Patterns of Bed Morphology at a Chute Cutoff Obstructed by Large Woody Debris

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INTRODUCTION

Meander bend chute cutoffs develop when erosion across a point bar or floodplain forms a new channel. The main flow of the river is subsequently redirected through the cutoff channel, abandoning the original meander channel before eventually infilling (Hooke, 1995; Zinger et al., 2013). Interpretation of repeat aerial photographs of a chute cutoff on the Embarras River in east central Illinois reveal the presence of a cutoff channel over a period of decades that has yet to capture the main flow. An accumulation of large woody debris (LWD) extends from the downstream corner at the entrance of the chute cutoff across a portion of the cutoff channel. The purpose of this field study is to investigate flow structure and bed morphology at the meander bend and chute cutoff and to begin to document the impact of the LWD on the development of the cutoff channel.

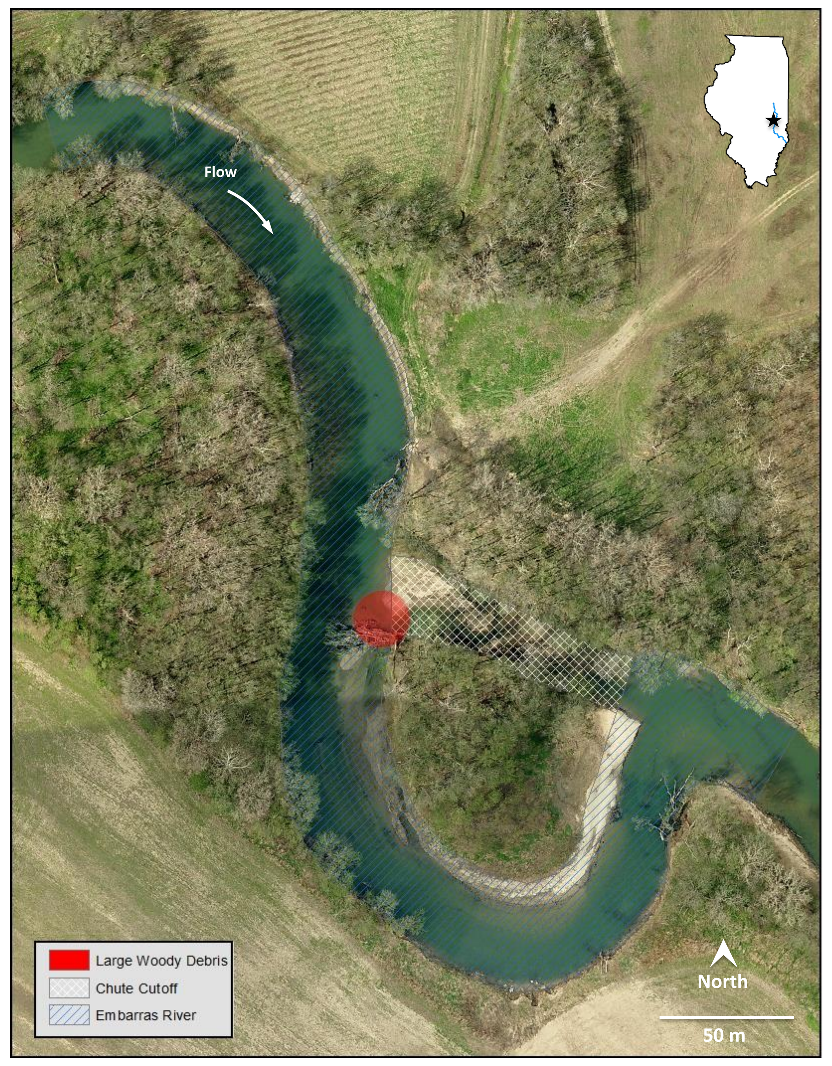

Figure 1. Aerial photo of the study site taken in spring 2007. An accumulation of large woody debris has since collected at the head of the small island between the cutoff and main channels. Star on inset map shows the location of this bend and chute cutoff on the Embarras River in east central Illinois.

FIELD SITE

The field site is a 0.65 km reach of the Embarras River, a tributary of the Wabash River, consisting of a compound meander loop and a chute cutoff (Figure 1). At the site, the low-gradient naturally meandering river drains 2,308 km^2 of mostly till plains. Many of the upstream tributaries and portions the main channel itself have been straightened and channelized for the purpose of agricultural drainage (Urban, 2002). LWD has accumulated at the downstream corner of the entrance of the cutoff channel and partially obstructs it (Figure 2). Woody debris usually enters the river as a result of bank failures caused by lateral erosion along the forested river corridor. Water flows through both channels, although most of the flow continues through the meander bend.

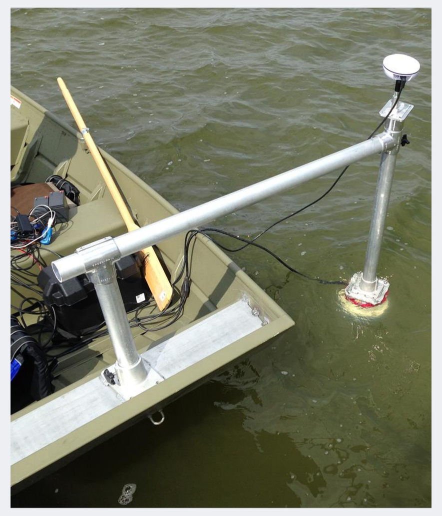

Figure 2 (left). Photograph of a portion of the LWD accumulation taken downstream on the main channel during summer 2014. Note the person for scale.
Figure 3 (right). Data collection equipment mounted to the jon boat, including ADCP and differential GPS antenna.

METHODS

3D velocity components and depth data were collected on March 19, 2015 with a 1200 kHz Workhorse Rio Grande acoustic Doppler current profiler (ADCP) affixed to a mount on a small jon boat (Figure 3). The Doppler shift between acoustic pulses transmitted by the ADCP and backscatter from suspended particles and the channel bed was used to resolve velocity components and water depth. A Hemisphere A100 differential global positioning system (GPS) captured boat position and velocity. The Velocity Mapping Toolbox (Parsons et al., 2013) was used to post-process ADCP data. Depth measurements were collected longitudinally and converted to elevations based on water stage data. ESRI ArcGIS was used to spatially interpolate via kriging the elevation data to produce a topographic map of the bed morphology. Historical aerial photographs of the study site were also obtained and georeferenced to evaluate channel change over time (Figure 4).

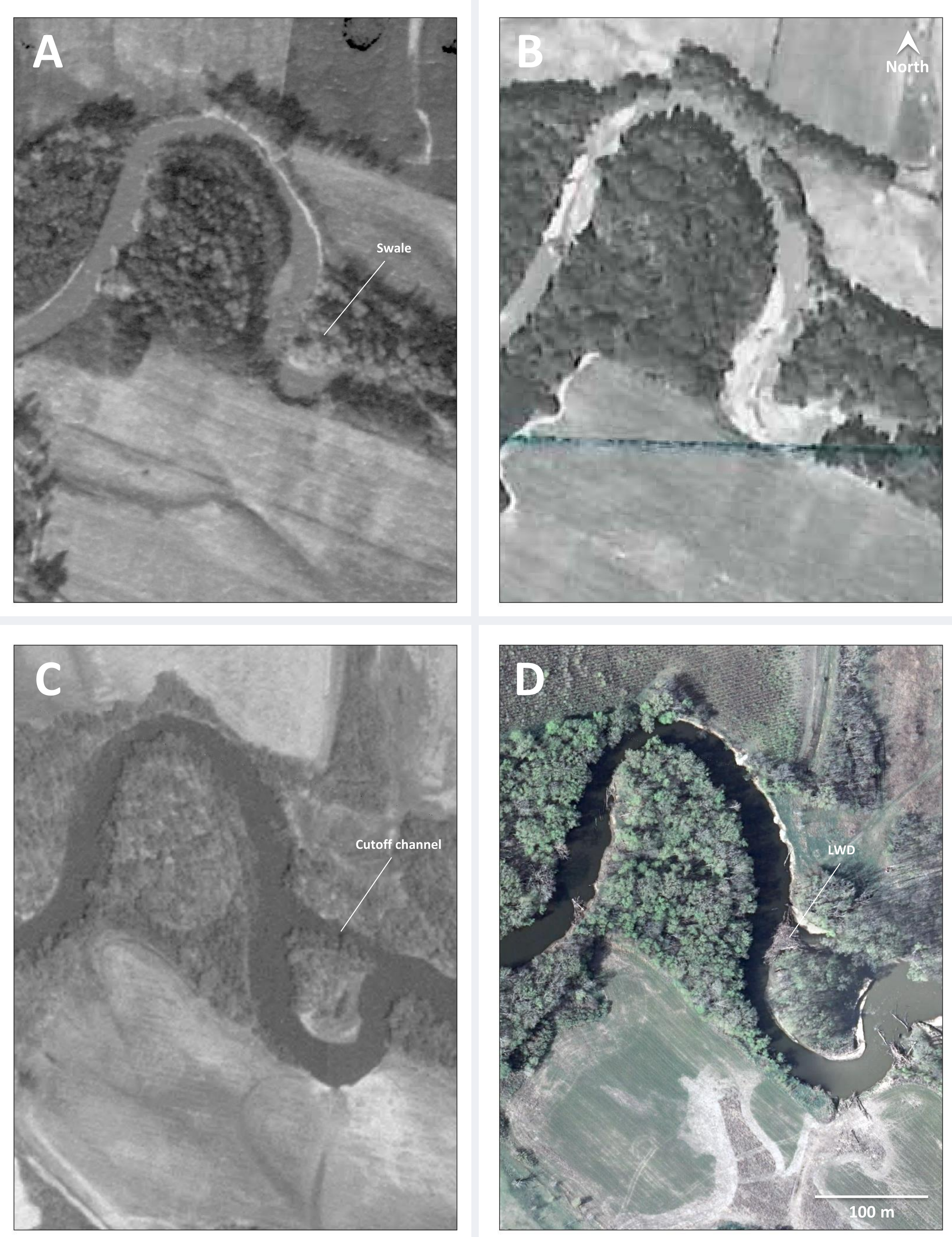

Figure 4. Aerial photographs of the study site: (A) 1938, (B) 1953, (C) 1998, and (D) 2011.

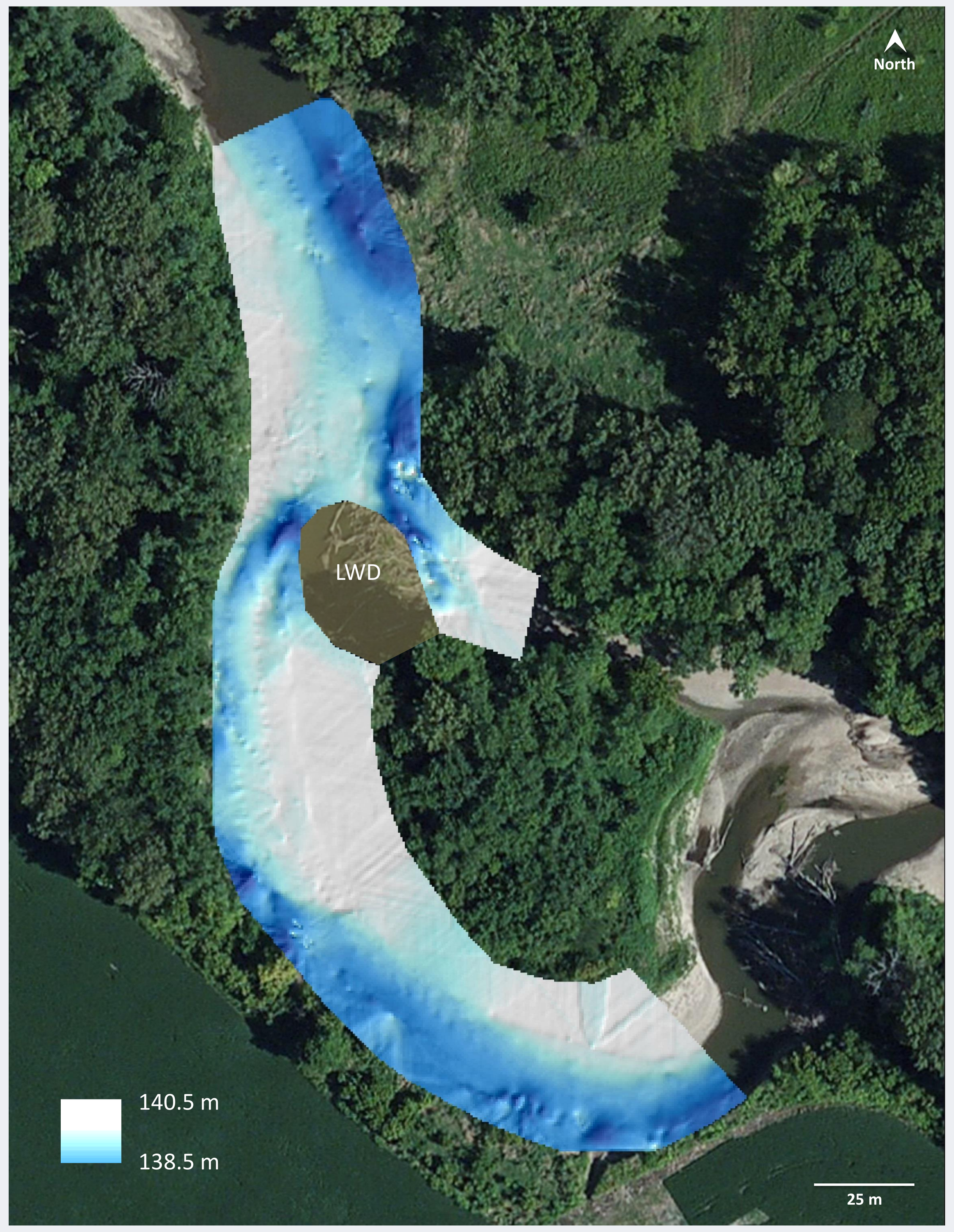

Figure 5. Bed topography of portions of the meander loop and chute cutoff, March 19, 2015. Elevation above sea level in meters.

RESULTS

The earliest aerial photos (1938, 1953) of the bend do not clearly indicate the presence of a cutoff channel, although a linear feature cutting across the point bar may depict a swale that eventually deepened to form the chute channel. Most aerial photos of the site from the 1950s–1970s have poor resolution and are not included here, but a distinct cutoff channel is present in 1966. LWD appears in numerous aerial photos and the current accumulation has been present since 2007. LWD has been shown to influence the initiation of chute cutoffs in low-gradient meandering streams (Keller and Swanson, 1979), however at this location, it seems that the LWD may increase flow resistance. When combined with the high angle that flow must turn to enter the chute, these factors may be acting to plug the cutoff. The river continues to flow through the bend of the main channel and the meander loop exhibits progressive elongation, extending toward the southeast over time.

Figure 6 (left). Bank failure at the upstream corner of the entrance to the chute cutoff.
Figure 7 (right). Bank erosion along the cut bank at the downstream end of the main channel.

The bed morphology of the meander loop conforms with patterns typically found in bends (Figure 5). The entrance to the chute cutoff is located near the inflection point between bends. The pool positioned against the outer bank of the main channel in the upstream bend extends toward a region of bed scour at the upper end of the cutoff channel. Flow entering this channel is confined to a narrow zone between the LWD and the north bank of the channel resulting in scouring of the bed and bank erosion (Figure 6). The cutoff channel rapidly shallows downstream from the LWD, where coarse gravel and even cobbles are deposited on the bed.

A pronounced scour hole is also found in the main channel adjacent to the LWD. Flow likely accelerates as it is pinned between the LWD and the west bank. The LWD protects a broad point bar immediately downstream that extends across most of the channel cross section. Farther downstream, a wide pool underlies an actively eroding cut bank where the bend has elongated (Figure 7).

Future work will investigate patterns of flow through the main and cutoff channels and evaluate change in the LWD and bed morphology in relation to different hydrologic events.

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Acknowledgments

Thanks to Sanjiv Vajjala for assistance in the field and to Frank Engel of the United States Geological Survey Illinois Water Science Center for technical support. Dan Parsons, Ryan Jackson, and Frank Engel contributed core algorithms for the development of VMT. This research was supported by the Eastern Illinois University Foundation, College of Sciences, and the Department of Geology/Geography.