The Phosphorus Site Index:

A Systematic Approach to Assess the Risk of Nonpoint Source Pollution of Idaho Waters by Agricultural Phosphorus

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INTRODUCTION

Why is phosphorus a concern for Idaho?

Water quality in Idaho has been negatively impacted by the inputs of nutrients from both point and nonpoint sources. The two nutrients of greatest concern are nitrogen (N) and phosphorus (P). Efforts to reduce nutrient enrichment of ground and surface waters have become a high priority for state and federal agencies and a matter of considerable importance to all nutrient users and nutrient generators in the state. Two actions in particular highlight the importance of this issue in Idaho:

- Total Maximum Daily Load (TMDL) Program: Section 303(d) of the Federal Clean Water Act (CWA) of 1972 requires states to develop a list of water bodies that need pollution reduction beyond that achievable with existing control measures. These water bodies are referred to as "Water Quality Limited" and are compiled by each state on a "303(d) list". States are required to develop a "total maximum daily load (TMDL)" for a number of pollutants, including nutrients for these "water quality limited" waters. A TMDL is defined as "the level of pollution or pollutant load below which a water body will meet water quality standards and thereby allow use goals such as drinking water supply, swimming and fishing, or shellfish harvesting". In ID, approximately 36% of streams were identified as not meeting water quality standards. The TMDL for the upper and middle Snake River was set at 0.075 mg total P L^{-1}.

- Cattle feedlots are regulated under Title 22, Chapter 49, Idaho Code "Beef Cattle Environmental Control Act" and IDAPA 02.04.15 "Rules Governing Beef Cattle Animal Feeding Operations". Beef cattle facilities over 1,000 head need to have a nutrient management plan, approved by the Idaho State Department of Agriculture.

What is a Phosphorus Site Index?

In the early 1990's the U.S. Department of Agriculture (USDA) began to develop assessment tools for areas with water quality problems. While some models such as the Universal Soil Loss Equation (USLE) for erosion, and Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) for ground water pollution, were already being used to screen watersheds for potential agricultural impacts on water quality, there was no model considered suitable for the field-scale assessment of the potential movement of P from soil to water. A group of scientists from universities and governmental agencies met in 1990 to discuss the potential movement of P from soil to water, and later formed a national work group (PICT: Phosphorus Index Core Team) to more formally address this problem. Members of the PICT soon realized that despite the many scientists conducting independent research on soil P, there was a lack of integrated research that could be used to develop the field scale assessment tool for P needed by USDA. Consequently, the first priority of PICT was a simple, field-based, planning tool that could integrate through a multi-parameter matrix, the soil properties, hydrology, and agricultural management practices within a defined geographic area, and thus to assess, in a relative way, the risk for P movement from soil to water. The initial goals of the PICT team were:

- *To develop an easily used field rating system (the* ***Phosphorus Site Index****) for Cooperative Extension, Natural Resource Conservation Service (NRCS) technical staff, crop consultants, farmers or others that rates soils according to the potential for P loss to surface waters*

- *To relate the P Site Index to the sensitivity of receiving waters to eutrophication.* This is a vital task because soil P is only an environmental concern if a transport process exists that can carry particulate or soluble P to surface waters where eutrophication is limited by P.

- *To facilitate adaptation of the P Site Index to site specific situations.* The variability in soils, crops, climates and surface waters makes it essential that each state or region modify the parameters and interpretation given in the original P Index to best fit local 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 *P Site Index* is designed to provide a systematic assessment of the risks of P loss from soils, but does not attempt to estimate the actual quantity of P lost in runoff. Knowledge of this risk not only allows us to design best management practices (BMPs) that can reduce agricultural P losses to surface waters, but to more effectively prioritize the locations where their implementation will have the greatest water quality benefits.

It has long been known that P loss depends on not only the amount of P in or added to a soil but the transport processes that control soil and water movement from fields to waterways. Therefore, when assessing the risk of P loss from soil to water, it is important that we not focus strictly on measures of P, such as agronomic soil test P value. Rather a much broader, multi-disciplinary approach is needed; one that recognizes that P loss will vary among watersheds and soils, due to the rate and type of soil amendments used, and due to the wide diversity in soils, crop management practices, topography, and hydrology. At a minimum, any risk assessment process for soil P should include the following:

- Characteristics of the P source (fertilizer, manure, biosolids) that influence its solubility and thus the potential for movement or retention of P once the source has been applied to a soil.

- The concentration and bioavailability of P in soils susceptible to loss by erosion.

- The potential for soluble P release from soils into surface runoff or subsurface drainage.

- The effect of other factors, such as hydrology, topography, soil, crop, and P source management practices, on the potential for P movement from soil to water.

- Any "channel processes" occurring in streams, field ditches, etc. that mitigate or enhance P transport into surface waters.

- The sensitivity of surface waters to P and the proximity of these waters to agricultural soils.

In summary, when resources are limited, it is critical to target areas where the interaction of P source, P management, and P transport processes result in the most serious risk of losses of P to surface and shallow ground waters. <u>This is the fundamental goal of the *P Site Index*.</u>

Phosphorus Site Index: Version 1.0

Version 1.0 of the *P Site Index* has two separate components (Table 1). Part A characterizes the risk of P loss based on site-specific soil properties and hydrologic considerations. Part B characterizes the risk of P loss based on site-specific past and current nutrient management practices that affect the concentration of P in the soil (soil test P) and the potential for P loss due to management of inorganic (fertilizer) and organic (manures, composts, etc.) P sources. Parts A and B are summarized below, followed by a detailed discussion and descriptions of each component of the two parts. Generalized interpretations of the *P Site Index* values arising from use of Version 1.0 are given in Table 2.

Part A: Phosphorus Loss Potential Due to Site and Transport Characteristics

Surface transport mechanisms, i.e. soil erosion and runoff are generally the main mechanisms by which P is exported from agricultural fields to receiving waters. In some areas, leaching of P can also be a significant method of P export, especially in areas with artificial subsurface drainage (e.g. tiles, mole drains) high water tables, or shallow soils overlying basalt. Therefore, the considerations of the methods of P transport factors affecting these transport mechanisms are critical to an understanding of P losses from watersheds. Part A includes the following four factors: (i) soil erodibility; (ii) soil surface runoff index; (iii) leaching potential; and (iv) distance from edge of field to surface water.

Part B: Phosphorus Loss Potential Due to P Source and Management Practices

Phosphorus losses are also related to the amount and forms of P at a site which can potentially be transported to ground or surface waters. The main sources of P at any site that must be considered in assessing the risk of P loss are (i) soil P (particulate and dissolved), a reflection of natural soil properties and past management practices: and (ii) P inputs such as inorganic fertilizers and organic P sources (manures, composts, biosolids). Also of importance are the management practices used for all P inputs, such as the rate, method, and timing of fertilizer and manure applications, as these factors will influence whether or not P sources will have negative impacts on water quality. Part B includes the following three factors: (i) soil test P value; (ii) P applications rate; and (iii) P application method.

Table 1. The *Phosphorus Site Index* proposed for use in Idaho

Part A: Phosphorus loss potential due to site and transport characteristics

Characteristics	**Phosphorus Loss Rating**					**Field Value**
Soil Erodibility	Very Low **0**	Low **1**	Medium **2**	High **4**	Very High **8**	
Soil Surface Runoff Index – Surface Irrigated	No Runoff **0**	Water runs off less than 50% of the irrigation set time **4**		Water runs off more than 50% of the irrigation set time **8**		
Soil Surface Runoff Index – Sprinkler or Non-Irrigated	Very Low **0**	Low **1**	Medium **2**	High **4**	Very High **8**	
Leaching Potential	Low **1**		Medium **2**	High **4**		
Distance from Edge of Field to Surface Water	> 2,640' **0**		200-2,640' **2**	< 200' **8**		

Part B: Phosphorus loss potential due to P source and management practices.

Characteristics	**Phosphorus Loss Rating**					**Field Value**
	Very Low	Low	Medium	High	Very High	
Soil Test P value	**0.05** x [Olsen Soil Test P (ppm)] **0.025** x Bray Soil Test P (ppm)]					
P Application Rate (lbs P_2O_5 applied per acre)	No Application **0**	< 60 **1**	60 – 150 **2**	151 – 300 **4**	>300 **8**	
P Application Method	None Applied **0**	Incorporated within 2 days or injected/banded below surface at least 3" **1**	Incorporated within 7 days of application **2**	Incorporated > 7 days or no incorporation when applied between February 16 and December 15 **4**	Application between December 16 and February 15 **8**	

Table 2. Generalized interpretations of the *P Site Index*.

***P Site Index* Value**	**Generalized Interpretation of the *P Site Index* Value**
< 75	**LOW** potential for P movement from this site given current management practices and site characteristics. There is a low probability of an adverse impact to surface waters from P losses from this site. Nitrogen-based nutrient management planning is satisfactory for this site. Soil P levels and P loss potential may increase in the future due to N-based nutrient management planning
75 - 150	**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, leaching and erosion. Phosphorus applications should be limited to the amount expected to be removed from the field by crop harvest or soil test-based P application recommendations, whichever is greater. Testing of manure P prior to application is required
151 – 225	**HIGH** potential for P movement from this site given the current management practices and site characteristics. Phosphorus applications should be limited to 50% of crop P uptake. Testing of manure P prior to application is required.
> 225	**VERY HIGH** potential for P movement from this site given current management practices and site characteristics. No P should be applied to this site.

Usage of the Idaho *Phosphorus Site Index*

The Phosphorus Site Index is a risk assessment tool to help determine the potential for off-site transport of phosphorus from agricultural fields. It is intended to be used as an integral and interactive part of the nutrient management plan to help guide applications of manure and fertilizers to minimize potential P losses from agricultural fields, and to identify fields that may require additional management to reduce P losses even when P applications are not planned. The PSI is also a valuable educational tool to assist producers in recognizing high risk areas, allowing them to focus conservation practices where they would be of most value.

A PSI rating should be done for each field. Fields that do not receive manure and fertilizer need to only be assessed once until there is a planned application of P. The PSI should be calculated prior to P application for each field using the planned management and P application rate along with current soil test P results. The risk rating will determine whether or not the P application on the field is allowable, given the current management. For example, if the risk assessment was completed with inputs for the field source factors (soil test P, planned P application rates, and planned application method and timing) and the field received a low rating, then application and management can continue according to plan. If, however, the risk rating is in a medium category, P application will be limited to crop uptake. If the risk rating is in a higher category, BMPs will need to be implemented on the field in order to reduce the potential for P loss, and/or the P application rates must be limited or prohibited in order to reduce the risk of P losses from the field. Producers can receive full credit for up to two BPMs per field at any given time. In addition, testing of manure prior to application will be required for fields having a risk rating above low.

When a perennial crop such as alfalfa is part of the rotation, or when allowable manure application rates are below a reasonable application rate (<10 tons/acre for manure and <5 tons/acre for composted manure) then a producer may be allowed to apply up to a four year application rate at one time with no further application over the remainder of the time period that the nutrients have been allocated to. For example, a field with a medium rating beginning a four-year rotation of alfalfa could apply a maximum of four times the annual excepted crop P uptake rate in the first year with no additional P application for the next three years; or a field with a high rating beginning a four-year rotation of alfalfa could apply a maximum of two times the annual expected crop P uptake rate in the first year, and the following three years of alfalfa could receive no additional P.

<u>Phosphorus Site Index: Version 1.0</u>

Part A: Phosphorus Loss Potential Due to Site and Transport Characteristics

Soil Erosion

Phosphorus is strongly sorbed by soils, therefore erosion of soil materials dominates the movement of particulate P in landscapes (Bjorneberg et al., 2002; Leytem and Westermann, 2003). Up to 90% of the P transported from surface irrigated crops is transported with eroded sediment (Berg and Carter, 1980). In contrast to rainfall, irrigation is a managed event. Runoff and soil erosion should be minimal from properly managed sprinkler irrigation or drip irrigation. Water flowing over soil during surface irrigation will detach and transport sediment. Annual soil loss from furrow irrigated fields can range from less than 1 to greater than 100 tons per acre (Berg and Carter, 1980; Koluvek et al., 1993). Typically, greater than 90% of the P in surface irrigation runoff from clean-tilled row-crop fields is transported with eroded sediment. Conversely, when erosion is minimal from crops such as alfalfa and pasture, greater than 90% of the total P is dissolved in the runoff water (Berg and Carter, 1980). Total P concentration in surface irrigation runoff correlates directly with sediment concentration (Fitzsimmons et al., 1972, Westermann et al., 2001). Dissolved reactive P concentration in surface irrigation runoff, on the other hand, correlates with soil test P concentration, but not with sediment concentration (Westermann et al., 2001). During detachment and movement of sediment in runoff, the finer-sized fractions of source material are preferentially eroded. Thus, the P content and reactivity of eroded particulate material is usually greater than the source soil (Carter et al., 1974; Sharpley et al., 1985). Therefore, to minimize P loss in the landscape, it is essential to control soil erosion. Particulate P movement in the landscape is a complex function of rainfall, irrigation, soil properties affecting infiltration and runoff of irrigation/rainfall/snowmelt, and soil management factors affecting erosion. Numerous management practices that minimize P loss by erosion are available including filter strips, contour tillage, cover crops, use of polyacrylamide and impoundments or small reservoirs.

Soil erosion can be estimated from erosion prediction models such as the Universal Soil Loss Equation (USLE) or the Revised Universal Soil Loss Equation (RUSLE) for water erosion and Wind Erosion Equation (WEQ) for wind erosion. However, neither USLE nor RUSLE can accurately predict irrigation erosion. Therefore, the potential for soil erosion is based on the erodibility of the soil along with the predominant slope of the field. While this factor does not predict sediment transport and delivery to a water body, it does indicate the potential for sediment and attached P movement across the slope or unsheltered distance toward a water body.

For the *Phosphorous Site Index*, the potential for soil erosion loss is determined by the erodibility of the soil (K_w factor) along with the slope of the field Table 3.

Table 3. Soil erodibility factor

Kw factor - soil surface mineral layer	Slope Gradients				
	< 2%	2 – 5%	5 – 10%	10 – 15%	> 15%
<= 0.10 Very low erodibility	Very Low	Very Low	Very Low	Very Low	Low
0.11 – 0.20 Low erodibility	Very Low	Very Low	Very Low	Low	Medium
0.21 – 0.32 Moderate erodibility	Very Low	Low	Low	Medium	High
0.33 – 0.43 High erodibility	Low	Low	Medium	High	Very High
0.44 – 0.64 Very high erodibility	Low	Medium	High	Very High	Very High

All factors can be determined by using the NRCS soil survey data (Web Soil Survey) with field verification of the predominant slope in the field. **The soil erodibility value will range from very low to very high and will be assigned a value of 0 (very low) to 8 (very high) and used in the calculation of the *P Site Index* (Table 1).**

Runoff Index

Dissolved P (DP) is another important source of P that is transported in surface runoff. Dissolved P exists mainly in the form of orthophosphate, which is available immediately for uptake by algae and other aquatic plants. The first step in the movement of DP in runoff is the desorption, dissolution, and extraction of P from soils, crop residues, and surface applied fertilizer and manure (Sharpley et al., 1994). These processes occur as irrigation water, rainfall, or snowmelt water interacts with a thin layer of surface soil (0.04 to 0.12 in) before leaving the field as runoff or leaching downward in the soil profile (Sharpley, 1995). The soil test P content of surface soils has been found to be directly related to DP concentrations in runoff. Field studies have shown that P losses by surface runoff are greater when soil test P values are above the agronomic optimum range (Turner et al., 2004). Laboratory research has also shown that soils with high agronomic soil test P values are more likely to have high concentrations of soluble, desorbable, and bioavailable P (Paulter and sims, 2000; Sibbensen and Sharpley, 1997; Sims, 1998b). In furrow irrigation runoff, even soil with low soil test P can have high runoff DP concentrations (Westermann et al., 2001).

For the *P Site Index*, soil runoff index is determined differently for surface irrigated vs sprinkler irrigated or fields with no irrigation. For surface irrigated fields use Table 4, for sprinkler irrigated or non-irrigated fields use Table 5.

Table 4. Runoff index for surface irrigated fields:

Criteria	**Value**
Fields with no runoff	0
Fields with water running off less than 50% of the irrigation set time	4
Fields with water running off 50% or more of the irrigation set time	8

Table 5. Runoff index for sprinkler or non-irrigated fields.

Hydrologic Soil Group	Slope Gradients				
	< 2%	2 – 5%	5 – 10%	10 – 15%	> 15%
A: Low Runoff Potential	Very Low	Very Low	Low	Medium	High
B: Moderately Low Runoff Potential	Very Low	Low	Medium	High	High
C: Moderately High Runoff Potential	Very Low	Medium	Medium	High	Very High
D, A/D, B/D, C/D: High Runoff Potential	Low	Medium	High	Very High	Very High

All factors can be determined by using the NRCS soil survey data (Web Soil Survey) with field verification of the predominant slope in the field.

Leaching Potential

While surface transport processes are the major contributing factors in P transport from soil to water in most cases, leaching of P can contribute significant amounts of P to surface waters in some situations, such as in areas where there is relatively flat topography, high water tables, shallow soils over basalt and any artificial drainage system (e.g. ditches, subsurface drains). While P leaching is typically considered to be small there is potential for significant movement of P through the soil profile when soil P values increase to very high or excessive values due to long-term over-fertilization or manuring (Sims et al., 1998). Whether this leached P will reach surface waters depends on the depth to which it has leached and the hydrology of the site in question. In flat areas with shallow groundwater levels, P loss by leaching through soils contributes significantly to the phosphorus loads of streams (Culley et al., 1983; Heathwaite & Dils, 2000). Soils that are poorly drained with high water tables have a higher possibility of P loss than soils that are well drained with deep water tables. Also soils that are shallow (<24") overlying basalt have a higher possibility of P loss than deeper soils. It is common in poorly drained soils to have water tables rise to the soil surface during the winter and spring months, during this time there is the potential for release of P into these drainage waters which can then be carried to nearby streams via subsurface flow. When soils are wet (during spring and late fall) or during time periods when irrigation exceeds ET, shallow soils can potentially leach P into the underlying basalt which can then be carried to surface waters (i.e. springs).

For the *P Site Index*, leaching potential is based on a USDA-NRCS categorization scheme based on the soil hydrologic group, predominant slope, saturated hydraulic conductivity, depth to high water table (HWT) and depth to bedrock (Table 6). This information can be found through site inspection and web soil survey.

Table 6. Leaching potential.

Soil Leaching Potential	Hydrologic Group A	Hydrologic Group B	Hydrologic Group C	Hydrologic Group D
Low	NA	NA	NA	All **except**: • Apparent HWT • Depth to bedrock < 24"
Medium	• Slope > 6% • No apparent HWT and Depth to bedrock > 24"	• Slope > 6% or slope ≤ 6% with K_{sat} < 0.24 in/hr • No apparent HWT and Depth to bedrock > 24"	All **except**: • Apparent HWT • Depth to bedrock < 24"	NA
High	• Slope < 6% • Apparent HWT or Depth to bedrock < 24"	• Slope < 6% with K_{sat} > 0.24 in/hr • Apparent HWT or Depth to bedrock < 24"	• Apparent HWT • Depth to bedrock < 24"	• Apparent HWT • Depth to bedrock < 24"

High Water Table (HWT) is defined as a saturated layer < 24" from the surface anytime during the year.

Distance from Edge of Field to Surface Water

Another factor that affects the risk of P transport from soils to surface waters is the distance between the P source (i.e., the field) and the receiving waters. In some areas, the nearest water body may be a mile or more from the field being evaluated with no connectivity between the field and surface water; in these cases, even high levels of soil P may have low risk for nonpoint source pollution since the potential for transport to the water body is low. On the other hand, fields that are directly connected to surface water, such as surface irrigated fields with tailwater ditches, directly convey runoff water to surface water bodies through the return flow system. In these cases, even fields with low soil P can convey a large amount of both particulate and soluble P to surface waters.

The *P Site Index* takes into account the distance from field edge to the nearest surface water body or other conveyance system connected to surface water (tailwater ditches, return flow ditches, laterals (Table 7).

Table 7. Distance from edge of field to surface water

Distance From Edge of Field to Surface Water	Value
> 2,640’ (0.5 mile)	0
200’ to 2,640’	2
< 200’	8

Best Management Practices for Reducing Transport Losses of P

There are several best management practices (BMPs) that can reduce the transport and loss of P from agricultural fields. In many situations, a combination of management practices is more effective than one BMP alone. To account for the effect of BMPs on the off-site transport of P from agricultural fields, a reduction in the overall transport factor is applied with varying BMPs that could be implemented on farm.

Contour farming, i.e. planting across the slope instead of up and down the hill can reduce soil erosion significantly. It is estimated that contour farming can reduce sediment loss by 20 to 50% depending on the slope of the field (Wischmeier and Smith, 1978). Keeping soil surfaces covered through cover or green manure crops can reduce losses of P by reducing erosion losses, however in some cases soluble P is either not affected or can increase. Sharpley and Smith (1991) reported reductions in total P losses of 54 to 66% with the use of cover crops while soluble P was reduced by 0 to 63%. The use of perennial crops such as alfalfa will also reduce the amount of sediment and therefore P leaving the field.

The installation of a dike or a berm that captures runoff from the field will prevent the loss of both soluble and total P. The effectiveness will depend on the holding capacity of the retention area. The use of drip irrigation vs. surface irrigation can significantly reduce the amount of runoff and therefore P that is transported off site. Mchugh et al. (2008) reported a 90% reduction in total P loss from fields with subsurface drip irrigation vs. furrow irrigation. Vegetative filter strips can trap sediment thereby reducing the offsite transport of P. Abu-Zreig et al. (2003) found that filter strips removed 31 to 89% of total P with filter length being the predominant factor affecting filter strip efficacy. The use of polyacrylamide (PAM) with irrigation has been shown to reduce losses of P from both furrow and sprinkler irrigated fields. Applying PAM with irrigation water or directly to furrow soil reduced soil erosion more than 90% on research plots (Lentz et al. 1992, Sojka and Lentz 1997, Trout et al. 1995). A conservative estimate for production fields is 50% to 80% reduction in soil loss. By reducing soil erosion, PAM treatment also reduced total P concentrations in runoff water (Lentz et al. 1998) but had little impact on dissolved P concentrations (Bjorneberg and Lentz, 2005). When used with sprinkler irrigation PAM has been shown to reduce P losses by 30%, but the effectiveness of PAM is minimal after three irrigations (Bjorneberg et al., 2000). Conservation tillage can also reduce soil erodibility and increase residue in furrows, both of which reduce soil loss to irrigation return flow (Carter and Berg 1991).

Sediment ponds remove suspended material from water by reducing flow velocity to allow particles to settle. Sediment ponds also remove nutrients associated with sediment particles. A large pond removed 65% to 75% of the sediment and 25% to 33% of the total P that entered the pond (Brown et al. 1981). A smaller percentage of total P was removed because only the P associated with sediment was removed and a large portion of the total P flowing into the pond was dissolved. Average total P concentrations significantly decreased by 13 to 42% in five ponds with 2 to 15 hour retention times, while dissolved P concentrations only decreased 7 to 16% in three of the five ponds (Bjorneberg et al., 2015). Dissolved P concentration may actually be greater in pond outflow than pond inflow because P may continue to desorb from sediment as water flows through the pond. Implementing sediment control practices on an 800 ha (2,000 ac) irrigation tract in the Columbia Basin of Washington reduced P discharges by 50% (King et al. 1982). Tailwater recovery systems that capture runoff from furrow irrigated fields and pump it back for re-use as irrigation water should eliminate the loss of P from the system, provided that no water leaves the field.

The reduction in transport factor due to the implementation of BMPs is listed in Table 8. For each BMP implemented, the transport factor should be reduced by the amounts listed in the tables. Combinations of BMPs will reduce the transport factor sequentially, for example if you had a score of 36 and you implemented contour farming and a sediment basin your score would then be:

$$36 - (0.2 \times 36) = 28.8 - (0.3 \times 28.8) = \mathbf{20.2}$$

Table 8. Management practices to reduce the loss of P from fields.

Management Practice[1]	BMP Coefficient
Contour Farming	0.20
Cover & Green Manure Crop	0.30
Dike or Berm	0.40 or 0.80
Drip Irrigation	0.80
Filter Strip[3]	0.35
PAM - Furrow Irrigation	0.60
PAM – Sprinkler Irrigation	0.30
Residue Management/Conservation Tillage[4]	0.30
Sediment Basin	0.30
Tailwater Recovery & Pumpback Systems[2]	0.80
Established Perennial Crop[5]	0.50

[1]BMPs designed by NRCS can receive full credit; otherwise the BMPs must meet the requirements set out in the BMP definition section.

Phosphorus Site Index: Version 1.0

Part A: Phosphorus Loss Potential Due to Site and Transport Characteristics

Sample Calculation

Part A: Phosphorus Loss Potential Due to Site and Transport Characteristics

Calculation of the Total Site and Transport Value for Part A of the P Site Index

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Once the values for soil erodibility, soil surface runoff, leaching potential and distance from edge of field to surface water have been obtained, these values are added together to obtain a total site and transport value (sum for Part A).

EXAMPLE:

A field located in the Magic Valley with a Portneuf silt loam soil, 1.5% slope, that is surface irrigated with water running off of the field >50% of the irrigation set time. Hydrologic soil group C, K_w factor for erosion is 0.43, K_{sat} 0.2 to 0.6 in/hr, depth to water table > 80". The surface irrigation runoff flows directly into the return flow system.

Soil Erodibility
Using Table 3, a K_w factor of 0.43 with a slope of < 2% puts this in the "Low" category, with a value of **1** (Table 1).

Soil Surface Runoff
This field is surface irrigated with runoff >50% of the set time, which is a value of **8** (Table 1).

Leaching Potential
This soil is in Hydrologic Group C without a high water table and is not a shallow soil, which is a medium risk (Table 6) with a value of **2** (Table 1).

Distance from edge of field to surface water
Since the runoff from this field flows directly into the return flow system the distance from edge of field to surface water is 0' which would be a value of **8** (Table 1).

All of the field values in Part A are then added together to obtain the Total Site Transport Value

1 + 8 + 2 + 8 = 19

**If this site had a tailwater recovery and pumpback system the transport value would be reduced by 80%*

19 – (19 x 0.8) = 3.8

Sum of Part A = 3.8

Phosphorus Site Index: Version 1.0

Part B: Phosphorus Loss Potential Due to P Source and Management Practices

Soil Test Phosphorus

Phosphorus exists in many forms in the soil, both inorganic and organic. Major inorganic forms are soluble, adsorbed, precipitated and minerals containing Al, Ca, and Fe. Each "pool" of soil P has a characteristic reactivity and potential for movement in either soluble or particulate forms. Iron and aluminum oxides, prevalent in most soils, strongly adsorb P under acidic conditions; under alkaline conditions, adsorption and precipitation are fostered by the presence of free calcium ions and calcium carbonate (Leytem and Westermann, 2003). Microorganisms and plant uptake can immobilize inorganic P by incorporation into biomass. Conversely, as organic materials decompose, soluble P can be released and made available for transport. How much P exists in each of these pools is determined by soil type, mineralogy, microbial activity, cropping, and fertilization practices (with both inorganic and organic sources of P).

Past and present research has demonstrated that there is a positive relationship between soil test P and dissolved P in surface runoff; that is, as soil test P increases, dissolved P in runoff also increases (Westermann et al., 2001; Turner et al., 2004). However, this relationship varies with soil type, cropping system and nature of the runoff episode. In addition to impacting P levels in surface waters, soil test P has also been found to affect P loss in drainage waters (Heckrath et al., 1995; Sims et al, 1998). Thus, as soils are fertilized to levels exceeding the soil test P values considered optimum for plant growth, the potential for P to be released to soil solution and transported by surface runoff, leaching, subsurface movement and even groundwater increases. Therefore, it is important to include a measure of the current soil test P values in any risk assessment tool for P.

For the *P Site Index,* soil test P values are expressed in ppm of either Olsen or Bray P. Olsen P is the most common (and appropriate) soil test for Idaho's calcareous soils. However certain regions of the state with lower soil pH (<7.4) may also use the Bray method for determination of soil test P.

P Site Index Value for Table 1 = 0.05 x Olsen Soil Test P (ppm), or

P Site Index Value for Table 1 = 0.025 x Bray Soil Test P (ppm)

Phosphorus Application Rate

The addition of fertilizer P or organic P to a field will usually increase the amount of P available for transport to surface waters. The potential for P loss when fertilizers, manures, or other P sources are applied is influenced by the rate, timing, and method of application and by the form of the P source (e.g. organic vs. inorganic). These factors also interact with others, such as the timing and duration of subsequent irrigation, rainfall or snowmelt and the type of soil cover present (vegetation, crop residues, etc.; Sharpley et al., 1993). Past research has established a clear relationship between the rate of fertilizer P applied and the amount of P transported in runoff (Baker and Laflen, 1982; Romkens and Nelson, 1974). These studies showed a linear relationship between the amount of P added as superphosphate fertilizer and P loss in runoff. Using manure as the source of P, Westerman et al. (1983) also demonstrated a direct relationship between the quality of runoff water and the application of manure. Therefore, it is important that the amount of P added to a site is accounted for in any risk assessment for nonpoint source pollution by P.

The P application rate is the amount of P in pounds P_2O_5 per acre that is applied to the crop. To determine the amount of P in manures, either have manure tested by a certified laboratory or use Table 10.

Table 9. Phosphorus application rate. Corresponding value to be included in the *P Site Index (Table 1).*

P Application Rate (lbs P_2O_5 applied per acre)	Value
No Application	0
< 60	1
60 - 150	2
151 - 300	4
> 300	8

Table 10. Phosphorus concentration of beef cattle manure

Beef cattle Manure Type	%P_2O_5 on a wet basis*
Solid (dirt lot)	1.15
Solid (bedded pack barn)	0.55

**University of Nebraska-Lincoln*

Phosphorus Application Method

Directly related to the amount of fertilizer and organic P sources applied to a field is the method and timing of the application. Baker and Laflen (1982) determined that the dissolved P concentrations of runoff from areas receiving broadcast fertilizer P average 100 times more than from areas where comparable rates were applied 5cm below the soil surface. Muller et al (1984) showed that incorporation of manure reduced total P losses in runoff five-fold compared to areas with broadcast applications. Surface applications of fertilizers and manures decrease the potential interaction of P with the soil, and therefore increase the availability of P for runoff from the site. When fertilizers and manures are incorporated into the soil, the soil is better able to sorb the added P and thus decrease the likelihood of P loss. It is particularly important that fertilizers and manures are not surface applied during times when there is no plant growth, when the soil is frozen, during or shortly before periods of irrigation, intense storms or times of the year when fields are generally flooded due to snowmelt. The major portion of annual P loss in runoff generally results from one or two intense transport periods. If P applications are made during any of these high risk times, the percentage of applied P lost would be higher than if applications are made when runoff probabilities are lower (Edwards et al., 1992). Also, the time between application of P and the first runoff event is important. Westerman and Overcash (1980) applied manure to plots and simulated rainfall at intervals ranging from one to three days following manure application. Total P concentrations in the runoff were reduced by 90% by delaying the first runoff event for three days. In order to manage manure and fertilizers to decrease potential for P transport off-site, they should be either applied below the surface or incorporated into the soil within a short period of time and should be applied shortly before the growing season when available P can be utilized by the plant.

For the *P site Index*: To determine the field value for application methods of P sources, information about the time of year and method of application must be obtained from the nutrient user. Once this information is collected, find the correct category and assign the value in Table 11.

Table 11. Values of P application methods for inclusion in *P Site Index (Table 1).*

P Application Method	Value
None applied	0
Incorporated within 2 day or injected/banded below surface at least 2”	1
Incorporated within 7 days of application	2
Incorporated >7 days or no incorporation when applied between February 16 and December 15	4
Application between December 16 and February 15	8

The Phosphorus Site Index: Version 1.0

Part B: Phosphorus Loss Potential Due to P Source and Management Practices

Sample Calculation

Part B: Phosphorus Loss Potential Due to P Source and Management Practices

Calculation of the Total P Source and Management Value for Part B of the P Site Index

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Once the values for soil test P, P application rate and P application method have been obtained, these values are added together to obtain a total P source and management practice value (sum for Part B).

EXAMPLE:
The field described for calculation of Part A has an Olsen soil test P value of 80 and solid manure is applied at 50 tons/acre in October and is not incorporated.

Soil Test P value
Olsen P of 80 x 0.05 = **4**

P Application Rate
50 tons/acre = (50 x 2,000 x (0.57/100)) = 570, this would be a value of **8**

P Application Method
Surface applied between Feb 16 and Dec 15 and not incorporated, this is a value of **4**

All of the field values in Part B are then added together to obtain the Total P Source and Management Value

4 + 8 + 4 = 16

Sum of Part B = 16

Calculation and Interpretation of the Overall P Loss Rating for a Site

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To find the overall *P Loss Rating* for a site (the final *P Site Index Value*), multiply the total site and transport value from Part A by the total management and source value from Part B as follows:

***P Site Index* = [Sum of Part A] x [Sum of Part B]**

Sum of Part A = 19

Sum of Part B = 16

***P Site Index* = 19 x 16 or 304**

A *P Site Index* value of **304** is classified as **Very High (See Tables 2 or 12)**

*If a tailwater recover with a pumpback system was used as a BMP then the P Site Index value would be

Sum of Part A = 3.8

Sum of Part B = 16

***P Site Index* = 3.8 x 16 or 61**

A *P Site Index* value of **61** is classified as **Low (See Tables 2 or 12)**

<u>Interpretation of the *P Site Index* Value</u>

Compare the *P Site Index* value calculated as show above with the ranges given in Table 12 for Low, Medium, High, or Very High risk of P loss. **It is important to remember that a P Site Index value is an indication of the degree of risk of P loss, not a quantitative prediction of the actual amount of P lost from a given field.** Fields in the "Low" category are expected to have a lower potential for P losses than fields in the "Medium P loss rating category, while fields in the "Medium P loss rating category are expected to have a relatively lower potential for P loss than fields in the "High" P loss rating category, and so on. The numeric values used in Table 12 to separate the various P loss categories are based on the best professional judgement of the individuals involved in the development of the *P Site Index* using data from fields and farms in Idaho where field evaluations were conducted in 2017.

Table 12. Interpretation of the *Phosphorus Site Index* Value

***P Site Index* Value**	**Generalized Interpretation of the *P Site Index* Value**
< 75	**LOW** potential for P movement from this site given current management practices and site characteristics. There is a low probability of an adverse impact to surface waters from P losses from this site. Nitrogen-based nutrient management planning is satisfactory for this site. Soil P levels and P loss potential may increase in the future due to N-based nutrient management planning
75 - 150	**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, leaching and erosion. Phosphorus applications should be limited to the amount expected to be removed from the field by crop harvest or soil test-based P application recommendations, whichever is greater. Testing of manure P prior to application is required
151 – 225	**HIGH** potential for P movement from this site given the current management practices and site characteristics. Phosphorus applications should be limited to 50% of crop P uptake. Testing of manure P prior to application is required.
> 225	**VERY HIGH** potential for P movement from this site given current management practices and site characteristics. No P should be applied to this site.

Best Management Practice Definitions

Contour Farming. Farming sloping land in such a way that planting is done on the contour (perpendicular to the slope direction). This practice would apply to fields having a slope of 2% or greater. When converting from surface to sprinkler irrigation, this can be as simple as planting across the direction of the surface water flow. For other more complex settings, the maximum row grade should not exceed half of the downslope grade up to a maximum of 4%. The minimum ridge height should be 2 inches for row spacing greater than 10 inches and 1 inch for row spacing less than 10 inches.

Cover & Green Manure Crop. A cover and/or green manure crop is a close-growing crop primarily for seasonal protection and soil improvement. This practice reduces erosion by protecting the soil surface. Cover crops must be established (have vegetative cover over a minimum of 30% of the soil) by November 1 and must be maintained to within 30 days prior to planting the following crop. There should be a minimum of 2 to 3 plants per square foot (about 100,000 plants/acre).

Dike or Berm. This practice applies to non-surface irrigated fields only and is comprised of an embankment to retain water on the field. The dike or berm must be engineered to retain runoff from a 25 year 24 hour storm event (0.8 BMP coefficient) or from 1 inch of runoff from the field (0.4 BMP coefficient).

Drip Irrigation. The credit for implementing this practice only applies when switching from surface irrigation to drip irrigation. A drip irrigation system shall be comprised of an irrigation system with orifices, emitters or perforated pipe that applies water directly to the root zone or soil surface. This practice efficiently applies water to the soil surface with low probability of runoff.

Filter Strip. A filter strip is a strip of permanent herbaceous dense vegetation in an area where runoff occurs. A filter strip can only be used on fields having < 10% slope. Ideally they are perpendicular to the flow of water and the runoff from the source area is such that flow through the strip is in the form of sheet runoff. Channeling of water through a filter strip will severely reduce its effectiveness. Filter strips must be a minimum of 20 feet in length. If the length of the field contributing runoff to the filter strip is greater than 1000 feet, then the minimum filter strip width shall be 50 feet. They must be irrigated and maintained so that there is a minimum of 75% vegetative cover. The seeding rate shall be sufficient to ensure that the plant spacing does not exceed 4 inches (about 16-18 plants per square foot).

Polyacrylamide (PAM). PAM is an organic polymer that stabilizes the soil surface when applied with irrigation water. This practice can increase infiltration and reduce soil erosion. The PAM must be a soluble anionic polyacrylamide. For usage instructions, follow NRCS Conservation Practice Standard "Anionic Polyacrylamide (PAM) Application" (450-CPS-1).

Residue Management/Conservation Tillage. Tillage practices that minimize the amount of residue buried. Conservation tillage results in crop residue on at least 30% of the soil surface. This practice reduces soil erosion by protecting the soil surface.

Sediment Basin. A basin or pond constructed to collect and retain sediment. This practice slows the velocity of flowing water which allows sediment to settle in the basin. Sediment basin size must be at least 500 cubic feet per acre of drainage area (20,000 ft^3 for 40 acre field or 20 ft x 200 ft x 5 ft). The length-to-width ratio should be 2 to 1 or greater with a minimum depth of 3 feet. Sediment basins must be cleaned on an annual basis or more frequently.

Tailwater Recovery & Pumpback Systems. This practice applies to surface irrigated fields only. Design standards and management must follow the ASABE Engineering Practice Standard 408.3 "Surface Irrigation Runoff Reuse Systems". Irrigation runoff reuse systems have four basic components: 1) runoff collection and conveyance channels (tailwater ditches, drains), 2) storage reservoir (tailwater pit, pond, sump), 3) pumping plant (reuse, return, pumpback pump), and 4) delivery pipe (return, pumpback pipe). Runoff from irrigated fields is intercepted by a system of open channels or pipelines and conveyed by gravity to a storage reservoir or pumping plant. Capacity of the channels and pipelines should be sufficient to convey the maximum expected runoff rate from irrigation. Also, the collection system should be able to safely convey or bypass runoff from precipitation. Reuse systems designed to capture 50% of the application volume will usually capture a large percentage of the total irrigation runoff.

Established Perennial Crop. This is a crop that is grown for more than one year. Perennial crop is considered to be "established" the season after it was seeded.

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