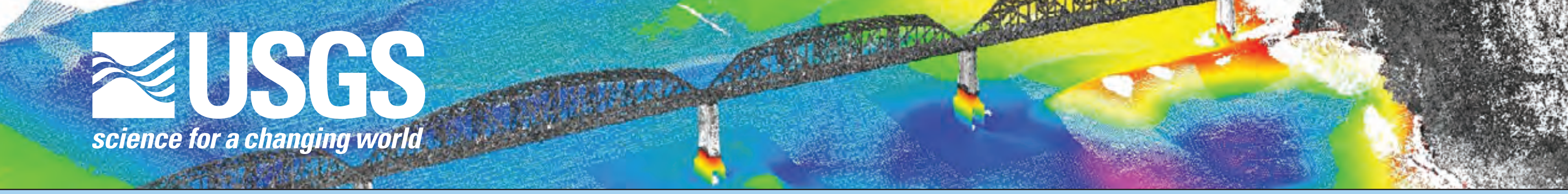

Hydrographic Surveys of Rivers and Lakes Using a Multibeam Echosounder Mapping System

Using Sound Waves to Map River and Lake Bottoms

A multibeam echosounder (MBES) is a type of sound navigation and ranging device that uses sound waves to “see” through even murky waters (fig. 1: Note that all figures used in this report are for an illustrative rather than an interpretive purpose, not all geographic locations will be shown). Unlike a single beam echosounder (also known as a depth sounder or fathometer) that releases a single sound pulse in a single, narrow beam and “listens” for the return echo, a multibeam system emits a multidirectional radial beam to obtain information within a fan-shaped swath (figs. 1, 2). The timing and direction of the returning sound waves provide detailed information on the depth of water and the shape of the river channel, lake bottom, or any underwater features of interest. This information has been used by the U.S. Geological Survey (USGS) to efficiently generate high-resolution maps of river and lake bottoms.

The Multibeam Echosounder Mapping System

A multibeam echosounder mapping system (MBMS) is an integration of several individual components: the MBES, an inertial navigation system (INS), and a data-collection and data-processing computer. The MBES that was used for numerous surveys completed by the USGS in Missouri is the Teledyne RESON SeaBat® 7125–SV2 (fig. 3), which is operated at a frequency of 200 or 400 kilohertz.

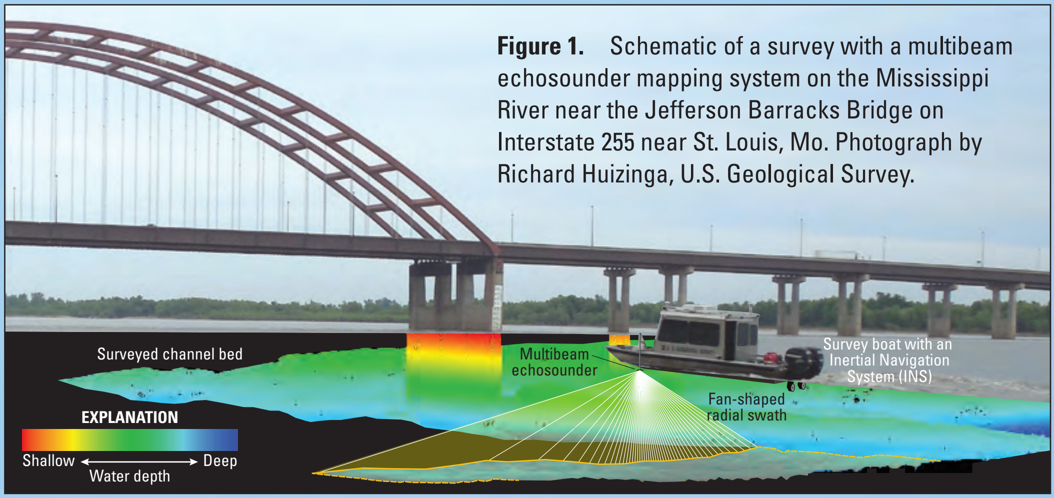

Figure 1. Schematic of a survey with a multibeam echosounder mapping system on the Mississippi River near the Jefferson Barracks Bridge on Interstate 255 near St. Louis, Mo. Photograph by Richard Huizinga, U.S. Geological Survey.

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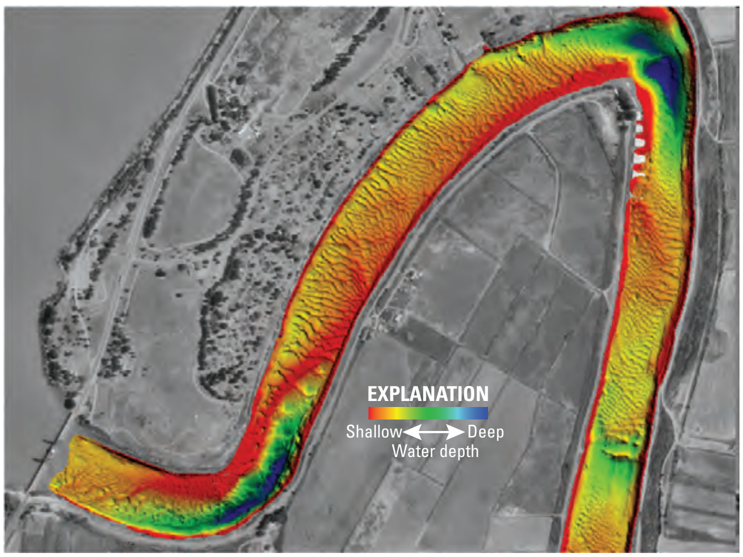


Figure 2. Example of single beam (top) and multibeam echosounder (bottom) output (modified from Alvarado and Robinson, 2011).

To accurately position and interpret the data received by the MBES, the INS uses two Global Navigation Satellite System antennae and an inertial motion unit to provide position in three-dimensional space and measure the heave, pitch, roll, and heading of the vessel (and, thereby, the MBES). A connection to a source of real-time kinematic corrections often is established to improve real-time display of a survey. Whether or not a source of real-time kinematic corrections is used during a survey, data from the INS typically are postprocessed to mitigate the effects of degraded positional accuracy of the vessel during the survey. After the survey is completed, the acquired data from the MBES are processed to remove data spikes and other spurious points in the MBES soundings, georeferenced using the postprocessed INS data, and visualized as a triangulated irregular network surface or a point cloud (figs. 1, 2). The various components of the MBES mapping system are described in detail in studies of the Missouri and Mississippi Rivers in Missouri (Huizinga, 2016, 2017; Huizinga and others, 2010).

Applications of the Multibeam Echosounder Mapping System

Channel-Bed Scour

Scour in river channels is the removal of channel-bed and bank material by flowing water and is the leading cause of bridge failures in the United States (Richardson and Davis, 2001). Scour at a bridge site is the result of short- and long-term geomorphic processes and local effects caused by elements of the structure (pier, footing) in or adjacent to the waterway (Richardson and Davis, 2001; Huizinga and Rydlund, 2004). Scour processes can be exacerbated during high-flow conditions because velocity and depth typically increase. Because the effects of scour can be severe and dangerous, bridges and other structures over waterways are inspected routinely. Multibeam surveys around bridges can reveal the short- and long-term effects of bed scour near the bridge structures (figs. 4, 5).

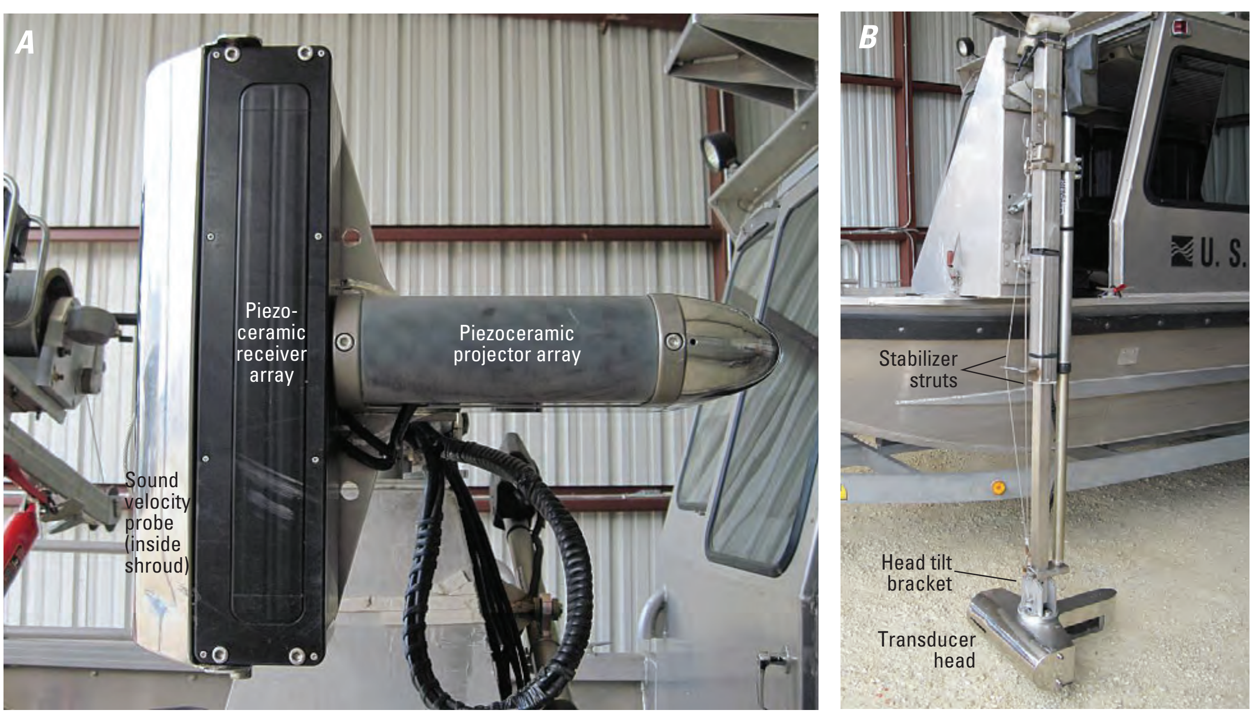
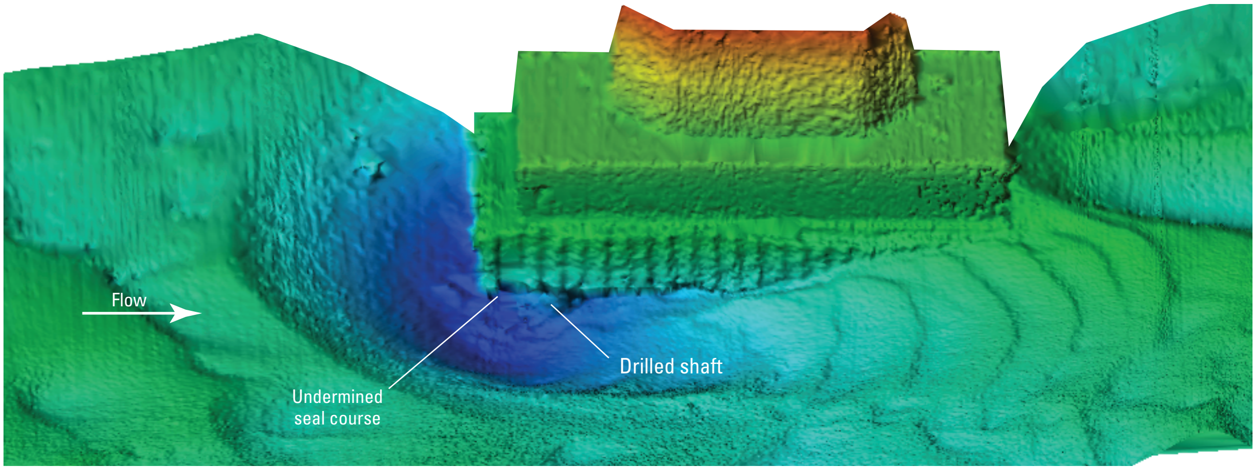


Figure 3. The Teledyne RESON SeaBat® 7125–SV2 multibeam echosounder. *A*, As viewed from the bottom. *B*, Mounted on the port side of the U.S. Geological Survey survey boat. Photograph by Richard Huizinga, U.S. Geological Survey. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.



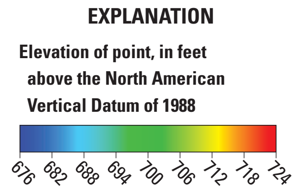
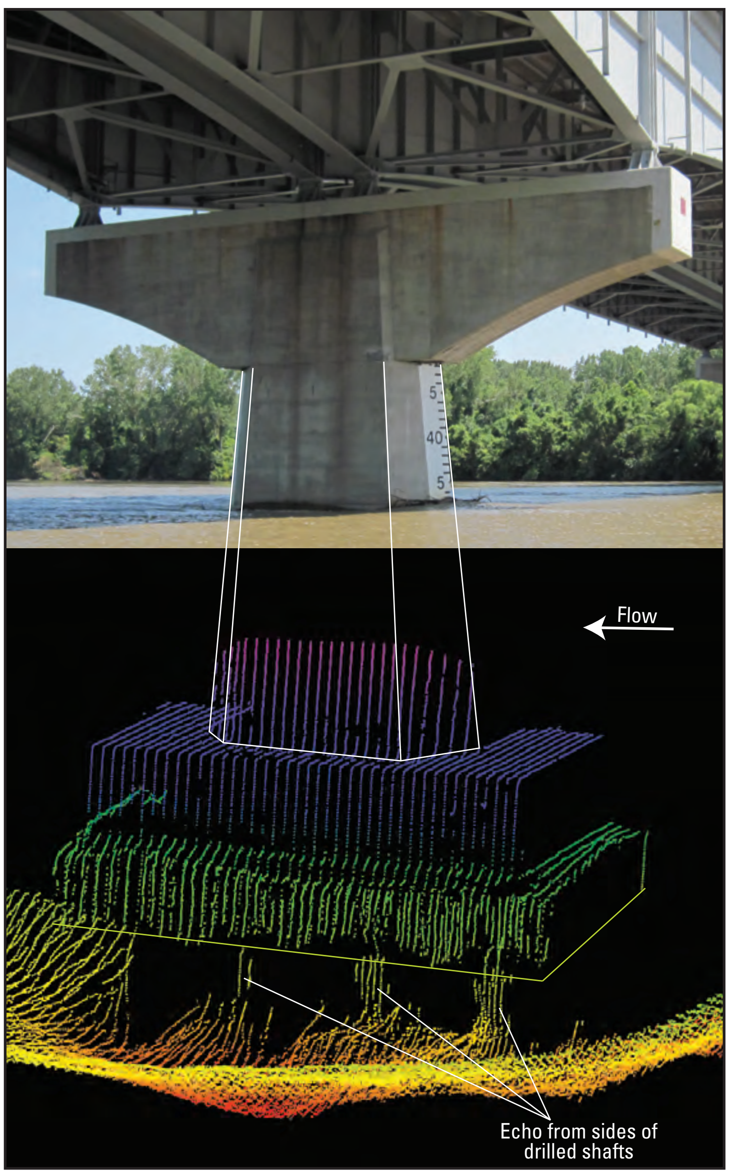
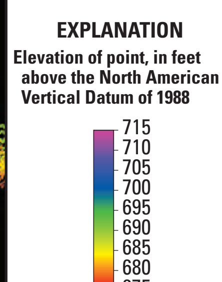


Figure 4. Examples of three-dimensional representations of scour around a bridge pier obtained using a multibeam mapping system. The top image is the Interstate 635 Bridge on the Missouri River at Riverside, Mo., and the bottom image is the Interstate 435 Bridge on the Missouri River at Randolph, Mo. (Huizinga 2016).





Channel-Bottom Characteristics

In rivers, the channel-bed features reflect dynamic interactions between flowing water and the mobile sediment available on the bed. These interactions generate a wide range in channel-bed characteristics depending on the hydrologic and geologic context and provide a variety of aquatic habitat conditions for fish and invertebrates. Knowing when and where selected channel-bed conditions are found, how these features are used by aquatic species of interest, and how these features may change with time are all valuable pieces of information for fisheries managers. For example, channel-bed features acquired using the MBMS, in conjunction with velocity distribution data provided by an acoustic Doppler current profiler (Mueller and others, 2013), were used to assess pallid sturgeon habitat in the Missssippi River near a proposed bridge construction site (fig. 6; Huizinga and others, 2010).

Multibeam echosounder surveys have been completed by the USGS at numerous bridge locations along the Missouri and Mississippi Rivers to determine channel-bed characteristics. At all the surveyed locations, a variety of fluvial features were detected in the channel, ranging from a planar or nearly planar bed—indicating minimal bedload transport in these areas—to large dunes that indicate substantial transport of bedload.

Rock outcrops also were detected at several sites where the alluvial material of the channel bed had been washed away. Repeated surveys at these locations have allowed for the quantification of bed changes (deposition and scour) with time and provide some indication of the bed volume change and the relation between streamflow changes and the associated channel-bed responses (fig. 7).

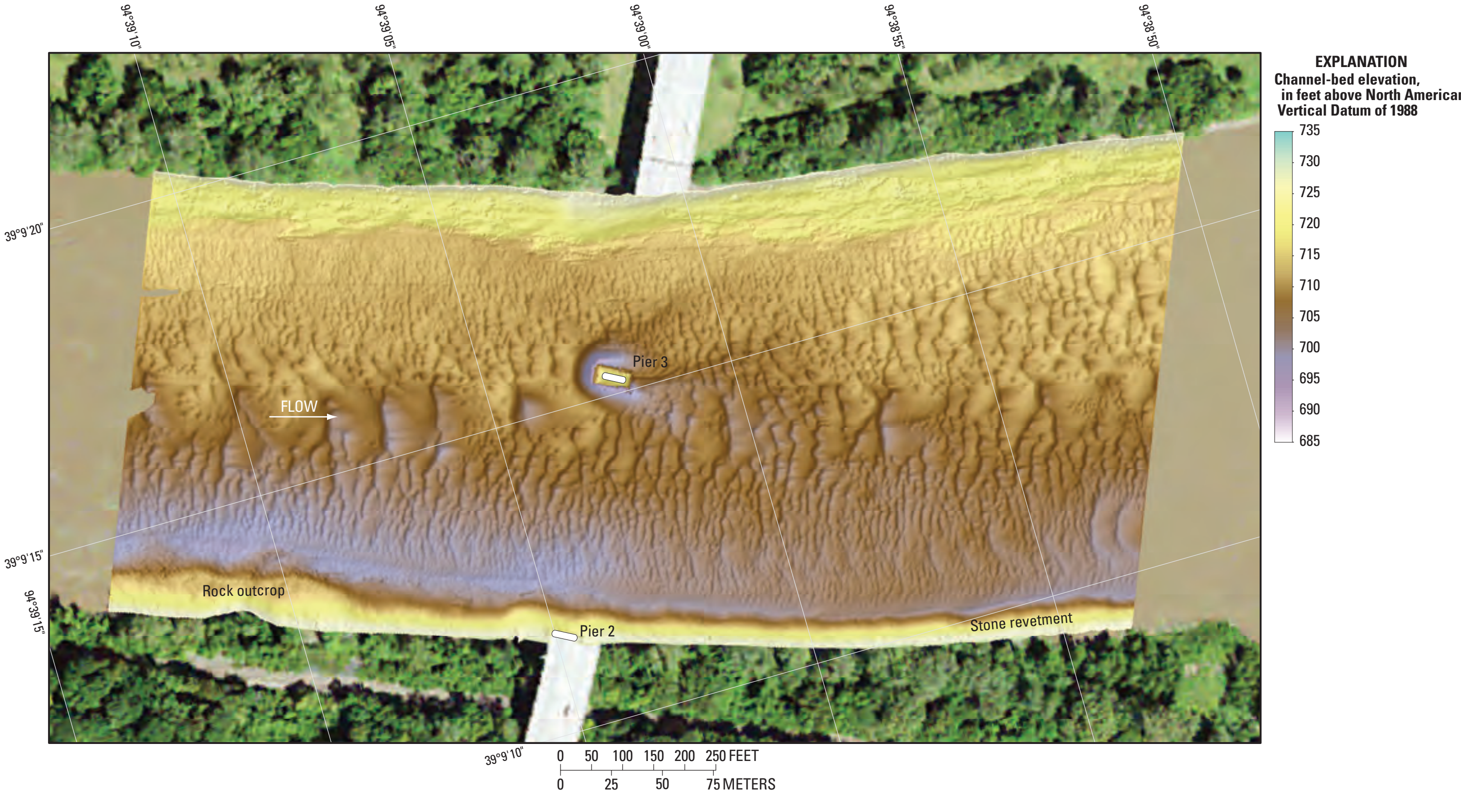


Figure 5. Planar view of mapped Missouri River channel reach indicating substantial scour around a bridge pier and other channel substrate features (Interstate 635 Bridge over the Missouri River at Riverside, Mo.; Huizinga, 2016).

Estimation of Bedload Transport

Bedload, defined as "the sediment that slides, rolls, or skips along in almost continuous contact with the streambed" (Hubbell, 1964, p. 2), currently (2018) is not measured consistently in most rivers. Direct measurement of bedload in large sand-bed rivers is highly inaccurate (Hubbell, 1964; Edwards and Glysson, 1999), and unconfirmed theoretical estimates commonly are used (Gomez, 2006). Techniques using time-lagged MBMS surveys (as demonstrated in figure 7), such as about an hour, have been developed to estimate bedload transport based on dune movement and the associated change in areas of scour and fill (Abraham and others, 2011).

Lake Surveys and Volume Calculations

Sedimentation in lakes and reservoirs can result in reduced capacity for flood storage and water supply and a loss of usable aquatic habitat over time. A detailed bathymetric survey allows for an accurate determination of available lake capacity for various uses. The MBMS has been used to map and determine accurate volume estimates for lakes in Missouri (fig. 8) and surrounding States. Such information can be used to determine water-supply availability, reservoir sedimentation rates and projected lifespans, and the spatial distribution of selected aquatic habitat.

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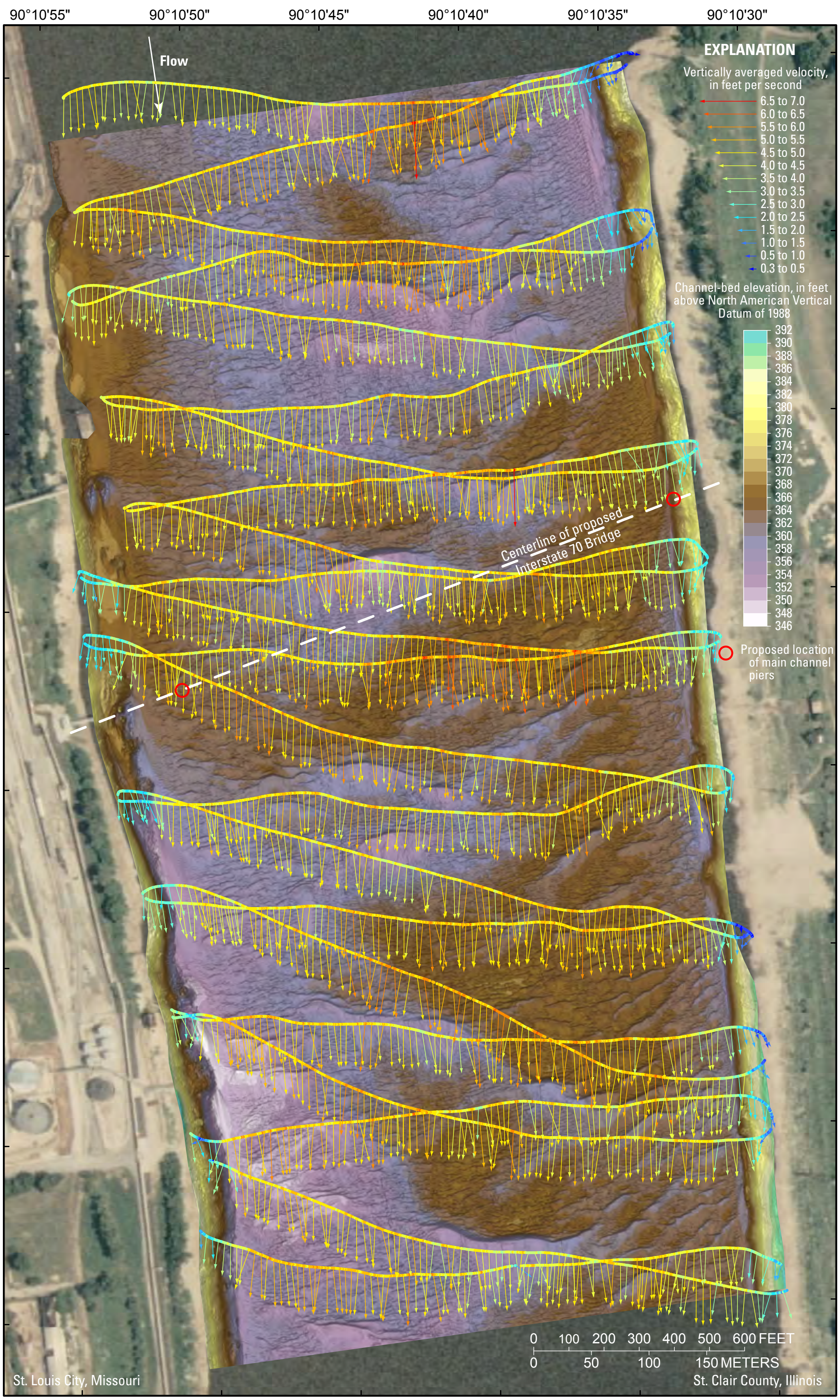

Figure 6. Planar view of mapped Mississippi River channel reach indicating bed features and corresponding velocity distribution (Huizinga and others, 2010).

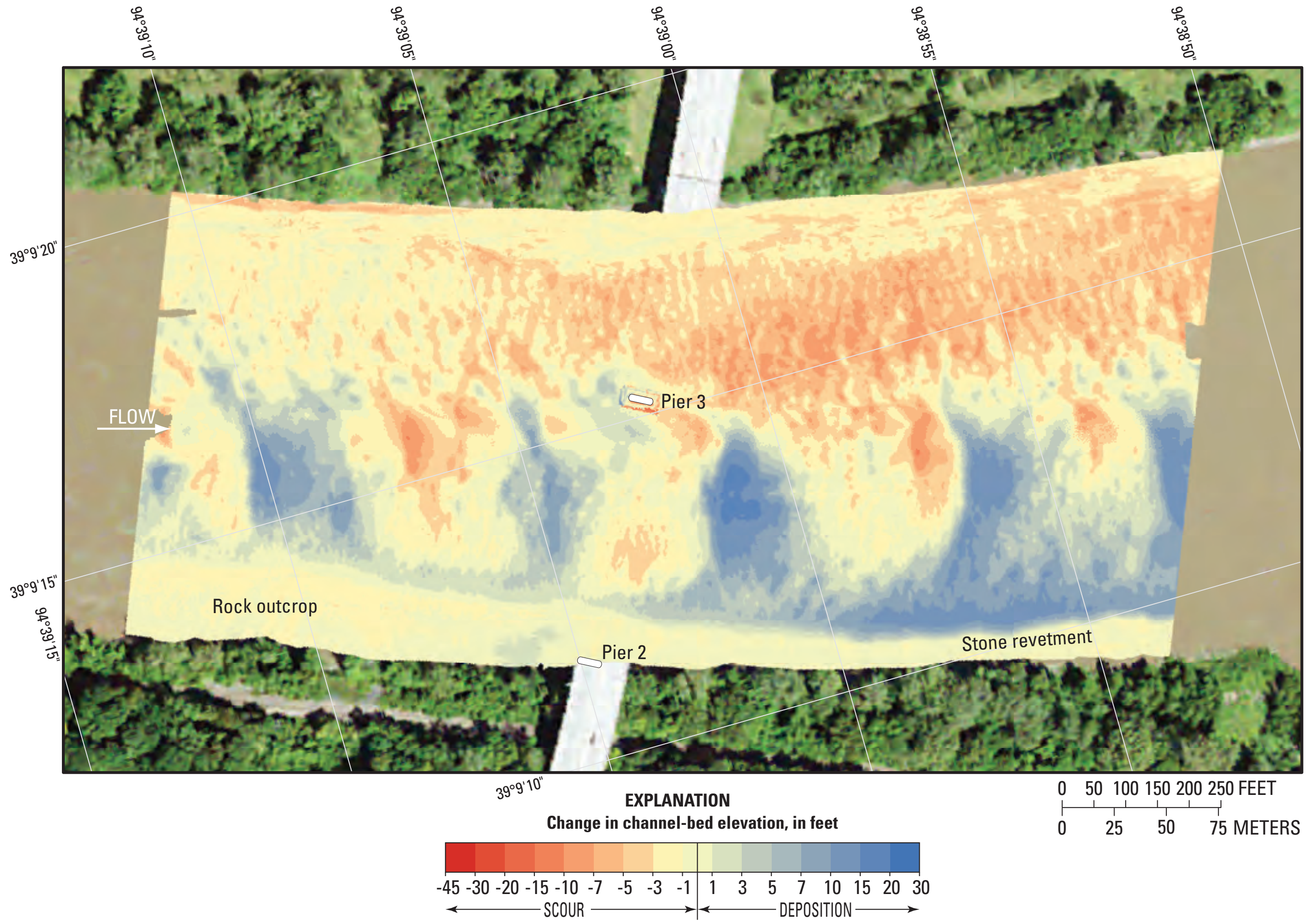

Figure 7. Planar view of mapped Missouri River channel reach at Kansas City, Mo., indicating the change in bed conditions between surveys in 2015 and 2011 (Interstate 635 Bridge over the Missouri River at Riverside, Mo.; Huizinga, 2016).

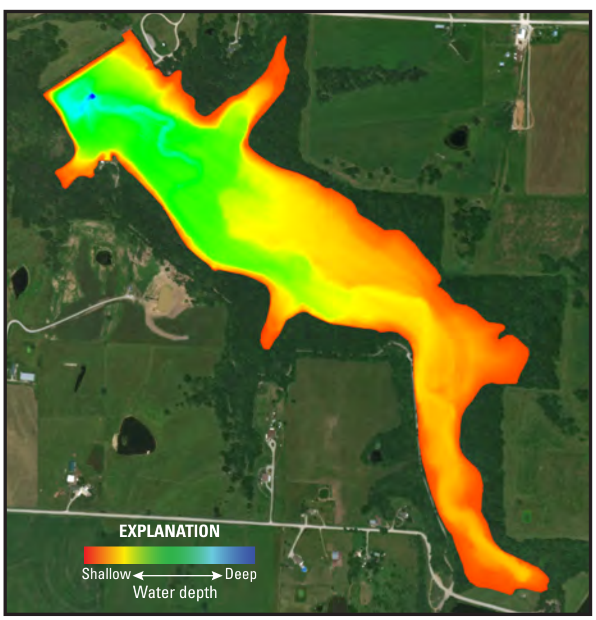

Figure 8. Planar view of mapped bottom of Reservoir 3 near Cameron, Mo., from a multibeam echosounder survey in July 2013 (Huizinga, 2014).

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