2019 Flood Impacts on the Missouri River near Kansas City

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Abstract

The Missouri River near Kansas City has experienced dramatic degradation over the past 30 years, which has led to over 100 million dollars in damages. In 2019, the Missouri River experienced a large flood, followed by two years of relatively low flows. This poster presents the analysis of cross sections before, during, and after the 2019 flood.

Introduction

The Missouri River has experienced three major floods in the past 40 years, including the 1993, 2011, and 2019 events. The floods of 1993 and 2011 deposited large volumes of sand on the floodplain and resulted in significant bed degradation (Gibson and Shelley, 2020).

The 2019 flood (most comparable to the 1993 event) was primarily caused by temperature changes and heavy precipitation (Meyer and Larson, 2021). Frozen ground with snowpack covered the Midwest when temperatures rose abruptly, causing high runoff due to melting. Along with the rapid increase in temperature, heavy rains fell in March of 2019. The 2019 cross section survey was collected from June 29, 2019 to September 19, 2019 (Figure 1). The survey was collected after the highest flood flows, which occurred in mid-March and early June. Cross sections were collected at approximately 500 ft intervals.

The bed of the lower 500 miles of the Missouri River degraded during the flood of 2011, then partially recovered in subsequent years (Gibson and Shelley, 2020). Measurements taken during the 2019 flood indicate degradation compared to before the flood (USACE, 2020). Measurements taken after the flood, during the summer of 2021, indicate continued degradation (USACE, 2021).

Bed degradation in the Kansas City Segment of the Missouri River (River Mile 351 to 396) has been of special concern due to high degradation rates and degradation-related infrastructure damage (USACE, 2017, USACE, 2021). This segment of the river has been continuously mined for sand and gravel for decades. Between 1994-2014, 61 million tons have been removed between St. Joseph and Waverly, MO (USACE, 2017).

From September to October of 2022, the Kansas City Segment of the Missouri River was re-surveyed with cross sections spaced every 500 ft, 480 cross sections in total. This extended abstract compares those cross sections to previous cross sections.

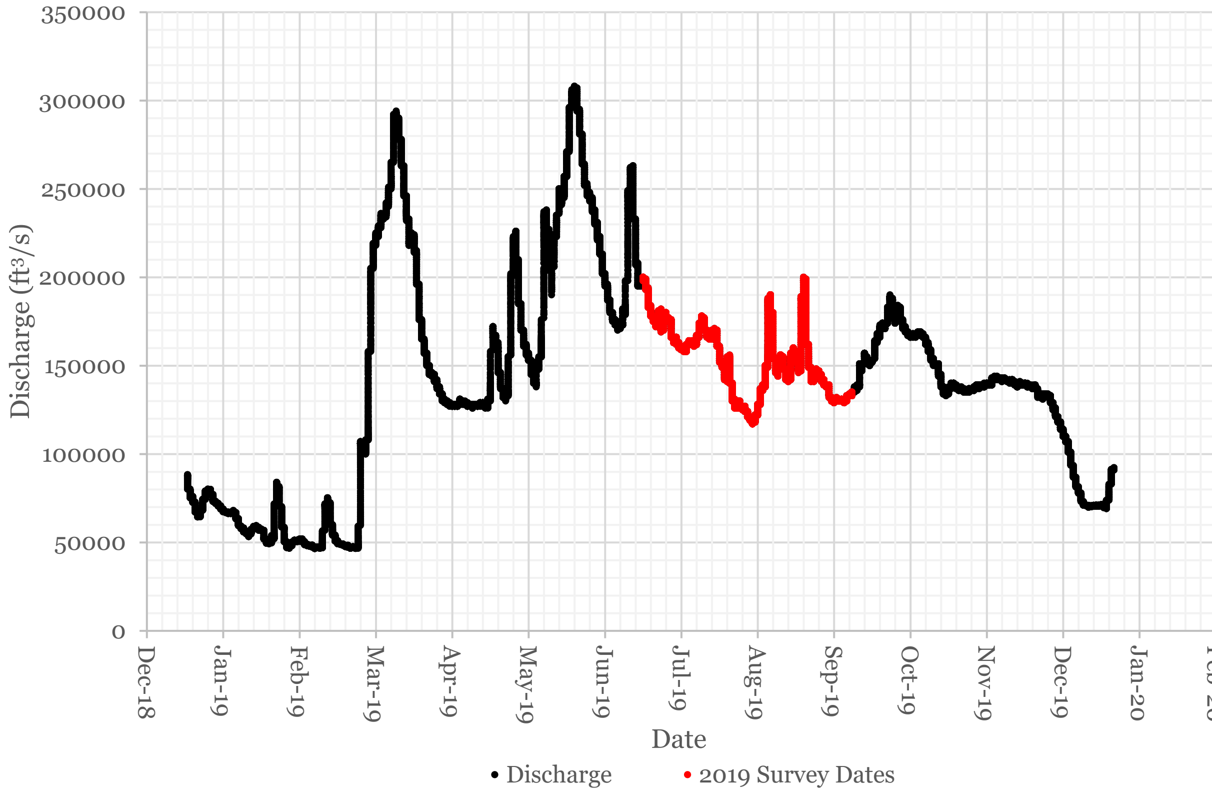

Figure 1. 2019 Survey Dates compared to daily discharge rates at the Kansas City USGS Gage.

Methods

This study used the Cross-Section Viewer tool (Shelley and Bailey, 2018) to compare the bed over time before, during, and after the 2019 flood in the Kansas City Reach. Cross sections from 2014 (pre-flood), 2019 (during flood), 2021 (post-flood), and 2022 (post-flood) were compared in the Kansas City Segment (RM 351 to 396). Three analyses were performed:

(1) A volumetric change analysis was performed using the longitudinal cumulative volume change tool in the Cross Section Viewer. This tool was used to compute the volume change from 2014 to 2019, 2014 to 2021, and 2014 to 2022 in Kansas City. Volume change is computed using an average end-area method, as explained in Shelley and Bailey (2018). This takes all compared cross sections and spatially integrates bed elevation changes. This method dampens the noise inherent in individual cross sections when applied to sufficiently long distances.

(2) A bed elevation change analysis was performed using the longitudinal cumulative volume change tool in the Cross Section Viewer. The area change was divided by the top width to yield an average bed elevation change. The extents of the 2014 survey were generally smaller than the 2019 survey; to account for this, only the common extent of both surveys was used so as to maintain a consistent top width.

(3)	A cross section shape analysis was performed using visual inspection of individual cross sections plotted in the Cross Section Viewer. The comparison of a cross section from two different surveys were divided into nine separate categories. This was performed first comparing the 2014 and 2019 surveys and then comparing the 2019 and 2022 surveys.

Results

Longitudinal Volume Change Analysis

The Longitudinal Cumulative Volume Change Curves for the 2014-2019, 2014-2021, and 2014-2022 can be found in Figure *2*. The results from the change analysis can be seen in Table 1 and Figure *3*. The volumetric change analysis showed the change from the five-year period of 2014-2019 to be only 33% of the total degradation in the seven-year period from 2014-2022. This leads the two-year period from 2019-2021 to account for 37% of the total degradation and the one-year period from 2021-2022 to account for 30%. This shows that increased degradation occurred during and right after the 2019 flood period. Overall, post-flood recovery has not occurred as of 2022.

The collection of the 2019 cross-sections occurred between June and September of 2019. As shown in Figure 1, this was after the largest flows of the event and after three months of sustained high water. It is therefore interesting that the vast majority of the degradation occurred after the highest flows of the event. One theory to explain this phenomenon is the hysteresis in the flow-sediment load measurements observed throughout the flood, which indicate that the sediment load drastically decreased at similar flows as the flood continued. This could have been due to bed armoring upstream. This could have also been due to the floodplain deposition, causing a sediment deficit that was realized once the flow receded back to within the banks.

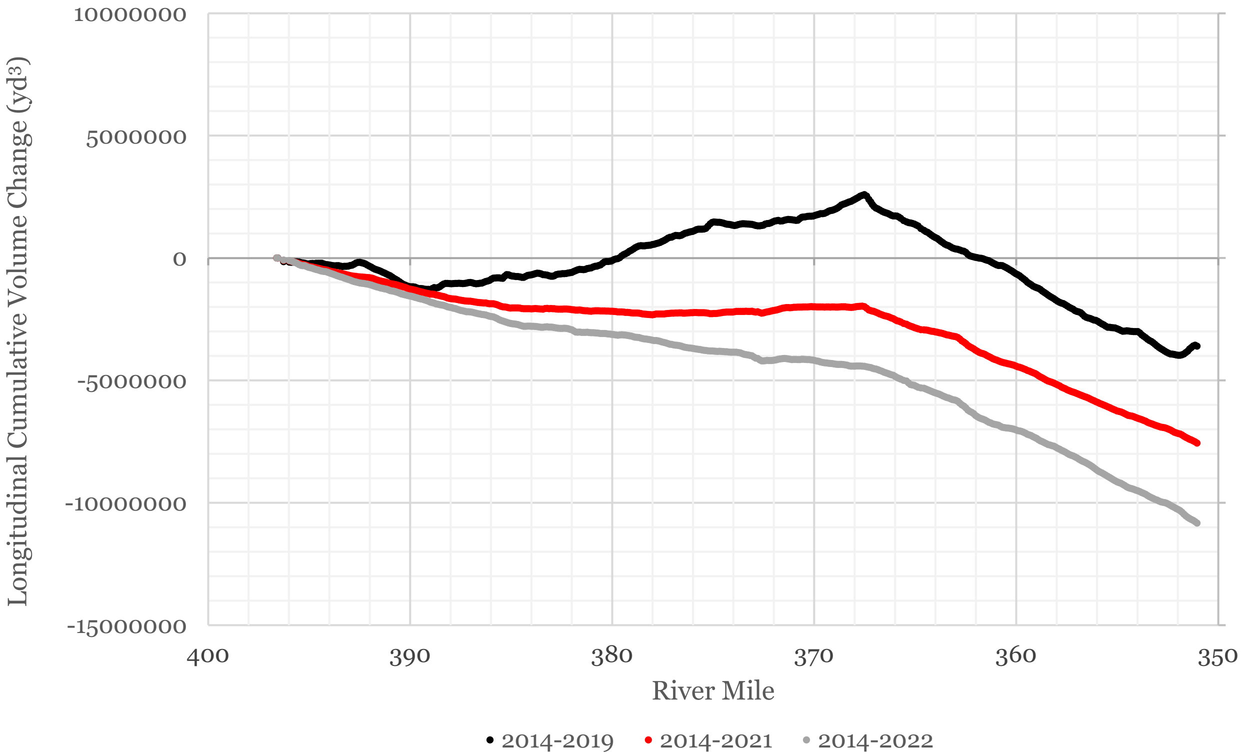

Figure 2. Longitudinal Cumulative Volume Change (yd^3) per river mile in the Kansas City Reach.

Table 1. Volume Change and Bed Elevation Change for the three time periods.

Time Period	Number of years	Cumulative Volume Change (yd^3)
2014-2019	5	-3,602,757
2014-2021	7	-7,563,831
2014-2022	8	-10,834,213

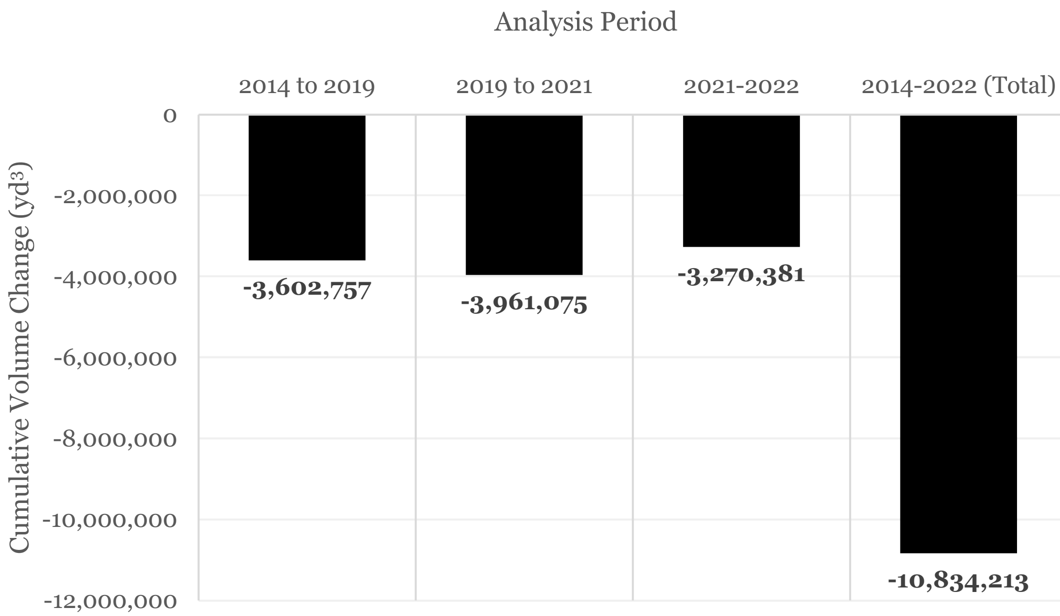

Figure 3. Incremental Volume Change Along Missouri River in the Kansas City Reach, computed from results displayed in Table 1.

Bed Change Analysis

The bed change analysis using the longitudinal cumulative volume change tool shows an average bed change in the Kansas City reach of -0.4 ft from 2014-2019, -1.1 ft from 2014-2021, and -1.6 ft from 2014-2022. A 5-mile rolling average was plotted in Figure 4 with the black line representing 2014 to 2019, the red line as 2014 to 2021, and the grey line as 2014 to 2022. Averages for five-mile reaches are plotted in Figure 5 showing an overall degradation rate, with every grey bar (2014-2022) showing a negative bed elevation change.

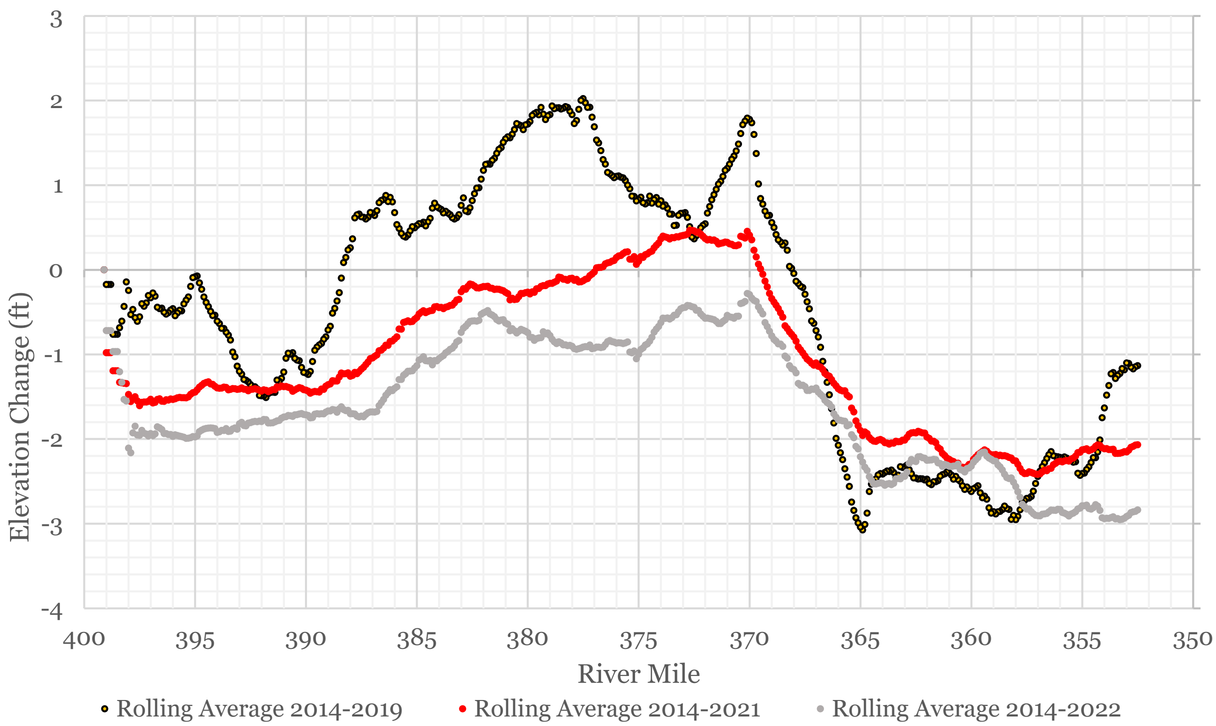

Figure 4. Rolling Average Bed Change throughout Kansas City Reach.

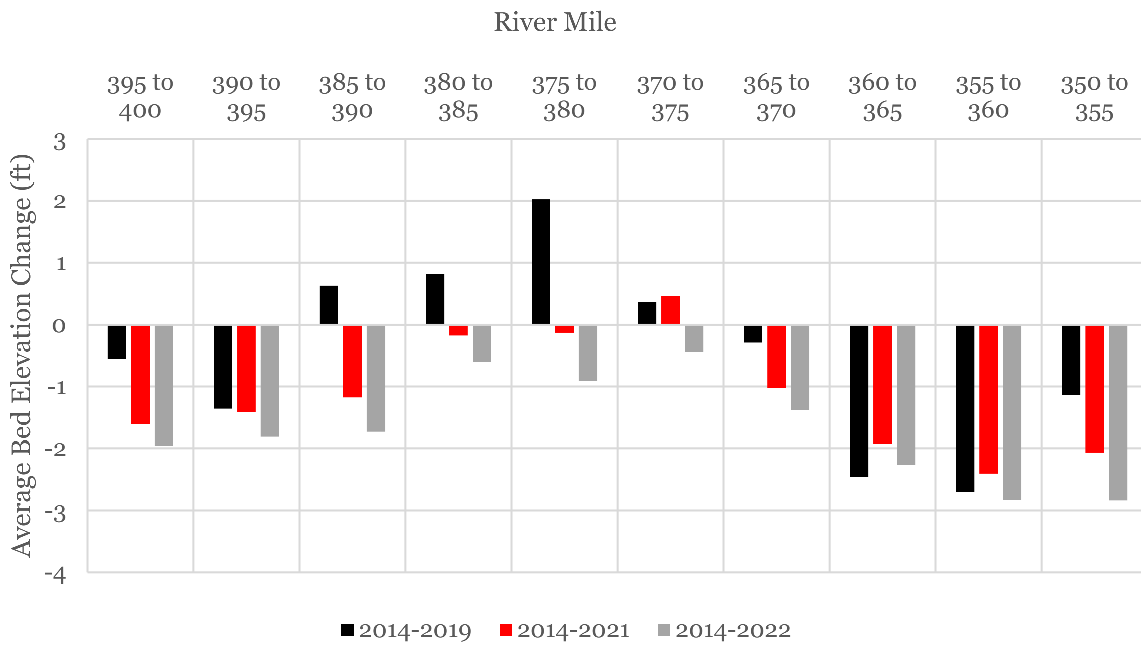

Figure 5. Change in Average Bed Elevation between 2009 and 2022 surveys over five-mile reaches.

Cross Section Comparison

Individual cross sections between the 2014, 2019, and 2022 surveys were categorized into the nine groups listed in Gibson and Shelley (2020) based on erosion, equilibrium, or deposition of the bar and erosion, equilibrium, or deposition of the thalweg. The thalweg is defined as the lowest elevation within the Rectified Channel Lines (generally used as the navigation channel) and the bar is defined as the highest elevation areas within the rectified channel lines. The trends of change within individual cross sections are discussed below.

The change in shape of Cross Sections: A total of 480 cross sections were examined visually and 341 were assigned to one of nine categories listed in Gibson and Shelley (2020). Only cross-sections with a clear thalweg-bar distinction were analyzed. The remaining cross sections were generally trapezoidal in shape and therefore did not contain the thalweg-bar geometry. This analysis was conducted for the relationship between the 2014 pre-flood and 2019 mid-flood survey and repeated for the 2019 mid-flood and 2022 post-flood survey. Results are shown in Figure 6.

From pre-flood to mid-flood, the most common tendency was for the complete erosion of the bed. The second most common tendency was for the thalweg to erode and for the bar to deposit. This tendency exaggerates the already defined, pre-flood shape. Conversely, the survey comparison from mid-flood to post-flood displayed that the most common tendency was for the thalweg to deposit and the bar to degrade. By doing this, the cross section shape is reverting itself or balancing out from the flood's disturbance.

Out of the 341 cross sections evaluated, 108 (approximately 32%) followed a rebound pattern. This included 10% that rebounded from complete erosion to complete deposition (or vice versa) and 22% that rebounded from mixed behavior to the opposite mixed behavior, i.e. erosion of thalweg and deposition on the bar to deposition of thalweg and erosion of bar (or vice versa). This also means that approximately 70% of the cross-sections did not rebound and are in some degree of instability. This confirms the initial findings from Figure 2, which indicated the river had not rebounded as in previous floods.

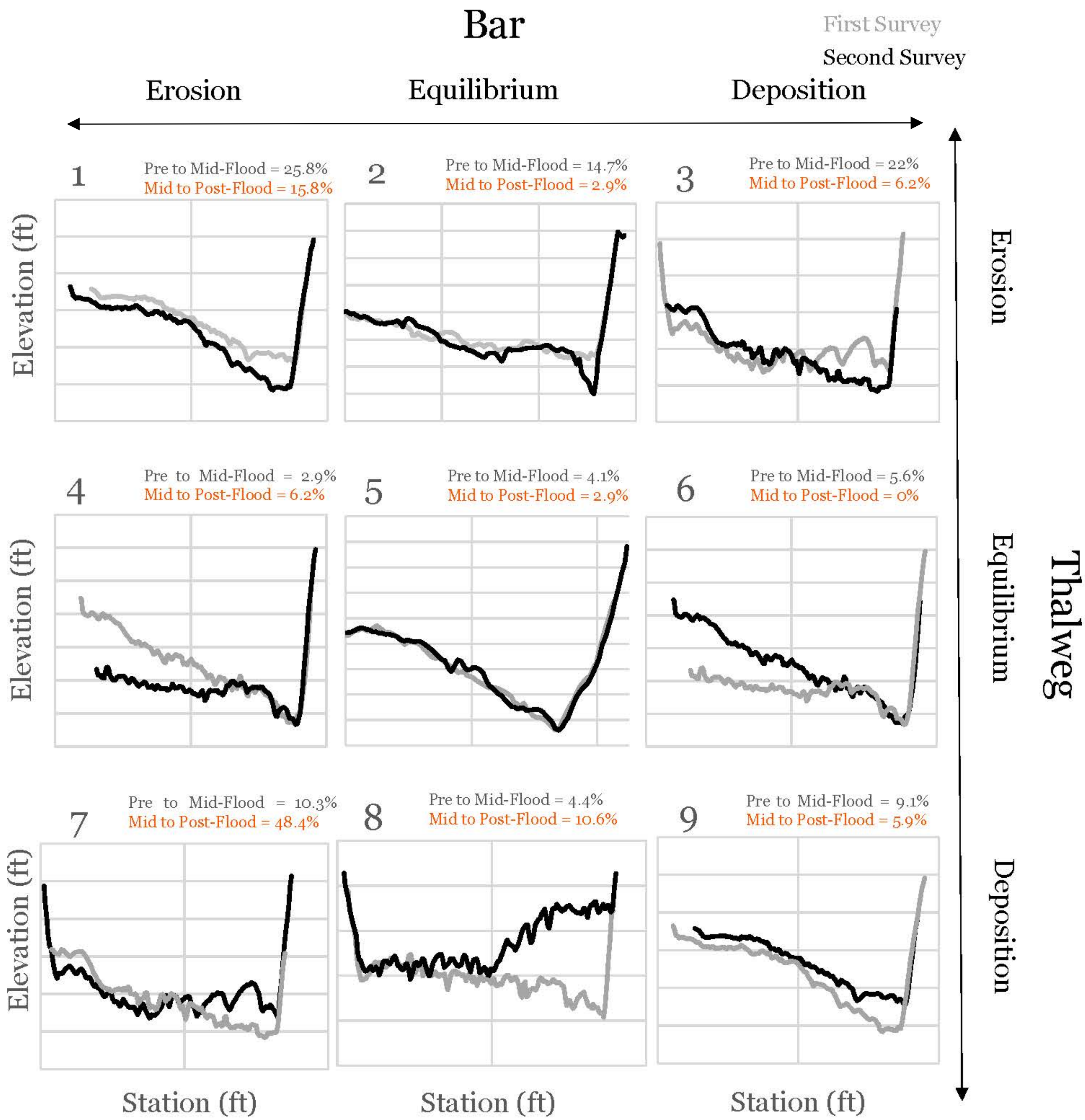

Figure 6. Visual Representation of Cross Section Analysis Results.

Conclusions

The 2019 flood had a significant impact on the Missouri River riverbed. Cross sections collected on the Missouri River near Kansas City showed a general degradation pattern from pre-flood to mid-flood and from mid-flood to post-flood. The highest annual rates of degradation occurred between the mid-flood and two years post-flood, but degradation continued from the second to the third year post-flood. Every 5-mile reach evaluated had lower average bed elevations in 2022 (three years post-flood) than in 2014 (five years pre-flood).

Cross sections changed shape during and after the flood. When comparing the change in the shape of the cross sections from the pre-flood to mid-flood and mid-flood to post-flood, only 3% of the total 341 cross sections were under the same categorization and 97% had different categorizations. This implies that the riverbed is constantly changing and rarely is a section going to follow the same pattern throughout a flood event.

As displayed in Figure 6, the first and second most common categorization for each comparison was the total erosion of the cross section. This shows that there is a clear trend in the riverbed for erosion over time.

References

Gibson, S., Shelley, J. 2020. Flood disturbance, recovery, and inter-flood incision on a large sand-bed river. Geomorphology. Vol 351.

Meyer, Juliann, and Larson, Lee. 2021. "Comparison of Two Major Floods, 1993 and 2019, on the Missouri River at Hermann, Missouri," Central Region Technical Attachment. Number 21-02.

Shelley, John, and Bailey, Philip. 2018. "The Cross Section Viewer: A Tool for Automating Geomorphic Analysis Using Cross Section Data," ERDC/TN RSM- 18-3. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

USACE, 2017. "Missouri River Bed Degradation Feasibility Study," Technical Report.

USACE, 2020. "Summary of Damages Related to Missouri River Bed Degradation in Kansas City," Technical Report.

USACE, 2021. "River Conditions as Evidenced by the 2020 Survey and An Initial Look at the Effects of the 2019 Flood: River Miles 498 to 0," Technical Report.