LiDAR QA/QC
- Quantitative and Qualitative Assessment Report -
Northwest Florida Water Management District
Sanborn Add-on;
Washington, Jackson and Calhoun Counties
September 2, 2008

Prepared by:

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Executive Summary

This LiDAR dataset, called NWFWMD LiDAR Add-on, was flown by Sanborn in February and March of 2007 and covers approximately 488 square miles. The LiDAR data covers the southern half of Washington County, the southwestern tip of Jackson County, and a western section of Calhoun County. This dataset was extracted from a larger dataset that was flown as part of the FDEM project and will be used to fill in a data gap for the Merrick LiDAR data that was flown for NWFWMD and reviewed by Dewberry in July 2008 (see Figure 1).

Dewberry's review of LiDAR data includes a quantitative (accuracy) and qualitative (usability) check of the data to ensure accuracy. For the vertical accuracy check, Dewberry reviewed the accuracy statistics from the checkpoints provided by Sanborn. The qualitative assessment included a completeness check and qualitative review. The LiDAR data was checked using the same accuracy standards as outlined in the *LiDAR QA/QC Quantitative and Qualitative Assessment Report, Northwest Florida Water Management District, July 17, 2008.*

First, based on the survey data provided by Sanborn, the LiDAR meets the accuracy required for this project (Consolidated RMSE of 0.34 ft. compared to the specified 0.61ft and Consolidated Vertical Accuracy of 0.71 ft compared to the specified 1.195 ft) per the NWFMED SOW to Sanborn. It should be noted that the methodology to assess accuracy does not explicitly comply with FEMA Appendix A Guidelines and Specifications but the same process is utilized to assess the accuracy. The data was also tested utilizing the National Digital Elevation Program methodology (NDEP), again meeting the desired accuracy requirements.

Second, Dewberry inventoried the files and inspected 100% of the data at a macro level. A missing scanline issue was found along the northern edge of the data but this area is covered by the Merrick data. This is discussed in further detail in the QA section. There were also a few potential missing tiles of data in southwest Calhoun County. The cleanliness of the bare earth model was assessed on 30% of the tiles at the micro level. Although there were a few minor errors found they are not representative of the entire dataset. In essence this LiDAR dataset produced by Sanborn exhibits very good quality and will meet the needs of NWFWMD. This memorandum will detail the QAQC process that Dewberry performed as well as discuss how the dataset compares to the Merrick datasets in the overlap area.

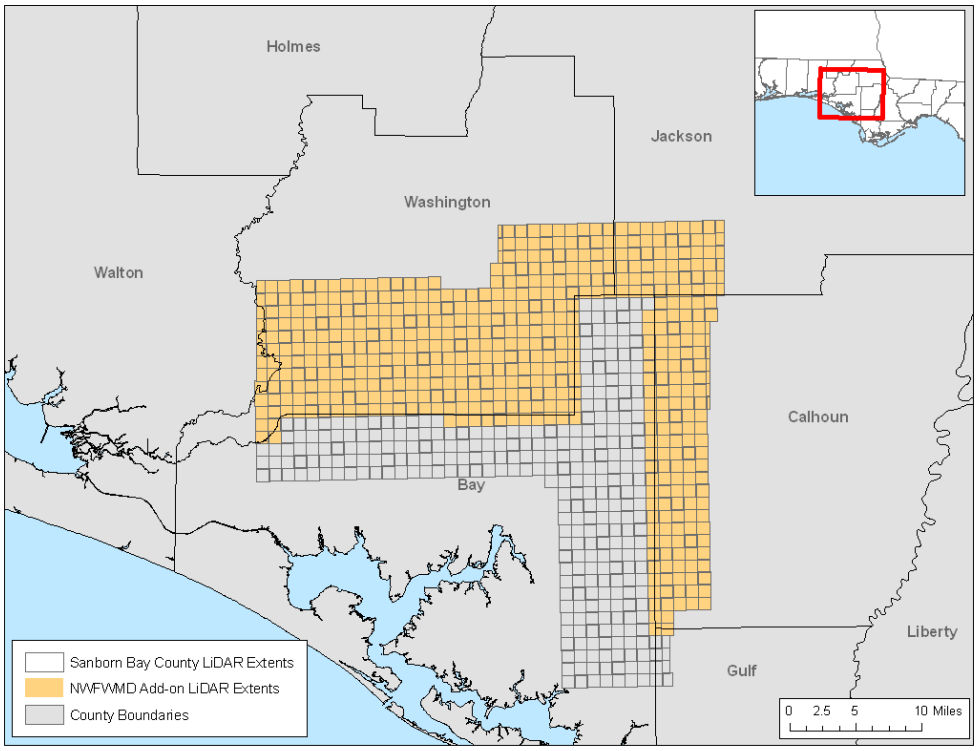

Figure 1 - This image shows the extents of the Sanborn LiDAR dataset reviewed by Dewberry. The orange tiles are the tiles extracted from the full deliverable that will fill in the data gap.

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1 NWFWMD LiDAR Add-on QAQC Review

1.1 Vertical Accuracy Assessment

To assess the vertical accuracy, Dewberry was to review the accuracy reports which were to be compiled by Sanborn. However these reports were not complete at the time of this LiDAR review so Dewberry requested the internal survey checkpoints that were utilized by Sanborn to perform our own vertical assessment. A total of 50 vertical checkpoints were captured throughout the project area; these points are listed in Appendix A. Figure 2 illustrates the distribution of the checkpoints throughout the Sanborn LiDAR extents.

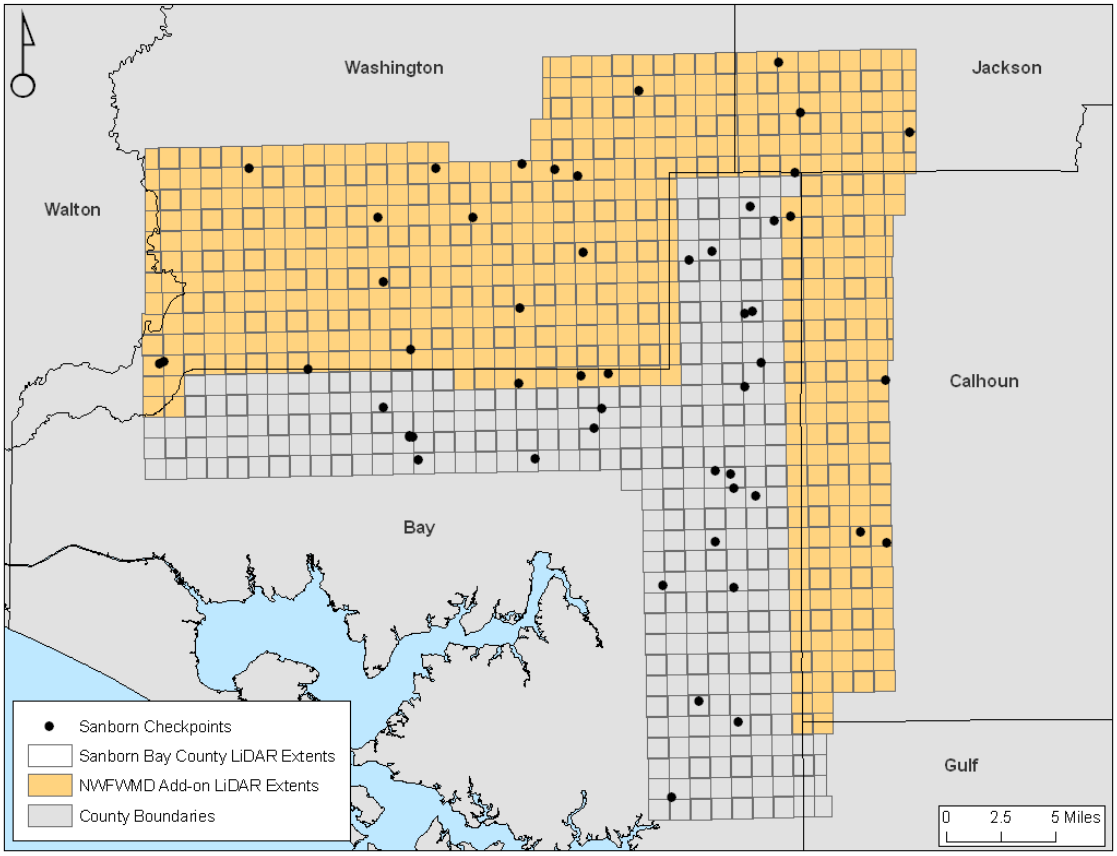


Figure 2 - Checkpoint locations for survey of Sanborn LiDAR data.

Tables 1 and 2 show the complete results of the Sanborn LiDAR dataset run through the Dewberry RMSE process which is similar to FEMA Appendix A methodology for computing Root Mean Square Error (RMSE) but with additional statistics. This methodology assumes that errors follow a normal distribution and this may not always be the case. Therefore we also reviewed the data based on the NDEP method which does not assume that errors follow a normal distribution which can be the case in vegetated areas. Using both methods the results proved to be well within the specified RMSE and the equivalent category of Consolidated Vertical Accuracy (CVA). Additionally the data also meets the fundamental as well as supplemental vertical accuracy (FVA and SVA).

Table 1 - Dewberry RMSE methodology accuracy assessment.

100 % of Totals	RMSE (ft) Spec=0.61ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	# of Points	Min (ft)	Max (ft)
Consolidated	0.338	-0.008	0.030	-0.119	0.341	50	-0.747	0.782
Bare earth	0.363	-0.008	-0.014	0.135	0.369	30	-0.747	0.782
High grass	0.317	-0.070	-0.002	-1.082	0.326	10	-0.705	0.311
Urban	0.271	0.055	0.093	-0.561	0.280	10	-0.458	0.427

Table 2 - NDEP methodology accuracy assessment.

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec=1.195 ft	CVA — Consolidated Vertical Accuracy (95th Percentile) Spec=1.195 ft	SVA — Supplemental Vertical Accuracy (95th Percentile) Target=1.195 ft
Consolidated	50		0.714	
bare earth	30	0.712		0.736
high grass	10			0.637
urban	10			0.444

Figure 3 illustrates the distribution of the elevation differences between the LiDAR data and the surveyed points. The bare earth elevation deltas are centered around zero which can also be seen in Table 1 in the mean and median columns. Based on the above testing methodologies this data meets the desired accuracy.

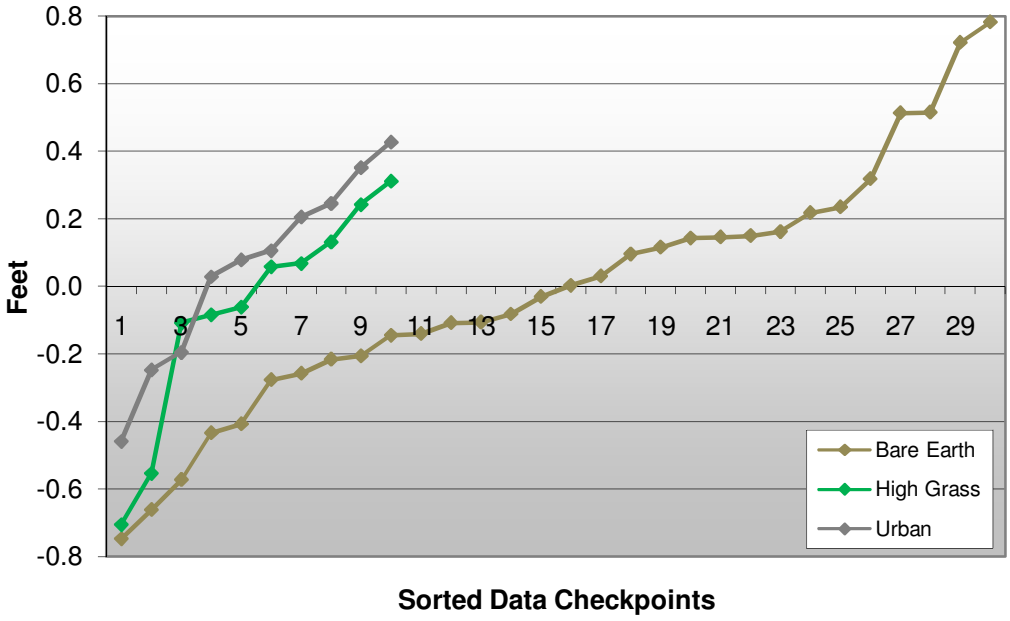


Figure 3 - Sorted elevation errors for 50 survey checkpoints.

Based on the supplied checkpoints, Dewberry's review of the vertical accuracy of the Sanborn LiDAR data confirms that the dataset meets the accuracy requirement as defined by NWFWMD.

1.2 Completeness of LiDAR Deliverables

To ensure data conformance to the deliverables a completeness check is performed. A total of 848 LAS tiles, 848 XML metadata files, and 848 DEM rasters in ArcGIS GRID format were delivered by Sanborn for the Bay County project area. Dewberry verified that the data is in the correct projection and each LAS file includes the following information:

- XYZ coordinates
- Intensity
- Flightline number
- Return number, number of returns
- Classification
    - Class 1 for unclassified
    - Class 2 for ground
    - Class 7 for low points
    - Class 9 for water
    - Class 12 for overlap points

This classification scheme differs from the NWFWMD specifications of Class 2 for ground and Class 5 for low vegetation. It was also discovered that there was an

inconsistency in the classification as only 9 LiDAR tiles actually included a Class 12 for overlap points. These tiles were scattered sporadically throughout the dataset. Upon further investigation it was revealed that the overlap points in the other tiles were put into Class 1 “unclassified”. Due to the processing methodology of classifying the data which includes overlap points (and not removing them) this is not an issue that needs to be resolved but should be noted.

The data was correctly projected to UTM Zone 16 North, NAD83 and the vertical datum is NADV88. The horizontal units are in meters and the vertical units in US Survey Feet.

It should also be mentioned that there was a small area in southwest Calhoun County where a few tiles of data are missing. It is unsure whether these tiles should have been flown by Sanborn or Merrick. The missing area is shown in the image below (see Figure 4).

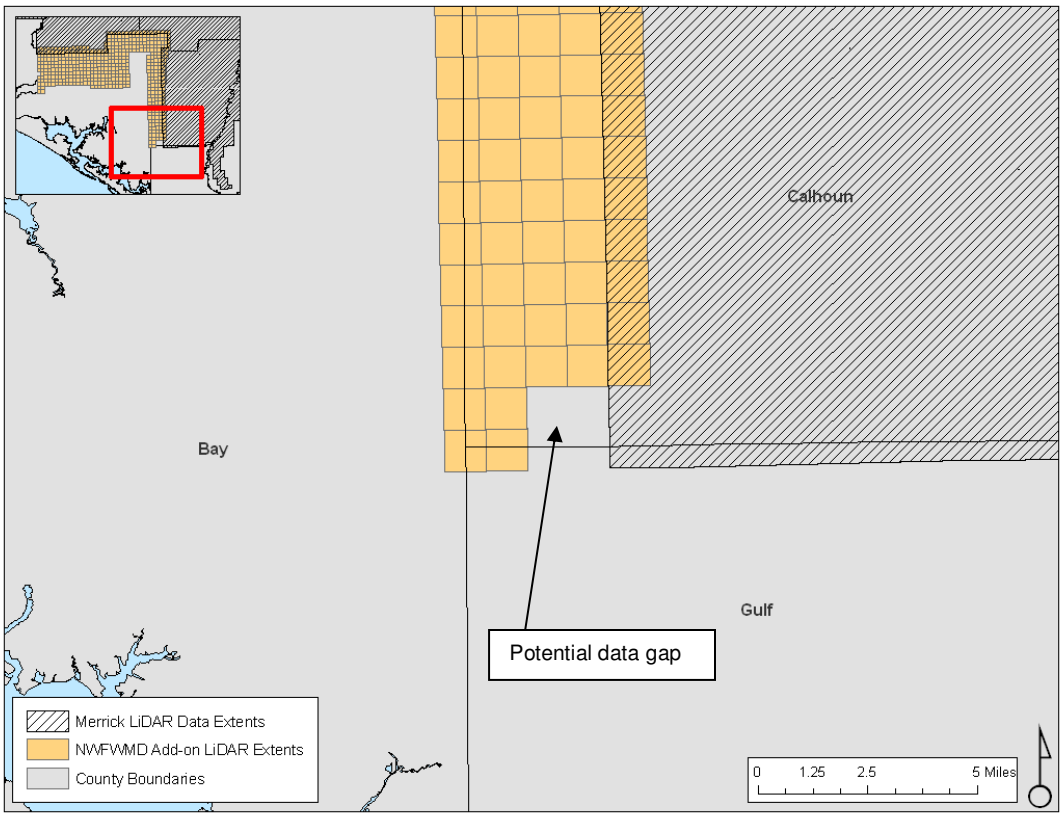


Figure 4 - This image shows a data gap where no LiDAR tiles were delivered by Sanborn or Merrick.

1.3 Statistical Analysis of Tile Content

The statistical analyses were only done on the NWFWMD LiDAR Add-on tiles rather than the full LiDAR dataset for Bay County that was delivered by Sanborn as the remainder of the data will be verified under the FDEM program. Statistics such as the number of LiDAR points, the number and type of classes, minimum and maximum

elevations as well as descriptive statistic (mean, median etc), are input to a database for analysis. This allows us to identify any gross errors in the data deliverable through the tabular data but it is also visually mapped. Each tile is queried to extract the number of LiDAR points and all tiles are statistically compared. The data are within the anticipated size range as shown in Figure 5. The green tiles on the edge of the dataset are not full tiles therefore there are less points in them.

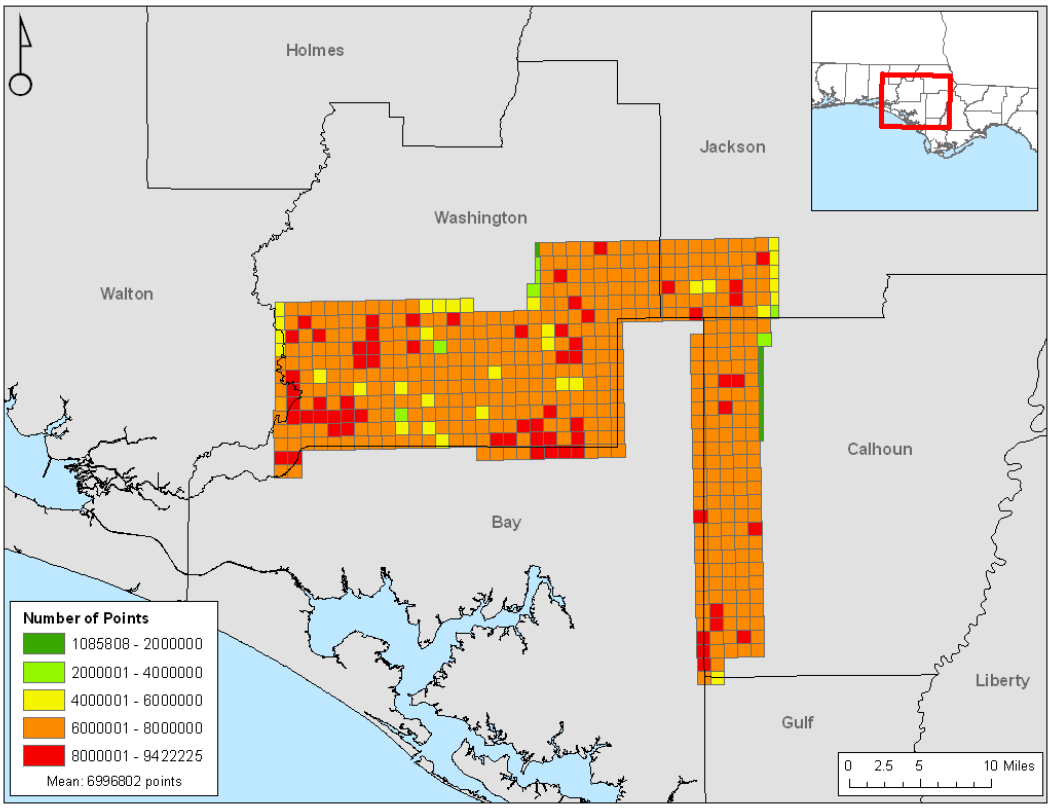


Figure 5 - Number of points per tile.

To first identify incorrect elevations, the z-minimum and z-maximum values for the ground class were reviewed. Figure 6 and Figure 7 illustrate the spatial distribution of these elevations. With maximum ground values between 18 and 328 ft, no noticeable anomalies were identified. Considering the natural decrease in elevation towards the coastal areas, the images of the lowest and highest elevations seem to correlate with one another. An additional visual verification is performed by creating a decimated image of the full LiDAR extents. Again this allows us to find missing tiles are data and to aid in identifying gross anomalies (see Figure 8).

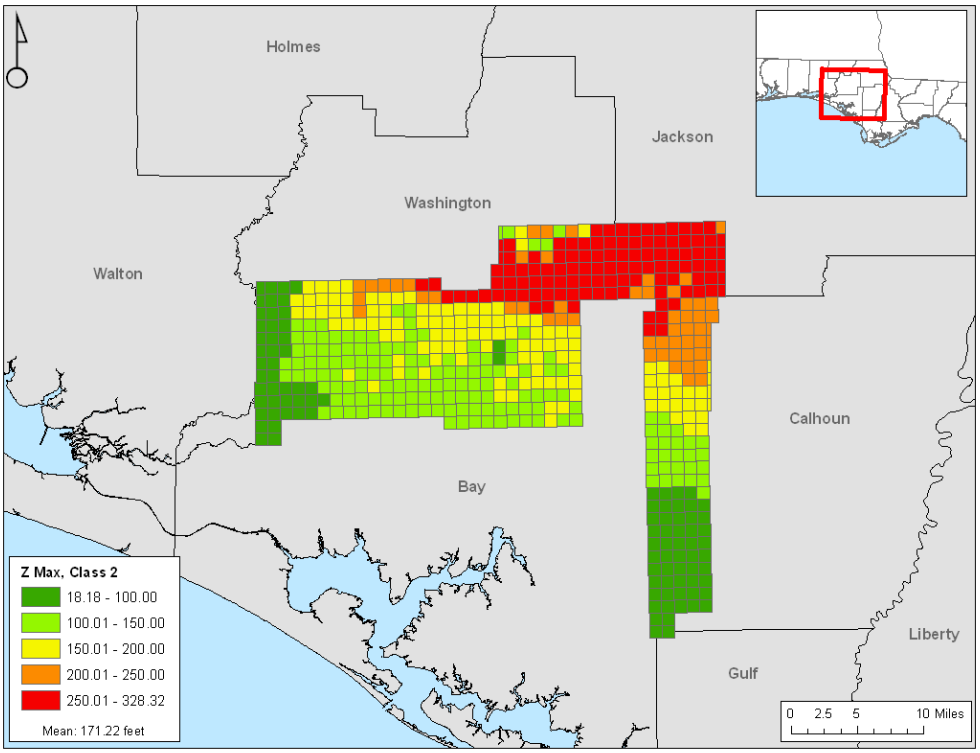


Figure 6 - Tiles classified by highest elevation in feet, class 2 (ground).

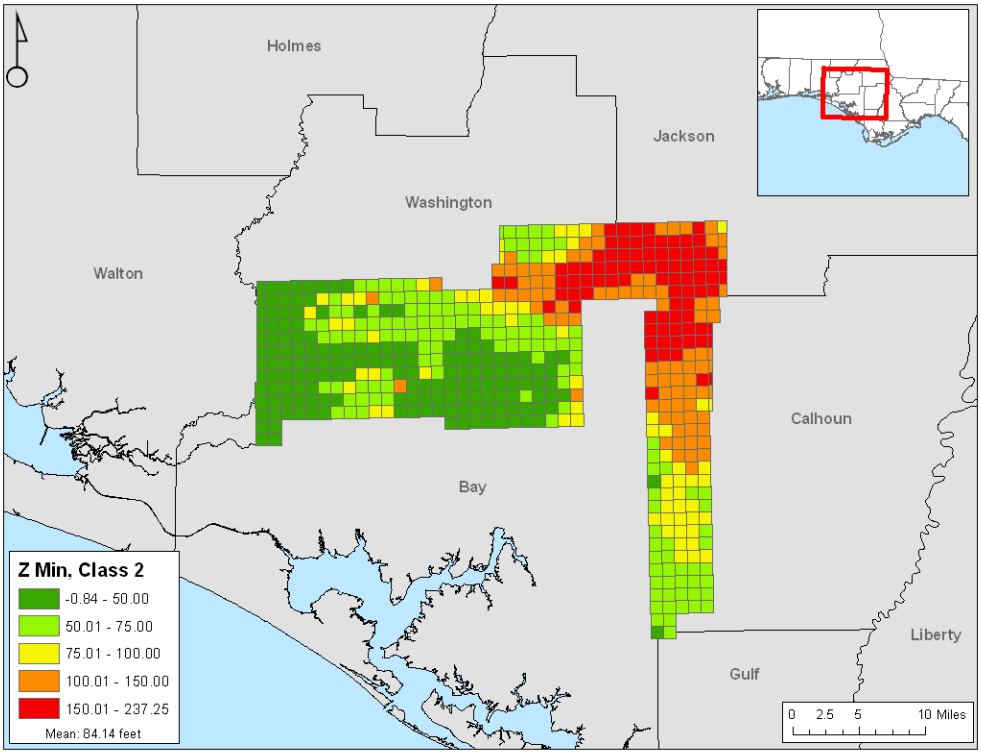


Figure 7 - Tiles classified by lowest elevation, class 2 (ground).

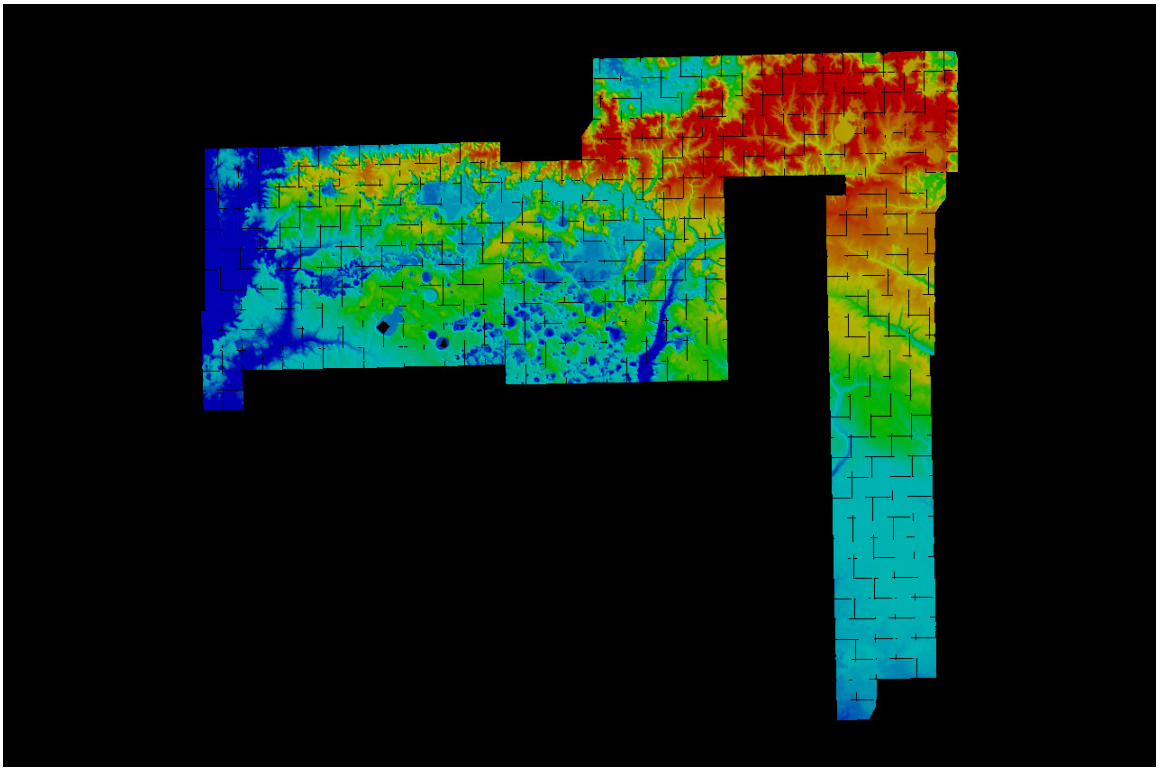


Figure 8 - Decimated image of the full extents of the NWFWMD LiDAR Add-on dataset.

1.4 Qualitative Assessment

Our qualitative review was to perform a macro visual inspection of all the tiles and to inspect a minimum of 30% at a micro level of detail. The NWFWMD LiDAR Add-on data proved to be of excellent quality and no significant anomalies were found. There were a few minor issues discovered which are outlined in the text and images below.

Missing Scanlines
One issue that was found in the tiles located along the northern and eastern edge of the dataset was areas of missing or incomplete scanlines. Figure 9 displays this phenomenon. The image on the left is a LiDAR tile classified by flightline. It is easy to see where the scans begin and end. The image on the right is the same LiDAR tile classified by elevation. This issue is commonly seen in LiDAR tiles along the edge of a dataset and is only problematic when there is no adjacent LiDAR data that overlaps these tiles. For this project, the Merrick LiDAR data covers this area along the outer edge eliminating the missing data problem. The extent of this overlap can be seen in Figure 15. Although we have indentified this issue as a missing scan line, we do not have the contractual boundaries to definitively define if it is in or outside the boundary. However this tile is full covered by LiDAR with the Merrick data.

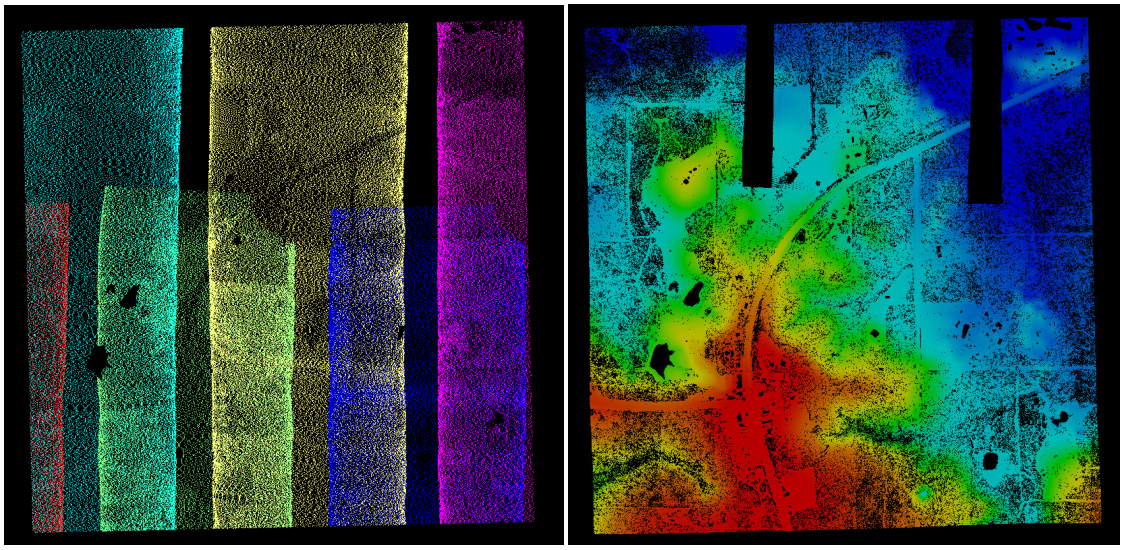


Figure 9 - Tile 15555750. Image on left is LiDAR points classified by flightline. Image on right is LiDAR points classified by elevation.

Artifacts

There were a few instances where the vegetation removal process was not completely successful resulting in artifacts. This is not a significant issue as it was not found to be widespread throughout the dataset and are within desirable limits. The artifacts were mostly found in areas of dense vegetation along a river bed where classification can become difficult. Figure 10 and Figure 11 display examples of the types of artifacts found in the data.

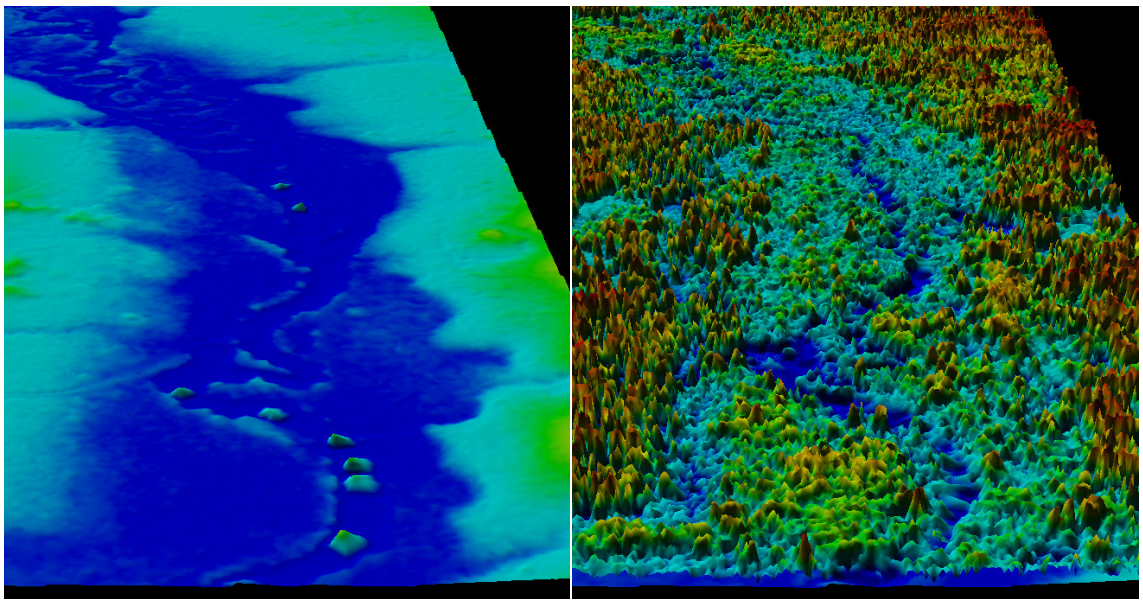


Figure 10 – Tile 15305150. Left image is ground model showing several artifacts left in after vegetation classification. Right image is full point cloud model of same area showing how dense the vegetation is in this area.

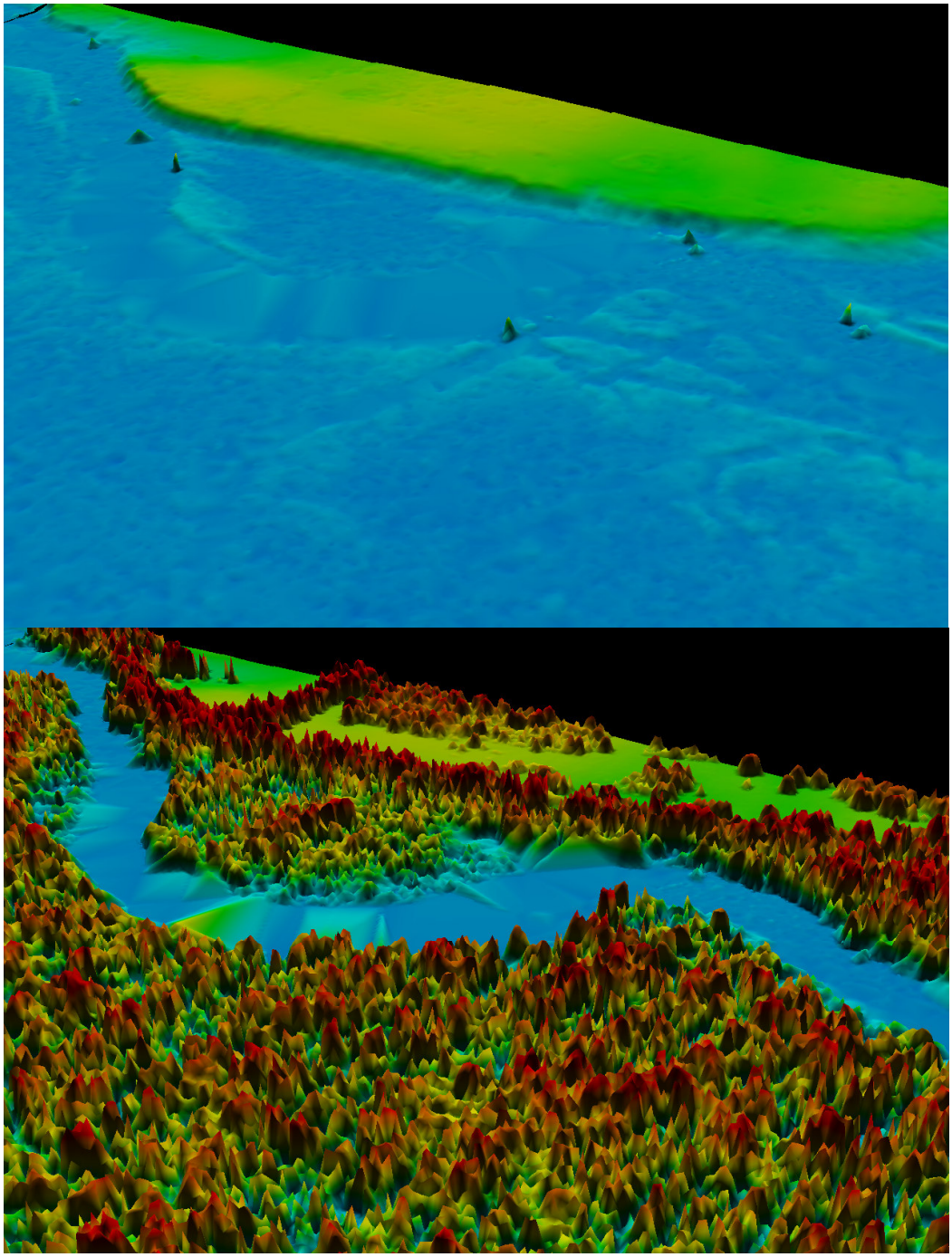


Figure 11 – Tile 15305600. Top image is ground model showing several artifacts. Bottom image is full point cloud model showing vegetation.

Poor Penetration

Several patches of sparse data were also found where the LiDAR did not get to the ground. This penetration problem was more pronounced in the southern section of the dataset in western Calhoun County which, as seen in Figure 14, which is characterized by dense vegetation. Figure 12 and Figure 13 display a couple examples of this. Due to the vegetation characteristics and the inability of no other technology achieving the same

accuracy as LiDAR in dense vegetation, the data is acceptable as no large significant gaps are present.

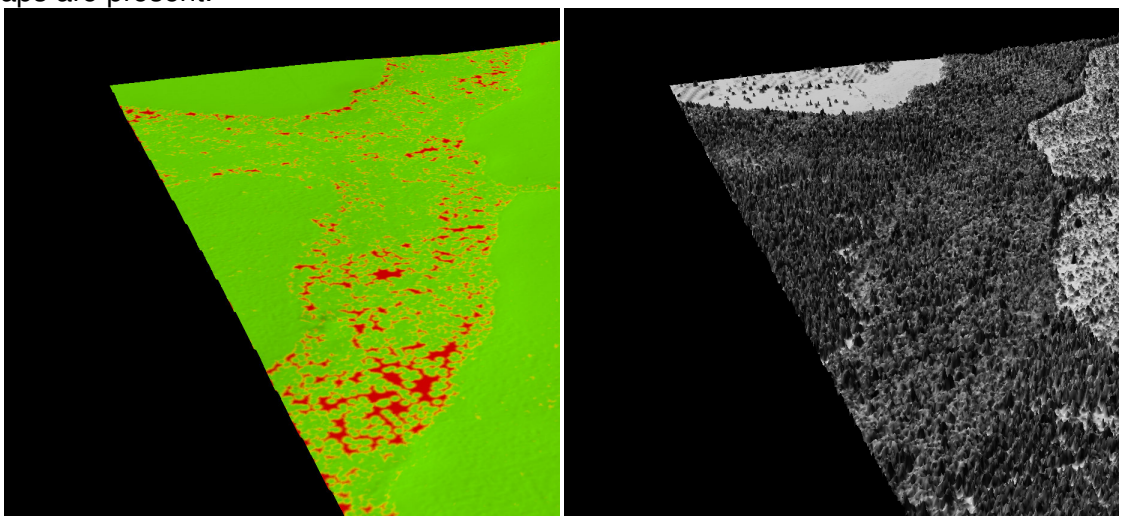


Figure 12 –Tile 17055400. Left is a density ground image where red indicates missing data. Right is full point cloud intensity image showing the vegetated area where the LiDAR pulse could not penetrate completely.

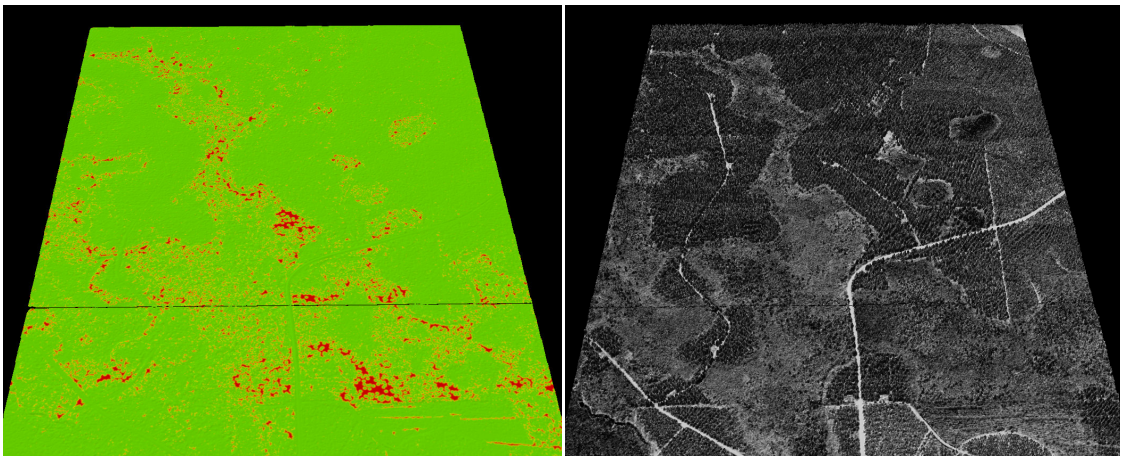


Figure 13 – Tile 16954850. Additional example of area of poor penetration.

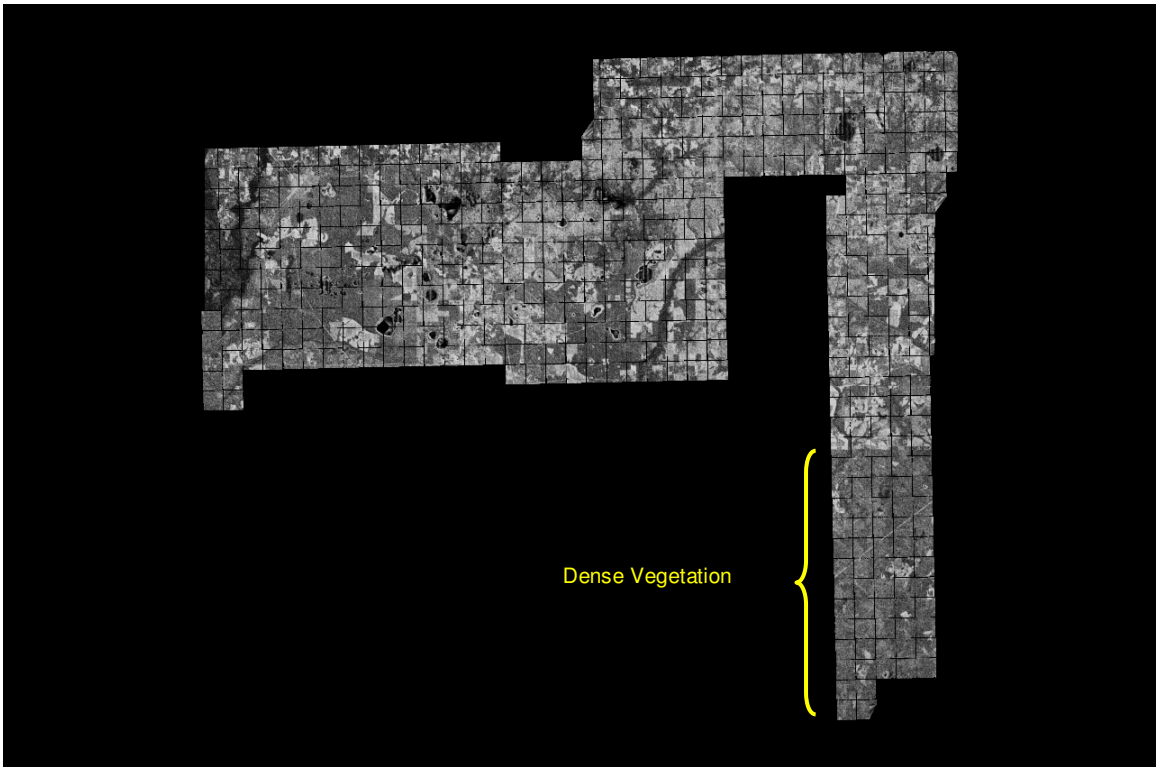


Figure 14 - Decimated image of full point cloud LiDAR points with intensity. This image aids in identifying land cover type. Forest areas are depicted by a darker color which reflects less energy of the LiDAR return.

1.5 Overlap Area

As this dataset is eventually going to be used in conjunction with the Merrick LiDAR data, it was important to take a look at the edges of each dataset to ensure that they could be effectively merged. There will always be a slight difference between adjoining datasets as different providers use different parameters to process and classify data based on the type of terrain as well as ground conditions at the time of acquisition. Additionally different survey control could have been used yielding slightly different results. In order to verify this, Dewberry examined 12 areas where the Sanborn data overlaps with the Merrick data. Figure 15 illustrates the location of these areas in context with the LiDAR datasets extents.

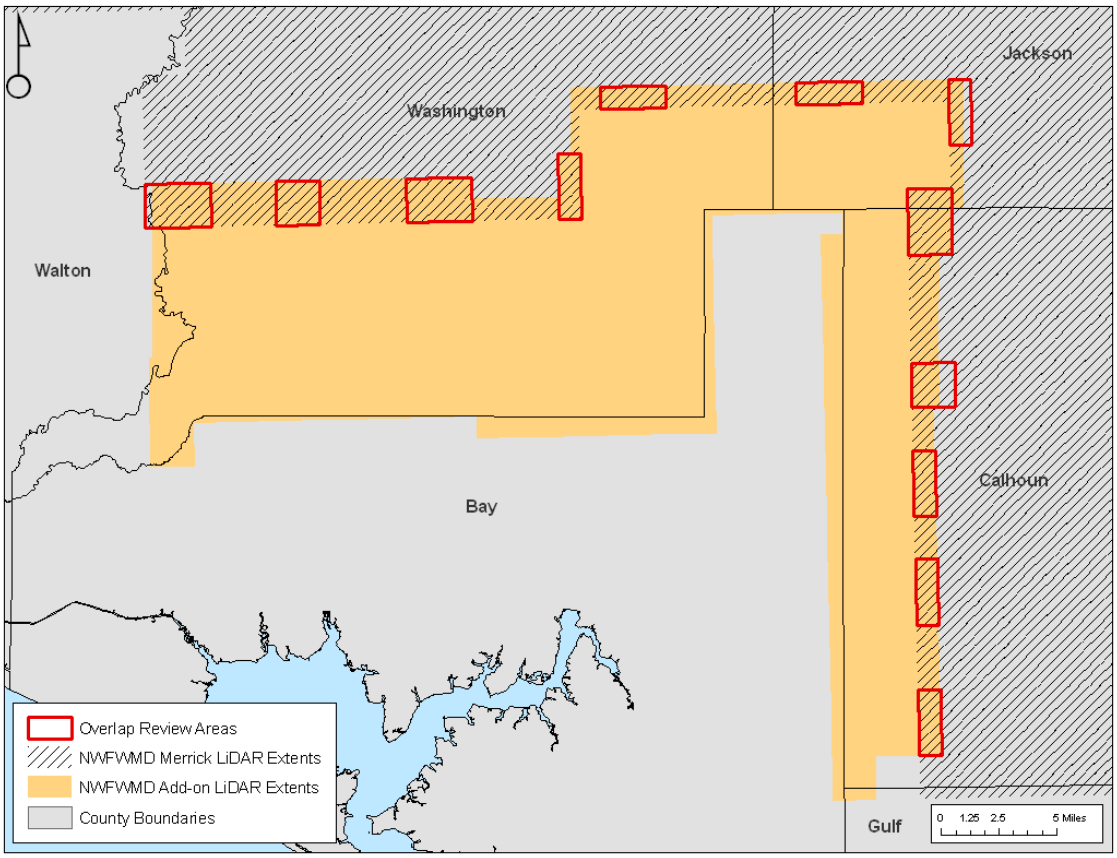


Figure 15 - Map of overlap analysis focus areas.

In order to analyze how well the datasets fit to each other, a number of cross sections were drawn in areas of various types of terrain. Dewberry found that for the most part the datasets were within 0.5 feet of each other however there were a few areas where there was almost one foot difference. These areas were located in the southern part of the dataset in western Calhoun County where there is much more vegetation and LiDAR pulses in both datasets had some difficulty in reaching the ground. Figure 16 displays a cross section where the two datasets fit together very well and Figure 17 displays a cross section where the datasets are not as close.

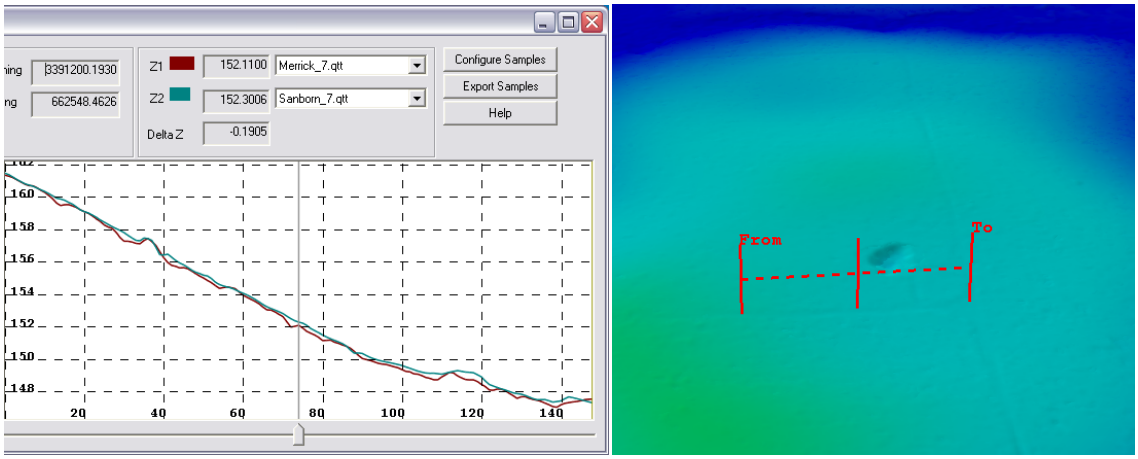


Figure 16 - Tile 17155950. Left is cross section showing small elevation difference of -0.19 ft. along a road. Right is ground model showing the location of the cross section.

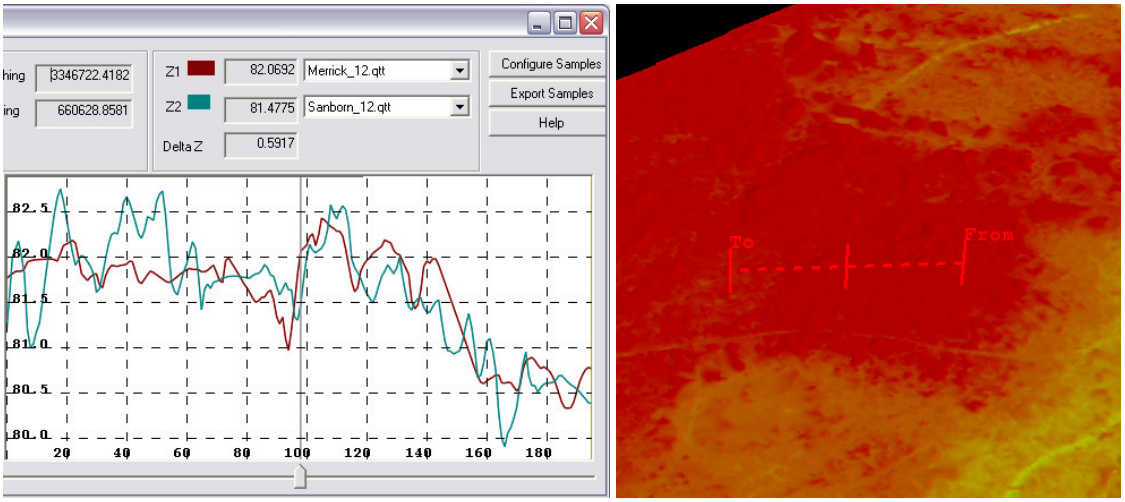


Figure 17 - Tile 17054500. Left is cross section showing a larger difference between the datasets. This cross section was taken from the southern section of the project area characterized by dense vegetation.

The main qualitative differences between the Merrick data and the Sanborn data had to do with smoothness and penetration. The Sanborn LiDAR data exhibited much smoother data and seemed to be able to penetrate vegetation more easily than the Merrick LiDAR data based on the density images we produced and as illustrated in some of the cross section comparisons (Figure 18 and Figure 19). This does not reflect that one data set is "better" than the other as the ground conditions may have changed between when these datasets were collected.

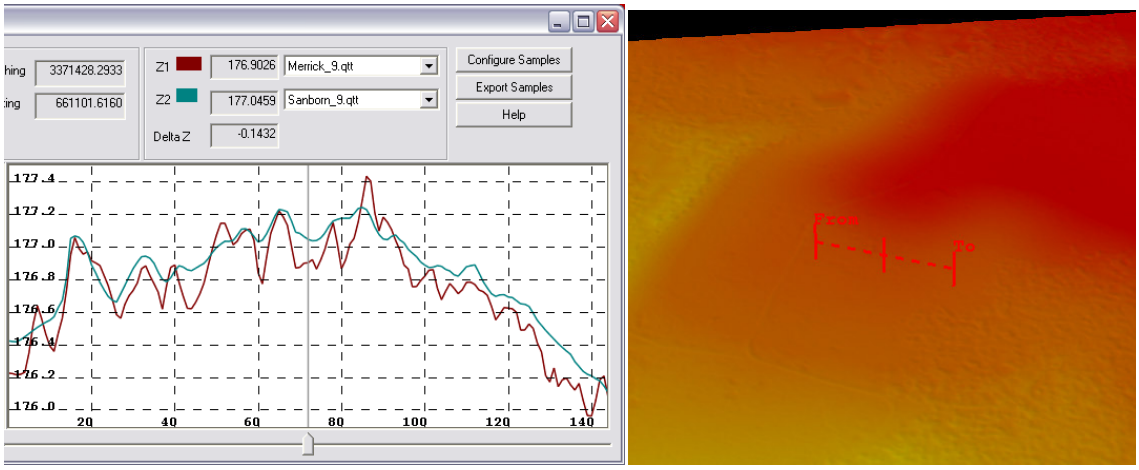


Figure 18 - Tile 17105300. The blue line is the Sanborn LiDAR data and the red line is the Merrick LiDAR data. The Sanborn data exhibits much smoother terrain than the Merrick at this location.

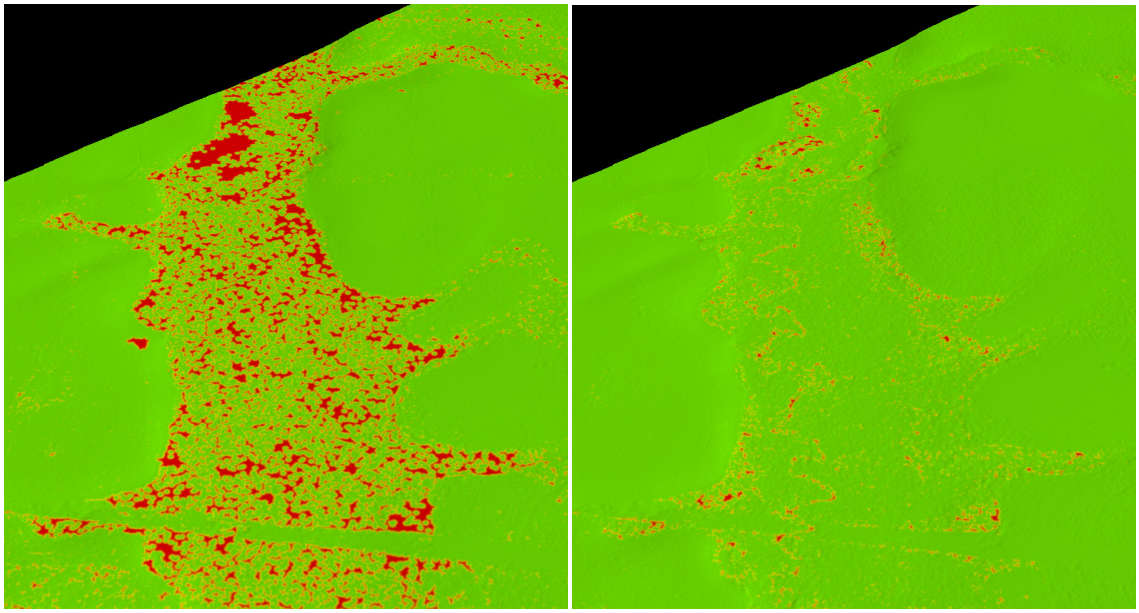


Figure 19 - Tile 17055250. Left is ground density image of the Merrick LiDAR data showing poor penetration along a stream. Right is Sanborn ground density image of same area showing excellent LiDAR coverage for this type of difficult terrain.

Conclusion

In essence this data is of good quality. The qualitative errors do not need to be rectified before using the data however they should be taken into account depending on the type of analyses to be performed. Although there were a few qualitative issues discovered, they are not considered major errors and will not render the data unusable for NWFWMD's needs. As with all data the user must be aware of the limitations of the data and the accuracy associated with it.

Appendix A

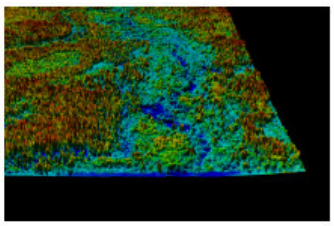
Survey Checkpoints as provided by Sanborn.

Survey Pt ID#	Easting (m)	Northing (m)	Known Z (ft)	Laser Z (ft)	dZ (ft)
Bay01	648638.26	3355437.21	34.05	34.28	0.24
Bay02	651663.47	3358870.93	86.26	86.15	-0.11
Bay03	659337.08	3356222.49	92.02	162.20	0.11
Bay04	652018.85	3368616.42	138.25	138.33	0.08
Bay05	638752.60	3367674.99	104.22	103.65	-0.57
Bay06	618681.44	3368167.20	94.28	94.43	0.15
Bay07	630827.83	3379380.71	161.90	162.62	0.72
Bay08	608028.41	3368705.43	63.70	62.95	-0.75
Bay09	626822.01	3361518.93	77.40	77.32	-0.08
Bay10	626270.04	3369606.47	113.61	113.06	-0.55
Bay11	607704.94	3368539.62	67.78	67.90	0.12
Bay12	644804.25	3352221.45	56.26	56.42	0.16
Bay13	650070.41	3352089.50	52.03	52.00	-0.03
Bay14	645482.53	3336618.43	34.28	34.07	-0.21
Bay16	650326.16	3342215.79	62.59	62.53	-0.06
Bay17	661329.30	3355359.23	86.95	229.34	0.78
Bay18	661188.06	3367375.51	162.09	87.30	0.35
Bay19	650822.72	3372252.96	180.20	180.51	0.31
Bay20	649829.93	3360442.23	71.58	71.90	0.32
Bay21	653368.30	3390762.78	293.40	293.83	0.43
Bay22	654941.46	3387106.79	199.45	92.23	0.21
Bay24	649993.23	3359421.00	76.21	76.24	0.03
Bay25	640771.03	3367863.69	104.68	104.57	-0.11
Bay27	635395.48	3361576.23	78.98	79.11	0.13
Bay28	634189.29	3367096.38	70.69	70.84	0.15
Bay29	634299.77	3372714.35	118.48	118.58	0.10
Bay30	626150.99	3363292.07	84.96	84.71	-0.25
Bay31	626166.63	3363193.79	85.50	84.84	-0.66
Bay32	626370.21	3363216.48	85.58	85.17	-0.41
Bay33	639731.40	3363791.92	78.29	78.03	-0.26
Bay34	640312.65	3365313.54	90.59	90.45	-0.14
Bay35	648630.63	3360656.92	81.46	81.97	0.52
Bay36	650844.05	3366886.77	139.38	139.44	0.06
Bay37	654507.02	3382661.48	177.00	198.99	-0.46
Bay38	652981.49	3379147.88	236.25	236.28	0.03

Bay39	651279.27	3380142.37	225.10	225.02	-0.08
Bay40	654216.90	3379447.36	244.31	176.80	-0.20
Bay41	646710.38	3376226.19	176.84	176.41	-0.43
Bay42	648432.47	3376893.87	180.07	179.96	-0.11
Bay43	651396.55	3372414.66	181.52	181.59	0.07
Bay44	624254.41	3365355.72	84.68	84.46	-0.22
Bay45	624243.14	3374630.03	132.72	132.57	-0.15
Bay46	623795.44	3379375.47	114.16	113.45	-0.71
Bay47	628105.15	3382991.40	204.46	204.70	0.24
Bay48	638903.23	3376811.84	97.51	97.23	-0.28
Bay49	638532.11	3382424.35	195.49	195.71	0.22
Bay50	643070.57	3388645.64	101.39	101.39	0.00
Bay51	634437.61	3383293.38	258.77	259.28	0.51
Bay52	636820.33	3382865.42	253.45	253.70	0.25
Bay53	614366.19	3383006.31	185.49	185.63	0.14

Appendix B

Screen captures of potential edit calls identified by Dewberry. These are for reference only and no corrections are required unless specifically requested by NWFWMD..



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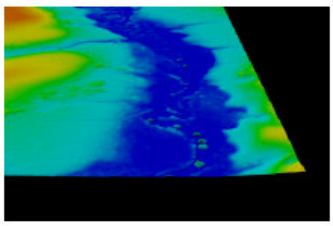

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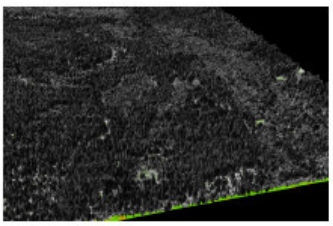

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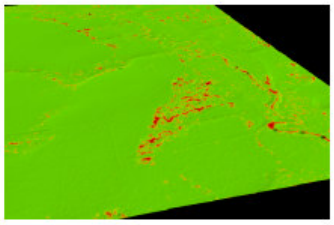

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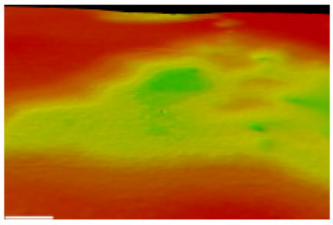

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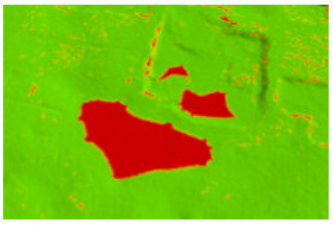

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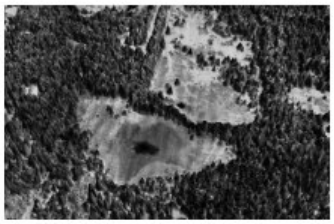

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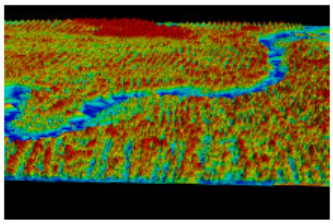

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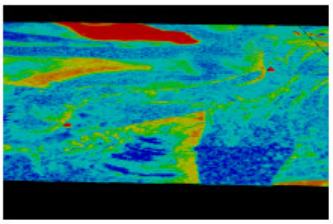

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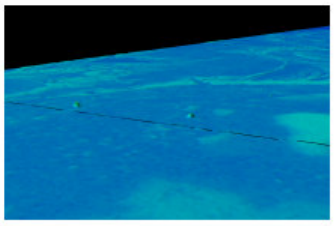

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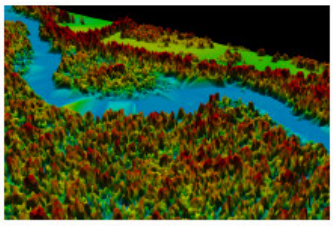

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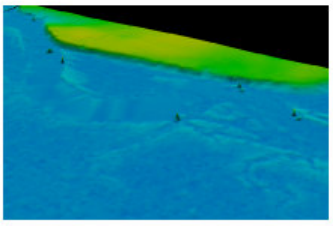

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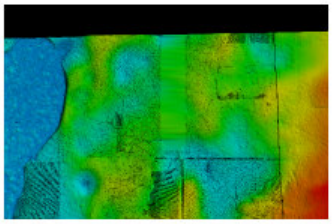

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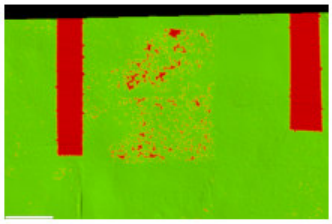
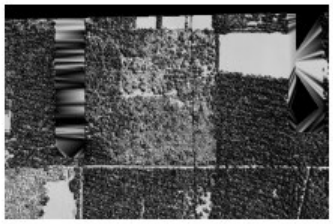


15305750_poorpen_missingscanline.bmp



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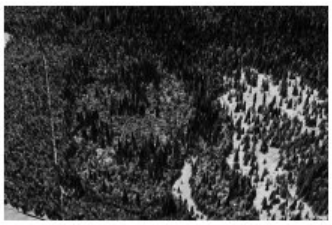

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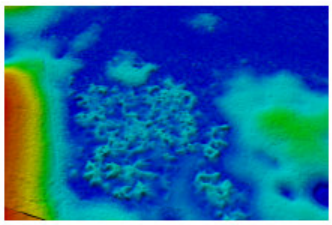

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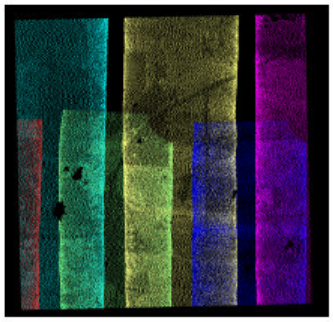
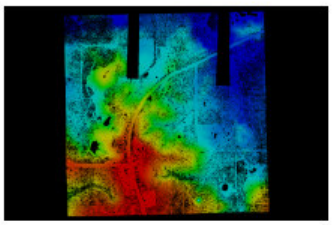
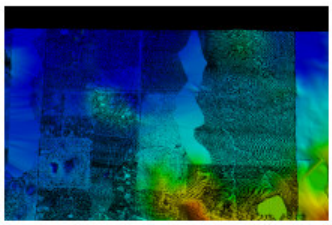


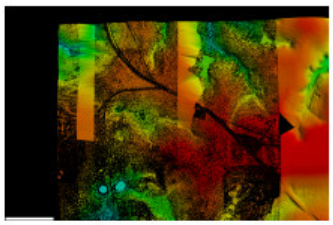
15555750_missingscanlines.bmp



15555750_missingscanlines_qtc.bmp



15605750_missingdata_strangepointpattern.bmp



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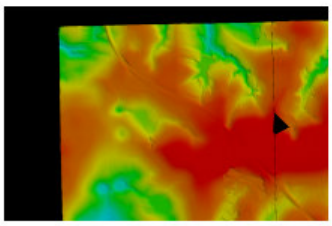

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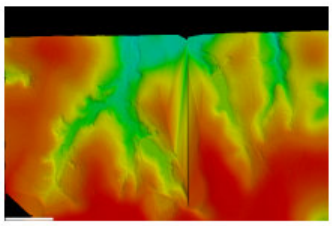

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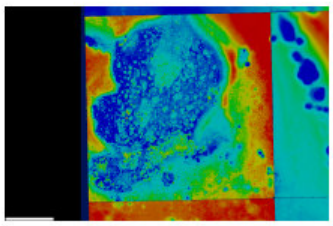
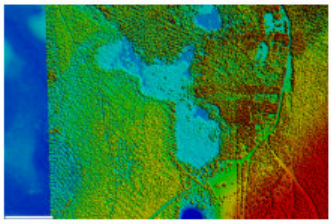


16255500_noise.bmp



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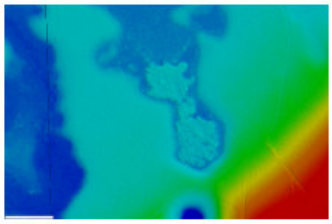

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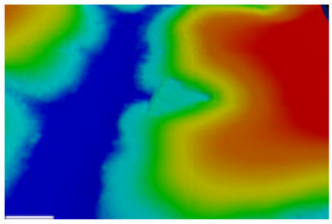

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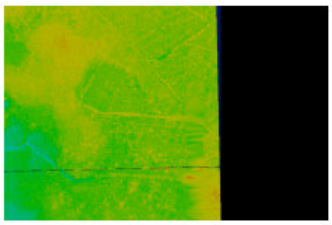
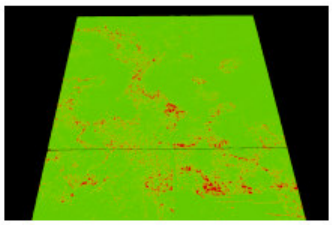
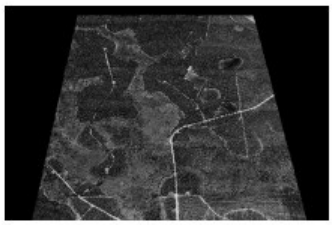


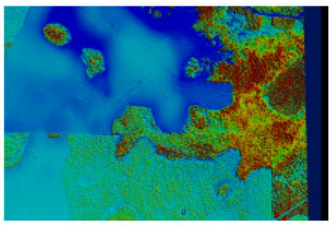
16904400_missing_data.bmp



16954850_poorpenetration_density.bmp



16954850_poorpenetration_fpc.bmp



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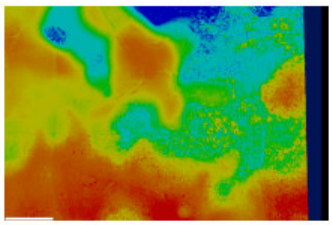

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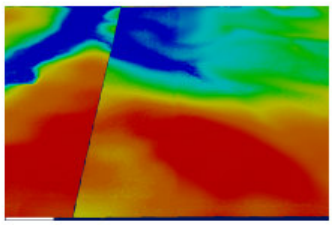

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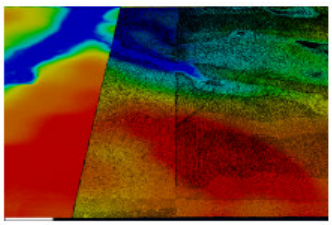
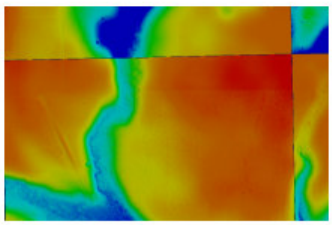


17005400_scanline_points.bmp



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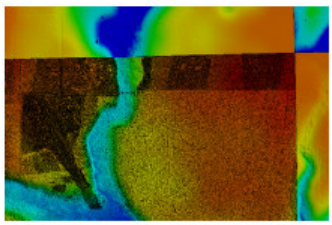

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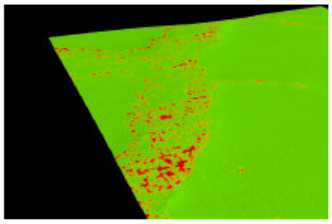

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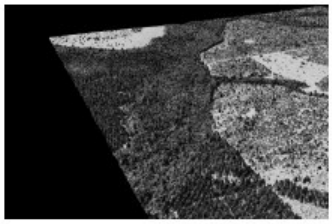

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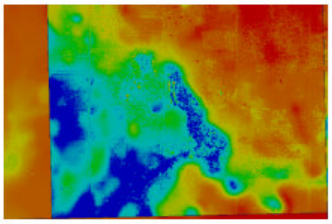

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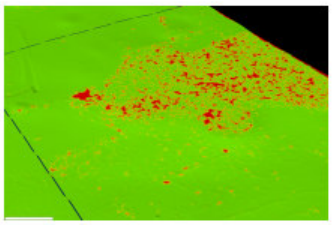

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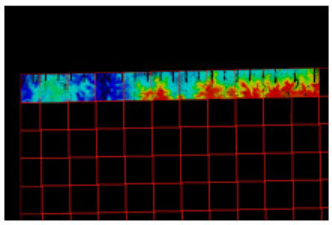

Sanborn_edgetiles_flightline_missing_points.bmp