Final Topographic Data Development Report

Task Order HSFE02-09-J-0001 for Atlantic, Ocean, and Monmouth Counties, NJ

FEMA Contract HSFEHQ-09-D-0369

August 31, 2011

FEMA

Federal Emergency Management Agency
Department of Homeland Security
26 Federal Plaza
Room 1337
New York, NY 10278

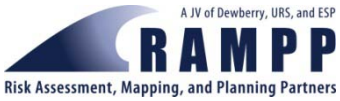
TECHNICAL SUPPORT DATA NOTEBOOK (TSDN)

for

Atlantic, Ocean, and Monmouth Counties, NJ

TOPOGRAPHIC DATA DEVELOPMENT TSDN

SUBMITTED BY:



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DATE SUBMITTED: August 31, 2011

TABLE OF CONTENTS

FIGURES

APPENDICES

ACRONYMS AND ABBREVIATIONS

AOI	Area of Interest
ALS	Airborne Laser scanner
ASPRS	American Society of Photogrammetry and Remote Sensing
DCS	Data Capture Standards
DEM	Digital Elevation Model
DFIRM	Digital Flood Insurance Rate Map
FEDI	Fugro-EarthData, Inc.
FEMA	Federal Emergency Management Agency
FGDB	File Geodatabase
G&S	*Guidelines and Specifications for Flood Hazard Mapping Partners*, as amended
LAS	LiDAR File Format
LiDAR	Light Detection And Ranging
MIP	Mapping Information Platform
NJ	New Jersey
NJDEP	New Jersey Department of Environmental Protection
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
QA/QC	Quality Assurance / Quality Control
RAMPP	Risk Assessment, Mapping, and Planning Partners
RMSE	Root Mean Square Error
Risk MAP	Risk Mapping, Assessment, and Planning
TIN	Triangulated Irregular Network
TSDN	Technical Support Data Notebook
USGS	Unites States Geological Survey

1.0 TASK SUMMARY

1.1 INTRODUCTION

This report presents the topographic data development Technical Support Data Notebook (TSDN) for the elevation data acquisition related to Atlantic, Ocean, and Monmouth Counties, NJ.

The deliverables for this TSDN submittal include written certification that the topographic data development meets minimum Federal Emergency Management Agency (FEMA) standards and specifications. In cases where data do not meet the required standards and specifications, an explanation is included. Additionally, the related metadata file has been uploaded to the Mapping Information Platform (MIP).

1.2 PROJECT WORK SCOPE

The following is the Risk Assessment, Mapping, and Planning Partners (RAMPP) Scope of Work for Task Order HSFE02-09-J-0001 for Atlantic, Ocean, and Monmouth Counties, NJ.

Scope: RAMPP used its subcontractor, Fugro-EarthData, Inc. (FEDI), to obtain topographic data for the areas within Atlantic, Ocean, and portions of Monmouth Counties, NJ. These data will be used for hydrologic analysis, hydraulic analysis, floodplain boundary delineation, and testing of floodplain boundary standard compliance. Both the *Guidelines and Specifications for Flood Hazard Mapping Partners, as amended* (G&S) Appendix A and the U.S. Geological Survey's (USGS) National Geospatial Program Baseline Specification Version 12 were used to satisfy the needs of FEMA, as part of FEMA's Map Modernization and Risk MAP (Risk Mapping, Assessment, and Planning), as well as the USGS requirement for the American Recovery and Reinvestment Act of 2009 in support of the National Map initiative. Because not all requirements in both specifications can be met, certain requirements and caveats are listed below.

Because the G&S Appendix A is well established, this served as the basis by which data was collected, with the following additions and modifications that incorporate the USGS baseline specification.

Collection:

The Light Detection And Ranging (LiDAR) collection utilized the current industry standard of G&S Appendix A and the USGS Baseline Specifications Version 12 except for the following points:

- Although not explicitly stated in the G&S, the point spacing meets a nominal spacing of 1 meter. This point density exceeds the USGS minimum requirement of a 2-meter point spacing product and meets the engineering studies that are required. However, the USGS baseline specification (**USGS I.6),** whereby 90 percent of cells in a grid shall contain 1 point was

not met based on a 1-meter grid. However, the specification that 90 percent of the cells be in a 2-meter grid was met.

- The vertical accuracy as defined by using the National Standard for Spatial Data Accuracy vertical Root Mean Square Error (RMSEz) exceeds the FEMA consolidated RMSE of 18.5 centimeter (cm) and is 15 cm or better (**USGS I.8**). The collection of checkpoints and accuracy testing conforms to the current G&S Appendix A.
- The relative accuracy as defined in the USGS baseline specification (**USGS I.9**) of 5 cm within a swath and from swath to swath is not consistently achievable, due to the relative accuracies of LiDAR technology, and, therefore, a relative accuracy from swath to swath is 10 cm and 5 cm within one swath.
- The collection area conforms to a 100-meter buffer outside the project area, instead of the 200 x Nominal Point Spacing buffer requirement (**USGS I.11**)
- LiDAR was collected at low tide, which is defined as when the height of tide is different from Mean Lower Low Water by 50 percent of the diurnal tide range or less, as predicted by the National Oceanic and Atmospheric Administration's National Oceanic Service Center for Operational Oceanographic Product and Services (http://www.co-ops.nos.noaa.gov/).

All other USGS collection parameters are met as defined in USGS I.1 – I.12 except for those listed above.

Data Processing and Handling

To the fullest extent possible, Data Processing and Handling conformed to G&S Appendix A and the USGS Baseline specification except for the following points:

- Data was processed and delivered in LiDAR File Format (LAS) 1.2 (**USGS II.1**), where all the required data structure is maintained by the LiDAR processing software, and the current version of TerraScan. Because some information is stripped from the source LAS during proprietary software processing, it was not possible to maintain every field in LAS 1.2, but all major fields were maintained.
- Data was processed in one horizontal coordinate system and units as decided by both FEMA and USGS (**USGS II.3**).
- The point order is subject to the existing processing software and therefore cannot be guaranteed to be maintained prior to tiling (**USGS II.6** and **II.9**).
- Outliers, blunders, noise points, etc. (**USGS II.10**) were classified in either LAS Class 7 or Class 1, unless the "point withheld" function was fully utilized in the current TerraScan version.
- The data was validated for positional accuracy (**USGS II.13**) prior to classification, but only using fundamental checkpoints consisting of bare-earth (short grass, dirt, or rock).

- FEMA Appendix A does not require swath data, but it is provided (**USGS II.8**).

All other USGS collection parameters were met as defined in II.1 – II.15 except for those listed above.

Hydro Flattening

Hydro Flattening is not required by the G&S, but was produced for all project areas as defined in the scope of work. All USGS requirements were met except for the following:

- All hydro flattening procedures pertain to creating a Digital Elevation Model (DEM), and the computed LAS elevations were not changed. However, the line work (breaklines and hydro-lines) may be used to help classify the LiDAR data.
- Inland ponds and lakes (**USGS III.1**) were classified for 2 acres or less at the time of data collection. The LiDAR and intensity were used to define the extents of these features.
- Inland streams and rivers (**USGS III.2**) were flattened bank-to-bank to the extent possible, but some artificial smoothing was required. The land/water interface does not depict the true elevation of the water and will only be representative to ensure that the water follows the gradient. Additionally, in complex areas such as braided streams and around multiple islands, the water surface may be stair-stepped in elevations to maintain bank-to-bank flatness.
- To maintain the ground elevations, some water surface elevations may appear higher than the upstream portion if affected by tidal waters (**USGS III.4**).
- Bare-earth points may be removed when in close proximity to breaklines to create the DEM, but may also be used if the accuracy is maintained or improved (**USGA III.4.1**).
- Due to the bank-to-bank flattening and the complexities of some hydro features, it may not be possible for the USGS to easily repeat this process (**USGS III.4.3**).

In addition to the aforementioned hydro flattening requirements, a meeting with USGS (05/12/11) underscored the interest in obtaining a hydro-flattened DEM that meets three basic requirements:

1) Dual waterways must flow downhill.
2) Water must be flat (no bubbles) closed water bodies and dual line waterways.
3) The horizontal placement of the breaklines must generally match the LiDAR data.

USGS communicated that if the hydro-flattened DEM meets the above basic requirements, the product will be in compliance with the agreed-upon project specifications, regardless of the methodology or process used to meet the basic

requirements. This shaped the approach this project used to meet the requirements and be deemed acceptable by USGS, as follows:

- The existing New Jersey Department of Environmental Protection (NJDEP) data was used.
- Any river or stream under the 100' USGS V.12 specification was deleted.
- New ponds or lakes that are over 2 acres were added.
- Any existing lakes smaller than 2 acres were left in the dataset.
- Only areas showing water in the LiDAR data were collected, no dry area collection.
- If the NJDEP hydro line is on the bank, it was moved off the bank.
- If the NJDEP hydro line was not on the bank, it was not touched.
- Hydro lines within the banks may cause DEM anomalies as points outside old bank may be lower.

Standards: All topographic development was performed in accordance with the G&S and Procedure Memorandums, FEMA's Geospatial Data Coordination Policy, FEMA's Geospatial, Data Coordination Implementation Guide, National Flood Insurance Program Metadata Profile Specifications, 44 Code of Federal Regulations Parts 65, 66, and 67. Deliverables will be provided according to FEMA G&S Appendix M.

Deliverables:

- Metadata: All deliverables to support the FEMA flood study process will be provided. All metadata requirements for the USGS will be provided with exceptions to the following:
  - All metadata requested (**USGS IV.1**) will be delivered, but some features such as geo-referenced, spatial representations cannot be inserted into metadata, and will instead be part of the metadata deliverable (reports) in digital format in both hard- and softcopy.
  - Metadata and associated reports will be provided for the project, by product group, and—if required—by swath, but not by lift (**USGS IV.1**).
  - Intensity values will be delivered in the dynamic range as collected, and no rescaling of the raw data will be performed (**USGS IV.2 and IV.3**).
  - Vertical accuracy of the bare-earth DEM will be assessed using the checkpoints, but it is understood that since the DEM is an interpolated dataset, some checkpoints may not yield the same accuracies as when comparing checkpoints to a Triangulated Irregular Network (TIN).
- Mass points and breaklines data
- Gridded DEM data
- Checkpoint analyses to assess the accuracy of data, including RMSE calculations to support vertical accuracy
- Void areas: identification of voids and methods used to supplement data voids

- National Geodetic Survey data sheets for Network Control Points used to control remote sensing and checkpoint ground surveys
- Other supporting files consistent with Data Capture Standards (DCS) in the G&S
- A Summary Report that describes and provides the results of all automated or manual QA/QC review steps taken during the preparation of the topographic data as outlined in the QA/QC plan
- Recommendations to resolve any problems that are identified during the independent QA/QC review
- A report summarizing the findings of the field reconnaissance
- Maps and drawings that provide the detailed survey results
- Documentation of the horizontal and vertical datum

2.0 METHODOLOGY

2.1 ACQUISITION

LiDAR acquisition and processing to bare-earth was conducted by FEDI for the Area of Interest (AOI) in Atlantic, Monmouth, and Ocean Counties, New Jersey. The AOI covers approximately 1,612 square miles. The AOIs were processed to a Level 2, which is a fully calibrated, classified point cloud LAS data set consisting of:

- Class 1 – Processed but unclassified
- Class 2 – Bare-earth ground
- Class 7 – Low points and noise
- Class 9 – Water
- Class 11 - Withheld

Figure 1 depicts the data area included in this delivery.

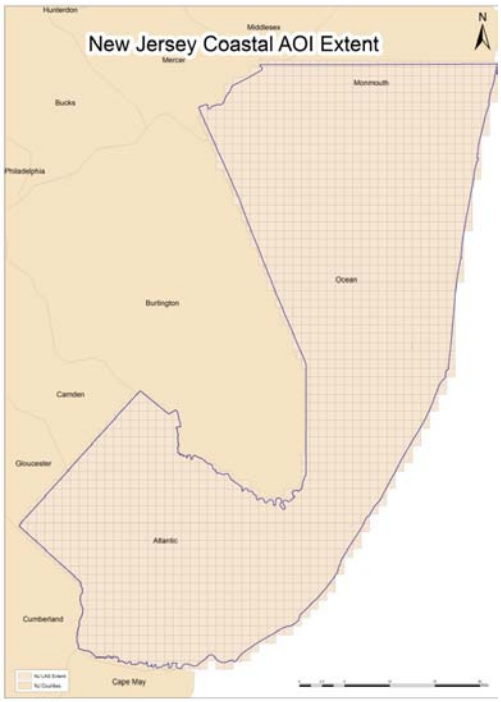


Figure 1. New Jersey Coastal AOI data coverage

2.2 PROCESSING

Processing of the LiDAR data begins with refinement of the initial boresight alignment parameter in the Airborne Laser Scanner Processor configuration file (.reg) delivered with the raw data. For projects that have more than one lift, the boresight for each lift has to be completed individually because it may differ slightly from lift to lift. Lift boresighting is accomplished using the tri-directional calibration flight lines over the project area. One calibration flight line is flown bi-directionally overlapping a project flight line within the lift. This bi-directional calibration will also be used as a parallel flight line with the adjacent flight line. There is a cross flight line collected perpendicular to both. All three lines along with the parallel project flight line are examined to ensure that they agree, within expected system tolerances, in the overlapping areas. The two bi-directional flight lines are used to diagnose Roll and Pitch. The two parallel flight lines are used to diagnose and correct Heading error. The two perpendicularly overlapping flight lines are used to examine Variable Scan Angle error. To begin lift boresight, the raw LiDAR data of the calibration flight lines is processed with the initial boresight parameters determined from the LiDAR Sensor Calibration. Once the boresighting is done for the calibration flight lines, the adjusted settings are applied to the complete lift and checked for consistency.

For a well-maintained LiDAR system, functioning correctly under normal operating conditions, actual boresight angles can be considered constant throughout a single mission. Therefore, once the boresight angles have been adjusted based on the calibration flight lines, the same corrections can be applied to the entire lift. Under

optimal circumstances, the boresight parameters determined for the calibration flight lines should be the same for all flight lines in the lift, but residual errors can occur. To correct for this, all of the overlaps between flight lines (side lap) and intersections of the project cross flight lines should be examined for internal consistency. If the results of the boresights start showing drift in the middle of the lift or the misalignment between flight lines starts exceeding project accuracy specifications, boresight parameters need to be adjusted to correct these errors.

Once boresight adjustments are completed for each individual lift, the technician checks and corrects the vertical misalignment of all the flight lines and also the matching between data and ground truth. This process includes calculating the z-bias value for each flight line so that all flight lines are vertically aligned and the entire dataset matches to the ground control points within the project specified accuracy range. The technician will run a final vertical accuracy check after the z correction. The result will be analyzed against the project-specified accuracy to verify it meets the requirement.

2.3 DATA EVALUATION

RAMPP evaluated the LAS and byproducts data and provided final LiDAR QA report for Atlantic, Ocean, and Monmouth Counties, NJ, confirming that the data meets the project specification.

3.0 TSDN

3.1 GENERAL

All the LiDAR and byproducts data for the Atlantic, Ocean, and Monmouth Counties, NJ, AOI were acquired and processed as part of the topographic data. TSDN documentation forms are provided in Appendix A.

3.2 DELIVERABLES

All topographic data development TSDN files were submitted via hard drives to the FEMA Engineering Library. Supporting documentation was uploaded to the MIP. The following folder structure of the digital data was used:

- \General
  - XML_format metadata file
  - Certification
    - Certification of Compliance
  - Project narrative
    - Detailed Check and ITR
    - LiDAR TSDN

        - Atlantic, Ocean, and Monmouth Counties, NJ LiDAR Survey Report
        - Atlantic, Ocean, and Monmouth Counties, NJ AOI QC Report
- \All_Returns
    - LAS_PointCloud
        - LAS
- \Supplemental_Data
    - Layout
        - NJ_LiDAR_Boundary
        - NJ_LiDAR_Sheets
    - Shapefile
        - FINAL_boundary_100m_buffer_NJ_SPNJ_NSRS2007_ft
        - FINAL_tile_index_NJ_SPNJ_N
    - Trajectory
- \HDEM
- \Breaklines
    - New_Jersey_Hydro.gdb

4.0 EXCEPTIONS

For this project the development of terrain and cartographic contours was not scoped.

5.0 CONCLUSIONS

RAMPP completed the acquisition and processing of the Atlantic, Ocean, and Monmouth Counties, NJ AOI as described in Tasks Order HSFE02-09-J-0001 under the prime contract HSFEHQ-09-D-0369.

Final deliverables have been shipped to the FEMA Engineering Library and USGS (Rolla, MO) via external hard drive, and the appropriate documentation has been uploaded to the MIP.

6.0 REFERENCES

Federal Emergency Management Agency, *Guidelines and Specifications for Flood Hazard Mapping Partners*, as amended, Washington, DC. 2003

APPENDIX A
TSDN DOCUMENTS

Table A-3. Digital Topographic Data Requirements Checklist

Surface Description (choose one)
- ☒ Bare-earth surface (FEMA default)
- ☐ Top surface (e.g., treetops/rooftops)
- ☐ Bathymetric surface

Reflective surface (if using LIDAR)
- ☐ First ☐ Last (FEMA default) ☐ All
- ☐ LIDAR intensity returns
- ☐ Other simultaneous imagery

Vertical Accuracy (choose one)
- ☐ 1' contour equiv. (Accuracy$_z$ = 0.6 ft.)
- ☒ 2' contour equiv. (Accuracy$_z$ = 1.2 ft.)
- ☐ 4' contour equiv. (Accuracy$_z$ = 2.4 ft.)
- ☐ 5' contour equiv. (Accuracy$_z$ = 3.0 ft.)
- ☐ Other: Accuracy$_z$ = ___ ft

Vertical accuracy at the 95% confidence level (Accuracy$_z$) = RMSE$_z$ x 1.9600 with normal distribution

Horizontal Accuracy (choose one)
- ☐ 1" = 500' equiv. (Accuracy$_r$ = 11' or 3.35 m)
- ☐ 1" = 1000' equiv. (Accuracy$_r$ = 22' or 6.7 m)
- ☐ RMSE$_r$ = 1 m
- ☒ RMSE$_r$ = _0.6m

Horizontal accuracy at the 95% confidence level (Accuracy$_r$) = RMSE$_r$ x 1.7308

Data Model (choose one or more)
- ☐ Contours ☒ Mass points ☐ TIN (average point spacing = _0.6 meters) *
- ☐ Cross sections ☒ Breaklines ☒ DEM (post spacing = 1meter)

* FEMA's standard DEM post spacing is 5-meters when mass points are supplemented with breaklines for hydraulic modeling. The TIN point spacing is typically smaller than the DEM post spacing to allow a denser network of irregularly-spaced points for interpolation of the uniformly-spaced DEM.

Horizontal Datum (choose one)
- ☐ NAD 27 ☒ NAD 83 (default)

Vertical Datum (choose one)
- ☐ NGVD 29 ☒ NAVD 88 (default)

Coordinate System (choose one)
- ☐ UTM ☒ State Plane ☐ Geographic

Units Note: For feet and meters, vertical (V) units may differ from horizontal (H) units
- ☒ Feet to 2 decimal places ☒ V ☒ H ☐ Decimal degrees to ___ decimal places
- ☐ Meters to _3_ decimal places ☐ V ☐ H ☐ DDDMMSS to ___ decimal places

Feet are assumed to be U.S. Survey Feet unless specified to the contrary

Data Format (choose one or more)

Digital contour lines and breaklines
- ☐ .DGN
- ☐ .DO (DLG Optional)
- ☐ .DXF
- ☐ .E00
- ☐ .MIF/.MID
- ☒ .SHP
- ☐ SDTS
- ☐ TAB
- ☐ Other _____

Mass points and TINs
- ☐ ASCII x/y/z
- ☐ ASCII with attribute data
- ☐ BIN
- ☐ TIN Arc/Info Export File
- ☒ LAS mass points

DEMs
- ☐ ASCII x/y/z
- ☐ .BIL
- ☐ .BIP
- ☐ .BSQ
- ☐ .DEM (USGS standard)
- ☒ ESRI Float Grid
- ☐ ESRI Integer Grid
- ☐ GeoTiff
- ☐ .RLE
- ☐ Other _____

File size or Tile size (choose one)
- ☐ File size 342 MB or 1 GB (max)
- ☐ Tile size 10,000 ft x 10,000 ft (specify feet or meters)
- ☒ Other tile size: Varies due to buffered processing
- ☐ Buffer size: _____

Other Quality Factors (optional, explain on separate page)
- ☒ Cleanness from artifacts
- ☐ Limits on size/location of void areas where there are no elevation data shown
- ☐ How elevations are to be shown for void areas
- ☒ Hydro-enforcement Bridges/culverts removed? ☒ Yes ☐ No
- ☒ Other requirements

L.5 Federal Emergency Management Agency

Digital Mapping Information Checklist

The following checklist is intended to solicit basic information about the format of digital mapping data submitted to the Federal Emergency Management Agency (FEMA) for preparation of a Digital Flood Insurance Rate Map (DFIRM). Please note that metadata compliant with the Federal Geographic Data Committee's *Content Standard for Digital Geospatial Metadata* should be submitted also. This metadata must include the following information and further details about the data submitted.

Point of Contact:

Name and/or Title: Regional Support Center-II Coordinator
Community/Agency: RAMPP
Address: 560 Broadway, Suite 304
New York, NY 10012
Telephone: 940-735-3322
Email: miphelp@riskmapcds.com

Data Type:

Pertinent information includes the following:

Format:

- ☐ ESRI Coverage
- ☒ ESRI Shapefile
- ☐ MapInfo
- ☐ Intergraph
- ☐ AutoCAD
- ☐ Digital Line Graph
- ☒ Other: Terrain, DEM and TINs
- ☐ Digital Orthophoto
  - ☐ Black & white
  - ☐ Color
  - ☐ TIF
  - ☐ JPEG
  - ☐ SID
  - ☐ PNG
  - ☐ Raw
- ☐ Scanned
  - ☐ Georeferenced _____
  - ☐ Dots per inch _____
  - ☐ Black & white
  - ☐ Grey scale
  - ☐ Color

Source Information:

How and when were the data compiled? By whom? At what scale? Pertinent information includes the following:

- ☐ Photogrammetrically compiled
- ☒ LiDAR

☐ Digitized from a hardcopy source
- ☐ Parcel maps/Plat maps
- ☐ USGS quadrangles
- ☐ Orthophotos
- ☐ Aerial photos
- ☐ Other community map: _____
- ☐ Generated using coordinate geometry (COGO)
- ☐ Scanned

Date of photography or source material: Collection dates: April 1st – 7th 2010 and April 10th 2010.

Scale of data creation:
Agency or firm that produced the data: Fugro EarthData.

Date of creation (if incomplete, provide estimated completion date): September 1, 2011

Projection, Datums, Accuracy:

What coordinate system and projection were used? What horizontal and vertical datums were used? What is the stated accuracy of the data?

Coordinate system/projection:
- ☒ State Plane: New Jersey
- ☐ UTM: _____
- ☐ Geographic (latitude and longitude)
- ☐ Other: _____

Units:
- ☒ Feet
- ☐ Meters
- ☐ Decimal degrees
- ☐ Degrees, minutes, seconds
- ☐ Other: _____

Horizontal datum:
- ☐ NAD27, Clarke 1866 spheroid
- ☒ NAD83, NSRS 2007

Vertical datum:
- ☐ NGVD29
- ☒ NAVD88, Geoid 09
- ☐ Other: _____

Accuracy: Vertical elevations will meet or exceed 12.5 cm RMSE (Accuracyz = 0.245m at the 95% confidence level)
Horizontal accuracy will meet or exceed 0.6m RMSE (Accuracyr = 1.04 m at the 95% confidence level).

Data Contents:

What features are contained in the data set(s)? Are feature names included? If so, are they available as attributes and/or graphic text (annotation)? Please provide file structure details in the form of metadata, a data dictionary, or a layer list in addition to this form

☐ Roads
- ☐ Centerlines

- ☐ Edge of pavement
- ☐ Right of ways

☐ Road names
Scale(s) at which they were intended to be used _____

☐ Railroads
- ☐ Railroad names

☐ Airports
- ☐ Airport names

☒ Streams, lakes, other water bodies
- ☐ Feature names

☐ Range & township/section lines and numbers

☐ Political boundaries
- ☐ Area names

☐ Flood control structures (dams, weirs, jetties, culverts, etc.)

☐ Floodplain boundaries and/or other FIRM features

☐ Contours
Contour interval:

☒ DEM/DTM/TIN

☐ Building outlines

☐ Parcels

Transfer Media:

What options are there for transferring the data to other users? What are the platform options?

Media:

- ☐ CD-ROM
- ☐ 8mm tape
- ☐ 4mm tape
- ☐ Zip disk
- ☐ Diskettes
- ☐ DVD
- ☐ Email
- ☒ Other: MIP

Platforms:

- ☐ UNIX
- ☒ PC
- ☐ NT
- ☐ Other: _____

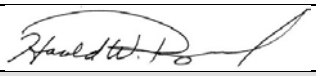
CERTIFICATION OF COMPLIANCE

Project Name:	FY09 LiDAR Acquisition – Atlantic, Ocean, and Monmouth, NJ
Statement of Work No.:	HSFE02-09-J-0001
Interagency Agreement No.:	
CTP Agreement No.:	
Statement/Agreement Date:	
Certification Date:	8/31/11

Tasks/Activities Covered by This Certification (Check All That Apply)

☐	**Entire Project**
☒	**Topographic Data Development**
☐	**Hydrologic Analyses**
☐	**Hydraulic Analyses**
☐	**Coastal Flood Hazard Analyses**
☐	**Floodplain Mapping**
☐	**Other (Specify):**

This is to certify that the work summarized above was completed in accordance with the statement/agreement cited above and all amendments thereto, together with all such modifications, either written or oral, as the Regional Project Officer and/or Assistance Officer or their representative have directed, as such modifications affect the statement/agreement, and that all such work has been accomplished in accordance with the provisions contained in *Guidelines and Specifications for Flood Hazard Mapping Partners* cited in the contract document, and in accordance with sound and accepted engineering practices within the contract provisions for respective phases of the work.

Name:	Harold W. Rempel
Title:	Senior Photogrammetrist
Firm/Agency Represented:	RAMPPP
Registration No.:	CP ASPRS #1418
Signature:	

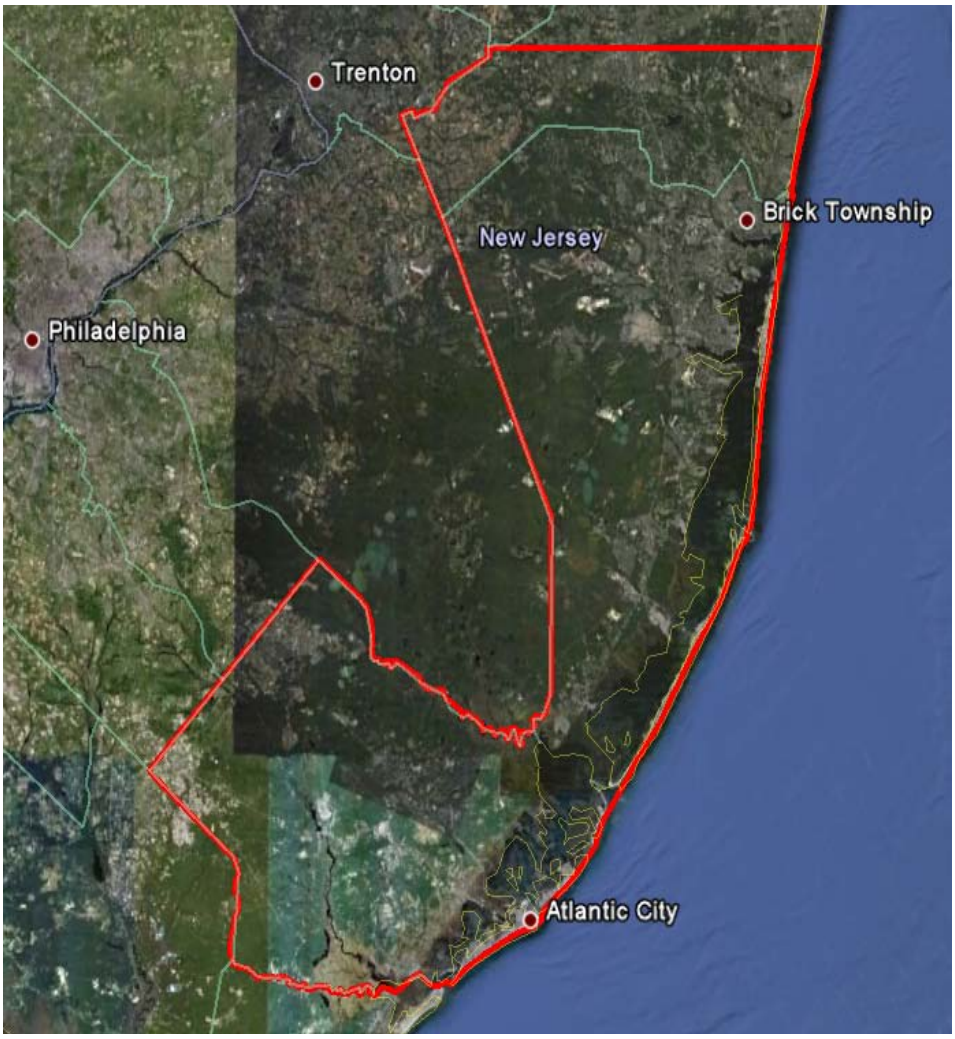
This form must be signed by a representative of the firm contracted to perform the work who is registered as a Professional Engineer or by the responsible official of a government agency.

APPENDIX B
LIDAR QUALITATIVE AND QUANTATIVE ASSESSMENT REPORT

A JV of Dewberry, URS, and ESP
RAMPP
Risk Assessment, Mapping, and Planning Partners

Atlantic, Monmouth and Ocean Counties, New Jersey

INDEPENDENT QUALITY CONTROL REPORT



FEMA Contract: HSFEHQ-09-D-0369
Task Order: HSFE02-09-J-0001
April 9, 2010
Revised July 2, 2010

A JV of Dewberry, URS, and ESP
RAMPP
Risk Assessment, Mapping, and Planning Partners

Atlantic, Monmouth and Ocean Counties, NJ
Independent Quality Control Report

1 Executive Summary

RAMPP performed a limited review of LiDAR data and LiDAR-derived data products for Atlantic, Ocean and portions of Monmouth counties in New Jersey. RAMPP reviewed 100% of the data for completeness and 5% for quality issues, according to the scope of work. Additionally a vertical accuracy assessment was performed and the dataset meets FEMA's vertical accuracy requirements and those described in the USGS NGP Base LiDAR Specifications v12.

2 Overview

The Independent Quality Control for the Atlantic, Monmouth and Ocean Counties, New Jersey, Areas of Interest (AOIs) was performed by RAMPP to validate LiDAR, 3D breaklines, and hydro-flattened DEM data quality for use in support of developing new flood hazard information that will be used in the update and creation of accurate flood zone maps in support of the National Flood Insurance Program. This document reports on the Atlantic, Monmouth and Ocean Counties AOI data delivery received from the RAMPP subcontractor Fugro EarthData, Inc. (FEDI) on January 24, 2011.

2.1 Project Area

LiDAR acquisition and processing to bare-earth was conducted by FEDI for the AOI in Atlantic, Monmouth and Ocean Counties, New Jersey. The AOI covers approximately 1,612 square miles. The AOIs were processed to a Level 2, which is a fully calibrated, classified point cloud LAS data set consisting of:

- Class 1 – Processed but unclassified
- Class 2 – Bare-earth ground
- Class 7 – Low points and noise
- Class 9 – Water
- Class 11 - Withheld

Figure 1 depicts the data area included in this delivery.

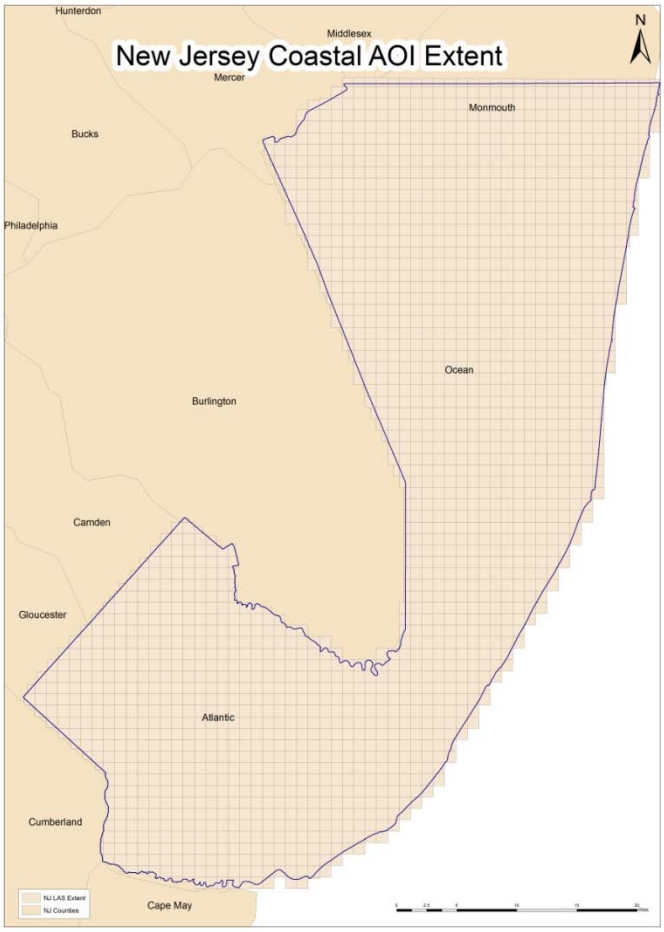


Figure 1 New Jersey Coastal AOI data coverage

2.2 Applicable Specifications & Guidelines

In addition to the project specifications, the following specifications/guidelines are applicable to this report:

A. *Guidelines and Specifications for Flood Hazard Mapping Partners* and Procedure Memorandums
B. FEMA's Geospatial Data Coordination Policy
C. FEMA's *Geospatial Data Coordination Implementation Guide*
D. Engineer Manual 1110-2-1003, *Hydrographic Surveys* (USACE), January 1, 2002
E. NFIP Metadata Profile Specifications
F. 44 CFR Parts, 65, 66, 67

3 Project Initiation Plan

The following quality control actions were taken prior to the aerial acquisition of LiDAR data for these AOIs and upon receipt of the Project Initiation Plan from FEDI.

3.1 Review of Project Initiation Plan

FEDI was required to submit a Project Initiation Plan for approval, prior to the commencement of data collection operations. The submitted Project Initiation Plan is dated March 10, 2010.

The required content for this plan included:

- Schedule (data acquisition, data processing, data delivery) including contact information for the project and field operation manager(s)
- Proposed flight lines in ESRI shapefile and graphic format
- GPS base station locations in ESRI shapefile and graphic format as well as supporting National Geodetic Survey (NGS) control information
- Proposed baseline lengths for aerial collection
- Calibration testing methodology
- LiDAR collection parameters (flying height, scan field of view, angle, pulse rate, scanner frequency, side-lap percentage, point density, etc.)
- Proposed acquisition windows including maximum position dilution of precision (PDOP) values
- Description of internal verification quality control processes:
    - Data validation
    - Pre-processing and accuracy check
    - Processing quality control
    - Product delivery quality control
- Communication of any issues that might affect the acquisition or processing of the intended project (such as restricted airspace)

3.1.1 Results

The following table outlines the results of the QA review of the Project Initiation Plan:

QA of Project Initiation Plan – Atlantic, Ocean, and Monmouth Counties, NJ		
Items Reviewed	**Pass / Fail**	**Comments**
Schedule provided for data acquisition, processing and delivery	Pass	None
Proposed flight lines submitted in GIS or graphic format	Pass	None
Base station location submitted in GIS or graphic format along with NGS control information	Pass, NO GIS FORMAT	None
Proposed baseline lengths for aerial data collection	Pass	None
Calibration testing methodology(s) described	Pass	None
LiDAR collection parameters described	Pass	None
Proposed acquisition windows and maximum PDOP values outlined	Pass	None
Description of internal verification QC processes:		
Data validation	Pass	None
Pre-processing and accuracy check	Pass	None
Processing quality control	Pass	None
Product delivery quality control	Pass	None

Description of any potential issues that may affect the acquisition or processing of data	Pass	None

3.1.2 Notes and Comments

The project initiation plan dated April 08, 2010 and named "Project Plan – RAMPP LiDAR Acquisition" was delivered to RAMPP for review.

4 Ground Survey and Data Acquisition

The following quality control actions were taken after the aerial acquisition of LiDAR data for the AOI and upon receipt of the following reports:

- Acquisition Report – RAMPP LiDAR Acquisition, New Jersey Coastal, NJ dated June 14, 2010
- Report of Survey – New Jersey Coastal, New Jersey, dated May 25, 2010

4.1 Review of Ground Survey Report

Terrasurv Inc. was tasked by FEDI to perform a ground control survey in support of data collections efforts in Atlantic, Monmouth, and Ocean Counties.

The survey conducted in support of data collection efforts was required to meet the following specifications for this project:

- All surveys conducted shall be referenced to National Geodetic Survey (NGS) control monuments in the National Spatial Reference System (NSRS) using appropriate horizontal and vertical control
- Base station locations should be the "best" horizontal (second order or better) and vertical (third order or better) available and have a stability of "C" or better
- New control established where suitable monuments do not exist shall conform to the Standards and Specifications for Geodetic Control Networks (1984), Federal Geodetic Control Committee (FGCC)
- Primary control monuments established with GPS shall meet or exceed NOS NGS-58 "Guidelines for Establishing GPS-Derived Ellipsoidal Heights (Standards: 2 cm and 5 cm)" using the appropriate and latest Geoid model and should be monumented to maintain stability and reoccupation if necessary
- Ground control stations are expected to have local network accuracy at the 95% accuracy level of 2 cm horizontally and vertically
- Supporting documentation such as processing reports, minimally and constrained 3-D least squares adjustment, pictures of the stations, etc.

4.1.1 Results

The following table outlines the results of the QA review of the Report of Survey for Atlantic, Monmouth, and Ocean Counties, NJ:

QA of Report of Survey – Atlantic, Ocean, and Monmouth, NJ		
Items Reviewed	**Pass / Fail**	**Comments**
Survey is referenced to NGS control monuments in the National Spatial Reference System (NSRS) using appropriate horizontal and vertical control	Pass	None
Base station locations are the "best" horizontal (second order or better) and vertical (third order or better) available and have a stability of "C" or better	Pass	None
New control conforms to the Standards and Specifications for Geodetic Control Networks (1984), FGCC	Pass	None
Primary control monuments established with GPS meets or exceeds NOS NGS-58 "Guidelines for Establishing GPS-Derived Ellipsoidal Heights (Standards: 2 cm and 5 cm)" using the appropriate and latest Geoid model and should be monumented to maintain stability and reoccupation if necessary	Pass	See comments
Ground control stations meet local network accuracy at the 95% accuracy level of 2 cm horizontally and vertically	Pass	See comments
Supporting documentation submitted such as processing reports, minimally and constrained 3-D least squares adjustment, pictures of the stations, etc.	PASS	None

4.1.2 Notes and Comments

The following exceptions and clarifications regarding the ground survey were submitted by FEDI in the Project Initiation Plan and approved by RAMPP:

1. Results of adjustment indicated accuracy of 3cm or better in relation to NAD 1983 (NSRS2007) and NAVD 1988

4.2 Data Acquisition Review

In addition to the Acquisition Report, RAMPP reviewed the submitted LAS data and the submitted Atlantic, Ocean and Monmouth Boresight Results Report to check the aerial acquisition results against the project specifications.

The following project specifications related to the data acquisition were checked for compliance:

- LiDAR is to be collected for the AOI in Atlantic, Monmouth and Ocean Counties with a 100 meter buffer
- LiDAR is to be collected using sensors capable of a minimum of 3 multiple discrete returns containing range and intensity values for first, intermediate and last returns for each emitted pulse
- The nominal post spacing (NPS) for all identified areas of interest within FEMA Regions II and VI will be 1 meter. 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 point spacing will be comparable

- Data Voids [areas => $(4*NPS)^2$, measured using 1st returns only] within a single swath will be deemed unacceptable, except where caused by water bodies, areas of low near infra-red reflectivity, or where filled appropriately by another swath
- Consistent with section 1.6 of the USGS LiDAR Guidelines and Specification, V.12, a regular grid with a cell size of equal to the design NPS*2 will be laid over the first return data within the geometrically usable center portion of each swath and at least 90% of the grid cells shall contain at least one LiDAR point
- The nominal side-lap between adjacent flight lines will be no less than 20%
- The scan angle total Field of View (FOV) shall not exceed 40º (+/- 20º off nadir) with an oscillating mirror scanner
- Relative accuracy shall exceed the FEMA consolidated RMSE of 18.5 cm and will be 15 cm or better.
- The project area shall be fully and sufficiently covered with no data voids caused by gaps between flight lines and/or sensor malfunctions
- Acquisition window and constraints:
    - Leaf-off conditions required
    - Area shall be free of snow and of flood condition with rivers remaining in their channels and near average heights or lower
    - Extraneous environmental conditions such as rain, fog or smoke shall be avoided
    - Low Tide which defined as when height of tide is different from Mean Lower Low Water by fifty percent of the diurnal tide range or less, as predicted by NOAA's National Oceanic Service (NOS) Center for Operational Oceanographic Product and Services
- Base stations used in support of acquisition shall be set for collecting dual frequency data at 1 Hz intervals
- Baseline lengths of base stations shall not exceed 30 miles unless the LiDAR provider can provide definitive proof that longer baseline length for this project can support the project accuracy requirements
- Quality statistics from the airborne GPS/IMU processing shall be made available upon request
- Ground surveys conducted in support of the boresight and processing of the LiDAR shall be tied into the base stations used for acquisition
- All collected swaths shall be delivered as part of the raw data deliverable. Swaths shall be split into segments no greater than 2 GB each with each swath assigned a unique File Source ID.

4.2.1 Results

The following table outlines the results of the QA review of the data acquisition phase for Atlantic, Ocean and Monmouth Counties:

QA of Data Acquisition – Atlantic, Ocean, and Monmouth, NJ		
Items Reviewed	**Pass / Fail**	**Comments**
LiDAR is to be collected for the Atlantic, Ocean and Monmouth AOI with a 100 meter buffer for a combined area of	Pass	None

QA of Data Acquisition – Atlantic, Ocean, and Monmouth, NJ		
Items Reviewed	**Pass / Fail**	**Comments**
LiDAR is to be collected using an approved, fully calibrated system capable of collecting multiple echoes per pulse with a minimum of first, last, and one intermediate echo	Pass	None
The system shall be capable of collecting the intensity (LiDAR pulse signal strength) for each echo signal at a minimum 8-bit depth	Pass	None
The nominal post spacing shall be no greater than 1 meter, 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 spacing should be comparable.	Pass	None
The nominal side-lap between adjacent flight lines will be no less than 20%	Pass	None
Total FOV shall not exceed 40º (+/- 20º off nadir)	FAIL	See Comments
The project area shall be fully and sufficiently covered with no data voids caused by gaps between flight lines and/or sensor malfunctions.	Pass	None
Data Voids [areas => $(4*NPS)^2$, measured using 1st returns only] within a single swath will be deemed unacceptable, except where caused by water bodies, areas of low near infra-red reflectivity, or where filled appropriately by another swath	Pass	None
Base stations used in support of acquisition shall be set for collecting dual frequency data at 1 Hz intervals	Pass	None
Baseline lengths of base stations shall not exceed 30 miles unless the LiDAR provider can provide definitive proof that longer baseline length for this project can support the project accuracy requirements	Pass	None
Quality statistics from the airborne GPS/IMU processing shall be provided	Pass	None
Relative accuracy – no flightline to flightline or point to point offsets present due to sensor anomalies or mismatches. •Relative accuracy shall be <=7cm RMSEz within individual swaths; <=10cm RMSEz within swath overlap areas	Pass	None
Ground surveys conducted in support of the boresight and processing of the LiDAR shall be tied into the base stations used for acquisition	Pass	None
Swaths split into segments no greater than 2 GB each with each having a unique File Source ID	Pass	None
Acquisition window and constraints:		
Leaf-off conditions required	Pass	None
Area shall be free of snow and of flood condition with rivers remaining in their channels and near average heights or lower (checked using stream gauges)	Pass	None
Extraneous environmental conditions such as rain, fog or smoke shall be avoided	Pass	None
LiDAR was acquired during Low Tide	Pass	None

QA of Data Acquisition – Atlantic, Ocean, and Monmouth, NJ		
Items Reviewed	**Pass / Fail**	**Comments**
Reports reviewed:	Pass	
Flight logs encompassing all collection dates	Pass	None
Aerial acquisition report	Pass	None
Ground survey report	Pass	none

4.2.2 Notes and Comments

1. While the majority of the tiles fail the requirement for FOV to not exceed 40º (+/- 20º off nadir) falling outside of the specification, the issues does not to affect the overall quality or usability of the data.
2. A few ridges that exceed the relative accuracy specification were discovered during the QA and are discussed in the sections below.

5 Project Data Deliverables

FEDI was required to deliver LAS data for the AOI processed to Level 2, bare earth.

5.1 Review of AOIs Processed to Level 1

All data was processed to Level 2.

5.2 Review of AOIs Processed to Level 2

The AOI of 1,612 square miles was processed to Level 2 which consists of post-processing to bare earth and other classifications.

The following graphic depicts the coverage of the data for the AOI:

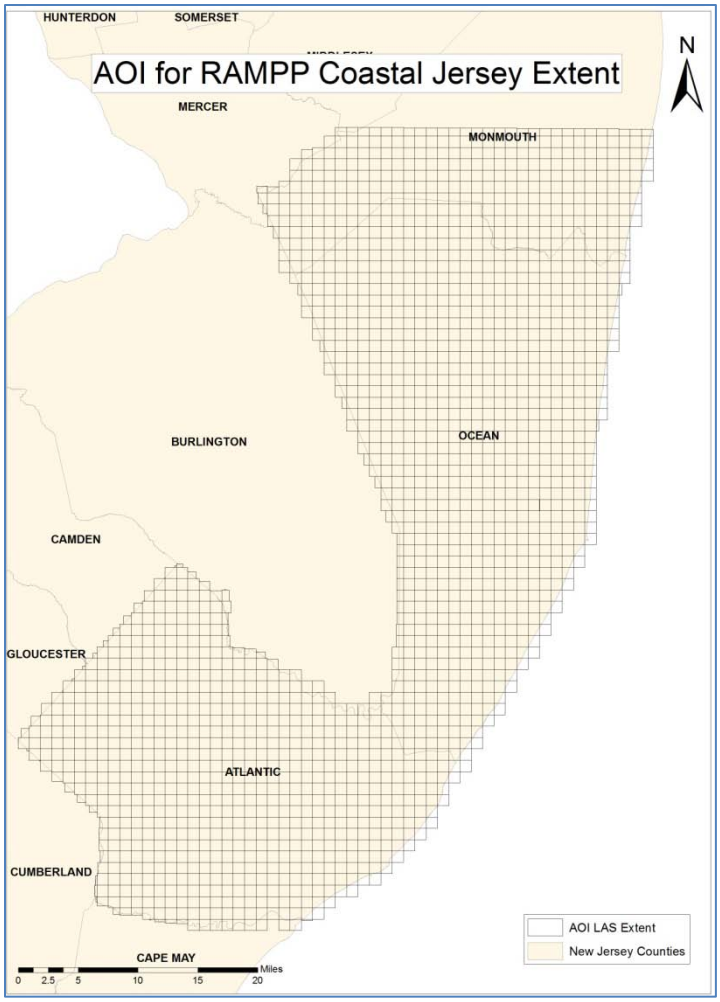


Figure 2 AOI extent depicted by the tile grid.

The following project specifications for the data delivery were checked for compliance using a combination of macro and micro checks on 100% of the data.

Macro checks:

- Data will be processed and delivered in LAS 1.2, where all the required data structure is maintained by the LiDAR processing software, and the current version of Terrascan. All major fields will be maintained
- The AOI will include a 100- meter buffer around the land-side perimeter
- Outliers, blunders, noise points, etc. will be classified to either Class 7 (Low Points and Noise) or Class 1 (Unclassified), unless the “point withheld” function can be fully utilized in the current Terrascan version.
- The header file shall contain, at a minimum, the “File Creation Year day” and “File Creation year” which shall represent the final deliverable LAS date.
- Projection information for the point data shall be specified in the Variable Length Record using the appropriate GeoTIFF tags

- The horizontal datum shall be referenced to the North American Datum of 1983 (NAD 1983) NSRS 2007.
- The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD88), with Geoid 09 used to convert ellipsoidal to orthometric heights.
- The coordinate system used shall be New Jersey State Plane, NAD 1983, U.S. Feet
- Classification codes for shall follow the ASPRS Standard LiDAR Point Classes utilizing only the following:
    - Class 1 – Processed but unclassified
    - Class 2 – Bare-earth ground
    - Class 7 – Low points and noise
    - Class 9 – Water
    - Class 11 - Withheld
- No points shall be deleted from the LAS file (all points must be included)

Micro checks:

- Consistent with section 1.6 of the USGS LiDAR Guidelines and Specification, v12, a regular grid with a cell size of equal to the design NPS*2 will be laid over the first return data within the geometrically usable center portion of each swath and at least 90% of the grid cells shall contain at least one LiDAR point
- Classifications shall adhere to the following guidelines through the use of automated and manual filtering routines:
    - 90% of artifacts classified
    - 95% of outliers classified
    - 95% of vegetation classified
    - 98% of buildings classified
- Outliers, blunders, noise points, etc. classified as Class 7 or 1 unless current version of Terrascan allows for use of Class 11 “Withheld”

5.2.1 Macro Check Results

Macro checks are conducted on 100% of the data. The following table outlines the results of the Macro Check QA review of the data set provided for the Atlantic, Ocean and Monmouth Counties, NJ, AOI:

Macro Check QA of AOIs – Atlantic, Ocean, and Monmouth, NJ		
Items Reviewed	**Pass / Fail**	**Comments**
Masspoint data delivered in LAS files utilizing the latest LAS specification (currently LAS 1.2) containing all LAS items of point data record format 1	PASS	None
The header file contains, at a minimum, the “File Creation Year day” and “File Creation year” and represents the final deliverable LAS date	PASS	None
Projection information for the point data specified in the Variable Length Record using the appropriate GeoTIFF tags	PASS	None
The horizontal datum referenced to the North American Datum NAD83 using the latest adjustment revision (NSRS 2007)	PASS	None
The vertical datum referenced to the North American Vertical	PASS	None

Macro Check QA of AOIs – Atlantic, Ocean, and Monmouth, NJ		
Items Reviewed	**Pass / Fail**	**Comments**
Datum of 1988 (NAVD88), Geoid 09 used		
The latest Geoid used to convert ellipsoidal heights to orthometric heights	PASS	None
The project data is in NAD 1983, New Jersey State Plane	PASS	None
Data will be contained within the tiling scheme of 5,000' X 5,000' tiles	PASS	None
Classification codes shall follow the ASPRS Standard LiDAR Point Classes utilizing only the following:		
Class 1 – Processed but not classified	PASS	None
Class 2 – Bare-earth ground	PASS	None
Class 7 – Low points and noise	PASS	None
Class 9 - Water	PASS	None
Class 11 - Withheld	PASS	None
No points shall be deleted from the LAS file (all points must be included)	PASS	None

5.2.2 Micro Check Results

Micro checks are conducted on 100% of the data.

The following table outlines the results of the Macro Check QA review of the data set provided for the Atlantic, Ocean and Monmouth Counties, NJ, AOI:

Micro Check QA of AOIs – – Atlantic, Ocean, and Monmouth, NJ		
Items Reviewed	**Pass / Fail**	**Comments**
Outliers, blunders, noise points, etc. classified as Class 7 or 1 unless current version of Terrascan allows for use of Class 11 "Withheld"	PASS	See Comments
Classifications shall adhere to the following guidelines through the use of automated and manual filtering routines:		
90% of artifacts classified	PASS	See Comments
95% of outliers classified	PASS	See Comments
95% of vegetation classified	PASS	See Comments
98% of buildings classified	PASS	See Comments

5.2.3 Notes and Comments

A. RAMPP conducted a macro and micro checks QA review of 100% of the project data and reporting and found no issues.

B. RAMPP conducted a micro check QA review of 100% of the project tiles and found that less than 90% of the reviewed data contained artifacts and that at least 95% of the LiDAR points consisting of outliers and vegetation were properly classified.

C. Issues that do not affect the quality of the final products or data application but should be noted by the end user are illustrated in the sections. 6.1.2

5.3 Intensity Images

Intensity images derived from the LiDAR point cloud were not required for this scope of work. However, intensity values were provided in the LAS files.

5.4 3D Breaklines

Breakline (hydro-line) generation was conducted in order to classify water points in the LAS and to meet the USGS V.12 specifications for flattening. The following project specifications for the data delivery were checked for compliance by conducting a 5% review of the delivered line work:

- Inland ponds, lakes and boundary waters greater than 2-acres or greater surface area (~350' diameter for a round pond) at the time of collection will be collected in the appropriate hydro-line feature class
- Inland streams and rivers with a 100' nominal width will be collected in the appropriate hydro-line feature class
- Hydro-lines will be delivered as an ESRI feature class (Polyline or Polygon format as appropriate to the type of feature represented and the methodology used) in a geodatabase
- Each feature class or shapefile will include properly formatted and accurate georeferencing information in the standard location. All feature classes must include a projection
- Breaklines must use the same coordinate reference system (horizontal and vertical) and units as the LiDAR points 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 the vertical.

Breakline Check QA of AOIs – Atlantic, Ocean, and Monmouth, NJ		
Items Reviewed	**Pass / Fail**	**Comments**
Inland ponds, lakes and boundary waters greater than 2-acres or greater surface area (~350' diameter for a round pond) at the time of collection collected in the appropriate hydro-line feature class	Pass	None
Inland streams and rivers with a 100' nominal width collected in the appropriate hydro-line feature class	Pass	None
Hydro-lines delivered as an ESRI feature class (Polyline or Polygon format as appropriate to the type of feature represented and the methodology used) in a geodatabase	Pass	See Comments

Breakline Check QA of AOIs – Atlantic, Ocean, and Monmouth, NJ		
Items Reviewed	**Pass / Fail**	**Comments**
Each feature class or shape file includes properly formatted and accurate georeferencing information in the standard location. All feature classes include a projection	Pass	None
Breaklines use the same coordinate reference system (horizontal and vertical) and units as the LiDAR points delivery	Pass	None
Breaklines delivered as a continuous layer or in tiles. If tiled deliveries, tiles edge-match seamlessly in both the horizontal and the vertical	Pass	None

5.4.1 Notes and Comments

Breaklines for Atlantic, Ocean, and Monmouth, NJ were delivered in a geodatabase. The following feature classes were provided:

- Lakes (Polyline ZM)
- River (Polyline ZM)
- Tidal_Waters (Polyline ZM)

6 QA Process

The following sections outline the general LiDAR QA process used by RAMPP for this project.

6.1 Software

The main software programs used by RAMPP in performing the qualitative assessment are as follows:

- GeoCue: a geospatial data/process management system especially suited to managing large LiDAR data sets;
- QT Modeler: used for analysis and visualization;
- FugroViewer: used for analysis and visualization;
- Proprietary tools: developed in-house to conduct a statistical analysis of LAS files.

6.2 Qualitative Assessment Process

The following systematic approach was used for performing the qualitative assessment of this delivery.

Macro Checks

Delivery was reviewed for completeness of content. In-house LAS statistics check was run to verify:

- Conformity of the data to the LAS 1.2 specification
- Completeness of header information
- Correctness of projection

  - Correctness of LAS classification
  - Verification of maximum/minimum x,y,z ranges
- Performed tile-by-tile analysis
  - Verified that tile naming conventions were followed
  - Verified that deliverable formats are correct
  - Conducted measurements to verify is there is an offset between the flight lines
  - Conducted measurements to verify the level of noise within tiles
- Reviewed each tile for anomalies to include:
  - Buildings are removed from bare-earth points
  - Vegetation are removed from bare-earth points
  - Proper definition of roads and drainage patterns
  - Bridges and large box culverts removed from bare-earth points
- Full points DZ Orthos from LiDAR were built to verify the data for data voids
- Ground DZ Orthos from LiDAR were built to verify the presence of flight lines ridges in the dataset
- General reviews
  - Verified that tile naming conventions were followed
  - Verified that deliverable formats are correct

The goal of the RAMPP qualitative review is to assess the continuity and the level of cleanliness of the bare earth product. Each LiDAR tile is expected to meet the following acceptance criteria:

- The point density is homogenous and sufficient to meet the user's needs;
- The ground points have been correctly classified (no man-made structures or vegetation remains, no gaps except over water bodies);
- The ground surface model exhibits a correct definition (no aggressive classification, no over-smoothing, no inconsistency in the post-processing);
- No obvious anomalies due to sensor malfunction or systematic processing artifacts are present (data voids, spikes, divots, ridges between flight lines or tiles, cornrows, etc);
- Residual artifacts <5%

A check of the swath overlap criteria was made by colorizing the LiDAR tiles by source identification (flight line) and making direct measurements in multiple locations of the tile. Figure 3 is an example from the AOI.

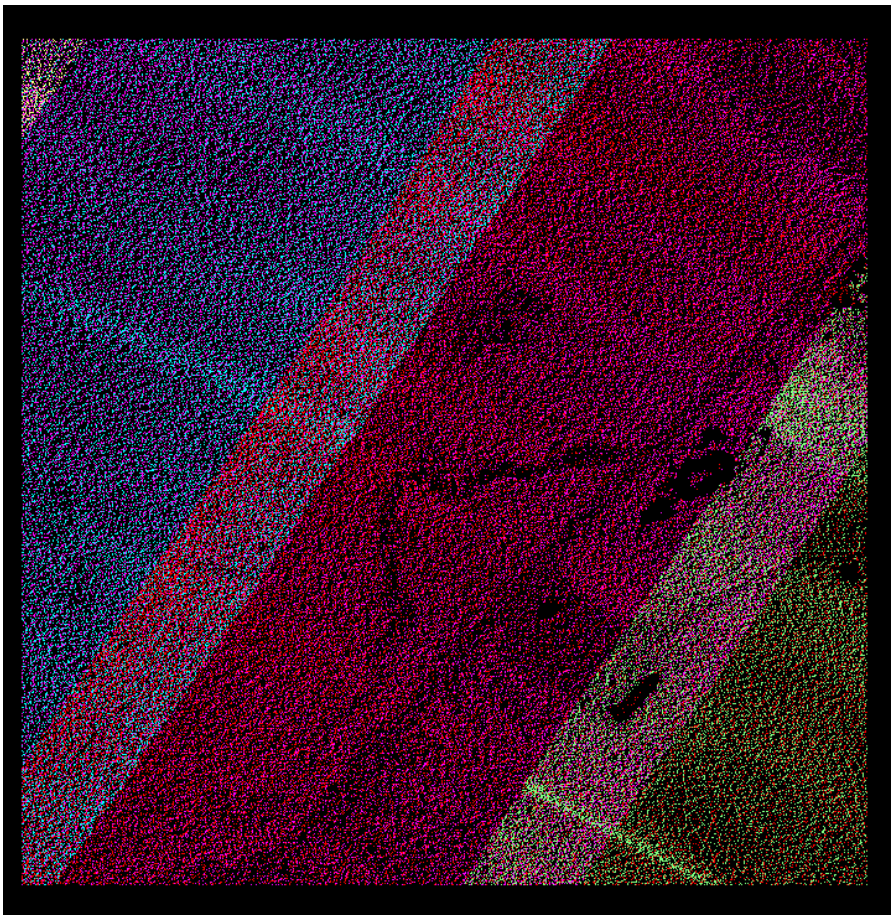


Figure 3 - Example of LiDAR points in tile colorized by source identification

Figure 4 depicts a data density check conducted on a tile (all-echo LAS). The LAS files are used to produce digital elevation models using the commercial software package "QT Modeler" which creates a 3-dimensional data model derived from Class 2 (ground points) in the LAS files.

Figure 4 - Density grid of point cloud tile, created using a green to red color ramp. Green areas meet project specifications; red delineates areas not meeting minimum density requirements (primarily water, removed buildings and low-confidence areas)

Figure 7 depicts one of the void/gap checks conducted on the New Jersey AOIs (all returns) using a LiDAR orthophoto generated in GeoCue. The imported LAS files were used to create LiDAR "orthos." The LiDAR orthos were one of the tools used to verify data coverage and point density, to check for data voids or gaps, and used as reference data during checks for data anomalies and artifacts. This product is not intended to be a project deliverable. The orthos were derived from the full point cloud elevations and LiDAR pulse return intensity values. Due to the point density of the original collection, the orthos were produced at a 1m pixel for the entire area of interest. Acceptable voids are those found over water features.

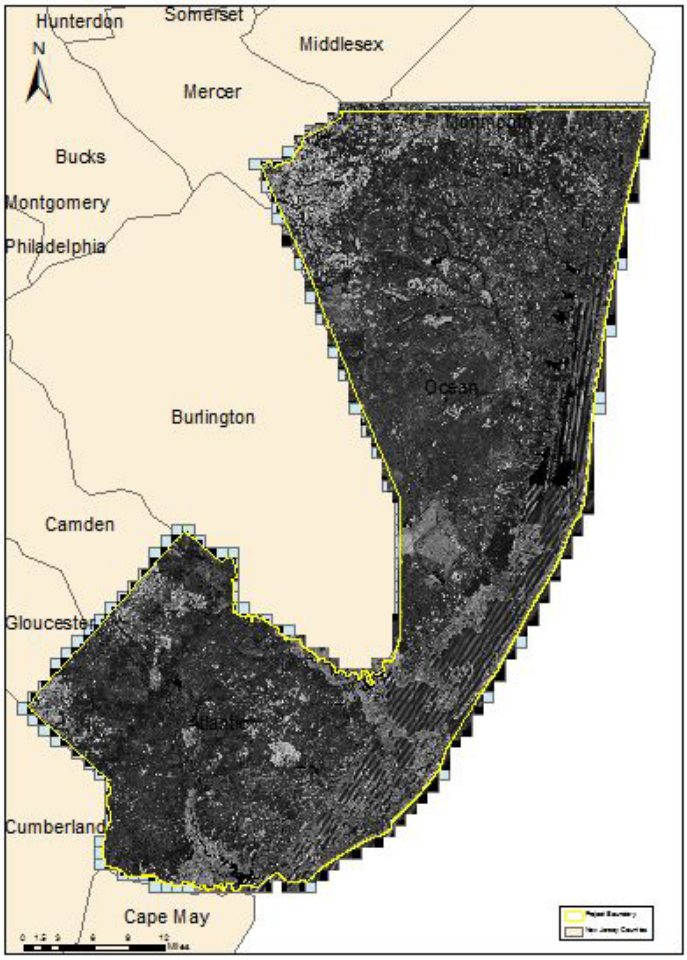


Figure 5 – Example of a void/gap check encompassing NJ AOI.

6.3 Sensor Quality Issues

This section describes issues in the LiDAR that are caused by the unique characteristics of the LiDAR sensor. The issues are described for user reference; in general they are minor and will not affect the usability of the data for flood hazard mapping.

6.3.1 Sensor Anomaly: Automatic Gain Control

During the LiDAR QA of the dataset, a sensor anomaly was noted that is likely caused by the Automatic Gain Control (AGC), which sets how the intensity should be recorded. This anomaly is visible in the intensity images and directly affects the LiDAR elevations. In these particular cases the intensity at or near nadir (perpendicular to the plane) is brighter than it should be, affecting the computation of the point elevation since the intensity is used to compute the range of the pulse. This error causes an issue during the ground classification algorithm by which the ground has an artificially high or low elevation, or ground points are improperly classified to class 1 (non-ground), leaving a void in the bare earth model. Examples of this issue are provided in the following images.

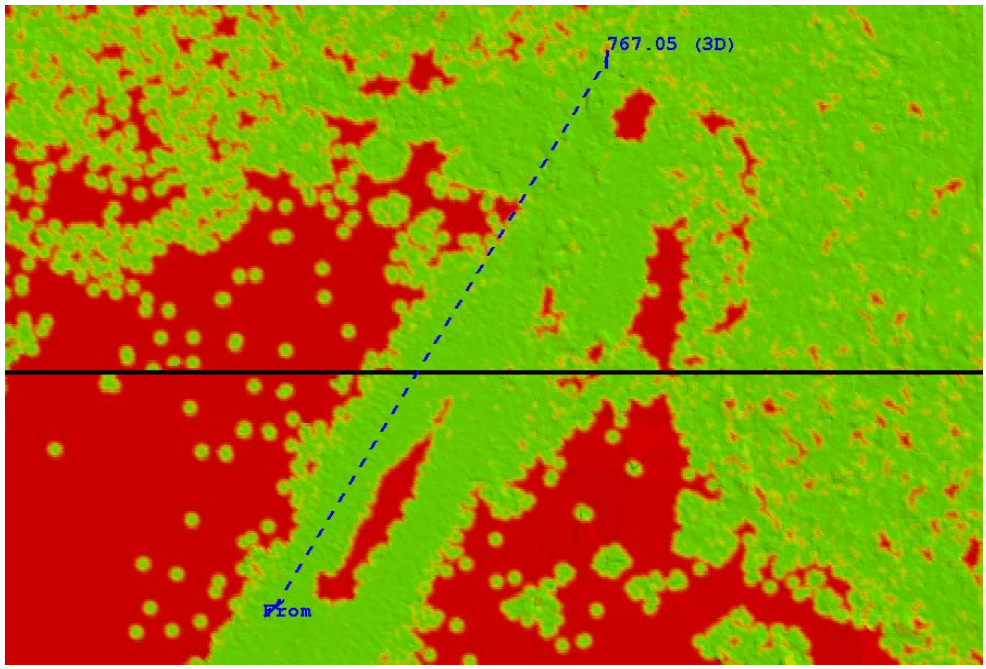


Figure 6: Tile number F17D7 (ground density model). The cross section shows the extent of an anomaly that spreads over two tiles. The anomalous elevations are removed from the ground, but this leaves a void of ground point in the data.

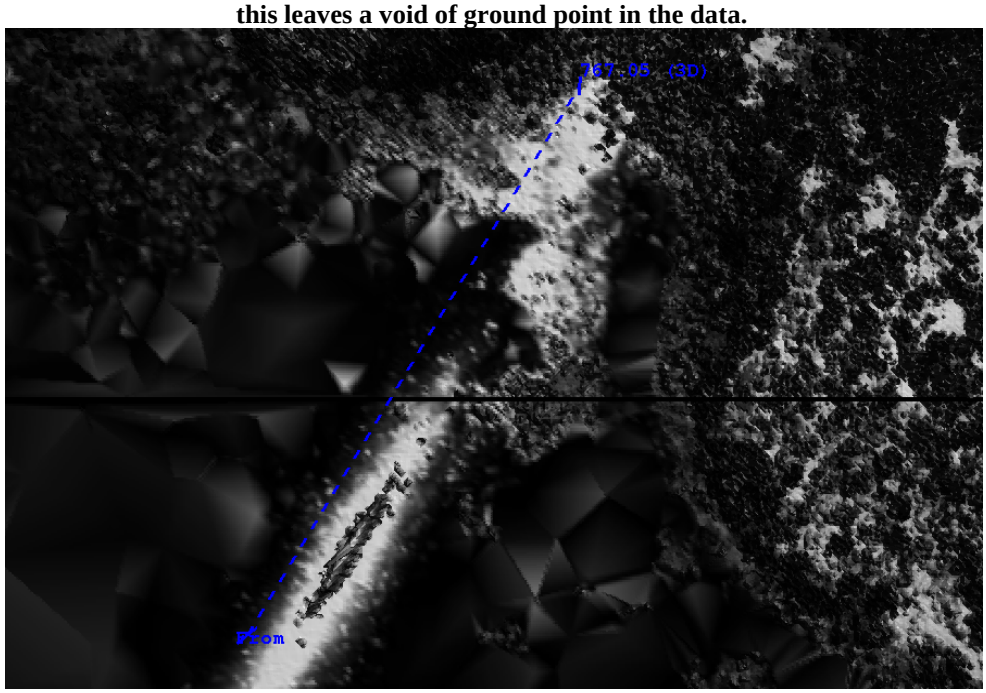


Figure 7: Tile number F17D7. The cross section points to the location of the high intensity values due to the sensor anomaly.

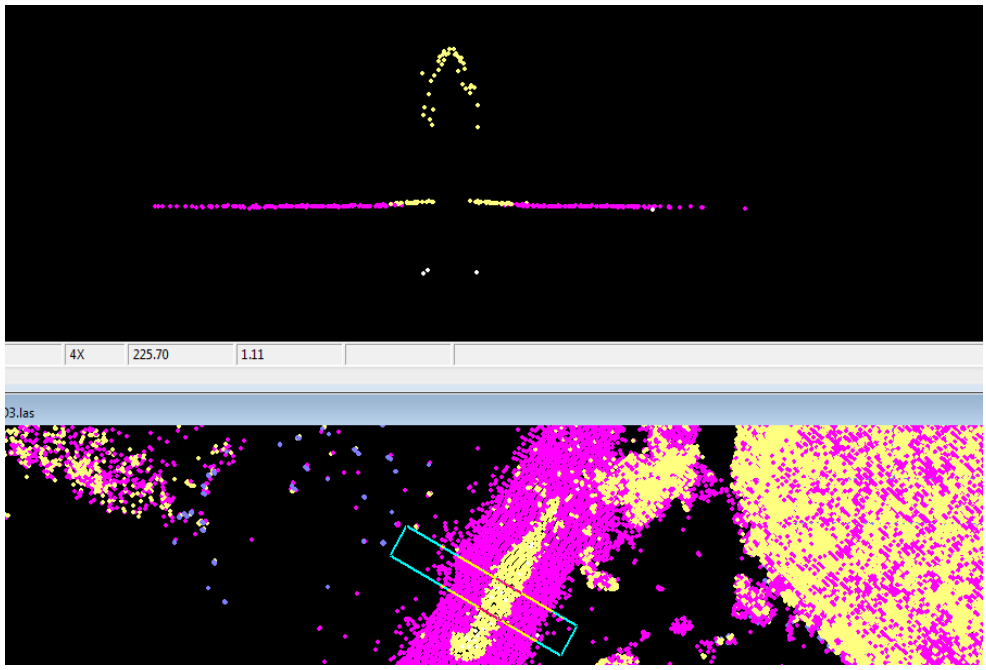


Figure 8: Tile number F17D7. LAS point cloud colored by classification. The yellow points are unclassified (class 1), purple points are ground (class 2), and white points are classified to low/noise (class 7). Due to the sensor anomaly, some ground points are classified to class 1 leaving a void in the bare earth surface.

6.3.2 Sensor Anomaly: Gain Control

During the LiDAR QA of the dataset, a sensor anomaly involving gain control at the water/land delineation line was noted. This type of anomaly is likely caused by the absorption of the laser pulse by the water along the land/water interface due to the gain control differences required for surface and hydro land cover types. The images below illustrate the lack of water points at the land/water interface as the sensor gradually adjusts itself to return points in the water.

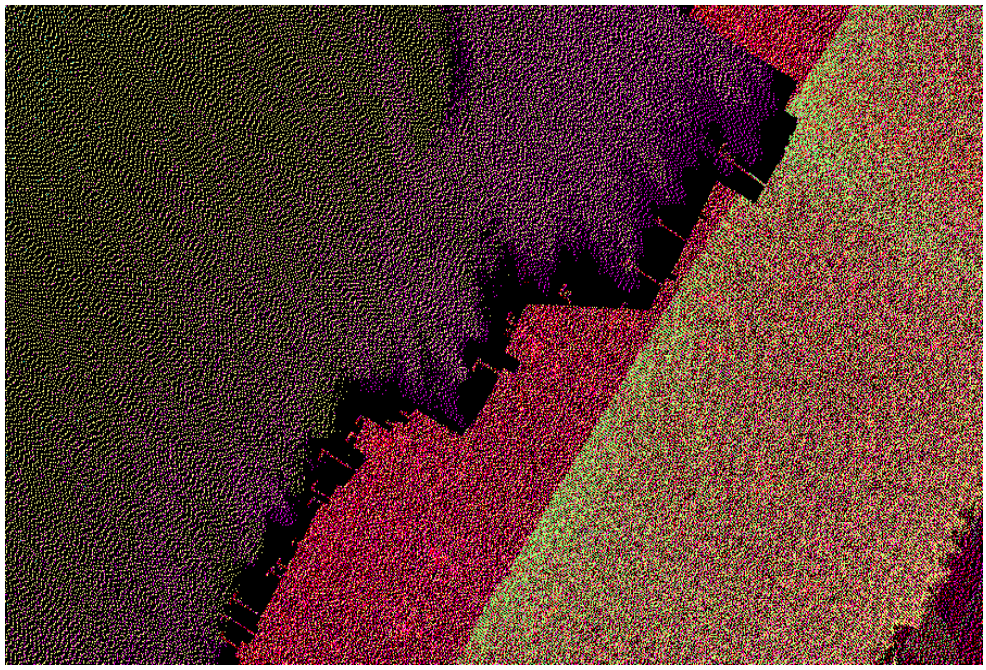


Figure 9: Tile number J16D11. LAS point cloud colored by source ID. Each color represents a flight line, the mixture of colors represent overlap. The image shows an absence of points at the water land interface.

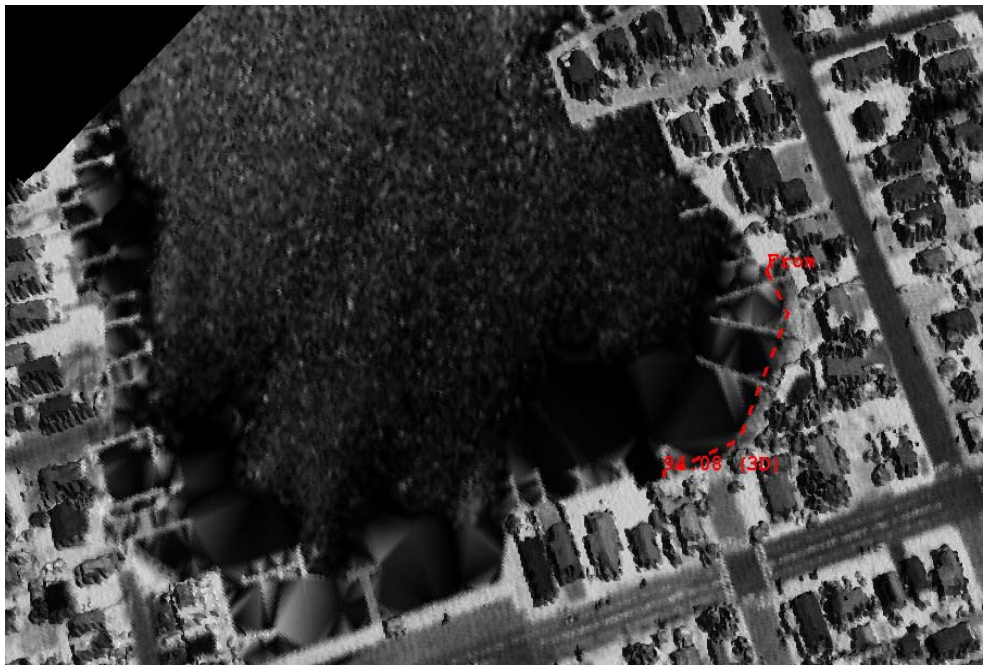


Figure 10: Tile number J16D11. Full point cloud model. The image shows the absence of points at the water land interface.

6.3.3 Sensor Anomaly: Acquisition Drop Off

During the LiDAR QA of the dataset, a sensor anomaly involving an acquisition drop off was noted in the dataset. The acquisition drop off happens when sensor pulses are

being absorbed by the ground cover and none of the points are being returned back to the sensor. This type of anomaly usually happens on freshly painted asphalt and illustrated in the images below.

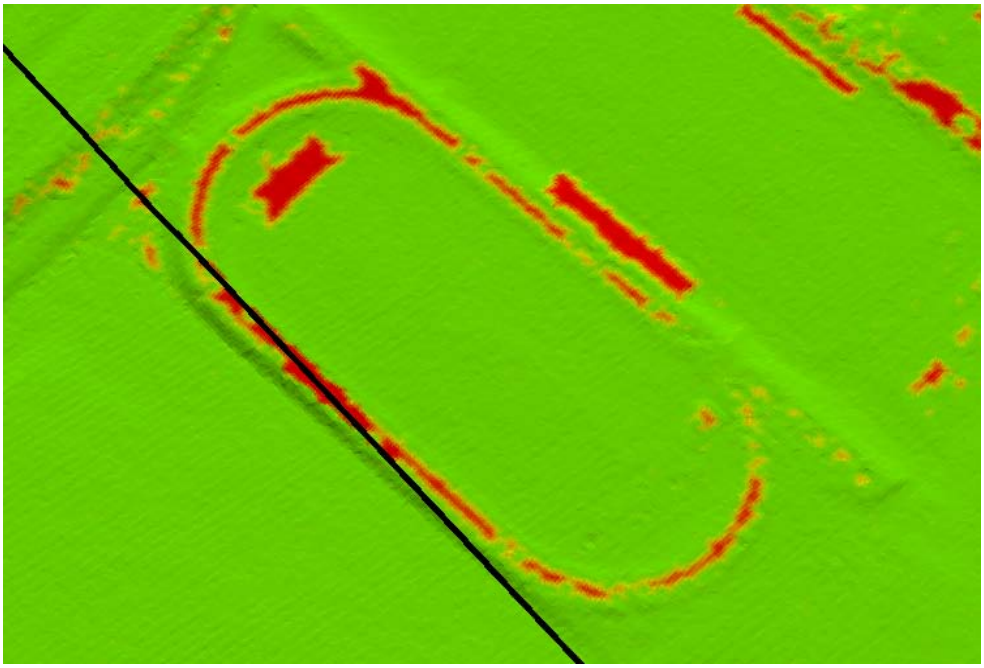


Figure 11: Tile number K11D14. Ground density model. The image shows an area of a data void in ground class on a track field.

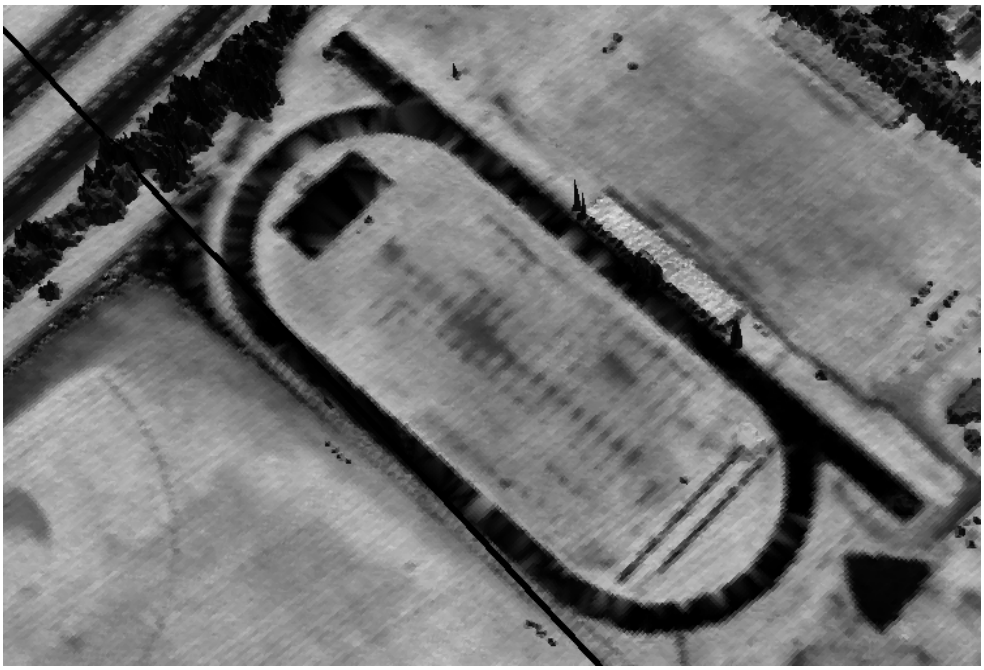


Figure 12: Tile number K11D14. Full point cloud. The image illustrates shows that the feature is actually a track field.

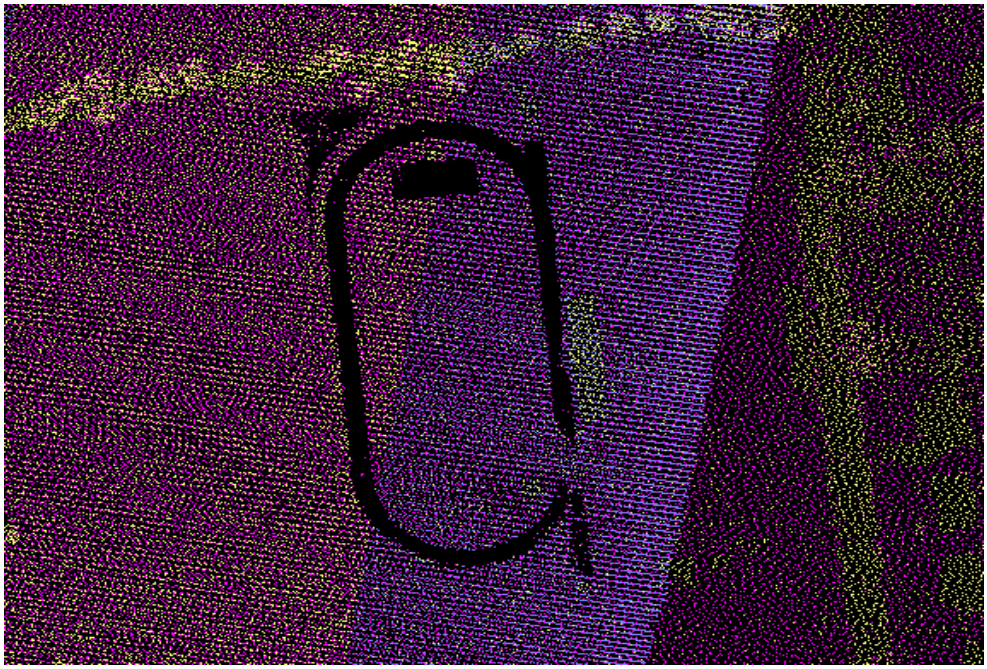


Figure 13: Tile number K11D14. LAS point cloud colored by classification. The yellow points are unclassified (class 1); purple points are ground (class 2). The image shows that there are no points on the field track.

7 Metadata

The project metadata was reviewed and checked using the following methods:

- Structure of the metadata file was compared against FGDC standards by using the USGS Geospatial Metadata Validation Service: http://geo-nsdi.er.usgs.gov/validation/
- Metadata content was reviewed using a visual check for accuracy.

8 Data Accuracy Report

RAMPP performed the LiDAR vertical accuracy assessment for the Atlantic, Ocean and Monmouth Counties AOI in accordance with ASPRS/NDEP and NSSDA/FEMA specifications and guidelines.

The LiDAR data produced for this project adheres to the ASPRS/NDEP and NSSDA/ FEMA accuracy standards, as referenced in the accuracy section of the Department of Homeland Security, Federal Emergency Management Agency Prime Contract # HSFEHQ-09-D-0369, Modification 1 to Task Order HSFE02-09-J-0001, Work Order # 01.

8.1 Data Accuracy Assessment

The data accuracy assessment for RAMPP New Jersey project was conducted for the AOI using the bare earth, forested and urban category checkpoints in order to assess the vertical accuracy of the data.

8.1.1 Software Used

- QT Modeler: used to create QTC models and to produce direct comparison of the QA checkpoints against the LiDAR class 2
- *Microsoft Excel:* used to calculate accuracy values and statistics from the measurements in QT Modeler

8.1.2 Vertical Accuracy Testing Process

The primary quantitative assessment steps were as follows:

1. FEDI acquired new raw LiDAR data on April 1st-7th, and April 10th and performed post-processing to derive the bare-earth digital terrain model.
2. Kennon Surveying Services, Inc. performed a control survey in support of LiDAR data collection. 150 checkpoints were evenly distributed within 5 categories: Bare Earth/Low Grass, Tall Grass/Low Weeds, Tall Weeds/Low Brush, Fully Forested and Urban Areas. Two (2) checkpoints were located outside of the AOI and were not used in the analysis.
3. Kennon Surveying Services, Inc provided RAMPP with a table of horizontal coordinates and orthometric heights for all survey checkpoints classified by land cover category. RAMPP created a triangulated irregular network (TIN) from the bare-earth LiDAR points, and interpolated a Z-value at each of the survey point locations.
4. RAMPP compared the LiDAR-derived elevations of the checkpoints to the surveyed checkpoint orthometric heights and computed the vertical accuracy assessment according to FEMA/NSSDA and ASPRS/NDEP specifications.

The spatial distribution of ground checkpoints surveyed by Kennon Surveying Services, Inc is shown in the figure below.

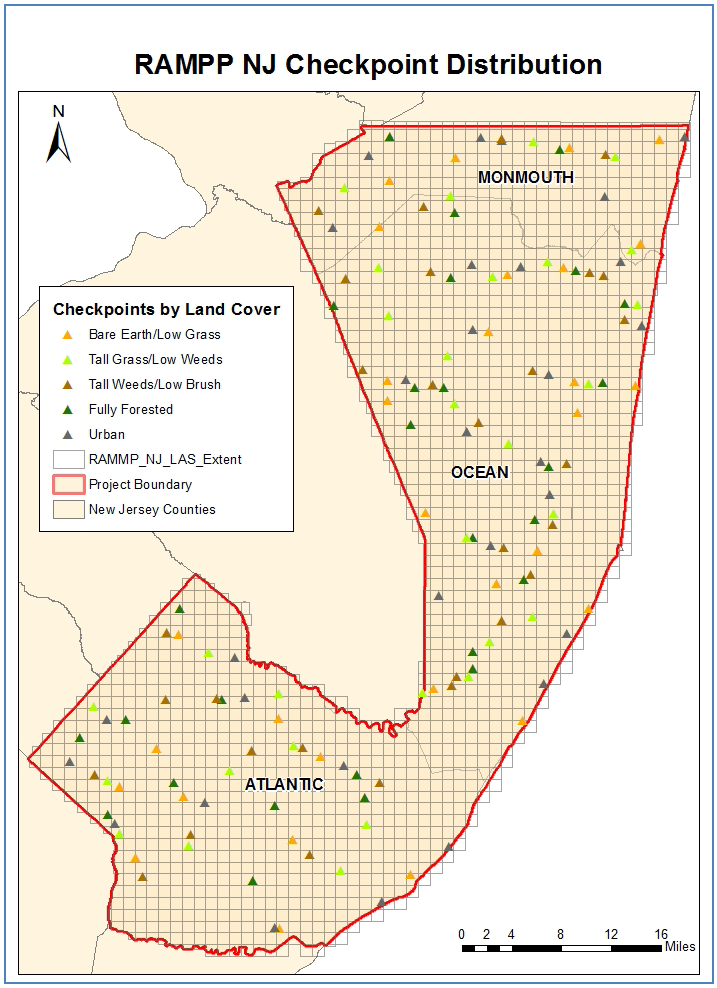


Figure 14 Atlantic, Ocean and Monmouth AOI checkpoints

8.1.3 Vertical Accuracy Testing – NDEP and ASPRS Procedures

Testing was conducted to determine how well the LiDAR sensor performed in the various land cover categories present within the New Jersey AOI and consisted of only the bare earth/low grass category land cover and was therefore only tested for Fundamental Vertical Accuracy (FVA).

FVA was determined across the entire acquisition area using checkpoints located only in land cover areas consisting of bare-earth and low grass, due to the high probability of detecting the ground surface, yielding a normal error distribution. The FVA is reported at a 95% confidence level, which is computed as the root mean square error of the checkpoint elevations ($RMSE_Z$) x 1.96. For this project the FVA requirement was 1.19 ft RMSE.

Supplemental Vertical Accuracy (SVA), though not a requirement for this project, was calculated separately for each land cover category: bare earth, urban, weeds, brush and

forested. SVA illustrates the quality of the post processing (filtering) of the LiDAR used to determine ground within each land cover category. Post processing may yield elevation errors that do not follow a normal error distribution; therefore the SVA at the 95% confidence level equals the 95th percentile error for all checkpoints in each individual land cover category.

Consolidated Vertical Accuracy (CVA) within the entire AOI was determined by using all checkpoints in all land cover categories combined. CVA assumes LiDAR errors may not follow a normal distribution error in vegetated categories and, at the 95% confidence level, equals the 95th percentile error for all checkpoints in all land cover categories combined.

Tables 1 and 2 summarize the vertical accuracy by fundamental, consolidated, and supplemental methods within the AOI:

AOI - Vertical Accuracy at 95% Confidence Level				
Land Cover Category	**# of Points**	**Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec = 0.96 ft**	**Consolidated Vertical Accuracy (95th Percentile) Spec = 0.96 ft**	**Optional Supplemental Vertical Accuracy (95th Percentile) Spec = 0.96 ft**
Consolidated	147		0.43	
BE & Low Grass	30	0.35		0.32
Tall Grass/Low Weeds	30			0.51
Tall Weeds/Low Brush	30			0.31
Fully Forested	27			0.47
Urban	30			0.53

Table 1 FVA at the 95% confidence level for the AOI

The following figure illustrates the magnitude of differences between the survey checkpoints and the processed LiDAR data by specific land cover category for the AOI:

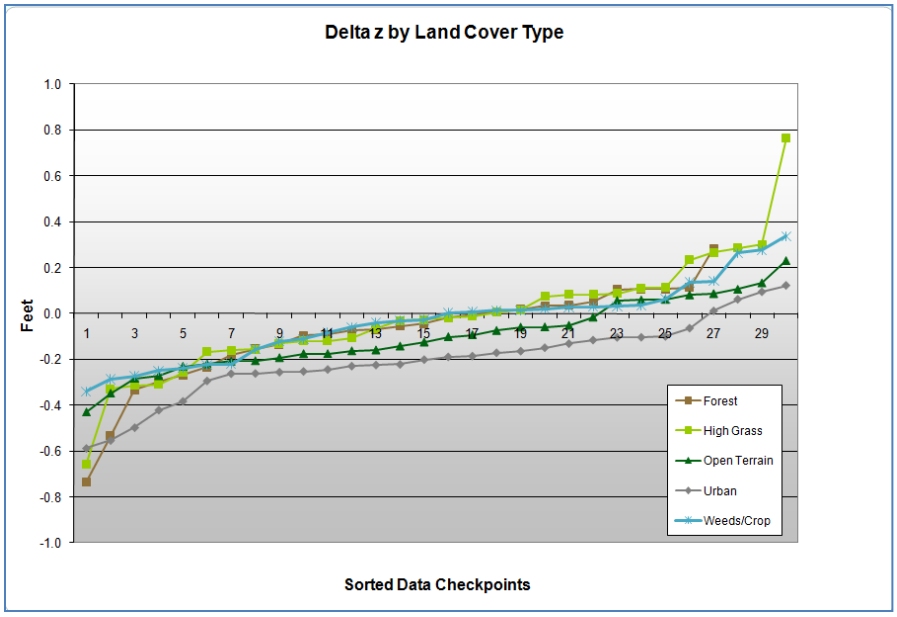


Figure 9 Magnitude of elevation discrepancies by land cover category for the AOI

8.1.3.1 Analysis of the 95th Percentile

Several checkpoints returned the results above the 95th percentile. These checkpoints are listed below:

Point No	Land Cover Type	Easting	Northing	Elevation, ft	Z LiDAR, ft	Delta Z, ft
OC-C5-57	Urban	514904.36	409368.39	143.56	143.06	-0.497
OC-C4-68	Forest	575579.67	372290.74	47.62	47.09	-0.534
AC-C5-122	Urban	388419.26	265216.68	99.75	99.20	-0.553
OC-C5-27	Urban	605986.99	459089.64	27.91	27.32	-0.588
AC-C2-143	High Grass	393690.86	217029.35	81.69	81.03	-0.659
OC-C4-50	Forest	598173.87	407931.21	2.56	1.82	-0.736
OC-C2-83	High Grass	550333.12	298287.00	32.55	33.32	0.766

8.1.4 Vertical Accuracy Testing – NSSDA and FEMA Procedures

To comply with current FEMA guidelines, RMSEz statistics were computed in the relevant land cover categories, individually and combined, as well as other recommended statistics for each AOI. This process assists in the analysis to help check for any anomalous characteristics that may be present in the LiDAR data. These statistics are summarized in the following table:

AOI - Descriptive Statistics							
100% of Totals	**Points**	**RMSE Spec=0.49 ft**	**Mean Error (ft)**	**Median Error (ft)**	**SKEW**	**STDEV (ft)**	**95th Percentile Spec=0.96 ft**
Consolidated	147	0.22	-0.09	-0.09	0.09	0.20	0.43
BE & Low Grass	30	0.18	-0.10	-0.11	0.10	0.15	0.32
Tall Grass/Low Weeds	30	0.25	0.01	0.01	0.25	0.25	0.51
Tall Weeds/ Low Brush	30	0.17	-0.04	-0.01	0.23	0.17	0.31
Fully Forest	27	0.23	-0.01	-0.02	0.94	0.23	0.47
Urban	30	0.26	-0.13	-0.18	0.95	0.23	0.53

Table 3: Descriptive statistics for the AOI.

Figures 13 illustrates a histogram of the associated elevation discrepancies between the QC checkpoints and elevations as interpolated from the LiDAR triangulated irregular network (TIN) for the AOI. The frequency of elevation differences is distributed within each band of elevation differences. Though the discrepancies vary between -0.74 ft and +0.77 ft, the histogram shows the expected bell-curve distribution of errors. As the checkpoints passed the vertical accuracy criterion, the elevation discrepancies illustrated in the figure are not cause for concern.

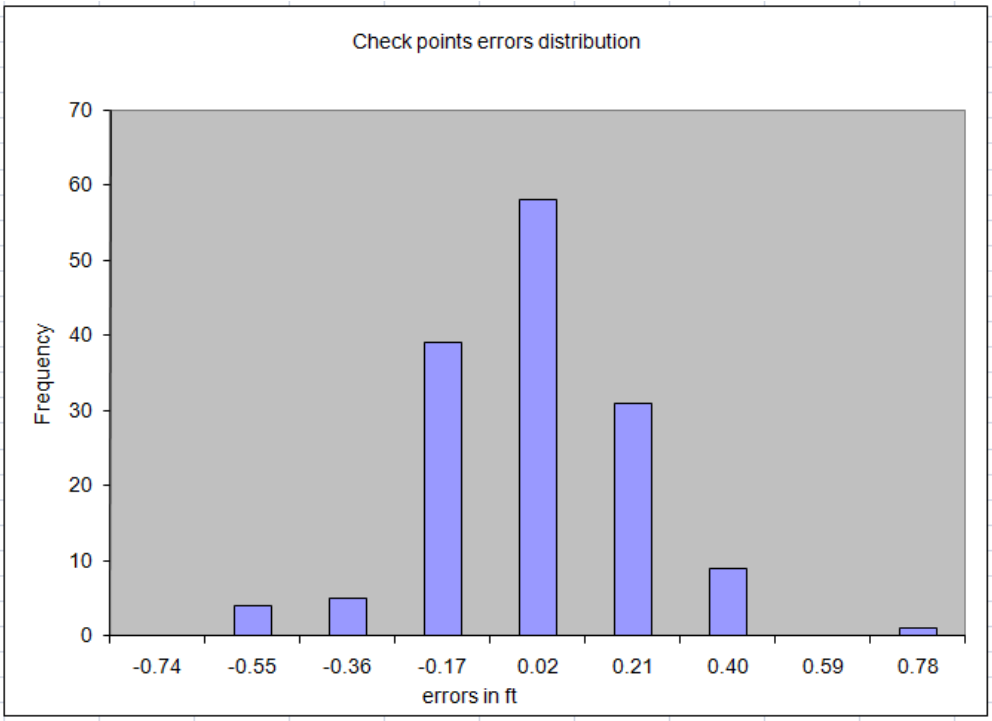


Figure 15: Histogram of elevation discrepancies for the AOI.

8.1.5 Checkpoints not used

One checkpoint was removed from the RMSE calculations. The checkpoint is located in a densely vegetated forest which can explain the difference between the checkpoint LiDAR elevations reaching over 4 ft. The checkpoint information is provided below.

Point No	Land Cover Type	Easting	Northing	Elevation, ft	Z LiDAR, ft	Delta Z, ft
MC-C4-30	Forest	618529.37	476731.02	1.71	6.24	4.531

Figure 16: Picture of checkpoint MC-C4-30 removed from the RMSE computation.

8.2 Credits

Organizations involved in the procurement, acquisition, processing, and quality control of the Atlantic, Monmouth and Ocean Counties, NJ LiDAR dataset are identified below.

Function	Responsible Organization
LiDAR procurement	FEMA
LiDAR acquisition and processing	Fugro EarthData, Inc.
Checkpoint surveys	Kennon Surveying Services, Inc
Accuracy assessment and reporting	RAMPP
Independent Technical Review	Dewberry

9 Conclusions

Based on the limited qualitative and vertical accuracy assessments conducted by RAMPP on the data delivered, the Atlantic, Monmouth and Ocean Counties, NJ AOIs deliveries meet the applicable project specifications as set forth by the Department of Homeland Security, Federal Emergency Management Agency Prime Contract # HSFEHQ-09-D-0369, Task Order # HSFE02-09-J-0001, April 9,2010, revised July 2, 2010.

Vertical Accuracy Assessment Conducted by:

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Polina Lyamtseva
GIS Analyst

Qualitative Assessment Conducted by:

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Stephen DiCicco,
Technical Supervisor

APPENDIX C
External Hard Drive or DVD with All Applicable Data