ONFARM

Water Quality Technical Report 2025-2026

Prepared by:

OSCIA

March 31, 2026

Acknowledgements

The On-Farm Applied Research and Monitoring (ONFARM) program is a nine-year applied research initiative managed by the Ontario Soil and Crop Improvement Association (OSCIA) on behalf of the Ontario Ministry of Agriculture, Food and Agribusiness (OMAFA). It aims to enhance soil health and water quality research on farms across Ontario. Funded by the Sustainable Canadian Agricultural Partnership, a five-year federal-provincial-territorial initiative, OSCIA also recognizes the valuable support from various organizations and agricultural community members that contribute to the program:

- Soil health data is gathered, compiled, and analyzed by the Soil Resource Group (SRG) based in Guelph, Ontario. SRG is crucial in working directly with ONFARM cooperators to coordinate and carry out soil health trials, as well as collecting data at edge-of-field locations.
- Three Conservation Authorities (CAs) collaborate to implement the edge-of-field monitoring aspect of ONFARM. They gather essential data on water quality, water quantity, and land use to meet the program's goals. Additionally, CAs offer technical guidance and collaborate directly with participants to conduct outreach activities associated with ONFARM. The partnering CAs are: Ausable Bayfield Conservation Authority (ABCA), Lower Thames Valley Conservation Authority (LTVCA), and Upper Thames River Conservation Authority (UTRCA).
- Representatives from Agriculture and Agri-Food Canada (AAFC), and OMAFA, who participate in the ONFARM Technical Working Group (TWG), offer valuable input on various technical aspects of the program, including data management and collection.
- OSCIA would like to highlight the critical role of the participating ONFARM cooperators in supporting the research program’s objectives on their respective farms. ONFARM is an applied research program being implemented on working farms across the province. ONFARM would not be possible without the dedication of cooperating farmers and the agricultural community.
- The water quality monitoring and data analysis were further enhanced through the Lake Erie Enhanced Agricultural Analysis Project (LEEAAP), funded by the Canada Water Agency.

Table of Contents

1.0 Introduction

The On-Farm Applied Research and Monitoring (ONFARM) program is a nine-year applied research initiative that supports soil health and water quality research on farms across Ontario.

The program is currently funded by the Sustainable Canadian Agricultural Partnership, a five-year federal-provincial-territorial initiative. Developed by the Ontario Ministry of Agriculture, Food and Agribusiness (OMAFA) and delivered by the Ontario Soil and Crop Improvement Association (OSCIA), ONFARM builds on work accomplished under the Great Lakes Agricultural Stewardship Initiative's (GLASI) Priority Sub-watershed Project, but with an expanded emphasis on soil health. The program encompasses a range of activities, including rigorous monitoring of soil health and year-round monitoring of water quality at select edge-of-field locations on working farms across the province. Through establishing paired plots and within-field watershed monitoring areas on these farms, different agricultural best management practices (BMPs) are assessed for their efficacy in improving soil health, water quality, and productivity.

ONFARM has three primary objectives:

1. Evaluate soil health indicators and test BMPs through continued paired plot trials at sites across Ontario.
2. Study impacts of BMPs on in-field soil-water dynamics and water quality.
3. Engage with farmers and stakeholders to transfer knowledge on BMP implementation and impact.

Following the successful completion of ONFARM's initial phase from 2019 to 2023, the program has been extended to continue through 2028.

The program's renewal allows for the continued collection of critical data supporting BMP outcomes from the long-term soil health trial and edge-of-field (EOF) water quality monitoring sites. This will enable a deeper understanding of the impacts of BMPs, such as cover cropping and organic amendment application, as well as the novel soil health indicators being tested.

Additionally, the program's extension seeks to gain insights into how these BMPs enhance soil-water dynamics to improve crop resilience and to better understand how profitability and site-specific agronomy can inform farmers' management decisions.

1.1 Organization Structure and Research Sites

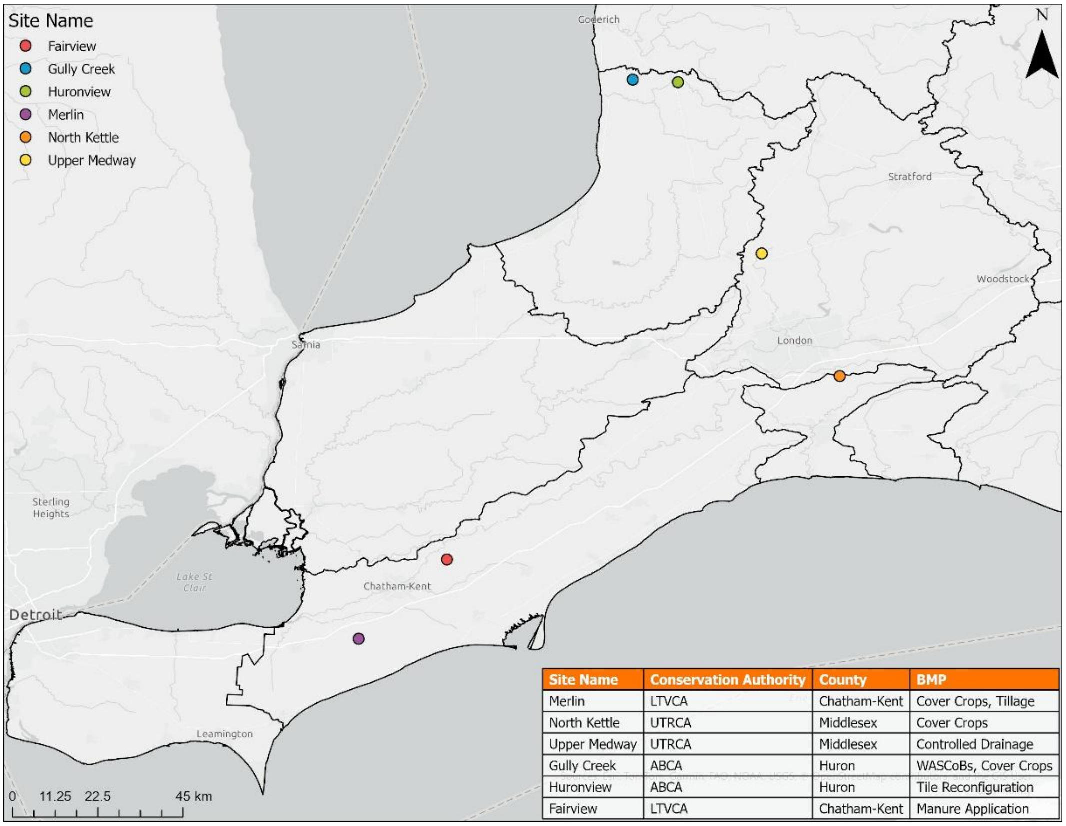
ONFARM comprises three main components aligned with the pillars of Soil Health, Water Quality, and Outreach and Engagement. OSCIA oversees all aspects, with the Soil Health and Water Quality initiatives guided by the ONFARM Technical Working Group. Founded in 2019, this group serves as a scientific advisory panel that helps select trial sites and BMPs for soil health testing. It also offers guidance to promote best practices in data collection, analysis, and reporting throughout the program. The Technical Working Group includes members from the following organizations:

- OSCIA
- OMAFA
- The Soil Resource Group (SRG)
- Ausable Bayfield Conservation Authority (ABCA)

- Lower Thames Valley Conservation Authority (LTVCA)
- Upper Thames River Conservation Authority (UTRCA)
- Agriculture and Agri-Food Canada (AAFC)

In addition to their responsibilities within the Technical Work Group, SRG and the Conservation Authorities (CAs) are key to gathering soil and water data for ONFARM. SRG handles activities related to soil health, while partnering CAs oversee the EOF runoff water quality and water quantity components. In April 2025, OSCIA hired a water quality specialist through LEEAAP to enhance water quality data analysis. The OSCIA water quality specialist frequently meets with CAs to assist them with water quality data curation, visualization, and analysis, and to provide insights to enhance water quality monitoring at the EOF sights.

The ONFARM program is being implemented on working farms across the province in collaboration with partner organizations and cooperating farmers. The locations of the ONFARM trials are shown in **Figure 1**. Each research site is owned and operated by an agricultural producer who has agreed to work with researchers to manage the field plots where trials are conducted. There are 25 active soil health sites and seven EOF water quality monitoring stations across the six ONFARM trial locations.



Site Name	Conservation Authority	County	BMP
Merlin	LTVCA	Chatham-Kent	Cover Crops, Tillage
North Kettle	UTRCA	Middlesex	Cover Crops
Upper Medway	UTRCA	Middlesex	Controlled Drainage
Gully Creek	ABCA	Huron	WASCoBs, Cover Crops
Huronview	ABCA	Huron	Tile Reconfiguration
Fairview	LTVCA	Chatham-Kent	Manure Application

Figure 1. Locations of ONFARM edge-of-field water quality monitoring sites. Merlin has two nearby sites (Merlin A and Merlin B)

1.2 ONFARM Water Quality Technical Report Overview

The objective of the EOF Technical Report is to describe the edge-of-field water quality research sites, summarize and discuss key results, and lay out next steps for the program. Technical reports for ONFARM are released annually as iterative updates on the program's progress. Previous technical reports can be found on the ONFARM Web Page.

2.0 Water Quality Monitoring and BMP Assessments

In the current phase of ONFARM, the water quality monitoring component focuses on evaluating BMP effectiveness at EOF sites. Each site captures tile and/or surface runoff as water exits the field. Together, the sites are being used to evaluate several BMPs, including cover crops, reduced tillage, nutrient application, and drainage water management.

2.1 Edge-of-Field Site Overview

Collection of data at the EOF scale began at different times, as some monitoring locations were established through other programs, whereas other EOF sites were established in either 2016 through GLASI or in 2019 directly through ONFARM. Each EOF site and monitoring location collects a variety of monitoring parameters, which are detailed in **Table 1**.

Table 1. List of data collected at each edge-of-field water quality monitoring location.

Data Collected	Examples
Weather	Precipitation, air temperature
Hydrologic layers	Stream/water body layer, municipal drainage layer (open and closed), tile surface inlet locations, subsurface tile drainage layer
Land management	Non-agricultural land use boundaries, land-based BMP layer (water and sediment control basins, buffer, etc.), field boundaries, agricultural land use by field
Field/soil characteristics	Soil phosphorus (P) and potassium (K) test, potentially mineralizable nitrogen (N), soil organic matter, soil aggregate stability, bulk density, and infiltration
Field activities	Fertilizer application, manure application, tillage, surface residue cover, planting, harvest, crop protection, controlled drainage
Water quantity	Surface runoff and tile flow
Water quality	Total suspended solids, total P, soluble reactive P, total organic P, total N, nitrate-N, ammonia-N, organic-N

Monitoring includes tile flow and surface water quality, and, where possible, subsurface (tile drainage) flow, surface runoff, at most sites. This monitoring is visualized in the conceptual diagram shown in **Figure 2**. Surface runoff patterns were assessed at site establishment to ensure all flow leaving a sub-watershed within the field area could be directed through flumes or surface inlets. Monitoring the flow rate and water depth allows calculation of discharge at any given time. Similarly, sensors in the tile drain capture tile water levels and/or flow rates to determine tile discharge volumes. Automated water samplers collect runoff samples for water-quality analysis at regular intervals, triggered by flow sensors. **Figure 3** shows one of the water quality monitoring stations with the equipment in place. **Figure 4** visually shows the variation in water quality that occurs across a sampling event at the Merlin B trial location, as discharge increases to a peak in the middle of the event, coinciding with the highest turbidity in the samples.

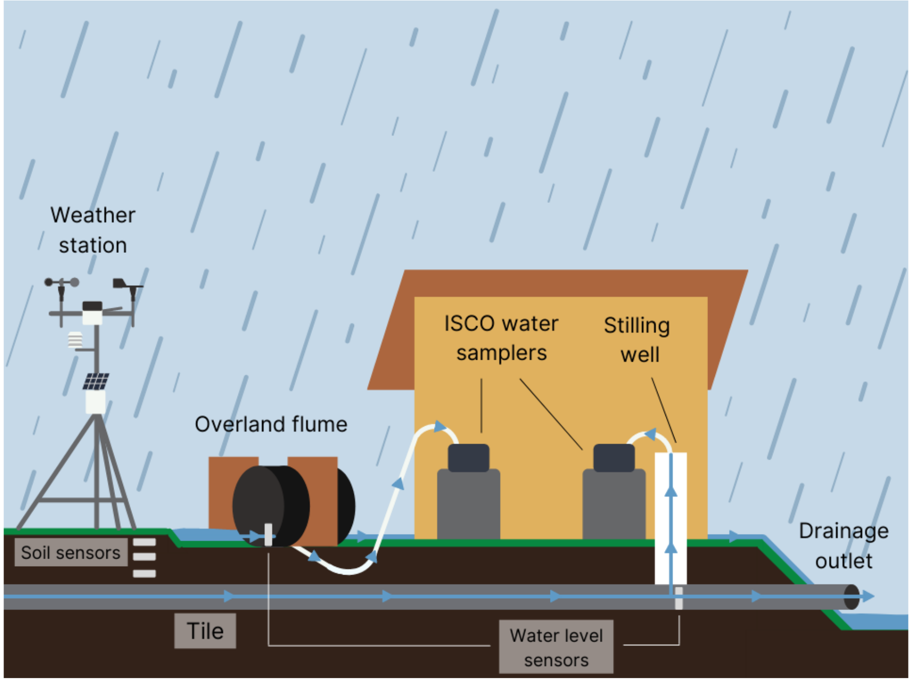


Figure 2. Conceptual diagram of an Edge of Field (EOF) monitoring station. Sensors capture weather, soil, and water level data, and water movement triggers automatic collection of water samples from overland flow or tile drains

Figure 3. The inside of a water monitoring station established by Lower Thames Valley Conservation Authority (LTVCA).

Figure 4. Visual assessment of variations in water quality following a sampling event, demonstrating baseline (left), rising flow (middle left), peak flow (middle), and descending limb of flow (right).

CA staff collect data and enter the results into the Water Information System by Kisters (WISKI) database for long-term storage and analysis. The WISKI database is well-suited for managing time-series data, such as water discharge, and offers features for quality-assurance tracking and for automating water-quality calculations, such as nutrient loading. Improving ONFARM's integration into WISKI was a major focus for CA staff in 2024, involving group training sessions to support the adoption of new features and collaborations to bring historical datasets up to date in the database. **Table 2** provides an overview of the sites, including treatments, monitored flow paths, and whether water quality and quantity are being captured.

Currently, EOF monitoring is conducted at seven farm fields (Merlin A, Merlin B, Fairview, Upper Medway, North Kettle, Gully Creek and Huronview demonstration farm). Some sites (e.g., Upper Medway, Gully Creek, North Kettle, and Huronview) are divided into subbasins to accurately capture surface runoff and accommodate multiple treatments. As such, runoff is monitored at 17 locations overall (**Table 2**). Among these, surface runoff and tile flow are separately monitored at four locations. At three locations, both surface runoff and tile flow leave through a combined outlet (no separation). Tile flow only is monitored at six locations, whereas only surface runoff is monitored at four locations.

Table 2. Summary of edge-of-field sites, treatments, and flow, paths.

CA	Site	Treatment	Tile Monitoring	Surface Monitoring	Combined Tile and Surface	Site Total	Water Quality and Quantity ?
LTVCA	Merlin A	Conventional	X	X		Addition	Yes
	Merlin B	No-till and cover crop	X	X		Addition	Yes
	Fairview	Manure application	X			Tile Only	Yes
UTRCA /AAFC	Upper Medway - CD1	Controlled drainage	X			Tile Only	Yes
	Upper Medway - CD2	Controlled drainage	X			Tile Only	Yes
	Upper Medway - FD	Free drainage	X			Tile Only	Yes
UTRCA	North Kettle - EOFN	Cover crop			X	Combined Outlet	Yes
	North Kettle - EOFS	No cover crop			X	Combined Outlet	Yes
ABCA	Gully-DFTEL3	Cover crop		X		Surface Only	Yes
	Gully-DFTEL5	No cover crop		X		Surface Only	Yes
	Gully-DFTILE	Field outlet			X	Combined Outlet	*Quantity Only, Historical Quality Data*
	Huronview Field A	Contour drainage	X	X		Addition	Yes
	Huronview Field B	Pattern drainage	X	X		Addition	Yes
	Huronview Tile 15’	Tile spacing 15’	X			*Tile Only*	*Quantity Only*
	Huronview Tile 30’	Tile spacing 30’	X			*Tile Only*	*Quantity Only*
	Huronview Field D	Untiled field		X		*Surface*	*Quantity Only*
	Huronview Woods	Natural area		X		Surface	Yes

2.2 Edge-of-Field Site Descriptions

2.2.1 Merlin A and B

The two Merlin sites (Merlin A and Merlin B) are adjacent to one another, and both lie on Brookston clay soils, with predominantly flat landscapes. The fields have differing management characteristics, which can provide great insight into these management effects on water quality (**Table 3**).

Table 3. Field and management characteristics at the Merlin A and Merlin B sites.

Site	**Field Size**	**Management Practices**
Merlin A	50 Acres	Conventional (2016 to May 2023), and no-till (June 2023 to 2025) and no cover cropping
Merlin B	90 Acres	No-till and cover cropping

Consistent monitoring setups are used for each site (**Figure 5**). Each site contains two tile sampling locations, one flume for surface runoff, and one near-surface groundwater monitoring well. There is some variation in the equipment used to measure depth, velocity, and flow (**Table 4**).

Table 4. Plots and equipment at Merlin A and Merlin B.

	Merlin A		**Merlin B**	
Type of Sites	Site ID	Equipment	Site ID	Equipment
Tile Sites	MAP2	1 ISCO 6712 sampler 1 Hach FL901 Logger with AV9000 Area Velocity Analyzer Module 1 Hach Sigma Submerged AV Sensor 1 Hach Combined Sampler to Flowmeter Cable + External Power Cable 1 HOBO U20 water level logger in tile 1 HOBO Barometric logger	MBP1	1 ISCO 6712 sampler 1 ECO Siren (4G LTE Wireless Module with Antenna, Internal Battery Holders and Multi Sensor Input Ports) 1 Blue Siren AV sensor (Digital Dual Wave Doppler Velocity, Pressure Depth Sensor, Embedded Temperature Sensor) 1 1640 Sampler Actuator 1 HOBO U20 water level logger in tile
	MAP3	1 ISCO 6712 sampler 1 Hach FL901 Logger with AV9000 Area Velocity Analyzer Module 1 Hach Sigma Submerged AV Sensor	MBP2	1 ISCO 6712 sampler 1 ECO Siren (4G LTE Wireless Module with Antenna, Internal Battery Holders and Multi Sensor Input Ports) 1 Blue Siren AV sensor (Digital Dual Wave Doppler Velocity,

		1 Hach Combined Sampler to Flowmeter Cable + External Power Cable 1 HOBO U20 water level logger in tile 1 HOBO Barometric logger		Pressure Depth Sensor, Embedded Temperature Sensor) 1 Blue Siren Sampler Trigger Cable 1 Blue Siren Power Cable 1 HOBO U20 water level logger in tile
Surface Flume Sites	MA-SW	1 ISCO 6712 sampler 1 ECO Siren (4G LTE Wireless Module with Antenna, Internal Battery Holders and Multi Sensor Input Ports) 1 1640 Sampler Actuator 1 5MP Low Light Vision Camera Sensor 1 Blue Siren Short Range Ultrasonic Level Sensor 1 HOBO U20 water level logger in flume	MB-SW / MBP4	1 ISCO 6712 sampler - at flume for surface water samples 1 ECO Siren (4G LTE Wireless Module with Antenna, Internal Battery Holders and Multi Sensor Input Ports) 1 1640 Sampler Actuator 1 5MP Low Light Vision Camera Sensor 1 Blue Siren Short Range Ultrasonic Level Sensor 1 HOBO U20 water level logger in flume
Well Monitoring Sites	MA Well	1 HOBO U20 water level logger in groundwater well	MB Well	1 HOBO U20 water level logger in groundwater well

Figure 5. Merlin A site's flume capturing surface flow entering the municipal drain, with the permanent ISCO enclosure.

2.2.2 Fairview

The Fairview site is located approximately 30 kilometres east of the Merlin A and B sites or 15 kilometres east of Chatham. The field is 100 acres, has high soil test phosphorus concentrations, silty clay loam soil, and receives annual spring liquid swine manure applications. Currently, only the inflow ISCO and an associated flowmeter are used to focus the study on the quality and quantity of tile runoff from a swine manure-applied field (**Table 5**). A Blue Siren ECOSiren module with an AV sensor and a ZL6 data logger with a hydrosensor is being used to quantify the amount and rate of tile water exiting the field. This site allows assessment of the effects of organic amendments on soil health and water quality. There is no well or flume monitoring at this site.

Figure 6. Fairview site containing an inflow and outflow permanent ISCO enclosures with solar panels and a weather station.

Table 5. Tile water quality monitoring equipment located at the Fairview site.

Type of Site	Fairview
Inflow Tile Site	1 ISCO 6712 sampler 1 ECO Siren (4G LTE Wireless Module with Antenna, Internal Battery Holders and Multi Sensor Input Ports) 1 Blue Siren AV sensor (Digital Dual Wave Doppler Velocity, Pressure Depth Sensor, Embedded Temperature Sensor) 1 Blue Siren Sampler Trigger Cable 1 Blue Siren Power Cable 1 ZL6 with a hydrosensor 1 uMetos 300 Weather Station 1 Sentek Triscan 120 CM Soil Probe (Salinity, temperature, soil moisture)

Recent improvements to the site include the installation of a Blue Siren trigger cable. The trigger cable enables water-level or velocity-based initiation of the water sampler, which can be remotely programmed. This helps ensure reliable event capture and reduces the travel and staff time required prior to each event. Additionally, a Bluesiren power cable was added. Typically, the internal ECOSiren batteries are the primary power source for the ECOSiren module. The addition of the Blue Siren power cable enables an external solar-powered battery to serve as the ECOSiren's main power source, providing internal backup power. This increases the reliability of the equipment power source and decreases the cost of seasonal battery replacements.

2.2.3 Gully

Gully EOF (DFTILE EOF) was established in 2012 by ABCA. The overall catchment is 46 acres, and the runoff leaving the catchment is monitored at the tile outlet (DFTILE) (**Table 6**). This larger catchment is further divided into sub-basins within the field and is monitored at two water and sediment control basin (WASCoB) sites (DFTEL3 and DFTEL5), with drainage areas ranging from three to five hectares (**Figure 7**). ABCA has used data from these established sites to understand the relationship between vegetative cover, residue, and surface runoff generation. Since 2017, vertical till and no-till practices have replaced more conventional tillage practices. In ONFARM, the site is used to monitor the impact of cover crops and vegetative cover on surface runoff generation by establishing cover/no-cover plots, with WASCoBs as monitoring points.

Table 6. Water quality monitoring at Gully EOF site.

Site ID	Runoff Pathway Monitored	Eqiupment
DEFTEL3	Surface runoff	1 Surface inlet (Hickenbottom) 1 Pressure transducer (HOBO level logger) 1 ISCO 6712 sampler)
DEFTEL5	Surface runoff	1 Surface inlet (Hickenbottom) 1 Pressure transducer (HOBO level logger) 1 ISCO 6712 sampler
DFTILE	Tile flow	1 pressure transducer (HOBO level logger)

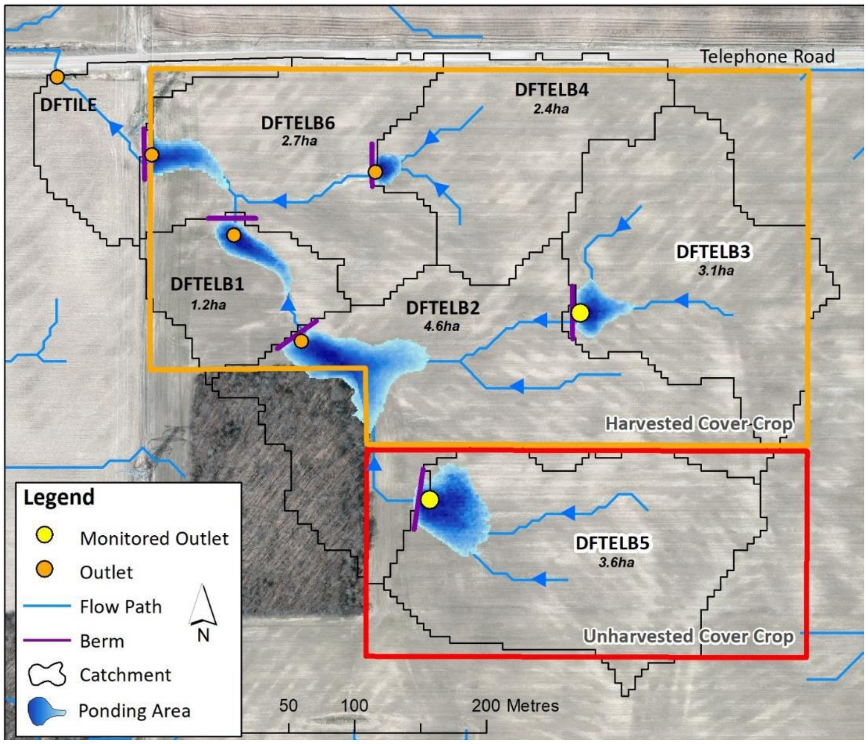


Figure 7. Map of Gully EOF (DFTILE EOF) site in the Gully Creek watershed. WASCoBs 2, 3, 5, were monitored for water quality from sub-basins within the field, and the tile outlet (top left) was monitored for water leaving the entire field.

2.2.4 Huronview

The Huronview Demonstration Farm is actively farmed by the Huron County Soil and Crop Improvement Association to demonstrate agricultural BMPs, particularly to inform management of tile drainage and its impact on water quality (**Table 7**). Huronview is located south of Clinton, Ontario, on a loam soil. The site has two permanent subsurface water quality monitoring stations located in Field A and Field B (**Figure 8**). There are four treatments of water management being measured: i) no drainage; ii) wetland treatment of tile water; iii) systematic drainage (with a side comparison of 15’ and 30’ spacing); and iv) contour drainage with control structures in the lateral lines.

Table 7. Water quality monitoring at the Huronview demonstration farm

Site ID	Runoff pathway monitored	Eqiupment
HURV_NW_FP1	Surface runoff	1 Surface weir 1 Pressure transducer (HOBO level logger) 1 ISCO 6712 sampler
HURV_SW_FP1	Surface runoff	1 Surface weir 1 Pressure transducer (HOBO level logger) 1 ISCO 6712 sampler

Field D	Surface runoff	1 Flume for surface water samples 1 Pressure transducer (HOBO level logger)
Field BG1 -Pattern	Tile flow	1 Pressure transducer (HOBO level logger)
Field BG1 -Contour	Tile flow	1 Pressure transducer (HOBO level logger)
Field RK15	Tile flow	1 Pressure transducer (HOBO level logger) to measure water quantity at 15’ spacing
Field RK30	Tile flow	1 Pressure transducer (HOBO level logger) to measure water quantity at 30’ spacing
Field A	Tile flow	1 Pressure transducer (HOBO level logger) 1 Magmeter 1 ISCO 6712 sampler
Field B	Tile flow	1 Pressure transducer (HOBO level logger) 1 Magmeter 1 ISCO 6712 sampler

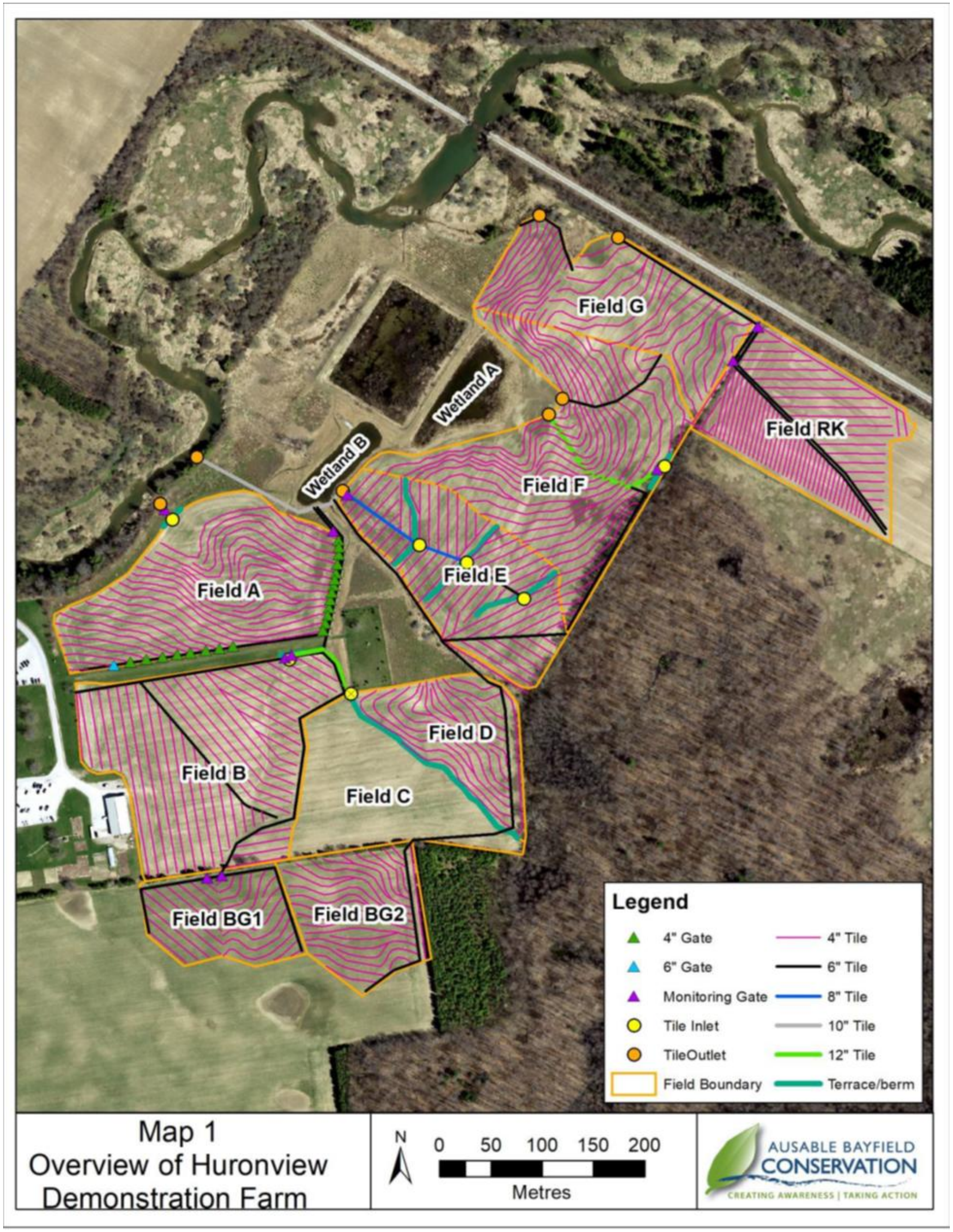
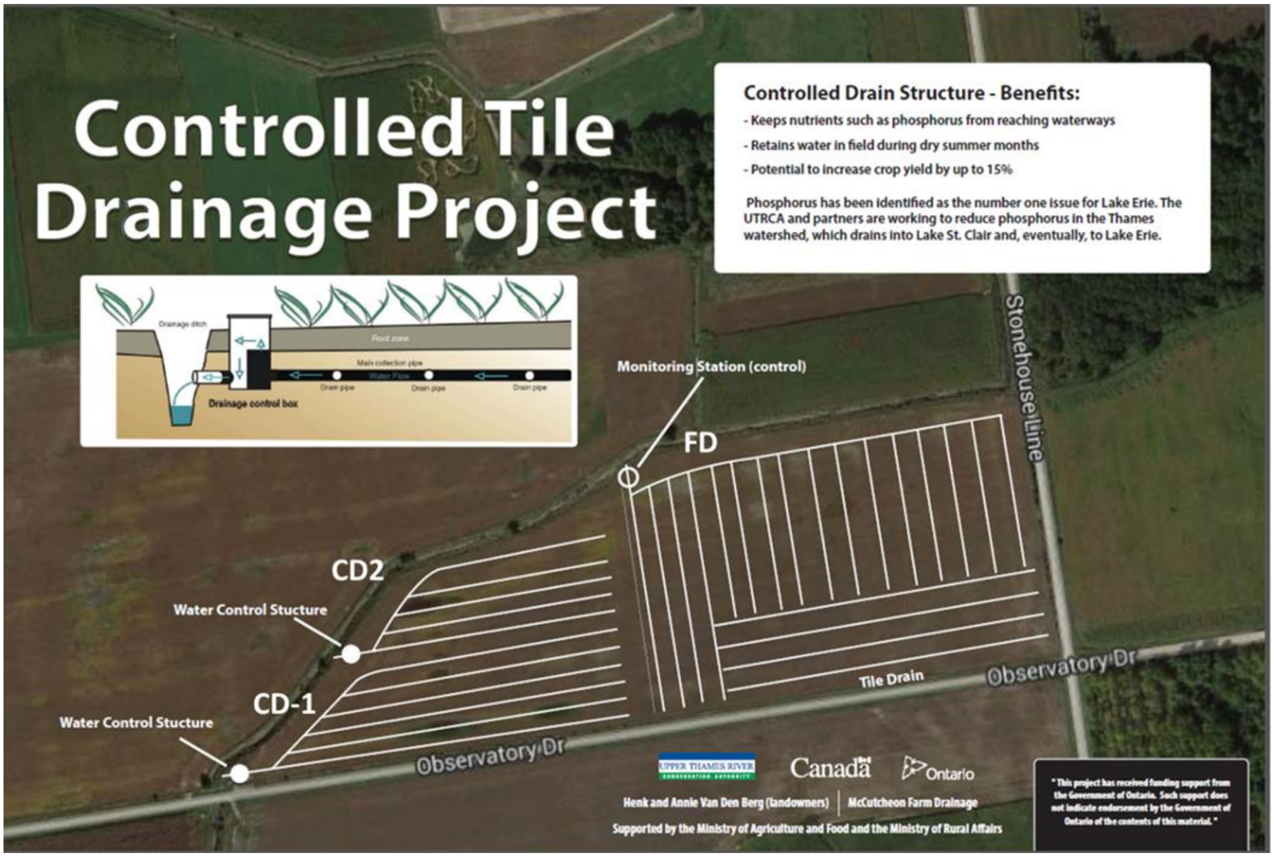


Figure 8. The Huronview Demonstration Farm, shown by field and drainage sub-basins with the various tile drain setups.

2.2.5 Upper Medway

Within the Upper Medway Creek subwatershed, water quality data are collected by AAFC from a unique EOF site to assess the water quality benefits and tradeoffs of controlled drainage. At this site, tile runoff is sampled from two controlled drainage plots (CD1 and CD2) and one free drainage (FD) plot (**Figure 9**).



Controlled Drain Structure - Benefits:

- Keeps nutrients such as phosphorus from reaching waterways
- Retains water in field during dry summer months
- Potential to increase crop yield by up to 15%

Phosphorus has been identified as the number one issue for Lake Erie. The UTRCA and partners are working to reduce phosphorus in the Thames watershed, which drains into Lake St. Clair and, eventually, to Lake Erie.

Henk and Annie Van Den Berg (landowners) | McCutcheon Farm Drainage
Supported by the Ministry of Agriculture and Food and the Ministry of Rural Affairs

" This project has received funding support from the Government of Ontario. Such support does not indicate endorsement by the Government of Ontario of the contents of this material. "

Figure 9. Upper Medway EOF Site.

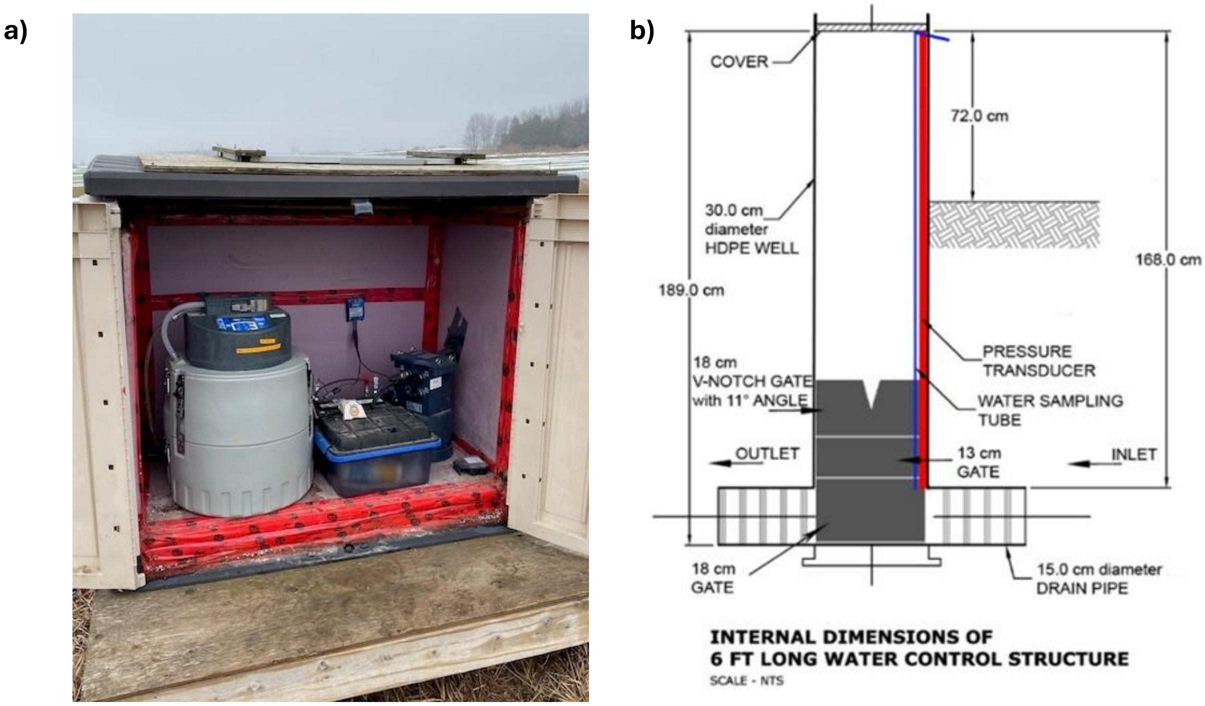


Figure 10. a) Equipment setup at FD: the shed with ISCO autosampler, a Hach water flow meter, and a ZL6 data logger (white box); b) Internal dimensions of the AgriDrain controlled structure at the controlled drainage outlet.

Flow meters and automated water samplers are used to monitor water flow and quality at each controlled drainage gate and at tile outlets (**Figure 10**). To ensure redundancy if the area-velocity flow sensors fail due to cold temperatures or power loss, the control structures are fitted with v-notch gates (weirs) and water-level sensors to provide supplementary flow data (**Figure 10**).

2.2.6 North Kettle

In the North Kettle Creek subwatershed, an EOF station was installed to monitor two subcatchments (Edge of Field North – EOFN and Edge of Field South – EOFS) separated by a double-basin WASCoB with a T-shaped berm (**Table 8**). Each side of the berm has a separate surface inlet and tile outlet, allowing for different management characteristics to be monitored on either side (**Figure 11**). The catchments are randomly tiled with equivalent drainage densities. The site has silt loam surface soils to silty clay loam subsurface soils.

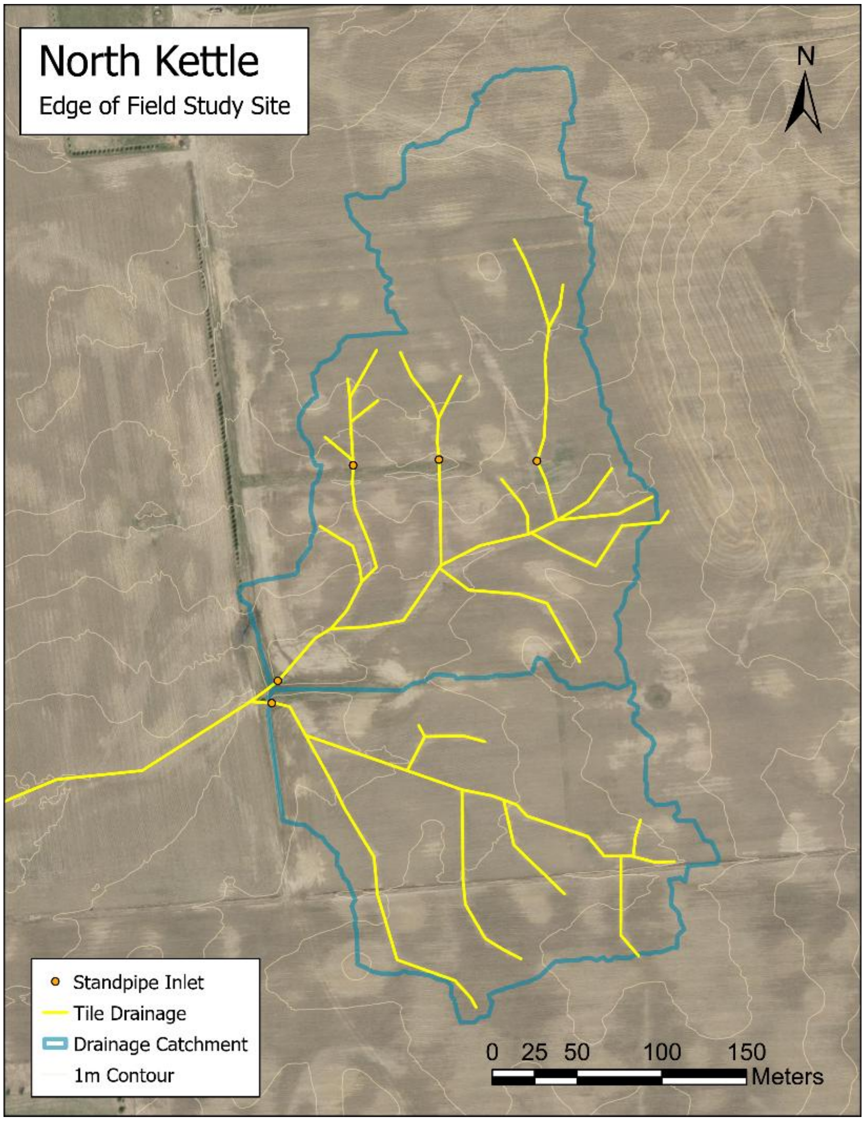


Figure 11. Site map showing the layout at the North Kettle EOF.

Table 8. Field and management characteristics at the North Kettle sites.

Site	Field Size	Management Practices
EOFN	13.6 Acres	Cover cropping Fertilizer and manure applications
EOFS	8.9 Acres	No cover cropping Fertilizer applications, no manure

Consistent monitoring setups are used for each site. There is also an on-site meteorological station (**Table 9**).

Table 9. Equipment present at EOFN, EOFS, and on-site Met Station.

North Kettle Edge of Field Site	
Site ID Name	Equipment
EOFN	1 ISCO 6712 sampler 1 Blue Siren AV sensor (EcoSiren model) 1 HOBO U20 water level logger in tile 1 HOBO U20 water level logger attached to Hickenbottom
EOFS	1 ISCO 6712 sampler 1 Blue Siren AV sensor (EcoSiren model) 1 HOBO U20 water level logger in tile 1 HOBO U20 water level logger attached to Hickenbottom 1 HOBO Barometric logger
On-Site Met Station	Measured parameters: Soil Moisture @ 5cm depth Soil Moisture @ 15cm depth Soil Temperature @ 5cm depth Soil Temperature @ 15cm depth Soil Temperature @ 30cm depth Air Temperature Dew Point Temperature Relative Humidity Evapotranspiration Solar Radiation Wind Speed/Direction

3.0 Water Quality Results and Discussion

3.1 The presence of winter wheat and oat cover crop significantly reduced surface runoff compared to corn or soybean residue

Having a continuous soil cover, whether as a cover crop or as soil residue, is expected to improve runoff water quality by slowing the generation of surface runoff and soil erosion (Du et al., 2022). Furthermore, cover crops can reduce the nutrients available for runoff losses by tying them up in biomass (Finney et al., 2016). However, the function of this soil cover depends on the type of crop or residue, the extent of the coverage and weather variables (Finney et al., 2016; Weyers et al., 2021).

The Gully Creek EOF site is divided into several WASCoBs to reduce runoff and sediment losses (**Figure 7**). Within each WASCoB, surface runoff is routed into the tile drain through a surface inlet. This study focused on Berm 3 (B3) and Berm 5 (B5) to examine the role of surface cover in generating surface runoff. Both WASCoBs follow a corn-soybeans-soybeans-winter wheat rotation. An oat cover crop is planted after the winter wheat harvest. The study examined surface runoff events from 2017 to 2024. In 2020, after the winter wheat harvest, the oat cover crop was planted across the entire study area but was harvested only in the B3 watershed before winter. In contrast, the cover crop was not harvested but left to overwinter within the B5 watershed.

For surface runoff activation, only precipitation events greater than 10 mm were considered, separated by a 12-hour dry window. The activation of surface runoff at B3 and B5 was determined from water levels at the surface inlets. A linear mixed model analysis was conducted to explore the complex relationships among seasonality, crop cover, and precipitation characteristics and their effects on surface runoff generation.

3.1.1 Exploratory analysis of surface runoff activation

Surface runoff generation was substantially affected by crop type or residue (**Table 10-Table 11**). For example, when corn was cropped, 25-35% of precipitation events during the growing season (GS) produced surface runoff, and the average event surface runoff coefficient (Surface runoff volume divided by total precipitation) ranged from 0.21 (B3) to 0.24% (B5). The event response ratio (The number of events where surface runoff was observed, divided by the total number of precipitation events) and surface runoff coefficient were further increased in the non-growing season (NGS) when the fields were left with only corn residue (**Figure 12**). The results indicated that approximately 40% (B5) to 50% (B3) of NGS precipitation events resulted in surface runoff when corn residue was present, highlighting its vulnerability during the NGS.

The surface runoff response was smaller for soybeans as compared to corn during GS, potentially due to their denser foliage (9% for B3 and 14% for B5). However, the runoff response increased to 40% during NGS when only soybean residue remained as cover, with more than 50% of precipitation leaving as surface runoff. The lower biomass and rapid degradation of soybean residue could have led to these contrasting observations between GS and NGS.

The results also showed that planting winter wheat after soybean harvest could substantially reduce surface runoff during NGS (**Table 11**). For example, winter wheat after soybeans reduced the event response ratio from 38% to 20% at B5. Although the reduction is smaller at B3, a significant decrease in the surface runoff coefficient was observed (from 0.52 to 0.28). Moreover, none of the 20 major precipitation events produced surface runoff at any of these fields in the summer when the winter wheat was cropped (**Figure 12**). It should be noted that some of these events reached 80 mm in size. While this study did not account for tile flow, the published literature shows significant reductions in deep drainage during the growing season in soybean-corn cropping systems with winter wheat (Yang et al., 2020). Winter wheat has also been shown to improve soil water storage capacity in the early cropping season from April to June (Yang et al., 2020). These results support the decision to incorporate winter wheat into the rotation, either as a cover crop or as a commodity. Not only can winter wheat improve field resiliency, but it can also yield water-quality benefits.

Surface runoff was also minimal when an oat cover crop was present (**Table 10-Table 11**). Only four of 41 precipitation events (across both GS and NGS) produced surface runoff at B5. At B3, only one of 13 events produced surface runoff during GS. However, the runoff response at B3 reached 20% during NGS, potentially because oats were harvested before winter. Although the oat stubble was left at B3 after harvest, our observations indicate that it couldn’t provide the same water quality benefits as the B5 unharvested over-winter whole crop could.

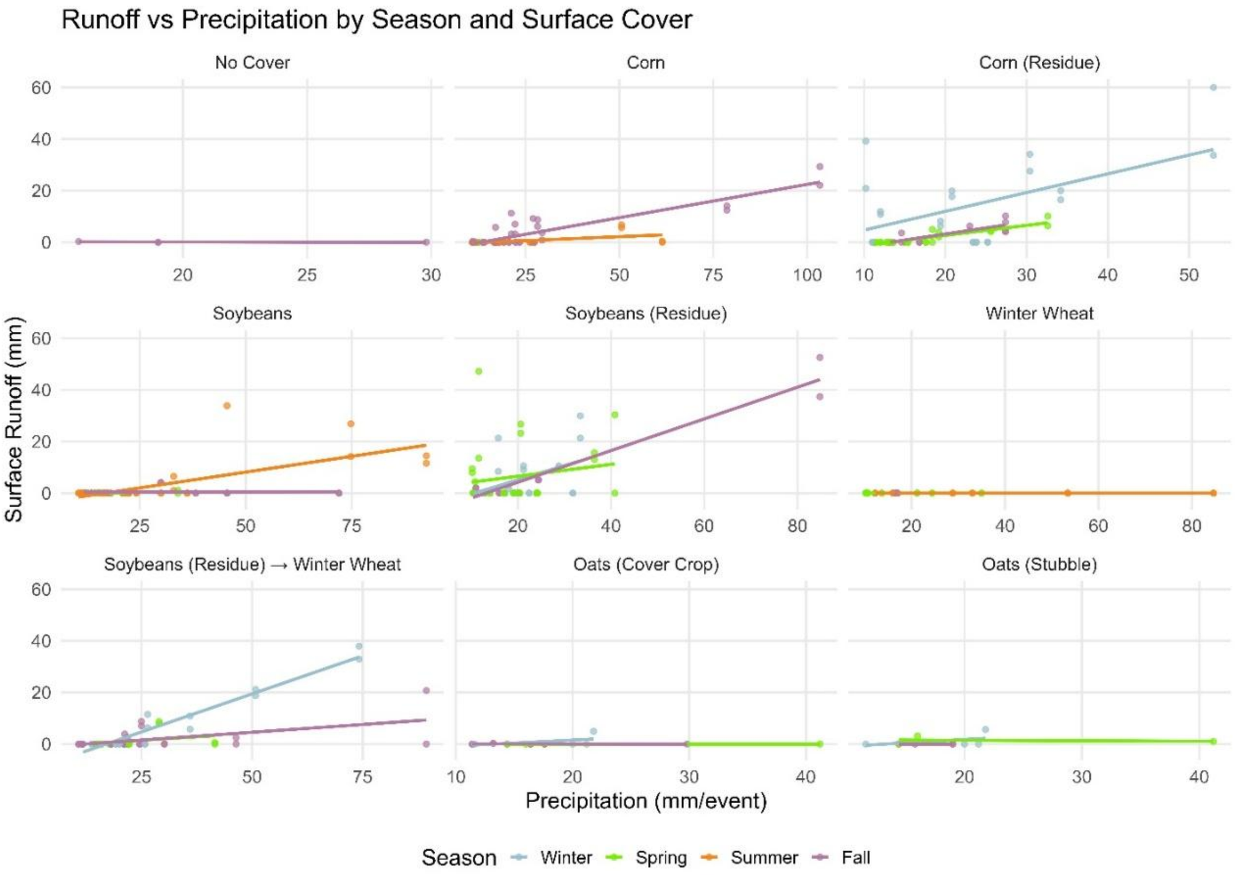


Figure 12. Relationships between surface runoff and event precipitation varied by the crop cover. Different colours represent different seasons.

Table 10. Surface runoff responses during the growing season (May to September 2017 – 2024) relative to the crop grown. Total events were provided within brackets. Runoff coefficient only indicates surface runoff.

Crop cover	**Response (Total Events)**		**Avg. Runoff Coefficient %**	
	B3	***B5***	***B3***	***B5***
Corn	13 (38)	9 (38)	0.21	0.24
Soybeans	4 (43)	6 (43)	0.16	0.26
Winter wheat	0 (20)	0 (20)	NA	NA
*Oats**	1 (13)	2 (25)	0.02	0.15

*Sometimes present in the non-growing season.

Table 11. Surface runoff responses during the non-growing season (October to April 2017 – 2024) relative to the crop grown. Total events were provided within brackets. Runoff coefficient only indicates surface runoff.

Cover	Response (Total Events)		Avg. Runoff Coefficient %	
	B3	***B5***	***B3***	***B5***
Oats stubble	5 (24)	2 (16)	0.21	0.24
Corn residue	15 (30)	13 (30)	0.52	0.64
Soybeans residue	13 (34)	13 (34)	0.5	0.72
Soybeans residue and winter wheat	11 (30)	6 (30)	0.28	0.33

Surface runoff was not triggered (or was less than 0.5 mm) for four events when no cover crop was grown (**Figure 12**). However, these rain events were generally smaller (10–30 mm), and all occurred under drier antecedent soil moisture conditions, with less than 5 mm of rainfall in the previous seven days.

3.1.2 Multivariate analysis

The linear mixed model analysis identified several key factors that could influence surface runoff at Gully Creek. Larger precipitation events favour surface runoff (**Table 12**). Although some studies (Kokulan et al., 2018; Ljutic et al., 2024) reported a positive relationship between runoff response and rainfall intensity, we did not observe this relationship in this study. The presence of different crop covers at different times may have confounded these relationships. For example, some high-intensity (> 30 mm hr^{-1}) summer thunderstorms did not produce surface runoff when winter wheat or soybeans were present. In contrast, several lower-intensity events produced winter surface runoff, potentially due to additional water from snow prior to the events, saturated soils, and minimal soil cover in certain years. Most research in the literature has focused on runoff activation during the growing season, primarily on rainfall-runoff events (Kokulan et al., 2018; Ljutic et al., 2024).

Surface runoff generation was also influenced by antecedent soil moisture, as indicated by the positive estimate for the seven-day antecedent precipitation index (7d_API), which serves as a proxy for soil moisture. Surface runoff is favoured in wetter soils because infiltration rates decline with increased moisture, leaving more water available for surface runoff.

Table 12. Results from the linear mixed model analysis to explore the factors that influence surface runoff generation at the Gully Creek site. Only significant parameters (p < 0.05) are provided.

Fixed effects	Estimate	P value
Precipitation size	0.03	<0.001
Antecedent precipitation index	0.01	<0.05
Season winter	0.51	<0.001
Corn residue * precipitation size	0.04	<0.05
Winter wheat * precipitation size	-0.03	<0.001

As expected, a strong seasonality influence on surface runoff was also observed. The potential for surface runoff is significantly higher in winter than in other seasons. This observation is consistent with previous research reporting significantly higher surface and tile flows in Ontario agricultural soils during non-growing seasons (Plach et al., 2019).

The results also revealed two interactions between cover type and precipitation event size. For example, a significant negative interaction between winter wheat and precipitation intensity was observed, indicating that winter wheat reduces runoff. The opposite was observed for precipitation event size: and corn residue presence in the field. Corn residue was associated with major surface runoff during larger precipitation events, despite its presence as a cover.

Overall, the results of this analysis show that winter wheat and oat cover crops reduce surface runoff on Ontario croplands. This can be critical during heavy precipitation or snowmelt events on wet soils, especially in winter. Further insights are needed to better understand the roles of winter wheat and cover crops in tile flow and nutrient transport.

3.2 Harvesting cover crops before winter may offset water quality benefits

At the Gully Creek site, an oat cover crop was planted in 2020 in both B5 and B3 WASCoBs, following the harvest of winter wheat. At B3, the cover crop was harvested by the end of the GS, and only the stubble was left. Oats were not harvested at B5 and left throughout the winter. This setup provided an opportunity to study the impacts of cover crop harvesting on runoff water quality.

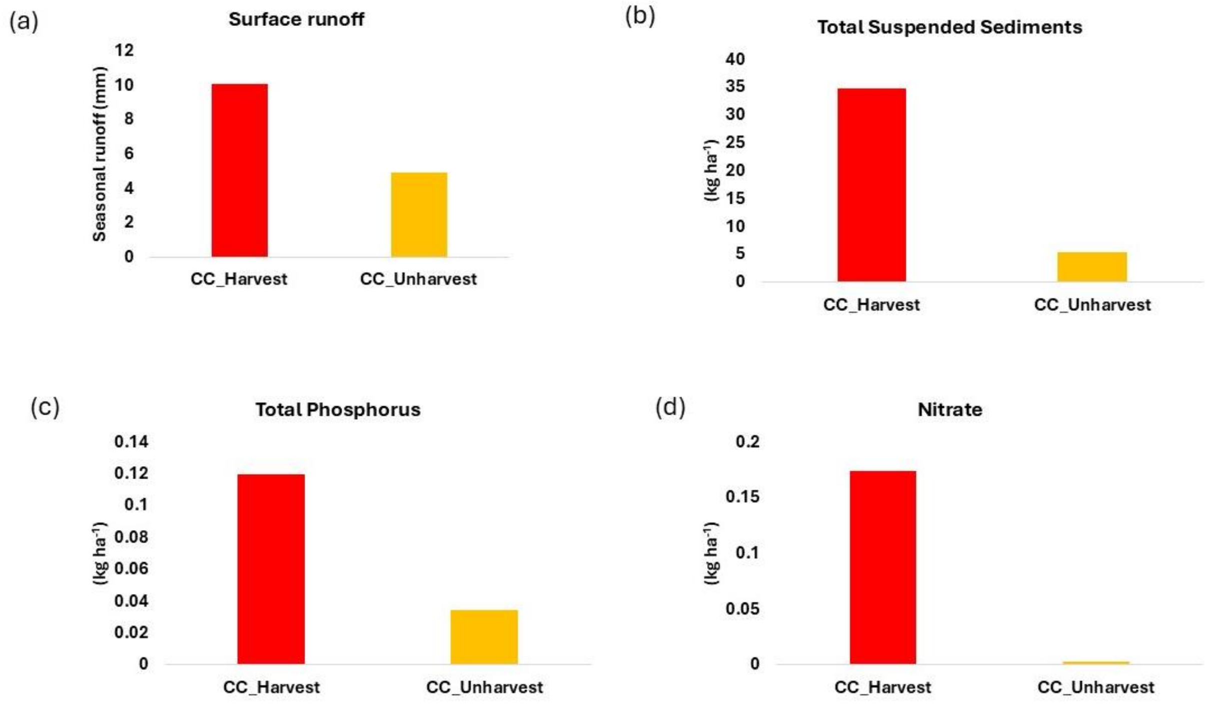


Figure 13. Total surface runoff (a), total suspended sediments (b), total phosphorus (c), and nitrate losses (d) in unharvested (CC_Unharvest) and harvested (CC_Harvest) cover crop fields at the Gully Creek site during the 2020-2021 non-growing season (NGS).

There were 12 precipitation/melt events observed from October 1, 2020, to April 30, 2021. Four of these events generated surface runoff at B3, where the cover crop was harvested, and two of these events were smaller in nature (<0.5 mm per event). A total of 10 mm left B3 as surface runoff (**Figure 13**). In contrast, only one of these 12 events resulted in surface runoff at B5, where oats were left unharvested throughout the winter. The runoff volume for that particular event was 4.9 mm. The WASCoB where the cover crop was unharvested, saw 50% less surface runoff (4.9 mm) during the non-growing season when compared to the field where the cover crop was harvested (10.1 mm).

The event-weighted mean concentrations (FWMC) of soluble reactive phosphorus (SRP) and total phosphorus (TP) in surface runoff at B3 were 0.46 and 1.17 ppm, respectively, yielding an SRP/TP ratio of 0.39. In contrast, the flow-weighted mean concentrations of SRP and TP for B5 were 0.41 and 0.64, yielding an SRP/TP ratio of 0.64. A lower SRP/TP ratio at B3 indicates greater particulate P losses, potentially including sediment, when soil cover is lower. At B3, 0.043 kg ha^{-1} SRP and 0.12 kg ha^{-1} TP were lost through surface runoff during the non-growing season (NGS) of 2020. Meanwhile, only 0.022 kg h^{-1} SRP and 0.034 kg ha^{-1} TP were lost via surface runoff at B5, where the cover crop was unharvested.

The greater P loss from the harvested field was also supported by the loss of sediments. The mean total suspended sediment (TSS) concentration for B3 was 371 ppm, whereas the TSS concentration for B5 was only 100 ppm. Higher TSS concentration and higher surface runoff from the B3 led to higher TSS losses. B3 surface runoff TSS losses for the 2020 non-growing season were around 12.9 kg ha^{-1}. In contrast, TSS losses for B5 were only around 5.4 kg ha^{-1}.

Surface mean nitrate concentrations were also higher for B3 (4 ppm when compared to 0.05 ppm at B5). At B3, around 0.17 kg ha^{-1} nitrate was lost via surface runoff during the 2020 non-growing season. In contrast, B5 nitrate losses were negligible (around 0.002 kg ha^{-1}).

Overall, the results show the water-quality benefits of cover cropping, including reduced surface runoff and sediment and nutrient losses. However, the role of cover crops can be affected by the size of the surface runoff event, cover crop establishment, cover crop type and topography. It should also be noted that tile drainage is the primary runoff pathway in the subsurface-drained landscapes of Southern Ontario. Although the Gully Creek site is tiled, we did not assess the role of cover cropping in tile flow and nutrient losses there due to logistical constraints.

3.3 Fall surface broadcasting fertilizers could offset water quality benefits from no-till

3.3.1 Case Study 1

No-till cultivation is expected to reduce surface runoff and nutrient losses by enhancing infiltration and reducing soil erosion. However, the benefits of no-till for water quality are less well understood when combined with other field management practices.

The Merlin A EOF site, located on Brookston Clay soil, is systematically tile-drained, and follows a Corn/Soy/Soy/Soy/Wheat rotation and typically conducts a fall fertilizer application. This site saw conventional tillage practices with fertilizer incorporation from 2016 to 2022. Since 2023, the grower has adopted no-till cultivation and has been broadcasting fertilizers. This conversion provided an opportunity to study the impact of this adoption on runoff water quality. This case study monitored surface runoff and tile drainage from this field during the non-growing season (NGS – October to April) of 2019-2020 (when the field was under conventional tillage) and NGS of 2023-2024 and 2024-

2025 (when the field was under no tillage). In 2019, the field underwent fall tillage with two passes using a cultivator to incorporate a fall application of 125lbs/acre monoammonium phosphate (MAP) and 125lbs/acre potash. For the 2023 and 2024 NGS, the site practiced no-till with a fall surface broadcast application of 125lbs/acre MAP and 125lbs/acre potash. The crop in the growing season prior to all treatments was soybean with no crop cover overwinter. The events selected for this example are a subset of events during the NGS, with reliable flow data and numerous water-quality samples. Selected events also demonstrated a range of event types, including a first flush, a winter snowmelt, and a spring rain event. The Mann-Whitney U test was used to assess the effects of conventional tillage and no-till practices on NGS water quality.

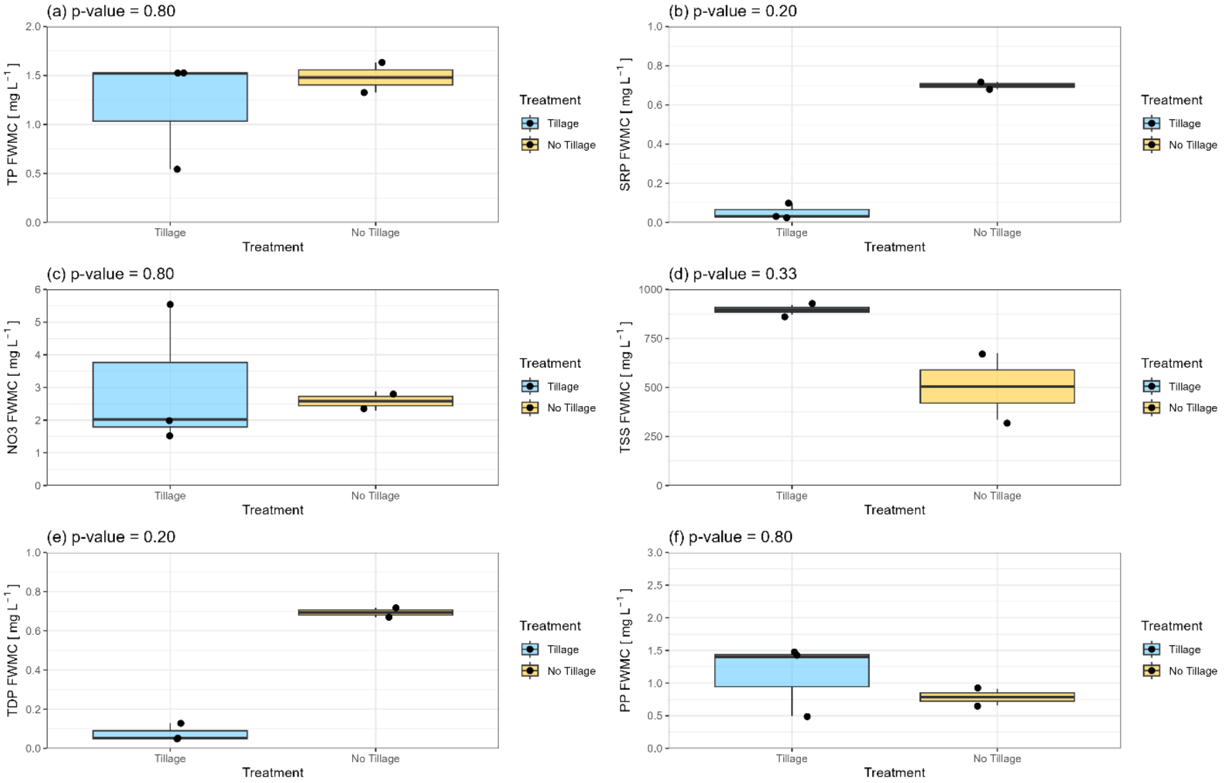


Figure 14. Comparison of flow-weighted mean concentrations in surface runoff from Merlin A under conventional tillage and no-till practices: total P (TP) (a), soluble reactive P (SRP) (b), nitrate (c), total suspended sediments (TSS) (d), total dissolved P (TDP) (e), and particulate P (PP) (f).

Despite the adoption, flow-weighted mean (FWM) TP concentrations in surface runoff did not differ significantly between conventional tillage and no-till (**Figure 14**). There is a considerable reduction in TP concentrations in tile drainage, with the median FWMC TP declining from just over 1 ppm to just over 0.75 ppm (**Figure 15**). Delving deeper into the different P fractions associated with these TP concentrations, however, revealed interesting differences. There was a significant reduction in particulate P concentration (PP) in tile drainage following the switch from conventional tillage to no-till. This change was also reflected in surface runoff, with FWMC PP declining by 50%. This observation is supported by reductions in TSS concentrations in both surface runoff and tile flow following the adoption of no-till. In fact, there was a strong correlation between TSS and TP concentrations at this site (r = 0.88; data not shown). Inherent soil properties of Brookston clay include nutrient-rich, very fine particles and high erosion risk. As tillage moves the soil, the topsoil is loosened. Loosened surface soil is at increased risk of movement by surface water, increasing the amount of PP leaving the field through surface runoff and tile drainage. A reduction in PP and TSS concentrations clearly shows that no-till cultivation could reduce erosion-related sediment and particulate P losses in this soil.

While there were considerable reductions in PP, the opposite was observed for dissolved P concentrations in both surface runoff and tile flow (**Figure 14-Figure 15**). The median SRP concentration in tile drainage increased to just over 2 ppm under no-till, from just under 1 ppm under conventional tillage. This is more pronounced in surface runoff, where the mean FWMC SRP was several-fold higher with no-tillage when compared to conventional tillage. In general, no-till cultivation in macroporous soils like Brookston clay offers fewer benefits in reducing soluble reactive P losses via tile drainage. Undisturbed soils preserve macropore pathways, such as desiccation cracks and earthworm burrows, increasing connectivity between surface and tile drainage. While the contribution of these macropore networks is anticipated for no-till tile P losses, the majority of SRP losses appear to come from the fall-applied P fertilizer. Readily soluble fertilizers like MAP, when broadcast in the fall in areas with no crops, become critical sources of P during subsequent precipitation events. In no-till cultivation, subsurface application of P fertilizers could enhance soil-fertilizer interactions and reduce runoff-related P losses. Application of fertilizers in spring, rather than in fall, may also reduce NGS runoff P losses from no-till systems while improving P fertilizer use efficiency.

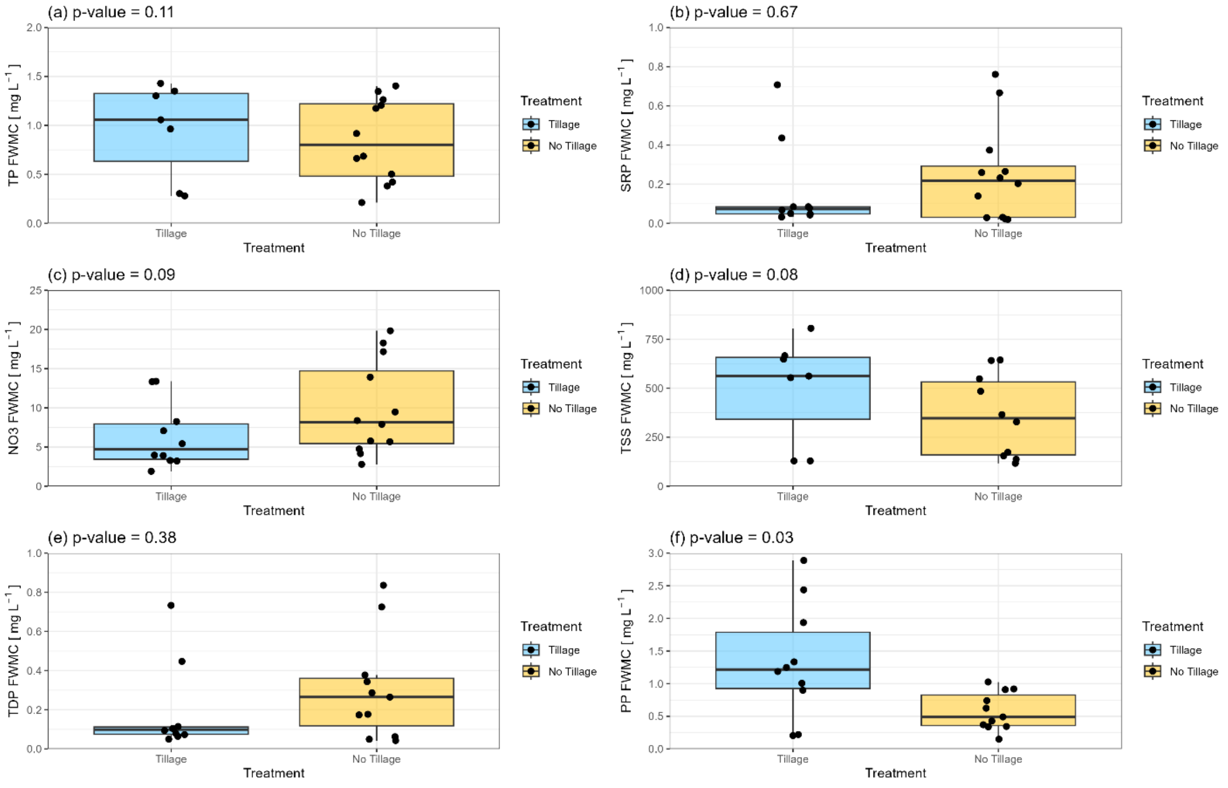


Figure 15. Comparison of flow-weighted mean concentrations in tile drainage from Merlin A under conventional tillage and no-till practices: total P (TP) (a), soluble reactive P (SRP) (b), nitrate (c), total suspended sediments (TSS) (d), total dissolved P (TDP) (e), and particulate P (PP) (f).

This study also compared nitrate losses between different pathways and management systems during the NGS (**Figure 14-Figure 15**). In general, FWM nitrate concentrations were higher in tile drainage than in surface runoff. Unlike phosphate ions, nitrate ions interact very little with the soil matrix and therefore leach with percolating water. As such, tile drainage is a critical pathway for nitrate losses. There was an increase in tile nitrate concentrations (p = 0.09) with no-till when compared to conventional tillage. Although the likelihood of high postharvest nitrate losses is lower due to crop uptake and aerial N losses, a few factors could have contributed to the elevated nitrate losses observed in this study. Although MAP is a P fertilizer, it contains 11% N. As such, nitrate is released from this fertilizer during subsequent precipitation events, which could have led to greater N leaching through tile drains in this no-till system. In addition, rainfall-runoff events followed by a dry summer spell could also have contributed to elevated nitrate losses by flushing residual nitrate. Such an occurrence was observed for the 2024-2025 season at this study site.

The case study illustrates a prominent trade-off. No-till improves infiltration and reduces erosion risk, especially on vulnerable soil types, but surface broadcast leads to high nutrient loss due to these more direct pathways. When fertilizer is incorporated, it reduces SRP loss by increasing the opportunity for it to bind to soil. However, conventional tillage increases the loss of sediment-associated PP. To address these trade-offs in the Brookston clay soils, no-till is a beneficial practice, but it needs to be combined with other BMPs to mitigate the trade-off. Incorporating 4R nutrient principles, subsurface application through fertilizer banding, spring applications, and reduced application rates can help minimize the risk of mobile nutrient loss.

3.3.2 Case Study 2

The runoff and nutrient losses through tile drainage at Merlin A site during the 2024-2025 NGS were also compared to those at Merlin B, which is situated close to Merlin A (**Figure 16**). Merlin A has adopted no-till practices since 2023. In the fall of 2024, 125 lbs/acre of MAP was broadcast at Merlin A. In contrast, Merlin B has a long history of no-till cultivation. Merlin B does receive fall fertilizer, but it is usually combined with a cover crop (before corn) or wheat planting. Before soybeans, the field received no fertilizer for the season. In 2024, soybeans were grown in both fields. Although cover cropping during the NGS is standard practice at Merlin B, cover crops were not planted in 2024 due to the late soybean harvest.

Four runoff events with reliable runoff and water-quality data were used for this study. These events included two early-winter runoff events (one of which was the first runoff event since summer), spring snowmelt, and an early-spring storm. In both fields, the tile water was monitored at two outlets each. The Mann-Whitney U test was employed to assess differences in flow-weighted mean concentrations between long-term no-till, no fall fertilizer (Merlin B) and recent no-till, fall-fertilizer-application (Merlin A) practices.

Total tile flow across all 4 events varied considerably between the two fields. Overall, tile flow from Merlin B (52 mm) was smaller than Merlin A (90 mm) (**Table 13**). It should be noted that some runoff also occurs via surface runoff, and it has not yet been quantified for Merlin B. The majority of these runoff events occurred during a December rain-on-snow event and during an early spring storm.

All TP, SRP, and PP concentrations from Merlin A were significantly higher compared to Merlin B. Spring soil sampling at these sites showed Merlin A has slightly higher Olsen soil test P concentrations (12.5 ppm) than Merlin B (10.5 ppm). Therefore, we can infer that most of the soluble

P in Merlin A may have come from the fall P fertilizer application. Case study 1 showed increased soluble P losses from no-till systems. Case Study 2 demonstrated that these losses can be reduced by avoiding P applications during periods sensitive to runoff. Previous research conducted at these sites also reported elevated NGS soluble P losses from no-till systems in which fall P fertilizer was broadcast (Macrae et al., 2023).

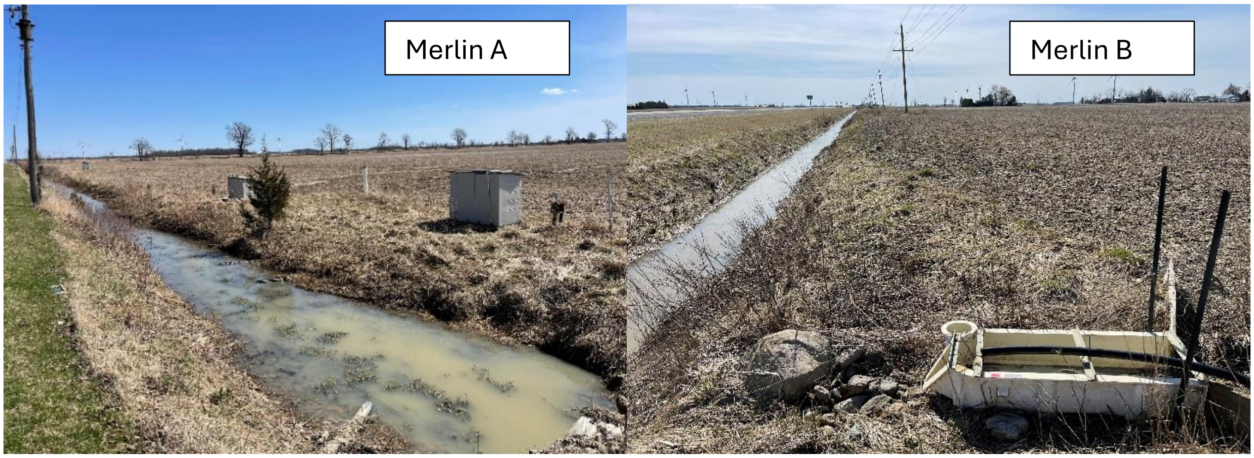


Figure 16. Merlin A and Merlin B sites following the early spring rainstorm event on April 2nd, 2025.

Although an increase in SRP concentrations was expected for Merlin A, the increase in particulate P concentrations was interesting. This is supported by a higher TSS concentration at Merlin A, which indicates significant sediment loss from the field that recently adopted no-till cultivation. Higher P and TSS concentrations and increased flows from Merlin A substantially increased sediment, soluble P, and total P losses during the NGS of 2024/2025 compared to Merlin B.

Although the flow was only 1.8 times higher, NGS TP and SRP losses were 4.5 and 9 times higher than Merlin B, respectively (**Table 13**). Sediment losses from Merlin A were also 3.5 times higher than those from Merlin B. The reduction of PP in Merlin B is likely attributed to the duration of the no-till and/or the field's history of cover crops. Long-term no-till systems are commonly associated with improved soil quality, reduced erosion, and greater moisture conservation. However, it may take several cropping seasons for soil health parameters and water-holding capacity to improve, especially after years of disturbance. This could explain why, although benefits are observed from short-term no-till in reducing PP and TSS compared to conventional tillage (see 3.3.1 Case Study 1), they are still higher than in a long-term no-till field.

Apart from sediments and P, Merlin A also lost higher nitrate through tile drainage during the 2024/2025 NGS (**Table 13**). Interestingly, both fields showed increased nitrate concentrations in tile during the first event (December 16 to 17, 2024) following the summer (**Figure 17)**. Potential mineralization of N-rich soybean residue can increase nitrate leaching losses from NGS (Nakayama et al., 2025). The addition of MAP could further increase nitrate concentrations and losses as observed in Merlin A (Nakayama et al., 2025).

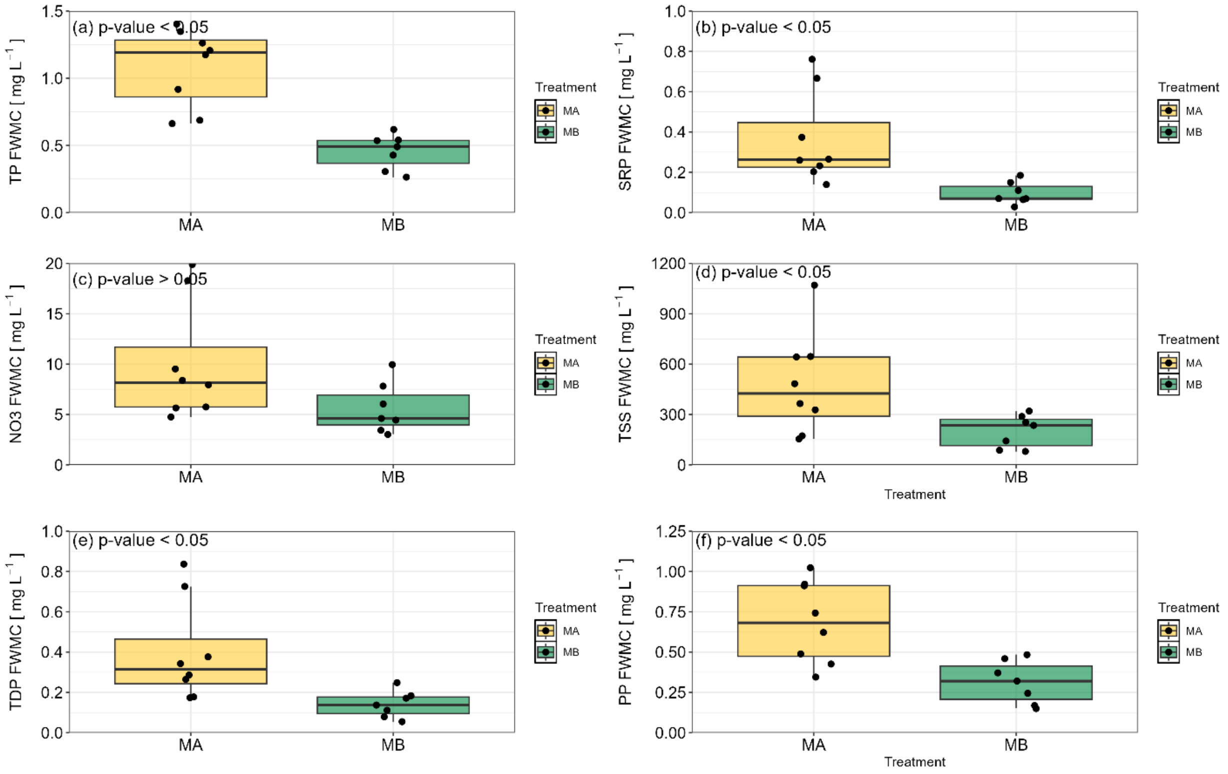


Figure 17. Comparison of tile flow-weighted mean concentrations (FWMC) from Merlin A (MA) and Merlin B (MB) for the monitored events for 2024/2025 non-growing season: total P (TP) (a), soluble reactive P (SRP) (b), nitrate (c), total suspended sediments (TSS) (d), total dissolved P (TDP) (e), and particulate P (PP) (f).

Table 13. Tile flow, total P (TP), soluble reactive P (SRP), nitrate, total suspended sediments (TSS), total dissolved P (TDP) and particulate P (PP) losses from Merlin A and Merlin B during the 2024/2025 non-growing season (NGS).

	NGS tile flow (mm)	TP (kg/ha)	SRP (kg/ha)	Nitrate (kg/ha)	TSS (kg/ha)	TDP (kg/ha)	PP (kg/ha)
Merlin A: Recent No-Till, Fall Surface Broadcast	89.63	1.15	0.44	7.56	422.21	0.48	0.66
Merlin B: Long-Term No-Till, No Fall Fertilizer	52.30	0.25	0.05	3.03	119.94	0.07	0.19

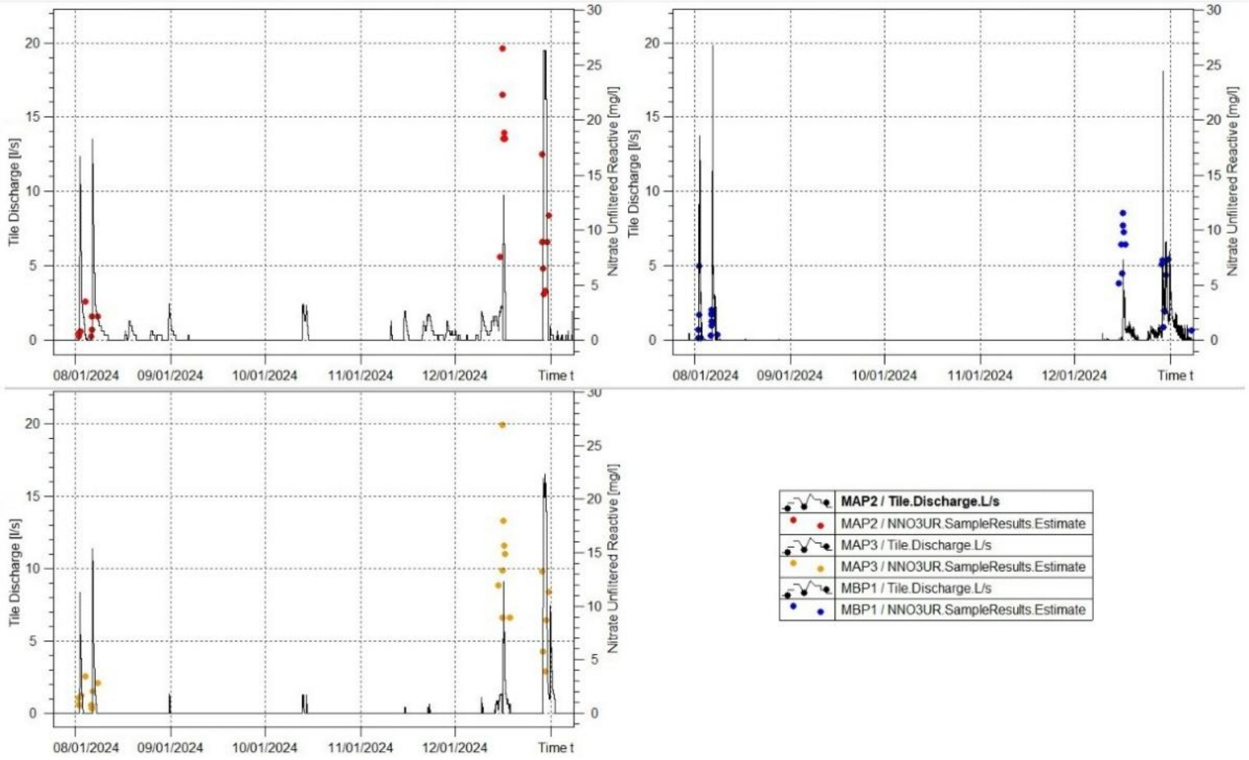


Figure 18. Tile flow and nitrate concentration at two Merlin A tile outlets and one Merlin B outlet from August 2024 to January 2025.

Results from both case studies indicate potential benefits of no-till cultivation for water quality through reduced sediment in runoff. This results in the reduction of PP. However, practices such as fall fertilizer application could offset these water quality benefits by increasing soluble P and nitrate losses (**Figure 18**). In addition, other water-quality benefits of no-till could be realized over time, as recent no-till cultivation still loses more sediment and PP than long-term no-till cultivation. Planting a cover crop following harvest could reduce potential NGS sediment and P losses through tile and surface runoff. A non-leguminous cover crop could be more advantageous for plants, especially following soybean harvest, as it could tie up N that would otherwise be released through mineralization of soybean residue.

3.4 Extreme precipitation events following nutrient application can exacerbate runoff nutrient losses in the growing season

In Ontario, NGS runoff and nutrient losses are considered significant. Runoff processes during GS are considered minor due to higher evapotranspiration rates and crop water uptake, creating drier antecedent moisture conditions. However, an increased frequency of extreme precipitation events can lead to substantial runoff and nutrient losses, as observed at the North Kettle EOF site during the 2024 GS.

This case study focuses on the north field of the North Kettle site. This site receives poultry manure and fertilizer applications, and a cover crop is planted in the fall. In the spring of 2024, liquid poultry manure was broadcast at a rate of 2000 gal/ac with a dragline applicator on the north field and incorporated with vertical tillage the following day. Following this, on July 1st, the field was cultivated ahead of the application of 200 lbs of split K-MAG fertilizer (0-0-22, 10Mg, 21S) and MESZ (MicroEssentials® SZ) at the time of sweet corn planting. The manure and fertilizer were incorporated, and applications were timed to occur when the likelihood of runoff is lower and ahead of planting, when the crop needs them.

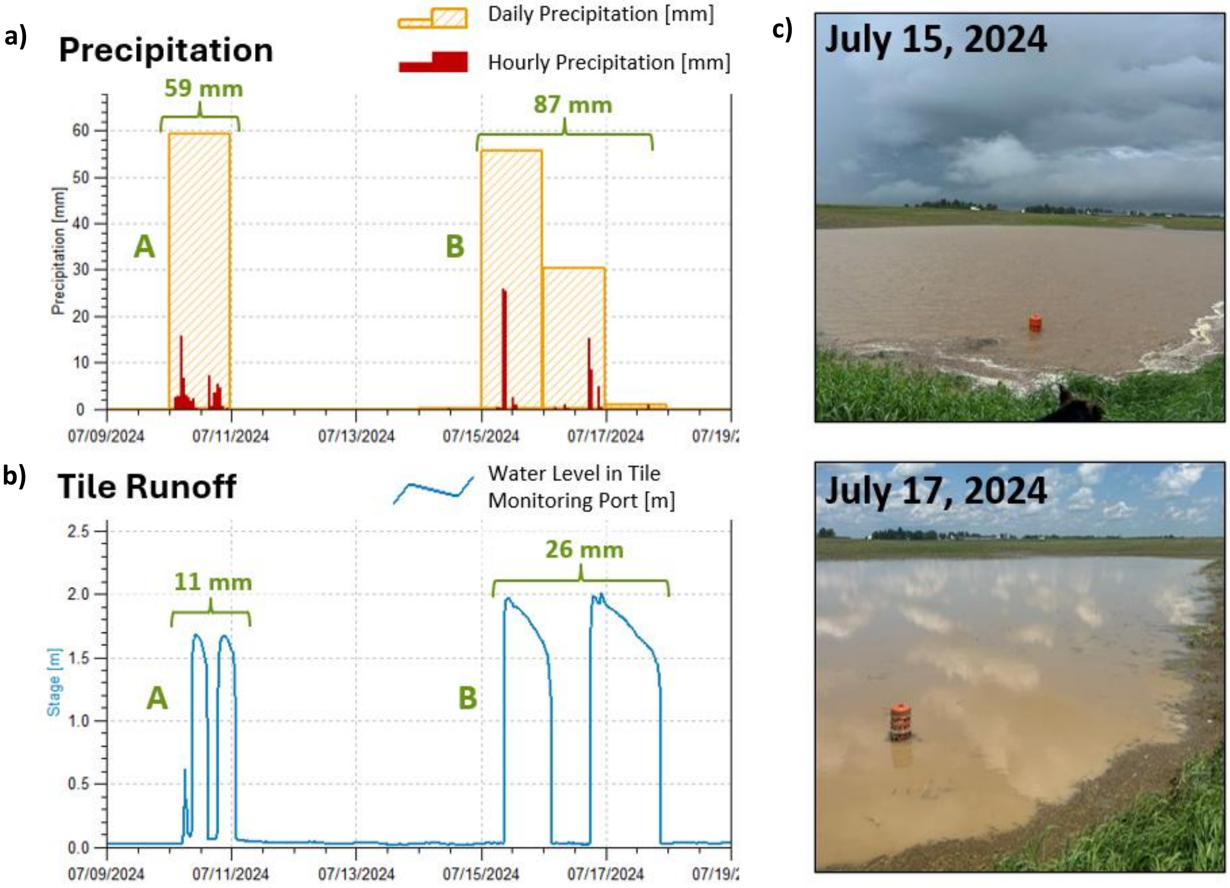


Figure 19. North Kettle precipitation events in July 2024 showing a) daily and hourly precipitation totals, b) tile runoff totals from the north field, and c) photos of ponding at the north field surface inlet on July 15 and 17, 2024.

However, two significant storm events occurred immediately after fertilization and planting. On July 10th (referred to as Event A), a prolonged precipitation event brought nearly 60 mm of rain, causing 11 mm of runoff from the north field. Soon after, starting on July 15th (referred to as Event B), two periods of heavy rain totalling almost 90 mm resulted in 26 mm of runoff from the north field. In this field, surface runoff is routed into tile drains via surface inlets, and the total runoff (surface plus tile) is monitored at the tile outlet. During event B, there was significant ponding at the surface inlets, with turbid water and evidence of foam on the north field, which received the manure application. These events show, in less than a month, how varied the responses can be from one event to another and how different drivers influence nutrient dynamics losses (**Figure 19**).

When water samples from events A and B were analyzed for sediment and nutrient concentrations, their trends differed, indicating the influence of management and precipitation drivers on runoff water chemistry. For example, greater nitrate and SRP concentrations were observed for event A, which immediately followed fertilization and was dominated by low-intensity, longer-duration rainfall. In fact, around 57% of the TP was comprised of SRP, and much of this soluble P and nitrate might have derived from applied fertilizer and manure. Lower-intensity, longer-duration rainfall events often favour greater infiltration, as their intensity is often lower than the soil's infiltration capacity. Even though manure and fertilizer are incorporated, they might have been transported further down through the soil profile by percolating water, eventually intercepted by tile drains (**Figure 20**).

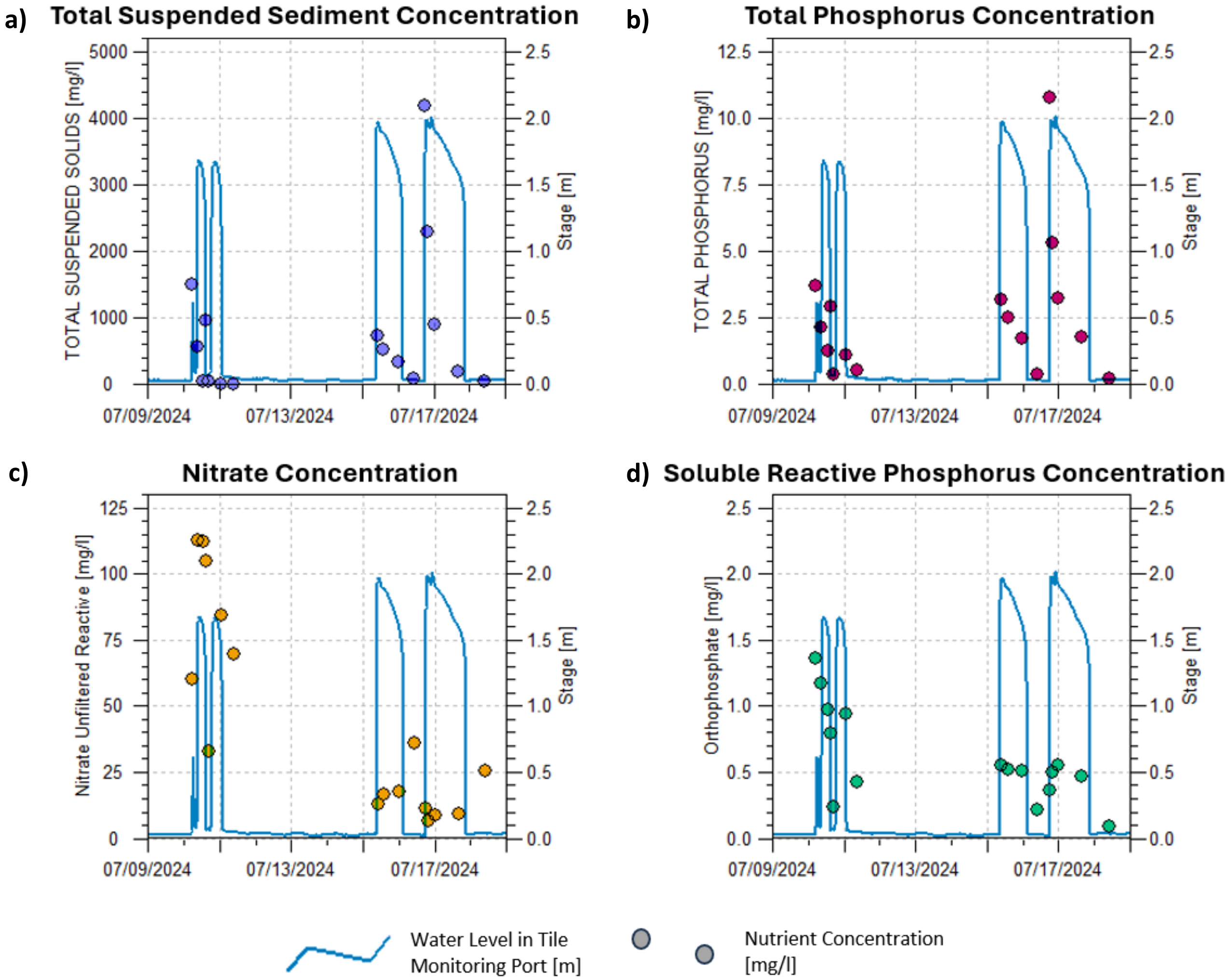


Figure 20. Water level measured in the tile monitoring port (m) and sampled nutrient concentrations (mg/L) from the north field outlet in July 2024 for a) Total Suspended Sediment, b) Total Phosphorus, c) Nitrate, and d) Soluble Reactive Phosphorus.

This dynamic was reversed during Event B, when higher-intensity (>20 mm hr^{-1}) rainfall dominated. Higher-intensity rainfall on already-saturated soils (due to event A) with reduced infiltration capacity might have triggered surface runoff leading to flooding. This extreme event did generate more runoff and elevated TSS concentrations. TP concentrations were also elevated, but this increase was primarily due to PP, which accounted for around 82% of TP. Meanwhile, considerable reductions in nitrate and SRP concentrations were observed, potentially due to source exhaustion or dilution (as event B generated larger runoff) (**Figure 21**).

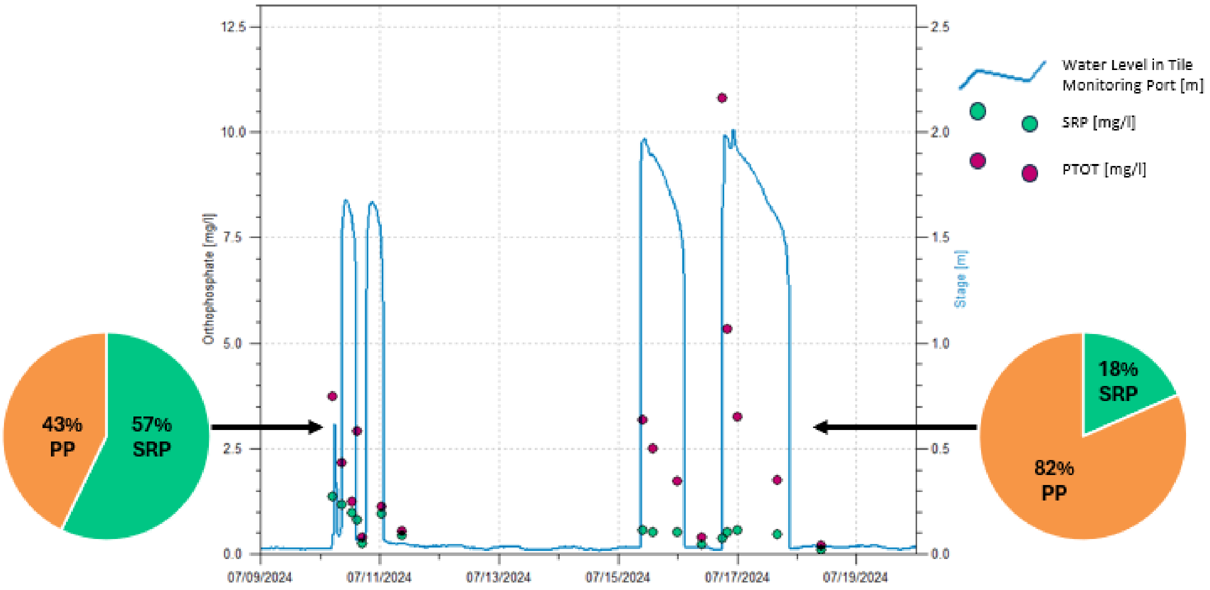


Figure 21. Proportions of particulate phosphorus (PP) and soluble reactive phosphorus (SRP) loads from two runoff events in the north field in July 2024.

Table 14. Nitrate, total P (TP), soluble reactive P (SRP), total suspended sediments (TSS), and particulate P (PP) losses for Events A and B from the North Kettle north field.

	Nitrate (kg ha^{-1})	**TP (kg ha^{-1})**	**SRP (kg ha^{-1})**	**PP (kg ha^{-1})**	**TSS (kg ha^{-1})**
Event A	9.05	0.166	0.095	0.071	35.14
Event B	3.19	0.687	0.126	0.56	174.46

Considerable differences were also observed in sediment and nutrient loads between these two events, which occurred within a week of each other (**Table 14**). Greater nitrate losses were observed for event A, indicating incidental losses from manure and fertilizer. Soluble P losses also accounted for a greater proportion of the TP losses for event A, indicating they might also have derived from the fertilizer. In contrast, TSS and PP were almost five times higher for event B runoff, which was driven by surface runoff/erosive forces.

Findings from this case study provide a clear picture of how management decisions and weather conditions dictate runoff and water quality. Although fertilization was done in the spring, just ahead of planting, major rainfall events can cause considerable nutrient loss through runoff. Crops had not established before the second storm (Event B), exposing the soil to high-intensity rainfall and resulting in the loss of substantial amounts of sediment and nutrients. Most Ontario croplands are planted in May or early June, allowing the crop to grow and establish cover before high-intensity summer storms. Growers who plan for late planting (as on this farm) or fallow the fields should consider covering the soil (with residue or a cover crop) to protect their soils from extreme precipitation and reduce edge-of-field nutrient losses.

The site was also monitored for runoff in the 2025 GS. However, the GS of 2025 was drier, with no major storms.

4.0 Next Steps

The current ONFARM water quality monitoring and historical data analysis are supported further by the LEEAAP program. The advances made over the past year in water quality data analysis will be further improved over the next two years, including increased water sample collection and analysis per runoff event.

At the Huronview site, past runoff data from Field A (the larger field with contour tile drainage) were compiled, curated, and corrected using the new rating curves obtained from the newly installed magnetic flowmeter. Another magnetic flowmeter was installed at Field B (pattern tile drainage) in spring 2025, but the drier conditions did not produce tile flows sufficient to develop new rating curves. Runoff from the 2025/2026 NGS will be used to develop rating curves for Field B, enabling comparisons between different tile configurations regarding tile flow and nutrient losses. The ABCA team will also work with the OSCIA to curate and compile runoff and water-quality data from other Huronview datasets over the coming months.

Over the past year, considerable progress has been made on cleaning and analyzing the data from the Fairview EOF site. Tile flow data were cleaned for the periods 2022 GS, 2022 NGS, and 2023 NGS. The newly installed EcoSiren flow meter continues to provide reliable flow measurements since the 2024 GS. LTVCA and OSCIA are exploring ways to correct the data for the 2023 GS, where the barometric HOBO sensor failed. Once corrected, tile flow data from 2022 GS to 2025 NGS will be compiled, and nutrient loads will be estimated to understand the impact of manure application on EOF nutrient losses.

OSCIA and AAFC have also initiated analyzing multi-year runoff data from the Upper Medway EOF site. Although progress has been made in estimating controlled and free drainage flows for 2018, further scrutiny is required due to uncertainty about a few winter runoff events. The new approach will examine more recent runoff data (2024-2025), with more field observations now available.

Runoff estimation at the North Kettle EOF site has been improved following a correction to the fields' contributing area, based on tile installation maps. Considerable progress has also been made in correcting and compiling the runoff at the north field. UTRCA also installed new EcoSiren flow meters in 2025 to enhance flow monitoring. This new flow data can also be used to correct past events with backflows, as runoff estimated from water-level sensor data often overestimates runoff during backflow periods. The level sensor data from the south field also needs significant correction, and the UTRCA and OSCIA are working on this.

References

Du, X., Jian, J., Du, C., & Stewart, R. D. (2022). Conservation management decreases surface runoff and soil erosion. International soil and water conservation research, 10(2), 188-196.

Finney, D. M., White, C. M., & Kaye, J. P. (2016). Biomass production and carbon/nitrogen ratio influence ecosystem services from cover crop mixtures. Agronomy journal, 108(1), 39-52.

Kokulan, V., Macrae, M. L., Ali, G. A., & Lobb, D. A. (2019). Hydroclimatic controls on runoff activation in an artificially drained, near-level vertisolic clay landscape in a Prairie climate. Hydrological Processes, 33(4), 602-615.

Ljutic, A., Moore, J., Ali, G., Van Eerd, L., Macrae, M. L., & Wagner-Riddle, C. (2024). Variable soil moisture responses to rainfall events in fields under different management practices. Hydrological Processes, 38(7), e15242.

Macrae, M. L., Plach, J. M., Carlow, R., Little, C., Jarvie, H. P., McKague, K., ... & Joosse, P. (2023). Trade-offs in nutrient and sediment losses in tile drainage from no-till versus conventional conservation-till cropping systems (Vol. 52, No. 5, pp. 1011-1023).

Nakayama, Y., Arreguin, S., Leon, P., Douglass, M., Becker, T., & Margenot, A. J. (2025). Nitrogen losses under soybean production are mitigated by substituting ammonium phosphates with triple superphosphate but non-fertilizer losses remain appreciable. Agriculture, Ecosystems & Environment, 378, 109274.

Plach, J., Pluer, W., Macrae, M., Kompanizare, M., McKague, K., Carlow, R., & Brunke, R. (2019). Agricultural edge-of-field phosphorus losses in Ontario, Canada: Importance of the nongrowing season in cold regions. Journal of Environmental Quality, 48(4), 813-821.

Weyers, S. L., Gesch, R. W., Forcella, F., Eberle, C. A., Thom, M. D., Matthees, H. L., ... & Strock, J. S. (2021). Surface runoff and nutrient dynamics in cover crop–soybean systems in the Upper Midwest. Journal of Environmental Quality, 50(1), 158-171.

Yang, W., Feng, G., Adeli, A., Tewolde, H., & Qu, Z. (2021). Simulated long-term effect of wheat cover crop on soil nitrogen losses from no-till corn-soybean rotation under different rainfall patterns. Journal of Cleaner Production, 280, 124255.

The Sustainable Canadian Agricultural Partnership (Sustainable CAP) is a 5-year (2023-2028), $3.5-billion investment by federal-provincial and territorial governments to strengthen competitiveness, innovation, and resiliency of Canada's agriculture, agri-food and agri-based products sector. This includes $1 billion in federal programs and activities and a $2.5 billion commitment that is cost-shared 60% federally and 40% provincially/territorially for programs that are designed and delivered by the provinces and territories.