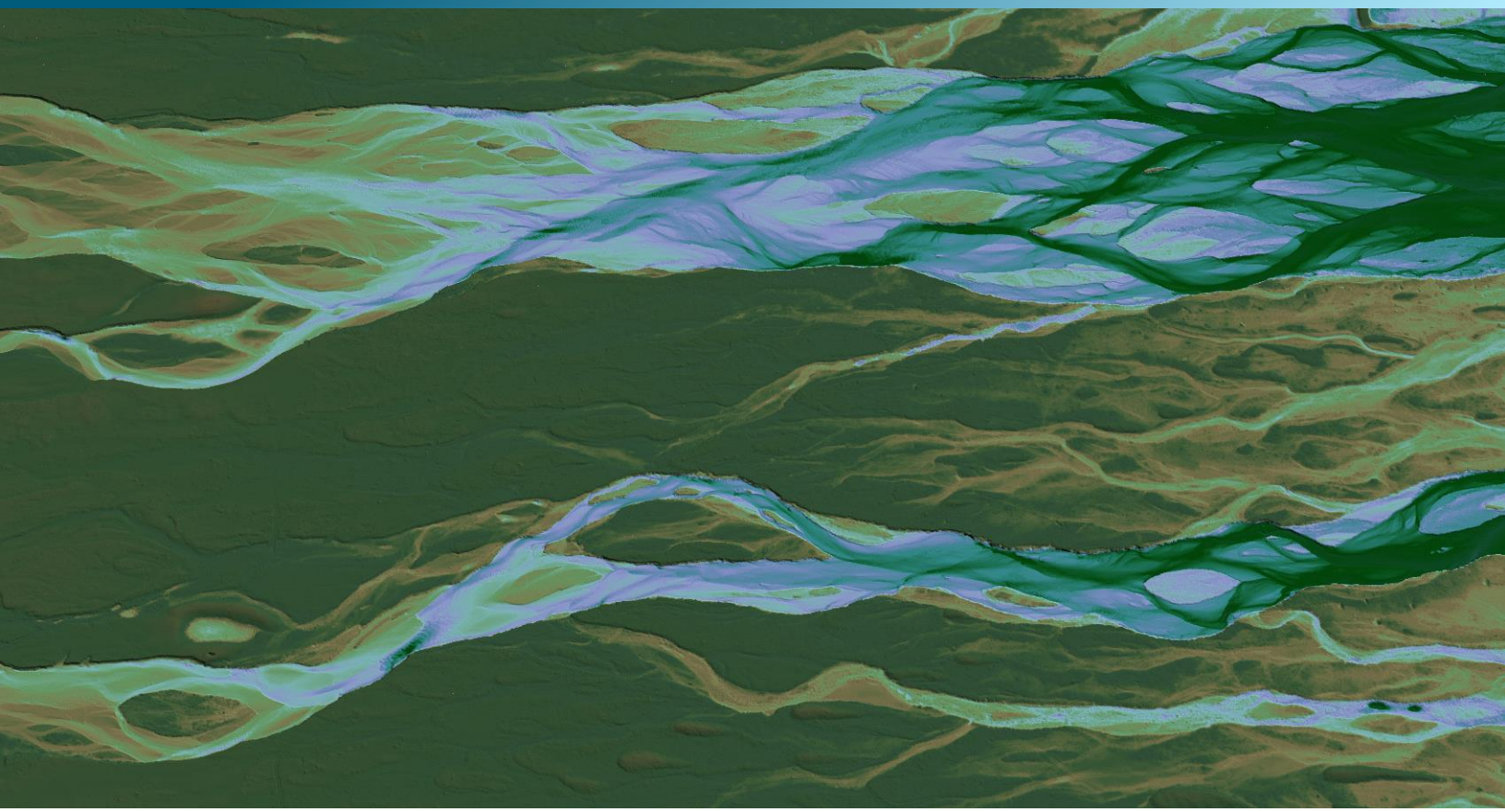
March 10, 2025



Platte River, Nebraska Fall 2024

Topobathymetric Lidar Technical Data Report

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Cover Photo: A view looking north at the Platte River. The image was created from the lidar bare earth model colored by elevation.

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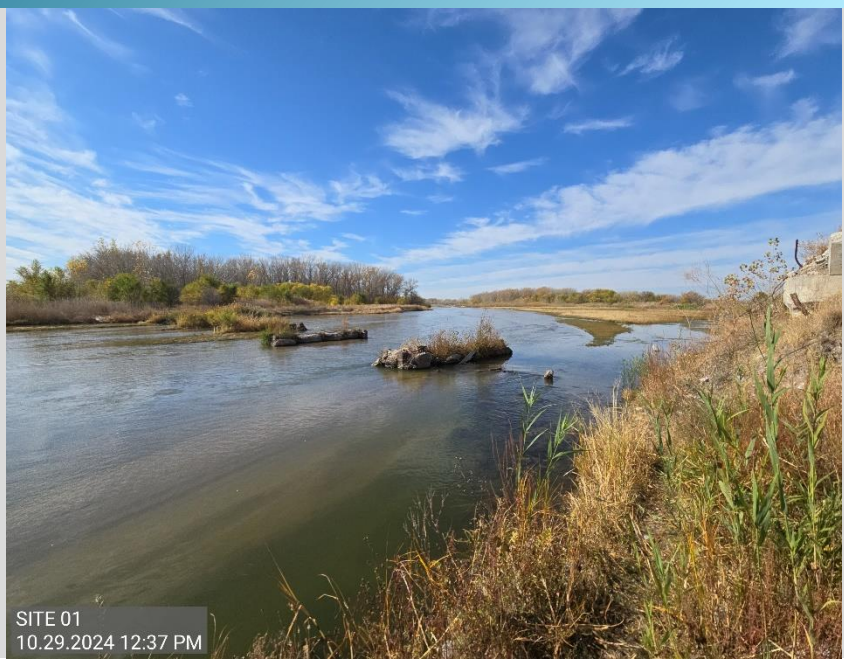
INTRODUCTION

This photo, taken by NV5 acquisition staff, shows a view of the Platte River at one of the bathymetric accuracy check point locations in the Platte River Fall 2024 ground survey.



In June 2024, NV5 was contracted by Headwaters Corporation to collect topobathymetric Light Detection and Ranging (lidar) data in the fall of 2024 as part of a multi-year (2024-2026) contract over the Platte River and Plum Creek in central Nebraska. This data collection is part of NV5's ongoing partnership with Headwaters Corporation to provide data aiding in the Platte River Recovery Implementation Program. The Program is aimed at enhancing, restoring, and protecting the habitat for endangered species associated with the river system, specifically targeting the whooping crane, least tern, piping plover, and pallid sturgeon species. Traditional near-infrared (NIR) lidar was fully integrated with green wavelength (bathymetric) lidar in order to provide a seamless topobathymetric lidar dataset for analysis. This type of lidar data is well-suited for use in riverine locations and is useful for assessing channel morphology and accurately modeling the topobathymetric surface inside of the study area.

This report accompanies the delivered topobathymetric lidar data and documents contract specifications, data acquisition procedures, processing methods, and analysis of the final dataset including lidar accuracy, depth penetration, and density. Acquisition dates and acreage are shown in Table 1, a complete list of contracted deliverables provided to Headwaters Corporation is shown in Table 3 with the coordinate reference system information for these deliverables shown in Table 2, and the project extent is shown in Figure 1.

Table 1: Acquisition dates, acreage, and data types collected on the Platte River site

Project Site	Total Acres	Aerial Acquisition Dates	Data Type
Platte River, Nebraska	89,953	10/28/2024 – 11/10/2024	Topobathymetric - Lidar
Plum Creek, Nebraska	1,241	10/28/2024 – 10/29/2024, 11/5/2024, 11/10/2024	Topobathymetric - Lidar

Deliverable Products

Table 2: Deliverable product coordinate reference system information

Projection	Horizontal Datum	Vertical Datum	Units
Nebraska State Plane	NAD83 (2011)	NAVD88 (GEOID03)	US Survey Feet

Table 3: Lidar products delivered for the Platte River site

Product Type	File Type	Product Details
Points	LAS v.1.4 (*.las)	• All Classified Returns
Rasters	3.0 foot ERDAS Imagine Files (*.img)	• Mosaicked and Tiled Void-Interpolated Topobathymetric Bare Earth Digital Elevation Model (DEM) • Mosaicked and Tiled Void-Clipped Topobathymetric Bare Earth Digital Elevation Model (DEM) • Mosaicked Bare Earth and Water Surface Models with Hydroflattened Ponds (DEM) • Mosaicked Highest Hit Digital Surface Model (DSM) • Mosaicked Depth Raster
Rasters	1.5 foot GeoTIFFs (*.tif)	• Green Sensor Intensity Images • NIR Sensor Intensity Images
Vectors	Shapefiles (*.shp)	• Area of Interest • Tile Index • Flightlines • Ground Survey Data • Bathymetric Coverage Shape • Water's Edge Breaklines • Hydroflattening Breaklines (Platte Only)
Metadata	Extensible Markup Language (*.xml)	• Metadata
Reports	Adobe Acrobat (*.pdf)	• Lidar Technical Data Report

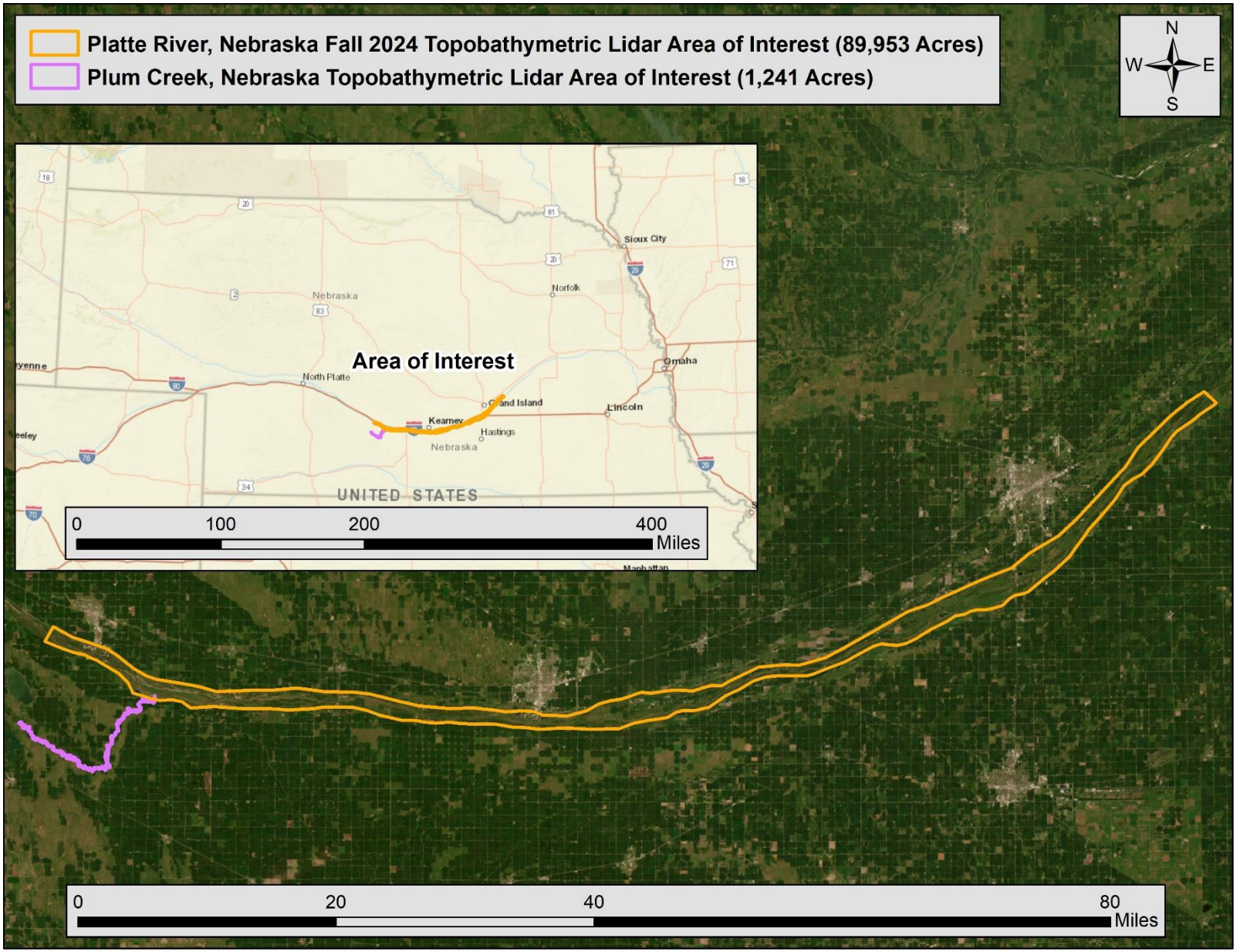


Figure 1: Location map of the Platte River site in Nebraska Fall 2024

ACQUISITION

NV5's ground acquisition equipment set up in the Platte River Lidar study area

Planning

In preparation for data collection, NV5 reviewed the project area and developed a specialized flight plan to ensure complete coverage of the Platte River Lidar study area at the target combined point density of at least 8 points/m^2 (0.74 points/ft^2). Acquisition parameters including orientation relative to terrain, flight altitude, pulse rate, scan angle, and ground speed were adapted to optimize flight paths and flight times while meeting all contract specifications. Figure 5 shows these optimized flight paths and dates.

Factors such as satellite constellation availability and weather windows must be considered during the planning stage. Any weather hazards or conditions affecting the flight were continuously monitored due to the potential impact on the daily success of airborne and ground operations. Logistical considerations including private property access and potential air space restrictions were also reviewed. Channel flow rates and gage height (Figure 2 and Figure 3) as well as water clarity (Figure 4) were monitored in the area of interest in order to target data acquisition while channel flow rates were below 1,000 CFU.

Turbidity Measurements and Secchi Depth Readings

In order to assess water clarity conditions prior to and during lidar and digital imagery collection, NV5 collected turbidity measurements, Secchi depth readings, and wind speed measurements. Readings were collected at 17 locations throughout the project site between October 29th and November 6th, 2024. Turbidity was recorded three times to confirm measurements. Table 4 below provides turbidity and Secchi depth results per site on each day of data collection. A true Secchi depth reading is where the Secchi depth reaches extinction. However, because of safety concerns and accessibility, all Secchi depth readings were noted to have reached the bottom surface of the riverbed.

Table 4: 2024 Water clarity observations for lidar flights

Date	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)*	Wind Speed (knots)
10/29	SITE_01	40° 44' 8.958"	-99° 44' 36.62"	12.9	13.8	8.27	0.40	5
10/29	SITE_20	40° 41' 2.687"	-99° 39' 12.74"	12.8	11.8	12.7	0.60	5
10/31	SITE_04	40° 40' 58.792"	-99° 22' 47.288"	5.61	5.83	5.11	0.40	5
10/31	SITE_05	40° 41' 13.079"	-99° 20' 24.336"	6.83	6.62	5.73	0.20	5
11/01	SITE_06	40° 40' 1.43"	-99° 15' 20.419"	4.05	3.78	3.94	0.50	10
11/01	SITE_07	40° 40' 10.773"	-99° 10' 5.983"	6.17	6.02	6.28	0.50	10
11/01	SITE_08	40° 39' 31.422"	-99° 5' 10.244"	3.74	4.24	3.53	0.20	5
11/01	SITE_09	40° 41' 2.388"	-98° 57' 3.704"	5.41	5.56	4.61	0.40	5
11/01	SITE_10	40° 40' 31.613"	-98° 50' 51.054"	4.42	4.37	4.64	0.50	5
11/05	SITE_12	40° 45' 0.116"	-98° 35' 8.926"	25.3	24.1	26.3	0.60	Calm
11/05	SITE_13	40° 46' 19.051"	-98° 29' 33.458"	18.3	17.9	15.2	0.40	Calm
11/06	SITE_14	40° 48' 52.537"	-98° 22' 46.658"	12.8	12.3	11.1	0.70	5
11/06	SITE_15	40° 48' 13.097"	-98° 22' 5.134"	9.11	9.77	10.3	0.20	5
11/06	SITE_16	40° 49' 48.019"	-98° 20' 22.195"	17.4	17.5	15.2	1.00	5
11/06	SITE_17	40° 49' 15.265"	-98° 20' 22.519"	8.03	8.86	7.94	0.20	5
11/06	SITE_18	40° 52' 20.82"	-98° 16' 47.354"	26.0	23.5	25.3	0.30	5
11/06	SITE_19	40° 59' 8.556"	-98° 8' 42.584"	17.7	17.6	15.5	0.80	5

** Measurement is depth to the bottom surface due to observational depth limitations*

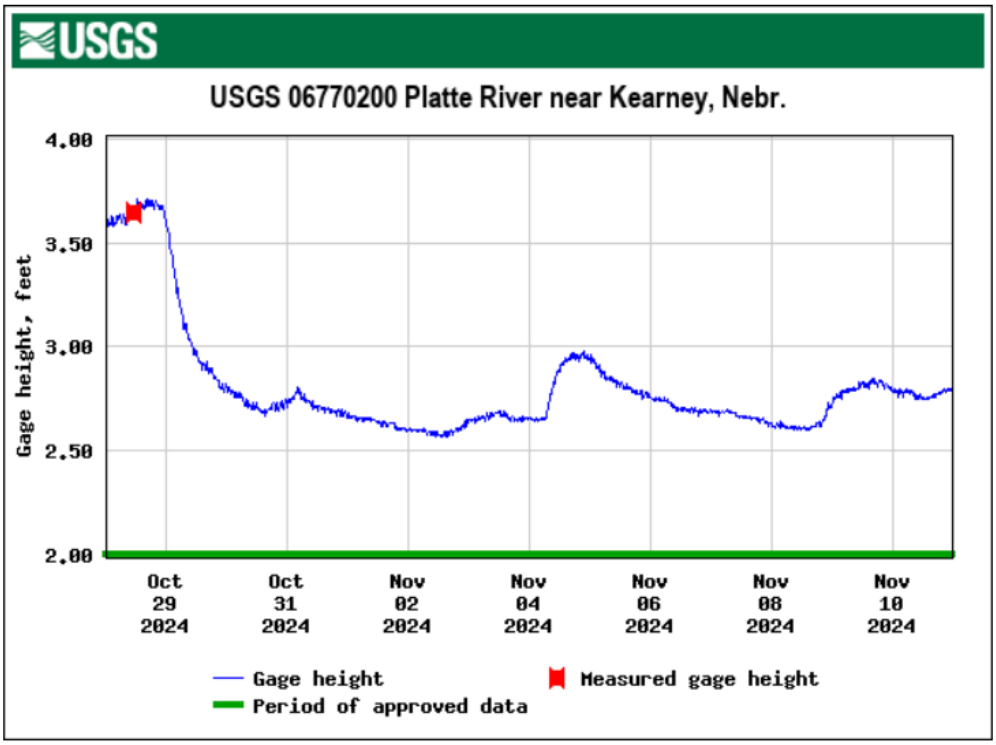


Figure 2: USGS Station 06770200 gage height along the Platte River near Kearney, Nebraska at the time of lidar acquisition.

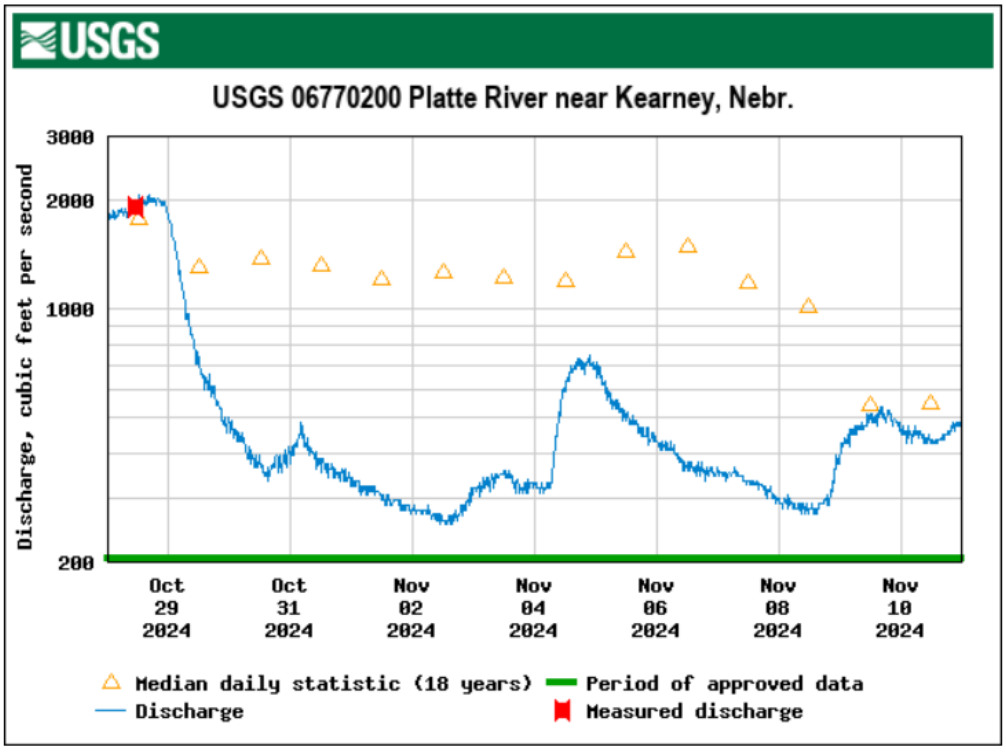


Figure 3: USGS Station 06770200 flow rates along the Platte River near Kearney, Nebraska at the time of lidar acquisition.

Figure 4: This photo taken by NV5 acquisition staff displays water clarity conditions within the Platte River site.

Airborne Lidar Survey

The lidar survey was accomplished using a Riegl VQ-880-GII green laser system mounted in a Cessna Grand Caravan. The Riegl VQ-880-GII boasts a higher repetition pulse rate (up to 550 kHz), higher scanning speed, small laser footprint, and wide field of view which allows for seamless collection of high-resolution data of both topographic and bathymetric surfaces. The green wavelength (ʎ=532 nm) laser is capable of collecting high resolution topography data, as well as penetrating the water surface with minimal spectral absorption by water. The Riegl VQ-880-GII contains an integrated NIR laser (ʎ=1064 nm) that adds additional topography data and aids in water surface modeling. The Riegl VQ-880-GII laser system can record unlimited range measurements (returns) per pulse, however a maximum of 15 returns can be stored due to LAS v1.4 file limitations.

The recorded waveform enables range measurements for all discernible targets for a given pulse. The typical number of returns digitized from a single pulse range from 1 to 8 in the Platte River project dataset. It is not uncommon for some types of surfaces (e.g., dense vegetation or water) to return fewer pulses to the lidar sensor than the laser originally emitted. The discrepancy between first return and overall delivered density will vary depending on terrain, land cover, and the prevalence of water bodies. All discernible laser returns were processed for the output dataset. Table 5 summarizes the settings used to yield an average pulse density of at least 8 pulses/m^2 over the Platte River project area. Figure 5 shows the flightlines acquired using these lidar specifications.

All areas were surveyed with an opposing flight line side-lap of ≥60% (≥120% overlap) in order to reduce laser shadowing and increase surface laser painting. To accurately solve for laser point position (geographic coordinates x, y, and z), the positional coordinates of the airborne sensor and the orientation of the aircraft to the horizon (attitude) were recorded continuously throughout the lidar data collection mission. Position of the aircraft was measured twice per second (2 Hz) by an onboard differential GPS unit, and aircraft attitude was measured 200 times per second (200 Hz) as pitch, roll, and yaw (heading) from an onboard inertial measurement unit (IMU). To allow for post-processing correction and calibration, aircraft and sensor position and attitude data are indexed by GPS time.

Table 5: Lidar specifications and aerial survey settings

Parameter	Green Laser	NIR Laser
Acquisition Dates	10/28/2024 – 11/10/2024	10/28/2024 – 11/10/2024
Aircraft Used	Cessna Grand Caravan	Cessna Grand Caravan
Sensor	Riegl	Riegl
Laser Channel	VQ-880GII-Green	VQ-880GII-IR
Maximum Returns	14	13
Resolution/Density	Average 8 points/m²	Average 8 points/m²
Nominal Pulse Spacing	0.35 m	0.35 m
Survey Altitude (AGL)	450 m	450 m
Survey speed	135 knots	135 knots
Field of View	40°	42°
Mirror Scan Rate	80 Lines per Second	Uniform Point Spacing
Target Pulse Rate	200 kHz	300 kHz
Pulse Length	1.5 ns	3 ns
Laser Pulse Footprint Diameter	31.5 cm	13.5 cm
Central Wavelength	532 nm	1064 nm
Pulse Mode	MTA (multiple times around)	MTA (multiple times around)
Beam Divergence	0.7 mrad	0.3 mrad
Swath Width	328 m	345 m
Swath Overlap	60%	60%
Intensity	16-bit	16-bit
Vertical Accuracy	$RMSE_Z \leq 9.2$ cm	$RMSE_Z \leq 9.2$ cm
Horizontal Accuracy	$RMSE_{NE} \leq 60$ cm	$RMSE_{NE} \leq 60$ cm

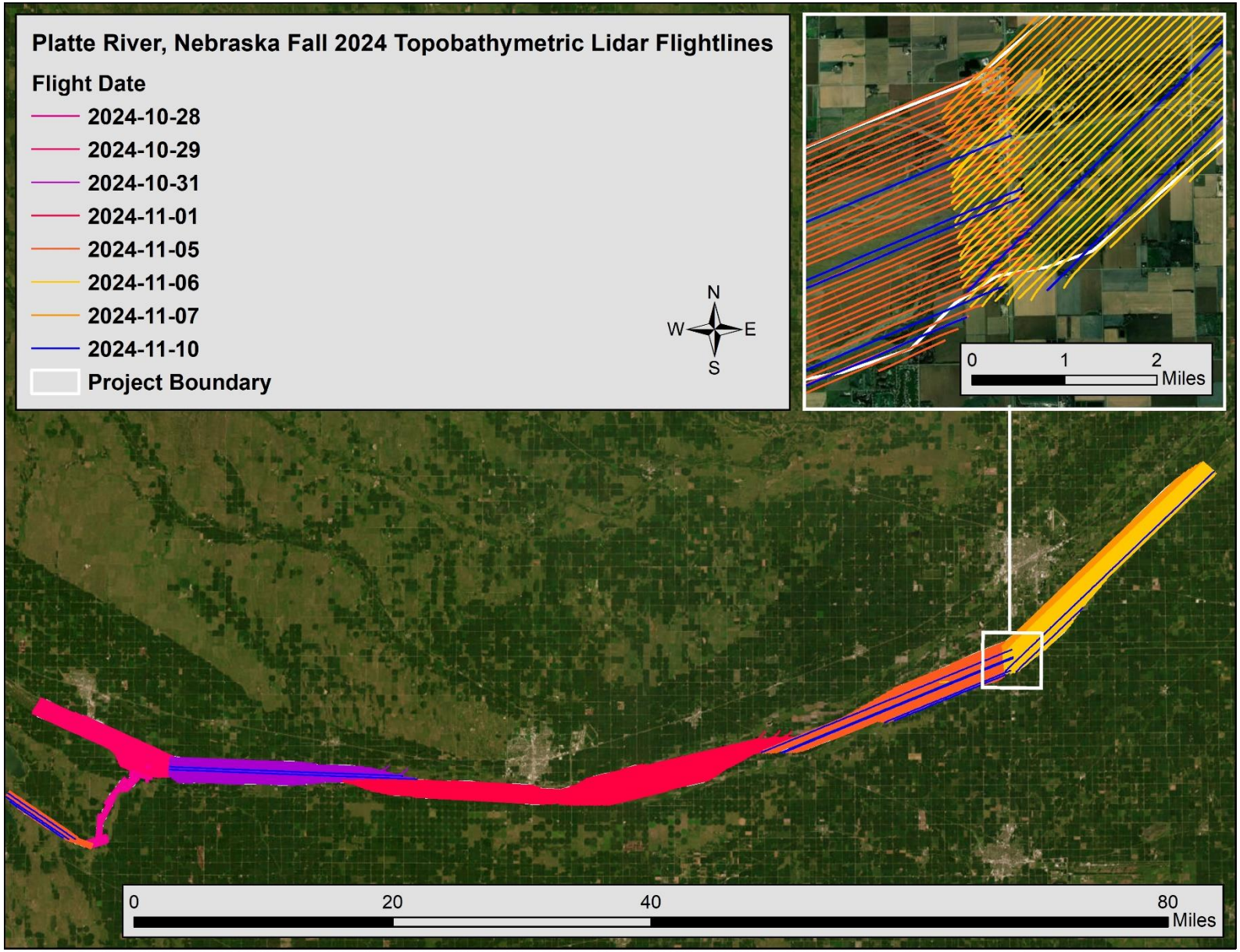


Figure 5: Flightlines map

Ground Survey

Ground control surveys, including monumentation and ground survey points (GSPs), were conducted to support the airborne acquisition. Previously acquired ground control data from Fall 2020 was used for calibration and to perform quality assurance checks on the final lidar data. Additional Fall 2024 ground control data were also used for quality assurance purposes.

Base Stations

Base stations were used for collection of ground survey points using real time kinematic (RTK), post processed kinematic (PPK), and fast static (FS) survey techniques.

Base station locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage. For the Fall 2024 ground survey, NV5 utilized one permanent real-time network (RTN) base station from the Trimble VRSNow network, two RTN base stations from the Hexagon SmartNet network, and one NGS monument. NV5 also established three new monuments using 6” mag hub nails with orange survey washers and 5/8” x 30” rebar topped with stamped 2 ½ " aluminum caps. (Table 6, Figure 6). Two of these base stations were also represented in the Fall 2020 ground survey (Table 7). NV5’s professional land surveyor, Steven J. Hyde (NEPLS#769), oversaw and certified the ground survey.

Table 6: Base station positions for the Platte River Fall 2024 acquisition. Coordinates are on the NAD83(2011) datum, epoch 2010.00

Monument ID	Latitude	Longitude	Ellipsoid (meters)	Owner
NELN	40° 46' 05.66516"	-99° 42' 43.38894"	708.806	VRSNow
NEGN	40° 54' 37.07488"	-98° 22' 51.42422"	555.380	SmartNet
NEKY	40° 42' 38.93413"	-99° 04' 44.99783"	647.052	SmartNet
LH1439	40° 42' 50.87194"	-99° 21' 00.62321"	662.992	NGS
PLATTE_01	40° 41' 19.90398"	-99° 32' 24.32367"	679.913	NV5
PLATTE_02	40° 45' 20.93547"	-98° 35' 18.10645"	574.673	NV5
PLATTE_03	40° 56' 42.56961"	-98° 12' 05.87548"	522.372	NV5

Table 7: Base station positions for Platte River Fall 2020 acquisition. Coordinates are on the NAD83(2011) datum, epoch 2010.00

Monument ID	Latitude	Longitude	Ellipsoid (meters)	Owner
NEAA	40° 07' 56.78007"	-99° 22' 13.81927"	612.413	VRSNow
NEDO	40° 46' 39.11703"	-98° 22' 36.49354"	576.962	VRSNow
NELN	40° 46' 05.66516"	-99° 42' 43.38894"	708.806	VRSNow
NEGN	40° 54' 37.07491"	-98° 22' 51.42422"	555.418	SmartNet
NEKY	40° 42' 38.93413"	-99° 04' 44.99783"	647.052	SmartNet

NV5 utilized static Global Navigation Satellite System (GNSS) data collected at 1 Hz recording frequency for each base station. During post-processing, the static GNSS data was triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS[1]) for precise positioning. Multiple independent sessions over the same monument were processed to confirm antenna height measurements and to refine position accuracy.

Ground Survey Points (GSPs)

Ground survey points were collected using real time kinematic (RTK), post-processed kinematic (PPK), and fast-static (FS) survey techniques. For RTK surveys, a roving receiver receives corrections from a nearby base station or Real-Time Network (RTN) via radio or cellular network, enabling rapid collection of points with relative errors less than 1.5 cm horizontal and 2.0 cm vertical. PPK and FS surveys compute these corrections during post-processing to achieve comparable accuracy. RTK and PPK surveys record data while stationary for at least five seconds, calculating the position using at least three one-second epochs. FS surveys record observations for up to fifteen minutes on each GSP in order to support longer baselines. All GSP measurements were made during periods with a Position Dilution of Precision (PDOP) of ≤ 3.0 with at least six satellites in view of the stationary and roving receivers. See Table 8 for NV5 ground survey equipment information.

GSPs were collected in areas where good satellite visibility was achieved on paved roads and other hard surfaces such as gravel or packed dirt roads. GSP measurements were not taken on highly reflective surfaces such as center line stripes or lane markings on roads due to the increased noise seen in the laser returns over these surfaces. GSPs were collected within as many flightlines as possible; however, the distribution of GSPs depended on ground access constraints and monument locations and may not be equably distributed throughout the study area (Figure 6).

Table 8: NV5 ground survey equipment identification

Receiver Model	Antenna	OPUS Antenna ID	Use	Year
Trimble R8	Integrated Antenna	TRM_R8_GNSS	Rover	2020
Trimble R750	Zephyr Model 3 GNSS	TRM115000.10	Static	2024
Trimble R12	Integrated Antenna	TRMR12	Rover	2024

[1] OPUS is a free service provided by the National Geodetic Survey to process corrected monument positions: OPUS website

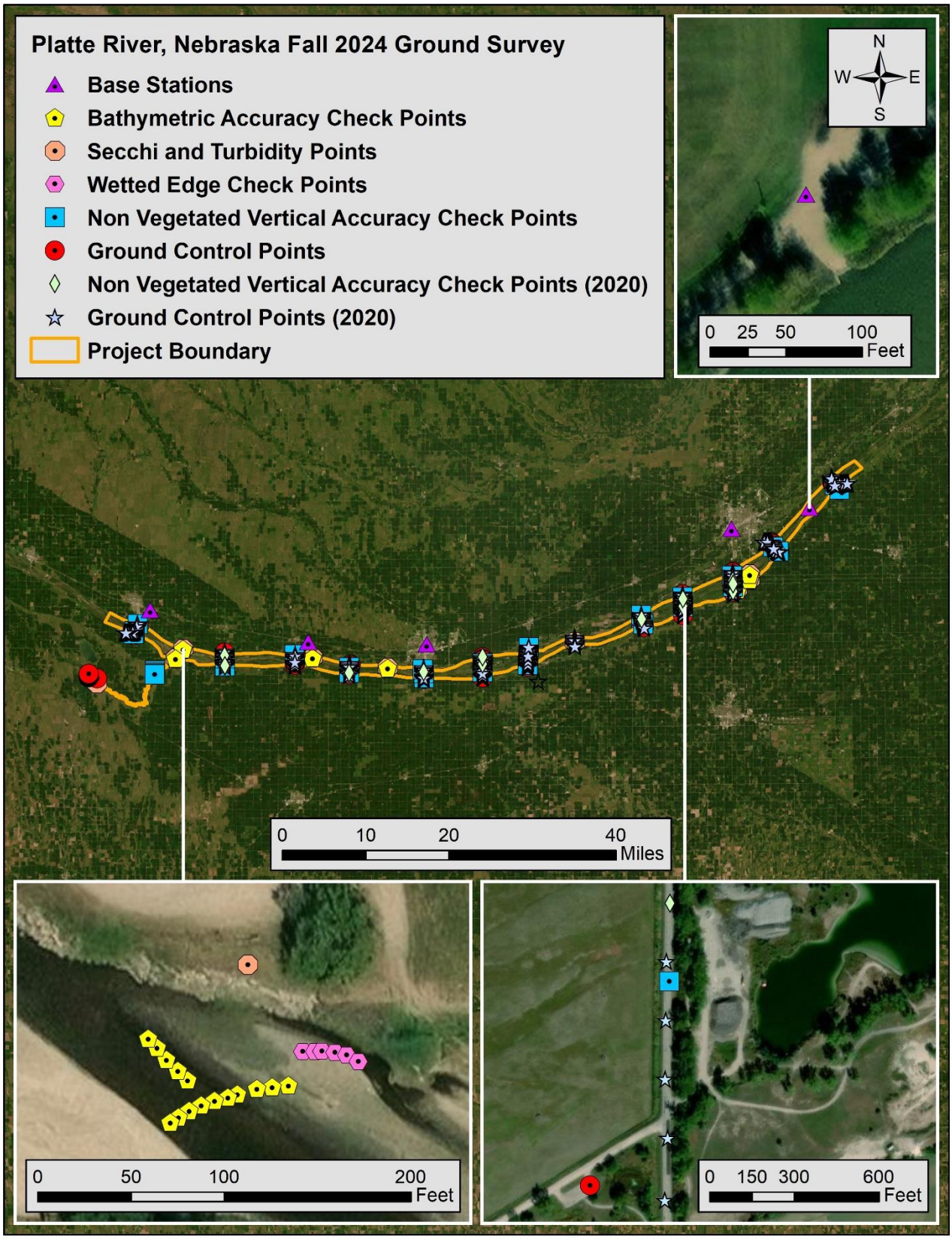
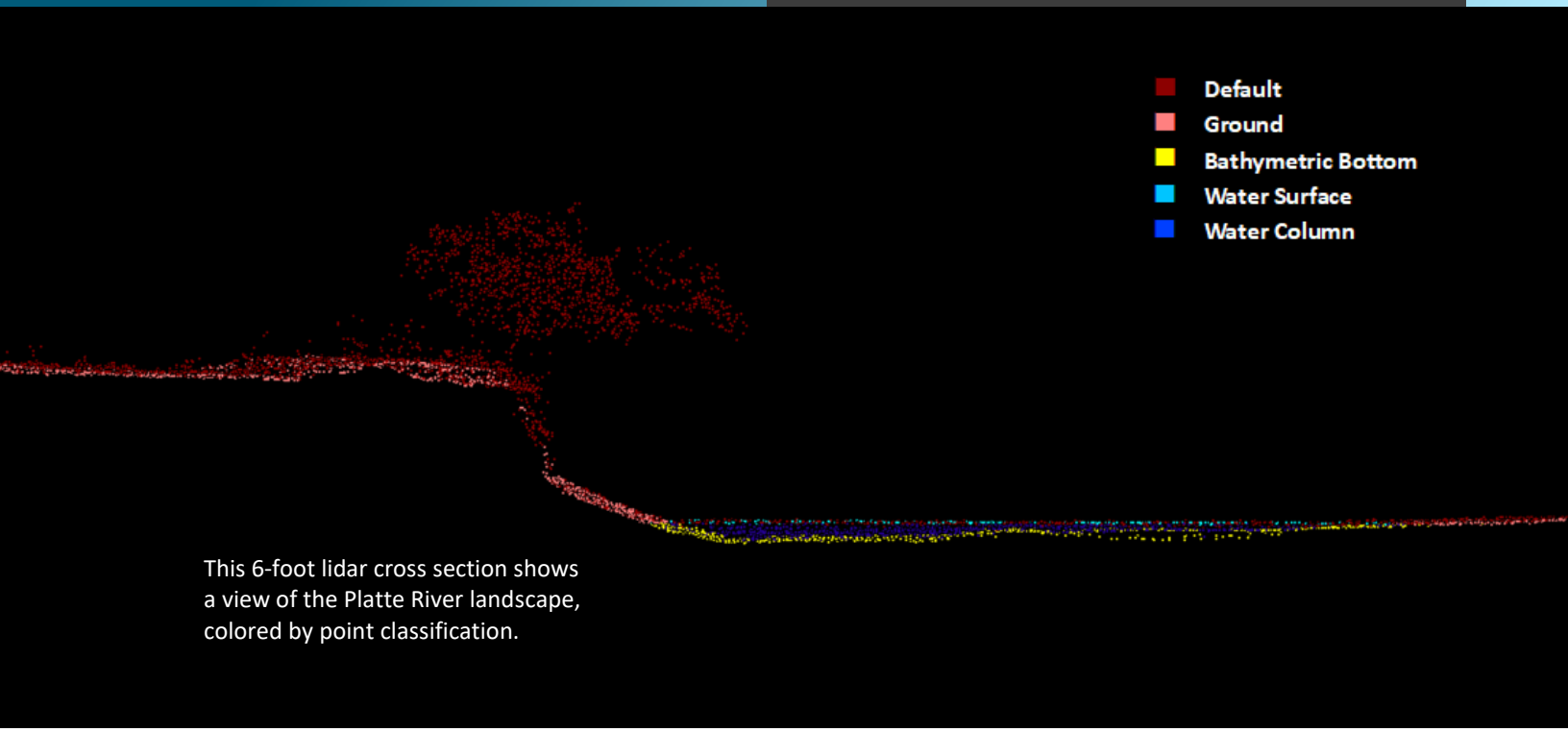


Figure 6: Ground survey location map



This 6-foot lidar cross section shows a view of the Platte River landscape, colored by point classification.

Topobathymetric Lidar Data

Upon completion of data acquisition, NV5 processing staff initiated a suite of automated and manual techniques to process the data into the requested deliverables. Processing tasks included GPS control computations, smoothed best estimate trajectory (SBET) calculations, kinematic corrections, calculation of laser point position, sensor and data calibration for optimal relative and absolute accuracy, and lidar point classification (Table 9).

Riegl's RiProcess software was used to facilitate bathymetric return processing. Once bathymetric points were differentiated, they were spatially corrected for refraction through the water column based on the angle of incidence of the laser. NV5 refracted water column points using NV5's proprietary LAS processing software, Las Monkey. The resulting point cloud data was classified using both manual and automated techniques. Processing methodologies were tailored for the landscape. Brief descriptions of these tasks are shown in Table 10.

Table 9: ASPRS LAS classification standards applied to the Platte River dataset

Classification Number	Classification Name	Classification Description
1	Default/Unclassified	Laser returns that are not included in the ground class, composed of vegetation and anthropogenic features
1-O	Edge Clip/Overlap	Laser returns at the outer edges of flightlines or in a flightline or swath within the boundary of another flightline that are geometrically unreliable
2	Ground	Laser returns that are determined to be ground using automated and manual cleaning algorithms
7	Noise	Laser returns that are often associated with birds, scattering from reflective surfaces, or artificial points below the ground surface
9	Water	Laser returns that are determined to be water using automated and manual cleaning algorithms
40	Bathymetric Bottom	Refracted green laser returns that fall within the water's edge breakline which characterize the submerged topography.
41	Water Surface	Green laser returns that are determined to be water surface points using automated and manual cleaning algorithms.
45	Water Column	Refracted green sensor returns that are determined to be water using automated and manual cleaning algorithms.

Lidar Calibration to Control Survey

The Platte River site experiences many geographical changes from year to year. Because the primary goal of the project is to map the changes within steam channel areas, it was determined that a single year of survey collection should be used as a primary reference dataset, in conjunction with the most current survey for both calibration and calculating accuracy statistics.

In accordance with NV5's change detection rework plan for the Platte River project, the Fall 2020 dataset and supporting ground survey control data were utilized as the primary control for the Platte River Fall 2024 topobathymetric lidar dataset. The decision to match Fall 2024's lidar data to the Fall 2020 "gold standard" survey control was based on Headwaters Corporation's paramount need to be able to compare the river's surface year-to-year relative to itself.

Lidar data was calibrated to the reference Fall 2020 dataset and then compared to the Fall 2024 ground survey. During the QA/QC process, NV5 created difference rasters between the Fall 2020 and Fall 2024 datasets to check for alignment and to verify results after shifting the data to the Fall 2020 control (Figure 7).

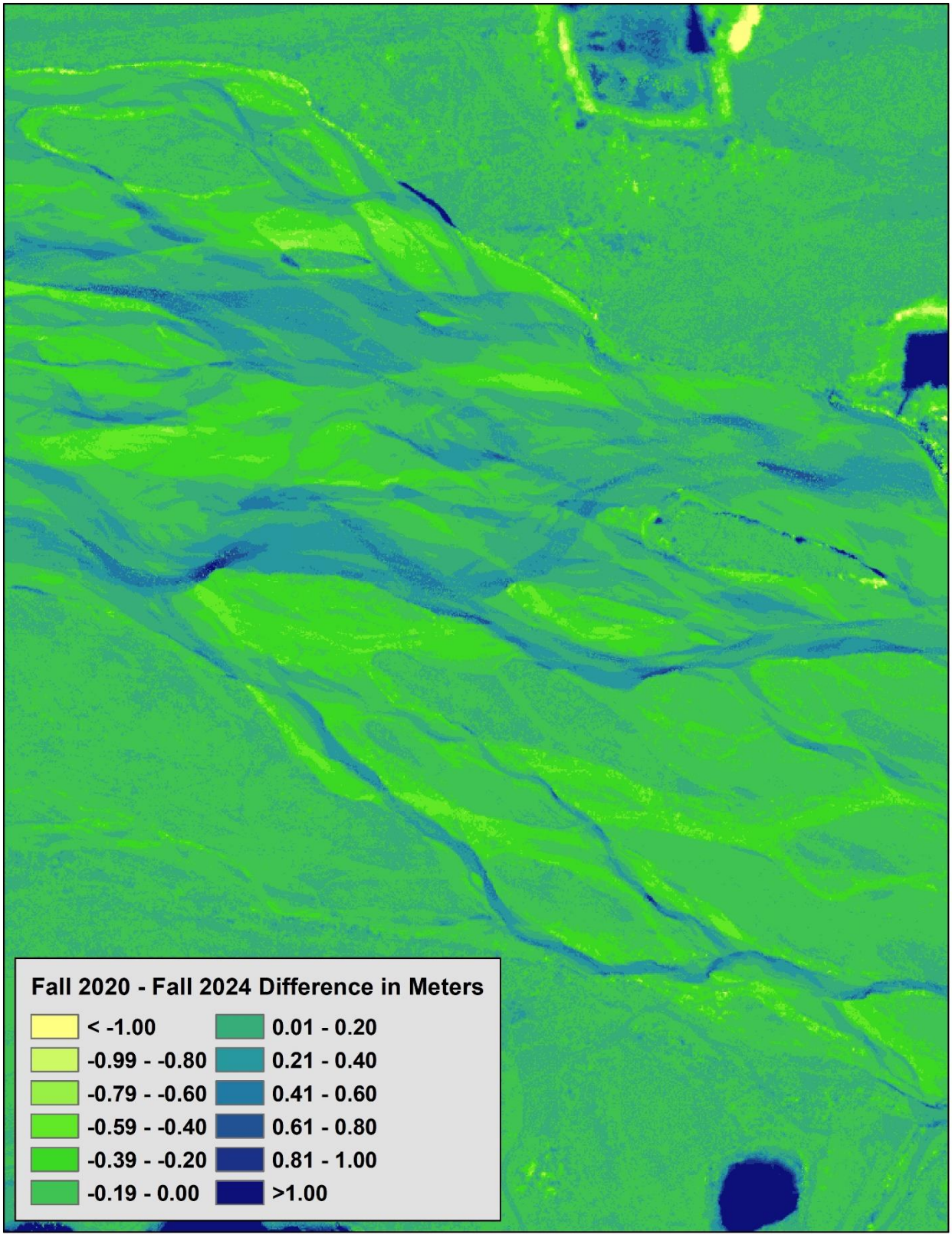


Figure 7: Raster model displaying the difference in meters for the Fall 2020 to Fall 2024 data.

Table 10: Lidar processing workflow

Lidar Processing Step	Software Used
Resolve kinematic corrections for aircraft position data using kinematic aircraft GPS and static ground GPS data. Develop a smoothed best estimate of trajectory (SBET) file that blends post-processed aircraft position with sensor head position and attitude recorded throughout the survey.	POSPac MMS v.8.9
Calculate laser point position by associating SBET position to each laser point return time, scan angle, intensity, etc. Create raw laser point cloud data for the entire survey in *.las (ASPRS v. 1.4) format. Convert data to orthometric elevations by applying a geoid correction.	RiUnite v1.0.5
Import raw laser points into manageable blocks to perform manual relative accuracy calibration and filter erroneous points. Classify ground points for individual flight lines.	TerraScan v.19.005
Using ground classified points per each flight line, test the relative accuracy. Perform automated line-to-line calibrations for system attitude parameters (pitch, roll, heading), mirror flex (scale), and GPS/IMU drift. Calculate calibrations on ground classified points from paired flight lines and apply results to all points in a flight line. Use every flight line for relative accuracy calibration.	StripAlign v.2.24
Apply refraction correction to all subsurface returns.	Las Monkey v.2.6.9 (NV5 proprietary software)
Classify resulting data to ground and other client designated ASPRS classifications (Table 9). Assess statistical absolute accuracy via direct comparisons of ground classified points to ground control survey data.	TerraScan v.24.004 TerraModeler v.19.003
Generate bare earth models as triangulated surfaces. Generate highest hit models as a surface expression of all classified points. Export all surface models in ERDAS Imagine (.img) format at a 3.0 foot pixel resolution.	Las Product Creator 4.0 (NV5 proprietary software) ArcMap v.10.8
Export intensity images as cloud optimized GeoTIFFs at a 1.5 foot pixel resolution.	ArcMap v.10.8 Las Product Creator 4.0 (NV5 proprietary software)

Bathymetric Refraction

Green lidar pulses that enter the water column must have their position corrected for refraction of the light beam as it passes through the water and its resulting decreased speed. NV5 has developed proprietary software (Las Monkey) to perform this processing based on Snell's law. The first step is to develop a water surface model (WSM) covering all submerged returns within the project boundary. The water surface model used for refraction is generated from points within the wetted edge breaklines that include NIR points representing the water surface as well as elevations sampled from the ground at the water's edge. Points are filtered and edited to obtain the most accurate representation of the water surface and are used to create a water surface model TIN. A TIN model is preferable to a raster based water surface model in obtaining the most accurate angle of incidence during refraction.

Once the WSM is generated, the Las Monkey refraction software then intersects the partially submerged green pulses with the WSM to determine the angle of incidence with the water surface and the submerged component of the pulse vector. This provides the information necessary to correct the position of underwater points by adjusting the submerged vector length and orientation. After refraction, the points are compared against bathymetric checkpoints to assess accuracy.

Lidar Derived Products

Because hydrographic laser scanners penetrate the water surface to map submerged topography, this affects how the data should be processed and presented in derived products from the lidar point cloud. The following section discusses certain derived products that vary from the traditional (NIR) specification and delivery format.

Topobathymetric DEMs

Bathymetric bottom returns can be limited by depth, water clarity, and bottom surface reflectivity. Water clarity and turbidity affects the depth penetration capability of the green wavelength laser with returning laser energy diminishing by scattering throughout the water column. Additionally, the bottom surface must be reflective enough to return remaining laser energy back to the sensor at a detectable level. Although the predicted depth penetration range of the Riegl VQ-880-GII sensor is 1.5 Secchi depths on brightly reflective surfaces, it is not unexpected to have no bathymetric bottom returns in turbid or non-reflective areas.

As a result, creating digital elevation models (DEMs) presents a challenge with respect to interpolation of areas with no returns. Traditional DEMs are "unclipped," meaning areas lacking ground returns are interpolated from neighboring ground returns (or breaklines in the case of hydro-flattening), with the assumption that the interpolation is close to reality. In bathymetric modeling, these assumptions are prone to error because a lack of bathymetric returns can indicate a change in elevation that the laser can no longer map due to increased depths. The resulting void areas may suggest greater depths, rather than similar elevations from neighboring bathymetric bottom returns. Therefore, NV5 created a water polygon with bathymetric coverage to delineate areas with successfully mapped bathymetry. This shapefile was used to control the extent of the delivered clipped topobathymetric model to avoid false triangulation (interpolation from TIN'ing) across areas in the water without bathymetric bottom returns.

Intensity Images

The first returns of all valid point classes were used for both the green and NIR sensors in order to create intensity images. With bathymetric lidar, a more detailed and informative intensity image can be created by using all or selected point classes, rather than relying on return number alone. If intensity information of the bathymetry is the primary goal, water surface and water column points can be excluded. However, water surface and water column points often contain potentially useful information about turbidity and submerged but unclassified features such as vegetation. For the Platte River Fall 2024 project, NV5 created one set of intensity images from NIR laser first returns and one set of intensity images from green laser returns (Figure 8).

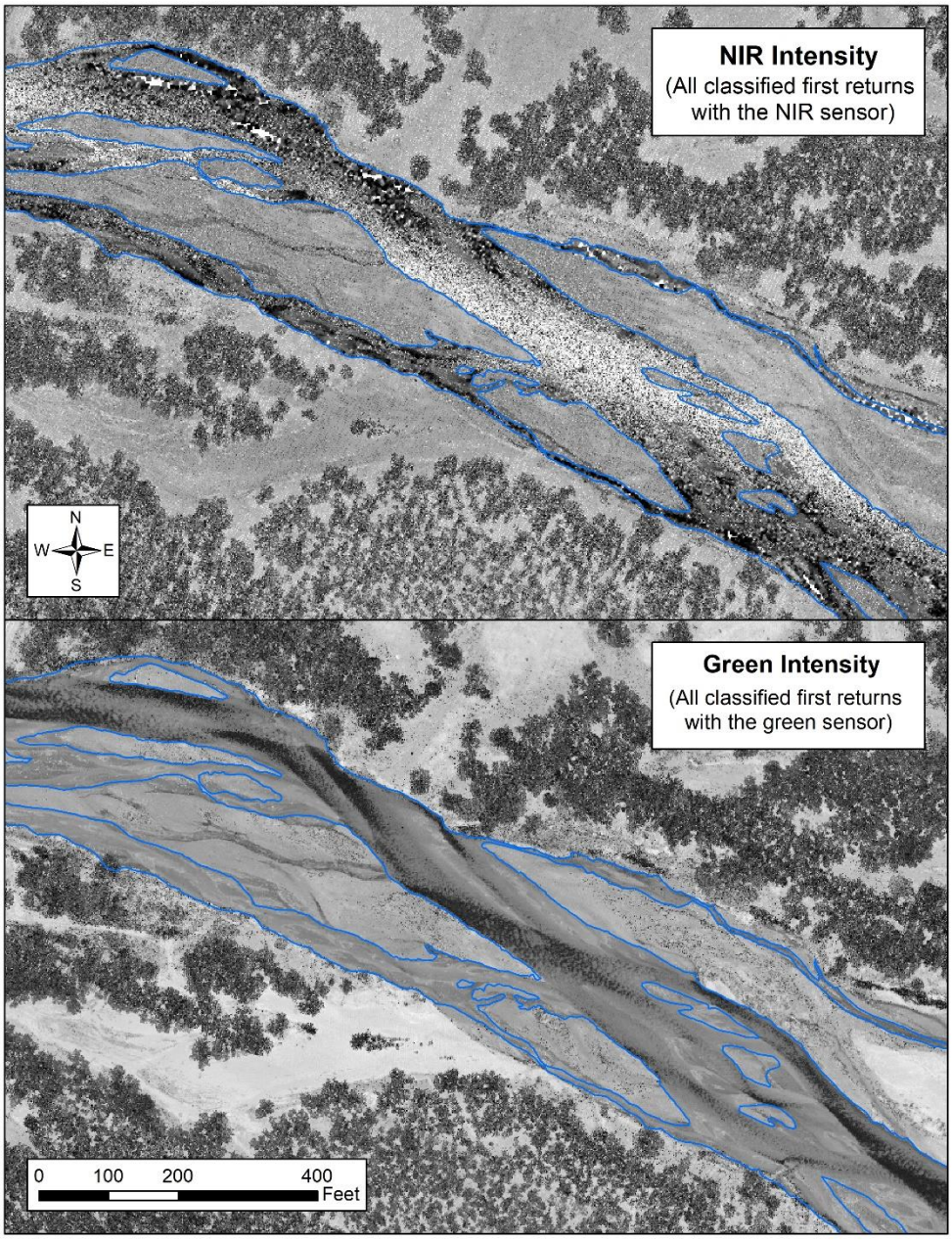


Figure 8: A comparison of intensity images from green and NIR` first returns in the Platte River area

Hydroflattening and Water's Edge Breaklines

Lakes and ponds with a surface area greater than 2 acres surrounding the Platte River were flattened to a consistent water level. The hydroflattening process eliminates artifacts in the digital terrain model caused by increased variability in ranges or dropouts in laser returns due to the low reflectivity of water.

Hydroflattening of closed water bodies was performed through a combination of automated and manual detection and adjustment techniques designed to identify water boundaries and water levels. Boundary polygons were developed using an algorithm which weights lidar-derived slopes, intensities, and return densities to detect the water's edge. The water edges were then manually reviewed and edited as necessary.

Once polygons were developed the initial ground classified points falling within water polygons were reclassified as water points to omit them from the final ground model. Elevations were then obtained from the filtered lidar returns to create the final breaklines. Lakes were assigned a consistent elevation for an entire polygon while rivers were assigned consistent elevations on opposing banks and smoothed to ensure downstream flow through the entire river channel.

Water boundary breaklines were then incorporated into the hydroflattened DEM by enforcing triangle edges (adjacent to the breakline) to the elevation values of the breakline. This implementation corrected interpolation along the hard edge. Water surfaces were obtained from a TIN of the 3-D water edge breaklines resulting in the final hydroflattened model (Figure 9).

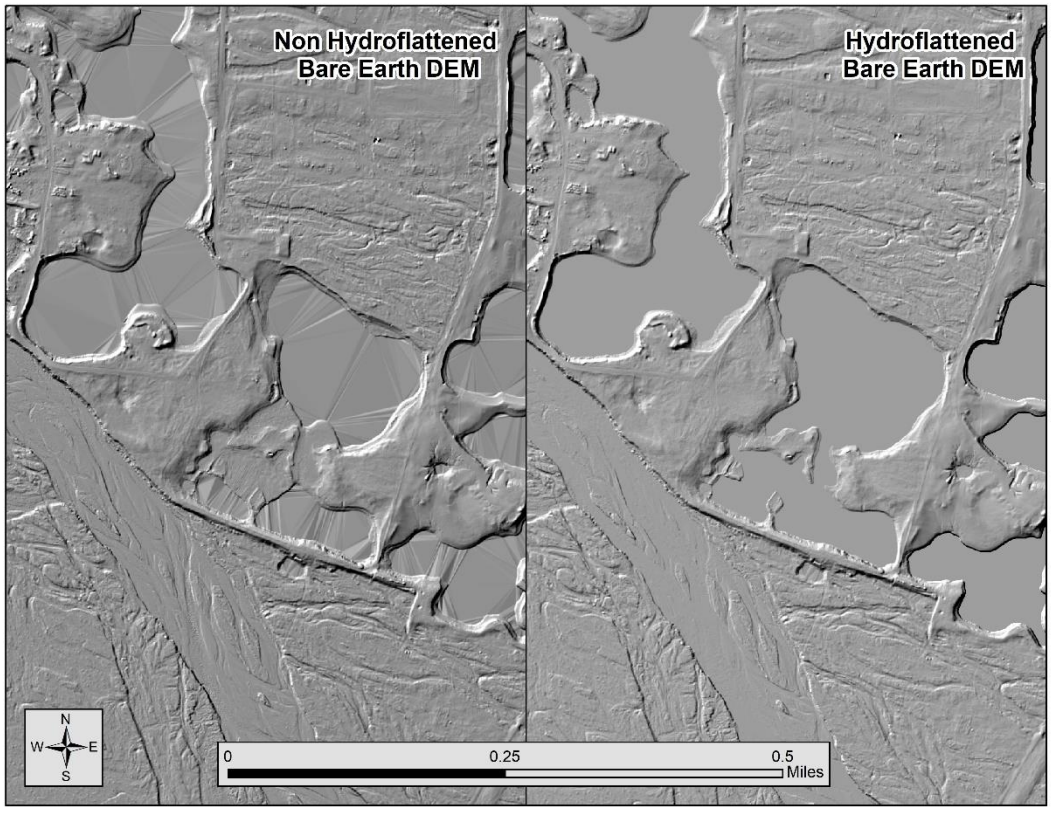
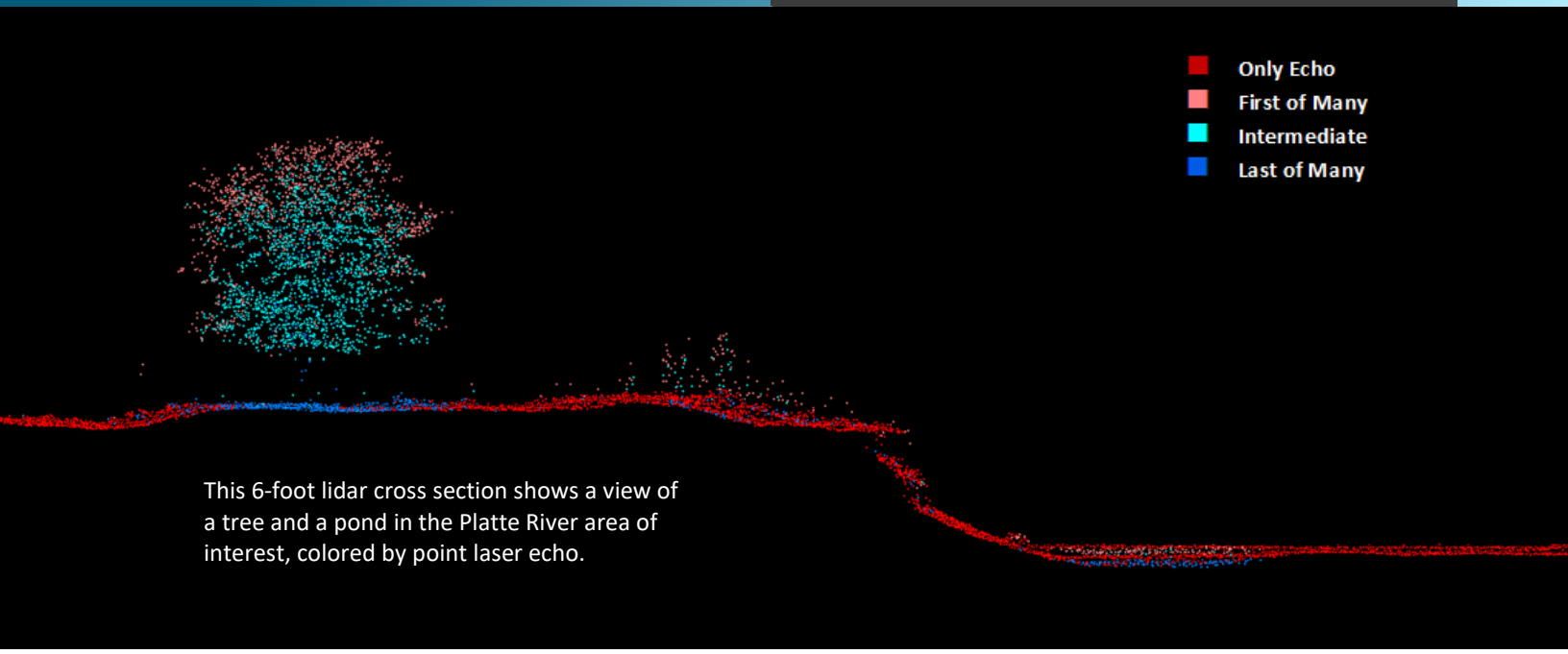


Figure 9: Example of hydroflattening in the Platte River lidar dataset



This 6-foot lidar cross section shows a view of a tree and a pond in the Platte River area of interest, colored by point laser echo.

Bathymetric Lidar

An underlying principle for collecting hydrographic lidar data is to survey near-shore areas that can be difficult to collect with other methods, such as multi-beam sonar, particularly over large areas. The capability and effectiveness of the bathymetric lidar is impacted by several parameters including depth penetrations below the water surface, bathymetric return density, and spatial accuracy.

Mapped Bathymetry and Depth Penetration

The specified depth penetration range of the Riegl VQ-880-GII sensor is 1.5 Secchi depths; therefore, bathymetry data below 1.5x Secchi depth at the time of acquisition is not to be expected. To assist in evaluating performance results of the sensor, a polygon layer was created to delineate areas where bathymetry was successfully mapped.

This shapefile was used to control the extent of the delivered clipped topobathymetric model and to avoid false triangulation across areas in the water with no returns. Insufficiently mapped areas were identified by triangulating bathymetric bottom points with an edge length maximum of 15.2 feet. This ensured all areas of no returns (> 96.88 ft^2), were identified as data voids. Overall NV5 successfully mapped 80.44% of the bathymetric areas in the Platte River AOI and 99.02% of the bathymetric areas in the Plum Creek AOI.

Of the areas successfully mapped in the Platte River AOI, 21.53% had a calculated depth of 0 to 0.10 feet, 65.30% had a calculated depth of 0.11 to 1.00 feet, 10.27% had a calculated depth of 1.01 to 2.00 feet, 1.45% had a calculated depth of 2.01 to 3.00 feet, 0.52% had a calculated depth of 3.01 to 4.00 feet, 0.27% had a calculated depth of 4.01 to 5.00 feet, and the remaining 0.67% had a calculated depth greater than

5.00 feet. These values are compared to previous years' bathymetric coverage and depth results in Table 11 and Table 13 and is visualized in Figure 10.

Of areas successfully mapped in the Plum Creek AOI, 17.59% had a calculated depth of 0 to 0.10 feet, 30.07% had a calculated depth of 0.11 to 1.00 feet, 39.26% had a calculated depth of 1.01 to 2.00 feet, 11.71% had a calculated depth of 2.01 to 3.00 feet, 1.29% had a calculated depth of 3.01 to 4.00 feet, 0.07% had a calculated depth of 4.01 to 5.00 feet, and the remaining 0.01% had a calculated depth greater than 5.00 feet Table 12.

Table 11: Depth coverage comparison from Fall 2020 to Fall 2024 for Platte River

Year	Shallow (< 0.10 feet)	0.11 – 1.00 feet	1.01 – 2.00 feet	2.01 – 3.00 feet	3.01 – 4.00 feet	4.01 – 5.00 feet	> 5.00 feet
Fall 2020	21.1%	69.5%	7.4%	1.1%	0.4%	0.1%	0.3%
Fall 2021	17.9%	64.2%	11.7%	2.4%	1.0%	0.7%	2.1%
Fall 2022	25.87%	59.85%	6.50%	2.58%	1.54%	0.96%	2.71%
Fall 2023	13.17%	69.14%	12.69%	2.22%	0.99%	0.56%	1.22%
Fall 2024	21.53%	65.30%	10.27%	1.45%	0.52%	0.27%	0.67%

Table 12: Depth coverage in Fall 2024 for Plum Creek

Shallow (< 0.10 feet)	0.11 – 1.00 feet	1.01 – 2.00 feet	2.01 – 3.00 feet	3.01 – 4.00 feet	4.01 – 5.00 feet	> 5.00 feet
17.59%	30.07%	39.26%	11.71%	1.29%	0.07%	0.01%

Table 13: Bathymetric coverage by year

Data Collection Year	Total Water (acres)	Covered (acres)	Void (acres)	Covered (%)	Void (%)
2016	7,668.15	6,182.83	1,485.32	80.63%	19.37%
2017	7,465.07	5,816.21	1,648.86	77.91%	22.09%
2018	6,940.51	5,292.10	1,648.41	76.25%	23.75%
2019	12,610.03	10,996.20	1,613.83	87.20%	12.80%
2020	5,369.20	3,735.98	1,633.22	69.58%	30.42%
2021	8,691.98	7,319.71	1,372.27	84.21%	15.79%
2022	5,396.61	3,955.78	1,440.83	73.33%	26.70%
2023	8,137.36	6,594.79	1,542.57	81.04%	18.96%
2024	8,393.00	6,750.92	1,642.08	80.44%	19.56%

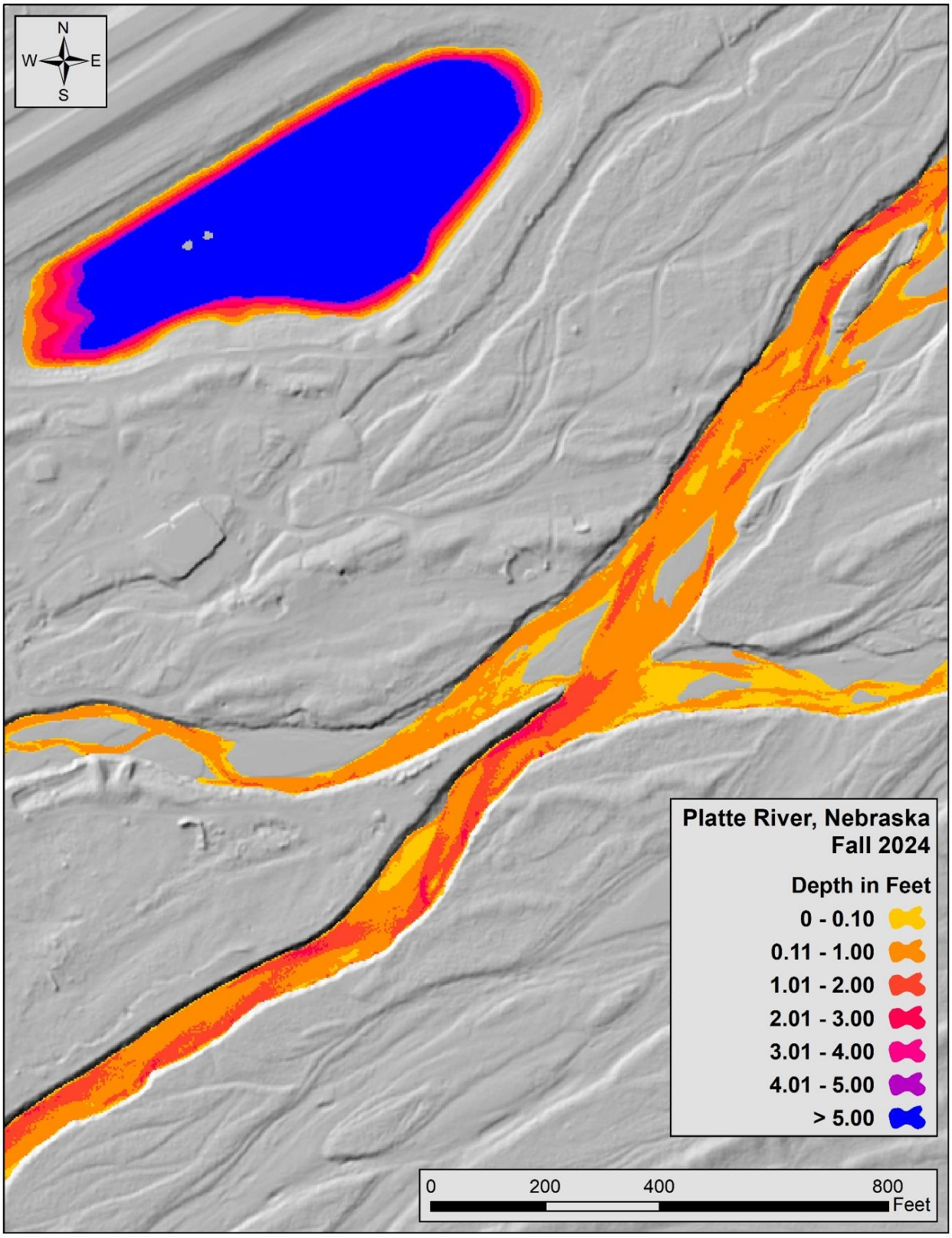


Figure 10: Depth model of the Platte River

Lidar Point Density

First Return Point Density

The acquisition parameters were designed to acquire an average first-return density of 8 points/m^2 (0.74 points/ft^2). First return density describes the density of pulses emitted from the laser that return at least one echo to the system. Multiple returns from a single pulse were not considered in first return density analysis. Some types of surfaces (e.g., breaks in terrain, water, and steep slopes) may have returned fewer pulses than originally emitted by the laser.

First returns typically reflect off the highest feature on the landscape within the footprint of the pulse. In forested or urban areas the highest feature could be a tree, building, or power line, while in areas of unobstructed ground, the first return will be the only echo and represents the bare earth surface.

The average first-return density of the Platte River Lidar project was 2.86 points/ft^2 (30.79 points/m^2) (Table 14). The statistical and spatial distributions of all first return densities per 100 m x 100 m cell are portrayed in Figure 11 and Figure 13.

Bathymetric and Ground Classified Point Densities

The density of ground classified lidar returns and bathymetric bottom returns were also analyzed for this project. Terrain character, land cover, and ground surface reflectivity all influenced the density of ground surface returns. In vegetated areas, fewer pulses may have penetrated the canopy, resulting in lower ground density. Similarly, the density of bathymetric bottom returns was influenced by turbidity, depth, and bottom surface reflectivity. In turbid areas, fewer pulses may have penetrated the water surface, resulting in lower bathymetric density.

The ground and bathymetric bottom classified density of lidar data for the Platte River project was 1.27 points/ft^2 (13.66 points/m^2) (Table 14). The statistical and spatial distributions per 100 x 100 m cell of the ground and bathymetric bottom classified return densities are shown in Figure 12 and Figure 13.

Additionally, for the Platte River project, density values of only bathymetric bottom returns were calculated for areas containing at least one bathymetric bottom return. Areas lacking bathymetric returns (voids) were not considered in calculating an average density value. Within the successfully mapped area, a bathymetric bottom return density of 1.12 points/ft^2 (12.05 points/m^2) was achieved.

Table 14: Average lidar point densities

Density Type	Point Density
First Returns	30.79 points/m² 2.86 points/ft²
Ground and Bathymetric Bottom Classified Returns	13.66 points/m² 1.27 points/ft²
Bathymetric Bottom Classified Returns	12.05 points/m² 1.12 points/ft²

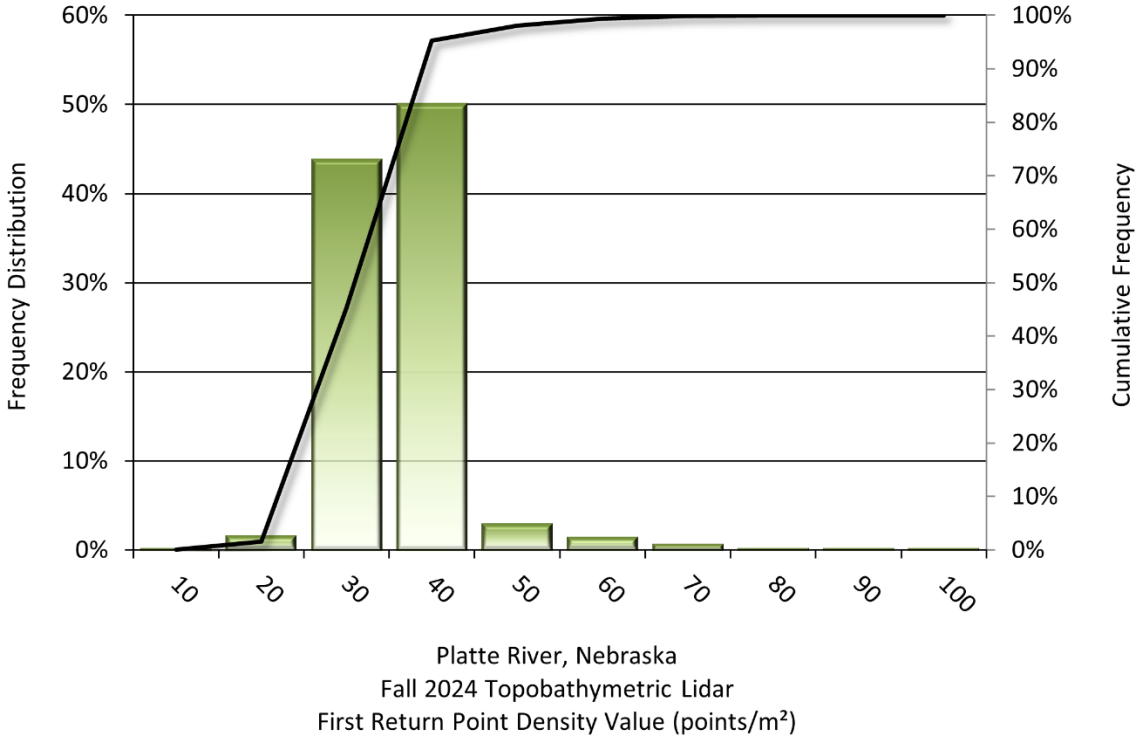


Figure 11: Frequency distribution of first return densities per 100 m x 100 m cell

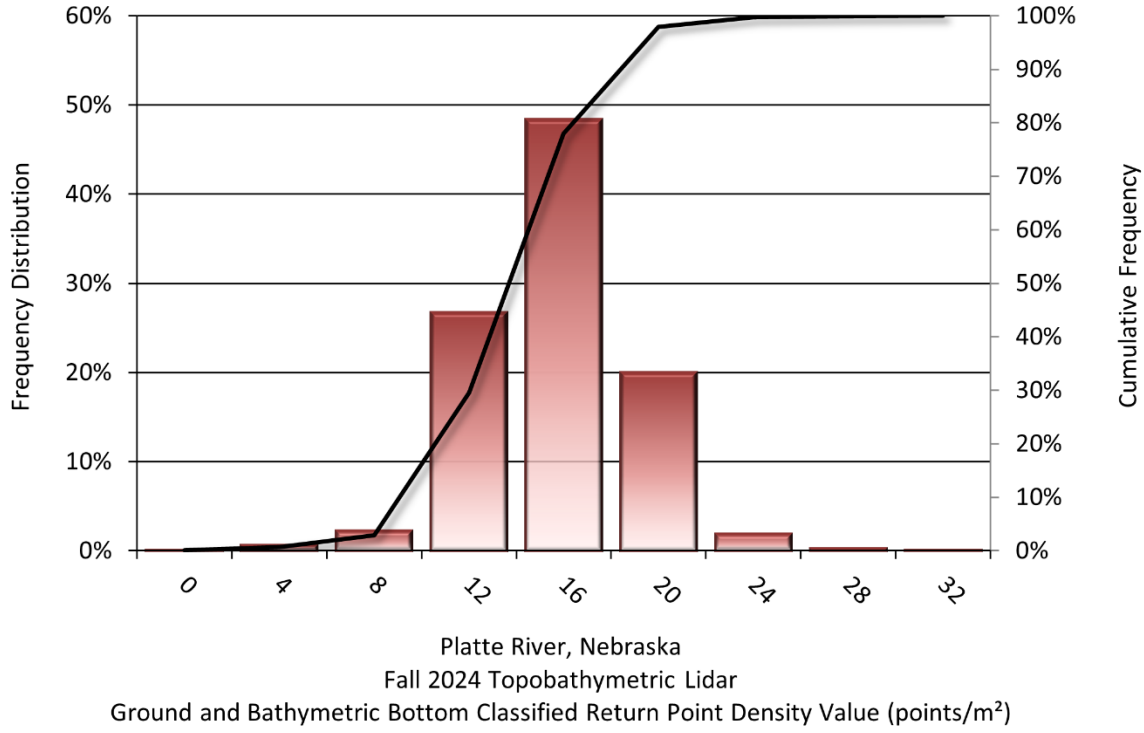


Figure 12: Frequency distribution of ground and bathymetric bottom classified return densities per 100 m x 100 m cell

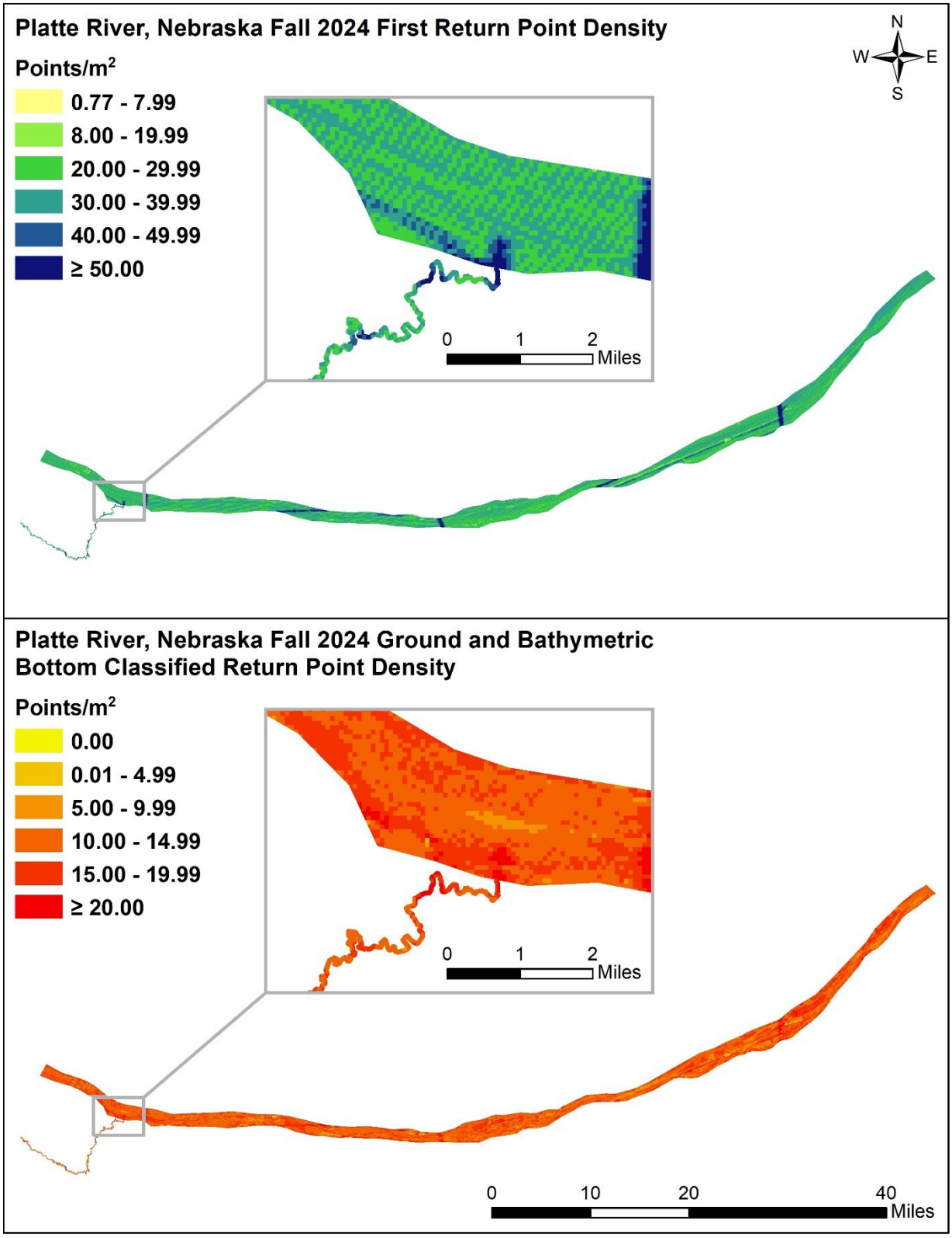


Figure 13: First return and ground and bathymetric bottom density map for the Platte River site (100 m x 100 m cells)

Lidar Accuracy Assessments

The accuracy of the lidar data collection can be described in terms of absolute accuracy (the consistency of the data with external data sources) and relative accuracy (the consistency of the dataset with itself). See Appendix A for further information on sources of error and operational measures used to improve relative accuracy.

Lidar Non-Vegetated Vertical Accuracy

Absolute accuracy was assessed using Non-vegetated Vertical Accuracy (NVA) reporting designed to meet guidelines presented in the FGDC National Standard for Spatial Data Accuracy.[2] NVA compares known ground check point data that were withheld from the calibration and post-processing of the lidar point cloud to the triangulated surface generated by the classified lidar point cloud as well as the derived gridded bare earth DEM. NVA is a measure of the accuracy of lidar point data in open areas where the lidar system has a high probability of measuring the ground surface and is evaluated at the 95% confidence interval (1.96 * RMSE), as shown in Table 16.

The mean and standard deviation (sigma σ) of divergence of the ground surface model from ground check point coordinates are also considered during accuracy assessment. These statistics assume the error for x, y, and z is normally distributed, and therefore the skew and kurtosis of distributions are also considered when evaluating error statistics.

For the Platte Fall 2024 project, absolute accuracy statistics derived from the Fall 2020 and Fall 2024 ground surveys were assessed independently due to variations observed in the multi-year ground surveys, as discussed at the end of this section. The Fall 2024 data was calibrated to the Fall 2020 lidar dataset and ground survey. This approach helps ensure year-over-year consistency between bathymetric and topographic lidar returns for accurately modeling temporal changes to the Platte River channel. To assist with evaluation of the accuracy of this dataset compared to other years and as a whole, accuracy statistics are presented for the entire project area and for the Platte River AOI and the Plum Creek AOI individually.

[2] Federal Geographic Data Committee, ASPRS POSITIONAL ACCURACY STANDARDS FOR DIGITAL GEOSPATIAL DATA EDITION 1, Version 1.0, NOVEMBER 2014. https://www.asprs.org/a/society/committees/standards/Positional_Accuracy_Standards.pdf.

Absolute Accuracy – Fall 2020 Ground Survey

Using the Fall 2020 ground survey to assess the Fall 2024 lidar data, 13 ground check points were withheld from the calibration and post-processing of the lidar point cloud, with resulting NVA of 0.166 feet (0.050 meters) as compared to the classified LAS, with 95% confidence (Figure 14, Table 15).

NV5 also assessed absolute accuracy using 697 ground control points. Although these points were used in the calibration and post-processing of the lidar point cloud, they still provide a good indication of the overall accuracy of the lidar dataset, and therefore have been provided in Table 15 and Figure 15.

Appendix B details the point offsets for the Platte Fall 2024 lidar as compared to the Fall 2020 ground survey data (Table 24).

Table 15: Absolute accuracy results – Fall 2024 lidar data compared to Fall 2020 ground survey

Parameter	NVA, as compared to Classified LAS	Ground Control Points
Sample	13 points	697 points
95% Confidence (1.96*RMSE)	0.166 ft 0.050 m	0.197 ft 0.060 m
Average	-0.055 ft -0.017 m	-0.026 ft -0.008 m
Median	-0.069 ft -0.021 m	-0.033 ft -0.010 m
RMSE	0.085 ft 0.026 m	0.101 ft 0.031 m
Standard Deviation (1σ)	0.067 ft 0.020 m	0.097 ft 0.030 m

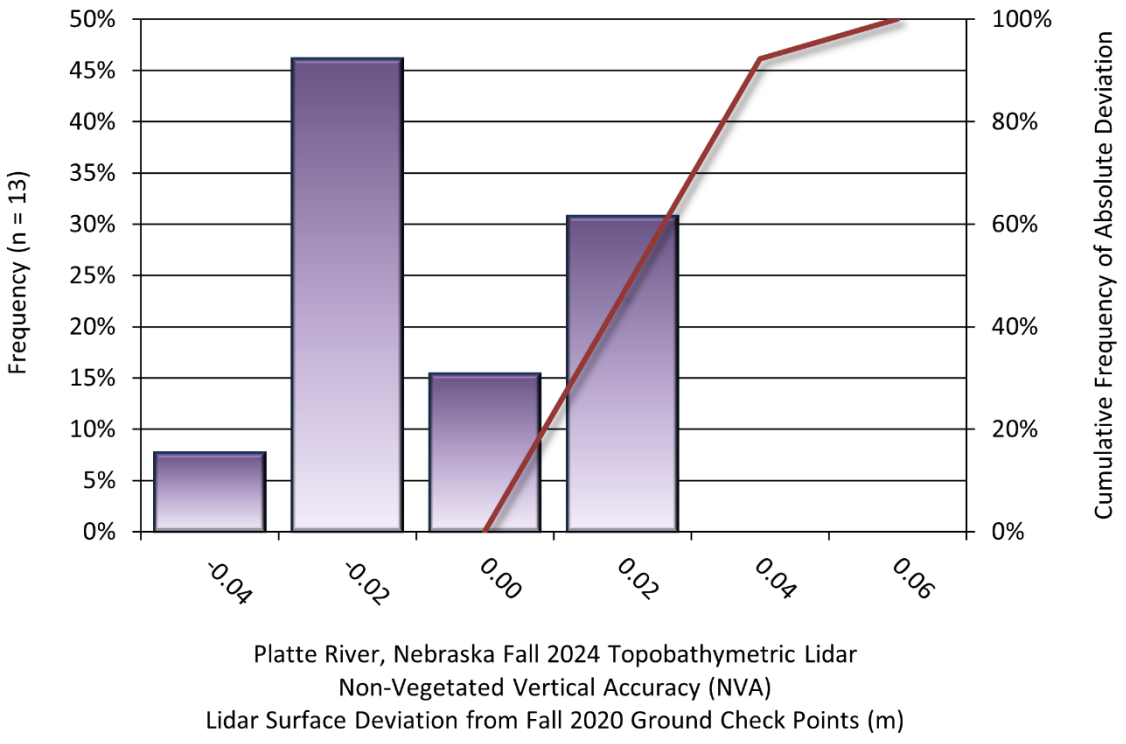


Figure 14: Frequency histogram for unclassified LAS deviation from ground check point values

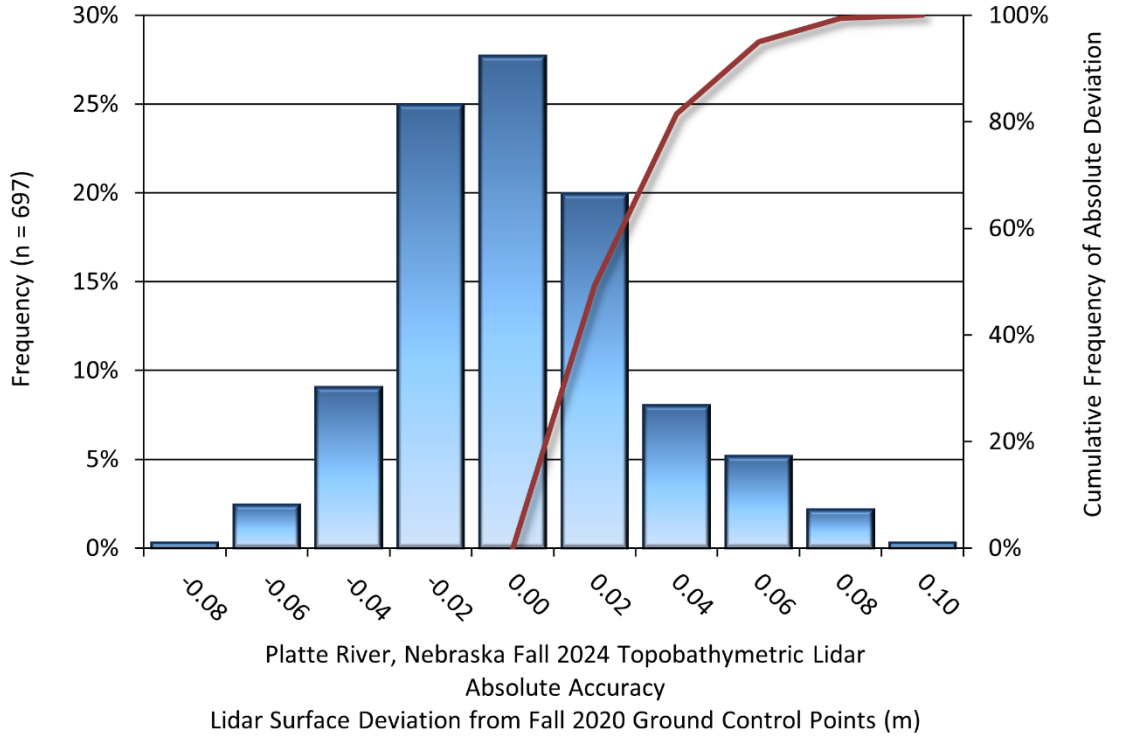


Figure 15: Frequency histogram for lidar surface deviation ground check point values

Absolute Accuracy – Fall 2024 Ground Survey

Platte River

For the Platte River Fall 2024 survey, 28 ground checkpoints were withheld from the calibration and post-processing of the lidar point cloud, with resulting non-vegetated vertical accuracy of 0.146 feet (0.045 meters) as compared to the classified LAS, and 0.154 feet (0.047 meters) against the bare earth DEM, with 95% confidence (Table 16, Figure 16, and Figure 17). NV5 also assessed absolute accuracy using 146 ground control points with a resulting accuracy of 0.167 feet (0.051 meters) at the 95% confidence level (Table 16, Figure 18).

Table 16: Absolute accuracy results – Fall 2024 lidar data compared to Fall 2024 ground survey in the Platte River AOI

Parameter	NVA, as compared to Classified LAS	NVA, as compared to Bare Earth DEM	Ground Control Points
Sample	28 points	28 points	146 points
95% Confidence (1.96*RMSE)	0.146 ft 0.045 m	0.154 ft 0.047 m	0.167 ft 0.051 m
Average	0.030 ft 0.009 m	0.026 ft 0.008 m	-0.008 ft -0.003 m
Median	0.031 ft 0.010 m	0.028 ft 0.008 m	-0.003 ft -0.001 m
RMSE	0.075 ft 0.023 m	0.079 ft 0.024 m	0.085 ft 0.026 m
Standard Deviation (1σ)	0.070 ft 0.021 m	0.076 ft 0.023 m	0.085 ft 0.026 m

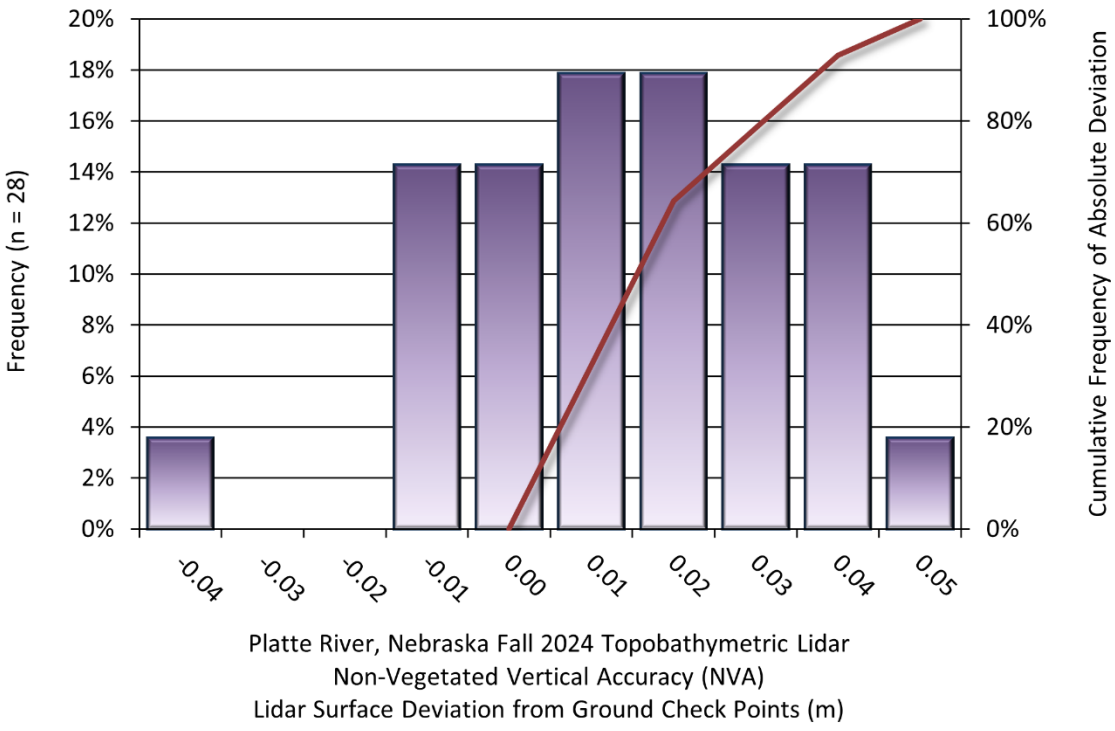


Figure 16: Frequency histogram for classified LAS deviation from ground check point values for Platte River

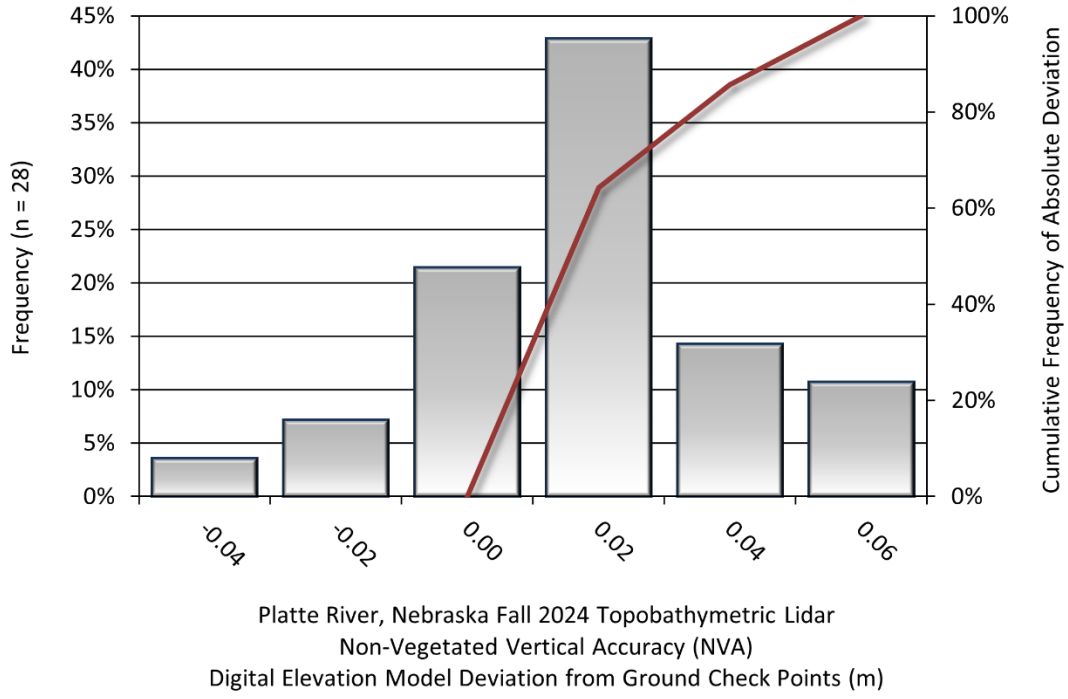


Figure 17: Frequency histogram for lidar bare earth DEM deviation from ground check point values for Platte River

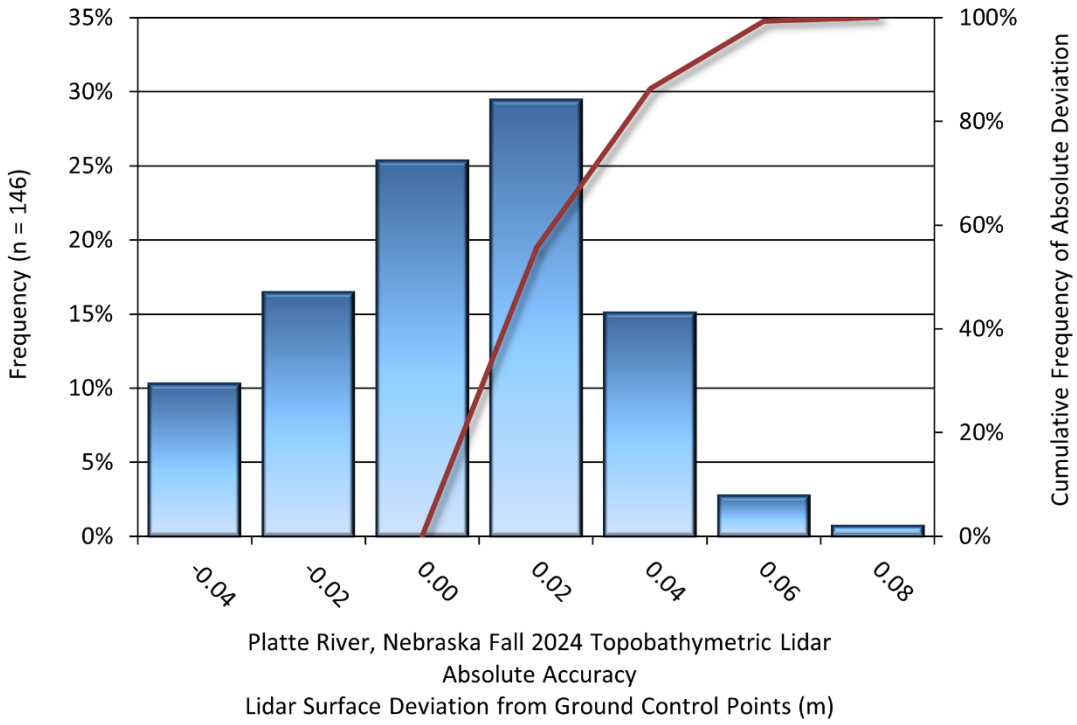


Figure 18: Frequency histogram for lidar surface deviation ground control point values for Platte River

Plum Creek

For the Plum Creek AOI, 5 ground checkpoints were withheld from the calibration and post-processing of the lidar point cloud, with resulting non-vegetated vertical accuracy of 0.145 feet (0.044 meters) as compared to the classified LAS, and 0.158 feet (0.048 meters) against the bare earth DEM, with 95% confidence (Table 17, Figure 19, Figure 20). NV5 also assessed absolute accuracy using 38 ground control points with a resulting accuracy of 0.134 feet (0.041 meters) at the 95% confidence level (Table 17, Figure 21).

Table 17: Absolute accuracy results – Fall 2024 lidar data compared to Fall 2024 ground survey in the Plum Creek AOI

Parameter	NVA, as compared to Classified LAS	NVA, as compared to Bare Earth DEM	Ground Control Points
Sample	5 points	5 points	38 points
95% Confidence (1.96*RMSE)	0.145 ft 0.044 m	0.158 ft 0.048 m	0.134 ft 0.041 m
Average	0.058 ft 0.018 m	0.049 ft 0.015 m	0.033 ft 0.010 m
Median	0.043 ft 0.013 m	0.052 ft 0.016 m	0.034 ft 0.011 m
RMSE	0.074 ft 0.023 m	0.081 ft 0.025 m	0.069 ft 0.021 m
Standard Deviation (1σ)	0.051 ft 0.016 m	0.072 ft 0.022 m	0.061 ft 0.019 m

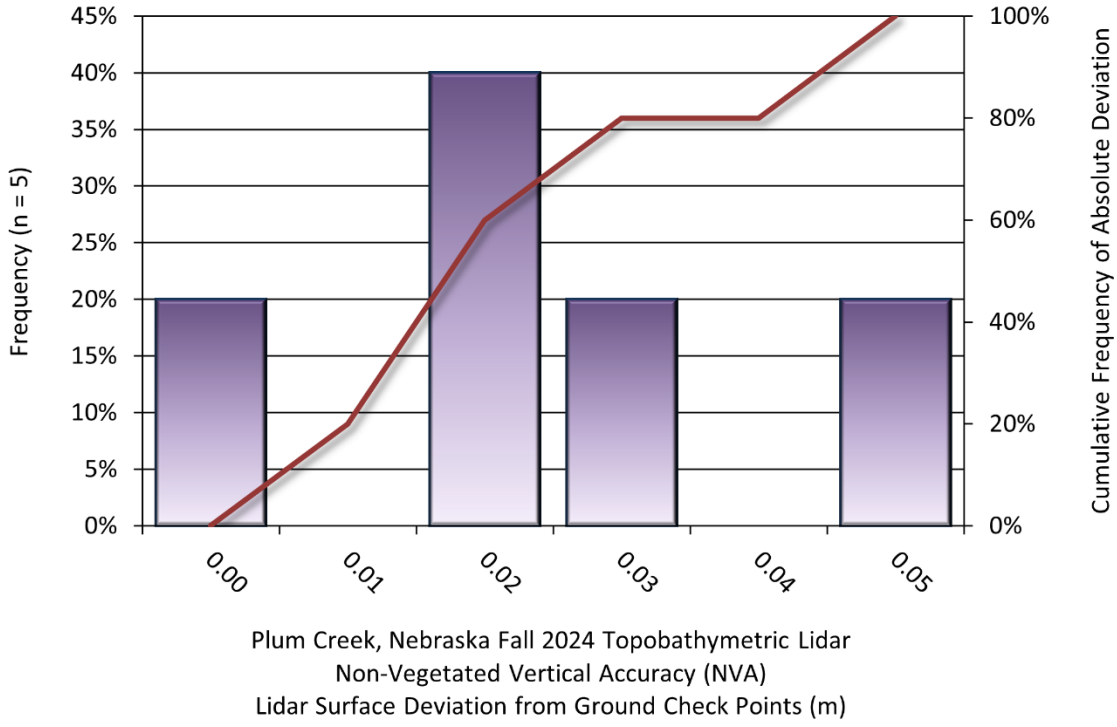


Figure 19: Frequency histogram for classified LAS deviation from ground check point values for Plum Creek

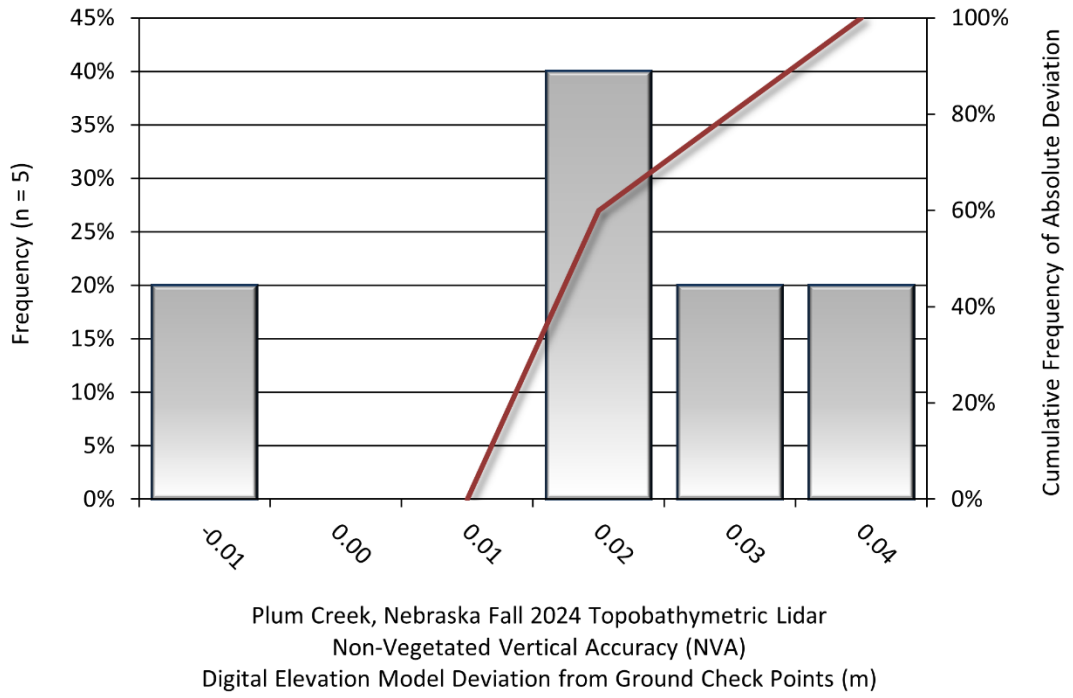


Figure 20: Frequency histogram for lidar bare earth DEM deviation from ground check point values for Plum Creek

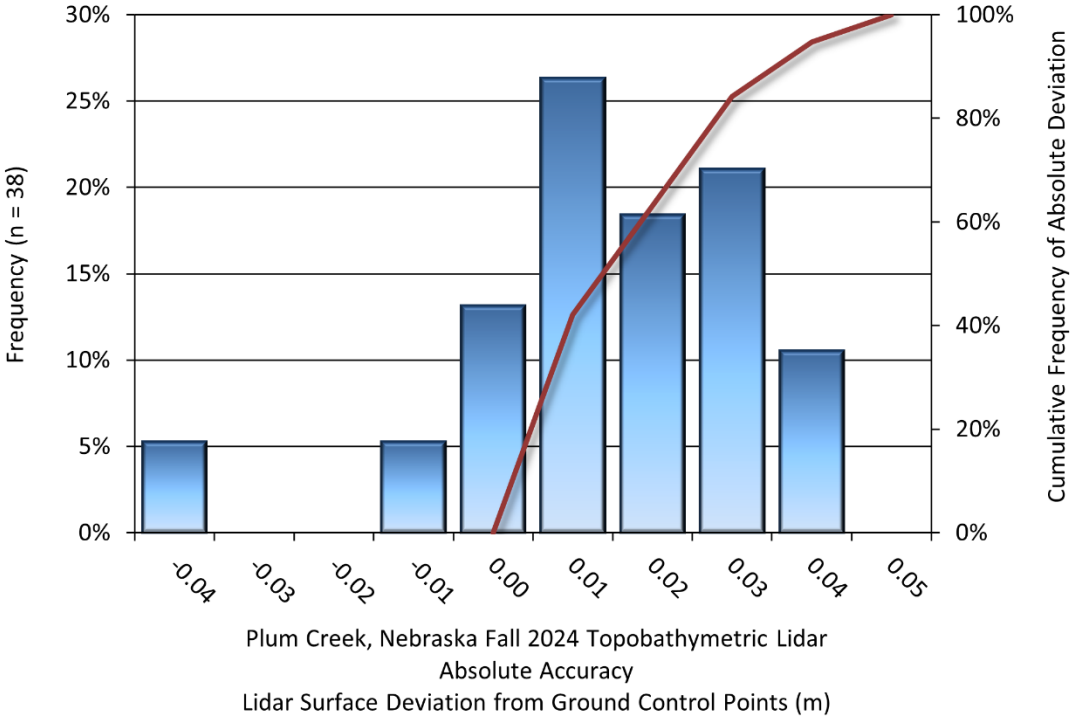


Figure 21: Frequency histogram for lidar surface deviation ground control point values

Combined

For the full project, 33 ground checkpoints were withheld from the calibration and post-processing of the lidar point cloud, with resulting non-vegetated vertical accuracy of 0.146 feet (0.045 meters) as compared to the classified LAS, and 0.155 feet (0.047 meters) against the bare earth DEM, with 95% confidence (Table 18, Figure 22, Figure 23). NV5 also assessed absolute accuracy using 184 ground control points with a resulting accuracy of 0.161 feet (0.049 meters) at the 95% confidence level (Table 18, Figure 24).

Appendix C details the point offsets for the Platte Fall 2024 lidar as compared to the Fall 2024 ground survey data (Table 25).

Table 18: Absolute accuracy results – Fall 2024 lidar data compared to Fall 2024 ground survey in the combined project area

Parameter	NVA, as compared to Classified LAS	NVA, as compared to Bare Earth DEM	Ground Control Points
Sample	33 points	33 points	184 points
95% Confidence (1.96*RMSE)	0.146 ft 0.045 m	0.155 ft 0.047 m	0.161 ft 0.049 m
Average	0.034 ft 0.010 m	0.029 ft 0.009 m	0.000 ft 0.000 m
Median	0.036 ft 0.011 m	0.039 ft 0.012 m	0.010 ft 0.003 m
RMSE	0.075 ft 0.023 m	0.079 ft 0.024 m	0.082 ft 0.025 m
Standard Deviation (1σ)	0.067 ft 0.020 m	0.075 ft 0.023 m	0.082 ft 0.025 m

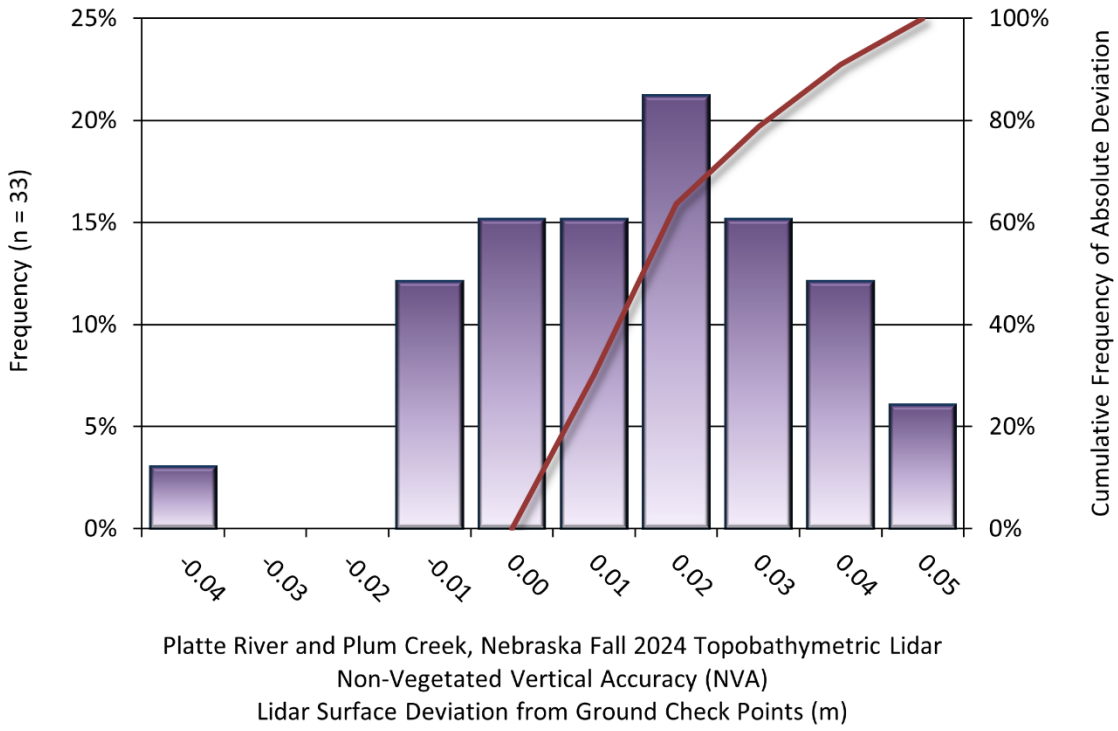


Figure 22: Frequency histogram for classified LAS deviation from ground check point values

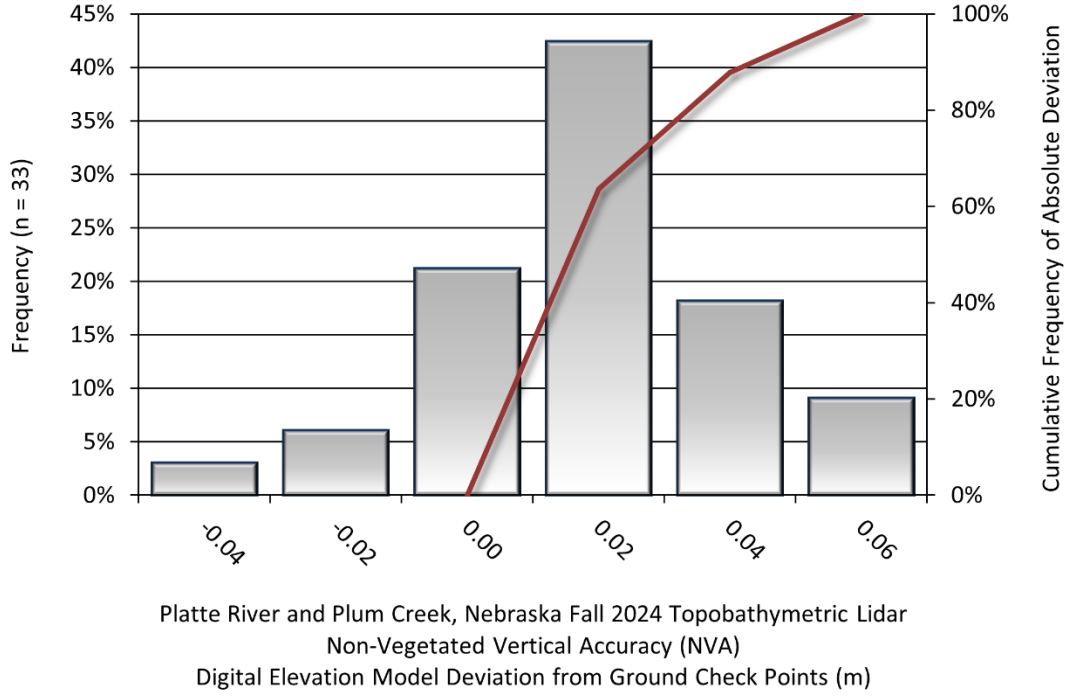


Figure 23: Frequency histogram for lidar bare earth DEM deviation from ground check point values

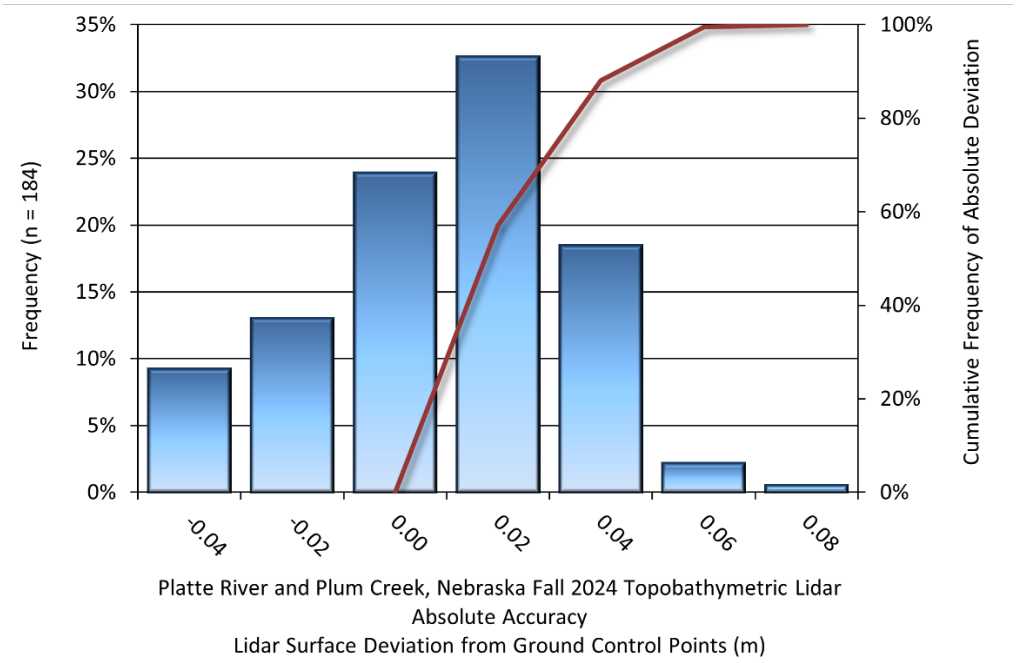


Figure 24: Frequency histogram for lidar surface deviation ground control point values

Lidar Bathymetric Vertical Accuracies

Platte River

Bathymetric (submerged or along the water's edge) checkpoints were also collected in the Platte River AOI in order to assess the submerged surface vertical accuracy. Assessment of 362 submerged bathymetric checkpoints resulted in a vertical accuracy of 0.257 feet (0.078 meters), while assessment of 146 wetted edge checkpoints resulted in a vertical accuracy of 0.192 feet (0.059 meters), evaluated at 95% confidence interval (Table 19, Figure 25, and Figure 26).

Table 19: Bathymetric vertical accuracy in the Platte River AOI

Parameter	Submerged Bathymetric Checkpoints	Wetted Edge Bathymetric Checkpoints
Sample	362 points	146 points
95% Confidence (1.96*RMSE)	0.257 ft 0.078 m	0.192 ft 0.059 m
Average Dz	-0.020 ft -0.006 m	0.006 ft 0.002 m
Median	-0.011 ft -0.004 m	0.000 ft 0.000 m
RMSE	0.131 ft 0.040 m	0.098 ft 0.030 m
Standard Deviation (1σ)	0.130 ft 0.040 m	0.098 ft 0.030 m

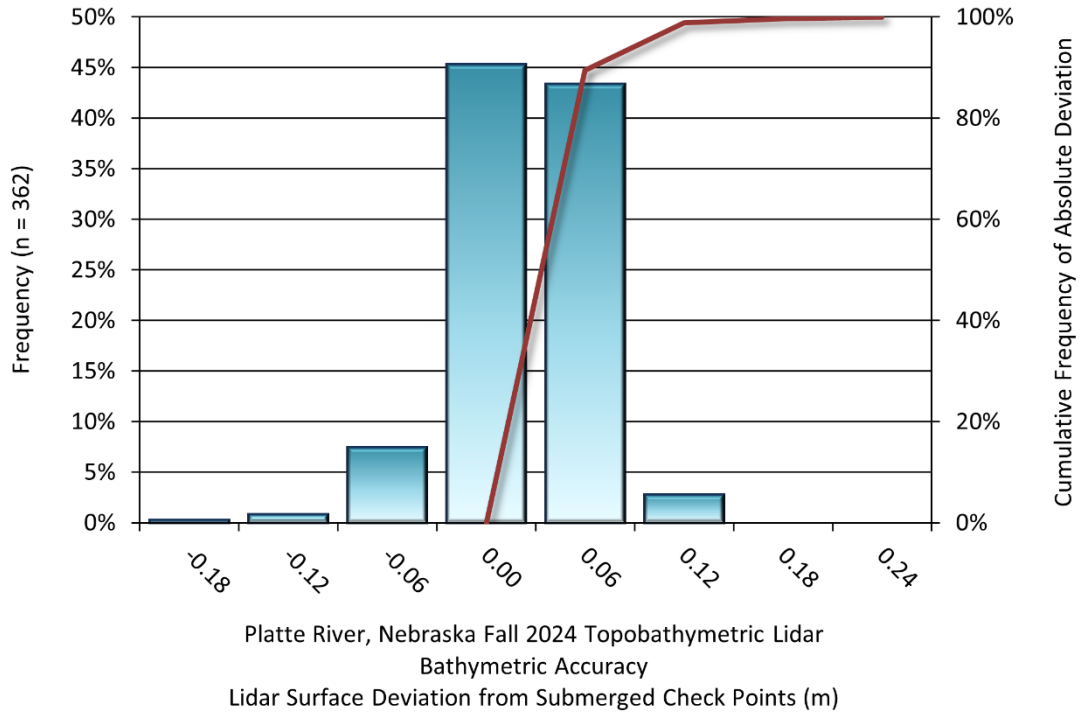


Figure 25: Frequency histogram for lidar surface deviation from submerged check point values

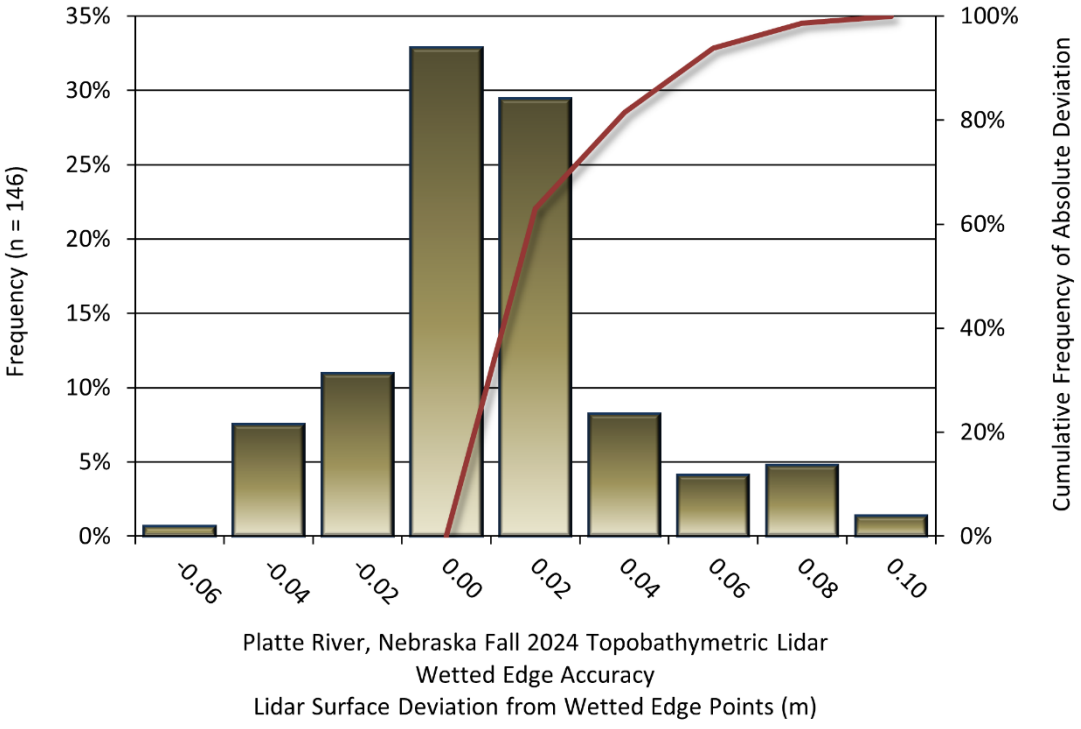


Figure 26: Frequency histogram for lidar surface deviation from wetted edge check point values

Plum Creek

Submerged bathymetric checkpoints were also collected in order to assess the submerged surface vertical accuracy. Assessment of 15 submerged bathymetric checkpoints resulted in a vertical accuracy of 0.186 feet (0.057 meters), evaluated at 95% confidence interval (Table 20, Figure 27).

Table 20: Bathymetric vertical accuracy in the Plum Creek AOI

Parameter	Submerged Bathymetric Checkpoints
Sample	15 points
95% Confidence (1.96*RMSE)	0.186 ft 0.057 m
Average Dz	0.075 ft 0.023 m
Median	0.082 ft 0.025 m
RMSE	0.095 ft 0.029 m
Standard Deviation (1σ)	0.060 ft 0.018 m

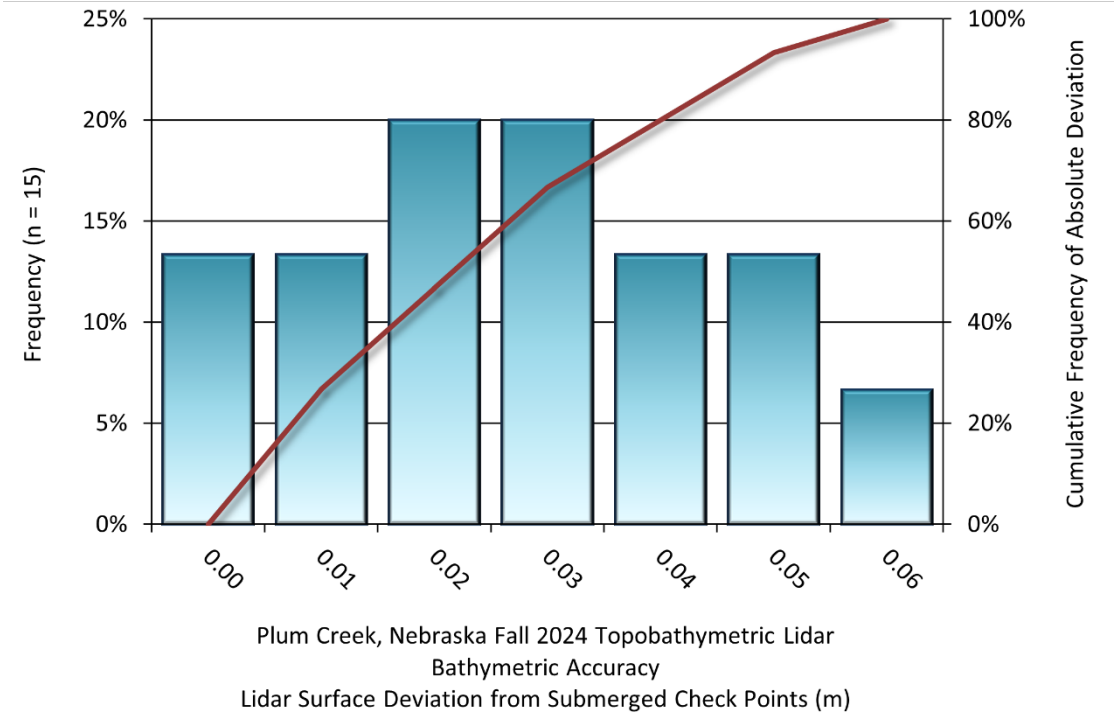


Figure 27: Frequency histogram for lidar surface deviation from submerged check point values

Combined

Bathymetric (submerged or along the water's edge) checkpoints were also collected in order to assess the submerged surface vertical accuracy. Assessment of 366 submerged bathymetric checkpoints resulted in a vertical accuracy of 0.281 feet (0.086 meters), while assessment of 151 wetted edge checkpoints resulted in a vertical accuracy of 0.222 feet (0.068 meters), evaluated at 95% confidence interval (Table 21, Figure 28, Figure 29).

Table 21: Bathymetric vertical accuracy in the combined Platte River project area

Parameter	Submerged Bathymetric Checkpoints	Wetted Edge Bathymetric Checkpoints
Sample	362 points	146 points
95% Confidence (1.96*RMSE)	0.257 ft 0.078 m	0.192 ft 0.059 m
Average Dz	-0.020 ft -0.006 m	0.006 ft 0.002 m
Median	-0.011 ft -0.004 m	0.000 ft 0.000 m
RMSE	0.131 ft 0.040 m	0.098 ft 0.030 m
Standard Deviation (1σ)	0.130 ft 0.040 m	0.098 ft 0.030 m

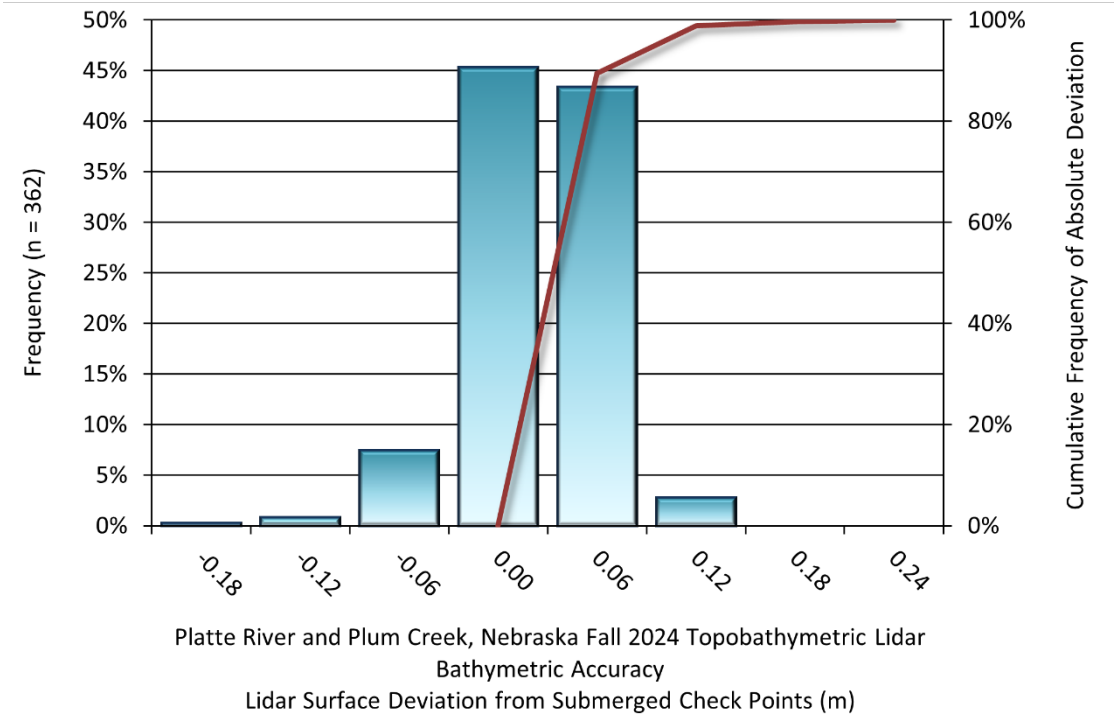


Figure 28: Frequency histogram for lidar surface deviation from submerged check point values

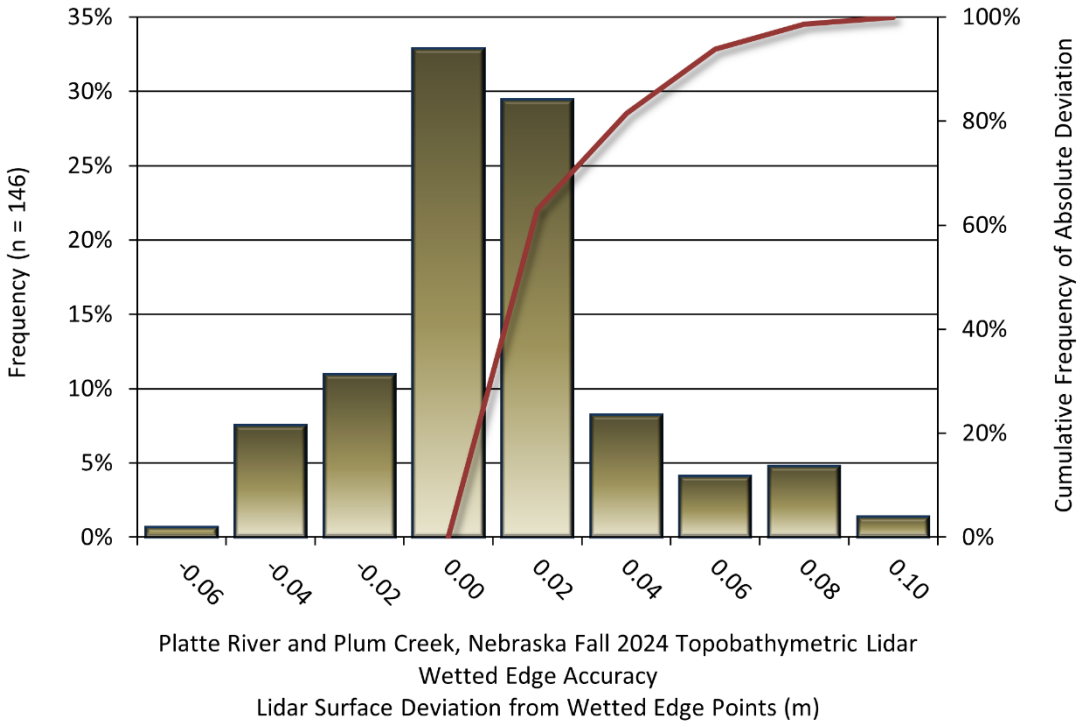


Figure 29: Frequency histogram for lidar surface deviation from wetted edge check point values

Lidar Relative Vertical Accuracy

Relative vertical accuracy refers to the internal consistency of the data set as a whole: the ability to place an object in the same location given multiple flight lines, GPS conditions, and aircraft attitudes. When the lidar system is well calibrated, the swath-to-swath vertical divergence is low (<0.10 meters). The relative vertical accuracy was computed by comparing the ground surface model of each individual flight line with its neighbors in overlapping regions. The average (mean) line to line relative vertical accuracy for the Platte River lidar project was 0.048 feet (0.015 meters) (Table 22, Figure 30 through Figure 32).

Table 22: Relative accuracy results

Parameter	Platte River AOI	Plum Creek AOI	Combined
Sample	388 flight line surfaces	139 flight line surfaces	500 flight line surfaces
Average	0.048 ft 0.015 m	0.043 ft 0.013 m	0.047 ft 0.014 m
Median	0.045 ft 0.014 m	0.043 ft 0.013 m	0.044 ft 0.014 m
RMSE	0.047 ft 0.014 m	0.043 ft 0.013 m	0.046 ft 0.014 m
Standard Deviation (1σ)	0.008 ft 0.003 m	0.004 ft 0.001 m	0.008 ft 0.002 m
1.96σ	0.016 ft 0.005 m	0.007 ft 0.002 m	0.015 ft 0.005 m

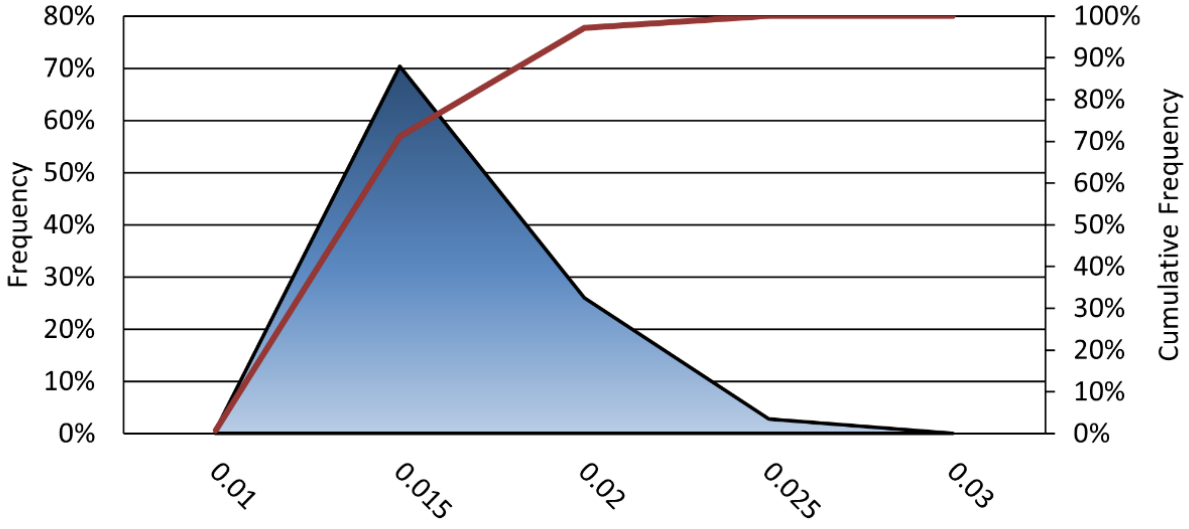


Figure 30: Frequency plot for relative vertical accuracy between flight lines for Platte River

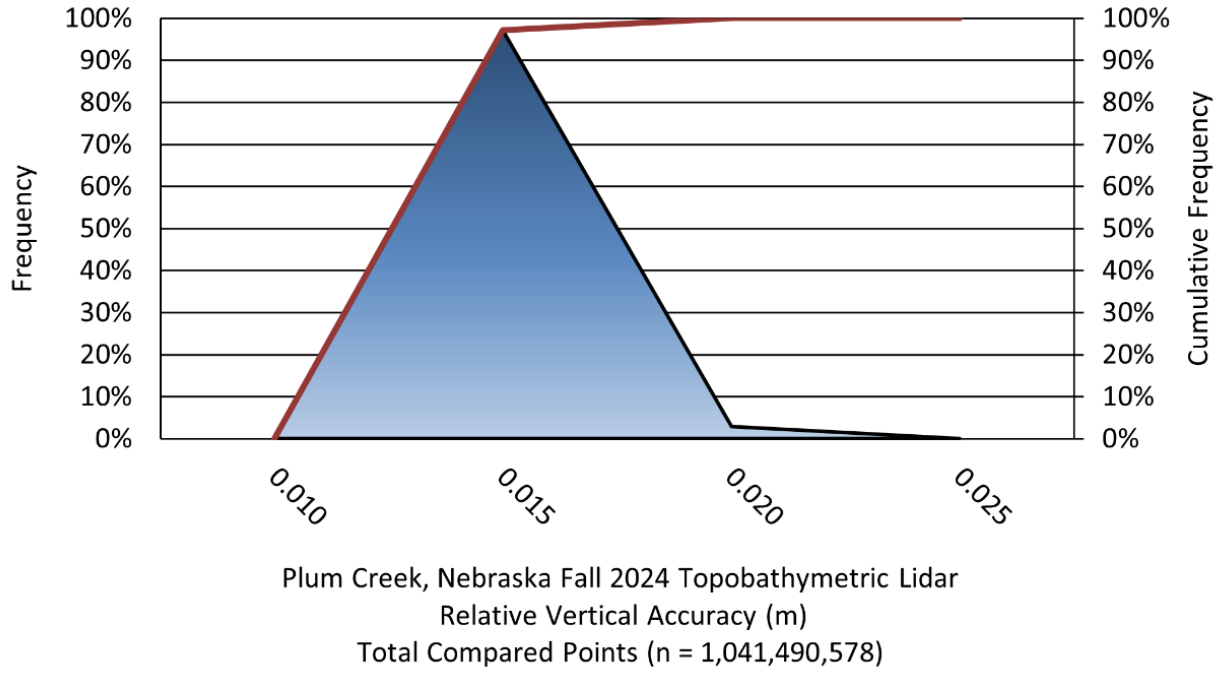


Figure 31: Frequency plot for relative vertical accuracy between flight lines for Plum Creek

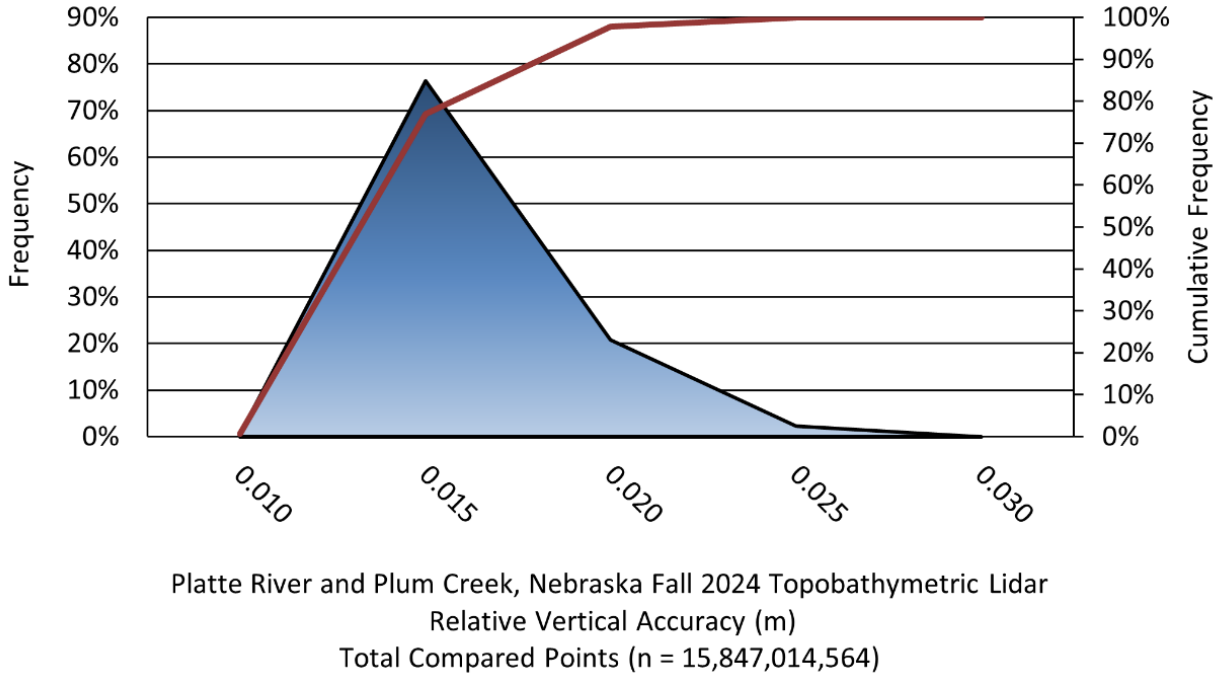


Figure 32: Frequency plot for relative vertical accuracy between flight lines

Lidar Horizontal Accuracy

Lidar horizontal accuracy is a function of Global Navigation Satellite System (GNSS) derived positional error, flying altitude, and inertial navigation system (INS) derived attitude error. The obtained $RMSE_r$ value is multiplied by a conversion factor of 1.7308 to yield the horizontal component of the National Standards for Spatial Data Accuracy (NSSDA) reporting standard where a theoretical point will fall within the obtained radius 95 percent of the time. Based on a flying altitude of 450 meters, an IMU error of 0.002 decimal degrees, and a GNSS positional error of 0.036 meters, this project was produced to meet 0.259 feet (0.079 meters) horizontal accuracy at the 95% confidence level (Table 23).

Table 23: Horizontal accuracy

Parameter	Horizontal Accuracy
$RMSE_r$	0.150 ft 0.046 m
ACC_r	0.259 ft 0.079 m

CERTIFICATIONS

NV5 provided lidar services for the Platte River project as described in this report.

I, Neil Pinto, have reviewed the attached report for completeness and hereby state that it is a complete and accurate report of this project.

Neil Pinto (Mar 14, 2025 09:50 EDT) Mar 14, 2025

Neil Pinto
Project Manager
NV5

I, Steven J. Hyde, PLS, being duly registered as a Professional Land Surveyor in and by the state of Nebraska, hereby certify that the methodologies, static GNSS occupations used during airborne flights, and ground survey point collection were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between October 28, 2024 and November 11, 2024.

Accuracy statistics shown in the Accuracy Section of this Report have been reviewed by me and found to meet the "National Standard for Spatial Data Accuracy".

NEBRASKA REGISTERED LS-769 LAND SURVEYOR STEVEN J. HYDE

Steven J. Hyde
NE PLS #769
NV5
3/11/25

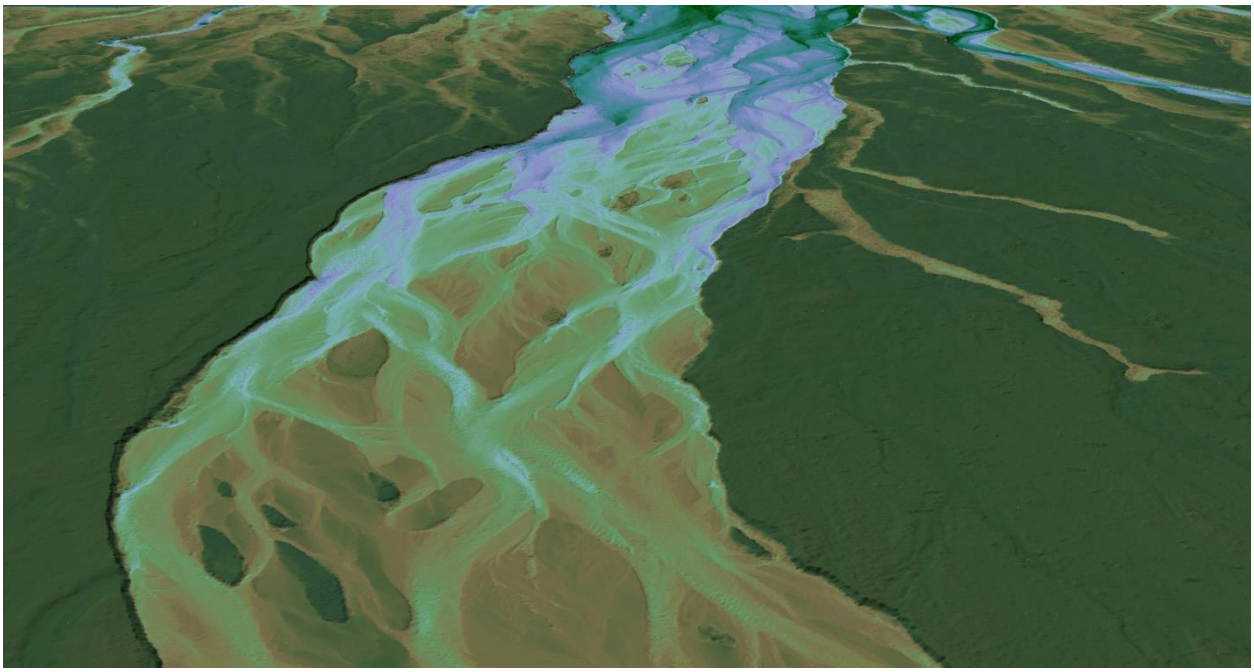


Figure 33: View looking east over Platte River. The image was created from the lidar bare earth model colored by elevation.

GLOSSARY

1-sigma (σ) Absolute Deviation: Value for which the data are within one standard deviation (approximately 68th percentile) of a normally distributed data set.

1.96 * RMSE Absolute Deviation: Value for which the data are within two standard deviations (approximately 95th percentile) of a normally distributed data set, based on the FGDC standards for Non-vegetated Vertical Accuracy (NVA) reporting.

Accuracy: The statistical comparison between known (surveyed) points and laser points. Typically measured as the standard deviation (sigma σ) and root mean square error (RMSE).

> **Absolute Accuracy:** The vertical accuracy of lidar data is described as the mean and standard deviation (sigma σ) of divergence of lidar point coordinates from ground survey point coordinates. To provide a sense of the model predictive power of the dataset, the root mean square error (RMSE) for vertical accuracy is also provided. These statistics assume the error distributions for x, y and z are normally distributed, and thus we also consider the skew and kurtosis of distributions when evaluating error statistics.
>
> **Relative Accuracy:** Relative accuracy refers to the internal consistency of the data set; i.e., the ability to place a laser point in the same location over multiple flight lines, GPS conditions and aircraft attitudes. Affected by system attitude offsets, scale and GPS/IMU drift, internal consistency is measured as the divergence between points from different flight lines within an overlapping area. Divergence is most apparent when flight lines are opposing. When the lidar system is well calibrated, the line-to-line divergence is low (<10 cm).
>
> **Root Mean Square Error (RMSE):** A statistic used to approximate the difference between real-world points and the lidar points. It is calculated by squaring all the values, then taking the average of the squares and taking the square root of the average.

Data Density: A common measure of lidar resolution, measured as points per square meter.

Digital Elevation Model (DEM): File or database made from surveyed points, containing elevation points over a contiguous area. Digital terrain models (DTM) and digital surface models (DSM) are types of DEMs. DTMs consist solely of the bare earth surface (ground points), while DSMs include information about all surfaces, including vegetation and man-made structures.

Intensity Values: The peak power ratio of the laser return to the emitted laser, calculated as a function of surface reflectivity.

Nadir: A single point or locus of points on the surface of the earth directly below a sensor as it progresses along its flight line.

Overlap: The area shared between flight lines, typically measured in percent. 100% overlap is essential to ensure complete coverage and reduce laser shadows.

Pulse Rate (PR): The rate at which laser pulses are emitted from the sensor; typically measured in thousands of pulses per second (kHz).

Pulse Returns: For every laser pulse emitted, the number of wave forms (i.e., echoes) reflected back to the sensor. Portions of the wave form that return first are the highest element in multi-tiered surfaces such as vegetation. Portions of the wave form that return last are the lowest element in multi-tiered surfaces.

Real-Time Kinematic (RTK) Survey: A type of surveying conducted with a GPS base station deployed over a known monument with a radio connection to a GPS rover. Both the base station and rover receive differential GPS data and the baseline correction is solved between the two. This type of ground survey is accurate to 1.5 cm or less.

Post-Processed Kinematic (PPK) Survey: GPS surveying is conducted with a GPS rover collecting concurrently with a GPS base station set up over a known monument. Differential corrections and precisions for the GNSS baselines are computed and applied after the fact during processing. This type of ground survey is accurate to 1.5 cm or less.

Scan Angle: The angle from nadir to the edge of the scan, measured in degrees. Laser point accuracy typically decreases as scan angles increase.

Native Lidar Density: The number of pulses emitted by the lidar system, commonly expressed as pulses per square meter.

Relative Accuracy Calibration Methodology:

Manual System Calibration: Calibration procedures for each mission require solving geometric relationships that relate measured swath-to-swath deviations to misalignments of system attitude parameters. Corrected scale, pitch, roll and heading offsets were calculated and applied to resolve misalignments. The raw divergence between lines was computed after the manual calibration was completed and reported for each survey area.

Automated Attitude Calibration: All data was tested and calibrated using TerraMatch automated sampling routines. Ground points were classified for each individual flight line and used for line-to-line testing. System misalignment offsets (pitch, roll and heading) and scale were solved for each individual mission and applied to respective mission datasets. The data from each mission were then blended when imported together to form the entire area of interest.

Automated Z Calibration: Ground points per line were used to calculate the vertical divergence between lines caused by vertical GPS drift. Automated Z calibration was the final step employed for relative accuracy calibration.

Lidar accuracy error sources and solutions:

Source	Type	Post Processing Solution
Long Base Lines	GPS	None
Poor Satellite Constellation	GPS	None
Poor Antenna Visibility	GPS	Reduce Visibility Mask
Poor System Calibration	System	Recalibrate IMU and sensor offsets/settings
Inaccurate System	System	None
Poor Laser Timing	Laser Noise	None
Poor Laser Reception	Laser Noise	None
Poor Laser Power	Laser Noise	None
Irregular Laser Shape	Laser Noise	None

Operational measures taken to improve relative accuracy:

Focus Laser Power at narrow beam footprint: A laser return must be received by the system above a power threshold to accurately record a measurement. The strength of the laser return (i.e., intensity) is a function of laser emission power, laser footprint, flight altitude and the reflectivity of the target. While surface reflectivity cannot be controlled, laser power can be increased and low flight altitudes can be maintained.

Reduced Scan Angle: Edge-of-scan data can become inaccurate. The scan angle was reduced to a maximum of ±20° to ±21° for the green and NIR lasers, respectively, from nadir, creating a narrow swath width and greatly reducing laser shadows from trees and buildings.

Quality GPS: Flights took place during optimal GPS conditions (e.g., 6 or more satellites and PDOP [Position Dilution of Precision] less than 3.0). Before each flight, the PDOP was determined for the survey day.

Ground Survey: Ground survey point accuracy (<1.5 cm RMSE) occurs during optimal PDOP ranges and targets a minimal baseline distance of 4 miles between GPS rover and base. Robust statistics are, in part, a function of sample size (n) and distribution. Ground survey points are distributed to the extent possible throughout multiple flight lines and across the survey area.

50% Side-Lap (100% Overlap): Overlapping areas are optimized for relative accuracy testing. Laser shadowing is minimized to help increase target acquisition from multiple scan angles. Ideally, with a 50% side-lap, the nadir portion of one flight line coincides with the swath edge portion of overlapping flight lines. A minimum of 50% side-lap with terrain-followed acquisition prevents data gaps.

Opposing Flight Lines: All overlapping flight lines have opposing directions. Pitch, roll and heading errors are amplified by a factor of two relative to the adjacent flight line(s), making misalignments easier to detect and resolve.

APPENDIX B – FALL 2020 GROUND SURVEY POINT TABLES

Table 24: Non-vegetated vertical accuracy – Fall 2024 lidar data vs. Fall 2020 ground survey points

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
1	534735.878	4511910.447	598.112	598.070	-0.042	-0.138
2	571885.587	4537569.270	541.926	541.930	0.004	0.013
4	534740.848	4511954.338	598.018	597.990	-0.028	-0.092
6	571830.946	4537617.791	541.749	541.760	0.011	0.036
7	552433.797	4518864.599	580.831	580.810	-0.021	-0.069
8	552434.296	4518804.720	579.933	579.910	-0.023	-0.075
9	571777.009	4537666.455	541.450	541.440	-0.010	-0.033
10	534746.118	4511998.005	598.010	598.000	-0.010	-0.033
13	571721.796	4537716.138	541.068	541.070	0.002	0.007
14	552437.356	4518746.728	578.683	578.650	-0.033	-0.108
15	574705.228	4537784.055	566.213	566.240	0.027	0.089
16	552435.501	4518687.921	577.514	577.500	-0.014	-0.046
17	571669.756	4537770.546	540.526	540.540	0.014	0.046
18	574636.857	4537781.998	567.303	567.340	0.037	0.121
21	571622.269	4537831.997	540.613	540.600	-0.013	-0.043
22	552440.789	4518648.060	576.849	576.830	-0.019	-0.062
23	574561.367	4537779.751	567.530	567.540	0.010	0.033
24	552440.309	4518587.355	576.771	576.740	-0.031	-0.102
25	534761.825	4512572.586	603.783	603.790	0.007	0.023
26	571597.2	4537903.23	540.169	540.21	0.041	0.135
27	574489.319	4537779.754	565.541	565.530	-0.011	-0.036
28	552440.854	4518525.523	576.677	576.650	-0.027	-0.089
29	571581.726	4537976.907	539.959	539.960	0.001	0.003
31	574417.385	4537777.046	562.471	562.480	0.009	0.030
32	571567.686	4538052.373	540.013	540.000	-0.013	-0.043

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
33	534763.320	4512484.240	604.565	604.580	0.015	0.049
34	552438.249	4518461.889	576.561	576.540	-0.021	-0.069
35	574345.368	4537774.508	558.972	558.940	-0.032	-0.105
36	571554.151	4538124.197	539.999	539.990	-0.009	-0.030
37	534764.285	4512441.618	603.834	603.850	0.016	0.052
38	552438.793	4518401.321	576.467	576.450	-0.017	-0.056
39	574273.505	4537768.714	556.207	556.190	-0.017	-0.056
40	571539.971	4538200.017	540.080	540.060	-0.020	-0.066
41	574202.697	4537766.508	553.653	553.630	-0.023	-0.075
42	552439.374	4518341.012	576.427	576.410	-0.017	-0.056
43	534764.577	4512397.644	602.170	602.170	0.000	0.000
44	574132.815	4537763.845	551.224	551.240	0.016	0.052
46	534765.459	4512353.310	600.170	600.180	0.010	0.033
47	534772.7	4512309.57	598.569	598.61	0.041	0.135
48	574061.511	4537761.117	549.284	549.290	0.006	0.020
49	571513.135	4538357.059	539.876	539.870	-0.006	-0.020
50	552440.303	4518218.633	576.214	576.200	-0.014	-0.046
51	534765.701	4512266.192	598.253	598.290	0.037	0.121
52	552440.592	4518166.069	576.151	576.120	-0.031	-0.102
53	573989.944	4537758.612	547.997	547.980	-0.017	-0.056
54	571509.625	4538434.669	539.647	539.640	-0.007	-0.023
55	552440.951	4518104.224	576.173	576.150	-0.023	-0.075
56	573918.222	4537756.556	546.367	546.360	-0.007	-0.023
57	534767.035	4512222.552	597.985	597.980	-0.005	-0.016
58	571505.026	4538511.343	539.607	539.610	0.003	0.010
59	573844.378	4537753.786	544.961	544.970	0.009	0.030
60	552441.559	4518043.218	576.303	576.280	-0.023	-0.075
61	534763.531	4512177.230	598.054	598.050	-0.004	-0.013
62	571504.441	4538589.935	539.712	539.710	-0.002	-0.007
63	571503.954	4538664.070	539.730	539.730	0.000	0.000

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
64	573769.832	4537751.369	544.337	544.350	0.013	0.043
65	552441.892	4517983.504	576.522	576.510	-0.012	-0.039
66	534761.295	4512133.413	598.094	598.100	0.006	0.020
67	552442.222	4517923.516	576.741	576.720	-0.021	-0.069
68	534757.838	4512092.395	598.095	598.110	0.015	0.049
69	573698.958	4537748.827	543.778	543.780	0.002	0.007
70	571503.579	4538742.167	539.760	539.750	-0.010	-0.033
71	573626.952	4537746.421	542.666	542.690	0.024	0.079
72	552442.478	4517875.871	576.895	576.870	-0.025	-0.082
73	534752.392	4512048.288	598.035	598.040	0.005	0.016
74	571503.165	4538817.764	539.786	539.820	0.034	0.112
75	573553.153	4537744.293	542.378	542.400	0.022	0.072
76	571502.748	4538894.607	539.762	539.780	0.018	0.059
77	552421.01	4520227.85	574.911	574.87	-0.041	-0.135
78	571502.214	4538968.971	539.742	539.780	0.038	0.125
79	573480.861	4537741.811	542.455	542.470	0.015	0.049
80	552421.926	4520166.881	575.367	575.330	-0.037	-0.121
81	573407.610	4537739.302	542.346	542.370	0.024	0.079
82	552422.572	4520107.313	575.681	575.670	-0.011	-0.036
83	571913.913	4537539.027	542.056	542.080	0.024	0.079
84	573336.906	4537733.281	542.020	542.040	0.020	0.066
85	552423.285	4520046.934	575.880	575.850	-0.030	-0.098
87	573241.653	4537714.006	541.656	541.610	-0.046	-0.151
88	552423.554	4520015.040	575.875	575.890	0.015	0.049
91	573173.181	4537692.421	541.494	541.510	0.016	0.052
92	572134.726	4537344.780	542.160	542.160	0.000	0.000
93	573107.208	4537663.830	541.232	541.250	0.018	0.059
94	552424.695	4519895.700	575.897	575.900	0.003	0.010
95	572190.685	4537293.610	541.985	542.010	0.025	0.082
96	573044.663	4537629.565	541.295	541.290	-0.005	-0.016

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
97	552425.474	4519834.145	575.978	575.940	-0.038	-0.125
98	572245.880	4537244.451	541.703	541.710	0.007	0.023
99	552426.082	4519773.308	575.976	575.950	-0.026	-0.085
100	572985.467	4537589.534	541.465	541.480	0.015	0.049
101	572925.985	4537545.425	541.689	541.710	0.021	0.069
102	552426.625	4519710.139	575.999	575.970	-0.029	-0.095
103	572290.164	4537197.051	542.133	542.150	0.017	0.056
104	552427.022	4519650.394	575.978	575.980	0.002	0.007
105	572359.791	4537217.550	541.883	541.880	-0.003	-0.010
106	572420.705	4537243.540	542.046	542.060	0.014	0.046
108	572488.845	4537272.801	542.251	542.240	-0.011	-0.036
109	552428.118	4519531.171	575.969	575.980	0.011	0.036
110	552429.999	4519469.682	575.939	575.910	-0.029	-0.095
111	572554.510	4537304.746	542.309	542.320	0.011	0.036
112	572622.614	4537335.819	542.339	542.350	0.011	0.036
113	552429.532	4519408.400	575.981	575.950	-0.031	-0.102
114	572686.045	4537370.552	542.198	542.230	0.032	0.105
115	552430.718	4519354.145	576.302	576.280	-0.022	-0.072
116	552433.287	4519291.960	577.088	577.060	-0.028	-0.092
117	572747.367	4537419.574	542.221	542.250	0.029	0.095
118	572808.707	4537460.093	542.442	542.460	0.018	0.059
119	552433.849	4519232.514	578.304	578.270	-0.034	-0.112
120	552431.053	4519175.325	579.683	579.650	-0.033	-0.108
121	552433.6	4519113.86	580.749	580.71	-0.039	-0.128
122	552433.561	4519051.929	581.486	581.450	-0.036	-0.118
124	552415.604	4520665.568	573.122	573.100	-0.022	-0.072
125	552416.243	4520607.308	573.090	573.110	0.020	0.066
126	552417.005	4520547.019	573.062	573.070	0.008	0.026
127	552417.82	4520486.78	573.14	573.1	-0.04	-0.131
128	552418.474	4520426.773	573.339	573.290	-0.049	-0.161

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
129	552419.327	4520365.852	573.707	573.680	-0.027	-0.089
130	552419.970	4520307.238	574.209	574.180	-0.029	-0.095
131	552420.665	4520254.874	574.677	574.640	-0.037	-0.121
134	542807.604	4513357.922	588.879	588.850	-0.029	-0.095
136	542821.36	4512184.64	589.454	589.38	-0.074	-0.243
137	542817.14	4512255.13	589.186	589.09	-0.096	-0.315
138	542816.33	4512323.87	588.582	588.51	-0.072	-0.236
139	542816.13	4512393.04	588.359	588.3	-0.059	-0.194
140	542815.61	4512463.88	588.347	588.28	-0.067	-0.220
141	542814.94	4512532.96	588.137	588.08	-0.057	-0.187
142	542814.56	4512600.56	588.254	588.2	-0.054	-0.177
143	542814.12	4512669.94	588.177	588.11	-0.067	-0.220
144	542813.55	4512738.18	588.287	588.22	-0.067	-0.220
145	542812.663	4512800.228	588.417	588.370	-0.047	-0.154
146	542812.23	4512869.33	588.387	588.33	-0.057	-0.187
147	542811.26	4512935.2	588.399	588.36	-0.039	-0.128
148	542810.715	4512997.449	588.336	588.310	-0.026	-0.085
149	542810.126	4513068.685	588.517	588.480	-0.037	-0.121
150	542809.324	4513138.001	588.622	588.590	-0.032	-0.105
151	542809.02	4513208.05	588.716	588.66	-0.056	-0.184
152	542808.37	4513276.18	588.682	588.63	-0.052	-0.171
153	542807.405	4513353.232	588.824	588.780	-0.044	-0.144
154	535030.56	4510904.51	600.237	600.32	0.083	0.272
155	535043.095	4510866.468	599.727	599.750	0.023	0.075
156	535056.285	4510827.051	599.197	599.230	0.033	0.108
157	535069.194	4510787.718	598.845	598.860	0.015	0.049
158	535082.079	4510748.393	598.684	598.680	-0.004	-0.013
159	535090.741	4510706.320	598.508	598.520	0.012	0.039
160	535105.755	4510665.963	598.667	598.680	0.013	0.043
161	535117.295	4510623.360	598.766	598.760	-0.006	-0.020

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
162	535126.923	4510581.676	598.551	598.540	-0.011	-0.036
163	535137.114	4510539.207	598.203	598.210	0.007	0.023
164	535145.999	4510499.868	598.032	598.080	0.048	0.157
165	535155.65	4510458.89	597.862	597.92	0.058	0.190
166	535165.619	4510416.907	597.841	597.890	0.049	0.161
167	535175.6	4510374.43	597.824	597.89	0.066	0.217
168	552447.955	4517090.599	577.265	577.260	-0.005	-0.016
169	535185.4	4510332.88	597.851	597.92	0.069	0.226
170	535195.66	4510288.8	597.871	597.94	0.069	0.226
173	535205.62	4510246.31	597.784	597.84	0.056	0.184
174	535216.1	4510203.25	597.735	597.82	0.085	0.279
175	552449.178	4516914.008	577.348	577.310	-0.038	-0.125
176	535226.392	4510160.783	597.707	597.750	0.043	0.141
177	552450.304	4516804.605	576.649	576.640	-0.009	-0.030
178	535235.95	4510120.85	597.701	597.74	0.039	0.128
179	552452.24	4516748.23	576.259	576.22	-0.039	-0.128
180	535246.38	4510077.99	597.664	597.74	0.076	0.249
181	535256.08	4510035.92	597.643	597.7	0.057	0.187
182	552451.296	4516693.187	575.880	575.860	-0.020	-0.066
183	535266.214	4509993.400	597.731	597.780	0.049	0.161
184	552451.790	4516637.452	575.616	575.590	-0.026	-0.085
185	535276.395	4509950.087	597.786	597.830	0.044	0.144
186	552452.456	4516582.039	575.528	575.510	-0.018	-0.059
187	535286.658	4509907.599	597.839	597.860	0.021	0.069
188	552452.968	4516532.075	575.578	575.560	-0.018	-0.059
189	535293.42	4509864.2	597.89	597.96	0.07	0.230
190	552453.604	4516475.529	575.662	575.650	-0.012	-0.039
192	552454.157	4516418.864	575.764	575.760	-0.004	-0.013
194	552454.572	4516362.690	575.850	575.830	-0.020	-0.066
200	552442.430	4517844.610	576.991	576.940	-0.051	-0.167

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
202	552443.058	4517786.360	577.071	577.040	-0.031	-0.102
203	552445.770	4517724.654	577.023	576.990	-0.033	-0.108
204	534957.292	4511115.835	600.283	600.320	0.037	0.121
205	552444.15	4517672.82	577.004	576.96	-0.044	-0.144
206	534942.909	4511160.962	599.815	599.790	-0.025	-0.082
207	534928.543	4511203.708	599.353	599.330	-0.023	-0.075
208	552444.28	4517617.47	576.829	576.79	-0.039	-0.128
209	534914.507	4511246.432	598.982	598.950	-0.032	-0.105
210	552444.89	4517561.91	576.566	576.51	-0.056	-0.184
211	534899.456	4511292.138	598.777	598.730	-0.047	-0.154
212	552445.113	4517505.769	576.280	576.230	-0.050	-0.164
213	534885.194	4511335.985	598.727	598.680	-0.047	-0.154
214	552445.51	4517451.03	576.003	575.95	-0.053	-0.174
215	552446.110	4517395.223	575.746	575.710	-0.036	-0.118
216	534870.782	4511379.919	598.683	598.660	-0.023	-0.075
217	534856.114	4511425.101	598.710	598.700	-0.010	-0.033
218	552446.181	4517353.299	575.705	575.660	-0.045	-0.148
219	552446.538	4517302.906	575.801	575.750	-0.051	-0.167
220	534840.489	4511473.057	598.916	598.900	-0.016	-0.052
221	552446.757	4517261.783	576.043	576.000	-0.043	-0.141
222	534814.641	4511563.638	599.683	599.660	-0.023	-0.075
223	552447.072	4517213.950	576.413	576.370	-0.043	-0.141
224	534801.04	4511593.56	599.873	599.95	0.077	0.253
225	552444.66	4517164.98	576.891	576.85	-0.041	-0.135
226	552447.63	4517126.11	577.099	577.06	-0.039	-0.128
228	534767.54	4511694.38	599.875	599.94	0.065	0.213
229	534751.138	4511735.244	599.680	599.690	0.010	0.033
230	534741.795	4511779.710	599.330	599.320	-0.010	-0.033
231	534734.266	4511824.180	598.955	598.930	-0.025	-0.082
232	534731.006	4511870.522	598.569	598.550	-0.019	-0.062

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
233	558390.863	4526429.505	562.333	562.310	-0.023	-0.075
234	542717.865	4516411.310	590.737	590.730	-0.007	-0.023
235	558477.798	4526430.261	562.308	562.290	-0.018	-0.059
236	542719.78	4516350.23	587.909	587.87	-0.039	-0.128
237	542715.362	4516286.188	586.451	586.450	-0.001	-0.003
238	558565.138	4526431.198	562.313	562.310	-0.003	-0.010
239	542709.966	4516221.887	586.745	586.710	-0.035	-0.115
240	558652.448	4526432.372	562.346	562.320	-0.026	-0.085
241	542708.582	4516158.225	586.790	586.770	-0.020	-0.066
242	558739.696	4526435.314	562.307	562.290	-0.017	-0.056
243	558846.043	4526438.045	562.266	562.250	-0.016	-0.052
244	542707.983	4516093.812	586.646	586.620	-0.026	-0.085
245	558934.821	4526434.529	562.423	562.390	-0.033	-0.108
246	542711.121	4516032.466	587.105	587.110	0.005	0.016
247	542718.346	4515969.964	587.636	587.600	-0.036	-0.118
248	559020.638	4526434.716	562.363	562.320	-0.043	-0.141
250	559105.391	4526435.011	562.278	562.260	-0.018	-0.059
252	559192.100	4526435.728	562.222	562.200	-0.022	-0.072
253	542743.525	4515781.436	587.803	587.790	-0.013	-0.043
254	559278.467	4526436.242	562.171	562.160	-0.011	-0.036
255	542754.895	4515721.816	587.638	587.630	-0.008	-0.026
256	559366.170	4526436.809	562.126	562.110	-0.016	-0.052
257	559440.61	4526437.28	562.129	562.09	-0.039	-0.128
258	542763.130	4515659.224	587.722	587.700	-0.022	-0.072
259	542771.828	4515594.631	587.769	587.750	-0.019	-0.062
260	559524.254	4526436.257	562.314	562.280	-0.034	-0.112
261	560438.299	4525033.717	563.219	563.210	-0.009	-0.030
262	542779.602	4515532.485	587.842	587.810	-0.032	-0.105
263	542788.131	4515468.661	587.916	587.910	-0.006	-0.020
264	560375.321	4525098.196	562.948	562.940	-0.008	-0.026

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
265	560321.725	4525166.289	562.518	562.510	-0.008	-0.026
266	542801.255	4515341.576	587.716	587.720	0.004	0.013
267	560275.548	4525240.446	562.058	562.080	0.022	0.072
268	560238.552	4525317.711	561.687	561.690	0.003	0.010
269	542810.04	4515277.67	587.86	587.82	-0.04	-0.131
270	560209.575	4525401.143	561.466	561.460	-0.006	-0.020
271	542816.550	4515215.850	587.852	587.810	-0.042	-0.138
272	542817.377	4515148.924	587.989	587.940	-0.049	-0.161
273	560190.054	4525486.027	561.143	561.150	0.007	0.023
274	542817.201	4515084.021	587.742	587.720	-0.022	-0.072
275	560165.749	4525572.083	560.836	560.840	0.004	0.013
276	560143.585	4525659.786	560.763	560.770	0.007	0.023
277	542816.921	4515018.794	587.791	587.770	-0.021	-0.069
278	560121.904	4525746.086	560.741	560.750	0.009	0.030
279	542816.37	4514954.39	587.759	587.72	-0.039	-0.128
280	560100.651	4525830.674	560.741	560.720	-0.021	-0.069
281	542819.66	4514888.89	587.799	587.73	-0.069	-0.226
282	542819.213	4514825.577	587.738	587.740	0.002	0.007
283	560078.779	4525917.466	560.716	560.680	-0.036	-0.118
284	542818.918	4514760.378	587.765	587.770	0.005	0.016
285	559591.46	4526429.93	562.221	562.18	-0.041	-0.135
286	542818.213	4514681.838	587.890	587.870	-0.020	-0.066
287	559676.713	4526409.897	562.120	562.070	-0.050	-0.164
288	559759.1	4526377.19	561.98	561.94	-0.04	-0.131
289	542817.785	4514616.872	587.871	587.850	-0.021	-0.069
290	559833.750	4526333.141	561.874	561.840	-0.034	-0.112
291	542817.47	4514555.07	587.923	587.85	-0.073	-0.240
292	542816.848	4514492.063	587.956	587.920	-0.036	-0.118
293	559902.086	4526277.745	561.709	561.660	-0.049	-0.161
294	542815.869	4514429.352	587.856	587.860	0.004	0.013

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
295	559968.9	4526203	561.587	561.53	-0.057	-0.187
296	542815.124	4514368.538	587.893	587.860	-0.033	-0.108
297	560014.875	4526131.952	561.410	561.390	-0.020	-0.066
298	542814.421	4514307.154	587.882	587.860	-0.022	-0.072
299	560053.497	4526044.460	561.299	561.250	-0.049	-0.161
300	560072.97	4525979.5	561.044	560.97	-0.074	-0.243
301	542813.527	4514245.204	587.793	587.770	-0.023	-0.075
302	542812.619	4514181.587	587.835	587.840	0.005	0.016
305	542811.969	4514119.090	587.750	587.730	-0.020	-0.066
306	542811.035	4514055.753	587.837	587.790	-0.047	-0.154
308	561521.237	4524585.704	572.168	572.150	-0.018	-0.059
309	542806.098	4513930.447	587.872	587.830	-0.042	-0.138
310	561434.331	4524569.698	572.098	572.080	-0.018	-0.059
311	561349.443	4524548.844	570.560	570.550	-0.010	-0.033
312	542805.34	4513866.92	588.019	587.95	-0.069	-0.226
313	561262.360	4524539.306	567.375	567.360	-0.015	-0.049
314	542804.61	4513802.93	588.129	588.07	-0.059	-0.194
315	561170.947	4524541.665	564.548	564.530	-0.018	-0.059
316	542807.404	4513739.306	588.438	588.410	-0.028	-0.092
317	542804.216	4513672.145	588.529	588.480	-0.049	-0.161
318	561089.416	4524559.260	563.059	563.010	-0.049	-0.161
319	561009.156	4524587.066	562.650	562.620	-0.030	-0.098
320	542804.92	4513608.41	588.734	588.68	-0.054	-0.177
321	560929.071	4524623.501	562.664	562.630	-0.034	-0.112
322	560853.84	4524666.71	562.754	562.71	-0.044	-0.144
323	560783.338	4524716.145	562.965	562.940	-0.025	-0.082
324	560715.043	4524773.027	563.242	563.210	-0.032	-0.105
325	560675.621	4524810.337	563.250	563.220	-0.030	-0.098
329	492824.343	4499919.197	654.293	654.280	-0.013	-0.043
330	478390.807	4502997.555	673.555	673.510	-0.045	-0.148

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
331	504097.245	4503277.433	639.900	639.900	0.000	0.000
332	504093.965	4503221.515	639.987	639.990	0.003	0.010
333	478390.557	4502952.216	675.500	675.490	-0.010	-0.033
334	492817.696	4499962.125	654.292	654.280	-0.012	-0.039
335	492809.641	4500005.385	654.296	654.260	-0.036	-0.118
336	504093.937	4503161.441	639.996	640.020	0.024	0.079
337	478390.082	4502905.049	677.667	677.690	0.023	0.075
338	492802.904	4500048.039	654.169	654.150	-0.019	-0.062
339	478389.892	4502859.334	679.115	679.110	-0.005	-0.016
340	504094.091	4503102.307	639.935	639.950	0.015	0.049
341	504094.046	4503041.740	640.020	640.040	0.020	0.066
342	492789.645	4500091.092	654.152	654.150	-0.002	-0.007
343	478392.752	4502762.962	679.339	679.340	0.001	0.003
344	504094.11	4502983.83	640.008	640.05	0.042	0.138
345	492779.701	4500132.690	654.136	654.130	-0.006	-0.020
346	478392.400	4502717.962	678.105	678.100	-0.005	-0.016
347	492768.977	4500175.983	654.172	654.160	-0.012	-0.039
348	478391.876	4502672.644	676.085	676.080	-0.005	-0.016
349	504094.348	4502924.506	640.028	640.070	0.042	0.138
350	492762.714	4500221.341	653.972	653.960	-0.012	-0.039
351	478391.440	4502626.853	674.218	674.190	-0.028	-0.092
352	504094.869	4502866.140	640.049	640.050	0.001	0.003
353	478391.499	4502581.455	673.437	673.430	-0.007	-0.023
354	492748.081	4500263.682	654.090	654.070	-0.020	-0.066
355	504094.917	4502746.151	640.099	640.120	0.021	0.069
356	478391.142	4502534.863	673.436	673.440	0.004	0.013
357	492739.030	4500307.833	654.179	654.180	0.001	0.003
358	478390.800	4502487.639	673.608	673.570	-0.038	-0.125
359	492731.785	4500352.310	654.299	654.280	-0.019	-0.062
360	504095.075	4502687.532	640.088	640.100	0.012	0.039

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
361	492726.439	4500396.327	654.478	654.470	-0.008	-0.026
362	478390.248	4502444.022	673.530	673.520	-0.010	-0.033
363	504099.007	4502625.105	639.944	639.960	0.016	0.052
364	504095.135	4502568.759	640.053	640.070	0.017	0.056
365	492722.402	4500441.356	654.723	654.730	0.007	0.023
366	478386.255	4502396.991	673.600	673.600	0.000	0.000
367	478384.576	4502351.596	673.590	673.610	0.020	0.066
368	504095.267	4502509.680	640.059	640.060	0.001	0.003
369	492720.018	4500486.745	655.056	655.050	-0.006	-0.020
370	504095.268	4502450.063	640.056	640.070	0.014	0.046
371	492719.820	4500530.989	655.392	655.400	0.008	0.026
372	478383.035	4502307.841	673.580	673.580	0.000	0.000
373	504095.788	4502391.154	640.034	640.060	0.026	0.085
374	492720.633	4500572.292	655.760	655.760	0.000	0.000
375	478381.474	4502264.772	673.527	673.530	0.003	0.010
376	504096.742	4502332.024	640.024	640.020	-0.004	-0.013
377	492720.824	4500614.370	656.003	656.020	0.017	0.056
378	478380.058	4502220.861	673.551	673.530	-0.021	-0.069
379	504096.048	4502275.335	640.062	640.080	0.018	0.059
380	478381.337	4502176.378	673.519	673.520	0.001	0.003
383	504095.945	4502215.084	640.098	640.140	0.042	0.138
384	478379.379	4502133.510	673.546	673.550	0.004	0.013
385	478378.040	4502089.736	673.524	673.560	0.036	0.118
387	504095.968	4502156.533	640.152	640.160	0.008	0.026
388	513052.536	4505658.160	633.241	633.240	-0.001	-0.003
389	513052.568	4505719.021	633.547	633.560	0.013	0.043
391	478376.406	4502046.803	673.521	673.550	0.029	0.095
392	504096.12	4502101.18	640.106	640.16	0.054	0.177
393	478371.347	4502001.220	673.510	673.500	-0.010	-0.033
395	513048.567	4505775.141	632.452	632.470	0.018	0.059

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
396	504096.138	4502045.825	640.126	640.140	0.014	0.046
397	504096.282	4501986.404	640.160	640.180	0.020	0.066
398	513048.667	4505833.149	630.018	630.030	0.012	0.039
399	478369.613	4501958.078	673.565	673.580	0.015	0.049
400	492726.738	4500935.808	655.932	655.920	-0.012	-0.039
401	478368.043	4501915.177	673.710	673.690	-0.020	-0.066
402	513044.162	4505891.452	627.645	627.640	-0.005	-0.016
403	504096.332	4501931.818	640.153	640.170	0.017	0.056
404	492727.903	4500978.705	655.606	655.590	-0.016	-0.052
405	513045.169	4505949.626	626.862	626.870	0.008	0.026
406	504096.612	4501870.895	640.158	640.200	0.042	0.138
408	492729.905	4501020.863	655.322	655.330	0.008	0.026
410	513048.440	4506007.907	626.847	626.860	0.013	0.043
411	504096.848	4501813.750	640.149	640.170	0.021	0.069
413	504096.897	4501754.723	640.170	640.190	0.020	0.066
414	513044.597	4506069.021	626.719	626.730	0.011	0.036
415	492731.464	4501062.341	655.078	655.080	0.002	0.007
416	513048.694	4506077.275	626.779	626.770	-0.009	-0.030
418	492732.678	4501104.540	654.782	654.780	-0.002	-0.007
419	504097.192	4501695.751	640.168	640.190	0.022	0.072
420	513048.616	4506136.213	626.742	626.750	0.008	0.026
421	492733.609	4501145.570	654.536	654.530	-0.006	-0.020
422	504097.258	4501636.854	640.199	640.210	0.011	0.036
425	492734.292	4501188.669	654.381	654.380	-0.001	-0.003
427	504097.277	4501576.773	640.254	640.260	0.006	0.020
428	513048.729	4506193.723	626.727	626.720	-0.007	-0.023
429	492735.027	4501230.800	654.256	654.270	0.014	0.046
430	513049.182	4506228.357	626.715	626.710	-0.005	-0.016
433	504097.525	4501517.391	640.358	640.360	0.002	0.007
434	504097.419	4501460.145	640.394	640.380	-0.014	-0.046

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
435	478354.379	4501563.454	673.631	673.610	-0.021	-0.069
436	492736.410	4501274.169	654.228	654.230	0.002	0.007
437	512919.430	4504365.366	628.790	628.810	0.020	0.066
439	512922.491	4504424.265	628.949	628.960	0.011	0.036
440	504097.532	4501398.551	640.374	640.360	-0.014	-0.046
441	478353.318	4501519.336	673.512	673.470	-0.042	-0.138
443	478354.561	4501475.805	673.443	673.430	-0.013	-0.043
445	512927.177	4504452.767	629.032	629.030	-0.002	-0.007
446	504097.523	4501339.315	640.438	640.420	-0.018	-0.059
447	492737.175	4501362.217	654.183	654.190	0.007	0.023
448	492734.229	4501405.407	654.297	654.300	0.003	0.010
451	504097.727	4501279.418	640.456	640.450	-0.006	-0.020
452	478353.451	4501438.821	673.442	673.480	0.038	0.125
454	492738.742	4501447.765	654.201	654.210	0.009	0.030
455	512928.472	4504583.295	628.918	628.960	0.042	0.138
456	478351.730	4501396.672	673.469	673.470	0.001	0.003
457	504097.821	4501218.664	640.551	640.550	-0.001	-0.003
458	492739.376	4501489.947	654.197	654.210	0.013	0.043
459	478349.621	4501354.364	673.505	673.530	0.025	0.082
460	512930.529	4504643.504	628.426	628.450	0.024	0.079
461	521908.936	4507365.963	617.154	617.180	0.026	0.085
462	504097.980	4501157.500	640.770	640.760	-0.010	-0.033
464	512933.29	4504701.84	628.138	628.19	0.052	0.171
465	492741.403	4501533.275	654.215	654.220	0.005	0.016
466	478348.428	4501312.542	673.542	673.530	-0.012	-0.039
467	521908.285	4507410.500	616.858	616.860	0.002	0.007
468	492740.377	4501577.795	654.204	654.210	0.006	0.020
470	512935.49	4504760.82	628.043	628.1	0.057	0.187
471	478346.672	4501267.587	673.507	673.510	0.003	0.010
472	521908.000	4507454.539	616.663	616.640	-0.023	-0.075

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
473	492741.150	4501620.330	654.209	654.210	0.001	0.003
474	478345.057	4501223.613	673.499	673.490	-0.009	-0.030
475	512937.535	4504821.095	628.044	628.080	0.036	0.118
477	521907.464	4507500.078	616.413	616.380	-0.033	-0.108
478	492742.138	4501664.656	654.200	654.200	0.000	0.000
480	478343.156	4501180.385	673.482	673.470	-0.012	-0.039
481	521907.278	4507546.665	616.158	616.130	-0.028	-0.092
482	512940.586	4504879.541	628.115	628.160	0.045	0.148
483	512949.193	4504938.078	628.096	628.130	0.034	0.112
484	521906.964	4507591.402	615.986	615.960	-0.026	-0.085
485	504098.487	4500845.575	640.677	640.670	-0.007	-0.023
486	492742.765	4501707.285	654.285	654.280	-0.005	-0.016
487	521906.39	4507635.12	615.891	615.83	-0.061	-0.200
488	512966.13	4504996.64	627.997	628.05	0.053	0.174
489	478340.423	4501093.337	673.471	673.480	0.009	0.030
490	492743.485	4501750.914	654.672	654.670	-0.002	-0.007
491	504098.830	4500783.222	640.497	640.480	-0.017	-0.056
492	512991.97	4505048.43	627.817	627.88	0.063	0.207
493	478340.263	4501049.855	673.458	673.480	0.022	0.072
494	492741.828	4501795.064	655.469	655.460	-0.009	-0.030
495	521905.887	4507684.437	615.834	615.810	-0.024	-0.079
496	504099.115	4500723.825	640.503	640.540	0.037	0.121
497	513016.732	4505103.705	627.766	627.770	0.004	0.013
498	521902.144	4507727.749	615.874	615.860	-0.014	-0.046
499	492745.780	4501839.171	656.427	656.440	0.013	0.043
500	478340.341	4501006.482	673.468	673.460	-0.008	-0.026
501	504099.026	4500662.651	640.412	640.440	0.028	0.092
502	478340.404	4500963.185	673.463	673.470	0.007	0.023
503	504099.464	4500602.721	640.368	640.400	0.032	0.105
504	492746.136	4501887.744	657.826	657.830	0.004	0.013

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
505	513036.2	4505160.38	627.683	627.74	0.057	0.187
506	521901.541	4507772.027	615.702	615.680	-0.022	-0.072
507	478340.218	4500920.712	673.459	673.490	0.031	0.102
508	504099.197	4500541.790	640.368	640.410	0.042	0.138
509	521901.402	4507815.470	615.779	615.760	-0.019	-0.062
510	513044.403	4505217.203	627.395	627.420	0.025	0.082
511	492746.882	4501932.890	659.098	659.080	-0.018	-0.059
512	504099.230	4500480.798	640.323	640.340	0.017	0.056
513	478340.313	4500878.564	673.369	673.380	0.011	0.036
514	521900.949	4507859.157	615.793	615.760	-0.033	-0.108
515	513048.099	4505279.510	627.371	627.420	0.049	0.161
516	492749.578	4502103.831	660.231	660.230	-0.001	-0.003
517	478340.122	4500835.818	673.338	673.310	-0.028	-0.092
518	492750.272	4502147.361	659.552	659.550	-0.002	-0.007
519	504099.526	4500419.604	640.268	640.270	0.002	0.007
520	521900.47	4507904.95	615.77	615.71	-0.06	-0.197
521	513048.009	4505339.662	627.409	627.420	0.011	0.036
522	513051.618	4505402.703	627.063	627.050	-0.013	-0.043
524	478340.119	4500784.891	673.200	673.180	-0.020	-0.066
525	504099.932	4500356.233	640.212	640.240	0.028	0.092
526	521900.27	4507948.61	615.446	615.37	-0.076	-0.249
527	521899.478	4507983.697	615.493	615.470	-0.023	-0.075
528	504096.66	4500214.24	640.134	640.21	0.076	0.249
529	513047.884	4505464.838	627.182	627.160	-0.022	-0.072
530	513047.854	4505518.394	628.139	628.120	-0.019	-0.062
531	521898.910	4508042.801	616.755	616.740	-0.015	-0.049
532	504112.036	4504175.130	639.692	639.650	-0.042	-0.138
533	521902.799	4508084.208	616.378	616.360	-0.018	-0.059
534	513056.124	4505591.262	631.092	631.080	-0.012	-0.039
535	504111.720	4504116.557	641.786	641.750	-0.036	-0.118

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
536	504107.599	4504058.741	644.195	644.160	-0.035	-0.115
537	512847.088	4502273.136	628.619	628.670	0.051	0.167
539	521911.639	4507010.700	617.230	617.200	-0.030	-0.098
540	504100.082	4503911.485	644.435	644.420	-0.015	-0.049
541	512844.92	4502333.68	628.796	628.86	0.064	0.210
542	512846.581	4502393.517	628.854	628.900	0.046	0.151
543	504096.2	4503854.9	642.24	642.2	-0.04	-0.131
544	521912.139	4506963.636	616.918	616.900	-0.018	-0.059
545	512847.999	4502453.107	628.828	628.870	0.042	0.138
546	504097.907	4503799.380	640.724	640.680	-0.044	-0.144
547	521912.163	4506919.189	616.680	616.690	0.010	0.033
548	454363.817	4503149.695	704.857	704.830	-0.027	-0.089
549	512852.663	4502509.593	628.858	628.880	0.022	0.072
550	521912.492	4506872.369	616.448	616.440	-0.008	-0.026
551	504092.519	4503741.217	640.527	640.550	0.023	0.075
553	512850.359	4502571.458	628.892	628.940	0.048	0.157
554	521913.196	4506779.670	616.161	616.160	-0.001	-0.003
556	512852.497	4502631.345	629.139	629.160	0.021	0.069
557	521913.278	4506732.184	616.087	616.090	0.003	0.010
558	521913.586	4506687.430	616.075	616.080	0.005	0.016
559	504097.007	4503563.198	640.353	640.340	-0.013	-0.043
560	512854.502	4502692.005	629.340	629.370	0.030	0.098
561	521914.051	4506643.339	616.021	616.020	-0.001	-0.003
563	504093.157	4503506.501	640.394	640.370	-0.024	-0.079
564	512859.261	4502810.220	629.407	629.410	0.003	0.010
565	504093.270	4503448.149	640.201	640.210	0.009	0.030
566	521914.195	4506597.573	615.991	615.990	-0.001	-0.003
567	521914.826	4506552.453	615.991	615.970	-0.021	-0.069
568	504093.511	4503390.482	640.091	640.100	0.009	0.030
569	512861.674	4502871.095	629.454	629.490	0.036	0.118

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
571	504093.724	4503332.425	640.028	640.020	-0.008	-0.026
572	521914.840	4506504.770	616.008	616.000	-0.008	-0.026
573	521914.949	4506459.599	615.970	615.970	0.000	0.000
574	521915.256	4506411.989	615.994	615.980	-0.014	-0.046
575	512868.413	4503043.889	629.222	629.270	0.048	0.157
576	512874.045	4503098.722	628.817	628.860	0.043	0.141
577	521915.262	4506362.190	616.045	616.020	-0.025	-0.082
578	512872.598	4503156.554	628.442	628.480	0.038	0.125
579	521915.638	4506313.999	616.069	616.060	-0.009	-0.030
580	521916.438	4506267.314	616.139	616.130	-0.009	-0.030
581	512874.99	4503216.22	628.348	628.4	0.052	0.171
583	512877.15	4503275.71	628.205	628.27	0.065	0.213
584	512879.667	4503336.511	628.139	628.170	0.031	0.102
586	512885.196	4503391.166	628.143	628.190	0.047	0.154
588	512887.803	4503449.614	628.012	628.050	0.038	0.125
591	512886.212	4503510.132	628.028	628.060	0.032	0.105
592	512889.467	4503587.571	628.035	628.060	0.025	0.082
595	512891.937	4503645.524	628.052	628.090	0.038	0.125
597	521911.686	4506434.383	615.964	615.970	0.006	0.020
598	512893.392	4503694.883	628.091	628.110	0.019	0.062
599	521910.764	4506623.396	616.002	615.990	-0.012	-0.039
601	521909.882	4506758.468	616.127	616.120	-0.007	-0.023
602	467907.844	4504753.070	687.239	687.210	-0.029	-0.095
603	512896.175	4503750.251	628.104	628.150	0.046	0.151
604	521909.998	4506829.307	616.243	616.230	-0.013	-0.043
605	467905.631	4504696.902	687.938	687.890	-0.048	-0.157
606	512898.23	4503804.38	628.077	628.15	0.073	0.240
607	512900.41	4503860.01	628.026	628.1	0.074	0.243
608	521908.233	4506988.397	617.035	617.040	0.005	0.016
609	467907.020	4504644.807	689.342	689.310	-0.032	-0.105

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
610	467899.123	4504590.550	691.087	691.040	-0.047	-0.154
611	512903.23	4503930.99	628.07	628.11	0.04	0.131
612	467903.008	4504537.188	692.658	692.620	-0.038	-0.125
613	512909.197	4503986.843	628.082	628.130	0.048	0.157
614	467901.870	4504489.678	693.622	693.610	-0.012	-0.039
615	512907.386	4504038.542	628.124	628.170	0.046	0.151
616	512909.456	4504089.663	628.095	628.140	0.045	0.148
617	512911.335	4504140.826	628.052	628.090	0.038	0.125
619	512916.692	4504187.040	628.035	628.060	0.025	0.082
620	467895.352	4504340.354	693.599	693.570	-0.029	-0.095
621	467892.260	4504287.962	692.576	692.550	-0.026	-0.085
622	512915.31	4504238.27	628.165	628.22	0.055	0.180
623	467886.055	4504234.170	690.976	690.940	-0.036	-0.118
624	512917.39	4504291.82	628.403	628.47	0.067	0.220
625	512919.31	4504344.03	628.647	628.72	0.073	0.240
626	467884.753	4504190.183	689.528	689.520	-0.008	-0.026
627	467882.038	4504142.141	688.337	688.320	-0.017	-0.056
628	467878.892	4504092.427	687.527	687.480	-0.047	-0.154
629	467875.186	4504044.130	687.132	687.100	-0.032	-0.105
630	467875.057	4503994.914	687.043	687.030	-0.013	-0.043
631	467872.667	4503945.258	687.002	686.970	-0.032	-0.105
632	467870.851	4503895.822	687.069	687.040	-0.029	-0.095
633	467869.748	4503845.193	687.286	687.280	-0.006	-0.020
634	467869.07	4503793.58	687.683	687.64	-0.043	-0.141
635	467868.283	4503743.262	688.045	688.020	-0.025	-0.082
636	467864.429	4503693.821	688.390	688.360	-0.030	-0.098
643	467859.505	4503338.941	688.339	688.320	-0.019	-0.062
644	467861.899	4503290.451	687.952	687.950	-0.002	-0.007
645	467860.910	4503240.015	687.553	687.540	-0.013	-0.043
646	467860.180	4503191.970	687.136	687.110	-0.026	-0.085

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
647	467859.344	4503144.045	686.829	686.820	-0.009	-0.030
648	467858.681	4503093.980	686.655	686.640	-0.015	-0.049
649	467858.039	4503043.992	686.535	686.570	0.035	0.115
650	467857.346	4502994.071	686.542	686.550	0.008	0.026
651	467856.289	4502944.225	686.581	686.570	-0.011	-0.036
652	467855.692	4502894.152	686.605	686.600	-0.005	-0.016
653	467854.877	4502844.706	686.597	686.600	0.003	0.010
654	467854.109	4502789.053	686.594	686.610	0.016	0.052
655	467853.242	4502739.644	686.568	686.570	0.002	0.007
656	467852.549	4502689.746	686.571	686.570	-0.001	-0.003
657	467851.811	4502637.652	686.615	686.590	-0.025	-0.082
658	467851.081	4502587.412	686.601	686.610	0.009	0.030
659	467850.339	4502537.682	686.619	686.610	-0.009	-0.030
661	454307.471	4505425.311	705.091	705.080	-0.011	-0.036
662	437499.518	4510661.563	727.925	727.890	-0.035	-0.115
663	437489.72	4510600.27	728.915	728.86	-0.055	-0.180
664	454307.549	4505386.938	704.986	704.960	-0.026	-0.085
665	437484.713	4510533.215	731.177	731.140	-0.037	-0.121
666	454307.973	4505348.885	704.944	704.910	-0.034	-0.112
667	437468.279	4510472.311	733.013	732.980	-0.033	-0.108
668	454308.23	4505311.38	704.87	704.83	-0.04	-0.131
669	437453.936	4510411.848	734.449	734.420	-0.029	-0.095
670	454308.833	4505272.335	704.829	704.810	-0.019	-0.062
672	454309.166	4505233.082	704.784	704.790	0.006	0.020
673	437423.907	4510281.217	733.734	733.700	-0.034	-0.112
674	454309.793	4505193.157	704.759	704.760	0.001	0.003
675	437410.322	4510223.041	731.995	731.960	-0.035	-0.115
676	454310.300	4505152.841	704.697	704.670	-0.027	-0.089
677	454310.499	4505114.568	704.621	704.610	-0.011	-0.036
678	437390.651	4510154.090	729.795	729.770	-0.025	-0.082

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
679	454310.939	4505074.884	704.510	704.480	-0.030	-0.098
680	437372.646	4510098.352	728.451	728.420	-0.031	-0.102
681	437350.559	4510040.909	728.227	728.190	-0.037	-0.121
682	454311.402	4505035.536	704.468	704.440	-0.028	-0.092
683	454311.834	4504995.362	704.358	704.330	-0.028	-0.092
684	437326.931	4509984.583	728.407	728.380	-0.027	-0.089
685	454312.369	4504956.008	704.350	704.320	-0.030	-0.098
686	437307.03	4509927.2	728.553	728.51	-0.043	-0.141
687	454312.726	4504915.851	704.298	704.260	-0.038	-0.125
688	437285.150	4509869.003	728.683	728.650	-0.033	-0.108
689	437257.88	4509808.47	728.749	728.71	-0.039	-0.128
690	454313.48	4504875.33	704.151	704.11	-0.041	-0.135
691	437234.963	4509748.959	728.949	728.930	-0.019	-0.062
692	454314.42	4504837	704.379	704.32	-0.059	-0.194
693	454317.219	4504797.098	705.232	705.190	-0.042	-0.138
694	437086.381	4509387.059	729.082	729.060	-0.022	-0.072
695	454317.666	4504758.213	706.796	706.770	-0.026	-0.085
696	437060.866	4509326.197	728.951	728.930	-0.021	-0.069
697	454318.131	4504717.977	708.726	708.690	-0.036	-0.118
698	437031.535	4509269.329	728.725	728.710	-0.015	-0.049
699	454311.698	4504680.221	710.268	710.230	-0.038	-0.125
700	437007.101	4509214.972	729.122	729.090	-0.032	-0.105
701	454316.33	4504556.66	710.725	710.66	-0.065	-0.213
702	436966.801	4509166.283	729.059	729.040	-0.019	-0.062
703	454319.849	4504516.802	709.372	709.320	-0.052	-0.171
704	436920.040	4509120.758	729.012	729.020	0.008	0.026
705	436872.385	4509080.994	729.119	729.110	-0.009	-0.030
706	454310.64	4504438.43	705.803	705.71	-0.093	-0.305
707	436818.543	4509046.592	729.169	729.130	-0.039	-0.128
708	436776.027	4509024.923	729.176	729.160	-0.016	-0.052

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
709	454307.97	4504400.1	704.687	704.62	-0.067	-0.220
710	454318.32	4504361.47	704.175	704.1	-0.075	-0.246
711	436731.529	4509006.111	728.946	728.920	-0.026	-0.085
712	454318.57	4504320.76	704.169	704.1	-0.069	-0.226
713	436686.368	4509002.364	728.670	728.660	-0.010	-0.033
714	454318.922	4504282.170	704.396	704.350	-0.046	-0.151
715	436642.053	4508984.416	728.661	728.680	0.019	0.062
716	436597.198	4508967.391	728.625	728.620	-0.005	-0.016
717	454319.913	4504243.513	704.506	704.480	-0.026	-0.085
718	454321.11	4504204.67	704.51	704.47	-0.04	-0.131
719	436551.314	4508954.332	728.572	728.570	-0.002	-0.007
720	454321.998	4504163.399	704.522	704.500	-0.022	-0.072
721	436504.503	4508945.510	728.596	728.580	-0.016	-0.052
722	454323.626	4504124.462	704.565	704.530	-0.035	-0.115
723	436456.912	4508941.047	728.726	728.710	-0.016	-0.052
724	454325.94	4504085.38	704.597	704.53	-0.067	-0.220
725	436397.000	4508940.535	728.775	728.750	-0.025	-0.082
726	454327.658	4504043.586	704.597	704.590	-0.007	-0.023
727	436333.184	4508941.444	728.768	728.760	-0.008	-0.026
728	454329.572	4504002.853	704.668	704.650	-0.018	-0.059
729	436269.365	4508942.025	728.731	728.700	-0.031	-0.102
730	436205.548	4508942.743	728.681	728.670	-0.011	-0.036
731	454331.549	4503966.047	704.743	704.730	-0.013	-0.043
732	436142.107	4508943.365	728.730	728.710	-0.020	-0.066
733	454333.064	4503927.693	704.882	704.850	-0.032	-0.105
734	436083.294	4508940.816	728.799	728.810	0.011	0.036
735	454334.856	4503888.192	705.015	704.970	-0.045	-0.148
736	454337.156	4503849.469	705.158	705.130	-0.028	-0.092
737	436023.958	4508941.278	728.806	728.790	-0.016	-0.052
738	454338.561	4503810.687	705.374	705.360	-0.014	-0.046

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
739	435964.997	4508941.858	728.903	728.890	-0.013	-0.043
740	454340.576	4503771.981	705.517	705.480	-0.037	-0.121
741	435907.635	4508942.417	729.026	729.020	-0.006	-0.020
742	454342.347	4503732.234	705.662	705.650	-0.012	-0.039
743	435849.178	4508943.465	729.061	729.070	0.009	0.030
744	454344.076	4503693.685	705.748	705.740	-0.008	-0.026
745	435790.756	4508947.466	729.081	729.080	-0.001	-0.003
747	435734.284	4508944.997	729.249	729.250	0.001	0.003
748	435674.164	4508945.809	729.365	729.350	-0.015	-0.049
750	435618.137	4508946.621	729.360	729.350	-0.010	-0.033
752	435560.407	4508947.494	729.473	729.470	-0.003	-0.010
754	435501.394	4508948.293	729.631	729.620	-0.011	-0.036
755	435444.750	4508949.292	729.695	729.690	-0.005	-0.016
757	435385.780	4508950.056	729.779	729.780	0.001	0.003
759	435328.739	4508954.075	729.743	729.750	0.007	0.023
761	454356.410	4503366.268	705.738	705.730	-0.008	-0.026
762	435269.427	4508951.603	729.931	729.910	-0.021	-0.069
763	454358.020	4503327.410	705.608	705.590	-0.018	-0.059
764	435211.495	4508952.527	730.036	730.030	-0.006	-0.020
765	454359.836	4503284.234	705.450	705.400	-0.050	-0.164
766	435153.052	4508956.488	730.176	730.140	-0.036	-0.118
767	454361.375	4503240.614	705.230	705.210	-0.020	-0.066
768	435105.03	4508957.26	730.161	730.12	-0.041	-0.135
769	454362.824	4503193.201	705.056	705.020	-0.036	-0.118
770	435054.532	4508954.920	730.313	730.280	-0.033	-0.108
771	435003.552	4508955.909	730.419	730.390	-0.029	-0.095
772	454361.166	4503108.103	704.661	704.630	-0.031	-0.102
774	454360.746	4503061.868	704.452	704.420	-0.032	-0.105
777	454360.184	4503018.202	704.325	704.290	-0.035	-0.115
778	454359.848	4502976.401	704.233	704.210	-0.023	-0.075

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
780	454359.051	4502933.570	704.190	704.180	-0.010	-0.033
782	454359.146	4502878.478	704.264	704.230	-0.034	-0.112
785	454361.258	4502836.213	704.222	704.210	-0.012	-0.039
786	454360.700	4502795.300	703.973	703.940	-0.033	-0.108
788	454360.589	4502752.852	703.869	703.870	0.001	0.003
789	454359.960	4502711.395	703.909	703.900	-0.009	-0.030
790	454359.302	4502668.683	703.891	703.890	-0.001	-0.003
791	454358.987	4502626.490	703.972	703.960	-0.012	-0.039
792	454358.293	4502584.891	704.015	704.000	-0.015	-0.049
793	454357.379	4502500.066	703.799	703.760	-0.039	-0.128
794	454357.114	4502456.189	703.746	703.740	-0.006	-0.020
795	454356.599	4502412.719	703.619	703.640	0.021	0.069

Table 25: Non-vegetated vertical accuracy – Fall 2024 lidar data vs. Fall 2024 ground survey points

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
1	454357.33	4502833.63	704.184	704.18	-0.004	-0.013
2	454354.6	4502600.21	703.998	704	0.002	0.007
3	454364.58	4503143.81	704.781	704.79	0.009	0.030
4	454340.54	4503357.87	704.708	704.7	-0.008	-0.026
5	454314.43	4504267.55	704.426	704.39	-0.036	-0.118
6	454321.44	4504088.21	704.548	704.5	-0.048	-0.157
7	454319.75	4504442.83	705.956	705.92	-0.036	-0.118
8	454319.24	4504531.05	709.881	709.86	-0.021	-0.069
9	454318.34	4504681.04	710.169	710.13	-0.039	-0.128
10	454327.84	4504809	704.671	704.64	-0.031	-0.102
11	454289.81	4505030.13	703.847	703.82	-0.027	-0.089
12	454289.42	4505039.06	703.753	703.71	-0.043	-0.141
13	534803.9	4511580.94	599.836	599.84	0.004	0.013
14	534853.58	4511430.48	598.68	598.71	0.03	0.098
15	534926.69	4511238.32	598.952	598.97	0.018	0.059
17	535046.62	4510842.51	599.382	599.4	0.018	0.059
18	535088.32	4510713.07	598.496	598.51	0.014	0.046
19	535157.35	4510422.42	597.769	597.78	0.011	0.036
20	535211.12	4510227.12	597.816	597.84	0.024	0.079
21	535239.02	4510109.51	597.73	597.74	0.01	0.033
22	535264.03	4510003.68	597.752	597.76	0.008	0.026
23	534725.55	4511891.89	598.422	598.44	0.018	0.059
24	534752.07	4512019.86	597.911	597.92	0.009	0.030
25	571616.58	4537829.95	540.522	540.52	-0.002	-0.007
26	571654.24	4537786.11	540.595	540.6	0.005	0.016

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
27	571748.06	4537687.74	541.273	541.27	-0.003	-0.010
28	571859.61	4537587.93	541.912	541.91	-0.002	-0.007
31	572250.58	4537236.6	541.704	541.7	-0.004	-0.013
32	572487.27	4537272.07	542.246	542.25	0.004	0.013
33	572754.86	4537421.27	542.272	542.28	0.008	0.026
34	572961.95	4537301.05	544.141	544.16	0.019	0.062
35	572961.8	4536941.96	552.043	552.01	-0.033	-0.108
36	572974.18	4536596.24	563.601	563.6	-0.001	-0.003
37	572985.34	4536323.42	566.673	566.69	0.017	0.056
38	559676.58	4526399.61	561.485	561.47	-0.015	-0.049
39	559836.48	4526319.24	561.22	561.22	0	0.000
40	559977.34	4526174.48	560.897	560.91	0.013	0.043
41	560047.44	4526032.32	560.706	560.7	-0.006	-0.020
42	560130.05	4525713.97	560.729	560.75	0.021	0.069
43	560246.19	4525297.74	561.744	561.76	0.016	0.052
44	560425.82	4525045.31	563.201	563.2	-0.001	-0.003
46	560771.79	4524725.51	562.971	562.97	-0.001	-0.003
47	560978.42	4524600.47	562.618	562.63	0.012	0.039
48	561170.29	4524542.74	564.528	564.5	-0.028	-0.092
49	561414.05	4524562.9	571.806	571.81	0.004	0.013
54	437201.98	4509729.18	728.47	728.5	0.03	0.098
55	429688.58	4500079.33	774.388	774.39	0.002	0.007
56	437267.5	4509890.83	728.28	728.28	0	0.000
57	428052.39	4500271.98	772.301	772.33	0.029	0.095
58	440831.36	4501577.31	733.405	733.43	0.025	0.082
59	437391.31	4510024.02	727.492	727.51	0.018	0.059
60	428052.47	4500300.55	772.203	772.23	0.027	0.089
61	428053.67	4500356.88	773.618	773.65	0.032	0.105
62	437507.5	4510161.21	727.027	727.06	0.033	0.108
63	440831.32	4501510.32	731.845	731.85	0.005	0.016

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
64	428052.81	4500479.17	768.373	768.4	0.027	0.089
65	437788.51	4510199.29	726.421	726.43	0.009	0.030
66	440831.28	4501481.28	731.34	731.35	0.01	0.033
67	428052.22	4500604.95	768.704	768.7	-0.004	-0.013
68	454327.94	4503677.04	704.561	704.56	-0.001	-0.003
69	440830.92	4501447.55	730.876	730.88	0.004	0.013
70	437072.42	4509357.36	728.874	728.87	-0.004	-0.013
71	440830.81	4501419.72	730.651	730.64	-0.011	-0.036
72	428051.93	4500657.46	766.269	766.27	0.001	0.003
73	440829.9	4501384.76	730.46	730.45	-0.01	-0.033
74	428051.08	4500721.9	764.006	764	-0.006	-0.020
75	436705.15	4508937.53	728.828	728.86	0.032	0.105
76	428050.38	4500757.72	763.629	763.63	0.001	0.003
77	440829.56	4501351.7	730.311	730.32	0.009	0.030
78	428049.82	4500801.03	763.841	763.8	-0.041	-0.135
79	440828.65	4501317.02	730.06	730.06	0	0.000
80	440828.41	4501288.52	729.929	729.94	0.011	0.036
81	436717.36	4508838.43	728.566	728.58	0.014	0.046
82	440828.95	4501250.93	729.679	729.7	0.021	0.069
83	436721.32	4508724.08	727.998	728.03	0.032	0.105
84	428048.86	4500865.86	764.329	764.34	0.011	0.036
85	440829.33	4501225.21	729.749	729.78	0.031	0.102
86	428048.87	4500901.21	764.827	764.78	-0.047	-0.154
87	440829.11	4501195.62	729.761	729.78	0.019	0.062
88	428048.68	4500936.62	764.719	764.71	-0.009	-0.030
89	436718.11	4508499.38	727.332	727.35	0.018	0.059
90	436717.32	4508404.19	727.345	727.38	0.035	0.115
91	440829.74	4501137.25	730.042	730.07	0.028	0.092
92	440829.74	4501105.93	730.239	730.26	0.021	0.069
93	440829.86	4501077.09	730.431	730.43	-0.001	-0.003

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
94	440829.57	4501049.11	730.497	730.51	0.013	0.043
95	440829.64	4501025.73	730.694	730.7	0.006	0.020
96	440829.66	4501002.49	730.922	730.93	0.008	0.026
97	440829.6	4500963.46	731.144	731.16	0.016	0.052
98	440829.41	4500938.93	731.533	731.54	0.007	0.023
99	440829.54	4500908.48	732.022	732.04	0.018	0.059
100	440829.53	4500880.27	732.54	732.56	0.02	0.066
101	440829.52	4500853.99	732.893	732.93	0.037	0.121
102	440829.59	4500826.95	733.303	733.34	0.037	0.121
103	440828.97	4500783.59	734.28	734.31	0.03	0.098
104	542723.18	4513688.07	587.209	587.2	-0.009	-0.030
105	542806.89	4513354.18	588.779	588.78	0.001	0.003
106	542814.62	4512960.86	588.336	588.3	-0.036	-0.118
107	542814.01	4512618.1	588.213	588.16	-0.053	-0.174
108	542816.21	4512270.8	588.982	588.97	-0.012	-0.039
109	542813.22	4514240.5	587.757	587.79	0.033	0.108
110	542817.31	4514465.93	587.886	587.92	0.034	0.112
111	542818.57	4514692.88	587.831	587.86	0.029	0.095
112	542820.61	4515001.61	587.747	587.76	0.013	0.043
113	542818.6	4515240.22	587.835	587.82	-0.015	-0.049
114	542779.88	4515533.84	587.772	587.82	0.048	0.157
115	542723.9	4515957.06	587.636	587.66	0.024	0.079
116	542712.88	4516151.4	586.756	586.76	0.004	0.013
117	542732.93	4516282.82	586.474	586.5	0.026	0.085
118	552385.46	4520678.74	573.031	573.06	0.029	0.095
119	552387.39	4520449.66	573.062	573.05	-0.012	-0.039
120	552299.34	4520168.77	574.102	574.09	-0.012	-0.039
121	552387.1	4519744.85	575.736	575.73	-0.006	-0.020
122	552364.39	4519398.65	575.085	575.08	-0.005	-0.016
123	552398.69	4519054.85	581.313	581.33	0.017	0.056

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
124	552343.23	4518698.96	574.284	574.29	0.006	0.020
125	552344.38	4518425.96	574.798	574.77	-0.028	-0.092
126	552468.98	4518056.4	575.078	575.07	-0.008	-0.026
127	552415.72	4517369.2	575.612	575.62	0.008	0.026
128	552417.09	4516752.89	576.148	576.13	-0.018	-0.059
129	552412.33	4516747.58	575.902	575.91	0.008	0.026
130	478694.9	4502711.63	671.345	671.3	-0.045	-0.148
131	478475.58	4502615.45	671.778	671.75	-0.028	-0.092
132	478386.27	4502416.16	673.579	673.56	-0.019	-0.062
133	478372.93	4502056.13	673.529	673.51	-0.019	-0.062
134	478367.56	4501913.94	673.715	673.69	-0.025	-0.082
137	478359.482	4501451.194	673.271	673.280	0.009	0.030
138	478344.343	4501300.670	673.480	673.510	0.030	0.098
139	478336.438	4500992.250	673.467	673.450	-0.017	-0.056
140	478336.901	4500871.544	673.393	673.380	-0.013	-0.043
141	478336.724	4500801.206	673.229	673.200	-0.029	-0.095
142	478336.749	4500792.681	673.195	673.170	-0.025	-0.082
143	492809.903	4499942.100	653.962	653.940	-0.022	-0.072
144	492826.130	4500047.775	654.106	654.100	-0.006	-0.020
145	492775.417	4500231.290	653.701	653.670	-0.031	-0.102
146	492729.792	4500361.708	654.372	654.350	-0.022	-0.072
147	492719.773	4500533.891	655.454	655.440	-0.014	-0.046
151	492732.599	4501108.892	654.770	654.750	-0.020	-0.066
152	492734.164	4501205.996	654.325	654.350	0.025	0.082
153	492665.626	4501342.521	653.558	653.560	0.002	0.007
154	492658.232	4501487.981	653.608	653.680	0.072	0.236
155	492685.687	4501600.522	653.835	653.870	0.035	0.115
156	492691.587	4501736.064	654.452	654.410	-0.042	-0.138
157	492592.999	4501881.966	652.559	652.580	0.021	0.069
158	504109.615	4504120.181	641.556	641.560	0.004	0.013

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
159	504090.219	4503863.502	642.499	642.510	0.011	0.036
160	504084.990	4503726.087	640.496	640.490	-0.006	-0.020
161	504086.037	4503556.579	640.403	640.380	-0.023	-0.075
162	504083.568	4503212.959	639.847	639.860	0.013	0.043
163	504088.359	4502657.959	640.032	640.040	0.008	0.026
164	504088.754	4502394.338	639.996	639.990	-0.006	-0.020
165	504089.572	4502125.552	640.094	640.090	-0.004	-0.013
166	504089.924	4501923.582	640.108	640.120	0.012	0.039
167	504090.540	4501689.394	640.113	640.110	-0.003	-0.010
168	504090.792	4501474.584	640.309	640.300	-0.009	-0.030
170	504090.992	4500856.024	640.682	640.660	-0.022	-0.072
171	504092.462	4500621.408	640.364	640.330	-0.034	-0.112
172	504092.713	4500403.211	640.212	640.190	-0.022	-0.072
173	504093.805	4500243.075	640.147	640.130	-0.017	-0.056
174	512848.093	4502314.321	628.777	628.810	0.033	0.108
175	512864.651	4502851.978	629.502	629.530	0.028	0.092
176	512878.177	4503205.115	628.388	628.400	0.012	0.039
177	512883.207	4503433.206	628.018	628.060	0.042	0.138
178	512896.909	4503684.607	628.120	628.130	0.010	0.033
179	512906.291	4503924.508	628.064	628.120	0.056	0.184
180	512914.668	4504144.915	628.081	628.090	0.009	0.030
181	512931.017	4504550.170	629.048	629.050	0.002	0.007
182	512940.119	4504788.366	628.054	628.070	0.016	0.052
183	512980.099	4505021.359	627.917	627.900	-0.017	-0.056
184	513057.162	4505363.495	627.109	627.130	0.021	0.069
185	513054.726	4505587.629	630.910	630.960	0.050	0.164
186	513055.377	4505782.023	632.142	632.170	0.028	0.092
187	467843.046	4502966.812	686.156	686.120	-0.036	-0.118
188	467851.720	4502826.815	686.556	686.520	-0.036	-0.118
189	467849.526	4502674.387	686.548	686.500	-0.048	-0.157

Number	Easting	Northing	Known Z	Laser Z	Dz (meters)	Dz (feet)
190	467865.157	4503081.436	686.597	686.550	-0.047	-0.154
191	467866.883	4503188.390	687.079	687.030	-0.049	-0.161
192	467872.822	4503333.589	688.198	688.150	-0.048	-0.157
193	467874.713	4503700.006	688.361	688.320	-0.041	-0.135
195	467882.336	4503875.578	686.758	686.700	-0.058	-0.190
196	467888.467	4504042.661	686.986	686.930	-0.056	-0.184
197	467906.310	4504274.298	692.269	692.220	-0.049	-0.161
198	467915.784	4504490.971	693.598	693.550	-0.048	-0.157
199	468062.499	4504721.396	686.639	686.590	-0.049	-0.161

Platte_River_Fall_2024_Topobathymetric_Lidar_Report_Final_S&S_straightened

Final Audit Report 2025-03-14

Created:	2025-03-12
By:	Emily Wood (Emily.Wood@nv5.com)
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"Platte_River_Fall_2024_Topobathymetric_Lidar_Report_Final_S&S_straightened" History

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