# Aerial Triangulation Report

## PALM BEACH COUNTY
## AERIAL PHOTOGRAPHY AND MAPPING
## OF SEAGRASS / MANGROVES / OYSTER / SPARTINA
## IN PALM BEACH COUNTY AND LAKE WORTH LAGOON

**Task Order 0688-01A**

**Prepared by:**

**Keith Patterson, PSM**
**Avineon, Inc.**
**15500 Lightwave Drive, Suite 200**
**Clearwater, Fl 33760**

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# Aerial Triangulation Report

## Project Name

2007 Aerial Photography and Mapping of Seagrass / Mangroves / Oyster / Spartina in Palm Beach County and Lake Worth Lagoon.

## Business Entity Name

Avineon, Inc.
15500 Lightwave Drive, Suite 200
Clearwater, Fl 33760

License Number: LB 7228

## Professional Surveyor and Mapper Name

Keith Patterson, PSM
Avineon, Inc.
15500 Lightwave Drive, Suite 200
Clearwater, Fl 33760

License Number: LS 5431

## Type of Survey

This report addresses the aerial triangulation of scanned aerial photography. Aerial triangulation is a method of ground control extension or densification performed mathematically and in conjunction with a limited number of ground control points. This is a control survey designed for the rectification of vertical aerial photography.

## Date of Survey

Aerotriangulation was completed on November 25, 2007.

## Revision Dates

No revisions have been implemented.

## Datum and Control Points

The following datum was used:

Horizontal: State Plane NAD 1983 HARN, Florida East Zone #0901, Units feet.

Vertical: NGVD 29, NAVD 88

A listing of the control points used for aerial triangulation is contained within Appendix A.

## Accuracy Statement

This project specified that the aerial triangulation solution allow for mapping which meets a horizontal accuracy as defined by the USGS National Map Accuracy Standards (NMAS) for 1:24,000 scale map products. The NMAS specification is re-printed below.

> Horizontal Accuracy. For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two roads or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.

No vertical accuracy was specified for the project.

## Intended Display Scale

1:24,000

## Data Sources and Data Lineage

The following data sources were used to accomplish aerial triangulation:

### *Aerial Photography*

A total of 146 aerial photographs were used for aerial triangulation. Three sets of 9” x 9” film-based aerial photographs were used to accomplish aerotriangulation as described below.

> Lake Worth Lagoon Set – Natural color aerial photography acquired on June 20, 2007, June 22, 2007, July 21, 2007 and August 4, 2007 at scale of 1:10,000. 86 exposures were contained within this set.
>
> Loxahatchee River Estuary – Natural color aerial photography acquired on July 1, 2007 at scale of 1:4,800. 52 exposures were contained within this set.
>
> Indian River Lagoon acquired on August 8, 2007 at scale of 1:10,000. 8 exposures were contained within this set.

The above aerial photographs were captured using a Wild RC30 photogrammetric camera, serial number 5334, with a Wild Universal Aviogon /4-S lens with serial number 13374. This camera has a calibrated focal length of 153.799 and the calibration date is January 5, 2007.

***Ground Control Coordinates***

A combination of 1) photo-identifiable ground control points recovered from previous aerial mapping projects; and 2) photo-identifiable ground control coordinates extracted from existing digital orthophotography were used as ground control for aerial triangulation.

Palm Beach County specified that photo-identifiable ground control coordinates be re-used from prior aerial mapping projects completed within Palm Beach County. Using ground control point documentation, Avineon transferred the existing ground control points to the 2007 photography used for this project. The majority of the pre-existing ground control points were recovered and used. Additional photo-identifiable points were selected from USGS digital orthophoto quarter quads (DOQQs).

## Measurement Methods

Aerial triangulation was performed for this project to produce rectified aerial photography suitable for stereo-compilation within a soft-copy photogrammetric stereoplotter.

The project is divided into three aerial triangulation blocks which equate to the three sets of aerial photography provided for the project. Each block contained a suitable distribution of control points.

The Fully Analytical Aerial Triangulation (FAAT) solution was computed using Intergraph Corporation's Z/I Imaging ImageStation Automatic Triangulation (ISAT) software. ISAT software possesses automatic error detection and self-calibration.

Ground control points were measured using ISAT software. Additional pass points and tie points were visually (i.e. manually) selected from the project's aerial photography to densify the control. This measurement provided the image coordinate for each point related to the fiducials of the aerial camera. The aerial triangulation process takes into account control point information, the camera calibration information supplied with the aerial photography, camera lens distortion, and the image coordinate of each point measured within the software.

For quality control purposes, photo-identifiable check point coordinates were used to compare the positions of static features on the project's adjusted aerial photography with identical points appearing on Palm Beach County's one foot resolution digital orthophotography.

## Feature List

This report addresses the results of aerial triangulation. No features have been mapped from the aerial photographs.

## Responsibility for Mapped Features

The signing PSM is responsible for the accuracy of the aerial triangulation accomplished for this project.

## Map Accuracy

The aerial triangulation solution meets the horizontal map accuracy as defined within the USGS National Map Accuracy Standards (NMAS) for 1:24,000 scale map products.

Appendix A contains tables showing the comparisons of 1) ground control points with the same points adjusted after aerial triangulation; and 2) photo-identifiable check points with the same points calculated within the aerial triangulation solution. Check points are known coordinates that are compared to the aerial triangulation result. The coordinate values for these check points were derived from Palm Beach County's county-wide imagery.

## Limitations of Information Presented

The information presented herein is limited to the aerial triangulation methods and subsequent accuracy results obtained from the aerial triangulation process.

## Validity

This report is not valid without the original signature and original raised seal of a Florida Licensed Professional Surveyor and Mapper (PSM).

This report is neither full nor complete without the attached map which consists of a digital aerial triangulation file that will be used for image rectification and stereo compilation.

Additions or deletions to survey maps and reports by other than the signing PSM are prohibited without the written consent of the signing PSM.

PSM in Responsible Charge:

4/30/2008

Keith Patterson, LS 5431 Date
Avineon, Incorporated LB 7228

*SEAL ON ORIGINAL*

# APPENDIX A - HORIZONTAL ACCURACY STATISTICS

**CONTROL POINT COORDINATES - AEROTRIANGULATION COORDINATES**

**THE TABLE BELOW SHOWS THE CONTROL POINTS USED FOR AERIAL TRANGULATION**

**THE TABLE COMPARES THE KNOWN CONTROL POINT COORDINATES (GROUND) WITH THE ADJUSTED COORDINATES WITHIN THE AERIAL TRIANGULATION SOLUTION (AT)**

| Point Number | x AT | x GROUND | diff in x | (diff in x)$^2$ | y AT | y GROUND | diff in y | (diff in y)$^2$ | (diff in x)$^2$ + (diff in y)$^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 955123.83 | 955123.43 | 0.396 | 0.157 | 724956.695 | 724955.94 | 0.755 | 0.57 | 0.727 |
| 2 | 958869.73 | 958869.93 | -0.2 | 0.04 | 723821.982 | 723822.39 | -0.408 | 0.166 | 0.206 |
| 5 | 962215.87 | 962215.46 | 0.407 | 0.166 | 757950.422 | 757950.98 | -0.558 | 0.311 | 0.477 |
| 6 | 961392.63 | 961393.19 | -0.559 | 0.312 | 769150.062 | 769149.94 | 0.122 | 0.015 | 0.327 |
| 8 | 962700.38 | 962700.29 | 0.09 | 0.008 | 793435.244 | 793435.38 | -0.136 | 0.018 | 0.027 |
| 9 | 964865.48 | 964865.69 | -0.211 | 0.045 | 796141.164 | 796141.18 | -0.016 | 0 | 0.045 |
| 10 | 966769.78 | 966770.43 | -0.647 | 0.419 | 795303.26 | 795302.84 | 0.42 | 0.176 | 0.595 |
| 11 | 958293.52 | 958292.9 | 0.623 | 0.388 | 919107.703 | 919107.51 | 0.193 | 0.037 | 0.425 |
| 12 | 961058.51 | 961058.6 | -0.086 | 0.007 | 919631.157 | 919631.15 | 0.007 | 0 | 0.007 |
| 13 | 959151.6 | 959152.13 | -0.53 | 0.281 | 932756.987 | 932756.82 | 0.167 | 0.028 | 0.309 |
| 14 | 951749.4 | 951749.56 | -0.164 | 0.027 | 941661.205 | 941662.06 | -0.855 | 0.731 | 0.758 |
| 15 | 950080.12 | 950080.41 | -0.293 | 0.086 | 950463.465 | 950464.51 | -1.045 | 1.092 | 1.178 |
| 16 | 954349.97 | 954350.22 | -0.252 | 0.064 | 952244.559 | 952243.27 | 1.289 | 1.662 | 1.725 |
| 18 | 954777.91 | 954779.66 | -1.751 | 3.066 | 950452.465 | 950451.83 | 0.635 | 0.403 | 3.469 |
| 22 | 949126.27 | 949125.35 | 0.918 | 0.843 | 949873.339 | 949872.66 | 0.679 | 0.461 | 1.304 |
| 23 | 953737.57 | 953735.73 | 1.839 | 3.382 | 950125.557 | 950126.4 | -0.843 | 0.711 | 4.093 |
| 27 | 961594.48 | 961593.96 | 0.524 | 0.275 | 906979.479 | 906980.02 | -0.541 | 0.293 | 0.567 |
| 28 | 963846.64 | 963847.51 | -0.874 | 0.764 | 907789.288 | 907788.9 | 0.388 | 0.151 | 0.914 |
| 29 | 970053.42 | 970053.42 | 0.003 | 0 | 818617.873 | 818617.73 | 0.143 | 0.02 | 0.02 |
| 30 | 966599.25 | 966599.2 | 0.054 | 0.003 | 852892.389 | 852892.06 | 0.329 | 0.108 | 0.111 |
| 31 | 968239.33 | 968238.98 | 0.348 | 0.121 | 863592.307 | 863592.98 | -0.673 | 0.453 | 0.574 |
| 32 | 969760.66 | 969760.54 | 0.117 | 0.014 | 828832.305 | 828832.42 | -0.115 | 0.013 | 0.027 |
| 33 | 966706.51 | 966706.649 | -0.141 | 0.02 | 891285.862 | 891286.447 | -0.585 | 0.342 | 0.362 |
| 34 | 971425.59 | 971424.745 | 0.845 | 0.714 | 891564.268 | 891565.355 | -1.087 | 1.182 | 1.896 |
| 35 | 969916.92 | 969917.775 | -0.851 | 0.724 | 888720.399 | 888718.687 | 1.712 | 2.931 | 3.655 |
| 36 | 965328.07 | 965328.113 | -0.044 | 0.002 | 877083.875 | 877082.848 | 1.027 | 1.055 | 1.057 |
| 37 | 971018.88 | 971019.101 | -0.22 | 0.048 | 876115.543 | 876116.437 | -0.894 | 0.799 | 0.848 |
| 38 | 970413.44 | 970413.374 | 0.068 | 0.005 | 841092.789 | 841093.401 | -0.612 | 0.375 | 0.379 |
| 39 | 964752.94 | 964752.361 | 0.578 | 0.334 | 809064.224 | 809064.691 | -0.467 | 0.218 | 0.552 |
| 40 | 965753.29 | 965753.427 | -0.133 | 0.018 | 840686.717 | 840685.873 | 0.844 | 0.712 | 0.73 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 41 | 963681.41 | 963680.901 | 0.512 | 0.262 | 780819.967 | 780820.173 | -0.206 | 0.042 | 0.305 |
| 42 | 958194.24 | 958194.074 | 0.164 | 0.027 | 734556.55 | 734557.483 | -0.933 | 0.87 | 0.897 |
| 43 | 957047.64 | 957047.635 | 0.009 | 0 | 746148.3 | 746147.855 | 0.445 | 0.198 | 0.198 |
| 44 | 957192.1 | 957192.563 | -0.466 | 0.217 | 746513.345 | 746512.716 | 0.629 | 0.396 | 0.613 |
| 45 | 969386.26 | 969386.331 | -0.075 | 0.006 | 809779.402 | 809779.212 | 0.19 | 0.036 | 0.042 |
| 9001 | 942052.91 | 942056.308 | -3.397 | 11.54 | 952677.587 | 952674.777 | 2.81 | 7.896 | 19.436 |
| 9003 | 944802.02 | 944802.137 | -0.117 | 0.014 | 951564.221 | 951564.111 | 0.11 | 0.012 | 0.026 |
| 9004 | 950308.98 | 950307.976 | 0.999 | 0.998 | 952810.507 | 952812.511 | -2.004 | 4.016 | 5.014 |
| 9006 | 954558.65 | 954559.401 | -0.747 | 0.558 | 951712.805 | 951712.645 | 0.16 | 0.026 | 0.584 |
| 9008 | 942502.58 | 942505.266 | -2.685 | 7.209 | 952959.91 | 952961.124 | -1.214 | 1.474 | 8.683 |
| 9009 | 947996.09 | 947995.261 | 0.825 | 0.681 | 954786.19 | 954786.148 | 0.042 | 0.002 | 0.682 |
| 9011 | 942312.85 | 942313.187 | -0.333 | 0.111 | 948524.298 | 948523.829 | 0.469 | 0.22 | 0.331 |
| 20071 | 939179.86 | 939179.852 | 0.01 | 0 | 955436.152 | 955436.812 | -0.66 | 0.436 | 0.436 |
| 90015 | 938497.66 | 938495.804 | 1.859 | 3.456 | 959115.599 | 959115.749 | -0.15 | 0.022 | 3.478 |
| 90016 | 939625.6 | 939627.507 | -1.908 | 3.64 | 957721.254 | 957721.646 | -0.392 | 0.154 | 3.794 |
| 90017 | 943476.92 | 943477.788 | -0.87 | 0.757 | 958264.256 | 958264.809 | -0.553 | 0.306 | 1.063 |
| 90018 | 946135.65 | 946132.902 | 2.744 | 7.53 | 958577.735 | 958577.367 | 0.368 | 0.135 | 7.665 |
| 90020 | 950844.86 | 950845.435 | -0.572 | 0.327 | 955839.717 | 955838.9 | 0.817 | 0.667 | 0.995 |
| 90021 | 947390.99 | 947391.68 | -0.691 | 0.477 | 947812.727 | 947812.658 | 0.069 | 0.005 | 0.482 |
| 90022 | 946566.27 | 946565.319 | 0.954 | 0.91 | 950149.364 | 950147.528 | 1.836 | 3.371 | 4.281 |
| 90023 | 951846.18 | 951846.975 | -0.8 | 0.64 | 948449.681 | 948449.056 | 0.625 | 0.391 | 1.031 |
| 90024 | 955389.35 | 955388.724 | 0.621 | 0.386 | 949552.505 | 949551.181 | 1.324 | 1.753 | 2.139 |
| 90025 | 957239.19 | 957238.852 | 0.341 | 0.116 | 952651.929 | 952652.625 | -0.696 | 0.484 | 0.601 |
| 920075 | 957563.91 | 957563.541 | 0.371 | 0.138 | 949376.793 | 949376.942 | -0.149 | 0.022 | 0.16 |
| 400003 | 953778.893 | 953783.948 | 5.055 | 25.553025 | 952940.671 | 952939.716 | -0.955 | 0.91 | 26.47 |
| 400004 | 956862.308 | 956861.619 | -0.689 | 0.474721 | 954187.419 | 954186.976 | -0.443 | 0.20 | 0.67 |
| 500113 | 954168.604 | 954167.498 | -1.106 | 1.223236 | 956715.846 | 956716.076 | 0.23 | 0.05 | 1.28 |
| 500114 | 957159.84 | 957159.797 | -0.043 | 0.001849 | 953465.179 | 953465.101 | -0.078 | 0.01 | 0.01 |
| | | | | | | | | sum | 118.72 |
| | | | | | | | | average | 2.05 |
| | | | | | | | | RMSE | 1.43 |
| | | | | | | | | NSSDA | 2.48 |
| | | | | | | | | **NMAS** | **2.17** |

**AEROTRIANGULATION COORDINATES - CHECK POINT COORDINATES**

**THE TABLE BELOW SHOWS THE HECK POINTS USED FOR QUALITY ASSURANCE**

**THE TABLE COMPARES THE ADJUSTED CONTROL POINT COORDINATES (AT) WITH INDEPENDENT CHECK POINTS (CHECK) WHICH WERE DERIVED FROM ANOTHER SOURCE**

| Point Number | x AT | x CHECK | diff in x | (diff in x)$^2$ | y AT | y CHECK | diff in y | (diff in y)$^2$ | (diff in x)$^2$ + (diff in y)$^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Check_A | 953410.73 | 953412.677 | -1.951 | 3.806 | 951558.296 | 951559.572 | -1.276 | 1.628 | 5.435 |
| Check_B | 953483.92 | 953486.076 | -2.16 | 4.666 | 945348.767 | 945349.924 | -1.157 | 1.339 | 6.004 |
| Check_C | 958249.31 | 958251.598 | -2.289 | 5.24 | 925673.204 | 925675.868 | -2.664 | 7.097 | 12.336 |
| Check_D | 963364.85 | 963366.927 | -2.079 | 4.322 | 913890.227 | 913892.425 | -2.198 | 4.831 | 9.153 |
| Check_E | 970341.59 | 970342.472 | -0.881 | 0.776 | 902777.911 | 902777.919 | -0.008 | 0 | 0.776 |
| Check_F | 968400.66 | 968400.886 | -0.229 | 0.052 | 893925.183 | 893928.036 | -2.853 | 8.14 | 8.192 |
| Check_G | 968807.38 | 968808.417 | -1.035 | 1.071 | 883914.709 | 883917.697 | -2.988 | 8.928 | 9.999 |
| Check_H | 966434.76 | 966434.097 | 0.662 | 0.438 | 872975.064 | 872978.989 | -3.925 | 15.406 | 15.844 |
| Check_I | 967081.31 | 967081.244 | 0.061 | 0.004 | 868157.98 | 868160.255 | -2.275 | 5.176 | 5.179 |
| Check_J | 966312.63 | 966313.321 | -0.695 | 0.483 | 857546.896 | 857549.67 | -2.774 | 7.695 | 8.178 |
| Check_K | 967189.51 | 967189.275 | 0.238 | 0.057 | 850959.414 | 850961.374 | -1.96 | 3.842 | 3.898 |
| Check_L | 967127.81 | 967129.502 | -1.691 | 2.859 | 843609.574 | 843612.717 | -3.143 | 9.878 | 12.738 |
| Check_M | 967070.05 | 967071.521 | -1.473 | 2.17 | 838046.339 | 838048.032 | -1.693 | 2.866 | 5.036 |
| Check_N | 967586.63 | 967588.4 | -1.771 | 3.136 | 822273.316 | 822273.139 | 0.177 | 0.031 | 3.168 |
| Check_O | 968266.18 | 968268.802 | -2.62 | 6.864 | 812165.274 | 812166.261 | -0.987 | 0.974 | 7.839 |
| Check_P | 967595.87 | 967597.315 | -1.447 | 2.094 | 803390.622 | 803392.344 | -1.722 | 2.965 | 5.059 |
| Check_Q | 964979.12 | 964982.771 | -3.649 | 13.315 | 792611.919 | 792614.644 | -2.725 | 7.426 | 20.741 |
| Check_R | 962984.35 | 962986.412 | -2.064 | 4.26 | 777931.283 | 777931.888 | -0.605 | 0.366 | 4.626 |
| Check_T | 961269.14 | 961271.884 | -2.748 | 7.552 | 753185.521 | 753189.044 | -3.523 | 12.412 | 19.963 |
| Check_U | 958981.12 | 958981.203 | -0.083 | 0.007 | 743153.471 | 743156.447 | -2.976 | 8.857 | 8.863 |
| Check_V | 958784.74 | 958785.788 | -1.051 | 1.105 | 732589.28 | 732592.9 | -3.62 | 13.104 | 14.209 |
| Check_W | 957100.55 | 957100.619 | -0.071 | 0.005 | 725256.581 | 725260.246 | -3.665 | 13.432 | 13.437 |
| Check | 954337.3 | 954336.747 | -0.554 | 0.306916 | 952787.263 | 952790.85 | 3.587 | 12.86657 | 13.173485 |
| | | | | | | | | sum | 213.85 |
| | | | | | | | | average | 9.30 |
| | | | | | | | | RMSE | 3.05 |
| | | | | | | | | NSSDA | 5.28 |
| | | | | | | | | **NMAS** | **4.63** |