Mapping Hydrogeomorphic Settings And Change In The Upper Mississippi River System

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Background

- There is a substantial body of scientific research and monitoring in the Upper Mississippi River System (UMRS) concerning long and short-term changes in hydrogeomorphic patterns, processes, and rates of change. To provide a context for synthesizing that information across the system, in 2018-20 a team of multi-disciplinary scientists in the Upper Mississippi River Restoration (UMRR) program developed a preliminary hydrogeomorphic conceptual model and related classification framework.
- This new study will further describe and map the linkages between landforms and their sensitivity to change. The goal of this project is to map areas of the UMRS that are most prone to hydrogeomorphic change along a continuum of erosional to depositional settings and to give context to questions of why, how, and where geomorphic change is happening in the river.
- This system-wide framework will provide a context for targeting research and monitoring efforts as well as for informing the design of restoration projects.

Conceptual Model and Classification Framework

- The conceptual model identifies major processes of hydrogeomorphic change within the UMRS and the physical drivers and boundary conditions relevant to those processes across a range of spatial and temporal scales (Fig. 1).
- Rates of geomorphic change are affected by factors inside and outside of the main river valleys. Tributary and watershed factors include geologic history, agricultural land-use practices, tributary channelization, bank stabilization, and large-scale climatic shifts in rainfall patterns. Reach-scale factors include location in relation to lock and dams and other artificial structures, input of tributary sediment loads, channel gradient, valley confinement and local topography, and floodplain vegetation.

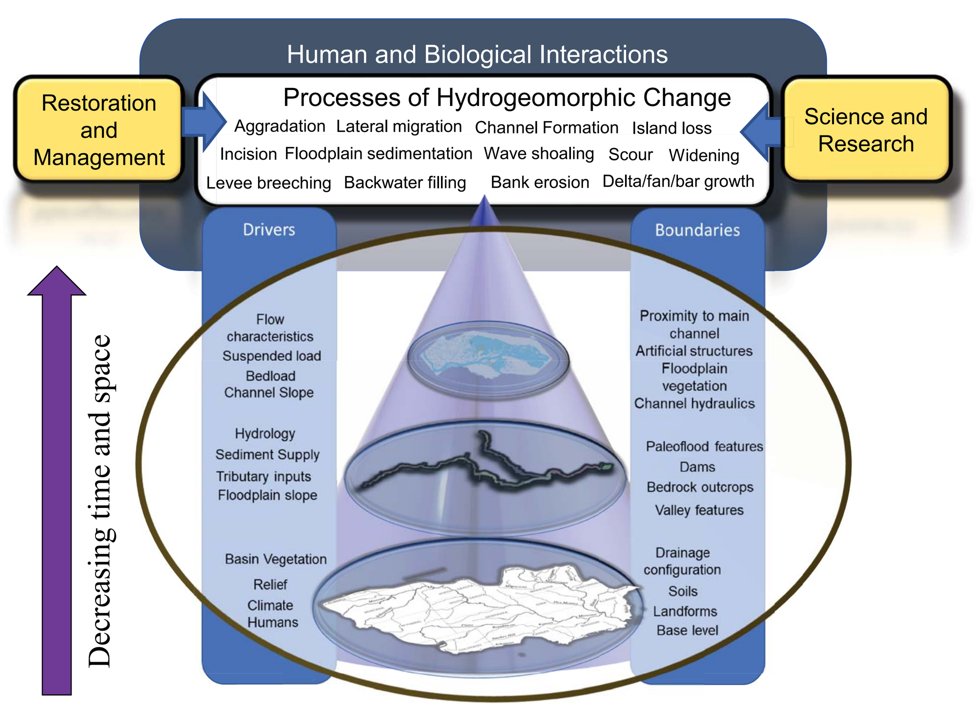

Figure 1. Conceptual model for hydrogeomorphic change in the UMRS.

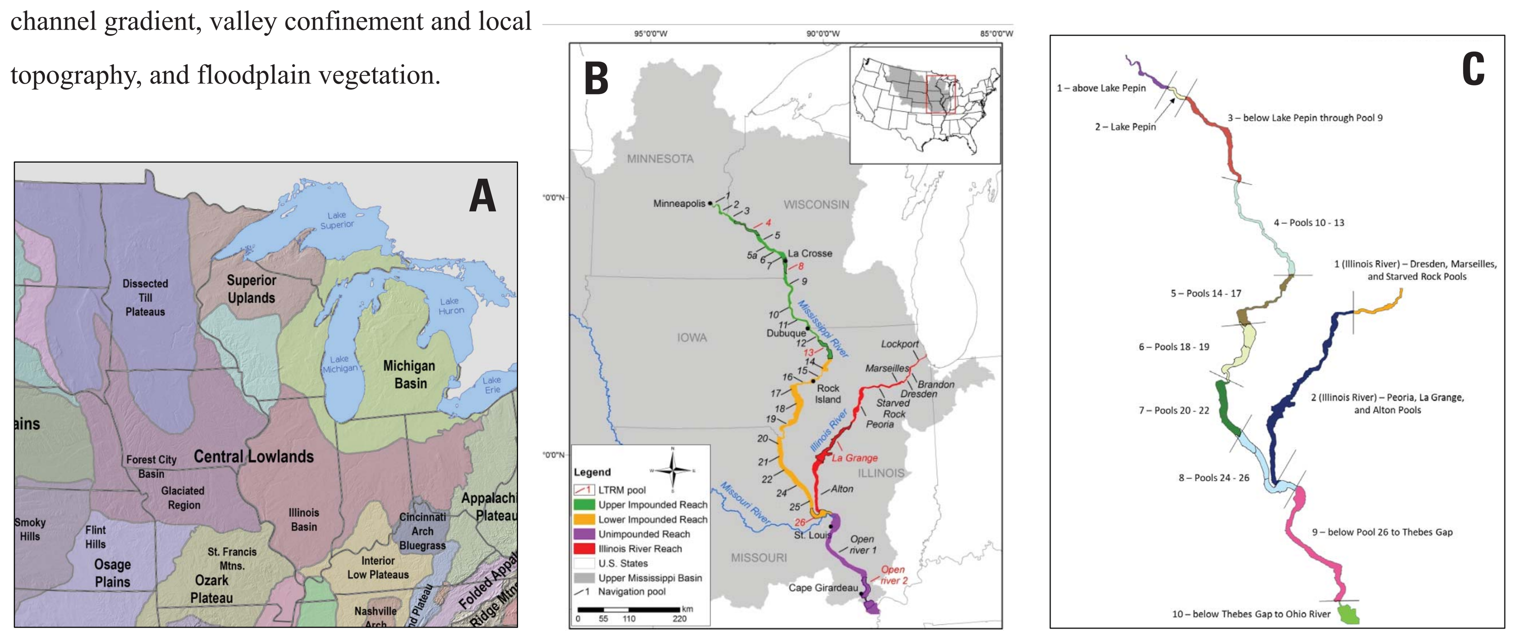

Figure 2. Top three levels of the classification framework. **A.** Physiographic provinces, **B.** Floodplain Reaches, and **C.** Geomorphic Segments.

- The classification framework comprises six hierarchical levels that describe the boundary conditions and drivers at scales ranging from individual geomorphic units to physiographic provinces. The three broadest levels in the classification draw on previous classification work. In descending order of scale:
  - Physiographic provinces delineate large-scale natural landscape features and geologic history, which determine the ultimate topographic and climatological conditions of the basin (Fig. 2A; Fenneman and Johnson, 1946).
  - "Floodplain reaches" are defined by anthropogenic factors such as degree of levying and impoundment (Fig. 2B).
  - Geomorphic segments determined by broad-scale valley and floodplain morphology and major slope breaks in the longitudinal profile (Fig. 2C; West Consultants, 2000).
- Methods for mapping features in the remaining classification levels are described in the next section.

Mapping Geomorphic Units, Catenae, and Process Zones

- The base component of the classification is the hydrogeomorphic unit, consisting of individual landforms that together comprise the building blocks of the fluvial landscape (for example bars, fans, channels, pools, backwaters, etc.) Several existing datasets were used to map these units coarsely, including maps of aquatic area habitat types (USACE UMRR LTRM, 2017), and maps of floodplain vegetation change interpreted as geomorphic planform change (Rohweder, 2019). Figure 3 shows these datasets and several examples of interpreted geomorphic units.
- Hydrogeomorphic units are grouped into a continuum of units (called catenae) based on connectivity of hydraulic and sediment dynamics. Also contributing to the mapping of the hydrogeomorphic catenae are information on tributary sediment loads, as estimated by the SPARROW model (Saad et al., 2019), and reach-scale gradient, determined by water surface elevations measured at stream gages along the channel (Fig. 4).
- The catenae are part of larger geomorphic "interdam process zones" that reflect a longitudinal gradient in sediment supply and transport capacity (Skalak, et al., 2013). Process zones range from sediment starved and erosion/transport dominated conditions below dams to depositional conditions at deltas within impoundments.

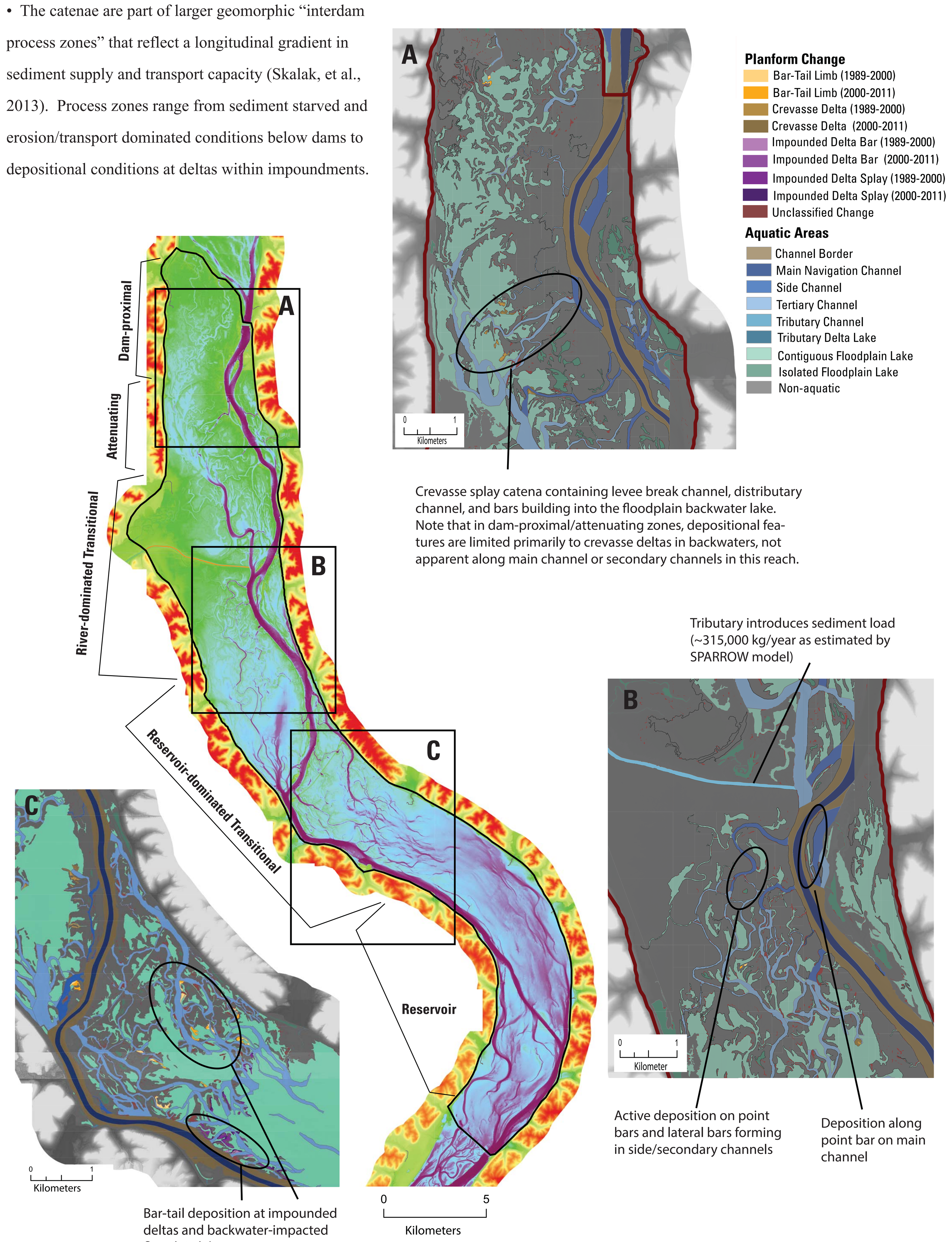

Figure 3. Interdam process zone sequences in UMR navigation pool 9. Inset maps show geomorphic units/catenae in different process zones mapped with aquatic areas and planform change datasets. Years in parentheses for planform change data refer to the period in which change ocurred.

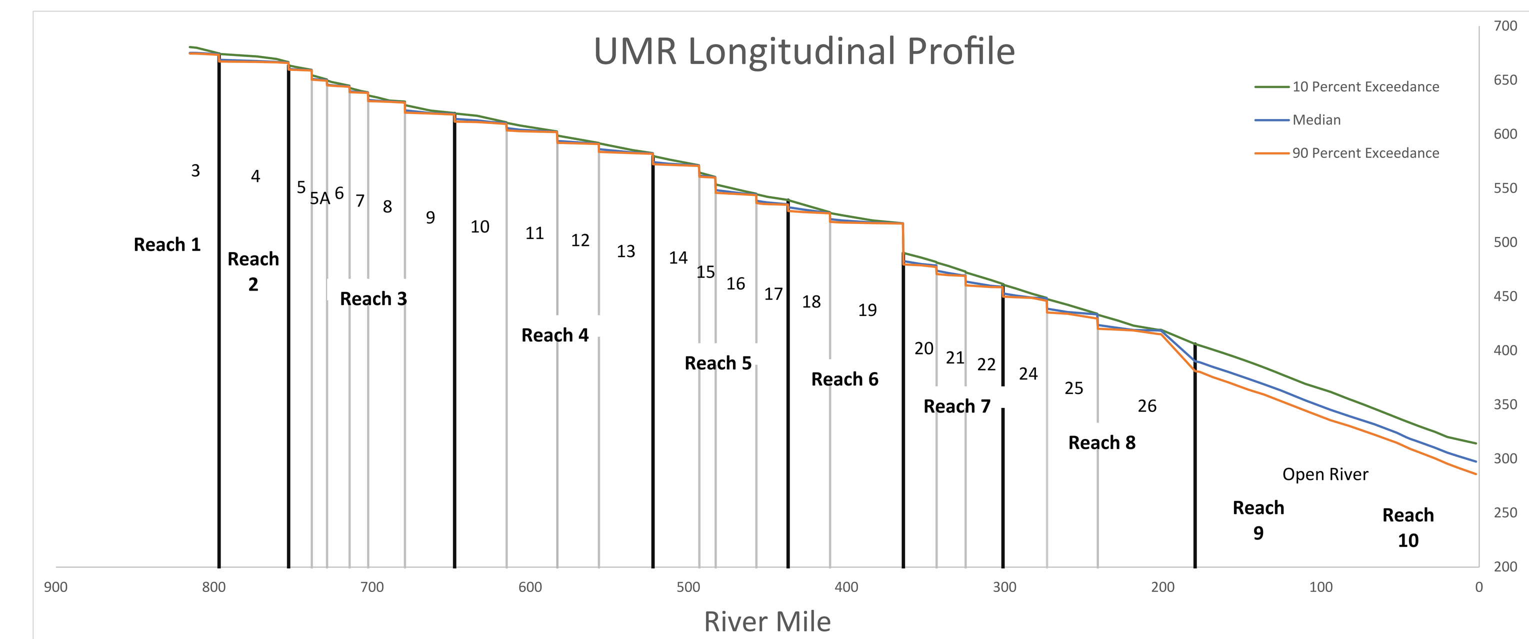

Figure 4. Longitudinal profiles generated from water year 1972-2011 water surface elevation data at US Army Corp of Engineers gages along the UMR. Separate profiles were created for low flow (90% exceedance), median, and high flow (10% exceedance) conditions at each gage. Water surface elevation data were compiled by Molly Van Appledorn, USGS UMESC.

Future Work

- Future work will include mapping hydrogeomorphic units in higher detail across the UMRS with the geomorphon tool (Jasiewicz and Stepinski, 2013a). Geomorphons are a terrain analysis method in which the sightlines from each pixel of a digital elevation model (DEM) are analyzed to objectively classify the landscape into component landforms (Jasiewicz and Stepinski, 2013b; Fig. 5).
- High-resolution topography/bathymetry data have been collected throughout the UMRS (USACE UMRR LTRM, 2016), allowing us to categorize landforms in the channel and floodplain system-wide (e.g., Fig. 6).

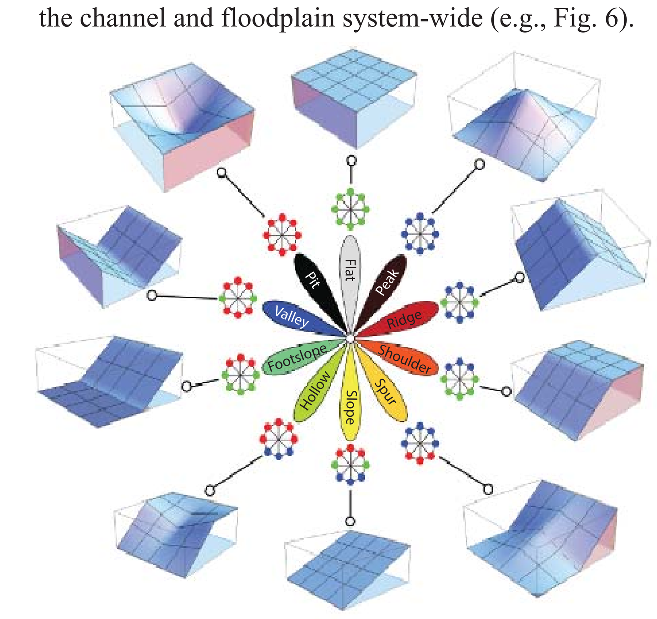

Figure 5. Machine vision approach used by the geomorphon tool to classify terrain into the ten most common geomorphic forms. From Jasiewicz and Stepinski, 2013.

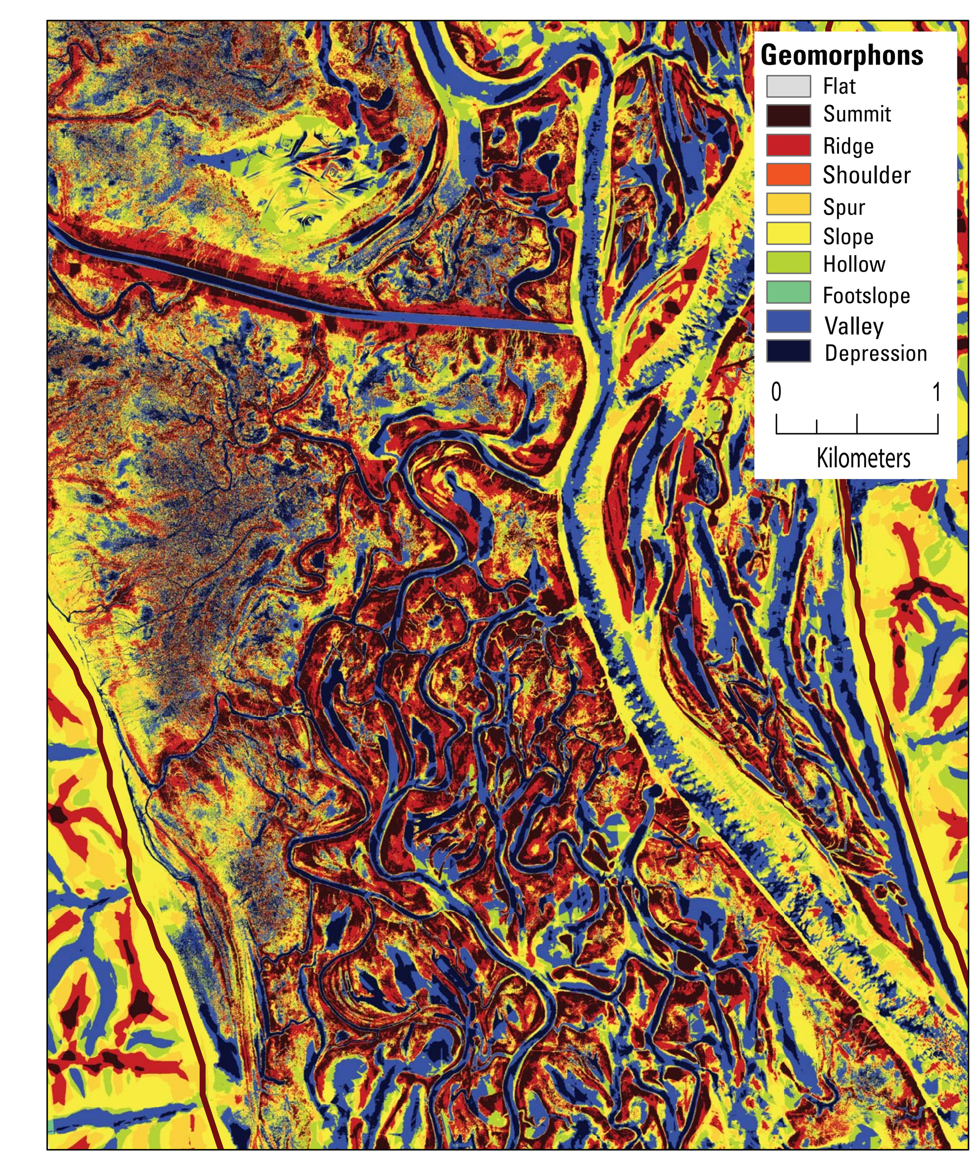

Figure 6. Example of geomorphon results. Area is the same as Fig. 3, inset map B.

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