NUTRIENT DELIVERY BY SHALLOW GROUNDWATER DISCHARGE TO HEADWATER STREAMS, THAMES RIVER BASIN, ONTARIO, CANADA

Dale R. Van Stempvoort, D. Ross Mackay and Pamela Collins
Water and Science Technology Directorate, Environment and Climate Change Canada, Canada
Contact E-mail: dale.vanstempvoort@canada.ca

Introduction

The role of shallow groundwater discharge in supplying nutrients to streams is often overlooked; when considered, data are generally lacking. This study probes the significance of this nutrient delivery process in a priority watershed in southern Ontario, Canada: the Thames River Basin (TRB). The TRB is known to be an important source of nutrients (notably phosphorus) to Lake St. Clair and Lake Erie, both of which are prone to eutrophication.

Study Sites

Shallow groundwater and streams were sampled in two rural headwater catchments (Cedar Creek, 9,515 ha; Nissouri Creek, 3,090 ha) in the TRB (Figure 1). These catchments are dominated by agricultural use, but include forest, wetlands and urban development. The small headwater streams and constructed drains in these catchments receive no influxes of treated municipal wastewater; one subcatchment (CC-SW-C) includes a small urban area with residential septic systems.

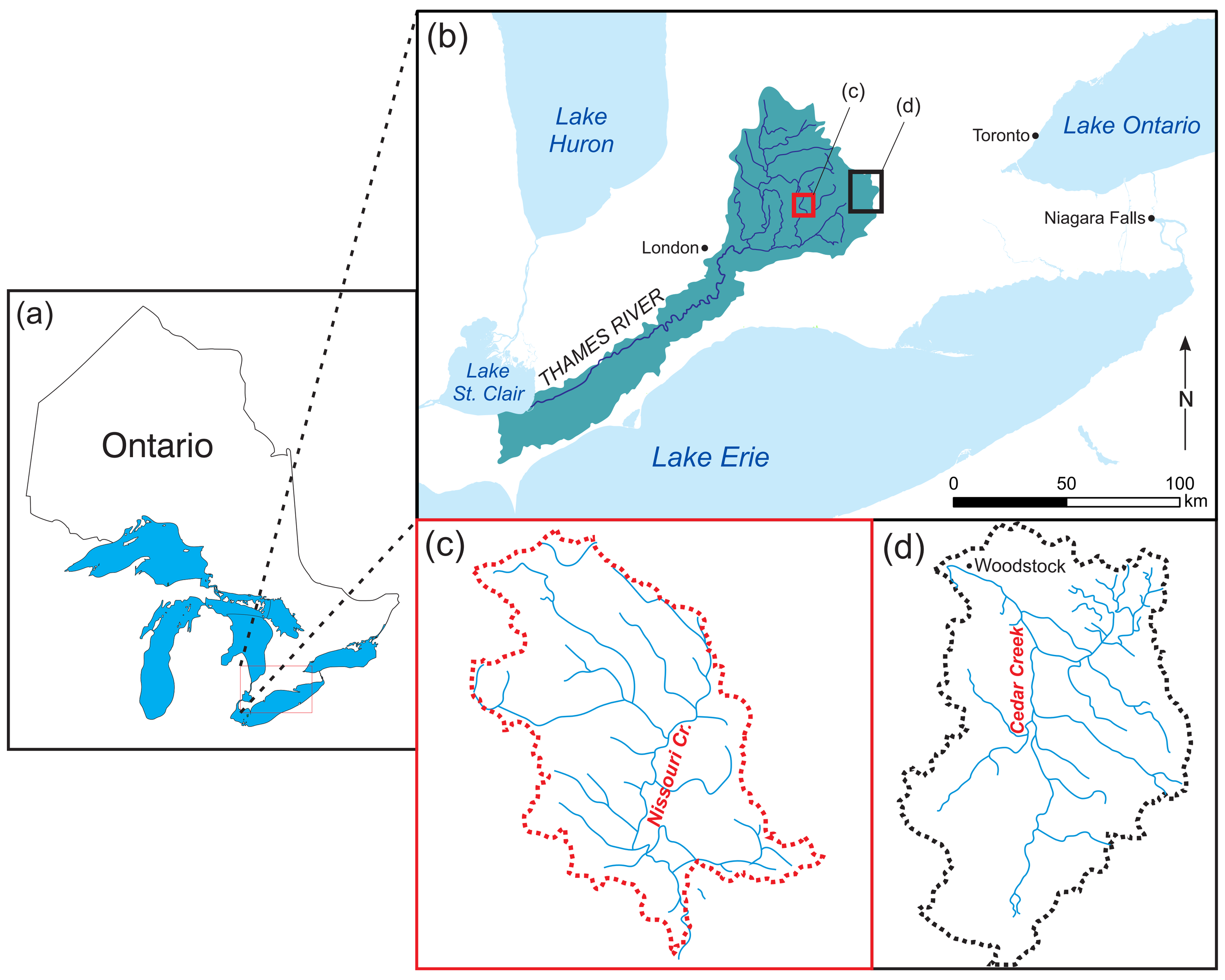

Figure 1. Locations of study catchments.

Sampling of Groundwater and Surface Water

Environmental water samples were collected at 2 to 4 week intervals between June 2017 and April 2019. Surface water was sampled from 10 headwater streams (including drains) in the study catchments. Groundwater samples were from drive points installed at shallow depths (< 2 m below ground) at 8 locations in riparian zones along headwater streams and drains.

Figure 2. Collecting a stream water sample at site CC-SW-A, August 2017.

Figure 3. Sampling groundwater next to a stream, site NC-GW2-E, February 2018.

Preliminary Results

Seasonal Trends

Nutrient concentrations in the streams and groundwater had similar ranges at all sites, but had different seasonal fluctuations (Figure 4). Other parameters (not shown) also exhibited seasonal variations. These fluctuations suggest dominance of shallow flow paths with short residence times in the subsurface.

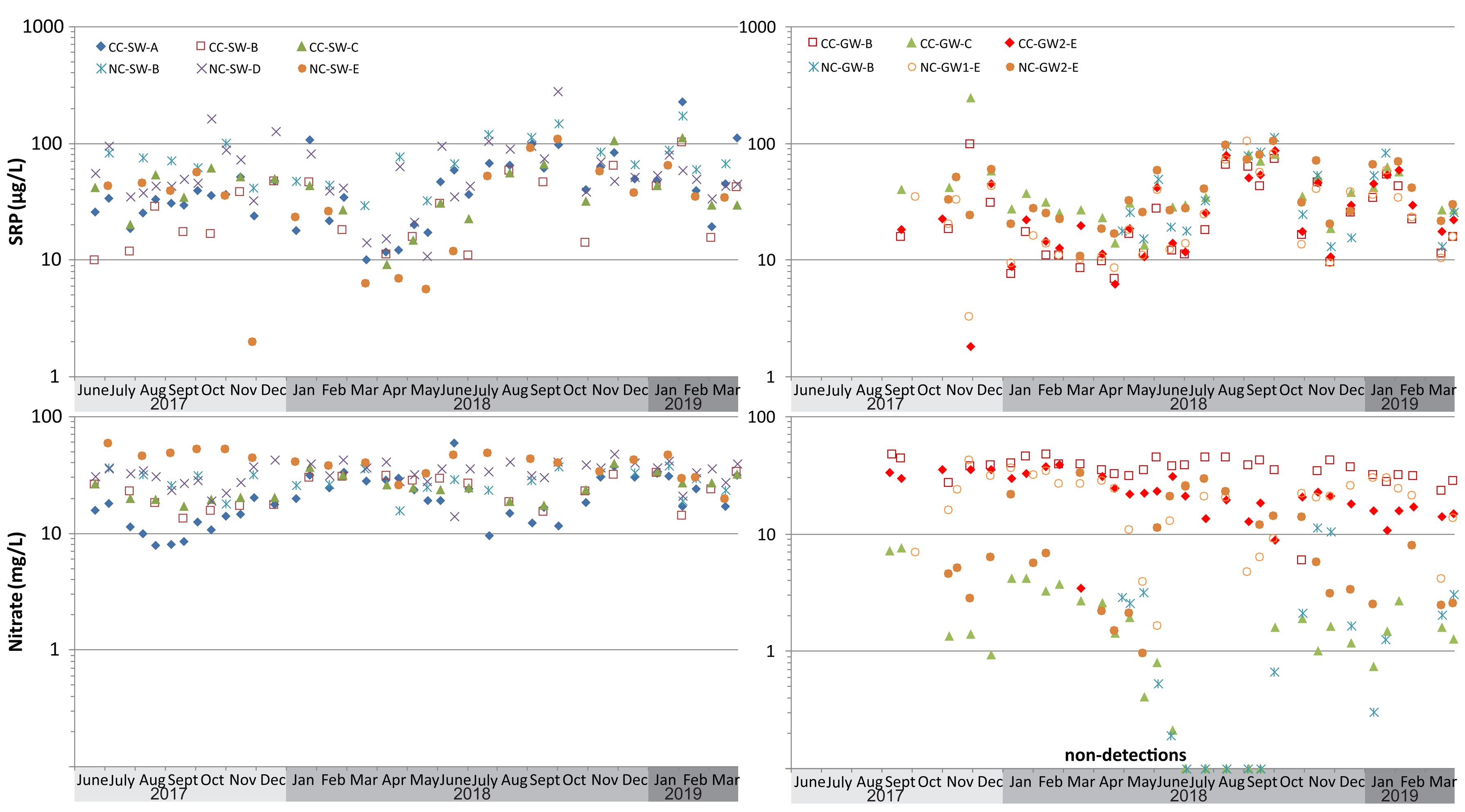

Figure 4. Graphs showing seasonal variations in nutrient concentrations at selected surface water (left panels) and groundwater (right panels) sample locations.

Relationship of Stream Water Quality to Land Use

Surprisingly, phosphorus (P) concentrations (total = TP, soluble reactive = SRP) tended to be higher in streams that drained subcatchments with greater fractions of wetlands, and P concentrations tended to decline with increasing agricultural land use (Figure 5). In contrast there was a weak negative relationship between nitrate concentrations and fraction of undeveloped wetlands in these subcatchments (Figure 5).

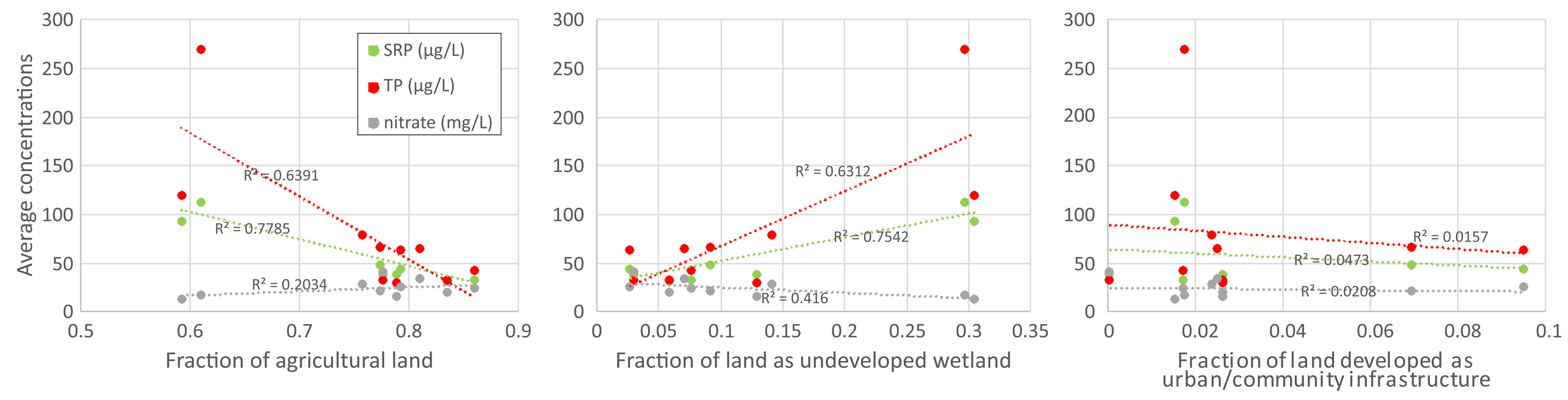

Figure 5. Relationship of stream water quality to land use in the stream catchment: Average nutrient concentrations in the ten sampled headwater streams versus fraction of land use.

Relationship of Stream Water Quality to Discharge

For the two largest subcatchments, there were weak to moderate positive correlation between stream discharge and nutrient concentrations (TP, SRP and/or nitrate) (Figure 6).

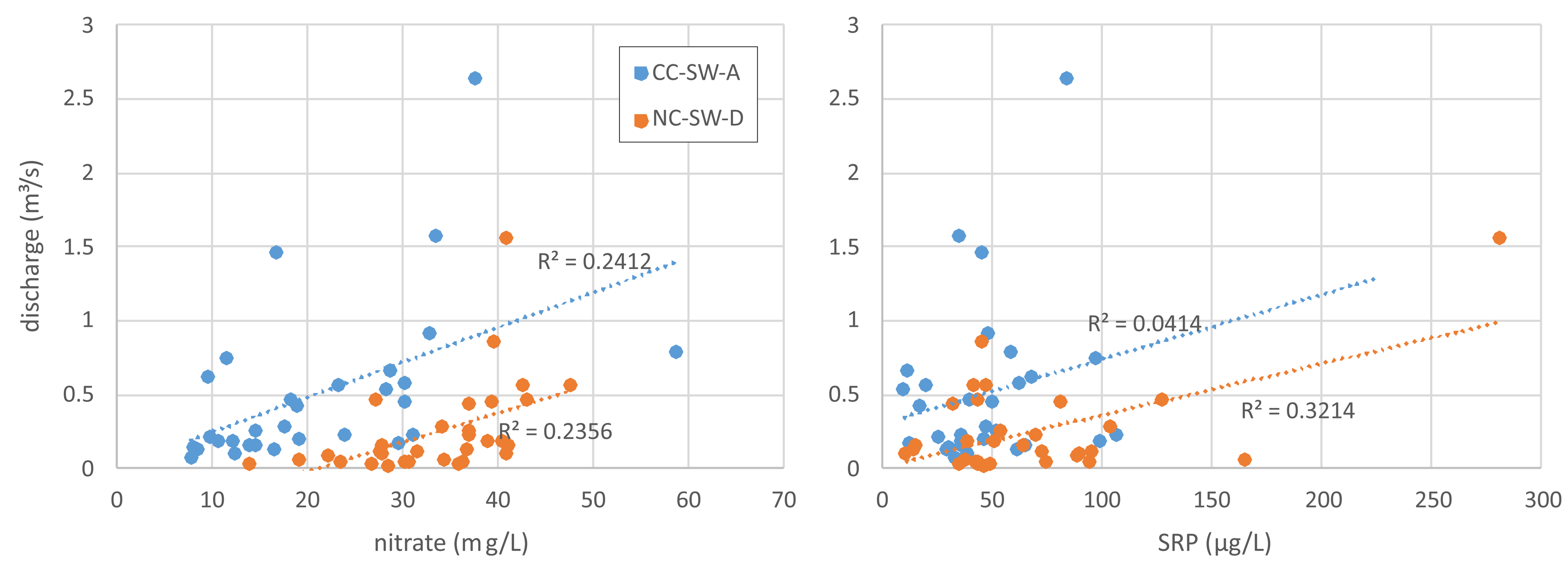

Figure 6. Relationship of stream water quality to discharge (two largest subcatchments).

Comparison of Nutrients in Shallow Groundwater and in Streams

Phosphorus (P)

Overall the concentrations of soluble reactive P (SRP) in shallow riparian groundwater were similar to those in the surface water (Figure 7). In both cases the majority of the samples had concentrations that ranged between 10 and 100 µg/L. The groundwater site with the highest SRP concentrations (average 266 µg/L) was associated with elevated ammonium (NH_4^+) N and low nitrate (NO_3^-) N (Figure 7).

In the surface waters, SRP (average 57.9 µg/L) makes up a large fraction of total P (TP, average 78 µg/L). Highest concentrations of both SRP and TP in streams were measured in samples collected in subcatchments with relatively high fractions of wetlands.

Nitrogen

Both ammonium and nitrate were detected in most of the samples; nitrate-N tended to dominate (Figure 7). Nitrate-N concentrations were similar in some of the shallow groundwater and in the surface water (Figure 7). Other groundwater had significantly lower nitrate concentrations (Figure 7), apparently affected both by land use in the vicinity and by denitrification in the subsurface.

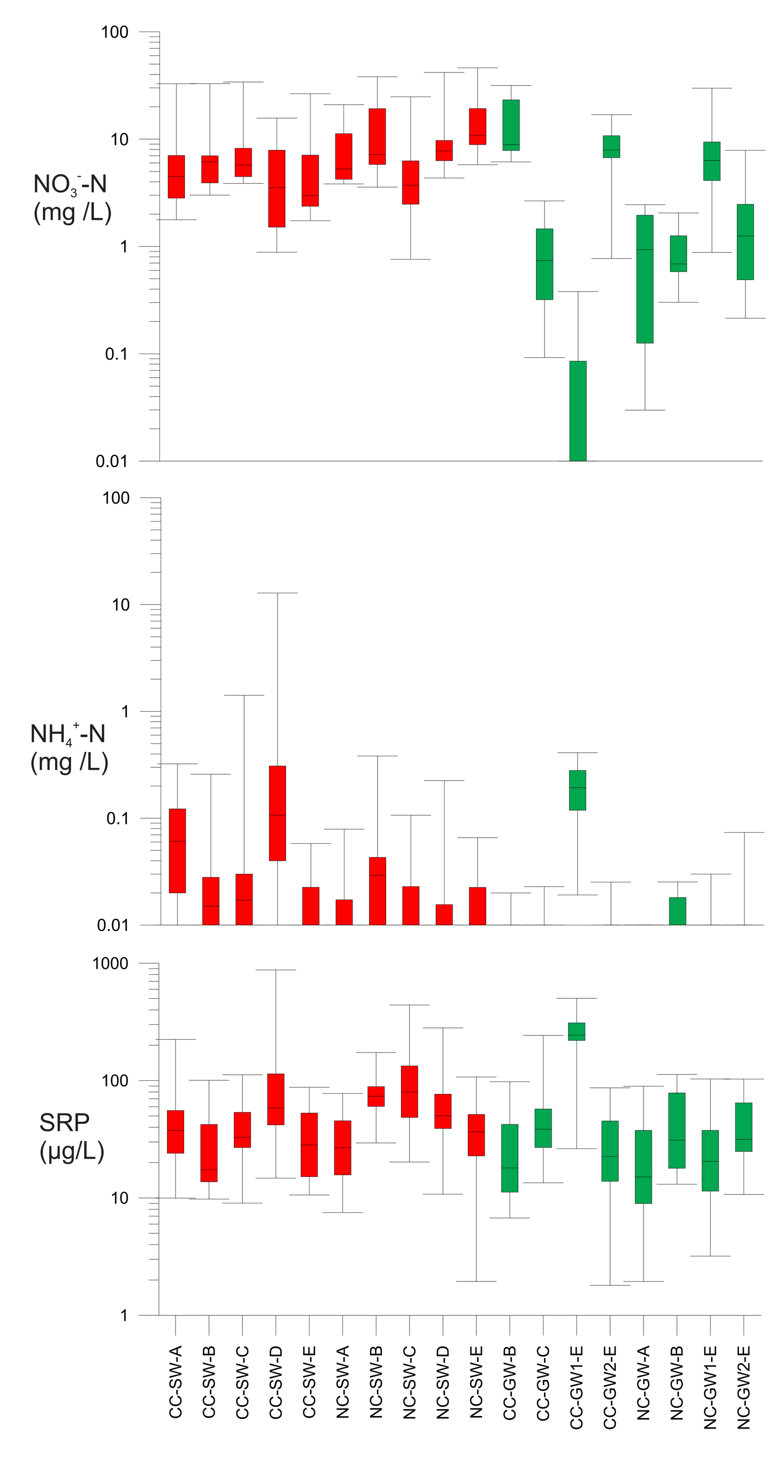

Figure 7. Site by site (x-axis) comparison of nutrients in surface water (red boxes) and groundwater (green boxes).

Implications of Preliminary Results

- The similarity of SRP concentrations in shallow groundwater and in headwater streams suggests that the groundwater contributes most of the SRP observed in these streams, particularly during baseflow conditions.
- The association of higher SRP in streams with greater fractions of wetlands in their catchments was surprising. Is this perhaps the result of these wetlands undergoing exceptional stress?
- Compared to the streams, groundwater chemistry is more variable from site to site. This makes it challenging to quantify nutrient fluxes contributed by groundwater discharge to surface water based solely on widely spaced groundwater data.

Acknowledgements

This study was funded by Environment and Climate Change Canada (ECCC). All laboratory analyses were conducted at the Canadian Centre for Inland Waters (Burlington, ON). The National Laboratory for Environmental Testing conducted the total phosphorus (TP) analyses. The County of Oxford and several anonymous private landowners permitted access to their sites for sampling of groundwater. Lucas Neilson of ECCC assisted with preparation of this poster.