Quantum Spatial, Inc.
517 SW 2nd St., Suite 400
Corvallis, OR 97333
TIN# 39-1133181

Nebraska Community Foundation
PO Box 83107
Lincoln, NE 68501-3107
TIN# 47-0769903

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM
Agreement between Nebraska Community Foundation, Platte River Recovery Implementation Program, and Quantum Spatial, Inc.

1. Parties.

This Agreement is made and entered into by and between the Nebraska Community Foundation ("Foundation") of Lincoln, Nebraska, representing all signatories to the Platte River Recovery Implementation Program ("Program") and Quantum Spatial, Inc. ("Contractor"). The following persons are authorized to represent the parties through this Agreement: Diane Wilson of the Foundation, Jason Farnsworth of the Program; and Dr. Andrew Brenner of the Contractor.

2. Purpose and Authority.

The purpose of this Agreement is to allow the Foundation, acting as the fiscal agent for the Governance Committee (GC) of the Program, and the Contractor to enter into a firm fixed price Agreement for the Project "P20-005: 2020-2023 Annual LiDAR and Aerial Photography."

TERMS AND CONDITIONS

3. Scope of Work and Schedule

The Contractor will complete the scope of work described in the Program's "P20-005: 2020-2023 Annual LiDAR and Aerial Photography" Request for Proposals (Attachment 1), and the Contractor's Response to Request for Proposal (Attachment 2).

The annual acquisition schedule for the base project is as follows:

- June 2020: Sub-project 2 - Aerial photography and Sub-project 2a - LiDAR
- November 2020: Sub-project 1 - LiDAR and concurrent aerial photography
- June 2021: Sub-project 2 - Aerial photography and Sub-project 2a - LiDAR
- November 2021: Sub-project 1 - LiDAR and concurrent aerial photography
- June 2022: Sub-project 2 - Aerial photography and Sub-project 2a - LiDAR
- November 2022: Sub-project 1 - LiDAR and concurrent aerial photography
- June 2023: Sub-project 2 - Aerial photography and Sub-project 2a - LiDAR
- November 2023: Sub-project 1 - LiDAR and concurrent aerial photography

These dates represent the intended target acquisition windows. Weather or river conditions may dictate that acquisitions move outside these windows. The Program's Executive Director's Office (ED Office) will issue a Notice to Proceed to the Contractor prior to each acquisition.

The Program, at its sole discretion, may choose to cancel any individual acquisition or part of an acquisition (aerial imagery, LiDAR) over the course of the project. This could occur if river conditions are such that the products received would not be of a quality acceptable to the Program. If an acquisition is partially or fully cancelled, the contract price would be adjusted and the cost of those acquisitions and products removed.

The Foundation shall be responsible only for the financial aspects of the Contractor's relationship with the Governance Committee. Technical aspects of the Contractor's relationship with the Governance Committee will be the sole responsibility of the ED Office.

4. Deliverables

a) **LiDAR (terrestrial and bathymetric)**

i) LiDAR point data meeting or exceeding 2.3 ft (0.7 m) GSD resolution in a classified LAS file format and adhering to the technical specifications in III.3 above. LAS file projected to Nebraska State Plane Feet (1983 datum) and vertical reference NAVD88 feet (Geoid 03). Classified LAS file will include all LiDAR points, including first and last returns.

ii) Daily reports during acquisition that display all flight lines, as well as completed areas. Once acquisition is complete, a project summary report that shows time and date of all flightline acquisitions. Time of day, not just the day, is important to match river flow condition to acquisition.

iii) Tiling scheme shapefile for identifying LAS and DEM file locations. Tile size and file size is flexible and will be discussed upon award of project.

b) **Digital Elevation Model**

i) Hydro-flattened bare-earth digital elevation model raster tiles (3-foot cell size), projected in Nebraska State Plane coordinate system – elevation and projection in feet.

1) See pages 11-13, 15, and Appendix 2 of the USGS LiDAR Guidelines and Base Specifications v13 for details on hydro-flattening: http://pubs.usgs.gov/tm/11b4/. In the proposal, provide details of the software/methodology to be used for this alternative.

2) Breaklines used in the generation of the hydro-enforced DEM are also a required deliverable.

ii) Highest-hit (first return) digital elevation model raster (3-foot cell size). Used to approximate vegetation height.

iii) Full project area mosaic of digital elevation model tiles (3-foot cell size).

iv) NOTE: For Bathymetric LiDAR acquisition, two versions of the DEM will be required. One hydro-enforced DEM for the given flow conditions during the flight, and one DEM that incorporates bathymetry below the water surfaces.

c) **Imagery**

i) Color-infrared (Sub-Project 1) and 4-band (Sub-Project 2) digital orthophotography with a six-inch (0.5 ft) pixel resolution (or better), covering the entire project area seamlessly and without data gaps.
ii) The imagery should be geo-referenced and provided in GeoTIFF (.tif) format.
iii) Shapefiles displaying photocenters and flight dates and times for image acquisitions. Time of day, not just the day, is important to match river flow condition to acquisition.
iv) Compressed imagery mosaic (.sid). Typically entire reach compiled into one mosaic, but may be split due to file size. Sub-Project 2 will require both a RGB mosaic and a CIR mosaic. Sub-Project 1 will be a CIR mosaic only.

d) **LiDAR and Imagery**

i) Shapefiles of LiDAR and aerial photography flight lines or photo centers that identify the date and time of the flight line or photo center.
ii) FGDC-compliant metadata to include, but not limited to: flight dates and times, flight altitude, camera system information, LiDAR system information, aircraft information, imagery resolution, LiDAR point density, horizontal accuracy, post-processing software and steps, and horizontal and vertical control references.
iii) Ground survey control points and reports on all points used in this project.
iv) All geo-referenced deliverables to be projected in Nebraska State Plane Feet (1983 datum).
v) All LiDAR data, photography, and supplemental products will be delivered on USB external hard drives or flash drives and will become the property of the Program. All media and data collected under the contract shall be the sole property of and can be freely distributed by the Program. No restrictions shall be placed on the data by the contractor.

5. Compensation

Compensation will occur for work in accordance with the approved scope of work and Firm Fixed Price Proposal submitted by the Contractor (Attachment 2). The duration of this contract will be the date of execution to December 31, 2023, with the budget allocated accordingly based on Program Fiscal Years (same as calendar years).

<u>Total Project Compensation</u>:
Subproject breakdown:
SP2 June Imagery: $68,529.00
SP2a June LiDAR: $69,770.00
SP1 November Imagery: $29,847.00
SP1 November LiDAR: $206,808.00

By Program Fiscal Year:
FY2020: $374,954.00
FY2021: $374,954.00
FY2022: $374,954.00
FY2023: $374,954.00

All LiDAR flights are subject to retiming or cancellation based on river conditions during the flight window and the billing will be adjusted accordingly.

Maximum Total Amount Funded for this Agreement: <u>$1,499,816.00</u>

Activities in 2021, 2022, and 2023 are subject to Program Governance Committee budget authorization and a subsequent Notice to Proceed from the ED Office.

Contractor shall provide written requests for payment to the ED Office (address included below). The Contractor may submit partial billing on a percent completed basis. Invoices should be accompanied by a summary of work completed under the invoice. Invoices should be submitted no less than twice per year (after each sub-project delivery). Request for final payment shall be submitted along with final deliverables. The Program's Executive Director, upon receiving a bill, will approve the bill and advise the Foundation of approval. The Foundation will make payment of these funds directly to the Contractor within 30 days. Payments of bills are due within 60 days after the billing date.

Billing Point of Contact (Program):
Jason Farnsworth, Executive Director
Platte River Recovery Implementation Program
Headwaters Corporation
4111 4th Avenue, Suite 6
Kearney, Nebraska 68845
Phone: (308) 237-5728
Fax: (308) 237-4651
Email: farnsworthj@headwaterscorp.com

6. Time Frame

This Agreement describes an approximately four-year program of work encompassing LiDAR and aerial photograph acquisitions and processing occurring twice annually prior to December 31, 2023. Under the Agreement, Notice to Proceed from the ED Office will be required prior to commencement of each sub-project acquisition.

The initial date of this agreement shall be the date of signing. The final date of this agreement shall be approximately December 31, 2023. This time frame may be extended upon mutual agreement of the parties and pursuant to the Program.

7. Amendments and Termination

This Agreement, scope, and budget may be amended by mutual written consent of the parties pursuant to the Program. This Agreement may be terminated within 30 days notice by any party.

8. Agreement Contingent Upon Available Funding

This Agreement is contingent upon funding availability and continuation of the Platte River Recovery Implementation Program.

9. Inspection and Acceptance

All deliverables furnished by the Contractor shall be subject to rigorous review by the ED Office prior to acceptance.

10. Office Space, Equipment, and Supplies

The Contractor will supply its own office space, equipment, and supplies.

11. Independent Party

The parties intend that the Contractor will not be considered an employee of the Foundation, but will act as an independent party for the Foundation. As an independent party, the Contractor will be responsible for all applicable taxes and is not eligible for any benefits provided by the Foundation.

12. Confidentiality

All documents, reports and any other work provided to or produced by the Contractor in the performance of this Agreement shall be kept confidential by the Contractor unless written permission for release is granted by the Program.

13. Publicity

Any publicity or media contact associated with the Contractor's services and the result of those services provided under this Agreement shall be the sole responsibility of the Program. Media requests of the Contractor should be directed to the Director of Outreach and Operations in the ED Office.

14. Publication

It is understood that the results of this work may be available to the Contractor for publication and use in connection with related work. Use of this work for publication and related work by the Contractor must be conducted with full disclosure to and coordination with the Program's Technical Point of Contact.

15. Rights in Data and Hardware

All rights in data will be vested to the Program with the intent of sharing among stakeholders and the public as appropriate. Hardware and software purchased under this agreement shall be the property of the Program.

16. Insurance

The Contractor will maintain insurance coverage for Workers' Compensation, General Liability, Professional Liability, and Automobile Liability and will provide certificates of insurance to Program upon request.

17. Indemnification and Mutual Waiver

A. *Indemnification by Contractor.* To the fullest extent permitted by law, Contractor shall indemnify and hold harmless Foundation and Program, Foundation and Program's officers, directors, partners, agents, consultants, and employees from and against any and all claims, costs, losses, and damages (including but not limited to reasonable fees and charges of engineers, architects, attorneys, and other professionals, and all court, arbitration, or other dispute resolution costs) arising out of or relating to the Project, provided that any such claim, cost, loss, or damage is attributable to bodily injury, sickness, disease, or death, or to damage to or destruction of tangible property, including the loss of use resulting therefrom, but only to the extent caused by any negligent act or omission of Contractor or Contractor's officers, directors, partners, employees, or sub-consultants.

B. *Indemnification by Foundation and Program.* To the fullest extent permitted by law, Foundation and Program shall indemnify and hold harmless Contractor, Contractor's officers, directors, partners, agents, employees, and sub-consultants from and against any and all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals, and all court, arbitration, or other dispute resolution costs) arising out of or relating to the Project, provided that any such claim, cost, loss, or damage is attributable to bodily injury, sickness, disease, or death, or to damage to or destruction of tangible property, including the loss of use resulting therefrom, but only to the extent caused by any negligent act or omission of Foundation or Program or Foundation or Program's officers, directors, partners, agents, consultants, or employees, or others retained by or under contract to the Contractor with respect to this Agreement or to the Project.

C. *Mutual Waiver*. To the fullest extent permitted by law, Foundation, Program and Contractor waive against each other, and the other's employees, officers, directors, agents, insurers, partners, and consultants, any and all claims for or entitlement to special, incidental, indirect, or consequential damages arising out of, resulting from, or in any way related to the Project.

18. <u>Contacts</u>

Administrative Point of Contact (Foundation):
Diane M. Wilson
Manager of Public/Private Partnerships
Nebraska Community Foundation
PO Box 83107
Lincoln, Nebraska 68501-3107
Phone: (402) 323-7330
Fax: (402) 323-7349
Email: dwilson@nebcommfound.org

Admin. Point of Contact (Program):
Jason Farnsworth, Executive Director
Platte River Recovery Implementation Prog.
Headwaters Corporation
4111 4th Avenue, Suite 6
Kearney, Nebraska 68845
Phone: (308) 237-5728
Fax: (308) 237-4651
Email: farnsworthj@headwaterscorp.com

Technical Point of Contact (Program):
Justin Brei, P.E., Biosystems Engineer
Platte River Recovery Implementation Prog.
Headwaters Corporation
405 Urban St, Suite 401
Lakewood, CO 80228
Phone: (720) 524-6115
Fax: (308) 237-4651
Email: breij@headwaterscorp.com

Media Point of Contact (Program):
Dr. Bridget Barron, Director of Outreach
Platte River Recovery Implementation Prog.
Headwaters Corporation
4111 4th Avenue, Suite E
Kearney, Nebraska 68845
Phone: (308) 237-5728
Fax: (308) 237-4651
Email: barronb@headwaterscorp.com

Administrative Point of Contact (Contractor):
Dr. Andrew Brenner, Sr. Program Director
Quantum Spatial, Inc.
517 SW 2nd St., Suite 400
Corvallis, OR 97333
Phone: (734) 680-6424
Email: abrenner@quantumspatial.com

Technical Point of Contact (Contractor):
Mr. Steven Miller, Sr. Project Manager
Quantum Spatial, Inc.
517 SW 2nd St., Suite 400
Corvallis, OR 97333
Phone: (720) 708-8555
Email: Stevenmiller@quantumspatial.com

IN WITNESS WHEREOF, the Parties have executed this Agreement.

Nebraska Community Foundation	Quantum Spatial, Inc.
By______________________________________	By___________________________________
DIANE M. WILSON, Manager of Public/Private Partnerships	Andrew Brenner, Senior Program Director
Date: _____________________	Date: _____________________

ATTACHMENT 1: 2020-2023 ANNUAL LIDAR AND AERIAL PHOTOGRAPHY REQUEST FOR PROPOSALS

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM
REQUEST FOR PROPOSALS

SUBJECT: 2020-2023 Annual LiDAR and Aerial Photography
PROJECT NUMBER: P20-005
REQUEST DATE: March 30, 2020
CLOSING DATE: April 24, 2020
POINT OF CONTACT: Justin Brei
Headwaters Corporation
4111 4th Ave, Suite 6
Kearney, NE 68845
(308) 237-5728 Ext. 4
breij@headwaterscorp.com

I. OVERVIEW

The Platte River Recovery Implementation Program (**Program**) was initiated on January 1, 2007 between Nebraska, Wyoming, and Colorado and the Department of the Interior to address endangered species issues in the central and lower Platte River basin. The species considered in the Program, referred to as "target species", are the whooping crane, piping plover, interior least tern, and pallid sturgeon.

A Governance Committee (**GC**) has been established that reviews, directs, and provides oversight for activities undertaken during the Program. The GC is comprised of one representative from each of the three states, three water user representatives, two representatives from environmental groups, and two members representing federal agencies. Headwaters Corporation serves as the Executive Director's Office of the Program. Program staff are located in Nebraska and Colorado and are responsible for assisting in carrying out the various Program-related activities.

Aerial photography has been collected annually by the Program since 2007. Annual LiDAR collection began in 2009. These data are integral to several of the Program's research and monitoring efforts and are our principle tools for assessing physical changes in river habitat through time.

The GC submits this Request for Proposals (**RFP**) to solicit proposals from contractors to acquire bathymetric LiDAR and aerial photography during the period of 2020 - 2023.

II. PROJECT DESCRIPTION

This scope of work set forth in this RFP includes four summer Program area aerial photography flights with a partial bathymetric LiDAR coverage and four fall/winter bathymetric LiDAR and Aerial photography flights that cover the entire 90-mile reach. Further background information on how the Program uses the data acquired through this RFP is available in an excerpt from the Program's Remote Geomorphology and Vegetation Monitoring Protocol located in Appendix A.

This RFP describes a multi-year program of work encompassing acquisition of aerial imagery and LiDAR in 2020 through 2023 according to the following schedule:

- **June 2020: Full Program area aerial photography and partial area bathymetric LiDAR**
- **November 2020: Bathymetric LiDAR and concurrent aerial photography**
- **June 2021: Full Program area aerial photography and partial area bathymetric LiDAR**
- **November 2021: Bathymetric LiDAR and concurrent aerial photography**
- **June 2022: Full Program area aerial photography and partial area bathymetric LiDAR**
- **November 2022: Bathymetric LiDAR and concurrent aerial photography**
- **June 2023: Full Program area aerial photography and partial area bathymetric LiDAR**
- **November 2023: Bathymetric LiDAR and concurrent aerial photography**

III. SCOPE OF WORK

The Program is requesting proposals from potential bidders to provide bathymetric LiDAR and digital aerial imagery of the project area as described below. Minimum product specifications follow:

1) **Schedule**

   a) <u>Sub-Project 1 - November concurrent bathymetric LiDAR and Aerial photography</u>.
      i) LiDAR and imagery will be acquired each year between November 1 and December 15 under leaf-off and low Platte River flow conditions beginning in November 2020. Bidder must be flexible and work with Program staff during that time to schedule flights such that river flows in the project area are as low as possible (ideally under 1,000 cfs).
      ii) Imagery will be acquired on cloud-free days with the sun at a sufficient angle to reduce the effect of shadows from trees and structures and efforts should be made to reduce sun glare on water surfaces.
      iii) Imagery will be acquired in combination with LiDAR such that the imagery reflects the condition of the river during the LiDAR acquisition. River conditions can change daily, and imagery must be flown at least the same day, if not at the exact same time as the LiDAR.
      iv) The Central Platte River is subject to artificial hydrocycling from hydropower operations, and close coordination and care in timing is required to acquire products acceptable to the Program.
      v) The acquisition area must be free of snow and ice, and extraneous environmental conditions such as rain, fog or smoke should be avoided.
      vi) <u>**Final delivery of Sub-Project 1 aerial imagery deliverables will be within 60 days of final acquisition flight each year.**</u>

vii) **Final delivery of all other Sub-Project 1 deliverables will be within 120 days of final acquisition flight each year.**

b) Sub-Project 2 - June Aerial photography.
   i) Imagery will be acquired each year between May 15 and June 30 beginning in May 2020. Bidder must be flexible and work with Program staff during that time to schedule flights such that river flows in the project area are as close to 1,200 cfs as possible.
   ii) The Central Platte River is subject to artificial hydrocycling from hydropower operations, and close coordination and care in timing is required to acquire products acceptable to the Program.
   iii) Imagery will be acquired on cloud-free days with the sun at a sufficient angle to reduce the effect of shadows from trees and structures and efforts should be made to reduce sun glare on water surfaces.
   iv) **Final delivery of Sub-Project 2 deliverables will be within 60 days of final acquisition flight each year.**

c) Sub-Project 2A – June bathymetric LiDAR
   i) LiDAR will be acquired each year between May 15 and June 30 in combination with the Sub-Project 2 imagery acquisition.
   ii) LiDAR will be acquired in combination with imagery such that the imagery reflects the condition of the river during the LiDAR acquisition. River conditions can change daily, and imagery must be flown at least the same day, if not at the exact same time as the LiDAR over the Sub-Project 2A area.
   iii) **Final delivery of Sub-Project 2A deliverables will be within 90 days of final acquisition flight each year.**

d) Flight Cancellations
   i) The Program, at its sole discretion, may choose to cancel any individual acquisition or part of an acquisition (aerial imagery, LiDAR) over the course of the project. This could occur if river conditions are such that the products received would not be of a quality acceptable to the Program. If an acquisition is partially or fully cancelled, the contract price would be adjusted and the cost of those acquisitions and products removed.

2) **Project Area**

a) The area of interest for Sub-Project 1 consists of an area generally between the high banks of the Platte River beginning near the junction of U.S. Highway 283 and Interstate 80 near Lexington, Nebraska, and extending eastward to near Chapman, Nebraska (approximately 128 square miles). A polygon shapefile of the acquisition area is included on the Program website (www.platteriverprogram.org) in the same location as this solicitation.

b) The area of interest for Sub-Project 2 consists of an area 3.5 miles either side of the centerline of the Platte River beginning at the junction of U.S. Highway 283 and Interstate 80 near Lexington, Nebraska, and extending eastward to Chapman, Nebraska (approximately 750 square miles). A polygon shapefile of the acquisition area is included on the Program website (www.platteriverprogram.org) in the same location as this solicitation.

c) The area of interest for Sub-Project 2A consists of an area generally between the high banks of the Platte River beginning near the J-2 Hydropower Return southeast of Lexington, NE and extending eastward to the Highway 183 bridge near Elm Creek, NE (approximately 26 square miles). A polygon shapefile of the acquisition area is included on the Program website (www.platteriverprogram.org) in the same location as this solicitation.

3) **Sub-Project 1 Technical Specifications**

CIR aerial photography and bathymetric LiDAR over approximately 128 sq. mi.

a) LiDAR Technical Specifications

i) Topo-bathymetric LiDAR (green LiDAR) is required.

ii) The LiDAR data will be collected at a mean resolution of 2.3 ft (0.7 m) GSD or better.

iii) The contractor shall ensure that the area of interest is fully and sufficiently covered with no data voids due to gaps between flightlines or system malfunction.

iv) Data voids in the bare-earth not caused by classification of geographic features shall not exceed three times the point spacing. Data voids of this size are sufficient reason to reject the dataset.

v) LiDAR data should be classified using the following ASPRS Standard LiDAR Point Classes:

- Class 1 – Unclassified
- Class 2 – Ground
- Class 7 – Low point and noise
- Class 9 – Water
- Class 12 – Overlap

(1) Class 1 will be used for feature points that are not in Classes 2, 7, 9, or 12. These typically represent returns from man-made structures, vegetation etc.

(2) Class 2 will be used for feature points that represent the bare-earth.

(3) Class 7 will be used for artifacts that do not represent the ground, manmade structures or vegetation. Typically these are extraneous points that are either below, or well above the surface not representing any true feature.

(4) Class 9 will be used to identify points found within water bodies, including streams and rivers.

(5) Class 12 will be used for LiDAR points in the overlap portion of flight lines that have been removed due to redundancy (if necessary).

(6) No points shall be deleted from the LAS files.

vi) Bare-earth classification shall adhere to the following specifications using both automated and manual filtering classification routines:
- 90% of artifacts classified
- 95% of outliers classified
- 95% of vegetation classified
- 98% of building classified

vii) Special attention must be applied to the classification process due to the geographic nature of the project area which consists of extremely flat terrain mixed with important hydrographic characteristics. Channel geometry of streams and drainage features must be maintained as well as the ability to identify sand bar features within the Platte River. Dense vegetation data voids must also be minimized by the automatic removal process and "over smoothing" due to aggressive classification must be avoided.

viii) Vertical accuracy for LiDAR will meet or exceed 0.3 ft (9.2 cm) RMSE ($Accuracy_z$ = 0.6 ft (0.18 m) at the 95% confidence level).

ix) Horizontal accuracy for LiDAR will meet or exceed 1.97 ft (0.6 m) RMSE ($Accuracy_r$ = 3.41 ft (1.04 m) at the 95% confidence level).

x) The vertical datum for LiDAR is NAVD88 (Geoid03), and the horizontal datum is Nebraska State Plane (1983). Elevation and projection in feet.

b) Aerial Photography Technical Specifications

i) The imagery will be six-inch (0.5 ft) pixel resolution.
ii) The imagery will be color-infrared.
iii) The imagery will be ortho-rectified and seamless, and will be tone-balanced with adjacent images across the project area.
iv) Imagery will be acquired on cloud-free days with the sun at a sufficient angle to reduce the effect of shadows from trees and structures and efforts should be made to reduce sun glare on water surfaces.
v) The imagery will be projected in Nebraska State Plane Feet (1983 datum).
vi) The imagery must be acquired concurrently with the LiDAR so as to reflect river conditions during acquisition. The imagery must be collected at least the same day, if not at the exact same time, as the LiDAR. Imagery acquired at flows significantly different than that of the LiDAR acquisition may require reflight.

4) **Sub-Project 2 and 2a Technical Specifications**

Four-band aerial photography over approximately 750 sq. mi. LiDAR over approximately 26 sq. mi.

a) Aerial Photography Technical Specifications

i) The imagery will be six-inch (0.5 ft) pixel resolution.
ii) The imagery will be 4-band (R, G, B, NIR).
iii) The imagery will be ortho-rectified and seamless, and will be tone-balanced with adjacent images across the project area.

iv) Imagery will be acquired on cloud-free days with the sun at a sufficient angle to reduce the effect of shadows from trees and structures and efforts should be made to reduce sun glare on water surfaces.
v) The imagery will be projected in Nebraska State Plane Feet (1983 datum).
vi) Deliverables will include both RGB and CIR products described in Section III.6.

b) LiDAR Technical Specifications
i) Same as Sub-Project 1 LiDAR Specifications in Section III.3.a above.

5) **Project Deliverables**
All project deliverables should be processed and delivered according to the schedule in Section III.1.

a) LiDAR (terrestrial and bathymetric)
i) LiDAR point data meeting or exceeding 2.3 ft (0.7 m) GSD resolution in a classified LAS file format and adhering to the technical specifications in III.3 above. LAS file projected to Nebraska State Plane Feet (1983 datum) and vertical reference NAVD88 feet (Geoid 03). Classified LAS file will include all LiDAR points, including first and last returns.
ii) Daily reports during acquisition that display all flight lines, as well as completed areas. Once acquisition is complete, a project summary report that shows time and date of all flightline acquisitions. Time of day, not just the day, is important to match river flow condition to acquisition.
iii) Tiling scheme shapefile for identifying LAS and DEM file locations. Tile size and file size is flexible and will be discussed upon award of project.

b) Digital Elevation Model
i) Hydro-enforced and bathymetric bare-earth digital elevation model raster tiles (3-foot cell size), projected in Nebraska State Plane coordinate system – elevation and projection in feet.
(1) See pages 11-13, 15, and Appendix 2 of the USGS LiDAR Guidelines and Base Specifications v13 for details on hydro-flattening: http://pubs.usgs.gov/tm/11b4/. In the proposal, provide details of the software/methodology to be used for this alternative.
(2) Breaklines used in the generation of the hydro-enforced DEM are also a required deliverable.
ii) Highest-hit (first return) digital elevation model raster (3-foot cell size). Used to approximate vegetation height.
iii) Full project area mosaic of digital elevation model tiles (3-foot cell size).
iv) NOTE: For Bathymetric LiDAR acquisition, two versions of the DEM will be required. One hydro-enforced DEM for the given flow conditions during the flight, and one DEM that incorporates bathymetry below the water surfaces.

c) Imagery
   i) Color-infrared (Sub-Project 1) and 4-band (Sub-Project 2) digital orthophotography with a six-inch (0.5 ft) pixel resolution (or better), covering the entire project area seamlessly and without data gaps.
   ii) The imagery should be geo-referenced and provided in tiled GeoTIFF (.tif) format.
   iii) Compressed imagery mosaic (.sid). Typically entire reach compiled into one mosaic, but may be split due to file size. Sub-Project 2 will require both a RGB mosaic and a CIR mosaic. Sub-Project 1 will be a CIR mosaic only.

d) LiDAR and Imagery
   i) Shapefiles of LiDAR and aerial photography flight lines or photo centers that identify the date and time of the flight line or photo center.
   ii) FGDC-compliant metadata to include, but not limited to: flight dates and times, flight altitude, camera system information, LiDAR system information, aircraft information, imagery resolution, LiDAR point density, horizontal accuracy, post-processing software and steps, and horizontal and vertical control references.
   iii) All LiDAR data, photography, and supplemental products will be delivered on USB external hard drives or flash drives and will become the property of the Program. All media and data collected under the contract shall be the sole property of and can be freely distributed by the Program. No restrictions shall be placed on the data by the contractor.

e) Ground Survey
   i) Proposals should discuss the ground control and survey approach for ensuring accuracy of elevation and imagery deliverables.
   ii) The Program owns several thousand acres of land across the entire acquisition area and can provide access to multiple river survey areas for bathymetric LiDAR ground survey verification.
   iii) Year-to-year compatibility of the deliverables is extremely important and post-processing and ground survey should ensure that datasets are comparable year to year (i.e. immobile objects such as paved roads should not report differing elevations across years).

6) **Permits and Clearances**

a) It is the contractor's responsibility to file all required flight plans and obtain all necessary approvals to fly over and acquire aerial imagery and LiDAR in the Project area.

IV. CONTRACT TERMS

The selected contractor will be retained by:

Nebraska Community Foundation
PO Box 83107
Lincoln, NE 68501

Terms and conditions will be negotiated as mutually agreeable. It is understood that the Governance Committee reserves the right to accept any proposal that, in its judgment, is the best proposal, and to waive any irregularities in any proposal.

Proposal costs incurred in response to this RFP will be the responsibility of the bidder. Neither the Nebraska Community Foundation nor the Governance Committee will be liable for any costs incurred by the bidder in the completion and submission of the proposal.

V. SUBMISSION REQUIREMENTS

All interested parties having experience providing the services listed in this RFP are requested to submit a proposal.

Instructions for Submitting Proposals

One electronic copy of your proposal must be submitted in PDF format to Justin Brei at breij@headwaterscorp.com no later than 5:00 p.m. Central Time on Friday, April 24, 2020. Maximum allowable PDF size is 8MB. A proposal is late if received any time after 5:00 p.m. Central Time and will not be eligible for consideration.

Questions regarding the information contained in this RFP must be SUBMITTED IN WRITING by 5:00 p.m. Friday, April 17, 2020. No questions on content can be submitted after this time. Questions and answers will be shared with all interested parties. These can be emailed to Justin Brei at *breij@headwaterscorp.com* or mailed to the address at the top of this RFP. Questions can be submitted any time before the above time and answers may be posted intermittently to the Program website during the proposal period. Final questions and answers will be made available on the Program website in the location of this RFP by EOB Monday, April 20, 2020.

Proposal Content

Proposals must include:

1) **Technical information including:**
    a. Aircraft/LiDAR/camera system details
    b. Ground control/verification methodology/plan
    c. Post-processing software and summary of methodology
    d. Design accuracy information

2) **Relevant LiDAR and aerial photography experience** from the last two years, especially projects related to natural resources and river geomorphology. Example projects should demonstrate experience collecting and processing bathymetric LiDAR in river systems. Please provide a minimum of two project references including the name, location, and brief summary of the projects; name, address, and phone number of the contracting officer for the client; and when the project was completed.

3) **Statement of annual availability** within the acquisition window of November 1 to December 15 for Sub-Project 1 and May 15 to June 30 for Sub-Project 2.

4) **Estimated timeline** for activities including mobilization, acquisition and processing. Also, specify the estimated flight time necessary to complete each acquisition over entire project area (for planning purposes related to river operations in order to achieve lowest possible flow).

5) **Detailed firm fixed price proposal**. At minimum, project budget should itemize Sub-Project 1 and Sub-Project 2 on an annual basis and include estimate of any applicable taxes. **Budget will be considered, but contract will not be awarded solely on a lowest cost basis.** Governance Committee approval is needed before the contractor is authorized to begin implementation. A sample budget table is included for reference. A similar table should be included in the proposal.

	June 2020 SP2	June 2020 SP2a	November 2020 SP1	June 2021 SP2	June 2021 SP2a	November 2021 SP1
Total Cost by Acquisition						

	June 2022 SP2	June 2022 SP2a	November 2022 SP1	June 2023 SP2	June 2023 SP2a	November 2023 SP1
Total Cost by Acquisition						

Total Project Cost

6) **Conflict of interest statement** addressing whether or not any potential conflict of interest exists between this project and other past or on-going projects, including any projects currently being conducted for the Program.

7) **Suspension and Debarment.** Contractor must not be suspended or debarred from receiving federal funds. Proposal must include statement of eligibility to receive federal funds and must provide contractor Dun & Bradstreet (D-U-N-S) number or other means of identification in the U.S System for Award Management site (www.sam.gov).

8) **Description of insurance** shall be provided with the proposal. Proof of insurance will be required before a contract is issued. Minimum insurance requirements will include $1,000,000 general liability per occurrence.

VI. CONTRACTOR SELECTION

The GC will appoint a selection committee to review responses to this RFP. Proposals will be reviewed and the award made to the lowest cost proposal that conforms to the specifications of this solicitation and is considered to provide the most value to the Program.

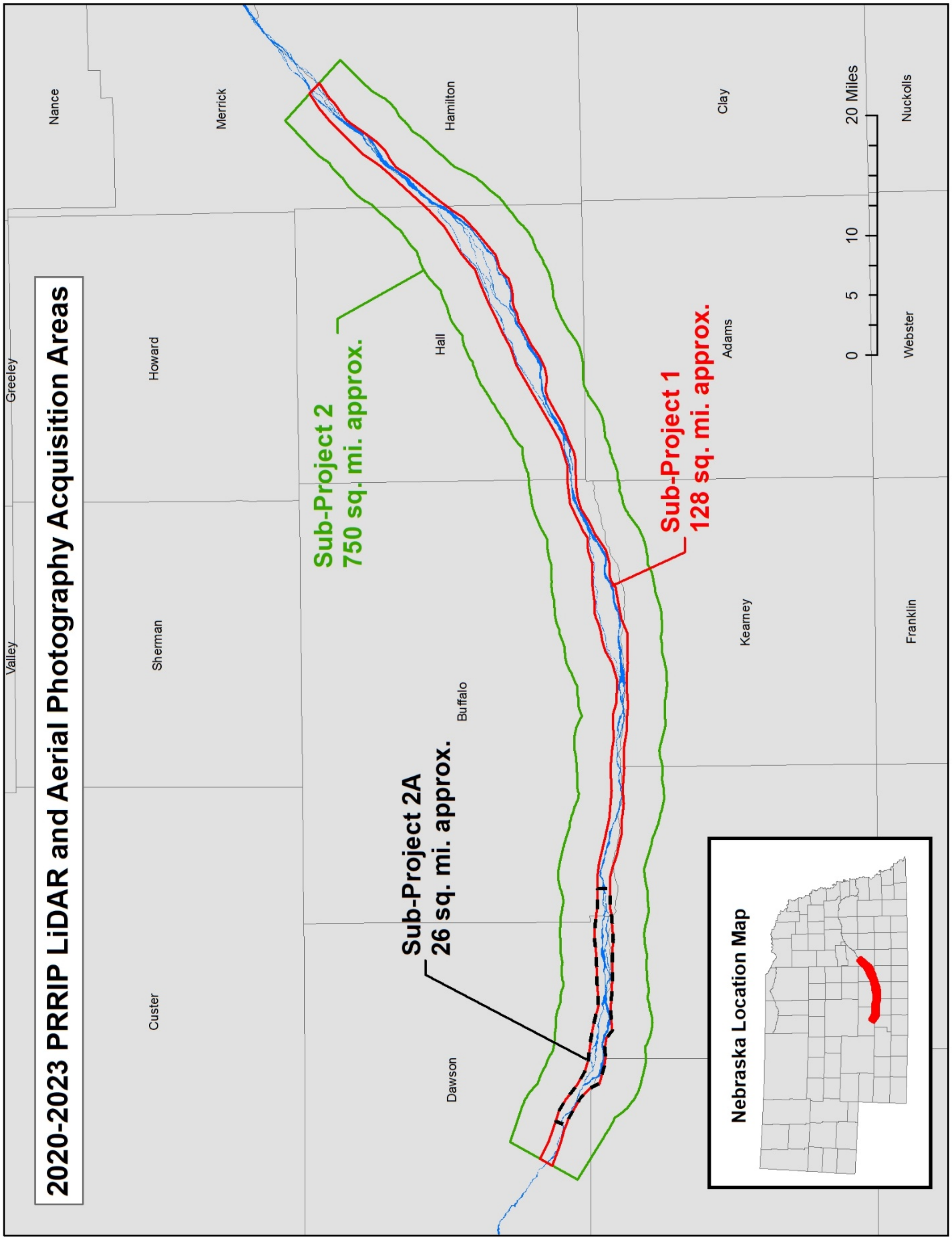
VII. PROGRAM PERSPECTIVE

The GC of the Program has the sole discretion and reserves the right to reject any and all proposals received in response to this RFP and to cancel this solicitation if it is deemed in the best interest of the Program to do so. Issuance of this RFP in no way constitutes a commitment by the Program to award a contract, or to pay contractor's costs incurred either in the preparation of a response to his RFP or during negotiations, if any, of a contract for services. The Program also reserves the right to make amendments to this RFP by giving written notice to contractors, and to request clarification, supplements, and additions to the information provided by a contractor.

By submitting a proposal in response to his solicitation, contractors understand and agree that any selection of a contractor or any decision to reject any or all responses or to establish no contracts shall be at the sole discretion of the Program. To the extent authorized by law, the contractor shall indemnify, save, and hold harmless the Nebraska Community Foundation, the states of Colorado, Wyoming, and Nebraska, the Department of the Interior, members of the GC, and the ED Office, their employees, employers, and agents, against any and all claims, damages, liability, and court awards including costs, expenses, and attorney fees incurred as a result of any act or omission by the contractor or its employees, agents, subcontractors, or assignees pursuant to the terms of this project. Additionally, by submitting a proposal, contractors agree that they waive any claim for the recovery of any costs or expenses incurred in preparing and submitting a proposal.

VIII. AVAILABLE INFORMATION

A shapefile of the acquisition area for Sub-Projects 1, 2, and 2A are available on the Program website (www.platteriverprogram.org) at the same location as this RFP solicitation. A map of the acquisition area is found on the last page of this solicitation.


2020-2023 PRRIP LiDAR and Aerial Photography Acquisition Areas
Sub-Project 2
750 sq. mi. approx.
Sub-Project 1
128 sq. mi. approx.
Sub-Project 2A
26 sq. mi. approx.
Nebraska Location Map
0 5 10 20 Miles
Nance
Merrick
Hamilton
Clay
Nuckolls
Greeley
Howard
Hall
Adams
Webster
Valley
Sherman
Buffalo
Kearney
Franklin
Custer
Dawson

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM
2020-2023 Annual LiDAR and Aerial Photography RFP

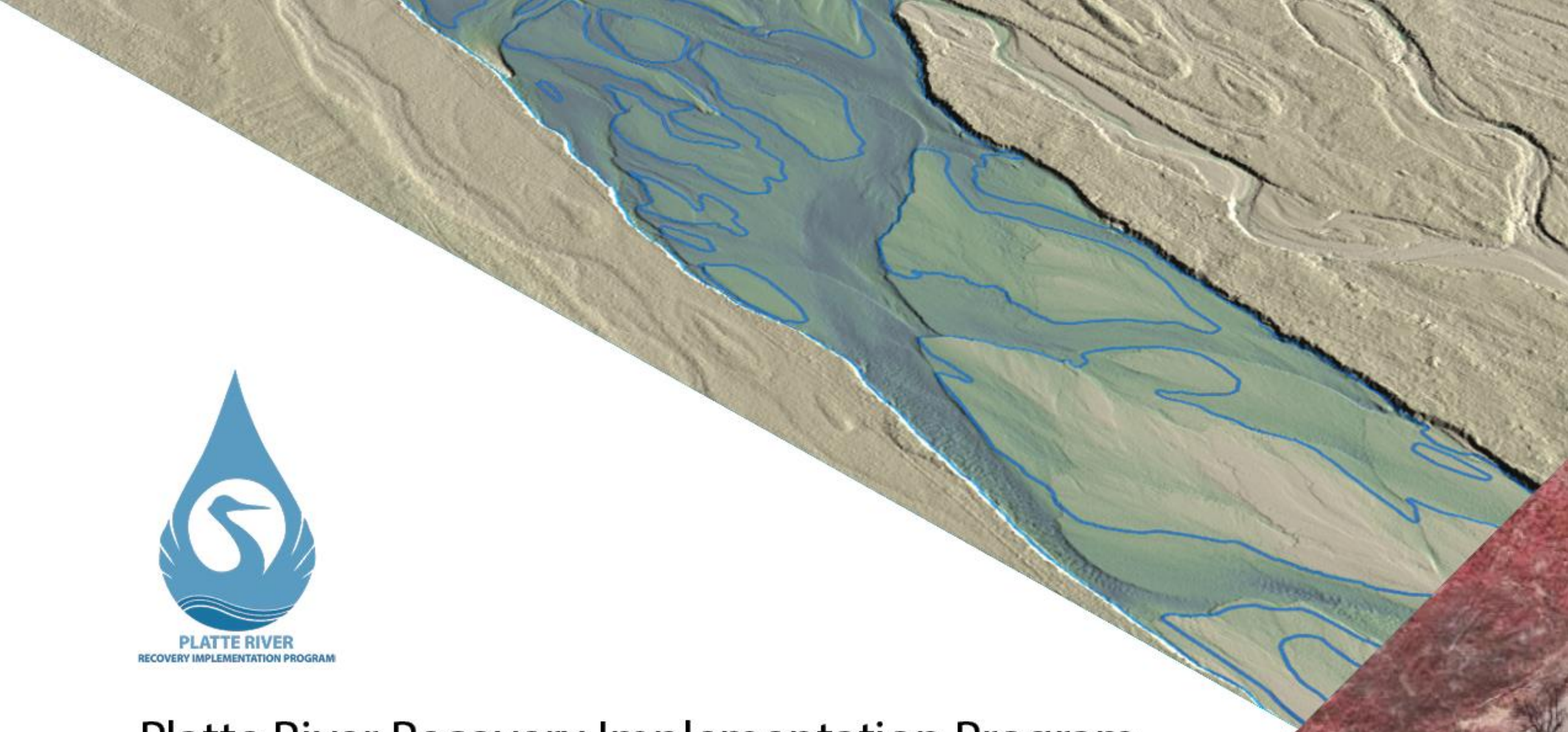
1) Is there Secchi depth requirement or ranges for the bathymetric LiDAR data?

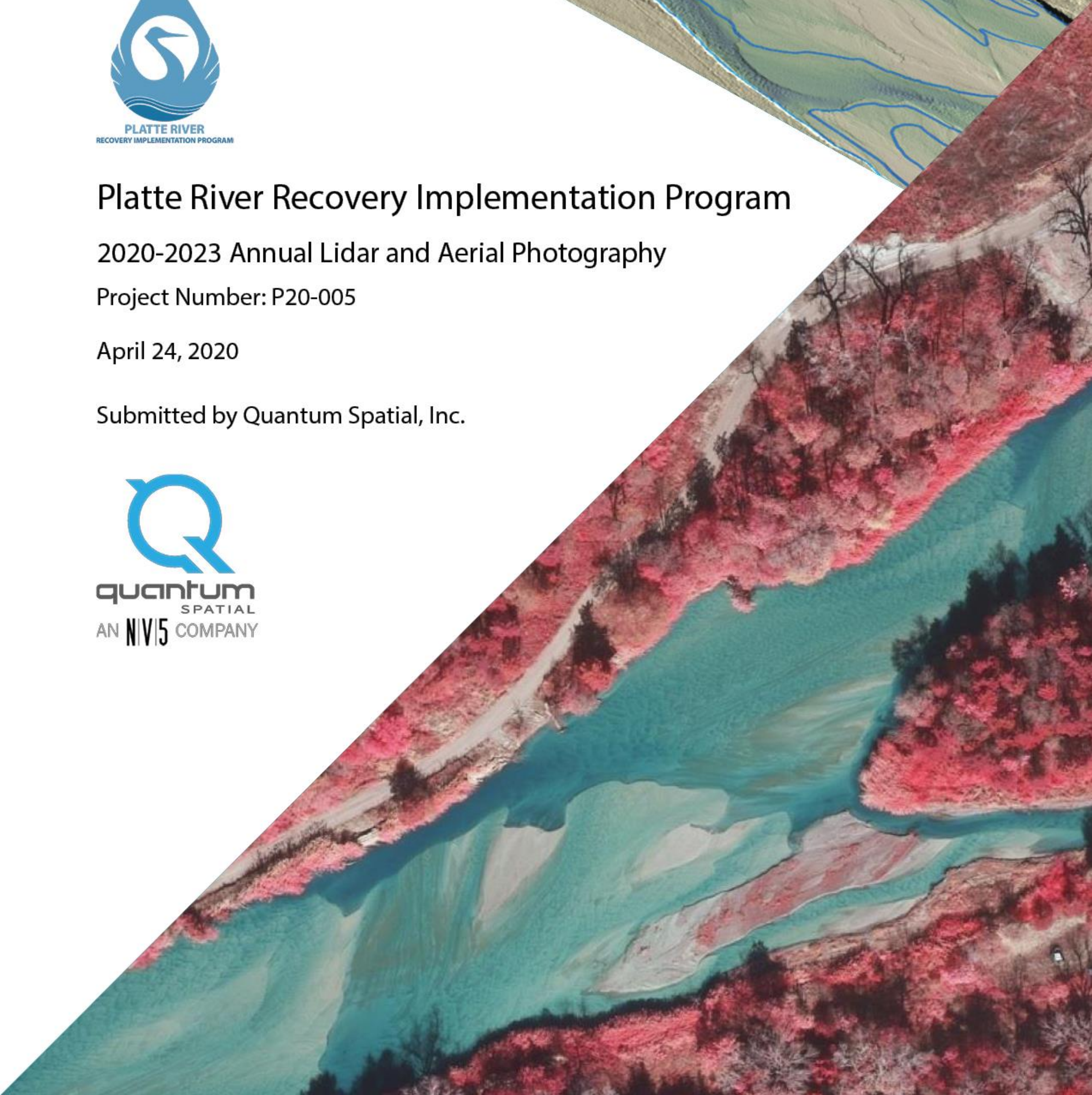
No Secchi requirements or ranges have been established. Flights could be postponed or cancelled if river flows are extremely high and suspended sediment is expected to be an issue. Under typical flows, acquisitions performed to-date have had minimal clarity issues. PRRIP will be looking for guidance/expertise from the Contractor on bathymetric river acquisitions for various sediment conditions. Proposals should describe the expected operating parameters for Contractors' systems as it relates to water clarity.

2) Please clarify the level of hydro enhancement required for your study data.

This project requires hydro-flattened DEMs. Bridges and other man-made structures over water bodies should be removed, and water surfaces should be flat (ponds) or uniformly sloped (rivers and streams) such that water flows "downhill". The river channel and island features are the primary concern. Maintenance of area and elevations of above-water in-channel sandbars and islands is very important. Removing culverts or other subsurface features for hydro-enforcement is not required.

ATTACHMENT 2: QUANTUM SPATIAL, INC RESPONSE TO REQUEST FOR PROPOSALS





PLATTE RIVER
RECOVERY IMPLEMENTATION PROGRAM

Platte River Recovery Implementation Program

2020-2023 Annual Lidar and Aerial Photography

Project Number: P20-005

April 24, 2020

Submitted by Quantum Spatial, Inc.

quantum
SPATIAL
AN NV5 COMPANY

April 24, 2020

Quantum Spatial, Inc.
1100 NE Circle Blvd, Suite 126
Corvallis, OR 97330

Justin Brei
Headwaters Corporation
4111 4th Ave., Suite 6
Kearney, NE 68845
308-237-5728, Ext. 4

RE: Platte River Recovery Implementation Program, 2016-2019 Annual LiDAR and Aerial Photography

Dear Mr. Brei,

Thank you for the opportunity to submit a response to the subject RFP, issued on March 30, 2020, calling for annual topobathymetric lidar and aerial photography over the next four years (2020-2023) to support the *Platte River Recovery Implementation Program* under the direction of the Headwaters Corporation (Headwaters). Quantum Spatial, Inc. (QSI) offers unparalleled expertise in riverine topobathymetric lidar applications across the U.S. and we are excited that the Program has adopted the use of this new technology to support your research questions and operational decision making. As the contract holder for remote sensing services from 2016-2019, QSI has focused on providing Headwaters with high quality, timely, and valuable topobathymetric lidar and orthoimagery for the Platte River areas of interest over the four years of campaigns executed in early summer (June) and fall (November). We understand your need for these data to support various long-term research, change detection, and monitoring goals and to aid in the management, restoration, and protection of this valuable river floodplain.

Below you will find our proposal response which outlines our understanding of the project scope; our technical approach including acquisition, survey control, processing, and QA/QC procedures; recent relevant topobathymetric lidar and aerial photography experience; our statement of availability during the requested flight timeframes; estimated timeline; a firm fixed price proposal; and other required documentation.

Our goal is to provide you with accurate datasets at a reasonable price, and we would be honored to continue our partnership with you on this important project. Based on our understanding of the need for multi-temporal comparisons and change detection analysis, for this cycle of data acquisitions, we will be providing a complimentary (no additional cost) change layer with the delivery of each November topobathymetric lidar dataset for the Sub-Project 1 area of interest. This difference raster DEM will characterize topographic change between the previous and current year. The change layer will be an accurate depiction of true change, supported by rigorous ground survey data collected from common benchmarks across years.

We are confident that you will find QSI highly qualified for this project and that our technical approach and cost structure will exceed your expectations. Please do not hesitate to contact me with any questions regarding our proposal, at (734) 680-6424 or by email to abrenner@quantumspatial.com.

Sincerely,

Andrew Brenner

Andrew Brenner, Ph.D.
Senior Program Director, Quantum Spatial, Inc.

TABLE OF CONTENTS

1.0 Overview

Quantum Spatial, Inc. (QSI), and NV5 Company, is pleased to present this statement of qualifications and cost proposal to the **Headwaters Corporation** (Headwaters) for the multi-temporal acquisition of topobathymetric lidar and aerial photography over a 90-mile reach of the Platte River floodplain in central Nebraska. These multi-temporal remote sensing data will continue to feed analysis of patterns of channel morphology and riverine vegetation within and across years for a full understanding of this dynamic landscape. Data will contribute to the Platte River Recovery Implementation (PRRI) Program to address endangered species issues in the central and lower Platte River Basin.

QSI is a full-service, geospatial firm specializing in spatial data generation, integration, and analysis for clients worldwide. We bring over four decades of experience in providing quality geospatial solutions. Our firm comprises some of the most experienced, well qualified, best equipped, and highly credentialed staff in the geospatial profession in North America. We have over 500 professional and technical staff with high company longevity (10+ years) in 11 facilities nationwide. Our operations staff includes pilots, sensor operators, imagery and lidar analysts, remote sensing specialists, and GIS professionals. We have been at the forefront of the collection and processing of high-resolution topobathymetric lidar data for riverine and water resources mapping for almost a decade and are intimately familiar and experienced with the various applications of bathymetric mapping for natural resource studies.

Bare earth combined topobathymetric surface model colored by elevation, illustrating the complexity of Platte River's braided channels.

A significant river within the Missouri/Mississippi drainage basin, the topography of the Platte River is dynamic and characterized by continual change. To manage water and riverine habitat for target species efficiently and effectively requires detailed understanding of geomorphology and how flows impact topography and vegetation throughout a given year. We understand that the ability to analyze change as impacted by anthropogenic and natural processes is of paramount importance to the Headwaters Corporation. As the contract holder for the 2016 – 2019 Annual LiDAR and Aerial Photography contract, Quantum Spatial collected aerial photography for the larger area of interest (Sub-Project 2) annually from 2016 to 2019, and we fielded the relatively new technology of topobathymetric lidar with great success for the Sub-Project 1 area during multiple spring and fall acquisitions. Throughout the contract, our acquisition team has perfected operational aspects of the project including coordination of lidar with imagery, coordinating acquisition with dam operations, and our production team has developed several unique classification algorithms and breakline generation workflows that are tailored to accurately model the complex topography of the Platte River. For the next contract cycle, we would be honored to continue to provide multi-temporal topobathymetric lidar and imagery services, as well as additional solutions that aid in change detection analyses for this important Program.

Our response below provides an overview of our Technical Approach, Relevant Lidar and Aerial Photography Experience; Annual Resource Availability during the June and November time periods; Estimated Timeline; and a

Firm Fixed Price Proposal for data acquisitions from 2020 – 2023. Additional administrative sections (Conflict of Interest Statement; Suspension and Debarment; Description of Insurance) are also provided, as requested.

2.0 Technical Information

The following technical information provides an overview of Project Scope (remote sensing collection plan for three project areas); a Synopsis of Lessons Learned from our experience in executing the 2016-2019 contract for Headwaters; our Acquisition Approach; Ground Control/Verification Methodology; Post Processing Methodologies; QA/QC for Accuracy; and a full list of Deliverables.

2.1 Project Scope

Headwaters has outlined three Sub-Project areas of interest (AOIs) with different remote sensing collection requirements and collection periods (in June and November) over a four year time span between June 2020 and November 2023 (Figure 1). Each year, for the Sub-Project 1 AOI (SP1; 128 sq. miles), topobathymetric lidar (≥ 8 pulses/m^2) and multispectral 4-band imagery (15 cm GSD) will be collected in fall during low flow and leaf-off conditions between November 1 – December 15; in early summer (May 15 – June 30), 4-band imagery will be collected for the Sub-Project 2 AOI (SP2; 750 sq. miles) and topobathymetric lidar will be collected for the smaller Sub-Project 2A (SP2A; 26 sq. miles). All AOIs will be buffered by 50-100 meters to ensure complete coverage and adequate lidar point densities at the study area boundary.

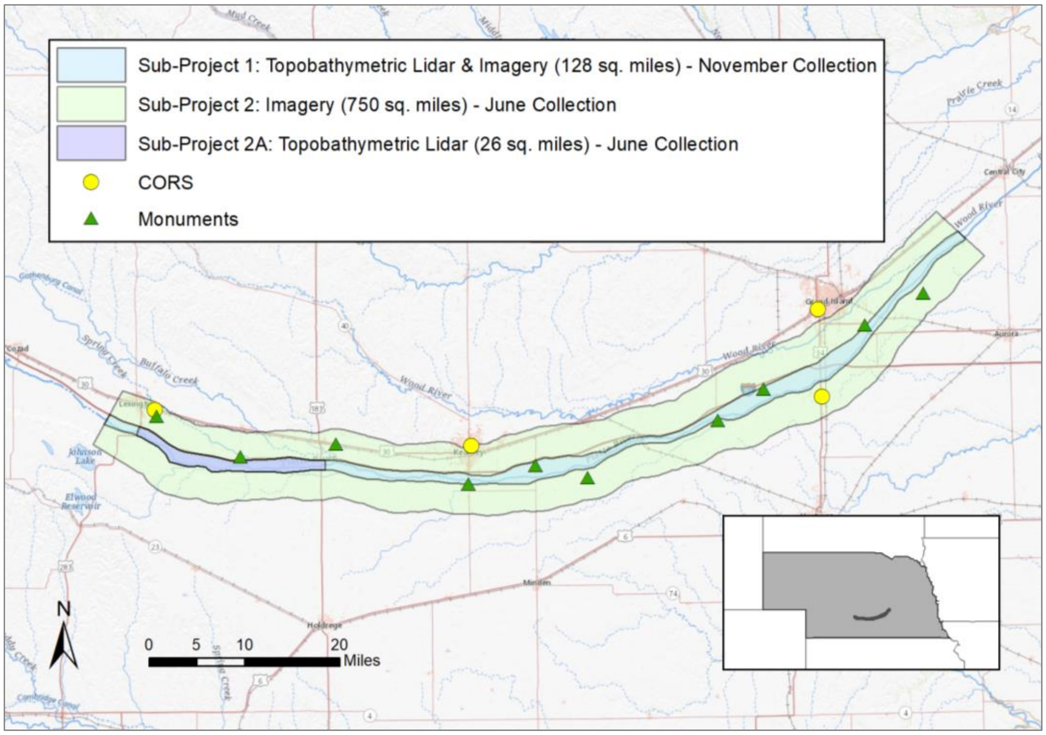


Figure 1. Map depicting scope and timeline for collection of topobathymetric lidar and 4-band imagery acquisition along the Platte River project area. CORS (RTN network) as well as prior monuments (NGS and QSI-established) are also shown.

2.2 Lessons Learned from 2016-2019 Contract

The advantages of having completed four years of acquisition for Headwaters is that QSI now has a thorough understanding of the challenges associated with the project. As a result, we are in a uniquely qualified position to mitigate risks and put in place contingencies to ensure that all aspects of the project run smoothly. One of the key challenges of the 2016-2019 project was meeting the previous schedule turnaround time. QSI worked diligently to accelerate every step in the processing workflow to meet the timeline requirements and in many cases did so.

However, the turnaround time was acknowledged to be a challenge and has been adjusted in this solicitation. Based on our experience with this Program, we have established procedures and approaches that will ensure we meet the new schedule and deliver data and products of the highest quality throughout the duration of the new contract.

The new delivery timelines will also ensure that time and effort are appropriately allocated by our QC teams to check against and adjust for any systematic shifts among repeat collections, ensuring that accurate change detection among repeat collections can be made by Headwaters analysts. Learning from prior experience with this multi-temporal project, our production teams have adjusted QC protocols to ensure that erroneous elevation shifts among datasets will not occur for the next contract cycle. These protocols include using the same benchmarks among acquisitions as well as resolving erroneous shifts in elevation identified at fixed surfaces between acquisitions. Because we will already be paying close attention to real change among these multi-temporal data as part of our more rigorous QC checks, it will be straightforward for us to include a complementary ground elevation change dataset with the required deliverables as a valuable dataset for Headwaters research.

Through our prior experience with this contract, we have learned that a major challenge is the delineation of the hydro breaklines. Breaklines are essential to correctly classify the water's edge for the accurate correction of refraction and its impact on bathymetric ground modeling. The hydro breaklines are generated through a semi-automated approach, but then manually reviewed by trained analysts. The magnitude of this effort changes significantly from year to year because of differences in the water levels and their interaction with the braided nature of the river's bathymetry. For this reason, the breaklines from one year are not applicable in subsequent years. As an example, in 2017, maximum breakline length among collections was 2,087 miles, whereas in 2019 the breakline length was 953 miles. Similarly, the wetted area enclosed by the breaklines in 2019 was 12,609 acres, whereas in 2018, it was 6,940 acres. This variation among years translates to variation in the manual QC time required to ensure the accurate rendition of breaklines in any given year. We will ensure that there are sufficient resources year-to-year to adequately handle this task so that it does not become a bottleneck in the production process, ensuring we provide Headwaters with on-time, first-time-right delivery regardless of the level of annual breakline complexity.

As indicated in the RFP, close coordination is essential to the success of the project. The timing of the acquisition requires excellent communication between QSI flight operations, Headwaters project staff, and the hydro-electric dam operations. Over the last four years, on many occasions we have mobilized and collected the data on short notice to take advantage of tight windows where the flow regime and weather coincided for successful data acquisition. As our flight operations team is extremely responsive, we have not missed an acquisition window over the course of the Program. In addition, our approach to collect imagery and lidar from separate platforms provides the flexibility to acquire the areas in quick succession when the acquisition windows open under conditions that are optimal for each data source collection. QSI will continue to ensure excellent communication between all parties for the next four years of the Program.

2.3 Acquisition Approach

All data collection missions will be accomplished with a fixed-wing aircraft (Cessna Caravan, Cessna Grand Caravan, Cessna Conquest II, or Piper Navajo). Our lidar systems are GPS/GNSS capable and include GNSS-IMU technology. This allows for greater flight (and cost) efficiencies by having a greater range of available satellites and no longer requiring maintaining satellite lock during turns. Data will not be collected with snow or ice on ground or during inclement weather conditions (high winds, rain, fog, low clouds, or smoke cover). Quantum Spatial will assume responsibility for filing all required flight plans and will obtain all necessary approvals to fly over and acquire remote sensing data in the project area.

We fully understand that It is essential that the lidar and imagery are collected at low flows. This maximizes the extent and depth of the channels that can be mapped, and aids in reducing the turbidity of the water to increase the penetration depth of the laser through water. Windows for acquisition are in general determined based on the ability of the dam operators to slow the flow in the river. We understand this restriction and will work closely with the Headwaters team to coordinate both the imagery and the lidar flights during these windows. Lidar and imagery are not acquired from the same platform because the optimal flight conditions are not the same for each technology. Nonetheless, the imagery and lidar will be flown as close as operationally possible to each other.

2.3.1 Topobathymetric Lidar

Topobathymetric lidar data will be acquired using a Tier 1 Riegl VQ-880-G hydrographic airborne laser system (Table 1). The system contains a fully integrated NIR channel (ʎ=1064 nm) and green channel (ʎ=532 nm) capable of penetrating water, and its high repetition pulse rate, high scanning speed, small laser footprint, and wide field of view together facilitate high resolution coverage of topographic and bathymetric surfaces. The Riegl instrument's short laser pulse length is ideal and critical for shallow-water systems as it allows for effective discrimination between water and bathymetric surfaces which can be challenging when mapping near-shore, shallow, and dynamic aquatic environments. Lidar data will be collected to produce a high resolution topobathymetric data set (≥ 8 pulses/m^2) with a maximum scan angle of ±20° (off nadir). All overlapping flight lines will be flown in opposing directions with ≥ 50% overlap. We will ensure that the area of interest is fully and sufficiently covered with no data voids between flight lines.

Table 1. Topobathymetric Lidar Specifications Summary

Sensor	Riegl VQ-880-GII sensor (or equivalent)
Pulse Density	≥ 8 pulses/m^2 (0.70 m post spacing)
Field of View (Scan Angle)	40° (± 20° off nadir)
Swath Overlap	≥ 50% side-lap
Field of View	40°, 20° forward fixed angle
Intensity	16-bit
Data Recording	Discrete (On-Line) Full Wave Form
Depth Ranging	1.5 Secchi Depth
Flightlines	Opposing
Vertical Accuracy$_z$ / RMSE	18 cm / 9.2 cm
Horizontal Accuracy$_z$ / RMSE	1.04 m / 60 cm

Table 2. Acquisition Software for Flight Planning, Aircraft Navigation and Positioning

Leica FlightPro
Track'air Flight Management Systems
Applanix POS/AV Systems
Applanix X-Track
Applanix POS PAC
Leica IPAS GNSS/IMU Navigation
FMS Nav Systems
Z/I InFlight
Novatel Inertial Explorer
Leica SPAN GNSS/IMU Navigation

Quantum Spatial is an industry leader in the use of Airborne GPS (ABGPS) technology, having completed more than 10,000 ABGPS missions nationwide in the last six years alone. We employ the latest in kinematic GPS technologies and offer significant knowledge and experience flying and post-processing ABGPS and inertial data. Our firm utilizes the latest available versions of software for post processing airborne data (Table 2). Our aircraft are equipped with Garmin or Trimble Navigational GPS and we utilize the latest software for flight planning and navigation while executing data collection missions.

Lidar data will be collected to produce a high-resolution (≥ 8 pulses/m^2) topobathymetric data set with a maximum scan angle of ± 20° (off nadir). The Riegl system has demonstrated hydrographic depth ranging capability of at least 1.5 Secchi depth (reliably up to ~30 ft in clear water) on bright reflective surfaces. We consider the Riegl VQ-880 model as the best bathymetric lidar system for this project, given the following features:

1. A narrow beam divergence and short pulse length that provides higher resolution in the shallow water zone. These features combined with a much higher pulse rate than other bathymetric lidar systems allows for a detailed definition of the land/water interface, which is very important in the complex shorelines found in most inland river systems and coastal estuaries.
2. The instrument has a high pulse rate that is also advantageous in providing more returns (i.e. pulses per square meter), which results in better resolution of the channel morphology and the opportunity to derive additional habitat metrics.
3. It was designed specifically to collect topobathymetric data for complex shallow water environments. QSI has deployed the Riegl line of sensors for riverine mapping for the past 7 years (since the technology entered the commercial market). Other sensors on the market were initially designed more for open water bathymetric applications and do not perform as well in complex riverine systems.

Data will be collected during the best possible conditions for success which include no fog/rain and other conditions affecting water clarity. The actual depth performance will depend on water clarity and bottom reflectivity at time of acquisition. Water clarity affects the depth penetration capability of the bathymetric 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. Finally, the laser will not penetrate dense aquatic vegetation. Data will be collected during the best possible conditions for success which include no fog/rain and any other conditions affecting water clarity. QSI will designate a Data Acquisition Manager responsible for scheduling and supervising aircraft and field crews. The acquisition manager will monitor both weather and water clarity conditions and make daily decisions on flight operations. The acquisition manager will coordinate with the QSI technical team and provide regular reports to Headwaters Corp and Program partners.

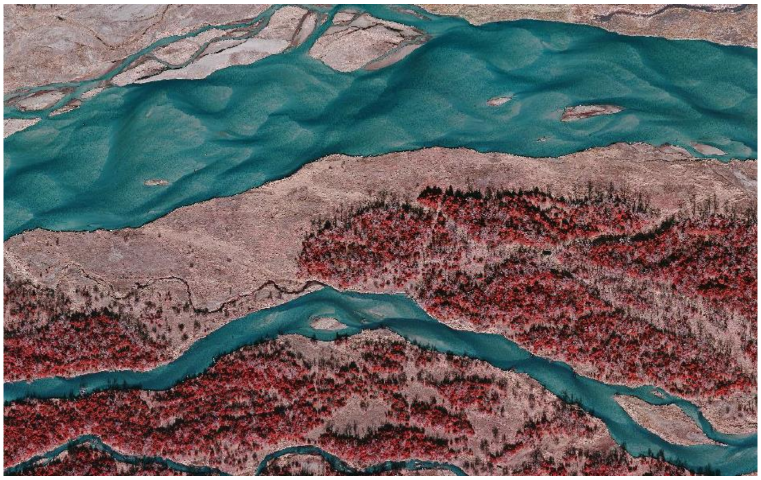
2.3.2 Aerial Photography

Digital imagery will be acquired for the full program area SP2 in early summer (every June, flow levels < 1,200 cfs) and co-acquired with lidar for the SP1 project every fall (November, flows < 1,000 cfs). Imagery will be collected in 4 spectral bands (R,G,B, NIR) with 30% sidelap and 60% forward lap using a Leica DMC I or Vexcel UltraCam Eagle M3 large format frame-based digital camera system (or equivalent; Table 3). The camera sensor simultaneously captures 4 co-registered bands (red, green, blue, and near-infrared) and imagery can be delivered as 8- and 16-bit digital orthophotos (CIR and/or RGB).

Table 3. Imagery Specifications Summary

Cameras	Leica DMC I or equivalent
Spectral Bands	Red, Green, Blue, NIR
Ground Sample Distance / Pixel Resolution (Scale)	15 cm (½ ft)
Horizontal Overlap	30%
Vertical Overlap	60%
Horizontal Accuracy	< 4 pixels (2 ft) RMSE

Atmospheric conditions will be closely monitored by our flight operations team prior to mobilizing, and during all collections. Given the different atmospheric requirements for collecting lidar compared to imagery (with imagery requiring clearer conditions), it is sometimes difficult to perfectly align the collection of these two datasets. However, to the best of our ability, all imagery will be collected as close as possible in time to lidar missions, targeting collection minimally on the same day. Imagery will be collected during cloud free conditions with no smoke, haze, fog and dust. Imagery acquisition will occur during the hours of 10 am and 3 pm local time (proper sun angle to minimize the effect of shadows from trees and other vertical structures). Efforts will be made to reduce sun glint on water surfaces. QSI will work with Headwaters to schedule all flights to achieve temporal alignment with the lidar as best as we possibly can. Lidar and imagery will not be collected at significantly different flow conditions.



False color image, Platte River November 2019.

2.4 Ground Control/Verification Methodology and Plan

The QSI acquisition and field survey team will use a combination of appropriate methods to enable geo-spatial correction of aircraft positional coordinate data. These include conventional base supported ('BS') survey control, TerraPos® Precise Point Positioning ('PPP'), or Trimble® CenterPoint™ Post-Processed Real-Time Extended ('PP-RTX'). To verify lidar point calibration and enable accuracy assessment, for each collection (June and November) our field crew will collect ground check points (GCPs) using GPS-based real-time kinematic (RTK) survey techniques.

For the RTK surveys, the ground crew will use a roving unit to receive radio-relayed corrected positional coordinates for all ground points from a GPS base unit set up over a survey control monument or CORS (RTN network). Monuments used in prior collections from 2016-2019 will be used to maintain consistency in survey control for this multi-temporal Program. The roving unit records precise location measurements with an error (σ) of ≤ 1.5 cm relative to the base control. Our team will distribute a suitable number of hard, bare earth ground check points (GCPs) on level slope throughout the project areas (Figure 2). Checkpoints will also be collected in shallow water in order to assess sub-surface accuracy of the bathymetric lidar. In addition, we will work with Headwaters to gain access to additional river survey areas for bathymetric lidar ground survey verification. The feasibility and number of check points/cross sections will depend on access and radio range on the RTK rover. The techniques for establishing all ground check points will be outlined in the Report of Survey, including the identity, locations, and position residuals of all GCPs used to evaluate survey accuracy.

Bathymetric checkpoint collection on the Platte

QSI understands the importance of year-to-year compatibility of the multi-temporal dataset, to ensure the ability to detect and map real topobathymetric change for Sub-Projects 1 (128 sq. miles) and 2A (26 sq. miles). Our ground survey design for the 2020-2023 contract will place additional emphasis and focus on re-occupying monuments, using the same CORS (RTN network), and/or collecting RTK along the same hard surfaces (paved roads) during each June or November flight mission for the lidar AOIs (see Figure 1 for monuments and CORS). This will facilitate proper calibration of flight lines and surface adjustments so that any erroneous elevation shifts among years does not occur and/or can be corrected. We will also monitor any road re-surfacing activities to provide additional context for any detected elevation differences.

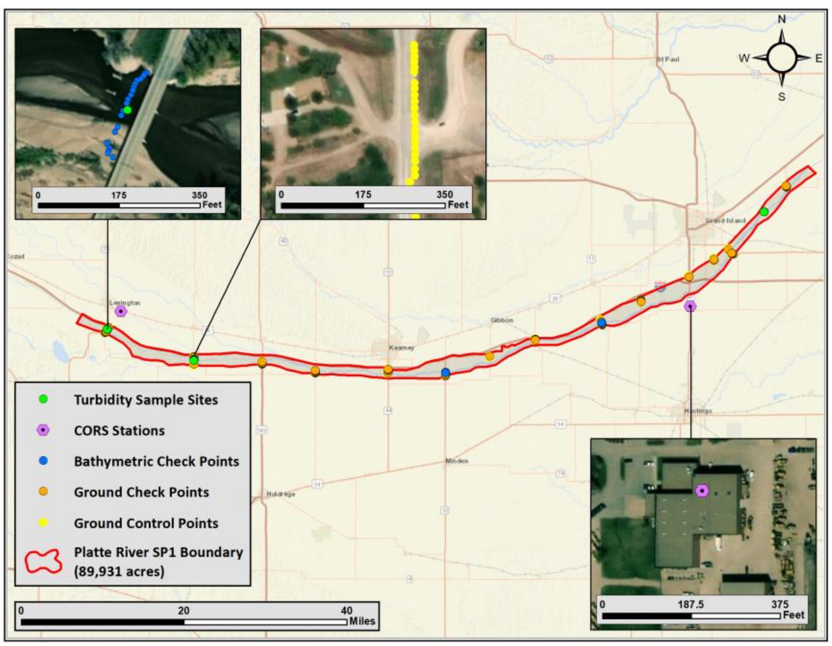


Figure 2. CORS stations, ground check points, and bathymetric checkpoints used for the October 2018 topobathymetric lidar collection of SP1. Checkpoints collected along several roads that cross perpendicular to the AOI provide for a robust validation dataset.

For the aerial photography, we will match new imagery to existing orthophotography previously collected. QSI will lay targets as necessary and use stable (i.e., outside of the active riverbed) photo-identifiable landscape features to provide additional control for new imagery. Targets laid at any lidar monuments will also aid in controlling the imagery.

2.5 Post Processing

2.5.1 Topobathymetric Lidar

Our general workflow for the topographic/bathymetric lidar data processing of Riegl data will include the following:

1. Resolve kinematic corrections for aircraft position data using kinematic aircraft GPS and static ground GPS data. Trimble Centerpoint RTX trajectory processing will also be used when necessary. 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.
2. 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 R14) format.
3. Classify water surface lidar points and develop water surface models in Riegl's RiHydro software. A hybrid approach of utilizing either the NIR and/or green laser points is used to select the most accurate points for water surface modeling. Perform QC of the water surface point data to identify and remove docks and any other artifacts for water surface generation.
4. Filter and edit points to obtain the most accurate representation of the water surface and create a water surface model triangulated irregular network (TIN). A TIN model is preferable to a raster-based water surface model to obtain the most accurate angle of incidence during refraction.
5. In RiHydro, a correction is applied to the bathymetric lidar points to account for the process of refraction. Angle and ranging are adjusted to correctly place bathymetric points under water.
6. Swath-to-swath adjustments of NIR and bathymetric/topographic lidar data, with adjustments to absolute control. Accuracy of alignment is checked and verified for the entire dataset.
7. Upland disconnected water features will sometimes bypass the refraction process in RiHydro. These areas are identified and a correction for refraction is applied.
8. Using QSI's in-house lidar processing tools, refraction processing considers laser angle of incidence on the water surface and corrects the beam's angle and range vector to compute a corrected point position. After refraction, the points are compared against bathymetric control points to assess accuracy.
9. Automated grounding and classification routines are run on the topobathymetric dataset. Careful consideration is taken with respect to environmental conditions and temporal differences to result in the most representative ground and bathymetric surfaces. The integrated topobathymetric point cloud will be processed following the LAS classification scheme:

Classification Value	Meaning
1	Processed, unclassified
2	Bare-earth ground
7	Noise (low or high; manually identified)
9	Water
12	Overlap

10. Develop final data products. Seamless topobathymetric digital elevation models (DEMs) are generated from a TIN of the ground and bathymetric bottom point classes. Voids in the bathymetric dataset are identified using a maximum triangle edge length. This void creation is performed to prevent false triangulation across areas in water without returns. Additionally, a confidence layer is generated representing regions of high and low confidence of bathymetric elevation based on the standard deviation (proxy for roughness) of the DEM.
11. Final data quality assurance/quality control (QA/QC), reporting, and delivery. Las File public header block will include all required fields according to LAS v1.4 R14 (March 26, 2019).

Seamless bathymetric and topographic data integration begins with accurately identifying all the bathymetric points needing an additional spatial correction for refraction. Demarcating points which need this correction can be determined through accurate water surface modeling and capturing all points below the water surface model. The additional aid of breaklines demarcating the water/land edge is often necessary. Their use is based on the terrain complexity and landcover type, when general water classification procedures can prove insufficient. For the Platte River, breakline generation is especially challenging. The unique combination of geomorphology (sand bars and braided channels) as well as the protocol to lower water levels to expose these features during the bathymetric lidar collections, results in an unusually high level of complexity for hydro breaklines (Figure 3). Our production teams have spent considerable time developing hydrologic breakline generation procedures and protocols that are specific to the Platte River system.

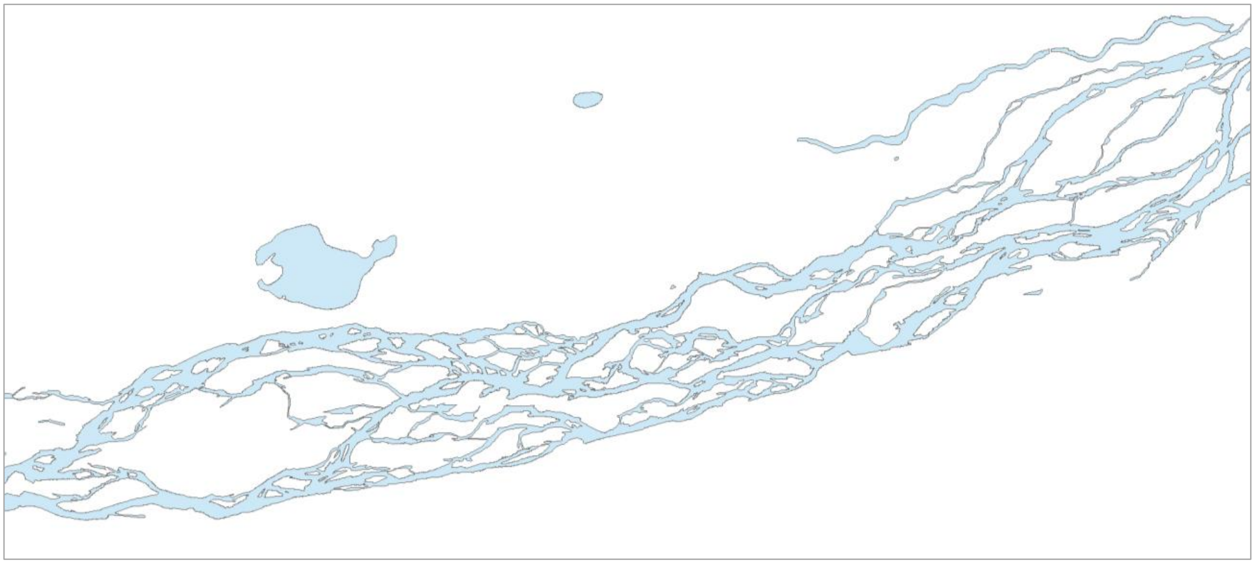
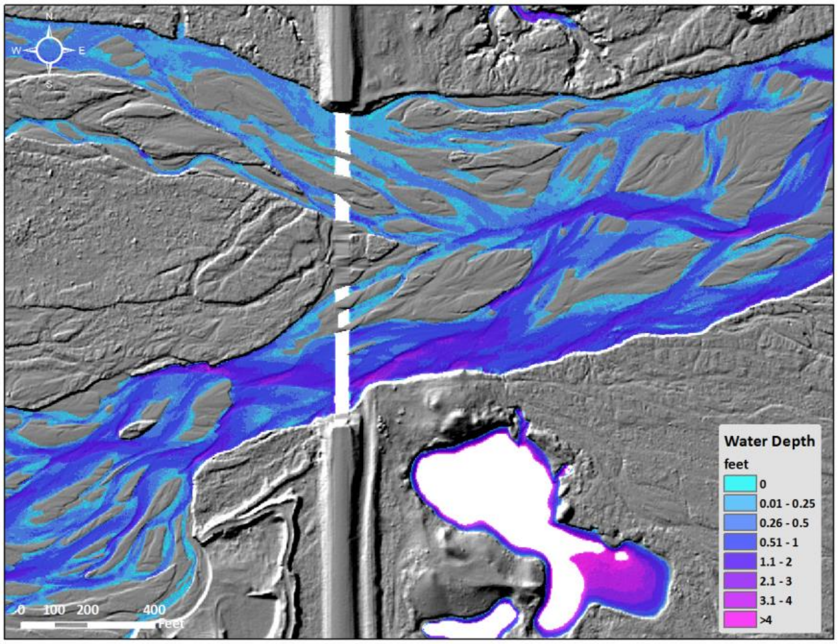


Figure 3. Example of the complexity of breaklines generated along a stretch of the Platte River, for the topobathymetric lidar collection in 2016.

A **water surface model** is used to determine the exact **refraction correction** for each return. This water surface is generated using both bathymetric and NIR lidar points within the waterbody. Where necessary, the water surface points are filtered and edited to obtain the most accurate representation of the water surface. These points are used to generate a **TIN water surface model**. A TIN model is preferable to a raster-based water surface model because it allows the angle of incidence to be easily calculated and included in the refraction correction. The refraction correction processing is performed using the RiHydro software and 'LAS Monkey,' QSI's proprietary lidar processing tool. After correcting for refraction, the points are compared against bathymetric control points to **assess accuracy**. Additionally, close inspection of the land/water interface is performed to ensure that the refraction correction has correctly positioned bathymetric bottom points.

In general, given the nature of the topography of the Platte River, which is characterized by subtle and gradual undulations or changes in depth, paleochannels, sand bar features, and other important hydrographic characteristics, the ground modeling process will pay special attention to capturing and mapping these micro features. Using both automated and manual classification routines, the resulting ground point data cloud will be filtered from 90% of artifacts, 95% of outliers, 95% of vegetation points, and 98% of building points. **Topobathymetric DEMs** will be derived once the seamless topographic/bathymetric lidar point cloud is finalized for positional and classification accuracy. Water clarity and turbidity affects the depth penetration capability of the bathymetric 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. Depths ranging beyond the sensor's detection capability will produce voids in the data set. As a result, creating DEMs presents a challenge with respect to interpolation of areas with no returns. In traditional DEM creation, 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. Thus, the resulting void areas may suggest greater depths rather than similar elevations from neighboring bathymetric bottom returns. As we recognize the importance of identifying such areas, we will delineate **insufficiently mapped areas** by triangulating bathymetric bottom points with an edge length maximum of 4.56 meters. This results in delineation of areas with no returns > 9 square meters identified as data voids. The resulting **void shapefile** will be used to control the extent of the delivered topobathymetric model and to avoid false triangulation across areas in the water with no returns.



Platte River, NE – Summer 2018 Depth Penetration Map. A maximum depth of 13.33 feet was recorded within the Platte River channel, and approximately 97% of the Platte River channel was mapped with bathymetric bottom returns.

A **confidence layer** will be provided showing the standard deviation of all ground and bathymetric bottom points located within a 1-meter cell size. This layer will be examined closely to ensure the most seamless dataset possible has been created. It also serves as an important QC layer by identifying areas of high standard deviation where point classification should be verified in case of a falsely classified water column. QSI will identify and **evaluate clarity and reflectivity** as they impact the dataset. Depths ranging beyond the sensor's detection capability will produce voids in the data set, and these will be identified in the dataset as well as evaluated in reporting. Our team will **assess the accuracy** of the lidar data using bare earth and any shallow water (for bathy) check points collected during the survey. Prior experience has shown topographic or topobathymetric surface accuracies of ≤ 10.0 cm RMSE. Absolute accuracy assessments will compare known RTK ground survey points to derived lidar points. Accuracies are described as the mean and standard deviation (sigma~σ) of divergence from RTK ground survey point coordinates. All accuracy statistics (RMSE, Accuracy$_z$ - 1.96σ, skewness/distribution, and percentile deviations) will be reported in the final report.

Finally, as we understand that evaluation of topographic change within the braided Platte River channel is of interest to Headwaters, for the Sub-Project 1 AOI, we will perform and change detection analysis between the current DEM and previously collected DEM at no additional cost. The **difference raster** will be provided as an additional deliverable (3-ft resolution Esri Grid format) with the November dataset provided to Headwaters each year.

2.5.2 Imagery

Imagery is geometrically and radiometrically corrected during multiple preprocessing phases to yield pan sharpened multispectral data. QSI will perform aerial triangulation (AT) on the collected imagery utilizing photo-identifiable ground control, to further refine the positional accuracy and improve the quality of the associated stereo-models. The combination of direct-georeferencing and AT will provide image products that meet or exceed the accuracy requirements of this project. QSI utilizes various triangulation software packages, including DAT/EM.

Sample images (per mission) are selected for look up table (LUT) generation, a process to optimize histogram exploitation, with Intergraph's DIA program. LUT settings are applied to sample images and adjusted to meet project specs or pre-approved sample image(s). The images are then processed with Intergraph's Post Processing Software (PPS) program to 8 bit, 4band TIFF files.

Orthorectified images are generated using Hexagon's OrthoPro software, using EO\AT data and the lidar-derived surface model. Mosaic seam-lines will be placed by orthophoto technicians with limited software assistance, and will not cross through buildings, bridges, or any other structure not at ground level. Seamlines will follow features such as roads, tree lines, edges of water bodies, or edges of cleared utility rights-of-way, to minimize the obtrusiveness of the seam and to reduce differences in tone and contrast between different images. The orthorectified images will be mosaicked so as to maximize single image tile coverage. Orthorectified image mosaics will be tiled as per the requested tiling scheme.

False Color imagery of the Platte River at Highway 183 Bridge.

2.6 Ensuring Design Accuracy and QA/QC

Lidar

The Lidar dataset undergoes the following quality assurance measures towards meeting and often exceeding all design accuracy requirements. Any rejection of data will be re-acquired or processed at QSI's expense.

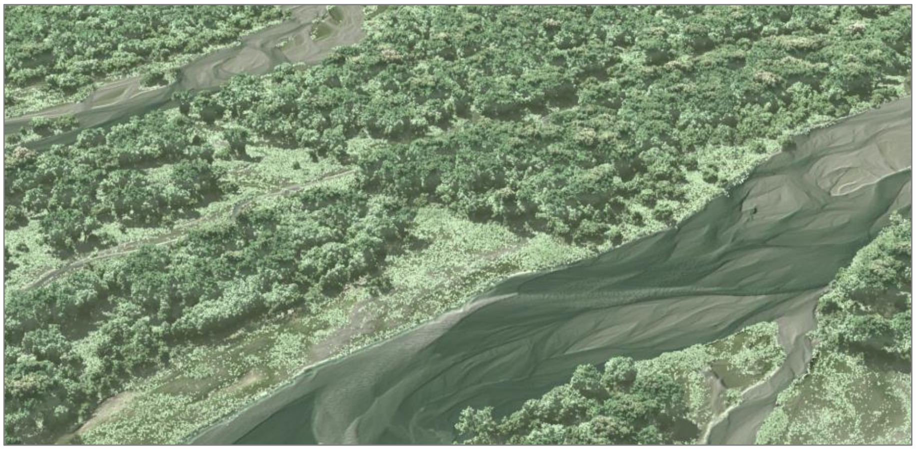
- ✓ **Sensor Calibration –** The success of any lidar mission is directly contingent on the accurate determination of the positional and alignment parameters of the sensor in the aircraft. QSI performs two levels of lidar boresighting and system testing to validate the calibration of our equipment prior to data acquisition. Periodic calibrations are conducted at our permanent calibration facility. This site has several large buildings, which are used in the process, and we have numerous control points that established throughout the area for data testing. Flights over QSI's permanent boresight location are conducted using orthogonal flight lines at two different altitudes. The calibration site includes a total of 26 control points established with precise survey methods that are used in the calibration process. Comprehensive calibration is routinely undertaken by QSI when: Hardware changes to the system have occurred; Environmental conditions are believed to have affected the current calibration; or the maximum period of three months from the previous comprehensive calibration. Additionally, project specific boresight calibration is locally conducted on each sensor at project commencement and completion.

- ✓ **Flight Crew QC -** QSI sensor operators monitor the diagnostic features of Riegl's RiAcquire software to provide quality assessment of the data as it is collected. RiAcquire has a new feature that allows the sensor operator to monitor bathymetric data collection and get real-time feedback on the depth performance of the sensor. This information will be used to quickly establish performance expectations for the water clarity conditions and determine possible re-flight areas. The lidar sensor operator will report significant areas of depth extinction, system errors, or other anomalies directly to the Acquisition Manager. The flight crew also provides detailed flight reporting that documents each lidar lift, and all lines collected. Specific information pertaining to aircraft and sensor utilized, atmospheric / ground conditions is recorded along with sensor parameters. Additionally, crews undertake a quality control review of the collected data while in the field. lidar data from each mission are sent over-night to the office.

- ✓ **Pre-Calibration QC** - The base station data, ground check points, executed flight plans, and daily field reports are transferred to the office nightly and evaluated within a day of acquisition. QSI survey and acquisition staff immediately evaluate acquired data for QA/QC purposes and for near real-time detection of any system issues. Mission GPS/IMU data are run through Applanix PosPac to look for gaps in data collection. QC begins as soon as the data arrives in the office. We have developed automated methods of checking coverage and density prior to initiating calibration. This allows the acquisition team to respond quickly to any data gaps or sensor issues before they have relocated to the next targeted area. Any areas with bathymetric voids are reviewed with QSI's technical lead and a decision is made on whether a re-flight of this area is necessary.

- ✓ **Calibration QC** - Lidar point data go through multiple inspections throughout the workflow to ensure the most representative models of the project area terrain and above ground features are ultimately delivered. We follow a stringent protocol for field validation methods (collection of calibration check points as previously described) and in-house calibration of flight lines, both to ensure high relative and absolute accuracy, and to facilitate data consistency among missions. In addition, native (first return density) and ground classified densities are verified again after calibration has been completed to further check that the nominal pulse density specified in the contract was met once error points have been removed and ground classification has occurred. Bathymetric relative accuracy of the will be reported similar to the topographic lidar data. Difference in the z (elevation) direction (or 'DZ') raster models will be generated between overlapping swaths and $RMSD_z$ will be assessed. Bathymetric relative accuracy will be checked during calibration, pre and post refraction correction, and further misalignment angles will be resolved as necessary to meet specification.

- ✓ **Point Cloud QC -** QSI utilizes TerraScan and TerraModeler applications to automate data classification, bare earth generation, and the streamlining of manual cleanup operations. Key project-specific variables such as point characteristics and classification maximums (terrain and iteration angles) are established in this phase. QSI has developed specification standards for this processing phase through development of customized variable macros. These proprietary macros are the result of several hundred man-hours of standards development, forming a means of project-to-project results consistency and quality assurance sustainment. All data are manually reviewed by QSI technicians for the purpose of artifact removal and verification of class assignments, using the functionality provided by TerraScan and TerraModeler applications. QSI point editors are trained to look for any anomalies in the point cloud including line-offsets, artifacts, abnormal noise, etc.



Lidar bare earth model colored by elevation and overlaid with the above-ground point cloud, July 2017 collection, Platte River, NE.

- ✓ **Accuracy Analysis and Reporting -** QSI will conduct field control surveys including base stationing observation (concurrent with flight acquisition), and bias (z-shift) control establishment. Absolute accuracy assessments will compare the x, y, z locations of known ground survey points to the triangulated ground surface generated from the lidar points. Accuracies are described as the mean and standard deviation (sigma~σ) of divergence from ground survey point coordinates. All accuracy statistics (RMSEz, Accuracyz - 1.96 σ, skewness/distribution, and percentile deviations) are reported in the Report of Survey. QA/QC results will be provided with each delivery; all results and corresponding reporting outlining quality control and verification methodologies will be included in metadata.

- ✓ **Multi-tile QC Assessment -** QSI will perform quality assurance on the final lidar topo/bathy merged LAS products. This will be done at the point cloud level starting with calibration of both the topographic and bathymetric flight lines. QSI uses a number of commercial software and in-house tools as a final means of quality verification of the merged products. We utilize ArcGIS to inspect a variety of raster QC mosaic layers, which enables the viewing of the dataset across multiple tiles simultaneously. Tile boundaries are inspected for continuity and any necessary adjustments are made and QC layers reiterated. This capability provides a quality data continuity assessment across tile boundaries.

Orthoimagery QC

Imagery acquisition involves the following to ensure high quality imagery collection. Customized programming is used to validate ABGPS exposure stations with frame download counts to ensure acquisition-to-data download consistency. All imagery will undergo a multi-tier process for quality acceptance during acquisition. The ABGPS / IMU data is checked for inaccuracies and strength of solution. During each mission, the camera operator records the general weather conditions including visibility, cloud types, if any, direction of the flight, etc. Additionally, the operator is responsible for determining tilt, tip, and crab conditions to ascertain if a re-flight of any area is needed. Pilots are responsible for monitoring of barometric pressure and GPS altitude during the flights to assure that the appropriate altitudes are maintained - the camera will not fire if the position at the time of exposure is not within prescribed environmental conditions. A rapid post-flight image quality review is conducted to expedite crew re-flight assignments, when necessary. After acquisition, the following quality control measures are employed during the orthophoto development phase:

- QSI's proprietary *Data Checker* tool produces hardcopy tracking documentation for additional checks and balances of data that has been collected and downloaded.
- Pre-approved sample image targets are established and maintained, along with a lookup table (LUT) created to make the best possible match to the target image.
- Using QSI's proprietary *Image Checker*, each image is individually inspected for image anomalies or other issues that would be cause for rejection.
- All imagery is tonally balanced to a pre-approved target. This is an additional tonal adjustment beyond the initial post processing of the imagery. In this tonal adjustment process, we will look at the frames in all missions and all flight dates. This will provide a better radiometric match between flight dates, while still hitting all best practice target requirements.
- All images are checked visually for completeness and quality.
- All coordinate system settings and units are checked for correctness.
- Each block is thoroughly reviewed and evaluated for smears, offsets, gaps, or other issues that requires attention.
- QSI will conduct statistic assessment of horizontal accuracy using surveyed air targets (described previously) and other photo-identifiable points. We will report the accuracy in the metadata and the report of survey.

QSI post-processing quality control procedures will ensure that horizontal accuracy RMSE is ≤ 2 ft (4 pixels), based on control points excluded from the AT process; seamlines, edge match issues, and bridge distortions, excessive building lean and related displacements have been resolved; blurred imagery, inconsistencies in color balancing, color bleeding, and shadow detail are all corrected; positional accuracy and relative accuracy between tiles have been checked.

Table 6: Orthophotography accuracy statistics for the Platter River Sub Project 1 study area

Platte River Photo Accuracy				
		ATP_x	ATP_y	ATP_{xy}
Count		23		
Mean	*ft*	0.095	-0.040	0.103
	m	0.029	-0.012	0.031
RMSE	*ft*	0.191	0.178	0.261
	m	0.058	0.054	0.080
1σ	*ft*	0.170	0.177	0.245
	m	0.052	0.054	0.075
1.96σ	*ft*	0.333	0.347	0.481
	m	0.102	0.106	0.147

Accuracy statistics table (from Jan 7, 2020 report) from the November 2019 aerial photography collection of Sub-Project 1 AOI.

2.7 Deliverables

QSI will provide the following standard and requested deliverables as described in the RFP. All data and imagery will be delivered on USB hard drives.

Topobathymetric Lidar

Point Cloud

- All returns, *Las 1.4 format*
  Point files will include the following fields: X,Y,Z, Return Intensity, Return Number, Point Classification (ground, default, water), Scan Angle, Adjusted GPS Time
  Class 1 – Unclassified ('Default' = non ground – buildings, vegetation, etc.)
  Class 2 – Ground
  Class 7 – Low point and noise
  Class 9 – Water
  Class 12 - Overlap

Surface Models

- Hydro-flattened Bare Earth DEM, 3-ft resolution, *Esri Grid format*
- Combined (topobathymetry) Surface Model (DEM), Tiles, 3-ft resolution, *Esri Grid format*
- Combined (topobathymetry) Surface Model (DEM), Mosaic, 3-ft resolution, *Esri Grid format*
- Highest Hit DEM (with water surface), 3-ft resolution, *Esri Grid format*
- Intensity Images, 1.5-ft resolution, *GeoTiff format*
- Difference Raster for SP1 (Change Layer for current year compared to previous year), 3-ft resolution, *Esri Grid format* – ***COMPLIMENTARY (no cost) Deliverable***

Vectors

- Survey Boundary, *shapefile format*
- Tile delineation, *shapefile format*
- Flightlines, attributed by date/time, *shapefile format*
- Hydro Breaklines, *shapefile format* (polyline)
- Submerged Topography Density*, *shapefile format* (polygon)

** Because point density decreases with depth, we will include a shapefile that summarizes areas with lower return densities and hence lower confidence in the resulting bathymetric model*

Orthoimagery

- Orthoimagery Frames (15 cm or 6") - CIR only for SP1, CIR and RGB for SP2, *GeoTIFF format*
- Orthoimagery Mosaic (15 cm or 6") – CIR mosaic for SP1, CIR and RGB mosaic for SP2, *.sid format*
- Photo Centers, attributed by flight dates/times, *shapefile format*

Reporting

- Daily Acquisition Reporting: displaying flight lines and completed areas.
- Project Summary Report: Methods (including time/date of all flightlines), Results, Accuracy Assessments
- Ground Check Points, *shapefile format*
- FGDC-compliant Metadata
- Coordinate System: Nebraska State Plane, NAD 1983, NAVD88 Geoid 03, Units Feet.

3.0 Relevant Lidar & Aerial Photography Experience

Topobathymetric lidar has become the new 'go-to' technology for topographic channel mapping of dynamic river systems or complex and changing coastal shorelines. Applications include habitat restoration and management, shoreline and channel characterization, flood hazard mapping, sea level rise forecasting, storm surge impacts, engineering design, coastal urban planning, and charting and navigation. Since 2012, QSI has amassed an impressive portfolio of experience and technical competency in collecting and processing high density topobathymetric lidar for a diversity of clients and interests (Figure 4). Since deploying our first topobathymetric systems only 8 years ago, QSI has worked in 25 US states and Canadian provinces in North America, for more than **140 contracts** covering over **18,000 sq. miles** (~12 million acres) providing bathymetric surface modeling for shorelines, bays, estuaries, lakes, wetlands, rivers, and streams in great detail for a variety of applications. Now widely recognized as a leader in topobathymetric mapping in North America, QSI deploys state-of-the-art systems and technologies to map shallow-water bathymetry in unprecedented detail. We have a comprehensive working knowledge of the many applications of topobathymetric lidar data used for effective water resources planning and mapping. Topobathymetric lidar projects have ranged in size from 200 to more than 2.5 million acres (4,000 sq. miles), with the median project size ~ 10,000 acres (15 sq. miles). Roughly ¾ of our topobathymetric lidar contracts have been for inland riverine environments, with the remaining ¼ over coastal near-shore project areas. Depending on the characteristics of the study area (depth, water clarity), we have achieved 70 - 95% bathymetric surface coverage to allow for a comprehensive topographic understanding of watersheds and coastal zones.

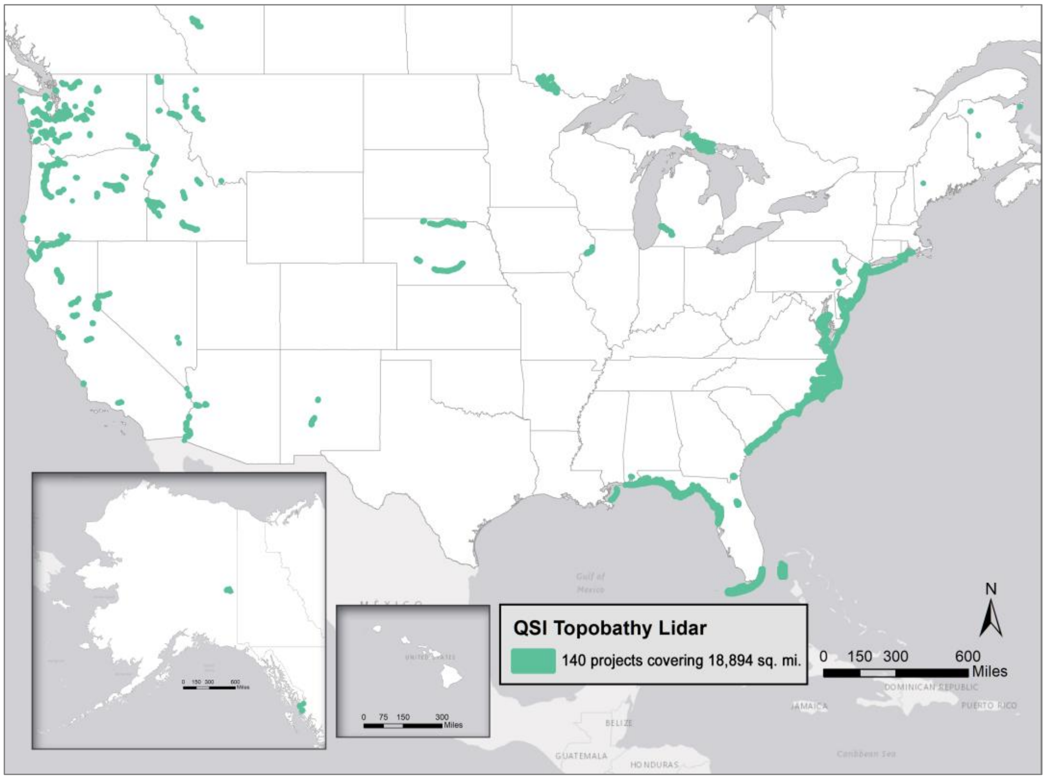


Figure 4. Map of topobathymetric lidar data collected in the U.S. by QSI since 2012.

Our continued level of commitment and investment in the latest topobathymetric lidar sensor technologies is a significant factor that is responsible for the quality of data we collect. Our topobathymetric lidar sensor collection represents a diversity of instruments that can be configured, assigned, and vetted appropriately for the specific task order project area, requirements, and intended data application at hand. We offer the latest-generation (Tier 1) topobathymetric 1.5 Secchi Depth sensors commercially available, including the Riegl VQ-880-GII and Leica Chiroptera 4x system (rated by Leica for survey depths up to 25m). QSI additionally has access to a deep bathymetric channel (3 Secchi Depth) for the Chiroptera 4x sensor to result in the HawkEye III (HE3) system. Furthermore, QSI works closely with lidar sensor manufacturers to move the technology forward and to pass on efficiencies and technological insights to its clients. We consider Riegl and Leica, the manufacturers of the sensors we depend on, to be true partners in their commitment to collaborate and support our Research & Development (R&D) team on innovative technical solutions for extracting and capturing valuable bathymetric data.

QSI also stands apart in our unique approach to integrating valuable environmental information on turbidity to ensure data collections are poised for success. From years of experience monitoring weather, winds, tides, and turbidity for topobathymetric lidar acquisition projects, we have developed a systematic, consistent, thorough, and standardized approach to monitoring turbidity. The QSI approach includes tracking historic trends and monitoring current water clarity conditions using a combination of methods to best determine when optimal water clarity conditions are expected to occur (Figure 5).

Figure 5. Variety of methods employed by QSI for measuring and monitoring turbidity – MODIS kd490 (left), turbidity meter (middle), and Secchi disk (right).

Aerial imagery acquisition has been a core capability of Quantum Spatial for over nine decades, and we continue to invest in and refine our ability to provide these services today. Quantum Spatial has acquired and processed aerial imagery for over a million square miles throughout the U.S. and its territories and has delivered diverse mapping products created from both digital and film aerial imagery. QSI owns or leases 19 camera systems including pushbroom, frame-based, and oblique cameras, supporting the acquisition of multispectral, hyperspectral, thermal infrared, and oblique imagery. We offer the ability to collect digital imagery through in several modes including via unmanned systems, or higher altitude airborne flights. All camera systems can be co-located with lidar sensors to allow for multi-modal data acquisition. QSI owns and operates the latest digital camera systems including the Vexcel UltraCam Eagle M3 (2), Leica ADS100 (3), and Zeiss DMC (3) multispectral cameras; a PhaseOneFlight (1) 3-band camera; a Leica RCD30 Trio (1) oblique camera; and three hyperspectral systems (CASI 1500H and Headwall Photonics VNIR and SWIR).

Co-acquired aerial photography with lidar is a common request by QSI clients, often collected to supplement analyses of lidar data for several applications, including engineering design, hydrologic analysis, urban planning, and evaluation of habitat/vegetation structure. We specialize in imagery collected at high resolutions (small pixel size of 1-ft pixel resolution or better) coincident with our high resolution lidar and providing for maximum utility in data fusion and GIS analyses.

True color 1:100,000 scale view of Platte River. Imagery collected in 2016.

3.1 Recent Experience Summary – 2018-2019

Below we present key QSI topographic/topobathymetric lidar and imagery contracts over the past two years (Table 4). Many also involved co-acquisition of imagery. All projects listed were collected at a pulse density of 4 pulses/m^2 (0.50 m post spacing) or greater. Contracts together represent over **$40M** in value.

Table 4. Quantum Spatial Topobathymetric Lidar Contracts, 2018-2019

Project Name	Client	Inland/ Coastal	Year(s)
Hurricane Florence (North Carolina) Topobathymetric Lidar, Orthoimagery & Shoreline Mapping	U.S. National Oceanic & Atmospheric Administration	Coastal	2019 - In Progress
Hurricane Michael (Florida) Topobathymetric Lidar, Orthoimagery & Shoreline Mapping	U.S. National Oceanic & Atmospheric Administration	Coastal	2019 - In Progress
Niobrara River, NE Topobathymetric Lidar	US Geological Survey	Inland	2019 - In Progress
Platte River, NE Topobathymetric Lidar & Imagery	Headwaters Corporation	Inland	2016-2019
Chesapeake Bay, MD/VA/DE Topobathymetric Lidar, Orthoimagery & Shoreline Mapping	U.S. National Oceanic & Atmospheric Administration	Coastal	2018-2019
King County North, WA Topographic Lidar and Imagery	King County, WA	Inland	2019
King County South Topographic Lidar and Imagery	King County, WA	Inland	2019
Waikoloa, HI Topographic Lidar and Imagery	U.S. Army Corps of Engineers	Inland	2019
San Juan County, WA Topographic Lidar & Orthoimagery	Washington Department of Natural Resources	Inland	2019
Monterey Peninsula and Point Lobos, CA Topographic Lidar and Imagery	Alion Science and Technology	Coastal	2019
Ala Wai Canal, HI Topographic Lidar and Imagery	Sam O. Hirota, Inc.	Inland	2019
Trinchera Ranch	Trinchera Ranch	Inland	2019
Snohomish Estuary Topographic Lidar & Orthoimagery	Washington Department of Natural Resources	Coastal	2019
Trinity River Restoration Program, Multiple Sites, Topographic Lidar & Orthoimagery	TRRP (Bureau of Reclamation)	Inland	2015-2019
North of Fresno, CA Orthoimagery	HDR Engineering, Inc.	Inland	2019
Orange County Aerial Imagery	Orange County Public Works	Inland	2019
Duckabush Topobathymetric Lidar	APS Surveying & Mapping, LLC	Inland	2019
Yakima River Topobathymetric Lidar	APS Surveying & Mapping, LLC	Inland	2019
Treasure Valley, ID Topobathymetric Lidar	Boise River Flood Control District	Inland	2019
Santa Clara River, CA Topobathymetric Lidar	Catalyst Environmental Solutions	Inland	2019
Elbow River, Calgary, Alberta Topobathymetric Lidar	Digital World Mapping	Inland	2019
Ocean City, MD Topobathymetric Lidar	Gahagan & Bryant Associates, Inc.		2019
Umbagog, NH and Aziscohos, ME Topobathymetric Lidar	Gomez & Sullivan Engineers, P.C.	Inland	2019
Quilcene River, WA Topobathymetric Lidar	Hood Canal Salmon Enhancement Group	Inland	2019
Bad Rock, MT Topobathymetric Lidar	Kadrmas, Lee & Jackson	Inland	2019
Grays River, WA Topobathymetric Lidar	Lower Columbia Fish Enhancement Group	Inland	2019
Upper Quinault River, WA Topobathymetric Lidar	Natural Systems Design	Inland	2019
Chester Morse Reservoir Topobathymetric Lidar	Seattle Public Utilities	Inland	2019
Coeur d'Alene, ID Topobathymetric Lidar	Solmar Hydro	Inland	2019
Quillayute River, WA Topobathymetric Lidar	Tetra Tech	Inland	2019
Colorado River Sites, Southwest, Topo and Topobathymetric Lidar	The Atlantic Group	Inland	2019
East Fork Illinois River, OR Topobathymetric Lidar & Thermal Infrared Imagery	The Freshwater Trust	Inland	2019
Morro Bay, CA Topobathymetric Lidar	NOAA	Coastal	2019
PN Lewis River, WA Topobathymetric Lidar	Wapato Valley Mitigation and Conservation Bank	Inland	2019

Table 4. Quantum Spatial Topobathymetric Lidar Contracts, 2018-2019			
Project Name	**Client**	**Inland/ Coastal**	**Year(s)**
Walla Walla and Umatilla Topographic Lidar and Imagery	Confederated Tribes of the Umatilla Indian Reservation	Inland	2019
Kalamazoo River Area, Allegan, MI Topobathymetric Lidar/Sonar	AMEC Foster Wheeler PLC	Inland	2018
Salmon and Pahsimeroi, ID Topobathymetric Lidar	Anchor QEA, LLC	Inland	2018
Swinomish River, WA Topobathymetric Lidar	APS Surveying and Mapping	Inland	2018
Grande Ronde River, OR Topobathymetric Lidar	Asotin County, WA - Conservation District	Inland	2018
Wakulla River, FL Topobathymetric Lidar	Aucilla Research Institute	Coastal	2018
NPRA Exploration Lake Volumes, AK Topobathymetric Lidar	Private Client (NDA)	Inland	2018
Entiat River, WA Topobathymetric Lidar	Cramer Fish Sciences	Inland	2018
Florida Topobathy Processing (Florida Peninsula QL1 Processing)	Dewberry (NOAA)	Coastal	2018
Snoqualmie River, WA Topobathymetric Lidar	King County, WA	Inland	2018
King County, WA Topographic Lidar & Orthoimagery	King County, WA	Inland	2018
White River Topobathymetric Lidar, Ortho Processing	King County, WA	Inland	2018
Quinault, WA Topobathymetric Lidar	Natural Systems Design	Inland	2018
Chambers Creek, WA	Natural Systems Design	Inland	2018
Northern Skagit River, WA Topobathymetric Lidar	Skagit River System Cooperative	Inland	2018
Lake Tahoe, CA Topobathymetric Lidar	Spatial Informatics Group	Inland	2018
Charleston District, SC Topobathymetric Lidar	U.S. Army Corps of Engineers	Coastal	2018
Gulf Coast (FL, LA) Topobathymetric Lidar	U.S. Geological Survey	Coastal	2018
Klamath River, CA Topobathymetric Lidar and Orthoimagery	U.S. Geological Survey	Inland	2018
Bahamas Topobathymetric Lidar	U.S. National Geospatial-Intelligence Agency	Coastal	2018
Florida Keys Topobathymetric Lidar, Multispectral Imagery and Shoreline Mapping	U.S. National Oceanic & Atmospheric Administration	Coastal	2018
South Carolina Topobathymetric Lidar, Multispectral Imagery and Shoreline Mapping	U.S. National Oceanic & Atmospheric Administration	Coastal	2018
North Fork Skokomish River, WA Topobathymetric Lidar	Washington Department of Natural Resources	Inland	2018
Flathead River Watershed Reservoirs, MT Topobathymetric Lidar	WGM Group, Inc. (Confederated Salish and Kootenai Tribes)	Inland	2018
Vancouver Island, BC Topographic Lidar and Imagery	British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development	Coastal	2018
Kuliouou, HI Topographic Lidar and Imagery	Sam O. Hirota, Inc.	Coastal	2018
Umatilla, OR Topographic Lidar and Imagery	Anderson-Perry & Associates, Inc. (USBR)	Inland	2018
ODOT Region 4 Imagery & Topographic Lidar	Oregon Geospatial Enterprise Office	Inland	2018
Charleston District, SC Topographic Lidar and Imagery	U.S. Army Corps of Engineers Mobile District	Coastal	2018
Upper Quartz Creek Topographic Lidar and Imagery	Yakama Nation Fisheries	Inland	2018

3.2 Example Projects

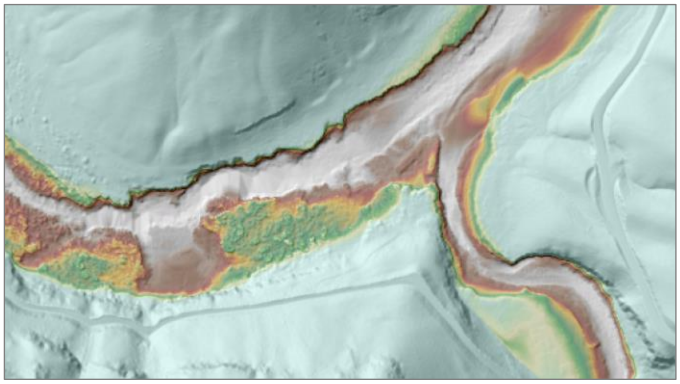
The following project narratives provide examples and key references for relevant topobathymetric lidar and aerial photography projects conducted by QSI within the last two years. Applications include natural resource management, evaluation of channel morphology for restoration, stream habitat mapping, analysis of woody debris, and many others. Please feel free to contact any of these references (email address and phone provided) for further feedback on the quality of our work including timeliness of delivery, and quality of the data and services.

Project Specifications
PROJECT SIZE: 4,189 acres
DATES OF SERVICE: Nov 2018 – Feb 2019
CLIENT: Asotin County Conservation District (ACCD)
CLIENT POC: Megan Stewart: 509-552-8117; megan@asotincd.org
DELIVERABLES: • Classified Returns (LAS) • Highest Hit DSM (1-m ESRI GRID) • Topobathymetric Bare Earth Digital Elevation Model (DEM, 1-m ESRI GRID) • Water Surface Elevation Model WSM (1-m ESRI GRID) • Intensity Images Green/NIR (0.5-m GeoTiff) • Bathymetric Coverage (SHP) • 2D Water's Edge Breaklines (SHP)
Relative elevation model, Grande Ronde River, WA.

GRANDE RONDE RIVER, WA

Topobathymetric Lidar

QSI collected topobathymetric and topographic lidar data over five areas of interest (68 river miles) within the Grande Ronde River Basin in Asotin County, WA. Data were collected to assess the channel morphology of the study area to support hydrologic modeling, habitat restoration planning, and time series analysis. Using the Riegl VQ-820-G sensor (1 Secchi depth), bathymetric surfaces were mapped with a bathymetric bottom return density of 3.22 points/m^2. Achieved relative accuracy (RMSE) was 4.5 cm, with an absolute accuracy of 1.4 cm (RMSE for NVA). QSI also developed a relative elevation model (REM) representing the bare earth terrain surface normalized to the water surface elevation of residual flow. This data layer is designed for visualization and coarse analysis of potential habitat features within the floodplain.

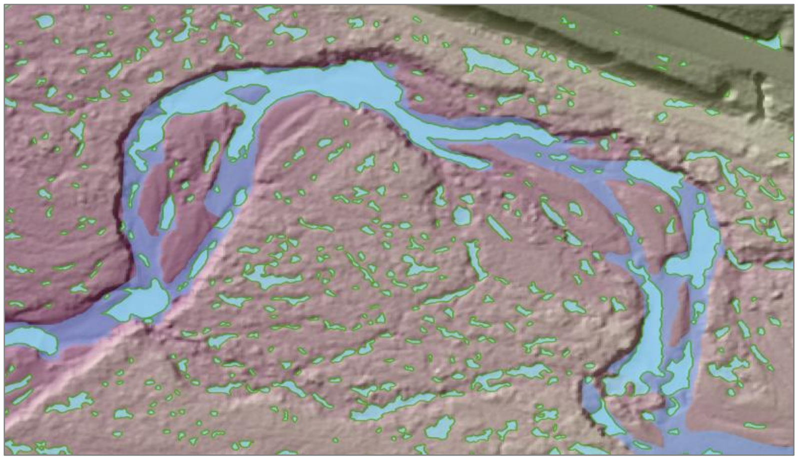


Project Specifications
PROJECT SIZE: 15,467 acres
DATES OF SERVICE: Nov 2017 – March 2018
CLIENT: GeoTerra and the Confederated Tribes of Umatilla Indian Reservation (CTUIR)
CLIENT POC: Bret Hazell: 541-343-8877, bhazell@GeoTerra.us Kris Fischer: 541-429-7547, krisfischer@ctuir.org
DELIVERABLES: • Classified Returns (LAS) • Highest Hit DSM (1-m ESRI GRID) • Topobathymetric Bare Earth Digital Elevation Model (DEM) • Intensity Images (0.5-m GeoTiff) • Bathymetric Coverage (SHP) • 3D Water's Edge Breaklines (SHP) • Pool map (SHP)
Bare earth model with 3D point cloud overlay colored by NAIP imagery, Tucannon River, WA.

TUCANNON RIVER, WA

Topobathymetric Lidar & Orthoimagery, Pool Mapping Analysis

In the fall of 2017, Quantum Spatial collected topobathymetric lidar data and orthoimagery along the Tucannon River in SE Washington. Data were collected to evaluate aquatic habitats for stream restoration. Using the Riegl VQ-880-G sensor (1.5 Secchi depth), bathymetric surfaces were mapped with an average ground return density of 6.89 points/m^2. QSI also derived a depth-attributed pool map using the bathymetric lidar. The mapping layer characterized geometry and potential connectivity to the main channel.

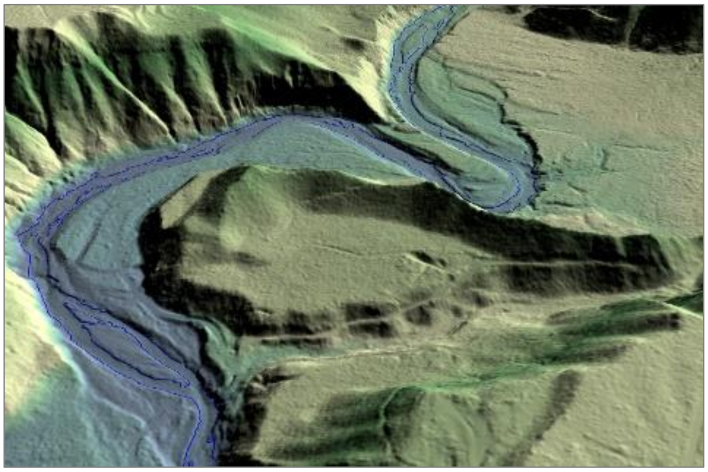


NORTH FORK SKOKOMISH RIVER, WA

Topobathymetric Lidar

Project Specifications
PROJECT SIZE: 3,535 acres
DATES OF SERVICE: March – June 2018
CLIENT: Washington Dept. of Natural Resources
CLIENT POC: Abigail Gleason: 360-902-1560; abigail.gleason@dnr.wa.gov
DELIVERABLES: • Classified Returns (LAS) • Topobathymetric Bare Earth Digital Elevation Model (DEM) • Highest Hit DSM (ESRI GRID) • Intensity Images, Green & NIR (GeoTiff) • Bathymetric Coverage (SHP) • Water's Edge Breaklines (SHP)
Lidar bare earth model colored by elevation, North Fork Skokomish River AOI.

In the spring of 2018, Quantum Spatial was contracted to collect topobathymetric lidar data along the North Fork of the Skokomish River in NW Washington. Data were collected to characterize bathymetric surfaces in support of restoration and monitoring activities along the reach. Using the Riegl VQ-820-G sensor (1 Secchi depth), topobathymetric surfaces were mapped with a bathymetric bottom return density of 2.28 points/m^2. Achieved relative accuracy (RMSE) was 5 cm, and absolute accuracy was 6 cm for bathymetric surfaces and 3 cm for terrestrial surfaces.



SKAGIT RIVER & DIABLO, GORGE, ROSS LAKES, WA

Topobathymetric Lidar, 4-Band Orthoimagery

Project Specifications
PROJECT SIZE: 16,106 acres (lidar); 10,441 acres (imagery)
DATES OF SERVICE: April 2017 – August 2018
CLIENT: Skagit River System Cooperative / Seattle City Light
CLIENT POC: Devin Smith: 360-391-1984; dsmith@skagitcoop.org
DELIVERABLES: • Classified Returns (LAS) • Highest Hit DSM (3 ft ESRI GRID) • Topobathymetric Bare Earth Digital Elevation Model (DEM) • Intensity Images (0.5 m GeoTIFF) • Bathymetric Coverage (SHP) • Water's Edge Breaklines (DGN)
Lidar-derived bare earth DEM overlaid with the above-ground point cloud and colored with NAIP imagery, looking northwest towards the Sauk River, WA.

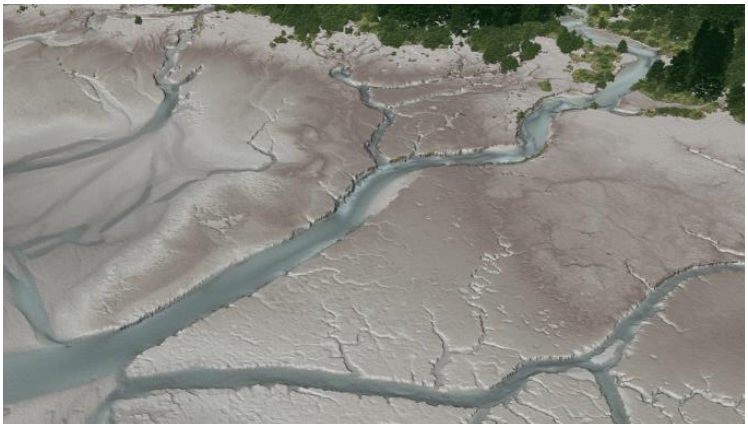
QSI has collected topobathymetric lidar data for several reaches along the Skagit River as well as three lakeshores in northern Washington. Data were collected to aid streambed mapping and facilitate watershed management and stream restoration to enhance fish habitats. Using a Riegl VQ-880-G sensor (1.5 Secchi depth) mounted in a helicopter, as much as 92% of river and lake shoreline topobathymetric surfaces were mapped (~80% average) with topobathy ground return density of 2 to 8 points/m^2 depending on project area. Achieved absolute accuracy was < 10 cm for all bathymetric surfaces.

Project Specifications
PROJECT SIZE: 2,013 acres
DATES OF SERVICE: January – May 2019
CLIENT: Hood Canal Salmon Enhancement Group
CLIENT POC: Camilla Popp: 360-275-3575, ext. 117
DELIVERABLES: • Classified Returns (LAS) • Highest Hit DSM (1-m ESRI GRID) • Topobathymetric Bare Earth Digital Elevation Model (DEM, 1-m ESRI GRID) • Green Sensor Intensity Images (0.5-m GeoTiff) • Bathymetric Coverage (SHP) • 2D Water's Edge Breaklines (SHP) • Contours (0.5-m DWG)
topobathymetric bare earth model colored by elevation, Quilcene River, WA

QUILCENE RIVER, WA

Topobathymetric Lidar

In the winter of 2019, Quantum Spatial (QSI) was contracted by the Hood Canal Salmon Enhancement Group (The Salmon Center) to collect topobathymetric lidar data over the Quilcene River in northwestern Washington State. Data were collected to aid The Salmon Center in mapping the channel morphology and topobathymetric surface of the Quilcene River in order to support salmon habitat evaluation and restoration efforts in the Hood Canal. Using the Riegl VQ-880-G sensor (1.5 Secchi depth), topobathymetric surfaces were mapped with a bathymetric bottom return density of 8.98 points/m^2. Achieved relative accuracy (RMSE) was 3.3 cm, with an absolute accuracy of 1.8 cm (RMSE for NVA).



Project Specifications
PROJECT SIZE: 27,268 acres
DATES OF SERVICE: Dec 2017 – March 2018
CLIENT: USACE, Rock Island District
CLIENT POC: Daniel McBride: 314-331-8385, Daniel.J.McBride@usace.army.mil
DELIVERABLES: • Classified Returns (LAS) • Highest Hit DSM (3-ft ESRI GRID) • Topobathymetric Bare Earth Digital Elevation Model (DEM) • Bentley In-Roads Digital Terrain Models (3-ft DTM) • Intensity Images (1.5-ft GeoTiff) • Bathymetric Coverage (SHP) • 3D Water's Edge Breaklines (SHP)
Lidar bare earth model colored by elevation and overlaid with the above-ground lidar point cloud, Mississippi River.

MISSISSIPPI RIVER, IA

Topobathymetric Lidar

In the fall of 2017, Quantum Spatial (QSI) was contracted by the United States Army Corps of Engineers, Rock Island District (USACE) to collect topobathymetric lidar data for the Mississippi River site along the Iowa-Illinois border. Data were collected to aid USACE in assessing the channel morphology and topobathymetric surface of the study area to support various mapping, research, and infrastructure planning purposes. Using the Riegl VQ-880-G sensor (1.5 Secchi depth), topobathymetric surfaces were mapped with a bathymetric bottom return density of 8.74 points/m^2. Achieved relative accuracy (RMSE) was 2.0 cm, and absolute accuracy was 6.3 cm for bathymetric surfaces and 2.7 cm for terrestrial surfaces.

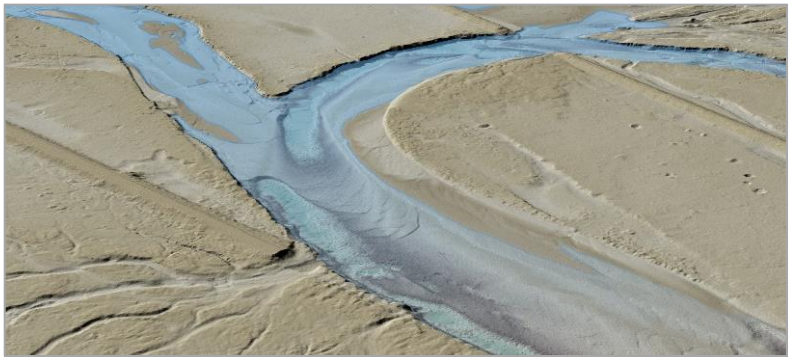
STEAMBOAT ISLAND, IA

Topobathymetric Lidar

Project Specifications
PROJECT SIZE: 3,511 acres
DATES OF SERVICE: Dec 2017 – March 2018
CLIENT: USACE, Rock Island District
CLIENT POC: Nicole Manasco: 309-794-5558, Nicole.M.Manasco@usace.army.mil

DELIVERABLES:
- Classified Returns (LAS)
- Highest Hit DSM (3-ft ESRI GRID)
- Topobathymetric Bare Earth Digital Elevation Model (DEM)
- Intensity Images (0.5-m GeoTiff)
- Bathymetric Coverage (SHP)
- 3D Water's Edge Breaklines (SHP)

In the fall of 2017, Quantum Spatial (QSI) was contracted by the United States Army Corps of Engineers, Rock Island District to collect topobathymetric lidar for the Steamboat Island site along the Iowa-Illinois border. The Steamboat Island area of interest covers the convergence of the Wapsipinicon River with the Mississippi River just north of Princeton, Iowa. Data were collected to aid USACE in assessing the channel morphology and topobathymetric surface of the study area to support various mapping, research, and planning purposes. Using the Riegl VQ-880-G sensor (1.5 Secchi depth), topobathymetric surfaces were mapped with an average return density of 8.65 points/m^2. Achieved relative accuracy (RMSE) was 7.1 cm, and absolute accuracy was 4.7 cm for bathymetric surfaces and 1.8 cm for terrestrial surfaces.



A view looking at the Wapsipinicon River. The image was created from the lidar bare earth model colored by elevation and overlaid with the water's edge breaklines.

UPPER SACRAMENTO RIVER, CA

Topobathymetric Lidar, Hyperspectral Imagery

Project Specifications
PROJECT SIZE: 20,908 acres (Lidar); 17,763 acres (Hyperspectral Imagery)
DATES OF SERVICE: Sept 2017 – Jan 2018
CLIENT: NOAA Southwest Fisheries Science Center
CLIENT POC: Dr. Lee Harrison: 805-407-2632, lee.harrison@noaa.gov

DELIVERABLES:
- Classified Returns (LAS)
- Topobathymetric Bare Earth Digital Elevation Model (1-m ESRI GRID)
- Highest Hit DSM (1-m ESRI GRID)
- NIR Intensity Images (0.5-m GeoTIFF)
- Bathymetric Coverage (SHP)
- Water's Edge Breaklines (DGN)
- 48-band Image Cube (GeoTIFF, ENVI IMG).

In the fall of 2017, QSI collected topobathymetric lidar data and hyperspectral imagery for the NOAA Southwest Fisheries Science Center on the Upper Sacramento River near Redding, CA. High resolution topobathymetric lidar data were collected to map the bathymetry and assess channel morphology to support restoration work to enhance fall Chinook salmon spawning and rearing habitat. Hyperspectral imagery (0.5 m GSD) was also collected using a CASI 1500H sensor installed in QSI's aircraft, providing information on water depth, sediment grain-size, in-stream habitats, and distribution of large wood. Using a Riegl VQ-880-G sensor (1.5 Secchi depth), bathymetric surfaces were mapped with an average ground return density of 10.14 points/m^2. Achieved relative accuracy (RMSE) was 2.8 cm, and absolute accuracy was 5.5 cm for bathymetric surfaces and 4.2 cm for terrestrial surfaces. Hyperspectral imagery was successfully acquired and will provide valuable in-stream habitat information.

Lidar-derived bare earth model colored by elevation overlaid with the above-ground point cloud colored using NAIP imagery, Upper Sacramento River near Red Bluff, CA.

Project Specifications
PROJECT SIZE: 8,407 acres
DATES OF SERVICE: Oct 2017 – Jan 2018
CLIENT: CBEC Inc. Eco Engineering
CLIENT POC: Matthew Weber: 961-231-6052, m.weber@cbecoeng.com
DELIVERABLES: • Classified Returns (LAS) • Combined topobathymetric DEM (3-ft ESRI GRID) • Highest Hit DSM (3-ft ESRI GRID) • Intensity Images (1.5-ft GeoTIFF) • Bathymetric Coverage (SHP) • Water's Edge Breaklines (DGN) • Imagery Mosaics, Tiled (TIF, SID)
Lidar bare earth DEM with point cloud and colored orthoimagery overlay, near the I-80 bridge on the American River, CA.

AMERICAN RIVER, CA

Topobathymetric Lidar, 3-band (RGB) Digital Imagery

In fall of 2017, CBEC Eco Engineering contracted QSI to collect topobathymetric lidar data and digital imagery along a stretch of the American River from its confluence with the Sacramento River upstream to Nimbus Dam. These data and imagery were collected to aid CBEC in assessing the channel morphology and topobathymetric surface of the study area to support river restoration activities such as erosion monitoring and habitat restoration. Using a Riegl VQ-880-G sensor (1.5 Secchi depth), topobathymetric surfaces were mapped with an average ground return density of 7.99 points/m^2. Achieved relative accuracy (RMSE) was 2.2 cm, and absolute accuracy 3.8 cm for bathymetric surfaces and 1.4 cm for terrestrial surfaces.

4.0 Statement of Annual Availability

One of the significant advantages of working with QSI is our capacity for multi-contract management. We understand that timing of the acquisition is critical to the success of the project, enabling consistent tracking of subtle between season and between year changes in habitat. As one of the largest geospatial companies in the U.S., QSI offers the least risk to the PRRI Program in terms of collection capacity. QSI is experienced in timing acquisitions around weather windows and environmental conditions and we are efficient at allocating resources across multiple contracts so that acquisitions occur when they are required for the success of the project.

The two acquisition periods of May 15 – June 30 and November 1 – December 15 coincide with traditionally low demand times for our assets (platforms and sensors) which are often in highest demand in the early spring and late summer, so we do not foresee any issues collecting the required datasets during these requested timeframes. QSI has 12 planes capable of the collection of these data, along with five (5) topobathymetric lidar sensors and 12 digital camera options. In addition, Quantum Spatial has demonstrated our commitment to the Program over the last four years by ensuring aircraft and sensor availability for every acquisition when required by Headwaters, even at short notice based on dam operations.

5.0 Estimated Timeline

All datasets will be targeted for collection during managed low flow conditions in May/June (< 1,000 cfs) and November (<1,200 cfs). Due to different mission parameters and sky/sun angle requirements, the lidar and 4-band imagery may be collected on different missions or from different aircraft. However, our acquisition team will coordinate all flights to the maximum extent possible so that the lidar and imagery are collected in the same day if not concurrently. Aircraft will only be mobilized to the site if a suitable weather window is forecasted and flows are appropriate.

Table 5 provides requested acquisition timelines (in days) for each sub-project area and technology to aid in low flow management planning and coordination. Timelines include flight time plus an appropriate buffer (typically 25%) for potential short interim weather delays. QSI will coordinate closely with Headwaters personnel on all acquisition scheduling, including contingency planning should conditions or opportunities preclude a co-acquire or same day collection of lidar and imagery. Imagery will be provided within 60 days after collection, and topobathymetric lidar within 90 days after acquisition.

Table 5. Summary of Acquisition and Product Delivery Timeline by Project Area and Technology

Collection Period Any Year	Project Area	Acquisition Timeline		Data and Product Delivery Timeline (after collection)
		Imagery	Topobathymetric Lidar	
Fall (Nov 1 – Dec 15)	Sub-Project 1 (128 sq. miles)	2 days if collected separately 8 days if co-acquired w/Lidar	8 days	Imagery: 60 days Lidar: 90 days
Early Summer (May 15 – June 30)	Sub-Project 2 (750 sq. miles)	4 days		Imagery: 60 days
	Sub-Project 2A (26 sq. miles)		3 days	Lidar: 90 days

6.0 Detailed Firm Fixed Price Proposal

The below table provides total cost by acquisition for each Sub-Project AOI at each collection time period across years, in the format requested in the RFP. Pricing includes costs for mobilization, acquisition, and processing and corresponds to all specifications and deliverables detailed in the RFP and outlined in our proposal. Given the multi-temporal nature of the Platte River dataset, we are offering a complementary (no charge) change layer (difference raster) among consecutive years for the SP1 AOI (128 sq. miles).

		June 2020 SP2	June 2020 SP2a	Nov 2020 SP1	June 2021 SP2	June 2021 SP2a	Nov 2021 SP1
Total Cost by Acquisition	Topobathymetric Lidar		$69,770	$206,808		$69,770	$206,808
	Imagery	$68,529		$29,847	$68,529		$29,847

		June 2022 SP2	June 2022 SP2a	Nov 2022 SP1	June 2023 SP2	June 2023 SP2a	Nov 2023 SP1
Total Cost by Acquisition	Topobathymetric Lidar		$69,770	$206,808		$69,770	$206,808
	Imagery	$68,529		$29,847	$68,529		$29,847

Total Project Cost
$1,499,816

7.0 Conflict of Interest Statement

Quantum Spatial, Inc. has no conflict of interest in providing this statement of qualifications and cost quote. There are no conflicts of interest between this project and other past or on-going projects, nor is our company conducting projects currently for the Program.

Signed,

Andrew Brenner

Andrew Brenner, Ph.D.
Senior Program Director, Quantum Spatial, Inc.

8.0 Suspension and Debarment

Quantum Spatial is eligible to receive federal funds and has not been suspended or debarred from receiving federal funds. QSI is registered under the U.S. System for Award Management (www.sam.gov) under DUNS Number: **050264662**.

9.0 Description of Insurance

quantum SPATIAL
AN NV5 COMPANY

INSURANCE HELD BY QUANTUM SPATIAL, INC.
4-1-20 to 4-1-21

TYPE	CARRIER/AGENT INFORMATION	BASE POLICY LIMITS
Workers Compensation	Travelers Property Casualty Co. of America Lockton Companies 1801 K Street NW, Suite 200 Washington, DC 20006 202-414-2400	WC Statutory Limits Each Accident: $1M Disease – Each Employee: $1M Disease – Policy Limit: $1M
Vehicle (Automobile Liability: Any Auto, Hired Autos, Non-owned Autos)	Travelers Property Casualty Co. of America Lockton Companies 1801 K Street NW, Suite 200 Washington, DC 20006 202-414-2400	Combined Single Limit: $1M (Each Accident)
General Liability Commercial General Liability Contractual Cross Liability General Aggregate Limit Applies Per Policy	The Charter Oak Fire Insurance Company Lockton Companies 1801 K Street NW, Suite 200 Washington, DC 20006 202-414-2400	Each Occurrence: $1M Damages to Rented Premises - (Each Occurrence): $1M Med Exp (Any one person): $10,000 Personal & Adv Injury: $1M General Aggregate: $2M Products: Comp/Op Agg: $2M
Umbrella Liability Occurrence Retention: $10,000	Travelers Property Casualty Co. of America Lockton Companies 1801 K Street NW, Suite 200 Washington, DC 20006 202-414-2400	Each Occurrence: $5M Aggregate: $5M
Professional Liability Retention: $100,000	Illinois Union Insurance Company Lockton Companies 1801 K Street NW, Suite 200 Washington, DC 20006 202-414-2400	$5M – Each Claim $5M – Aggregate
Aircraft Deductibles (NIM/IM): $250/$2,000	Starr Indemnity & Liability Company Lockton Companies 1801 K Street NW, Suite 200 Washington, DC 20006 202-414-2400	Liability Limit: $5M - $25M – varies per insured aircraft Passenger Liability: $250,000