

Geologic Influence on 2008 Midwest Levee Failures

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NSF CMMI-GTE Grant 0842801

Levee Investigation Overview

The potential for catastrophic failure of the levees, and subsequent flooding, in the Mississippi River Valley had long been foreseen by technical experts. The Midwest is not the only region in the United States in which this type of catastrophic hazard exists, but goes largely unaddressed.

There are lessons of potentially vital importance to be learned from the performance of the levee systems. It is vitally important to absorb these lessons from the engineers and personnel who observed the levee breaching and performed/oversaw the repairs, and that these lessons be effectively transmitted to levee repair experts, emergency planners, and risk assessment experts in other regions. Lessons that can improve speed and efficiency are invaluable in large (catastrophic) emergencies.

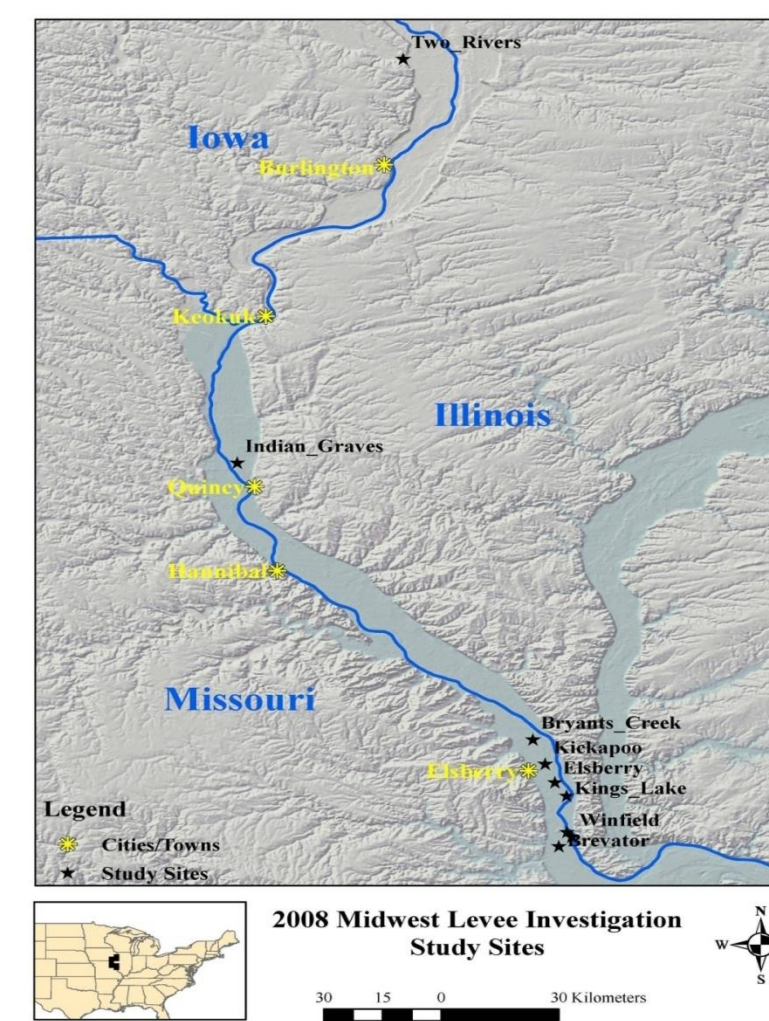
Levee Investigation Data Collection

This effort to collect sensitive and time-dependent perishable data will comprehensively characterize select levee breach locations to provide essential levee characterization and performance data for use in subsequent numerical analyses (supplemental studies per authorization). The levee characterization consisted of:



Collection and documentation of the characterization categories above are critical elements required to advance the state of the knowledge on earthen levee performance and reliability.

Sites Selected for Further Study



The Pillsbury Road Levee failure in the Cap au Gris District east of Winfield being overtopped on June 18, 2008. The crown of the levee was below design grade here because of the encroachment of the homes, which prevented the district from maintaining the design crest elevation.



Hesco Bastions employed as "Port-a-dams" with sand bags as interactive flood management.



Erosion tests of samples recovered from the Brevator Levees revealed they have a slightly higher clay content than levees closer to the Mississippi River, which did not survive overtopping.

Levee Investigation Overview

A total of eight sites were investigated following the floods of 2008 in the Midwest. These sites (Two Rivers, Indian Graves, Bryants Creek, Kickapoo, Elsberry, Kings Lake, Winfield, and Brevator) reflected a wide range of levee loadings (flood stage) and performance (no breaching to breaching). The two extreme cases encountered are presented below.

No Breaching - Brevator

The Brevator Levee System was continuously overtopped by 0.5 to 1 meter of water for several weeks and experienced no detrimental erosion or breaching. This levee system was designed for a 14-year return period flood event and protects an area of over 740 hectares. The utilization of high cohesion clays and presence of grass turf greatly influenced the robustness and resiliency of this levee system.



Aerial imagery wrapped on the LiDAR and DEM surface, showing development of the Mississippi River flood plain at mouth of the Cuivre River, in the Brevator Levee District. These levees survived 3 weeks of overtopping.



Resilient, overtopping resistant clay levee

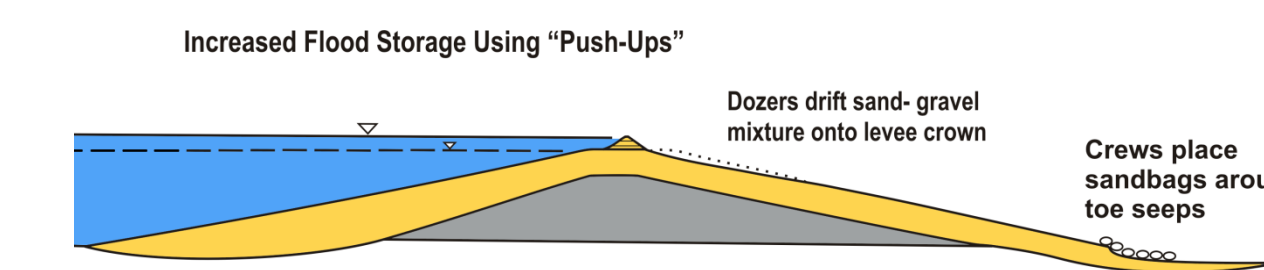
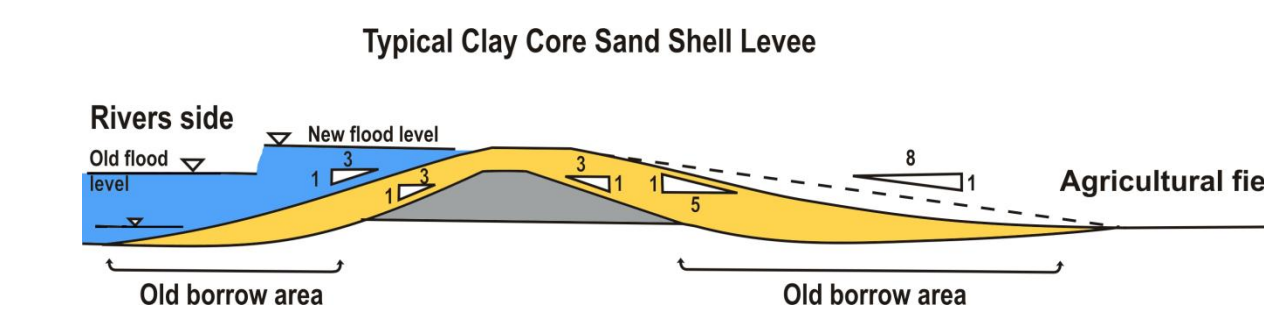
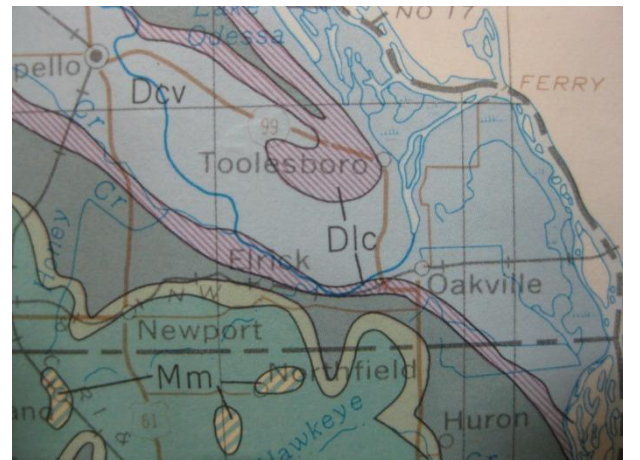
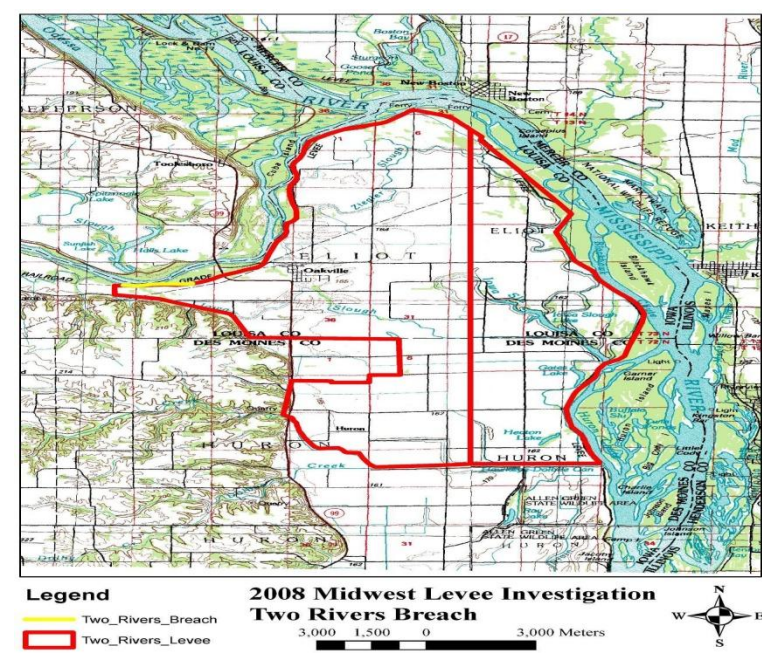


The Brevator District levees near Winfield survived 14 days of near-continuous overtopping, without failing

Significant Breaching – Two Rivers

The Two Rivers Levee system was designed for a 100-year flood event and protects over 7,100 hectares. It was reported that the flood stage (prior to catastrophic breaching) was 2 to 3 meters above the 500-year flood stage. The sand levee breach zone was over 1,450 meters long. The sand levees constructed along the Iowa River were completely washed away within the breach area. Significant scour holes were observed along the entire breach extents.

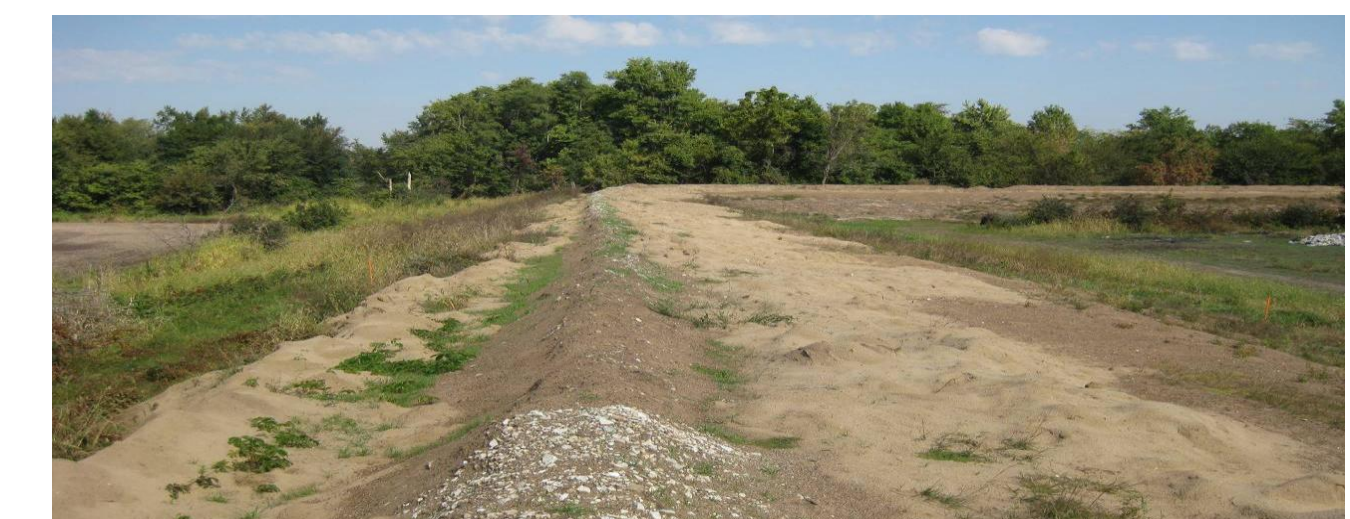
The levee foundation was a thin veneer of alluvial sands and gravels over lying on dark olive-gray shale of the Sheffield Formation, within the Devonian age Yellow Springs Group (Dys), close to its basal contact, with the gray shales of the Lime Creek Formation (Dlc), also of Devonian age. This created an unusual foundation condition in the upper Mississippi Valley, because of the enormous permeability contrast between the channel fill and the shallow bedrock.



Interactive flood fighting measures at the Two Rivers site included a 'push-up' technique where levee materials on the protected side are 'pushed up' to the crest of the levee in order to increase the crest elevation. Unfortunately, the interactive flood fighting measures were insufficient to prevent the catastrophic failure and resulting flooding of this area.



Catastrophic breaching of sand levees.



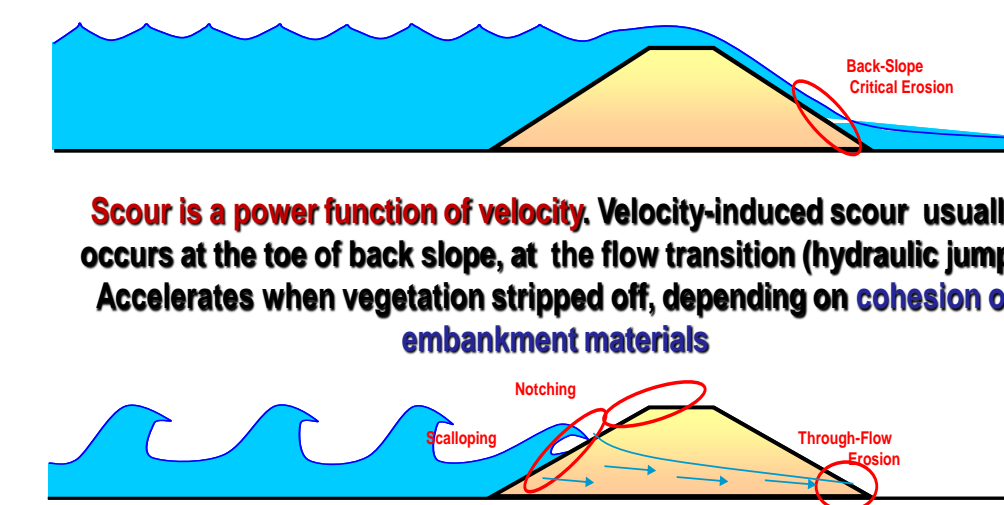
Remnant push-up features after interactive flood-fighting efforts.



Aerial oblique view of the inundated upper Mississippi River flood plain in late June 2008. Note turbidity of the main channel at lower left, as compared to the stagnant flood water.

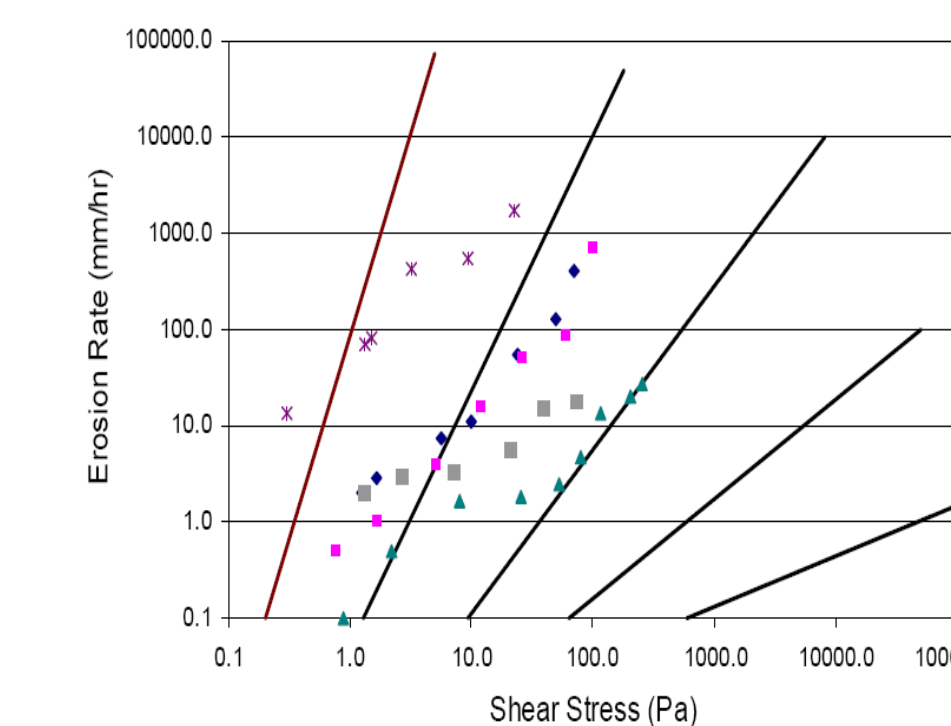


Two kinds of overtopping-induced damage

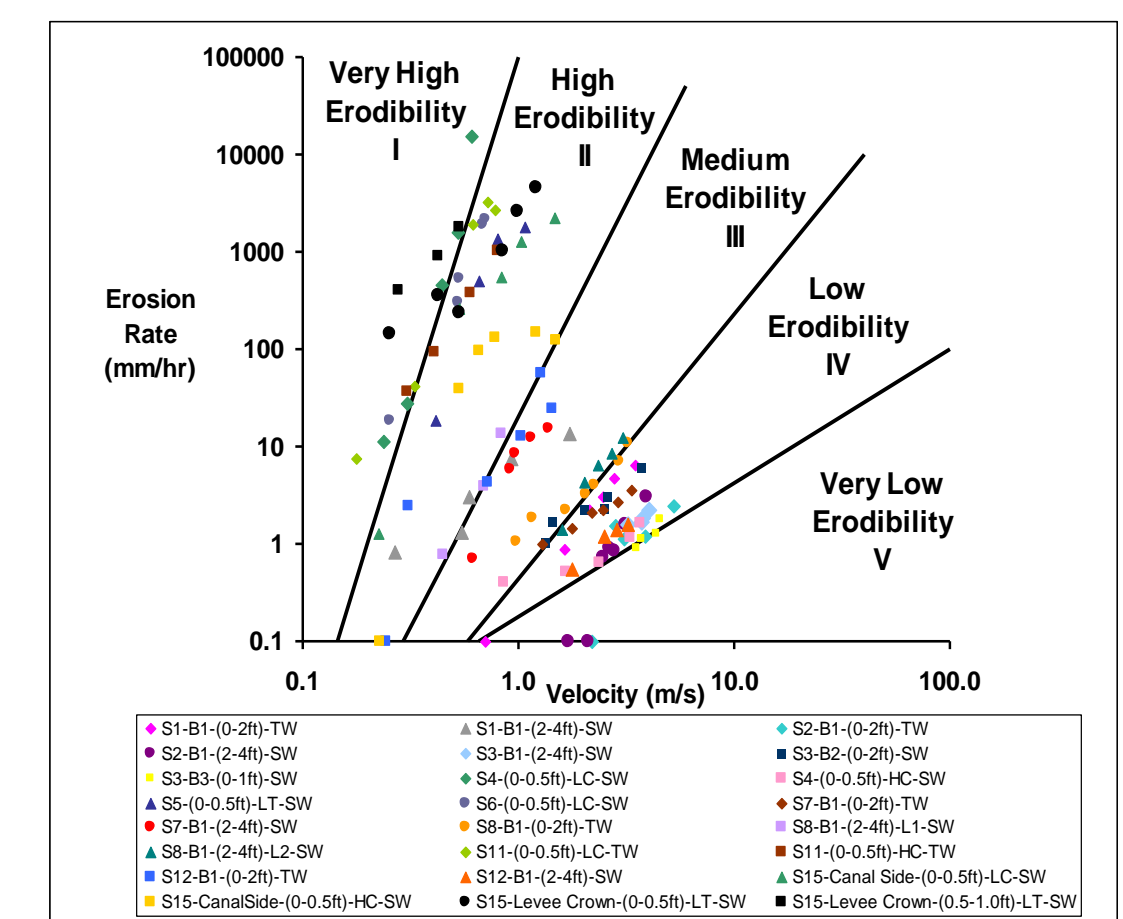


Scalloping and notching on the fetch side of the levee, due to wave pounding; and piping fomented by emergent seepage at the toe of the back slope
Note: damage at back slope toe looks similar for both modes

Erosion Rate vs. Shear Stress



Soil erodability data for Midwestern Levees sampled just after the 2008 floods. Small percentages of clay have a profound impact on levee resilience. Data from Michelle Bernhardt at Texas A&M, on our NSF investigative team.



Soil erodability potential gleaned from laboratory tests by Prof. Jean-Louis Briaud at Texas A&M University. This plot shows data from the Mississippi Delta collected after Hurricane Katrina.