Generating Surface Flow Features from 1-meter Lidar-Derived Digital Elevation Models

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Abstract

The U.S. Geological Survey (USGS) is incorporating digital elevation models (DEMs) derived from Light Detection and Ranging (lidar) data into the National Elevation Dataset (NED), the elevation layer of The National Map (http://nationalmap.gov/) (Stoker and others, 2008). High-resolution lidar-derived DEMs have the accuracy needed to systematically quantify surface flow and create a drainage network that is fully integrated with elevation. In 2008, 1-meter resolution lidar data were acquired for Minnehaha County, South Dakota. The acquisition was a collaborative effort between Minnehaha County, the city of Sioux Falls, and the USGS Earth Resources Observation and Science (EROS) Center. From the newly acquired lidar data, USGS scientists generated high-resolution DEMs and surface flow features (fig. 1). Surface flow features generated from lidar-derived DEMs are consistently integrated with elevation. This helps scientists to better understand the effects of surface-water movement, including surface-water runoff, flood inundation, and erosion. Many topographic and hydrologic applications will benefit from the increased availability of accurate, high-quality, and high-resolution surface-water data derived from lidar.

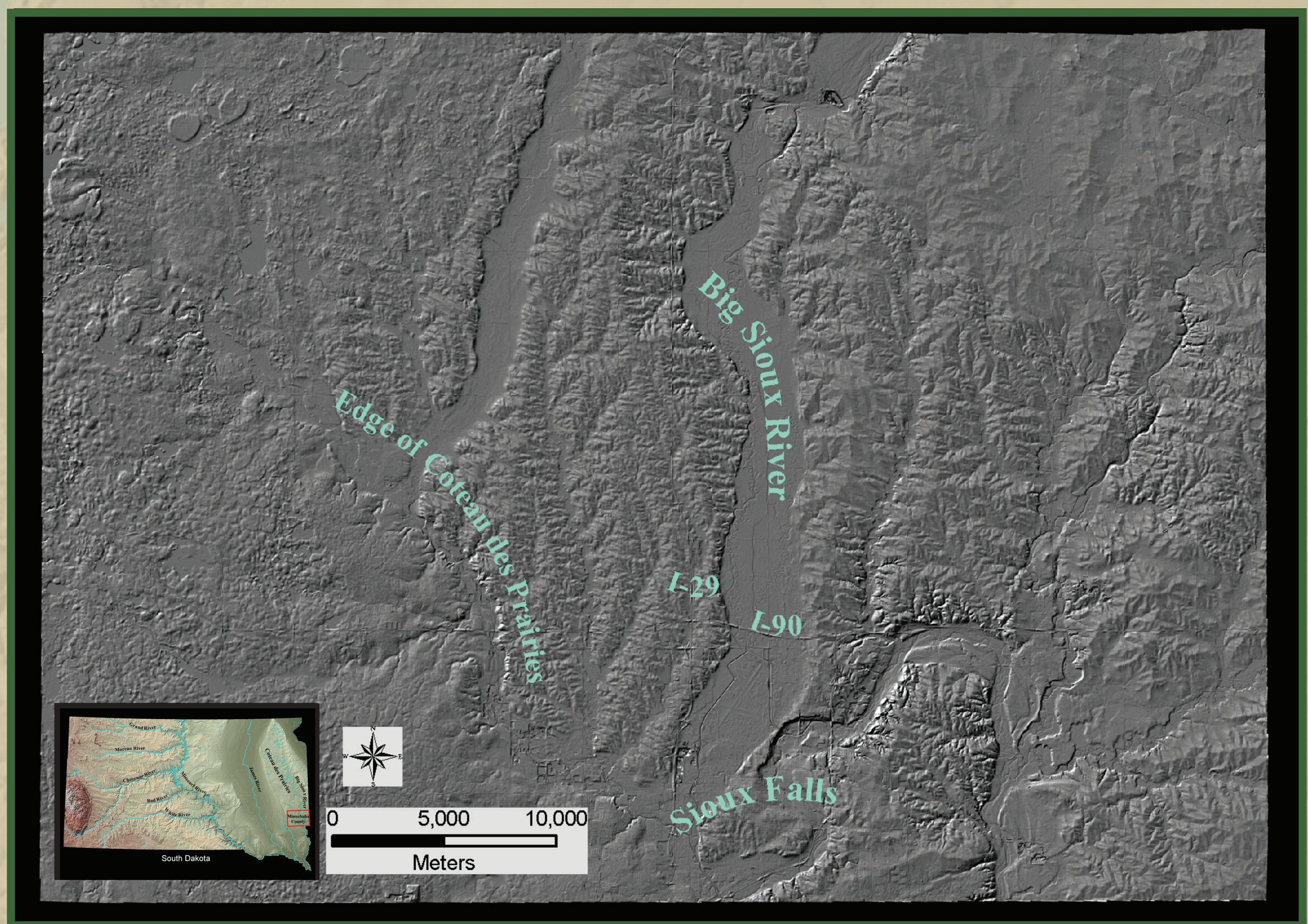

Figure 1. Minnehaha County lidar-derived elevation.

Introduction

Lidar data were collected for Minnehaha County by an airborne platform with a combination of laser range finding, global positioning system, and inertial measurement technologies by Sanborn Map Company Inc. Lidar data accuracy determination uses the National Standard for Spatial Data Accuracy at 18.5-centimeter root mean square error (RMSE) on open bare terrain and 37.0-centimeter RMSE in obscured "vegetative" areas. The Minnehaha County bare earth lidar data were used to produce 1-meter DEMs with a Universal Transverse Mercator Zone 14 projection and a North American Datum of 1983 horizontal datum. The 1-meter DEM is a detailed representation of the earth's topography and drainage networks. Artificial structures (Sioux Falls Regional Airport, north of Sioux Falls), transportation networks (Interstates 29 and 90), and drainage networks (Big Sioux River) can all be easily identified (fig. 1).

Background/Methods

Because elevation is a key factor in deriving surface flow, high-resolution lidar-derived DEMs have the detail needed to systematically quantify and fully integrate surface flow features and to supply topographic spatial information and data integration capabilities. USGS scientists generated surface flow features from the newly acquired Minnehaha County lidar-derived DEM. The elevation data were hydrologically conditioned using techniques developed by Jenson and Domingue (1988). This method is a conditioning phase that generates three datasets: the original DEM with depressions filled, a dataset indicating the flow direction that represents the steepest down slope direction for each cell, and a flow accumulation dataset in which each cell receives a value equal to the number of cells that drain to it.

Results

The 1-meter lidar elevation data more accurately represent surface flow in low relief areas than the historical 10-meter elevation data, which were previously incorporated into the NED (fig. 2). In this figure, the Big Sioux River, channelized throughout the years, flows to the west of the airport, and a diversion channel drains to the east of the airport. This temporal elevation comparison emphasizes the need for elevation data currency to provide the best publicly available elevation framework for precise representation of surface flow. Because of lidar's fine-scale ability to represent the topographic surface of the earth, a vast amount of detail is captured in the bare earth lidar data. Using a depressionless DEM to create overland surface flow provides more accurate surface channels when obstructions, such as bridges, are removed from the data. However, if such obstructions are not removed, the filling of sinks to create overland flow tends to either unnecessarily spill the flow over the obstruction in the wrong location or drain the flow in the opposite direction (fig. 3). Scientists at the USGS EROS Center are testing a selective draining method that involves generating a difference grid created by subtracting the values of the original lidar DEM from the filled depressionless DEM. The deepest and shallowest cells are identified in the sink(s) by using the highest and lowest values of the difference grid (fig. 4). In many cases, the deepest point in the sink could be used to drain through or under an obstruction, such as a bridge. Knowing the shallowest point is valuable in determining where water would overflow from the sink in the event of a flood when the drainage channels (through a culvert or bridge) could not accommodate the floodwaters (Poppenga and others, 2009).

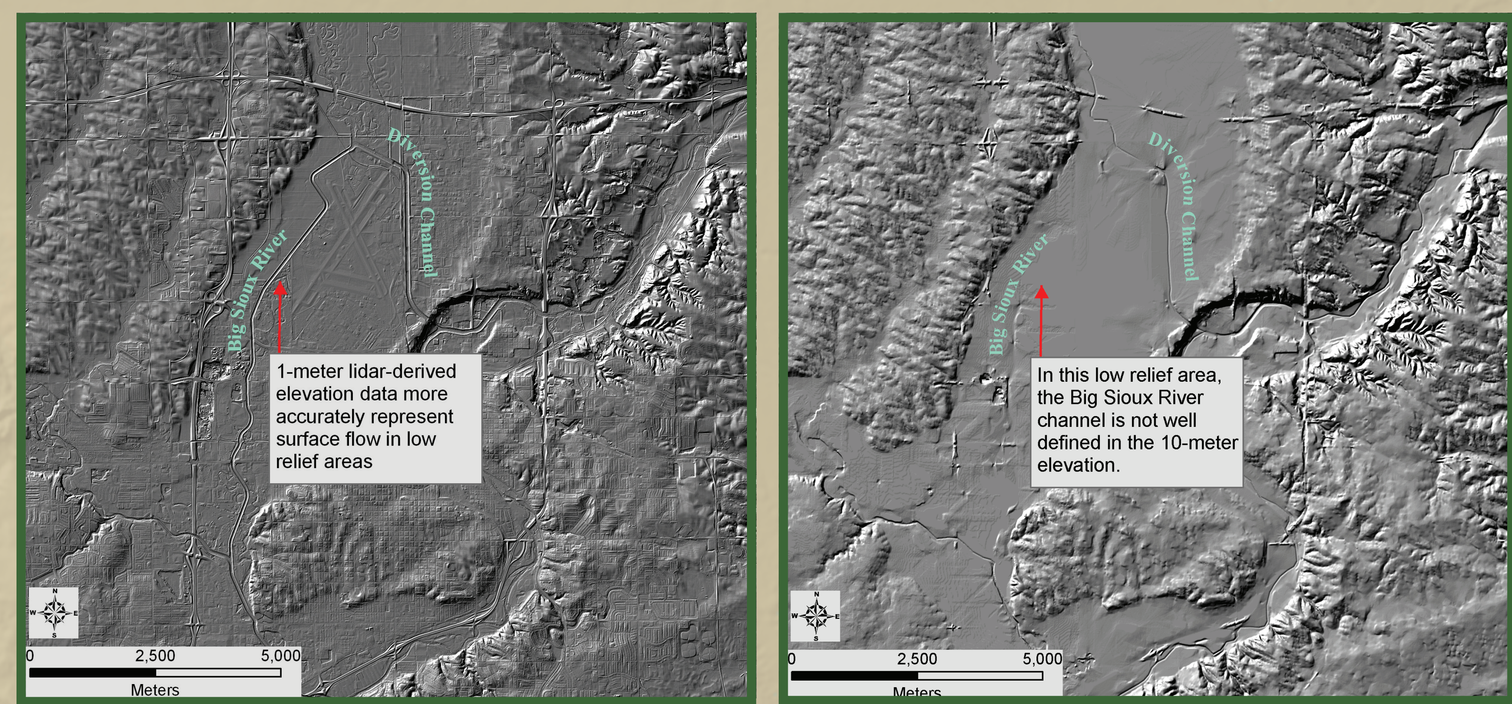

Figure 2. 1-meter lidar-derived elevation (left) and 10-meter data (right) incorporated in the National Elevation Dataset.

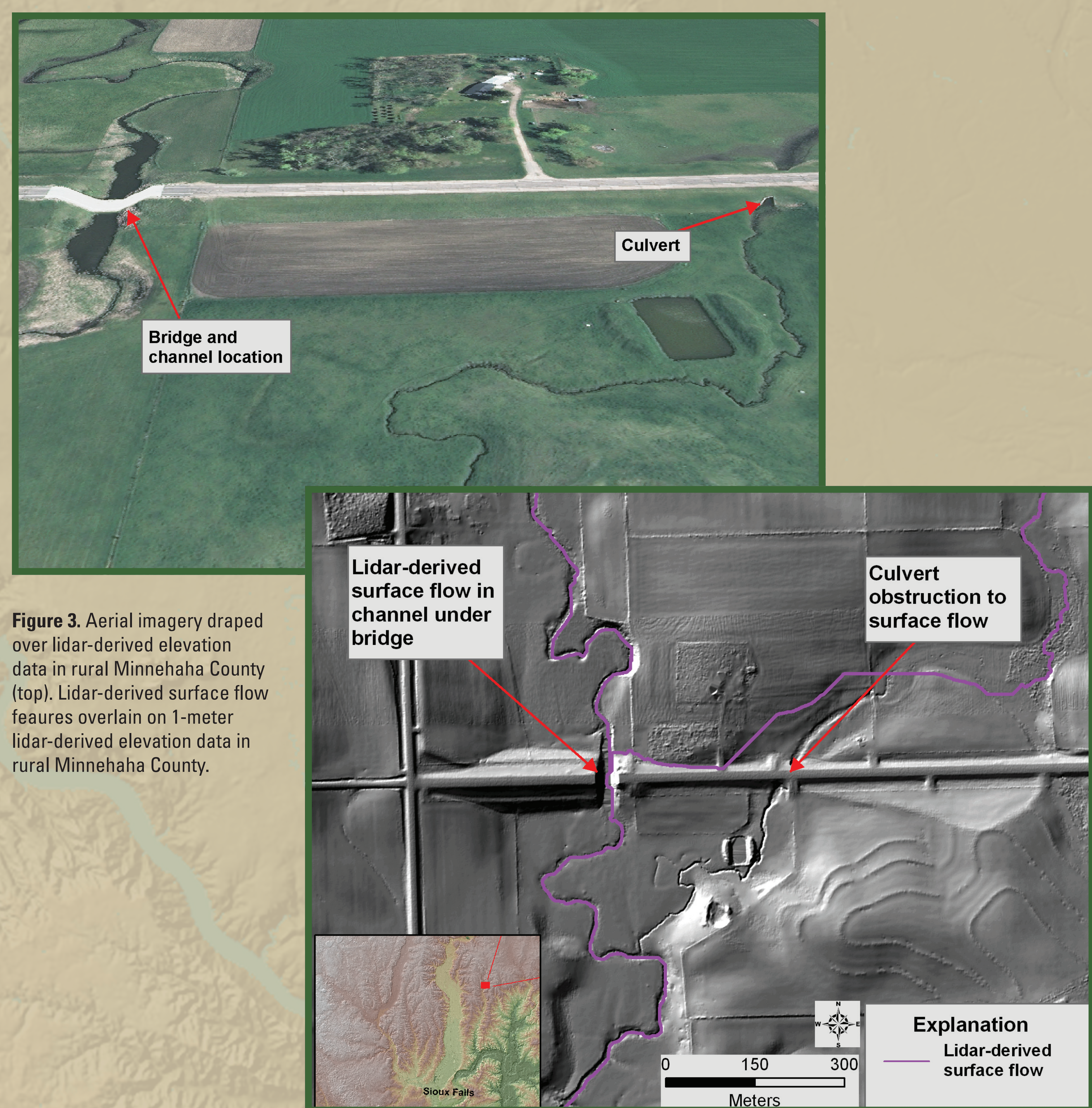

Figure 3. Aerial imagery draped over lidar-derived elevation data in rural Minnehaha County (top). Lidar-derived surface flow feaures overlain on 1-meter lidar-derived elevation data in rural Minnehaha County.

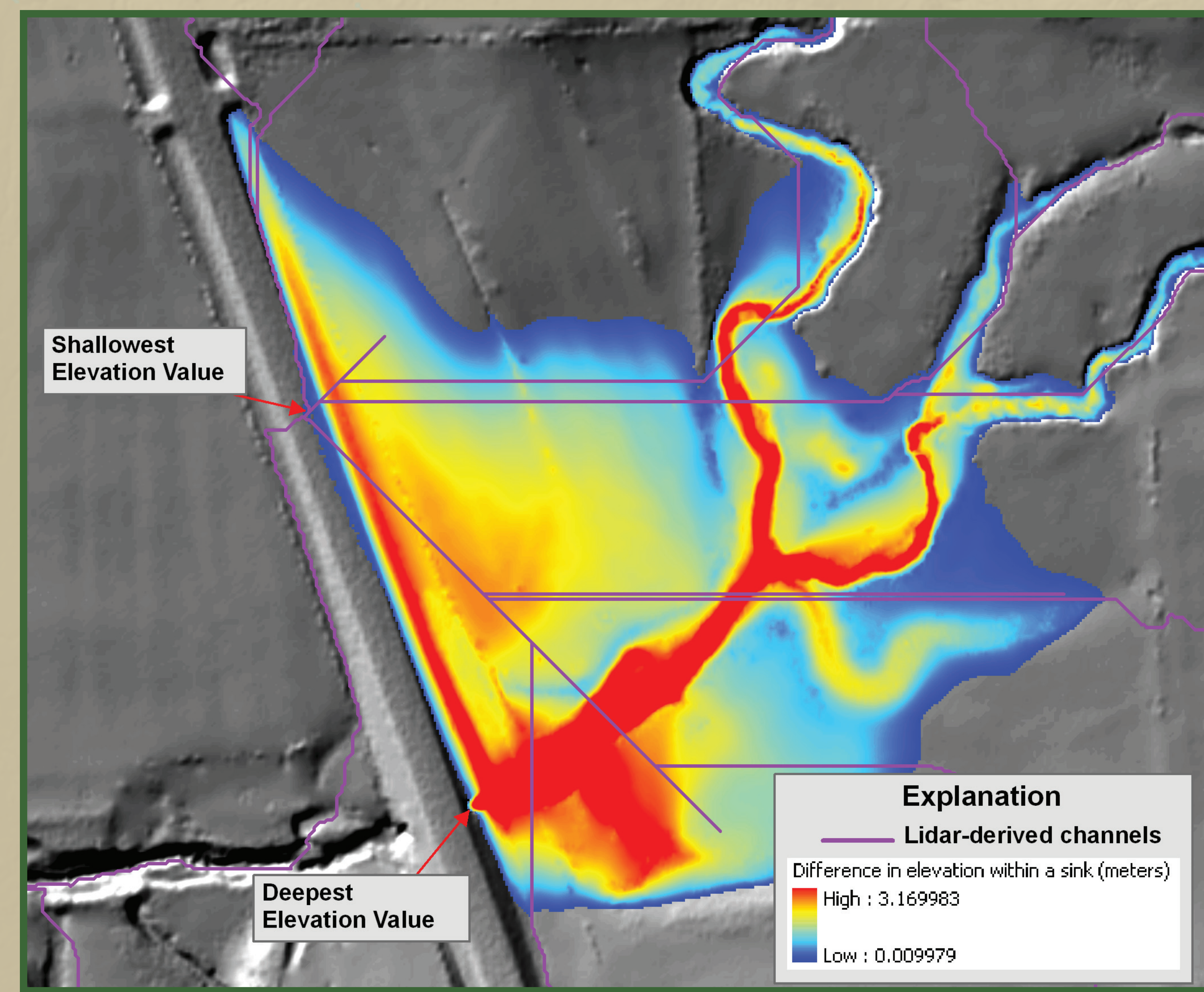

Figure 4. Difference grid resulting from subtracting values of the original lidar-derived digital elevation model (DEM) from the filled depressionless DEM.

Conclusion

The USGS is the primary source for seamless elevation models at global, national, and local scales (Gesch, 2007). By implementing remotely sensed lidar-derived DEMs into the NED, the elevation layer for The National Map, the USGS has developed a multiresolution, evolving elevation dataset that provides the best publicly available elevation data for research, applications, and data distribution. This perpetual development method needs to be applied to hydrologic derivatives to provide valuable surface flow information for surface-water applications. Because elevation is a key factor in deriving surface flow features, the best publicly available elevation data (high-resolution 1-meter lidar-derived DEMs) were used to create surface flow features in Minnehaha County, South Dakota. Surface flow features generated from lidar-derived DEMs are high resolution and produce highly integrated hydrologic data. These remotely sensed data and their derivatives provide topographic information and data integration capabilities needed for meeting current and future human and environmental needs.

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