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Turbidity and precipitation in a small watershed in Northeast Tennessee

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INTRODUCTION AND BACKGROUND

Excess sediment in surface water is a primary pollutant in Tennessee, streams. Precipitation and turbidity are usually correlated, and a lag (time of concentration) generally exists between onset of precipitation and the stream's response.

- This research analyzes precipitation and turbidity at the hourly timescale to calculate this lag for Sinking Creek (HUC14-06010103000325) in Johnson City, TN (Figure 1).
- The 15.7 km (9.8 mi) stream has forested headwaters and flows through agricultural and urban lands before flowing into a sinkhole. The study reach is in a recently restored wetlands 365 m (1200 ft) downstream of Sinking Creek's largest tributary (Catbird Creek), which is sediment impaired.
- Soils: loam to silt loam and show evidence of frequent flooding.
- Geology: Cambrian-Ordivician Knox Group carbonates (limestone & dolomite).
- Climate: Humid Subtropical (Köppen Cfa) with average annual rainfall of 111 cm (44 in) and snowfall of 20 cm (8 in). Monthly average temperature ranges from 27°C (86°F) in July to -3°C (26°F) in January.

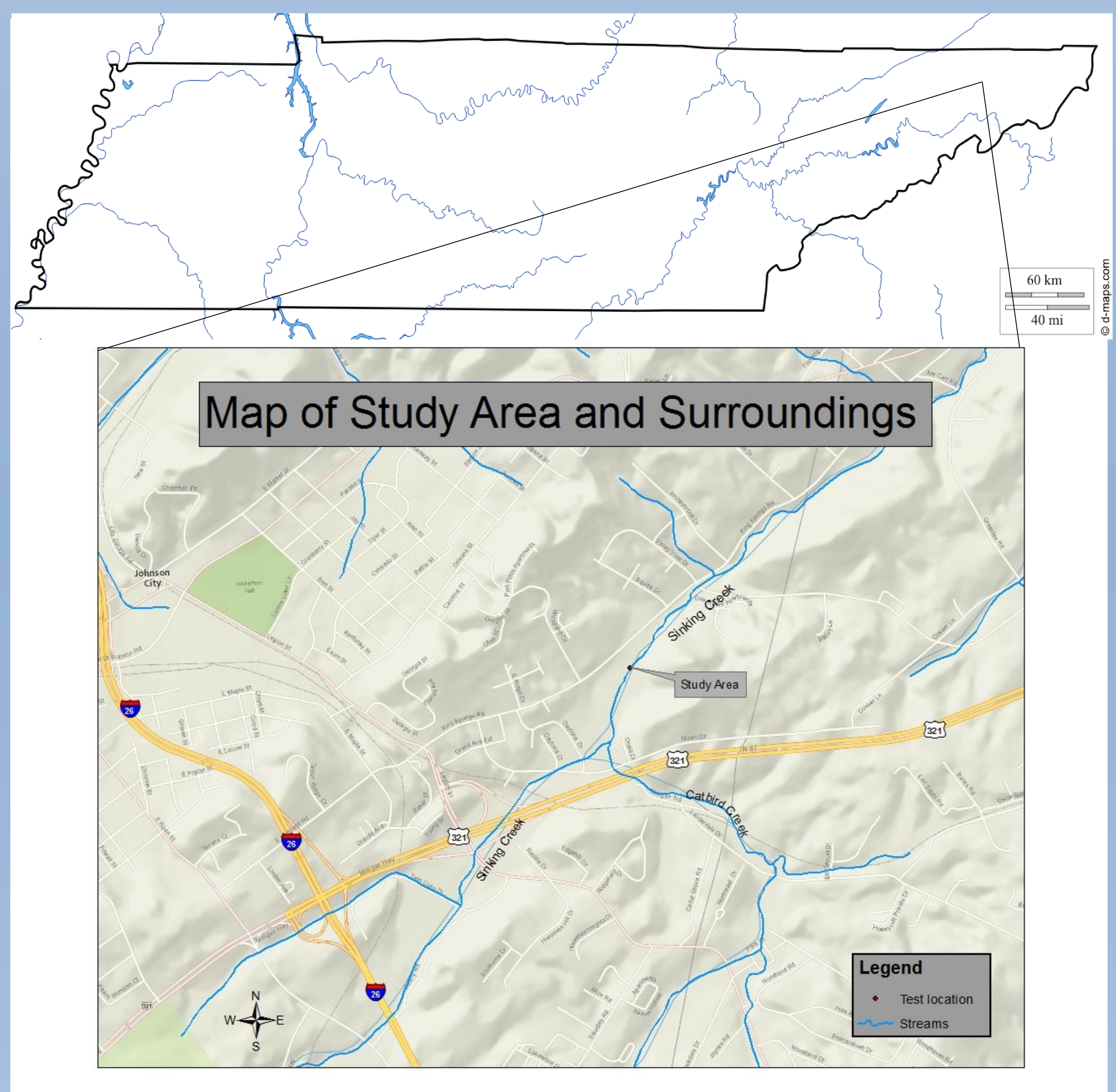

Figure 1. Study Area.

METHODS

Methods are outlined in the flow chart below (Figure 2). Field data collection was conducted 10-22-15 to 11-5-15 (Figure 3). Water samples were analyzed for turbidity at the ETSU Geosciences Hydrology Lab. Statistical analyses were completed in SPSS 22.

1. Field Data Collection
- Collect precipitation data with Onset RG2 raingauge (5 mins).
- Collect 300 mL water samples with ISCO6712 sampler (hourly).
- Measure stream discharge daily using hand–held flow meter.

2. Laboratory Analysis
- Retrieve water samples daily.
- Measure turbidity in lab using HF-Scientific DRT-15CE turbidimeter.
- Enter all data in Excel spreadsheet for analysis.

3. Statistical Analysis
- Calculate precipitation accumulation and intensity
- Calculate cross-correlation statistics in SPSS 22.0.
- Identify time of concentration for Sinking Creek.

Figure 2. Description of methods.

Abstract

Excess turbidity is a cause of surface water impairment for fish and aquatic life, and is positively correlated to pathogen impairment. Turbidity in Tennessee streams is of special concern as sedimentation is the second ranking cause of surface water impairment after *Escherichia Coli*, with 9934.15 km (6,172.8 miles) of sediment impaired streams reported in the state for 2012 (21.7% of assessed waters). During a 14-day period in Fall 2015, a data-logging rain gauge was deployed, and n=337 hourly water samples were collected from Sinking Creek (HUC14-06010103000325) at Jacob's Nature Park in Johnson City, Tennessee. The collection site was 365 m (1,200 ft) downstream from a sediment impaired tributary (Catbird Creek). Two small rainfall events occurred during the study and turbidity was compared to precipitation accumulation and intensity using cross-correlation. A small statistically significant Spearman correlation between precipitation accumulation and turbidity exists at lags of 2 through 8 hours following a rainfall event (r=0.127 to 0.203, p<0.05). Similarly, a small statistically significant Spearman correlation exists between precipitation rate and turbidity at lags of 2 through 8 hours following a rainfall event (r=0.123 to 0.2, p<0.05). Linear regression models on turbidity at various lags using precipitation explained only 15% of the variability in the data.

Figure 3. From left, water samples are retrieved from 24-bottle automated sampler; discharge is measured; water samples are analyzed and data entry is completed in the ETSU Geosciences Hydrology Lab.

RESULTS

Table 1: Data summary

Rainfall:	The rain gauge captured 3.3 cm (1.3 in) of rain in 3 separate events.
Discharge:	Three elevated discharge events were related to rainfall.
Turbidity:	The majority of the turbidity readings were between .12 to .16 NTU with a range of .06 NTU to .48 NTU. Higher values were recorded after rainfall events.
Environmental parameters:	Air temperature ranged from a low of -0.2° C (32° F) to a high of 34°C (93°F) with a daytime average of 20°C (67°F) and a nighttime average of 11°C (51°F). Water temperature ranged from a low of 12.7°C (55°F) to a high of 16.9°C (62.5°F).

Data are summarized in Table 1.

- Three distinct rainfall events were recorded with different durations (11 hrs, 5 hrs, and 14 hrs), captured by the rain gauge and discharge measurements.
- An increase in turbidity was observed beginning two hours after a rain event, peaking at a lag of 3 hours (Figure 4). The precipitation-turbidity response is evaluated statistically using Spearman's correlation coefficients (Table 2).
- OLS regression models on turbidity (dependent variable) using rainfall data explained 15% of the variability in turbidity (Figures 5 and 6).

Table 1. Spearman's correlation.

	PrecipTotal	PrecipRate
Turbidity_Lag1	-	-
Turbidity_Lag2	.174**	.173**
Turbidity_Lag3	.254**	.250**
Turbidity_Lag4	.252**	.249**
Turbidity_Lag5	.239**	.239**
Turbidity_Lag6	.234**	.232**
Turbidity_Lag7	.182**	.178**
Turbidity_Lag8	.173**	.168**
Turbidity_Lag9	.136*	.140*

* significant at p=0.05; **significant at p=0.01

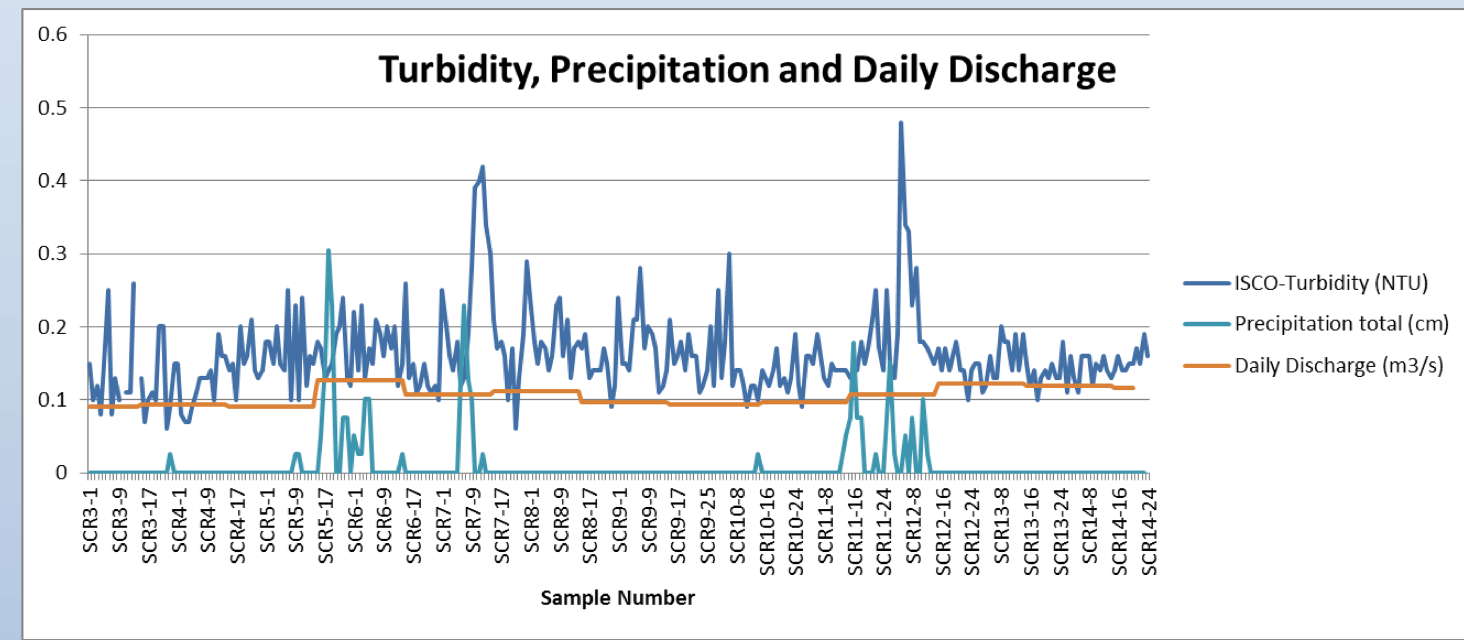

Figure 4. Turbidity, Precipitation and Daily Discharge by sample number. Daily samples were coded using SCR# (each day was one round) followed by the sample number (hourly samples numbered from 1-24).

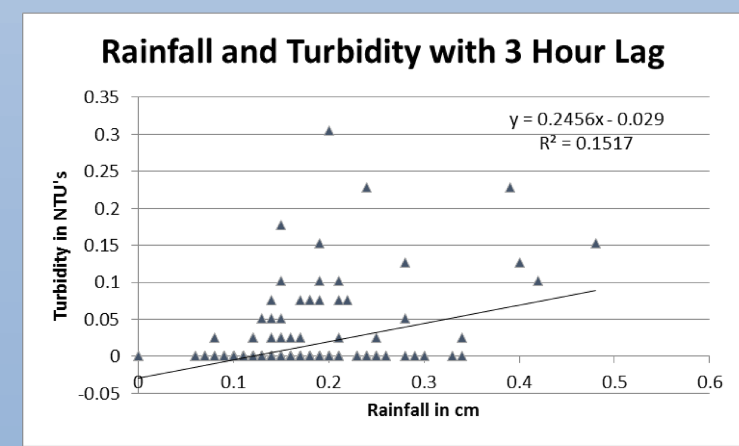

Figure 5. Rainfall and Turbidity with 3 Hour Lag

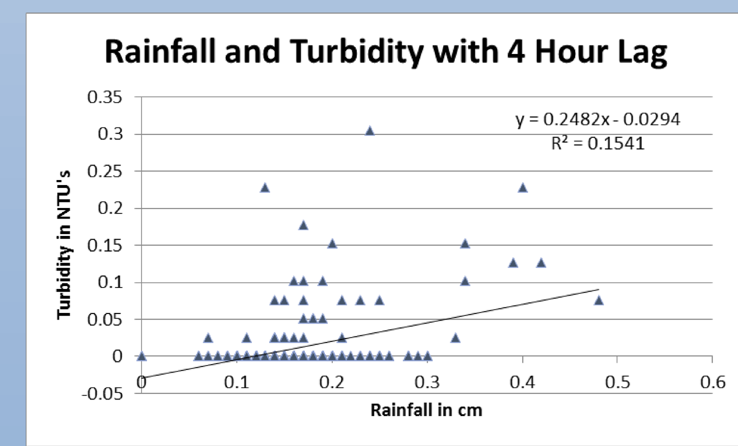

Figure 6. Rainfall and Turbidity with 4 Hour Lag

DISCUSSION

- Turbidity response was smaller for the first rainfall event, even though discharge was increased. This suggests infiltration is an important factor in rainfall-turbidity relationships for this watershed.
- Karst landforms provide transport pathways for groundwater to enter the stream after rainfall (fluviokarst effluent conditions), but prolonged rainfall is necessary to generate a runoff-associated turbidity response. An early rainfall event on Days 5 and 6 of the study did not generate a significant turbidity response (Figure 7). Limited rainfall in the weeks prior to the study likely contributed to increased infiltration of this first rainfall event. Following events generated a marked turbidity response (Figure 4).

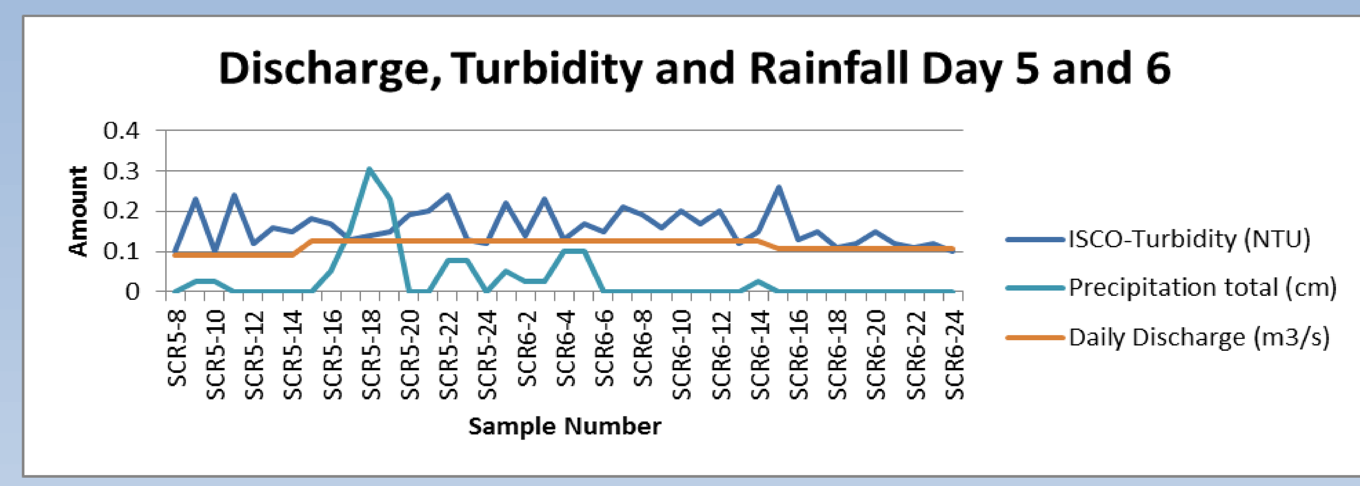

Figure 7: Discharge, Turbidity and Rainfall Day 5 and 6

SUMMARY AND CONCLUSION

While previous studies identified a correlation between turbidity and rainfall, this study quantifies the rainfall-turbidity lagged response for a small karst stream in a humid subtropical climate. Turbidity in Sinking Creek exhibits an approximately 3 hour lag between onset of rain and an increase in turbidity.

Limitations of this study are two-fold: 1) only three rainfall events were captured during the study period, and 2) none of these events were sufficiently large to generate a large turbidity response. Additional study over a longer time frame is recommended to better capture this response.

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