# Hydrographic Surveys at Seven Chutes and Three Backwaters on the Missouri River in Nebraska, Iowa, and Missouri, 2011-13

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science for a changing world

Prepared in cooperation with the U.S. Army Corps of Engineers, Omaha District

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Data Series 909

U.S. Department of the Interior
U.S. Geological Survey

**Front cover:** U.S. Geological Survey (USGS) hydrographer surveying the top of bank at Deroin chute in 2013. Photograph by Justin Krahulik, USGS.

**Back cover:** (Top) Tobacco chute, 2014. Photograph by Justin Krahulik, USGS.
(Bottom) USGS hydrographers collecting bathymetry data at Deroin chute in 2013 with construction on the left bank of the chute. Photograph by Brenda Densmore, USGS.

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**U.S. Department of the Interior**
SALLY JEWELL, Secretary

**U.S. Geological Survey**
Suzette M. Kimball, Acting Director

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# Conversion Factors

[International System of Units to inch/pound]

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| centimeter (cm) | 0.3937 | inch (in.) |
| millimeter (mm) | 0.03937 | inch (in.) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |
| | Area | |
| square meter ($m^2$) | 0.0002471 | acre |
| hectare (ha) | 2.471 | acre |
| square kilometer ($km^2$) | 247.1 | acre |
| | Flow rate | |
| meter per second (m/s) | 3.281 | foot per second (ft/s) |
| cubic meter per second ($m^3/s$) | 35.31 | cubic foot per second ($ft^3/s$) |
| | Frequency | |
| kilohertz (kHz) | 1,000 | cycle per second |

# Supplemental Information

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

# Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

# Abbreviations

| | |
|---|---|
| csv | comma-separated values |
| DGPS | differentially corrected Global Positioning System |
| GNSS | Global Navigation Satellite System |
| GPS | global positioning system |
| HAMP | Pallid Sturgeon Habitat Assessment and Monitoring Program |
| NGS | National Geodetic Survey |
| OPUS | Online Positioning Users Service |
| ppm | part per million |
| QA/QC | quality assurance and quality control |
| RM | river mile |
| RMS | root mean square |
| RTK | Real-Time Kinematic |
| SWH | shallow water habitat |
| USACE | U.S. Army Corps of Engineers |
| USGS | U.S. Geological Survey |

# Hydrographic Surveys at Seven Chutes and Three Backwaters on the Missouri River in Nebraska, Iowa, and Missouri, 2011–13

By Justin R. Krahulik, Brenda K. Densmore, Kayla J. Anderson, and Cory L. Kavan

## Abstract

The U.S. Geological Survey cooperated with the U.S. Army Corps of Engineers (USACE), Omaha District, to complete hydrographic surveys of seven chutes and three backwaters on the Missouri River yearly during 2011–13. These chutes and backwaters were constructed by the USACE to increase the amount of available shallow water habitat (SWH) to support threatened and endangered species, as required by the amended "2000 Biological Opinion" on the operation of the Missouri River main-stem reservoir system. Chutes surveyed included Council chute, Plattsmouth chute, Tobacco chute, Upper Hamburg chute, Lower Hamburg chute, Kansas chute, and Deroin chute. Backwaters surveyed included Ponca backwater, Plattsmouth backwater, and Langdon backwater. Hydrographic data from these chute and backwater surveys will aid the USACE to assess the current (2011–13) amount of available SWH, the effects river flow have had on evolving morphology of the chutes and backwaters, and the functionality of the chute and backwater designs. Chutes and backwaters were surveyed from August through November 2011, June through November 2012, and May through October 2013. During the 2011 surveys, high water was present at all sites because of the major flooding on the Missouri River. The hydrographic survey data are published along with this report in comma-separated-values (csv) format with associated metadata.

Hydrographic surveys included bathymetric and Real-Time Kinematic Global Navigation Satellite System surveys. Hydrographic data were collected along transects extending across the channel from top of bank to top of bank. Transect segments with water depths greater than 1 meter were surveyed using a single-beam echosounder to measure depth and a differentially corrected global positioning system to measure location. These depth soundings were converted to elevation using water-surface-elevation information collected with a Real-Time Kinematic Global Navigation Satellite System. Transect segments with water depths less than 1 meter were surveyed using Real-Time Kinematic Global Navigation Satellite Systems. Surveyed features included top of bank, toe of bank, edge of water, sand bars, and near-shore areas.

Discharge was measured at chute survey sites, in both the main channel of the Missouri River upstream from the chute and the chute. Many chute entrances and control structures were damaged by floodwater during the 2011 Missouri River flood, allowing a larger percentage of the total Missouri River discharge to flow through the chute than originally intended in the chute design. Measured discharge split between the main channel and the chute at most chutes was consistent with effects of the 2011 Missouri River flood damages and a larger percent of the total Missouri River discharge was flowing through the chute than originally intended. The U.S. Army Corps of Engineers repaired many of these chutes in 2012 and 2013, and the resulting hydraulic changes are reflected in the discharge splits.

## Introduction

The operations of the Missouri River main-stem reservoir system and the operation and maintenance of the Missouri River Bank Stabilization and Navigation Project were determined to jeopardize the recovery of least terns (*Sternula antillarum*), piping plovers (*Charadrius melodus*), and pallid sturgeon (*Scaphirhynchus albus*) (U.S. Fish and Wildlife Service, 2003). Modification of the Missouri River from its original form, caused by the main-stem reservoirs and bank stabilization, has led to loss of shallow water habitat (SWH) (U.S. Fish and Wildlife Service, 2000). The U.S. Army Corps of Engineers (USACE) has completed many construction projects along the Missouri River in an effort to increase the amount of available SWH as required by the amended "2000 Biological Opinion" (U.S. Fish and Wildlife Service, 2003). The "2000 Biological Opinion" defined SWH to be less than 1.5 meters (m) (approximately 5 feet [ft]) deep and with a current velocity less than 0.6 meters per second (m/s) (approximately 2 feet per second [ft/s]), and set forth guidelines for the amount of SWH that should be present on the river to meet the needs of endangered fish and bird species, that is, an average of 8–12 hectares (20–30 acres) per river mile. One of the primary means of creating SWH on the Missouri River is construction and restoration of chutes and backwaters (U.S. Army Corps of Engineers, 2011). Chutes are constructed by excavating a pilot channel through the overbank that allows water to flow from the river into the chute at the inlet and reenter the river downstream at the chute outlet. The chutes are then allowed to widen and meander in a controlled manner (U.S. Army Corps of Engineers, 2011). Backwaters are constructed by dredging out new or reconstructed SWH that has an inlet connected to the main channel of the river or to a chute. Backwaters differ from chutes in that they do not have an outlet.

To evaluate the amount of SWH within the river and the physical performance of SWH construction projects, the Pallid Sturgeon Habitat Assessment and Monitoring Program (HAMP) was implemented in 2005 (U.S. Army Corps of Engineers, 2010). The HAMP focuses on monitoring physical and biological responses to SWH creation and uses the information collected to improve future habitat creation efforts (U.S. Army Corps of Engineers, 2010). The initial efforts of the HAMP were focused on main channel habitat at designated river bends (Jalili and Pridal, 2010; U.S. Army Corps of Engineers, 2010), but were expanded in 2011 to include other types of SWH. The expanded monitoring included constructed or restored chutes and backwaters along the Missouri River. The U.S. Geological Survey (USGS) has cooperated with the USACE since 2005 to complete monitoring activities as part of the HAMP. These monitoring activities have focused on chutes and backwaters since 2011. Hydrographic data from these chute and backwater surveys will aid the USACE to assess the current (2011–13) amount of available SWH, the effects river flow have had on evolving morphology of the chutes and backwaters, and the functionality of the chute and backwater designs.

## Purpose and Scope

This report presents the survey data for seven chutes and three backwaters on the Missouri River, which provides yearly (2011–13) measurements for the U.S. Army Corps of Engineers to calculate geomorphic change to understand chute and backwater evolution. The report describes the survey methods used to collect hydrographic survey data, including Real-Time Kinematic (RTK) Global Navigation Satellite System (GNSS) data, bathymetric survey data, and discharge measurements at each of the survey sites. Hydrographic survey data are published along with this report in a comma-separated-values (csv) format with the associated metadata. Discharge measurements also are presented for each chute survey site. In this report, "hydrographic survey" will refer to the entire survey including RTK GNSS and bathymetric surveys. In this report, the term RTK GNSS surveys or data refer to all data points collected using RTK GNSS equipment, which includes data collected on the banks, in shallow water that was wadeable, and water-surface elevations. The term RTK GNSS topographic surveys or data only refer to data collected on the banks or in shallow water that was wadeable. Bathymetric surveys or data refer to depth data collected using an echosounder coupled with a single-beam transducer, positioned using differentially corrected GNSS, and converted to elevation using water-surface elevations measured with RTK GNSS equipment.

## Description of Survey Sites

Seven chutes and three backwaters were surveyed on the Missouri River in Nebraska, Iowa, and Missouri from 2011–2013 (fig. 1). Chutes surveyed included Council chute, Plattsmouth chute, Tobacco chute, Upper Hamburg chute, Lower Hamburg chute, Kansas chute, and Deroin chute. Backwaters surveyed included Ponca backwater, Plattsmouth backwater, and Langdon backwater. All survey sites were located between river mile (RM) 516.4 and 755.1 (system of river miles established by the USACE that originates at the mouth of the Missouri River at the confluence of the Missouri and Mississippi Rivers and is based on the 1960 channel) (table 1). Table 1 provides an approximate latitude and longitude at the mouth of each survey site as well as the nearest town located on the same side of the river as the site. The oldest site surveyed was Upper Hamburg chute, which was constructed in 1996; all other sites were constructed in 2000 or later (table 1). The length of the chutes surveyed ranged from 1,716–5,529 m, and the area of the backwaters surveyed ranged from 37,232–283,290 square meters ($m^2$) (table 1). Sand is the dominant bed substrate at most survey sites; however, some backwaters and slow flowing chutes had substantial amounts of fine sediment (silts and clays) as well.

Many of the banks of the survey sites are forested and those sites that are not forested typically have small trees and shrubs. The 2011 Missouri River flood left many of the trees dead and forested banks were challenging to survey because fallen trees made walking difficult; additionally, trees that fell in the water had to be avoided during bathymetric data collection.

The effects of the 2011 Missouri River flood on these chute and backwater habitat restoration sites were substantial (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013). As a result of the flood, several survey sites were damaged by deposition and erosion, and structures that were created to control flow were no longer functioning properly. Sites where sediment was deposited were Ponca backwater, Plattsmouth backwater and chute, and Langdon backwater. Sediment deposition at Plattsmouth chute was so great that the sustainability of the chute is uncertain. Sites that were eroded because of the flood in 2011 were Council chute, Upper and Lower Hamburg chute, Kansas chute, and Deroin chute. Deposition, erosion, and damage to site control structures (fig. 2) changed the structure and function of these sites, and many control structures required repair and maintenance (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013).


**Figure 1.** Location of the seven chutes and three backwaters on the Missouri River that were surveyed yearly, 2011–13.

**Table 1.** Location, construction information, and survey information for the seven chutes and three backwaters on the Missouri River in Nebraska, Iowa, and Missouri that were surveyed yearly, 2011–13.

[DMS, degrees, minutes, seconds; NAD 83, North American Datum of 1983; RM, river mile; m, miles; $m^2$, square miles; Nebr., Nebraska; %, percent; Mo., Missouri]

| Survey site (fig. 1) | Nearest town (located on the same side of the Missouri River) | Latitude (DMS) (NAD 83)[1] | Longitude (DMS) (NAD 83)[1] | Down-stream RM (1960) | Upstream RM (1960) | Year constructed | Area ($m^2$) or length (m) | Dates surveyed | Number of survey points | Coverage[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| Ponca backwater | Ponca, Nebr. | 42°37′14.68″ | 96°42′42.11″ | 753.0 | 755.1 | 2004 | 283,290 $m^2$ | 8/18/2011 | 42,431 | 100% |
| | | | | | | | | 10/23 and 11/14/2012 | 9,008 | 75% |
| | | | | | | | | 10/25/2013 | 368 | 50% |
| Council chute | Council Bluffs, Iowa | 41°16′26.69″ | 95°54′00.23″ | 616.8 | 617.8 | 2007 | 1,716 m | 8/8/2011 | 49,865 | 100% |
| | | | | | | | | 6/14/2012 | 31,554 | 100% |
| | | | | | | | | 7/7/2013 | 28,723 | 100% |
| Plattsmouth chute | Plattsmouth, Nebr. | 41°02′55.54″ | 95°52′36.67″ | 592.1 | 594.5 | 2008 | 3,679 m | 8/22–23/2011 | 89,224 | 100% |
| | | | | | | | | 7/12–13 and 8/23/2012 | 730 | 50% |
| | | | | | | | | 5/22–23/2013 | 1,038 | 50% |
| Plattsmouth backwater | Plattsmouth, Nebr. | 41°01′35.51″ | 95°52′14.13″ | 591.5 | 592.5 | 2008 | 202,350 $m^2$ | 11/11/2011 | 27,958 | 100% |
| | | | | | | | | 10/15/2012 | 15,653 | 50% |
| | | | | | | | | 10/31/2013 | 418 | 50% |
| Tobacco chute | Plattsmouth, Nebr. | 40°59′23.91″ | 95°51′05.57″ | 586.3 | 589.6 | 2002 | 4,709 m | 10/13–14/2011 | 49,478 | 100% |
| | | | | | | | | 7/11–12/2012 | 20,190 | 75% |
| | | | | | | | | 8/20–22/2013 | 72,344 | 100% |
| Upper Hamburg chute | Nebaska City, Nebr. | 40°37′04.03″ | 95°46′01.77″ | 552.2 | 555.9 | 1996 | 4,862 m | 8/24–25/2011 | 158,637 | 100% |
| | | | | | | | | 6/19–20 and 10/2–3/2012 | 97,924 | 75% |
| | | | | | | | | 6/26–27 and 7/3/2013 | 136,591 | 100% |
| Lower Hamburg chute | Hamburg, Iowa | 40°35′19.42″ | 95°45′26.54″ | 550.6 | 553.4 | 2005 | 4,023 m | 10/5–6 and 10/2011 | 108,133 | 100% |
| | | | | | | | | 7/9–10/2012 | 81,915 | 100% |
| | | | | | | | | 7/23–24/2013 | 54,221 | 75% |
| Kansas chute | Peru, Nebr. | 40°31′29.6″ | 95°43′46.33″ | 544.6 | 546.4 | 2005 | 2,789 m | 10/10/2011 | 40,913 | 100% |
| | | | | | | | | 6/21/2012 | 46,209 | 100% |
| | | | | | | | | 7/25/2013 | 16,370 | 50% |
| Langdon backwater | Nemaha, Nebr. | 40°19′43.57″ | 95°38′25.58″ | 529.0 | 531.4 | 2000 | 37,232 $m^2$ | 10/26/2011 | 20,885 | 100% |
| | | | | | | | | 8/8/2012 | 164 | 50% |
| | | | | | | | | 10/28/2013 | 182 | 50% |
| Deroin chute | Corning, Mo. | 40°16′43.16″ | 95°33′02.46″ | 516.4 | 520.5 | 2002 | 5,529 m | 9/7–9/2011 | 213,840 | 100% |
| | | | | | | | | 6/11–13/2012 | 168,090 | 100% |
| | | | | | | | | 6/18–20/2013 | 128,227 | 100% |

[1]Latitude and longitude were measured near the mouth of each chute or backwater.

[2]One-hundred percent (100%), full coverage of site with bathymetry alone or bathymetry and terrestrial Real-Ttime Kinetic (RTK) Global Navigation Satellite System (GNSS) surveys; 75%, limited bathymetry and full terrestrial RTK GNSS surveys; 50%, no bathymetry and full terrestrial RTK GNSS surveys or limited bathymetry and limited terrestrial RTK GNSS survey; 25%, limited terrestrial RTK GNSS surveys only.


**Figure 2.** Control structures at Missouri River chutes, 2011–13. *A*, Construction of a new inlet control structure at Deroin chute, 2013. *B*, Turbulent water around the inlet control structure and snags at Lower Hamburg chute, 2014. *C*, New control structure within Lower Hamburg chute, 2014. *D*, Limited bank protection on an eroded bank at Tobacco chute, 2014.

# Surveying Methods

The RTK GNSS and bathymetric surveys were completed on predetermined transects that were and spaced every 30.48 m (100 ft) at chute survey sites or in a 76.20-m grid (250-ft grid) at backwater survey sites. Survey data were collected along transects to delineate the channel cross section from top of bank to top of bank. Locations on transects where water depth was more than 1 m were surveyed using a single-beam echosounder to measure depth and a differentially corrected global positioning system (DGPS) with OmniSTARTM (OmniSTARTM, 2014) to measure location. These depth soundings were converted to elevation by subtracting the depth from the corresponding water-surface elevation, which was surveyed using RTK GNSS. All locations on the transects that were covered with less than 1 m of water were surveyed using RTK GNSS; these locations included top of bank, toe of bank, edge of water, sand bars, and near-shore areas. Discharge was measured at chute sites, both in the main channel of the Missouri River upstream from the chute and in the chute.

## Real-Time Kinematic Global Navigation Satellite System Surveying

The RTK GNSS surveys were completed using Ashtech Z–Xtreme receivers with Geodetic IV revision A antennas [global positioning system (GPS) only] in 2011. A description of this equipment, including accuracy information, is presented in Thompson and others (2007). For the 2012 and 2013 RTK GNSS surveys, Trimble® R8 GNSS receivers (Trimble® Navigation, 2009) were used. The stated accuracies of a Trimble® R8 GNSS receiver for kinematic surveying are 10 millimeters (mm) plus 1 part per million (ppm) root mean square (RMS) error for horizontal position and 20 mm plus 1 ppm RMS error for vertical position (Trimble® Navigation, 2009).

The RTK GNSS surveys consisted of one receiver remaining static as a “base station” (fig. 3), which provided position-correction information to rover receivers. The information sent from the base station to the rover receivers by radio link allowed the rover to more accurately measure its position. Before beginning a RTK GNSS survey, a bench mark (fig. 3) was physically established at each survey site, where the base station was set. Establishing permanent bench marks in an effective (radio link covering the entire survey site) and accessible location was a challenge because of 2011 floodwater, sandy soils, riparian vegetation, and construction activities. At most survey sites, a new USGS bench mark was set; however, at a few survey sites an existing USACE bench mark was used (table 2). Newly set bench marks were typically located on a high bank with limited tree cover along the middle part of the chute or backwater. If the radio link from the base station occupying the bench mark near the middle of the chute or backwater did not reach the upstream and downstream extent of the survey site, then an additional bench mark was established and the base station was moved to complete the survey. Some newly established USGS bench marks were monumented (with agency name, bench mark name, and establishment date imprinted) and some were nonmonumented (just a reference mark with no printed information). Monumented bench marks were typically 1-m long stakes with extendable anchors and a cap secured to the top, known as Feno Markers (Rydlund and Densmore, 2012). Nonmonumented bench marks were temporary, typically constructed using rebar or wooden stakes. The GNSS base stations occupied bench marks on top of a 2-m fixed-height tripod during RTK GNSS surveys to provide correction information to rover units. The coordinates, for bench marks with known survey-grade coordinates, were manually entered into the handheld datalogger when setting up the base station. If survey-grade coordinates (centimeter-level horizontal and vertical accuracy) were not known for the bench mark before using it for the RTK GNSS survey, then the base station was set using estimated coordinates. These coordinates were estimated from an average of 250 autonomous satellite readings. All satellite data logged by the base-station receiver were postprocessed through the National Geodetic Survey (NGS) Online Positioning Users Service (OPUS) (National Geodetic Survey, 2014) to determine survey-grade coordinates for the bench mark before or after the surveying was complete. Once the bench mark data were post-processed, offsets from the estimated coordinates to the survey-grade coordinates were calculated and the RTK GNSS data were corrected, that is, whenever estimated bench mark coordinates were used during surveying. Most of the surveys that established survey-grade coordinates on bench marks met the Level II, single-base static quality (Rydlund and Densmore, 2012).

The RTK GNSS surveying required USGS surveyors to walk along the banks with an RTK GNSS rover with an antenna mounted on a 2-m adjustable-height pole. The surveyors located each transect and collected elevation measurements by setting the foot of the pole flat on the riverbed or riverbank, leveling the pole, and taking a measurement. The RTK GNSS surveys included main-objective points to be surveyed at three positions on each transect, whenever possible: top of bank (left and right), toe of bank (left and right), and edge of water (left and right, denoted in the data file as “we”). Additional data points were collected between these main-objective points and into the channel to ensure a point spacing less than 15 m. The RTK GNSS surveys extended into the channel as far as water depths and substrates allowed for safe wading conditions. Water-surface elevations (denoted in the data file as “ws”) were surveyed at the same point at the beginning of the day and at the end of the day, and these locations extended upstream and downstream from the bathymetric survey data collected during that day. Similarly, water-surface elevations were collected at the upstream and downstream cross section of backwaters. This water-surface elevation collection method allowed the hydrographic surveying software to account for water-surface slope as well as changing river stage when converting the bathymetric survey depth to elevation.


**Figure 3.** Real-Time Kinematic (RTK) Global Navigation Satellite System (GNSS) base station and bench mark at Deroin chute, Missouri, 2013.

**Table 2.** Bench marks used for the hydrographic surveys on the Missouri River in Nebraska, Iowa, and Missouri, 2011–13.

[UTM, Universal Transverse Mercator; NAVD 88, North American Vertical Datum of 1988; USACE, U.S. Army Corp of Engineers]

| Site (fig. 1) | Year established | Northing, UTM Zone 15, meters | Easting, UTM Zone 15, meters | Orthometric height, NAVD 88 meters derived from Geoid12A | Ellipsoid height (meters) | Status (2013) | Mark |
|---|---|---|---|---|---|---|---|
| Ponca backwater | 2013 | 4725576.282 | 195460.983 | 336.731 | 311.139 | Most currently used | Monumented. |
| Ponca backwater | 2012 | 4722089.617 | 196299.491 | 407.442 | 381.862 | Destroyed | Not monumented. |
| Ponca backwater | 2011 | 4725902.234 | 195226.439 | 313.358 | 338.919 | Destroyed | Monumented. |
| Council chute | 2012 | 4573085.908 | 256613.727 | 297.584 | 269.955 | Most currently used | Monumented. |
| Council chute | 2011 | 4572909.935 | 256555.252 | 274.945 | 302.545 | Destroyed | Not monumented. |
| Plattsmouth chute and backwater | 2012 | 4545882.493 | 258556.596 | 292.012 | 264.628 | Most currently used | Monumented. |
| Plattsmouth chute | 2011 | 4546469.125 | 258539.769 | 268.833 | 296.179 | Destroyed | Monumented. |
| Plattsmouth backwater | 2011 | 4544483.755 | 258564.545 | 265.473 | 292.851 | Destroyed | Monumented. |
| Tobacco chute | 2013 | 4539215.396 | 260363.388 | 289.340 | 261.727 | Most currently used | Monumented. |
| Tobacco chute | 2013 | 4540781.372 | 260144.825 | 290.162 | 262.605 | Most currently used | Monumented. |
| Tobacco chute | 2012 | 4539571.572 | 260086.958 | 290.472 | 262.883 | Destroyed | Monumented. |
| Tobacco chute | 2011 | 4539452.710 | 260171.527 | 262.585 | 290.150 | Destroyed | Monumented. |
| Upper Hamburg chute | 2012 | 4497206.854 | 265796.854 | 279.217 | 249.519 | Most currently used | Monumented. |
| Upper Hamburg chute | 2011 | 4497875.482 | 265922.157 | 250.497 | 280.170 | Destroyed | Monumented. |
| Lower Hamburg chute | Unknown USACE bench mark | 4495114.054 | 266681.501 | 280.969 | 251.212 | Most currently used | Monumented. |
| Kansas chute | 2013 | 4489284.911 | 269256.913 | 277.417 | 247.524 | Most currently used | Not monumented. |
| Kansas chute | 2012 | 4489280.641 | 269257.467 | 277.515 | 247.622 | Destroyed | Not monumented. |
| Kansas chute | 2011 | 4489420.402 | 269202.841 | 247.511 | 277.388 | Destroyed | Monumented. |
| Langdon backwater | Unknown USACE bench mark | 4467794.603 | 275795.974 | 271.617 | 241.455 | Most currently used | Monumented. |
| Deroin chute | 2013 | 4459728.455 | 284302.578 | 268.431 | 237.964 | Most currently used | Monumented. |
| Deroin chute | 2012 | 4459727.306 | 284304.971 | 268.513 | 238.046 | Destroyed | Monumented. |
| Deroin chute | 2011 | 4459726.771 | 284305.552 | 238.393 | 268.852 | Destroyed | Monumented. |

Terrestrial RTK GNSS surveys were not necessary in 2011 at Council chute, Plattsmouth chute, Upper Hamburg chute, and Deroin chute because floodwater stages exceeded the top of bank allowing the inundated overbank areas to be surveyed completely by boat. The RTK GNSS surveys at these sites in 2011 were only used to collect water-surface elevations. In 2012 and 2013, some chutes and backwaters were either dry or the water was very shallow (less than 1 m) and were surveyed using only RTK GNSS.

Data collected in 2011 were referenced to the North American Datum of 1983 (NAD 83), Continuously Operating Reference Stations 1996 (CORS96), and elevation was referenced to the North American Vertical Datum of 1988 (NAVD 88) as calculated using GEOID09 (National Geodetic Survey, 2011) and the Geodetic Reference System 1980 (GRS 80) ellipsoid. Survey data collected in 2012 at Upper Hamburg chute, Lower Hamburg chute, and Langdon backwater were all referenced to NAD 83 (CORS96) and used GEOID09. In July 2012, NGS began using a new realization of the NAD 83 datum in conjunction with an updated geoid model. Therefore, data collected at all other chutes and backwaters in 2012 and all data collected in 2013 were referenced to the updated datum of NAD 83 (2011) and GEOID12A (National Geodetic Survey, 2012).

The RTK GNSS data collected during this survey met a real-time positioning quality of Level IV (Rydlund and Densmore, 2012). No checks on published bench marks were included in the surveys because of the remote location and the intended application of the data. Likewise, no main-objective points were re-observed, and were not completed when surveying each main-objective point. Instead, transect data were collected for topography only (Rydlund and Densmore, 2012). Daily quality assurance and quality control (QA/QC) procedures included checking each rover in at the beginning of the day and out at the end of the day over a common check point. At some sites, this common check point was a second bench mark with known horizontal and vertical survey-grade coordinates. Static base-station receivers logged satellite data every survey day, and these data were post-processed using the NGS OPUS to verify the base-station setup. When a water-surface elevation was surveyed for converting bathymetric data, three data point replicates were collected in succession. Re-initialization (reacquisition of satellite communication) (Rydlund and Densmore, 2012) was completed before each replicated point was collected, and all elevations were compared. Additional replicate points were collected if the range of elevations of the first three data points exceeded 0.03 m.

## Bathymetric Surveying

Bathymetric survey data were collected along survey transects using a DGPS unit with OmniSTAR VBSTM (OmniSTAR, 2014). HYPACK® data acquisition software (HYPACK, Inc., 2011) was used to create survey transects for data collection and for boat navigation. Centerline files were created from channel locations determined from aerial imagery by creating points at locations in the chutes and backwaters that represented midpoints between high banks. Survey transects were created using the "centerline offset" function in HYPACK®; transects were spaced at 30.48-m intervals (100-ft intervals) along the centerline and oriented perpendicular to the flow of water. At backwater sites, a centerline was used to create both perpendicular and parallel transects that were spaced 76.20 m (250 ft) apart to construct the survey grid.

The bathymetric survey data were collected using an Innerspace 456 dual-frequency echosounder powering a 200-kilohertz (kHz) transducer with an 8-degree beam angle. More specifications and information about this echosounder were reported in Kress and others (2005) and Thompson and others (2007).

QA/QC procedures were followed during bathymetric data collection. Each day the speed of sound was directly measured using a speed-of-sound depth-profiling probe (averaged through the water column) or was calculated based on surface water temperature. The speed-of-sound data were entered into the echosounder so that depth could accurately be calculated from time of travel. In addition, bar checks, or manual water depth, was measured twice daily to check the accuracy of the echosounder. These bar checks were performed typically at depths 1.5 and 2.1 m (5 and 7 ft) or, in survey areas with deeper water, at 1.5 and 3 m (5 and 10 ft) of water. During data collection, the echosounder operator reviewed the depth data in real time and would adjust the gain, depth range, and power on the echosounder to increase the accuracy of the depth soundings. Under certain conditions, it was occasionally impossible to extend the RTK GNSS survey down the bank to the edge of water, resulting in incomplete survey coverage between the RTK GNSS survey and the bathymetry survey. An edge-of-water offset was collected in HYPACK® when the RTK GNSS surveys could not be collected to the edge of the water. The boat operator maintained the boat position as close to the edge of the water as possible and measured the edge-of-water distance offset using a handheld laser rangefinder. The offset was used by HYPACK® to collect an additional data-point offset along the survey transect at the distance entered with a depth reading of zero. The boat operator navigated along each transect with usually no more than 6.1 m (20 ft) of deviation in either direction so that surveyed elevations were collected at nearly the same transect for each year of the study to allow reliable analysis of change. If the boat deviated more than 6.1 m from a transect, that transect usually was resurveyed within the tolerance limits. However, fallen trees, debris piles, and control structures limited accessibility at some transects requiring occasional deviations from the transect exceeding 6.1 m. When obstacles were located on a transect, data were collected upstream or downstream from the obstacle as close to the transect as possible. All final data are published, including data points that were more than 6.1 m from the transects. The echosounder operator recorded metadata for each survey line, including data-file name, direction of survey, description of debris, and other notes.

Following data collection, USGS surveyors used HYPACK® to manually edit the depth data. Data filters were rarely used. Instead, erroneous depth data or data outliers were manually deleted to produce a clean depth dataset. In addition to entering the speed of sound into the echosounder during data collection, speed-of-sound profiles were collected in backwaters where stratification was possible. During data processing, these profiles were reviewed to see if stratification of the water column was evident in the backwaters during the time of the survey. Stratification was not observed during the surveys of any backwaters; therefore, the speed-of-sound profiles were not entered into HYPACK® to correct the depth soundings. Once manual editing of the depth data was complete, water-surface elevations collected using RTK GNSS surveys were used to convert the depth data to riverbed elevation. Water-surface elevations were applied to the data as HYPACK® tide files. Each tide file contained water-surface elevation at the start and end of one day from one location. All the tide files from one survey day were used, along with their location in relation to the centerline, by HYPACK® to convert the depth data to riverbed elevation. This method allows HYPACK® to calculate water-surface slope throughout the survey reach as well as water level change throughout the survey day. This same process was repeated for depth data from each survey day, along with the corresponding tide files for that day.

## Discharge Measurements

Discharge was measured using an acoustic Doppler current profiler (ADCP) at each chute. Discharge was measured in the chutes and main channel of the Missouri River daily in conjunction with bathymetric surveys. If a chute did not have adequate flow for bathymetric surveys, discharge was not measured. In a few instances, discharge was not measured at a chute site because of time constraints, weather conditions, or equipment malfunction. Discharge was measured in the main channel of the Missouri River upstream from the chute inlet. Discharge was measured in the chute at varying locations depending on where bathymetric surveying was taking place that day and where suitable channel cross-sections were located. The ADCP used to measure discharge was a Teledyne Rowe Deines Instruments (San Diego, Calif.) 1200-kHz Rio Grande. The ADCP measurement procedures and QA/QC followed those described in Mueller and Wagner (2009).

# Hydrographic Survey of the Chutes and Backwaters

Hydrographic surveys of the chutes and backwaters were completed from August through November 2011, from June through November 2012, and from May through October 2013. During the 2011 surveys, water was high at all sites because of major flooding on the Missouri River. Therefore, several sites did not require RTK GNSS topographic surveys because even high bank areas were inundated with floodwater more than 1 m deep, allowing the sites to be surveyed by boat. Even though many sites did not need RTK GNSS topographic surveys in 2011, RTK GNSS was still used at all sites in 2011 to collect water-surface elevation data to convert the bathymetric data to riverbed elevation. Although the 2012 surveys were completed during a drought, it had little to no effect on streamflow at survey sites because a constant discharge from Gavins Point Dam was maintained during the navigation season. In 2013, the drought had subsided, but discharge fluctuated during the survey periods making access by boat to some areas in some chutes impossible because of shallow water.

Bathymetric survey data and RTK GNSS survey data are published as part of this report as tabular data files in comma-separated-values (csv) format with associated metadata (see appendix for file names and an example of metadata for both a backwater and a chute). There is one csv file for each survey site that contains both RTK GNSS survey data and bathymetric survey data for the site from all 3 years. The tabular information contained in each csv file consists of seven fields (columns): northing (Universal Transverse Mercator [UTM] zone 15 North), in meters; easting (UTM zone 15 North), in meters; orthometric height (NAVD 88), in meters; date surveyed, survey method, horizontal datum, and Geoid model.

The split of total discharge between the Missouri River main channel and the chutes was consistent with observed effects of the 2011 Missouri River flood (deposition, erosion, degradation of entrance control structures, flanking of internal control structures, chute widening) at most chutes as noted by the U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service (2013). Many chute entrances and control structures were damaged by floodwater in 2011, allowing a larger percent of the Missouri River total discharge to flow through the chute than originally intended in the chute design. The designed flow split varies by chute, but is typically 10–12 percent of the total discharge (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013). The USACE repaired many of these chutes in 2012 and 2013, and effects of these repairs as well as changes in total discharge can be seen in the discharge split between the Missouri River main channel and the chute in data collected for this study. It is likely that the repairs affected the water depths and riverbed elevations not only at the construction site, but throughout the chutes and backwaters—however, there is no way to distinguish the changes contributed specifically to the repairs from general post-flood geomorphic changes. Also, survey data could not be collected over newly built and repaired structures because of safety concerns (rough water flowing over the new structures, heavy machinery still working on structures, and difficultly walking on new structures because the rip-rap was still settling into place). In addition to total discharge and discharge splits, the mean velocity of the cross section collected during each discharge measurement is reported. Cross sections selected for discharge measurements typically were uniform, narrow areas of the chute, and are not necessarily representative of the entire chute, but represented the best locations to accurately measure discharge. Therefore, even when mean velocities of discharge measurement cross sections were greater than 0.6 m/s, there were likely areas along the cross section and many areas throughout the chute that did have flow velocities less than 0.6 m/s.

## Ponca Backwater

Ponca backwater was surveyed on August 18, 2011; October 23 and November 14, 2012; and October 25, 2013 (table 1 and figs. 1 and 4). Surveyed elevations ranged from 328 to 337 m in 2011, from 330 to 337 m in 2012, and from 332 to 336 m in 2013. In 2011, RTK GNSS topographic surveys were not collected because the entire backwater area was inundated with floodwater, allowing all areas to be surveyed by boat. The 2011 survey was completed near the discharge peak of the long-duration flood. In 2012, both RTK GNSS and limited (fig. 4) bathymetric survey data were collected and in 2013 only RTK GNSS data were collected (table 1). In 2012, bathymetric surveying was limited because the entrance to the larger branch of the backwater was too shallow for boat navigation. Therefore, the survey coverage in 2011 was much greater than in 2012 and 2013 because areas that were too deep to wade and not accessible by boat were not surveyed in 2012 and 2013.

**Figure 4.** Hydrographic survey data for Ponca backwater near Ponca, Nebraska, 2011–13. Available at http://pubs.usgs.gov/ds/0909/downloads/ds909_figure4.pdf.

## Council Chute

Council chute was surveyed on August 8, 2011; June 14, 2012; and July 7, 2013 (table 1 and figs. 1 and 5). Surveyed elevations ranged from 280 to 299 m in 2011, from 281 to 300 m in 2012, and from 282 to 299 m in 2013. In 2011, RTK GNSS topographic surveys were not completed because the high banks of the chute were inundated with floodwater, allowing them to be surveyed by boat.

Council chute was substantially deepened, and the island separating it from the river was mostly eroded during the 2011 Missouri River flood (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013). The inlet-control structure, island revetment, and internal chute-control structures were repaired after the 2011 Missouri River flood and before the 2012 surveys (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013).

Discharge measured in Council chute ranged from 69–855 cubic meters per second ($m^3/s$) and mean velocity ranged from 0.3–1.1 m/s (table 3). Discharges measured at Council chute indicate that in 2011 the chute was carrying 20.1 percent of the total Missouri River discharge; however, the chute was only carrying 6.5 percent of total Missouri River discharge in 2012 (table 3). Total Missouri River discharge in 2012 was about 25 percent of the total Missouri River discharge measured during the 2011 surveys.

**Figure 5.** Hydrographic survey data for Council chute near Council Bluffs, Iowa, 2011–13. Available at http://pubs.usgs.gov/ds/0909/downloads/ds909_figure5.pdf.

**Table 3.** Discharge measurements collected in the Missouri River above Council chute and in Council chute, Council Bluffs, Iowa, 2011–12.

[$m^3/s$, cubic meters per second; m/s, meters per second; NA, no discharge measured]

| Date | Discharge ($m^3/s$) | Location | Percent of total Missouri River discharge | Mean velocity (m/s) |
|---|---|---|---|---|
| 8/17/2011 | 4,260 | Missouri River above Council chute | 100.0 | 1.5 |
| 8/17/2011 | 855 | Council chute | 20.1 | 1.1 |
| 6/14/2012 | 1,060 | Missouri River above Council chute | 100.0 | 1.0 |
| 6/14/2012 | 69 | Council chute | 6.5 | 0.3 |
| 7/7/2013 | NA | Missouri River above Council chute | NA | NA |
| 7/7/2013 | NA | Council chute | NA | NA |

## Plattsmouth Chute

Plattsmouth chute was surveyed on August 22 and 23, 2011; July 12 and 13, and August 23, 2012; and May 22 and 23, 2013 (table 1 and figs. 1 and 6). Surveyed elevations ranged from 278 to 293 m in 2011, from 284 to 296 m in 2012, and from 287 to 293 m in 2013. In 2011, RTK GNSS topographic data were not collected because the entire backwater area was inundated with floodwater, allowing all areas to be surveyed by boat. In 2012, no bathymetric survey data were collected because the chute was not connected to the river as a result of deposition at the chute entrance from the 2011 Missouri River flood (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013), and the channel was almost dry with only a few isolated areas of water. In 2013, no bathymetric survey data were collected because water levels were not greater than 1 m despite a new pilot channel constructed during spring 2013. Even though riverbed elevation ranges may suggest deposition occurred from 2011 to 2012–2013, the lower elevations surveyed in 2011 were located at small scour holes and at the mouth of the chute almost in the main channel of the Missouri River. These areas were inaccessible for RTK GNSS survey crews during the 2012 and 2013 surveys. When comparing elevations in the chute channel, surveys from 2011 and 2012 documented similar elevations, but the 2013 riverbed was approximately 0.5–3 m lower throughout 60 percent of the chute channel, most likely because of the dredge work completed in the channel (U.S. Army Corps of Engineers and other, 2013).

Discharge measured in Plattsmouth chute ranged from 362–405 $m^3/s$ and mean velocity ranged from 1.0–1.2 m/s (table 4). Discharge measured in 2011at Plattsmouth chute documented that the chute was carrying approximately 9 percent of the total Missouri River discharge; however, in 2012 and 2013 water depth was too low to measure discharge in the chute with an ADCP.

**Figure 6.** Hydrographic survey data for Plattsmouth chute near Plattsmouth, Nebraska, 2011–13. Available at http://pubs.usgs.gov/ds/0909/downloads/ds909_figure6.pdf.

## Plattsmouth Backwater

Plattsmouth backwater was surveyed on November 11, 2011; October 15, 2012; and October 31, 2013 (table 1 and figs. 1 and 7). Surveyed elevations ranged from 285 to 292 m in 2011, from 285 to 292 m in 2012, and from 286 m to 292 m in 2013. No bathymetric survey data were collected in 2013 because wet soil and crops in the surrounding field limited access to the site by vehicle so a boat could not be launched; consequently, only RTK GNSS surveys were completed.

**Figure 7.** Hydrographic survey data for Plattsmouth backwater near Plattsmouth, Nebraska, 2011–13. Available at http://pubs.usgs.gov/ds/0909/downloads/ds909_figure7.pdf.

## Tobacco Chute

Tobacco chute was surveyed on October 13 and 14, 2011; July 11 and 12, 2012; and August 20–22, 2013 (table 1 and figs. 1 and 8). Surveyed elevations ranged from 276 to 303 m in 2011, 278 to 293 m in 2012, and 277 to 293 m in 2013. Maximum elevations from 2011 were surveyed on the bluff of the Missouri River that functions as the high bank of the chute. In 2012 and 2013, data on the high bluff were not collected. During the 2012 survey, limited bathymetric data were collected because construction activity blocked the inlet of the chute, disconnecting it from the river. As a result, most of the water in the chute was too shallow for bathymetric surveys. Where possible, RTK GNSS surveys were collected instead.

**Table 4.** Discharge measurements collected in the Missouri River above Plattsmouth chute and in Plattsmouth chute near Plattsmouth, Nebraska, 2011.

[$m^3/s$, cubic meters per second; m/s, meters per second; NA, no discharge measured]

| Date | Discharge ($m^3/s$) | Location | Percent of total Missouri River discharge | Mean velocity (m/s) |
|---|---|---|---|---|
| 8/22/2011 | 4,490 | Missouri River above Plattsmouth chute | 100.0 | 1.4 |
| 8/22/2011 | 405 | Plattsmouth chute | 9.0 | 1.2 |
| 8/23/2011 | 3,920 | Missouri River above Plattsmouth chute | 100.0 | 1.4 |
| 8/23/2011 | 362 | Plattsmouth chute | 9.2 | 1.0 |
| 7/12–13 and 8/23/2012 | NA | Missouri River above Plattsmouth chute | NA | NA |
| 7/12–13 and 8/23/2012 | NA | Plattsmouth chute | NA | NA |
| 5/22–23/2013 | NA | Missouri River above Plattsmouth chute | NA | NA |
| 5/22–23/2013 | NA | Plattsmouth chute | NA | NA |

In 2013, construction on the chute was completed, and new sections of chute channel had been constructed (fig. 8). These new sections of the chute were included in the 2013 survey.

Measured discharge in Tobacco chute ranged from 15–62 $m^3/s$ and mean velocity ranged from 0.7–0.8 m/s (table 5). Measured discharge at Tobacco chute documented that in 2011 the chute was carrying 3.3–3.6 percent of the total Missouri River discharge (table 5). Because the chute was disconnected from the river flow in 2012, discharge was not measured in the chute. In 2013, when total Missouri River discharge was about 50 percent of the October 2011 total Missouri River discharge, the chute was carrying 1.8–1.9 percent of the total Missouri River discharge (table 5).

**Figure 8.** Hydrographic survey data for Tobacco chute near Plattsmouth, Nebraska, 2011–13. Available at http://pubs.usgs.gov/ds/0909/downloads/ds909_figure8.pdf.

## Upper Hamburg Chute

Upper Hamburg chute was surveyed on August 24 and 25, 2011; June 19 and 20 and October 2 and 3, 2012; and June 26 and 27 and July 3, 2013 (table 1 and figs. 1 and 9). Surveyed elevations ranged from 259 to 279 m in 2011, from 262 to 282 m in 2012, and from 262 to 284 m in 2013. In 2011, RTK GNSS topographic data were not collected because the entire area was inundated with floodwater, allowing all areas to be surveyed by boat. Construction to repair scour holes and damaged flow-control structures from the 2011 flood (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013) was in progress during the 2012 surveys. During this time, the mouth of the chute was disconnected from the river to control the amount of water entering the chute. The upstream 0.65 km of the chute channel was not surveyed in 2012 because the water was too deep for RTK GNSS surveys, and the water levels were too low to navigate around or over control structures to collect bathymetric data. In 2013, construction on the chute was complete, and hydrographic survey data of the entire chute were collected.

Measured discharge in Upper Hamburg chute ranged from 24–911 $m^3/s$ and mean velocity ranged from 0.1–1.0 m/s (table 6). In 2011, Upper Hamburg chute was carrying almost 30 percent of the total Missouri River discharge (table 6). In June 2012, before repairing the flood damage, total Missouri River discharge was 38 percent of the 2011 total Missouri River discharge, and the chute was carrying 10 percent. During repair work at the end of 2012 and after the repairs in 2013 total Missouri River discharge was similar to 2012 total Missouri River discharge, but the chute was carrying only approximately 2–3 percent (table 6).

**Figure 9.** Hydrographic survey data for Upper Hamburg chute near Nebraska City, Nebraska, 2011–13. Available at http://pubs.usgs.gov/ds/0909/downloads/ds909_figure9.pdf.

## Lower Hamburg Chute

Lower Hamburg chute was surveyed on October 5, 6, and 10, 2011; July 9 and 10, 2012; and July 23 and 24, 2013 (table 1 and figs. 1 and 10). Surveyed elevations ranged from 260 to 281 m in 2011, from 259 to 281 m in 2012, and from 259 to 281 m in 2013. Construction on the chute to repair damage caused by the 2011 Missouri River flood included restriction of flow into the chute while a new rock entrance

**Table 5.** Discharge measurements collected in the Missouri River above Tobacco chute and in Tobacco chute near Plattsmouth, Nebraska, 2011–13.

[$m^3/s$, cubic meters per second; m/s, meters per second; NA, no discharge measured]

| Date | Discharge ($m^3/s$) | Location | Percent of total Missouri River discharge | Mean velocity (m/s) |
|---|---|---|---|---|
| 10/13/2011 | 1,730 | Missouri River above Tobacco chute | 100.0 | 1.4 |
| 10/13/2011 | 62 | Tobacco chute | 3.6 | 0.8 |
| 10/14/2011 | 1,660 | Missouri River above Tobacco chute | 100.0 | 1.2 |
| 10/14/2011 | 54 | Tobacco chute | 3.3 | 0.7 |
| 7/11/2012 | 1,020 | Missouri River above Tobacco chute | 100.0 | 1.2 |
| 7/11/2012 | NA | Tobacco chute | NA | NA |
| 8/20/2013 | 839 | Missouri River above Tobacco chute | 100.0 | 1.1 |
| 8/20/2013 | 15 | Tobacco chute | 1.8 | 0.7 |
| 8/22/2013 | 877 | Missouri River above Tobacco chute | 100.0 | 1.1 |
| 8/22/2013 | 16 | Tobacco chute | 1.9 | 0.8 |

**Table 6.** Discharge measurements collected in the Missouri River above Upper Hamburg chute and in Upper Hamburg chute near Nebraska City, Nebraska, 2011–13.

[$m^3/s$, cubic meters per second; m/s, meters per second]

| Date | Discharge ($m^3/s$) | Location | Percent of total Missouri River discharge | Mean velocity (m/s) |
|---|---|---|---|---|
| 8/24/2011 | 3,120 | Missouri River above Upper Hamburg chute | 100.0 | 1.7 |
| 8/24/2011 | 911 | Upper Hamburg chute | 29.2 | 1.0 |
| 8/25/2011 | 2,940 | Missouri River above Upper Hamburg chute | 100.0 | 1.6 |
| 8/25/2011 | 823 | Upper Hamburg chute | 28.0 | 0.9 |
| 6/19/2012 | 1,190 | Missouri River above Upper Hamburg chute | 100.0 | 1.1 |
| 6/19/2012 | 119 | Upper Hamburg chute | 10.0 | 0.4 |
| 10/2/2012 | 1,080 | Missouri River above Upper Hamburg chute | 100.0 | 1.1 |
| 10/2/2012 | 30 | Upper Hamburg chute | 2.8 | 0.1 |
| 6/26/2013 | 1,180 | Missouri River above Upper Hamburg chute | 100.0 | 1.2 |
| 6/26/2013 | 32 | Upper Hamburg chute | 2.7 | 0.1 |
| 7/3/2013 | 1,140 | Missouri River above Upper Hamburg chute | 100.0 | 1.2 |
| 7/3/2013 | 24 | Upper Hamburg chute | 2.1 | 0.1 |

structure and two new internal rock control structures were built (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013). The USGS is uncertain when these construction activities began and when all construction was completed. In 2013, a complete hydrographic survey was not possible because low water levels over control structures restricted boat access to part of the chute. Some of these inaccessible areas contained water that was too deep to collect RTK GNSS survey data by wading and therefore were not surveyed.

Measured discharge in Lower Hamburg chute ranged from 13–314 $m^3/s$ and mean velocity ranged from 0.1–0.7 m/s (table 7). Lower Hamburg chute was carrying 24.4–26.4 percent of the total Missouri River discharge in 2011. In 2012 and 2013, the total Missouri River discharge was approximately 70 percent of the 2011 total Missouri River discharge and the chute carried approximately 1–5 percent (table 7).

**Figure 10.** Hydrographic survey data for Lower Hamburg chute near Hamburg, Iowa, 2011–13. Available at http://pubs.usgs.gov/ds/0909/downloads/ds909_figure10.pdf.

## Kansas Chute

Kansas chute was surveyed on October 10, 2011; June 21, 2012; and July 25, 2013 (table 1 and figs. 1 and 11). Surveyed elevations ranged from 263 to 277 m in 2011, from 261 to 278 m in 2012, and from 265 to 277 m in 2013. Damage caused by the 2011 Missouri River flood (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013) on the chute was repaired before the 2012 survey. In 2013, more than one-half of the chute was not surveyed because low water levels made navigation over control structures impossible, leaving the area inaccessible by boat. Many of the inaccessible areas also were too deep for RTK GNSS surveys by wading.

Measured discharge in Kansas chute ranged from 40–312 $m^3/s$ and mean velocity ranged from 0.3–1.4 m/s (table 8). Kansas chute was carrying more than 20 percent of the total Missouri River discharge as the 2011 flood receded. In 2012 and 2013, the total Missouri River discharge was 71–89 percent of the 2011 total Missouri River discharge and the chute carried approximately 4–6 percent (table 8). Discharge was measured in 2012 and 2013 after repairs had been made to the chute.

**Figure 11.** Hydrographic survey data for Kansas chute near Peru, Nebraska, 2011–13. Available at http://pubs.usgs.gov/ds/0909/downloads/ds909_figure11.pdf.

## Langdon Backwater

Langdon backwater was surveyed on October 26, 2011; August 8, 2012; and October 28, 2013 (table 1 and fig. 12). Surveyed elevations ranged from 267 to 271 m in 2011, 267 to 274 m in 2012, and 267 to 269 m in 2013. Water levels were low in Langdon backwater when surveyed in 2011 and the backwater was not connected to the river, most likely because of sedimentation at the inlet of the backwater attributed to the 2011 flood (U.S. Army Corps of Engineers and U.S. Fish and

Wildlife Service, 2013). There was sufficient water to complete a partial bathymetric survey in 2011, in addition to the RTK GNSS topographic surveys, which allowed survey data to be collected along all planned transects. In 2012 and 2013, no bathymetric-survey data were collected because most of the backwater was dry; thus, RTK GNSS surveying techniques were used instead.

**Figure 12.** Hydrographic survey data for Langdon backwater near Nemaha, Nebraska, 2011–13. Available at http://pubs.usgs.gov/ds/0909/downloads/ds909_figure12.pdf.

## Deroin Chute

Deroin chute was surveyed on September 7, 8, and 9, 2011; June 11, 12, and 13, 2012; and June 18, 19, and 20, 2013 (table 1 and figs. 1 and 13). Surveyed elevations ranged from 250 to 267 m in 2011, from 248 to 276 m in 2012, and from 249 to 273 m in 2013. In 2011, RTK GNSS topographic surveys were not collected because the entire backwater area was inundated with floodwater, allowing all areas to be surveyed by boat. A backwater connected to the chute was surveyed in 2011 but was not surveyed in subsequent years because it no longer was connected to the chute. Before the 2013 survey, construction began on the chute to repair damage caused by the 2011 Missouri River flood (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013). In 2013, it was not possible to collect bathymetric-survey data in part of

**Table 7.** Discharge measurements collected in the Missouri River above Lower Hamburg chute and in Lower Hamburg chute near Hamburg, Iowa, 2011–13.

[$m^3/s$, cubic meters per second; m/s, meters per second]

| Date | Discharge ($m^3/s$) | Location | Percent of total Missouri River discharge | Mean velocity (m/s) |
|---|---|---|---|---|
| 10/5/2011 | 1,190 | Missouri River above Lower Hamburg chute | 100.0 | 1.1 |
| 10/5/2011 | 314 | Lower Hamburg chute | 26.4 | 0.7 |
| 10/6/2011 | 1,270 | Missouri River above Lower Hamburg chute | 100.0 | 1.2 |
| 10/6/2011 | 311 | Lower Hamburg chute | 24.4 | 0.6 |
| 7/9/2012 | 943 | Missouri River above Lower Hamburg chute | 100.0 | 1.1 |
| 7/9/2012 | 47 | Lower Hamburg chute | 4.9 | 0.3 |
| 7/23/2013 | 923 | Missouri River above Lower Hamburg chute | 100.0 | 1.1 |
| 7/23/2013 | 13 | Lower Hamburg chute | 1.4 | 0.1 |
| 7/24/2013 | 909 | Missouri River above Lower Hamburg chute | 100.0 | 1.1 |
| 7/24/2013 | 14 | Lower Hamburg chute | 1.6 | 0.1 |

**Table 8.** Discharge measurements collected in the Missouri River above Kansas chute and in Kansas chute near Peru, Nebraska, 2011–13.

[$m^3/s$, cubic meters per second; m/s, meters per second]

| Date | Discharge ($m^3/s$) | Location | Percent of total Missouri River discharge | Mean velocity (m/s) |
|---|---|---|---|---|
| 10/12/2011 | 1,330 | Missouri River above Kansas chute | 100.0 | 1.1 |
| 10/12/2011 | 312 | Kansas chute | 23.5 | 1.4 |
| 6/21/2012 | 1,150 | Missouri River above Kansas chute | 100.0 | 1.1 |
| 6/21/2012 | 70 | Kansas chute | 6.1 | 0.4 |
| 7/25/2013 | 942 | Missouri River above Kansas chute | 100.0 | 1.0 |
| 7/25/2013 | 40 | Kansas chute | 4.3 | 0.3 |

the chute because ongoing construction was a safety concern. Also, a second short length of the chute was not surveyed in 2013 because of weather conditions and time constraints.

Measured discharge in Deroin chute ranged from 323–727 $m^3/s$ and mean velocity ranged from 0.8–1.1 m/s (table 9). Deroin chute was carrying was 22.8 to 26.5 percent of the total Missouri River discharge (table 9). Although the highest discharge for this site (in both the Missouri River and the chute) was measured in 2011, the percentage of total Missouri River discharge carried by the chute was smaller than in 2012 and 2013 (table 9).

**Figure 13.** Hydrographic survey data for Deroin chute near Corning, Missouri, 2011–13. Available at http://pubs.usgs.gov/ds/0909/downloads/ds909_figure13.pdf.

## Summary

The U.S. Geological Survey (USGS), in cooperation with the U.S. Army Corps of Engineers (USACE), Omaha District, completed hydrographic surveys of seven chutes and three backwaters yearly during 2011–13. These chutes and backwaters were constructed by the USACE to increase the amount of available shallow water habitat to support threatened and endangered species, as required by the amended "2000 Biological Opinion" on the operation of the Missouri River main-stem reservoir system. Chutes surveyed included Council chute, Plattsmouth chute, Tobacco chute, Upper Hamburg chute, Lower Hamburg chute, Kansas chute, and Deroin chute. Backwaters surveyed included Ponca backwater, Plattsmouth backwater, and Langdon backwater. Hydrographic surveys of the chutes and backwaters occurred August through November 2011, June through November 2012, and May through October 2013. During the 2011 surveys, high water was present at all sites because of major flooding on the Missouri River. Bathymetric survey data and Real-Time Kinematic Global Navigation Satellite System (RTK GNSS) survey data are published along with this report in comma-separated-values (csv) format with associated metadata. In this report, "hydrographic survey" refers to the entire survey including both RTK GNSS and bathymetric surveys. In this report, the term RTK GNSS surveys or data refer to all data points collected using RTK GNSS equipment that includes data collected on the banks, in shallow water that was wadeable, and water-surface elevations. Bathymetric surveys or data refer to depth data collected using a echosounder, positioned using differentially corrected global positioning system (GPS), and converted to elevation using water-surface elevations measured with RTK GNSS equipment.

Hydrographic survey data were collected along transects to delineate the channel cross section from top of bank to top of bank. Hydrographic surveys over the entire transect were not always collected because of low water over control structures, equipment malfunction, time constraints,

**Table 9.** Discharge measurements collected in the Missouri River above Deroin chute and in Deroin chute near Corning, Missouri, 2011–13.

[$m^3/s$, cubic meters per second; m/s, meters per second]

| Date | Discharge ($m^3/s$) | Location | Percent of total Missouri River discharge | Mean velocity (m/s) |
|---|---|---|---|---|
| 9/7/2011 | 3,180 | Missouri River above Deroin chute | 100.0 | 1.3 |
| 9/7/2011 | 727 | Deroin chute | 22.8 | 1.1 |
| 6/11/2012 | 1,270 | Missouri River above Deroin chute | 100.0 | 1.2 |
| 6/11/2012 | 323 | Deroin chute | 25.4 | 0.9 |
| 6/12/2012 | 1,300 | Missouri River above Deroin chute | 100.0 | 1.2 |
| 6/12/2012 | 345 | Deroin chute | 26.5 | 0.9 |
| 6/13/2012 | 1,290 | Missouri River above Deroin chute | 100.0 | 1.3 |
| 6/13/2012 | 330 | Deroin chute | 25.6 | 0.8 |
| 6/18/2013 | 1,610 | Missouri River above Deroin chute | 100.0 | 1.5 |
| 6/18/2013 | 374 | Deroin chute | 23.2 | 0.9 |
| 6/19/2013 | 1,520 | Missouri River above Deroin chute | 100.0 | 1.4 |
| 6/19/2013 | 357 | Deroin chute | 23.4 | 0.9 |
| 6/20/2013 | 1,410 | Missouri River above Deroin chute | 100.0 | 1.4 |
| 6/20/2013 | 345 | Deroin chute | 24.4 | 0.9 |

or weather conditions. Segments along transects that were covered by more than 1 meter of water were surveyed using a single-beam echosounder to measure depth and a differentially corrected GPS to measure location. These depth soundings were converted to elevation by subtracting the depth from the corresponding water-surface-elevation information collected using a RTK GNSS. Segments along transects that were covered with less than 1 meter of water were surveyed using RTK GNSS. This included top of bank, toe of bank, edge of water, sand bars, and near shore areas. For survey control, bench marks were established at each survey site or previously existing bench marks were located. Some of these bench marks were monumented and some were nonmonumented bench marks. Most of the surveys that established survey-grade coordinates on bench marks met the USGS Level II, single-base static quality which requires satellite data logged by a static-base receiver for at least four hours and processed through the National Geodetic Survey Online Positioning Users Service.

Discharge was measured at chute survey sites. Discharge was measured both in the main channel of the Missouri River upstream from the chute and in the chute. The split of total discharge between the Missouri River main channel and the chutes was consistent with observed effects of the 2011 Missouri River flood (deposition, erosion, degradation of entrance control structures, flanking of internal control structures, chute widening) at most chutes as noted by the USACE and U.S. Fish and Wildlife Service. In 2011, many chute entrances and control structures were damaged by floodwater, allowing a larger percentage of the total Missouri River discharge to flow through the chutes than originally intended in each chute design. Almost 30 percent of the total Missouri River discharge flowed through Upper Hamburg chute in 2011. The USACE repaired many of these chutes in 2012 and 2013 and many chutes carried a smaller percent of total Missouri River discharge when measured in 2012 and 2013 likely because of lower flow and the effects of these repairs. For example, Upper Hamburg chute was carrying 10 percent of the total Missouri River discharge in 2012 before repairing the flood damage and at total Missouri River discharges approximately 38 percent of the 2011 total Missouri River discharge. In 2013, Upper Hamburg chute was only carrying 2–3 percent of the total Missouri River discharge following repairs and at a total Missouri River discharge similar to 2012. Lower Hamburg chute was carrying approximately 25 percent of the total Missouri River discharge in 2011 and 1–5 percent in 2012 and 2013 when the total Missouri River discharge was approximately 70 percent of the 2011 total Missouri River discharge and repairs from the 2011 flood had been completed. Kansas chute was carrying more than 20 percent of the total Missouri River discharge as the 2011 flood receded and 4–6 percent in 2012 and 2013 after repairs and when total Missouri River discharge was approximately 71–89 percent of 2011 total Missouri River discharge.

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# Appendix

## Data Files

Files available for download include:
ds909_Ponca_backwater.csv
ds909_Council_chute.csv
ds909_Plattsmouth_chute.csv
ds909_Plattsmouth_backwater.csv
ds909_Tobacco_chute.csv
ds909_Upper_Hamburg_chute.csv
ds909_Lower_Hamburg_chute.csv
ds909_Kansas_chute.csv
ds909_Langdon_backwater.csv
ds909_Deroin_chute.csv

## Metadata

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*Edition:* Version 1.0
*Geospatial_Data_Presentation_Form:* vector digital data
*Publication_Information:*
*Publication_Place:* Reston, Va.
*Publisher:* U.S. Geological Survey
*Online_Linkage:* http://water.usgs.gov/lookup/getspatial?ds909_Ponca_backwater
*Larger_Work_Citation:*
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*Originator:* Justin R. Krahulik and Brenda K. Densmore
*Publication_Date:* March 2015
*Title:* Hydrographic Surveys at Seven Chutes and Three Backwaters on the Missouri River in Nebraska, Iowa, and Missouri, 2011–13
*Geospatial_Data_Presentation_Form:* document
*Series_Information:*
*Series_Name:* U.S. Geological Survey Data Series
*Issue_Identification:* ds909
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*Publisher:* U.S. Geological Survey
*Description:*
*Abstract:* An Innerspace 456 single-beam echosounder in conjunction with a Trimble® differential Global Positioning System (DGPS) and HYPACK® navigation software, and Ashtech Z-Xtreme and Trimble® R8 GNSS receivers was used to survey 7 chutes and 3 backwaters on the Missouri River yearly from 2011–13. These chutes and backwaters are located on the Missouri River between Newcastle, Nebraska and Rulo, Nebraska in the States of Nebr., Iowa, and Mo. Surveys of chutes consisted of topographic and bathymetric data collected along transects spaced 30.48 meters (m) apart from high bank to high bank. Surveys of backwaters consisted of topographic and bathymetric data collected along a transect grid of 76.2 m spacing. The format of this data is point data. The data were collected by the U.S. Geological Survey in cooperation with the U.S. Army Corps of Engineers Omaha District as part of the Missouri River Habitat Assessment and Monitoring Program.
*Purpose:* The purpose of collecting this survey data was to provide yearly measurements of the chutes and backwaters for the U.S. Army Corps of Engineers to calculate yearly geomorphic change to understand chute and backwater evolution. This data is also used by the U.S. Army Corps of Engineers for measuring the amount of shallow water habitat available for endangered species for compliance with the “2000 Biological Opinion” and the “2003 Amendment to the Biological Opinion” on the Missouri River as part of the Habitat Assessment and Monitoring Program.
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*Contact_Organization:* U.S. Geological Survey
*Contact_Position:* Hydrologic Technician
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*Online_Linkage:* http://www.hypack.com/new/Training/Documentation/tabid/239/DMXModule/1018/Default.aspx?EntryId=179

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base station accuracy, but also by the accuracy of the rover unit. Only data with a "fixed" position (where the exact number of radio wavelengths between the satellites and the base station antenna were calculated—a process known as ambiguity resolution—to yield a whole number, or integer) were used for topographic surveys. The receiver accuracy is 1 centimeter (cm) + 2 parts per million (ppm) (based on the distance the rover is from the base) for RTK points with five satellites and PDOP less than 4.
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*Horizontal_Positional_Accuracy_Explanation:* Accuracy of topographic data points collected using RTK GPS/GNSS surveying methods
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*Vertical_Positional_Accuracy_Report:* Vertical accuracy is dependent on the accuracy of the GPS-surveyed elevation and the accuracy of the depth estimation. The GPS survey is based off USGS established bench marks utilizing the NGS OPUS. The bench marks processed through OPUS with peak-to-peak error estimates in the ellipsoid ranging from 0.012 to 0.035 m and in the orthometric ranging from 0.022 to 0.059 m. GPS elevation accuracy is not only determined by the base station accuracy, but also by the accuracy of the rover unit. The rover unit used during terrestrial and bathymetric surveying was either an Ashtech Z-Xtreme receiver and Geodetic IV revision "A" antennae or a Trimble® R8 antenna. Only data coded as a "fixed" position by the GPS/GNSS receivers are used to determine water-surface elevations and topographic elevations. The accuracy of the receivers is 2 centimeters + 2 ppm (based on the distance the rover is from the base) with 5 satellites and a PDOP of less than 4. Depth was determined by using an Innerspace 456 single-beam echosounder. Echosounder depth estimates can be affected by the motion of the boat most generally pitch and roll. Depth was collected in a manner that minimized these factors by not allowing movement around the boat during data collection and by not collecting data during times of high wind/rough water. The stated accuracy for the echosounder is +/- 0.15 m.
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*Vertical_Positional_Accuracy_Explanation:* Accuracy of topographic data points collected using RTK GPS/GNSS surveying methods
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*Attribute_Measurement_Frequency:* None planned

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*State_or_Province:* Virginia
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*Country:* USA
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*Contact_Electronic_Mail_Address:* http://water.usgs.gov/user_feedback_form.html
*Resource_Description:* Downloadable Data
*Distribution_Liability:* The U.S. Geological Survey makes no guarantee nor offers any warranty concerning the accuracy, condition, or application of the information contained in this geographic data release.

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*Fees:* None. This dataset is provided by the USGS as a public service.

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*Publication_Date:* March 2015
*Title:* ds909_Council_chute.csv
*Edition:* Version 1.0
*Geospatial_Data_Presentation_Form:* vector digital data
*Publication_Information:*
*Publication_Place:* Reston, Va.
*Publisher:* U.S. Geological Survey
*Online_Linkage:* http://water.usgs.gov/lookup/getspatial?ds909_Council_chute
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*Publication_Date:* March 2015
*Title:* Hydrographic Surveys at Seven Chutes and Three Backwaters on the Missouri River in Nebraska, Iowa, and Missouri, 2011–13
*Geospatial_Data_Presentation_Form:* document
*Series_Information:*
*Series_Name:* U.S. Geological Survey Data Series
*Issue_Identification:* ds909
*Publication_Information:*
*Publication_Place:* Reston, Va.
*Publisher:* U.S. Geological Survey
*Description:*
*Abstract:* An Innerspace 456 single-beam echosounder in conjunction with a Trimble® differential Global Positioning System (DGPS), HYPACK® navigation software, and Ashtech Z-Xtreme and Trimble® R8 Global Navigation Satellite System (GNSS) receivers was used to survey 7 chutes and 3 backwaters on the Missouri River yearly from 2011–13. These chutes and backwaters are located on the Missouri River between Newcastle, Nebraska and Rulo, Nebraska in the States of Nebraska, Iowa, and Missouri. Surveys of chutes consisted of topographic and bathymetric data collected along transects spaced 30.48 m apart from high bank to high bank. Surveys of backwaters consisted of topographic and bathymetric data collected along a transect grid of 76.2 m spacing. The data were collected by the U.S. Geological Survey in cooperation with the U.S. Army Corps of Engineers (USACE) Omaha District as part of the Missouri River Habitat Assessment and Monitoring Program.
*Purpose:* The purpose of this survey was to provide annual measurements of the chutes and backwaters for the USACE to calculate yearly geomorphic change to understand chute and backwater evolution. This dataset is also used by the USACE for measuring the amount of shallow water habitat available for endangered species to comply with the “2000 Biological Opinion” and “2003 Amendment to the 2000 Biological Opinion” on the Missouri River as part of the their Habitat Assessment and Monitoring Program.
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*Use_Constraints:* The U.S. Geological Survey makes no guarantee nor offers any warranty concerning the accuracy, condition, or application of the information contained in this geographic data release. Although these data have been used successfully on computers of the USGS, no warranty, expressed or implied, is made by USGS regarding the use of these data on any other system, nor does the fact

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*Contact_Person_Primary:*
*Contact_Person:* Justin R. Krahulik
*Contact_Organization:* U.S. Geological Survey
*Contact_Position:* Hydrologic Technician
*Contact_Address:*
*Address_Type:* mailing and physical
*Address:* 5231 S 19th St
*City:* Lincoln
*State_or_Province:* NE
*Postal_Code:* 68512
*Country:* USA
*Contact_Voice_Telephone:* 1-402-328-4100
*Contact_Electronic_Mail_Address:* jkrahuli@usgs.gov
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*Originator:* HYPACK®
*Publication_Date:* 2013
*Title:* 2013 HYPACK User Manual
*Geospatial_Data_Presentation_Form:* document
*Publication_Information:*
*Publication_Place:* Online
*Publisher:* Hypack, Inc.
*Online_Linkage:* http://www.hypack.com/new/Training/Documentation/tabid/239/DMXModule/1018/Default.aspx?EntryId=179

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*Data_Quality_Information:*

*Logical_Consistency_Report:* Reviewers examined attributes and elevation values.
*Completeness_Report:* Surveys were completed along transects spaced at 30.48 or 76.2 m. Occasionally areas of transects were not able to be surveyed if depth and substrate were not adequate or weather did not permit.
*Positional_Accuracy:*
*Horizontal_Positional_Accuracy:*
*Horizontal_Positional_Accuracy_Report:* Horizontal accuracy is dependent on the accuracy of the GPS-surveyed position. There were two GPS/GNSS surveying methods used for this data collection effort. The first method, for horizontal position of the hydrographic sounding data, is DGPS. The stated horizontal accuracy for the DGPS is less than one meter assuming there are greater than 5 satellites, a Position Dilution Of Precision (PDOP) of less than 4, Signal to Noise Ratio (SNR) of greater than 6, elevation mask greater than 7.5, and a differential correction equivalent to a Trimble® 4000RSi. The second method, GPS/GNSS Real Time Kinematic (RTK) surveying, was used to survey the banks and shallow water areas. GPS/GNSS RTK surveying used either an Ashtech Z-Xtreme receiver and Geodetic IV revision “A” antenna or a Trimble® R8 antenna. RTK surveys were completed using USGS established bench marks utilizing the NGS Online Positioning Users Service (OPUS). The peak-to-peak error estimates in the latitudinal and longitudinal directions calculated by OPUS ranged from 0.006 to 0.020 m and 0.001 to 0.034 m respectively. GPS accuracy is not only determined by the base station accuracy, but also by the accuracy of the rover unit. Only data with a “fixed” position (where the exact number of radio wavelengths between the satellites and the base station antenna were calculated—a process known as ambiguity resolution—to yield a whole number, or integer) were used for topographic surveys. The receiver accuracy is 1 centimeter + 2 ppm (based on the distance the rover is from the base)for RTK points with five satellites and PDOP less than 4.
*Quantitative_Horizontal_Positional_Accuracy_Assessment:*
*Horizontal_Positional_Accuracy_Value:* 1.0 m
*Horizontal_Positional_Accuracy_Explanation:* Accuracy for DGPS used to locate hydrographic soundings
*Quantitative_Horizontal_Positional_Accuracy_Assessment:*
*Horizontal_Positional_Accuracy_Value:* 0.044 m
*Horizontal_Positional_Accuracy_Explanation:* Accuracy of topographic data points collected using RTK GPS/GNSS surveying methods
*Vertical_Positional_Accuracy:*

*Vertical_Positional_Accuracy_Report:* Vertical accuracy is dependent on the accuracy of the GPS-surveyed elevation and the accuracy of the depth estimation. The GPS survey is based off USGS established bench marks utilizing the NGS OPUS. The bench marks processed through OPUS with peak-to-peak error estimates in the ellipsoid ranging from 0.012 to 0.035 m and in the orthometric ranging from 0.022 to 0.059 m. GPS elevation accuracy is not only determined by the base station accuracy, but also by the accuracy of the rover unit. The rover unit used during terrestrial and bathymetric surveying was either an Ashtech Z-Xtreme receiver and Geodetic IV revision "A" antennae or a Trimble® R8 antenna. Only data coded as a "fixed" position by the GPS/GNSS receivers are used to determine water-surface elevations and topographic elevations. The accuracy of the receivers is 2 centimeters + 2 ppm (based on the distance the rover is from the base) with 5 satellites and a PDOP of less than 4. Depth was determined by using an Innerspace 456 single-beam echosounder. Echosounder depth estimates can be affected by the motion of the boat most generally pitch and roll. Depth was collected in a manner that minimized these factors by not allowing movement around the boat during data collection and by not collecting data during times of high wind/rough water. The stated accuracy for the echosounder is +/- 0.15 m.
*Quantitative_Vertical_Positional_Accuracy_Assessment:*
*Vertical_Positional_Accuracy_Value:* 0.15 m
*Vertical_Positional_Accuracy_Explanation:* Accuracy of the echosounder used to measure depth
*Quantitative_Vertical_Positional_Accuracy_Assessment:*
*Vertical_Positional_Accuracy_Value:* 0.08 m
*Vertical_Positional_Accuracy_Explanation:* Accuracy of topographic data points collected using RTK GPS/GNSS surveying methods
*Lineage:*
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*Process_Description:* Surveys were collected during the summer of 2011–13. Surveys consisted of GNSS topographic surveys utilizing either an Ashtech Z-Xtreme receiver and Geodetic IV revision "A" antennae or a Trimble® R8 antenna. The survey extent included high bank to edge of water and some in channel locations where depth permitted. Bathymetric data were collected using an Innerspace 456 echosounder with an 8° beam and HYPACK® navigation software in conjunction with a Trimble® Ag 132 DGPS.
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*Process_Description:* GNSS data were exported and corrected based on bench mark position as processed through OPUS-S (USGS Level II static methods) and exported as xyz text.
*Process_Date:* Unknown
*Process_Step:*
*Process_Description:* Bathymetric data were processed using HYPACK® single beam editor using a centerline slope model for elevation from water surface elevation collected during the GNSS survey. Data was then exported as xyz text.
*Process_Date:* Unknown

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*SDTS_Terms_Description:*
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*Point_and_Vector_Object_Count:* 110142

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*Attribute_Measurement_Frequency:* None planned

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*Contact_Organization:* U.S. Geological Survey
*Contact_Position:* Ask USGS—Water Webserver Team
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*State_or_Province:* Virginia

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*Access_Instructions:*
Access links through the USGS Publications Warehouse associated with the Larger Works Citation.
*Fees:* None. This dataset is provided by the USGS as a public service.

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*City:* Reston
*State_or_Province:* Virgina
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*Country:* USA
*Contact_Voice_Telephone:* 1-888-275-8747 (1-888-ASK-USGS)
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*Metadata_Standard_Name:* FGDC Content Standard for Digital Geospatial Metadata
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*Metadata_Security_Information:*
*Metadata_Security_Classification_System:* text
*Metadata_Security_Classification:* Unclassified
*Metadata_Security_Handling_Description:* no restrictions

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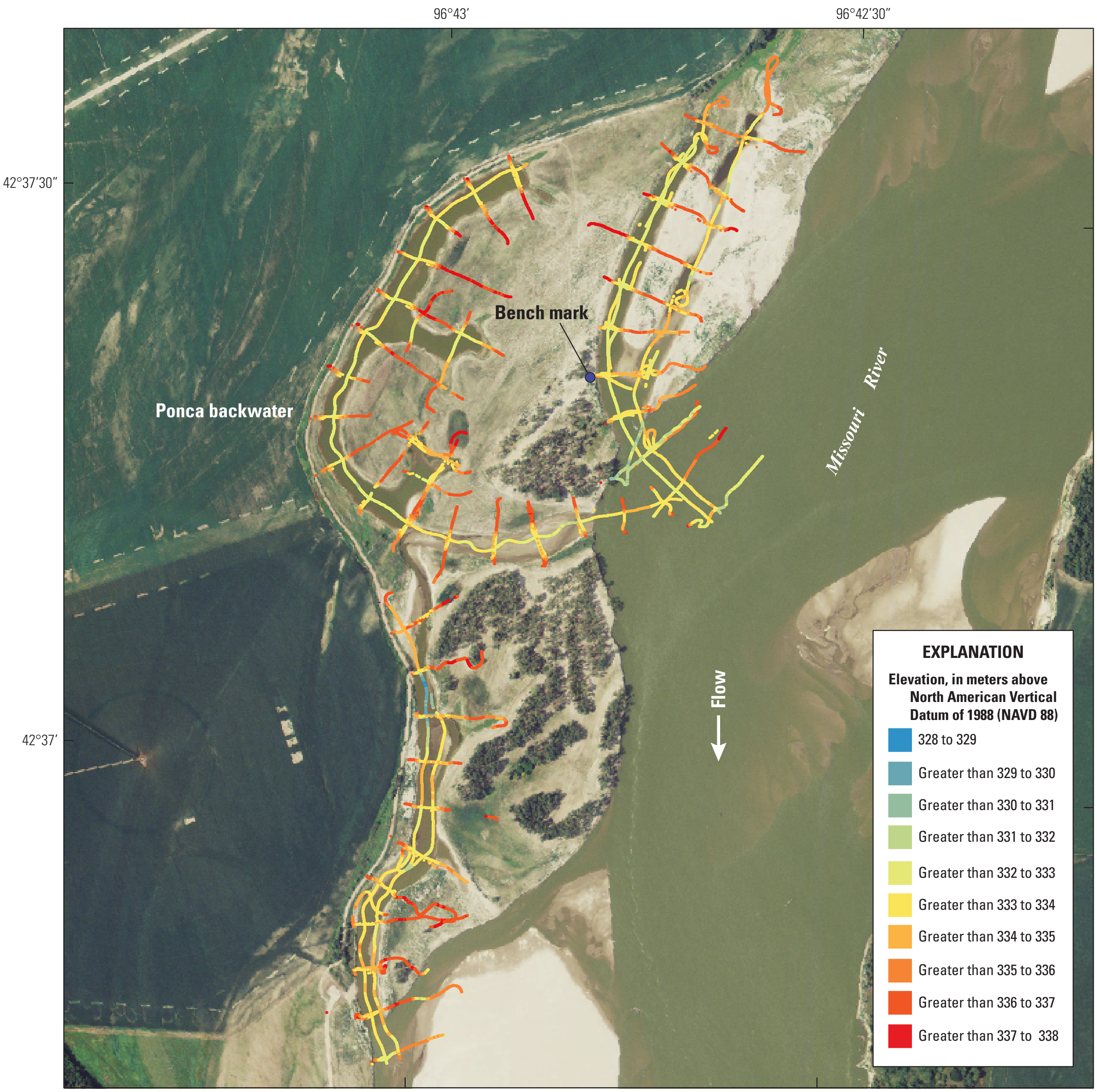
http://ne.water.usgs.gov

USGS

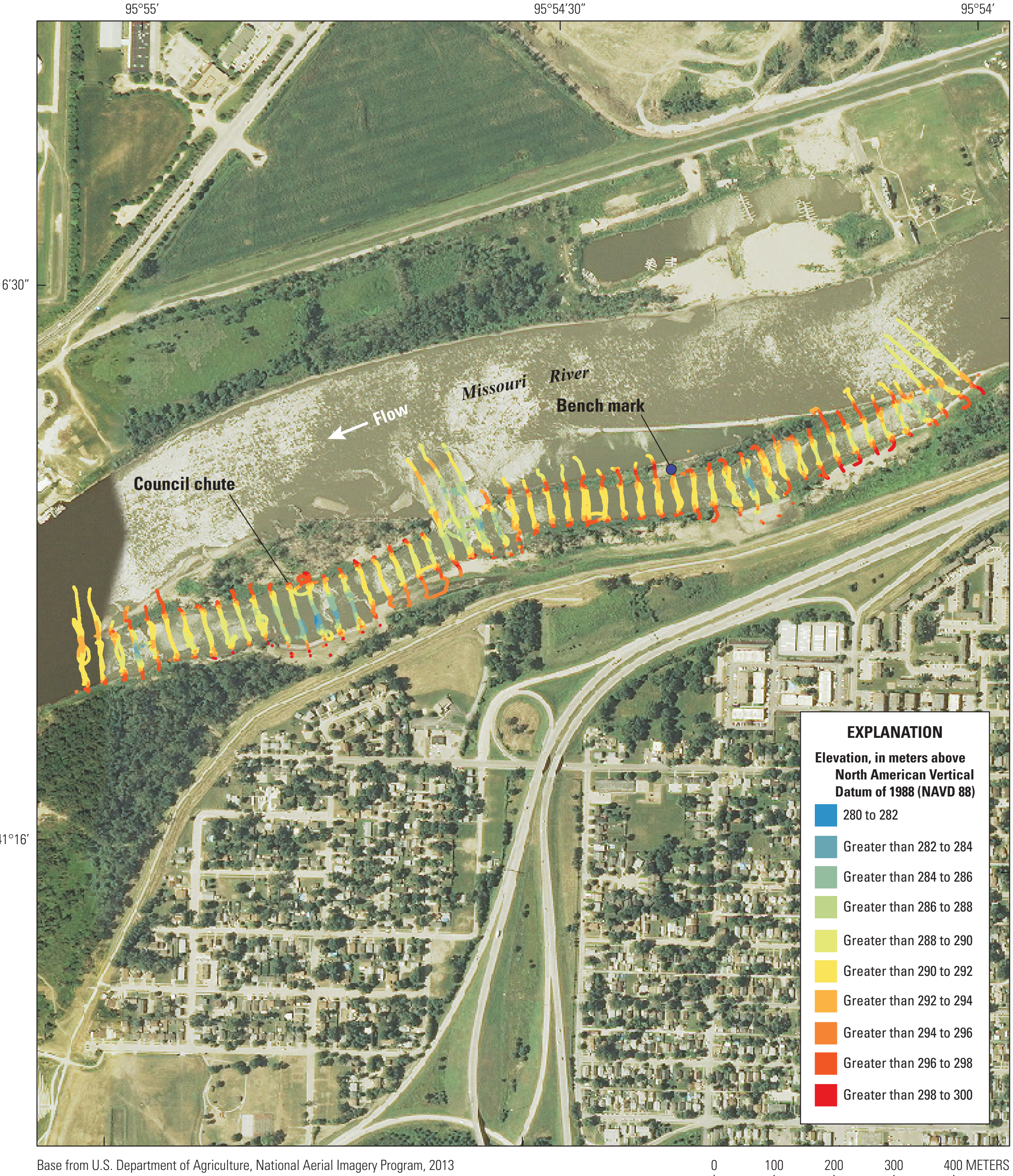
Krahulik and others—**Hydrographic Surveys at Seven Chutes and Three Backwaters on the Missouri River, 2011–13**—Data Series 909

ISSN 2327-638X (online)
http://dx.doi.org/10.3133/ds909



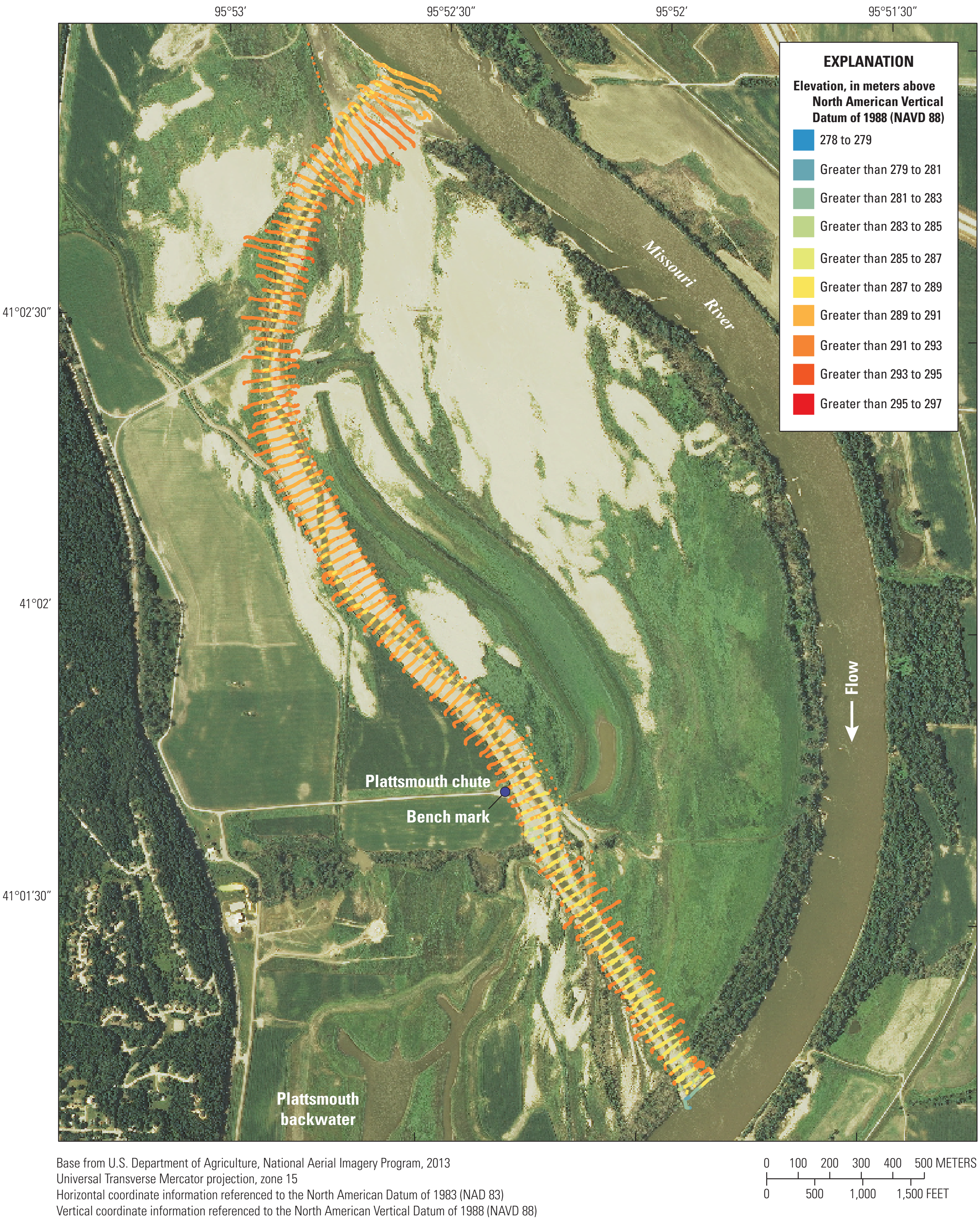

Base from U.S. Department of Agriculture, National Aerial Imagery Program, 2012
Universal Transverse Mercator projection, zone 15
Horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83)
Vertical coordinate information referenced to the North American Vertical Datum of 1988 (NAVD 88)

**Figure 4.** Hydrographic survey data for Ponca backwater near Ponca, Nebraska, 2011–13.



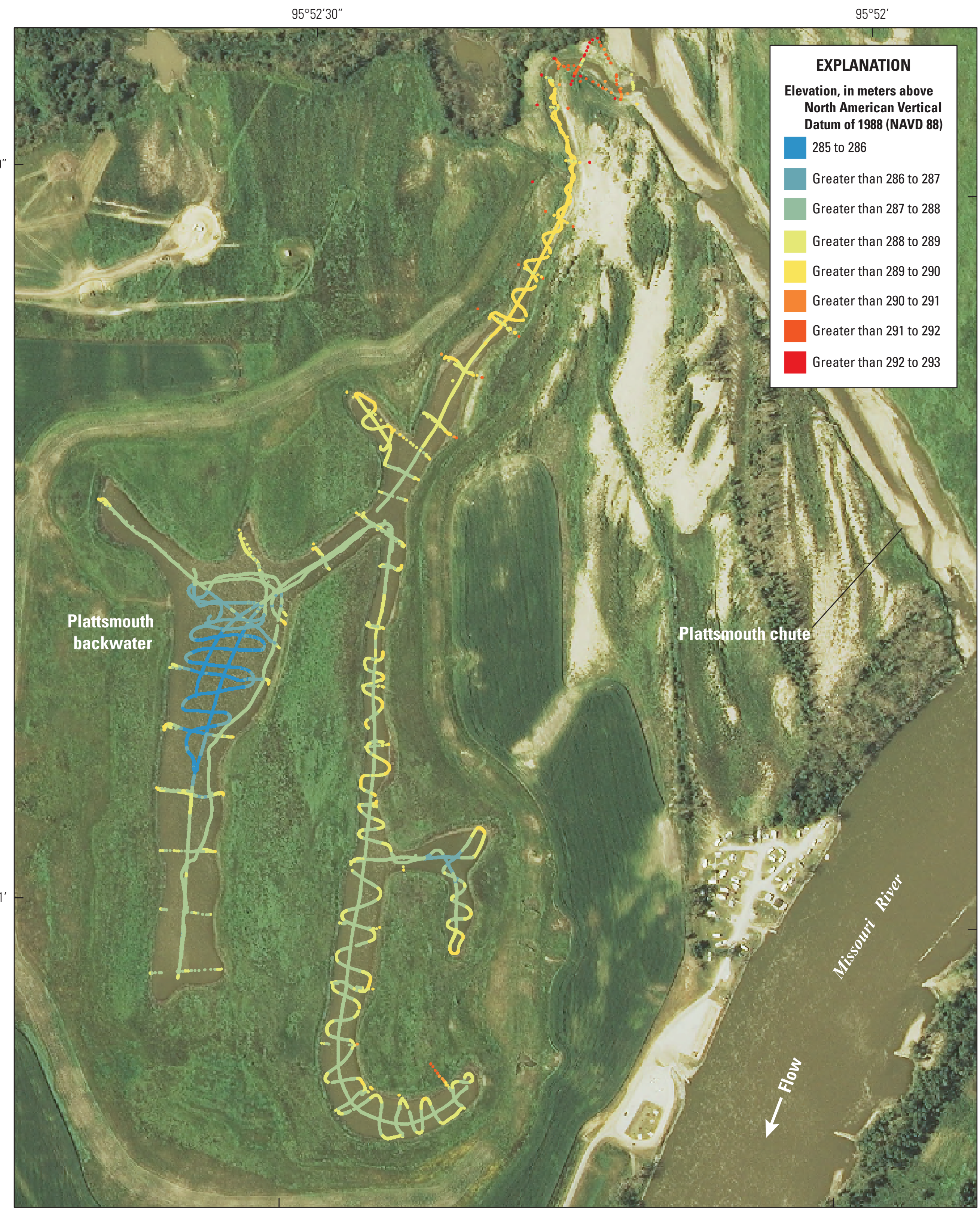

Base from U.S. Department of Agriculture, National Aerial Imagery Program, 2013
Universal Transverse Mercator projection, zone 15
Horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83)
Vertical coordinate information referenced to the North American Vertical Datum of 1988 (NAVD 88)

**Figure 5.** Hydrographic survey data for Council chute near Council Bluffs, Iowa, 2011–13.




Base from U.S. Department of Agriculture, National Aerial Imagery Program, 2013
Universal Transverse Mercator projection, zone 15
Horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83)
Vertical coordinate information referenced to the North American Vertical Datum of 1988 (NAVD 88)

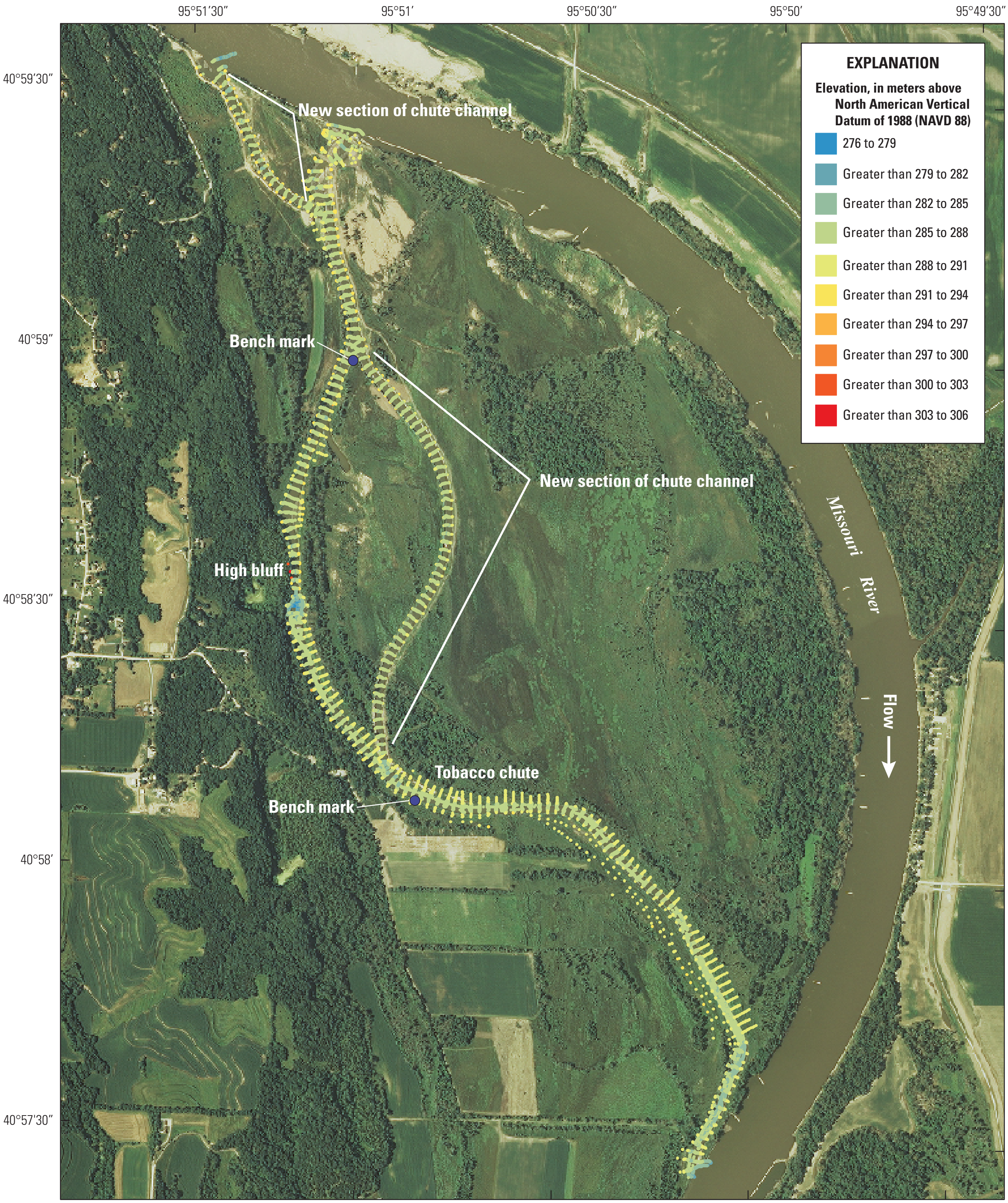
**Figure 6.** Hydrographic survey data for Plattsmouth chute near Plattsmouth, Nebraska, 2011–13.




Base from U.S. Department of Agriculture, National Aerial Imagery Program, 2013
Universal Transverse Mercator projection, zone 15
Horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83)
Vertical coordinate information referenced to the North American Vertical Datum of 1988 (NAVD 88)

0 100 200 300 METERS
0 200 400 600 800 1,000 FEET

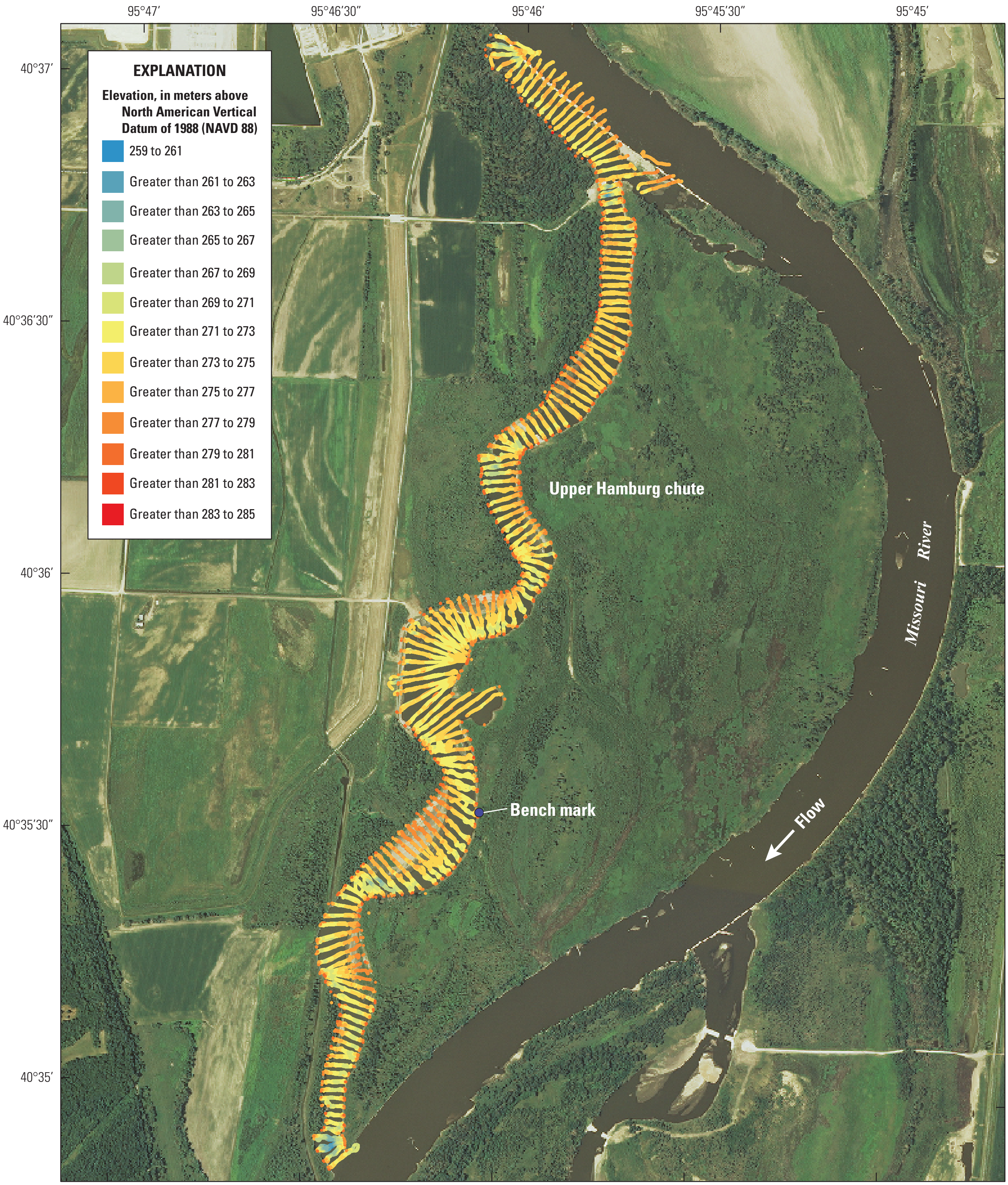
**Figure 7.** Hydrographic survey data for Plattsmouth backwater near Plattsmouth, Nebraska, 2011–13.




Base from U.S. Department of Agriculture, National Aerial Imagery Program, 2013
Universal Transverse Mercator projection, zone 15
Horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83)
Vertical coordinate information referenced to the North American Vertical Datum of 1988 (NAVD 88)

0 200 400 600 800 METERS
0 600 1,200 1,800 2,400 FEET

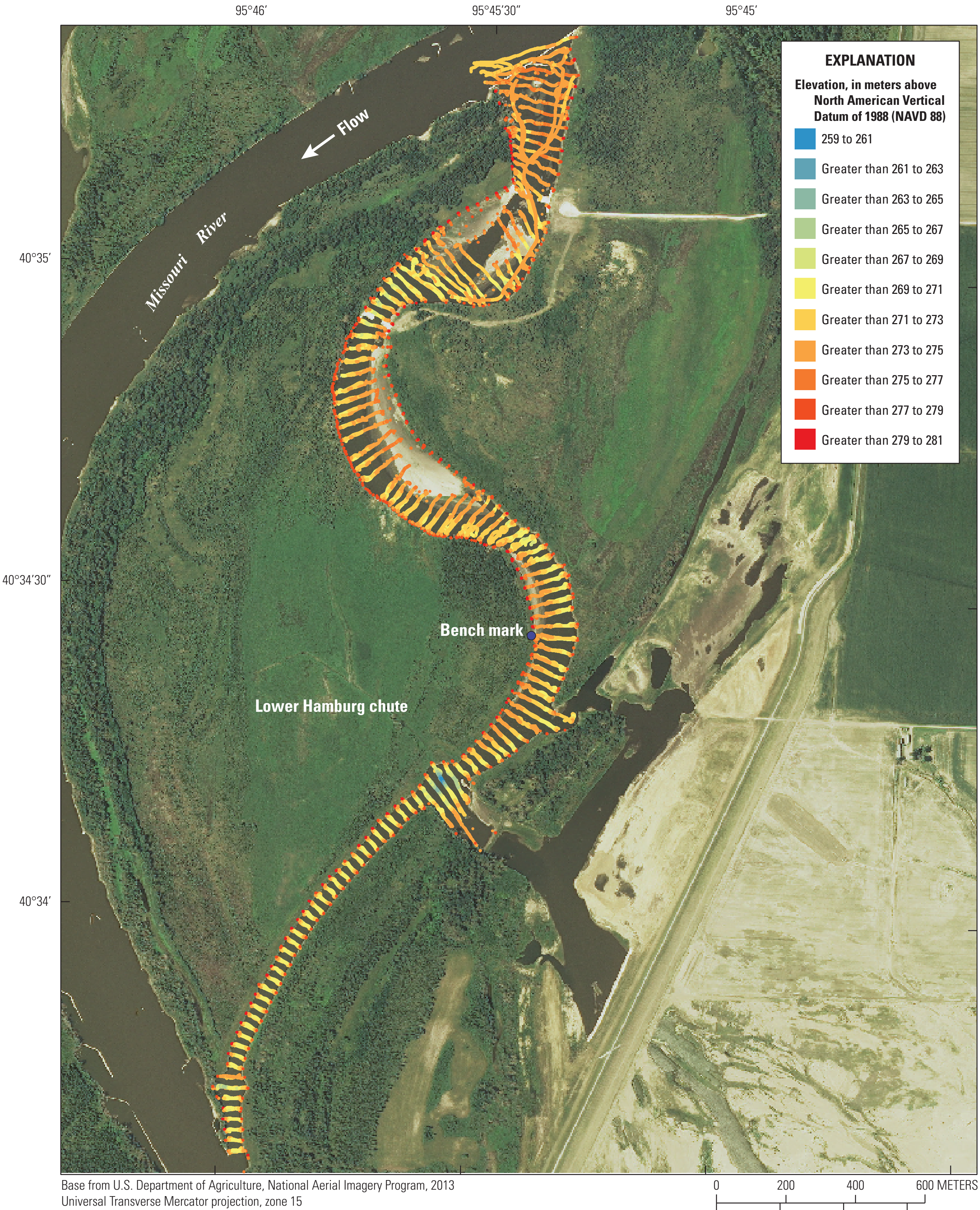
**Figure 8.** Hydrographic survey data for Tobacco chute near Plattsmouth, Nebraska, 2011–13.




Base from U.S. Department of Agriculture, National Aerial Imagery Program, 2013
Universal Transverse Mercator projection, zone 15
Horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83)
Vertical coordinate information referenced to the North American Vertical Datum of 1988 (NAVD 88)



**Figure 9.** Hydrographic survey data for Upper Hamburg chute near Nebraska City, Nebraska, 2011–13.




Base from U.S. Department of Agriculture, National Aerial Imagery Program, 2013
Universal Transverse Mercator projection, zone 15
Horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83)
Vertical coordinate information referenced to the North American Vertical Datum of 1988 (NAVD 88)

**Figure 10.** Hydrographic survey data for Lower Hamburg chute near Hamburg, Iowa, 2011–13.

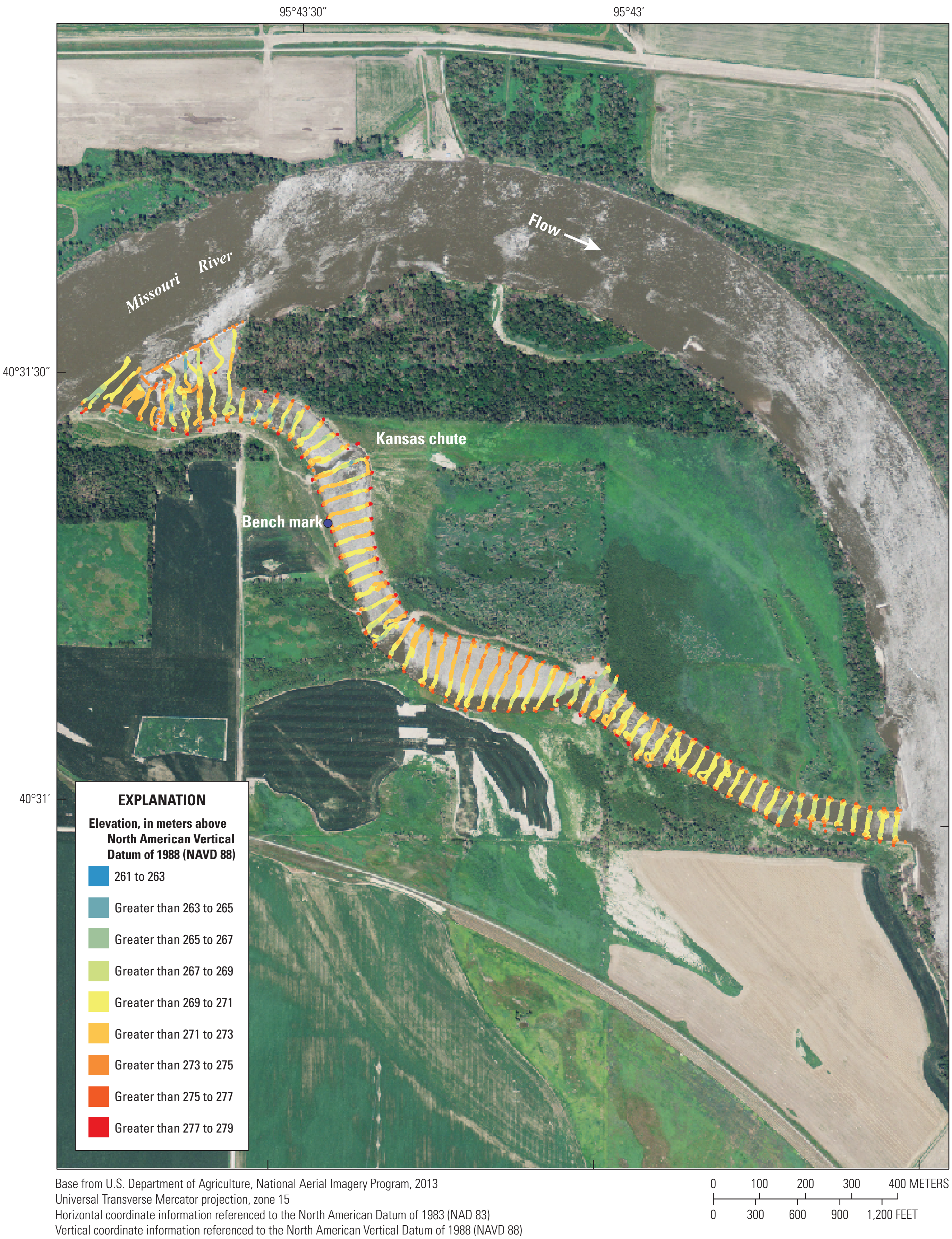



**Figure 11.** Hydrographic survey data for Kansas chute near Peru, Nebraska, 2011–13.

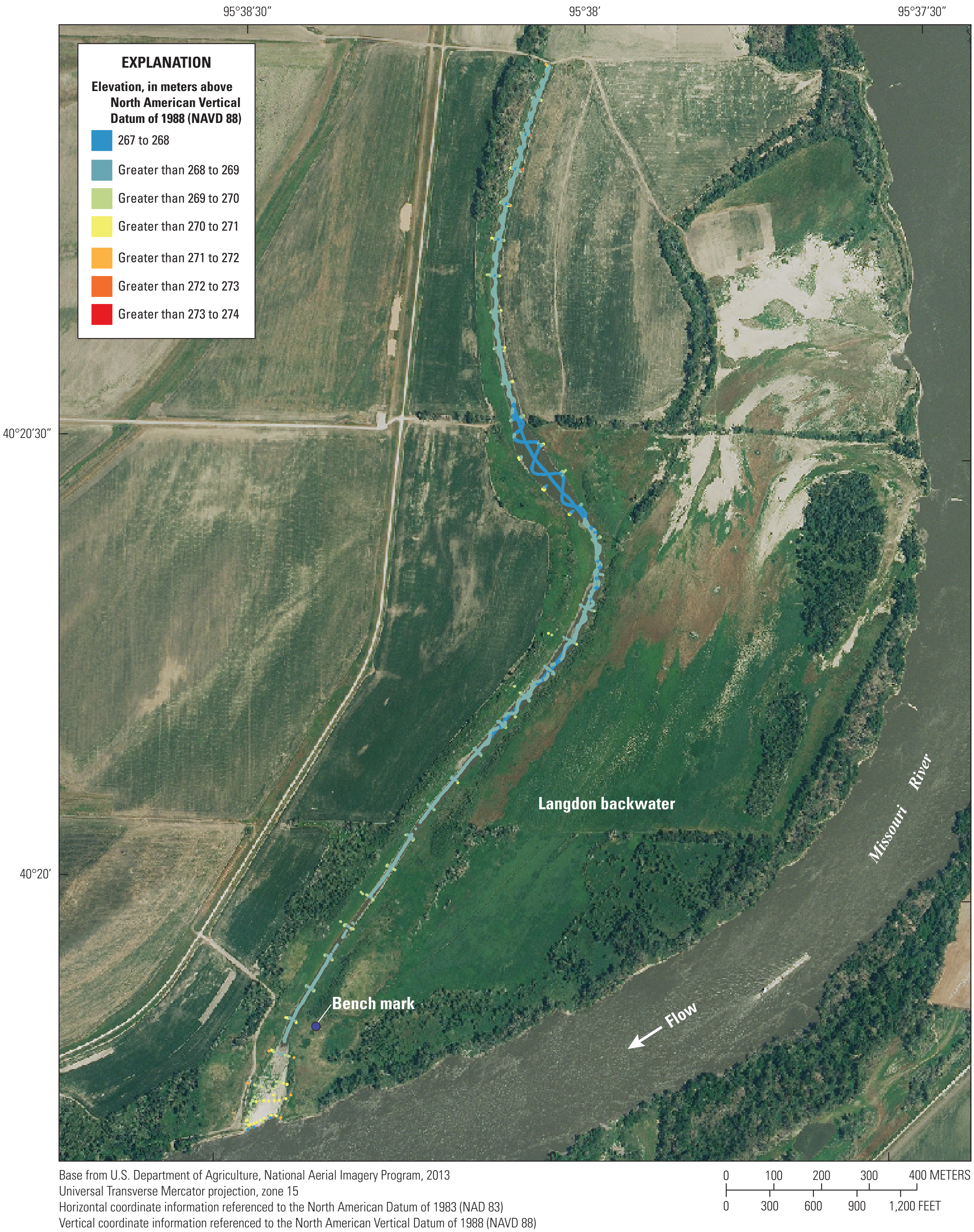
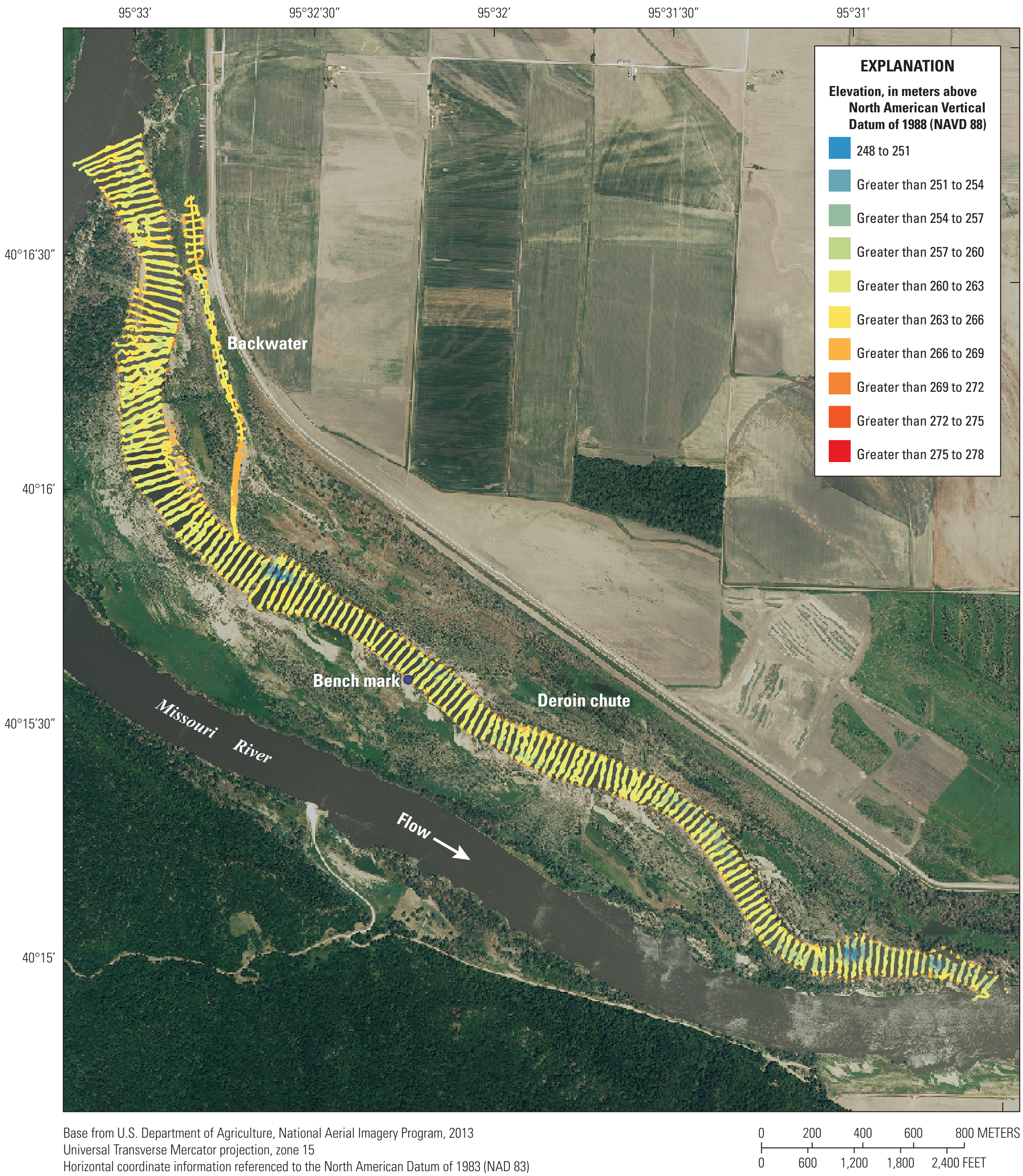



**Figure 12.** Hydrographic survey data for Langdon backwater near Nemaha, Nebraska, 2011–13.




Base from U.S. Department of Agriculture, National Aerial Imagery Program, 2013
Universal Transverse Mercator projection, zone 15
Horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83)
Vertical coordinate information referenced to the North American Vertical Datum of 1988 (NAVD 88)

**Figure 13.** Hydrographic survey data for Deroin chute near Corning, Missouri, 2011–13.