CHAPTER 8

Project Planning

8-1. General. This chapter contains guidance for US Army Corps of Engineers (USACE) project engineers, project managers, or project engineering technicians who are required to plan projects for photogrammetric or LiDAR mapping projects to be executed under negotiated qualification-based Architect-Engineer (A-E) contracts.

8-2. Technical Specifications. Each contract or task order for a USACE mapping project must refer to a technical specification that provides the necessary technical details about the specific requirements to be satisfied by a photogrammetric or LiDAR mapping project. A technical specification for a mapping project is a list of acceptance criteria that a mapping product must conform to in order to be considered acceptable for its intended use.

a. For standardization and interoperability purposes, USACE mapping specifications may cross-reference mapping standards published by the Federal Geographic Data Committee (FGDC), the American Society for Photogrammetry and Remote Sensing (ASPRS), the U.S. Geological Survey (USGS), or others, but specifications normally include acceptance criteria that do not need to be standardized across government organizations.

b. Chapter 3 of this manual, Applications and Accuracy Standards, includes USACE specifications for nine standard data accuracy classes for: (1) orthoimagery, based on ortho pixel size and horizontal accuracy requirements; (2) photogrammetrically-compiled planimetric data, based on source image ground sample distance (GSD) and horizontal accuracy requirements; and (3) LiDAR, based on point density and vertical accuracy requirements. Formulas are provided for comparable specifications when requirements differ from the nine standard data accuracy classes specified.

c. In addition to Accuracy Standards in Chapter 3, Chapter 4 provides additional specifications for orthoimagery and photogrammetric mapping, and Chapter 5 provides additional specifications for LiDAR projects.

8-3. Data Acquisition Planning. Planning for aerial data acquisition is always critical because of the importance of acquisition deadlines and considerations for weather and atmospheric conditions, sun angle conditions, leaf-on or leaf-off acquisition, flying heights, forward overlap and sidelap, LiDAR nominal pulse spacing (NPS), airborne GPS and survey ground control, available airports, flight restrictions, etc. These planning considerations, and others, are discussed in greater detail in Chapters 4 and 5.

8-4. Photogrammetric Mapping Production Workflow. In order to bring the various photogrammetric mapping procedures together in a logical sequence, Figures 8-1 and 8-2 illustrate a typical large scale photogrammetric and orthophoto production workflow. Orthophoto production is typically part of a standard large scale photogrammetric project and utilizes much of the same information collected for photogrammetric mapping to include aerial photography, ground control, aerial triangulation and digital terrain model development. However, when only orthophotos are required for a project, the amount of digital elevation model collection can be greatly reduced as well as the need for larger amounts of vertical control. The end user should be aware that a digital elevation model developed ONLY for orthophoto production will not be suitable for contour generation. This workflow diagram references several items that are described in detail in Chapter 4 - Aerial Photogrammetry.

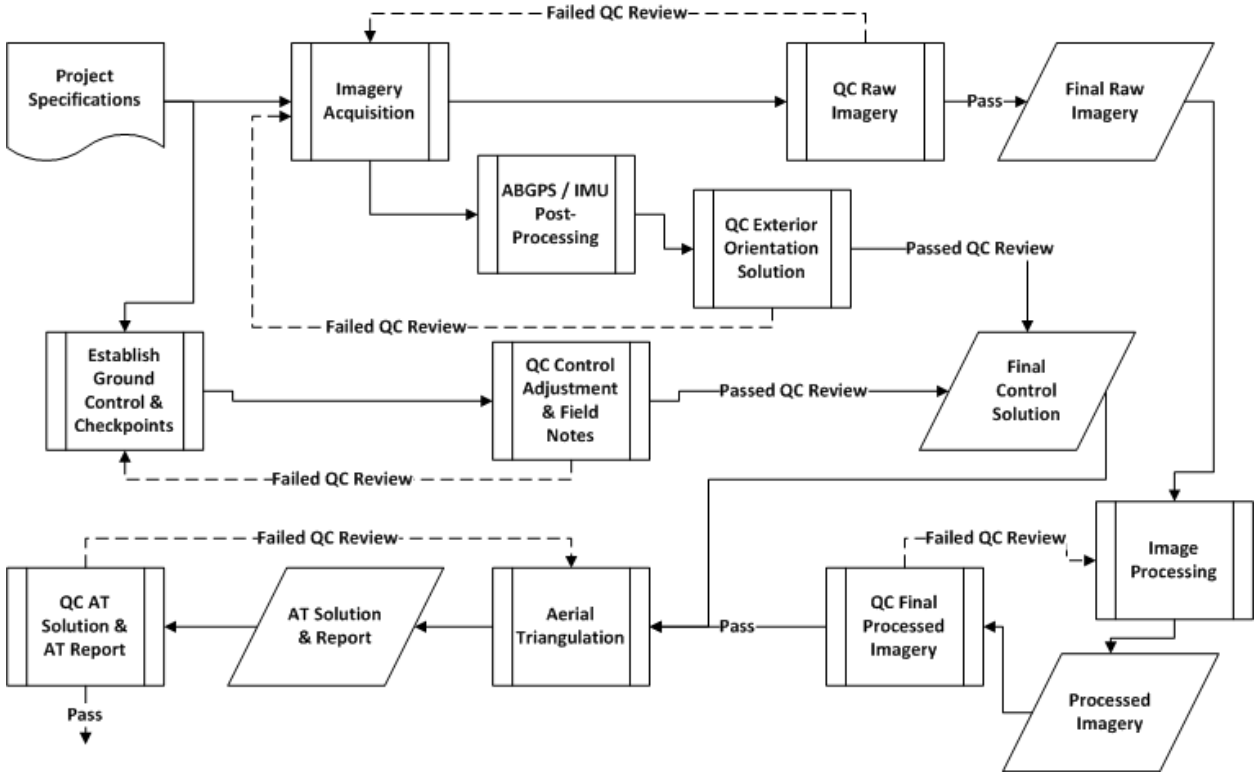

Figure 8-1 Typical Photogrammetric Mapping Production Flow Diagram through Aerial Triangulation

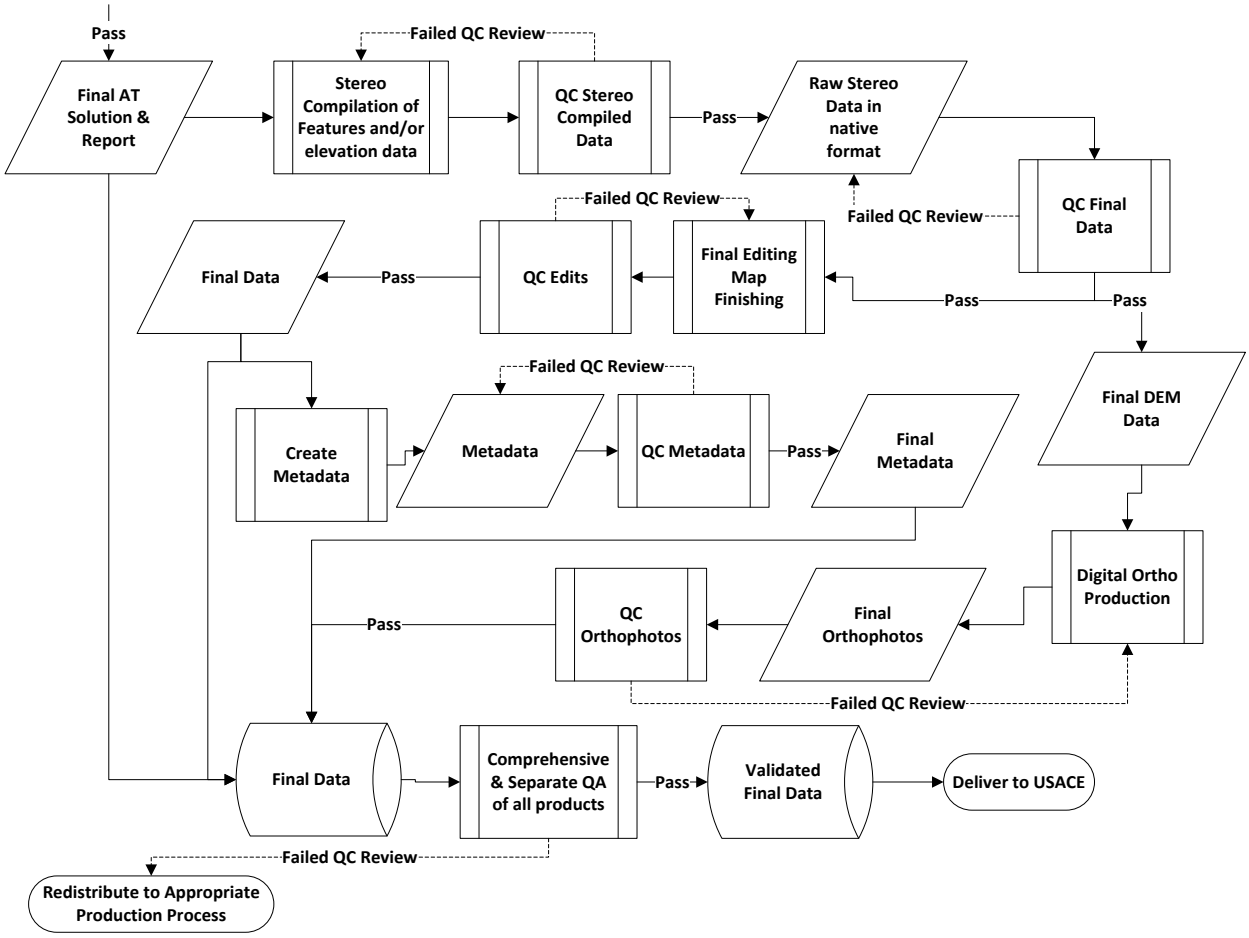

Figure 8-2 Typical Photogrammetric Mapping Production Flow Diagram after Aerial Triangulation

8-5. LiDAR Mapping Production Workflow. In order to bring the various LiDAR mapping procedures together in a logical sequence, Figure 8-3 illustrates a typical large scale LiDAR data production workflow. The end user should be aware that a LiDAR project will not necessarily yield the "typical" planimetric mapping features that are collected with a photogrammetric mapping project nor will it provide digital orthophotography. This particular workflow references a practice known as "lidargrammetry." In lidargrammetry, breakline feature collection is performed in a photogrammetric software environment using stereo pairs created from the LiDAR intensity information – please refer to Chapter 5 of this manual for more information about lidargrammetry. This workflow diagram references several items that are described in detail in Chapter 5- LiDAR.

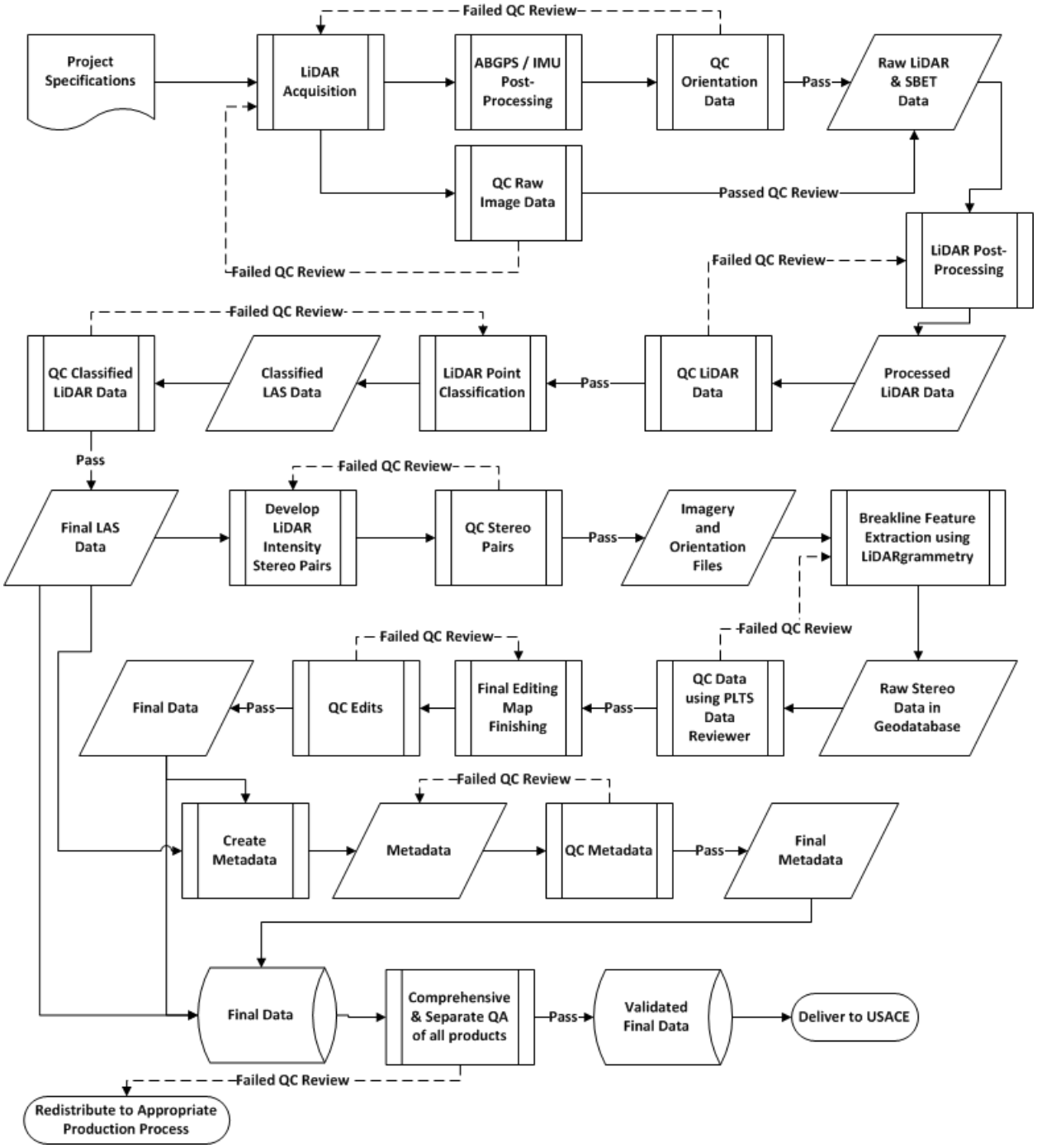

Figure 8-3 Typical LiDAR Mapping Production Flow Diagram

8-6. Collaboration. A collaborative mapping initiative is ideal for achieving the highest return on investment for the US government. Often, federal agencies will collaborate with other

federal, state or local government partners to perform detailed mapping that is suitable for a multitude of business applications. Working together fosters cost sharing and greatly reduces duplicative efforts. Within the federal and state government, there are established working groups that are designed to foster collaborative efforts.

a. National Digital Orthophoto Program (NDOP). The NDOP was established as a consortium of Federal agencies with the purpose of developing and maintaining national orthophotography in the public domain through established partnerships with other federal, state, local, tribal and private organizations. The NDOP operates a project tracking system whereby information on proposed, planned, in-work or completed orthophoto projects. The project tracking tool can be useful for the USACE to seek partners looking to acquire data over a specific area. http://www.ndop.gov

b. National Digital Elevation Program (NDEP). The NDEP is the coordinating body for the National Elevation Dataset (NED). The NDEP is a consortium of federal agencies working together to satisfy multiple elevation data requirements. The NDEP operates a project tracking system whereby information on proposed, planned, in-work or completed elevation projects is posted and shared. The project tracking tool can be useful for the USACE to seek partners looking to acquire data over a specific area. http://www.ndep.gov

c. The Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX). JALBTCX performs operations, research and development in airborne lidar bathymetry and complementary technologies to support the coastal mapping and charting requirements of the US Army Corps of Engineers (USACE), the US Navy (USN), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS). This is a highly successful collaboration that satisfies needs of engineers, scientists, hydrographers, and technicians throughout USACE and collaborating agencies. http://www.jalbtcx.org

8-7. Data Mining. Data mining in this context is the process of examining known geospatial data portals to see if data already exists in the public domain that may support the specific USACE requirement in the defined area of interest. Many federal and state groups have established data portals for identifying and downloading data. Data on these sites have varying degrees of completeness, accuracy, lineage and currency so it is critical to evaluate all project reports and metadata before making a determination that the publicly available data will be suitable for the intended application. The programs and websites noted below are not a fully exhaustive list and focus on the primary data resources used by the Federal Government. In addition to these programs, many states maintain their own data warehouses that can also be found through a simple web search using keywords “GIS Data Portal”.

a. Center for LiDAR Information, Coordination and Knowledge (CLICK). CLICK was developed by the United States Geological Survey (USGS) to foster LiDAR information

exchange and topographic data discovery. The website includes a tool for viewing the coverage of available data and downloading elevation point cloud data. http://LiDAR.cr.usgs.gov

b. OpenTopography Portal. The OpenTopography Portal is a collaborative partnership between computer scientists at San Diego Supercomputer Center at the University of California, San Diego and the School of Earth and Space Exploration at Arizona State University. Core operational support for OpenTopography comes from the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) to support various research and development activities. http://www.opentopography.org

c. Random Access Metadata for Online Nationwide Assessments (Ramona). The National States Geographic Information Council (NSGIC) established the Ramona GIS Inventory as a tool for states and their partners. The primary purpose of Ramona is to track data availability and the status of geographic information system (GIS) implementation within state and local governments. The tool is searchable and can return information about geospatial data available for specific areas of interest. http://gisinventory.net

d. NOAA's Digital Coast. The Digital Coast is a collaborative project and partnership between the NOAA Coastal Services Center, the National Association of Counties (NACo), the National States Geographic Information Council (NSGIC), The Nature Conservancy (TNC), the Association of State Floodplain Managers (ASFPM), the Coastal States Organization (CSO), and the American Planning Association (APA). This website includes data, tools, training and actions. The majority of the data holdings on the digital coast are topographic and bathymetric data. In addition to NOAA, many of the project's partners contribute to the vast LiDAR data collection housed in the Digital Coast. Data are available for all of the coastal states and range from strips of data along the shore to full counties of data that touch the coast. http://www.csc.noaa.gov/digitalcoast

e. Data.gov. This website was developed through an Executive Order and is designed to increase public access to high value, machine readable datasets generated by the Executive Branch of the Federal Government. This website has integrated what was formally known as the "Geospatial One-Stop." It has migrated from Geodata.gov to its current data.gov configuration. http://www.data.gov

8-8. Summary of Deliverables for Photogrammetric Projects. This section contains a comprehensive summary of deliverable products that are typical for photogrammetric projects procured by the USACE. Additional deliverables may be requested by the contracting officer to support mission-specific applications within the Area of Interest (AOI) providing that the additional deliverables are possible outputs from a photogrammetric survey.

a. Project Reports. Reporting is a critical communication tool that provides important information about the overall project from the beginning of the project planning phase through

development of all project deliverables. All reports should be provided in a digital file format like .pdf and should be provided on deliverable media. The following reports are considered standard by both USACE and the photogrammetric industry.

(1) Work Plan. A work plan is typically developed immediately following award by the government. The work plan should contain, at a minimum, all of the critical communication, technical and quality components that will be exercised throughout the project to ensure that the contractor meets the requirements of the government. The work plan should also include a comprehensive list of deliverables and an initial schedule for the project. Digital maps of the planned flight lines and the planned GPS base stations should also be provided with the work plan. The government should provide a comprehensive review and approval of the work plan before allowing work to proceed.

(2) Aerial Acquisition Report. A detailed acquisition report is typically developed immediately after the conclusion of the data acquisition activities. The report should contain, at a minimum, details about the mission planning, flight parameters utilized, and the ground control layout for all base stations and supporting control. The report should also contain a detailed daily log of all missions flown, the weather conditions during flight and the number of missions and flight lines captured per day. As-flown maps of the flight lines, control utilized and GPS base stations should be included in the report. For digital frame photography, a digital file of the processed photo centers should also be provided to be used as a photo index.

(3) Aerial Triangulation Report. A comprehensive aerial triangulation report is typically developed and delivered before the final datasets are produced. The aerial triangulation report should contain, at a minimum, information about the processes and procedures used for aerial triangulation and data QA/QC. This report should also contain a comprehensive statistical assessment of the aerial triangulation data developed by the project.

(4) GPS Survey Report. A detailed GPS survey report should be developed that includes two types of control points. The first type of control points are the GPS locations used to aid in the positioning and aerial triangulation of the photogrammetric data. The second type of control points are independent checkpoints that are used in the quantitative assessment of the final data. This report should include the survey methods and the survey equipment utilized. It should also include the detailed network adjustment results and the final data processing procedures. Finally, it should contain the final processed coordinates for each survey point and detailed photographs and field notes for those points. Digital maps of the survey network and digital files of the actual coordinates are also typically provided with this report.

b. Project Metadata. In addition to the project reports, a comprehensive set of FGDC-compliant metadata should be delivered for each deliverable. Important decisions that should be made during the project planning phase should be whether the project requires tile level metadata

or project level metadata. Metadata are generally provided in an XML file format on deliverable media.

(1) File Level Metadata. File level FGDC-compliant metadata contains a corresponding metadata record for each individual deliverable. If the project contains 500 orthophoto tiles, for example, there would be 500 corresponding metadata records associated with those tiles. The advantages of file level metadata are that each record contains unique information about each individual tile. The disadvantage of this approach is that it is more costly for the contractor to produce.

(2) Project Level Metadata. Project level FGDC-compliant metadata contains a single metadata record for a full set of deliverables. If the project contains 500 orthophoto tiles, there would be a single metadata record associated with those tiles.

c. Photogrammetric Data. The term photogrammetric data can have a wide variety of meanings depending on the specific Scope of Work developed for each specific project. The items mentioned below are not always required but are common deliverables developed for large scale photogrammetric mapping projects.

(1) Digital Imagery. Digital copies of the aerial photographs are a standard deliverable regardless of whether the image was captured with an analog camera system and then scanned into a digital format or if the project imagery was captured with a direct-to-digital imaging sensor. Commonly, this imagery should contain minimal, if any, compression. The file format for this imagery can vary but are most often provided in TIFF or JPEG2000 formats. There should be one image associated with every camera station provided in the aerial acquisition report. The “camera station” defines the position (x/y/z coordinates) and orientation (roll/pitch/yaw) of the camera when each image is acquired from a digital frame camera. In the case of pushbroom sensors, swaths of imagery are acquired (e.g., 12,000 to 24,000 pixel-wide swaths) while sensors record the positioning and orientation of the sensor for each swath.

(2) Planimetry. Many large scale photogrammetric projects involve the development of vector planimetric data layers to represent important physical or cultural features on the map. These features are developed photogrammetrically and are typically delivered in accordance with the SDSFIE (Spatial Data Standard for Facilities, Infrastructure & Environment) data standards in a file format structure that is acceptable within the SDSFIE standard. It is important to specify exactly which photogrammetric features should be captured within the contract Scope of Work so as to avoid any potential miscommunication about the government’s expectations.

(3) Digital Terrain Model. When developing a large scale photogrammetric solution, it is typical for the contractor to develop a DTM (Digital Terrain Model). The DTM contains linear vector features known as breaklines and single, discrete points known as mass points. DTM’s

are commonly associated with the development of topographic contours to be shown on the map. DTM data are generally delivered in either a vector format or in ASCII file format.

(4) Contours. A contour is a vector line that represents a single elevation as depicted on a map. Contours are most commonly used for human interpretation of terrain or natural relief within a project. Contour deliverables should include the specific interval at which the contours were developed and should be delivered in a vector format in accordance with the SDSFIE requirements. The contour interval should always be greater than or equal to 3.2898 times the vertical RMSE (RMSEz) and in whole integer values (normally, 1, 2, 4, 5 or 10) feet or meters.

(5) Digital Orthophotography. Orthophotos are digital images that have been rectified to an elevation model to remove relief displacement and distortion from the raw digital imagery. Multiple orthophotos of single frames are mosaicked together to remove tonal discrepancies from frame-to-frame and then are cut into tiles of a size to be specified in the Scope of Work. The Scope of Work for the contractor should include specifics about both the size of each orthophoto tile and the specific naming convention to be utilized. Orthophotos are usually delivered as uncompressed GeoTIFF's. Additionally, they are also sometimes merged and compressed to form a single mosaic of a larger area and those compressed files can be delivered in JPEG2000, MrSID or ECW file formats on hard drive.

8-9. Summary of Deliverables for LiDAR Projects. This section contains a comprehensive summary of deliverable products that are typical for LiDAR projects procured by the USACE. Additional deliverables may be requested by the contracting officer to support mission-specific applications within the AOI providing that the additional deliverables are possible outputs from a LiDAR Survey.

a. Project Reports. Reporting is a critical communication tool that provides important information about the overall project from the beginning of the project planning phase through development of all project deliverables. The following reports are considered standard by both USACE and the LiDAR industry.

(1) Work Plan. A work plan is typically developed immediately following award by the government. The work plan should contain, at a minimum, all of the critical communication, technical and quality components that will be exercised throughout the project to ensure that the contractor meets the requirements of the government. The work plan should also include a comprehensive list of deliverables and an initial schedule for the project. Digital maps of the planned flight lines and the planned GPS base stations should also be provided with the work plan. The government should provide a comprehensive review and approval of the work plan before allowing work to proceed.

(2) LiDAR Acquisition Report. A detailed acquisition report is typically developed immediately after the conclusion of the data acquisition activities. The report should contain, at a minimum, details about the mission planning, flight parameters utilized, and the ground control layout for all base stations and supporting control. The report should also contain a detailed daily log of all missions flown, the weather conditions during flight and the number of missions and flight lines captured per day. As-flown maps of the flight lines, control utilized and GPS base stations should be included in the report. A GPS processing summary should be included in the report. The GPS report should include maps showing the quality of the GPS trajectory solution, forward-reverse combined separation, PDOP, and number of satellites. An IMU processing report with graphs showing sensor errors and other navigation quality parameters should be included. In some cases, the LiDAR Acquisition Report can be incorporated into a comprehensive LiDAR report and delivered at the conclusion of the project.

(3) LiDAR Processing Report. A comprehensive processing report is typically developed and delivered with the final datasets. The processing report should contain, at a minimum, information about the processes and procedures used for data calibration, LiDAR classification and data QA/QC. This report should also contain a comprehensive quantitative assessment of the LiDAR data developed by the project. If supplementary data products, such as breaklines, DEM's and contours are developed for the project, detailed information explaining how those products were developed should also be included. In some cases, the LiDAR Processing Report can also include the LiDAR Acquisition Report to form a comprehensive LiDAR Report.

(4) GPS Survey Report. A detailed GPS survey report should be developed that includes two types of control points. The first type of control points are the GPS locations used to aid in the positioning and calibration of the LiDAR data. The second type of control points are independent checkpoints that are used in the quantitative assessment of the final data. This report should include the survey methods and the survey equipment utilized. It should also include the detailed network adjustment results and the final data processing procedures. Finally, it should contain the final processed coordinates for each survey point and detailed photographs and field notes for those points. Digital maps of the survey network and digital files of the actual coordinates are also typically provided with this report.

b. Project Metadata. In addition to the project reports, a comprehensive set of FGDC-compliant metadata should be delivered for each deliverable. Important decisions that should be made during the project planning phase should be whether the project requires tile level metadata or project level metadata.

(1) File Level Metadata. File level FGDC-compliant metadata contains a corresponding metadata record for each individual deliverable. If the project contains 500 LiDAR data tiles, for example, there would be 500 corresponding metadata records associated with those tiles. The advantages of file level metadata are that each record contains unique information about each

individual tile. The disadvantage of this approach is that it is more costly for the contractor to produce.

(2) Project Level Metadata. Project level FGDC-compliant metadata contains a single metadata record for a full set of deliverables. If the project contains 500 LiDAR data tiles, there would be a single metadata record associated with those tiles.

c. LiDAR Data. The LiDAR data contains individual point cloud information for each individual pulse emitted from the LiDAR sensor. LiDAR data is typically delivered in the ASPRS LAS format. LAS is a public file format for the interchange of 3-D point cloud data between data users. The LAS standard is published by ASPRS (American Society for Photogrammetry and Remote Sensing) and is updated regularly. The point cloud data contains information about each point that allows it to be further categorized into sub-categories.

(1) Classified Point Cloud Data. This deliverable should contain all LiDAR records classified by type into logical classes associated with the LAS standard. Most common classifications include Class 1 – Unclassified, Class 2 – Ground, Class 7 – Noise, Class 9 – Water and Class 12 – Overlap.

(2) Bare Earth LiDAR Data. Once the full point cloud has been classified within the LAS structure, it is a relatively simple process to extract to a separate LAS deliverable the records from Class 2 only that are associated with the bare earth LiDAR data.

(3) First Return LiDAR Data. A first return LiDAR dataset consists of heights of the first discernible object within the path of the illuminated footprint of the laser pulse. In forested areas, these heights typically represent the tops of tree canopies. The first return dataset also includes heights of hard surfaces illuminated by the entire footprint of the laser pulse, such as roads or rooftops. These data can be extracted from the LAS file format by selecting all records with return number = 1.

(4) Last Return LiDAR Data. Similar to the First Return LiDAR Data, the Last Return LiDAR consists of the heights of the last discernible object within the path of the illuminated footprint of the laser pulse. In forested areas, these heights may represent bare earth or low lying vegetation so long as there are gaps in the canopy for the laser pulse to penetrate through to reach those features. On hard surfaces, where there is only one return, the first and last returns represent the heights of the same object. The last return data are most often used in the process of classifying the bare earth surface. These can be extracted from the LAS file format by selecting all records with return number = number of returns.

(5) Model Key Point LiDAR Data. Model key points are determined through an algorithmic process to develop a subset of points from the Class 2 ground points that are considered to be

"key" points for that particular dataset. Typically, this output represents a thinned version of the final bare earth points. These points are frequently used to generate contours that may be developed for a project. These data are stored in the classified LAS file format (class code = 8).

d. Ancillary Data. A typical LiDAR project often involves the creation of other ancillary data developed directly from the LiDAR data. These additional datasets are valuable inputs into many engineering projects and should be considered as critical deliverables if they are developed in support of the overall LiDAR approach.

(1) Breaklines. LiDAR breaklines can be developed using a number of acceptable methods. In general, they are vector-based features added to the LiDAR data to develop a more robust 3-D model of the Earth's surface. The breaklines themselves can be both 2-D and 3-D features and are frequently developed to assist with the classification of features in Class 9 – water. Breaklines should be delivered in a digital file format clearly defined in the Scope of Work.

(2) Digital Elevation Models. A DEM (Digital Elevation Model) is a raster interpretation of the final LiDAR surface. The Scope of Work should clearly explain whether the DEM should have characteristics of hydro-enforcement or hydro-flattening as explained in Chapter 5. DEM's are generally delivered in a tiling structure that matches the LAS files and are usually delivered in ERDAS .img format or in an ESRI ArcGrid float format.

(3) LiDAR Intensity Orthophotos. Each LiDAR discrete return carries a unique signature with information about the intensity of the pulse as it returns to the sensor. This intensity record can be converted into a raster image file through LiDAR processing software. Many contractors develop intensity orthophotos to support their internal QA/QC of the LiDAR data and to use in the development of breaklines. Intensity orthophotos are generally delivered in a tiling structure that matches the LAS files and are typically delivered in an uncompressed GeoTIFF format.

8-10. Sample Project Checklist. The following checklist from a sample LiDAR project represents

- ☐ **Raw Point Cloud Data**
  - ☐ LAS version 1.2
  - ☐ Georeferenced
  - ☐ Unique GPS Times for each LiDAR return are included
  - ☐ Intensity values are included
  - ☐ Full swaths
  - ☐ 1 file per swath, 1 swath per file, file size does not exceed 2GB
- ☐ **Classified Point Cloud Data**
  - ☐ LAS Version 1.2
  - ☐ Correct Georeference Information
  - ☐ Contains unique GPS Times for each LiDAR return

- ☐ Contains Intensity Values
- ☐ Tiled to 5000’ x 5000’ Tile Grid
- ☐ Classified with class 1 – Unclassified, class 2 – Bare-earth Ground, 7 – Noise, 9 – Water, 10 – Ignored ground.

☐ **Bare Earth Surface (Raster DEM)**

- ☐ Cell size of 5’
- ☐ ERDAS .img File format
- ☐ Georeference information included (xml files)
- ☐ Tiled with no overlap
- ☐ Reviewed for edge matching and artifacts
- ☐ Free of void areas
- ☐ Hydrographic features have been hydro-flattened/hydro-enforced per the SOW

☐ **Digital Surface Model (Raster DSM)**

- ☐ Cell size of 5’
- ☐ ERDAS .img File format
- ☐ Georeference info included (xml files)
- ☐ Tiled with no overlap
- ☐ Reviewed for edge matching
- ☐ Free of void areas
- ☐ Created with all first return LiDAR data (no noise points used)

☐ **Survey Data**

- ☐ Supplemental Ground Control and reports
- ☐ Ground Control Quality Check points and reports
- ☐ Control and calibration points

☐ **Metadata**

- ☐ FGDC Compliant Metadata for:
- ☐ Deliverables (LAS, DEM, DSM, Breakline)

☐ **Project Reports**

- ☐ Collection Report detailing mission planning and flight logs
- ☐ Survey Report
- ☐ Processing Report
- ☐ QA/QC Reports

☐ **Extents**

- ☐ Tile grid derived from the LiDAR Deliverable
- ☐ Project Boundary delivered as shapefile

- ☐ Project Boundary buffered 140 meters and delivered as shapefile

☐ **Breakline Data**
- ☐ Breakline Data in GDB
- ☐ Breakline Data as Shapefiles

8-11. Quality Assurance and Quality Control (QA/QC)

a. Quality Assurance (QA). QA activities are process oriented and can include all processes from the original articulation of product specifications and acceptance criteria through the final delivery of geospatial products, including a determination that the final deliverables are usable and appropriate for their intended applications. QA ensures that the correct quality processes are used.

b. Quality Control (QC). QC includes methods or activities designed to test or evaluate a geospatial product. QC is initially performed by the geospatial vendor to identify and correct any deficiencies prior to delivery. QC reviews are performed to determine if the deliverables satisfy the product specifications and acceptance criteria. QC activities are product oriented. QC validates that the QA processes worked effectively.

c. Independent QA/QC. USACE Divisions and Districts may choose to consider separate contracts for independent QA/QC for the following reasons:

(1) Intense cost competition and rushed schedules have caused production firms to rely largely on automated QC processes. As a result, many geospatial products are untested and unseen by human eyes prior to delivery.

(2) Producers deliver many hundreds of Gigabytes of data per week, and they deserve prompt acceptance or rejection comparable to the urgency of deliverables in their Scope of Work.

(3) Although there is an obvious need to ensure that USACE receives the quality products it pays for, few USACE Divisions or Districts have Certified Photogrammetrists, geodesists, or LiDAR specialists on staff, or the professional expertise, technical capabilities and capacity to perform QA/QC in-house cost-effectively.

(4) In some cases, USACE Divisions or Districts may require independent QA consulting services to determine geospatial product(s), accuracy classes and acceptance criteria best suited to satisfy user requirements – prior to contracting for data acquisition and deliverables.

d. Acceptance Criteria. Quality should never be assured only at the end of the production line. Quality should be designed into the process from the beginning, starting with a thorough

analysis of user requirements, product specifications and acceptance criteria for which there is complete consensus prior to aerial data acquisition. This is the most important step in project planning for any photogrammetric or LiDAR mapping project.

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