EFFECTS OF WATERSHED RESTORATION ON HILLSLOPE STABILITY AND ECOHYDROLOGICAL FUNCTIONS

Mapping Project Report

Principal Investigator: Rebecca A. Lloyd

University of Arizona
School of Natural Resources, Biological Sciences East
Tucson, AZ 85721

e-mail :ralloyd@email.arizona.edu
Phone : 520-307-8891
Fax : 520-621-8801

Mapping Project Report Table of Contents

1. LiDAR System Description and Specifications

This survey was performed with an Optech GEMINI Airborne Laser Terrain Mapper (ALTM) serial number 06SEN195 mounted in a twin-engine Cessna Skymaster (Tail Number N337P). The instrument specifications are listed in table 1.

Operating Altitude	150 - 4000 m, Nominal
Horizontal Accuracy	1/5,500 x altitude (m AGL); 1 sigma
Elevation Accuracy	5 - 30 cm; 1 sigma
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, last returns
Intensity Capture	12-bit dynamic range for all recorded returns, including last returns
Scan FOV	0 - 50 degrees; Programmable in increments of ±1degree
Scan Frequency	0 – 70 Hz
Scanner Product	Up to Scan angle x Scan frequency = 1000
Roll Compensation	±5 degrees at full FOV – more under reduced FOV
Pulse Rate Frequency	33 - 167 kHz
Position Orientation System	Applanix POS/AV 510 OEM includes embedded BD950 12-

	channel 10Hz GPS receiver
Laser Wavelength/Class	1047 nanometers / Class IV (FDA 21 CFR)
Beam Divergence nominal (full angle)	Dual Divergence 0.25 mrad (1/e) or 0.80 mrad (1/e)

Table 1 – Optech GEMINI specifications.

See http://www.optech.ca for more information from the manufacturer.
http://www.optech.ca/pdf/Brochures/ALTM-GEMINI.pdf

2. Description of PI's Areas of Interest.

The areas of interest are two experimental watersheds, Shotgun Creek and Twin Creek located in the Clearwater National Forest of northern Idaho. These areas are roughly 70 km southwest of Missoula, MT. and are delimited by two irregular polygons as shown in figure 1 (Google Maps image). The survey polygon for Shotgun Creek (Area 1) is approximately 15.8 square kilometers and for Twin Creek (Area 2) is 26.34 square kilometers. The polygon for area 1 is roughly 5 km long in the East-West orientation and 3.5 km long in the North-South direction. Area 2 has a maximum length of 8.86 km in the 155°azimuth with an average width of 2.77 km.

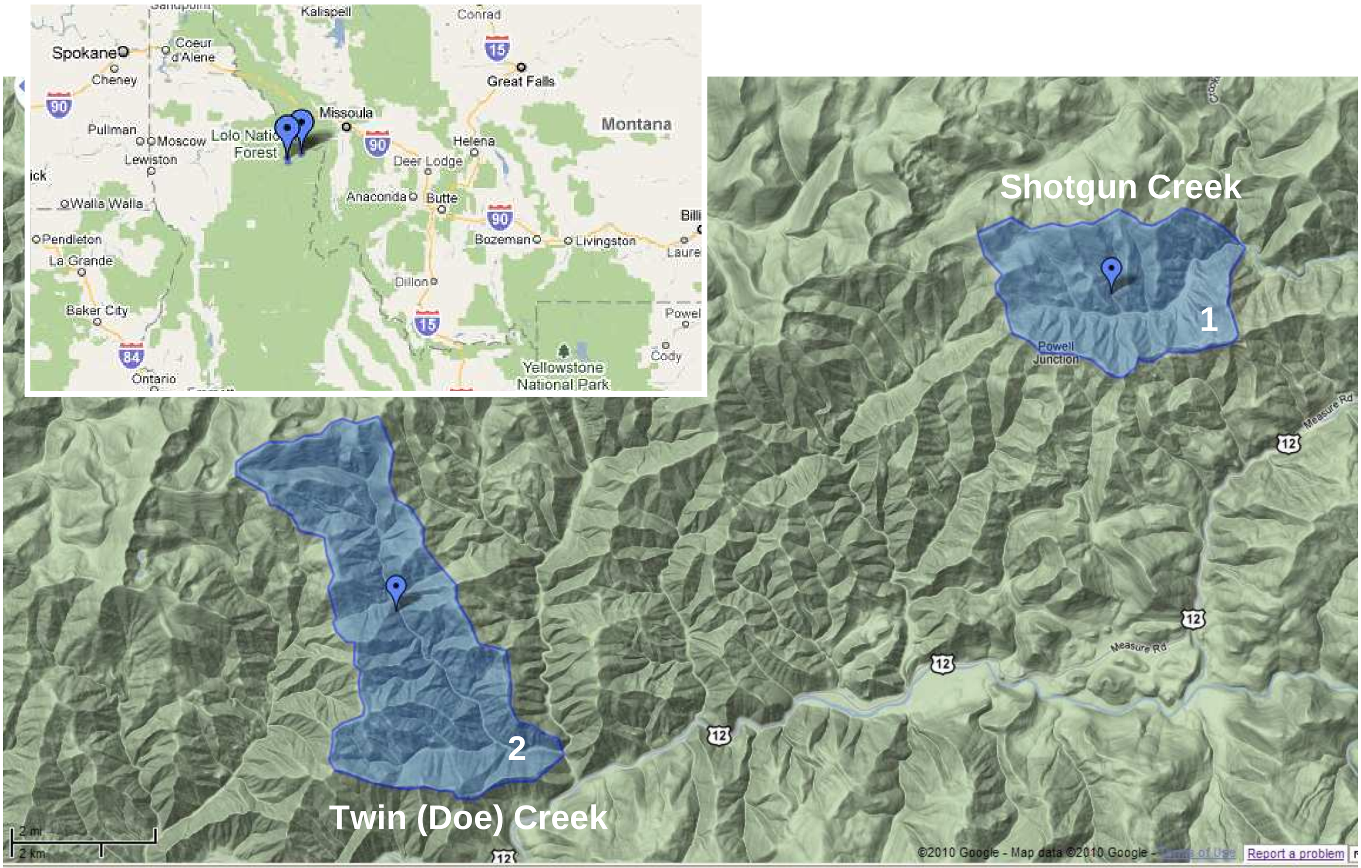

Figure 1 – Shape and location of survey polygon (Google Maps).

3. Airborne Survey Planning Process.

The survey planning was performed considering nominal values of 650m for flight altitude above the terrain, a mean flying speed of 60 m/s and a swath overlap of 50%. Taken into account these values and the layout of the areas of interest the optimized flight plan consisted of a total of 45 flight lines, 19 for Shotgun creek at azimuths of 90/270° and 26 for Twin creek at azimuths of 155/335°. In order to obtain the highest point density the laser Pulse Repetition Frequency (PRF) was set to 70 kHz. Scan frequency (mirror oscillation rate) was held to 40 Hz and the scan angle (Field-of-View or FOV) was limited to +/- 21 degrees. These parameters yield a scan product (frequency x angle) of 840 out of a system maximum of 1000, or about 84% of system limits. The combination of all these parameters should yield a point density of 4.7 points per m². Figure 2 show screen captures from the planning software displaying the planned flight lines along with other survey parameters for the Shotgun Creek area; these are also summarized in table 2.

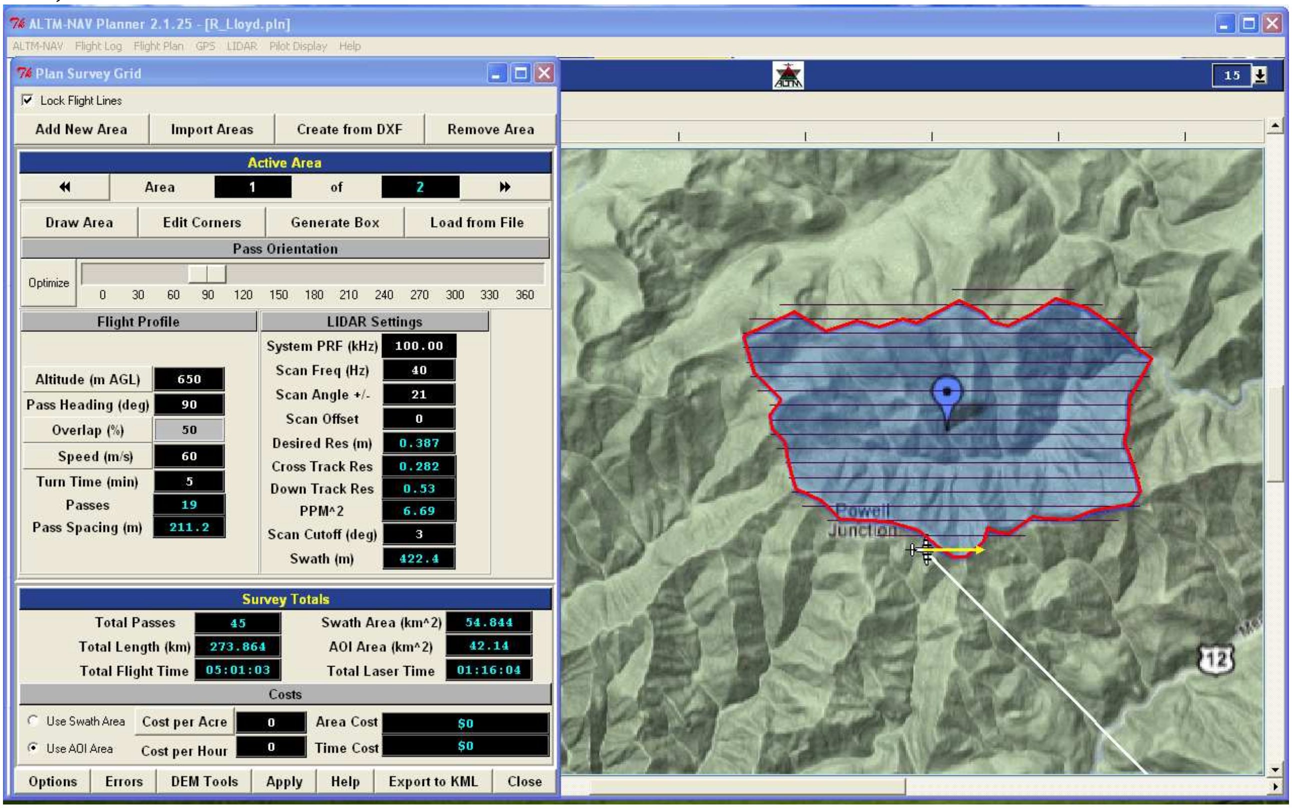

Figure 2. East-West flight lines for Shotgun Creek from the planning software.

Nominal Flight Parameters		Equipment Settings		Area Totals	
Flight Altitude	650 m	Laser PRF	70 kHz	Total Passes	19
Flight Speed	60 m/s	Beam Divergence	0.25 mrad	Total Length	89.749 km
Swath Width	422.4 m	Scan Frequency	40 Hz	Total Flight Time	1.9797 hrs
Swath Overlap	50%	Scan Angle	± 21°	Total Laser Time	0.4156 hrs
Point Density	4.68 p/m²	Scan Cutoff	3°	Total Swath Area	18.955 km²
		Scan Offset	0	Total AOI Area	15.8 km²

Table 2 – Shotgun Creek area survey totals. Area of Interest is abbreviated AOI.

Figure 3 show screen captures from the planning software displaying the planned flight lines along with other survey parameters for the Twin Creek area; these are also summarized in table 3. Finally the combined survey totals for both areas are presented in table 4.

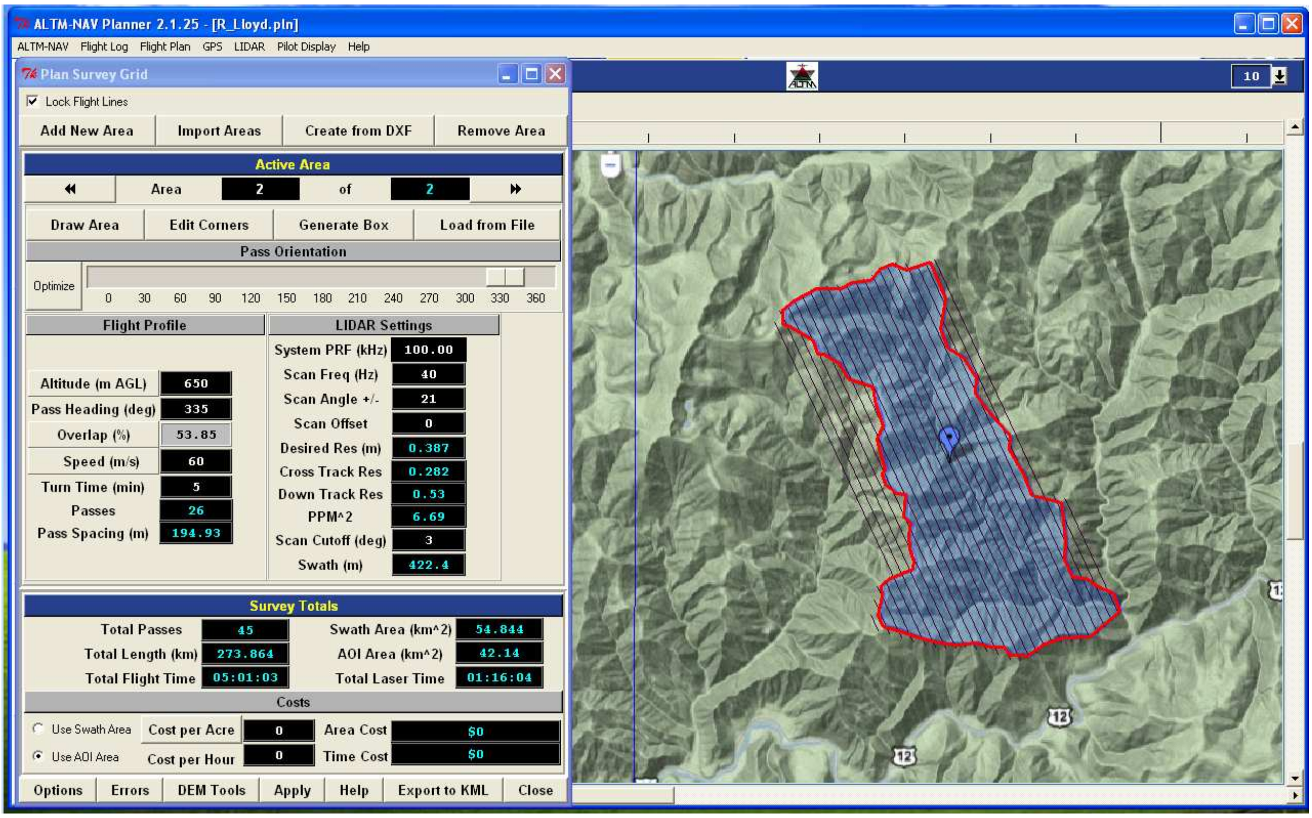

Figure 3 Flight lines for the Twin Creek from the planning software.

Nominal Flight Parameters		Equipment Settings		Area Totals	
Flight Altitude	650 m	Laser PRF	70 kHz	Total Passes	26
Flight Speed	60 m/s	Beam Divergence	0.25 mrad	Total Length	184.115 km
Swath Width	422.4 m	Scan Frequency	40 Hz	Total Flight Time	3.0024 hrs
Swath Overlap	50%	Scan Angle	± 21°	Total Laser Time	0.8525 hrs
Point Density	4.68 p/m²	Scan Cutoff	3°	Total Swath Area	35.889 km^2
		Scan Offset	0	Total AOI Area	26.34 km^2

Table 3 – Shotgun Creek area survey totals. Area of Interest is abbreviated AOI.

Survey Totals	
Total Passes	45
Total Length	273.684 km
Total Flight Time	5.0175 hrs
Total Laser Time	1.2678 hrs
Total Swath Area	54.844 km^2
Total AOI Area	42.14 km^2

Table 4 – Both areas survey totals. Area of Interest is abbreviated AOI.

4. LiDAR and GPS Data Collection Campaign.

This survey was flown on August 31, 2009 (DOY 243) in a single flight consisting of 50 flight lines (including cross lines). The total flight time was over 4.6 hours, with a total Laser-On Time of 1.58 Hours.

Two GPS reference station locations were temporary set by NCALM during the survey; labeled MISL and LOLA. MISL was set on the grounds of the Missoula Regional Airport and LOLA was set up near the intersection of Lolo Creek Road (State Road 12) with Elk Meadows Rd. The distance between MISL and the center of the polygons of Shotgun Creek and Twin Creek are roughly 37.51 and 55 km respectively and from MISI were roughly 60.3 and 77.3 km. All reference GPS observations were logged at 1 Hz. GPS ground station equipment consisted of ASHTECH (Thales Navigation) Z-Extreme receiver, with choke ring antenna (Part# 700936.D) mounted on 1.3-meter fixed-height tripod. The airborne receiver is an integrated GPS receiver module Trimble BD950, logging at 10 Hz. Figure 4 shows the location of the stations relative to the survey polygons.

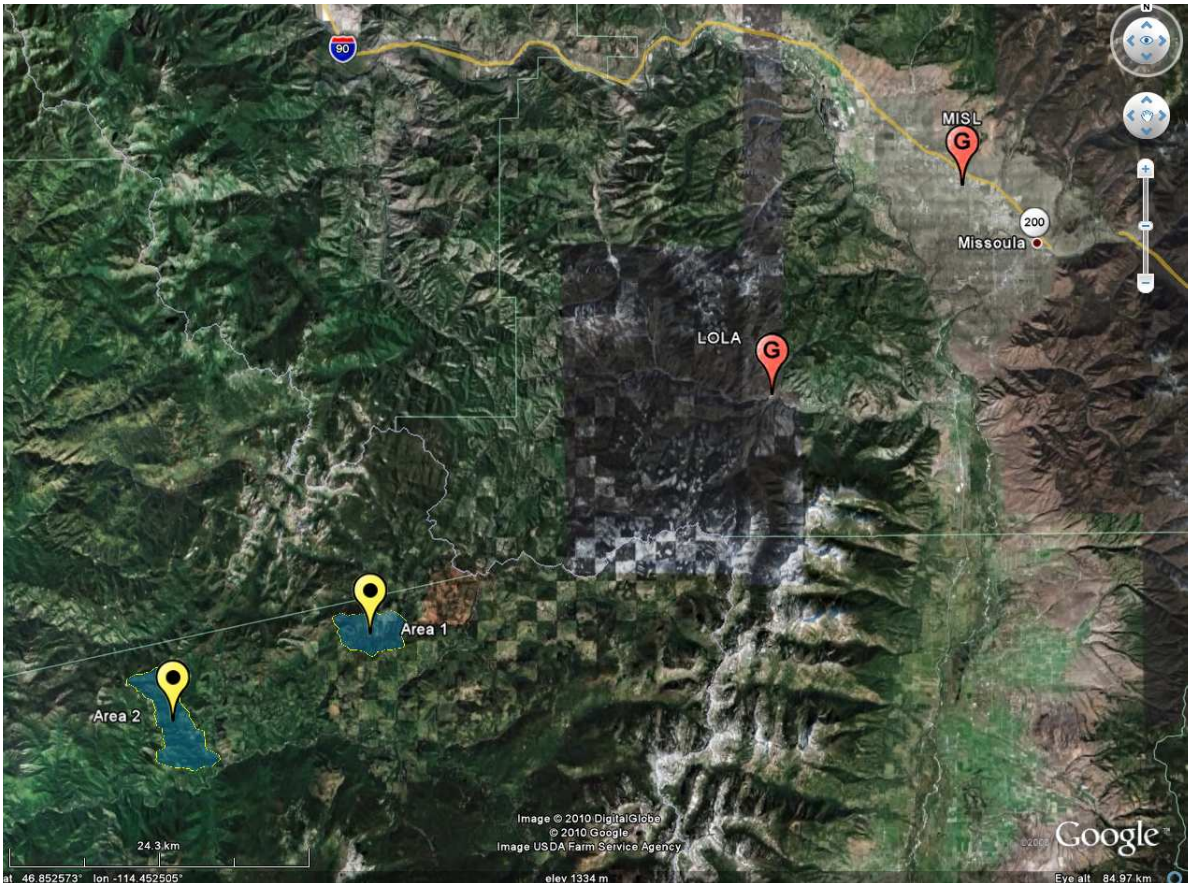

Figure 4. GPS stations and survey polygon location.

5. Data Processing and Final Product Generation.

5.1 GPS & INS Navigation Solution.

Reference coordinates for the MISL and LOLA stations were derived from a single observation session taken over the project duration and submitted to the NGS on-line processor OPUS which processes static differential baselines tied to the international CORS network. The OPUS solutions for both stations yielded reference station coordinate solutions with differences less than 0.050 meters in both horizontal and vertical components. For further information on OPUS see http://www.ngs.noaa.gov/OPUS/ and for more information on the CORS network see http://www.ngs.noaa.gov/CORS/ . OPUS solutions for reference stations MISL and LOLA for DOY 243 are included as Appendix A & B.

Airplane trajectories for this survey were processed using KARS (Kinematic and Rapid Static) software by Dr. Gerald Mader of the NGS Research Laboratory. KARS kinematic GPS processing uses the dual-frequency phase history files of the reference and airborne receivers to determine a high-accuracy fixed integer ionosphere-free differential solution at 1 Hz. Trajectories are obtained per reference station then the trajectories are differenced with one another. The standard deviation of the difference components for trajectories processed from LOLA and MISL are 0.017, 0.022, and 0.027 meters for the East, North and Up component respectively. The final selected trajectory was derived from the KPEL station observations.

After GPS processing, the trajectory solution and the raw inertial measurement unit (IMU) data collected during the flights are combined in APPLANIX software POSPac MMS (Mobile Mapping Suite Version 5.2). POSPac MMS implements a Kalman Filter algorithm to produce a final, smoothed, and complete navigation solution including both aircraft position and orientation at 200 Hz. This final navigation solution is known as an SBET (Smoothed Best Estimated Trajectory).

5.2 Laser point processing

An SBET together with laser ranges and mirror angles are finally combined in Optech's DashMap software (Version 4.0027) to generate a flight-strip point cloud in LAS format. All point cloud coordinates were processed with respect to **NAD83** and referenced to the international CORS network. The projection is UTM Zone 11, with units in meters**.**

Scan angle cut-offs are done to improve the overall DEM accuracy as points farthest from the scan nadir are the most affected by small errors in pitch, roll and scanner mirror angle measurements. Moreover, scan angle cut-offs are done to eliminate points at the edge of the scan lines for improving the overall DEM accuracy as the points farthest from the scan nadir are the most affected by small errors in pitch, roll and scanner mirror angle measurements. A scan cutoff angle of 4 degrees was used.

The elevation values outputted by the DashMap software are ellipsoid heights above the NAD83 ellipsoid. These values were converted to **NAVD88 orthometric heights** computed using the **NGS GEOID 03** with the Corpscon 6 conversion software. A second set of flight-strip point cloud data files in LAS format was generated by the elevation conversion. This dataset was used for all further processing.

5.3 Calibration

Relative calibration is done for each flight by the following method:

1. Planning and flying swaths with 50% side lap.
2. Surveying crossing flight-lines over calibration areas and over the project polygon.
3. Analyzing these overlaps and cross-lines in TerraMatch software. (see http://www.terrasolid.fi/en/products/4).

TerraMatch employs a least-squares approach (minimizing the height differences between computed laser surfaces from individual crossing and/or overlapping flight lines) to calculate the best-fit values for four parameters: three bore sight angle alignments (roll, pitch, and yaw), and the scanner mirror-angle scale factor.

The TerraMatch relative calibration procedure reduced the flighlines dz RMS from a starting value of 0.097 to 0.075.

Below is the TerraMatch report for the calibration site:

```
Used loaded points
Trajectories: E:\09_242_Lloyd\TerraScan\trj
No known points
Observe every 1th point
Solution for whole data set

Starting dz RMS:        0.0975
Final dz RMS:           0.0750

Standard error of unit  0.0335

Execution time: 6450.5 sec
Number of iterations: 24

Points        5971363
H shift       +0.0309    Std dev  0.0003
R shift       +0.0173    Std dev  0.0002
P shift       +0.0098    Std dev  0.0001
Scale        +0.00018
```

5.4 Classification

TerraSolid's TerraScan software was used to classify the raw laser point into the following categories: ground, non-ground (default), aerial points and low points. The processing is done by dividing each section into 1000m X 1000m tiles. For the two project areas a total of 112 tiles were created. A macro containing the classification steps is created, which is run on each tile with a 40 m buffer. This overlap ensures consistent results for corners and edges of the tile.

Various classification algorithms which were used are given below:

1) Isolated Points: This routine classifies points which do not have very many other points within a 3D search radius. This routine is useful for finding isolated points up in the air (fog) or below the ground (multipath). When possibly classifying one point, this routine will find how many neighboring points there are within a given 3D search radius. It will classify the point if it does not have enough neighbors.

2) Air points: It classifies points which are clearly higher than the median elevation of surrounding points. It can be used to classify noise up in the air. When possibly classifying one point, this routine will find all the neighboring source points within a given search radius. It will compute the median elevation of the points and the standard deviation of the elevations. The point will be classified only if it is more than a certain limit (user defined) times the standard deviation above the median elevation. Comparison using standard deviation results in the routine being less likely to classify points in places where there is greater elevation variation.

3) Low Points: This routine was used to search for possible error points which are clearly below the ground surface. The elevation of each point (=center) is compared with every other point within a given neighborhood and if the center point is clearly lower then any other point it will be classified as a "low point". This routine can also search for groups of low points where the whole group is lower than other points in the vicinity. Input parameters used were:

4) Ground Classification: This routine classifies ground points by iteratively building a triangulated surface model. The algorithm starts by selecting some local low points assumed as sure hits on the ground, within a specified windows size. This makes the algorithm particularly sensitive to low outliers in the initial dataset, hence the requirement of removing as many erroneous low points as possible in the first step. The routine builds an initial model from selected low points. Triangles in this initial model are mostly below the ground with only the vertices touching ground. The routine then starts molding the model upwards by iteratively adding new laser points to it. Each added point makes the model follow ground surface more closely.

Ground classification parameters used:

```
Max Building Size (window size): 40.0 m
Max Terrain Angle: 88.0
Iteration Angle: 6.2
Iteration Distance: 2.0 m
```

5) Classify By Height Above Ground: It classifies points which are within a given height range compared to the ground points surface model. The routine requires that you have already classified ground points successfully. This routine will build a temporary triangulated surface model from ground points and compare other points against the elevation of the triangulated model. This routine was used to filter out the noise because of clouds hovering above the ground surface around a constant altitude.

6) Classify Below Surface: This routine classifies points which are lower than neighboring points in the source class. This routine was run after ground classification to locate points which were below the true ground surface

The use of these classification algorithms depends on the nature of topography, vegetation characteristics and extent of urbanization.

5.5 DEM production

After classification two separate sets of overlapping (40m overlap) data tiles were outputted in ASCII XYZ format: one for the ground points (filtered) and one for ground and non-ground points combined (unfiltered). The ASCII tiles were gridded using Kriging interpolation at 1m cell size resolution using Golden Software's SURFER ver. 8.01. The tile overlap is required in order to obtain a consistent surface transition from one tile to the adjacent ones when merged.

The following parameters were used for Kriging:

```
Variogram type: Linear
Nugget Variance: 0.15 m
MicroVariance: 0.00 m
SearchDataPerSector: 7
SearchMinData: 5
SearchMaxEmpty: 1
SearchRadius: 5m (unfiltered), 40m (filtered)
```

The resulted Surfer binary grids were converted to ArcInfo raster format and mosaicked together into a seamless DEM using in-house Perl and AML scripts. Two separate mosaics were produced: one for the bare-earth surface (filtered) and one for the unfiltered (default) surface.

6. Deliverables Description.

Deliverables include the following:
1. Point Cloud in LAS format, classified as ground or non-ground, in 1 sq. km tiles.
2. ESRI format 1-m DEM from ground classified points.
3. ESRI format 1-m DEM from all points (canopy included).
4. Unfiltered point cloud in ASCII format.
5. Filtered (bare-earth) point cloud in ASCII format.

The point cloud files are delivered in the 1000m x 1000m tiles in LAS 1.1 format. It is a binary format contains all the information associated with each point i.e. its position in X,Y,Z, intensity, flight line, timestamp, scan angle etc. The individual Las files can be converted to ASCII using the LAS to ASCII converter tool developed by the UNC. It can be accessed at http://www.cs.unc.edu/~isenburg/lastools
It gives users the freedom to create ASCII files with whichever point features they want to access.
The complete LAS 1.1 specification can be found at this address:
http://liblas.org/raw-attachment/wiki/WikiStart/asprs_las_format_v11.pdf

The point classes used for this project are slightly different from the ASPRS list found in the LAS 1.1 specification. The following values can be found in the LAS Classification field:

1 - unclassified
2 - ground
7 - low point
9 - aerial point
10 - isolated point

The file naming convention for the LAS tiles is the following: bXXXXXX_YYYYYYY.las
, where (XXXXX, YYYYYYY) is the lower left corner tile coordinate in UTM projection.

For convenience, filtered (bare-earth) and unfiltered tiles are also provided in ASCII XYZ format. These files follow the same naming convention as the LAS tiles. Bare-earth point cloud tiles are prefixed with "f" and unfiltered point cloud tiles are prefixed with "u".

The project for all point cloud data (LAS and ASCII) is UTM zone 11N, NAVD88.

7. Appendices

APPENDIX A – OPUS Solutions for MISL GPS Reference Station

```
FILE: MISL243z.09o 000057831

1008   NOTE:  Antenna offsets supplied by the user were zero.  Coordinates
1008   returned will be for the antenna reference point (ARP).
1008
                             NGS OPUS SOLUTION REPORT
                             ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.html#accuracy

     USER: jcfernan@ufl.edu                        DATE: February 10, 2010
RINEX FILE: misl243o.09o                            TIME: 17:31:05 UTC


 SOFTWARE: page5  0909.08 master.pl 0810233       START: 2009/08/31  14:51:00
EPHEMERIS: igs15471.eph [precise]                  STOP: 2009/08/31  20:47:00
 NAV FILE: brdc2430.09n                        OBS USED: 15629 / 16293   :  96%
 ANT NAME: ASH700936D_M    NONE             # FIXED AMB:    66 /    75   :  88%
ARP HEIGHT: 0.0                           OVERALL RMS: 0.009(m)


REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2009.6650)

        X:     -1780582.138(m)   0.018(m)          -1780582.914(m)   0.018(m)
        Y:     -3985592.738(m)   0.016(m)          -3985591.525(m)   0.016(m)
        Z:      4636019.699(m)   0.015(m)           4636019.703(m)   0.015(m)

      LAT:   46 54 54.02585      0.006(m)        46 54 54.04464      0.006(m)
    E LON:  245 55 37.46510      0.010(m)       245 55 37.40824      0.010(m)
    W LON:  114  4 22.53490      0.010(m)       114  4 22.59176      0.010(m)
   EL HGT:          963.932(m)   0.026(m)               963.394(m)   0.026(m)
ORTHO HGT:          978.857(m)   0.095(m) [NAVD88 (Computed using GEOID09)]

                       UTM COORDINATES    STATE PLANE COORDINATES
                        UTM (Zone 11)        SPC (2500 MT  )
Northing (Y) [meters]     5199878.908           306294.338
Easting (X)  [meters]      722878.727           252059.188
Convergence  [degrees]     2.13863868          -3.34511486
Point Scale                1.00021058           0.99939408
Combined Factor            1.00005948           0.99924310

US NATIONAL GRID DESIGNATOR: 11TQM2287899878(NAD 83)



                             BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
DK4101 PLS5 POLSON 5 CORS ARP              N473949.553 W1140650.078   83314.0
DE8232 MSOL MISSOULA CORS ARP              N465545.837 W1140631.846    3169.8
DI2254 P046 CLEARWATERMT2006 CORS ARP      N470146.523 W1131954.185   57833.7

                NEAREST NGS PUBLISHED CONTROL POINT
RY0010      MISSOULA BASE A STA RM 1       N465448.702 W1140401.344     476.9

This position and the above vector components were computed without any
knowledge by the National Geodetic Survey regarding the equipment or
field operating procedures used.
```

APPENDIX B – OPUS Solutions for LOLA GPS Reference Station

```
FILE: LOLA243z.09o 000057829

1008   NOTE:  Antenna offsets supplied by the user were zero.  Coordinates
1008   returned will be for the antenna reference point (ARP).
1008
                             NGS OPUS SOLUTION REPORT
                             ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.html#accuracy

     USER: jcfernan@ufl.edu                        DATE: February 10, 2010
RINEX FILE: lola243n.09o                            TIME: 17:30:47 UTC


 SOFTWARE: page5  0909.08 master50.pl 081023      START: 2009/08/31  13:57:00
EPHEMERIS: igs15471.eph [precise]                  STOP: 2009/08/31  21:30:30
 NAV FILE: brdc2430.09n                        OBS USED: 18813 / 19506   :  96%
 ANT NAME: ASH700936D_M    NONE              # FIXED AMB:    71 /    81   :  88%
ARP HEIGHT: 0.0                                OVERALL RMS: 0.011(m)


REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2009.6650)

        X:     -1799914.309(m)   0.017(m)          -1799915.084(m)   0.017(m)
        Y:     -3990472.739(m)   0.012(m)          -3990471.526(m)   0.012(m)
        Z:      4624574.574(m)   0.006(m)           4624574.578(m)   0.006(m)

      LAT:   46 45 48.40125      0.011(m)        46 45 48.41991      0.011(m)
    E LON:  245 43 19.58378      0.011(m)       245 43 19.52700      0.011(m)
    W LON:  114 16 40.41622      0.011(m)       114 16 40.47300      0.011(m)
   EL HGT:         1076.529(m)   0.015(m)              1075.993(m)   0.015(m)
ORTHO HGT:         1091.139(m)   0.093(m) [NAVD88 (Computed using GEOID09)]

                       UTM COORDINATES    STATE PLANE COORDINATES
                        UTM (Zone 11)         SPC (2500 MT  )
Northing (Y) [meters]     5182475.654           290417.854
Easting (X)  [meters]      707856.618           235456.243
Convergence  [degrees]     1.98384798          -3.49504910
Point Scale                1.00013106           0.99940204
Combined Factor            0.99996232           0.99923342

US NATIONAL GRID DESIGNATOR: 11TQM0785682475(NAD 83)



                             BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
DK4103 PLS6 POLSON 6 CORS ARP              N473949.529 W1140651.393  100872.0
DE8232 MSOL MISSOULA CORS ARP              N465545.837 W1140631.846   22511.8
DI2254 P046 CLEARWATERMT2006 CORS ARP      N470146.523 W1131954.185   77949.2

                NEAREST NGS PUBLISHED CONTROL POINT
RY0075      HIGHWAY 12 STA 819+94          N464551.    W1141647.        161.0

This position and the above vector components were computed without any
knowledge by the National Geodetic Survey regarding the equipment or
field operating procedures used.
```

```
NGS OPUS SOLUTION REPORT
                              ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: www.ngs.noaa.gov/OPUS/Using_OPUS.html#accuracy

      USER: michaels@ufl.edu                        DATE: May 05, 2009
RINEX FILE: 5sis118m.09o                            TIME: 18:30:17 UTC


  SOFTWARE: page5  0810.20 master12.pl 081023      START: 2009/04/28  12:53:00
 EPHEMERIS: igr15292.eph [rapid]                    STOP: 2009/04/28  22:48:30
  NAV FILE: brdc1180.09n                        OBS USED: 25524 / 26064   :  98%
  ANT NAME: ASH700936D_M    NONE             # FIXED AMB:    94 /   106   :  89%
ARP HEIGHT: 1.300                            OVERALL RMS: 0.018(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2009.3225)

         X:       111002.407(m)   0.012(m)           111001.736(m)   0.012(m)
         Y:     -6099384.360(m)   0.034(m)         -6099382.692(m)   0.034(m)
         Z:      1856993.382(m)   0.022(m)          1856993.106(m)   0.022(m)

       LAT:   17  2 16.95295      0.027(m)        17  2 16.96038      0.027(m)
     E LON:  271  2 33.38910      0.012(m)       271  2 33.36744      0.012(m)
     W LON:   88 57 26.61090      0.012(m)        88 57 26.63256      0.012(m)
    EL HGT:          458.025(m)   0.029(m)              456.338(m)   0.029(m)
 ORTHO HGT: [No NGS Geoid Model Available (FAQ 21).]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 16)         *** NOTE ***
Northing (Y) [meters]     1884806.536      Please manually select
Easting (X)  [meters]      291657.153      SPC zone.
Convergence  [degrees]    -0.57373658
Point Scale                1.00013675
Combined Factor            0.00000000

US NATIONAL GRID DESIGNATOR: 16QBD9165784807(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AI7441 GUAT GUATEMALA CITY CORS ARP        N143525.448 W0903112.637  318427.6
AI8353 SSIA SAN SALVADOR CORS ARP          N134149.499 W0890659.724  370059.6
DH8188 CHET CHETUMAL CORS ARP                                        175737.7

                 NEAREST NGS PUBLISHED CONTROL POINT
AJ8058      SANTA ELENA CORS ARP           N165457.793 W0895203.387   97855.9

This position and the above vector components were computed without any knowledge by the National
Geodetic Survey regarding the equipment or field operating procedures used.
```