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

Sediment Loads and Transport at Constructed Chutes along the Missouri River—Upper Hamburg Chute near Nebraska City, Nebraska, and Kansas Chute near Peru, Nebraska, 2012

Scientific Investigations Report 2016–5002

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

Cover photograph. U.S. Geological Survey Physical Scientist, Matt Moser, looking upstream and checking equipment on the left bank at Upper Hamburg chute downstream transect. Photograph taken by U.S. Geological Survey personnel.

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54 x 107	nanometer
inch (in.)	25.4	millimeter (mm)
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
	Volume	
ounce, fluid (fl. oz)	0.02957	liter (L)
	Flow rate	
feet per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
ton per day (ton/d)	0.90702	metric ton per day
ounce (oz)	28.35	gram
	Frequency	
kilohertz (kHz)	1,000	cycles per second

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F = (1.8 × °C) + 32.

Datum

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).

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Turbidity units given in formazin nephelometric units (FNU) instead of the more common nephelometric turbidity units (NTU).

Abbreviations

ADVMs	acoustic Doppler velocimeters
BiOp	Missouri River Biological Opinion
BSNP	Missouri River Bank Stabilization and Navigation Project
EWI	equal-width increment
FNU	formazin nephelometric units
KANS–CH–DS	Kansas chute downstream
KANS–CH–US	Kansas chute upstream
KANS–MR–DS	Kansas Missouri River downstream
KANS–MR–US	Kansas Missouri River upstream
MLR	multiple linear regression
NTU	nephelometric turbidity units
SF	sand-fines, that is, the threshold (0.0625 mm) between sand-size and finer-than-sand-size particles of sediment
SLR	simple linear regression
SSC	suspended-sediment concentration
SSC_{auto}	suspended-sediment concentration from an autosampler (collected by the programmable pumping sampler)
SSC_{EWI}	suspended-sediment concentration from equal-width increment samples
SSiltC	suspended-silt-clay concentration
SSandC	suspended-sand concentration
SSL	total suspended-sediment load
SSL_{silt}	silt-clay suspended-sediment load
SSL_{sand}	sand suspended-sediment load
SWH	shallow-water habitat
UHAM–CH–DS	Upper Hamburg chute downstream
UHAM–MR–DS	Upper Hamburg Missouri River downstream
UHAM–MR–US	Upper Hamburg Missouri River upstream
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
YSI	Yellow Springs Instrument Company (now known as YSI Inc.)

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Abstract

The U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, monitored suspended sediment within constructed Missouri River chutes during March through October 2012. Chutes were constructed at selected river bends by the U.S. Army Corps of Engineers to help mitigate aquatic habitat lost through the creation and maintenance of the navigation channel on the Missouri River. The restoration and development of chutes is one method for creating shallow-water habitat within the Missouri River to meet requirements established by the amended 2000 Biological Opinion. Understanding geomorphic channel-evolution processes and sediment transport is important for the design of chutes, monitoring and maintenance of existing chutes, and characterizing the habitat that the chutes provide. This report describes the methods used to monitor suspended sediment at two Missouri River chutes and presents the results of the data analysis to help understand the suspended-sediment characteristics of each chute and the effect the chutes have on the Missouri River. Upper Hamburg chute, near Nebraska City, Nebraska, and Kansas chute, near Peru, Nebraska, were selected for monitoring. At each study site, monthly discrete samples were collected from April through October in the Missouri River main-channel transects upstream from the chute inlet, downstream from the chute outlet, at the outlet (downstream transect) of both chutes, and at the inlet (upstream transect) of Kansas chute. In addition, grab samples from all chute sampling locations were collected using autosamplers. Suspended-sediment concentration (SSC) and grain-size metrics were determined for all samples (discrete and grab). Continuous water-quality monitors recorded turbidity and water temperature at 15-minute intervals at the three chute sampling locations. Two acoustic Doppler velocimeters, one within each chute, measured water depth and current velocities continuously. The depth and velocity data were used to estimate streamflow within each chute. The sampling design was developed to understand the suspended-sediment differences within each chute and between the chute and the Missouri River main channel during discrete sampling. The sampling design also allowed for site-specific surrogate relations between SSC and turbidity to be developed, which could be used to compute real-time estimates of SSC and sediment loads within the chutes. Real-time estimates of SSC and sediment loads enable a better understanding of sediment transport within the chutes during times when physical samples are not collected, including periods of high flow.

High flows during the summer of 2011 resulted in substantial alterations to both studied chutes; therefore, the U.S. Army Corps of Engineers repaired and modified both chutes during 2012. These unforeseen repairs and modifications within the chutes added uncertainty to the analysis because concentrations were altered by construction equipment and flow alteration.

Daily suspended-sediment and suspended-silt loads were estimated based on surrogate relations with turbidity. A linear regression was used to estimate equal-width increment (EWI)-equivalent SSC from autosampler SSC before using the model-calibration dataset to determine the best-fit model for prediction of SSC from the turbidity and, in some cases, discharge. Correlation between suspended-sand concentration (*SSandC*) in EWI samples and concurrent samples collected by an autosampler was low; therefore, *SSandC* was excluded from development of surrogate relations because a large part of the calibration dataset was from autosamples. Instead, *SSandC* was estimated as SSC minus suspended-silt-clay concentration (*SSiltC*). At all sites, the best-fit models included the base-10 logarithm of concentration and turbidity, and at Kansas chute upstream, the base-10 logarithm of streamflow was also included in the best-fit models. These surrogate models were used to estimate continuous time series of SSC and *SSiltC*. Estimated concentrations of suspended sediment were used to estimate instantaneous and daily loads for total suspended sediment, suspended silt-clay, and suspended sand. Estimated daily suspended-sediment loads were not significantly different between upstream and downstream

transects within the Kansas chute, and most individual daily loads within the chute were not significantly different between upstream and downstream transects when evaluated using overlap in daily 95-percent confidence intervals. The comparison of daily load values for upstream and downstream chute transects, as estimated from turbidity-based surrogate models for Kansas chute, documents the daily dynamic nature of sediment transport within the chute with a temporal resolution that is not practical with discrete suspended-sediment sampling alone.

Comparisons of concentrations and loads from EWI samples collected from different transects within a study site resulted in few significant differences, but comparisons are limited by small sample sizes and large within-transect variability. When comparing the Missouri River upstream transect to the chute inlet transect, similar results were determined in 2012 as were determined in 2008—the chute inlet affected the amount of sediment entering the chute from the main channel. In addition, the Kansas chute is potentially affecting the sediment concentration within the Missouri River main channel, but small sample size and construction activities within the chute limit the ability to fully understand either the effect of the chute in 2012 or the effect of the chute on the main channel during a year without construction. Finally, some differences in SSC were detected between the Missouri River upstream transects and the chute downstream transects; however, the effect of the chutes on the Missouri River main-channel sediment transport was difficult to isolate because of construction activities and sampling variability.

Introduction

The restoration and preservation of Missouri River habitat and fish and wildlife species is a focus for numerous government agencies and the public. Development on the Missouri River, including the Missouri River main stem reservoir system and the operation and maintenance of the Missouri River Bank Stabilization and Navigation Project (BSNP), has modified the availability of aquatic and terrestrial habitat in the river corridor (Funk and Robinson, 1974). The U.S. Army Corps of Engineers (USACE) has led numerous Missouri River projects as part of the BSNP Fish and Wildlife Mitigation Program that began in 1986 (Reinig and Roth, 2010). The goal of the BSNP Fish and Wildlife Mitigation Program was to restore fish and wildlife habitat that was lost or damaged because of the channelization and bank stabilization of the river downstream from Sioux City, Iowa (fig. 1). Since 1996, chutes have been constructed at selected river bends by the USACE to help mitigate aquatic habitat lost. The 2000 Missouri River Biological Opinion (BiOp; U.S. Fish and Wildlife Service, 2000) determined that the operation of the Missouri River main stem reservoir system and the operation and maintenance of the Missouri River BSNP jeopardized threatened and endangered species. The BiOp suggested as part of a reasonable and prudent alternative the creation or restoration of 20–30 acres per river mile of shallow-water habitat (SWH; U.S. Fish and Wildlife Service, 2000). The BiOp defined SWH to be less than 5 feet deep and with current velocity less than 2 feet per second. The restoration and development of chutes is one method for creating SWH (U.S. Army Corps of Engineers, 2014). Chutes are small, typically shallow, side channels that provide more diverse habitat than the main navigation channel, with a variety of substrates, depths, and velocities. Chutes are constructed by excavating a shallow pilot channel through the bottomland so the water can flow from the river into the chute at the inlet and re-enter the river downstream at the chute outlet. Chutes are designed with vertical grade control structures that typically are at the inlet or outlet, or both. The structures reduce the effects that the chute may otherwise have on the navigation channel. The constructed chutes then widen and meander as a result of geomorphic processes such as bank erosion, aggradation or degradation of the bed, or meander migration (U.S. Army Corps of Engineers, 2014).

Understanding geomorphic evolution of chutes and their sediment transport is important for designing new chutes, maintenance and monitoring of existing chutes, and characterizing the habitat that the chutes provide. Chutes have different sediment-transport characteristics than the main channel and the contribution of the chutes to the river sediment budget is largely unquantified. Understanding fluvial processes within chute boundaries and how chutes function biologically are fundamental to ensure that the habitat developed is sustained and satisfies the needs of the Missouri River biota. Monitoring is necessary to evaluate the habitat being provided, to understand how the chute is affecting the Missouri River main channel, to evaluate geomorphic change and longevity, and to understand the overall effectiveness of the chutes at restoring Missouri River habitat. The biological community and the physical structure of SWH sites have been monitored annually since 2005 (Sterner and others, 2009; Gosch and others, 2015; Krahulik and others, 2015). During March through October of 2012, the U.S. Geological Survey (USGS), in cooperation with the USACE, monitored suspended sediment within two selected Missouri River chutes; discrete suspended-sediment samples and real-time continuous water-quality data were collected. The objectives of the study were (1) to provide sediment and water-quality data on chutes to better understand their geomorphic processes; (2) to quantify and compare suspended-sediment concentrations (SSC), loads, and size distributions of the chutes to those of the Missouri River main channel; (3) to determine variation among water-quality properties within chutes; and (4) to develop a model of the relation between turbidity and SSC that evaluates the use of turbidity as a surrogate for SSC. Objective 2 will help answer questions such as (1) does the chute sediment load produce a measurable difference in the main-channel sediment load, (2) do the chute sediment characteristics change from upstream to downstream, and (3) are the sediment characteristics within the upstream section of the chute different than those within the Missouri River main channel upstream from the chute?

The benefit of using continuous water-quality monitoring has been demonstrated in previous surface-water monitoring (Christensen, 2001; Rasmussen and others, 2005). Turbidity is a measure of the clarity of water that is affected by suspended matter such as sediment, particulate-organic matter, plankton, and other microscopic organisms (U.S. Geological Survey, variously dated). More specifically, turbidity is a measure of the optical properties of water that cause light to be scattered or absorbed. Turbidity serves as a proxy for suspended sediment and is sensitive to sediment delivery from erosional processes. Erosional processes include eroded upland sediment transported to the stream during rainfall runoff and bank failures that generally are either coincident with runoff or follow runoff because of increased streamflow. The suspended particles associated with turbidity provide attachment sites for bacteria, metals, nutrients, and pesticides (Rasmussen and others, 2005). The particles may disturb aquatic communities, and the particles may lead to sedimentation problems. Water temperature plays a critical role in the chemistry of freshwater ecosystems by affecting the solubility of dissolved constituents, conductance, biological activity, and rates of reactions (U.S. Geological Survey, variously dated).

The use of statistical relations to predict the concentration of water-quality constituents based on their relation to continuously measured properties of water (surrogates) is a valid technique (Rasmussen and others, 2005; Schaepe and others, 2014). Turbidity is commonly used as a surrogate for the measurement of SSC (Rasmussen and others, 2005). Combining continuous turbidity and streamflow measurements with discrete suspended-sediment sampling allows for the computation of a time-series record of the SSC and load within a waterway (Rasmussen and others, 2009). The method described in Rasmussen and others (2009) has been widely used and provides reliable time series of SSC with low uncertainty values through the development of regression equations (Rasmussen and others, 2009; Schaepe and others, 2014).

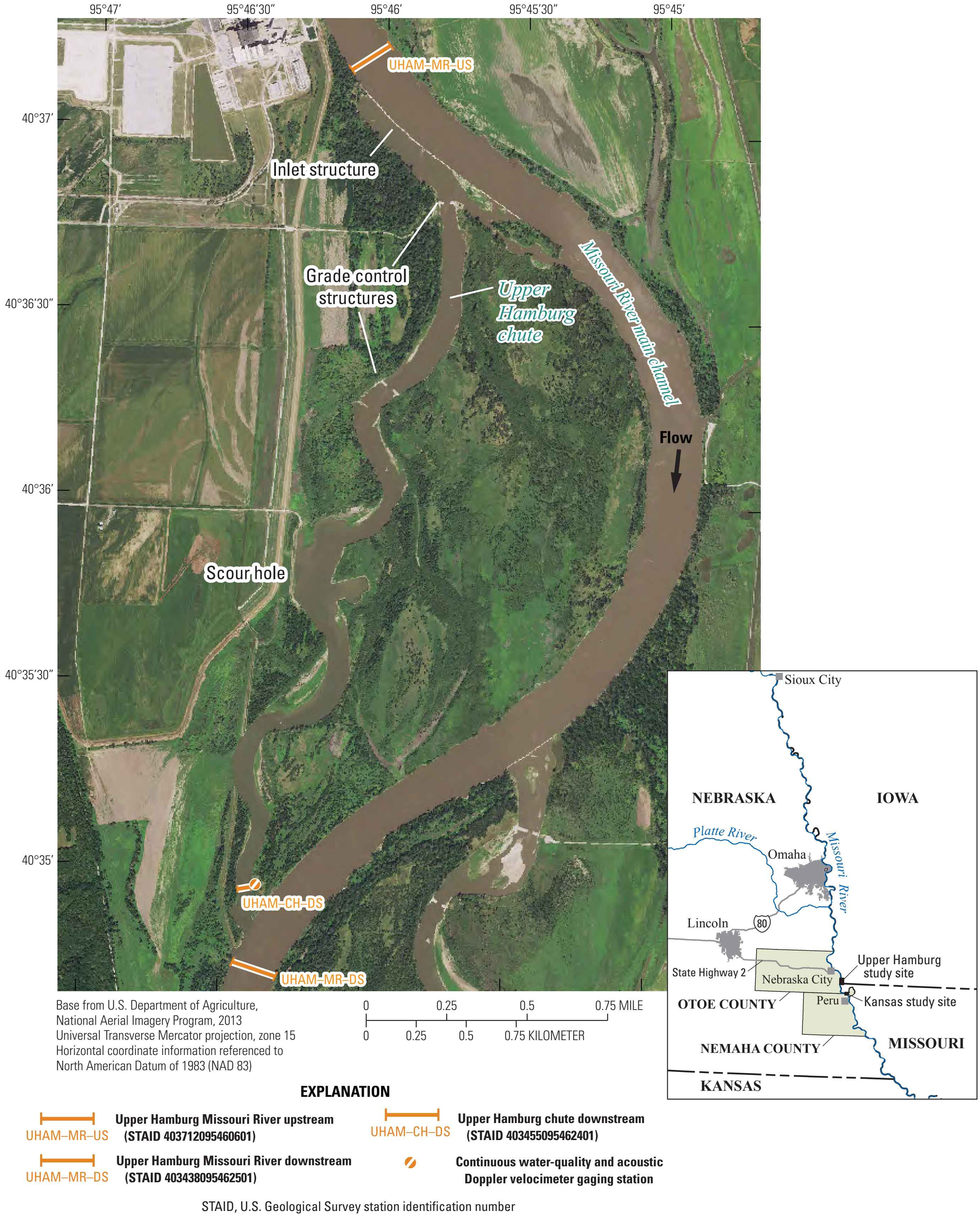
Purpose and Scope

The purpose of this report is to present the results of the data analysis to improve the understanding of the suspended-sediment load and transport processes of constructed chutes, Upper Hamburg near Nebraska City, Nebr., and Kansas Chute near Peru, Nebr., and the effect the chutes have on the Missouri River. Discrete suspended-sediment samples were collected during April through October 2012, and real-time continuous water-quality monitoring recorded turbidity and water temperature at 15-minute intervals during March through October 2012. This report describes the methods used to monitor suspended sediment at two Missouri River chutes and presents the results of the data analysis.

Description of Study Sites

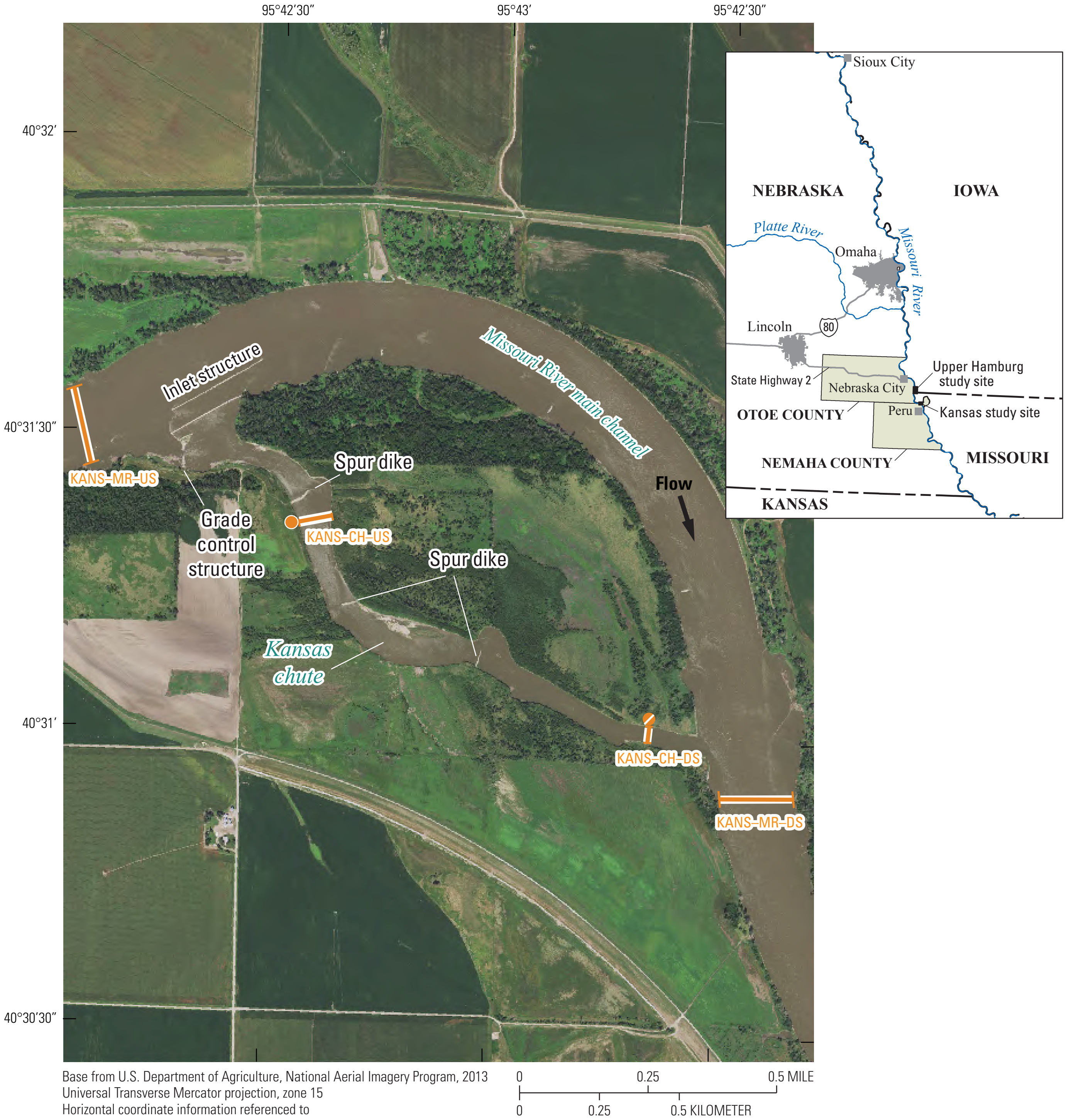
Missouri River chutes selected for monitoring include Upper Hamburg chute (fig. 1) on the right bank (looking downstream) at river mile 552–556 and Kansas chute (fig. 2) on the right bank at river mile 544–546. Upper Hamburg Bend and its associated chute are in Otoe County in Nebraska and are approximately 5.6 miles (mi) downstream from the State Highway 2 bridge at Nebraska City, Nebr. (fig. 1). Kansas Bend and its associated chute are in Otoe and Nemaha Counties in Nebraska and are approximately 15 mi downstream from the State Highway 2 bridge at Nebraska City, Nebr. near Peru, Nebr. (fig. 2). Upper Hamburg chute was constructed in 1996, and Kansas chute was constructed in 2004. In 2012, Upper Hamburg chute was approximately 3 mi long and averaged 430 feet wide, and Kansas chute was approximately 1.2 mi long and averaged 260 feet wide. Upper Hamburg chute is a more mature chute and Kansas chute is newer. Mature chutes might be more stable and closer to equilibrium, whereas a newer chute might be expected to be rapidly evolving. A chute in equilibrium is theoretically able to transport its sediment load during high-flow events without significant degradation or aggradation to the channel, and lateral movement is offset within the chute. As described in Woodward and Rus (2011), the streamflow regime imposed on each chute is an important factor that affects chute evolution. The hydraulic power of streamflow provides the sediment-transport mechanism by which the chutes erode or aggrade toward their chute-specific equilibrium state. Upper Hamburg chute and Kansas chute are close in proximity; therefore, the measured streamflow was similar for both chutes after 2004. During 1996–2012, the most geomorphically effective peak streamflow was in 2011 for both chutes (fig. 3).

High flows during the summer of 2011 resulted in substantial alterations to the chutes; therefore, the USACE repaired and modified both chutes during 2012 (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, 2013). At Upper Hamburg chute, the inlet was modified and closed, and two grade control structures were constructed. Additionally, a large scour hole that threatened the toe of the nearby levee was filled, and the chute banks were restored and protected near the scour hole (fig. 1). The inlet was closed on July 6, 2012, and remained closed for the remainder of the study. The inlet was closed off with riprap (high porosity) such that flow was still observed in the chute following the closure. The downstream grade control structure was completed by August 1, 2012, and the upstream grade control structure was completed by February 15, 2013. At Kansas chute, the inlet structure was modified and enhanced, a grade control structure was added, and three spur dikes were installed (fig. 2). The upstream spur dike, completed in early June 2012, was installed approximately 328 feet upstream from, and on the same bank as, the real-time continuous water-quality monitor and autosampler at the upstream sampling location. All



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

Figure 1. Aerial orthophotograph showing Upper Hamburg chute study site, 2012.



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

EXPLANATION

KANS–MR–US	**Kansas Missouri River upstream (STAID 403126095435301)**	KANS–CH–US	**Kansas chute upstream (STAID 403135095431201)**
KANS–MR–DS	**Kansas Missouri River downstream (STAID 403055095422901)**	KANS–CH–DS	**Kansas chute downstream (STAID 403134095431101)**

⊘ **Continuous water-quality and acoustic Doppler velocimeter gaging station**

● **Continuous water-quality monitoring station**

STAID, U.S. Geological Survey station identification number

Figure 2. Aerial orthophotograph showing Kansas chute study site, 2012.

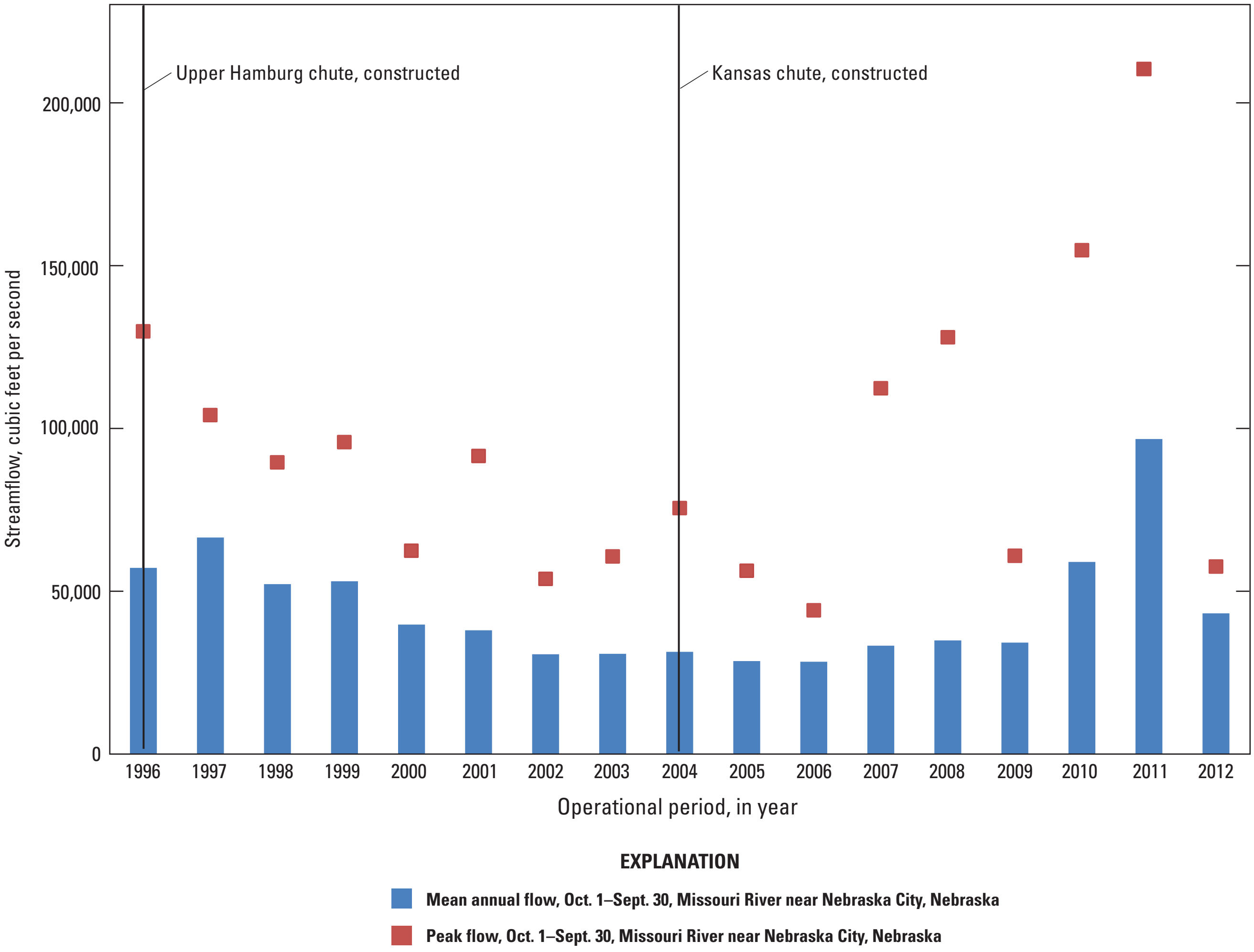


Figure 3. Missouri River streamflow (measured U.S. Geological Survey streamflow-gaging station Missouri River near Nebraska City, Nebraska, 06807000 located at State Highway 2) during the operational period of Upper Hamburg chute and Kansas chute, 1996–2012.

structures were completed at Kansas chute by June 29, 2012. The construction and maintenance activities were not typical but were necessary to maintain the chutes following the flooding of 2011. The chute repairs and modifications are referred to as construction activities or construction throughout this report. These unforeseen repairs and modifications within the chutes added uncertainty to the analysis because sediment concentrations within both chutes were altered by construction equipment and flow alteration.

Previous Studies

The sediment characteristics of Missouri River chutes and the main channel were investigated based on discrete suspended- and streambed-sediment samples by Woodward and Rus (2011). Results indicated that the inlet structures tended to restrict coarse suspended sediments from entering the chutes from the Missouri River main channel. A statistical difference in the suspended-sediment characteristics did not exist between the inlet and outlet of the chutes, and the chutes did not significantly change the sediment characteristics of the main channel. The report noted that the small number of samples constrained the statistical power to detect subtle differences (Woodward and Rus, 2011).

Methods

The following sections describe the sampling design for this study and the methods used to collect monthly suspended-sediment samples, operate real-time continuous water-quality monitors, measure streamflow, and operate acoustic Doppler velocimeters (ADVMs). This section also describes data analysis methods.

Sampling Design

At each monitored chute, the following four sampling transects were established—Missouri River main-channel transect upstream from the chute inlet, main-channel transect downstream from the chute outlet, within-chute transects near the upstream end, and within-chute transects near the downstream end. Transects at Upper Hamburg chute study site are referred to as Upper Hamburg Missouri River upstream (UHAM–MR–US; fig. 1), Upper Hamburg Missouri River downstream (UHAM–MR–DS; fig. 1), Upper Hamburg chute upstream (not shown), and Upper Hamburg chute downstream (UHAM–CH–DS; fig. 1). Upper Hamburg chute upstream transect was not sampled because of chute closure and construction activities. Similarly, transects at Kansas chute study site are referred to as Kansas Missouri River upstream (KANS–MR–US; fig. 2), Kansas Missouri River downstream (KANS–MR–DS; fig. 2), Kansas chute upstream (KANS–CH–US; fig. 2), and Kansas chute downstream (KANS–CH–DS; fig. 2).

At each study site, monthly suspended-sediment samples were collected from April through October 2012 in Missouri River main-channel transects upstream from the chute inlet and downstream from the chute outlet. Monthly suspended-sediment samples were also collected from April through October 2012 at the chute transects (UHAM–CH–DS, KANS–CH–US, and KANS–CH–DS). These discrete samples were collected from the channel transect at equal-width increments (EWI) using a depth-integrated, isokinetic method (Edwards and Glysson, 1999). In addition, grab samples were collected for all three chute sampling locations by using autosamplers throughout the study period. Continuous water-quality monitors recorded turbidity and water temperature at 15-minute intervals during March through October 2012 at three chute sampling locations (UHAM–CH–DS, KANS–CH–US, and KANS–CH–DS) and transmitted the data in near real time to the USGS database and Web site (U.S. Geological Survey, 2012).

In addition to water sampling, two ADVMs were deployed, one at Upper Hamburg chute and one at Kansas chute. The ADVMs continuously measured water depth and current velocities in real-time and transmitted the information from the up-looking beam and selected ensembles back to the USGS Web site. Measured depth and velocity were used to estimate continuous streamflow within the chutes after a relation was defined on the basis of discrete streamflow measurements made during sampling and equipment maintenance trips (Levesque and Oberg, 2012).

The sampling design was developed to understand the suspended-sediment differences within each chute and to understand the differences between the chute and the Missouri River main channel during discrete sampling. The sampling design also was developed to expand on site-specific surrogate relations between SSC and turbidity, which could be used to compute real-time estimates of SSC and sediment loads within the chutes. This design provides the potential to improve understanding of sediment transport within the chutes during times when physical samples are not collected, including during periods of high flow that can be protracted on large rivers.

Suspended-Sediment Sampling

The SSCs were determined for water samples collected using two methods. Monthly discrete (or manually collected) samples were collected from a boat at all sampling transects. “Automatic samples” were collected by programmed pumping samplers (autosamplers) from a point near the bank at chute sampling transects.

Discrete Sampling

All water samples were collected following the accepted protocols of the USGS (U.S. Geological Survey, variously dated; Edwards and Glysson, 1999). All transects at each study site were unwadeable; therefore, a US DH–2 sampler (suspended-sediment/water-quality collapsible-bag sampler capable of isokinectically collecting a 1–L sample; Davis, 2005) was transited through the water column using a crane and reel mounted on the bow of a boat. In all cases, a constant, isokinetic transit rate (Edwards and Glysson, 1999) was used to collect the sample at each vertical station along a transect. Samples were collected at the center vertical from each of 10 EWI of a transect and composited into a polyethylene churn-splitter container. These composited samples are henceforth referred to as EWI samples. Subsequently, an aliquot was split from the composite sample and submitted for laboratory analysis.

Turbidity was recorded in conjunction with the suspended-sediment sampling. An aliquot of the composite sample was split from the churn for turbidity analysis. Turbidity readings were recorded of five different aliquots and the median value of five readings was documented. Turbidity was measured using a calibrated Yellow Springs Instrument Company (YSI) 6136 turbidity probe onsite.

Automatic Sampling

Grab samples for all chute sampling locations were collected using ISCO autosamplers (Teledyne Isco^{TM}, Lincoln, Nebr.). The autosampler was deployed on the bank with tubing extended to the water with a maximum head difference of approximately 14 feet. The orifice of the line was deployed approximately 1 foot below the surface and 2 feet from the streambed at time of deployment. The autosamplers were equipped with stage triggers that would enable the autosampler and begin the sampling when the stage of the chute overtopped the trigger device; the triggering devices were set at various stages. Once triggered, the autosamplers collected samples every 6 hours until a maximum of 24 possible samples were collected. Midway through the year, the autosamplers were converted from stage-triggered sampling to a scheduled sampling interval. The lack of high flows combined with faulty triggering of the autosamplers necessitated the change. A new sampling interval was established and samples were collected at noon every 2 days throughout the remainder of the year.

Turbidity values that correspond to autosampler grab samples were recorded from the continuous water-quality monitor deployed at the chute sampling location. When grab samples from the autosampler did not fall exactly on the 15-minute interval of the turbidity reading, the turbidity value closest in time was used.

Quality Control

During 10 EWI sampling events, the autosamplers were triggered to collect a concurrent sample; however, after data evaluation only 7 pairs of concurrent EWI and autosampler results were usable. In addition, sequential replicates samples were collected for 6 percent of the EWI samples (49 EWI samples collected, 3 replicates) to document the precision and reproducibility in field sampling procedures. Sequential replicate samples were collected immediately after the primary sample at the same transect using a separate set of sampling equipment.

Laboratory Analyses

Samples were analyzed by the USGS Iowa Sediment Laboratory at Iowa City, Iowa, for total SSC and the fraction of sediment mass finer than sand or sand-fines, that is, the threshold (0.0625 mm) between sand-size and finer-than-sand-size particles of sediment (SF; also referred to as SF split in this report). A subset of samples also was analyzed for grain-size distribution using a visual-accumulation-tube technique (Guy, 1969). This technique characterized samples by determining the corresponding fractions of suspended sediment finer than 0.0625, 0.125, 0.25, and 0.5 mm in diameter. Suspended-silt-clay concentration (*SSiltC*) is defined as particles finer than 0.062 mm in diameter and is calculated as SSC x SF split / 100 for all EWI samples. Suspended-sand concentration (*SSandC*) is defined as particles larger than 0.062 mm in diameter and is calculated as SSC x (100 – SF split) / 100 for all EWI samples. The *SSiltC* includes silt and clay in suspension, and *SSandC* includes only sand; gravel is not likely present in the suspended load of a low-gradient river (Edwards and Glysson, 1999).

Continuous Water-Quality Monitoring

Real-time continuous water-quality monitors were deployed at three locations (UHAM–CH–DS, KANS–CH–US, and KANS–CH–DS) from late March to late October 2012 (fig. 4). Deployment configurations included a polyvinyl-chloride conduit that was anchored to the bank and protected the meter and the communications cable.

Each monitor recorded at a 15-minute interval and provided a continuous record of turbidity and water temperature. Monitors were operated and maintained in accordance with the standard procedures described in Wagner and others (2006). This study used model 6136 sensors that measure the amount of light scattered at a right angle from a near-infrared light source. The sensors were developed by YSI, Incorporated (Yellow Springs, Ohio) to collect turbidity measurements. Because the sensors use a near-infrared light rather than a white (broad spectrum) light source, turbidity is reported in formazin nephelometric units (FNU) instead of the more common nephelometric turbidity units (NTU; U.S. Geological Survey, variously dated). These reporting units are compatible in standard solutions but may deviate in environmental samples (U.S. Geological Survey, variously dated). The probes can accurately measure turbidity to approximately 1,000 FNU; a lower reporting limit of 1 FNU was assigned for this study.

Streamflow Measurements

Streamflow measurements were made using discrete methods, and streamflow was estimated using the index velocity method from continuous velocity and stage data from an ADVM; both methods followed USGS standard protocols. Discrete measurements were made monthly in association with sampling in the Missouri River main channel and in the chute. Continuous streamflow records were produced only within the chutes.

Discrete Streamflow Measurements

Discrete streamflow measurements were made during March through October 2012 following USGS standard protocols (Oberg and others, 2005; Mueller and Wagner, 2009). All streamflow measurements were made using an acoustic Doppler current profiler mounted to a boat in association with a differentially corrected global positioning system receiver. During each sampling event, streamflow was measured at one main-channel transect and one chute transect. Concurrent streamflow for all other transects at that study site was estimated from the two measurements.

Continuous Streamflow Measurements

A Sontek 1500-kilohertz Argonaut SL (YSI Sontek, San Diego, California) ADVM was deployed on the left bank at the downstream sampling location of each monitored chute. The ADVMs send out an acoustic pulse of a known frequency. The acoustic pulse is reflected by small particles in the water, returning to the transducer at a frequency that has been shifted because of the Doppler effect. The water velocity is determined on the basis of the change in the transmitted acoustic frequency and the geometric configuration of the transducers (SonTek Corporation, 2000; Ruhl and Simpson, 2005). The ADVMs were mounted on 2-inch galvanized pipes that were

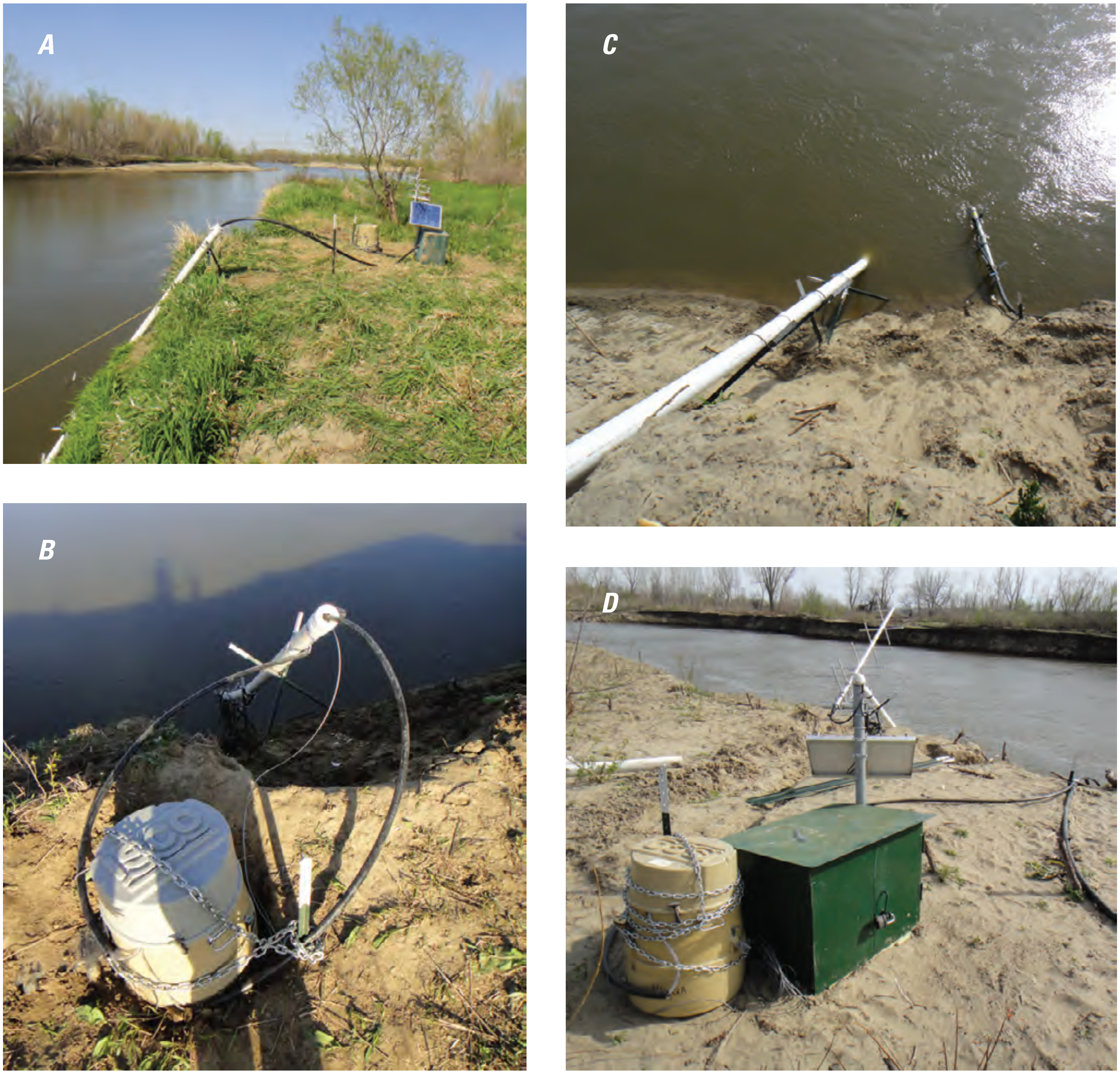


Figure 4. Photographs showing (*A*) Upper Hamburg chute downstream gage house with solar panel and autosampler on the bank and real-time continuous water-quality monitor conduit (white) running down the bank; (*B*) autosampler on the bank and real-time continuous water-quality monitor conduit (white) running down into the chute deployed at Kansas chute upstream sampling location; (*C*) real-time continuous water-quality monitor conduit (white) and acoustic Doppler velocimeter cables running down the bank at Kansas chute downstream sampling location; and (*D*) Kansas chute downstream autosampler, gage house with solar panel and transmitting antenna, and sampling line and acoustic Doppler velocimeter cable running over the bank and into the chute.

anchored to the bank and into the streambed. When mounted, the ADVMs were oriented to emit a 2-beam horizontal signal to determine water velocity and direction and a single vertical beam to determine stage. The ADVMs were configured to record and transmit water velocity and stage every 15 minutes to the USGS Web site. The ADVMs were configured to average velocity and stage data for 300 seconds. The velocity data were divided into 10 cells; each cell was 6 feet. The blanking distance at UHAM–CH–DS was 5 feet and the measured zone extended from 30 to 50 feet. The blanking distance at KANS–CH–DS was 2 feet and the measured zone extended from 45 to 50 feet. The cross-sectional geometry of the transect at each ADVM was defined and surveyed once to develop a stage-area rating. Maintenance and operation of the ADVMs through the period of study followed the recommendations and guidelines contained in Levesque and Oberg (2012) and included water-temperature comparisons and beam checks on a regular basis.

As described in the previous sections of this report, discrete streamflow measurements were made within the chute. Streamflow measurements were used in conjunction with the data collected by the ADVMs to create an index velocity equation. Computing streamflow using the index velocity method differs from the traditional stage-discharge method by separating velocity and area into separate ratings—the index velocity rating and the stage-area rating. The outputs from these ratings, channel-mean velocity (V) and cross-sectional area (A), are factors multiplied together to compute a streamflow. For the index velocity method, V is a function of parameters such as streamwise velocity, stage, cross-stream velocity, and velocity head; and A is a function of stage and cross-section shape (Levesque and Oberg, 2012). The index velocity equation created for each chute was used to compute real-time chute streamflow.

Data Analysis

Data analysis for this study included two different components as follows: (1) analysis of calculated continuous sediment load based on estimated continuous SSC from a turbidity surrogate and (2) analysis of EWI SSC and loads within each study site. These analysis methods are described in three subsections of the report, including estimation of continuous suspended-sediment loads in the chutes using surrogate relations, comparisons involving continuous suspended-sediment loads in Kansas chute, and comparisons involving discrete suspended-sediment samples.

Estimation of Continuous Suspended-Sediment Loads in the Chutes using Surrogate Relations

Calculation of continuous sediment loads, as daily and hydrologic-event loads, began with the estimation of continuous SSC from continuous turbidity data that followed USGS guidelines detailed by Rasmussen and others (2009). The calibration dataset, which included the physical samples (discrete EWI and automatic sampling), was quality-assured by comparing the turbidity and streamflow range between the real-time data and the calibration data and by comparing the SSC and turbidity values measured during EWI sampling with the values obtained from the autosampler and continuous water-quality monitor, respectively.

To determine if the suspended-sediment concentrations from an autosampler (SSC_{auto} ; collected by the programmable pumping sampler) were similar to suspended-sediment concentrations from the discrete equal-width increment samples (SSC_{EWI}), the data were plotted and Pearson's r correlation coefficient (a measurement of the strength of a linear relation ranging from -1 to 1) was calculated. A simple linear regression (SLR) model was developed to predict SSC values that were equivalent to SSC_{EWI} using SSC_{auto} as the independent variable. Equivalent silt and sand concentrations were then calculated using the autosample SF split. These EWI-equivalent values of SSC*, SSiltC,* and *SSandC* were used in the development of the regression relations of SSC to turbidity. Data outliers in the final dataset were evaluated and, if warranted, were omitted from the dataset (Rasmussen and others, 2009).

Surrogate models were developed for SSC as a function of turbidity, and the models were evaluated based on regression statistics and residual diagnostics. Multiple linear regression (MLR) models of SSC were fitted using turbidity with the addition of either streamflow or construction (construction was included as a binary independent variable, coded as "yes" if the data were collected during the construction period and represented by a 1 in the data analysis) as explanatory variables. Candidate MLR models were investigated and compared with their SLR counterparts to obtain the best-fit model for each site. All best-fit models were evaluated using multiple criteria—statistical significance (F test for overall model and *t*-tests for individual coefficients), residual plots, normality plots, adjusted R-squared values, and residual standard error values. The MLR models were also evaluated by calculating the variance inflation factor and the model standard percent error of the SLR model (Rasmussen and others, 2009). The variance inflation factor provides a measure of the correlation among explanatory variables and describes how including correlated variables in the model affects the ability of the model to predict SSC. Linear regression models were developed for each of the three chute sampling locations for total SSC and *SSiltC*. A bias-correction factor was calculated from model residuals following the method of Rasmussen and others (2009). A bias-correction factor was necessary because log-transformed values of SSC were used to fit a power equation, and the residual errors (which have a mean of zero in logarithmic units) do not have a mean of zero after SSC values are back-transformed from log space to arithmetic space; therefore, unless an adjustment is made, a small bias is introduced (Newman, 1993).

The linear regression models were used to predict total SSC and *SSiltC* every 15 minutes from late March to late October 2012 when turbidity and streamflow data were available. The *SSandC* was estimated by subtracting *SSiltC* from total SSC.

Instantaneous suspended-sediment loads (tons per day; for total suspended load, silt-clay load, and sand load) were calculated from the 15-minute concentration and streamflow data (Lee and others, 2012):

$$SSL_{in} = SSC_{in} \text{ x } Q_{in} \text{ x } C \tag{1}$$

where

SSL_{in} is instantaneous suspended-sediment load, in tons per day;

SSC_{in} is instantaneous suspended-sediment concentration, in milligrams per liter;

Q_{in} is instantaneous streamflow, in cubic feet per second; and

C is a constant, 0.0027, for converting the load units to tons per day.

These instantaneous suspended-sediment loads were then used to estimate total load during the 15-minute period, calculated as follows:

$$SSL_{15} = SSL_{in} \text{ x } \left(\frac{15}{1440}\right) \tag{2}$$

where

SSL_{15} is total suspended-sediment load during the 15-minute period, in tons per day;

SSL_{in} is instantaneous suspended-sediment load, in tons per day.

Total load during 15-minute periods were summed for the 24-hour period to get daily total suspended-sediment load (SSL), silt-clay suspended-sediment load (SSL_{silt}), and sand suspended-sediment load (SSL_{sand}). If continuous turbidity or streamflow data were not available for all 15-minute periods in a day, SSC and instantaneous suspended-sediment load could not be calculated; therefore, a daily load was not estimated even if data were missing for only a small part of the day. Selected flow events, either high flow or stable normal flow, were similarly summarized to estimate the event-total loads for SSL, SSL_{silt}, and SSL_{sand}.

Comparisons Involving Continuous Suspended-Sediment Loads in Kansas Chute

Daily and event-based loads at KANS–CH–US were compared to those at KANS–CH–DS (fig. 2) to determine if geomorphic processes were affecting sediment transport within the chute. Paired *t*-tests were used to determine the significance of differences in daily sediment loads between the two sites; and, from these results, an interpretation was made as to if the chute was generally experiencing net erosion or net deposition during the monitoring period. A second approach used 95-percent confidence intervals to determine if KANS–CH–US daily loads were significantly different than KANS–CH–DS daily loads on a given day to document periods of erosion or deposition within the chute at a daily time scale.

For the daily load comparison, 100 daily loads were randomly selected from KANS–CH–US, and the same daily loads were selected from KANS–CH–DS. Paired *t*-tests (Helsel and Hirsch, 2002) were used to determine if a statistical difference existed between SSL, SSL_{silt}, or SSL_{sand} at the upstream and downstream sample locations. Random selection of daily loads was used to minimize serial autocorrelation between loads computed from consecutive days, and five replications of the randomized selection followed by hypothesis testing were used to estimate sampling variability of this method. Event-based loads were also compared between the upstream and downstream monitoring stations in the chute using a paired *t*-test.

A second comparative approach that factored in the uncertainty of the SLR estimates was used to compare daily loads between KANS–CH–US and KANS–CH–DS. Daily loads were evaluated by defining a 95-percent confidence interval around each daily load (Helsel and Hirsch, 2002; Lee and others, 2012; Schaepe and others, 2014) and assessing overlap between the confidence intervals for the day between upstream and downstream load estimates. Confidence intervals are calculated using Student's *t* distribution critical values and the standard error of the mean (Helsel and Hirsch, 2002). Residual standard error of the regression model was used to calculate confidence intervals around the daily load values. Lee and others (2012) and Schaepe and others (2014) also used the residual standard error of similar regression models to calculate confidence intervals around values predicted using those models. Confidence interval limits were calculated as follows:

$$\begin{aligned} LCL95 &= 10\text{^}(\log_{10}(SSL_{daily}) - \tau_{(0.025,n\text{-}1)}\ x\ RSE) \\ UCL95 &= 10\text{^}(\log_{10}(SSL_{daily}) - \tau_{(0.025,n\text{-}1)}\ x\ RSE) \end{aligned} \tag{3}$$

where

$LCL95$ is the lower confidence limit of total daily load at 95-percent confidence level,

SSL_{daily} is the estimated daily suspended-sediment load,

$\tau_{(0.025,n\text{-}1)}$ is the Student's τ distribution critical value at $\alpha/2=0.025$ and n-1 degrees of freedom,

RSE is the residual standard error of the regression model (table 2), and

$UCL95$ is the upper confidence limit of total daily load at 95-percent confidence level.

Use of this linear regression-based method carries an implicit assumption that no error is associated with streamflow values used to calculate the loads. The resulting daily confidence intervals around the load estimate were evaluated for overlap between KANS–CH–US and KANS–CH–DS. If the confidence intervals did not overlap, then the loads were statistically different for that day and represented measurable net erosion or deposition within the Kansas chute.

Comparisons Involving Discrete Suspended-Sediment Samples

Analysis of differences in EWI SSC and loads between transects within each study site used methods similar to those completed by Woodward and Rus (2011) and used Student's *t* distribution because there were only seven sampling events. The distribution of the *t* statistic is similar to a normal distribution but presumes more variance as a function of the sample size; therefore, the *t* statistic is preferable for small sample sizes such as were available in this study (Ott and Longnecker, 2001). Paired *t*-tests with unequal variance and a 95-percent significance level (alpha equals 0.05) were used to test for a difference between two subsets of samples. Paired *t*-tests can detect smaller differences by removing extraneous intersite variability (such as might be caused by varying streamflow conditions) from the comparisons. Samples were paired by the day of sample collection. For each test result reported, the corresponding *p*-value also is reported. The *p*-value represents the probability that the statistical test results, or more extreme values, could have occurred if the null hypothesis was true. In the comparisons, the null hypothesis is that the two samples were drawn from populations that are not different. A *p*-value smaller than the alpha level (or rejection level) of 0.05 indicates that the statistical test outcome provides evidence that the null hypothesis is false; results are rare where the null hypothesis is true. If the resulting *p*-value is less than 0.05, the test statistic is significant, meaning that the null hypothesis (the two samples being the same) is rejected and the two samples are declared with 95-percent confidence to be significantly different. Paired *t*-tests of loads, SSC, and turbidity values from EWI samples were used to answer three questions as follows: (1) does the chute sediment load produce a measurable difference in the main-channel sediment load, (2) do the chute sediment characteristics change from upstream to downstream, and (3) are the chute upstream sediment characteristics different than the Missouri River upstream sediment characteristics. In addition, 2008 EWI sample data (Woodward and Rus, 2011) were included in the analysis when applicable.

Quality Control

Quality-control data (three pairs of EWI replicate samples total from all sites) were analyzed for precision, which was measured as the relative percent difference between the original sample and the replicate sample ([original sample – replicate]/[(original sample + replicate)/2] * 100). This analysis of sequential replicates indicates how imprecise the overall sampling and laboratory analysis were, even with the small number of quality-control samples.

Turbidity values exceeded the maximum sensor limit of 1,000 FNU (as specified by the manufacturer) at the KANS–CH–US and KANS–CH–DS sites. The sensors appeared to operate adequately at the levels that were exceeded (1,038 FNU at KANS–CH–US and 1,000 FNU at KANS–CH–DS); therefore, the values were not censored in the analyses. Furthermore, these values represent less than 0.17 percent of the stream volume monitored during the study and are not expected to significantly affect the load comparisons.

Sediment Loads in the Chutes

Daily suspended-sediment loads were estimated based on surrogate relations of SSC with turbidity (and streamflow at one transect). The statistical model-calibration dataset of EWI and autosampler data were evaluated and determined to be adequate for predicting SSC from turbidity. A linear regression was used to estimate EWI-equivalent SSC from autosampler SSC before using the model-calibration dataset to determine the best regression model of the turbidity and SSC relation. Construction period was considered for inclusion as a binary independent variable in the relation between turbidity and SSC but was not included in any of the best-fit models; therefore, the conclusion was made that construction did not strongly affect the relation between turbidity and SSC. Daily suspended-sediment loads were significantly reduced by the closure of Upper Hamburg chute inlet structure. Daily suspended-sediment loads were not significantly different between upstream and downstream sites within Kansas chute, as indicated using paired *t*-tests, and most individual daily loads were not significantly different between upstream and downstream sites, as indicated by overlap in confidence intervals.

Surrogate Relations in the Chutes

Evaluation of the model-calibration datasets used in developing surrogate relations between turbidity and SSC at UHAM–CH–DS, KANS–CH–US, and KANS–CH–DS determined that the model-calibration datasets were adequate. The model-calibration datasets consisted of the SSC results from physical samples (discrete EWI and automatic sampling) and associated turbidity values. Turbidity had been measured along with the EWI using an aliquot from the churn, and turbidity values also were recorded by the continuous water-quality monitor during the time of EWI or autosampler sampling. Turbidity values measured from the EWI samples were compared with the corresponding turbidity values from the continuous water-quality monitor (one single reading during the EWI mean sample time) using paired *t*-tests. The results did not determine differences in the values (n=21 and p=0.7182), which indicate that the continuous water-quality monitor values measured near the bank are representative of the values from the entire transect and can be used for regression equation development. Strong linear correlation exists between SSC and *SSiltC* from EWI samples and concurrent samples collected by an autosampler as indicated by Pearson's r value of 0.93 (n=7 from all three sites combined), which was the same for SSC and *SSiltC* correlation. In addition, slopes in both linear regression models (again, *n*=7 from all three sites combined) for SSC and *SSiltC* from EWI samples and concurrent samples collected by an autosampler were near one; however, no correlation was evident in the SF split (Pearson's r value of -0.06, *n*=7 from all three sites combined) between the EWI and autosamples. Correlation between *SSandC* in EWI samples and concurrent samples collected by an autosampler was low with a Pearson's r value of only 0.07 (*n*=7 from all three sites combined). The low correlation in the SF split and *SSandC* values may be explained by the majority of the sediment being silt-sized or finer; therefore, linear correlation in the coarser fractions was obscured by measurement imprecision. This imprecision may have been the result of a depth dependence in the concentration of larger particles like sand (Julien, 2010) that was not captured from the fixed-point sampling location of the autosampler. The low correlation may also be the result of inefficient sample splitting of the sand-size particles in the composite EWI sample using a churn splitter (Capel and Larson, 1996). Based on the results and considerations, no further steps were made to develop a surrogate relation of *SSandC* to turbidity because a large number of samples in the calibration dataset were from autosamplers; therefore, any relation between turbidity and *SSandC* would likely be poor. Instead, *SSandC* was estimated as SSC minus *SSiltC*. Physical samples collected by EWI sampling or autosamplers represented a substantial part of the ranges of streamflow and turbidity observed in the chutes during the summer of 2012 (figs. 5, 6; table 1). The greatest difference in data ranges between the model-calibration dataset and the time-series dataset is in the maximum turbidity at Kansas chute. The maximum turbidity during a physical sample at KANS–CH–US was only 379 FNU, and the maximum turbidity from the time-series data was 1,038 FNU (table 1); therefore, the calibration dataset from KANS–CH–US does not fully represent the range of turbidity. During the study period, however, only 8 percent of the total flow volume was when FNU was greater than 310. In addition, the calibration dataset at KANS–CH–US and KANS–CH–DS does not

Table 1. Summary of the model-calibration dataset and the time-series dataset at Upper Hamburg chute and Kansas chute.

[mg/L, milligrams per liter; FNU, formazin nephelometric units; ft^3/s, cubic foot per second; UHAM–CH–DS, Upper Hamburg chute downstream; KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream]

Summary statistic	Suspended-sediment concentration (mg/L)	Turbidity (FNU)		Streamflow (ft^3/s)	
	Model-calibration dataset	Model-calibration dataset	Time-series dataset	Model-calibration dataset	Time-series dataset
UHAM–CH–DS					
34 samples and 16,737 15-minute values					
Minimum	32	14	15	873	395
Maximum	622	150	460	6,752	7,894
Mean	91	42	57	1,993	2,719
Median	57	34	34	1,270	1,380
Standard deviation	112	29	58	1,688	1,842
KANS–CH–US					
31 samples and 18,896 15-minute values					
Minimum	42	18	3	1,880	960
Maximum	794	379	[1]1,038	13,900	19,186
Mean	320	112	65	6,800	3,659
Median	291	93	34	7,200	1,967
Standard deviation	209	82	88	3,691	2,781
KANS–CH–DS					
34 samples and 20,623 15-minute values					
Minimum	55	31	21	1,669	960
Maximum	3,190	940	[1]1,000	18,844	19,186
Mean	489	193	78	6,603	3,659
Median	110	71	51	1,996	1,967
Standard deviation	711	229	80	6,484	2,781

[1] Value at or above the manufacturer-specified sensor limit for the turbidity probe.

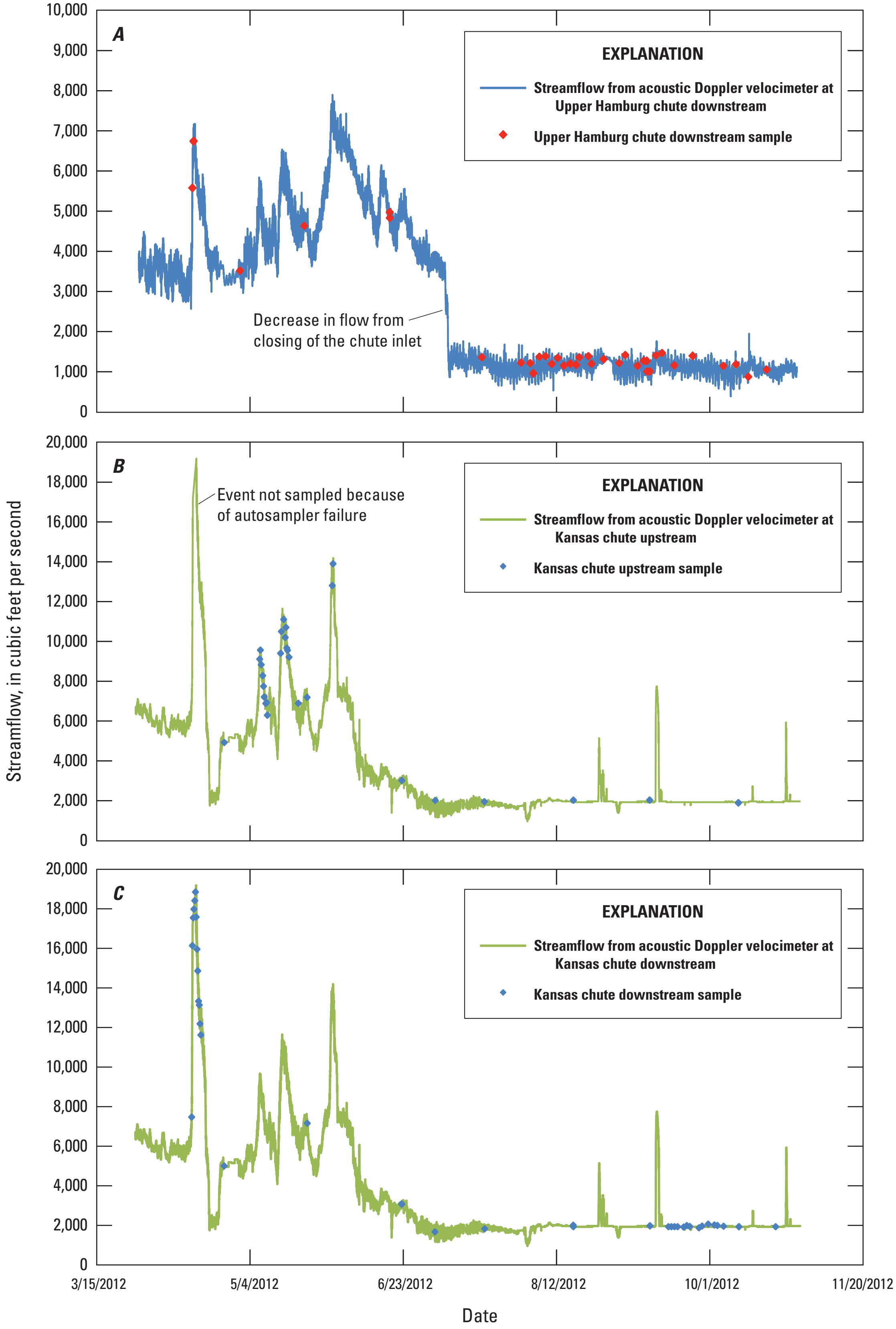


Figure 5. Streamflow and dates of physical samples, April through October 2012 at (*A*) Upper Hamburg chute downstream, (*B*) Kansas chute upstream, and (*C*) Kansas chute downstream.

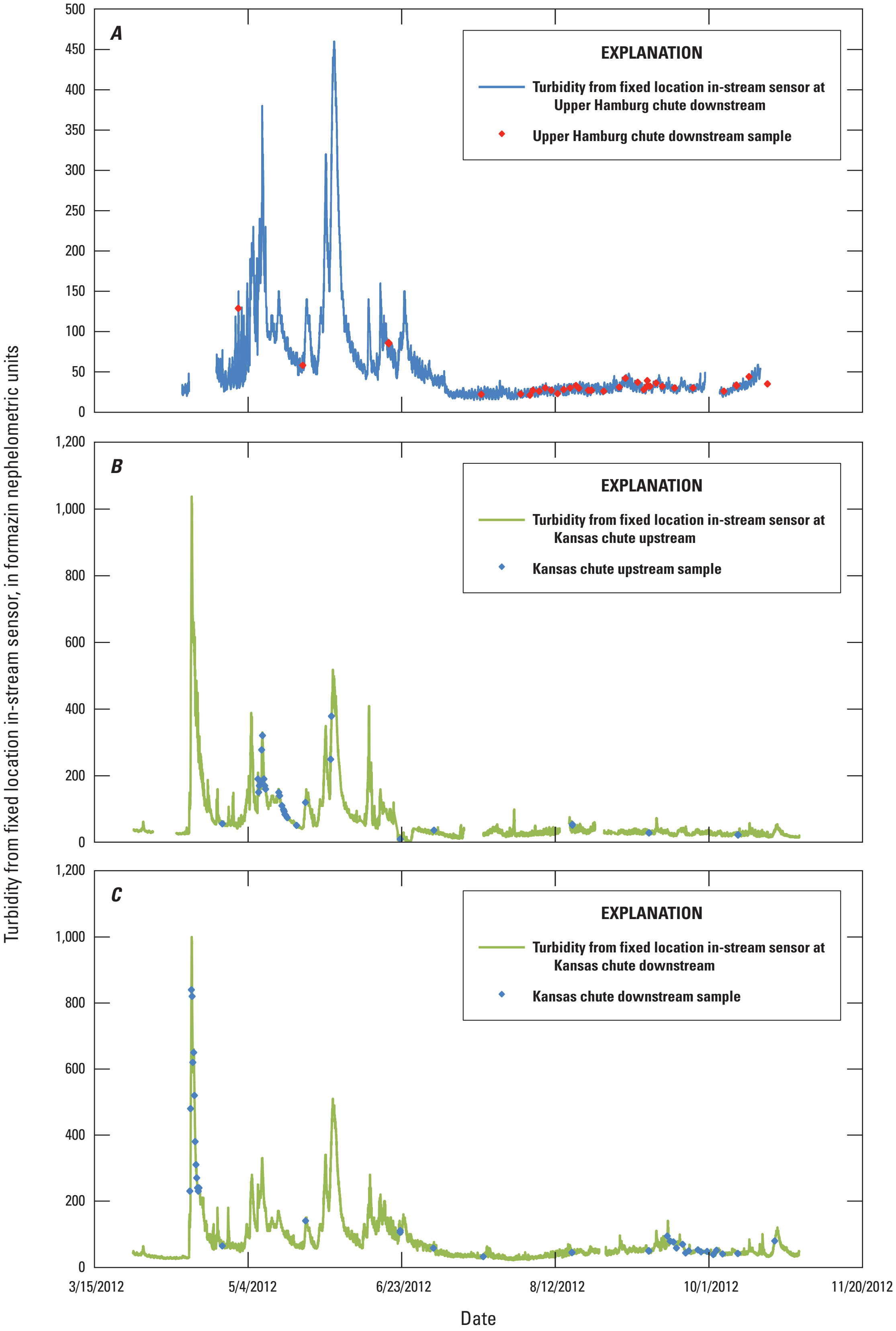


Figure 6. Fixed location in-stream turbidity and dates of physical samples, April through October 2012 at (*A*) Upper Hamburg chute downstream, (*B*) Kansas chute upstream, and (*C*) Kansas chute downstream.

represent the range of low streamflow. For KANS-CH-US and KANS-CH-DS, the minimum streamflow recorded in the time-series dataset was 960 cubic feet per second (ft^3/s), but the minimum streamflow during a physical sample was 1,880 and 1,669 ft^3/s, respectively (table 1). During the study period, however, only 1.7 percent of total flow was when streamflow was less than 1,669 ft^3/s.

The hydrographs for each chute (fig. 5) show that only a few flow events occurred during the study period. The hydrograph at Upper Hamburg chute shows the substantial decrease in streamflow because of the closing of the chute inlet in early July. Samples collected at Upper Hamburg chute before the closing of the inlet were mostly monthly EWI samples because of autosampler failure; therefore, data from Upper Hamburg chute are more representative of the low-flow condition. Similarly, the initial high-flow event, April 15, 2012, at Kansas chute was not sampled at KANS–CH–US because of autosampler failure; however, several autosampler samples were collected and analyzed during the high-flow event at KANS–CH–DS. Additional samples were analyzed from KANS–CH–US during the three smaller events on May 7, 14, and 30, 2012. Samples adequately represented the range in streamflow and turbidity throughout the sampling period (table 1); however, the samples did not represent the same high-flow events at each site, and the distribution of samples was uneven across the quantiles of streamflow frequency.

Results for total SSC were evaluated and some concentrations were deemed erroneous. Erroneous total SSC generally either did not agree with EWI and real-time turbidity values or had an unrealistically high proportion of sand (implying that the sample may have been contaminated by streambed sediments). Samples that were deemed erroneous and removed from the calibration dataset before fitting the final regression models are shown in the plot of turbidity and SSC (fig. 7).

The last step before developing best-fit models for estimating SSC from turbidity was to estimate EWI-equivalent SSC from autosampler SSC. Because a significant linear correlation was determined between autosampler SSC and EWI SSC (Pearson's r of 0.93) a linear regression equation was used to estimate EWI-equivalent SSC. The SLR developed from seven sets of paired EWI samples and autosamples combined from all three sites is as follows:

$$\text{Estimated } SSC_{EWI} = SSC_{auto} \text{ x } 0.8834 + 11.3738 \tag{4}$$

where

Estimated SSC_{EWI} is the EWI-equivalent suspended-sediment concentration;

SSC_{auto} is suspended-sediment concentration from an autosampler.

The regression equation had a large residual standard error of 30.03 milligrams per liter because of the small sample size but a good adjusted R-squared value of 0.8463. Because no correlation was indicated between EWI and autosampler values of SF split, the estimated EWI SSC was used with the autosampler SF split to estimate *SSiltC* and *SSandC*.

After the model-calibration dataset had been fully evaluated, the EWI SSC with the estimated EWI SSC and the EWI *SSiltC* with the estimated EWI *SSiltC* were used with the continuous turbidity data to develop best-fit SLR or MLR models. At all sites, the best-fit models included the base-10 logarithm of concentration and turbidity, and at Kansas chute upstream, the base-10 logarithm of streamflow was also included in the best-fit models (table 2). At KANS–CH–US, the base-10 logarithm of streamflow was included in the best-fit models because the variance inflation factor between turbidity and streamflow was acceptable (variance inflation factor equals 2.48; variance inflation factor less than 10 indicates that the variables are not multicollinear [Rasmussen and others, 2009]). Also, the base-10 logarithm of streamflow was included in the best-fit models at KANS-CH-US because the standard percent error of the SLR models, derived as a percentage of the model standard error, was 34.48–52.62 percent; if greater than 20 percent then the addition of

Table 2. Regression equations for estimation of suspended-sediment concentrations in two sediment size classes.

[*n*, number of samples; *RSE*, residual standard error; mg/L, milligram per liter; R^2, coefficient of determination; MSPE, model standard percent error; UHAM–CH–DS, Upper Hamburg chute downstream; SSC, suspended-sediment concentration; Turb, turbidity in formazin nephelometric units; *SSiltC*, suspended-silt concentration; KANS–CH–US, Kansas chute upstream; *Q*, streamflow; KANS–CH–DS, Kansas chute downstream]

Site identifier	Equation	*n*	*RSE*, in log (mg/L) units	Adjusted R^2 (dimensionless)	Bias correction factor	MSPE
UHAM–CH–DS	$\log_{10}(\text{SSC})=1.0132\log_{10}(\text{Turb})+0.2838$	32	0.092	0.78	1.02	+23.6, -19.1
	$\log_{10}(SSiltC)=0.9088\log_{10}(\text{Turb})+0.4229$	31	0.085	0.69	1.02	+21.6, -17.8
KANS–CH–US	$\log_{10}(\text{SSC})=0.4524\log_{10}(\text{Turb})+0.6217\log_{10}(Q)-0.8658$	27	0.130	0.87	1.04	+34.9, -25.9
	$\log_{10}(SSiltC)=0.4961\log_{10}(\text{Turb})+0.61391\text{og}_{10}(Q)-0.9431$	26	0.120	0.88	1.04	+31.8, -24.1
KANS–CH–DS	$\log_{10}(\text{SSC})=1.1317\log_{10}(\text{Turb})+0.0120$	33	0.110	0.95	1.03	+28.8, -22.4
	$\log_{10}(SSiltC)=1.1351\log_{10}(\text{Turb})+0.0059$	33	0.110	0.95	1.03	+28.8, -22.4

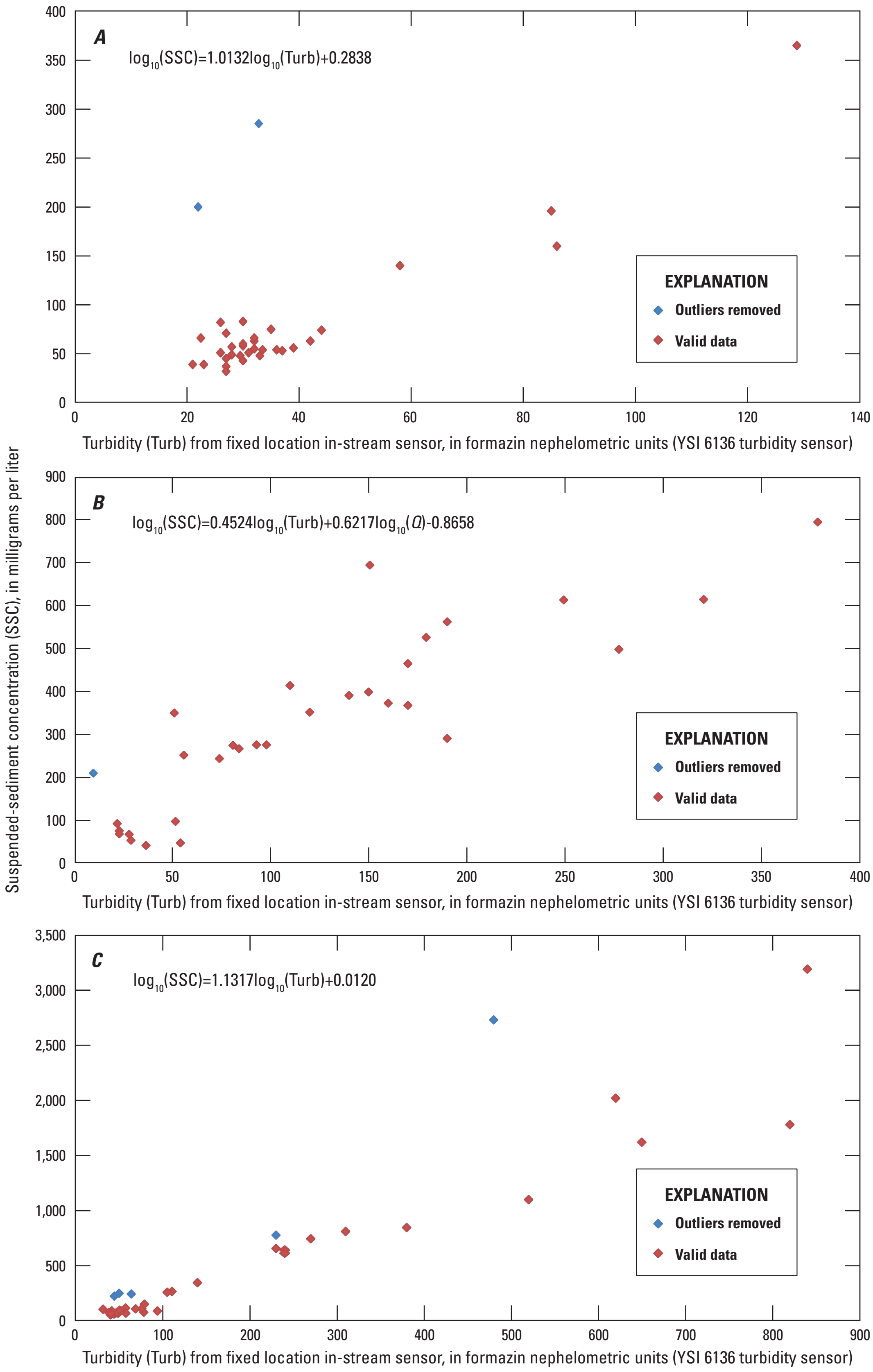


Figure 7. Turbidity in relation to total suspended-sediment concentration, including outliers excluded from regression analysis of data collected at (*A*) Upper Hamburg chute downstream, (*B*) Kansas chute upstream, and (*C*) Kansas chute downstream.

an additional explanatory variable is reasonable (Rasmussen and others, 2009). The selected models had high R-squared values (0.69–0.95) and model standard percent errors of 35 percent or less between turbidity and SSC (and streamflow at KANS–CH–US; table 2). The values indicate that turbidity typically predicted SSC within 35 percent at these study sites. Because of the number of samples, separate models could not be developed for construction and nonconstruction periods. Construction period was considered for inclusion as a binary independent variable in the relations between turbidity and SSC but was not included in any of the best-fit models. The result indicates that any sediment-transport effect from construction was already represented by changes in the turbidity or streamflow. Bias-correction factors were calculated based on model residuals as described in Rasmussen and others (2009), and the back-transformed concentration estimate was multiplied by the bias-correction factor, which ranged from 1.02 to 1.04 (table 2).

Suspended-Sediment Load Estimates

Suspended-sediments loads were estimated using computed SSC values (calculated from the developed models), continuous turbidity data (March 27, 2012, through October 31, 2012), and continuous streamflow data. Instantaneous loads were calculated from SSC and *SSiltC* and were used to estimate total SSL and SSL_{silt} for each 15-minute period. Daily total SSL and SSL_{silt} were estimated by totaling all 15-minute loads for the day (table 3, at the back of this report). Sand load was calculated using the same method, except *SSandC* was estimated as the difference between SSC and *SSiltC*. The sum of the daily silt and sand load rarely is greater than the daily total load because of rounding (table 3). As expected, the estimated daily loads indicated a substantial drop in sediment transport at Upper Hamburg chute following the closure of the inlet structure on July 6, 2012. For the two Kansas chute sites, hydrologic event loads (table 4) were also calculated by summing the 15-minute loads for the duration of events selected on the basis of the hydrograph (figure 5, *B* and *C*). Loads for the rising and falling limbs of the hydrograph of the selected hydrologic events also were calculated.

Comparisons Involving Suspended-Sediment Loads in Kansas Chute

Suspended-sediment loads were compared between upstream and downstream transects to determine if a pattern or trend existed between sites during high- or low-flow events. Data collected during high-flow events indicated no consistent pattern of higher loads at KANS–CH–DS when compared to KANS–CH–US, as might be expected (table 4). During a high-flow event, scour erosion would be expected during the rise (and possibly the fall) of the hydrograph; bank erosion and bed deposition would be expected during the fall of the hydrograph. Data collected during the rise of the hydrograph and data collected during the fall of the hydrograph during high-flow events indicate no consistent patterns (table 4). During a low-flow event, little scour or deposition would be expected. During low-flow events, an aggradational pattern of higher loads at KANS–CH–US as compared to loads at KANS–CH–DS was observed for the sand-size fraction for all four events. If the chute was aggrading (as might be expected based on the physical characteristics of chutes to create complex, low velocity SWH) net deposition is expected of the coarsest size fraction of the suspended load reflected in a measurable difference in SSL_{sand} between the chute inlet and outlet for some part of the event hydrograph (table 4).

The results of paired *t*-tests indicate no difference between KANS–CH–US and KANS–CH–DS in five different randomly selected subsets of 100 daily values (actual *n* ranged from 80 to 85 once “no data” values were removed) of total SSL (*p* values from 0.2189 to 0.9837) or SSL_{silt} (*p* values from 0.1762 to 0.8765). Two of the five randomly selected subsets of 100 daily SSL_{sand} did indicate significant differences between upstream and downstream, with an estimated difference of 39–52 tons, but the test results for the other three subsets had *p* values from 0.1029 to 0.1564. These results indicate that the chute sediment transport was variable; therefore, daily load comparisons on a smaller time scale than the 7-month monitoring period, such as daily, might lead to a better understanding of sediment transport processes within the chute.

Confidence intervals were calculated around each daily total, silt, and sand load estimate at KANS–CH–US and KANS–CH–DS as described by Lee and others (2012) and Schaepe and others (2014) using the residual standard error of each model. Most daily loads indicate overlap in the confidence intervals for the upstream and downstream stations (table 5, at the back of this report). Confidence intervals did not incorporate the uncertainty in the estimate of streamflow. Confidence intervals at the 95-percent level ranged from (difference between the upper and lower limit) 139 to 66,390 tons per day for total load, from 128 to 65,130 tons per day for silt load, and from 4 to 1,456 tons per day for sand load.

These confidence intervals indicate that most daily loads are not significantly different between upstream and downstream. Confidence intervals for SSL and SSL_{silt} indicate that significant erosion only occurred 4 days during the sampling period (June 22, 2012, through June 25, 2012) and that significant deposition only occurred 4 days during the sampling period (April 1, 2012, and April 11, 2012, through April 13, 2012). When confidence intervals for SSL_{sand} were compared, significant deposition was commonly indicated (table 5).

A plot of the difference (KANS–CH–US and KANS–CH–DS) in the total suspended-load estimate (fig. 8) shows the dynamic nature of sediment transport within the chute. Although differences outside of the confidence intervals were only identified for two 4-day periods listed earlier, the pattern of differences demonstrated in the plot is still informative. Before the first high-flow event on April 15, 2012, deposition was occurring, and then approximately 31,000 tons (during 2 days) of sediment eroded from the chute during the peak

Table 4. Event loads calculated from instantaneous estimates of suspended-sediment concentrations from turbidity surrogate at Upper Hamburg and Kansas chute, 2012.

[ft³/s, cubic foot per second; KANS–CH–US, Kansas chute upstream; SSL, suspended-sediment load; KANS–CH–DS, Kansas chute downstream; SSL_{silt}, silt suspended-sediment load; SSL_{sand}, sand suspended-sediment load. Higher value between upstream and downstream is color coded blue, and lower value is color coded green]

Start date and time	End date and time	Peak streamflow (ft³/s)	Average streamflow (ft³/s)	KANS–CH–US total SSL (ton per day)	KANS–CH–DS total SSL (ton per day)	KANS–CH–US SSL_{silt} (ton per day)	KANS–CH–DS SSL_{silt} (ton per day)	KANS–CH–US SSL_{sand} (ton per day)	KANS–CH–DS SSL_{sand} (ton per day)
High-flow events									
4/14/12 at 17:00	4/19/12 at 14:00	19,200	13,400	149,000	170,000	149,000	166,000	987	3,440
5/6/12 at 1:00	5/9/12 at 15:00	9,670	7,760	28,500	32,700	27,600	31,900	906	754
5/13/12 at 16:00	5/17/12 at 5:00	11,700	9,780	32,400	21,800	30,500	21,300	1,810	545
5/27/12 at 11:00	6/6/12 at 16:30	14,200	8,270	105,000	125,000	103,000	122,000	2,170	2,760
Rise of high-flow event									
4/14/12 at17:00	4/16/12 at 9:00	19,200	15,400	76,500	108,000	77,900	106,000	204	2,070
5/6/12 at 1:00	5/7/12 at 8:30	9,670	7,700	8,950	8,570	8,540	8,360	402	206
5/13/12 at 16:00	5/14/12 at 11:30	11,700	7,530	8,290	6,720	7,940	6,560	352	162
5/27/12 at 11:00	5/31/12 at 1:30	14,200	8,760	39,200	41,800	38,300	40,800	988	947
Fall of high-flow event									
4/16/12 at 9:00	4/19/12 at 14:00	18,700	12,300	71,500	61,500	70,900	60,100	783	1,360
5/7/12 at 8:30	5/9/12 at 15:00	9,620	9,620	19,400	24,000	18,900	23,500	500	546
5/14/12 at 11:30	5/17/12 at 5:00	8,340	6,500	23,900	15,000	22,500	14,700	1,450	381
5/31/12 at 1:30	6/6/12 at 16:30	14,200	8,010	65,500	83,000	64,500	81,200	1,180	1,800
Low-flow events									
4/20/12 at 22:00	4/23/12 at 13:00	2,640	2,190	1,880	2,360	1,780	2,300	101	62
7/9/12 at 6:00	7/11/12 at 6:00	2,000	1,720	473	548	419	533	55	16
8/9/12 at 10:30	8/11/12 at 10:30	2,140	2,050	835	682	759	662	77	20
9/25/12 at 9:00	10/2/12 at 3:30	1,930	1,930	2,540	2,900	2,300	2,820	235	82

flows, followed by progressively decreasing deposition during 3 days of the falling hydrograph, and finally several days of erosion from the chute again as the hydrograph settled out to a low-flow period before the next event. Examination of the other three high-flow events in the early summer of 2012 indicates that during two of the three events, the chute was eroding; however, during the May 14, 2012, high-flow event, deposition was estimated to have been uninterrupted. In addition, the data indicate that net deposition was typical until shortly after construction activities began, when results indicate net erosion became dominant during a generally receding hydrograph (fig. 8). Net erosion was estimated for an extended period of time even after the completion of construction; likely the effect of the newly installed spur dikes.

Suspended-sediment loads for the total and silt-clay size fractions were successfully estimated for the three continuous water-quality monitoring locations based on concentrations in EWI and automatic samples, a surrogate relation with turbidity, and streamflow within the chute (at KANS–CH–US). Sand load was not well estimated using autosamplers and turbidity surrogate relations for these sites. Paired *t*-tests were not the best statistical analysis for differences between upstream and downstream sediment load at Kansas chute because of the dynamic nature of sediment transport, which required analysis at a smaller time scale such as daily instead of during the entire season. Calculated confidence intervals for each daily load estimate were used to determine if the difference between upstream and downstream loads differed significantly at the daily time scale. The confidence intervals, however, did not incorporate the error in the estimate of streamflow used in calculating the loads. Confidence intervals indicated that most daily load estimates were not significantly different between KANS–CH–US and KANS–CH–DS. A review of the differences between the upstream and downstream loads indicated that when large erosion events were occurring, the hydrograph peaked or a construction period was ongoing within the chute. Similarly, when the difference in the load estimates between upstream and downstream chute sites indicated a large deposition event, there was an associated change in the hydrograph. The comparison of daily load values estimated from turbidity surrogates for upstream and downstream chute sites documents the dynamic nature of sediment transport within the chute. Understanding loads at this daily time scale is not possible with discrete suspended-sediment sampling alone.

Sediment Transport Characteristics Within and Adjacent to the Chutes

The final analysis completed for this study was a comparison of discrete or EWI sediment data collected within the chutes and within the main channel of the Missouri River upstream and downstream from the chutes. These analyses are similar to those reported by Woodward and Rus (2011). Paired *t*-tests were used to evaluate the difference in sediment concentrations and loads between sampling locations or transects (table 6). Comparisons made included (1) Missouri River upstream to chute upstream to understand how the chute inlet structures affect sediment entering the chute; (2) chute upstream to chute downstream to identify any change in sediment characteristics within the chutes; (3) Missouri River upstream to Missouri River downstream to determine if the chutes had an overall effect on sediment characteristics in the main channel; (4) Missouri River upstream to chute downstream to determine if sediment concentrations at the downstream chute transect are significantly higher or lower than concentrations in the Missouri River upstream from the chute, which indicates that the chute is adding sediment to the main channel or the chute is diluting the sediment within the main channel. All four of these comparisons were made for each studied chute separately, and an additional set of comparisons was completed with the dataset that included data from both chutes together. Some of these same comparisons were also made with 2008 data included (comparison 3 and 4 described earlier; table 6).

The interpretive power of these comparisons was constrained by small sample sizes in relation to the inherent variability of suspended-sediment sampling as well as the anticipated small sediment-transport contributions from the chute relative to the sediment transport of the Missouri River main channel. Three replicate samples, two from the Missouri River main channel and one from a chute, were collected during the study to better understand sampling variability (data are in appendix 1). Laboratory results for these samples were analyzed by computing the relative percent difference between the original sample and the replicate sample. For SSC, the relative percent difference values were 4.6, 22, and 9.7 percent. The grain-size distribution, as percentage finer than sand, had relative percent difference values of 0 and 9.6 percent (no data for the KANS–MR–US sample pair from July 19, 2012).

Concentrations were compared between Missouri River upstream and the chute upstream to understand how the chute inlet structures affect sediment entering the chute (table 6). Sampling was not completed upstream within Upper Hamburg chute; therefore, the comparison was only made for Kansas chute. Total SSC was significantly greater in the Missouri River main channel upstream from the chute inlet than within the chute at KANS–CH–US transect (p=0.0393 and n=6); with a mean difference of 120 milligrams per liter (table 6). Differences in silt-clay and sand concentrations could not be evaluated because several of the Missouri River samples at Kansas chute were analyzed only for SSC and SF-split data were not available. Similar sampling in 2008 indicated that the inlet structures at Upper Hamburg chute and Glovers chute (not shown) reduced the total SSC and the *SSandC* entering the chutes but did not significantly affect the silt concentration (Woodward and Rus, 2011).

Comparisons among concentration, load, and turbidity from the chute upstream transect to the chute downstream transect indicated no significant difference (table 6). The sample size, however, was small after erroneous sample data had

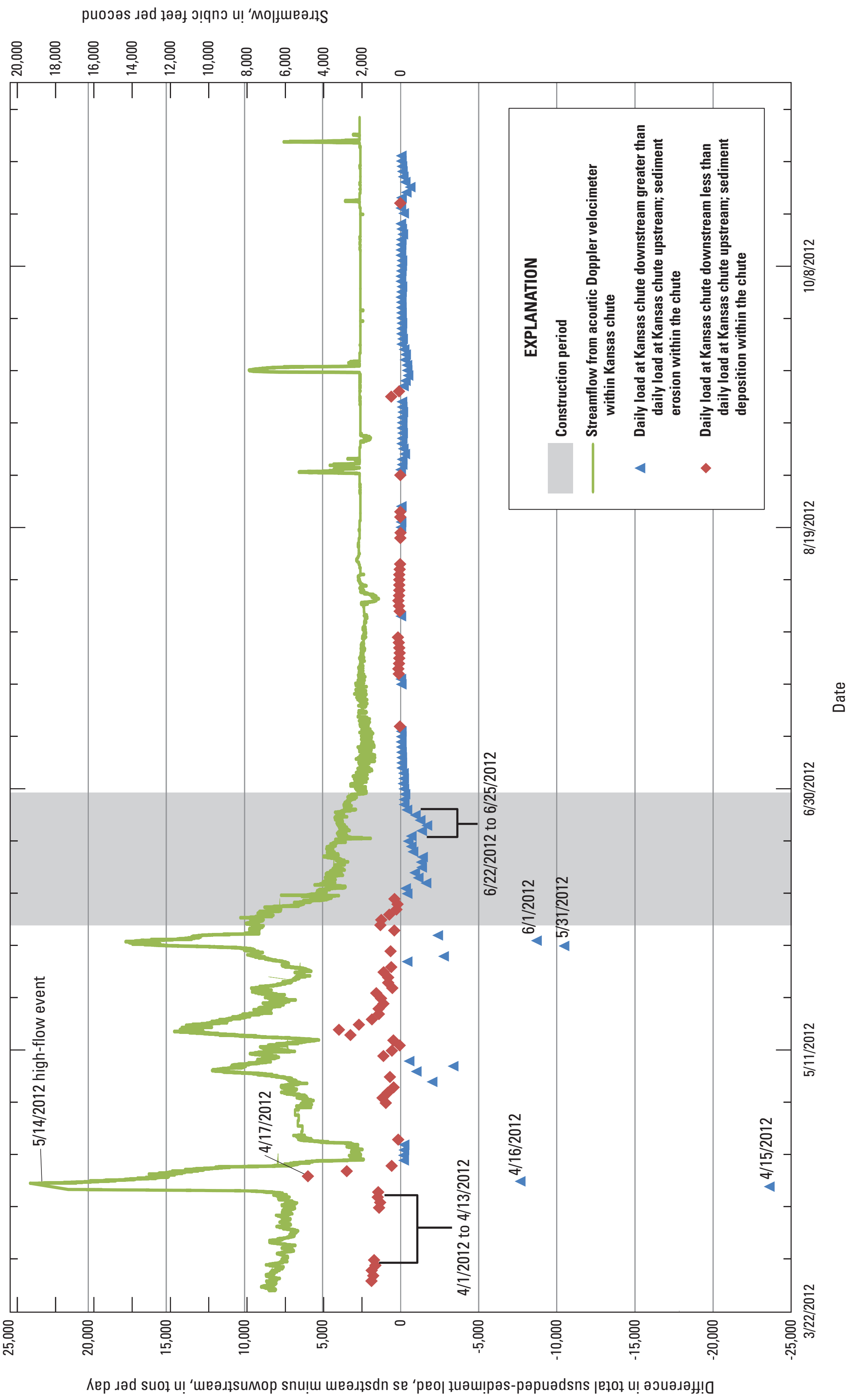


Figure 8. Difference in total daily suspended-sediment load estimate at Kansas chute upstream and Kansas chute downstream.

Table 6. Comparison of sediment characteristics between the Missouri River and the chutes and within the chutes using paired *t*-tests, 2012 and 2008.

[Transect groups represent a subset of data associated with a given transect; UHAM, Upper Hamburg Bend; KANS, Kansas Bend; *n*, number of samples; *p*-value, probability value; d, mean of differences between the paired groupings calculated as trasect group 1 minus transect group 2; <SITE>–MR–US refers to Kansas or Upper Hamburg at Missouri River upstream;<SITE>–CH–US refers to upstream of Kansas or Upper Hamburg chute; SSC_t, suspended-sediment concentration, total; mg/L, milligrams per liter; na, not applicable; *SSiltC*, suspended-sediment concentration of materials finer than 0.062 millimeters (mm) in diameter; --, insignificant difference; *SSandC*, suspended-sediment concentration of materials coarser than 0.062 mm in diameter; FNU, formazin nephelometric units; <SITE>–CH–DS refers to downstream of Kansas or Upper Hamburg chute; SSL_t, suspended-sediment load, total; ton/d, ton per day; SSL>0.062, suspended-sediment load of materials coarser than 0.062 mm in diameter; SSL<0.062, suspended-sediment load of materials finer than 0.062 mm in diameter; <SITE>–MR–DS refers to Kansas or Upper Hamburg at Missouri River downstream; nd, no data]

Transect group 1	Transect group 2	Constituent	UHAM site			KANS site			Both sites		
			n	*p*-value	d	*n*	*p*-value	d	*n*	*p*-value	d
Comparisons related to the effects of the inlet structure on sediment transport											
<SITE>–MR–US	<SITE>–CH–US	SSC_t (mg/L)	na	na	na	6	0.0393	120	na	na	na
		SSiltC (mg/L)	na	na	na	--	nd	--	na	na	na
		SSandC (mg/L)	na	na	na	--	nd	--	na	na	na
		Turbidity (FNU)	na	na	na	4	0.3243	--	na	na	na
Comparisons related to sediment-transport changes within the chute											
<SITE>–CH-US	<SITE>–CH–DS	SSC_t (mg/L)	na	na	na	3	0.7382	--	na	na	na
		SSL_t (ton/d)	na	na	na	3	0.3655	--	na	na	na
		$\text{SSL>}_{0.062}$ (ton/d)	na	na	na	3	0.3351	--	na	na	na
		$\text{SSL<}_{0.062}$ (ton/d)	na	na	na	3	0.3912	--	na	na	na
		Turbidity (FNU)	na	na	na	7	0.3747	--	na	na	na
Comparisons related to the effects of the chutes on sediment transport in the main channel											
<SITE>–MR–US	<SITE>–MR–DS	SSC_t (mg/L)	7	0.2885	--	7	0.0500	-110	14	0.0582	--
		SSL_t (ton/d)	7	0.2793	--	7	0.0477	-12,000	14	0.0530	--
		$\text{SSL>}_{0.062}$ (ton/d)	5	0.8365	--	--	nd	--	7	0.7311	--
		$\text{SSL<}_{0.062}$ (ton/d)	5	0.6333	--	--	nd	--	7	0.5900	--
		Turbidity (FNU)	3	0.8399	--	4	0.1271	--	7	0.1231	--
<SITE>–MR–US	<SITE>–CH–DS	SSC_t (mg/L)	5	0.3107	--	4	0.0711	--	9	0.0996	--
		SSiltC (mg/L)	4	0.0243	33	--	nd	--	5	0.0204	28
		SSandC (mg/L)	4	0.2681	--	--	nd	--	5	0.1476	--
		Turbidity (FNU)	3	0.2887	--	4	0.3846	--	7	0.7916	--
Comparisons related to the effects of the chutes on sediment transport in the main channel including 2008 data											
<SITE>–MR-US	<SITE>–MR–DS	SSC_t (mg/L)	11	0.2283	--	na	na	na	18	0.0461	-100
		SSL_t (ton/d)	11	0.2203	--	na	na	na	18	0.0420	-11,000
		$\text{SSL>}_{0.062}$ (ton/d)	9	0.3673	--	na	na	na	11	0.3758	--
		$\text{SSL<}_{0.062}$ (ton/d)	9	0.5821	--	na	na	na	11	0.5503	--
		Turbidity (FNU)	8	0.4540	--	na	na	na	12	0.0959	--
<SITE>–MR–US	<SITE>–CH–DS	SSC_t (mg/L)	9	0.1345	--	na	na	na	13	0.0414	130
		SSiltC (mg/L)	8	0.6357	--	na	na	na	9	0.5949	--
		SSandC (mg/L)	8	0.0692	--	na	na	na	9	0.0352	160
		Turbidity (FNU)	8	0.1502	--	na	na	na	12	0.5265	--

been removed from the dataset, which limited the power of the analysis to detect differences. Data were not collected from the upstream transect within Upper Hamburg chute; therefore, the comparison was only made for Kansas chute.

Concentrations and loads from the Missouri River upstream from the chutes and Missouri River downstream from the chutes were compared. If concentrations and loads were significantly different between the two transects, then the chutes probably are affecting sediment transport within the Missouri River main channel. If concentrations and loads were not significantly different between the two transects, then the chute contributions to the main channel are not detectable. Comparisons of concentrations and loads from the Missouri River upstream transect with those of the Missouri River downstream transect indicated no statistical difference for the Upper Hamburg study site (table 6). The total SSC and the total SSL, however, were significantly different between the Missouri River upstream transect and the Missouri River downstream transect at Kansas chute (n=7 and p=0.0500 and 0.0477, respectively; table 6). The test indicated that the Missouri River downstream had SSC approximately 110 milligrams per liter higher and SSL approximately 12,000 tons per day greater than upstream from the chute inlet (table 6), which indicates a large amount of sediment delivery or resuspension to the Missouri River between the two sampling transects when samples were collected, possibly originating in the chute. The significant difference between upstream and downstream total SSC and total SSL in the main channel is possible evidence of induced erosion from construction-related disturbance, natural erosion along either the main channel or in the chute, or measurement error (mean sample variability in SSC ranged from 4.6 to 22 percent). In addition, the total daily loads estimated within the chute using turbidity surrogates indicated that when main-channel EWI samples were collected, 2 of the 7 days had slight deposition in the chute, 3 of the 7 days had slight erosion within the chute, and 2 of the 7 days did not have continuous data available; therefore, loads could not be estimated. The possibility exists that the small sample size; the variability within the data (concentrations for each EWI sample are in appendix 1); and, to some extent, the construction within the chute may have some effect on these results. When data for the Missouri River transects at both study chutes (Upper Hamburg and Kansas) were combined and upstream and downstream transects compared, no significant differences were detected (table 6).

An additional comparison that analyzed the effect a chute might have on the main channel used the concentration of sediment at the downstream transect of the chute and the concentration of sediment at the Missouri River upstream transect. If the chute concentrations are significantly higher, then theoretically, the chute is adding sediment to the main channel even if the contribution was not detected when comparing the Missouri River upstream transect to the Missouri River downstream transect. In contrast, if the chute concentrations are significantly lower, then the outflow of the chute is diluting the sediment within the main channel; however, the only comparison that was significant was that the *SSiltC* was greater at the Missouri River upstream transect than at the chute downstream transect of Upper Hamburg chute (table 6). Four of the seven pairs of samples collected at Upper Hamburg were collected after the chute inlet had been closed; this likely had the effect of decreasing the SSC within the chute (table 3). If inlet closure were causing the significant difference in *SSiltC*, the corresponding difference also would be expected to be significant for comparisons using total SSC and *SSandC*. These results are inconsistent, likely because of the small sample size and the inherent variability of suspended-sediment sampling techniques.

Comparisons of concentrations and loads between the Missouri River upstream and downstream transects, as well as comparison of concentrations between the Missouri River upstream and the chute downstream, were also completed with the addition of four to five samples collected in 2008 at the Upper Hamburg study site (table 6). The results indicated that the differences between the Missouri River upstream and the Missouri River downstream in SSC and total SSL were significant only when both chutes were combined; therefore, data from Kansas study site were included. In addition, the inclusion of Kansas chute data in the comparison of Missouri River upstream and chute downstream concentrations also resulted in significant differences with higher SSC and *SSandC* in the Missouri River upstream. The comparison results likely were affected by the number of samples collected from Upper Hamburg study site when the inlet to the chute was closed and by the variability in other samples. For example, in the October sample, the SSC was 296 milligrams per liter for the sample collected at the Missouri River upstream from Kansas chute, whereas the SSC was only 64 milligrams per liter for the sample collected at the chute (appendix 1). Also for the October Missouri River sample, the percentage finer than 0.062 millimeter was low because the sand concentration was high. These data were not censored because similar results were observed at the Missouri River downstream transect during the October sample as well (total SSC was 317 milligrams per liter and a low SF split). The significant differences in SSC and the *SSandC* indicate that the Missouri River had a higher sediment concentration; therefore, the chute outflow was diluting the sediment within the main channel on the 8 or 9 days that the sites were sampled.

Comparison of EWI samples between different transects within a study site were limited by few samples and large variability. When comparing the Missouri River upstream transect to the upstream transect of the chute, however, similar results were determined in 2012 (table 6) as were determined in 2008 at Upper Hamburg and Glovers chutes (Woodward and Rus, 2011); the chute inlet affected the amount of sediment entering the chute from the main channel. In addition, the Kansas chute is potentially affecting the sediment concentration within the Missouri River main channel, but small sample size and construction activities within the chute limited the ability in this study to fully understand either the effect of the chute in 2012 or the effect of the chute on the main channel during a "typical year" without construction. Some differences in SSC were detected between the Missouri River upstream transect and the downstream transect of the chute; however, general conclusions about the typical effect of the chutes on the Missouri River main-channel sediment transport were difficult to determine because of the effect of the closure of the inlet structure at Upper Hamburg chute and the presence of one nontypical sample from the Missouri River transect at Kansas chute.

Summary

Understanding chute evolution through sediment movement is important for the design of chutes, monitoring and maintenance of existing chutes, and characterizing the habitat that the chutes provide. The U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, monitored suspended sediment within constructed Missouri River chutes during March through October 2012. Chutes were constructed at selected river bends by the U.S. Army Corps of Engineers to help mitigate aquatic habitat lost through the creation and maintenance of the navigation channel on the Missouri River. The restoration and development of chutes is one method for creating shallow-water habitat within the Missouri River to meet requirements established by the amended 2000 Biological Opinion. Specific objectives of this study were to (1) provide sediment and water-quality data on chutes to better understand their geomorphic processes; (2) to quantify and compare suspended-sediment concentrations (SSC), loads, and size distributions of the chutes to those of the Missouri River main channel; (3) to determine variation among water-quality properties within chutes; and (4) to develop a model of the relation between turbidity and SSC that evaluates the use of turbidity as a surrogate for SSC. This report describes the methods used to monitor suspended sediment at two Missouri River chutes and presents the results of the data analysis to help understand the suspended-sediment characteristics of each chute and the effect the chutes have on the Missouri River.

Upper Hamburg chute, near Nebraska City, Nebraska, and Kansas chute, near Peru, Nebraska, were selected for monitoring. At each study site, monthly suspended-sediment samples were collected from April through October in Missouri River main-channel transects upstream from the chute inlet and downstream from the chute outlet. Monthly suspended-sediment samples were also collected from April through October 2012 at the outlet (downstream transect) of both chutes and at the inlet (upstream transect) of Kansas chute. These discrete samples were collected from the channel cross section at equal-width increments (EWI) using depth-integrating methods. In addition, grab samples were collected for all chute sampling locations by using automatic samplers throughout the study period. Continuous water-quality monitors recorded turbidity and water temperature at 15-minute intervals at the three chute sampling locations, and two acoustic Doppler velocimeters, one within each chute, measured water depth and current velocities continuously during March through October 2012. The depth and velocity data were used to estimate continuous streamflow within each chute. The sampling design was developed to understand the suspended-sediment differences within each chute and between the chute and the Missouri River main channel during discrete sampling. The sampling design also allowed for site-specific surrogate relations between SSC and turbidity to be developed, which could be used to compute real-time estimates of SSC and sediment loads within the chutes. Real-time estimates of SSC and sediment loads enable a better understanding of sediment transport within the chutes during times when physical samples are not collected, including periods of high flow.

High flows during the summer of 2011 resulted in substantial alterations to both studied chutes; therefore, the U.S. Army Corps of Engineers repaired and modified both chutes during 2012. These unforeseen repairs and modifications within the chutes added an unknown degree of uncertainty to the analysis because concentrations were altered by construction equipment and flow alteration.

A linear regression was used to estimate EWI-equivalent SSC from autosampler SSC before using the model-calibration dataset to determine the best-fit model for prediction of SSC from the turbidity and, in some cases, streamflow. Correlation between suspended-sand concentration (*SSandC*) in EWI samples and concurrent samples collected by an autosampler was low; therefore, *SSandC* was excluded from development of surrogate relations because a large part of the calibration dataset was from automatic samples. Instead, *SSandC* was estimated as SSC minus suspended-silt-clay concentration (*SSiltC*). At all sites, the best-fit models included the base-10 logarithm of concentration and turbidity, and at Kansas chute upstream, the base-10 logarithm of streamflow was also included in the best-fit models. Estimated daily suspended-sediment loads from the turbidity-based surrogate models were not significantly different between upstream and downstream transects within the Kansas chute, and most individual daily loads within the chute were not significantly different between the upstream and downstream transects when evaluated using overlap in daily 95-percent confidence intervals. The comparison of daily load values for upstream and downstream transects, estimated from turbidity-based surrogate models for the Kansas chute, documents the dynamic nature of sediment transport within the chute with a temporal resolution that is not practical with discrete suspended-sediment sampling alone.

Comparisons of concentrations and loads from EWI samples collected from different transects (Missouri River upstream as compared to chute upstream, chute upstream as compared to chute downstream, Missouri River upstream as compared to Missouri River downstream, and Missouri River upstream as compared to chute downstream) within a study site resulted in few significant differences because comparisons were limited by small sample sizes and large within-transect variability. When comparing the Missouri River upstream transect to the chute upstream transect, similar results were determined in 2012 as were determined in 2008—the chute inlet affected the amount of sediment entering the chute from the main channel. In addition, the Kansas chute is potentially affecting the sediment concentration within the Missouri River main channel, but small sample size and construction activities within the chute limit the ability to fully understand either the effect of the chute in 2012 or the effect of the chute on the main channel during a “typical year” without construction. Finally, some differences in SSC were detected between the Missouri River upstream transects and the chute downstream transects; however, the effect of the chutes on the Missouri River main-channel sediment transport was difficult to isolate because of construction activities and sampling variability.

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Tables 3 and 5

Table 3. Total daily loads calculated from instantaneous estimates of suspended-sediment concentration from turbidity surrogate at Upper Hamburg chute and Kansas chute, 2012.

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; UHAM–CH–DS, Upper Hamburg chute downstream; nd, no data. Green highlighted cells indicate construction]

Date	KANS–CH–US			KANS–CH–DS			UHAM–CH–DS		
	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)
3/27/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd
3/28/2012	3,100	2,800	290	1,200	1,200	35	nd	nd	nd
3/29/2012	2,900	2,600	280	1,100	1,100	33	nd	nd	nd
3/30/2012	3,300	3,000	280	1,500	1,400	41	nd	nd	nd
3/31/2012	2,700	2,400	260	1,100	1,100	32	nd	nd	nd
4/1/2012	2,600	2,400	260	960	930	28	nd	nd	nd
4/2/2012	nd	nd	nd	850	830	25	nd	nd	nd
4/3/2012	nd	nd	nd	830	810	24	nd	nd	nd
4/4/2012	nd	nd	nd	760	740	23	nd	nd	nd
4/5/2012	nd	nd	nd	840	820	25	nd	nd	nd
4/6/2012	nd	nd	nd	680	660	20	nd	nd	nd
4/7/2012	nd	nd	nd	650	640	20	nd	nd	nd
4/8/2012	nd	nd	nd	710	690	21	nd	nd	nd
4/9/2012	nd	nd	nd	700	670	21	nd	nd	nd
4/10/2012	nd	nd	nd	720	690	21	nd	nd	nd
4/11/2012	2,000	1,800	220	680	660	20	nd	nd	nd
4/12/2012	2,000	1,800	210	740	720	22	nd	nd	nd
4/13/2012	2,200	2,000	230	770	750	23	480	470	16
4/14/2012	3,200	3,000	250	1,800	1,800	48	nd	nd	nd
4/15/2012	49,000	50,000	0	72,000	71,000	1,400	nd	nd	nd
4/16/2012	49,000	50,000	0	57,000	55,000	1,100	nd	nd	nd
4/17/2012	25,000	25,000	170	19,000	19,000	430	nd	nd	nd
4/18/2012	17,000	17,000	380	14,000	13,000	310	nd	nd	nd
4/19/2012	7,800	7,500	290	7,200	7,100	170	nd	nd	nd
4/20/2012	2,100	2,000	98	2,300	2,200	57	nd	nd	nd
4/21/2012	780	750	33	960	940	25	nd	nd	nd
4/22/2012	660	620	40	870	840	23	nd	nd	nd
4/23/2012	880	830	49	1,100	1,100	28	nd	nd	nd
4/24/2012	2,300	2,100	150	2,100	2,100	55	960	880	81
4/25/2012	nd	nd	nd	nd	nd	nd	750	700	52
4/26/2012	nd	nd	nd	nd	nd	nd	660	620	38
4/27/2012	nd	nd	nd	nd	nd	nd	800	740	61
4/28/2012	nd	nd	nd	nd	nd	nd	820	760	64
4/29/2012	nd	nd	nd	nd	nd	nd	1,100	950	110
4/30/2012	nd	nd	nd	nd	nd	nd	1,300	1,100	160
5/1/2012	2,300	2,100	160	1,300	1,300	36	1,300	1,100	150
5/2/2012	2,700	2,500	180	1,500	1,500	42	1,100	1,000	110
5/3/2012	4,000	3,800	180	3,200	3,100	81	2,000	1,700	300
5/4/2012	4,800	4,700	120	4,400	4,300	110	2,600	2,200	460
5/5/2012	5,000	4,900	100	7,000	6,800	160	3,900	3,100	800

Table 3. Total daily loads calculated from instantaneous estimates of suspended-sediment concentration from turbidity surrogate at Upper Hamburg chute and Kansas chute, 2012.—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; UHAM–CH–DS, Upper Hamburg chute downstream; nd, no data. Green highlighted cells indicate construction]

Date	KANS–CH–US			KANS–CH–DS			UHAM–CH–DS		
	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)
5/6/2012	5,400	5,100	290	4,700	4,600	120	3,000	2,500	490
5/7/2012	9,800	9,500	340	11,000	11,000	250	5,500	4,300	1,100
5/8/2012	9,100	9,000	160	12,000	12,000	280	6,500	5,000	1,500
5/9/2012	6,100	5,900	200	6,700	6,500	160	3,800	3,000	720
5/10/2012	5,300	5,000	260	4,200	4,100	100	2,300	2,000	350
5/11/2012	5,200	5,000	220	4,600	4,500	110	2,800	2,300	430
5/12/2012	3,600	3,400	150	3,500	3,400	87	2,200	1,900	320
5/13/2012	6,200	6,000	250	5,800	5,600	140	3,400	2,800	580
5/14/2012	11,000	11,000	540	7,900	7,700	190	3,900	3,200	640
5/15/2012	9,700	9,100	580	5,800	5,700	150	3,100	2,600	450
5/16/2012	7,100	6,600	470	4,500	4,300	110	2,600	2,200	340
5/17/2012	5,200	4,800	370	3,400	3,300	88	2,000	1,800	250
5/18/2012	4,100	3,800	310	2,700	2,600	72	1,700	1,500	200
5/19/2012	3,400	3,100	270	2,000	1,900	54	1,600	1,400	170
5/20/2012	3,000	2,800	250	1,900	1,900	52	1,400	1,300	130
5/21/2012	3,400	3,100	300	2,100	2,100	58	1,500	1,400	150
5/22/2012	5,500	5,200	280	3,900	3,800	99	2,700	2,300	430
5/23/2012	4,300	4,100	190	3,800	3,700	94	2,600	2,200	430
5/24/2012	3,000	2,800	170	2,200	2,100	57	1,700	1,500	210
5/25/2012	2,400	2,200	170	1,600	1,500	42	1,400	1,200	140
5/26/2012	2,900	2,700	210	1,900	1,800	50	1,700	1,500	190
5/27/2012	4,600	4,400	220	4,000	3,900	100	3,200	2,700	530
5/28/2012	7,300	7,100	220	7,700	7,500	180	5,400	4,300	1,100
5/29/2012	9,200	9,100	140	12,000	12,000	270	8,000	6,200	1,800
5/30/2012	17,000	17,000	490	17,000	16,000	380	8,600	6,700	1,900
5/31/2012	25,000	25,000	0	35,000	34,000	720	17,000	13,000	4,600
6/1/2012	14,000	14,000	0	23,000	22,000	470	14,000	11,000	3,700
6/2/2012	8,500	8,400	150	11,000	11,000	240	8,700	6,800	1,900
6/3/2012	6,900	6,600	270	6,500	6,400	160	5,500	4,500	1,000
6/4/2012	5,800	5,500	290	4,500	4,300	110	4,000	3,300	620
6/5/2012	4,800	4,600	280	3,600	3,500	92	3,400	2,900	490
6/6/2012	3,600	3,400	230	2,900	2,800	75	2,800	2,400	360
6/7/2012	2,300	2,100	150	2,000	1,900	52	2,300	2,100	280
6/8/2012	1,800	1,700	120	1,600	1,600	42	2,000	1,800	220
6/9/2012	1,700	1,600	110	1,300	1,200	34	1,700	1,500	170
6/10/2012	1,200	1,100	83	1,600	1,600	42	1,500	1,400	140
6/11/2012	1,700	1,600	81	2,000	2,000	51	1,900	1,700	230
6/12/2012	2,300	2,300	32	3,900	3,800	91	2,600	2,200	380
6/13/2012	1,400	1,300	66	2,500	2,500	61	1,400	1,300	140
6/14/2012	1,000	940	70	1,900	1,800	47	1,300	1,200	120

Table 3. Total daily loads calculated from instantaneous estimates of suspended-sediment concentration from turbidity surrogate at Upper Hamburg chute and Kansas chute, 2012.—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; UHAM–CH–DS, Upper Hamburg chute downstream; nd, no data. Green highlighted cells indicate construction]

Date	KANS–CH–US			KANS–CH–DS			UHAM–CH–DS		
	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)
6/15/2012	1,400	1,300	78	2,700	2,700	66	2,600	2,200	370
6/16/2012	1,700	1,600	75	3,000	2,900	72	3,100	2,700	480
6/17/2012	1,700	1,600	81	3,100	3,000	73	2,900	2,400	420
6/18/2012	1,300	1,200	74	2,100	2,000	52	2,100	1,800	270
6/19/2012	980	930	56	1,700	1,600	42	1,900	1,600	230
6/20/2012	1,100	1,000	61	1,500	1,500	39	1,500	1,400	170
6/21/2012	710	640	66	1,400	1,300	36	1,600	1,400	170
6/22/2012	470	410	65	1,800	1,800	46	2,400	2,100	330
6/23/2012	550	490	68	2,200	2,200	54	3,400	2,,800	570
6/24/2012	310	270	48	1,500	1,500	39	2,500	2,100	380
6/25/2012	240	200	42	1,200	1,100	31	1,800	1,600	210
6/26/2012	540	490	51	930	900	25	1,400	1,300	150
6/27/2012	460	420	38	690	670	18	1,300	1,100	130
6/28/2012	460	430	38	690	670	18	1,100	1,000	100
6/29/2012	460	420	40	730	710	20	1,100	990	94
6/30/2012	440	400	38	640	620	17	1,000	940	85
7/1/2012	360	330	32	510	500	14	1,100	960	94
7/2/2012	350	320	32	550	530	15	890	820	65
7/3/2012	320	290	28	490	470	13	790	740	49
7/4/2012	300	270	27	360	350	10	780	730	48
7/5/2012	290	260	28	350	340	10	770	720	50
7/6/2012	250	230	25	320	310	9	680	640	42
7/7/2012	230	210	24	290	280	8.3	300	290	8.2
7/8/2012	230	200	24	270	260	7.8	150	150	1.2
7/9/2012	230	200	26	260	250	7.5	160	160	0.8
7/10/2012	240	210	28	280	270	8.1	170	170	2.2
7/11/2012	260	230	30	300	290	8.7	160	160	1.7
7/12/2012	330	300	32	290	290	8.5	170	160	2.6
7/13/2012	nd	nd	nd	280	270	8.2	130	130	0.78
7/14/2012	nd	nd	nd	280	270	8.1	160	160	1.4
7/15/2012	nd	nd	nd	310	300	8.9	160	160	1.3
7/16/2012	nd	nd	nd	300	300	8.8	140	140	1.1
7/17/2012	nd	nd	nd	280	280	8.3	150	150	2.1
7/18/2012	nd	nd	nd	250	250	7.5	140	140	1
7/19/2012	nd	nd	nd	270	270	8	160	160	2.3
7/20/2012	340	310	34	380	370	11	160	160	2.6
7/21/2012	370	330	33	370	360	11	140	140	1.5
7/22/2012	390	360	32	280	270	8.1	130	130	1.4
7/23/2012	390	360	31	250	240	7.3	130	130	1.9
7/24/2012	360	330	31	260	250	7.7	150	140	4.2

Table 3. Total daily loads calculated from instantaneous estimates of suspended-sediment concentration from turbidity surrogate at Upper Hamburg chute and Kansas chute, 2012.—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; UHAM–CH–DS, Upper Hamburg chute downstream; nd, no data. Green highlighted cells indicate construction]

Date	KANS–CH–US			KANS–CH–DS			UHAM–CH–DS		
	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)
7/25/2012	320	290	30	240	230	7.1	140	140	3
7/26/2012	280	250	28	220	210	6.4	150	150	2.9
7/27/2012	270	240	27	180	180	5.5	120	120	0.79
7/28/2012	300	270	28	190	180	5.7	110	110	0.42
7/29/2012	350	320	26	180	170	5.4	120	120	1.3
7/30/2012	nd	nd	nd	nd	nd	nd	120	120	1.1
7/31/2012	nd	nd	nd	nd	nd	nd	130	130	1.1
8/1/2012	nd	nd	nd	nd	nd	nd	130	130	1.6
8/2/2012	140	130	14	150	150	4.5	130	130	1.6
8/3/2012	250	230	25	190	190	5.7	120	120	1.2
8/4/2012	330	300	33	240	230	7.1	150	150	3.3
8/5/2012	390	350	35	250	250	7.5	140	140	2.5
8/6/2012	370	330	36	270	270	8.1	150	140	3
8/7/2012	350	320	34	270	260	8	170	170	4.8
8/8/2012	380	350	36	300	290	8.8	170	170	4.9
8/9/2012	430	390	39	340	330	9.9	180	180	4.6
8/10/2012	400	360	37	320	310	9.3	170	160	4
8/11/2012	400	360	37	340	330	9.9	170	170	4.5
8/12/2012	430	390	38	400	390	11	190	180	5.7
8/13/2012	nd	nd	nd	390	380	11	180	180	6
8/14/2012	nd	nd	nd	350	340	10	160	160	3.9
8/15/2012	nd	nd	nd	400	390	11	170	160	4
8/16/2012	nd	nd	nd	490	470	13	200	190	7.6
8/17/2012	430	400	34	410	400	12	180	170	5.5
8/18/2012	410	370	34	400	390	11	190	190	6.9
8/19/2012	430	390	34	440	430	12	180	180	6.4
8/20/2012	420	390	34	450	430	12	200	190	7.2
8/21/2012	380	350	35	370	360	11	170	170	4.5
8/22/2012	380	350	35	360	350	10	170	170	4.6
8/23/2012	430	390	35	470	450	13	170	170	5.3
8/24/2012	nd	nd	nd	460	450	13	200	190	7.4
8/25/2012	nd	nd	nd	610	590	17	210	200	7.1
8/26/2012	nd	nd	nd	nd	nd	nd	200	190	5.3
8/27/2012	nd	nd	nd	nd	nd	nd	200	190	5.9
8/28/2012	400	360	38	nd	nd	nd	210	200	6.7
8/29/2012	390	350	36	370	360	11	210	200	7.7
8/30/2012	380	340	35	380	370	11	210	200	9.6
8/31/2012	320	290	31	410	400	11	190	180	8.9
9/1/2012	300	270	28	380	370	11	170	170	6.7
9/2/2012	390	360	35	650	640	18	210	200	11

Table 3. Total daily loads calculated from instantaneous estimates of suspended-sediment concentration from turbidity surrogate at Upper Hamburg chute and Kansas chute, 2012.—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; UHAM–CH–DS, Upper Hamburg chute downstream; nd, no data. Green highlighted cells indicate construction]

Date	KANS–CH–US			KANS–CH–DS			UHAM–CH–DS		
	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)
9/3/2012	370	340	34	540	520	15	220	210	14
9/4/2012	370	330	34	440	420	12	230	210	15
9/5/2012	380	340	34	480	470	13	210	200	10
9/6/2012	390	350	35	510	500	14	180	180	7.8
9/7/2012	380	350	35	460	450	13	190	180	8.4
9/8/2012	380	350	35	480	470	13	180	170	6.8
9/9/2012	390	350	36	480	470	13	170	160	5.2
9/10/2012	400	370	35	530	520	15	180	170	7.8
9/11/2012	380	340	35	470	460	13	180	170	7.6
9/12/2012	370	340	35	460	450	13	210	200	9.4
9/13/2012	2,600	2,400	230	2,100	2,000	54	260	240	13
9/14/2012	1,600	1,400	130	1,500	1,400	39	270	250	16
9/15/2012	460	420	40	630	620	17	210	200	8.6
9/16/2012	400	360	36	700	680	19	200	200	8.6
9/17/2012	380	350	35	850	820	22	220	210	11
9/18/2012	340	310	34	760	740	20	180	180	6.8
9/19/2012	330	300	34	730	710	19	170	170	5.6
9/20/2012	340	310	34	620	610	17	170	170	4.8
9/21/2012	410	370	35	730	710	19	220	210	12
9/22/2012	410	380	34	630	610	17	220	210	12
9/23/2012	380	340	34	440	430	12	180	170	6.4
9/24/2012	330	300	34	450	440	13	180	170	6.5
9/25/2012	340	310	34	400	390	11	180	180	6.6
9/26/2012	380	340	34	440	430	12	190	180	7.4
9/27/2012	390	360	35	480	460	13	200	190	9.9
9/28/2012	370	330	34	410	400	12	180	170	6.5
9/29/2012	370	330	34	420	400	12	nd	nd	nd
9/30/2012	380	350	35	420	410	12	nd	nd	nd
10/1/2012	370	330	34	400	390	11	nd	nd	nd
10/2/2012	340	310	34	360	350	10	nd	nd	nd
10/3/2012	350	320	34	410	400	12	nd	nd	nd
10/4/2012	370	340	34	460	440	13	nd	nd	nd
10/5/2012	330	300	34	350	340	10	130	130	1.9
10/6/2012	340	300	35	360	350	10	140	140	2.7
10/7/2012	330	300	35	360	350	10	140	130	3.7
10/8/2012	340	310	35	400	390	11	150	140	5.4
10/9/2012	360	320	34	430	420	12	180	170	7.3
10/10/2012	350	320	34	370	360	10	170	160	6.9
10/11/2012	350	310	34	360	350	10	200	190	9.3
10/12/2012	340	310	34	370	360	11	190	180	9.2

Table 3. Total daily loads calculated from instantaneous estimates of suspended-sediment concentration from turbidity surrogate at Upper Hamburg chute and Kansas chute, 2012.—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; UHAM–CH–DS, Upper Hamburg chute downstream; nd, no data. Green highlighted cells indicate construction]

Date	KANS–CH–US			KANS–CH–DS			UHAM–CH–DS		
	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)	Total load (ton per day)	Silt load (ton per day)	Sand load (ton per day)
10/13/2012	350	320	35	400	380	11	220	210	12
10/14/2012	420	390	37	560	550	15	290	270	21
10/15/2012	410	370	38	470	460	13	270	250	20
10/16/2012	340	310	35	360	350	10	290	260	25
10/17/2012	330	300	34	420	410	12	nd	nd	nd
10/18/2012	340	310	35	530	520	15	nd	nd	nd
10/19/2012	330	290	34	340	330	9.8	nd	nd	nd
10/20/2012	300	270	33	290	290	8.6	nd	nd	nd
10/21/2012	320	290	34	370	360	11	nd	nd	nd
10/22/2012	420	380	34	770	750	20	nd	nd	nd
10/23/2012	440	410	34	1,000	1,000	27	nd	nd	nd
10/24/2012	380	340	34	660	640	18	nd	nd	nd
10/25/2012	490	440	52	650	630	18	nd	nd	nd
10/26/2012	480	430	53	600	580	17	nd	nd	nd
10/27/2012	310	280	35	390	380	11	nd	nd	nd
10/28/2012	300	260	34	330	320	9.7	nd	nd	nd
10/29/2012	290	260	34	330	320	9.5	nd	nd	nd
10/30/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd
10/31/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd

Table 5. Daily 95-percent confidence intervals for suspended load estimates. (Methods described by Lee and others [2012], and Schaepe and others [2014].)

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; LCL95, lower limit of 95-percent confidence interval; UCL, upper limit of 95-percent confidence interval; nd, no data. Blue-highlighted cells indicate overlapping confidence intervals between KANS–CH–US and KANS–CH–DS or no significant difference; green-highlighted cells indicate net deposition; red-highlighted cells indicate net erosion]

Date	Total suspended-sediment load (ton per day)				Total suspended-silt load (ton per day)				Total suspended-sand load (ton per day)			
	KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS	
	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95
3/27/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3/28/2012	1,900	5,100	790	1,900	1,700	4,500	760	1,900	130	590	23	55
3/29/2012	1,700	4,700	730	1,800	1,600	4,200	710	1,700	130	560	21	51
3/30/2012	2,000	5,400	940	2,300	1,900	4,900	920	2,200	130	590	26	64
3/31/2012	1,600	4,400	700	1,700	1,500	3,900	680	1,700	120	520	20	49
4/1/2012	1,600	4,300	620	1,500	1,500	3,800	600	1,500	120	520	18	44
4/2/2012	nd	nd	550	1,300	nd	nd	530	1,300	nd	nd	16	39
4/3/2012	nd	nd	530	1,300	nd	nd	520	1,300	nd	nd	16	38
4/4/2012	nd	nd	490	1,200	nd	nd	480	1,200	nd	nd	14	35
4/5/2012	nd	nd	540	1,300	nd	nd	520	1,300	nd	nd	16	39
4/6/2012	nd	nd	440	1,100	nd	nd	420	1,000	nd	nd	13	32
4/7/2012	nd	nd	420	1,000	nd	nd	410	990	nd	nd	13	30
4/8/2012	nd	nd	460	1,100	nd	nd	440	1,100	nd	nd	14	33
4/9/2012	nd	nd	450	1,100	nd	nd	430	1,100	nd	nd	13	32
4/10/2012	nd	nd	460	1,100	nd	nd	450	1,100	nd	nd	14	33
4/11/2012	1,200	3,400	440	1,100	1,100	2,900	430	1,000	100	430	13	32
4/12/2012	1,200	3,300	470	1,200	1,100	2,900	460	1,100	100	430	14	34
4/13/2012	1,400	3,700	500	1,200	1,200	3,200	480	1,200	110	460	15	36
4/14/2012	2,000	5,300	1,200	2,900	1,900	4,800	1,100	2,800	110	540	31	75
4/15/2012	30,000	80,000	46,000	110,000	31,000	80,000	45,000	110,000	0	340	880	2,100
4/16/2012	30,000	81,000	36,000	88,000	31,000	80,000	36,000	87,000	0	1,100	730	1,800
4/17/2012	15,000	41,000	12,000	30,000	15,000	40,000	12,000	29,000	0	1,200	280	670
4/18/2012	10,000	28,000	8,700	21,000	10,000	27,000	8,500	21,000	0	1,300	200	490
4/19/2012	4,700	13,000	4,600	11,000	4,700	12,000	4,500	11,000	60	780	110	270
4/20/2012	1,300	3,500	1,500	3,600	1,200	3,200	1,400	3,500	28	240	37	90
4/21/2012	470	1,300	620	1,500	460	1,200	600	1,500	8.4	84	16	39
4/22/2012	400	1,100	560	1,400	380	990	540	1,300	15	91	15	36
4/23/2012	530	1,500	700	1,700	520	1,300	690	1,700	17	110	18	44

Table 5. Daily 95-percent confidence intervals for suspended load estimates. (Methods described by Lee and others [2012], and Schaepe and others [2014].)—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; LCL95, lower limit of 95-percent confidence interval; UCL, upper limit of 95-percent confidence interval; nd, no data. Blue-highlighted cells indicate overlapping confidence intervals between KANS–CH–US and KANS–CH–DS or no significant difference; green-highlighted cells indicate net deposition; red-highlighted cells indicate net erosion]

Date	Total suspended-sediment load (ton per day)				Total suspended-silt load (ton per day)				Total suspended-sand load (ton per day)			
	KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS	
	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95
4/24/2012	1,400	3,800	1,400	3,300	1,300	3,400	1,300	3,200	58	330	35	85
4/25/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4/26/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4/27/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4/28/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4/29/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4/30/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5/1/2012	1,400	3,700	850	2,100	1,300	3,400	820	2,000	64	350	23	56
5/2/2012	1,600	4,400	980	2,400	1,600	4,000	960	2,300	68	390	27	65
5/3/2012	2,400	6,600	2,000	5,000	2,400	6,100	2,000	4,800	48	440	52	130
5/4/2012	2,900	8,000	2,800	6,900	2,900	7,600	2,800	6,700	0.48	390	68	170
5/5/2012	3,000	8,200	4,500	11,000	3,000	7,900	4,400	11,000	0	360	100	250
5/6/2012	3,300	8,900	3,000	7,400	3,200	8,200	3,000	7,200	96	680	75	180
5/7/2012	6,000	16,000	7,000	17,000	5,900	15,000	6,800	17,000	58	940	160	390
5/8/2012	5,500	15,000	8,000	19,000	5,600	14,000	7,800	19,000	0	630	180	430
5/9/2012	3,700	10,000	4,300	10,000	3,700	9,500	4,200	10,000	31	570	100	250
5/10/2012	3,200	8,700	2,700	6,500	3,100	8,000	2,600	6,300	79	630	67	160
5/11/2012	3,100	8,500	3,000	7,200	3,100	8,000	2,900	7,100	59	570	73	180
5/12/2012	2,200	5,900	2,300	5,500	2,100	5,500	2,200	5,400	40	390	56	140
5/13/2012	3,800	10,000	3,700	9,000	3,700	9,600	3,600	8,800	59	650	90	220
5/14/2012	6,800	18,000	5,100	12,000	6,600	17,000	5,000	12,000	170	1,300	120	300
5/15/2012	5,900	16,000	3,700	9,100	5,700	15,000	3,600	8,800	210	1,300	95	230
5/16/2012	4,300	12,000	2,900	7,000	4,100	11,000	2,800	6,800	180	1,000	74	180
5/17/2012	3,200	8,600	2,200	5,300	3,000	7,700	2,100	5,100	150	810	57	140
5/18/2012	2,500	6,700	1,700	4,200	2,400	6,100	1,700	4,100	130	660	46	110
5/19/2012	2,000	5,500	1,300	3,100	1,900	5,000	1,200	3,000	120	570	34	84
5/20/2012	1,800	5,000	1,200	3,000	1,700	4,400	1,200	2,900	110	530	33	81
5/21/2012	2,100	5,600	1,400	3,400	1,900	5,000	1,300	3,300	130	610	37	91

Table 5. Daily 95-percent confidence intervals for suspended load estimates. (Methods described by Lee and others [2012], and Schaepe and others [2014].)—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; LCL95, lower limit of 95-percent confidence interval; UCL, upper limit of 95-percent confidence interval; nd, no data. Blue-highlighted cells indicate overlapping confidence intervals between KANS–CH–US and KANS–CH–DS or no significant difference; green-highlighted cells indicate net deposition; red-highlighted cells indicate net erosion]

Date	Total suspended-sediment load (ton per day)				Total suspended-silt load (ton per day)				Total suspended-sand load (ton per day)			
	KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS	
	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95
5/22/2012	3,300	9,000	2,500	6,100	3,200	8,400	2,500	6,000	89	670	64	160
5/23/2012	2,600	7,100	2,400	5,900	2,600	6,600	2,400	5,700	50	470	60	150
5/24/2012	1,800	4,900	1,400	3,400	1,700	4,500	1,400	3,300	61	400	37	89
5/25/2012	1,400	3,900	1,000	2,400	1,400	3,500	980	2,400	68	360	27	66
5/26/2012	1,800	4,800	1,200	2,900	1,700	4,400	1,200	2,800	84	450	32	78
5/27/2012	2,800	7,600	2,600	6,300	2,700	7,000	2,500	6,100	66	540	64	160
5/28/2012	4,400	12,000	5,000	12,000	4,400	11,000	4,800	12,000	23	650	120	280
5/29/2012	5,600	15,000	7,600	19,000	5,600	15,000	7,500	18,000	0	590	170	410
5/30/2012	11,000	29,000	11,000	26,000	11,000	27,000	11,000	26,000	34	1,500	240	590
5/31/2012	15,000	40,000	22,000	55,000	15,000	40,000	22,000	53,000	0	820	460	1,100
6/1/2012	8,500	23,000	15,000	35,000	8,800	23,000	14,000	35,000	0	520	300	740
6/2/2012	5,200	14,000	7,000	17,000	5,200	13,000	6,800	17,000	0	580	160	380
6/3/2012	4,200	11,000	4,200	10,000	4,100	11,000	4,100	9,900	60	710	100	240
6/4/2012	3,500	9,500	2,900	7,000	3,400	8,800	2800	6,800	93	700	72	170
6/5/2012	2,900	8,000	2,300	5,600	2,800	7,300	2,300	5,500	98	640	59	140
6/6/2012	2,200	6,000	1,900	4,500	2,100	5,500	1,800	4,400	88	520	48	120
6/7/2012	1,400	3,700	1,300	3,100	1,300	3,400	1,200	3,000	58	330	33	81
6/8/2012	1,100	2,900	1,000	2,500	1,000	2,700	1,000	2,400	45	260	27	66
6/9/2012	1,000	2,700	810	2,000	970	2,500	790	1,900	43	240	22	53
6/10/2012	740	2,000	1,000	2,500	700	1,800	1,000	2,500	33	180	27	65
6/11/2012	1,100	2,900	1,300	3,200	1,000	2,600	1,300	3,100	24	200	33	80
6/12/2012	1,400	3,800	2,500	6,100	1,400	3,700	2,500	6,000	0	140	59	140
6/13/2012	850	2,300	1,600	3,900	830	2,200	1,600	3,800	20	160	39	95
6/14/2012	610	1,700	1,200	2,900	580	1,500	1,200	2,900	28	150	30	74
6/15/2012	840	2,300	1,700	4,200	810	2,100	1,700	4,100	27	180	42	100
6/16/2012	1,000	2,800	1,900	4,600	1,000	2,600	1,900	4,500	21	190	46	110
6/17/2012	1,000	2,700	2,000	4,800	990	2,500	1,900	4,600	25	200	47	110
6/18/2012	780	2,100	1,300	3,200	760	2,000	1,300	3,200	26	170	33	81

Table 5. Daily 95-percent confidence intervals for suspended load estimates. (Methods described by Lee and others [2012], and Schaepe and others [2014].)—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; LCL95, lower limit of 95-percent confidence interval; UCL, upper limit of 95-percent confidence interval; nd, no data. Blue-highlighted cells indicate overlapping confidence intervals between KANS–CH–US and KANS–CH–DS or no significant difference; green-highlighted cells indicate net deposition; red-highlighted cells indicate net erosion]

Date	Total suspended-sediment load (ton per day)				Total suspended-silt load (ton per day)				Total suspended-sand load (ton per day)			
	KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS	
	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95
6/19/2012	600	1,600	1,100	2,600	580	1,500	1,000	2,500	20	130	27	65
6/20/2012	650	1,800	990	2,400	630	1,600	970	2,300	22	140	25	61
6/21/2012	430	1,200	880	2,100	400	1,000	860	2,100	30	130	23	56
6/22/2012	290	780	1,200	2,800	260	660	1,100	2,700	33	120	29	71
6/23/2012	340	910	1,400	3,500	300	780	1,400	3,400	34	130	35	85
6/24/2012	190	520	990	2,400	170	430	960	2,300	25	90	25	60
6/25/2012	150	400	760	1,800	120	320	740	1,800	22	77	20	48
6/26/2012	330	880	600	1,400	300	780	580	1,400	24	100	16	38
6/27/2012	280	760	440	1,100	260	680	430	1,000	16	79	12	29
6/28/2012	280	770	440	1,100	270	690	430	1,000	16	80	12	29
6/29/2012	280	760	470	1,100	260	670	460	1,100	18	82	13	30
6/30/2012	260	720	410	1,000	250	640	400	970	17	78	11	27
7/1/2012	220	590	330	800	200	520	320	780	14	65	9.0	22
7/2/2012	210	580	350	860	200	510	340	830	15	66	9.6	23
7/3/2012	190	520	310	760	180	460	300	740	13	58	8.5	21
7/4/2012	180	490	230	560	170	430	220	540	12	56	6.5	16
7/5/2012	180	480	230	550	160	420	220	540	13	56	6.4	16
7/6/2012	150	420	200	490	140	370	200	480	12	51	5.7	14
7/7/2012	140	380	190	450	130	330	180	440	12	48	5.3	13
7/8/2012	140	370	170	420	130	320	170	410	12	49	5.0	12
7/9/2012	140	380	170	400	130	330	160	390	13	51	4.8	12
7/10/2012	150	390	180	440	130	340	170	420	14	54	5.2	13
7/11/2012	160	420	190	470	140	360	190	460	15	59	5.6	14
7/12/2012	200	540	190	460	190	480	180	440	15	65	5.5	13
7/13/2012	nd	nd	180	440	nd	nd	180	430	nd	nd	5.3	13
7/14/2012	nd	nd	180	440	nd	nd	170	420	nd	nd	5.2	13
7/15/2012	nd	nd	200	480	nd	nd	190	460	nd	nd	5.7	14
7/16/2012	nd	nd	200	470	nd	nd	190	460	nd	nd	5.7	14

Table 5. Daily 95-percent confidence intervals for suspended load estimates. (Methods described by Lee and others [2012], and Schaepe and others [2014].)—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; LCL95, lower limit of 95-percent confidence interval; UCL, upper limit of 95-percent confidence interval; nd, no data. Blue-highlighted cells indicate overlapping confidence intervals between KANS–CH–US and KANS–CH–DS or no significant difference; green-highlighted cells indicate net deposition; red-highlighted cells indicate net erosion]

Date	Total suspended-sediment load (ton per day)				Total suspended-silt load (ton per day)				Total suspended-sand load (ton per day)			
	KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS	
	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95
7/17/2012	nd	nd	180	440	nd	nd	180	430	nd	nd	5.3	13
7/18/2012	nd	nd	160	400	nd	nd	160	380	nd	nd	4.8	12
7/19/2012	nd	nd	180	430	nd	nd	170	410	nd	nd	5.1	12
7/20/2012	210	560	250	600	190	500	240	580	16	68	7.0	17
7/21/2012	220	610	240	580	210	540	230	570	15	68	6.8	17
7/22/2012	240	640	180	430	220	570	170	420	14	68	5.2	13
7/23/2012	240	650	160	390	230	580	150	370	13	66	4.7	11
7/24/2012	220	590	170	410	200	520	160	390	14	64	4.9	12
7/25/2012	200	530	150	380	180	470	150	370	14	61	4.6	11
7/26/2012	170	460	140	340	150	400	130	330	13	57	4.1	10
7/27/2012	160	440	120	290	150	390	110	280	13	55	3.6	8.6
7/28/2012	180	490	120	290	170	440	120	290	13	58	3.6	8.9
7/29/2012	210	580	110	280	200	520	110	270	11	56	3.5	8.4
7/30/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
7/31/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
8/1/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
8/2/2012	87	240	97	240	81	210	94	230	6.6	29	2.9	7.0
8/3/2012	150	420	120	300	140	370	120	290	12	51	3.7	9.0
8/4/2012	200	550	150	370	190	480	150	360	15	66	4.5	11
8/5/2012	240	640	160	390	220	570	160	380	16	72	4.8	12
8/6/2012	220	610	180	430	210	540	170	410	17	74	5.2	13
8/7/2012	210	580	170	420	200	510	170	410	16	69	5.1	12
8/8/2012	230	630	190	470	220	560	190	460	16	73	5.7	14
8/9/2012	260	700	220	530	240	620	210	520	18	81	6.3	15
8/10/2012	240	660	200	500	230	580	200	480	17	76	5.9	14
8/11/2012	240	660	220	540	220	580	210	520	17	76	6.4	15
8/12/2012	260	700	250	620	240	630	250	600	17	78	7.2	18
8/13/2012	nd	nd	250	610	nd	nd	240	590	nd	nd	7.1	17

Table 5. Daily 95-percent confidence intervals for suspended load estimates. (Methods described by Lee and others [2012], and Schaepe and others [2014].)—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; LCL95, lower limit of 95-percent confidence interval; UCL, upper limit of 95-percent confidence interval; nd, no data. Blue-highlighted cells indicate overlapping confidence intervals between KANS–CH–US and KANS–CH–DS or no significant difference; green-highlighted cells indicate net deposition; red-highlighted cells indicate net erosion]

Date	Total suspended-sediment load (ton per day)				Total suspended-silt load (ton per day)				Total suspended-sand load (ton per day)			
	KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS	
	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95
8/14/2012	nd	nd	230	550	nd	nd	220	540	nd	nd	6.5	16
8/15/2012	nd	nd	260	620	nd	nd	250	600	nd	nd	7.2	18
8/16/2012	nd	nd	310	760	nd	nd	300	740	nd	nd	8.7	21
8/17/2012	260	710	270	650	250	640	260	630	15	72	7.5	18
8/18/2012	250	670	260	620	230	600	250	610	15	72	7.3	18
8/19/2012	260	700	280	690	240	630	270	670	15	73	7.9	19
8/20/2012	260	700	290	700	240	630	280	680	15	72	8.0	19
8/21/2012	230	630	240	570	220	560	230	560	16	71	6.7	16
8/22/2012	230	630	230	570	220	560	230	550	16	72	6.7	16
8/23/2012	260	710	300	730	250	630	290	710	15	74	8.3	20
8/24/2012	nd	nd	300	720	nd	nd	290	700	nd	nd	8.3	20
8/25/2012	nd	nd	390	950	nd	nd	380	920	nd	nd	11	27
8/26/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
8/27/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
8/28/2012	240	650	nd	nd	220	580	nd	nd	17	76	nd	nd
8/29/2012	240	640	240	580	220	570	230	570	16	73	6.8	17
8/30/2012	230	620	240	600	210	550	240	580	16	72	7.0	17
8/31/2012	190	530	260	640	180	460	260	620	14	62	7.4	18
9/1/2012	180	490	250	600	170	430	240	580	13	56	6.9	17
9/2/2012	240	640	420	1,000	220	570	410	990	15	71	11	27
9/3/2012	230	620	340	840	210	550	340	820	16	71	9.4	23
9/4/2012	220	610	280	680	210	540	270	660	16	70	7.8	19
9/5/2012	230	620	310	750	210	550	300	730	16	71	8.5	21
9/6/2012	240	640	330	800	220	570	320	770	16	71	9.0	22
9/7/2012	230	630	300	720	220	560	290	700	16	71	8.2	20
9/8/2012	230	630	310	750	220	560	300	730	16	72	8.5	21
9/9/2012	230	640	310	750	220	560	300	730	16	73	8.5	21
9/10/2012	240	660	340	830	230	590	330	810	16	73	9.4	23

Table 5. Daily 95-percent confidence intervals for suspended load estimates. (Methods described by Lee and others [2012], and Schaepe and others [2014].)—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; LCL95, lower limit of 95-percent confidence interval; UCL, upper limit of 95-percent confidence interval; nd, no data. Blue-highlighted cells indicate overlapping confidence intervals between KANS–CH–US and KANS–CH–DS or no significant difference; green-highlighted cells indicate net deposition; red-highlighted cells indicate net erosion]

Date	Total suspended-sediment load (ton per day)				Total suspended-silt load (ton per day)				Total suspended-sand load (ton per day)			
	KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS	
	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95
9/11/2012	230	620	300	730	210	550	290	710	16	72	8.4	20
9/12/2012	230	620	300	720	210	550	290	700	16	71	8.2	20
9/13/2012	1,600	4,400	1,300	3,200	1,500	3,900	1,300	3,100	100	470	35	85
9/14/2012	960	2,600	950	2,300	900	2,300	920	2,200	58	280	25	61
9/15/2012	280	760	410	990	260	670	400	960	18	83	11	27
9/16/2012	240	660	450	1,100	230	580	430	1,100	16	73	12	29
9/17/2012	230	630	540	1,300	220	560	530	1,300	16	71	14	34
9/18/2012	210	560	490	1,200	190	490	470	1,100	16	69	13	31
9/19/2012	200	540	470	1,100	180	480	460	1,100	16	68	12	30
9/20/2012	210	570	400	970	190	500	390	950	16	69	11	26
9/21/2012	250	670	470	1,100	230	600	450	1,100	15	72	12	30
9/22/2012	250	680	400	980	230	600	390	950	15	72	11	26
9/23/2012	230	620	280	690	210	550	270	670	16	71	7.9	19
9/24/2012	200	540	290	700	180	480	280	680	16	68	8.1	20
9/25/2012	210	560	260	620	190	490	250	600	16	69	7.2	18
9/26/2012	230	620	280	690	210	550	270	670	16	71	7.9	19
9/27/2012	240	640	310	750	220	570	300	720	15	71	8.5	21
9/28/2012	220	600	270	640	210	530	260	630	16	70	7.5	18
9/29/2012	220	610	270	650	210	530	260	630	16	70	7.5	18
9/30/2012	230	630	270	650	220	560	260	630	16	71	7.5	18
10/1/2012	220	600	260	620	210	530	250	610	16	70	7.2	18
10/2/2012	210	560	230	550	190	500	220	540	16	69	6.5	16
10/3/2012	210	580	260	640	200	510	260	620	16	69	7.4	18
10/4/2012	230	620	290	710	210	550	280	690	16	71	8.1	20
10/5/2012	200	550	220	550	180	480	220	530	16	68	6.4	16
10/6/2012	210	560	230	560	190	490	220	540	16	69	6.6	16
10/7/2012	200	550	230	570	180	480	230	550	16	69	6.7	16
10/8/2012	210	560	260	630	190	490	250	610	16	70	7.3	18

Table 5. Daily 95-percent confidence intervals for suspended load estimates. (Methods described by Lee and others [2012], and Schaepe and others [2014].)—Continued

[KANS–CH–US, Kansas chute upstream; KANS–CH–DS, Kansas chute downstream; LCL95, lower limit of 95-percent confidence interval; UCL, upper limit of 95-percent confidence interval; nd, no data. Blue-highlighted cells indicate overlapping confidence intervals between KANS–CH–US and KANS–CH–DS or no significant difference; green-highlighted cells indicate net deposition; red-highlighted cells indicate net erosion]

Date	Total suspended-sediment load (ton per day)				Total suspended-silt load (ton per day)				Total suspended-sand load (ton per day)			
	KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS		KANS–CH–US		KANS–CH–DS	
	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95	LCL95	UCL95
10/9/2012	220	590	280	670	200	520	270	650	16	70	7.8	19
10/10/2012	210	580	240	570	200	510	230	560	16	69	6.7	16
10/11/2012	210	570	230	570	190	500	230	550	16	69	6.7	16
10/12/2012	210	570	240	580	190	500	230	570	16	69	6.8	17
10/13/2012	220	580	250	620	200	510	250	600	16	70	7.2	17
10/14/2012	260	700	360	880	240	620	350	850	16	76	9.9	24
10/15/2012	250	680	300	740	230	600	300	720	18	78	8.5	21
10/16/2012	210	570	230	560	190	500	220	540	16	70	6.6	16
10/17/2012	200	550	270	650	190	480	260	630	16	68	7.5	18
10/18/2012	210	560	340	830	190	490	330	810	16	69	9.3	23
10/19/2012	200	540	220	530	180	470	210	520	16	68	6.3	15
10/20/2012	180	500	190	460	170	430	180	440	16	66	5.5	13
10/21/2012	200	530	240	580	180	460	230	560	16	68	6.7	16
10/22/2012	250	690	500	1,200	240	610	480	1,200	15	72	13	32
10/23/2012	270	730	670	1,600	250	650	650	1,600	15	73	17	42
10/24/2012	230	620	420	1,000	210	550	410	1,000	16	71	11	27
10/25/2012	300	800	410	1,000	270	700	400	980	25	100	11	28
10/26/2012	290	800	380	930	270	690	370	910	25	100	11	26
10/27/2012	190	520	250	610	170	450	240	590	17	70	7.1	17
10/28/2012	180	490	210	520	160	420	210	510	17	67	6.2	15
10/29/2012	180	480	210	510	160	410	200	500	17	67	6.1	15
10/30/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
10/31/2012	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Appendix 1

Appendix 1. Suspended sediment on the Missouri River main channel and within side channel chutes at Upper Hamburg Bend and Kansas Bend, 2012.

[yyyymmdd, date format in 4-digit year, 2-digit month, and 2-digit day; hhmm, 24-hour time format in 2-digit hour and 2-digit minute; USGS National Water Information System parameter numbers given in parentheses after the parameter description and units; LED, light-emitting diode; nm, nanometer; +/-, plus or minus; S/F, sand-fine; EWI, equal width increment; STAID, U.S. Geological Survey station identification number; na, not applicable; --, not measured; SS pumping, sample collected by an autosampler; N, no; Y, yes]

Date, yyyymmdd	Time, hhmm	Sampling method code (82398)	Con-struction	Discharge, instantaneous, cubic foot per second (00061)	Temperature, water, degrees Celsius (00010)	Turbidity, water, unfiltered, monochrome near infra-red LED light, 780–900 nm, detection angle 90 +/-2.5 degrees, formazin nephelometric units (63680)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.0625 millimeter (70342)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.125 millimeter (70343)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.25 millimeter (70344)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.5 millimeter (70345)	Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeter (70331)	S/F split	Suspended sediment, sieve diameter, percent smaller than 1 millimeter (70335)	Suspended sediment, sieve diameter, percent smaller than 2 millimeters (70336)	Suspended sediment concentration, milligrams per liter (80154)	Suspended sediment concentration, milligrams per liter, estimated EWI concentration	Suspended silt sediment concentration, milligrams per liter, estimated EWI concentration	Suspended sand sediment concentration, milligrams per liter, estimated EWI concentration
Upper Hamburg Missouri River upstream (STAID 403712095460601)																		
20120430	1240	EWI	na	--	15.2	57	--	--	--	--	--	--	--	--	230	230	--	--
20120521	1730	EWI	na	43,300	--	67	81	84	95	100	--	81	--	--	188	188	152	36
20120618	1530	EWI	na	42,600	26.3	--	65	69	93	99	--	65	100	--	283	283	184	99
20120718	1245	EWI	na	36,100	--	40	50	57	90	100	--	50	--	--	141	141	71	71
20120816	1420	EWI	na	36,900	--	--	13	19	36	57	--	13	98	100	730	730	95	635
20120816	[1]1435	EWI	na	36,900	--	--	13	16	32	51	--	13	94	100	697	697	91	606
20120910	1150	EWI	na	38,500	--	--	75	80	92	96	--	75	100	--	136	136	102	34
20121009	1330	EWI	na	39,200	--	--	36	45	91	100	--	36	--	--	178	178	64	114
Upper Hamburg Missouri River downstream (STAID 403438095462501)																		
20120430	1340	EWI	na	--	15.7	60	--	--	--	--	--	--	--	--	346	346	--	--
20120521	1600	EWI	na	43,300	--	65	88	92	97	100	--	88	--	--	171	171	150	21
20120618	1437	EWI	na	42,600	25.3	--	66	71	95	100	--	66	--	--	272	272	180	92
20120718	1645	EWI	na	36,100	--	40	11	13	40	95	--	11	100	--	680	680	75	605
20120816	1340	EWI	na	36,900	--	--	28	33	47	80	--	28	98	100	365	365	102	263
20120910	1540	EWI	na	38,500	--	--	25	26	31	36	--	25	40	43	380	380	95	285
20121009	1540	EWI	na	39,200	--	--	--	14	37	62	--	--	97	100	613	613	--	--
Upper Hamburg chute downstream (STAID 403455095462401)																		
20120415	0337	SS pumping	N	5,580	14.0	--	--	--	--	--	97	97	--	--	622	561	544	17
20120415	1204	SS pumping	N	6,740	14.0	--	--	--	--	--	100	100	--	--	--	--	--	--
20120415	1251	SS pumping	N	6,750	14.1	--	--	--	--	--	99	99	--	--	--	--	--	--
20120430	1600	EWI	N	3,690	16.6	130	--	--	--	--	--	--	--	--	365	365	--	--
20120521	1500	EWI	N	4,880	21.1	58	99	99	100	--	--	99	--	--	140	140	139	1
20120618	1310	EWI	N	4,810	25.1	81	--	--	--	--	97	97	--	--	160	160	155	5
20120618	1340	SS pumping	N	4,810	25.2	85	--	--	--	--	97	97	--	--	196	185	179	6
20120718	1545	EWI	Y	1,240	25.7	78	97	97	99	100	--	97	--	--	--	--	--	--
20120731	1030	SS pumping	Y	1,220	28.8	22	--	--	--	--	73	73	--	--	66	70	51	19
20120803	1030	SS pumping	Y	1,210	30.0	21	--	--	--	--	97	97	--	--	39	46	44	1
20120804	1030	SS pumping	Y	962	29.3	27	--	--	--	--	98	98	--	--	71	74	73	1
20120806	1030	SS pumping	Y	1,370	28.1	26	--	--	--	--	98	98	--	--	51	56	55	1
20120808	1030	SS pumping	Y	1,390	28.2	30	--	--	--	--	99	99	--	--	43	49	49	0
20120810	1030	SS pumping	Y	1,200	27.3	27	--	--	--	--	98	98	--	--	45	51	50	1
20120812	1030	SS pumping	Y	1,340	27.1	23	--	--	--	--	96	96	--	--	39	46	44	2
20120814	1030	SS pumping	Y	1,150	25.7	28	--	--	--	--	98	98	--	--	49	55	54	1
20120816	1300	EWI	Y	1,210	24.7	26	--	--	--	--	97	97	--	--	58	58	56	2
20120818	1030	SS pumping	Y	1,170	24.6	33	--	--	--	--	99	99	--	--	48	54	53	1
20120819	1030	SS pumping	Y	1,360	23.6	30	--	--	--	--	97	97	--	--	48	54	52	2
20120822	1030	SS pumping	Y	1,390	24.1	27	--	--	--	--	99	99	--	--	37	44	44	0

Appendix 1. Suspended sediment on the Missouri River main channel and within side channel chutes at Upper Hamburg Bend and Kansas Bend, 2012.—Continued

[yyyymmdd, date format in 4-digit year, 2-digit month, and 2-digit day; hhmm, 24-hour time format in 2-digit hour and 2-digit minute; USGS National Water Information System parameter numbers given in parentheses after the parameter description and units; LED, light-emitting diode; nm, nanometer; +/-, plus or minus; S/F, sand-fine; EWI, equal width increment; STAID, U.S. Geological Survey station identification number; --, not measured; SS pumping, sample collected by an autosampler; N, no; Y, yes]

Date, yyyymmdd	Time, hhmm	Sampling method code (82398)	Con-struction	Discharge, instantaneous, cubic foot per second (00061)	Temperature, water, degrees Celsius (00010)	Turbidity, water, unfiltered, monochrome near infra-red LED light, 780–900 nm, detection angle 90 +/-2.5 degrees, formazin nephelometric units (63680)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.0625 millimeter (70342)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.125 millimeter (70343)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.25 millimeter (70344)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.5 millimeter (70345)	Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeter (70331)	S/F split	Suspended sediment, sieve diameter, percent smaller than 1 millimeter (70335)	Suspended sediment, sieve diameter, percent smaller than 2 millimeters (70336)	Suspended sediment concentration, milligrams per liter (80154)	Suspended sediment concentration, milligrams per liter, estimated EWI concentration	Suspended silt sediment concentration, milligrams per liter, estimated EWI concentration	Suspended sand sediment concentration, milligrams per liter, estimated EWI concentration
Upper Hamburg chute downstream (STAID 403455095462401)—Continued																		
20120823	1030	SS pumping	Y	1,200	23.9	27	--	--	--	--	96	96	--	--	32	40	38	2
20120827	1030	SS pumping	Y	1,410	25.0	26	--	--	--	--	98	98	--	--	51	56	55	1
20120901	1200	SS pumping	Y	1,220	26.8	31	--	--	--	--	99	99	--	--	51	56	56	1
20120903	1200	SS pumping	Y	1,420	27.4	42	--	--	--	--	100	100	--	--	63	67	67	0
20120907	1200	SS pumping	Y	1,150	25.5	37	--	--	--	--	98	98	--	--	53	58	57	1
20120909	1200	SS pumping	Y	1,270	23.6	28	--	--	--	--	98	98	--	--	57	62	60	1
20120910	1200	SS pumping	Y	1,270	23.3	32	--	--	--	--	97	97	--	--	63	67	65	2
20120910	1510	EWI	Y	1,010	23.7	41	--	--	--	--	92	92	--	--	56	56	52	4
20120911	1200	SS pumping	Y	1,010	23.2	32	--	--	--	--	95	95	--	--	55	60	57	3
20120913	1200	SS pumping	Y	1,410	21.4	36	--	--	--	--	98	98	--	--	54	59	58	1
20120915	1200	SS pumping	Y	1,460	21.3	32	--	--	--	--	95	95	--	--	66	70	66	3
20120919	1200	SS pumping	Y	1,160	20.5	30	--	--	--	--	100	100	--	--	83	85	85	0
20120925	1200	SS pumping	Y	1,390	19.2	30	--	--	--	--	97	97	--	--	60	64	62	2
20121005	1200	SS pumping	Y	1,150	17.2	26	--	--	--	--	99	99	--	--	82	84	83	1
20121009	1420	SS pumping	Y	1,180	14.4	34	95	96	96	97	--	95	100	--	54	59	56	3
20121009	1500	EWI	Y	1,040	14.0	33	--	93	98	100	--	--	--	--	--	--	--	--
20121013	1600	SS pumping	Y	1,170	14.0	44	--	--	--	--	98	98	--	--	74	77	75	2
20121019	1600	SS pumping	Y	1,170	13.0	35	--	--	--	--	100	100	--	--	75	78	78	0
Kansas Missouri River upstream (STAID 403126095435301)																		
20120425	1130	EWI		35,100	15.0	62	--	--	--	--	--	--	99	100	260	260	--	--
20120522	1130	EWI		46,800	21.8	120	--	--	--	--	--	--	100	--	418	418	--	--
20120622	1130	EWI		44,700	26.2	120	--	--	--	--	--	--	100	--	314	314	--	--
20120719	1000	EWI		34,800	30.9	41	--	--	--	--	--	--	100	--	206	206	--	--
20120719	[1]1007	EWI		34,800	30.9	39	--	--	--	--	--	--	100	--	257	257	--	--
20120817	1418	EWI		38,400	--	--	--	--	--	--	--	--	82	100	347	347	--	--
20120911	0916	EWI		38,800	--	--	91	92	100	--	--	91	--	--	86	86	78	8
20121010	0926	EWI		38,600	--	--	23	30	85	100	--	23	--	--	296	296	68	228
Kansas Missouri River downstream (STAID 404030550954229 01)																		
20120425	1430	EWI		35,100	14.9	66	--	--	--	--	--	--	97	100	363	363	--	--
20120522	1730	EWI		46,800	21.4	150	--	--	--	--	--	--	100	--	438	438	--	--
20120622	1332	EWI		44,700	26.2	130	--	--	--	--	--	--	99	100	548	548	--	--
20120719	1500	EWI		34,800	--	47	--	--	--	--	--	--	82	98	537	537	--	--
20120817	1535	EWI		38,400	--	--	--	--	--	--	--	--	93	100	435	435	--	--
20120911	1330	EWI		38,800	--	--	83	91	98	100	--	83	--	--	90	90	75	15
20121010	1245	EWI		38,600	--	--	22	26	58	93	--	22	98	100	317	317	70	247

Appendix 1. Suspended sediment on the Missouri River main channel and within side channel chutes at Upper Hamburg Bend and Kansas Bend, 2012.—Continued

[yyyymmdd, date format in 4-digit year, 2-digit month, and 2-digit day; hhmm, 24-hour time format in 2-digit hour and 2-digit minute; USGS National Water Information System parameter numbers given in parentheses after the parameter description and units; LED, light-emitting diode; nm, nanometer; +/-, plus or minus; S/F, sand-fine; EWI, equal width increment; STAID, U.S. Geological Survey station identification number; --, not measured; SS pumping, sample collected by an autosampler; N, no; Y, yes]

Date, yyyymmdd	Time, hhmm	Sampling method code (82398)	Con-struction	Discharge, instantaneous, cubic foot per second (00061)	Temperature, water, degrees Celsius (00010)	Turbidity, water, unfiltered, monochrome near infra-red LED light, 780–900 nm, detection angle 90 +/-2.5 degrees, formazin nephelometric units (63680)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.0625 millimeter (70342)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.125 millimeter (70343)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.25 millimeter (70344)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.5 millimeter (70345)	Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeter (70331)	S/F split	Suspended sediment, sieve diameter, percent smaller than 1 millimeter (70335)	Suspended sediment, sieve diameter, percent smaller than 2 millimeters (70336)	Suspended sediment concentration, milligrams per liter (80154)	Suspended sediment concentration, milligrams per liter, estimated EWI concentration	Suspended silt sediment concentration, milligrams per liter, estimated EWI concentration	Suspended sand sediment concentration, milligrams per liter, estimated EWI concentration
Kansas chute upstream (STAID 403135095431201)																		
20120425	1300	EWI	N	4,920	14.6	53	--	--	--	--	--	--	--	--	252	252	--	--
20120507	0237	SS pumping	N	9,110	22.9	190	--	--	--	--	94	94	--	--	291	268	252	16
20120507	0837	SS pumping	N	9,560	22.2	151	--	--	--	--	99	99	--	--	694	624	618	6
20120507	1437	SS pumping	N	8,830	21.8	170	--	--	--	--	98	98	--	--	465	422	414	8
20120508	0237	SS pumping	N	8,280	21.6	179	--	--	--	--	99	99	--	--	526	476	471	5
20120508	0837	SS pumping	N	7,740	20.9	277	--	--	--	--	99	99	--	--	498	451	447	5
20120508	1437	SS pumping	N	7,210	20.5	321	--	--	--	--	100	100	--	--	614	554	554	0
20120509	0237	SS pumping	N	6,880	20.2	190	--	--	--	--	99	99	--	--	562	508	503	5
20120509	0837	SS pumping	N	6,920	19.4	170	--	--	--	--	99	99	--	--	368	336	333	3
20120509	1457	SS pumping	N	6,290	19.1	160	--	--	--	--	98	98	--	--	373	341	334	7
20120513	2235	SS pumping	Y	9,400	19.1	150	--	--	--	--	98	98	--	--	399	364	357	7
20120514	0435	SS pumping	Y	10,500	19.9	140	--	--	--	--	98	98	--	--	391	357	350	7
20120514	2235	SS pumping	Y	11,100	19.5	110	--	--	--	--	96	96	--	--	414	377	362	15
20120515	1035	SS pumping	Y	10,200	18.9	98	--	--	--	--	98	98	--	--	276	255	250	5
20120515	1635	SS pumping	Y	10,700	18.4	93	--	--	--	--	99	99	--	--	276	255	253	3
20120515	2235	SS pumping	Y	9,660	19.6	84	--	--	--	--	98	98	--	--	267	247	242	5
20120516	0435	SS pumping	Y	9,550	19.3	81	--	--	--	--	97	97	--	--	275	254	247	8
20120516	1635	SS pumping	Y	9,210	19.4	74	--	--	--	--	97	97	--	--	244	227	220	7
20120519	1635	SS pumping	Y	6,890	20.4	51	--	--	--	--	98	98	--	--	350	321	314	6
20120522	1415	EWI	Y	7,190	21.2	130	79	81	87	98	--	79	100	--	352	352	278	74
20120530	1938	SS pumping	Y	12,800	22.8	249	--	--	--	--	99	99	--	--	613	553	547	6
20120531	0138	SS pumping	Y	13,900	22.3	379	--	--	--	--	100	100	--	--	794	713	713	0
20120622	1200	EWI	Y	3,010	25.0	18	98	98	99	100	--	98	--	--	--	--	--	--
20120703	1030	SS pumping	N	2,010	29.8	37	--	--	--	--	96	96	--	--	42	48	47	2
20120719	1145	EWI	N	1,950	25.6	25	95	95	96	100	--	95	--	--	70	70	67	4
20120817	1235	SS pumping	N	2,020	24.7	54	--	--	--	--	98	98	--	--	48	54	53	1
20120817	1240	EWI	N	2,020	24.8	44	93	94	95	100	--	93	--	--	98	98	91	7
20120911	1023	SS pumping	N	2,030	22.5	29	--	--	--	--	99	99	--	--	54	59	58	1
20120911	1040	EWI	N	2,030	22.9	33	--	--	--	--	97	97	--	--	68	68	66	2
20121010	1000	EWI	N	1,900	13.6	23	79	82	92	100	--	79	--	--	76	76	60	16
20121010	[1]1007	EWI	N	1,900	13.6	23	87	88	89	90	--	87	100	--	69	69	60	9
20121010	1015	SS pumping	N	1,880	13.7	22	--	--	--	--	97	97	--	--	93	94	91	3
Kansas chute downstream (STAID 403134095431101)																		
20120414	2336	SS pumping	N	7,470	13.6	230	--	--	--	--	94	94	--	--	--	--	--	--
20120415	0536	SS pumping	N	16,100	13.4	480	--	--	--	--	95	95	--	--	--	--	--	--
20120415	1136	SS pumping	N	17,500	13.6	840	--	--	--	--	96	96	--	--	3,190	2,829	2,716	113
20120415	1736	SS pumping	N	18,000	14.0	820	--	--	--	--	99	99	--	--	1,780	1,584	1,568	16

Appendix 1. Suspended sediment on the Missouri River main channel and within side channel chutes at Upper Hamburg Bend and Kansas Bend, 2012.—Continued

[yyyymmdd, date format in 4-digit year, 2-digit month, and 2-digit day; hhmm, 24-hour time format in 2-digit hour and 2-digit minute; USGS National Water Information System parameter numbers given in parentheses after the parameter description and units; LED, light-emitting diode; nm, nanometer; +/-, plus or minus; S/F, sand-fine; EWI, equal width increment; STAID, U.S. Geological Survey station identification number; --, not measured; SS pumping, sample collected by an autosampler; N, no; Y, yes]

Date, yyyymmdd	Time, hhmm	Sampling method code (82398)	Con-struction	Discharge, instantaneous, cubic foot per second (00061)	Temperature, water, degrees Celsius (00010)	Turbidity, water, unfiltered, monochrome near infra-red LED light, 780–900 nm, detection angle 90 +/-2.5 degrees, formazin nephelometric units (63680)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.0625 millimeter (70342)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.125 millimeter (70343)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.25 millimeter (70344)	Suspended sediment, fall diameter (deionized water), percent smaller than 0.5 millimeter (70345)	Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeter (70331)	S/F split	Suspended sediment, sieve diameter, percent smaller than 1 millimeter (70335)	Suspended sediment, sieve diameter, percent smaller than 2 millimeters (70336)	Suspended sediment concentration, milligrams per liter (80154)	Suspended sediment concentration, milligrams per liter, estimated EWI concentration	Suspended silt sediment concentration, milligrams per liter, estimated EWI concentration	Suspended sand sediment concentration, milligrams per liter, estimated EWI concentration
Kansas chute downstream (STAID 403134095431101)—Continued																		
20120415	2336	SS pumping	N	18,400	14.5	620	--	--	--	--	99	99	--	--	2,020	1,796	1,778	18
20120416	0536	SS pumping	N	18,800	14.2	650	--	--	--	--	99	99	--	--	1,620	1,442	1,428	14
20120416	1136	SS pumping	N	17,600	14.0	520	--	--	--	--	99	99	--	--	1,100	983	973	10
20120416	1736	SS pumping	N	16,000	14.2	380	--	--	--	--	99	99	--	--	846	759	751	8
20120416	2336	SS pumping	N	14,900	14.3	310	--	--	--	--	98	98	--	--	810	727	712	15
20120417	0536	SS pumping	N	13,300	13.9	270	--	--	--	--	96	96	--	--	745	670	643	27
20120417	1136	SS pumping	N	13,100	13.7	240	--	--	--	--	98	98	--	--	643	579	568	12
20120417	1736	SS pumping	N	12,200	14.2	230	--	--	--	--	98	98	--	--	656	591	579	12
20120417	2336	SS pumping	N	11,600	14.7	240	--	--	--	--	96	96	--	--	614	554	532	22
20120425	1330	EWI	N	5,050	15.6	70	--	--	--	--	--	--	--	--	--	--	--	--
20120522	1645	EWI	Y	7,460	21.4	52	93	95	98	100	--	93	--	--	346	346	322	24
20120622	1240	EWI	Y	2,880	25.0	120	98	98	100	--	--	98	--	--	267	267	262	5
20120622	1250	SS pumping	Y	2,880	25.0	105	--	--	--	--	98	98	--	--	259	240	235	5
20120703	0810	SS pumping	N	1,710	28.9	57	--	--	--	--	99	99	--	--	116	114	113	1
20120719	1330	EWI	N	1,980	29.2	31	97	97	100	--	--	97	--	--	105	105	102	3
20120817	1100	EWI	N	2,050	24.8	77	96	97	97	100	--	96	--	--	--	--	--	--
20120817	1140	SS pumping	N	2,050	24.9	44	--	--	--	--	94	94	--	--	62	66	62	4
20120911	1125	SS pumping	N	2,030	22.4	48	--	--	--	--	99	99	--	--	71	74	73	1
20120911	1200	EWI	N	1,840	22.8	70	81	97	99	100	--	81	--	--	--	--	--	--
20120917	1200	SS pumping	N	1,980	20.5	94	--	--	--	--	99	99	--	--	89	90	89	1
20120918	1200	SS pumping	N	1,990	19.8	78	--	--	--	--	97	97	--	--	78	80	78	2
20120919	1200	SS pumping	N	2,000	19.6	76	--	--	--	--	98	98	--	--	110	109	106	2
20120920	1200	SS pumping	N	1,990	19.7	58	--	--	--	--	97	97	--	--	70	73	71	2
20120922	1200	SS pumping	N	1,910	18.9	69	--	--	--	--	98	98	--	--	109	108	106	2
20120923	1200	SS pumping	N	1,980	18.2	43	--	--	--	--	99	99	--	--	73	76	75	1
20120924	1200	SS pumping	N	1,940	18.0	49	--	--	--	--	99	99	--	--	70	73	72	1
20120927	1200	SS pumping	N	1,870	17.9	52	--	--	--	--	97	97	--	--	90	91	88	3
20120928	1200	SS pumping	N	1,960	18.1	46	--	--	--	--	96	96	--	--	69	72	69	3
20120930	1200	SS pumping	N	2,060	18.5	47	--	--	--	--	97	97	--	--	77	79	77	2
20121002	1200	SS pumping	N	2,010	18.5	38	--	--	--	--	98	98	--	--	76	79	77	2
20121003	1200	SS pumping	N	1,990	18.5	51	--	--	--	--	99	99	--	--	97	97	96	1
20121005	1200	SS pumping	N	1,950	17.0	40	--	--	--	--	98	98	--	--	55	60	59	1
20121010	1120	SS pumping	N	1,930	12.9	42	--	--	--	--	98	98	--	--	90	91	89	2
20121010	1220	EWI	N	1,900	13.2	41	--	--	--	--	91	91	--	--	64	64	58	6
20121022	1200	SS pumping	N	1,930	12.0	79	--	--	--	--	99	99	--	--	151	145	143	1

[1] Replicate sample collected to assess field variability.

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