The Relation Between Flow Turbulence and Mixing Along A Stream Confluence Shear Layer

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INTRODUCTION

Confluences are critical zones of mixing within stream networks. The confluent streams often carry significantly different loads or contain water at dissimilar temperatures. The normally slow mixing processes in streams are considerably enhanced at confluences, where non-zero junction angles and intense velocity shear promote strong cross-stream flow and large amounts of velocity turbulence. Those changes in velocity, temperature, and turbidity can have a significant influence on the local environment and ecological system.

DATA DESCRIPTION

- **57618 3D velocity data points**: 19206 data from the surface, 19206 from the mid-depth and 19206 from the bed.
- **900 data points** recording temperature, and turbidity were collected in 300 seconds: 300 measurements from the surface, 300 from the mid-depth and 300 from the bed.
- X is the downstream velocity, Y is the cross-stream velocity and Z is the vertical velocity.

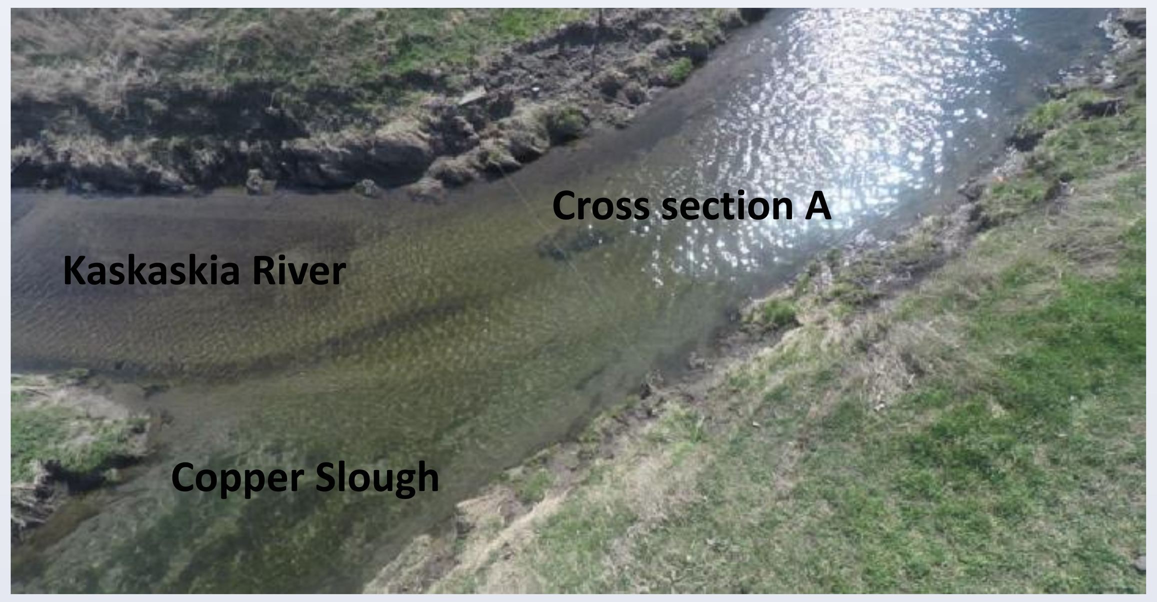
METHODOLOGY

- **Data Source**: data points were collected from the 3D acoustic probes running at 32 Hz (generated 32 samples per second), and the mixing probes running at 1 Hz (generated 1 sample per second).
- **Analyzed Plots**: plot 3D velocity, temperature, and turbidity versus time, and analyze the rates of change and difference to better understand how velocity fluctuations lead to increased mixing.
- **Handling Noise in Data**: A small percentage of the Y velocity and of the turbidity seem to be outliers. We de-spiked those points from the time series based on the criteria of 2 multiples of the standard deviations.
- **Defining Directions**: Downstream is positive; flow towards the right bank (Copper Slough) is positive; flow towards bed is negative.
- Focused on the first 10 seconds to analyze the movement of the water flow in more detail.

RESULTS

	Area (m^2)	Velocity (m/s)	Discharge (m^3/s)	Density (kg/m^3)	Moment Flux ($kg \cdot m/s^2$)
Copper Slough	1.22	0.43	0.35	999.76	151.35
Kaskaskia	1.98	0.25	0.13	999.88	33.61

- **Momentum Ratio (MR) = 4.50**: According to Rhoads and Lewis (2016), MR indicates how strong a flow is in the tributary (Copper Slough) compared to the main stream. MR = 4.50 > 1, the Copper Slough is much stronger.



Cross Section A

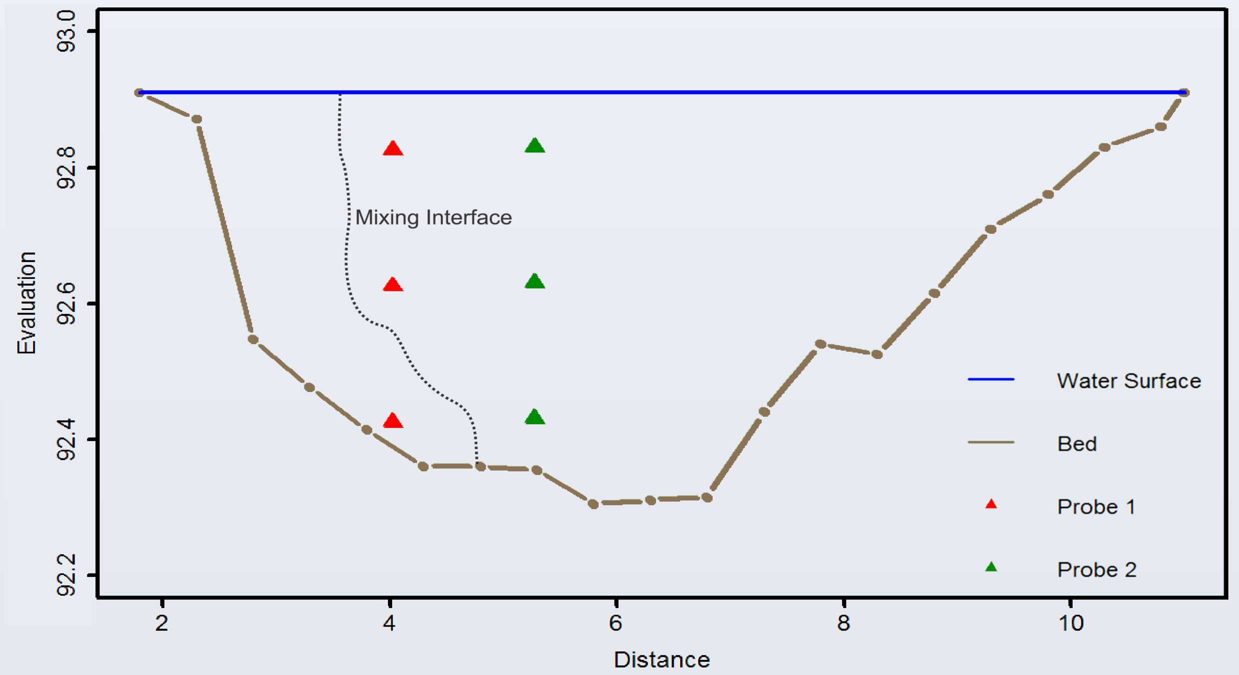


Figure 1. Probe 1: 3D Velocity At The Surface

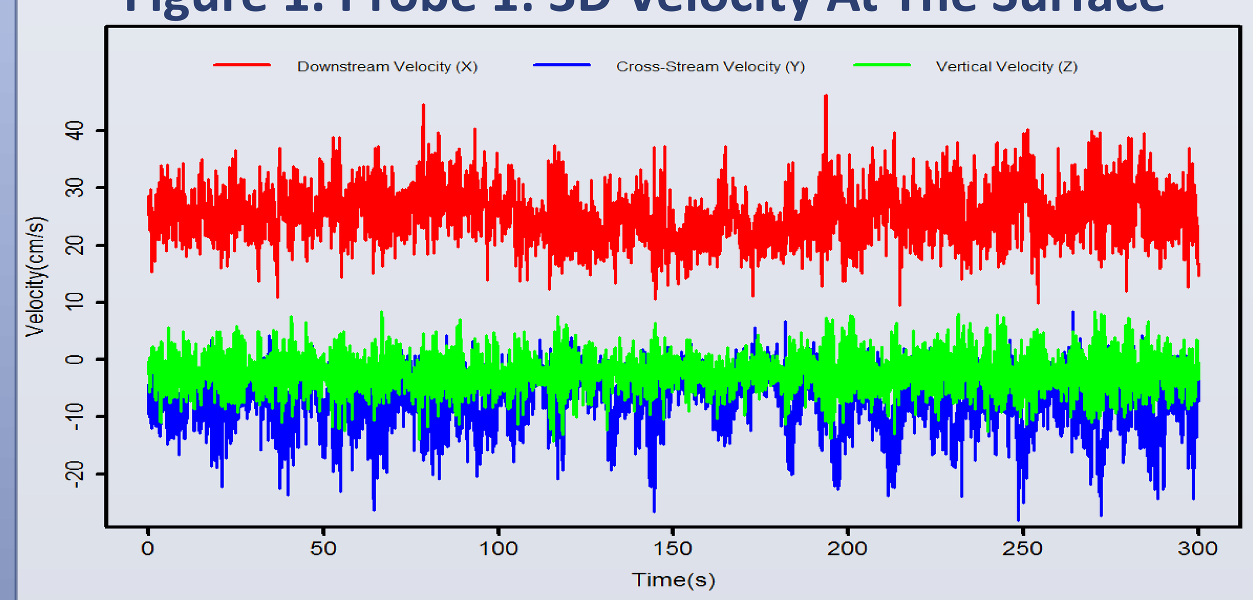
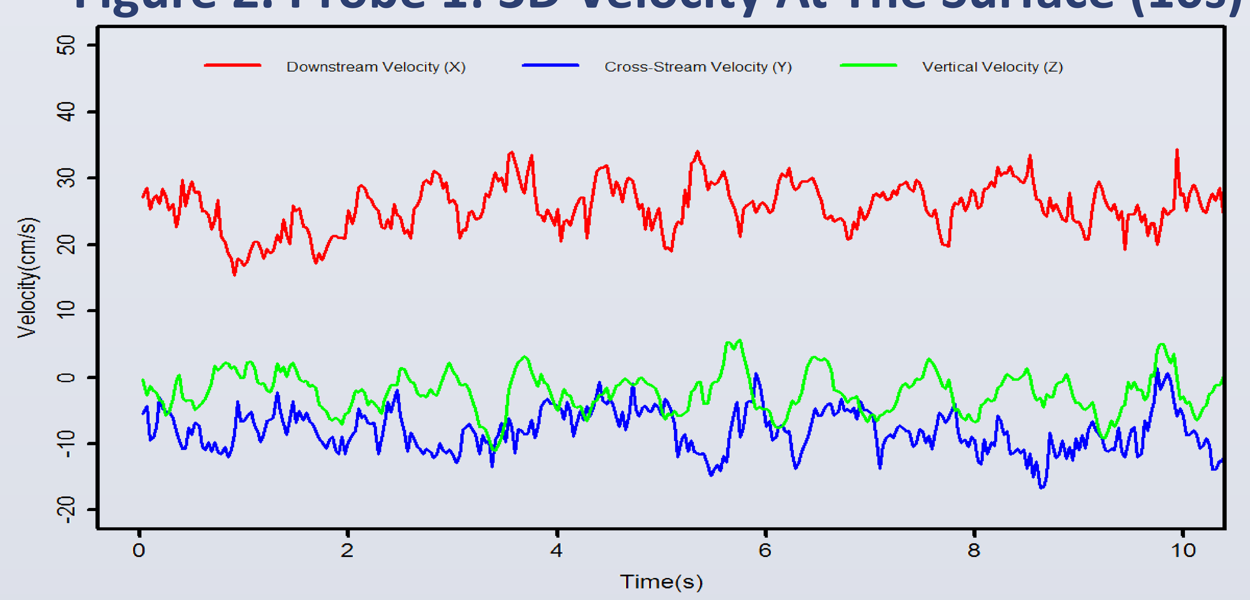


Figure 2. Probe 1: 3D Velocity At The Surface (10s)



Velocity Mean (cm/s)	Surface		Mid-Depth		Bed	
	Probe 1	Probe 2	Probe 1	Probe 2	Probe 1	Probe 2
X (Downstream)	25.58	38.54	18.20	29.06	10.66	15.77
Y (Cross-stream)	-7.25	-12.74	0.31	-4.46	-0.57	0.94
Z (Vertical)	-2.31	-1.37	-2.45	-1.83	-1.20	-0.88

- Kaskaskia River has greater velocity and flows faster than Copper Slough.
- Water from Copper Slough was “pushed” into the confluence and forces flow in Kaskaskia River towards the left bank.
- In the first 10s (Fig. 2), all velocities fluctuate back and forth. It indicates a short-frequency periodicity.

Figure 3. Temperature Along Time

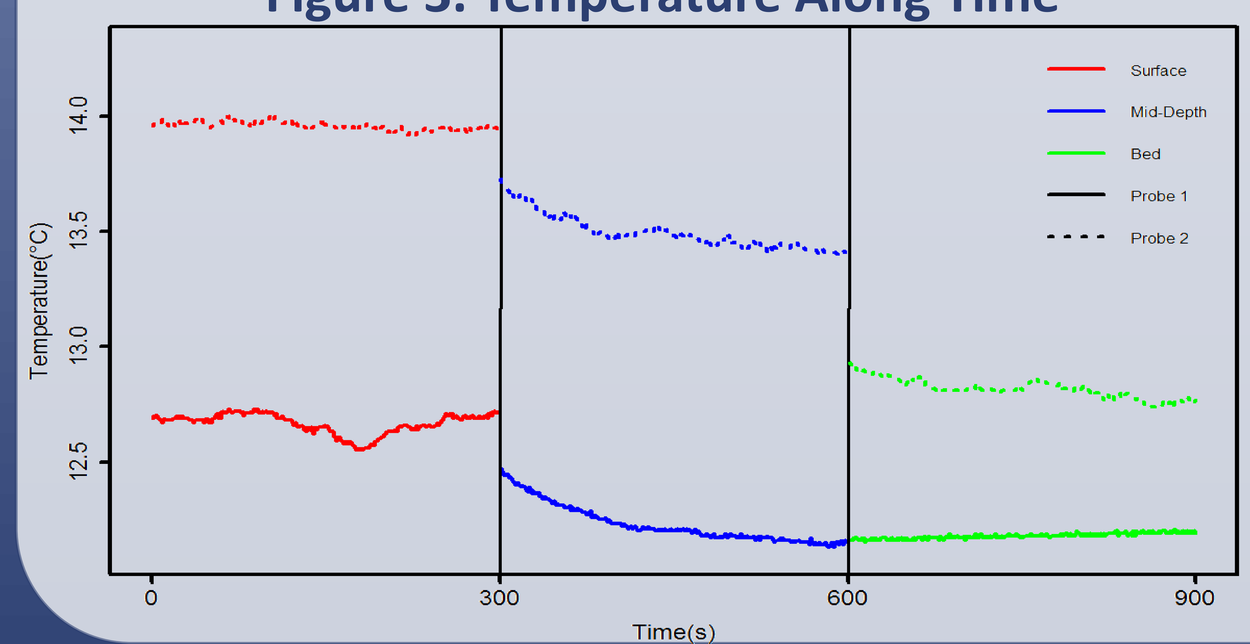
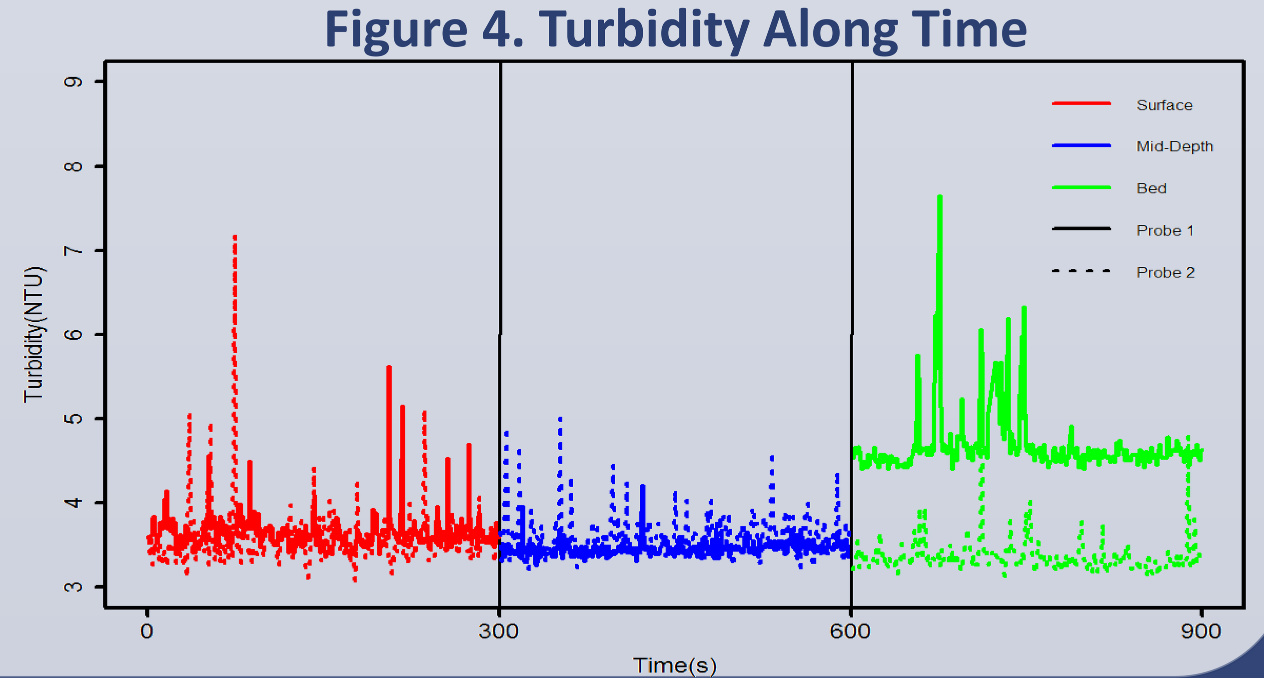


Figure 4. Turbidity Along Time



SUMMARY OF RESULTS

I. 3D Velocity

- As water nears the bed, frictional resistance causes mean velocities to slow down.
- Bed friction has the greatest influence on decreasing the downstream velocity X, slightly changes the cross-stream velocity Y and almost does not influence the vertical velocity Z. However, both Y and Z velocities are low in comparison to X, so the relative decrease in velocity would not be as evident.

II. Temperature (Fig. 3)

Temperature Mean (°C)	Surface	Mid-Depth	Bed
Probe 1 (Kaskaskia)	12.67	12.23	12.18
Probe 2 (Copper)	13.96	13.50	12.83
Difference	-1.29	-1.27	-0.65

- Kaskaskia River is colder and Copper Slough is warmer by comparison.
- Probe 2 is closer to the mixing interface as moving from the surface to bed.
- For both flows, the deeper the location, the lower the temperature is, and the more complete the mixing is.

III. Turbidity (Fig. 4)

Turbidity Mean (NUT)	Surface	Mid-Depth	Bed
Probe 1 (Kaskaskia)	3.65	3.46	5.05
Probe 2 (Copper)	3.57	3.64	3.36
Difference	0.08	-0.18	1.69

- Kaskaskia River is more muddy (i.e., contains more suspended sediments) and Copper Slough contains fewer suspended sediments.
- At the bed, Probe 1 has obviously greater turbidity. More data is required to more completely assess the reason. The influence of vegetation on the bed may have interfered with the turbidity probe, blocking more light and artificially increasing the turbidity.

REFERENCE

- **Rhoads, B.L. and Lewis, Q.W.** *accepted*. The Relation between Mean Flow, Turbulence, and Mixing at a Small Stream Confluence, 8th International Conference on Fluvial Hydraulics (River Flow). Taylor & Francis Group, 2016.