SOLUBLE REACTIVE PHOSPHORUS STREAM LOADS DECREASE FOLLOWING LEGACY SEDIMENT REMOVAL IN A RESTORED FLOODPLAIN

Big Spring Run, PA

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Legacy sediment removal may create a phosphorus retentive system

In streams with deeply incised banks, often associated with downcutting of legacy sediments, stream water and groundwater are physically separated from the floodplain. When legacy sediments are removed, the surface water and groundwater are better connected because of the renewed connectivity with the restored hydric floodplain. At Big Spring Run located in Lancaster County, Pennsylvania, an ecosystem restoration was undertaken to remove legacy sediment generated from previous historic development damming effects, with the aim to reduce nutrient and suspended sediment loads, and to improve water quality. Utilizing three years of pre-restoration monitoring data (2008-2011), and four years of post-restoration monitoring data (2012-2016), we evaluate soluble reactive phosphorous (SRP) output from the basin to determine whether retention or release of SRP to the system occurs following legacy sediment removal.

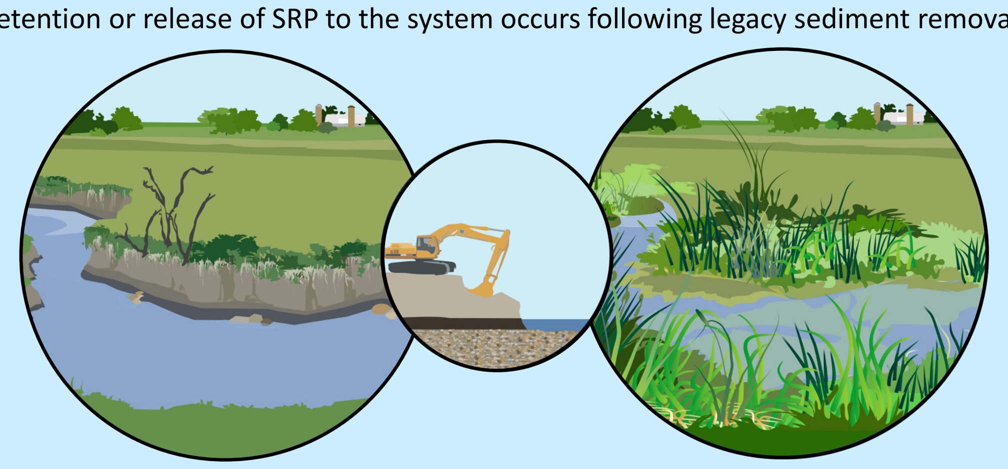

Figure 1. Big Spring Run Restoration Event. Restoration to remove legacy sediments was conducted at Big Spring Run beginning in October 2011, and ending November 2011. Mill pond reservoir sediment stacks, i.e. 'legacy sediment', were cleared away, exposing the once- buried relic hydric soil (Holocene *pre-settlement* wetlands on Pleistocene gravel), leading to drops in base level and the widening of channels (Walter & Merritts 2008).

Does stream restoration decrease soluble reactive phosphorus (SRP) loading to stream ecosystems?

From 2008-2016, we sampled ~ bi-monthly 50 shallow groundwater wells (groundwater sites: n= 1598) and 7 surface water sites (surface water sites: n= 302) excluding the active restoration period in 2011 within and outside of a legacy sediment restored riparian zone in southeastern Pennsylvania. Surface water samples identified as *upstream* and *downstream* of the legacy sediment restoration zone were differentiated at the confluence. Groundwater samples identified as *IN* and *OUT of* the legacy sediment restoration zone were delineated by field observation and visual observation of elevation changes from pre and post Light Detection and Ranging (LiDAR) based maps (Weitzman et al. 2014).

- Flow Injection Analysis method 10-115-01-1-A for ortho-Phosphate as P
- Shimadzu TOC-VCPH Analyzer for NPDOC
- Perkin Elmer Optima 8300DV ICP-OES for Mn^{2+}
- Streamflow gaging stations: USGS01576516, USGS015765195, USGS015765185

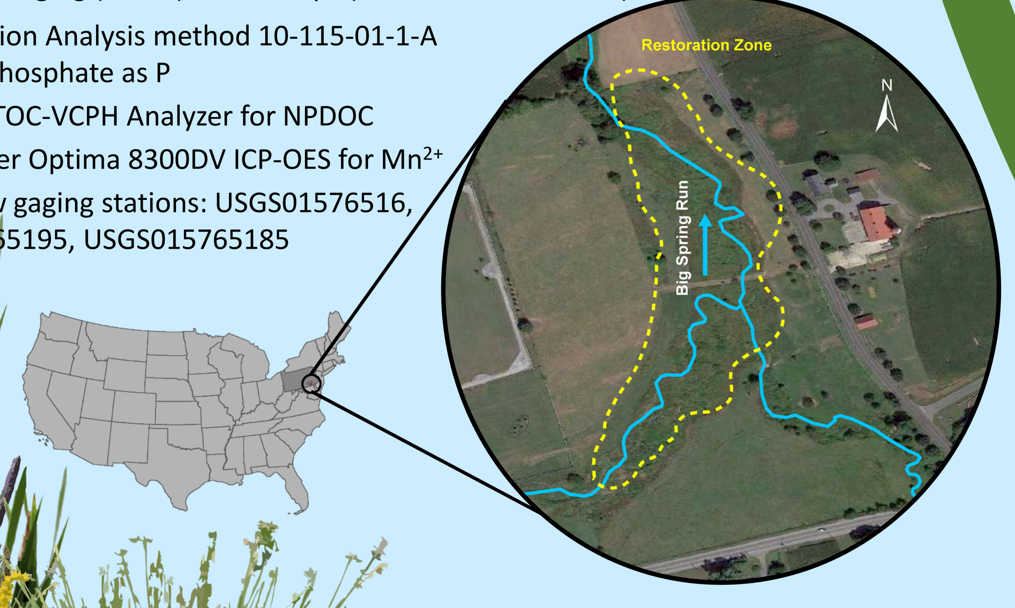

Figure 2. Site map. Restoration zone at Big Spring Run located in Lancaster County, Pennsylvania evaluated for nutrient and suspended sediment loading and retention.

SRP in surface water downstream of the restored site decreased over time in response to legacy sediment removal

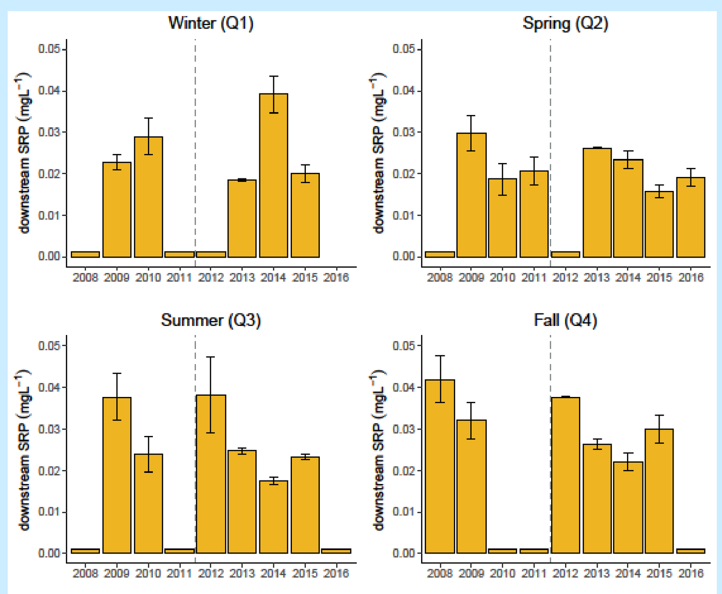

Figure 4. Seasonal fluctuations in SRP concentrations. Dashed line indicates legacy sediment removal.

Table 1. Seasonality assessed through ANOVA.

Pre-restoration groundwater SRP, in the restoration zone					
	Sum of Squares	df	Mean Square	F	Sig.
Seasonality	0.00	1	0.0011	1.234	0.268
Residuals	0.17	193	0.0009		

Post-restoration groundwater SRP, in the restoration zone					
	Sum of Squares	df	Mean Square	F	Sig.
Seasonality	0.00	1	0.0014	4.603	0.0323 *
Residuals	0.20	654	0.0003		

Pre-restoration surface water SRP, downstream of the restoration zone					
	Sum of Squares	df	Mean Square	F	Sig.
Seasonality	0	1	0.0003	2.379	0.13
Residuals	0	47	0.0001		

Post-restoration surface water SRP, downstream of the restoration zone					
	Sum of Squares	df	Mean Square	F	Sig.
Seasonality	0.001	1	0.0013	5.25	0.0249 *
Residuals	0.017	71	0.0002		

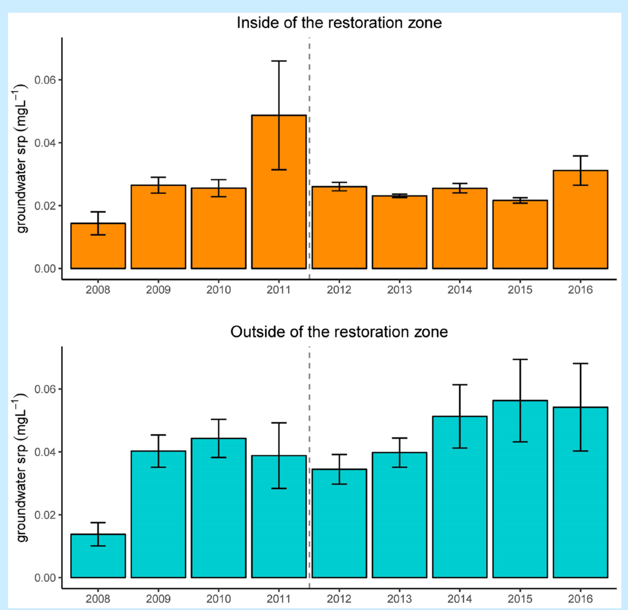

Figure 5. Groundwater SRP inside and outside of the restoration zone over time. Dashed line indicates legacy sediment removal.

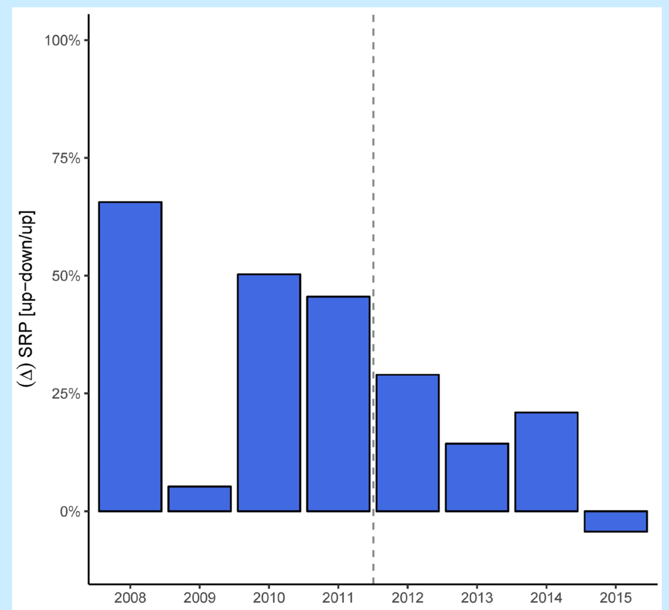

Figure 6. Surface water SRP mass balance model over time. Dashed line indicates legacy sediment removal.

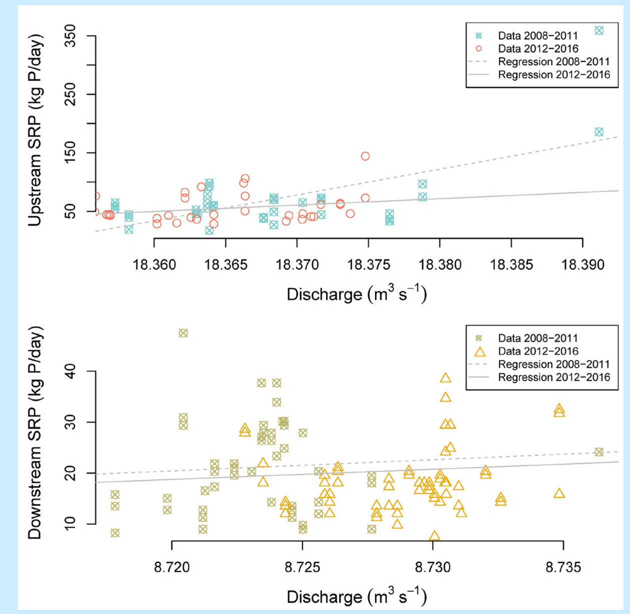

Figure 7. Upstream and downstream SRP flux.

Possible drivers of SRP mobilization and retention

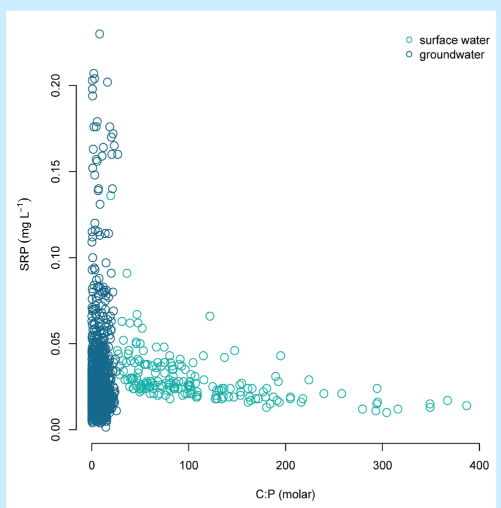

Figure 8. Carbon to phosphorus in surface and groundwater. Ratio indicates DOC: SRP vs SRP. Dark blue circles indicate groundwater SRP concentrations, and light blue indicate surface water concentrations.

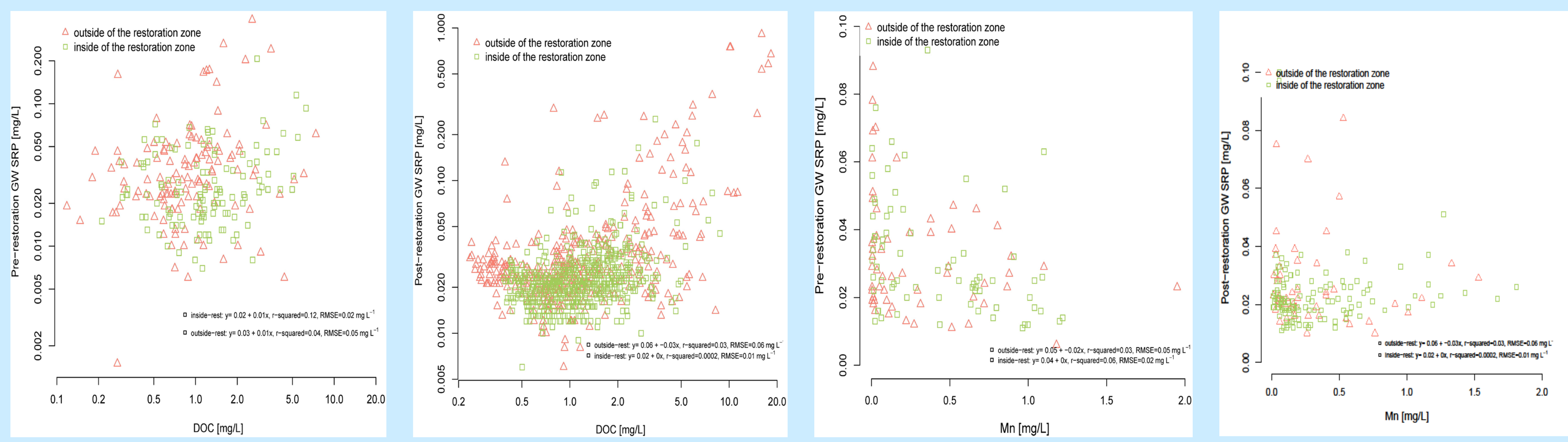

Figure 9. Pre-/post-restoration (2008-2016) relationships between groundwater SRP concentrations and DOC and Mn^{2+} inside (green squares) and outside (red triangles) of the restoration zone.

Seasonal response of SRP fluctuates between winter and summer collection periods

- We observe post-restoration decreases in SRP during warm weather months (Q2 and Q3), in relation to cold weather months (Q1 and Q4).
- Statistical significance in seasonality was observed in post-restoration downstream surface waters (*p=0.0249*) and groundwater inside of the restoration zone (*p=0.0323*). No statistical difference (p value > .05) in seasonality was observed for pre-restoration downstream surface waters (p=0.13) or groundwater inside of the restoration zone (p=0.0323).

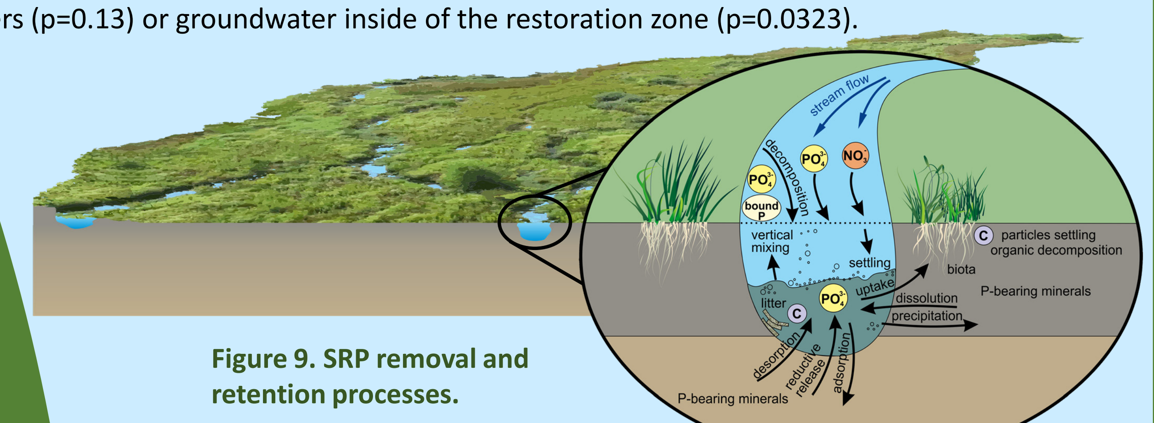

Figure 9. SRP removal and retention processes.

- A mass balance model yields a net change in cumulative upstream SRP concentrations vs downstream SRP concentrations that were greater pre-restoration (16282.4 kg yr-1 ± 1642.7) (mean±s.e.) and declined post-restoration (10264.4 kg. yr-1 ± 707.7).
- Following restoration, dissolved organic carbon (DOC) and reduction oxidation conditions (Mn^{2+}) appear to predict for SRP concentrations.

Net loss and net decrease in SRP mobilization in surface waters occurs because of a greater retention rate within the system

- We found that following restoration at Big Spring Run, SRP retention was favored within the system.
- A mass balance model of upstream compared to downstream surface water SRP loads showed overall net retention (upstream-downstream load) within the floodplain system with a decrease in SRP flux observed from pre-restoration (16282.4 kg yr-1 ± 1642.7) (mean±s.e.) to post-restoration (10264.4 kg. yr-1 ± 707.7), a net reduction of 37%.
- The decrease in available SRP in streamwater may be a result of SRP association with minerals. SRP often binds to and moves with sediments (Walling et al. 2003), and the association between pre-restoration SRP and post-restoration DOC may illustrate a resulting SRP reserve in the restored environment.
- Studies have found that longer P buffer time lags may be a product of SRP saturation in sediments in floodplains, large sediment storage in contact with channels, and high ratio of catchment to water area (Hamilton et al. 2011).
- Understanding SRP response to a restored floodplain system will help watershed managers and policy makers to make decisions about restoration practices to best support a holistic aquatic ecosystem condition.

Acknowledgements

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