APPLYING A PHOSPHORUS RISK INDEX IN A MIXED-USE MOUNTAIN WATERSHED

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ABSTRACT

Surface waters in the Wallsburg, UT watershed have been identified as a relatively high contributor of phosphorus (P) to nearby Deer Creek Reservoir. Identifying the major contributors of P is critical for developing effective management practices. Phosphorus Risk Indices have been widely developed as a tool to identify areas with high risk of P movement, but these tools have mostly been applied to watersheds dominated by agricultural land use. While agriculture is often a source of nutrient pollution, in this watershed forest and shrubland dominate and agriculture lands are less than 10% of land area. In this study, we evaluate the use of the Minnesota P Index in the Wallsburg watershed. We used the Minnesota P Index because it includes a risk evaluation for snowmelt, which is a dominant factor in Wallsburg. We collected soil samples from major landcover types in distinct watershed subsections, and analyzed for Olsen extractable P. Soil samples collected from cropland and pasturesaveraged 25 $mg \cdot kg^{-1}$P and 38 $mg \cdot kg^{-1}$P respectively, whereas shrublands and woodlands averaged 43 $mg \cdot kg^{-1}$P and 63 $mg \cdot kg^{-1}$P respectively.Without modification, results of the Minnesota P Index indicate that P transport risk is dominated bysoluble P movement in snowmelt and that risk is greater for woodlands and shrublands than for croplands and pasture.On-going work will make adjustment to the P Index to improve application to mixed use watershed and to validate risk calculations.

INTRODUCTION

Phosphorus (P) is an economically important input in both crop and livestock production systems (Hansen et al. 2002, Mallarino and Blackmer 1992,Valk et al. 2000). Careful application and management of P is essential, however, since the transport of P from soil to nearby surface waters through various mechanisms, such as erosion and runoff, has been linked to the degradation of water quality, particularly through the acceleration of eutrophication. The eutrophication cycle can lead to low dissolved oxygen levels, reduced diversity of aquatic species, turbidity, and various challenges for municipal water treatment facilities (Carpenter et al. 1998; NRC 2000; Sharpley 1994; Smith 1998).

Phosphorus Risk Indices (P Index) have become widely used toolsused to assess the risk of P movement from land to water. First proposed by Lemunyon and Gilbert in 1993, states have adopted P indices to target improved management in areas of highestwater quality risk. To determine risk, a P Indexestimates P source and transport factors such as soil erosion, runoff, inorganic and organic applied P fertilizer, soil P test, tillage and other management practices, and then weights them to create an aggregated risk score. Factors included and calculation methodsused vary widely among P Index versions. P Index use has primarily focused on watersheds dominated by agriculture.

Our study was conducted in the Wallsburg, UT watershed located in the Wasatch Mountains. The Wallsburg watershed encompasses approximately 45,000 acres, including the farming town of Wallsburg, and land cover dominated by woodlands and shrublands (Table 1.) This study is unique because it evaluates the usefulness of a P Index in a mixed use watershed.

Table 1.Composition of different land cover types in the Wallsburg watershed (Wallsburg CRMP, 2012).

Land Cover Type	Acres	Percent of Watershed (%)
Woodland	15,653	34.4
Shrubland	13,864	30.4
Pasture and Rangland	12,930	28.4
Cropland	3,117	6.8

Major surface waters in the Wallsburg watershed include Little Hobble Creek, Spring Creek, Main Creek, and Maple Creek (Wallsburg CRMP 2012). Maple Creek is entirely diverted for irrigation and does not flow into Main Creek. All surface waters eventually discharge into Deer Creek Reservoir, a part of the Provo River Watershed.

The Provo River Watershed Council has documented poor water quality in Main Creek for years. Best management practices (BMP's) have been implemented over the years to target the restoration of degraded stream banks and the reduction of erosion from crop fields. Despite the BMP's, the levels of total phosphorus and dissolved total phosphorus at various reaches of each major tributary still exceeded the water quality standards set for the watershed in the recent 2009-2010 water quality assessment (Boyd 2012).Our objective is to evaluate the potential use of a Phosphorus Risk Index in the Wallsburg watershed and whether it can help identify high risk areas for P transport to surface waters.

METHODS

Minnesota Phosphorus Risk Index

For our study, we chose to use the Minnesota P Index, a pathway approach that accounts for total P from snowmelt runoff, in addition to the commonly accessed sediment-bound P and dissolved P from rainfall runoff. The three pathways account for transport mechanisms, sources of P, and management practices (Figure 1). Details about the inputs and calculation procedures are given in the Minnesota Phosphorus Site Risk Index: Worksheet User's Guide (Moncrief et al., 2006). Loss of P in particulate forms is estimated by predicting long term average annual erosion using the Revised Universal Soil Loss Equation (RUSLE 2.0) and a sediment delivery ratio based on distance from the site to the surface receiving water.

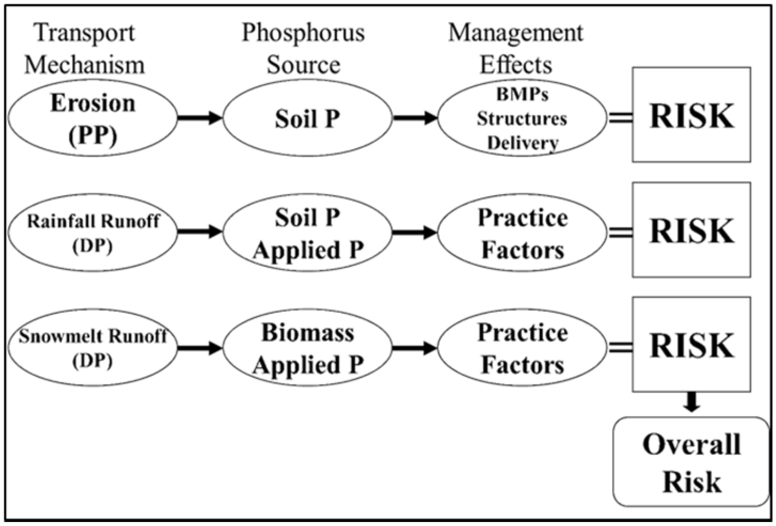

Figure 1.Conceptual illustration of the risk calculation in the Minnesota P Site Risk Index. The erosion pathway accounts for P loss in particulate forms (PP) and rainfall and snowmelt runoff pathways account for P loss in dissolved forms (DP).

Site Assessment and Sampling

We collected soil samples from major land use types in distinct watershed subsections. A total of 33 sites were visited, most being within cropland and shrubland areas. At each site, the following observations and data were recorded for inputs to our P Index: erosion estimation, slope steepness, vegetative cover, cover type, land use, infiltration rate, and management practices. Susceptibility to erosion was estimated visually, on a subjective scalefrom 1 to 5. Slope steepness was calculated by measuring change in height over a 25 m distance. Vegetative cover was determined by the line-transect method. Notes about cover type and land use were also recorded at the sample site. Infiltration was measured by adding 0.5 L of water to a 15 cm infiltrometer, and timing until no standing water could be seen on the soil surface. Management practices were determined through direct communication with landowners or through observation. Lastly, surface soil samples werecollected from a depth of 2.5 cm, to be analyzed for Olsen extractable P.

Soil P Testing

All soil samples were submitted to the Environmental Analytical Lab at Brigham Young University for soil P testing. Soils were tested byOlsen sodium bicarbonate extraction and molybdenum-blue spectroscopy on a ThermoSpectronicGenesys 20 at 880 nm wavelength (Olsen, SR et al. 1954). Olsen extractable P then was converted to runoff soluble P and total P based on linear equations derived during the development of the Minnesota P Index (Moncrief et al. 2006, p 32-33).

RESULTS AND DISCUSSION

The soil analysis revealed a wide range in Olsen extractable P levels, ranging from 8 mg kg^{-1} from an alfalfa field to 83 mg kg^{-1} from a scrub oak-maple-grass system. Averaged over all samples, Olsen extractable P was 42 mg kg^{-1}, illustrating that the soils in this watershed are have high relative concentrations of extractable P, even in areas not influenced by fertilizer or manure application. Average soil P was numerically least for the cropland and greatest for the woodlands

(Table 2). Finding lower soil P levels in the agricultural soils was not expected and may suggest depletion of P levels compared to native soil conditions.

Table 2.Average, minimum, and maximum Olsen extractable P concentrations for all 33 samples.

	Soil Test P *(mg·kg^{-1})*		
	Avg.	**Min.**	**Max.**
Cropland	25	8	70
Pasture	38	24	52
Shrubland	46	17	78
Woodland	58	17	83

The risk levels calculated with the Minnesota P Index levels varied by land use (Table 3) and geographically in the watershed (Figure 2). Average P Index risk was low for cropland (1.5) and pasture (1.9). The croplands were dominated by perennial hay crops, had high levels of cover, and low erosion risk. Average P Index risk was high for shrublands (5.9) and woodlands (5.9). The risk for these areas was dominated by risk calculated for the snowmelt pathway. The P Index results are consistant with stream water analysis we have performed (data not shown) that show dissolved P in runoff is more significant than P associated with soil particles from erosion. The risk calculation for the snowmelt pathway is sensitive to the amount of plant matter on the soil surface when snow melts because there is the potential for nutrients to leach out of the plant material into the runoff water. The woodlands and shrublands have significantly higher plant residue and biomass than do the agricultural fields where biomass is harvested and removed. The handling of P loss to snowmelt in the Minnesota P Index is based on several sets of cited research data, but none of the citations are for mountain ecosystems. Thus, there is good conceptual justification for the results reported here, but some additional work is need to validate them. The results call into question the common assumption that croplands are the most likely source of nutrient pollution. It is possible that, due to high P in the soils and parent materials in the Wallsburg watershed, the P concentraitons in surface waters are area are inherently high in P. Two factors present in the Wallsburg watershed that are not accounted for in the Minnesota P Index are1) the potential for P to be mobilized in irrigation return flow, and 2) the potential for P movement in subsurface drainage.

Table 3.P Index results by land cover category.

	Cropland	**Pasture**	**Shrubland**	**Woodland**
Total # of samples	13	6	11	3
Total P *(lbs./ton)*	1.08	1.16	1.22	1.29
Slope *(% gradient)*	0.35	0.90	3.2	4.5
Percent Cover *(%)*	91	66	59	52
Erosion Risk	0.04	0.14	0.19	0.15
Rainfall Runoff Risk	0.08	0.18	0.09	0.04
Snowmelt Runoff Risk	1.43	1.44	5.60	5.67
P Index Risk Total	**1.5 (Low)**	**1.8 (Low)**	**5.9 (High)**	**5.9 (High)**

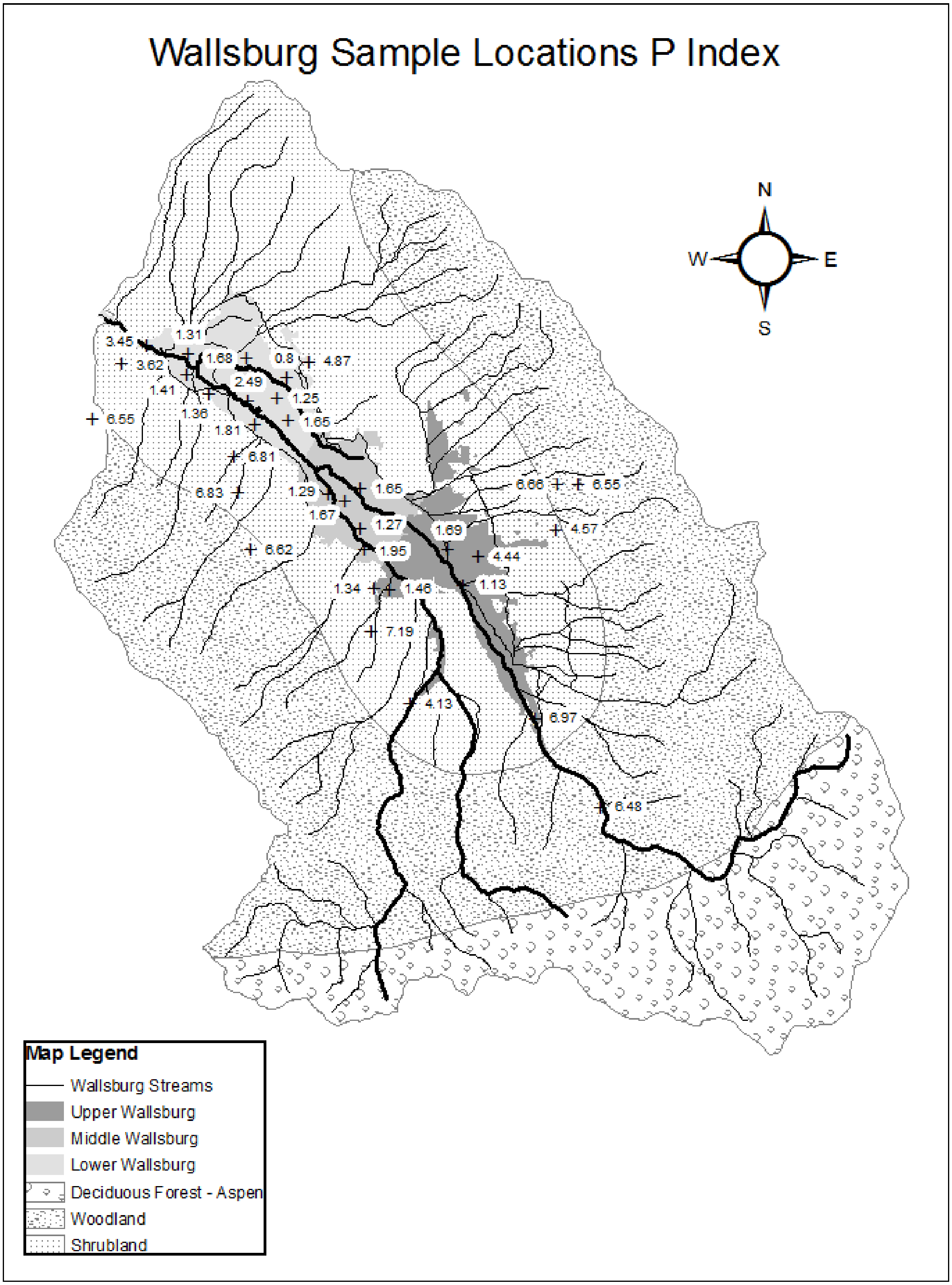

Figure 2. Map of P Index values for all sample sites across the Wallsburg watershed.

SUMMARY

Water quality standards for the surface waters in the Wallsburg, UT watershed are not being met in terms of total phosphorus and dissolved total phosphorus concentrations. Agriculture and its byproducts are often assumed to be the cause of nutrient pollution. By applying the Minnesota P Index, which assesses erosion, rainfall and snowmelt runoff pathways, showed snowmelt runoff from forested and shrublands to be the most significant pathway for dissolved phosphorus entering surface waters. Given this conclusion, we suggest studying further the contribution of phosphorus from the native slopes and hillsides in Wallsburg.We plan for furthers studies that focus on the contribution of shrubland plant species to the phosphorus concentrations in snowmelt. Other possible factors not evaluated in the P Index are irrigation return flows and subsurface drainage systems.

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