

Field Observation and Numerical Modeling of Bed-Material Transport Dynamics in the Lower Mississippi River

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Understanding specific pathways for sand transport through the lower reaches of large rivers like the Mississippi is a key to addressing (1) significant source-to-sink geologic problems for sediment and particulate organic carbon and (2) environmental restoration efforts in deltas under threat from climate change. Five field studies were performed in the Mississippi River 75-100 km upstream of the Gulf of Mexico outlet in 2010 and 2011 at discharges ranging from 18,500 to 32,000 m³ s⁻¹ to examine sand transport phenomena in the river channel. These studies utilized multibeam sonar bathymetric surveys, acoustic Doppler current profiler measurements of current velocity and acoustic backscatter, point-integrated isokinetic suspended sediment sampling, and channel-bed grab sampling to examine fluid flow and suspended/bedload sediment transport. Substantial interaction was observed between flow conditions in the river (boundary shear stress, turbulence intensity), channel-bed morphology (size and extent of sandy bedforms), and bed-material sand transport (quantity, transport mode, and spatial distribution). A lateral shift was observed in the region of maximum dune size and water column turbulence intensity from deep to shallow areas of lateral sand bars as water discharge increased, and is associated with the expansion of the bar top area experiencing critical shear stress conditions. Bed material was transported both in traction and in suspension at these water discharges, with the highest suspended mass flux rates associated with the part of the channel cross-section where the largest dunes were present, as a result of a relationship between bed shear stress, dune size, and turbulence intensity. We posit that the downriver flux of sand grains alternates between these two modes over relatively short spatial (up to a few km) and temporal scales. These results complicate the task of using cross-sectional flux measurements taken in lower reaches of large river channels to infer bed-material discharge to the ocean because the transport trajectories and velocities of individual grains can vary appreciably. This suggests that 3D numerical simulations, calibrated and validated by comprehensive field measurements, will provide the path forward in understanding bed material fluxes in these systems. These model simulations, utilizing Delft3D and Flow3D and these observational data, are under development to investigate the relationship between flow conditions and sediment transport at finer spatial scales.

Keywords: Mississippi River, fluvial geomorphology, river channels, sediment transport