimize the risk of P loss. |
| 100 or greater | Very High | **No Phosphorus can be applied.** *Very high* potential for P loss and adverse impacts on surface waters. Conservation measures and a P-based management plan must be implemented to minimize the P loss. |

In addition to providing an indication of the relative risk of P loss, the P Index ratings set a limit on the nutrient application. At Low or Medium ratings the nutrient applications can be based on an N balance that is the amount of available N from all sources cannot exceed the N requirement of the crop. In these categories standard best management practices for manure management should be followed. Even though the limits are the same for Low and Medium, the Medium range indicates a higher risk of adverse impact on surface water and is a warning that management practices should be evaluated to make sure that the risk of P loss does not increase. Things to consider are the manure application rate, timing and method of manure application and the adequacy and function of conservation practices.

At the High rating nutrient applications are limited to the lower of the N or P balanced rate, that means the total of all P applications must be reduced so that no more P is applied than will be removed by the current crop. This will significantly reduce the amount of P applied compared to an N balanced rate and should not result in further buildup of soil P. Other management practices such as timing and method of manure application and conservation practices should also be considered. In some cases these other changes in management may lower the risk, and thus the P Index, to the point where the manure application rate is not restricted to the P removal rate. Because the manure application rates based on P balance can be very low and sometimes not practical for manure application equipment, up to three years of P crop removal may be applied in one application with no manure applied in the following 2 years. However, there are several important limitations. First, the manure rate cannot exceed the rate based on N balance under any circumstance. Second, the higher rate must be evaluated in the P Index and if this multi-year rate causes the P Index to go into the Very High rating for that year, this rate cannot be applied. Then the maximum rate would be whatever rate resulted in a P Index value below the Very High category.

A Very High rating indicates a very high risk of P loss. No P from any source can be applied to a field with a Very High P Index rating. Even if P is not applied, management practices, such as soil conservation practices, should be evaluated to make sure that P is not lost from the field. As with the high category, changing management practices such as manure rate, timing or method of application may also reduce the P Index at least to the High range where some manure could be applied.

At a High or Very High rating, the planner should go back to the individual factors in the P Index to determine why the overall P Index value is in that category. This information can then be used as a guide to changes in management that might reduce the risk of P loss to surface water. For example, a high manure source rating may be reduced by changing the time or method of manure application. Or a high erosion factor may be reduced by implementing conservation practices. Thus, the final P based plan for a field that has a High or Very High P Index rating will likely be an iterative process involving changing management in the plan and reevaluating the P Index to make sure that the plan is within the limitations specified in Table 2. This process may have to be repeated several times until an acceptable combination of practices is found.

To meet the requirements for a nutrient management plan in Pennsylvania the P Index calculation for the final planned applications on a crop management unit must be included in the plan. The planned management must be consistent with this final P Index value and interpretation reported in the plan. For example, if the final P Index in the plan has a high value, the P applied in the plan must not exceed crop P removal. The initial P Index calculation and any interim calculations that are done as part of the planning process are not required and probably should not be included with the plan, as they may cause confusion with the farmer or the plan reviewer.

**Example: Integrating the P Index into a Nutrient Management Plan**

The following example will illustrate how to use the P Index in developing a Nutrient Management plan. The first step is to determine which fields will need to be evaluated using Part B of the P Index. This determination is made using Part A or the screening tool of the P Index. Part A requires the user to determine if the soil test P level for the field is greater than or equal to 200 ppm Mehlich 3 P or if the field is within 150 ft. from water. If either of these criteria are met, the field may be a risk for P loss which require management changes and therefore must be evaluated using Part B of the P Index. In the following examples, the results of the Part A evaluation are included as the "P Index Part A Summary" columns. Once the Part A evaluation is completed, begin allocating manure to fields as you would in an N based plan. As the manure is being allocated on an N basis, the fields identified as requiring evaluation using Part B need to be addressed. Usually, a preliminary allocation based on N is done and then this proposed allocation is evaluated by completing the Part B of the P Index using the information from this proposed N based plan for the crop management unit. If the P Index Rating from Part B is Low or Medium, then no changes are required and the proposed N based management can be used on this field. You must however, include the Part B P Index evaluation, showing all inputs, with the N base plan information for verification. If the P Index is High or Very High the application rate and manure allocation must be modified accordingly.

Following is a section from a nutrient management plan illustrating how the P Index is integrated into nutrient management plan development using three common scenarios. In *scenario (1)*, the Part B evaluation will show that the N based plan is acceptable and all that is required is proper documentation. In *scenario (2)*, the Part B evaluation using an N based rate results in a High P Index rating. However, modifying the manure management by changing the timing of application lowers the P Index Value and Rating allowing for the application of manure using an N based rate. Finally, in *scenario (3)*, the Part B evaluation using an N based rate results in a Very High P Index rating. In this case, the only practical management option is to reduce the planned manure rate.

Scenario 1

The Part A evaluation directed the planner to complete a Part B evaluation of Field 13. For this field, the manure allocation information from the proposed N based plan for this field (see Field 13 below), is entered into the P Index (see page 14). Using the information from the N based plan, the Part B evaluation resulted in a P Index value of 51 which is Low and means that that "Nutrients can be applied to meet the Nitrogen crop requirement". Therefore, no change is required in this field. The nutrient management plan must include the P Index calculation (see page 14), with all inputs, to document that the N based rate is acceptable.

Manure allocation and associated nutrient application summary for Field 13 (taken from the N based nutrient management plan).

| | | | | | | | Other Fertilizer Planned | | | Supplemental Fertilizer | | Final Nutrient Balance | | | P Index Part A Summary | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Field | Acres | Crop | Manure Group | Application Season | Incorporation | Planned Rate (gal or ton/A) | N (lb/A) | P2O5 (lb/A) | Method | N (lb/A) | P2O5 (lb/A) | N (lb/A) | P2O5 (lb/A) | | Soil Test P (ppm) | Distance < 150 ft. | Part B Req'd | P2O5 Applied at planned rate (lb/A) |
| 11 | 6.8 | corn silage>Leg | Spring Dairy | Spring | None - Rain 5-7 days | 6000 | 10 | 20 | Starter | 0 | | (2) | (92) | | 78 | No | | |
| 12 | 2.9 | old alfalfa | | | | | 0 | 0 | | 0 | | 0 | 0 | | 102 | No | | |
| 13 | 2.9 | corn silage | Spring Dairy | Spring | None - Rain 5-7 days | 6000 | 10 | 20 | Starter | 65 | | 3 | (92) | | 256 | No | X | 72 |

P Index Evaluation, Part B for Field 13.

| **PART B: SOURCE FACTORS** | | | | | | **Field ID** | **13** |
|---|---|---|---|---|---|---|---|
| SOIL TEST | Mehlich-3 Soil Test P (ppm P) | | | | | | 256 |
| | **Soil Test Rating = 0.20* Mehlich-3 Soil Test P (ppm P)** | | | | | | 51 |
| FERTILIZER P RATE | Fertilizer P (lb $P_2O_5$/acre) | | | | | | 20 |
| FERTILIZER APPLICATION METHOD | 0.2<br>Placed or injected 2" or more deep | 0.4<br>Incorporated <1 week following application | 0.6<br>Incorporated > 1 week or not incorporated following application in April - October | 0.8<br>Incorporated >1 week or not incorporated following application in Nov. - March | 1.0<br>Surface applied to frozen or snow covered soil | | 0.2 |
| | **Fertilizer Rating = Fertilizer Rate x Fertilizer Application Method** | | | | | | 4 |
| MANURE P RATE | Manure P (lb $P_2O_5$/acre) | | | | | | 72 |
| MANURE APPLICATION METHOD | 0.2<br>Placed or injected 2" or more deep | 0.4<br>Incorporated <1 week following application | 0.6<br>Incorporated > 1 week or not incorporated following application in April - October | 0.8<br>Incorporated >1 week or not incorporated following application in Nov. - March | 1.0<br>Surface applied to frozen or snow covered soil | | 0.6 |
| MANURE P AVAILABILITY | Refer to P Index Fact Sheet Table 1: Organic P source availability coefficients | | | | | | 0.9 |
| | **Manure Rating = Manure Rate x Manure Application Method x Manure P Availability** | | | | | | 39 |
| | | | | **Source Factor Sum** | | | 94 |

| **PART B: TRANSPORT FACTORS** | | | | | | **Field ID** | 13 |
|---|---|---|---|---|---|---|---|
| EROSION | Soil Loss (ton/A/yr) | | | | | | 2 |
| RUNOFF POTENTIAL | 0<br>Very Low | 2<br>Low | 4<br>Medium | 6<br>High | 8<br>V. High | | 2 |
| SUBSURFACE DRAINAGE | 0<br>None | | 1<br>Random | | 2*<br>Patterened | | 0 |
| CONTRIBUTING DISTANCE | 0<br>> 500 ft. | 2<br>500 to 350 ft. | 4<br>349 to 250 ft. | 6<br>150 to 249 ft. | 8<br>< 150 ft. | | 2 |
| | **Transport Sum = Erosion+ Runoff Potential + Subsurface Drainage + Contributing Distance** | | | | | | 6 |
| MODIFIED CONNECTIVITY | 0.7<br>Riparian Buffer APPLIES TO DIST < 150 FT | | 1.0<br>Grassed Waterway or None | | 1.1<br>Direct Connection APPLIES TO DIST > 150 FT | | 1.0 |
| | | | | | **Transport Sum x Modified Connectivity/22** | | 0.27 |
| | | | | | **P Index Value = 2 x Source x Transport** | | **51** |

Scenario 2

As the planner moved on through the fields, Field 17 was the next field that Part A of the P Index indicated that a Part B evaluation is required. The information from the proposed N based plan calculated for Field 17 (see Field 17-1 below) is then entered into the P Index as Field 17-1 (see page 16). In this case, the N based information resulted in a P Index value of 89 which is High and means that that "Nutrients can be applied to meet the Phosphorus crop removal". Therefore, a management change is required in this field. The planner noted that he had planned to apply manure to this field in the fall. A possible management change was to apply manure on this field in the spring instead. The second column in the P Index, labeled Field 17-2 reflects this change (see page 16). By changing the manure application to a different time of year, the planner reduces the factor for M*anure Application Method* from 0.8 to 0.6. Subsequently, the P Index value is reduced to 77 (from the initial value of 89). A value of 77 allows for the application of the N based rate. This change would be need to be included in all appropriate sections of the nutrient management plan. In an actual plan, the line for 17-1, the column for 17-1 in the P Index and any other "interim" calculations would not be submitted. They are shown here for illustration only. A planner may have to try several different approaches until a workable and practical approach is found. Once a final approach is determined, the approach must match the nutrient management plan, P Index inputs, calculated P Index value, and P Index guidance provided for the field.

Manure allocation and associated nutrient application summary for Field 17 (taken from the N based nutrient management plan).

| | | | | | | | Other Fertilizer Planned | | | Supplemental Fertilizer | | Final Nutrient Balance | | P Index Part A Summary | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Field | Acres | Crop | Manure Group | Application Season | Incorporation | Planned Rate (gal or ton/A) | N (lb/A) | P2O5 (lb/A) | Method | N (lb/A) | P2O5 (lb/A) | N (lb/A) | P2O5 (lb/A) | Soil Test P (ppm) | Distance < 150 ft. | Part B Req'd | P2O5 Applied at planned rate (lb/A) |
| 11 | 6.8 | corn silage>Leg | Spring Dairy | Spring | None - Rain 5-7 days | 6000 | 10 | 20 | Starter | 0 | | (2) | (92) | 78 | No | | |
| 12 | 2.9 | old alfalfa | | | | | 0 | 0 | | 0 | | 0 | 0 | 102 | No | | |
| 13 | 2.9 | corn silage | Spring Dairy | Spring | None - Rain 5-7 days | 6000 | 10 | 20 | Starter | 65 | | 3 | (92) | 256 | No | X | 72 |
| 14 | 2.0 | alfalfa | | | | | 0 | 0 | | 0 | | 0 | 0 | 126 | No | | |
| 15 | 1.8 | corn silage | Spring Dairy | Spring | None - Rain 5-7 days | 6000 | 10 | 20 | Starter | 65 | | 3 | (92) | 96 | No | | |
| 16 | 8.1 | alfalfa | | | | | 0 | 0 | | 0 | | 0 | 0 | 72 | No | | |
| 17-1* | 5.0 | corn | Fall Dairy | Fall | None | 6000 | 10 | 20 | Starter | 65 | | 3 | (92) | 211 | No | X | 72 |
| 17-2 | 5.0 | corn | **Spring Dairy** | **Spring** | None | 6000 | 10 | 20 | Starter | 65 | | 3 | (92) | 211 | No | X | 72 |

* This line and the number after the dash in the next line would not appear in the final plan. These are just interim calculations shown here for illustration.

P Index Evaluation, Part B for Field 13.

| **PART B: SOURCE FACTORS** | | | | | **Field ID** | **17-1*** | **17-2** |
|---|---|---|---|---|---|---|---|
| SOIL TEST | Mehlich-3 Soil Test P (ppm P) | | | | | 211 | 211 |
| | **Soil Test Rating = 0.20* Mehlich-3 Soil Test P (ppm P)** | | | | | 42 | 42 |
| FERTILIZER P RATE | Fertilizer P (lb $P_2O_5$/acre) | | | | | 20 | 20 |
| FERTILIZER APPLICATION METHOD | 0.2 Placed or injected 2" or more deep | 0.4 Incorporated <1 week following application | 0.6 Incorporated > 1 week or not incorporated following application in April - October | 0.8 Incorporated >1 week or not incorporated following application in Nov. - March | 1.0 Surface applied to frozen or snow covered soil | 0.2 | 0.2 |
| | **Fertilizer Rating = Fertilizer Rate x Fertilizer Application Method** | | | | | 4 | 4 |
| MANURE P RATE | Manure P (lb $P_2O_5$/acre) | | | | | 72 | 72 |
| MANURE APPLICATION METHOD | 0.2 Placed or injected 2" or more deep | 0.4 Incorporated <1 week following application | 0.6 Incorporated > 1 week or not incorporated following application in April - October | 0.8 Incorporated >1 week or not incorporated following application in Nov. - March | 1.0 Surface applied to frozen or snow covered soil | 0.8 | ***0.6*** |
| MANURE P AVAILABILITY | Refer to P Index Fact Sheet Table 1: Organic P source availability coefficients | | | | | 0.9 | 0.9 |
| | **Manure Rating = Manure Rate x Manure Application Method x Manure P Availability** | | | | | 52 | 39 |
| | | | | **Source Factor Sum** | | 98 | 85 |
| **PART B: TRANSPORT FACTORS** | | | | | | | |
| EROSION | Soil Loss (ton/A/yr) | | | | | 2 | 2 |
| RUNOFF POTENTIAL | 0 Very Low | 2 Low | 4 Medium | 6 High | 8 V. High | 4 | 4 |
| SUBSURFACE DRAINAGE | 0 None | | 1 Random | | 2* Patterened | 0 | 0 |
| CONTRIBUTING DISTANCE | 0 > 500 ft. | 2 500 to 350 ft. | 4 349 to 250 ft. | 6 150 to 249 ft. | 8 < 150 ft. | 4 | 4 |
| | **Transport Sum = Erosion + Runoff Potential + Subsurface Drainage + Contributing Distance** | | | | | 10 | 10 |
| MODIFIED CONNECTIVITY | 0.7 Riparian Buffer APPLIES TO DIST < 150 FT | | 1.0 Grassed Waterway or None | | 1.1 Direct Connection APPLIES TO DIST > 150 FT | 1.0 | 1.0 |
| | | | | **Transport Sum x Modified Connectivity/22** | | .45 | .45 |
| | | | | **P Index Value = 2 x Source x Transport** | | **89** | **77** |

* This column would not appear in the final plan.

Scenario 3

The next field requiring Part B of the P Index is Field 21. The information from the N based plan calculated for Field 21 (see Field 21-1 below) is then entered into the P Index as 21-1 (see page 18). In this case, the N based information resulted in a P Index value of 115 which is Very High and means that that "No Phosphorus can be applied". Therefore, a management change is required in this field. In this case, the option to reduce the manure rate was selected because the farmer was not willing to inject or immediately incorporate the manure. Therefore, the planner reduced the manure rate to P crop removal (4000 gal/A = 48 lb $P_2O_5$/A). In the P Index, the second column for Field 21-2 reflects this change (see page 18). With this change to a 4000 gal/A rate, the P Index value is reduced to 93 which is High and indicates that "Nutrients can be applied to meet the Phosphorus crop removal". However, this illustrates a common mistake. All P must be included when calculating whether the application is less than P crop removal. On this field, since there is 20 lb $P_2O_5$ /A applied in the starter, the application exceeds the P removal rate (48 lb $P_2O_5$/A Manure + 20 lb $P_2O_5$/A from fertilizer = 68 lb $P_2O_5$. The total is more than the P crop removal of 48 lb $P_2O_5$/A). Therefore, either the rate must be reduced further or the starter P must be eliminated. If the starter is eliminated the P Index value must be recalculated as shown in column 21-3 (see page 18). The recalculated P Index value is 86 indicating that "Nutrients can be applied to meet the Phosphorus crop removal". This amount, 48 lb $P_2O_5$/A, is being applied from manure only. As in Scenario 2, only the final plan for Field 21 (shown as 21-3 below and in the P Index on the next page) would be included and consistent in the nutrient management plan and the P Index.

Manure allocation and associated nutrient application summary for Field 21 (taken from the N based nutrient management plan).

| | | | | | | | Other Fertilizer Planned | | | Supplemental Fertilizer | | Final Nutrient Balance | | P Index Part A Summary | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Field | Acres | Crop | Manure Group | Application Season | Incorporation | Planned Rate (gal or ton/A) | N (lb/A) | P2O5 (lb/A) | Method | N (lb/A) | P2O5 (lb/A) | N (lb/A) | P2O5 (lb/A) | Soil Test P (ppm) | Distance < 150 ft. | Part B Req'd | P2O5 Applied at planned rate (lb/A) |
| 11 | 8 | corn silage>Leg | Spring Dairy | Spring | None - Rain 5-7 days | 6000 | 10 | 20 | Starter | 0 | | (2) | (92) | 78 | No | | |
| 12 | 9 | old alfalfa | | | | | 0 | 0 | | 0 | | 0 | 0 | 102 | No | | |
| 13 | 9 | corn silage | Spring Dairy | Spring | None - Rain 5-7 days | 6000 | 10 | 20 | Starter | 65 | | 3 | (92) | 256 | No | X | 72 |
| 14 | 10 | alfalfa | | | | | 0 | 0 | | 0 | | 0 | 0 | 126 | No | | |
| 15 | 8 | corn silage | Spring Dairy | Spring | None - Rain 5-7 days | 6000 | 10 | 20 | Starter | 65 | | 3 | (92) | 96 | No | | |
| 16 | 8 | alfalfa | | | | | 0 | 0 | | 0 | | 0 | 0 | 72 | No | | |
| 17 | 5 | corn | Spring Dairy | Spring | None | 6000 | 10 | 20 | Starter | 65 | | 3 | (92) | 211 | No | X | 72 |
| 18 | 6 | alfalfa | | | | | 0 | 0 | | 0 | | 0 | 0 | | 88 | No | |
| 19 | 8 | corn silage | Spring Dairy | Spring | None - Rain 5-7 days | 6000 | 10 | 20 | Starter | 65 | | 3 | (92) | | 169 | No | |
| 20 | 9 | alfalfa | | | | | 0 | 0 | | 0 | | 0 | 0 | | 88 | No | |
| 21-1* | 8 | corn | Spring Dairy | Spring | None - Rain 5-7 days | 6000 | 10 | 0 | Starter | 65 | | 3 | (92) | 120 | Yes | X | 72 |
| 21-3 | 7 | corn | Spring Dairy | Spring | None - Rain 5-7 days | **4000** | **0** | **0** | | 65 | | 3 | (92) | 120 | Yes | X | **48** |

* This line and the number after the dash would not appear in the final plan. These are interim calculations.

P Index Evaluation, Part B for Field 21.

| **PART B: SOURCE FACTORS** | | | | | **Field ID** | **21-1*** | **21-2*** | **21-3** |
|---|---|---|---|---|---|---|---|---|
| SOIL TEST | Mehlich-3 Soil Test P (ppm P) | | | | | 120 | 120 | 120 |
| | **Soil Test Rating = 0.20* Mehlich-3 Soil Test P (ppm P)** | | | | | 24 | 24 | 24 |
| FERTILIZER P RATE | Fertilizer P (lb $P_2O_5$/acre) | | | | | 20 | 20 | 0 |
| FERTILIZER APPLICATION METHOD | 0.2 Placed or injected 2" or more deep | 0.4 Incorporated <1 week following application | 0.6 Incorporated > 1 week or not incorporated following application in April - October | 0.8 Incorporated >1 week or not incorporated following application in Nov. - March | 1.0 Surface applied to frozen or snow covered soil | 0.2 | 0.2 | |
| | **Fertilizer Rating = Fertilizer Rate x Fertilizer Application Method** | | | | | 4 | 4 | |
| MANURE P RATE | Manure P (lb $P_2O_5$/acre) | | | | | 72 | 48 | 48 |
| MANURE APPLICATION METHOD | 0.2 Placed or injected 2" or more deep | 0.4 Incorporated <1 week following application | 0.6 Incorporated > 1 week or not incorporated following application in April - October | 0.8 Incorporated >1 week or not incorporated following application in Nov. - March | 1.0 Surface applied to frozen or snow covered soil | 0.6 | 0.6 | 0.6 |
| MANURE P AVAILABILITY | Refer to P Index Fact Sheet Table 1: Organic P source availability coefficients | | | | | 0.9 | 0.9 | 0.9 |
| | **Manure Rating = Manure Rate x Manure Application Method x Manure P Availability** | | | | | 39 | 26 | 26 |
| | | | | **Source Factor Sum** | | 67 | 54 | 50 |
| **PART B: TRANSPORT FACTORS** | | | | | | | | |
| EROSION | Soil Loss (ton/A/yr) | | | | | 3 | 3 | 3 |
| RUNOFF POTENTIAL | 0 Very Low | 2 Low | 4 Medium | 6 High | 8 V. High | 8 | 8 | 8 |
| SUBSURFACE DRAINAGE | 0 None | | 1 Random | | 2* Patterened | 0 | 0 | 0 |
| CONTRIBUTING DISTANCE | 0 > 500 ft. | 2 500 to 350 ft. | 4 349 to 250 ft. | 6 150 to 249 ft. | 8 < 150 ft. | 8 | 8 | 8 |
| | **Transport Sum = Erosion + Runoff Potential + Subsurface Drainage + Contributing Distance** | | | | | 19 | 19 | 19 |
| MODIFIED CONNECTIVITY | 0.7 Riparian Buffer APPLIES TO DIST < 150 FT | | 1.0 Grassed Waterway or None | | 1.1 Direct Connection APPLIES TO DIST > 150 FT | 1.0 | 1.0 | 1.0 |
| | | | | **Transport Sum x Modified Connectivity/22** | | .86 | .86 | .86 |
| | | | | **P Index Value = 2 x Source x Transport** | | **115** | **93** | **86** |

* These columns would not appear in the final plan.

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