INVESTIGATING THE TEMPORAL SCALES OF NUTRIENT TRANSPORT IN A PRAIRIE WATERSHED USING HIGH-FREQUENCY HYDROLOGICAL AND WATER QUALITY DATA.

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INTRODUCTION

A greater understanding of hydrological processes is needed to interpret patterns present in water quality data under various climatic conditions (wet, intermediate, dry), seasons (spring, summer, fall), and events (snowmelt-driven, rainfall-triggered). This is especially true in intensely managed Prairie watersheds which are vulnerable to faster flows due to engineered stormwater-control infrastructure (surface drains) and high nutrient loading from agricultural fields. The extent to which those water management practices determine short-term, medium-term and long-term water quality dynamics remains unclear. Here we relied on high-frequency meteorological data, water level fluctuation data, and nutrient concentrations data to examine the relationships between runoff processes and water quality dynamics in a typical Prairie landscape. **Three specific objectives were pursued: (1) compare sub-watershed input-output dynamics; (2) analyze nutrient export dynamics as a function of flow rise and flow recession periods; and, (3) determine the season-averaged time lags between flow peaks and nutrient concentration peaks.**

STUDY SITE DESCRIPTION

The 594.4 km^2 Catfish Creek Watershed (CCW) is located within the Canadian Prairies (Manitoba, Canada, see Figure 1) in a region that experiences an open water season from spring thaw until fall freeze-up (approximately late-April until early-November). Although snowfall is not a major hydrologic input for this region, snowmelt dominates the hydrologic regime and spring flooding on frozen ground is commonplace. The CCW includes a near even mix of forest and agriculture land, has a heterogeneous topography (e.g., flat, hilly) and contains a number of surface drains in both its agricultural and forested portions, notably two large man-made drainage channels referred to as Main Drain 1 and Main Drain 2. While multiple outlets have been instrumented in the CCW, here we only focus on two sites monitored from April to September 2013.

Site SW1 (or SW1 (CFCK-11) is the outlet of the CCW that flows into Traverse Bay then Lake Winnipeg. Figure 2 is a photo taken of the site in mid-August 2013.

Site SW5 (or SW5 (MD2-304) is an upstream site located along Main Drain 2 and drains an area of 99.9 km^2 of forest, thus offering contrast with the outlet that drains a mix of agricultural and forested areas. Figure 3 is a photo taken of the site in mid-August 2013.

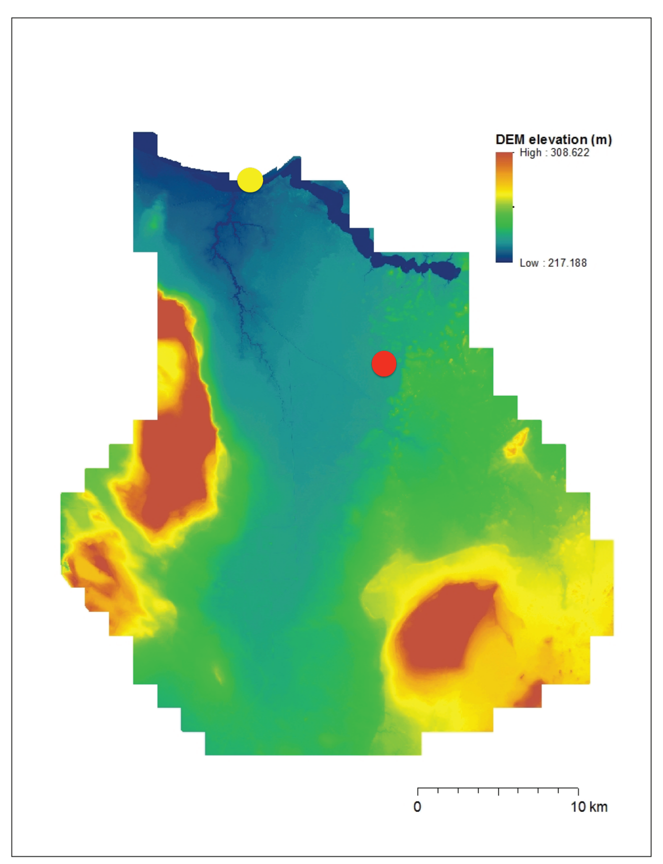

Figure 1. LiDAR map of the Catfish Creek Watershed (as collected by Manitoba Infrastructure and Transportation in May 2013). Sites SW1 and SW5 are indicated

Figure 2. Photo of SW1, facing upstream (west) at Catfish Creek from the top of a bridge (© Halya Petzold, August 21, 2013).

Figure 3. Photo of SW5, facing downstream (west) at Main Drain 2 from below a bridge (© Halya Petzold, August 14, 2013).

METHODOLOGY

Rainfall data from one weather station (1-minute recording frequency) was used to quantify the hydrologic input signal. At the two targeted outlets, water level loggers were installed in the creek or the drain to monitor water level fluctuations. Automatic samplers were also installed to allow water sample collection for water quality testing. The autosamplers were programmed to pump water samples at different frequencies: SW1 was considered a high intensity site (1 sample every 7 hours) while SW5 was a moderate intensity site (1 composite sample per day). Data for SW1 was aggregated on a daily basis to facilitate comparison with SW5. All collected samples were tested for pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), salinity, turbidity, phosphate and nitrate concentrations.

Table 1. Comparison of water quality, water level, and rainfall characteristics

Site	Parameter	Characteristic						
		Maximum Value		Minimum Value		Range	Mean	Median
Site SW1	Water Level (mm)	1227	July 18, 2013	7	April 30, 2013	1220	777	791
	Rainfall (mm)	29.60	August 28, 2013	0.00	Multiple Days	29.60	1.57	0.00
	Nitrate (ppm)	5.63	May 6, 2013	0.01	Multiple Days	5.62	0.32	0.09
	Phosphate (ppm)	0.99	May 2, 2013	0.01	Multiple Days	0.98	0.06	0.03
	Electrical Conductivity (EC)	348.67	June 3, 2013	119.50	June 23, 2013	229.17	198.02	178.80
	Turbidity (FAU)	273.03	July 14, 2013	16.12	August 29, 2013	256.91	77.31	58.85
Site SW5	Water Level (mm)	2500	May 2, 2013	372	September 15, 2013	2128	653	504
	Rainfall (mm)	29.60	August 28, 2013	0.00	Multiple Days	29.60	1.58	0.00
	Nitrate (ppm)	4.47	April 29, 2013	0.01	Multiple Days	4.46	0.39	0.09
	Phosphate (ppm)	0.37	June 24, 2013	0.01	Multiple Days	0.36	0.08	0.07
	Electrical Conductivity (EC)	433.00	September 17, 2013	158.67	May 1, 2013	274.33	281.76	272.00
	Turbidity (FAU)	77.85	May 1, 2013	25.17	September 16, 2013	52.68	39.15	38.01

Table 2. Cross-correlation coefficients and lag times (days) for water quality parameters and water level at each site. Positive lags show that the parameter peaked after water level, and negative lags show that the parameter peaked before water flow.

	Parameter	Water Level (mm)	
		Correlation Coefficient	Lags (days)
Site SW1	Nitrate (ppm)	0.3417	16
	Phosphate (ppm)	0.3669	12
	Electrical Conductivity (EC)	0.3672	12
	Turbidity (FAU)	0.8441	-1
Site SW5	Nitrate (ppm)	0.3619	1
	Phosphate (ppm)	0.3225	-29
	Electrical Conductivity (EC)	0.3213	-29
	Turbidity (FAU)	0.8718	0

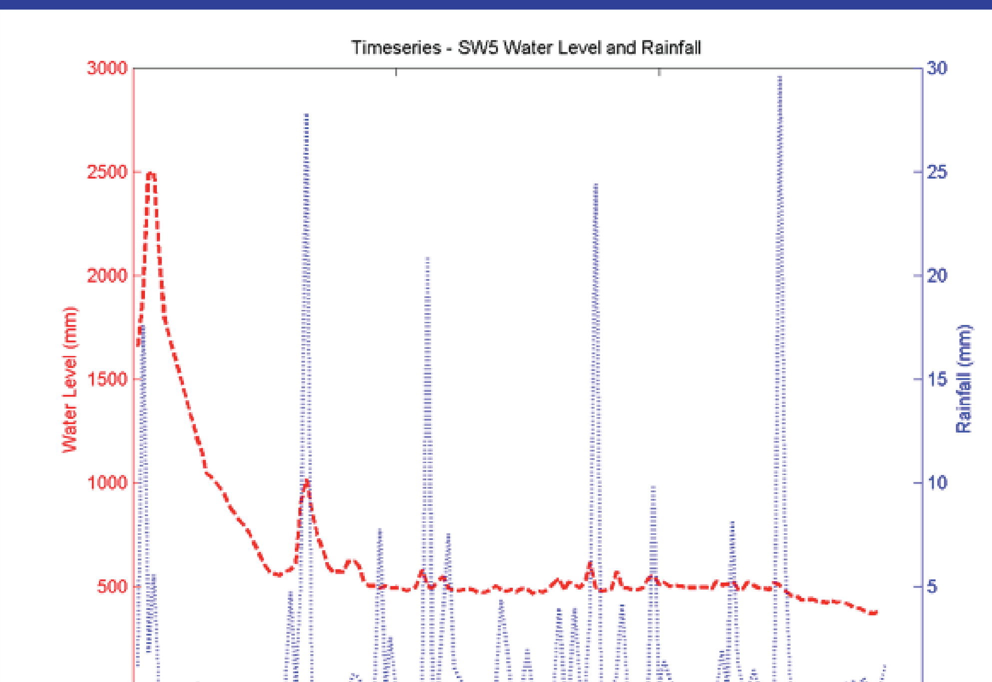

Figure 5. NB Day 0 = April 29 and Day 142 = September 17, 2013.

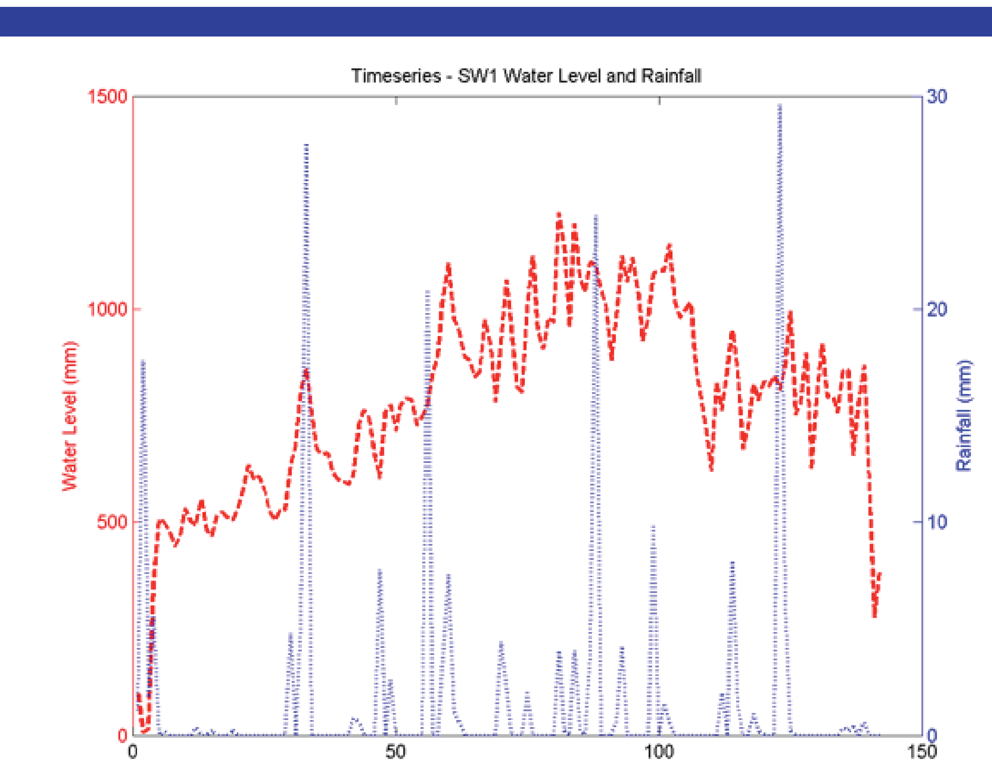

Figure 6. NB Day 0 = April 29 and Day 142 = September 17, 2013.

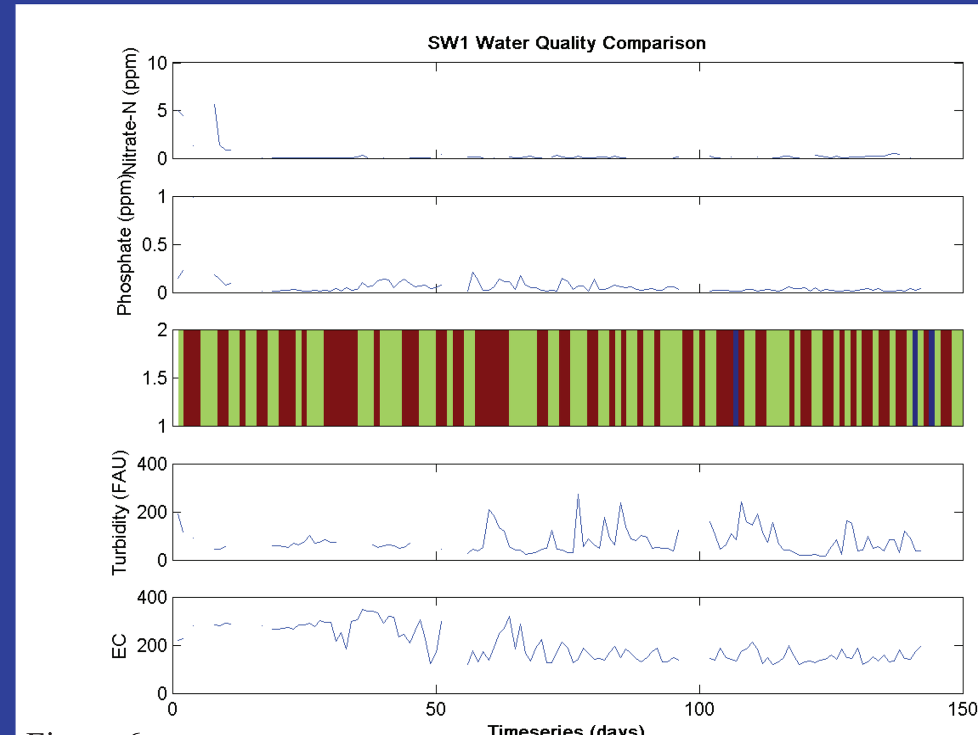

Figure 6

Figures 6 and 7 show an illustration of flow and water quality fluctuation patterns at site SW1 and SW5, respectively, between April 29 (day 0), and September 17, 2013 (day 142).
Panel 1: Nitrate (ppm)
Panel 2: Phosphate (ppm)
Panel 3: Flow timeseries classified as rises (red), falls (green) and baseflow (blue)
Panel 4: Turbidity (FAU)
Panel 5: Electrical conductivity (µS).

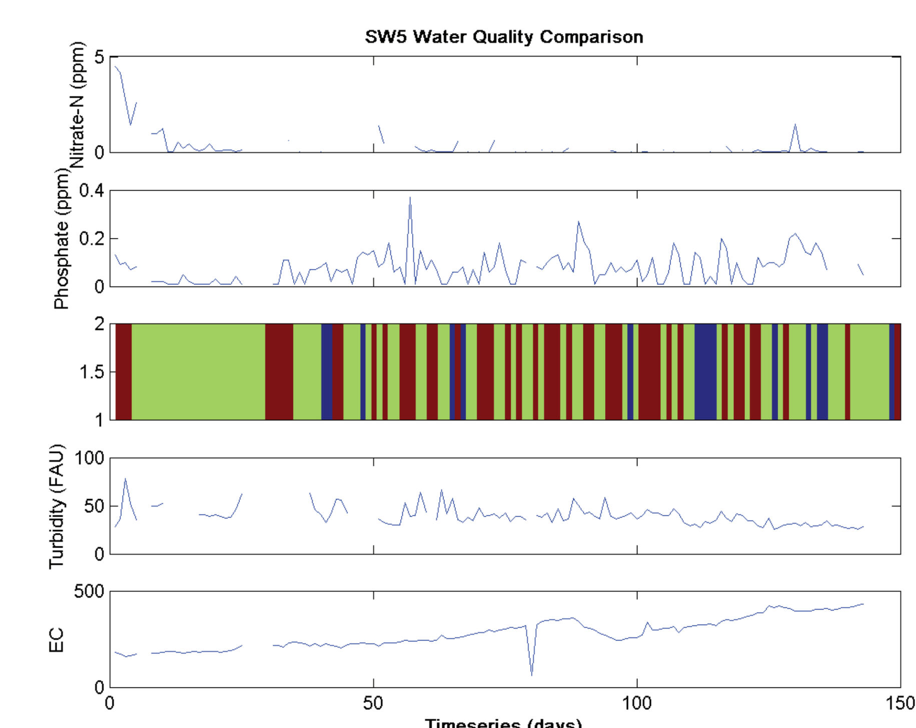

Figure 7

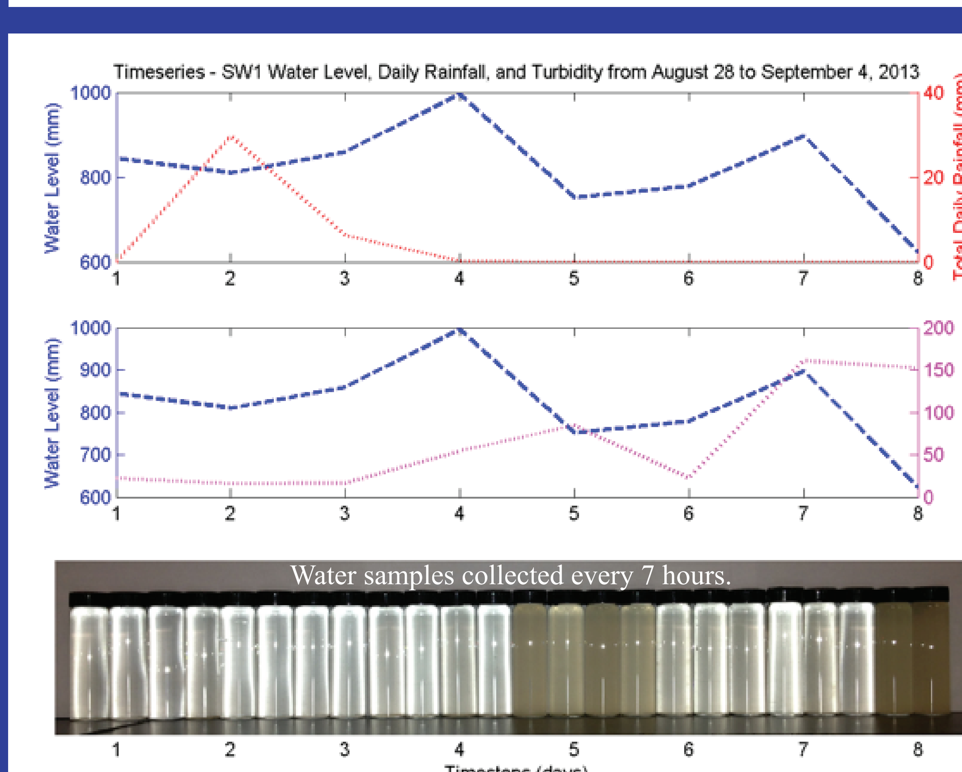

Figure 8

RESULTS & DISCUSSION

Objective 1: Comparing Sub-watershed Input-Output Dynamics

Site SW1: In 2013, site SW1 did not experience its highest water level concurrently with the spring 2013 thaw (Table 1); this is likely due to frozen culverts and ice jams that hindered the downstream progression of snowmelt runoff. Large rainfall events are generally followed by a large increase in stream water level (Figure 4).

Site SW5: In 2013, this site experienced an overall decreasing water level from mid-May until monitoring ceased. Large rainfall events were only followed by a minimal water level reaction (Figure 5).

Objective 2: Analyzing Nutrient Export Dynamics as a Function of Flow Rise and Flow Recession Periods

Site SW1: Increases and decreases in nitrate, phosphate, turbidity, and electrical conductivity are well aligned with periods of flow rise and flow recession (Figure 4). Nitrate, however, does not show similar fluctuations; concentrations peaked during the spring season, and then declined to a consistently low level throughout the rest of the field season (Figure 6).

Site SW5: This site has very different flow patterns than SW1 and was notably characterized, in 2013, by a long snowmelt runoff recession (approximately 35 days, from May 3 to June 7, see Figure 5). After June 7, flow rises and recessions followed a similar pattern to SW1 and fluctuations in phosphate and turbidity were aligned with flow fluctuations. However EC showed a relatively steady increase from April 29 to September 17 (Figure 7).

Objective 3: Determining the Season-Averaged Time Lags Between Flow Peaks and Nutrient Concentration Peaks

The strongest cross-correlations were achieved between water level and turbidity (Table 2) at both site SW1 and site SW5, with a very short lag time of -1 day lag (i.e. turbidity peaked before flow, refer to Figure 8).

Site SW1: The cross-correlation between water level and nitrate was 0.3417, with nitrate time offset of 16 days (Table 2). The cross-correlation between water level and phosphate was very similar (0.3669), but with a shorter delay of 12 days (Table 2).

Site SW5: Nitrate levels were highest in the spring and maintained low levels throughout the summer season. The cross-correlation between water level and nitrate was 0.3619, with a time delay of 1 day (Table 2). Phosphate concentrations fluctuated largely from 0.37 ppm to 0.01 ppm throughout the 2013 field season. The cross-correlation between water level and phosphate was 0.3225, with time offset of -29 lags (i.e., phosphate peaked before flow)-.

CONCLUSION

Sites SW1 and SW5 did not demonstrate many similarities in behavior based on data collected in 2013, despite their relative proximity within the Catfish Creek Watershed. It was assumed that the highest stream water levels would be observed during and immediately after the spring-thaw event (from end of April to the middle of May); site SW1 did not respond as anticipated while site SW5 did. In addition, both sites did not show similar fluctuations in water quality parameters when confronted with flow dynamics (i.e. flow rise versus flow recession periods, time lags).

This highlights the need for comparing the dominant runoff processes prevailing in the forested versus agricultural areas upstream of SW1 and SW5, identifying specific nutrient sources, and investigating whether the data collected at SW1 might be biased by a lake effect from Traverse Bay.

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