SCOPE OF SERVICES

Matanuska-Susitna Borough LiDAR & Imagery Acquisition Project

Contents

INTRODUCTION

The Matanuska-Susitna Borough (MSB) is requesting proposals from qualified consultants for;

1) the acquisition of high resolution Light Detection and Ranging (LiDAR) and aerial photography data for a portion of the Matanuska-Susitna Borough, Alaska; and 2) the development of a 2 meter digital elevation model, 2 and 5-foot contours, ortho-rectified imagery, and additional deliverables as outlined within this document.

This project is being managed by the MSB in collaboration with the US Geological Survey (USGS) and US Fish and Wildlife Service (USFWS) (further referred as Partners). Current funding sources include the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), USGS, Mat-Su Salmon Partnership, and the MSB.

GENERAL INFORMATION

The Matanuska-Susitna Borough is one of the fastest growing areas of Alaska; it is rich in natural resources and innumerable opportunities. Unfortunately, comprehensive topographic information at the resolution needed for sound analysis and decision-making is limited or non-existent and the most widely available imagery for the area is nearly 8 years old and is frequently insufficient as a result of its age.

The intent of this project is to obtain data that can be used for a variety of mapping purposes including, but not limited to, FEMA flood hazard mapping, transportation planning, asset collection/management, building site suitability analysis, storm water planning, land cover analysis, hydrographic delineation, and terrain analysis all of which can in turn can be used for better decision making.

All efforts must be made to collect these data during the spring leaf off period, with minimal snow cover, and low water levels. These three variables typically occur between mid-April to late-May for the lowland areas and late-June to early-July for upland areas. It should be noted that the timing of leaf-out and snow melt varies across the project area, moving from south to north and from lower elevations to higher elevations. For example, leaf-out in the Willow area typically occurs one to two weeks after leaf-out in the Wasilla area.

Depending on the per square mile costs, the total area of acquisition is expected to be approximately 3,500 square miles. The current funding available for the project is roughly $1.5 million with an additional $500,000 anticipated by the start of the project. It is expected that all the data will be collected, processed, and delivered within 2011. Proposals should include the percentage of the total cost that goes towards each of the following eight components; LiDAR mobilization, LiDAR acquisition, LiDAR demobilization, LiDAR processing/delivery and Imagery mobilization, Imagery acquisition, Imagery demobilization, & Imagery processing/delivery.

The total project area shall be divided into at least six blocks (aka areas) for the purpose of data delivery. The size and locations of these blocks will be determined in conjunction with the Partners. Each of these blocks shall be delivered to an independent 3rd party for a QA/QC evaluation before being delivered as a final product to the MSB. The MSB will select and contract directly with the independent 3rd party review team. Once the data is reviewed and meets the QA/QC criteria it can then be delivered to the MSB as a final product and invoiced.

Detailed data specifications and deliverables have been outlined further in this scope of work.

PROJECT SCHEDULE

A generalized schedule for this project over the 2011 calendar year is as follows:

- April – May Acquisition period for lowland areas.
- June – July Acquisition period for upland areas.
- Sept – Oct Data clean up and re-flights.
- May – Dec Post processing and data delivery in batches.
- Dec Project wrap up.

Spring is the period during which the bulk of the data acquisition should occur. Fall data collection should only be considered a contingency plan and will need to be approved by the Partners. It should be noted that the cost of weather delays are not covered under this agreement. Proposals should include a detailed project schedule including: anticipated number of days required for data collection, period of time required to process each block of data, and a payment schedule that includes anticipated invoice dates for mobilization, de-mobilization, and data delivery.

SPECIAL REQUIREMENTS

Flight Notification Requirements

Several of the Partners will collect field data concurrent to the LiDAR acquisition period. As a result, a MSB project manager must be notified in advance of all anticipated windows of acquisition and then be notified as soon as the decision to fly is made. Notification will be made to a MSB project phone that will be manned 24/7 during the project acquisition period. If for some reason the phone is not answered a message should be left on the voice mail by the contractor. The following information should be relayed; the estimated period of time the aircraft will be in the air collecting data and the area(s) for which data is being collected. An update call must be made if any changes occur once the aircraft is in the air (i.e. aborted flight, change in area of acquisition, etc.). Finally a call should be made to notify when the acquisition period is completed. These calls are for information purposes only, and are not intended as permission to proceed. Acquisition flights should occur regardless of whether or not contact is successful.

Permits

The vendor shall be responsible for obtaining all permits required for the performance of this acquisition, which shall include, but not be limited to any permits for controlled or restricted airspace and access to control points on the ground.

Use and Distributions Rights

All deliverable data and documentation shall be free from restrictions regarding use and distribution. Data and documentation provided under this acquisition shall be freely distributable in the public domain and to all government agencies.

LiDAR TECHNICAL SPECIFICATIONS

The following specifications are for the acquisition of high-quality LiDAR (Light Detection and Ranging) data and derived products for a portion of the Matanuska-Susitna Borough.

Although the scope presents a sound approach, the Partners are willing to consider revisions based on the experience and expertise of the Contractor. The first task for the selected contractor will be to review the scope of work and recommend alternatives or changes. Contractors are encouraged to suggest any innovative approaches that are not addressed in this scope. However, the proposal must include each of the tasks listed below. Changes to the scope of work will only be considered after the Contractor has been selected.

All work undertaken by the contractor shall conform to these specifications and to the applicable portions of *USGS National Geospatial Program (NGP) LiDAR Guidelines and Base specifications v13* and *FEMA LiDAR Specifications for Flood Hazard Mapping/Procedure Memorandum 61; Standards for LiDAR and other High Quality Digital Topography*. In the event of conflicts between these standards and the specifications given in this section, the specifications given in this section shall govern. Minimally, it is the expectation that the bare earth DEM is suitable for ingest into the USGS 1/9 arc-second NED.

GPS and Survey Control

It is the expectation of the Partners to establish a rigorous approach to all geodetic control in order to ensure a fully constrained, persistent network which is able to bear the scrutiny of independent, 3rd party quality assurance checks. Therefore, the Contractor shall exercise extraordinary care and diligence in the planning, permitting, executing, and quality control of the GPS/IMU (Global Positioning System/Inertial Measurement Unit) collection.

The Contractor shall be responsible for establishing GPS base stations for GPS/IMU collection, as required to meet the specified accuracy criteria depicted herein. Survey control is required to tie into published NGS monuments whenever possible. The Contractor is responsible for providing a survey control report as part of the deliverables.

The Contractor shall make their own permitting and arrangements and pay for field survey personnel, helicopters, fixed wing aircraft, accommodation, ground transportation, and any other associated costs, as required to place, monitor and retrieve GPS base stations.

The *Survey Control Report* shall document the identity, published position, and measured position of all existing National Geodetic Survey (NGS) marks used for reference stations. The locations of new marks shall be described, along with their measured positions and the identity and published positions of Continuously Operating Reference Stations (CORS) to which their locations were tied. It is expected that all new marks be recoverable for a period of no less than ten years. The *Survey Control Report* shall describe the technique(s) used to establish Ground Control Points (GCPs) and document the positions and residuals of all GCPs used to evaluate survey accuracy.

GCPs used for both survey calibration and assessment of absolute vertical accuracy, shall be established using GPS and (or) other techniques that are expected to result in accuracies of 1.5 cm (RMSE) or better. Vertical accuracy shall be assessed by calculating and averaging the distances between a subset of at least 20 GCPs each for a minimum of five land cover categories that are not clustered and a surface interpolated from LiDAR first returns. Land cover categories may consist of bare earth, urbanized areas and three additional categories to be determined in conjunction with the Partners. Proposal should provide a survey control plan including a map showing planned ground control survey points.

The following are suggestions, and represent the preferred methodology of GPS and survey control. Whether or not utilizing the suggestions below, proposals should address specifically GPS and survey control methodology to be used. If using an alternative survey methodology, bidder must specifically address methodology and how that methodology will result in accuracies required.

All GPS measurements shall be made with dual frequency L1–L2 receivers with carrier phase correction. All GPS measurements shall be made during periods with PDOP ≤ 3.0 and with at least 9 satellites in common view of both a stationary reference receiver and the roving receiver. Stationary reference receivers shall be located at existing, published NGS marks or at new marks. In the case of an existing mark, its location shall be verified by processing one GPS session of at least two hours duration and comparing the computed position with the position published by NGS. Each new mark shall be located by establishing a fully constrained geodetic network which references two or more existing NGS marks and the two most appropriate NGS CORS by static GPS methods. If the distance to the nearest CORS is less than 80 km, use at least 2 independent GPS sessions, each at least 2 hours long. If the distance to the nearest CORS is greater than 80 km, use at least 2 sessions each at least 4 hours long. All independent GPS sessions will require completely unique station set ups. In cases where an existing NGS mark is optimal yet satellite signal cannot be attained due to forest cover or other conditions, a new mark may be set nearby by referencing the NGS mark through conventional survey methods. New marks set using this methodology will require a record of survey stamped by a surveyor licensed to practice in the State of Alaska. New marks will be Stability C or better monuments; a stainless steel rod driven to refusal or a minimum of 18 inches below grade, with a datum point affixed at the top, inside a sand-filled 3 foot long PVC sleeve with a rubber cap. A Carsonite witness post will be installed to mark the location of the monument.

At least two GPS reference receivers shall be in operation during all LiDAR missions, sampling positions at ≥1 Hz. IMU data will be sampled at a minimum of 50 Hz. The roving GPS receiver in the aircraft shall sample positions at ≥2 Hz. Differential GPS baseline lengths shall be no longer than 25 km.

LiDAR Mission

The successful Contractor will clearly define planned flight procedures and control specifications in their work plan. A pilot experienced with South Central Alaska flying conditions will obtain the LiDAR data with an appropriate team of surveyors. The Contractor will provide a summary of their acquisition equipment and calibration techniques. The Contractor will describe their Aerial GPS (AGPS) and Inertial Measurement Unit (IMU) equipment.

For the purposes of this proposal, consideration will be given to contractors that can provide priority schedules and have an aircraft consistently based close to the project area to meet collection condition requirements until all of the collection is complete.

The Contractor will provide a proposed schedule plan for flight periods with detailed contingency plans for inclement weather or poor collection conditions. An estimate of the number of flight days needed to meet specified collection conditions and an estimate of mobilization days shall also be provided.

The contractor shall be responsible for applying for, and obtaining, any required permit for access, overflight, or intrusion into restricted or otherwise limited ground access and/or airspace, which may be included within the requirement of this scope of services.

Collection

1. Multiple Discrete Return, capable of at least 3 returns per pulse.

    Note: Full waveform collection is both acceptable and welcomed; however, waveform data is regarded as supplemental information. The requirement for deriving and delivering multiple discrete returns remains in force in all cases.

2. Intensity values for each return.

3. Nominal Pulse Spacing (NPS) of 1 meter, dependent on the local terrain and land cover conditions. Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath. Average along-track and cross-track point spacings should be comparable. 1.4 meter NPS will be considered for certain "upland" areas (i.e. high elevation and/or relief) providing the product goals and specifications depicted herein are met and in coordination with the Partners. A possible means of delineating upland areas vs. lowland areas might be the elevation at which predominantly forested vegetative cover types transition to treeless, alpine vegetation (commonly referred to as "treeline"). Respondents to this RFP should include a plan for identifying high relief/elevation areas within the project boundary where opportunities for cost-savings may exist through a slight relaxation of NPS requirements while still meeting the product specifications described in this RFP.

4. Collections designed to achieve the NPS through swath overlap or multiple passes are generally discouraged. Such collections may be permitted with prior approval.

5. Data Voids [areas $\geq (4*NPS)^2$ measured using 1st-returns only] within a single swath are not acceptable, except:

    a. where caused by water bodies

    b. where caused by areas of low near infra-red (NIR) reflectivity such as asphalt or composition roofing

    c. where appropriately filled-in by another swath

6. The spatial distribution of geometrically usable points is expected to be uniform and free from clustering. In order to ensure uniform densities throughout the data set:

    a. A regular grid, with cell size equal to the design NPS*2 will be laid over the data.

    b. At least 90% of the cells in the grid shall contain at least 1 LiDAR point.

    c. Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

    d. Acceptable data voids identified previously in this specification are excluded.

    Note: This requirement may be relaxed in areas of significant relief where it is impractical to maintain a consistent NPS.

7. Scan Angle: Total FOV should not exceed 40° (+/-20° from nadir). Quality assurance on collections performed using scan angles wider than 34° will be particularly rigorous in the edge-of-swath areas. Horizontal and vertical accuracy shall remain within the requirements as specified below.

   Note: This requirement is primarily applicable to oscillating mirror LiDAR systems. Other instrument technologies may be exempt from this requirement.

8. Horizontal Accuracy: 0.5 meters RMSE

9. Vertical Accuracy of the LiDAR data will be assessed and reported in accordance with the guidelines developed by the NDEP and subsequently adopted by the ASPRS. The complete guidelines may be found in Section 1.5 of the Guidelines document. See:
   http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf
   (http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf)

   Vertical accuracy requirements using the NDEP/ASPRS methodology are:
   FVA ≤ 24.5cm ACCz, 95%   (12.5cm RMSEz)
   CVA ≤ 36.3cm, 95th Percentile
   SVA ≤ 36.3cm, 95th Percentile

   a. Accuracy for the LiDAR point cloud data is to be reported independently from accuracies of derivative products (i.e. DEMs). Point cloud data accuracy is to be tested against a TIN constructed from bare-earth LiDAR points.

   b. Each land cover category representing 10% or more of the total project area must be tested and reported as an SVA.

   c. For SVAs, the value is provided as a target. It is understood that in areas of dense vegetation, swamps, or extremely difficult terrain, this value may be exceeded. Overall CVA requirements must be met in spite of "busts" in individual SVAs.

   Note: These requirements may be relaxed in cases: where there exists a demonstrable and substantial increase in cost to obtain this accuracy; where an alternate specification is needed to conform to previously contracted phases of a single larger overall collection effort, i.e., multi-year statewide collections, etc.; where the Partners agree that it is reasonable and in the best interest of all stakeholders to use an alternate specification.

10. Relative accuracy ≤7cm RMSEZ within individual swaths; ≤10cm RMSEz within swath overlap (between adjacent swaths).

11. Flightline overlap 20% or greater, as required to ensure there are no data gaps between the usable portions of the swaths. Collections in high relief terrain are expected to require greater overlap. Any data with gaps between the geometrically usable portions of the swaths will be rejected.

12. Collection Area: Defined Project Area, buffered by a minimum of 100 meters.

13. Collection Conditions:
    a. Atmospheric:
        i. cloud and fog-free between the aircraft and ground

b. Ground:
    i. snow free
    ii. very light, undrifted snow may be acceptable in special cases, with prior approval
    iii. no unusual flooding or inundation

c. Vegetation:
    i. leaf-off is preferred, however,
    ii. as numerous factors will affect vegetative condition at the time of any collection, this specification requires that penetration to the ground must be adequate to produce an accurate and reliable bare-earth surface suitable for incorporation into a 2-meter post spacing DEM.

d. Coastal:
    i. flown when tide phases are below mean sea level

Note: Should conditions preclude acquisition during the anticipated acquisition dates, alternative acquisition dates can be determined in conjunction with the Partners.

14. Routine sensor calibration and maintenance are required to ensure proper function of the LiDAR system. Calibration of the Sensor/IMU shall be conducted prior to every flight and whenever otherwise necessary. Any requests by the Partners to submit evidence that the sensor system was calibrated before the project began to identify and correct systematic errors must be met.

Data Processing and Handling

1. All processing should be carried out with the understanding that all point deliverables are required to be in fully compliant LAS format, v1.2 or v1.3. Data producers are encouraged to review the LAS specification in detail. The headers shall also specifically include the date and time of collection in order to reference tidal stages during acquisition times.

2. If full waveform data is collected, delivery of the waveform packets is required. LAS v1.3 deliverables with waveform data are to use external "auxiliary" files with the extension ".wdp" for the storage of waveform packet data. See the LAS v1.3 Specification for additional information.

3. GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse. Adjusted GPS Time is defined to be Standard (or satellite) GPS time minus $1*10^9$. See the LAS Specification for more detail.

4. Horizontal datum shall be referenced to the North American Datum of 1983. Vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88). The most recent NGS-approved Geoid model shall be used to perform conversions from ellipsoidal heights to orthometric heights.

5. Horizontal coordinates shall be projected to Alaska State Plane Zone 4 and will be expressed in US Survey Feet to the nearest tenth (0.1).

6. Each swath shall be assigned a unique File Source ID. The Point Source ID field for each point within each LAS swath file shall be set equal to the File Source ID prior to any processing of the data. See the LAS Specification.

7. Long swaths (those which result in a LAS file larger than 2GB) should be split into segments

no greater than 2GB each. Each segment will thenceforth be regarded as a unique swath and shall be assigned a unique File Source ID. Other swath segmentation approaches may be acceptable, with prior approval. Renaming schemes for split swaths are at the discretion of the data producer. The Processing Report shall include detailed information on swath segmentation sufficient to allow reconstruction of the original swaths if needed.

8. Point Families (multiple return "children" of a single "parent" pulse) shall be maintained intact through all processing prior to tiling. Multiple returns from a given pulse shall be stored in sequential (collected) order.
9. All collected swaths are to be delivered as part of the "Raw Data Deliverable". This includes calibration swaths and cross-ties. All collected points are to be delivered. No points are to be deleted from the swath LAS files. This in no way requires or implies that calibration swath data are to be included in product generation. Excepted from this are extraneous data outside of the buffered project area (aircraft turns, transit between the collection area and airport, transit between fill-in areas, etc.). These points may be permanently removed.
10. Outliers, blunders, noise points, geometrically unreliable points near the extreme edge of the swath, and other points deemed unusable are to be identified using the "Withheld" flag, as defined in the LAS specification. This applies primarily to points which are identified during preprocessing or through automated post-processing routines. If processing software is not capable of populating the "Withheld" bit, these points may be identified using Class=11. "Noise points" subsequently identified during manual Classification and Quality Assurance/Quality Control (QA/QC) may be assigned the standard LAS classification value for "Noise" (Class=7), regardless of whether the noise is "low" or "high" relative to the ground surface.
11. The ASPRS/LAS "Overlap" classification (Class=12) shall not be used. ALL points not identified as "Withheld" are to be classified. If overlap points are required to be differentiated by the data producer or cooperating partner, they must be identified using a method that does not interfere with their classification, such as:
    a. Overlap points are tagged using Bit:0 of the User Data byte, as defined in the LAS specification (SET=Overlap)
    b. Overlap points are classified using the Standard Class values + 16
    c. Other techniques as agreed upon in advance
    d. The technique utilized must be clearly described in the project metadata files
12. Positional Accuracy Validation: The absolute and relative accuracy of the data, both horizontal and vertical, and relative to known control, shall be verified prior to classification and subsequent product development. This validation is obviously limited to the Fundamental Vertical Accuracy, measured in clear, open areas. A detailed report of this validation is a required deliverable. Control points used for quality checking cannot be the same points used for the ground control. The respondent must describe how the control points will be selected. Information identifying or describing the control points used for the RMSE analysis shall be provided with the accuracy reporting.

13. Classification Accuracy: It is expected that due diligence in the classification process will produce data that meets the following test:

    a. Within any 1km x 1km area, no more than 2% of non-withheld points will possess a demonstrably erroneous classification value.

    b. This includes points in Classes 0 and 1 that should correctly be included in a different Class as required by the contract.

    Note: This requirement may be relaxed to accommodate collections in areas where the Partners agree classification to be particularly difficult.

14. Classification Consistency: Point classification is to be consistent across the entire project.

15. Noticeable variations in the character, texture, or quality of the classification between tiles, swaths, lifts, or other non-natural divisions will be cause for rejection of the entire deliverable.

16. Tiles:

    Note: This section assumes a projected coordinate reference system.

    a. A single non-overlapped tiling scheme will be established and agreed upon by the data producer and the Partners prior to collection. Tiling size is meant to be reasonably useful for the purposes of the project by small scale developers, local engineers, as well as the partners. This scheme will be used for all tiled deliverables.

    b. Tile size must be an integer multiple of the cell size of raster deliverables.

    c. Tiles must be sized using the same units as the coordinate system of the data.

    d. Tiled deliverables shall conform to the tiling scheme, without added overlap.

    e. Tiled deliverables shall edge-match seamlessly and without gaps in both the horizontal and vertical.

    f. An ESRI polygon feature class will be submitted as a tile index. The tile naming scheme will be consistent with this index.

Hydro-Flattening Requirements

*Note: Please refer to **Appendix 2** for reference information on hydro-flattening.*

Hydro-flattening pertains only to the creation of derived DEMs. No manipulation of or changes to originally computed LiDAR point elevations are to be made. Breaklines may be used to help classify the point data.

1. Inland Ponds and Lakes:

    a. Include ~1-acre or greater surface area (~250’ diameter for a round pond) at the time of collection.

    b. Flat and level water bodies (single elevation for every bank vertex defining a given water body).

    c. The entire water surface edge must be at or below the immediately surrounding terrain.

    d. Long impoundments such as reservoirs, inlets, and fjords, whose water surface elevations drop when moving downstream, should be treated as rivers.

2. Inland Streams and Rivers:

   100’ nominal width: This should not unnecessarily break a stream or river into multiple segments. At times it may squeeze slightly below 100’ for short segments. Data producers should use their best professional judgment. Double line breaklines will be developed on nineteen inland streams and rivers under 100’ nominal width. These waterways are identified in **Appendix 4**.

   a. Flat and level bank-to-bank (perpendicular to the apparent flow centerline); gradient to follow the immediately surrounding terrain.

   b. The entire water surface edge must be at or below the immediately surrounding terrain.

   c. Streams channels should break at road crossings (culvert locations). These road fills should not be removed from the DEM. However, streams and rivers should not break at elevated bridges. Bridges should be removed from DEM. When the identification of a feature as a bridge or culvert cannot be made reliably, the feature should be regarded as a culvert.

3. Non-Tidal Boundary Waters:

   a. Represented only as an edge or edges within the project area; collection does not include the opposing shore.

   b. The entire water surface edge must be at or below the immediately surrounding terrain.

   c. The elevation along the edge or edges should behave consistently throughout the project. May be a single elevation (i.e. lake) or gradient (i.e. river), as appropriate.

4. Tidal Waters:

   a. Water bodies such as oceans, seas, gulfs, bays, inlets, salt marshes, very large lakes, etc. Including any water body that is affected by tidal variations.

   b. All attempts will be made to acquire data over tidally-influenced areas when the tidal phase is below mean sea level. Tidal variations over the course of a collection or between different collections will result in discontinuities along shorelines. This is considered normal and these “anomalies” should be retained. The final DEM should represent as much ground as the collected data permits.

   c. Variations in water surface elevation resulting in tidal variations during a collection should NOT be removed or adjusted, as this would require either the removal of valid, measured ground points or the introduction of unmeasured ground into the DEM. The USGS NGP priority is on the ground surface, and accepts there may be occasional, unavoidable irregularities in water surface.

5. Breaklines of single line streams:
    a. Single line streams are those less than 100’ nominal width with the exception of those identified in **Appendix 4**. Streams greater than 100’ nominal width shall have double line breaklines. Braided streams shall have breaklines delineated around islands to capture all channels regardless of size. This is particularly important for the Susitna, Little Susitna, Matanuska, and Knik Rivers.
    b. All vertices along single-line stream breaklines are at or below the immediately surrounding terrain.
    c. Single-line stream breaklines are not to be used to introduce cuts into the DEM at road crossings (culverts), dams, or other such features. This is hydro-enforcement and creates a non-traditional DEM that is not suitable for integration into the NED.
    d. All breaklines used to modify the surface are to be delivered to the Partners with the DEMs.
6. Breakline methodology:

    The Partners do not require any particular process or methodology be used for breakline collection, extraction, or integration. However, the following general guidelines must be adhered to:

    a. Bare-earth LiDAR points that are in close proximity to breaklines should be excluded from the DEM generation process. This is analogous to the removal of masspoints for the same reason in a traditional photogrammetrically compiled DTM.
    b. The proximity threshold for reclassification as “Ignored Ground” is at the discretion of the data producer, but in general should be approximately equal to the NPS.
    c. These points are to be retained in the delivered LiDAR point dataset and shall be reclassified as “Ignored Ground” (class value = 10) so that they may be subsequently identified.
    d. Delivered data must be sufficient for the Partners to effectively recreate the delivered DEMs using the LiDAR points and breaklines without significant further editing.

LiDAR DELIVERABLES

The Partners shall have unrestricted rights to all delivered data and reports, which will be placed in the public domain. This specification places no restrictions on the data provider's rights to resell data or derivative products as they see fit. Five (5) copies/sets of all finalized deliverables are required. It is expected that each copy be delivered on separate, USB-based, PC-Compatible external hard drive(s), each of which shall have a minimum of 20% free space. The Contractor will maintain a copy of all project deliverables, notes, reports and any other pertinent information for a period of not less than two years subsequent to the final submittal of all project deliverables to the Partners. With the exception of raster data, GIS-based project deliverables such as breaklines, contours, flight lines and project extents will be submitted as feature classes in ESRI file geodatabases; no shapefiles will be accepted. It is expected that the Contractor will “trim” the LiDAR coverage to the extents of the project limits and buffer specified herein.

Itemized Products

1. Pilot Project

Prior to beginning the full production of LiDAR deliverables, the Contractor must provide raw, unclassified point cloud data for a prototype area of a minimum 5 square miles. The locational extent of the pilot project will be determined by the Partners and selected Contractor during negotiations and consist of urban and rural areas. Upon review and approval of the pilot area by the Partners, the Contractor will use resultant adjustments as a guide of data quality and spatial accuracy for the rest of the project area.

2. Metadata

Note: "Metadata" refers to all descriptive information about the project. This includes textual reports, graphics, supporting ESRI feature classes, and FGDC-compliant metadata files. All Metadata will comply with the requirements in the USGS LiDAR Guidelines and Base Specifications v13

http://lidar.cr.usgs.gov/USGS-NGP%20Lidar%20Guidelines%20and%20Base%20Specification%20v13(ILMF).pdf

a. Collection Report detailing mission planning and flight logs.

b. Survey Report detailing the collection of control and reference points used for calibration and QA/QC.

c. Processing Report detailing calibration, classification, and product generation procedures including methodology used for breakline collection and hydro-flattening (see Sections III and **Appendix 1** for more information on hydro-flattening).

d. QA/QC Reports detailing the analysis, accuracy assessment and validation of:

   i. Control and Calibration points: All control and reference points used to calibrate, control, process, and validate the LiDAR point data or any derivative products are to be delivered. This will include the vertical accuracy calculations as a Microsoft Excel spreadsheet

   ii. The point data (absolute, within swath, and between swath)

   iii. The bare-earth surface (absolute)

   iv. Other optional deliverables as appropriate

e. Geo-referenced, digital spatial representation of the precise extents of each delivered dataset. This should reflect the extents of the actual LiDAR source or derived product data, exclusive of Triangular Irregular Network (TIN) artifacts or raster NODATA areas. A union of tile boundaries or minimum bounding rectangle is not acceptable. ESRI Feature classes and file geodatabase format is expected.

f. Product metadata (FGDC compliant, XML format metadata). One file for each:

   i. Lift (flight)

   ii. Tiled deliverable product group (classified point data, bare-earth DEMs, breaklines, etc.); metadata files for individual tiles are not required. FGDC compliant metadata must pass the USGS metadata parser ("mp") with no errors or warnings

3. Raw Point Cloud

a. All returns, all collected points, fully calibrated and adjusted to ground, by swath

b. Fully compliant LAS v1.2 or v1.3, Point Record Format 1, 3, 4, or 5

c. LAS v1.3 deliverables with waveform data are to use external "auxiliary" files with the extension ".wdp" for the storage of waveform packet data. See the LAS v1.3 Specification for additional information

d. Georeference information included in all LAS file headers

e. GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse

f. Intensity values (native radiometric resolution)

g. 1 file per swath, 1 swath per file, file size not to exceed 2GB

4. Classified Point Cloud

a. Fully compliant LAS v1.2 or v1.3, Point Record Format 1, 3, 4, or 5

b. LAS v1.3 deliverables with waveform data are to use external "auxiliary" files with the extension ".wdp" for the storage of waveform packet data. See the LAS v1.3 Specification for additional information

c. Georeference information included in LAS header

d. GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse

e. Intensity values (native radiometric resolution)

f. Tiled delivery, without overlap (tiling scheme TBD)

g. Classification Scheme (minimum):

Code	Description
1	Processed, but unclassified
2	Bare-earth ground
7	Noise (low or high, manually identified, if needed)
9	Water
10	Ignored Ground (Breakline Proximity)
11	Withheld (if the "Withheld" bit is not implemented in processing software)

Note: Class 7, Noise, is included as an adjunct to the "Withheld" bit. All "noise points" are to be identified using one of these methods.

Note: Class 10, Ignored Ground, is for points previously classified as bare-earth but whose proximity to a subsequently added breakline requires that it be excluded during Digital Elevation Model (DEM) generation.

5. Bare Earth Surface (Raster DEM)

a. Cell size will be no greater than 2 meters or 6.5 feet, and no less than the design Nominal Pulse Spacing (NPS).

b. Delivery in an industry-standard, GIS-compatible, 32-bit floating point raster format (ESRI ArcInfo binary grid format preferred).

c. Georeference information shall be included in each raster file.

d. Tiled delivery, without overlap.

e. DEM tiles will show no edge artifacts or mismatch. A quilted appearance in the overall project DEM surface, whether caused by differences in processing quality or character between tiles, swaths, lifts, or other non-natural divisions, will be cause for rejection of the entire DEM deliverable.

f. DEM Void areas (i.e., areas outside the project boundary but within the tiling scheme) shall be coded using a unique "NODATA" value. This value shall be identified in the appropriate location within the file header. DEM Void areas may be caused by locations where bare earth returns are minimal due to forest canopy or other reasons. The Contractor will discuss these areas with the Partners to determine whether DEM void areas will be classified as NO DATA or interpolated to ensure a continuous surface.

g. Vertical Accuracy of the bare earth surface will be assessed and reported in accordance with the guidelines developed by the NDEP and subsequently adopted by the ASPRS. The complete guidelines may be found in Section 1.5 of the Guidelines document. See:

   http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf

   Vertical accuracy requirements using the NDEP/ASPRS methodology are:
   FVA ≤ 24.5cm ACCz, 95% (12.5cm RMSEz)
   CVA ≤ 36.3cm, 95th Percentile
   SVA ≤ 36.3cm, 95th Percentile

   All QA/QC analysis materials and results are to be delivered to the Partners.

h. Depressions (sinks), natural or man-made, are **not** to be filled (as in hydro-conditioning and hydro-enforcement).

i. Water Bodies (ponds and lakes), wide streams and rivers ("double-line"), and other non-tidal water bodies are to be hydro-flattened within the DEM. Hydro-flattening shall be applied to all water impoundments, natural or man-made, that are larger than ~1 acre in area (equivalent to a round pond ~250' in diameter), to all streams that are nominally wider than 100', and to all non-tidal boundary waters bordering the project area regardless of size. The methodology used for hydro-flattening is at the discretion of the data producer.

*Note: Please refer to the **Appendix 2** for detailed discussions of hydro-flattening.*

6. Breaklines

Note: Delivery of the breaklines used in hydro-flattening is a standard requirement for USGS NGP LiDAR projects.

All breaklines developed for use in hydro-flattening shall be delivered as ESRI feature classes (PolylineZ or PolygonZ format, as appropriate to the type of feature represented and the methodology used by the data producer) nested within an ESRI file geodatabase. It is expected that all breaklines are topologically correct and validated by the contractor prior to delivery to the Partners.

- Each feature class will include properly formatted and accurate georeference information in the standard location.
- Breaklines must use the same coordinate reference system (horizontal and vertical) and units as the LiDAR point delivery.
- Breakline delivery may be as a continuous layer or in tiles, at the discretion of the data producer. Tiled deliveries must edge-match seamlessly in both the horizontal and vertical.

7. Contours

Two foot interval for lowland areas, five foot interval for entire project. Contours shall be delivered as ESRI feature classes nested in a file geodatabase and as an Autocad .dwg.

8. Intensity Images

Intensity images will follow the same tiling and resolution requirements as those specified previously for the bare earth DEM.

9. First Return Surface

A "top of canopy" DEM developed using the highest returns, which follows the same tiling and resolution requirements as the bare earth DEM.

10. Shaded Relief Mosaic

A shaded relief raster image of the bare earth DEM which follows the same tiling and resolution requirements as the bare earth DEM.

11. Block Deliverables

The project area will be subdivided into delivery blocks, the size and location of which will be determined in conjunction with the Partners. Blocks will be delivered as complete subsets of project deliverables. Acceptance of each block by the Partners will be contingent on an independent, 3rd party QA/QC analysis which will determine if each block meets the horizontal, vertical and density specifications depicted herein. This analysis will require 30 days per block. It is the expectation of the Partners that blocks of data should be delivered to the 3rd party QA/QC team at least 30 days apart to prevent a backlog of data in need of review. If multiple blocks are delivered concurrently, each block will require 30 days (non-concurrent) of QA/QC analysis before the Partners accept each block. Blocks not meeting specifications will be rejected by the Partners. Re-delivery of rejected blocks will be within 30 days from the date the original block was rejected. There will be a teleconference between the Contractor, the Partners and representatives from the 3rd party QA/QC effort for each block delivery to discuss any issues which might be inconsistent with the specifications depicted herein.

A folder and file naming structure for all deliverables will be agreed upon prior to delivery of the first block and maintained for delivery of each subsequent block. It is expected that if a block is re-delivered, the same file and folder structure and naming conventions will be adhered to.

12. Progress Reports

In addition to all reporting requirements, The Contractor will provide the Partners, via e-mail and/or FTP, weekly progress reports. These reports shall consist of a summary of production status, major activities completed during the most recent reporting period, description of issues and corrections, and associated status maps or acquired flight lines. Each progress report will include the progress, expressed as a percentage of completion, of the delivery block(s) currently being processed, the anticipated completion date and details regarding any issues which might extend the anticipated completion date.

ORTHORECTIFIED IMAGERY TECHNICAL SPECIFICATIONS

The following specifications are for the acquisition of high-quality aerial orthorectified digital imagery for a portion of the Matanuska-Susitna Borough.

For the purposes of this RFP, a digital orthophotograph is defined as a geo-referenced image prepared from perspective photography, in which the displacement within the image due to sensor orientation and terrain relief has been removed. A digital orthophotograph represents the combination of photographic image characteristics with the geometric qualities of a map.

Some examples of what the product of this RFP should allow users to identify are: hydrants, manholes, road striping and individual trees. It is intended that the orthoimagery products will allow the Partners to provide an accurate digital representation of what is actually on the ground. The Partners may use this imagery to refine and improve upon the digital parcel boundary data, develop more accurate storm water infrastructure delineations, map water and sewer system lines and connections, and inform land use planning projects and inventory public assets.

Although the scope presents a sound approach, the Partners are willing to consider revisions based on the experience and expertise of the Contractor. The first task for the selected contractor will be to review of the scope of work and recommend changes. Contractors are encouraged to suggest any innovative approaches that are not addressed in this scope. However, the proposal must include each of the tasks listed below. Changes to the scope of work will only be considered after the Contractor has been selected. Furthermore, it is the expectation that all orthoimagery products, including metadata, meet the *Federal Geographic Data Committee Content Standards for Digital Orthoimagery,* and *American Society for Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards for Large-Scale Maps, Class 1 Accuracy Standards* for the map scale set forth in these specifications.

The Partners seek the highest resolution imagery that can be purchased under the limitations of this solicitation. Pixel resolutions in the final ortho tiles and mosaic products greater than 1 foot will not be accepted.

Table 1. Summary of Orthophoto project specifications. Review text for details.

Data Acquisition	Specification
Project Area	See project area map in **Appendix 3**
Collection Area	Defined project area buffered by100 meters with at least the first two and last two exposures of each flight strip falling outside the project area boundaries.
Output Pixel Resolution	0.5-foot (anticipated)
Above Mean Terrain	Approx. 5,000 feet to meet a nominal scale of 1 inch = 800 feet.
Imagery Type	4-band (RGB and NIR)
End Overlap	60% (80% for canyons)
Side Overlap	30% (60% for canyons)
Collection Conditions	• 30-degree sun angle (high angle in urban canyons to minimize shadows) • cloud-free with minimal smoke, smog, haze, fog, and dust • minimal flooding or excessive soil moisture • leaf-off
Horizontal Accuracy	1 inch = 100 feet *FGDC, Geospatial Positioning Accuracy Standards, Part 3: National Standards for Spatial Data Accuracy*.
GPS & Survey Control	Combination of AGPS, IMU, and supplemental ground control points.
Vertical Datum	NAVD88 (North American Vertical Datum of 1988)
Horizontal Datum	NAD83
Projection	Alaska State Plane Zone 4
Horizontal & Vertical Units	U.S. Survey Foot and will be expressed to the nearest tenth (0.1)
Image Format	Uncompressed GeoTIFF format, version 1.8.2
Imagery Products	Seamless mosaic covering the project area and non-overlapping, edge-matched tiles based on a tile scheme provided by the Partners.
Radiometric Resolution	Minimum 8-bit in accordance with GeoTIFF specification, revision 6.

Collection Area

The project area for orthophotography will cover the same geographic area as the project area for LiDAR acquisition, as shown in **Appendix 3**. A buffer of 100 meters outside the project area boundaries will be collected with at least the first two and last two exposures of each flight strip falling to outside the project area to ensure collection along project boundaries.

Photographic Mission

The successful Contractor will clearly define planned flight procedures and control specifications in their work plan. A pilot experienced with South Central Alaska flying conditions will obtain the aerial digital imagery with an appropriate team of surveyors. The Contractor will provide a summary of their acquisition equipment and calibration techniques. The Contractor will describe their Aerial GPS (AGPS) and Inertial Measurement Unit (IMU) equipment and verify that the digital sensors meet the U.S. Geological Survey (USGS) Digital Aerial Type Certification.

For the purposes of this proposal, consideration will be given to contractors that can provide priority schedules and have an aircraft consistently based close to the project area to meet collection condition requirements until all of the collection is complete. The successful contractor may have the ability to collect Orthoimagery and LiDAR concurrently.

The Contractor will provide a proposed schedule plan for flight periods with detailed contingency plans for inclement weather or poor collection conditions. An estimate of the number of flight days needed to meet specified collection conditions and an estimate of mobilization days shall also be provided.

The contractor shall be responsible for applying for, and obtaining, any required permit for access, overflight, or intrusion into restricted or otherwise limited ground access and/or airspace, which may be included within the requirement of this scope of services.

Every effort shall be made to avoid breaks within individual flight lines. Where breaks within a flight line are necessary, the entire flight line composed of the resulting segments shall meet all of the requirements set forth in these specifications. Where breaks occur, these shall have an overlap of at least four frames to ensure a stereo model of overlap or tie. All photos within a single flight line shall be acquired with the same aerial camera and with the camera oriented in the same direction.

Collection Conditions

1. Sun angle:
    a. minimal shadow conditions
    b. sun angle is greater than 30 degrees
    c. in canyons (urban or geologic), imagery shall be acquired at high sun angles to minimize shadows caused by steep canyon walls or buildings
2. Atmospheric:
    a. free of clouds and cloud shadows
    b. minimal smoke, haze, fog, and dust to produce a clear image
    c. areas where it is difficult to obtain a cloud free image (i.e. mountains) a low percentage (5%) of cloud cover will be acceptable pending review by the partners
3. Ground:
    a. no flooding
    b. no snow
    c. no excessive soil moisture
4. Vegetative:
    a. leaf off conditions

Quality Control and Accuracy

The contractor shall perform quality assurance tasks on the orthorectified imagery to ensure the product meets all of the requirements for horizontal and vertical accuracy, image resolution, and image characteristics in this scope of work.

1. Horizontal accuracy shall meet the 1 inch = 100 feet *Federal Geographic Data Committee, Geospatial Positioning Accuracy Standards, Part 3: National Standards for Spatial Data Accuracy*.
2. Anticipated output pixel resolution: 0.5 feet. Ground sample distance (GSD) shall be determined.
3. Apparent Crab (yaw, pitch, roll): ≤ 5 degrees between any two successive exposures.
4. Tilt: < 3 degrees for any single exposure, < 4 degrees relatives, and < 1 degree overall average.
5. Minimum number of check points covering the project area: 20
6. Visual inspection of geometry will be performed to remove seams, edge match issues, bridge distortions, excessive building lean, and related displacements.
7. Visual inspection of the mosaic product to correct blurred imagery, inconsistencies in color balancing, color bleeding, and shadow detail.
8. Random geometric checks for positional accuracy and relative accuracy between tiles.
9. Overlap/Sidelap: All photography shall be acquired to provide adequate stereo coverage. Minimum overlap shall be 60% forward and 30% side. However, additional exposures shall be captured over urban core areas and mountain areas to ensure that roadways/transportation features are not obscured in urban areas and valley bottoms are visible in the mountains. The imagery should not contain any shadows caused by terrain relief or low solar altitude resulting in inconsistencies with specifications depicted herein.
10. Metadata will be verified to ensure completeness and compliance with Federal Geospatial Data Consortium (FGDC) standards.

Digital Camera

1. Direct digital, frame-based system with calibration that meets USGS Digital Aerial Type standards.
2. Precision, large format with low distortion, high-resolution optics and high pixel count charged coupled device (CCD) sensors.
3. Red, green, blue, and near infrared channels.
4. Minimum radiometric resolution of 8 bit accordance with GeoTIFF specification, revision 6 (http://www.remotesensing.org/geotiff/spec/geotiffhome.html). 12 bit or higher in all channels are preferred.
5. Gyro-stabilization and forward motion compensation.
6. Output pixel resolution of 0.5 feet.

Camera Station Control

1. Airborne GPS (AGPS): Camera position (latitude, longitude, and elevation) shall be recorded at the instant of exposure with AGPS. AGPS data shall be differentially corrected and organized as individual datasets grouped by flight line. The absolute accuracy of AGPS control data shall not exceed 1 foot.
2. Inertial Measurement Unit (IMU): Camera attitude shall be recorded at the instant of exposure and the data shall be adjusted and organized as individual datasets grouped by flight line. The absolute accuracy of adjusted IMU data shall not exceed 1 foot.

GPS and Survey Control

Whenever possible, it is the expectation of the Partners that the Contractor utilize the GPS and Survey Control set forth for the LiDAR component of this RFP to control the orthoimagery acquisition as well as to utilize the finalized DEM for orthorectification of orthoimagery products.

If supplemental ground control is necessary, the Contractor shall be responsible for collecting and setting the survey control and photo targets, at the appropriate accuracies required for the project.

Data Processing Plan

The successful Contractor will provide a detailed technical plan of aerial triangulation, orthorectification and quality control and assurance. An estimate of the number of processing days after aerial imagery acquisition shall also be provided.

All data and rectification solutions will meet the following spatial reference system standards:

1. Vertical Datum: North American Vertical Datum of 1988
2. Horizontal Datum: North American Datum of 1983
3. Projection: Alaska State Plane Zone 4
4. Horizontal/Vertical Units: U.S. Survey Foot and will be expressed to the nearest tenth (0.1)

Aerial Triangulation

Aerial triangulation forms the basis for the accuracy of all derived products. Therefore, the successful Contractor shall provide a detailed technical approach to this process.

1. The aerial triangulation solution shall cover the entire project area. All photos shall be evaluated and point anomalies identified to the Partners.
2. Independent check points will be used and evaluated to validate the accuracy of the solution.

Orthorectification

1. The digital elevation data required for this process shall be provided by the LiDAR deliverables specified in this RFP.
2. Resampling: The rectification process shall use the cubic convolution resampling technique to ensure high accuracy and image quality.
3. Mosaicking: The mosaicking process shall minimize image distortions and smearing and produce a seamless edge-matched product.

4. Above Ground Transportation Features: Processes will be used during orthophoto production to avoid the presences of warped and misaligned above ground transportation features.
5. Orthorectified Image Chips: Shall be tonally balanced prior to generation of an image mosaic. Building tilt shall be corrected to the extent that transportation features are not obscured (as outlined above). Relative join (misalignment) of transportation features between adjacent image chips/tiles shall be within the tolerance defined by the horizontal positional accuracy requirement set out above. Any methods of mosaicking orthoimagery to reduce relief displacement of buildings and terrain should be detailed in the technical proposal. Ground features appearing in the orthophoto imagery, such as building rooftops, water towers, and radio towers, shall not be clipped at seamlines or between individual tiles.
6. The rectification process shall involve a solution of the appropriate photogrammetric equations for each pixel in the output image. It will not be permissible to solve photogrammetric equations at anchor points only and then warp the content of the original image between the anchor points.

Radiometry

All images should be clear and sharp in detail with no light streaks, static marks, scratches, dust marks, or other noticeable blemishes. The imagery should be free from defects, such as out-of-focus imagery, and should not contain inconsistencies in tone and/or density between individual orthos and/or adjacent sheets. To ensure consistency, the imagery should be radiometrically and geometrically corrected to enable adjacent files to be displayed simultaneously without obvious distinctions between them.

The Contractor will describe their technical approach to producing radiometry balance.

1. No null pixels will be allowed within resulting tiles.
2. Minimize brightness, contrast, and color differences between join areas.
3. Minimize color bleeding on features.

Image Format

Orthorectified images shall be in 4-band color (red, green, blue, and near infrared) and color balanced to the Partners' preference. All imagery shall be at a minimum 8-bit in accordance with the GeoTIFF specification. Presence of compression artifacts from any stages of the production process shall result in rejection of data. GeoTIFF files shall include the following minimum tags and keys:

1. ModelTiepointTag and ModelPixelScaleTag OR ModelTransformationTag
2. GTModelTypeGeoKey
3. GTRasterTypeGeoKey
4. Image header tag: SampleFormat, MinSampleValue, and MaxSampleValue.
5. Uncompressed GeoTIFF format, version 1.8.2.

ORTHORECTIFIED IMAGERY DELIVERABLES

The Partners shall have unrestricted rights to all delivered data and reports, which will be placed in the public domain. This specification places no restrictions on the data provider's rights to resell data or derivative products as they see fit. Five (5) copies/sets of all finalized deliverables are required. It is expected that each copy be delivered on separate, USB-based, PC-Compatible external hard drive(s), each of which shall have a minimum of 20% free space. The Contractor will maintain a copy of all project deliverables, notes, reports and any other pertinent information for a period of not less than two years subsequent to the final submittal of all project deliverables to the Partners. With the exception of raster data, GIS-based project deliverables such as breaklines, contours and project extents will be submitted as feature classes in ESRI file geodatabases; no shapefiles will be accepted.

The Contractor shall provide a detailed product delivery schedule and describe their methods, reporting skills, and compliance with FGDC metadata standards. All spatial data deliverables shall meet the spatial reference system standards depicted herein.

All deliverables must pass through a comprehensive evaluation and review process. This process will verify the positional accuracy of the data, and ensure its aesthetic and functional quality. The Partners will oversee this quality control process using in-house resources, project partners, a third party vendor, or some combination of all three. The Partners may reject any or all tiles that fail to meet the project's positional accuracy or aesthetic and functional quality requirements.

Prior to delivery of the product, horizontal positional accuracy testing will be performed following the methods proposed by the contractor in the technical proposal.

Itemized Products

1. Pilot Project:

Prior to beginning the full production of digital orthophotography, the Contractor must provide deliverables for a prototype area of a minimum 5 square miles. The locational extent of the pilot project will be determined by the Partners and selected Contractor during negotiations and consist of urban and rural areas. Upon review and approval of the pilot area by the Partners, the Contractor will use resultant adjustments as a guide of image quality and spatial accuracy for the rest of the project area.

2. Flight Plan and Logs:

a. The flight plan shall be distributed to and approved by the Partners prior to acquisition. Flight logs shall be provided within two days of each flight acquisition to verify flight times related to sun angle specifications.

b. Projected flight lines on a map displaying the project area and distributed as a feature class nested in an ESRI file geodatabase. Flight lines shall include flight line numbers within the feature attribution, and metadata shall describe the software used to generate the flight plan.

c. Approximate number of exposures for the intended coverage area.

d. Image centers of each exposure with date and time of acquired photo included. The data shall be distributed as a feature class nested in an ESRI file geodatabase.

e. Upon completion of acquisition, the Contractor shall provide a collection report summarizing the flight and logs.

3. Calibration Reports:

Camera and digital sensor calibration reports along with a product characterization report validating USGS Digital Aerial Type standards shall be provided.

4. Survey Control Report:

a. Positional AGPS data and a statistical summary of the AGPS adjustment results.

b. IMU sensor orientation and a statistical summary describing the overall accuracy of adjusted IMU data.

c. Differentially corrected GPS ground control data used to supplement the AGPS data and a narrative describing all aspects of the ground survey including locations and extent of the network.

d. The results and analysis of the constrained least squares adjustment, tables summarizing GPS misclosures, and a description of equipment and software used.

5. Aerial Triangulation Report:

An aerial triangulation report shall be provided upon completion of all adjustments. This report shall include:

a. An executive summary of the aerotriangulation solution and its results.

b. A detailed narrative of the adjustment process and quality checks for accuracy.

c. A description of the software and equipment used to perform the adjustments.

d. A listing of the final adjusted coordinates in a spreadsheet or format agreed upon during contract negotiations.

6. Digital Orthorectified Images:

a. All imagery data shall meet the accuracy and GeoTIFF standards defined herein.

b. Seamless mosaic at anticipated 0.5-foot pixel resolution.

c. Edge-matched, non-overlapping tiles at anticipated 0.5-foot pixel resolution based on the tile scheme provided by the Partners.

d. Images with edge artifacts, mismatch, or voids will be rejected.

e. Breaklines used to correct bridge and overpass distortion shall be provided as a feature class feature class nested in an ESRI file geodatabase.

7. Metadata:

Complete FGDC-compliant metadata shall be provided for all data in an XML format. The metadata shall provide a complete description of identification, data quality, spatial data organization, spatial reference, and entity and attribute information. The metadata for orthorectified imagery shall also include acquisition dates.

8. Progress Reports:

Progress reports shall be provided by email on a weekly basis. These reports shall consist of a summary of production status, major activities completed during the most recent reporting period, description of issues and corrections, and associated status maps or acquired flight lines.

9. Project Report:

A final project report summarizing the flight acquisition, orthorectification process, quality control and assurance, and deliverables provided shall be provided upon completion of the project. This report shall include a detailed narrative of the analysis, accuracy assessment, and validation of all deliverables.

APPENDIX 1: COMMON OPTIONS ABOVE BASE SPECIFICATIONS

1. Higher Nominal Pulse Spacing (Point Density)
2. Increased Vertical and/or Horizontal Accuracy
3. Full Waveform Collection and Delivery
4. Higher Resolution Imagery/DEM
5. Extracted Buildings (PolygonZ): Footprints with maximum elevation and/or height above ground as an attribute.
6. Other Urban Modeling Products
7. Detailed Classification (additional classes):

Code	Description
3	Low vegetation
4	Medium vegetation (use for single vegetation class)
5	High vegetation
6	Buildings, bridges, other man-made structures
n	additional Class(es) as agreed upon in advance

8. Hydro-Enforced and/or Hydro-Conditioned DEMs
9. Breaklines (PolylineZ and PolygonZ) for other features (TBD), including appropriate integration into delivered DEMs.
10. Additional Environmental Constraints:
    a. Tidal coordination, flood stages, crop/plant growth cycles, etc.
    b. Shorelines corrected for tidal variations within a collection.
11. Other products as defined by requirements and agreed upon in advance of funding commitment.

APPENDIX 2: HYDRO-FLATTENING REFERENCE

The subject of modifications to LiDAR-based DEMs is somewhat new, and although authoritative references are available, there remains significant variation in the understanding of the topic across the industry. The following material was developed to provide a definitive reference on the subject only as it relates to the creation of DEMs intended to be integrated into the USGS NED. The information presented here is not meant to supplant other reference materials and it should not be considered authoritative beyond its intended scope.

Hydro-flattening of DEMs is predominantly accomplished through the use of breaklines, and this method is considered standard. Although other techniques may exist to achieve similar results, this section assumes the use of breaklines. The USGS does not require the use of any specific technique.

The Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition (Maune *et al.*, 2007) provides the following definitions related to the adjustment of DEM surfaces for hydrologic analyses:

1. **Hydrologically-Conditioned (Hydro-Conditioned)** – Processing of a DEM or TIN so that the flow of water is continuous across the entire terrain surface, including the removal of all spurious sinks or pits. The only sinks that are retained are the real ones on the landscape. Whereas "hydrologically-enforced" is relevant to drainage features that are generally mapped, "hydrologically-conditioned" is relevant to the entire land surface and is done so that water flow is continuous across the surface, whether that flow is in a stream channel or not. The purpose for continuous flow is so that relationships/links among basins/catchments can be known for large areas. This term is specifically used when describing EDNA (see Chapter 4), the dataset of NED derivatives made specifically for hydrologic modeling purposes.

2. **Hydrologically-Enforced (Hydro-Enforced) –** Processing of mapped water bodies so that lakes and reservoirs are level and so that streams flow downhill. For example, a DEM, TIN or topographic contour dataset with elevations removed from the tops of selected drainage structures (bridges and culverts) so as to depict the terrain under those structures. Hydro-enforcement enables hydrologic and hydraulic models to depict water flowing under these structures, rather than appearing in the computer model to be dammed by them because of road deck elevations higher than the water levels. Hydro-enforced TINs also utilize breaklines along shorelines and stream centerlines, for example, where these breaklines form the edges of TIN triangles along the alignment of drainage features. Shore breaklines for streams would be 3-D breaklines with elevations that decrease as the stream flows downstream; however, shore breaklines for lakes or reservoirs would have the same elevation for the entire shoreline if the water surface is known or assumed to be level throughout. See figures 1.21 through 1.24. See also the definition for "hydrologically-conditioned" which has a slightly different meaning.

While these are important and useful modifications, they both result in surfaces that differ significantly from a traditional DEM. A "hydro-conditioned" surface has had its sinks filled and may have had its water bodies flattened. This is necessary for correct flow modeling within and across large drainage basins. "Hydro-enforcement" extends this conditioning by requiring water bodies be leveled and streams flattened with the appropriate downhill gradient, and also by cutting through road crossings over streams (culvert locations) to allow a continuous flow path for water within the drainage. Both treatments result in a surface on which water behaves as it physically does in the real world, and both are invaluable for specific types of hydraulic and hydrologic (H&H) modeling activities. Neither of these treatments is typical of a traditional DEM surface.

A traditional DEM such as the NED, on the other hand, attempts to represent the ground surface more the way a bird, or person in an airplane, sees it. On this surface, natural depressions exist, and road fills create apparent sinks because the road fill and surface is depicted without regard to the culvert beneath. Bridges, it should be noted, are removed in most all types of DEMs because they are man-made, above-ground structures that have been added to the landscape.

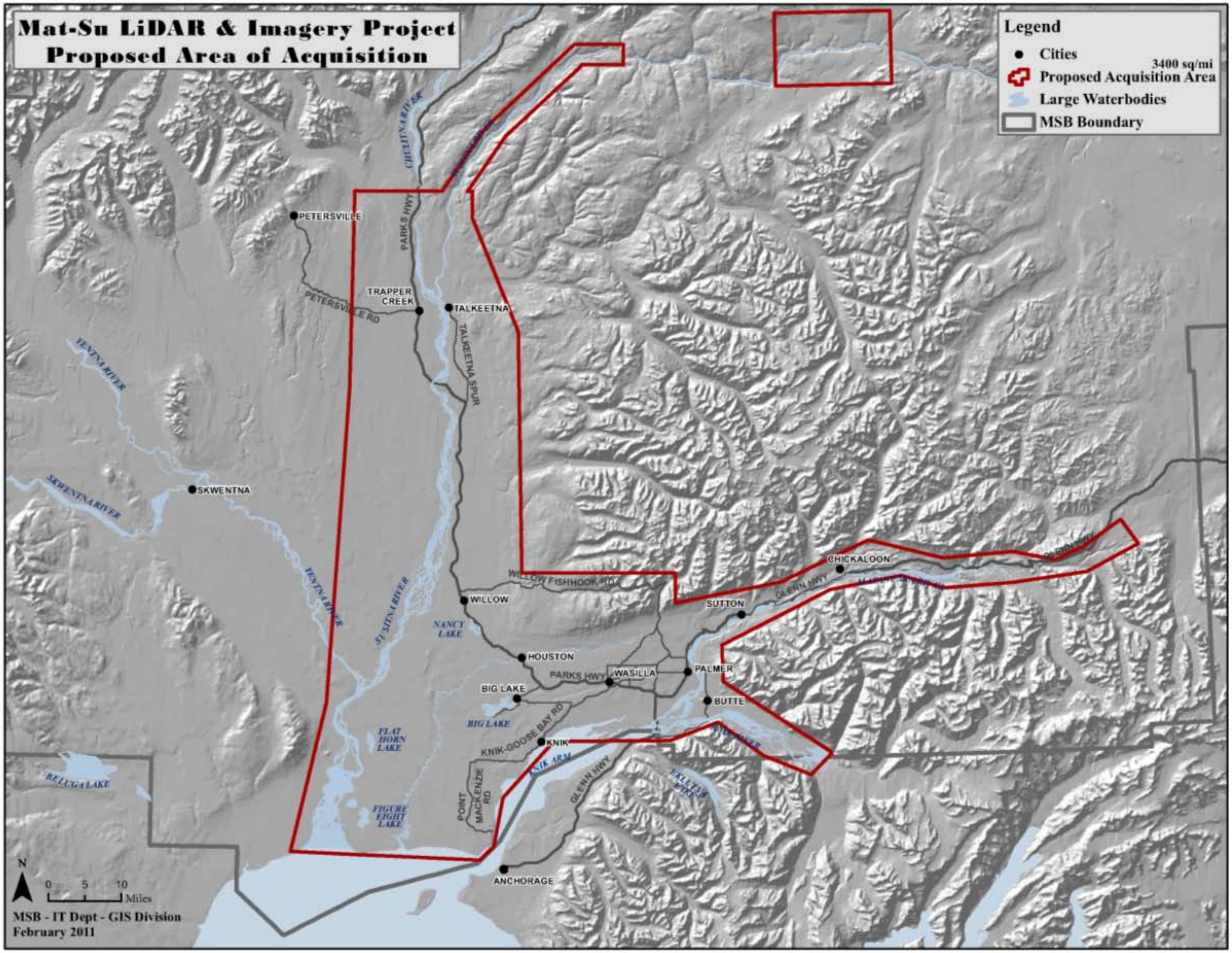
Note: DEMs developed solely for orthophoto production may include bridges, as their presence can prevent the "smearing" of structures and reduce the amount of post-production correction of the final orthophoto. These are "special use DEMs" and are not relevant to this discussion.

For years, raster Digital Elevation Models (DEMs), have been created from a Digital Surface Model (DSM) of masspoints and breaklines, which in turn were created through photogrammetric compilation from stereo imagery. Photogrammetric DSMs inherently contain breaklines defining the edges of water bodies, coastlines, single-line streams, and double-line streams and rivers, as well as numerous other surface features.

LiDAR technology, however, does not inherently collect the breaklines necessary to produce traditional DEMs. Breaklines have to be developed separately through a variety of techniques, and either used with the LiDAR points in the generation of the DEM, or applied as a correction to DEMs generated without breaklines.

In order to maintain the consistent character of the NED as a traditional DEM, the USGS NGP requires that all DEMs delivered have their inland water bodies flattened. This does not imply that a complete network of topologically correct hydrologic breaklines be developed for every dataset; only those breaklines necessary to ensure that the conditions defined in Section III exist in the final DEM.

APPENDIX 3: PROJECT AREA MAP



APPENDIX 4a: ADDITIONAL DOUBLE BREAKLINE WATERBODIES

Double line breaklines will be developed on portions of 19 inland streams and rivers that fall under the 100' nominal width outlined in the technical specifications. The following is a list of those waterbodies; the start and end point of the river segment as described by meridian, township, range, and section; and the distance of the segment.

Bodenberg Creek – S017N002E11 to S016N002E02 – 7 miles

Caswell Creek – S023N003W30 to S021N004W06 – 18 miles

Chunilna River – S027N004W02 to S026N004W03 – 8 miles

Cottonwood Creek – S018N001E28 to S016N002W10 – 16 miles

Deception Creek – S019N003W35 to S019N004W05 – 15 miles

Goose Creek – S024N003W32 to S023N005W25 – 16 miles

Little Meadow Creek – S017N002W04 & S018N002W26 to S017N003W14 – 12 miles

Little Susitna River – S018N001E07 to S017N005W34 – 62 miles

Little Willow Creek – S021N003W15 to S020N005W27 – 30 miles

Lucille Creek – S017N001W08 to S017N003W15 – 13 miles

Meadow Creek – S017N003W14 to S017N003W19 – 6 miles

Montana Creek – S024N004W11 to S023N004W07 – 9 miles

Moose Creek (Petersville Area) – S026N006W30 to S025N006W30 – 12 miles

Moose Creek (Sutton Area) – S019N002E23 to S018N002E02 – 7 miles

Ninemile Creek – S026N006W23 to S025N006W10 – 6 miles

Sheep Creek – S023N003W10 to S022N004W30 – 24 miles

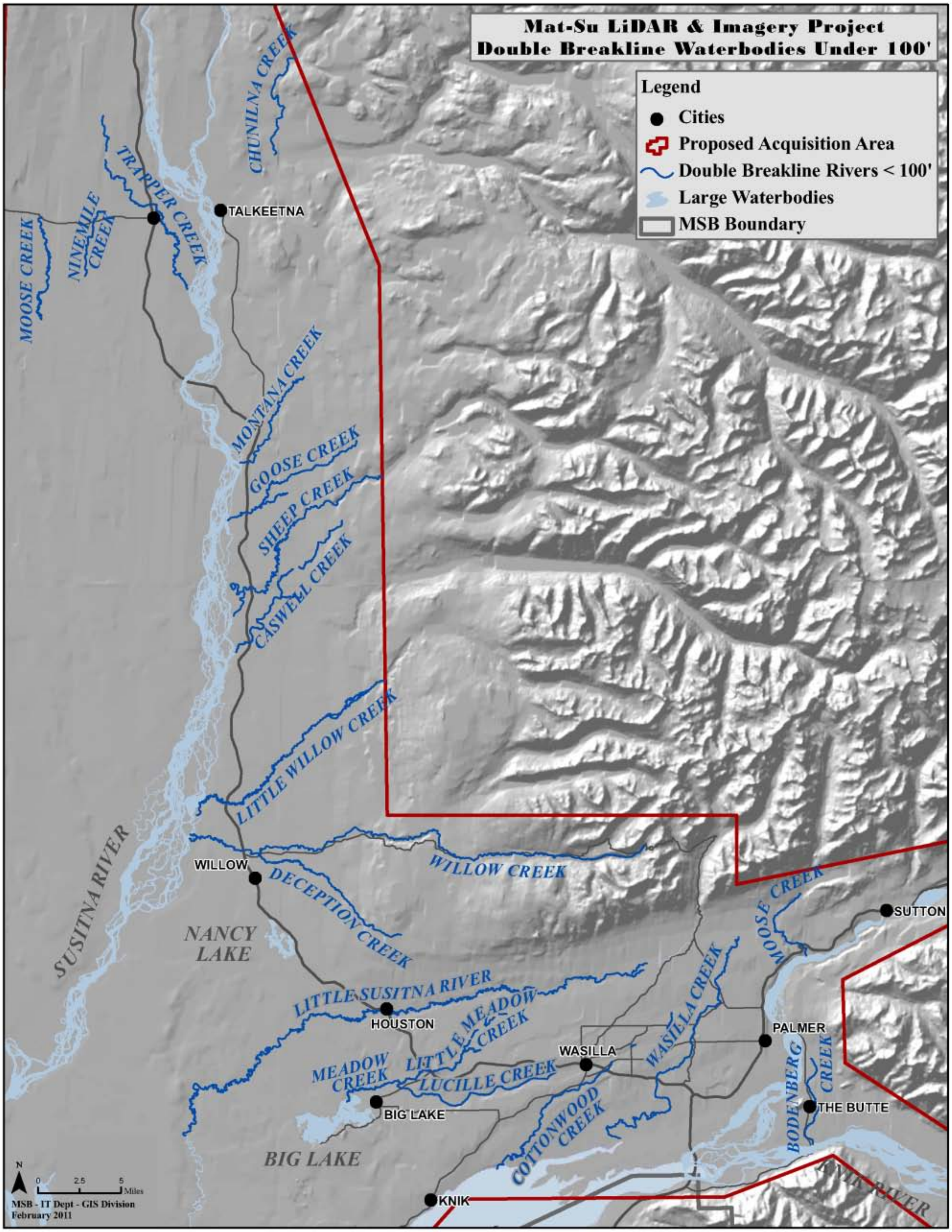
Trapper Creek – S027N006W26 to S025N005W15 – 20 miles

Wasilla Creek – S019N002E31 to S017N001W36 – 26 miles

Willow Creek – S019N001E06 to S020N005W34 – 38 miles

Please see map on next page.

APPENDIX 4b: ADDITIONAL DOUBLE BREAKLINE WATERBODIES



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