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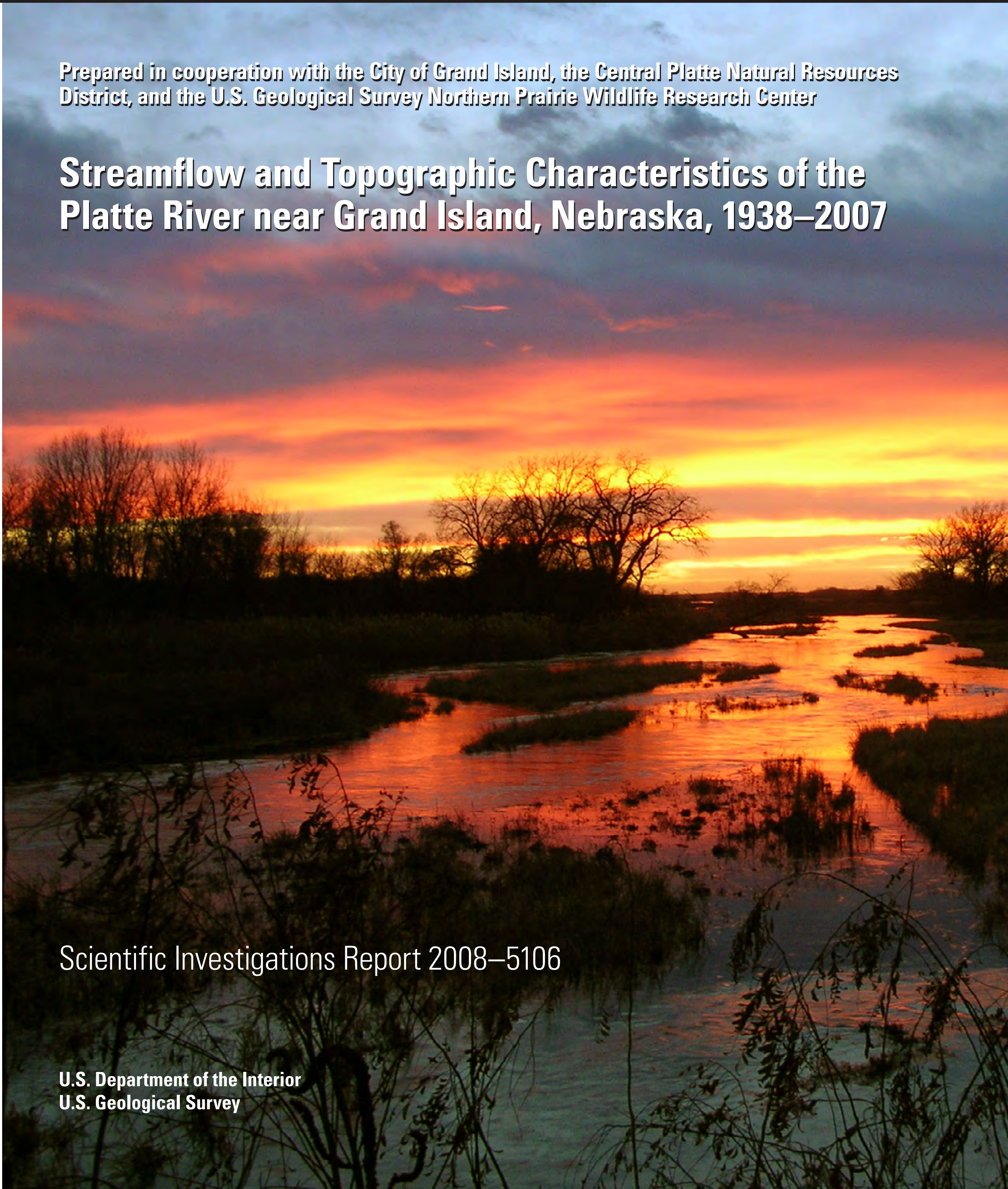

Prepared in cooperation with the City of Grand Island, the Central Platte Natural Resources District, and the U.S. Geological Survey Northern Prairie Wildlife Research Center

Streamflow and Topographic Characteristics of the Platte River near Grand Island, Nebraska, 1938–2007

Scientific Investigations Report 2008–5106

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

Cover photograph. North Channel of the Platte River near Alda, Nebraska, November 6, 2006 (photograph by Robert B. Swanson, U.S. Geological Survey).

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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609344	kilometer (km)
	Area	
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.589988	square kilometer (km^2)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.028317	cubic meter per second (m^3/s)

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

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to North American Vertical Datum of 1988 (NAVD 88), unless otherwise specified.

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

Streamflow and Topographic Characteristics of the Platte River near Grand Island, Nebraska, 1938–2007

By Brenda K. Woodward

Abstract

The central Platte River is a dynamic, braided, sand-bed river located near Grand Island, Nebraska. An understanding of the Platte River channel characteristics, hydrologic flow patterns, and geomorphic conditions is important for the operation and management of water resources by the City of Grand Island. The north channel of the Platte River flows within 1 mile of the municipal well field, and its surface-water flow recharges the underlying aquifer, which serves as a water source for the city. Recharge from the north channel helps minimize the flow of contaminated ground water from the north of the channel towards the well field. In recent years the river channels have experienced no-flow conditions for extended periods during the summer and fall seasons, and it has been observed that no-flow conditions in the north channel often persist after streamflow has returned to the other three channels. This potentially allows more contaminated ground water to move toward the municipal well field each year, and has caused resource managers to ask whether human disturbances or natural geomorphic change have contributed to the increased frequency of no-flow conditions in the north channel.

Analyses of aerial photography, channel surveys, Light Detection and Ranging data, discharge measurements, and historical land surveys were used to understand the past and present dynamics of the four channels of the Platte River near Grand Island and to detect changes with time. Results indicate that some minor changes have occurred in the channels. Changes in bed elevation, channel location, and width were minimal when compared using historical information. Changes in discharge distribution among channels indicate that low- and no-flow conditions in the north channel may be attributed to the small changes in channel characteristics or small elevation differences, along with recent reductions in total streamflow within the Platte River near Grand Island, or to factors not measured in this study, such as increased channel roughness from increased vegetation within the channel.

Introduction

The Platte River flows through Wyoming, Colorado, and Nebraska. The Platte River is the largest river in Nebraska other than the Missouri River, which flows along Nebraska's eastern border (fig. 1). The river supplies water for irrigation, domestic and industrial use, fish and wildlife, and provides recreational opportunities. The Platte River, a shallow braided river, drains 57,650 square miles (mi^2) above Grand Island, Nebraska. Grand Island (fig. 1), with a population of 44,000 (U.S. Census Bureau, 2007), is located in Hall County, Nebraska.

The Platte River flows in four channels south of Grand Island, Nebraska, and previous studies (Nguyen and Gilliland, 1988; Nguyen and Gilliland, 1985) have suggested that not only total flow, but the distribution of flow among channels is important to the municipal water supply. Ground-water flows in the area generally are to the northeast, however, recharge from the south channel and the ground water south of the south channel downstream from South Locust Street flow south east (Nguyen and Gilliland, 1985; University of Nebraska—Lincoln, Conservation and Survey Division, 2001). The City of Grand Island operates a municipal well field just south of the north channel. All channels of the Platte River near the well field are a significant source of recharge to the ground water (Nguyen and Gilliland, 1988). Recharge from the north channel is of special interest because an area of known ground-water contamination is located to the north of the river (Nguyen and Gilliland, 1985; U.S. Environmental Protection Agency, 2007; Central Platte Natural Resources District, 2007). Two U.S. Environmental Protection Agency (EPA) superfund sites are located 3 and 5 miles (mi) north of the city wells (U.S. Environmental Protection Agency, 2007). In addition, the ground water in the vicinity of the municipal wells is in an area designated for Phase II (7.6–15 parts per million (ppm) nitrate as N concentration) of the Central Platte Natural Resources District (CPNRD) Groundwater Quality Management Program and small areas to the north, closer to Grand Island, are designated for Phase III (greater than15 ppm nitrate concentration; Central Platte Natural Resources

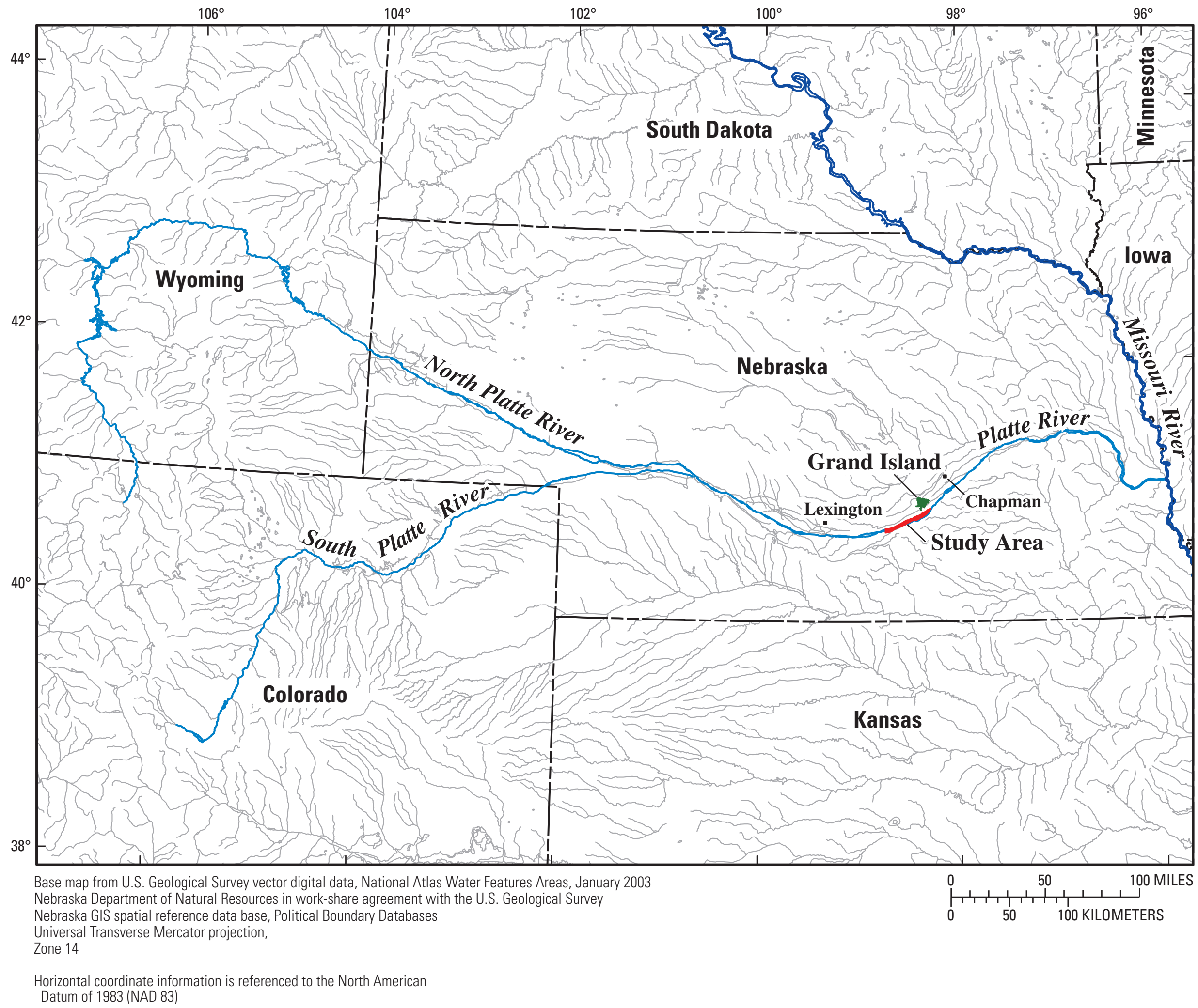


Figure 1. Location of the Platte River and study area.

District, 2007). Most of these nitrate concentrations exceed the EPA maximum contaminant level for drinking water of 10 milligrams per liter (mg/L) as N (approximately 10 ppm). Maintaining recharge from the north channel could possibly reduce the amount of ground water drawn from the contaminated area to the municipal wells, because, as pumping occurs, flow direction near the wells changes based on water-table elevations near the pumping wells (Nguyen and Gilliland, 1988). This means that even though ground-water flow direction in the area is to the northeast, pumping can modify ground-water flow direction slightly and draw water from the north toward the wells. When the north channel is contributing recharge, the recharge will help maintain water-table elevations that prevent flow of the contaminated ground water toward the well field.

Water managers have noticed what they perceive to be declines in streamflow in the north channel since at least 2002 (Duane A. Woodward, Central Platte Natural Resources District; Gary R. Mader, City of Grand Island Utilities Department, oral commun., 2006), and this has raised concerns about possible changes in distribution of streamflow among the channels of the Platte River near the well field and the cause of such changes. Questions arose, such as, would reduced streamflows in the north channel have occurred despite recent drought conditions? Do the data indicate a real change in streamflow distribution, or only an overall decrease in streamflows in the river? If there is a real change in the amount of streamflow in the north channel, is it caused by physical changes at the channel inlet or outlet? Is this a long-term change? Are there management actions that could redistribute streamflow differently to enhance streamflow in the north channel? To address these questions, the current (2006) streamflow and geomorphic conditions of the river and the history of channel degradations and aggradations are important considerations. A study and reporting of streamflow and topographic characteristics of the Platte River near Grand Island, Nebraska, was completed by the U.S. Geological Survey (USGS) in cooperation with the city of Grand Island, Nebraska, the CPNRD, and the USGS Northern Prairie Wildlife Research Center. Data collected and analyzed during this study showed one of three results: Streamflow distribution among the channel is substantially different than historical distributions leading to the conclusion that changes have occurred, but the primary causes of the changes are unknown; Minimal changes were detected in topographic and streamflow characteristics, leading to the conclusion that reduced flows in the north channel are due to low total flows in the river or other factors not evaluated as part of this study; Topographic characteristics explain why flow would not be entering or would be diverted out of the north channel.

The severity of recent drought conditions can be seen in summaries of streamflow data (fig. 2). Historically, during July, August, and September, the mean monthly streamflow of the Platte River near Grand Island declines to 500–1,200 cubic feet per second (ft^3/s) (U.S. Geological Survey, 2007c). Recent drought conditions in the Platte River have decreased the mean monthly discharge to less than 100 ft^3/s for these 3 months since 2002 (fig. 2). As streamflow declines so does recharge, which may increase the amount of ground water drawn from the contaminated area into the municipal well field.

Purpose

The purpose of this report is to present the data-collection methods, analysis, and results of the study of streamflow and topographic characteristics of the Platte River near Grand Island, Nebraska. The report presents information useful for those managing the water within the Platte River channels in this area as well as data sets that will be useful for future study into the functioning of this part of the Platte River. The study aimed to evaluate changes in streamflow distribution among the four channels of the Platte River near Grand Island, Nebraska, and to understand if 2006–2007 flows are lower in the north channel. This report describes long-term changes in the distribution of streamflow among the four channels of the Platte River near Grand Island and topographic and geomorphic characteristics of the channels.

Description of Study Area

The study area is located in Hall County, Nebraska, which covers 546 mi^2 and had a population of 54,862 in 2000 (U.S. Census Bureau, 2008). In this area, the Platte River is a wide braided channel and is part of what is referred to as the “big bend” or central Platte River which stretches from Lexington to Chapman, Nebraska. The area is given this name because the river changes directions, initially flowing southeast at Lexington to flowing northeast at Chapman. The actual study area includes all Platte River channels from State Route L10D south of Shelton, Nebraska, to U.S. Highway 34 southeast of Grand Island (fig. 3). Channel survey study sites 1 and 2 are located on the north channel 2 mi west of U.S. Highway 281 and on the combined channel 2.5 mi west of State Route S40D south of Wood River, respectively (fig. 3). Study sites were chosen because streambed elevations at each site could potentially play an important role in determining the amount of streamflow in the north channel because channel splits are located in these areas. The longest operated streamflow-gaging station in the study area is station 06770500, Platte River near Grand Island, Nebraska. This gage is located at the downstream and eastern end of the study area. The watershed upstream from USGS streamflow-gaging station 06770500 has a drainage area of about 57,650 mi^2, of which about 52,940

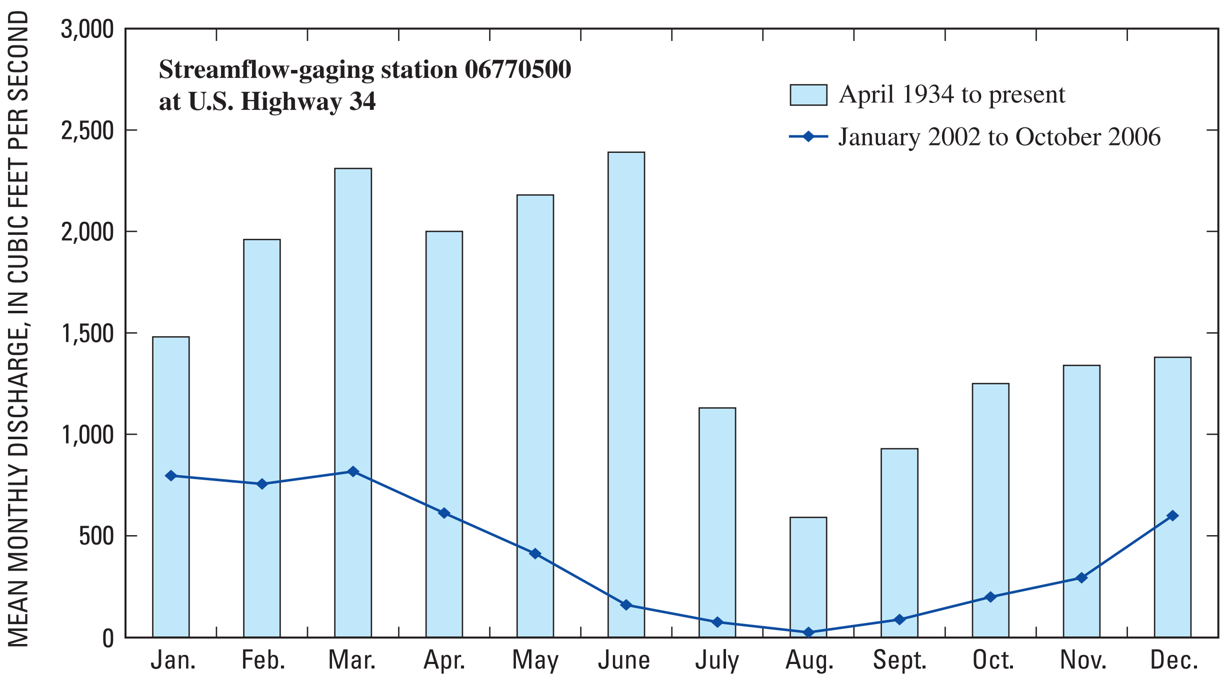
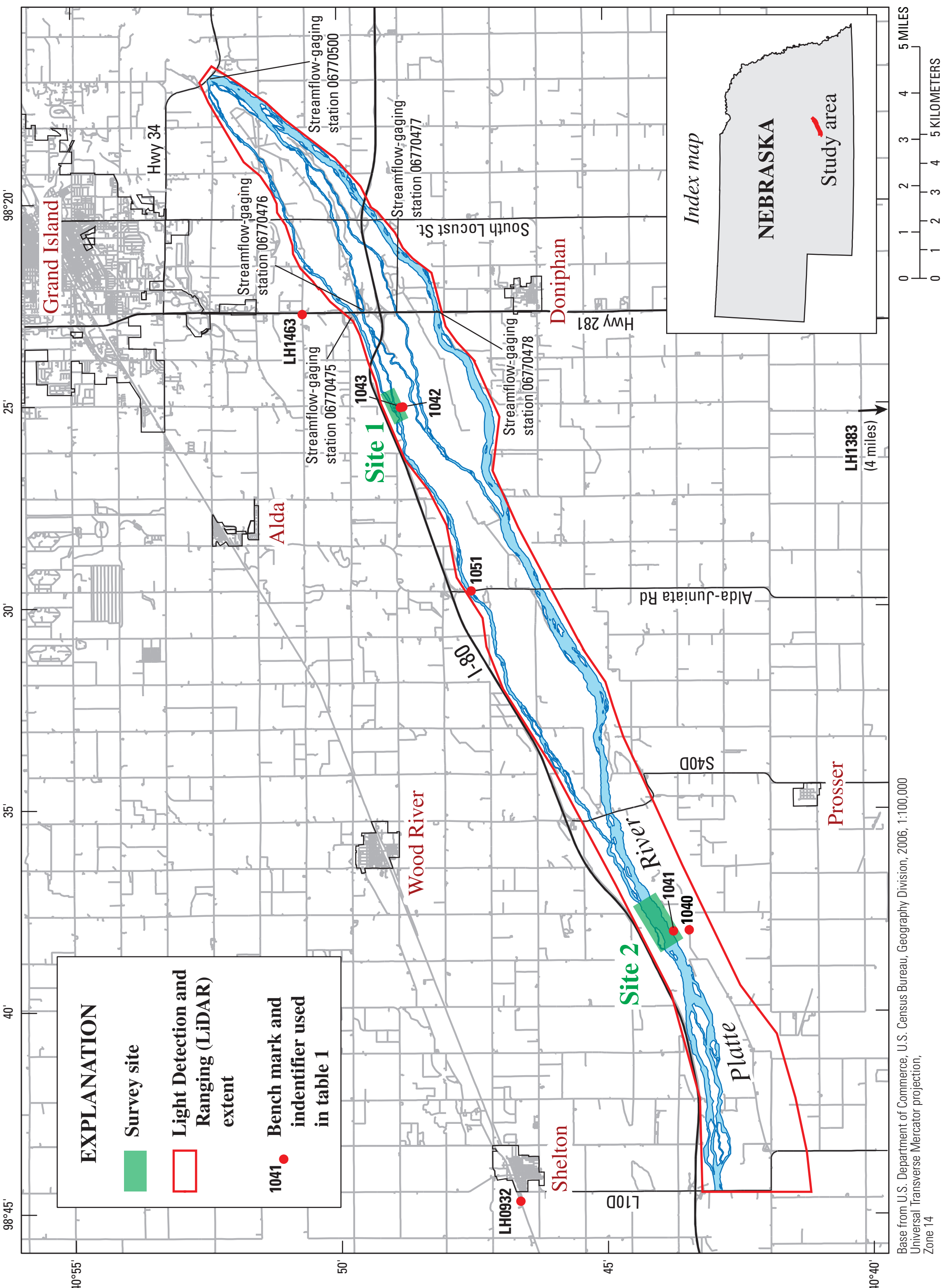


Figure 2. Monthly mean discharge of the Platte River at Grand Island, Nebraska.



Base from U.S. Department of Commerce, U.S. Census Bureau, Geography Division, 2006, 1:100,000
Universal Transverse Mercator projection,
Zone 14

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

Figure 3. Location of study area, survey sites, and bench marks.

mi^2 contributes directly to surface runoff (U.S. Geological Survey, 2007a).

Hall County, Nebraska, receives on average 20–30 inches (in.) of precipitation annually. The annual mean maximum temperature is 63–66 degrees Fahrenheit (°F), but ranges from 80–87 °F in August to 33–36 °F in January. The annual mean minimum temperature is 36–39 °F, but ranges from 57–60 degrees in August to 12–15 °F in January (High Plains Regional Climate Center, 2008). The major land use in Hall County, Nebraska, is agriculture row crops including corn (58 percent of the county in 2007) and soybeans (5 percent of the county in 2007); the other substantial land uses include urban and pasture (U.S. Department of Agriculture, 2008).

Upstream withdrawals for recreation, hydropower, and irrigation as well as storage for fish and wildlife habitat maintenance have decreased the availability of water in the Platte River. Reduced streamflow during certain times of the year allows woody seedlings and other plant species to encroach on dry sandbars (Johnson, 1994). Some species spread rapidly and add to the demand for water in the river; for example, common reed (*Phragmites australis*) has expanded rapidly in recent years into the once open floodplain (fig. 4). Controlling these encroaching plant species has become a focus for those managing habitat for endangered species, such as the whooping crane (*Grus americana*), leading to the mechanical removal of cottonwood (*Populus deltoides*) stands and disking of vegetated sandbars in many channels of the study area (fig. 5).

Land use along the Platte River within the study area has potential effects on streamflow. Numerous land owners reside and recreate along the Platte River channels in the study area. Some create hunting blinds and ponds within the channel and others create small ponds beside the channel for fishing and swimming. Some of the land surrounding the channels is owned and used by the Nebraska Department of Roads to extract materials needed to maintain and enhance roads. Other human disturbances to the river in the study area include bridges, recreation such as all-terrain vehicle (ATV) use within dry channels, and commercial development on islands between the channels along U.S. Highway 281.

The Platte River within the study area has dynamic ground- and surface-water interaction (Stanton, 2000). Nguyen and Gilliland (1985) calculated recharge rates from the surface water to the ground water to be 17.6 to 23.3 gallons per day per square foot of wetted streambed. Soils along and streambed material within the Platte River channels are described as

Figure 4. Common reed in the north channel of the Platte River upstream from U.S. Highway 281 (winter of 2007).

Figure 5. Results of in-channel disking of the north channel at the Alda-Juniata Road.

very sandy and shallow bottom lands, part of the Platte-Sarpy series, and deep and moderately deep bottom lands, part of the Wann-Leshara-Cass series (Yost and others, 1962). Nguyen and Gilliland (1985) tested the in-field hydraulic conductivity of the Platte River streambed material and found it to range from 1.03 x 10^{-3} to 6.06 x 10^{-3} feet per second (ft/s).

Acknowledgements

Thanks to Gary Mader, Emily Wise, and Tim Luchsinger from the City of Grand Island Utilities Department and Duane Woodward from the CPNRD for providing input on study design and direction. The author also acknowledges Charles R. Kelly and Patrick F. Emmett from the USGS Central Region Geospatial Information Office for assisting with contracting services to collect Light Detection and Ranging (LiDAR) data. A special thanks to Wesley Newton, USGS Northern Prairie Wildlife Research Center, for contributing expertise in the LiDAR data-collection effort.

Study Methods

The primary purpose of the study was to evaluate changes in streamflow distribution among the four channels of the Platte River near Grand Island, Nebraska, to understand if flows are lower in the north channel. To understand this, percentage of the total streamflow in the north channel will be compared to historic percentages, and topographic chacteristics will be examined to determine if reduced flows are from deposition, obstruction of inlets, or changes in channel form and location. Data will be reviewed to understand current water distribution, water loss, and the effect of low-flow conditions. This will be done through comparison of historical and current discharge measurements, analysis of wetted width and channel location in aerial photography, and evaluation of elevations collected on channel-transect surveys. Field data collection began in May 2006 and was completed in March 2007. The following sections describe methods used to collect discharge measurements, global positioning system (GPS) and historical data for channel-transect surveys, aerial photographs, and LiDAR data.

Discharge Measurements

Discharge measurements were made on May 25, 2006; June 1, 2006; December 18, 2006; and March 14, 2007, typically only for the north channel. Velocity was measured using an Acoustic Doppler Velocity Meter (ADVM) following standard USGS protocol (Blanchard, 2004). A seepage run (longitudinal series of discharge measurements) through the study area was conducted on June 1, 2006, to identify areas of ground-water/surface-water interaction; discharge measurements made on other dates were limited to the north channel. Field notes from 53 discharge measurements made on all 4 channels of the Platte River at U.S. Highway 281 in the 1980s were compiled for historical comparison (fig. 3; appendix 1, at the back of this report). Discharge measurements were analyzed by comparing the percentage of total streamflow in the north channel to that recorded in discharge measurements from the 1980s.

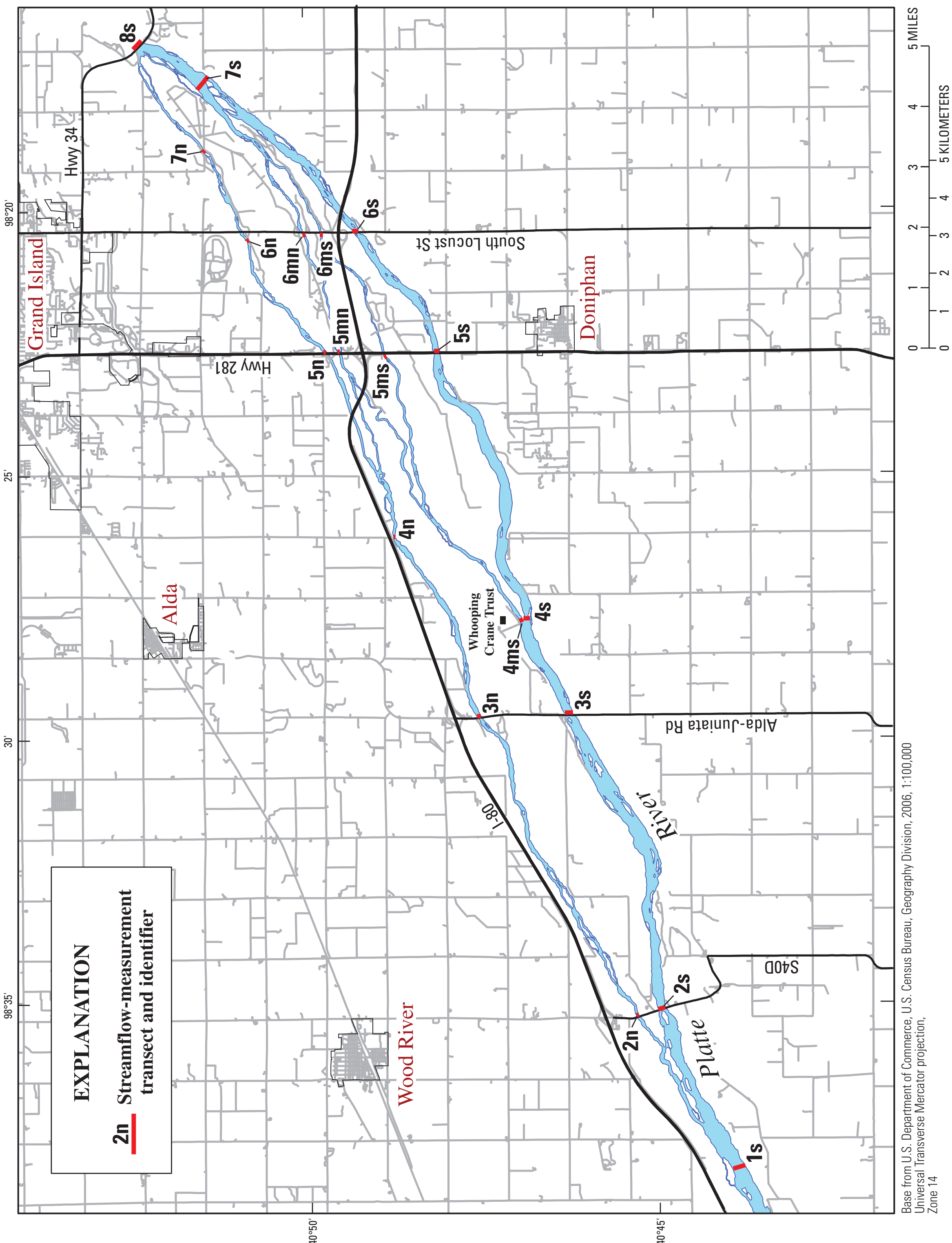
Discharge-measurement transects were numbered 1 through 8 from upstream to downstream and each transect component was further described by channel designation as south (s), north (n), middle south (ms), or middle north (mn) (fig. 6). When there was only one channel, it was designated as south (s). Transect 1 is located 2.5 mi west of State Route S40D, transects 2s and 2n correspond to the Wood River bridges; transects 3s and 3n are located at the Alda bridges; transects 4s, 4ms, and 4n are near the Whooping Crane Trust facility; transects 5s, 5ms, 5mn, and 5n are located at U.S. Highway 281 bridges; transects 6s, 6ms, 6mn, and 6n follow South Locust Street; transects 7n and 7s are near the well field; and transect 8s corresponds to the U.S. Highway 34 bridge.

Channel-Transect Surveys

Real-time kinematic global positioning system (RTK GPS) includes a stationary base station and mobile rovers both receiving triangulation information from a constellation of satellites. The base station is located over a known reference position (bench mark) and transmits data through radio signal to the mobile rovers. This information is used to increase the accuracy of the data being collected by the mobile GPS receivers. Real-time kinematic global positioning system data were collected using Ashtech Z-Xtreme and Z-Max receivers in conjunction with the Geodetic IV and Z-max antennas. Real-time kinematic global positioning systems have a static (stationary collection post-processed with data from a known base) vertical accuracy of 0.016 foot (ft) + 1 ppm (meaning that accuracy is 0.016 ft plus 1 ft for every million feet in distance from the base station), and RTK (a mobile data collection in which information is received from a base station in real time to determine a location) vertical accuracy is 0.052 ft + 2 ppm (0.052 ft plus 2 ft for every million feet the rover is away from the base) as described by the manufacturer (Ashtech Precision Products, 2001). Instrument accuracy, processing accuracy, and reference bench-mark accuracy are all considered to determine actual accuracy of static sessions. Accuracy of the base-station bench mark, distance from base station, tolerance levels set while surveying, and method of survey are all considered when assigning accuracy to RTK GPS data.

Five new USGS bench marks were established in the study area (table 1; fig. 3). Bench marks 1040 and 1042 were installed by digging a 4-ft deep hole and driving a 5-ft length of rebar down in the middle. Then a 1-ft deep concrete cylinder was poured around the rebar and covered with soil. The mark was surrounded by a 3-in. polyvinyl chloride (PVC) pipe (not cemented in) with threaded plug. A USGS cap (fig. 7) was secured to the top of the rebar inside the PVC. These two marks are considered the primary bench marks, which were used as base-station locations. Bench marks 1041 and 1043 were located in close proximity to the two primary bench marks and are Bertśen feno markers, which are 3.5-ft rods with extendable anchors. These bench marks are used for accuracy checks of each mobile rover at the beginning and the end of each surveying day. Bench mark 1051 was established because radio signals did not reach several of the discharge transects from base stations at any existing National Geodetic Survey (NGS) or USGS bench mark, and was set by driving a 5-ft rebar to ground surface, securing a USGS cap on top, and pouring concrete 1 ft deep around the top of the marker. The two primary bench marks, 1040 and 1042, and one check point, 1041, were surveyed by recording data on three high-order NGS bench marks and the new bench marks simultaneously, and post-processing or creating a network with distance and angle information known from location data received from GPS satellites. Small adjustments were made to the location of the new bench marks based on the known location of NGS bench marks. The NGS bench marks used were Shelton East Base Reset [Permanent Identifier (PID) LH0932] on the south side of U.S. Highway 30 west of Shelton (fig. 3); B 436 (PID LH1463) off U.S. Highway 281 approximately 1.5 mi north of Interstate 80 (fig. 3); and HIS ARP 2 (PID LH1383) at the Hastings Airport (about 11 mi south of Doniphan). In addition, data collected at each newly established bench mark were processed through NGS Online Positioning Users Service (OPUS)(National Geodetic Survey, 2008), which again creates a network from the newly established bench marks to Continuously Operating Reference Stations (CORS) (GPS base stations that continuously record satellite data at known points) and adjusts the location of the new bench marks. Processed positions from each method were compared and matched within 0.06–0.16 ft. The remaining two bench marks, 1043 and 1051, were surveyed only by processing data through OPUS. Vertical accuracy of newly established bench marks is the square root of the sum of squared errors associated with processing accuracy (worst being 0.128 ft) and stated equipment accuracy (0.016 ft plus 0.085 ft for the longest baseline gives an accuracy of 0.101 ft) (Ashtech Precision Products, 2001), making vertical accuracy of the five new bench marks 0.163 ft in relation to each other. Accuracy of the NGS bench marks used in the adjustment would need to be considered to understand accuracy in relation to the North American Vertical Datum of 1988 (NAVD 88).

The five new USGS bench marks were used as base stations during RTK GPS surveying of 95 transects. Initial RTK GPS surveying was conducted on May 18 and 19, 2006, on 38 transects at study site 2 and on May 22, 2006, on 24 transects at study site 1 (fig. 3). From May 2006 through December



Base from U.S. Department of Commerce, U.S. Census Bureau, Geography Division, 2006, 1:100,000
Universal Transverse Mercator projection,
Zone 14

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

Figure 6. Location of discharge-measurement transects.

Table 1. Summary of bench marks established along the Platte River near Grand Island, Nebraska, for this study.

[°, degree; ', minute; ", second; ft, feet]

Bench-mark identifier (fig. 3)	Monument type	North American Datum of 1983		Elevation (feet above North American Vertical Datum of 1988)	Nebraska State Plane Zone 2600	
		Latitude	Longitude		Northing (ft)	Easting (ft)
1040	Primary[1]	40° 43' 27.52"	98° 37' 59.47"	1,981.02	327,547.51	2,019,164.96
1041	Feno[2]	40° 43' 45.12"	98° 38' 00.94"	1,980.08	329,325.36	2,019,023.13
1042	Primary[1]	40° 48' 47.26"	98° 25' 02.58"	1,894.41	360,912.11	2,078,364.97
1043	Feno[2]	40° 48' 48.69"	98° 25' 02.60"	1,895.03	361,057.42	2,078,361.07
1051	Cemented at surface	40° 47' 31.43"	98° 29' 35.79"	1,927.97	352,865.95	2,057,500.31

[1]5-ft rebar cemented with U.S. Geological Survey cap.

[2]3.5-ft spike with extendable anchors with U.S. Geological Survey cap.

2006, 19 transects also were surveyed in conjunction with discharge measurements throughout the study area, 7 of which (transects 6s, 6ms, 6mn, 6n, 7n, 7s, and 8s) were in close proximity to transects surveyed by Nguyen and Gilliland (1985). In December 2006, eight additional transects upstream from study site 2 were surveyed, three of which were originally surveyed by the Bureau of Reclamation in 1985 (Holburn and others, 2006) and again in 2000 and 2005. These transects are referenced as 8B-TR1, 8B-TR2, and 8B-TR3. The final RTK GPS surveys were conducted in March 2007 on six transects originally surveyed by the Bureau of Reclamation in 1989 (transects 172.6s, 172.6mn, 172.6n, 177.3s, 177.3m, and 177.3n) (Holburn and others, 2006).

Resurveying of historic surveys presented a number of challenges including determining the location of historic transects, current conditions not allowing for resurveys, and data conversion. Actual locations were known for only 5 of the 16 resurveyed transects, including transects 8B-TR1, 8B-TR2, 8B-TR3, 172.6s, and 177.3s. Location of transects 172.6s and 177.3s were known by locating monuments in the field and the location of 8B-TR transects were determined from coordinates given by Holburn and others (2006). Survey notes were obtained from the CPNRD describing the location of monuments for transects 177.3n, 177.3m, 172.6n, and 172.6mn, however none could be located in the field; therefore, transects were estimated from maps in Holburn and others (2006). Transect 172.6 located near the South Locust Street bridges included 172.6ms in the original survey; however, this channel was too deep and swift to be resurveyed in 2007 using available equipment. In order to compare historical surveys it is often necessary to convert the data into current coordinates. Elevation data from Nguyen and Gilliland transects of 1985 were converted from referencing the National Geodetic Vertical Datum of 1929 (NGVD 29) to NAVD 88 using the National Geodetic Survey's VERTCON 2.0 software (National Geodetic Survey, 2003). These transformations are adequate for general mapping purposes;

Figure 7. U.S. Geological Survey bench-mark cap.

they are not intended for detailed elevation comparisons, so transformations may have introduced error. Coordinates were selected within the area of each transect to determine the transformation parameters using VERTCON 2.0. Transformation parameters varied little across all transects. Holburn and others (2006) used similar conversion methods, VERTCON 2.0 and linear regression techniques, to convert 1989 Bureau of Reclamation surveys from the original NGVD 29 elevation data to reference NAVD 88.

Transect naming convention varied in each of these surveys because names of transects with historical surveys were often retained from the original surveys (table 2). Backpack-mounted GPS antennas were used for the initial surveying, whereas pole-mounted antennas were used for all other surveys during 2006–07. Methods were changed to pole-mounted surveying for improved precision and surveying logistics. Accuracy of the backpack-mounted surveying is the square root of the sum of squared errors associated with bench mark accuracy (0.163 ft), equipment accuracy (0.073 ft) (Ashtech Precision Products, 2001), and assumed method error associated with backpack-surveying (0.500 ft), for a total of 0.531-ft vertical accuracy in relation to all points collected within the survey. Method error associated with pole-mounted surveying is assumed to be 0.2 ft. Vertical accuracy of data points collected using the pole mounted method is 0.268 ft in relation to other points in the survey data set (or internal survey accuracy not in relation to NAVD 88). Global positioning system data were used to examine topographic features at the two study sites and changes at resurveyed historical transects.

Aerial Photographs

A series of aerial photographs from 1938 to 2006, taken during a variety of streamflow conditions, were used to examine changes in wetted width by measuring wetted widths, normalizing by total flow at the USGS streamflow-gaging station (06770500) at U.S. Highway 34, and looking for downward trends in the data over time. This was not ideal because in several instances upstream channels contained water, but discharge at U.S. Highway 34 was zero; however this was the only discharge data available in the study area during the time all aerial photographs were collected. Wetted width measurements were not measured from the 2001 aerial photographs (U.S. Department of Agriculture, Farm Services Agency, 2001) because the exact date of collection, and therefore, discharge data, could not be obtained. The aerial photographs were obtained from several agencies and organizations. Aerial photography collected in 1993 and 1999 (Nebraska Department of Natural Resources, 1994 and 2000) and in 2001 (U.S. Department of Agriculture, Farm Service Agency, 2001) was downloaded from the Nebraska Department of Natural Resources Spatial/Geographic Information System (at *http://www.dnr.state.ne.us/databank/spat.html*, last accessed on May 23, 2007). U.S. Department of Agriculture, Farm Services Agency's photography from 2003, 2004, 2005, and 2006 (U.S. Department of Agriculture, Farm Service Agency, 2003, 2004, 2005, 2007) was downloaded from the U.S. Department of Agriculture Geospatial Data Gateway (at *http://datagateway.nrcs.usda.gov/GatewayHome.html*, last accessed on May 23, 2007). Aerial photography from fall of 2003, spring and fall

Table 2. Summary of surveyed channel transects.

[RTK GPS, Real-time kinematic global positioning system; na, not applicable; fig., figure]

Transects	Survey date	Data collected	Historical transects	Resurveyed transects	Historical survey year(s)	Historical surveying agency	Location map
Study site 1 Transects 1–24	May 2006	RTK GPS	na		na	na	fig. 3
Study site 2 Transects 1–38	May 2006	RTK GPS	na		na	na	fig. 3
Study site 2 Extra Transects 1–8 including three Bureau of Reclamation transects	December 2006	RTK GPS	8B-TR1, 8B-TR2, 8B-TR3	4, 3, 2	1985, 2000, 2005	Bureau of Reclamation	fig. 3 upstream from site 2 and fig. 19
1s, 2s, 2n, 3s, 3n, 4s, 4ms, 4n, 5s, 5ms, 5mn, 5n, 6s, 6ms, 6mn, 6n, 7s, 7n, 8s	May–December 2006	Discharge and RTK GPS	1, 2, 3, 4, 5, 6, 7	6n, 6mn, 6ms, 6s, 7n, 7s, 8s	1985	Nguyen and Gilliland	fig. 6
177.3n, 177.3m, 177.3s	March 2007	RTK GPS	177.3n, 177.3m, 177.3s	177.3n, 177.3m, 177.3s	1985, 1989, 2000	Bureau of Reclamation	fig. 19
172.6n, 172.6mn, 172.6s	March 2007	RTK GPS	172.6n, 172.6mn, 172.6s	172.6n, 172.6mn, 172.6s	1989 and 1998	Bureau of Reclamation	fig. 19

of 2004, and fall of 2005 was received from the U.S. Fish and Wildlife Service, Grand Island, Nebraska. Aerial photographs from 1998 (Bureau of Reclamation, 1999) collected as part of the Platte River Cooperative Agreement also were used. The Bureau of Reclamation scanned photographs from 1983, 1984, 1986, and 1989 that were digitally georeferenced (photo-identifiable features were cross matched between an unreferenced photo and a georeferenced photograph to assign a coordinate system to a resampled version of the unreferenced photograph) to 1993 aerial photographs by the USGS using ArcMap software (Environmental Systems Research Institute, Inc., 2007). Photographs from 1957 and 1963 were obtained in electronic format from the University of Nebraska—Lincoln, Nebraska, and were subsequently georeferenced to 1983 photographs using ArcMap software (Environmental Systems Research Institute, Inc., 2007). Aerial photographs of the study area taken in 1938 were downloaded from the U.S. Geological Survey (2007b).

Geometrically rectified aerial photographs were used to delineate and digitize the active channel to give an understanding of channel movement and change over time. The active channel in aerial photographs from 1983, 1986, 1998 (Bureau of Reclamation, 1999), and 2005 (U.S. Department of Agriculture, Farm Services Agency, 2005) was digitized using ArcMap software (Environmental Systems Research Institute, Inc., 2007) to compare channel change through the years. Years were selected based on the hydrograph recorded at USGS streamflow-gaging station (06770500, U.S. Highway 34) and the availability of aerial photography. Active channel included all areas between banks, excluding islands with tree cover (any area with woody vegetation was excluded even if it was a mix of woody and non-woody vegetation), but including islands with non-woody vegetation. Most aerial photographs were clear enough that coloration and patterns could be used to distinguish the difference between woody and non-woody vegetation.

LiDAR

Light Detection and Ranging data were collected in addition to GPS data to further examine elevation differences among the four channels to find areas where elevation may influence streamflow to reduce flows in the north channel. LiDAR data were collected by Sanborn (Colorado Springs, Colorado). Light Detection and Ranging data were collected from the entire study area (46.8 mi^2) at a 2.3-ft post spacing density (the average distance between two discrete data points). Bare-earth point data (points extracted from the point cloud that have been evaluated and where determined to be collected on the ground surface), 1-ft contour-interval hypsography (contour lines), and a triangulated irregular network (TIN) model representing land surface were produced from the LiDAR data. The LiDAR data acquisition occurred August 9 through August 12, 2006, to ensure a high probability of low or no flow in the channels and leaf-on condition of trees and shrubs, which was needed for an unrelated study of riparian vegetation. Low- or no-flow conditions were preferred to maximize the collection of streambed elevations because water is opaque to the LiDAR system used. Actual data collection occurred on August 10, 2006, when mean daily discharge at USGS streamflow-gaging station (06770500) at U.S. Highway 34 was 0.96 ft^3/s, but data recorded during the actual time of data collection showed discharge to be around 13 ft^3/s, showing that discharge was changing (increasing) through the day.

The level of LiDAR accuracy was planned to support the development of a terrain elevation model and American Society of Photogrammetry and Remote Sensing (ASPRS) class II contours at 1-ft intervals (Flood, 2006; Federal Geographic Data Committee, 1998). Quality-control and quality-assurance procedures allowed correction for systematic bias in scale, pitch, and roll, as well as documentation of data-quality standards. Vertical root mean square deviation (RMSD) was calculated to be approximately 0.361 ft by comparing processed bare-earth point data at 10 ground-control points surveyed using GPS. Vertical RMSD was calculated to be 0.656 ft for the hypsography in relation to the 10 ground-control points surveyed by Sanborn. Details of the LiDAR data collection and processing are presented in Appendix 2, at the back of this report.

Streamflow Characteristics

Streamflow data collected on a seepage run including all channels of the river, along with additional north-channel measurements, were analyzed to understand how total discharge is distributed recently among the Platte River channels throughout the study area and how this distribution relates to historical distribution of flow.

Discharge-measurement data from a seepage run on June 1, 2006, indicated little water was in the north or the middle-north channels of the Platte River (fig. 8). Most of the discharge was in the south channel, and diverged to the middle-south channel near the Whooping Crane Trust facility (discharge-measurement transects 4s and 4ms in fig. 6) until all channels converge again near U.S. Highway 34 (fig. 8). Total discharge in all channels (sum for all transects with the same number) decreased downstream showing that in June 2006 this was an overall losing section of the river in which surface water was lost through seepage into the streambed. The lowest total discharge, 59.5 ft^3/s, was measured between South Locust Street and U.S. Highway 34 at transect 7 (fig. 8).

Ten discharge measurements were made along the north channel on three additional dates (two in 2006, one in 2007) to better understand flow distribution at different river stages (table 3). At total flows less than 100 ft^3/s, streamflow in the north channel was less than 5 ft^3/s. Measurements made in December 2006 indicated that even when total discharge exceeded 500 ft^3/s, flow in the north channel was still less than 5 ft^3/s. Measurements made in March 2007, at a total discharge

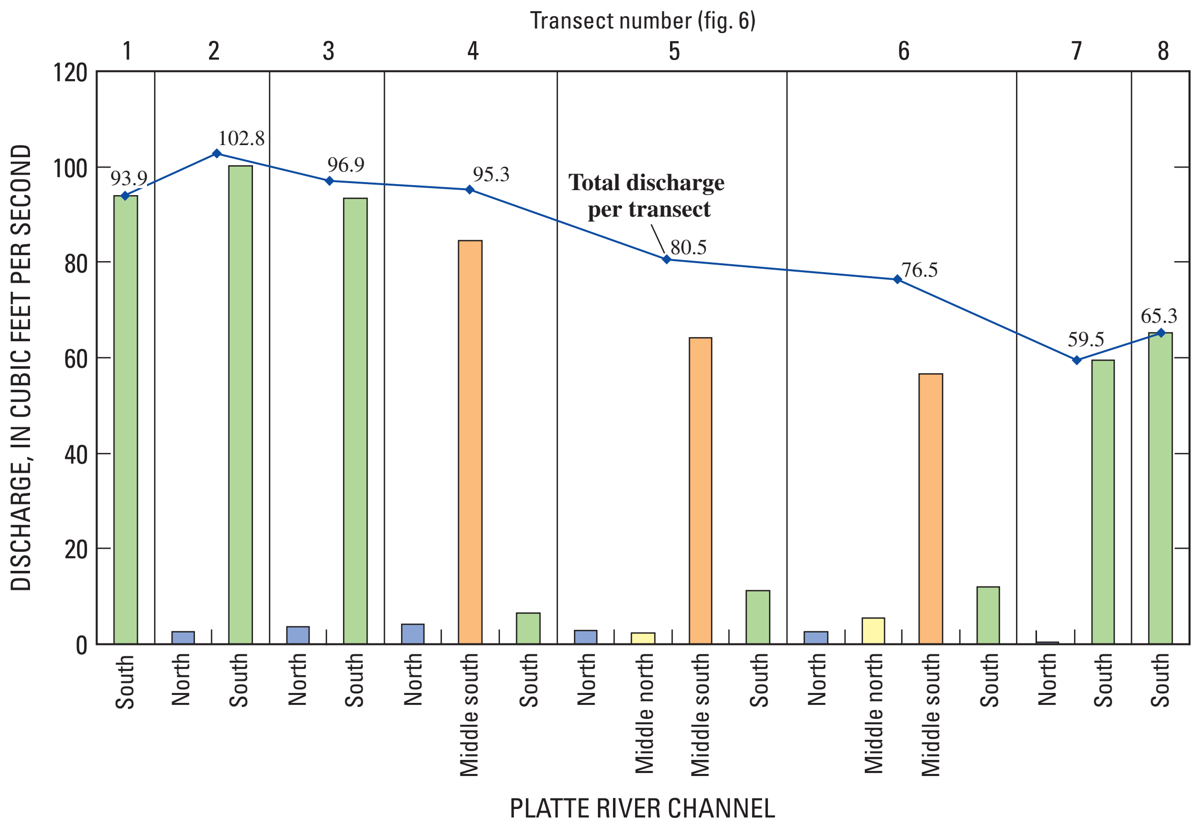


Figure 8. Discharge-measurement data from June 1, 2006, seepage run for 19 transects located from 2.5 miles west of State Route S40D to Highway 34.

of 756 ft^3/s, indicated increased flow in the north channel, 90.8 ft^3/s, but a 41 percent loss, 37.3 ft^3/s, between transect 2n (Wood River) and transect 5n (U.S. Highway 281). Much of this water likely is lost to the middle-north channel where it diverges west of Interstate 80 (within study site 1; fig. 3); however, with the limited number of measurements made, this is an uncertain conclusion.

Recent discharge information (2006–07) allows insight into present distribution of total flow among the four Platte River channels near Grand Island, but comparison to historical discharge distribution is necessary to determine changes. A USGS streamflow-gaging station (06770478) on the south channel at U.S. Highway 281 (5s) was operated from October 10, 1983, to June 27, 1989. Monthly discharge measurements were made from October 1983 through January 1988 to maintain the continuous record at the gaging station. Each month, streamflow in the three other channels was measured along U.S. Highway 281, in addition to the south channel. Summary data for each measurement are given in Appendix 1.

From 1983 to 1989, the south channel routinely carried most of the flow at U.S. Highway 281(5s) and only occasionally did the middle-north channel have the greatest discharge (fig. 9). However, discharge measurements from June 1, 2006, indicate the middle-south channel currently (2006) carries most of the streamflow. The middle-south channel diverges from the south channel near the Whooping Crane Trust facility

Table 3. Discharge measured in the north channel of Platte River near Grand Island, Nebraska.

[Total discharge was measured at U.S. Highway 34 gaging station (06770500). --, not measured]

Measurement date	Discharge, in cubic feet per second, by transect number (fig. 6)						Total discharge, in all channels, in cubic feet per second
	2	3	4	5	6	7	
5/25/2006	2.64	4.38	4.24	--	--	--	88
6/1/2006	2.69	3.55	4.14	2.94	2.62	0.11	71
12/18/2006	3.43	2.09	--	1.50	0	--	593
3/14/2007	90.85	--	--	53.52	53.39	--	756

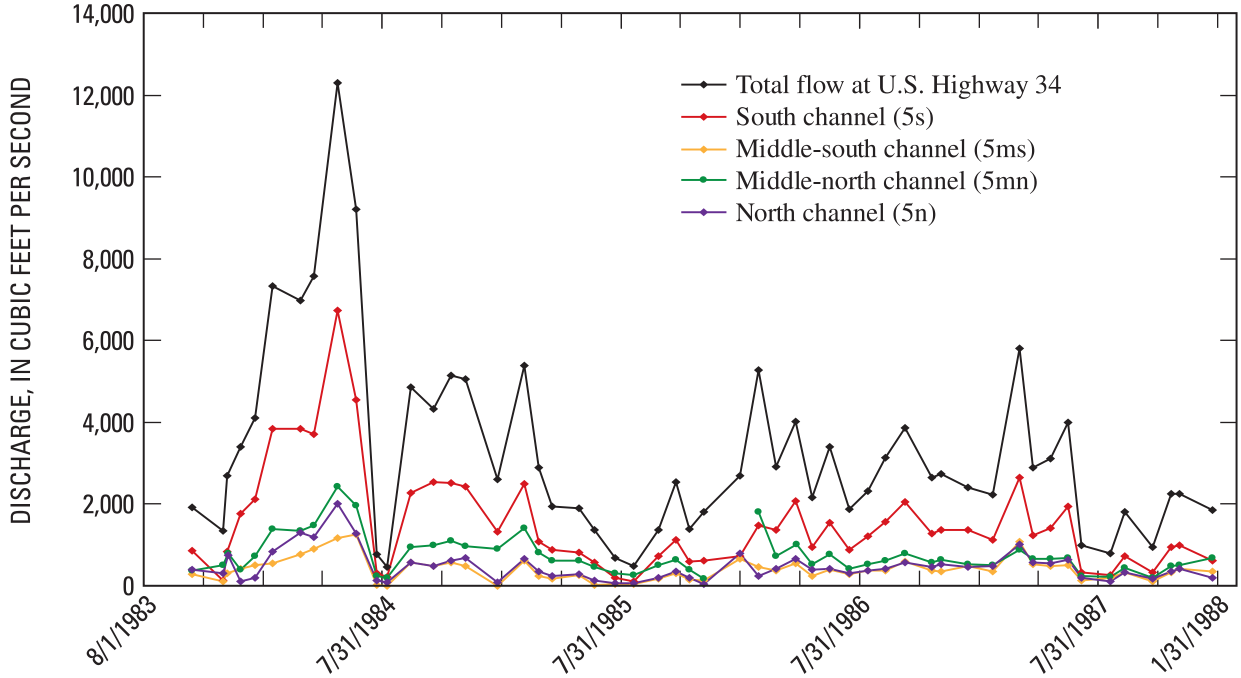


Figure 9. Streamflow distribution among the Platte River channels at Highway 281 through the 1980s.

(discharge-measurement transects 4s and 4ms in fig. 6) and loses some of its flow to the middle-north channel approximately 2 mi west of U.S. Highway 281. Although an aggraded streambed might explain the change, resurveys in 2007 of 1989 transects 177.3s, 177.3m, and 177.3n located approximately 2 mi west of U.S. Highway 281 indicate little change in streambed elevation in this area.

The ratio of north-channel flow to total flow was used to compare flow during the 1980s with the 2006 discharge measurements. In the 1980s the greatest percentage of flow in the north channel occurred during times of ice cover. The greatest percentage was 36 percent on January 29, 1986, when total flow was just over 2,000 ft^3/s (fig. 10). Discharge-measurement notes for this date describe the north channel as clear, but because of debris and ice the middle-north channel could not be measured. The two other occasions when large percentages occurred were in December 1983; field notes describe all channels as having heavy ice cover. The extremely low percentages also were recorded during times of ice cover on the river in December 1983, January 1984, and January and December 1985. The only extremely low percentage occuring without ice cover was 0.06 percent of total flow in February 1986; however, ice cover was recorded on the middle-north channel. Percentage of flow in the north channel during times when total discharge was less than 1,000 ft^3/s typically ranged between 11 and 22 percent when no ice cover was reported (excluding the December 1985 measurement; fig. 10). This range includes only seven discharge measurements with the lowest total flow being 512 ft^3/s, with 17.5 percent of flow in the north channel. Discharge measurements in 2006 and 2007 indicate 4.1 percent of flow in the north channel, with a total discharge of 71 ft^3/s; 0.2 percent, with a total discharge of 593 ft^3/s; and 7.1 percent, with a total discharge of 756 ft^3/s. These percentages are lower than those measured in the 1980s. During the 1980s and under ice-free conditions, the percentage of flow in the north channel ranged from 11 to 22 percent, which is at least two to three times greater than the 7 percent measured in 2007. However, additional discharge measurements and, in particular, measurements at higher flows, would be needed for more conclusive comparisons.

Analysis of the new data in comparison to historical data indicate a measurable change in discharge distribution may have occurred; however, because discharge was measured only on three recent occasions, and total discharges on these occasions were much less than the majority of historical measurements, these results are inconclusive. It is possible that the recent lower percentages are because of overall low-flow condition, and are not a long-term change that will persist once drought conditions cease.

Topographic Characteristics

Channel-Transect Surveys

Study sites 1 and 2 were selected to evaluate the two main channel splits (points of flow divergence) that largely determine the discharge flowing through the north channel. Other transects were surveyed to make comparisons of current

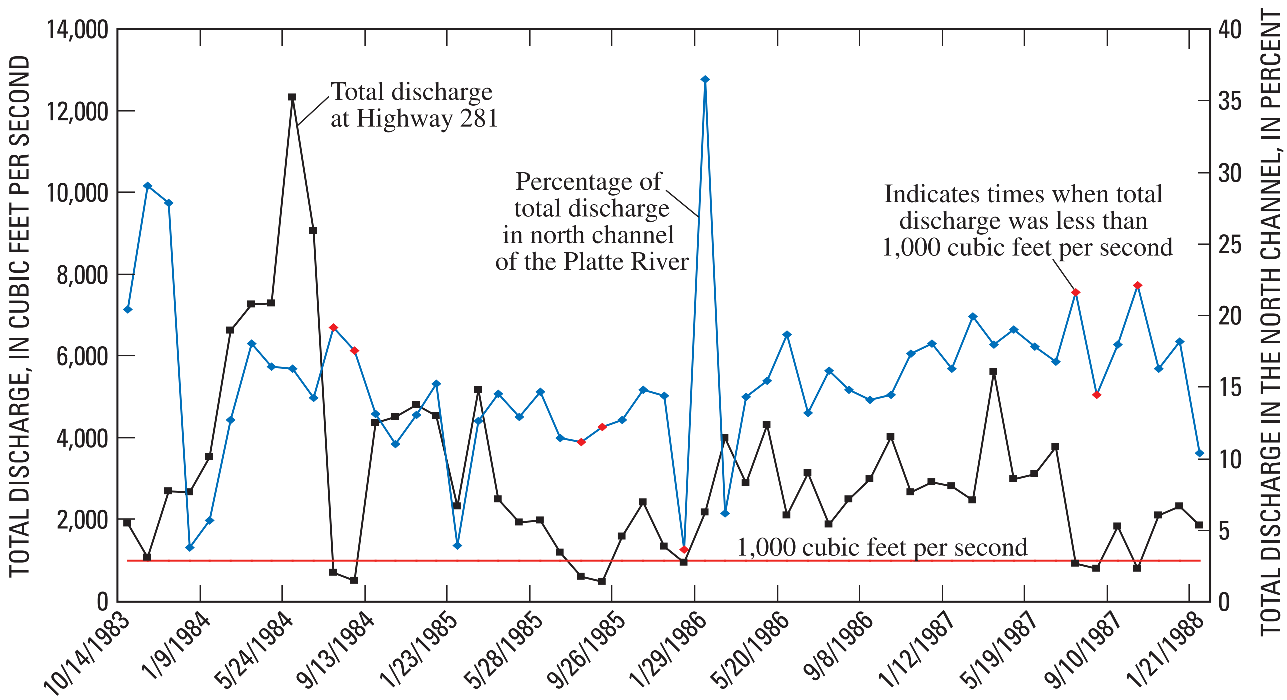


Figure 10. Total discharge measured in the Platte River at U.S. Highway 281 near Grand Island, Nebraska, and percentage of the total discharge in the north channel.

conditions to historical conditions. All transects were surveyed using RTK GPS (Appendix 3, at the back of this report).

Twenty-four transects were surveyed at study site 1, and results showed little difference in stream-bed elevation of either channel between the reaches upstream or downstream from the split (figs. 11 and 12) located between transects 12 and 13. Similar bed elevations at and downstream of the channel split indicate no restriction to flow in the north channel due to deposition or aggradation at this location. Just to the east of study site 1, the channel that split from the north channel and flows south, joins a channel split from the middle-south channel (can be seen at the bottom of the aerial photographs in fig. 11) to form the middle-north channel upstream from U.S. Highway 281. The north channel lost about 29 percent of its flow when discharge measurements were made in June (1.20 ft^3/s lost) and December (0.60 ft^3/s lost), but when increased flows were measured in March, the north channel lost 41 percent (37.33 ft^3/s) from transect 2n to 5n (fig. 6), most presumably at this channel split.

Thirty-eight transects were surveyed within study site 2 (fig. 13) and an additional 8 transects were surveyed just upstream from site 2 (fig. 14), for a total of 46 transects at this channel split (including 3 transects previously surveyed in 1985 by the Bureau of Reclamation).

The north channel on transect 2 (fig. 15) had a thalweg elevation (in this report the thalweg, or point in the transect that has the greatest discharge, will be represented by the deepest point) about 0.98 ft higher than the south channel. This transect is located just downstream from what seems to be the primary channel split allowing water to flow into the north channel. This difference in thalweg elevation will allow less flow (especially during low total discharge) into the north channel, functioning like an inlet-control weir. Other smaller braids downstream from transect 2 also allow some surface water to flow into the north channel. At transect 11 (fig. 15), thalweg elevations differed by 0.65 ft between the north channel and the south channel. Transect 11 is located where the north channel is still able to receive surface-water flow through some small braids, but most of the total discharge is located along the south bank of the south channel. Transects 23 and 36 (figs. 15 and 16, respectively) show an increasing separation between the north and south channel with an island of woody vegetation in between. The north channel thalweg elevation was 0.98 ft higher than the south channel thalweg at transect 23. The south channel at transect 23 consists of multiple braids and the thalweg elevation of the northern most braids was similar to the thalweg elevation of the north channel. There was little difference in thalweg elevation between the channels at transect 36.

The additional eight transects upstream from study site 2 are located along a small north braid (fig. 14) that was active in aerial photos prior to 1999. Flow through this braid could have an effect on the amount of streamflow entering the north channel within study site 2. The thalweg of this small north braid at transect 6 (fig. 16) was about 2.6 ft higher in elevation than the December 2006 thalweg of the south channel. With decreased flows during the past 6 years, this braid carried less water,

Figure 11. Transects 8, 16, and 23 from the channel survey at study site 1.

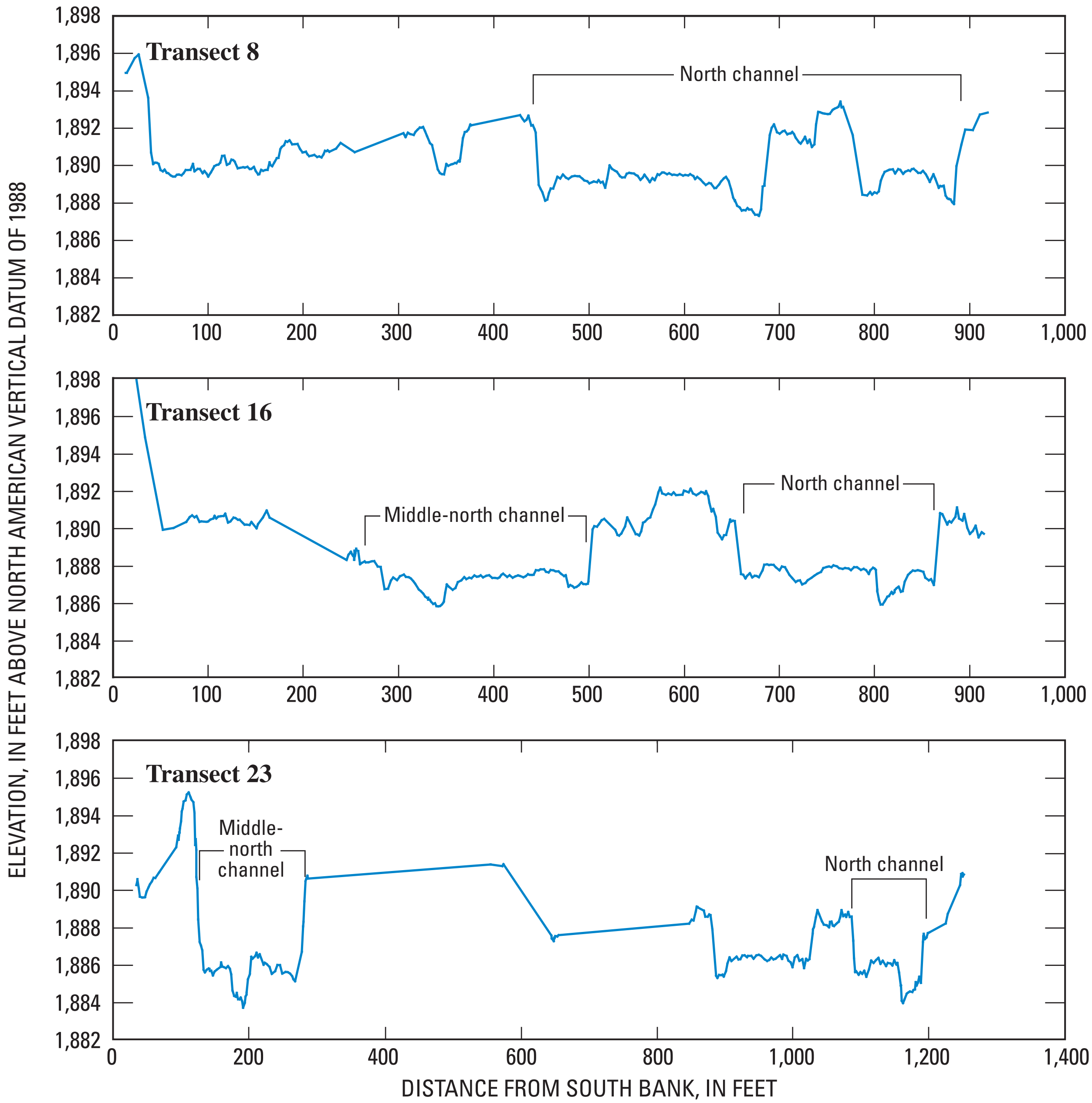


Figure 12. Results for transects 8, 16, and 23 from the channel survey at study site 1.

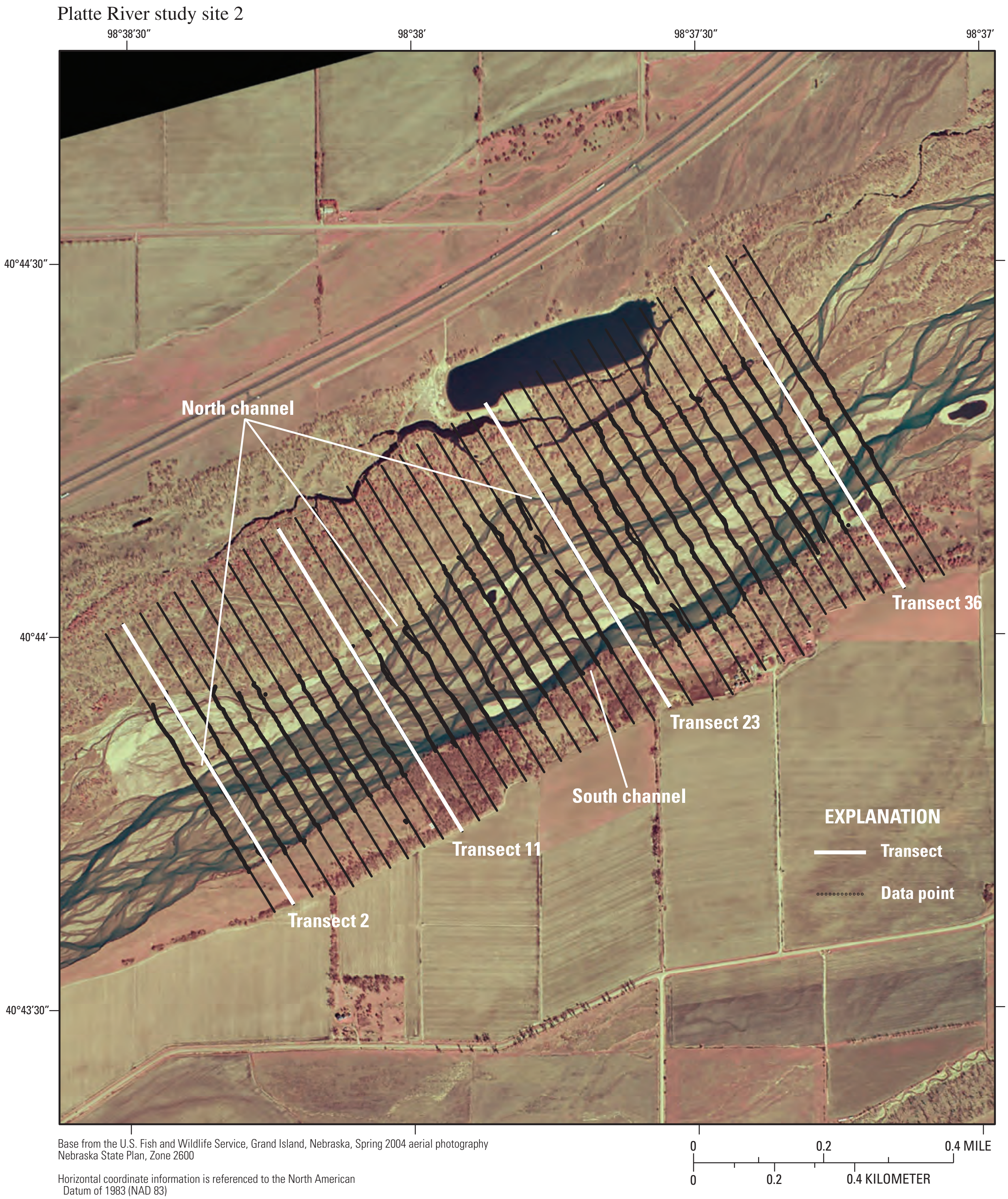
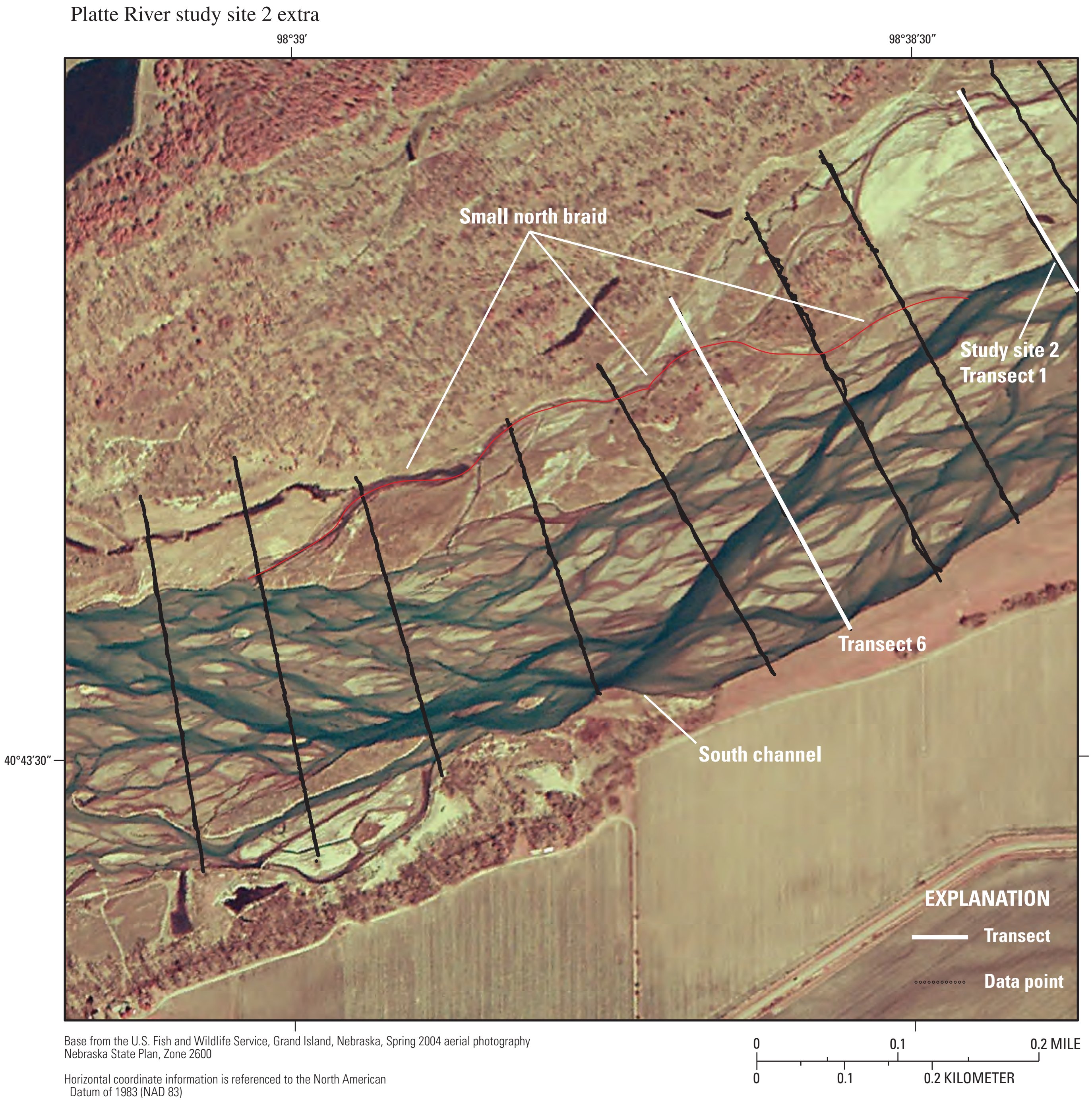


Figure 13. Transects 2, 11, 23, and 36 from the channel survey at study site 2.



Base from the U.S. Fish and Wildlife Service, Grand Island, Nebraska, Spring 2004 aerial photography
Nebraska State Plan, Zone 2600

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

Figure 14. Transects 1–8 surveyed upstream from study site 2.

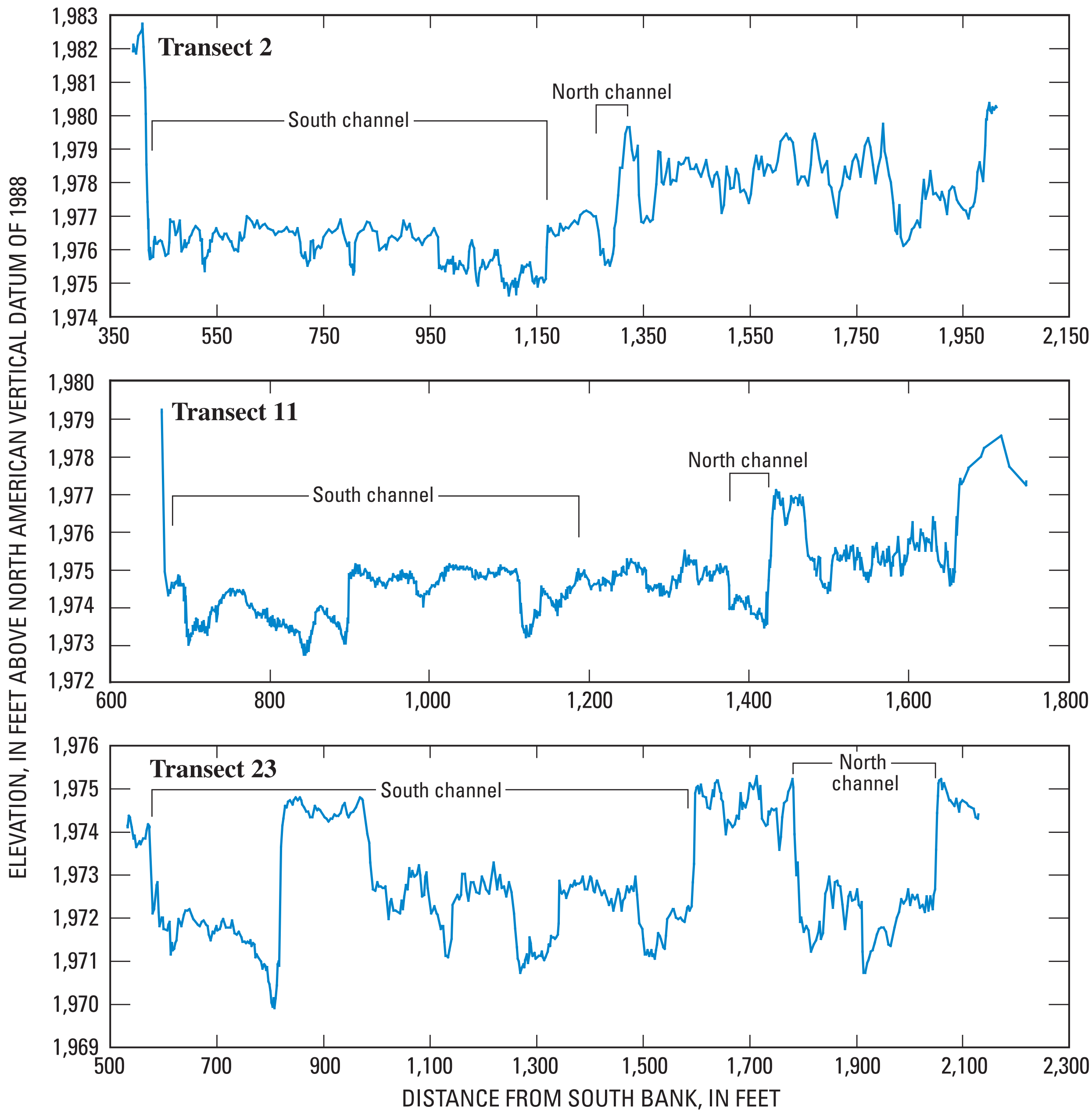


Figure 15. Results for transects 2, 11, and 23 from the channel survey at study site 2.

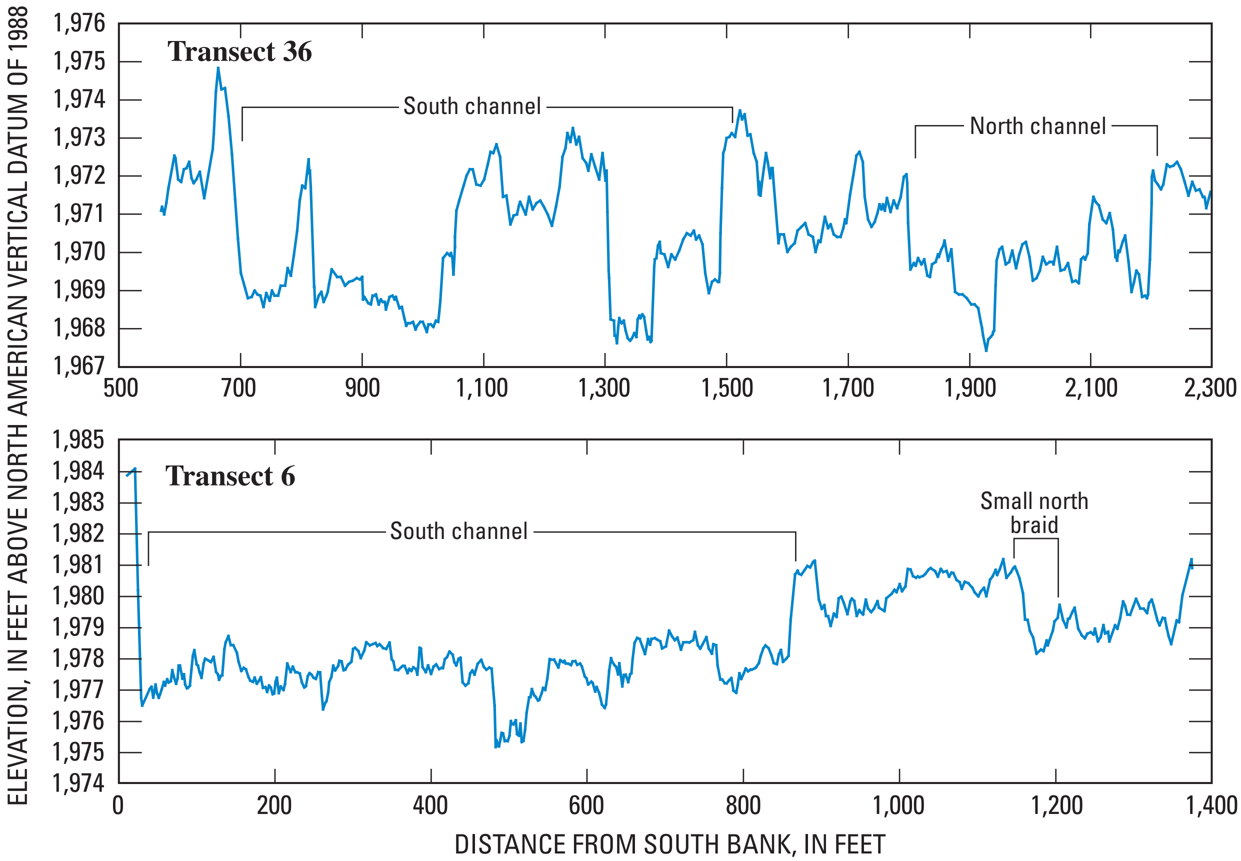


Figure 16. Results for transect 36 from the channel survey at study site 2 and transect 6 from the channel survey upstream from study site 2.

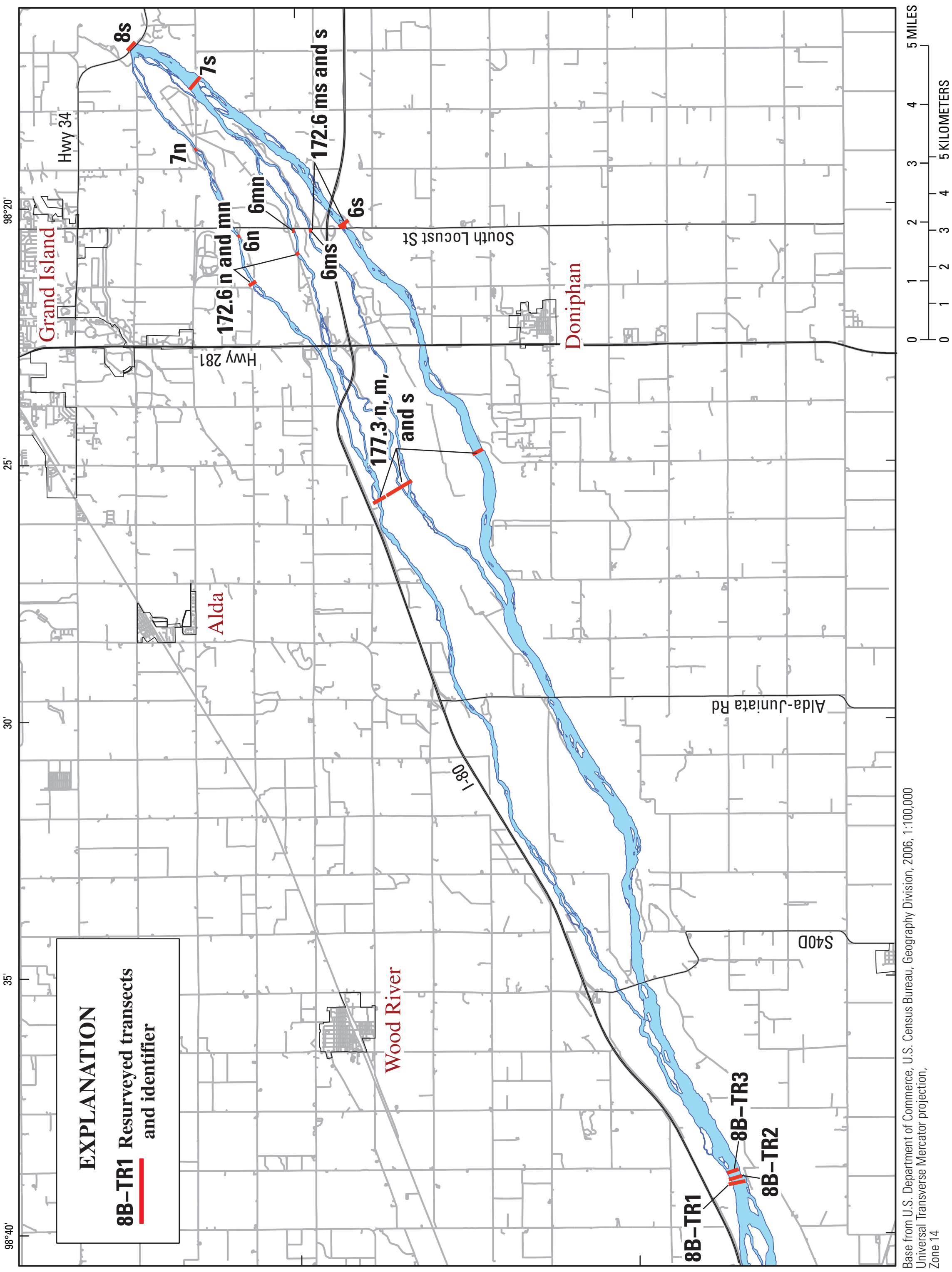
and the southern braids have carried most of the streamflow. Most of the flow was well to the south where this north braid diverged, similar to the split within study site 2 just downstream.

Results for many of the 46 transects surveyed at study site 2 indicated that the north channel had an elevated thalweg in comparison to the south channel, and because the Platte River channel is so wide in this area, a 1-ft difference in elevation might be a substantial restriction to flow. However, the Platte River's sand substrate has large hydraulic conductivity (Nguyen and Gilliland, 1985), and it may be possible for flow to be exchanged between two channels having no surface connection. In addition, these differences in elevation do not provide information about temporal changes in the channel or the distribution of flow among channels. These topographic differences did not appear to correspond to a new feature, but rather that during low flows, the channel form limits the amount of surface water entering the north channel. Such flows have been prevalent over the past several years (2002–2006).

This evaluation looked only at elevation and did not consider other factors influencing flow such as in-channel roughness. Hydraulic roughness or relative roughness comes from objects submerged in the flow such as vegetation. The invasive common reed is found in several channels of the Platte River in the study area. These plants and other in-channel vegetation may have a strong influence over flows within a channel. However, no data were collected as to which channels contained vegetation or how this influenced streamflow. As described in the introduction, agencies such as the Nature Conservancy and the Whooping Crane Trust have been using mechanical methods to remove in-channel vegetation, such as the common reed, in an effort to maintain habitat for endangered bird species. This work provides opportunities for future research to evaluate velocity and flow in channels with and without the influence of in-channel vegetation.

Historical Survey Comparisons

Using RTK GPS methods, 16 historically surveyed channel transects were resurveyed to allow for comparison of riverbed elevations and channel shape (fig. 17). Resurveyed transects shown in figure 17 include the three transects previously surveyed by the Bureau of Reclamation in 1985 (8B-TR1, 8B-TR2, and 8B-TR3); three transects located just west of study site 1, previously surveyed by the Bureau of Reclamation in 1989 (transects 177.3s, 177.3m, and 177.3n); and three transects originally surveyed by the Bureau of Reclamation in 1989 near the South Locust Street bridges (transects172.6s, 172.6mn, 172.6n). In addition, seven



Base from U.S. Department of Commerce, U.S. Census Bureau, Geography Division, 2006, 1:100,000
Universal Transverse Mercator projection,
Zone 14

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

Figure 17. Location of resurveyed transects.

transects originally surveyed by Nguyen and Gilliland (1985) at the South Locust Street bridges, U.S. Highway 34, and in the Grand Island municipal well field were compared to transects surveyed in association with discharge measurements (transects 6s, 6ms, 6mn, 6n, 7s, 7n, and 8s).

Comparisons to 1985 UNL Study Surveys

Transects surveyed June 1, 2006, were compared to transects surveyed in similar locations by Nguyen and Gilliland (1985). Only four of seven transects where channel surveys and discharge measurements occurred on June 1, 2006, were colocated at Nguyen and Gilliland's (1985) transects. Bank elevations in 2006 were surveyed only on transect 7n because trees obstructed GPS reception on other transects, resulting in narrower channel widths in the 2006 surveys, because only a part of the channel was surveyed (except on transect 7n). Transect 6n corresponds to transect 1 in Nguyen and Gilliland's 1985 survey. Transect 1 was downstream from the South Locust Street bridge, but transect 6n was surveyed 980 ft upstream from the bridge because beaver dams had altered flow just upstream from the bridge in 2006. The minimum channel elevation was along the north bank in both surveys, but the elevation was 1.9 ft lower in 2006 (fig. 18). Channel width at transect 1 measured 252.6 ft in 1985, but only 138.6 ft of the channel was surveyed in 2006 on transect 6n. Nguyen and Gilliland's transect 2 relates to transect 6mn, which was located approximately 87 ft upstream from transect 2. Minimum channel elevation was 1.6 ft lower in the 2006 survey and occurred near the north bank, whereas it was located near the south bank in 1985. Nguyen and Gilliland's transects 3, 4, 5, and 7 corresponded to transect 6ms, 6s, 7n, and 8s, respectively, and all were resurveyed in close proximity to the 1985 transects. Differences in minimum channel elevations ranged from 0.8 to 4.2 ft and varied in location on all transects except transect 6s. The vertical difference of 4.2 ft was noted on transect 6s (fig. 18); the south channel of transect 172.6 was surveyed approximately 180 ft downstream from 6s, and also had channel-bed elevations around 1,864 ft. Results for transect 7n, located on the north channel at the Grand Island municipal well field, indicated three changes since 1985: the development of a sandbar near the south bank, a shift of the minimum elevation from the north to the south side of the channel, and increased channel width (fig. 19). The increase in channel width may be caused by the development of the sandbar or may be an artifact of slight variation in the angle of the surveyed transect. Transect 7s was surveyed approximately 710 ft upstream from Nguyen and Gilliland's transect 6 and at a different angle across the channels; therefore, if no degradation or aggradation has occurred minimum elevations should be similar, but the cross sectional shape did not compare well (fig. 19). This transect crossed several small channels separated by large, heavily vegetated islands. In 1985, the minimum elevation was located along the north bank, and in 2006 it was surveyed 0.2 ft lower and in the middle of the transect (fig. 19). The 2006 survey results for transect 8s indicated four primary braids separated by large sandbars, whereas the 1985 transect had many small braids. Transects 8s and 7n were the only two transects where an increase in minimum bed elevation occurred from 1985 to 2006. Transects 6ms and 6s had the greatest decrease in minimum bed elevation among the seven transects surveyed.

In addition to thalweg location and elevation, mean transect elevation was evaluated at transects 6mn, 6s, 7n, and 8s (those transects that were surveyed in close proximity to the 1985 transects). Mean transect elevations were always lower in 2006 than in 1985 with the greatest difference, 4.17 ft, on transect 6s, followed by 2.44 ft on transect 6ms. Results for the north channel comparison at 7n showed the 2006 transect elevations to average 0.41 ft lower than the 1985 transect elevations. The results for average elevation on transect 7n seem to disagree with figure 19; however the 1985 survey only consisted of nine points, two of which where at high points on the bank. The least amount of difference between mean transect elevations was documented at transect 8s with 0.28 ft.

The difference in the thalweg elevation and the mean elevations at transect 6s was 4.2 ft lower in 2006. This same situation occurs on transect 6ms; both the difference in the thalweg elevation and the mean elevation was 2.4 ft lower in 2006. Transect 6mn and 6n were both surveyed upstream from the 1985 transects yet elevations across the transect are lower than those surveyed in 1985 (fig. 18). Elevation differences in transects 7n, 7s, and 8s are much less, both in the mean difference and in the thalweg difference. These facts lead to the conclusion that elevation differences detected on transects 6n, 6mn, 6ms, and 6s are not true elevation change in the channel but are artifacts of coordinate conversion or poor survey control.

Overall, the temporal changes in minimum bed elevation for these transects did not indicate a consistent pattern. Therefore, because of the inconsistency in elevation change and differences in survey locations (the exact historical locations not being known, locations chosen in 2006 based on the need for adequate discharge cross sections, and natural disturbances) these transects do not provide conclusive evidence of physical change that would affect flow in the north channel.

Comparisons to 1985 Bureau of Reclamation Surveys

Two large vegetated sandbars were present in the area upstream from study site 2 in 1986 (fig. 20). The downstream sandbar completely eroded away by 1998, but the south side of the upstream sandbar has remained (as of December 19, 2006; fig. 21, 8B-TR3). In addition, the north side of all transects have increased in elevation approximately 2 to 2.5 ft (fig. 21). Transect 8B-TR1 crossed the upstream tip of the downstream sandbar at a distance of approximately 200 ft from the south bank in 1985, but the sandbar had eroded by 2000. Also, all three transects indicate bank erosion has occurred on the south side. All these changes indicate that the primary flow has shifted laterally toward the south, causing the sandbar and

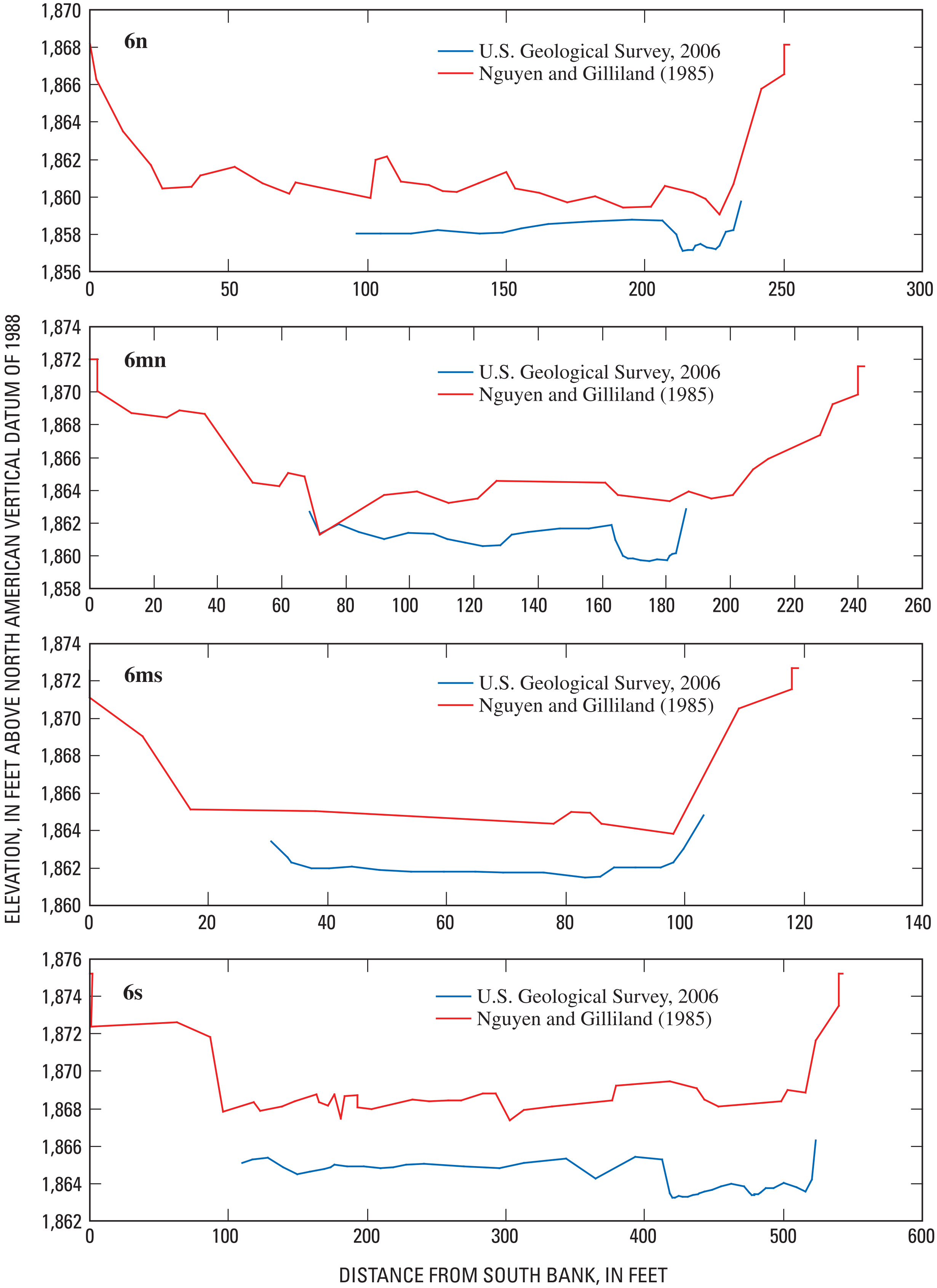


Figure 18. Results for resurveys of Nguyen and Gilliland (1985) transects near transect 6.

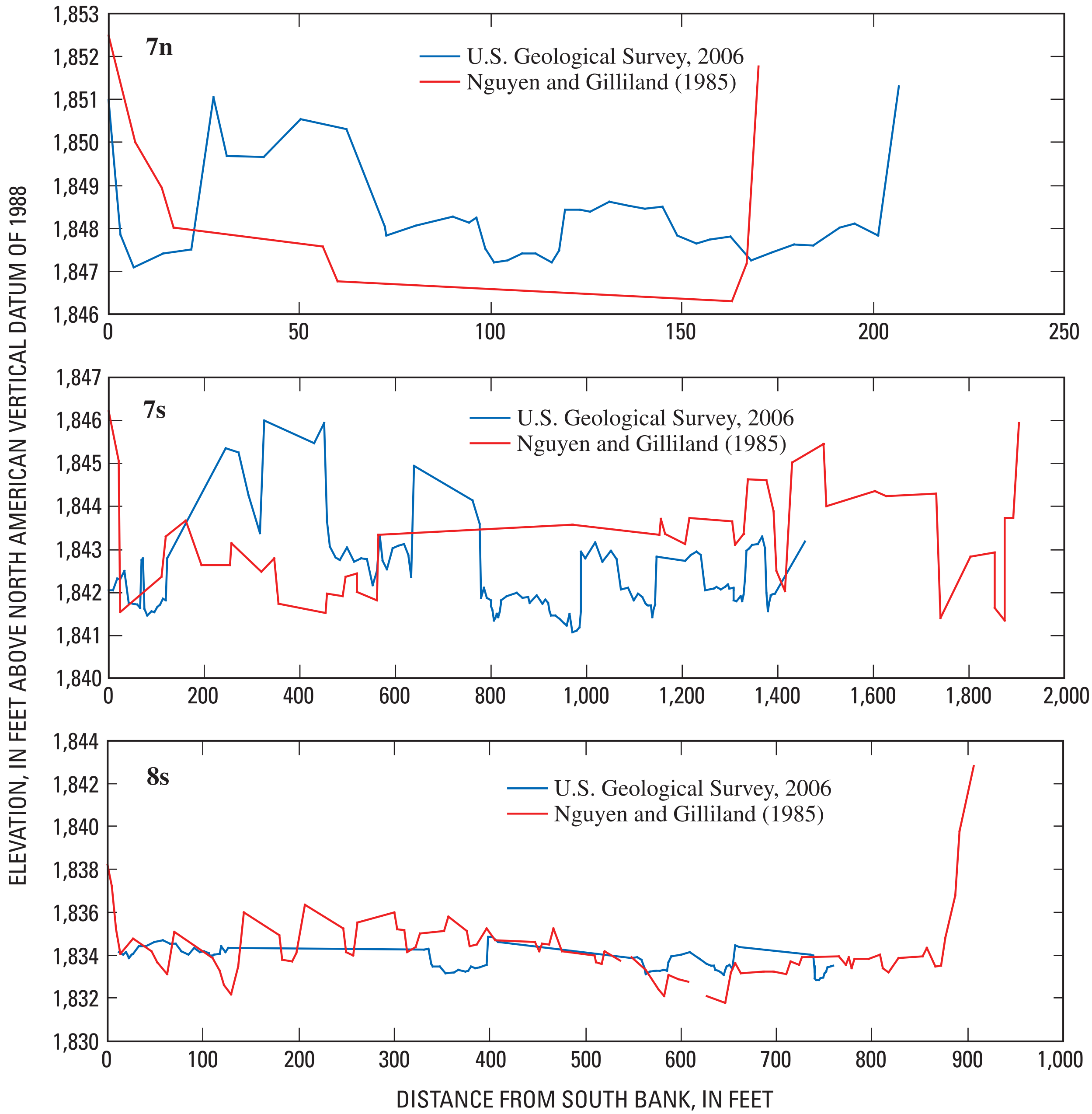
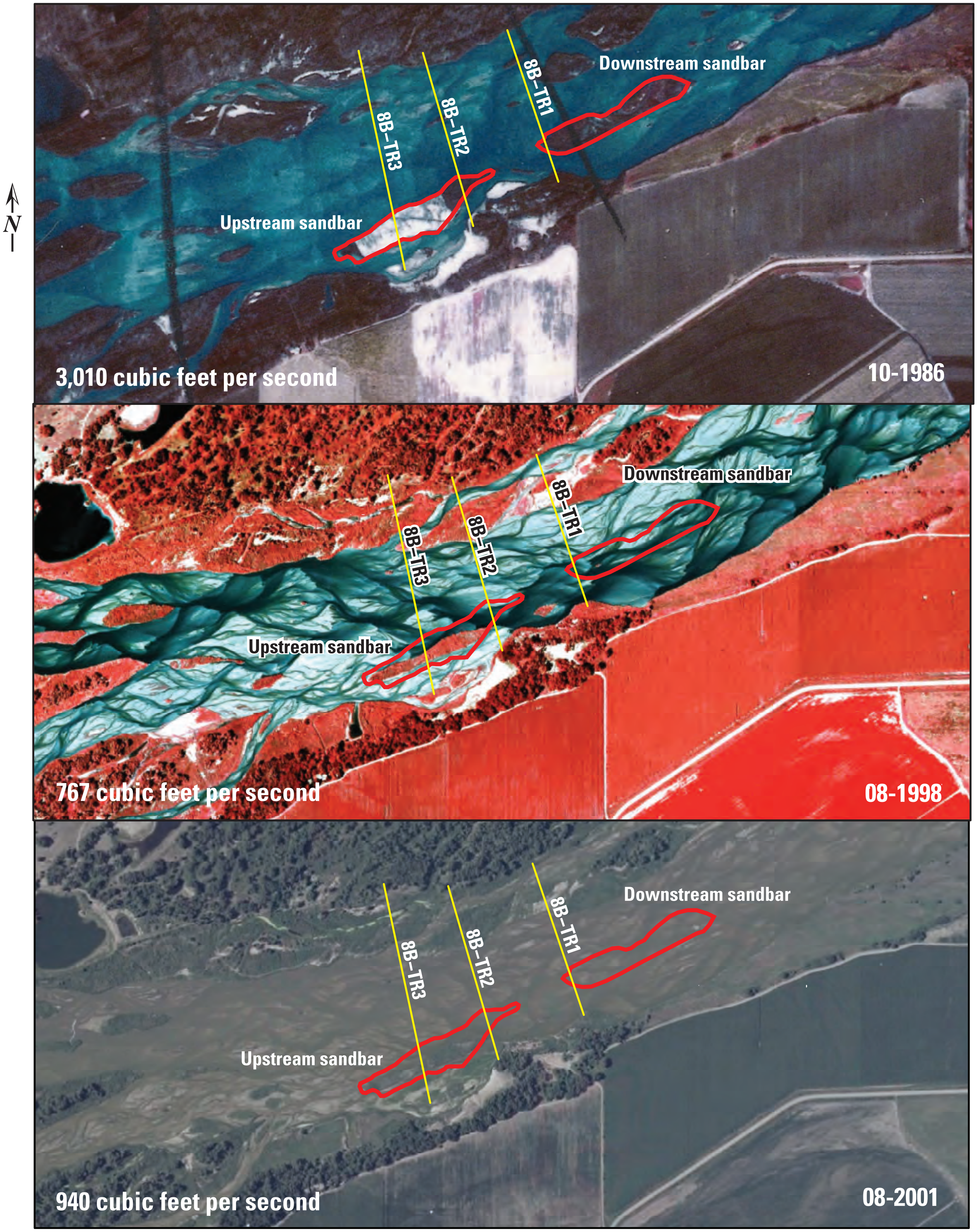


Figure 19. Results for resurveys of Nguyen and Gilliland (1985) transects near transects 7 and 8.

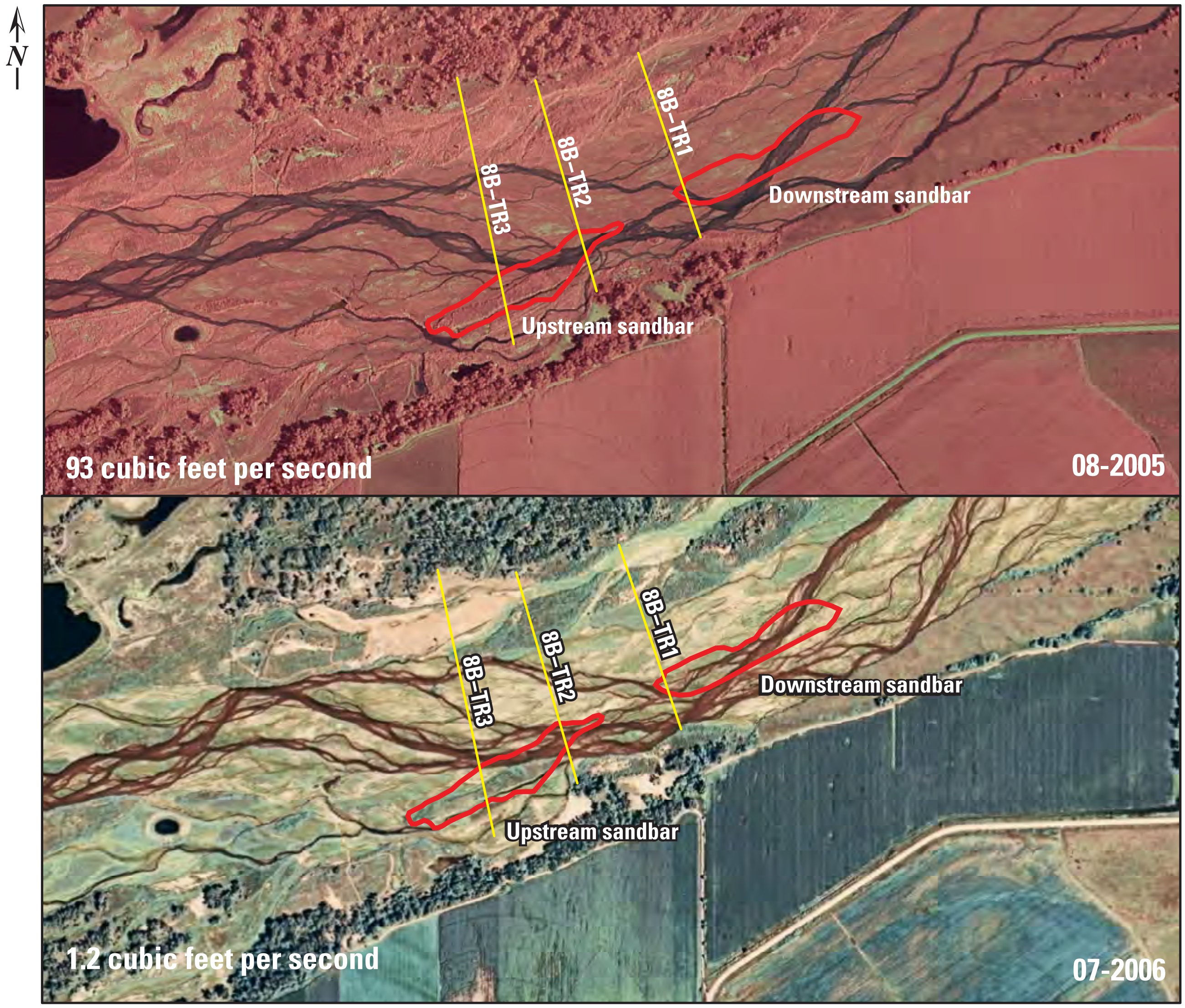


Base from the U.S. Department of Agriculture, Farm Service Agency, Aerial Photography Field Office, 2001 and 2006 and Bureau of Reclamation, 1999
Universal Transverse Mercator projection,
Zone 14

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

Note: Discharge at U.S. Highway 34 streamflow-gaging station 06770500 shown in left corner and date shown in right corner of each aerial photograph.

Figure 20. Time series of aerial photgraphs showing the area of extra transects upstream from study site 2, and location of 8B transects and 1986 sandbars.



Base from the U.S. Department of Agriculture, Farm Service Agency, Aerial Photography Field Office, 2001 and 2006
and Bureau of Reclamation, 1999
Universal Transverse Mercator projection,
Zone 14

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

Figure 20. Time series of aerial photgraphs showing the area of extra transects upstream from study site 2, and location of 8B transects and 1986 sandbars.—Continued

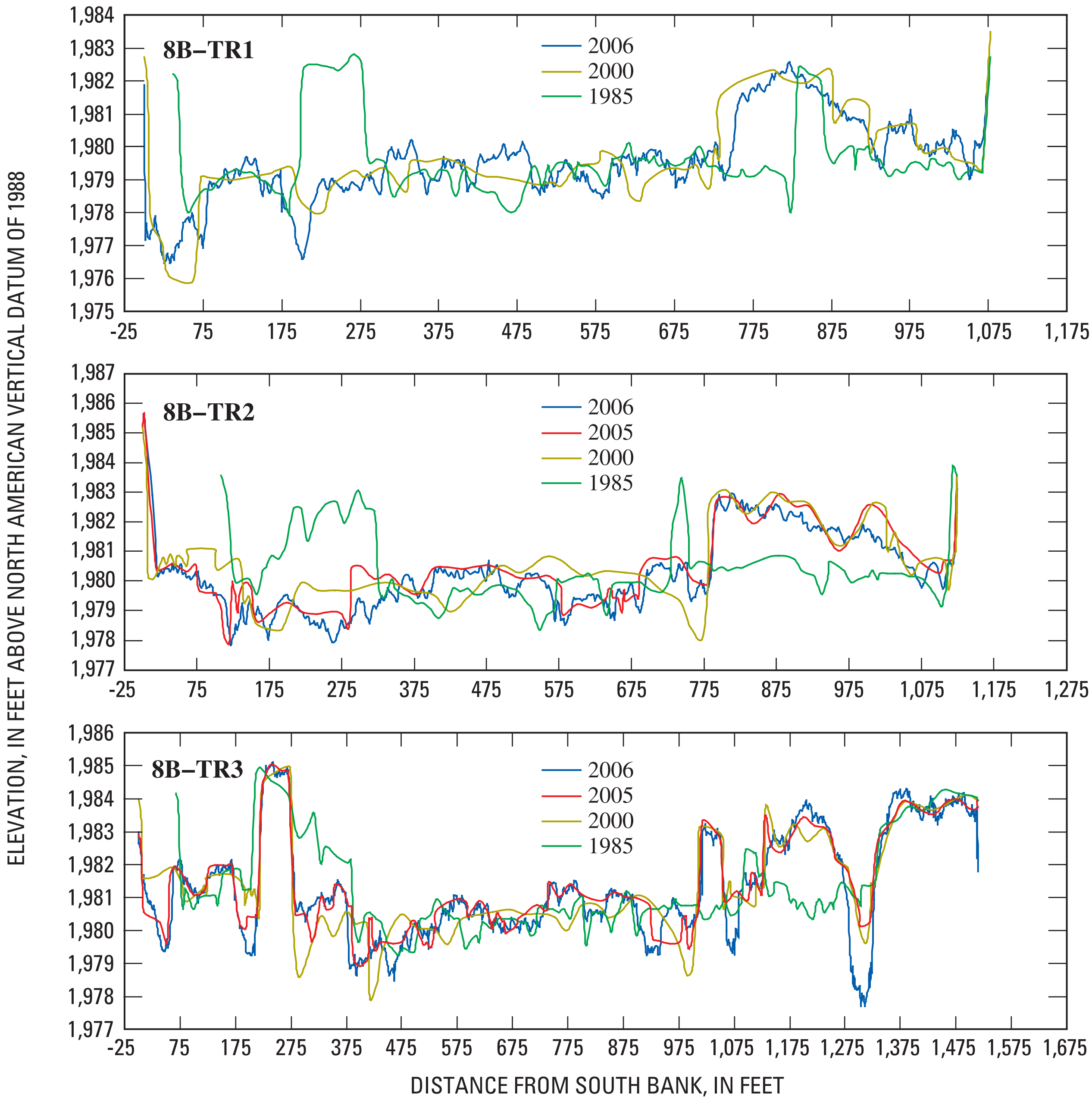


Figure 21. Results for resurveys of Bureau of Reclamation (1985) transects 8B-TR1, 8B-TR2, and 8B-TR3.

bank erosion. Evaluation of mean elevations at each transect showed no consistent change among the resurveys, with the greatest difference being 0.56 ft.

Examination of these transect data shows that the erosion of the sandbar and the south bank occurred between 1985 and 2000. Aerial photographs from 1993 (not shown in fig. 20) show the two sandbars to be present, narrowing the time of change to within 1993–2000. What effect these channel bedforms had on the amount of flow entering the north channel is unknown. However, the deposition on the north side of the transects may have caused some shift in water distribution among channels.

Comparisons to 1989 Bureau of Reclamation Surveys

Comparison of the 2007 survey results and 1989 survey results for transects 172.6n and 172.6mn indicated minimal change in minimum streambed elevations, but considerable change in thalweg location (fig. 22). Transect 172.6s shows 1 to 2 ft of decrease in streambed elevation in two of the main braids. The south channel has developed three primary braids (fig. 22), similar to changes evident on transect 8s (fig. 19) in comparison to Nguyen and Gilliland (1985).

Comparison of the 2007 survey results and 1989 survey results for transect 177.3n indicates degradation of 1 to 2 ft across the channel (fig. 23); however, because the exact location of the 1989 transect could not be determined by survey monuments, the transect surveyed may be as much as 130 ft from the historic transect. Results for transect 177.3m indicate minimal change in elevation or location (fig. 23). Transect 177.3s has been resurveyed four times (fig. 23) and results indicate no trend in elevation. Greater than 1 ft elevation change was measured on the mean transect elevations at transect 177.3n and 177.3s, a 2.76-ft decrease was measured on the north channel and a 1.38-ft increase on the south channel. Mean transect elevations gradually increased with each resurvey at transect 177.3s. Less than 0.5-ft differences in mean elevations were measured on other transects.

Resurveys of historical transects indicated localized change in channel topography. Increases of streambed elevation were indicated prior to 2000 on the north side of transects 8B-TR1, 8B-TR2, and 8B-TR3 upstream from study site 2. No substantial changes were noted in thalweg elevation or mean transect elevations on 6n, 7n, or 172.6n. Decreased elevations documented on transect 177.3n may be unreliable due to different survey locations; changes documented at other north channel transects were minimal. Decreased thalweg elevations were indicated on the south channel at transect 172.6s, but not on other resurveyed south channel transects (disregarding transect 6s). On all channels, changes in streambed elevation due to aggradation or degradation were inconsistent, the north channel was not aggrading while the south channel degraded. However, small changes particularly in areas such as the north side of the south channel upstream from study site 2 could have an affect on the distribution of flow among the Platte River channels, especially at low total discharge. The reason for this aggradation is unclear, but mechanical manipulation of the channel at this location would likely have an effect on the amount of water entering the north channel if aggraded sediments were removed. This localized aggradation should only affect flow into the north channel during times of low flow and could change dramatically during a large flood event or with heavy ice scour in a braided sand bed river such as the Platte River. Vegetation growth has the ability to hinder natural scour of deposited sediments. Therefore, maintaining an open, vegetation-free channel could possibly allow for natural scour as well as maintain flow in the channel at higher total discharge. Other channel splits were evaluated including the middle-south channel split from the south channel (4s and 4ms), the middle-north channel split from the middle-south channel (177.3m), and the channel split at study site 1, which showed no elevational differences that would obviously restrict flow into one channel or another.

Aerial Photographs

Wetted width is a function of channel geometry and stage, and for a braided channel would be more dynamic at low discharges because sandbars are being submerged, rather than at higher discharge until flooding overtopped the banks. Wetted width on the north and middle-north channels (fig. 24) responded to total discharge change more at low-flow conditions than at high-flow conditions. Wetted widths from the south channel (fig. 24) indicated this same pattern but with greater variability because of the size of the channel. Wetted widths from the middle-south channel (fig. 24) at transect 4ms varied greatly with discharge, but wetted widths at transects 5ms and 6ms were constant with discharge. Transects 4s and 4ms (fig. 6) are located just south of the Whooping Crane Trust facility where the middle-south channel first diverges from the south channel. This section of the river is wide, and rarely did the wetted width equal the channel width. At transects 5ms and 6ms along U.S. Highway 281 and South Locust Street, respectively, the channel is constrained, and the banks are fairly steep; therefore, the wetted widths did not indicate much correlation with discharge.

To determine if wetted widths within the north channel have changed in recent years, the logs of wetted widths were normalized by the log of total discharge:

$$\left(Log(W_N) \Big/ Log(Q_{Total}) \right),$$

where W_N is wetted width and Q_{Total} is total daily mean discharge at the USGS streamflow-gaging station at U.S. Highway 34 (number 06770500, fig. 3). Normalized wetted width was plotted against time. It must be noted that a true total discharge for each wetted-width measurement is not known, a presumed general streamflow condition from the only streamflow-gaging station that was operated in the study area from 1938 to 2007 was used. This introduces uncertainty into the analysis. If true total discharge was known for each

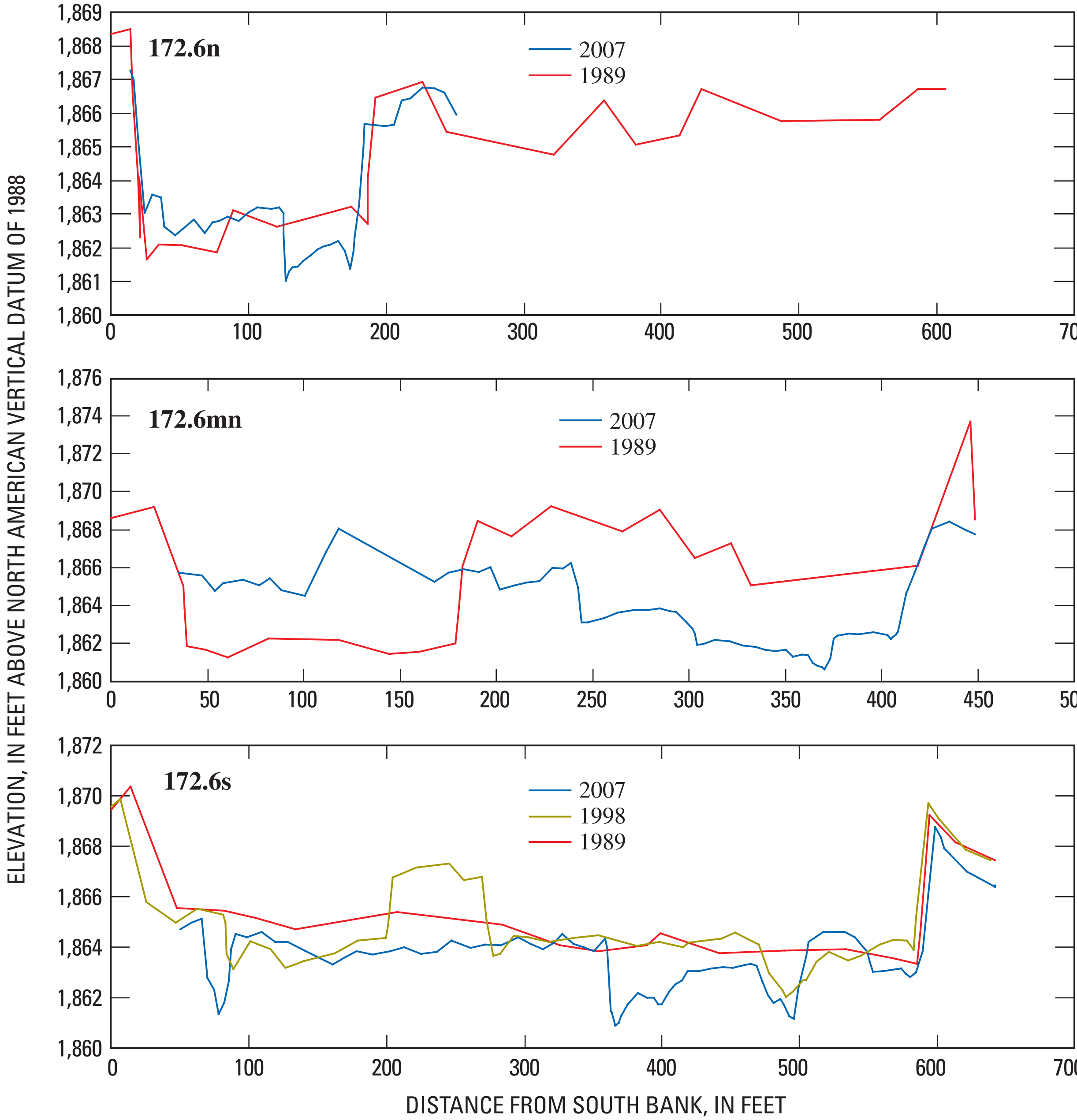


Figure 22. Results for resurveys of Bureau of Reclamation (1989) transects at river mile 172.6.

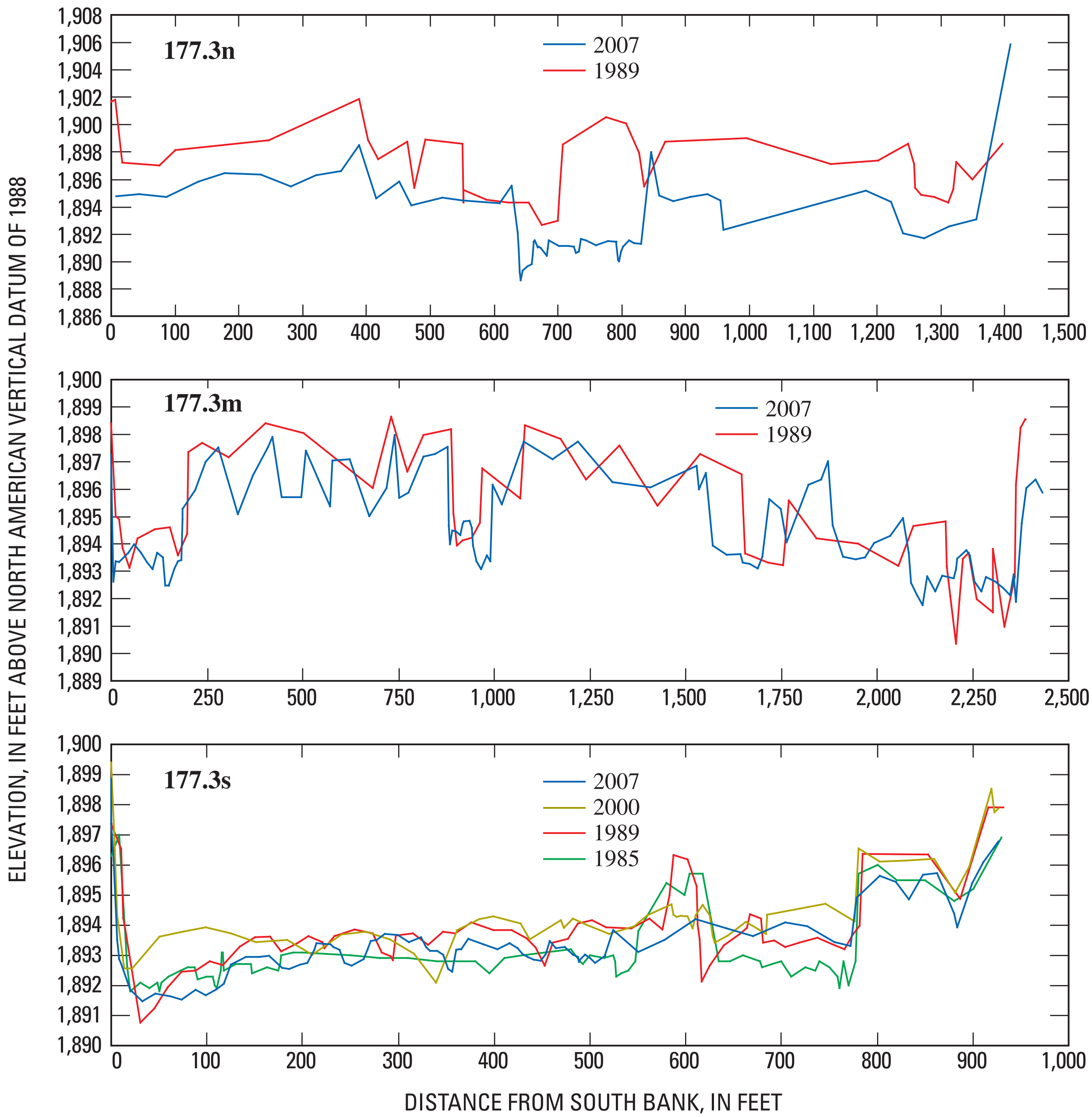
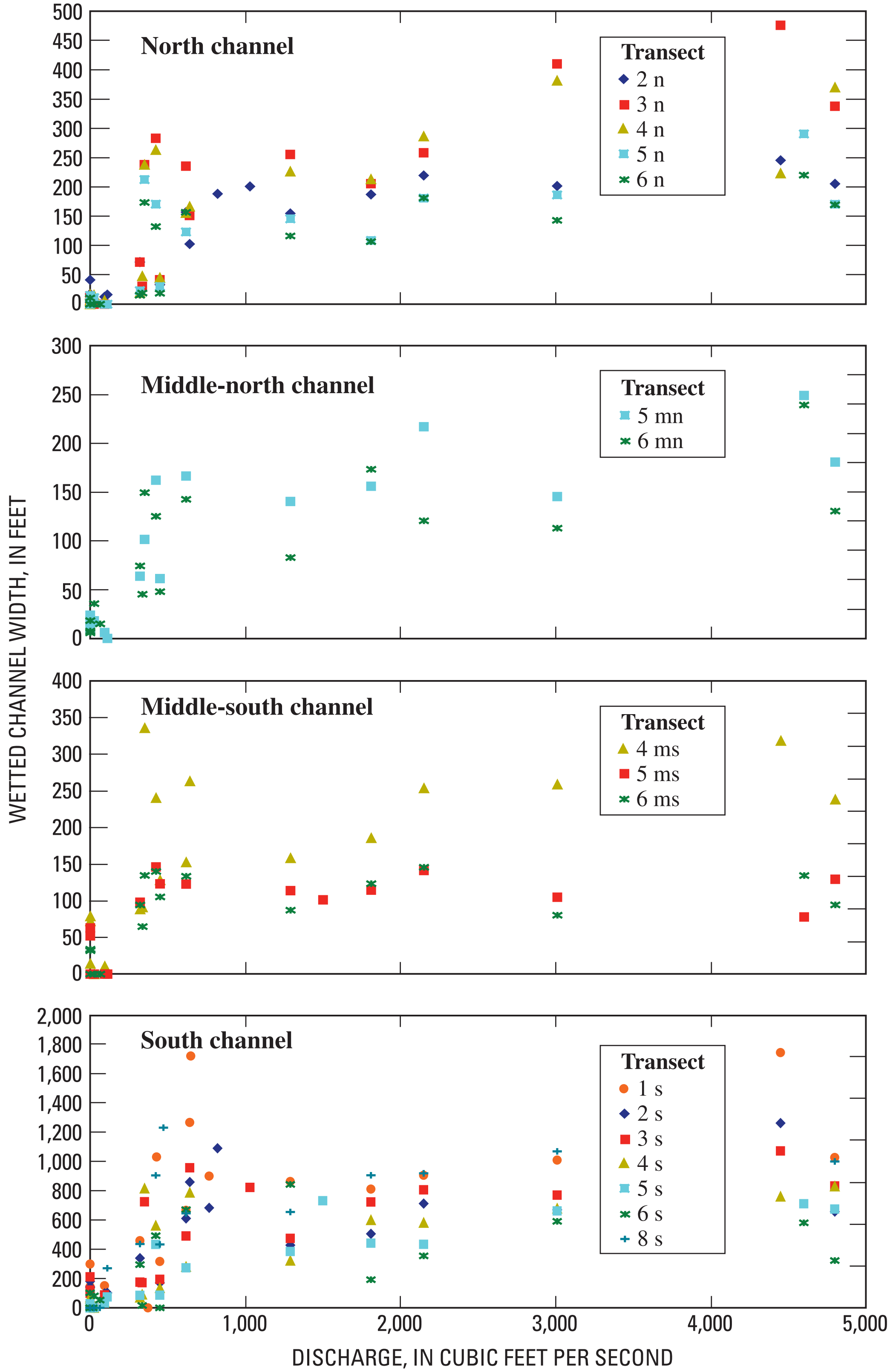


Figure 23. Results for resurveys of Bureau of Reclamation (1989) transects at river mile 177.3.



Note: Daily mean discharge at U.S. Highway 34 streamflow-gaging station 06770500, July 3, 1938, to July 29, 2006.

Figure 24. Relation of wetted width and total discharge for discharge-measurement transects.

wetted-width measurement and similar total discharges were producing narrower wetted widths in the north channel in recent years, the data would indicate a downward trend. In this analysis, wetted widths normalized by total discharge at U.S. Highway 34 indicated no apparent trends at Wood River (2n), Alda (3n), and U.S. Highway 281 (5n) (figs. 6 and 25). Wetted widths measured at these locations when total discharge at U.S. Highway 34 was zero were not included. In addition to the assumption that general streamflow conditions within each channel are adequately represented by total discharge at U.S. Highway 34, this analysis also assumes that the discharge-wetted width relation was constant over the years; however, changes in a channel such as scour, bank failure, and so forth could change this relation and complicate the analysis.

Total active-channel area within the study area changed little with time; the greatest was 5.75 mi^2 in 2005, and the least was 5.41 mi^2 in 1983. Total active channel in 1998 was 5.44 mi^2 and 5.72 mi^2 in 1986. The Nature Conservancy and the Whooping Crane Trust have cleared trees in this section of the river to improve habitat for whooping cranes (*Grus Americana)* and sandhill cranes (*Grus canadensis*) (Platte River Whooping Crane Maintenance Trust, Inc, 2000). This likely had some effect on the differences in active channel area. Channel location did not change with time, but vegetated islands covered the largest amount of area in 1983. Examination of changes near study site 1 (fig. 26) indicates the loss of one large island from the middle-south channel between 1986 and 1998, and the development of an island at the split on the north channel between 1983 and 1986. Changes near study site 2 (fig. 27) indicate the loss of several small islands in the south channel with time, but little change in the north channel. Elevated flows between 1983 and 1986 reopened some secondary braids that were present in the digitized active channel of 1986 (fig. 27). The west end of the digitized channels upstream from study site 2 indicates that the entire channel is shifting towards the south bank. Results of this lateral shift are that the upstream section of the small north braid along the north side of the channel (see “Channel-Transect Surveys” and “Historical Survey Comparisons” sections) was lost between 1986 and 1998, and the islands along the south bank have either eroded or became attached to the bank (see fig. 27) between 1983 and 2005.

Overall, analysis of aerial photography indicated no unexpected or substantial changes in wetted widths of the channels over the years. Active channel mapping indicated no change in location, but some small changes in island size and numbers. These results indicate that physical changes occurring within the channels of the Platte River are minimal. One exception noted that may affect flow divergence into the north channel is the apparent loss of the small north braid west of site 2 (fig. 27).

LiDAR

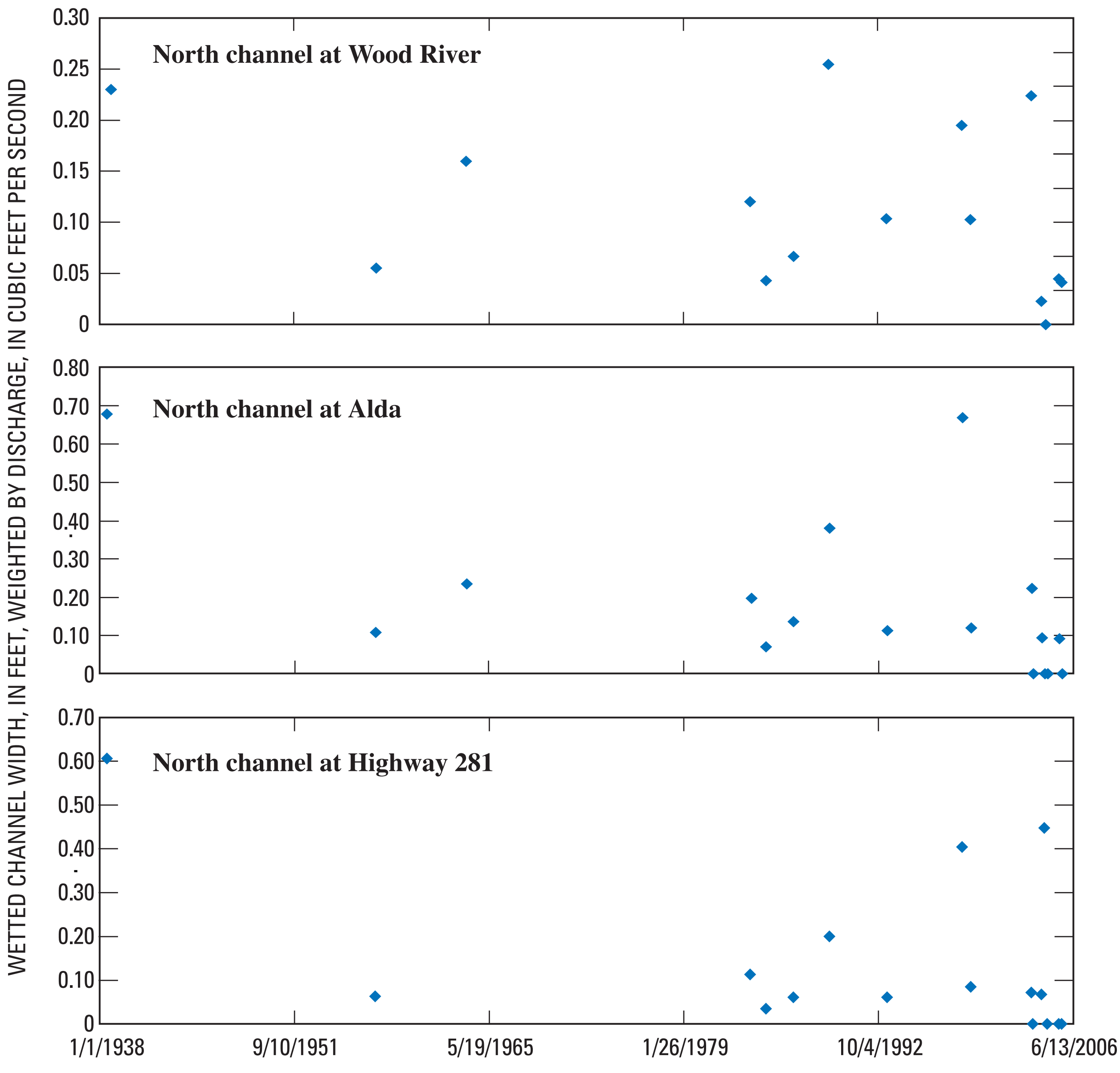
Light Detection and Ranging data are available as bare-earth points (Appendix 4, at the back of this report). Light Detection and Ranging data were processed into a TIN surface model and 1-ft contours for analysis.

Bare-earth points, TINs, and contours were compared to five new USGS GPS bench marks (table 4). Sanborn (Appendix 2) determined the vertical RMSD of the bare-earth points to be 0.36 ft in relation to 10 reference stations. Differences between bare-earth points and USGS GPS bench marks yielded a RMSD of 0.46 ft. Light Detection and Ranging points near bench mark 1040 did not correlate well with the elevation established for the bench mark using static GPS methods. This bench mark is located near study site 2; the cause of these differences is unknown. Processing bench mark 1040 through OPUS resulted in a peak to peak (the maximum difference between results of triangulation with each of the three CORS) vertical error of 0.105 ft. Vertical RMSD of the bare-earth points, not including bench mark 1040, is 0.33 ft similar to that calculated by Sanborn.

Evaluation of the TIN surface in relation to USGS bench marks indicated all five points to agree within 0.45 ft, except those around bench mark 1040. The RMSD of the contours was 0.66 ft according to Sanborn, and most USGS bench-mark comparisons support this. Contours around bench mark 1051 are almost 1 ft lower than the bench-mark elevation. This bench mark is located south of the north channel along the Alda-Juniata Road (fig. 3) near the bridge rails adjacent to a steep slope extending down to the east. This means that several of the points collected in close proximity to the bench mark are expected to be at different elevations than the bench mark, so this bench mark is not the best choice for quality-control checks.

Transects 8B-TR1, 8B-TR2, and others were used as sources of elevation data to compare additional GPS data points to the LiDAR TIN surface (fig. 28). For this evaluation, bare-earth points that were within 3.28 ft of transect 8B-TR1 or 8B-TR2 were used to construct a transect profile from LiDAR data for comparison to GPS transect-survey data (fig. 29). Both evaluations indicate that GPS and LiDAR data correlate well. Areas where the two data sets do not correlate seem to be areas of the channel that likely had flow during LiDAR data collection. Streamflow at USGS gaging station 06770500 at U.S. Highway 34 during LiDAR data collection was only 13 ft^3/s, however, discharge in upstream channels may have been slightly greater. Channel-transect surveys of 8B-TR1 and 8B-TR2 were collected during a discharge of 756 ft^3/s. Overall, the GPS transect-survey data agree within specified accuracy standards with the LiDAR data; only in areas with steep slopes (surveyed bench marks and LiDAR points did not fall exactly in the same location, so LiDAR points near bench marks did not compare to bench-mark elevations) or streamflow did the two data sets vary.

Light Detection and Ranging data are useful for evaluating channel shape and elevation at any location in the 47 mi^2 study area. Potential future uses of the data may include comparisons with new surveys and development of streamflow hydraulic models. The LiDAR data gave a more spatially detailed look into the study sites, but no abnormalities or large differences in elevation among the channels were detected thereby leading to no further details of flow distribution among the channels (figs. 28 and 30).



Note: Daily mean discharge at U.S. Highway 34 streamflow-gaging station 06770500, July 3, 1938, to July 29, 2006.

Figure 25. Relation of normalized wetted width and total discharge.

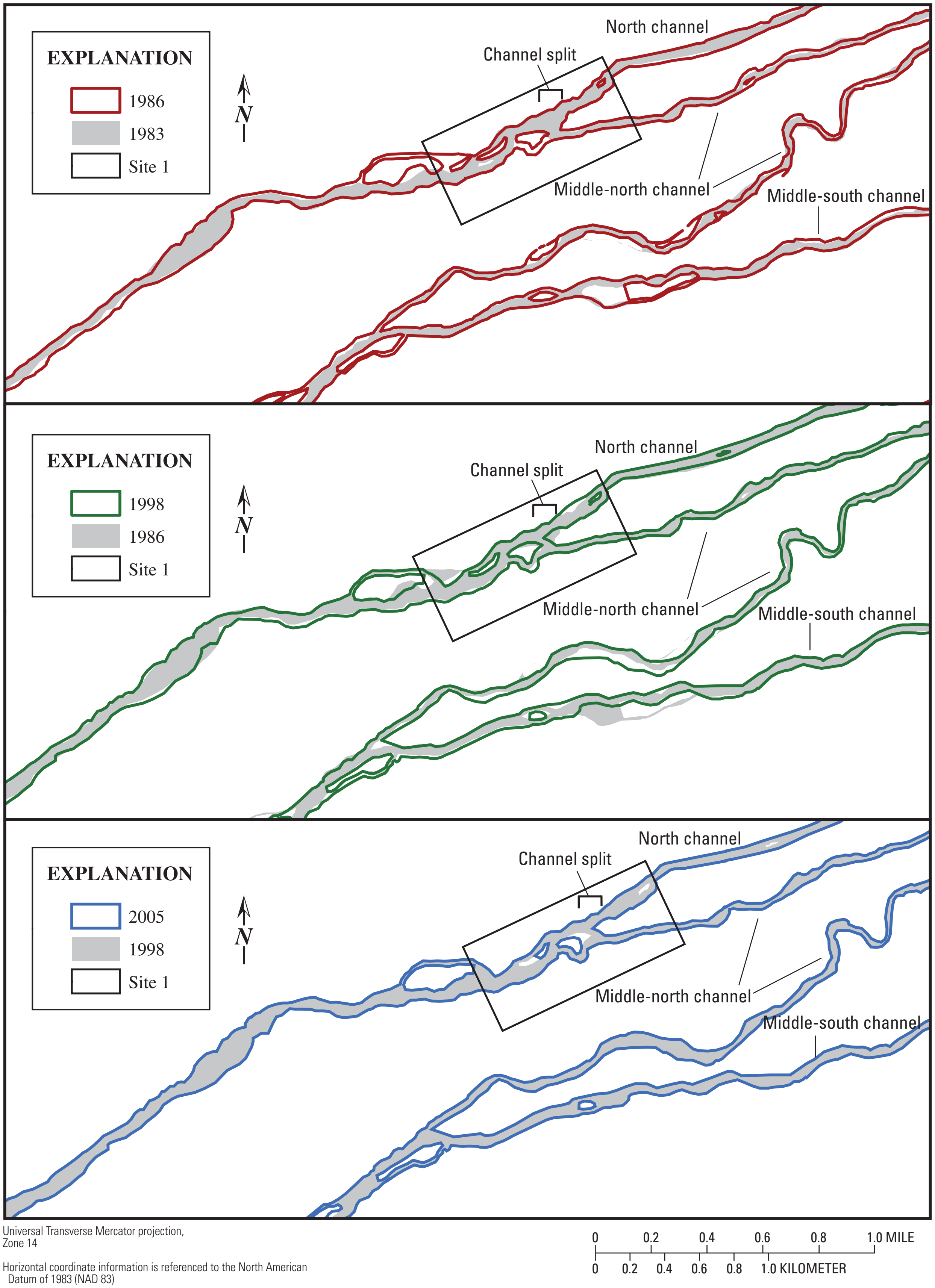


Figure 26. Active-channel areas, middle-south, middle-north, and north channels near study site 1.

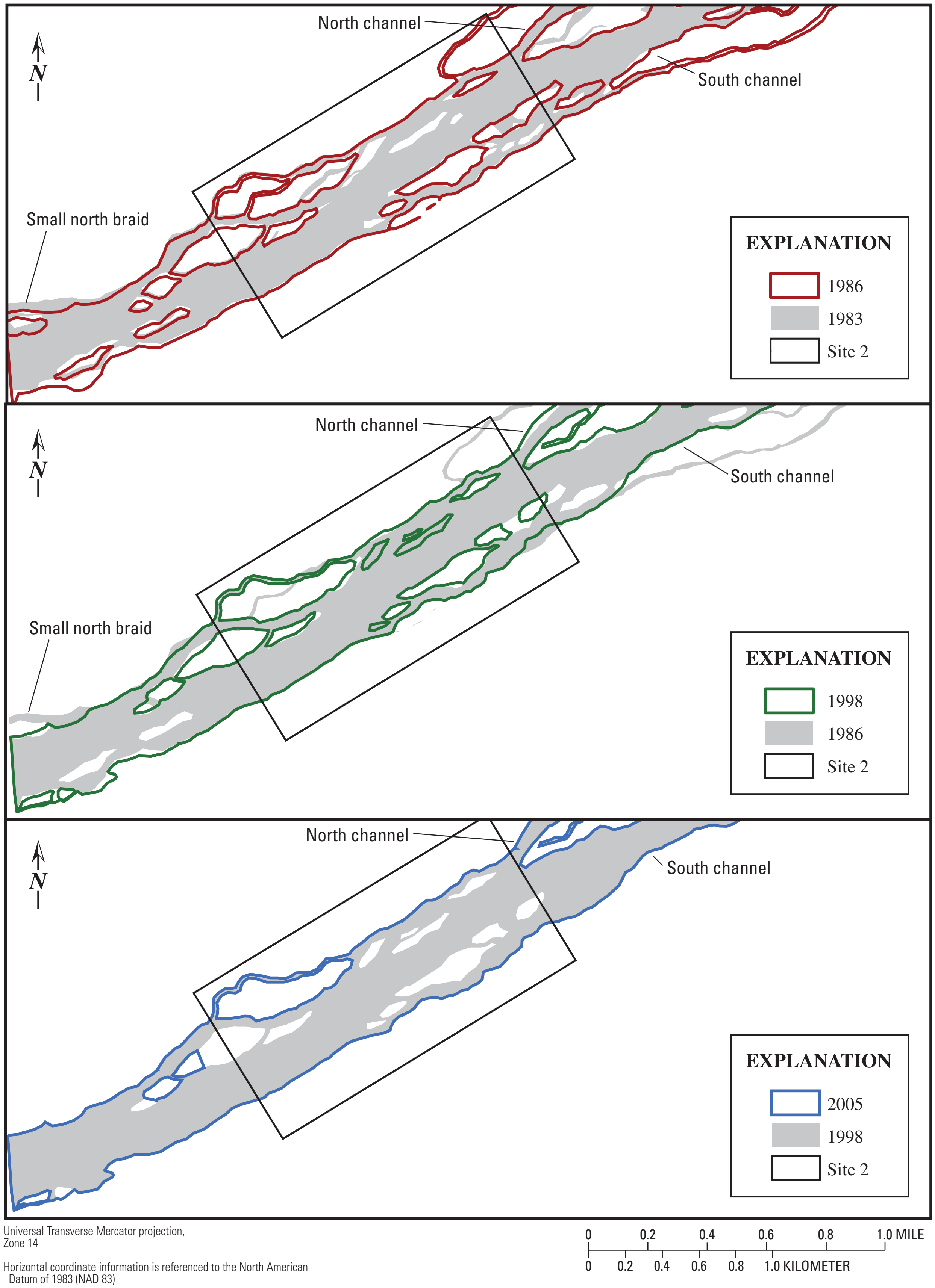
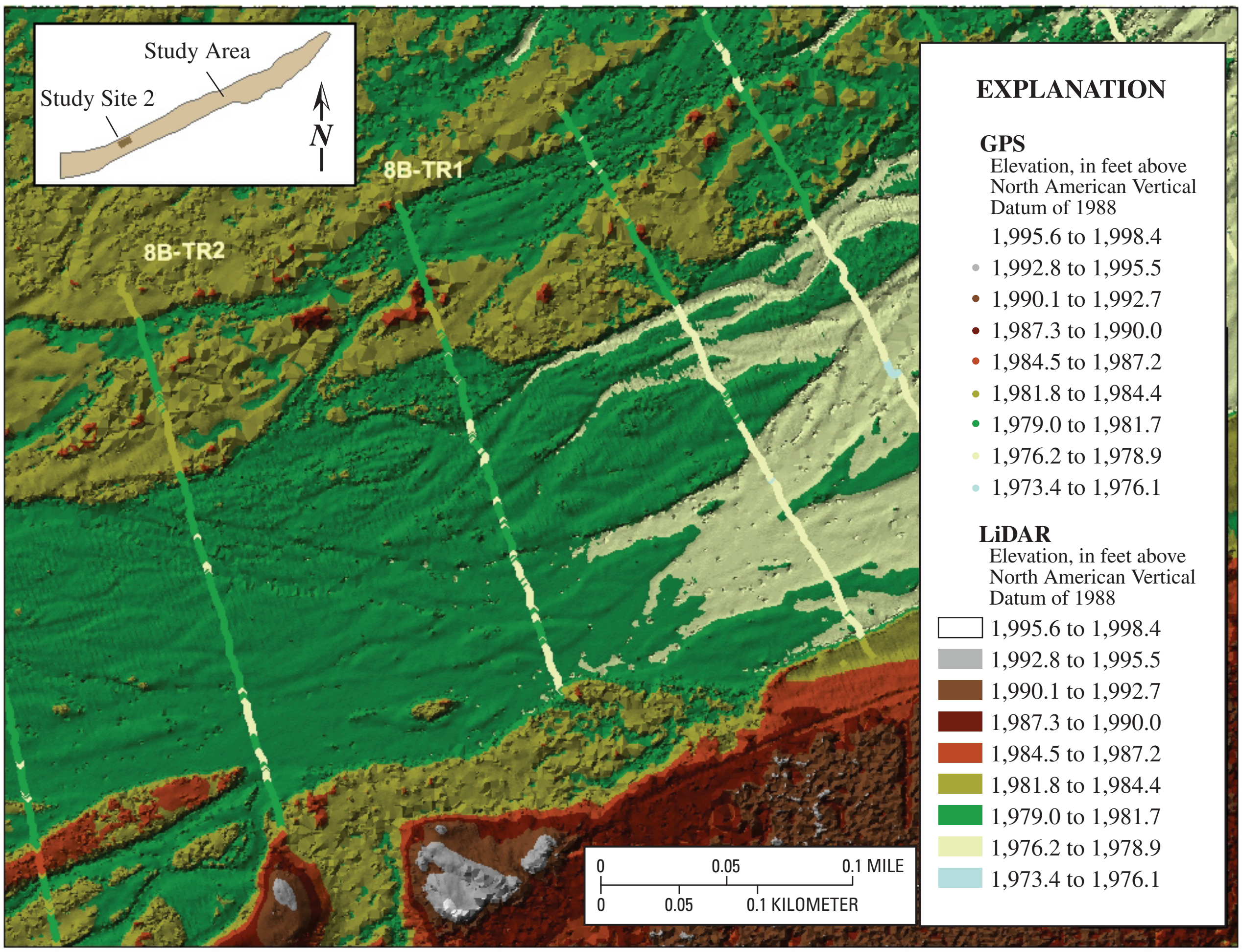


Figure 27. Active-channel areas, south and north channels near study site 2.

Table 4. Elevations of Light Detection and Ranging (LiDAR) triangulated irregular network (TIN) surface, hypsography contours, and bare-earth comparisons to new U.S. Geological Survey global positioning system (GPS) bench marks along the Platte River near Grand Island, Nebraska.

[NAVD 88, North American Vertical Datum of 1988; GPS, global positioning system; LiDAR TIN, Light Detecting and Ranging Triangulated Irregular Network; --, not measured]

Bench mark (fig. 1)	Elevation (feet above NAVD 88)			Hypsography contours (feet above NAVD 88)			Bare-earth elevations (feet above NAVD 88)			
	GPS survey	LiDAR TIN	Difference	GPS elevation	Lower contour elevation	Upper contour elevation	GPS survey	Elevation of points within about 6 feet	Elevation of points within about 3 feet	Difference (feet)
1040	1,981.024	1,981.788	0.764	1,981.024	1,980	1,981	1,981.024	--	1,981.739	0.715
							1,981.024	--	1,981.739	.715
							1,981.024	--	1,981.837	.814
							1,981.024	--	1,981.969	.945
1041	1,980.075	1,980.387	.312	1,980.075	1,980	1,980	1,980.075	--	1,980.344	.269
							1,980.075	--	1,980.344	.269
							1,980.075	--	1,980.410	.335
							1,980.075	--	1,980.410	.335
							1,980.075	--	1,980.377	.302
1042	1894.409	1894.780	.371	1,980.076	1,980	1,980	1,894.409	--	1,894.865	.456
							1,894.409	--	1,894.865	.456
							1,894.409	--	1,894.865	.456
1043	1,895.033	1,895.046	.013	1,895.033	1,894		1,895.033	--	1,895.059	.026
1051	1,927.969	1,927.523	-.446	1,927.969	1,926	1,927	1,927.969	1,927.992	--	.023
							1,927.969	1,928.222	--	.253



Universal Transverse Mercator projection,
Zone 14

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

Figure 28. Elevation from Light Detection and Ranging (LiDAR) triangulated irregular network (TIN) surface data and comparison to global positioning system (GPS) transect surveys of 8B-TR1, 8B-TR2, and other transects upstream from study site 2.

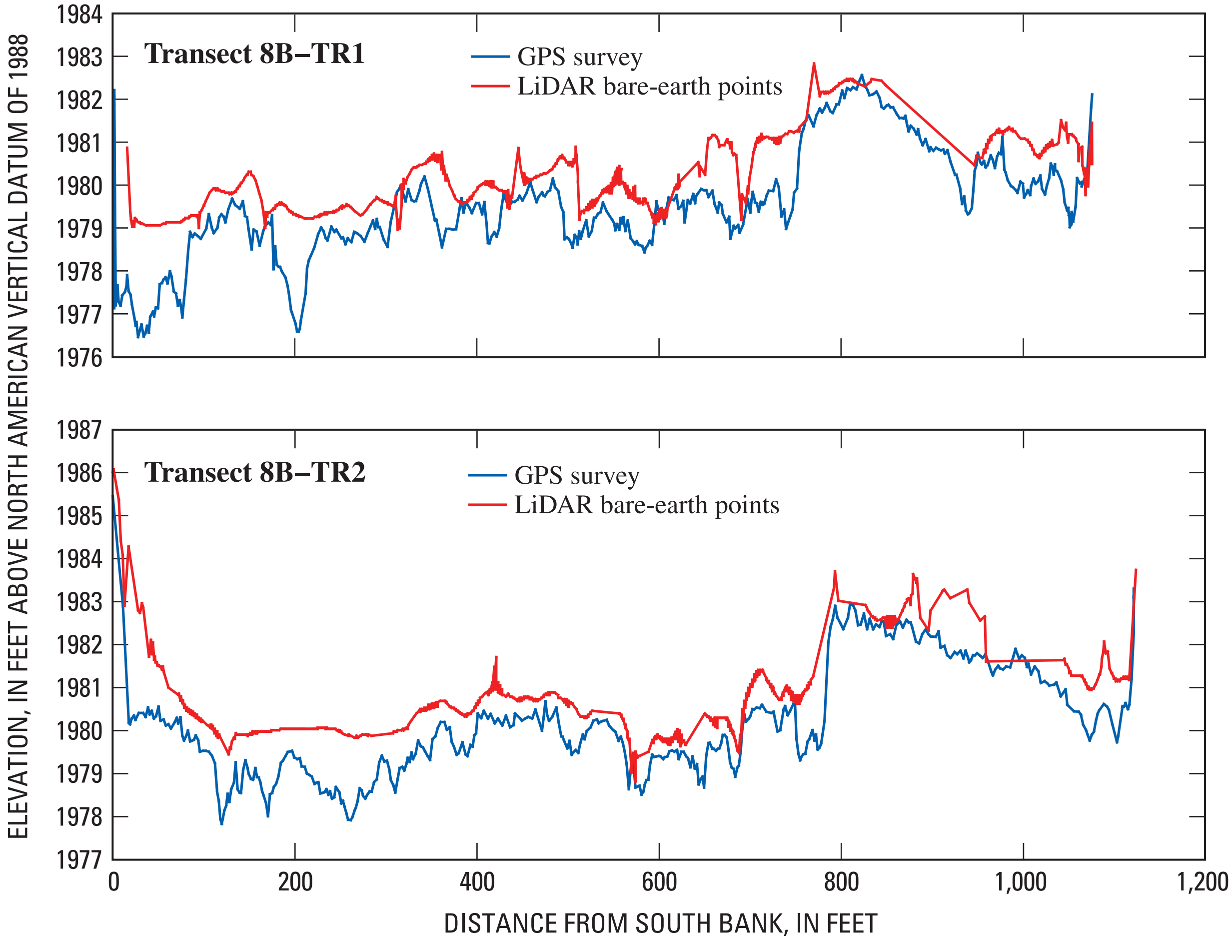
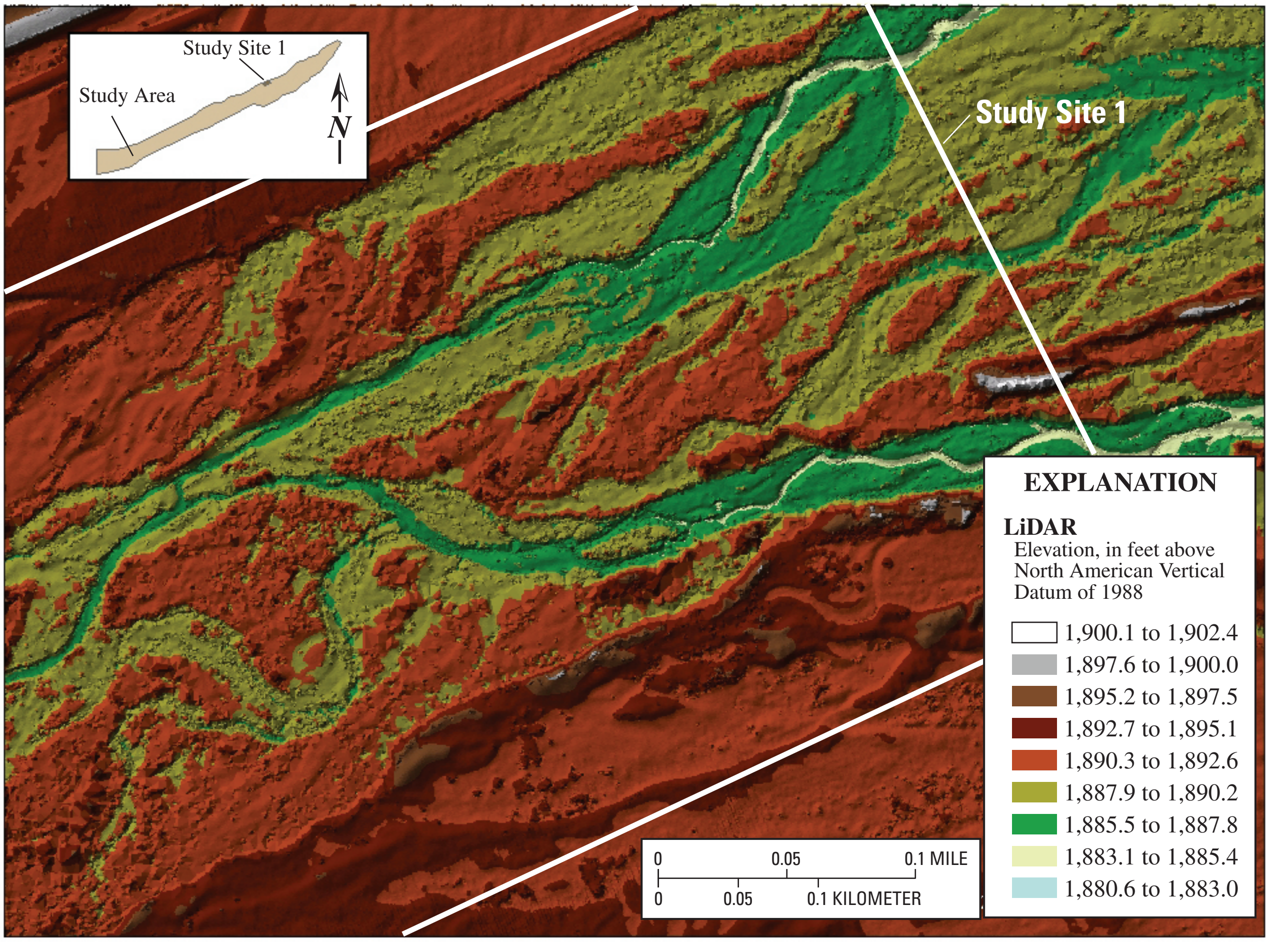


Figure 29. Elevation from Light Detection and Ranging (LiDAR) bare-earth points and global positioning system (GPS) transect surveys of 8B-TR1 and 8B-TR2.



Universal Transverse Mercator projection,
Zone 14

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

Figure 30. Elevation from Light Detection and Ranging (LiDAR) triangulated irregular network (TIN) surface at study site 1.

Conclusions

This report provides the findings of a streamflow and topographic study conducted by the U.S. Geological Survey on the Platte River, near Grand Island, Nebraska, to management agencies and future researchers. This study was conducted to evaluate the current (2006) distribution of flow among the four Platte River channels in comparison to historical streamflow and determine if there are topographic characteristics of the current (2006) channel that would account for any differences found in the comparison. This study and report were conducted in cooperation with the City of Grand Island, Nebraska, the Central Platte Natural Resources District, and U.S. Geological Survey Northern Prairie Wildlife Research Center.

After reviewing historical discharge data, channel-transect survey data, aerial photography, and LiDAR only minor changes were detected within the Platte River channels near Grand Island, Nebraska. Even with minor changes detected, these results do not conclusively indicate that these changes are hindering flow into the north channel.

Discharge data indicated a lower than historical percentage of the total flow was conveyed in the north channel, but small sample size and lack of comparability to historical discharges precluded further statistical analyses until more data are available. No analysis conducted explained why at similar total discharge (512 cubic feet per second compared to 593 cubic feet per second) the percentage of total flow in the north channel was 17.5 percent in August 1984 and only 0.2 percent in December 2006.

Channel-transect surveys showed slightly higher elevations in the north braids at study site 2. Whether changes have occurred at study site 2 to increase elevations along the north braids can not be determined because of lack of historical surveys, however, changes are documented upstream from study site 2. It is possible that these elevation differences reduce the amount of water flowing into the north channel during times of low flow. Reduced flows caused by these small elevation differences would not have occurred without the recent drought conditions and likely is not a permanent change (flow will return when overall total flows increase). In addition, other factors besides elevation that could influence streamflow, such as in-channel roughness, were not evaluated. Comparisons with historical transect data indicated small localized changes in channel topography with time.

Aerial photographs did not indicate temporal trends in wetted width normalized by discharge. Analysis of aerial photography indicated little change in channel location, but some change in island size and numbers. Review of LiDAR data shows no large elevation differences that would strongly influence flow among channels.

Results of this study indicate that minimal changes were detected in topographic and streamflow characteristics, leading to the conclusion that reduced flows in the north channel are due to low total flows in the river or other factors not evaluated as part of this study.

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Appendix 1. Discharge measurements of the Platte River made at U.S. Highway 281 near Grand Island, Nebraska, 1983–88

Appendix 1. Discharge measurements of the Platte River made at U.S. Highway 281 near Grand Island, Nebraska, 1983–88.

[ft, feet; ft², square feet; ft/s, feet per second; ft³/s, cubic feet per second; USGS, U.S. Geological Survey; G, good; F, fair; P, poor; --, not determined]

Date	Width (ft)	Area (ft²)	Velocity (ft/s)	Outside gage height (ft)	Discharge (ft³/s)	Time (24-hour)	Number of measurement sections	Measurement rating	Control	Measurement type
USGS streamflow-gaging station number 06770478 (south channel) near Grand Island, Nebraska										
10/14/1983	334	424	2.01	3.7	853	1100	26	G	Wading	Clear
12/1/1983	445	200	.67	3.99	134	1325	22	F	Ice	Ice cover
12/7/1983	445	476	1.76	4.62	836	1455	35	G	Ice	Ice cover
12/28/1983	445	777	2.27	5.56	1,760	1045	33	G	Ice	Ice cover
1/19/1984	450	964	2.2	5.88	2,120	1330	33	G	Ice	Ice cover
2/14/1984	422	1,520	2.53	5.58	3,840	1310	46	G	Handline	Clear
3/28/1984	424	1,140	3.38	5.55	3,850	1315	30	G	Handline	Clear
4/18/1984	424	1,270	2.92	5.61	3,710	1415	29	G	Handline	Clear
5/24/1984	455	1,720	3.92	6.51	6,740	1440	32	G	Handline	Clear
6/21/1984	424	1,380	3.3	5.58	4,550	1310	33	G	Handline	Clear
7/23/1984	162	154	2.01	3.4	310	1300	43	G	Wading	Clear
8/8/1984	254	139	1.53	3.33	213	1320	35	G	Wading	Clear
9/13/1984	424	867	2.62	4.88	2,270	1335	27	G	Handline	Clear
10/17/1984	424	926	2.74	5.13	2,540	1515	27	G	Handline	Clear
11/13/1984	425	1,070	2.35	5.29	2,510	1505	28	G	Handline	Clear
12/5/1984	422	898	2.69	5.05	2,420	1025	31	F	Handline	Clear
1/23/1985	445	684	1.94	5.29	1,330	1310	46	F	Ice	Ice cover
3/5/1985	421	926	2.7	5.02	2,500	1550	34	G	Handline	Clear
3/27/1985	444	513	2.11	4.09	1,080	1530	36	F	Wading	Clear
4/17/1985	457	496	1.8	4.02	892	1125	27	F	Wading	Clear
5/28/1985	470	440	1.88	4.01	828	1330	30	G	Wading	Clear
6/20/1985	475	345	1.67	3.8	577	1335	32	F	Wading	Clear
7/22/1985	275	137	1.43	3.4	196	1300	31	F	Wading	Clear
8/19/1985	314	109	1.1	3.33	120	1340	52	F	Wading	Clear
9/26/1985	470	414	1.74	4	722	1335	31	G	Wading	Clear
10/23/1985	475	548	2.04	4.42	1,120	1325	29	F	Wading	Clear
11/13/1985	480	356	1.69	4	603	1435	36	G	Wading	Clear
12/5/1985	445	426	1.47	4.82	625	1330	33	F	Ice	Ice cover
1/29/1986	415	427	1.69	4.19	721	1445	30	F	Wading	Shore ice
2/26/1986	480	803	1.86	4.82	1,490	1350	30	F	Wading	Clear
3/26/1986	480	670	2.06	4.66	1,380	1445	32	G	Wading	Clear
4/24/1986	422	910	2.29	5.15	2,080	1435	30	F	Handline	Clear

Appendix 1. Discharge measurements of the Platte River made at U.S. Highway 281 near Grand Island, Nebraska, 1983–88.—Continued

[ft, feet; ft², square feet; ft/s, feet per second; ft³/s, cubic feet per second; USGS, U.S. Geological Survey; F, fair; G, good; P, poor; --, not determined]

Date	Width (ft)	Area (ft²)	Velocity (ft/s)	Outside gage height (ft)	Discharge (ft³/s)	Time (24-hour)	Number of measurement sections	Measurement rating	Control	Measurement type
USGS streamflow-gaging station number 06770478 (south channel) near Grand Island, Nebraska—Continued										
5/20/1986	470	526	1.81	4.3	950	1340	33	G	Wading	Clear
6/16/1986	480	704	2.2	4.73	1,550	1330	30	G	Wading	Clear
7/16/1986	480	486	1.81	4.17	881	1400	33	G	Wading	Clear
8/13/1986	483	636	1.92	4.51	1,220	1330	28	F	Wading	Clear
9/8/1986	485	748	2.1	4.74	1,570	1355	30	G	Wading	Clear
10/9/1986	480	892	2.31	5.04	2,060	1405	29	F	Wading	Clear
11/18/1986	480	650	1.95	4.59	1,270	1415	31	G	Wading	Clear
12/2/1986	475	666	2.07	4.71	1,380	1405	33	G	Wading	Clear
1/12/1987	475	651	2.09	4.65	1,360	1440	31	G	Wading	Clear
2/19/1987	480	556	2.01	4.39	1,120	1350	36	F	Wading	Clear
4/2/1987	466	986	2.68	5.23	2,640	1035	33	F	Handline	Clear
4/22/1987	480	584	2.12	4.6	1,240	1330	28	F	Wading	Clear
5/19/1987	480	679	2.09	4.71	1,420	1325	31	G	Wading	Clear
6/15/1987	485	834	2.33	4.94	1,940	1420	32	G	Wading	Clear
7/6/1987	340	225	1.49	3.68	335	1520	34	F	Wading	Clear
8/19/1987	440	203	1.35	3.63	274	1415	35	F	Wading	Clear
9/10/1987	485	433	1.7	4.12	736	1410	33	G	Wading	Clear
10/22/1987	460	265	1.22	3.72	323	1450	33	G	Wading	Clear
11/19/1987	485	486	1.95	4.34	950	1400	31	G	Wading	Clear
12/3/1987	485	519	1.9	4.36	984	1355	33	G	Wading	Clear
1/21/1988	475	456	1.38	5.03	627	1420	34	F	Ice	Ice cover
USGS streamflow-gaging station number 06770477 Platte River (middle-south channel) near Grand Island, Nebraska										
10/14/1983	116	138	2.06	--	284	1205	19	F	Clear	Wading
12/1/1983	95	110	1.06	--	117	1115	10	G	Ice cover	Ice
12/7/1983	100	162	1.94	12.07	314	1545	16	F	Ice cover	Ice
12/28/1983	100	186	2.26	11.15	420	0955	16	G	Ice cover	Ice
1/19/1984	103	209	2.40	10.89	501	1240	17	G	Ice cover	Ice
2/14/1984	118	248	2.22	12.21	550	1155	14	G	Clear	Wading
3/28/1984	101	280	2.76	12.19	772	1045	14	G	Clear	Handline
4/18/1984	102	303	2.99	11.79	906	1110	22	G	Clear	Handline
5/24/1984	108	369	3.17	11.36	1,170	1105	13	G	Clear	Handline
6/21/1984	110	405	3.09	11.16	1,250	1105	13	G	Clear	Handline

Appendix 1. Discharge measurements of the Platte River made at U.S. Highway 281 near Grand Island, Nebraska, 1983–88.—Continued

[ft, feet; ft^2, square feet; ft/s, feet per second; ft^3/s, cubic feet per second; USGS, U.S. Geological Survey; F, fair; G, good; P, poor; --, not determined]

Date (month/day/year)	Width (ft)	Area (ft^2)	Velocity (ft/s)	Outside gage height (ft)	Discharge (ft^3/s)	Time (24-hour)	Number of measurement sections	Measurement rating	Control	Measurement type
USGS streamflow-gaging station number 06770477 Platte River (middle-south channel) near Grand Island, Nebraska—Continued										
7/23/1984	42	15.8	1.22	14.57	19.2	1110	22	G	Clear	Wading
8/8/1984	7	1.02	.79	14.88	.81	1140	15	G	Clear	Wading
9/13/1984	126	221	2.58	12.68	571	1020	21	G	Clear	Wading
10/17/1984	127	232	2.12	12.61	493	1425	21	G	Clear	Wading
11/13/1984	121	233	2.45	12.61	570	1125	26	G	Clear	Wading
12/5/1984	125	208	2.29	12.73	477	1430	24	G	Clear	Wading
1/23/1985	87	41.2	.14	13.74	5.87	1215	15	P	Ice cover	Ice
3/5/1985	141	255	2.43	12.41	620	1140	28	G	Clear	Wading
3/27/1985	116	122	1.91	13.47	233	1350	29	G	Clear	Wading
4/17/1985	115	106	1.75	13.50	185	1045	24	G	Clear	Wading
5/28/1985	123	132	1.92	13.37	254	1115	21	G	Clear	Wading
6/20/1985	114	77.4	1.61	13.81	12.5	1135	27	G	Clear	Wading
7/22/1985	88	30	1.35	14.21	40.5	1125	20	G	Clear	Wading
8/19/1985	108	35.6	1.38	14.21	49.1	1035	25	G	Clear	Wading
9/26/1985	121	106	1.6	13.57	170	1230	26	G	Clear	Wading
10/23/1985	115	145	2.10	13.21	304	1145	27	G	Clear	Wading
11/13/1985	118	102	1.50	13.64	153	1235	26	G	Clear	Wading
12/5/1985	174	96.2	1.33	14.80	128	1125	27	P	Ice cover	Ice
1/29/1986	85	256	2.62	11.16	672	1315	27	G	Shore ice	Handline
2/26/1986	128	194	2.39	12.91	463	1140	33	G	Clear	Wading
3/26/1986	126	179	2.08	12.99	372	1330	25	G	Clear	Wading
4/24/1986	167	249	2.24	12.58	559	1205	29	G	Clear	Wading
5/20/1986	130	140	1.76	13.38	247	1140	31	G	Clear	Wading
6/16/1986	122	180	2.23	12.92	402	1145	25	G	Clear	Wading
7/16/1986	101	135	2.06	13.31	278	1155	27	G	Clear	Wading
8/13/1986	120	174	2.20	12.99	382	1220	30	G	Clear	Wading
9/8/1986	115	185	2.08	12.84	384	1150	26	G	Clear	Wading
10/9/1986	128	255	2.33	12.33	594	1140	29	G	Clear	Wading
11/18/1986	125	180	2.09	12.88	377	1245	29	G	Clear	Wading
12/2/1986	124	168	2.21	12.91	356	1210	27	G	Clear	Wading
1/12/1987	127	226	2.15	12.64	485	1200	31	G	Clear	Wading
2/19/1987	130	179	1.96	12.99	351	1200	30	G	Clear	Wading

Appendix 1. Discharge measurements of the Platte River made at U.S. Highway 281 near Grand Island, Nebraska, 1983–88.—Continued

[ft, feet; ft², square feet; ft/s, feet per second; ft³/s, cubic feet per second; USGS, U.S. Geological Survey; F, fair; G, good; P, poor; --, not determined]

Date (month/day/year)	Width (ft)	Area (ft²)	Velocity (ft/s)	Outside gage height (ft)	Discharge (ft³/s)	Time (24-hour)	Number of measurement sections	Measurement rating	Control	Measurement type
USGS streamflow-gaging station number 06770477 Platte River (middle-south channel) near Grand Island, Nebraska—Continued										
4/2/1987	111	381	2.83	11.04	1,080	1440	30	G	Shore ice	Handline
4/22/1987	124	233	2.24	12.62	521	1125	31	G	Clear	Wading
5/19/1987	126	221	2.24	12.66	495	1115	26	G	Clear	Wading
6/15/1987	152	228	2.25	12.65	513	1210	28	G	Clear	Wading
7/6/1987	98	87.5	1.60	13.69	140	1405	27	G	Clear	Wading
8/19/1987	104	103	1.83	13.54	189	1215	27	G	Clear	Wading
9/10/1987	115	157	2.09	13.05	328	1215	29	G	Clear	Wading
10/22/1987	141	79.3	1.50	13.74	119	1335	29	G	Clear	Wading
11/19/1987	103	171	1.96	12.93	336	1215	28	G	Clear	Wading
12/3/1987	133	202	2.07	12.81	419	1200	30	G	Clear	Wading
1/21/1988	121	209	1.69	11.77	353	1420	29	P	Ice cover	Ice
USGS streamflow-gaging station number 06770476 Platte River (middle-north channel) near Grand Island, Nebraska										
10/14/1983	171	209	1.84	--	384	1125	21	F	Clear	Wading
12/1/1983	170	344	1.48	--	509	1015	16	F	Ice	Ice
12/8/1983	170	421	1.90	12.35	802	0935	28	G	Ice	Ice
12/28/1983	165	222	1.78	13.60	396	0915	19	F	Ice	Ice
1/19/1984	128	269	2.68	13.29	720	1120	20	F	Ice	Wading
2/14/1984	158	479	2.90	12.92	1,390	1435	16	G	Clear	Handline
3/28/1984	158	433	3.09	13.19	1,340	0955	16	G	Clear	Handline
4/18/1984	157	496	2.98	12.94	1,480	0955	24	G	Clear	Handline
5/24/1984	164	676	3.58	11.94	2,420	1010	18	G	Clear	Handline
6/21/1984	165	566	3.48	12.27	1,970	1020	17	G	Clear	Handline
7/23/1984	116	126	2.00	15.15	252	1025	24	G	Clear	Wading
8/8/1984	129	119	1.75	15.17	208	1055	29	G	Clear	Wading
9/13/1984	158	345	2.78	13.77	959	1245	21	G	Clear	Handline
10/17/1984	158	380	2.59	13.73	984	1320	28	G	Clear	Handline
11/13/1984	158	403	2.73	13.53	1,100	1305	27	G	Clear	Handline
12/5/1984	157	362	2.67	13.73	965	1150	24	G	Clear	Handline
1/23/1985	150	334	2.74	13.66	914	1050	24	F	Shore ice	Handline
3/5/1985	157	463	3.05	13.30	1,410	1325	30	G	Clear	Handline
3/27/1985	220	380	2.17	14.18	826	1105	31	G	Clear	Wading
4/17/1985	176	279	2.18	14.66	609	1000	27	G	Clear	Wading

Appendix 1. Discharge measurements of the Platte River made at U.S. Highway 281 near Grand Island, Nebraska, 1983–88.—Continued

[ft, feet; ft^2, square feet; ft/s, feet per second; ft^3/s, cubic feet per second; USGS, U.S. Geological Survey; F, fair; G, good; P, poor; --, not determined]

Date (month/ day/year)	Width (ft)	Area (ft^2)	Velocity (ft/s)	Outside gage height (ft)	Discharge (ft^3/s)	Time (24-hour)	Number of measurement sections	Measurement rating	Control	Measurement type
USGS streamflow-gaging station number 06770476 Platte River (middle-north channel) near Grand Island, Nebraska—Continued										
5/28/1985	159	279	2.20	14.69	615	1020	25	G	Clear	Wading
6/20/1985	183	220	2.15	15.04	473	1045	25	G	Clear	Wading
7/22/1985	183	158	1.90	15.41	300	1040	24	G	Clear	Wading
8/19/1985	183	147	1.80	15.52	265	1125	25	G	Clear	Wading
9/26/1985	189	242	2.07	14.96	502	1100	27	G	Clear	Wading
10/23/1985	200	295	2.21	14.63	651	1055	28	G	Clear	Wading
11/13/1985	189	209	1.94	15.17	406	1105	29	G	Clear	Wading
12/5/1985	110	103	1.73	12.73	178	1245	29	G	Ice	Ice
1/29/1986	--	--	--	11.44	--	1545	--	--	--	--
2/26/1986	190	750	2.41	11.54	1,810	1535	35	F	Ice	Handline
3/26/1986	208	338	2.16	14.53	730	1110	28	G	Clear	Wading
4/26/1986	209	420	2.43	14.08	1,020	1105	30	G	Clear	Wading
5/20/1986	190	251	2.08	14.90	521	1055	25	G	Clear	Wading
6/16/1986	210	339	2.29	14.45	775	1055	25	G	Clear	Wading
7/16/1986	190	213	2.02	15.13	430	1110	25	G	Clear	Wading
8/13/1986	193	276	1.96	14.84	540	1055	26	G	Clear	Wading
9/8/1986	210	295	2.13	14.68	628	1100	25	G	Clear	Wading
10/9/1986	210	361	2.22	14.35	800	1055	25	G	Clear	Wading
11/18/1986	186	268	2.14	14.81	573	1055	29	G	Clear	Wading
12/2/1986	189	301	2.16	14.64	651	1115	27	G	Clear	Wading
1/12/1987	187	248	2.14	14.88	530	1110	26	G	Clear	Wading
2/19/1987	217	247	2.05	14.93	507	1110	28	G	Clear	Wading
4/2/1987	163	348	2.55	14.36	886	1320	35	G	Clear	Handline
4/22/1987	220	341	1.95	14.54	666	1035	26	G	Clear	Wading
5/19/1987	215	324	2.03	14.54	658	1030	27	G	Clear	Wading
6/15/1987	191	320	2.17	14.58	694	1120	29	G	Clear	Wading
7/6/1987	189	147	1.71	15.42	251	1315	28	G	Clear	Wading
8/19/1987	198	145	1.54	15.45	223	1120	27	G	Clear	Wading
9/10/1987	188	225	2.00	14.94	449	1120	27	G	Clear	Wading
10/22/1987	197	117	1.64	15.54	192	1205	28	G	Clear	Wading
11/19/1987	202	240	2.05	14.79	491	1120	28	G	Clear	Wading
12/3/1987	201	256	1.95	14.85	499	1105	29	G	Clear	Wading
1/21/1988	185	345	1.99	13.3	686	1150	29	P	Ice	Ice

Appendix 1. Discharge measurements of the Platte River made at U.S. Highway 281 near Grand Island, Nebraska, 1983–88.—Continued

[ft, feet; ft², square feet; ft/s, feet per second; ft³/s, cubic feet per second; USGS, U.S. Geological Survey; F, fair; G, good; P, poor; --, not determined]

Date (month/ day/year)	Width (ft)	Area (ft²)	Velocity (ft/s)	Outside gage height (ft)	Discharge (ft³/s)	Time (24-hour)	Number of measure- ment sections	Measure- ment rating	Control	Measure- ment type
USGS streamflow-gaging station number 06770475 Platte River (north channel) near Grand Island, Nebraska										
10/14/1983	172	189	2.06	--	390	1050	19	F	Clear	Wading
12/1/1983	180	226	1.38	--	311	0915	13	P	Ice cover	Ice
12/8/1983	221	386	1.96	15.00	755	0835	18	F	Ice cover	Wading
12/28/1983	170	93.7	1.09	16.22	102	0825	16	F	Ice cover	Ice
1/19/1984	172	123	1.63	16.12	201	1020	18	F	Ice cover	Ice
2/14/1984	170	354	2.38	15.53	842	1110	20	G	Clear	Wading
3/28/1984	212	590	2.22	15.02	1,310	0850	19	F	Clear	Handline
4/18/1984	264	489	2.45	14.91	1,200	0845	26	G	Clear	Wading
6/21/1984	223	558	2.31	14.69	1,290	0935	16	G	Clear	Handline
7/23/1984	94	83.4	1.65	16.86	138	0935	24	G	Clear	Wading
8/8/1984	110	58.2	1.54	17.01	89.9	1010	33	G	Clear	Wading
9/13/1984	173	245	2.34	15.75	574	0905	23	G	Clear	Wading
10/17/1984	176	232	2.14	15.77	496	1145	21	G	Clear	Wading
11/13/1984	189	283	2.22	15.49	628	1030	22	G	Clear	Wading
12/5/1984	210	279	2.48	15.41	692	1340	24	G	Clear	Wading
1/23/1985	73	83.5	1.09	16.51	91.3	1005	23	G	Shore	Wading
3/5/1985	191	286	2.29	15.56	654	1040	24	G	Clear	Wading
3/27/1985	171	181	2.01	15.88	363	1015	26	G	Clear	Wading
4/17/1985	186	145	1.72	16.08	250	0940	27	F	Clear	Wading
5/28/1985	170	153	1.91	16.07	292	0925	27	G	Clear	Wading
6/20/1985	163	93.9	1.46	16.46	137	1005	20	G	Clear	Wading
7/22/1985	138	53.0	1.27	16.64	67.3	0940	29	G	Clear	Wading
8/19/1985	138	48.3	1.25	16.64	60.4	0940	30	G	Clear	Wading
9/26/1985	178	122	1.66	16.25	203	1005	30	G	Clear	Wading
10/23/1985	201	193	1.87	15.82	361	1005	22	G	Clear	Wading
12/5/1985	180	41.6	.85	16.62	35.4	1025	26	P	Ice cover	Ice
1/29/1986	191	320	2.50	15.23	801	1040	31	G	Clear	Wading
2/26/1986	200	178	1.39	16.00	248	1035	28	G	Clear	Wading
3/26/1986	187	214	1.94	15.66	415	1015	28	G	Clear	Wading
4/24/1986	198	297	2.25	15.41	667	0955	26	G	Clear	Wading
5/20/1986	188	197	2.01	15.76	395	1000	28	G	Clear	Wading
6/16/1986	225	216	1.92	15.75	414	1000	29	G	Clear	Wading

Appendix 1. Discharge measurements of the Platte River made at U.S. Highway 281 near Grand Island, Nebraska, 1983–88.—Continued

[ft, feet; ft^2, square feet; ft/s, feet per second; ft^3/s, cubic feet per second; USGS, U.S. Geological Survey; F, fair; G, good; P, poor; --, not determined]

Date (month/day/year)	Width (ft)	Area (ft^2)	Velocity (ft/s)	Outside gage height (ft)	Discharge (ft^3/s)	Time (24-hour)	Number of measurement sections	Measurement rating	Control	Measurement type
USGS streamflow-gaging station number 06770475 Platte River (north channel) near Grand Island, Nebraska—Continued										
7/16/1986	170	150	2.04	16.07	306	1010	39	G	Clear	Wading
8/13/1986	171	177	2.10	15.73	372	1020	24	G	Clear	Wading
9/8/1986	195	216	1.97	15.67	425	1015	25	G	Clear	Wading
10/9/1986	240	277	2.11	15.44	584	1000	30	G	Clear	Wading
11/18/1986	185	237	1.96	15.70	465	830	30	G	Clear	Wading
12/2/1986	239	259	2.03	15.49	525	1020	29	G	Clear	Wading
1/12/1987	251	224	2.06	15.66	461	0955	28	G	Clear	Wading
2/19/1987	226	229	2.15	15.57	492	1020	27	G	Clear	Wading
4/2/1987	235	466	2.17	14.91	1,010	1225	34	G	Clear	Handline
4/22/1987	233	278	2.05	15.39	569	930	25	G	Clear	Wading
5/19/1987	173	243	2.29	15.41	557	925	29	G	Clear	Wading
6/15/1987	252	293	2.18	15.32	634	1025	30	G	Clear	Wading
7/6/1987	216	126	1.59	16.33	200	1130	33	G	Clear	Wading
8/19/1987	131	76.3	1.52	16.40	116	1030	25	G	Clear	Wading
9/10/1987	173	176	1.88	15.96	331	1025	33	G	Clear	Wading
10/22/1987	209	120	1.50	16.21	180	1105	23	F	Clear	Wading
11/19/1987	222	186	1.86	15.79	346	1030	27	G	Clear	Wading
12/3/1987	221	224	1.89	15.68	423	1005	31	G	Clear	Wading
1/21/1988	158	126	1.53	14.78	193	1110	32	F	Ice cover	Ice
5/24/1989	219	806	2.49	14.19	2,010	0905	19	G	Clear	Handline

Appendix 2. LiDAR Processing—Sanborn Final Report

USGS

Platte River, NE - LiDAR/Contour Project

August-November, 2006

Final Report

Prepared by:

Sanborn

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EXECUTIVE SUMMARY

In the spring of 2006, Sanborn was contracted by the USGS to execute a LIDAR (Light Detection and Ranging) survey campaign in the state of Nebraska. LIDAR data in the form of 3-dimensional positions of a dense set of masspoints was collected for the area defined by -provided shapefile. These data were used in the development of the bare-earth-classified elevation point data and digital topographic contours.

Sanborn's Optech ALTM LIDAR system was used to perform the aerial survey. The ALTM is calibrated by conducting flight passes over a known ground surface before and after each LIDAR mission. During final data processing, the calibration parameters are inserted into post-processing software.

Two airborne GPS (Global Positioning System) base stations were required in this project, one located at the Central Nebraska Regional Airport, and the other located in the project area. These stations were tied to one additional NGS marker to create a GPS survey network. The network observations and adjustment were completed on the GRS8O ellipsoid.

The acquired LIDAR data were processed to a standard LAS format in the project coordinate system, then filtered and edited to yield a LIDAR surface representing the bare earth.

The contents of this report summarize the methods used to establish the base station network, perform the LIDAR survey and post-processing, subsequent breakline compilation and contour generation, and the results of these methods.

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1 INTRODUCTION

This report contains a technical write-up of the August-2006 USGS Platte River, NE LIDAR and topographic contour project (Task Order 01014C0047). The report includes descriptions and details of the processes undertaken by Sanborn to execute the scope of work including system calibration, establishment of base stations by a differential GPS network survey, the collection and post- processing of the LIDAR data, and the development of 1-foot interval digital contours from the bare-earth-classified LiDAR elevations points.

1.1 Duration/Time Period

The LIDAR aircraft arrived on site August 09, 2006 and the LIDAR data collection was accomplished between this date and August 12, 2006. The Central Nebraska Regional Airport was used as the base of operation. The LiDAR data processing was completed by the end of September and the development of digital contours was completed in November, 2006.

1.2 Contact Info

Questions regarding the technical aspects of this report should be addressed to:

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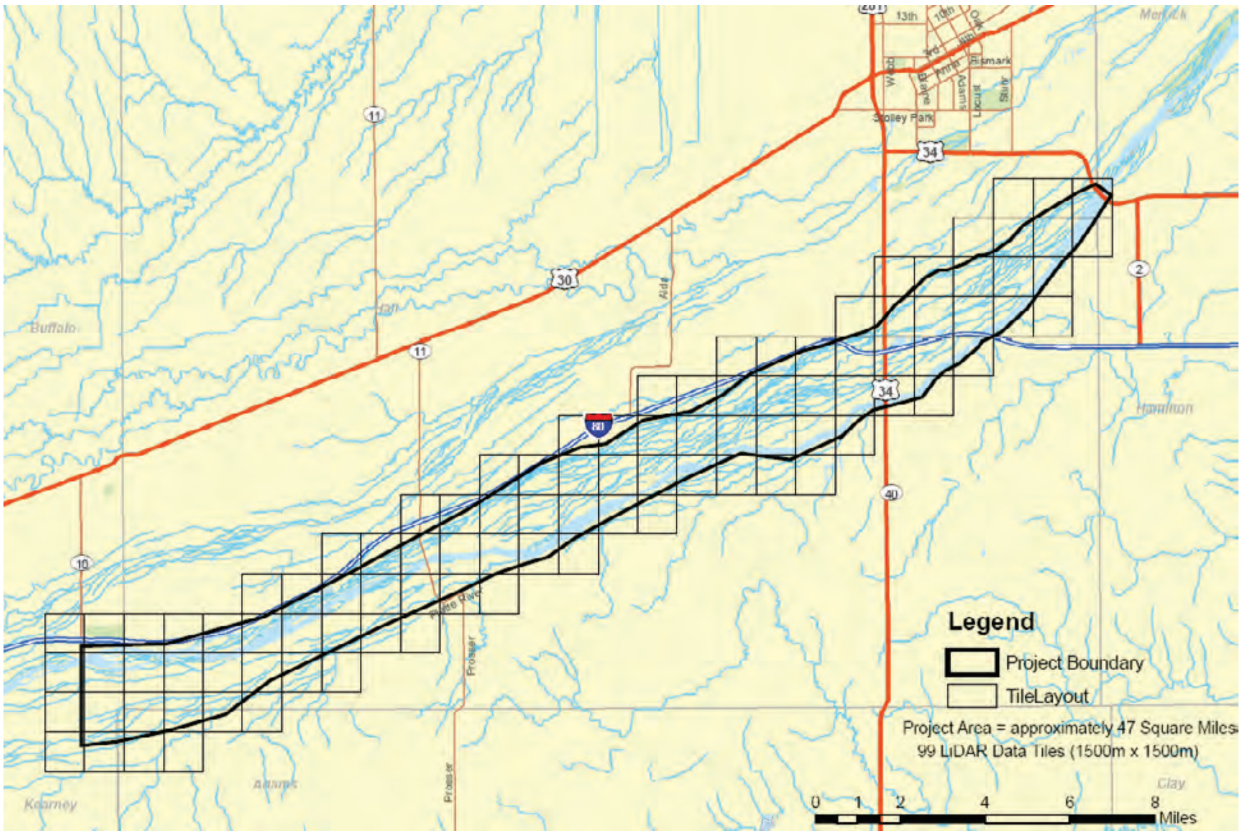
1.3 Purpose of the LIDAR Acquisition

This LIDAR operation was designed to provide a ground surface dataset to be used for the development a terrain elevation model, including ASPRS Class II contours at a 1 foot interval. The scheduling of the LiDAR acquisition mission was targeted for early August to coincide with low water levels in the Platte River prior to the end crop irrigation season.

1.4 Project Location

The project location is a 47 square-mile corridor along the Platte River in Central Nebraska, near Grand Island.

Figure 1: Area of Interest



1.5 Project Datum

The base stations used for this project were tied to one existing horizontal/vertical NGS point. A network adjustment was performed to refine the published coordinates of the base station

Horizontal Datum The horizontal datum associated with the LIDAR data is NAD83 (1996), as realized by the physical control monuments used to constrain the survey control network.

1.6.2 Vertical Datum

The vertical datum associated with the LIDAR data is the NAVD88, as realized by the physical benchmarks used to constrain the survey control network.

2 LIDAR CALIBRATION

2.1 Introduction

LIDAR calibrations are performed to determine and therefore eliminate systematic bias' that occur within the hardware of the ALTM system. Once the bias' are determined they can be modeled out. The systematic bias' that are corrected for include scale, roll, and pitch.

The following procedures are intended to eliminate blunders in the field and office work, and are designed to detect inconsistencies. The emphasis is not only on the quality control (QC) aspects, but also on the documentation, i.e., on the quality assurance (QA).

The following procedures are intended to prevent operational errors in the field and office work, and are designed to detect inconsistencies. The emphasis is not only on the quality control (QC) aspects, but also on the documentation, i.e., on the quality assurance (QA).

2.2 Calibration Procedures

Sanborn performs two types of calibrations on its LIDAR system. The first is a building calibration, and it is done any time the LIDAR system has been moved from one plane to another. New calibration parameters are computed and compared with previous calibration runs. If there is any change, the new values are updated internally or during the LIDAR post-processing. These values are applied to all data collected with this plane/ALTM system configuration.

Once final processing calibration parameters are established from the building data, a precisely-surveyed surface is observed with the LIDAR system to check for stability in the system. This is done several times during each mission. An average of the systematic bias' are applied on a per mission basis.

2.2.1 Building Calibration

Whenever the ALTM is moved to a new aircraft, a building calibration is performed. The rooftop of a large, flat, rectangular building is surveyed on the ground using conventional survey methods, and used as the LIDAR calibration target. The aircraft flies several specified passes over the building with the ALTM system set in both scan and profile modes (scan angle set to zero degrees).

Figure 2 shows a pass over the center of the building. The purpose of this pass is to identify a systematic bias in the scale of the system.

Figure 3 demonstrates a pass along a distinct edge of the building to verify the roll compensation performed by the INS.

Additionally, a pass is made in profile mode across the middle of the building to compensate for any bias in pitch.

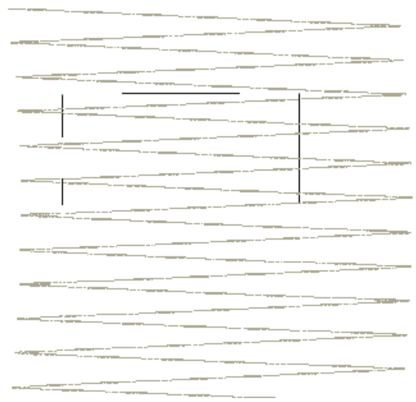


Figure 2: Calibration Pass 1

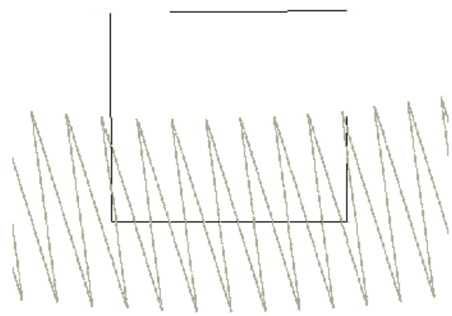


Figure 3: Calibration Pass 2

2.2.2 Runway Calibration, System Performance Validation

An active asphalt runway was precisely-surveyed at the Central Nebraska Regional airport using kinematic GPS survey techniques (accuracy: ±3cm at 1σ, along each coordinate axis) to establish an accurate digital terrain model of the runway surface. The LIDAR system is flown at right angles over the runway several times and residuals are generated from the processed data. Figure 4 shows a typical pass over the runway surface.

Approximately 25,000 LIDAR points are observed with each pass. These points are "draped" over the runway surface TIN (Triangular Irregular Network) to compute vertical residuals for every data point. The residuals are analyzed with respect to the location *along* the runway to identify the level of noise and system biases.

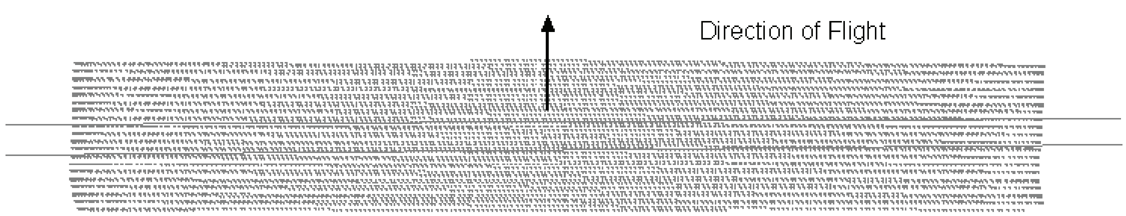


Figure 4: Runway Calibration

2.3 Calibration Results

The LIDAR data captured over the building are used to determine whether there have been any changes to the alignment of the IMU with respect to the laser system. The parameters are designed to eliminate systematic biases within certain system parameters.

The runway over-flights are intended to be a quality check on the calibration and to identify any system irregularities and the overall noise. IMU misalignments and internal system calibration parameters are verified by comparing the collected LIDAR points with the runway surface.

Figure 5 below shows the typical results of a runway over-flight analysis. The X-axis represents the position *along* the runway. The overall statistics from this analysis provides evidence of the overall random noise in the data (typically, 7cm standard deviation (an unbiased estimator) and 8cm RMS which includes any biases and indicates that the system is performing within specifications. As described in later sections of this report, this analysis will identify any peculiarities within the data along with mirror-angle scale errors (identified as a “smile” or “frown” in the data band) or roll biases.

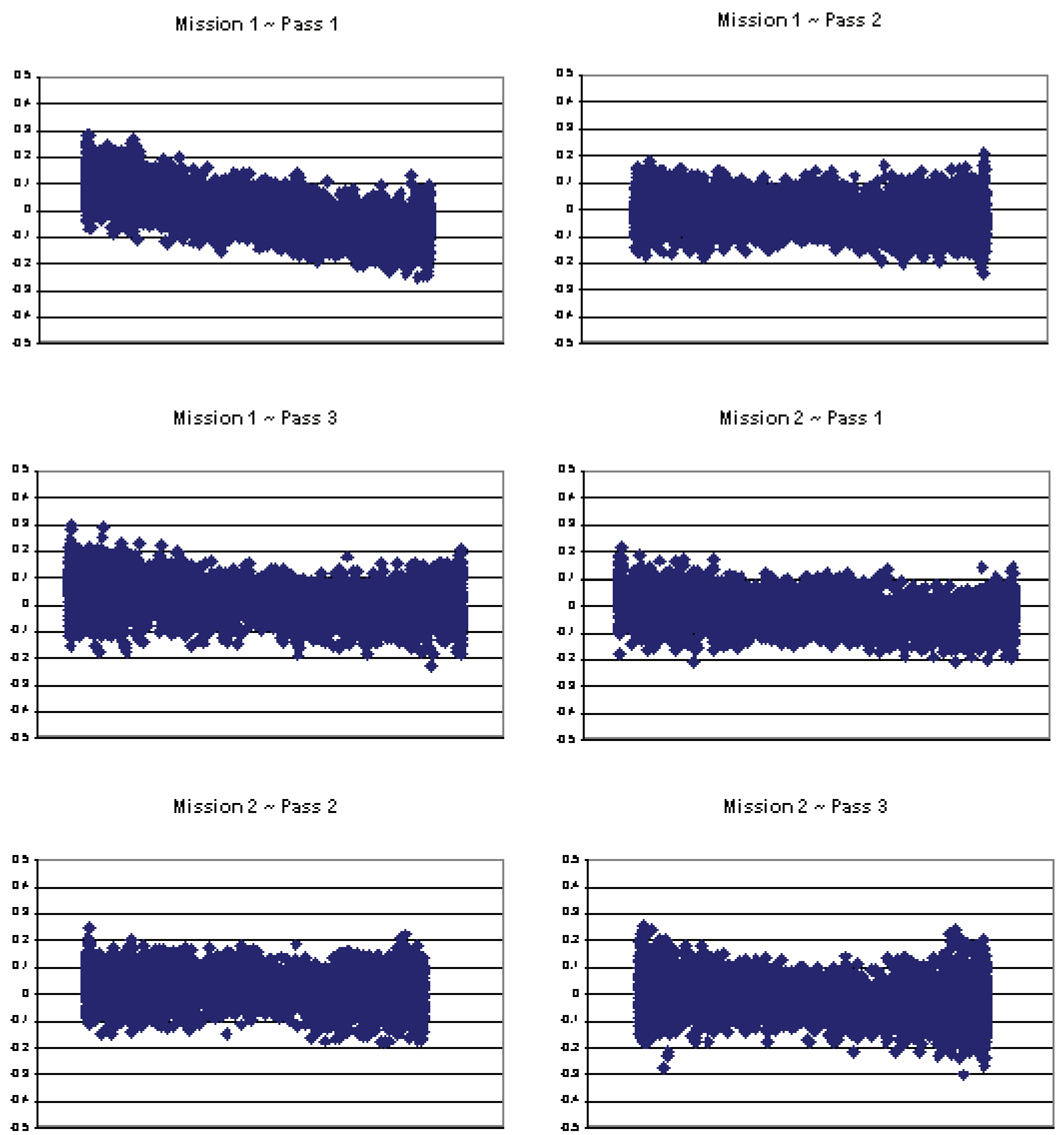


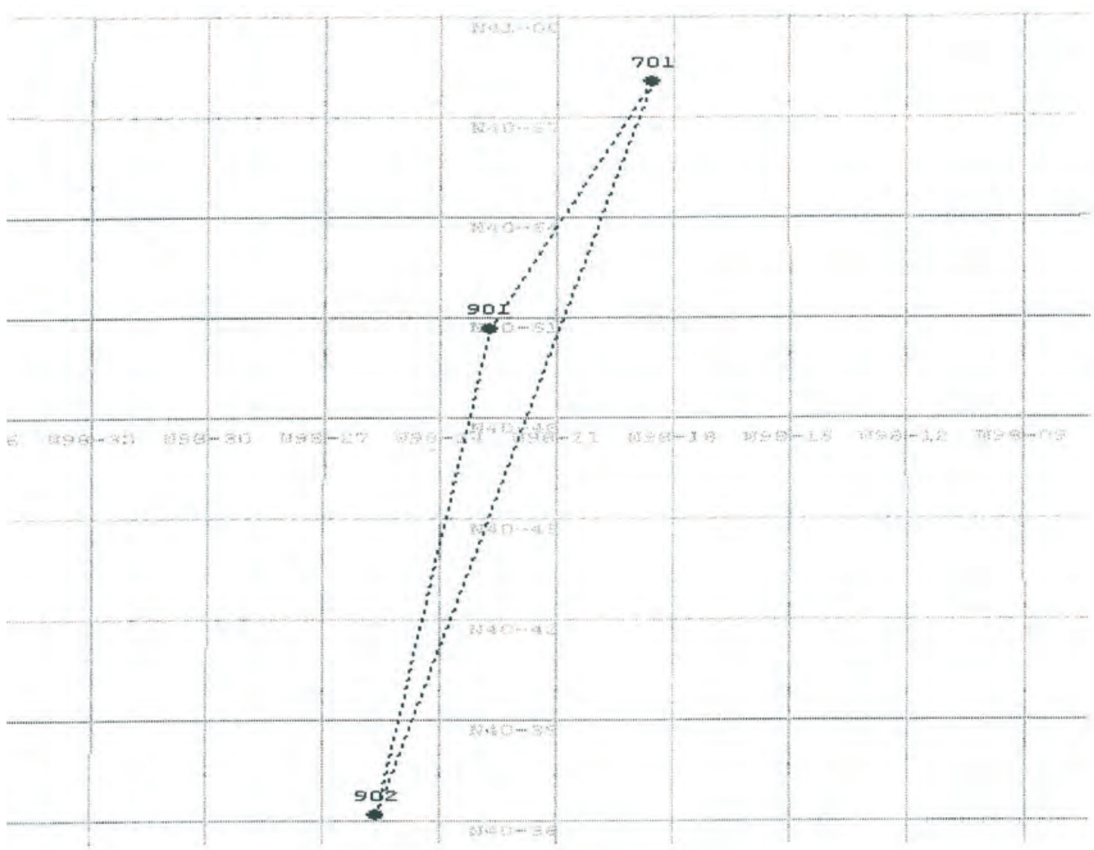
Figure 5: Runway Calibration Results

3 GEODETIC BASE NETWORK

3.1 Network Scope

During the LIDAR campaign, the Sanborn field crew conducted a GPS field survey to establish a survey network (Figure 6) containing the GPS base stations used to support the campaign. Points 701, located at Central Nebraska Regional Airport and point 901 were used as base stations for LIDAR missions. Also point 902 was used to adjust the coordinates of point 701 and 901 See Table 2 for station names, orders and constraints.

Figure 6: Survey Network Diagram



3.2 Data Processing and Network Adjustment

All static baseline vectors were processed using Trimble Navigation's GPSurvey (Ver. 2.35a) software. Fixed bias solutions were obtained for all baselines. The broadcast ephemeris was used, since the accuracy and extent of the network does not warrant the use of the precise ephemeris. The loop misclosures are summarized in Table 1 below.

The misclosures in each component (X, Y and Z) are given in millimeters and parts per million (ppm) in an ECEF Cartesian coordinate system. The spatial misciosure in ppm is also provided. All loops comprise of quasi—independent baselines from at least two different sessions. Every station in the network appears at least once in a loop. All loops, in fact, satisfy GPS guidelines for first order work, namely.

- in any component (X, Y, Z), the maximum misclosure does not exceed 250 mm,
- in any component (X, Y, Z), the maximum misclosure in terms of the loop length does not exceed 12.5 ppm,
- in any component (X, Y, Z), the average misclosure in terms of the loop length does not exceed 8 ppm

Table 1: Loop Closure

LOOP	Horizontal	Vertical	Distance	PPM
	(m)	(m)	(m)	
701-901-902-701	0.22	-0.18	83740.712	0.336

A 3-dimensional network adjustment was carried out using GeoLabTM (version 3.61) 3-D adjustment software. Initially, a minimally constrained adjustment was performed to examine the internal accuracy of the network. The geodetic latitude, longitude, and elevation of one existing control point were held fixed. The adjustment comprises 3 stations and 9 baseline vector components (3 baselines). *A priori weights* for the observations were based on the (scaled) variance-covariance sub-matrices from the GPSurveyTM solutions. The relative confidence regions and the associated relative horizontal and vertical precisions were computed for all pairs of points that were directly connected by vectors. All station pairings meet the horizontal positioning standard for *first order* surveys, i.e., the relative horizontal precision between each pair of points does not exceed 10 mm + 10 ppm of their horizontal separation, at the 95 percent level of confidence. The network is therefore classified as *first order* in terms of its *internal* accuracy. To complete a fully constrained adjustment, the network was horizontally constrained to control points 901 and 902, and vertically constrained by orthometric elevation to 901 and 902. See Table 2: NGS Control Constraints for associated orders and assigned standard deviations

Table 2: NGS Control Constraints

Horizontal

Code	NGS Station Name	Order	ϕ	λ
701	GRI ARP 2	B	0.01	0.01
901	B 436	B	0.01	0.01
902	HIS ARP 2	B	0.01	0.01

Vertical

Code	NGS Station Name	Order	Ht
901	B 436	1 – II	0.02
902	HIS ARP 2	1 – II	0.02

4 LIDAR COLLECTION AND PROCESSING

4.1 Field Work / Procedures

Data capture was conducted on August10th. A minimum of two GPS base stations were set up, with one receiver located at the airport, and the secondary OPS receiver placed at a survey control point in the project area.

Pre-flight checks such as cleaning the sensor head glass are performed. A five minute INS initilization is conducted on the ground, with the engines running, prior to flight, to establish fine-alignment of the INS. GPS ambiguities are resolved by initializing within ten kilometers of the base stations.

The flight mission was about three hours in duration including runway calibration flights flown at the beginning and the end of each mission. During the data collection, the operator recorded information on logsheets which includes weather conditions, LIDAR operation parameters, and flight line statistics. Near the end of the mission GPS abiguities are again resolved by landing and initializing within ten kilometers of the base stations, to aid in post-processing.

Table 3 shows the LIDAR acquisition parameters with a flying height of 1,200 meters above gound level (AGL) on a mission to mission basis.

Table 3: LIDAR Acquisition Parameters

Mission	Date	Start Time	End Time	Altitude (m)	Airspeed (knots)	Scan Angle	Scan Rate	Pulse Rate	PDOP	GPS Station / Stability
222a	8/10/06	21:59	02:08	1200	120	20	32	50000	1.57	701, 901

Preliminary data processing was performed in the field immediately following the missions for quality control of GPS data and to ensure sufficient overlap between flight lines. Any problematic data would have been re-flown immediately as required. Final data processing was completed in the Colorado Springs office.

4.2 Final LIDAR Processing

Final post-processing of LIDAR data involves several steps. The airborne GPS data were post-processed using Waypoint's GravNAVTM software (version 7.50). A fixed-bias carrier phase solution was computed in both the forward and reverse chronological directions. Whenever practical, LIDAR acquisition was limited to periods when the PDOP was less than 3.0.

The GPS trajectory was combined with the raw IMU data and post-processed using Optech postprocessor software. This results in a two-fold improvement in the attitude accuracies over the real-time INS data. The best estimated trajectory (BET) and refined attitude data are then re-introduced into the Optech software to compute the laser point-positions – the trajectory is combined with the attitude data and laser range measurements to produce the 3-dimensional coordinates of the mass points.

First and last return values are produced within Optech software. The first return information provides a useful depiction of the "canopy" within the project area. The last return is further processed to obtain ground-filtered data.

LiDAR return filtering was accomplished using TerraScan LIDAR processing and modeling software. The general procedure for classifying bare earth returns is as follows:

1. Filter for and classify anomalous low points (below ground level).
2. Filter for and classify isolated points (single returns in a water body, bird shot, etc).
3. Filter for and classify bare earth.
4. Interactive quality control of the classified bare earth result to identify and correct artifacts remaining from steps 1 & 2, data voids, or other indications of over-aggressive filtering from step 3. The QC process uses a combination of tools including TIN and profile views of the bare earth surface.
5. Perform an RMSE test against ground control check points to assess the vertical accuracy of the final bare-earth classified points.

Table 4 and Table 5 below show Sanborn's minimum accuracy specification and the results of the RMSE test which indicate a vertical RMSE of approximately 11cm relative to the 10 ground control points surveyed for this project.

Table 4: LiDAR Product Accuracy Specification

Criteria	Minimum Accuracy
Horizontal Accuracy of LiDAR Data	0.5m RMSE
Vertical Accuracy of LiDAR data in bare areas	15cm RMSE
Vertical Accuracy of LiDAR data in vegetated areas	27 cm RMSE
Percent of Artifacts removed (terrain and vegetation dependent)	95%
Percent of all outliers removed	98%
Percent of all vegetation removed	97%
Percent of all buildings removed	99%

Table 5: Vertical RMSE Test Results

Number	Easting	Northing	Known Z	Laser Z	Dz
1	542794.425	4513575.351	562.854	562.930	+0.076
2	537986.151	4511924.501	568.943	569.020	+0.077
3	535147.310	4510442.247	571.981	572.050	+0.069
4	524988.400	4506986.740	585.823	585.900	+0.077
5	521966.736	4507729.536	590.522	590.630	+0.108
6	531089.136	4510251.499	577.468	577.660	+0.192
7	553559.407	4518364.809	547.684	547.790	+0.106
8	550859.785	4516911.914	551.350	551.470	+0.120
9	552598.208	4519410.243	547.439	547.560	+0.121
10	554841.448	4520421.861	544.245	544.350	+0.105

Average dz	+0.105
Minimum dz	+0.069
Maximum dz	+0.192
Average magnitude	0.105
Root mean square	0.111
Std deviation	0.036

5 BREAKLINE AND CONTOUR DEVELOPMENT

The Platte River, Nebraska project scope included the creation of breaklines to support the generation of 1-foot contours meeting ASPRS Class II vertical accuracy standards. The breaklines would be combined with the LiDAR bare-earth mass-points to derive a surface from which contours can be programmatically generated.

Normally, breakline augmentation of a LiDAR mass-point surface would involve a limited amount breaklines due to the high density of the mass points relative to a compilation from stereo photographic imagery.

Due to a miscue in project coordination at Sanborn, our compilation team applied a full conventional effort to the entire project area, resulting in a digital terrain model (DTM) of compiled breaklines and mass points, at a density and quality more than suitable for ASPRS Class II 1-foot contour generation. The conventional compilation effort omitted specific features required for contour generation from LiDAR, such as polygons to exclude invalid areas like voids and mature cornfields. A set of contours was then generated from the stereo-intensity-compiled breaklines and mass points instead of a surface derived from breaklines and LiDAR mass points (as defined in the Task Order).

Sanborn reviewed the results of the manually compiled breakline/mass point product and found it to be of excellent quality. Sanborn is confident that the resulting contours will meet or exceed requirements for ASPRS Class II 1-foot contours. The breaklines and resulting contours are solidly on the LiDAR-defined surface and, as a result of the detailed compilation work; they are also smoother than contours generated directly from the LiDAR mass points.

Because of the additional cost and schedule delay that would be incurred to revisit the compilation and contour generation effort, Sanborn requested that the compiled-surface-contours be reviewed and considered acceptable as the deliverable for the project. After review with the USGS and its Nebraska customer on November 28, 2006, the USGS agreed that the contours as-produced should meet all project requirements and would be accepted as the project deliverable.

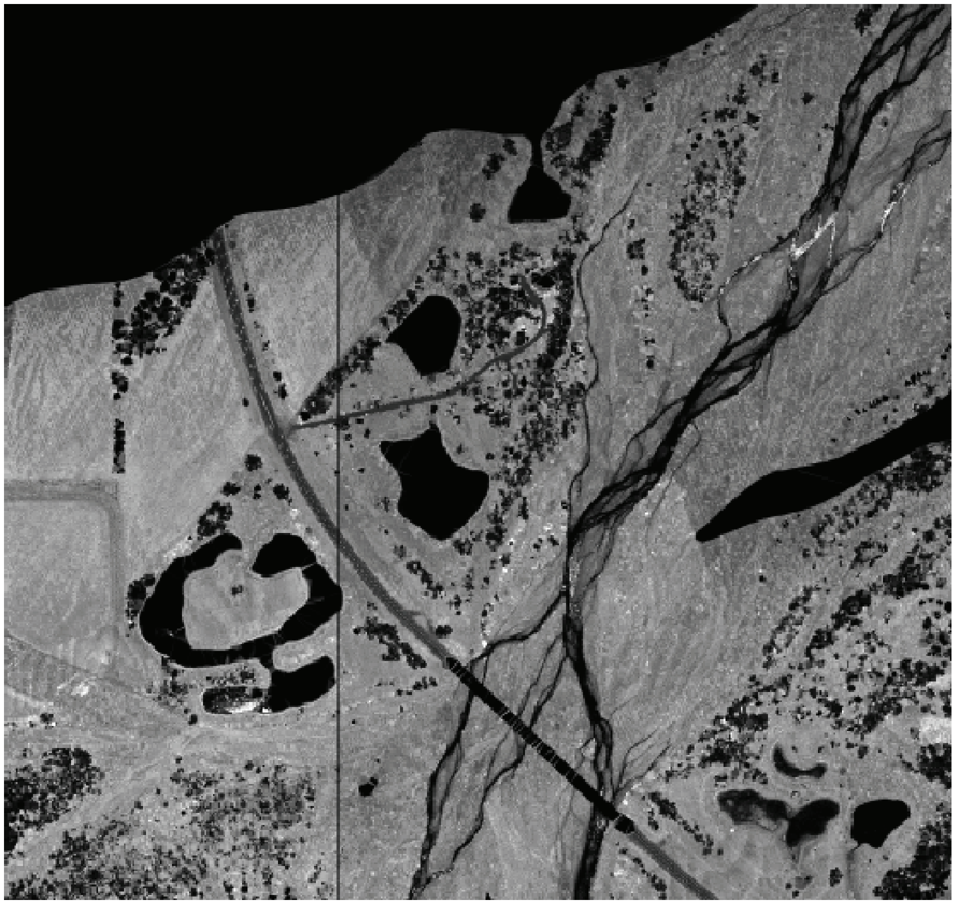
The following is a description of the process used to create the deliverable breaklines, mass-points, and contours.

5.1 Intensity Image Compilation

After completion and quality control of the LiDAR bare-earth point classification process, intensity image pairs are generated directly from the LAS LiDAR data files.

Sanborn uses GeoCue Corporation’s GeoCue software to generate the image pairs and orientation data. The intensity images are a rasterized version of a triangulated irregular network (TIN) produced from the bare-earth LiDAR points. The image files are in a grayscale TIFF-World format. Intensity values from the LiDAR elevation points are used to set the grayscale value for the pixels. The result is an image that appears photographic as shown in Figure 7 below.

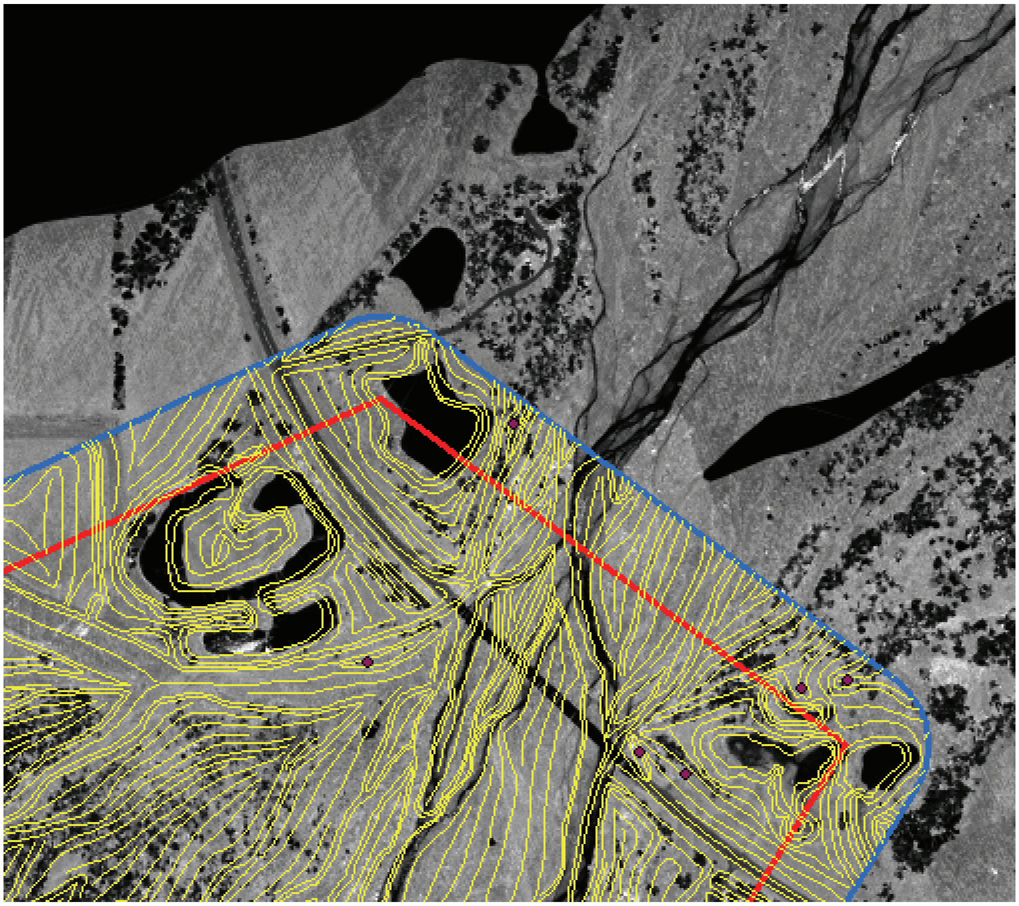
Figure 7: LiDAR Intensity Image



Sanborn's compilation team is then able to apply the same softcopy stereo-compilation software and techniques used to compile breaklines from photography.

Compilation of breaklines and mass points was completed in great detail across the entire project area and extending an additional 150 feet beyond the area of interest (Figure 8 below). Extra digital terrain model outside the project area is necessary to ensure the derived surface and contour lines are accurate all the way up to the desired boundary.

Figure 8: Breakline Image



Note: The apparent offset of the breaklines relative to the intensity image in Figure 8 is because only one image of the stereo pair is shown.

5.2 Contour Generation

Upon completion of the breakline and mass point compilation, Sanborn used its proprietary APS mapping software tools to generate the 1-foot contour lines.

The tiled DTM data files associated with an APS project definition which enables batch processing of contour generation and logical data validation checks. The general process includes:

1. Generate Contours – APS constructs a TIN surface from the project breakline/mass-point data and interpolates contour vectors and attributes from that surface.
2. Discrepancy Flags – APS traverses the completed contour data and flags a variety of graphical and logical discrepancies. Discrepancies include:
    a. Dangling contour lines
    b. Crossing contour lines
    c. Mismatched attributes at tile edges

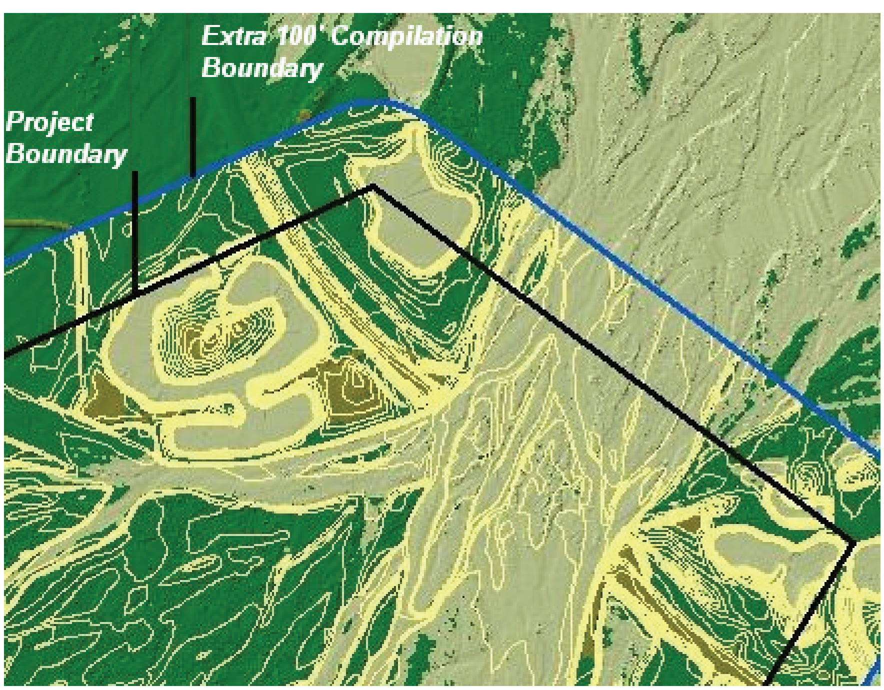
3. Discrepancy Flag Review – A technician interactively reviews the discrepancy flags set by the APS application and edits the underlying DTM data or contours as needed
4. Visual Review – A technician visually scans a color-ramped view of the contours across the entire project area checking for anomalies such as high and low spikes.
5. Validation Point Check – The APS system will perform an RMSE test against a set of ground control check points.

Sanborn performed an APS Validation Point Check against the final DTM data using the deliverable check points surveyed during the LiDAR collection mission. The test results shown below indicate that the data set meets the ASPRS Class II accuracy standard for 1-foot contours. Sanborn is confident that subsequent accuracy testing performed by the USGS will return similar results.

RMSE :	0.20m
Mean (meas) :	588.40m
Mean (int) :	588.42m
Diff mean :	-0.02m
Maximum negative error :	-0.32m
Maximum positive error :	0.27m
Accuracy(Z) at 95% confidence:	0.32m
RMSE at 95%:	0.19m

With USGS' approval, Sanborn was able to deliver an additional 100ft of contour data outside the project area due to the size of the buffer area we surveyed and compiled. Sanborn actually produced extra 150 feet of breaklines and mass points so we are confident with the generated contours to at least the extra 100 feet delivered.

Figure 9: Contours and Buffer Area



Appendix 3. Channel-Transect Survey Data

```
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      Publication_Date: 2008
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Platte River, 2006-2007
      Edition: Version 1.0
      Geospatial_Data_Presentation_Form: vector digital data
      Publication_Information:
        Publication_Place: Reston, Virginia
        Publisher: U.S. Geological Survey
      Online_Linkage: /lookup/getspatial?SIR_Platte_GPS
      Larger_Work_Citation:
        Citation_Information:
          Originator: Brenda K. Woodward
          Publication_Date: 2008
          Title: Streamflow and Topographic Characteristics of the Platte River
near Grand Island, Nebraska, 1938-2007
          Series_Information:
            Series_Name: Scientific Investigations Report
            Issue_Identification: SIR 2008-5106
          Publication_Information:
            Publication_Place: Reston, Virginia
            Publisher: U.S. Geological Survey
          Online_Linkage: http://pubs.usgs.gov/
  Description:
    Abstract: Real-time kinematic (RTK) global positioning system (GPS)
receivers were used to survey 95 transects on the Platte River near Grand
Island, Nebraska.  The format of the data collected is XYZ (Easting, Northing,
and Elevation referenced to the North American Vertical Datum of 1988 (NAVD88)).
Data were collected from May 2006 through March 2007 on multiple channels of the
Platte River.  The data were collected by the U.S. Geological Survey using
Ashtech Z-Xtreme and Z-Max GPS receivers.  Transect data points were linearly
referenced from the south bank.
    Purpose: The data were collected to compare topographic characteristics
among the four channels of the Platte River near Grand Island to understand
streamflow distribution.  In addition, these surveyed transects were compared
with historical transect surveys where available.
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          Calendar_Date: 20060519
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      Theme_Keyword: topography
      Theme_Keyword: terrain
      Theme_Keyword: river channels
      Theme_Keyword: channel morphology
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      Place_Keyword: Platte River
      Place_Keyword: Nebraska
      Place_Keyword: Hall County
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  Use_Constraints: None
  Point_of_Contact:
    Contact_Information:
      Contact_Person_Primary:
        Contact_Person: Brenda K. Woodward
        Contact_Organization: U.S. Geological Survey
      Contact_Position: Hydrologist
      Contact_Address:
        Address_Type: mailing and physical address
        Address: 5231 S 19th St
        City: Lincoln
        State_or_Province: Nebraska
        Postal_Code: 68512
        Country: USA
      Contact_Voice_Telephone: 402.328.4100
      Contact_Facsimile_Telephone: 402.328.4101
      Contact_Electronic_Mail_Address: bkwoodwa@usgs.gov
  Data_Set_Credit: City of Grand Island, Nebraska, and the Central Platte
Natural Resources District
  Security_Information:
    Security_Classification_System: None
    Security_Classification: Unclassified
    Security_Handling_Description: None
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Service Pack 2; ESRI ArcCatalog 9.2.4.1420
Data_Quality_Information:
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  Logical_Consistency_Report: Reviewers examined attributes and ran statistics
to ensure valid values.  Only point topology was present.
  Completeness_Report: Many surveyed transects were interrupted by bank
vegetation interference with reception of GPS satellite signals.  Other
transects were not fully surveyed because information was needed only to locate
discharge measurements.  Most SS1, SS2, and SS2_extra transects as well as 8B,
177.3, and 172.6 transects are full transect surveys.
  Positional_Accuracy:
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from the average error in Northing and Easting coordinates collected on known
bench marks during daily checks.  Average errors were 0.002 m in the Northing
and 0.066 m in the Easting.  The greatest error observed in the Northing
coordinates was 0.126 m and in the Easting coordinates was 0.171 m.
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the average error in elevation collected on known benchmarks was 0.079 m, well
within the project's stated vertical accuracy of 0.162 m (Woodward, 2008).  The
largest vertical error observed was 0.148 m.
      Quantitative_Vertical_Positional_Accuracy_Assessment:
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mounted on a backpack and  0.268 ft when surveying with a pole-mounted antenna.
        Vertical_Positional_Accuracy_Explanation: Determined as the square root
of the sum of squared nominal errors of the equipment, estimated error for each
surveying method, and estimated error in bench mark establishment.
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software on Ranger handheld data collectors.  Coordinate data were collected in
meters in the North American Datum of 1983 as projected in Nebraska State Plane
2600 coordinate system.
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    Process_Step:
      Process_Description: Data collected were limited to data points with
horizontal root mean squared errors (hrms) of less than 0.04 meters and vertical
root mean squared error (vrms) of less than 0.05 meters.  This insured low
dilution of precision (DOP).  In addition, a data point was typically collected
by each rover on a known bench mark at the start and finish of each data-
collection day.  These points were compared with the true coordinates for each
bench mark and were within the project's stated vertical accuracy of 0.162 m
(the largest difference of a recorded check elevation from its bench mark
elevation was 0.148 m; but such differences averaged 0.079 m).  Data sets were
evaluated for outliers, which were removed (Woodward, 2008).
      Process_Date: 20070322
    Process_Step:
      Process_Description: Corpscon6 software (USACE, 2004) was used to convert
Nebraska State Plane 2600 coordinates into Universal Transverse Mercator, Zone
14-North coordinates.
      Process_Date: 20070401
    Process_Step:
      Process_Description: Survey data points were then imported to ArcMap 9.1
and the spatial tool for locating features along routes was used to determine
```

```
distance from south bank.  The south bank starting point was arbitrary except
when historical survey markers could be located.
      Process_Date: 20070401
    Process_Step:
      Process_Description: Metadata created
      Process_Date: 20080409
    Process_Step:
      Process_Description: Data reviewed by Ryan Thompson, USGS, Huron, South
Dakota
      Process_Date: 20080425
    Process_Step:
      Process_Description: Data reviewed by Michaela Johnson, USGS, Lincoln,
Nebraska
      Process_Date: 20080511
Spatial_Data_Organization_Information:
  Direct_Spatial_Reference_Method: Vector
  Point_and_Vector_Object_Information:
    SDTS_Terms_Description:
      SDTS_Point_and_Vector_Object_Type: Entity point
      Point_and_Vector_Object_Count: 20744
Spatial_Reference_Information:
  Horizontal_Coordinate_System_Definition:
    Planar:
      Grid_Coordinate_System:
        Grid_Coordinate_System_Name: Universal Transverse Mercator
        Universal_Transverse_Mercator:
          UTM_Zone_Number: 14
          Transverse_Mercator:
            Scale_Factor_at_Central_Meridian: 0.999600
            Longitude_of_Central_Meridian: -99.000000
            Latitude_of_Projection_Origin: 0.000000
            False_Easting: 500000.000000
            False_Northing: 0.000000
      Planar_Coordinate_Information:
        Planar_Coordinate_Encoding_Method: coordinate pair
        Coordinate_Representation:
          Abscissa_Resolution: 0.001
          Ordinate_Resolution: 0.001
        Planar_Distance_Units: meters
    Geodetic_Model:
      Horizontal_Datum_Name: North American Datum of 1983
      Ellipsoid_Name: Geodetic Reference System 80
      Semi-major_Axis: 6378137.000000
      Denominator_of_Flattening_Ratio: 298.257222
  Vertical_Coordinate_System_Definition:
    Altitude_System_Definition:
      Altitude_Datum_Name: North American Vertical Datum of 1988
      Altitude_Resolution: 0.001
      Altitude_Distance_Units: meters
      Altitude_Encoding_Method: Explicit elevation coordinate included with
horizontal coordinates
Entity_and_Attribute_Information:
  Detailed_Description:
    Entity_Type:
      Entity_Type_Label: SIR_Platte_GPS
      Entity_Type_Definition: GPS points
      Entity_Type_Definition_Source: U.S. Geological Survey
```

```
    Attribute:
      Attribute_Label: Line
      Attribute_Definition: Line name or bench mark identifier
      Attribute_Definition_Source: U.S. Geological Survey
      Attribute_Domain_Values:
        Enumerated_Domain:
          Enumerated_Domain_Value: SS1n n= 1-24
          Enumerated_Domain_Value_Definition: Study Site 1 transects 1-24
          Enumerated_Domain_Value_Definition_Source: U.S. Geological Survey
        Enumerated_Domain:
          Enumerated_Domain_Value: SS2n n= 1-38
          Enumerated_Domain_Value_Definition: Study Site 2 transect 1-38
          Enumerated_Domain_Value_Definition_Source: U.S. Geological Survey
        Enumerated_Domain:
          Enumerated_Domain_Value: SS2extran n= 1 and 5-8
          Enumerated_Domain_Value_Definition: Study Site 2 extra transects 1 and
5-8
          Enumerated_Domain_Value_Definition_Source: U.S. Geological Survey
        Enumerated_Domain:
          Enumerated_Domain_Value: 1s, 2s, 2n, 3s, 3n, 4s, 4ms, 4n, 5s, 5ms,
5mn, 5n, 6s, 6ms, 6mn, 6n, 7s, 7n, 8s
          Enumerated_Domain_Value_Definition: Discharge transects 1-8 with
channel designation; s, south channel; n, north channel; mn, middle north
channel; ms, middle south channel
          Enumerated_Domain_Value_Definition_Source: U.S. Geological Survey
        Enumerated_Domain:
          Enumerated_Domain_Value: 8B-TR1, 8B-TR2, 8B-TR3
          Enumerated_Domain_Value_Definition: Bureau of Reclamation transects
8B-TR 1-3
          Enumerated_Domain_Value_Definition_Source: Bureau of Reclamation
        Enumerated_Domain:
          Enumerated_Domain_Value: 1773n, 1773m, 1773s
          Enumerated_Domain_Value_Definition: Bureau of Reclamation transects
surveyed at RM 177.3, channels designated as; s, south channel; n, north
channel; m, middle channel.
          Enumerated_Domain_Value_Definition_Source: Bureau of Reclamation
        Enumerated_Domain:
          Enumerated_Domain_Value: 1726n, 1726mn, 1726s
          Enumerated_Domain_Value_Definition: Bureau of Reclamation transects
surveyed at RM 172.6, channels designated as; s, south channel; n, north
channel; mn, middle north channel.
          Enumerated_Domain_Value_Definition_Source: Bureau of Reclamation
Distribution_Information:
  Distributor:
    Contact_Information:
      Contact_Organization_Primary:
        Contact_Organization: U.S. Geological Survey
      Contact_Position: Ask USGS- Water Webserver Team
      Contact_Address:
        Address_Type: mailing address
        Address: 507 National Center
        City: Reston
        State_or_Province: Virginia
        Postal_Code: 20192
        Country: USA
      Contact_Voice_Telephone: 1-888-275-8747 (1-888-ASK-USGS)
```

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

    Although these data have been used successfully on computers of the USGS, no
warranty, expressed or implied, is made by WRD regarding the use of these data
on any other system, nor does the fact of distribution constitute or imply any
such warranty.

    In no event shall the USGS have any liability whatsoever for payment of any
consequential, incidental, indirect, special, or tort damages of any kind,
including, but not limited to, any loss of profits, arising out of the delivery,
installation, operation, or use of these data.

    This database has been approved for release and publication by the Director
of the USGS.  Although this database has been subjected to rigorous review and
is substantially complete, the USGS reserves the right to revise the data
pursuant to further analysis and review.  Furthermore, it is released on
condition that neither the USGS nor the United States Government may be held
liable for any damages resulting from its authorized or unauthorized use.

    Any use of trade, product, or firm names is for descriptive purposes only
and does not imply endorsement by the U.S. Government.
  Standard_Order_Process:
    Digital_Form:
      Digital_Transfer_Information:
        Format_Name: text
        Format_Version_Number: Version 1.0
        Format_Information_Content: X,Y,Z coordinate data with survey date,
distance along transect, and other descriptions
        File_Decompression_Technique: no compression applied
        Transfer_Size: 3.6
      Digital_Transfer_Option:
        Online_Option:
          Computer_Contact_Information:
            Network_Address:
              Network_Resource_Name:
http://water.usgs.gov/GIS/dsdl/SIR_Platte_GPS.csv
          Access_Instructions: The Standard_Order_Process explains the files
that are available for downloading.  Several files may be available. Click on
the link following Network_Resource_Name to get the file you want.  Save this
file to a disk.
    Fees: None. This dataset is provided by USGS as a public service.
Metadata_Reference_Information:
  Metadata_Date: 20080410
  Metadata_Review_Date: 20080511
  Metadata_Contact:
    Contact_Information:
      Contact_Organization_Primary:
        Contact_Organization: U.S. Geological Survey
        Contact_Person: Brenda K. Woodward
      Contact_Position: Hydrologist
      Contact_Address:
```

```
      Address_Type: mailing address
      Address: 5231 S 19th St
      City: Lincoln
      State_or_Province: Nebraska
      Postal_Code: 68512
      Country: USA
    Contact_Voice_Telephone: 1-402-328-4100
    Contact_Electronic_Mail_Address: bkwoodwa@usgs.gov
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Extensions:
  Online_Linkage: http://www.esri.com/metadata/esriprof80.html
  Profile_Name: ESRI Metadata Profile
```

Appendix 4. LiDAR Bare-Earth Data

```
Identification_Information:
  Citation:
    Citation_Information:
      Originator: Brenda K. Woodward
      Publication_Date: 2008
      Title: Index of Bare-Earth LiDAR Points for Platte River Channel Survey,
August 2006
      Edition: Version 1.0
      Geospatial_Data_Presentation_Form: vector digital data
      Series_Information:
        Series_Name: Scientific Investigations Report
        Issue_Identification: 2008-5106
      Publication_Information:
        Publication_Place: Reston, Virginia
        Publisher: U.S. Geological Survey
      Online_Linkage: /lookup/getspatial?SIR2008-5106_Platte_LiDAR_index
      Larger_Work_Citation:
        Citation_Information:
          Originator: Brenda K Woodward
          Publication_Date: 2008
          Title: Streamflow and Topographic Characteristics of the Platte River
near Grand Island, Nebraska, 1938-2007
          Series_Information:
            Series_Name: Scientific Investigations Report
            Issue_Identification: SIR 2008-5106
          Publication_Information:
            Publication_Place: Reston, Virginia
            Publisher: U.S. Geological Survey
          Online_Linkage: http://pubs.usgs.gov/
  Description:
    Abstract: This data set provides an index for the Light Detection and
Ranging (LiDAR) survey conducted on August 10, 2006 on a total of 47 square
miles of the Platte River near Grand Island, Nebraska.  The data obtained from
this survey were in the format XYZI (Easting, Northing, Elevation referenced to
the North American Vertical Datum of 1988 (NAVD88), and Intensity).  The data
were collected using an Airborne Laser Terrain Mapper (ALTM) LiDAR system.
Filtering and manual editing the orginal data set removed non-ground points from
the point cloud.  The final data set provided here includes several text files;
each contains the bare-earth points covering a subsection of the 47 square
miles.
    Purpose: The LiDAR data were collected to compare topographic
characteristics among the four channels of the Platte River near Grand Island to
understand streamflow distribution.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 20060810
    Currentness_Reference: ground condition
  Status:
    Progress: Complete
    Maintenance_and_Update_Frequency: None planned
  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate: -98.757417
      East_Bounding_Coordinate: -98.261729
      North_Bounding_Coordinate: 40.884900
      South_Bounding_Coordinate: 40.678316
```

```
  Keywords:
    Theme:
      Theme_Keyword_Thesaurus: ISO 19115
      Theme_Keyword: inlandWaters
    Theme:
      Theme_Keyword_Thesaurus: none
      Theme_Keyword: Light Detection and Ranging
      Theme_Keyword: LiDAR
      Theme_Keyword: Bare-earth
      Theme_Keyword: topography
      Theme_Keyword: terrain
      Theme_Keyword: river channels
      Theme_Keyword: channel morphology
    Place:
      Place_Keyword_Thesaurus: Geographic Names Information System (GNIS)
      Place_Keyword: Grand Island
      Place_Keyword: Platte River
      Place_Keyword: Nebraska
      Place_Keyword: Hall County
  Access_Constraints: None
  Use_Constraints: None
  Point_of_Contact:
    Contact_Information:
      Contact_Person_Primary:
        Contact_Person: Brenda K. Woodward
        Contact_Organization: United States Geological Survey
      Contact_Position: Hydrologist
      Contact_Address:
        Address_Type: mailing and physical address
        Address: 5231 S 19th St
        City: Lincoln
        State_or_Province: Nebraska
        Postal_Code: 68512
        Country: USA
      Contact_Voice_Telephone: 402.328.4100
      Contact_Facsimile_Telephone: 402.328.4101
      Contact_Electronic_Mail_Address: bkwoodwa@usgs.gov
  Data_Set_Credit: City of Grand Island, Nebraska and the Central Platte Natural
Resources District.
  Security_Information:
    Security_Classification_System: None
    Security_Classification: Unclassified
    Security_Handling_Description: None
  Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build 2600)
Service Pack 2; ESRI ArcCatalog 9.2.4.1420
Data_Quality_Information:
  Attribute_Accuracy:
    Attribute_Accuracy_Report: The cell size selected in creating the raster
files from the point data was 100 meters
  Logical_Consistency_Report: All polygons are closed and contain attributes
cateloging LiDAR panels.  Reviewers examined selected polygons to ensure panels
and attributes were consistent.
  Completeness_Report: This index covers LiDAR data collected along the Platte
River between Shelton, NE and Grand Island, NE.  Overlap between LiDAR scans
does occur, so this index approximates the area of each.
  Positional_Accuracy:
    Horizontal_Positional_Accuracy:
```

```
      Horizontal_Positional_Accuracy_Report: This index provides an
approximation of the extent of the individual panels.  The horizontal accuracy
was not assessed.
  Lineage:
    Source_Information:
      Source_Citation:
        Citation_Information:
          Originator: Sanborn
          Publication_Date: 2008
          Title: Platte River LiDAR data collected near Grand Island, Nebraska,
2006.
          Series_Information:
            Series_Name: Scientific Investigations Report
            Issue_Identification: 2008-5106
      Type_of_Source_Media: CD-ROM
      Source_Time_Period_of_Content:
        Time_Period_Information:
          Single_Date/Time:
            Calendar_Date: 20060810
        Source_Currentness_Reference: ground condition
      Source_Citation_Abbreviation: LiDAR Text
      Source_Contribution: Extent of LiDAR panels
    Process_Step:
      Process_Description: LiDAR point cloud data filtered and edited to remove
points corresponding to any elevations other than bare-earth
      Source_Used_Citation_Abbreviation: Platte River LiDAR data collected near
Grand Island, Nebraska, 2006
      Process_Date: 20061115
    Process_Step:
      Process_Description: Creating shapefiles from each text file and adding a
long integer attribute item named "NUMBER" to the attribute table of each.
Populated "NUMBER" with the value corresponding to the text file number: 1
through 125.
      Process_Date: 20070608
    Process_Step:
      Process_Description: Spatial Analyst (ESRI, 2007) was used to convert the
shapefiles of point features to a raster with a cell size of 100 meters.  Cell
value was assigned by field "NUMBER", which created a grid of cells that
indicated which text file covered that area.
      Process_Date: 20070608
    Process_Step:
      Process_Description: All grids were combined into a single grid file using
the merge command.
      Process_Date: 20070608
    Process_Step:
      Process_Description: The one grid file was converted to polygons.  The
resulting attribute value for each polygon is the reference number of the
corresponding text file.
      Process_Date: 20070608
    Process_Step:
      Process_Description: Metadata created
      Process_Date: 20080315
    Process_Step:
      Process_Description: Data reviewed by Ryan Thompson, USGS, Huron, South
Dakota
      Process_Date: 20080425
    Process_Step:
```

```
      Process_Description: Data reviewed by Michaela Johnson, USGS, Lincoln,
Nebraska
      Process_Date: 20080511
Spatial_Data_Organization_Information:
  Direct_Spatial_Reference_Method: Vector
  Point_and_Vector_Object_Information:
    SDTS_Terms_Description:
      SDTS_Point_and_Vector_Object_Type: G-polygon
      Point_and_Vector_Object_Count: 212
Spatial_Reference_Information:
  Horizontal_Coordinate_System_Definition:
    Planar:
      Grid_Coordinate_System:
        Grid_Coordinate_System_Name: Universal Transverse Mercator
        Universal_Transverse_Mercator:
          UTM_Zone_Number: 14
          Transverse_Mercator:
            Scale_Factor_at_Central_Meridian: 0.999600
            Longitude_of_Central_Meridian: -99.000000
            Latitude_of_Projection_Origin: 0.000000
            False_Easting: 500000.000000
            False_Northing: 0.000000
      Planar_Coordinate_Information:
        Planar_Coordinate_Encoding_Method: coordinate pair
        Coordinate_Representation:
          Abscissa_Resolution: 0.001
          Ordinate_Resolution: 0.001
        Planar_Distance_Units: meters
    Geodetic_Model:
      Horizontal_Datum_Name: North American Datum of 1983
      Ellipsoid_Name: Geodetic Reference System 80
      Semi-major_Axis: 6378137.000000
      Denominator_of_Flattening_Ratio: 298.257222
Entity_and_Attribute_Information:
  Detailed_Description:
    Entity_Type:
      Entity_Type_Label: SIR2008-5106_Platte_LiDAR_index
      Entity_Type_Definition: Spatial index of text files containing LiDAR
surveyed bare-earth points
      Entity_Type_Definition_Source: U.S. Geological Survey
    Attribute:
      Attribute_Label: FID
      Attribute_Definition: Internal feature number.
      Attribute_Definition_Source: ESRI
      Attribute_Domain_Values:
        Unrepresentable_Domain: Sequential unique whole numbers that are
automatically generated.
    Attribute:
      Attribute_Label: Shape
      Attribute_Definition: Feature geometry.
      Attribute_Definition_Source: ESRI
      Attribute_Domain_Values:
        Unrepresentable_Domain: Coordinates defining the features.
    Attribute:
      Attribute_Label: GRID_CODE
      Attribute_Definition: Number corresponding to the text file that contains
LiDAR bare-earth point data for the polygon
```

```
      Attribute_Definition_Source: U.S. Geological Survey
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 1
          Range_Domain_Maximum: 125
Distribution_Information:
  Distributor:
    Contact_Information:
      Contact_Organization_Primary:
        Contact_Organization: U.S. Geological Survey
      Contact_Position: Ask USGS- Water Webserver Team
      Contact_Address:
        Address_Type: mailing address
        Address: 507 National Center
        City: Reston
        State_or_Province: Virginia
        Postal_Code: 20192
        Country: USA
      Contact_Voice_Telephone: 1-888-275-8747 (1-888-ASK-USGS)
      Contact_Electronic_Mail_Address:
http://water.usgs.gov/user_feedback_form.html
  Resource_Description: Downloadable Data
  Distribution_Liability:
    The U.S. Geological Survey makes no guarantee nor offers any warranty
concerning the accuracy, condition, or application of the information contained
in this geographic data release.

    Although these data have been used successfully on computers of the USGS, no
warranty, expressed or implied, is made by WRD regarding the use of these data
on any other system, nor does the fact of distribution constitute or imply any
such warranty.

    In no event shall the USGS have any liability whatsoever for payment of any
consequential, incidental, indirect, special, or tort damages of any kind,
including, but not limited to, any loss of profits, arising out of the delivery,
installation, operation, or use of these data.

    This database has been approved for release and publication by the Director
of the USGS.  Although this database has been subjected to rigorous review and
is substantially complete, the USGS reserves the right to revise the data
pursuant to further analysis and review.  Furthermore, it is released on
condition that neither the USGS nor the United States Government may be held
liable for any damages resulting from its authorized or unauthorized use.

    Any use of trade, product, or firm names is for descriptive purposes only
and does not imply endorsement by the U.S. Government.
  Standard_Order_Process:
    Digital_Form:
      Digital_Transfer_Information:
        Format_Name: shapefile
        Format_Version_Number: Version 1.0
        Format_Information_Content: Index of LiDAR point data sets
        File_Decompression_Technique: zip
        Transfer_Size: 0.120
      Digital_Transfer_Option:
        Online_Option:
          Computer_Contact_Information:
```

```
            Network_Address:
              Network_Resource_Name:
http://water.usgs.gov/GIS/dsdl/SIR_Platte_LiDAR_index.shp
          Access_Instructions: The Standard_Order_Process explains the files
that are available for downloading.  Several files may be available. Click on
the link following Network_Resource_Name to get the file you want.  Save this
file to a disk.
    Fees: None. This dataset is provided by USGS as a public service.
  Available_Time_Period:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 20060810
Metadata_Reference_Information:
  Metadata_Date: 20080403
  Metadata_Review_Date: 20080511
  Metadata_Contact:
    Contact_Information:
      Contact_Organization_Primary:
        Contact_Organization: U.S. Geological Survey
        Contact_Person: Brenda K. Woodward
      Contact_Position: Hydrologist
      Contact_Address:
        Address_Type: mailing address
        Address: 5231 S 19th St
        City: Lincoln
        State_or_Province: Nebraska
        Postal_Code: 68512
        Country: USA
      Contact_Voice_Telephone: 1-402-328-4100
      Contact_Electronic_Mail_Address: bkwoodwa@usgs.gov
  Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
  Metadata_Standard_Version: FGDC-STD-001-1998
  Metadata_Time_Convention: local time
  Metadata_Extensions:
    Online_Linkage: http://www.esri.com/metadata/esriprof80.html
    Profile_Name: ESRI Metadata Profile
```

```
Identification_Information:
  Citation:
    Citation_Information:
      Originator: Brenda K. Woodward
      Publication_Date: 2008
      Title: Bare-Earth LiDAR Points for Platte River Channel Survey, August
2006
      Edition: Version 1.0
      Geospatial_Data_Presentation_Form: vector digital data
      Publication_Information:
        Publication_Place: Reston, Virginia
        Publisher: U.S. Geological Survey
      Online_Linkage: /lookup/getspatial?SIR2008-5106_Platte_LiDAR_000001-000125
      Larger_Work_Citation:
        Citation_Information:
          Originator: Brenda K. Woodward
          Publication_Date: 2008
          Title: Streamflow and Topographic Characteristics of the Platte River
near Grand Island, Nebraska, 1938-2007
          Series_Information:
            Series_Name: Scientific Investigations Report
            Issue_Identification: SIR 2008-5106
          Publication_Information:
            Publication_Place: Reston, Virginia
            Publisher: U.S. Geological Survey
          Online_Linkage: http://pubs.usgs.gov/
  Description:
    Abstract: A Light Detection and Ranging (LiDAR) survey was conducted on
August 10, 2006 on a total of 47 square miles of the Platte River near Grand
Island, Nebraska.  The data obtained from this survey were in the format XYZI
(Easting, Northing, Elevation referenced to the North American Vertical Datum of
1988 (NAVD88), and Intensity).  The data were collected using an Airborne Laser
Terrain Mapper (ALTM) LiDAR system.  Filtering and manual editing of the
original data set removed non-ground points from the point cloud.  The final
data set provided with this metadata includes only the bare-earth points
separated into 123 text files that together cover the study area of 47 square
miles.
    Purpose: LiDAR data were collected to compare topographic characteristics
among four channels of the Platte River near Grand Island to better understand
streamflow distribution among these channels.  The bare-earth points are being
published as a public information resource to allow their repeated use.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 20060810
    Currentness_Reference: ground condition
  Status:
    Progress: Complete
    Maintenance_and_Update_Frequency: None planned
  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate: -98.757417
      East_Bounding_Coordinate: -98.261729
      North_Bounding_Coordinate: 40.884900
      South_Bounding_Coordinate: 40.678316
  Keywords:
    Theme:
```

```
      Theme_Keyword_Thesaurus: ISO 19115
      Theme_Keyword: inlandWaters
    Theme:
      Theme_Keyword_Thesaurus: None
      Theme_Keyword: Light Detection and Ranging
      Theme_Keyword: LiDAR
      Theme_Keyword: Bare-earth
      Theme_Keyword: topography
      Theme_Keyword: terrain
      Theme_Keyword: river channels
      Theme_Keyword: channel morphology
    Place:
      Place_Keyword_Thesaurus: Geographic Names Informaiton System (GNIS)
      Place_Keyword: Grand Island
      Place_Keyword: Platte River
      Place_Keyword: Nebraska
      Place_Keyword: Hall County
  Access_Constraints: None
  Use_Constraints: None
  Point_of_Contact:
    Contact_Information:
      Contact_Person_Primary:
        Contact_Person: Brenda K. Woodward
        Contact_Organization: U.S. Geological Survey
      Contact_Position: Hydrologist
      Contact_Address:
        Address_Type: mailing and physical address
        Address: 5231 S 19th St
        City: Lincoln
        State_or_Province: Nebraska
        Postal_Code: 68512
        Country: USA
      Contact_Voice_Telephone: 402.328.4100
      Contact_Facsimile_Telephone: 402.328.4101
      Contact_Electronic_Mail_Address: bkwoodwa@usgs.gov
  Data_Set_Credit: Prepared in cooperation with the City of Grand Island,
Nebraska, and the Central Platte Natural Resources District.  Also, the USGS
Northern Prairie Wildlife Research Center is thanked for xxx Program contributed
funding to expand the LiDAR collection effort.
  Security_Information:
    Security_Classification_System: None
    Security_Classification: Unclassified
    Security_Handling_Description: None
  Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build 2600)
Service Pack 2; ESRI ArcCatalog 9.2.4.1420
Data_Quality_Information:
  Logical_Consistency_Report: These point data were examined and found to be
topologically clean.  Reviewers imported text files and compared it with
existing data to check for valid elevational information.  Visual inspection of
spatial elevation data was conducted to look for patterns inconsistant with land
features.
  Completeness_Report: Small data voids exist in parts of the channel that
contained water.  This is because the type of laser used does not penetrate
water.  Data covered the dry channel bed and parts of the upland from Shelton,
NE to Grand Island, NE.
  Positional_Accuracy:
    Horizontal_Positional_Accuracy:
```

Horizontal_Positional_Accuracy_Report: The horizontal accuracy was assessed relative to 10 known bench marks with a resulting root mean squared error (RMSE) of 0.5 m.
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: The vertical accuracy was assessed with a resulting RMSE of 15 cm in bare-earth areas and RMSE of 27 cm in vegetated areas. The increased RMSE in vegetated areas is because these areas require additional processing; this additional processing was not completed due to cost and because the main focus of the research was in channel areas. The majority of these heavily vegetated and less accurate areas fall in cornfields along the banks of the river. Processing the original data to retain only the bare-earth points resulted in the removal of 95% of artifacts, 98% of outliers, 97% of vegetation points, and 99% of points from structures from the point data set. Vertical RMSE was calculated using 10 ground control points. The geodetic control network used to survey the 10 ground control points included three high-order National Geodetic Survey benchmarks. In addition, two types of calibrations were performed to identify systematic bias in scale, verify pitch and roll compensation, and identify the level of noise and system biases in vertical coordinates.
Lineage:
Process_Step:
Process_Description: LiDAR point data were collected by Sanborn (Colorado Springs, CO) using an Airborne Laser Terrain Mapper (ALTM) LiDAR system (Optech, Vaughan, Ontario, Canada). Detailed descriptions of these methods are provided in Woodward (2008, Appendix 2).
Process_Date: 20060810
Process_Step:
Process_Description: Airborne GPS data for georeferencing the LiDAR points were post-processed using NovAtels waypoint GrafNAVTM software (version 7.50) (Alberta, Canada). A fixed-bias carrier phase solution was computed in both the forward and reverse chronological directions. Whenever practical, LiDAR acquisition was limited to periods when the positional dilution of precision (PDOP) was less than 3.0. Detailed descriptions of these methods are provided in Woodward (2008, Appendix 2).
Process_Date: 20060810
Process_Step:
Process_Description: The GPS-derived trajectory was combined with the raw Inertial Movement Unit (IMU) data and post-processed using Optech(Vaughan, Ontario, Canada) software to create the best estimated trajectory (BET). The trajectory is combined with the altitude data and laser range measurements to produce the 3-dimensional coordinates of the mass points (all points not just bare-earth). Detailed descriptions of these methods are provided in Woodward (2008, Appendix 2).
Process_Date: 20061115
Process_Step:
Process_Description: Mass points were classified into first and last returns. Last-return points were further processed to produce the data set described as bare-earth points. Filtering of the last-return points was accomplished using TerraScan (Finland) LiDAR processing and modeling software. Processing steps were as follows: filter for and classify anomalously low points; filter for and classify isolated points (single returns in a water body, bird shot, and so forth); filter for and classify bare earth; interactive quality control of the points classified as bare earth, as well as data voids; Tested vertical accuracy of bare-earth points through comparison with ground control check points. Detailed descriptions of these methods are provided in Woodward (2008, Appendix 2).
Process_Date: 20061115

```
    Process_Step:
      Process_Description: metadata created
      Process_Date: 20080303
    Process_Step:
      Process_Description: Data reviewed by Ryan Thompson, USGS, Huron, South
Dakota
      Process_Date: 20080425
    Process_Step:
      Process_Description: Data reviewed by Michaela Johnson, USGS, Lincoln,
Nebraska
      Process_Date: 20080511
Spatial_Data_Organization_Information:
  Direct_Spatial_Reference_Method: Vector
  Point_and_Vector_Object_Information:
    SDTS_Terms_Description:
      SDTS_Point_and_Vector_Object_Type: Entity point
      Point_and_Vector_Object_Count: 207,386,619
Spatial_Reference_Information:
  Horizontal_Coordinate_System_Definition:
    Planar:
      Grid_Coordinate_System:
        Grid_Coordinate_System_Name: Universal Transverse Mercator
        Universal_Transverse_Mercator:
          UTM_Zone_Number: 14
          Transverse_Mercator:
            Scale_Factor_at_Central_Meridian: 0.999600
            Longitude_of_Central_Meridian: -99.000000
            Latitude_of_Projection_Origin: 0.000000
            False_Easting: 500000.000000
            False_Northing: 0.000000
      Planar_Coordinate_Information:
        Planar_Coordinate_Encoding_Method: coordinate pair
        Coordinate_Representation:
          Abscissa_Resolution: 0.001
          Ordinate_Resolution: 0.001
        Planar_Distance_Units: meters
    Geodetic_Model:
      Horizontal_Datum_Name: North American Datum of 1983
      Ellipsoid_Name: Geodetic Reference System 80
      Semi-major_Axis: 6378137.000000
      Denominator_of_Flattening_Ratio: 298.257222
  Vertical_Coordinate_System_Definition:
    Altitude_System_Definition:
      Altitude_Datum_Name: North American Vertical Datum of 1988
      Altitude_Resolution: 0.001
      Altitude_Distance_Units: meters
      Altitude_Encoding_Method: Explicit elevation coordinate included with
horizontal coordinates
Entity_and_Attribute_Information:
  Detailed_Description:
    Entity_Type:
      Entity_Type_Label: SIR2008-5106_Platte_LiDAR.csv
      Entity_Type_Definition: Bare-earth LiDAR points in individual panels
numbered from 000001-000125
      Entity_Type_Definition_Source: U.S. Geological Survey
    Attribute:
      Attribute_Label: FID
```

```
      Attribute_Definition: Internal feature number.
      Attribute_Definition_Source: ESRI
      Attribute_Domain_Values:
        Unrepresentable_Domain: Sequential unique whole numbers that are
automatically generated.
    Attribute:
      Attribute_Label: Shape
      Attribute_Definition: Feature geometry.
      Attribute_Definition_Source: ESRI
      Attribute_Domain_Values:
        Unrepresentable_Domain: Coordinates defining the features.
    Attribute:
      Attribute_Label: Easting
      Attribute_Definition: Universal Tranverse Mercator, Zone 14 Easting
coordinate, in meters
      Attribute_Definition_Source: Sanborn
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 520000
          Range_Domain_Maximum: 565000
          Attribute_Units_of_Measure: meters
    Attribute:
      Attribute_Label: Northing
      Attribute_Definition: Universal Tranverse Mercator, Zone 14 Northing
coordinate, in meters
      Attribute_Definition_Source: Sanborn
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 4500000
          Range_Domain_Maximum: 4525500
          Attribute_Units_of_Measure: meters
    Attribute:
      Attribute_Label: Elevation
      Attribute_Definition: Elevation referenced to the North American Vertical
Datum of 1988, in meters
      Attribute_Definition_Source: Sanborn
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 550
          Range_Domain_Maximum: 620
          Attribute_Units_of_Measure: meters
    Attribute:
      Attribute_Label: Intensity
      Attribute_Definition: Brightness value representing relative intensity of
light return, where larger values correspond to more intense returns
      Attribute_Definition_Source: Sanborn
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0
          Range_Domain_Maximum: 255
          Attribute_Units_of_Measure: none
      Attribute_Value_Accuracy_Information:
        Attribute_Value_Accuracy: 0.1
        Attribute_Value_Accuracy_Explanation: Intensity values provided by
contractor (Sanborn, Colorado Springs, CO) with precision to one decimal place.
However, rank order was not evaluated
      Attribute_Measurement_Frequency: None planned
```

```
Distribution_Information:
  Distributor:
    Contact_Information:
      Contact_Organization_Primary:
        Contact_Organization: U.S. Geological Survey
      Contact_Position: Ask USGS- Water Webserver
      Contact_Address:
        Address_Type: mailing address
        Address: 507 National Center
        City: Reston
        State_or_Province: Virgina
        Postal_Code: 20192
        Country: USA
      Contact_Voice_Telephone: 1-888-275-8747 (1-888-ASK-USGS)
      Contact_Electronic_Mail_Address:
http://water.usgs.gov/users_feedbakc_form.html
  Resource_Description: Downloadable Data
  Distribution_Liability:
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    Any use of trade, product, or firm names is for descriptive purposes only
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  Standard_Order_Process:
    Digital_Form:
      Digital_Transfer_Information:
        Format_Name: text
        Format_Version_Number: Version 1.0
        Format_Information_Content: LiDAR 3-dimensional point data with
intensity values
        File_Decompression_Technique: Winzip
        Transfer_Size: 188.675
      Digital_Transfer_Option:
        Online_Option:
          Computer_Contact_Information:
            Network_Address:
              Network_Resource_Name:
http://water.usgs.gov/GIS/dsdl/SIR_Platte_LiDAR_000001-000125.zip
```

```
          Access_Instructions: The Standard_Order_Process explains the files
that are available for downloading.  Several files may be available. Click on
the link following Network_Resource_Name to get the file you want.  Save this
file to a disk.
    Fees: None. This dataset is provided by USGS as a public service.
Metadata_Reference_Information:
  Metadata_Date: 20080228
  Metadata_Review_Date: 20080511
  Metadata_Contact:
    Contact_Information:
      Contact_Organization_Primary:
        Contact_Organization: U.S. Geological Survey
      Contact_Position: Hydrologist
      Contact_Address:
        Address_Type: mailing and physical address
        Address: 5231 S 19th St
        City: Lincoln
        State_or_Province: Nebraska
        Postal_Code: 68512
        Country: USA
      Contact_Voice_Telephone: 402-328-4100
      Contact_Electronic_Mail_Address: bkwoodwa@usgs.gov
  Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
  Metadata_Standard_Version: FGDC-STD-001-1998
  Metadata_Time_Convention: local time
  Metadata_Extensions:
    Online_Linkage: http://www.esri.com/metadata/esriprof80.html
    Profile_Name: ESRI Metadata Profile
```

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