Improving and testing in-stream phosphorus cycling in SWAT

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INTRODUCTION

1. Phosphorus (P) is one of the key elements fueling Harmful Algae Blooms (HABs) worldwide, and specifically in the Western Basin of Lake Erie (WBLE).
2. Reducing P loading to surface waters is often complicated when the nutrient source is diffuse, as is generally the case in agriculturally-dominated watersheds such as those draining to western Lake Erie.
3. Further, the sediments lining a network of ditches, streams, and rivers can attenuate or exacerbate transport of soluble P (SP) downstream.
4. The Equilibrium Phosphorus Concentration (EPC) is one method of predicting whether in-stream sediments will serve as a P source (i.e., sediment releases P when EPC > SP) or sink (i.e., sediment sorbs P when EPC < SP).

KEY OBJECTIVES

1. The overarching objective is to implement the EPC algorithm proposed in White et al. (2014) in the most widely used watershed-scale model, Soil and Water Assessment Tool (SWAT), and eventually SWAT+, to understand in-stream P source and sink dynamics in the Maumee River Watershed draining to the WBLE.
2. The objective of this poster is to understand the behavior of P absorption coefficients in determining absorption and desorption of SP over time in two reaches of the watershed.

METHODS

Study Site:

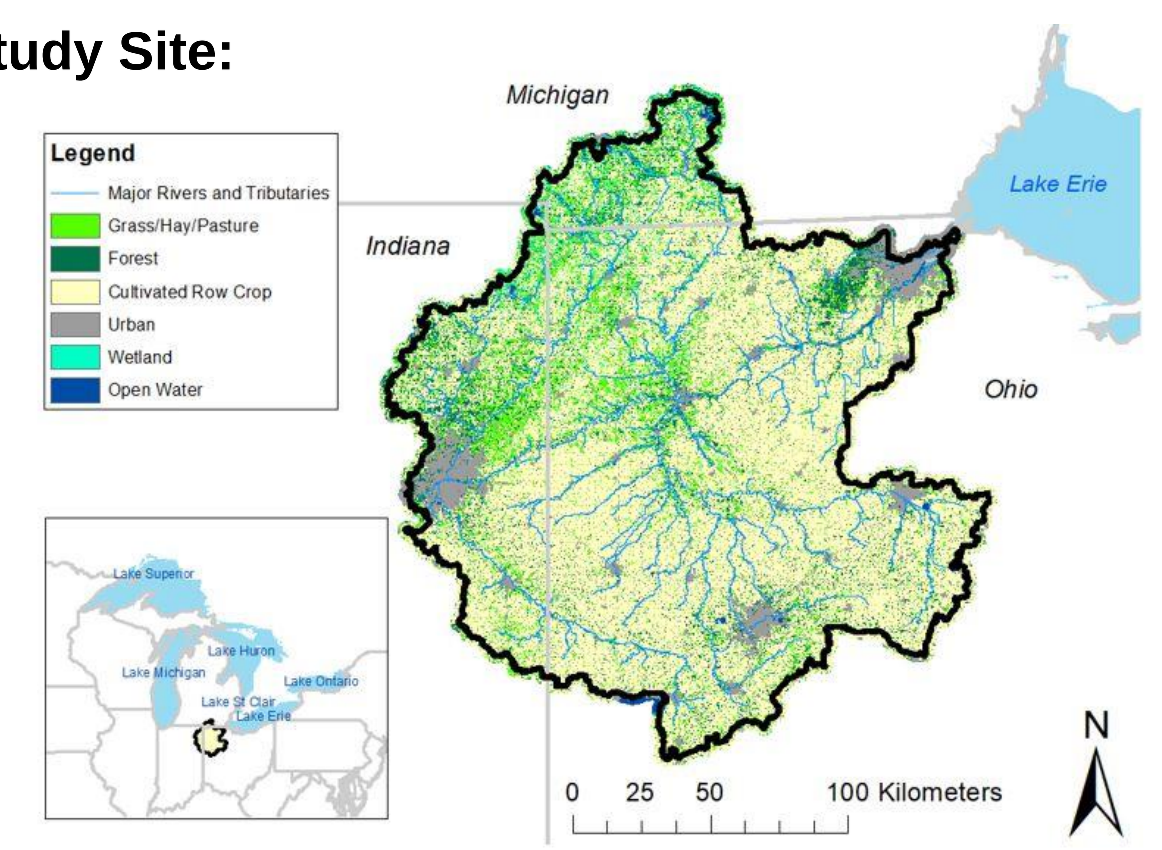

Figure 1. The Western Lake Erie Basin (WLEB) delineated to create rivers and streams of various sizes using SWAT 2012 Rev 635 (Adapted from Apostel et al. (2021)).

Equilibrium Phosphorus Concentration (EPC):

EPC includes the contribution for solution cations and sediment composition which is not well tested in SWAT. Once incorporated, tested, and modified, the EPC algorithm will help to simulate the net sorption and desorption from benthic sediments.

EPC is calculated using equation 1:

$$EPC = \frac{\sum_{t=1}^{-DI} SP_t^* \left(1 + \frac{t}{DI}\right)}{\sum_{t=1}^{-DI} \left(1 + \frac{t}{DI}\right)} \quad \text{Equation 1}$$

where,
- EPC = Equilibrium Phosphorus Concentration, mg/l
- SP = Soluble Phosphorus, mg/l
- DI is Period of Influence, days
- t is the day

In a condition, where:

$EPC\ is\ either\ smaller\ or\ larger\ than\ SP_{in}$

$$SP_{out} = EPC + \left(SP_{in} - EPC\right)e^{(-Kout\ or\ -Kin)\ TT} \quad \text{Equation 2}$$

where,
- SP_{in} is the amount of SP coming into the channel and SP_{out} is the amount of SP leaving the channel
- K_in and K_out are SP transformation coefficients
- TT is travel time in minutes and calculated as:

$$TT = L\ \left(S^{0.375} Q^{0.25} n^{-0.75}\right)^{-1} \quad \text{Equation 3}$$

where,
- L is the channel length (km)
- S is the mean river slope
- Q is the discharge (m^3/min)
- n is Manning's roughness coefficient ($m^{1/3}\ min^{-1}$)

Study Variables

(a) Choice of River Channel

Channel Property	Unit	Small Channel	Long Channel
Main Channel Width	m	72.24	18.71
Main Channel Depth	m	1.9	0.77
Main Channel Slope	m	0.00135	0.0007
Main Channel Length	m	162	26872
Channel Width to Depth Ratio	No Units	37.9	24.2

(b) Different values of absorption (K_in) and desorption (K_out) coefficients with various days of influence (DI) to understand EPC variations

K_in and K_out	sorption and desorption coefficients	0.1,0.3,0.5,0.7,1
DI	Period of Influence, days	2,5,10,100,500

RESULTS

(a) Period of Influence (DI)

1. *Varying the Period of influence (DI) indicated that at low values (2-10 days) EPC tracks with daily SP, while at higher values (100-500 days) EPC becomes fairly steady over time.*

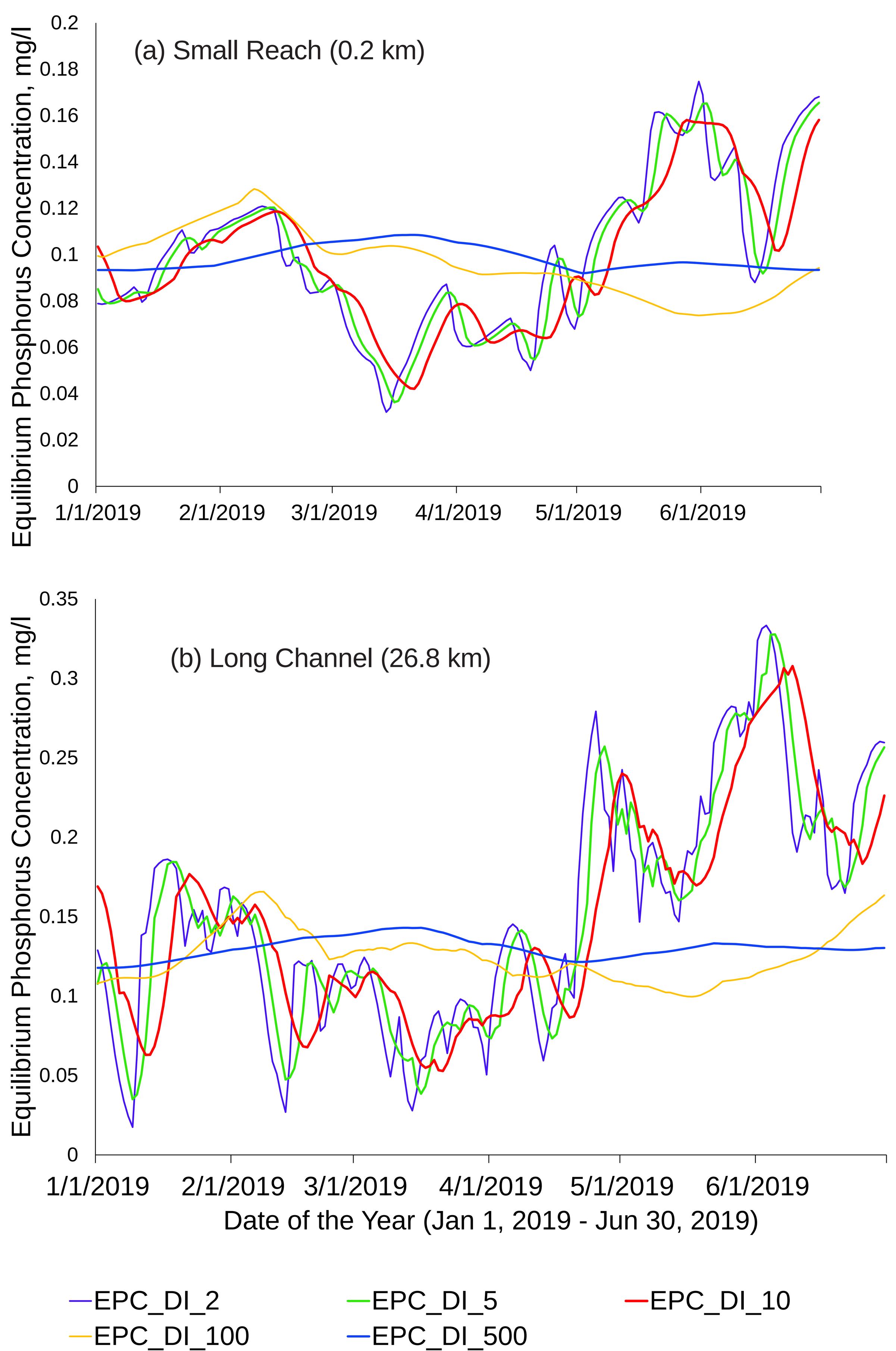

Figure 2. Variations of Period of Influence (DI) and their effect on EPC.

(b) Soluble Phosphorus (SP) transformation coefficients (K_in and K_out)

We compared SWAT's current in-stream module, which lacks transformation coefficients, with the EPC. With DI set at 10 days, and varying K_in and K_out (Figure 3), and found:

1. Higher SP transformation coefficient values (> 0.7) showed a considerable discrepancy in SP concentration simulation by SWAT in its current state and EPC algorithm.
2. The SP transformation coefficients compounded with DI values are important to assess the impact the SP concentration simulations by either SWAT or EPC.

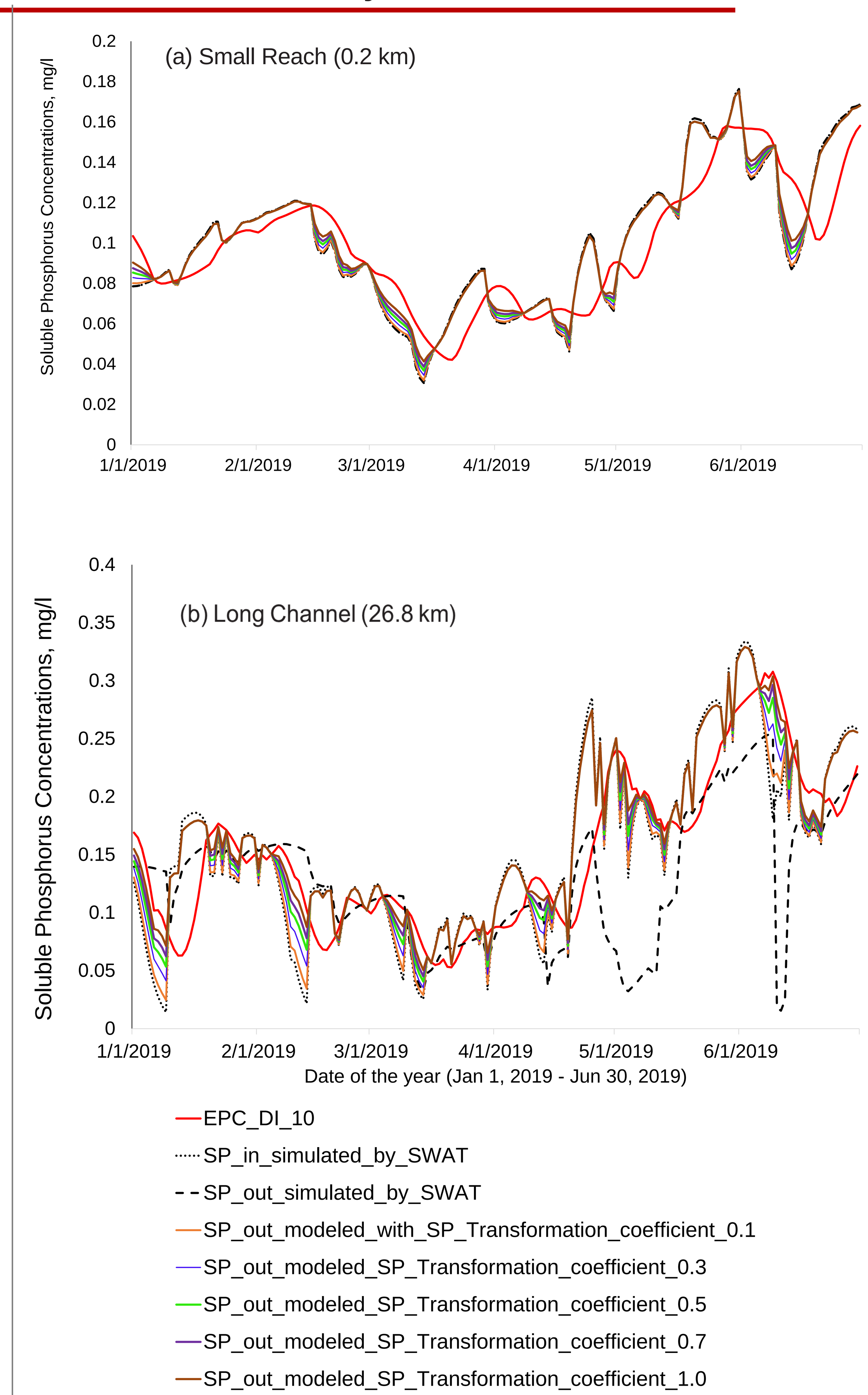

Figure 3. Simulated SP concentrations (mg/l) from January 1, 2019 – June 30, 2019, calculated using different values of sorption and desorption coefficients (K_in and K_out).

FINDINGS

1. The EPC concept has the potential to alter simulation of river P cycling considerably in SWAT.
2. Lab and field data at varying spatial and temporal scales could be used to estimate the values of SP transformation coefficients (K_in and K_out) and Period of Influence (DI).

FUTURE WORK

Incorporate EPC algorithm in SWAT and eventually with SWAT+ in-stream modules and assess the impact of different management practices on sorption and desorption of P within streams in the Maumee River Basin.

REFERENCES

1. Apostel, A., Kalcic, M., Dagnew, A., Evenson, G., Kast, J., King, K., Martin, J., Muenich, R.L. and Scavia, D., 2021. Simulating internal watershed processes using multiple SWAT models. *Science of the Total Environment*, *759*, p.143920.
2. White, M.J., Storm, D.E., Mittelstet, A., Busteed, P.R., Haggard, B.E. and Rossi, C., 2014. Development and testing of an in-stream phosphorus cycling model for the soil and water assessment tool. *Journal of environmental quality*, *43*(1), pp.215-223.