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# Sediment Transport in Skewed Kinoshita Meandering Channels: Implications for Contaminated Sediments

*David Nguyen, Andrew Binns, Bahram Gharabaghi*
*University of Guelph*

## Summary

Sediment transport is an important mechanism for contaminant migration in alluvial rivers. As a result, a better understanding of the spatial and temporal characteristics of sediment movement in these channels can yield useful information for predicting contaminant movement, assessing risks, and for the design of better remedial or containment solutions. Thus far, few sediment transport studies have investigated skewed river channels, also known as Kinoshita channels. The addition of a skewness factor to the planform shape of a river channel can impact flow conditions and change the sediment transport patterns within the channel. Previous research has also suggested that the skewness of the channel may contribute an additional flow resistance component [1]. This research aims to expand the understanding of how skewness affects sediment transport, flow conditions, and morphological characteristics in alluvial rivers and streams, especially in comparison to more well-studied channel geometries. The study also aims to investigate the possible additional flow resistance component and quantify its contribution to the overall flow resistance in the channel. Knowledge gained from this study will have useful implications for studying sediment transport patterns, particle tracking, and migration of contaminant-sorbed sediments in alluvial rivers having skewed meander bend orientations.

## Theory

The planform meandering shape of a river channel can be described with a sine-generated curve using the maximum deflection angle ($\theta_0$) to account for different meandering intensities. A larger $\theta_0$ would create an increasingly sinuous channel. This curve was later modified into Eq. (1) shown below to include additional parameters which introduce the skewness observed in Kinoshita meandering channels [2].

$$\theta(s) = \theta_0 \sin(ks) + {\theta_0}^3\left[J_s \cos(3ks) - J_f \sin(3ks)\right] \qquad \text{Eq. (1)}$$

In Eq. (1) (the Kinoshita equation), $\theta(s)$ is the deflection angle at any given stream-wise distance coordinate $s$, $k$ is the wave number associated with the channel wavelength, $J_s$ is the skewness coefficient, and $J_f$ is the flatness coefficient. The original sine-generated curve can be obtained by setting $J_s$ and $J_f$ equal to zero, removing the skewness component from the equation. The skewness added in this equation also disappears with smaller values of $\theta_0$, becoming less skewed with less meandering.

In this study, the skewness coefficient of the Kinoshita equation was varied while holding all other parameters of channel geometry, sediment composition, and flow rate constant. This was done to investigate the effect of changing the skewness intensity and direction on flow conditions, sediment transport characteristics, and erosion-deposition patterns.

To investigate the existence of a flow resistance component attributable to skewness, this work builds on previous research by da Silva and Binns [3]. In that study, the Chézy equation was used to evaluate the contribution of meandering to the flow resistance. The Chézy coefficient that describes flow resistance can be broken down into components of friction, bedform effects, and meandering effects. The first two components can be calculated from measured data, leaving the remaining unaccounted resistance to be attributed to meandering effects. In that study, a relationship was found between the relative contribution of meandering flow resistance and $\theta_0$. Since $\theta_0$ is constant in all experiments of the current study, it is hypothesized that any difference in flow resistance caused by the direction and intensity of skewness will be observable as a trend of deviations from the aforementioned relationship.

## Methodology

The experimental channels in this study were physically modelled in a 5.56m long, 1.96m wide laboratory flume pictured in Figure 1. The sediment used was a cohesionless sand with a $D_{50}$ of 0.83mm. The channel cross-section was the same for all channels with 5cm total depth, 27.5cm width at the top, and 13.2cm width at the bed. The sloping bank was designed at the measured friction angle of 35°. This initial trapezoidal cross-section was intended to reduce bank collapse at the beginning of an experiment which is prevalent when an initial rectangular cross-section is used. The channel slope was 0.79% with an approximate flow width of 20cm when subject to a flow rate of 0.5 LPS and the maximum deflection angle was 100° for all experiments. Each experiment was divided into a series of time steps in order to monitor the temporal channel evolution, with a total runtime of two hours. A period of increased discharge conditions (e.g., flood stage) of 0.9 LPS was introduced after this period for several more time steps, adding another hour of total runtime. No sediment was fed to the flume during the experiments. Periodic measurements of flow depth were made at each inflection point and apex during each time step, and a dry channel digital elevation model (DEM) was developed using photogrammetry between each time step. Transported sediment was also collected at the outlet of the flume and analyzed for grain size distribution. The tested skewness coefficients were ±1.5/32 and ±0.5/32 to complement existing data for skewness coefficients of ±1/32 and 0/32.

**Figure 1:** Initial Flume Setup for +1.5/32 Skewness Test (Flow Moves Right to Left)

## Results and Conclusions

The results of this study can be used to identify relationships between skewness and characteristics of flow, sediment transport, erosion-deposition patterns, and flow resistance. Moving forward, the findings may have useful implications for studying contaminated sediments in Kinoshita channels.

### References

[1] R. Good, "Effects of Skewness on the Morphological Response of Unconfined Alluvial Meandering Streams in a Laboratory Flume," MASc thesis, University of Guelph, Guelph, 2018.
[2] G. Parker, P. Diplas and J. Akiyama, "Meander Bends of High Amplitude," Journal of Hydraulic Engineering, vol. 109, no. 10, pp. 1323-1337, 1983.
[3] A. M. F. da Silva and A. D. Binns, "On the Resistance to Flow of Alluvial Meandering Streams," in Proceedings of 33rd Congress of IAHR, Vancouver, Canada, 2009.