

Mapping Building Heights Using GIS and Photogrammetric Technologies

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Presentation Overview

- Introduction
- Methodology
- Results
- Discussion
- Conclusion

Introduction

- Building heights
 - Used for a variety of maps and assessments
- Quicker data collection method
 - Reduce the time and cost of field data collection
- User-friendly procedures

Introduction

- Purpose of this research is to collect and maintain building height data to support staff with various management activities and improve government operations.

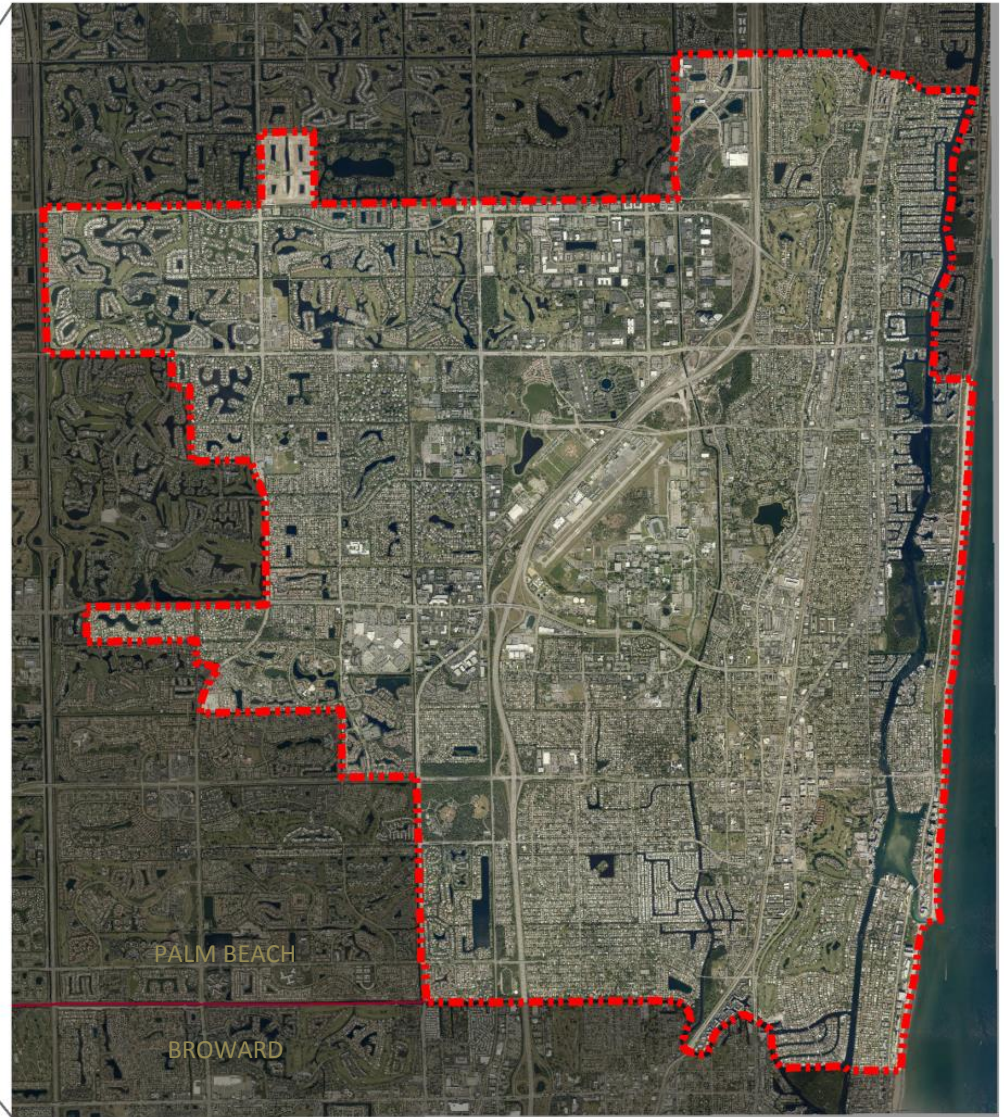
Introduction

- Research goal is to develop a framework using recent GIS and photogrammetric technologies to identify, measure, and map the height of buildings with high relative measurement accuracy.

City of Boca Raton, Florida, USA



Study Area



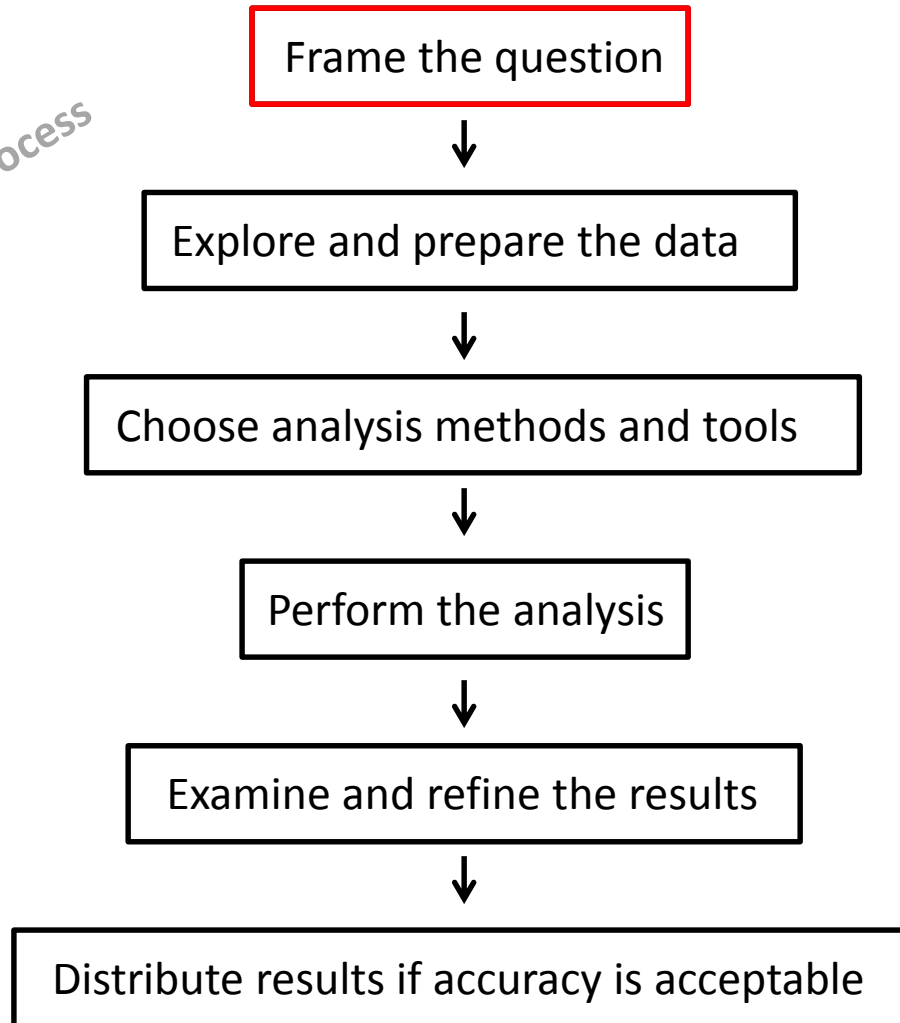
0 0.5 1 2 Miles

Area = 18,390.66 ac, or 36 sq mi

Population (US Census 2014 Estimate) = 91,332

Steps in the Analysis Process

Based on Esri's
Five-Step GIS Analysis Process



Source: Esri Training Matters, 2009

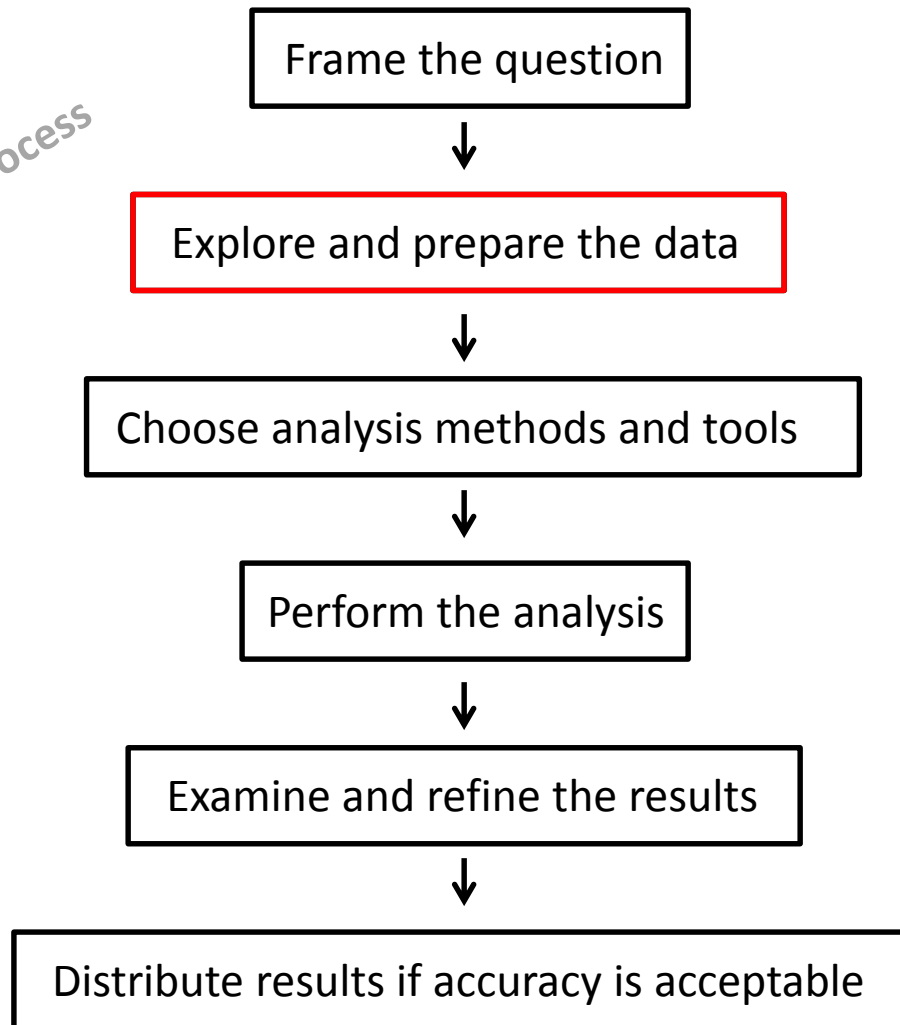
<http://blogs.esri.com/esri/esrainingmatters/2009/10/08/use-the-five-step-gis-analysis-process/>

Frame the Question

- *Where are buildings with three or more stories in height, or 35 ft or taller, located within the City of Boca Raton, Florida?*
- *What is the actual number of stories and/or height denoted in feet for each of these buildings?*

Steps in the Analysis Process

Based on Esri's
Five-Step GIS Analysis Process



Explore and Prepare the Data

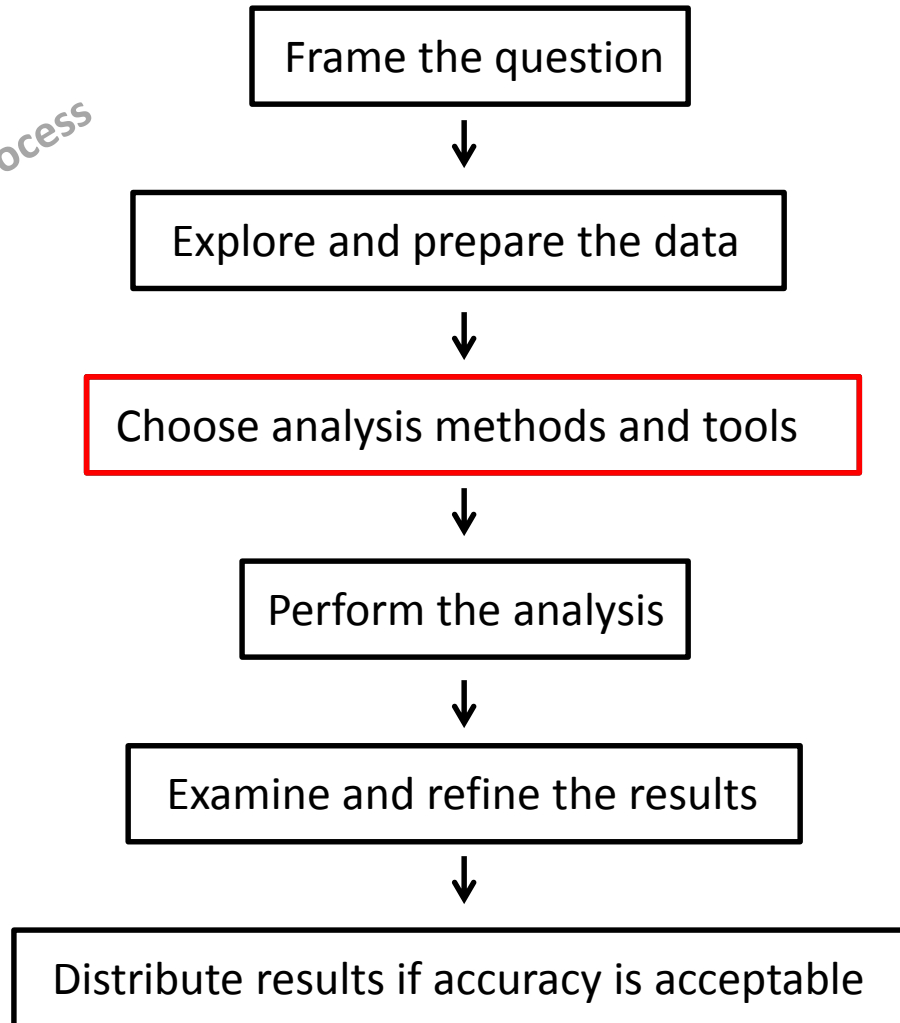
- Existing building data (i.e., shape file; point)
- High resolution imagery
- Define: “Building height”
 - Height to eave [lowest]
 - Not 0.5 stories
 - No steeples
 - Must be an independent floor w/roof on top
 - Count stories, or measure height
 - Both residential or commercial
 - If 3 full stories (w/ roof on third floor), or 35 ft in height or taller

Explore and Prepare the Data

- Aerial imagery
- High resolution (9 in) 4-way ('Community')
- Very high resolution (3 in) 4-way ('Neighborhood')
 - Oblique and orthogonal
- Digital Elevation Model (DEM)
 - (Pictometry supplied)
- Pictometry Web-based imagery application
 - Visualization and analytical tools for imagery
 - See Pictometry white papers:
 - Zoltek, M. J. and Wang, Y. 2014. Relative Measurement Accuracies within Pictometry's Individual Orthogonal and Oblique Frame Imagery, p. 10.
 - Zoltek, M. J. and Solter, T.S., 2014. Absolute Horizontal Accuracies of Pictometry's Individual Orthogonal Frame Imagery, p.6.

Steps in the Analysis Process

Based on Esri's
Five-Step GIS Analysis Process



Source: Esri Training Matters, 2009

<http://blogs.esri.com/esri/esritrainingmatters/2009/10/08/use-the-five-step-gis-analysis-process/>

Analysis Methods and Tools

ArcGIS 10.3 (ArcMap, ArcCatalog, ArcToolbox)

Geoprocessing and analysis:

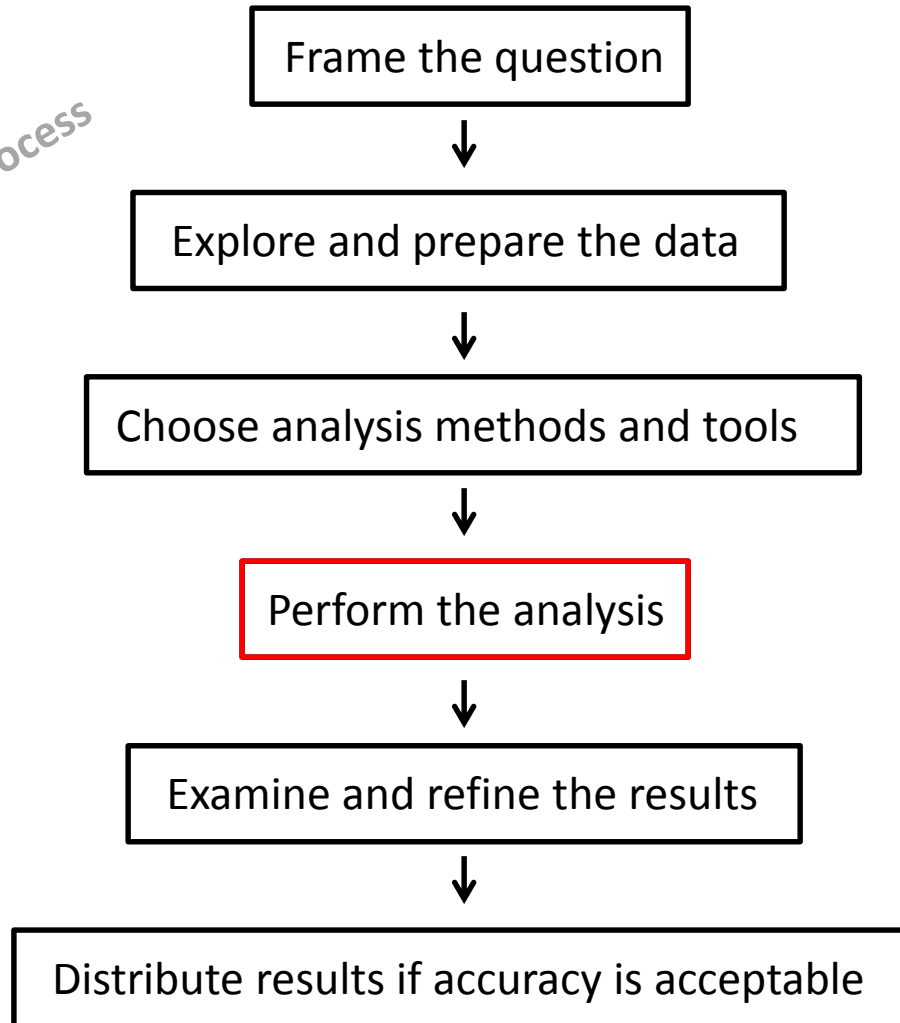
- Clipping
 - Spatial joins
 - Spatial queries
 - Adding attribute fields in tables
 - Recording data collected from imagery
-

Pictometry Analytics Server Edition

- Visual analysis of imagery
 - Measure the distance between features
-

Steps in the Analysis Process

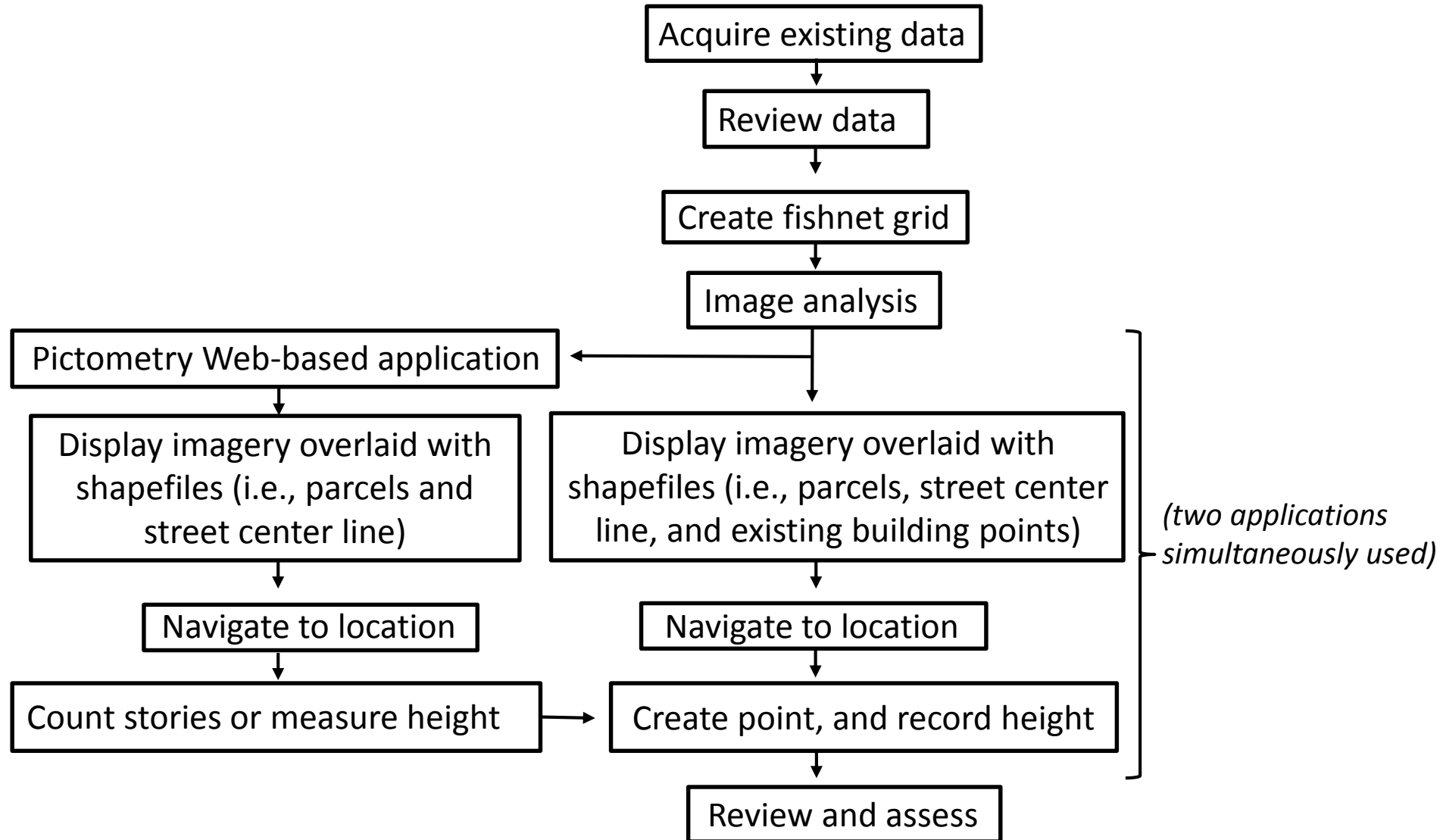
Based on Esri's
Five-Step GIS Analysis Process



Source: Esri Training Matters, 2009

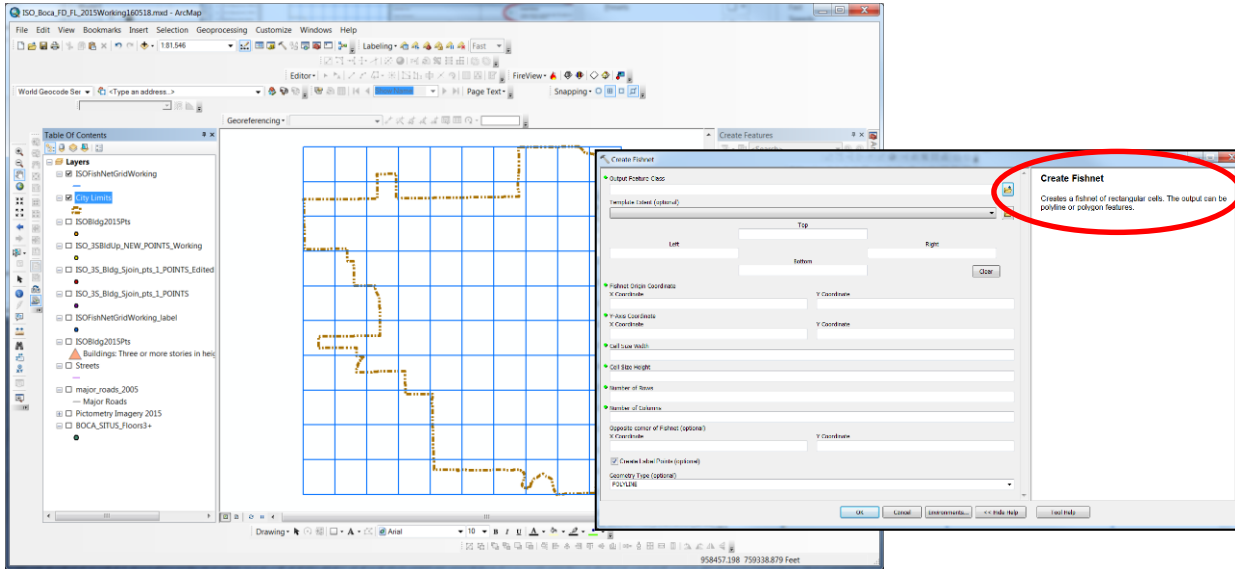
<http://blogs.esri.com/esri/esrtrainingmatters/2009/10/08/use-the-five-step-gis-analysis-process/>

Framework for Building Heights



ArcGIS

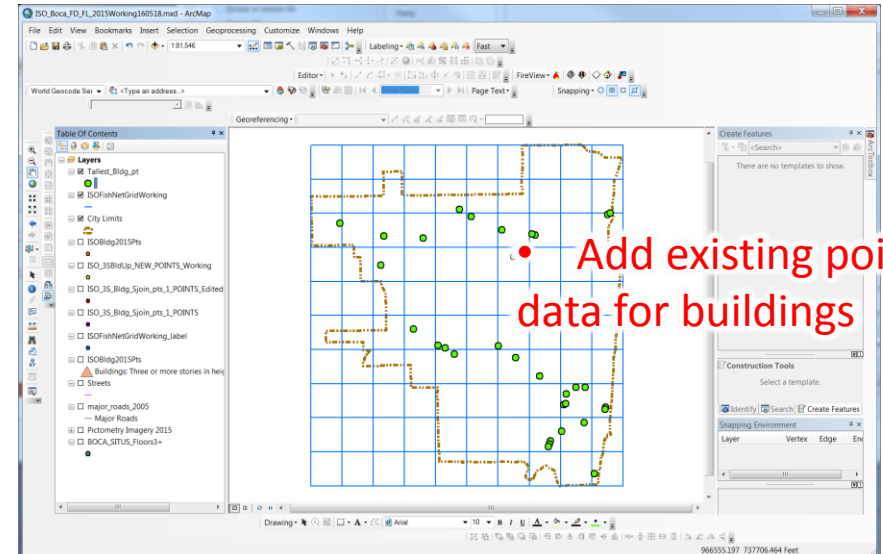
1.



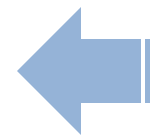
- Create fishnet grid
- ~3425 x 3775 ft (w x h)
- 10 x 10 cells



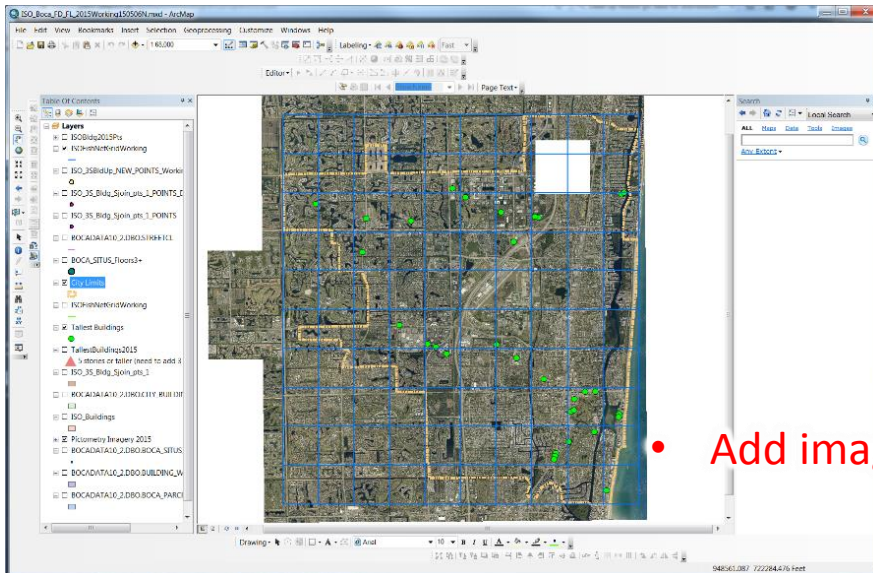
2.



- Add existing point data for buildings



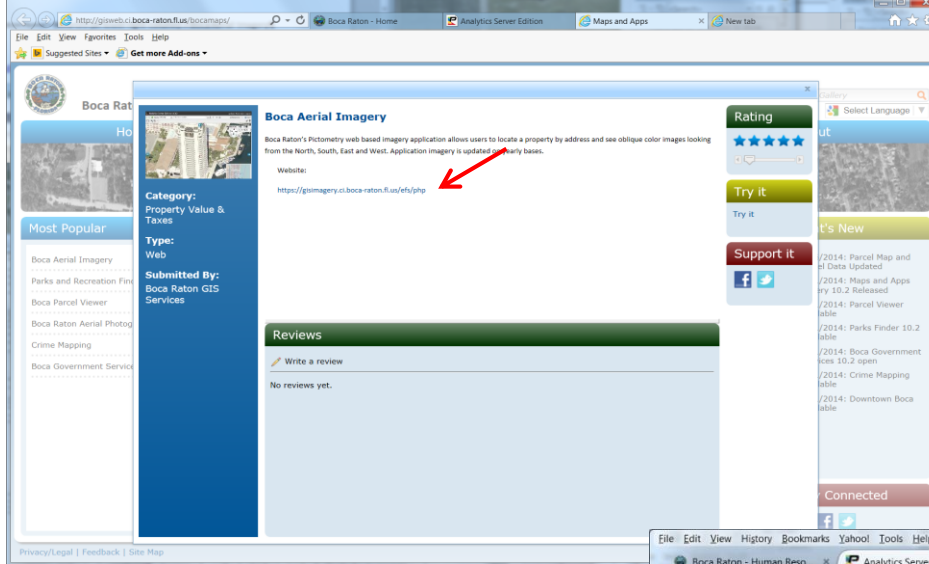
3.



- Add imagery

Pictometry Analytics Web-viewer

1.

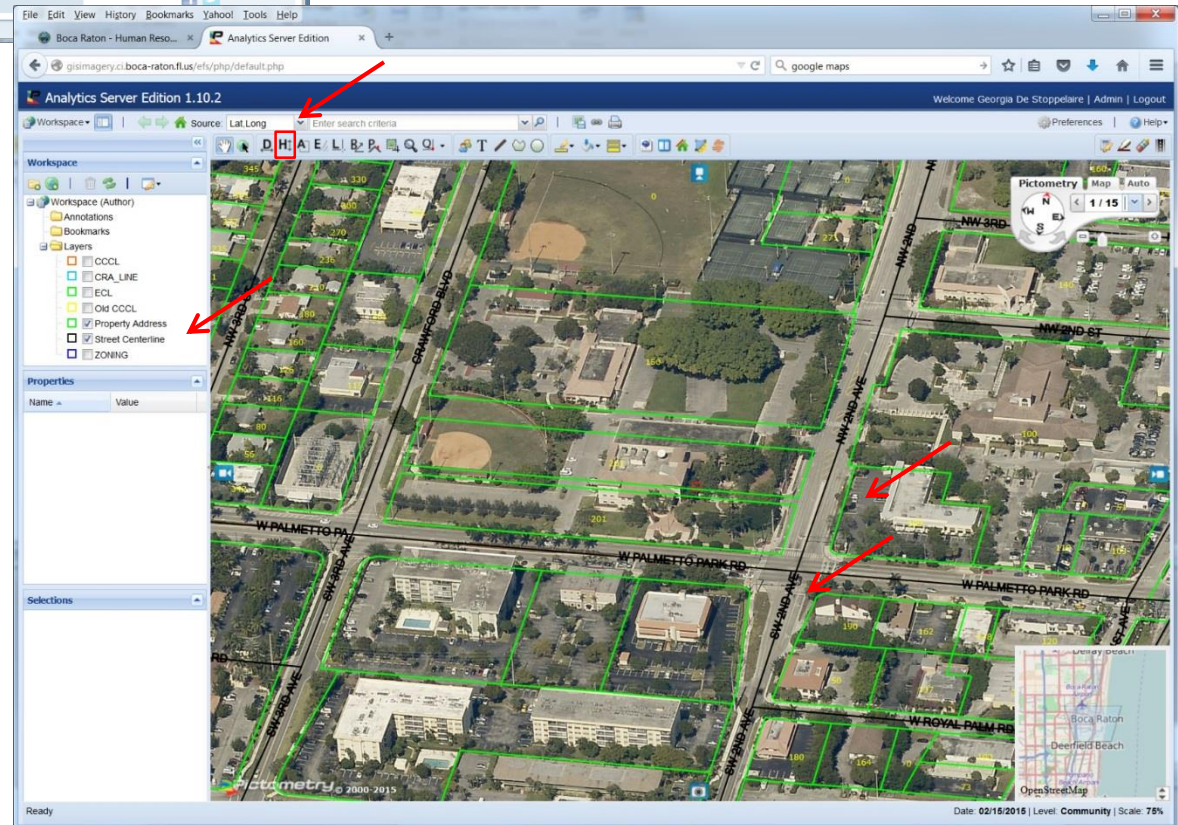


- Open Web-viewer application
- Click on link via intranet link
- User logs in to application

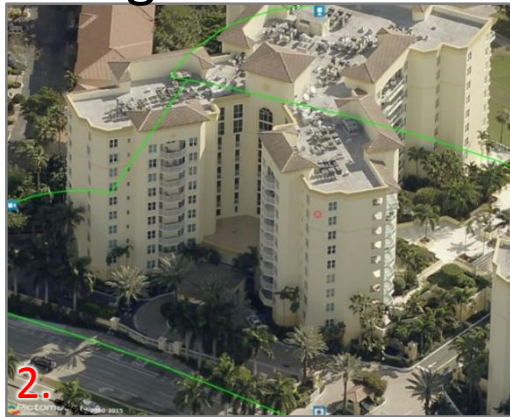
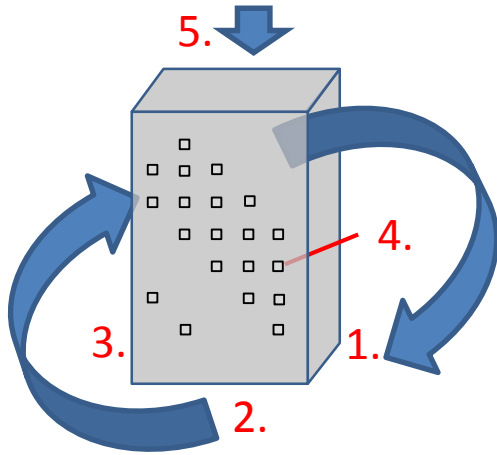


2.

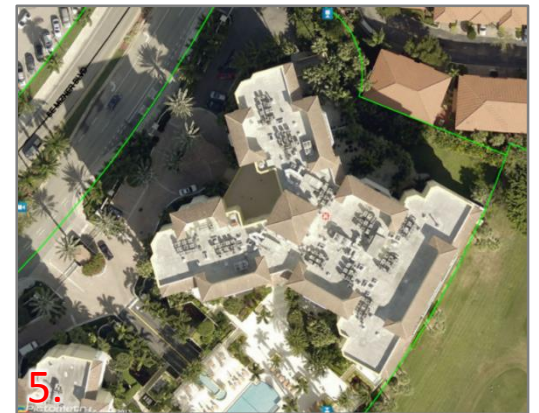
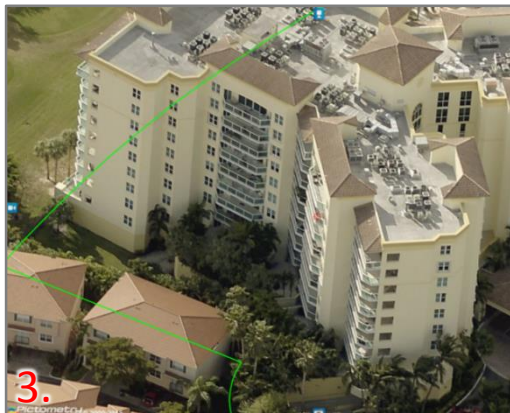
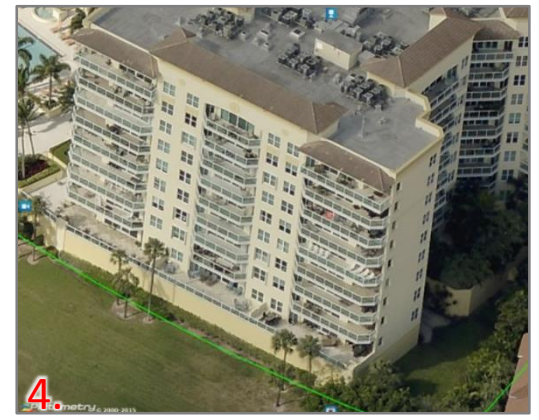
- Imagery is overlaid with geospatial data (shapefiles)
 - Parcels
 - Streets center line



Navigate to location

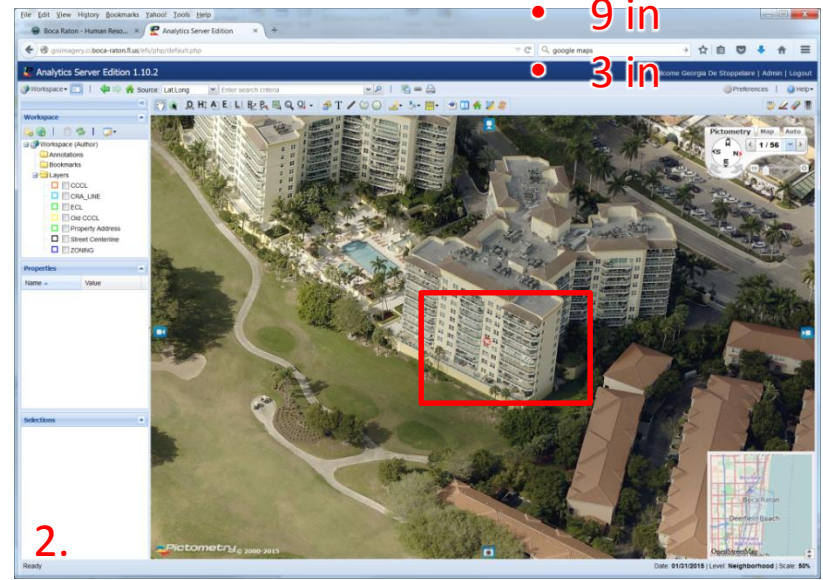
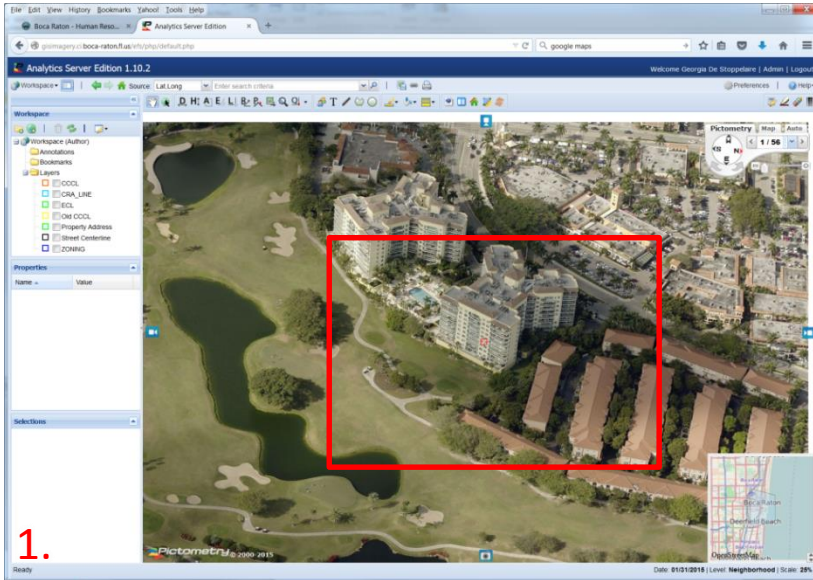


- High resolution (9 in.) 4-way
- Oblique and orthogonal
 - every pixel in the image is georeferenced
 - mosaicked imagery

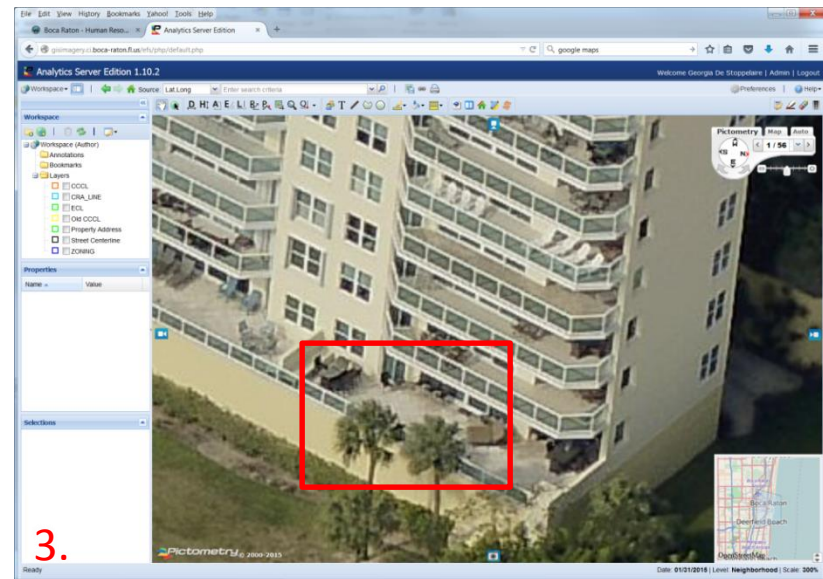
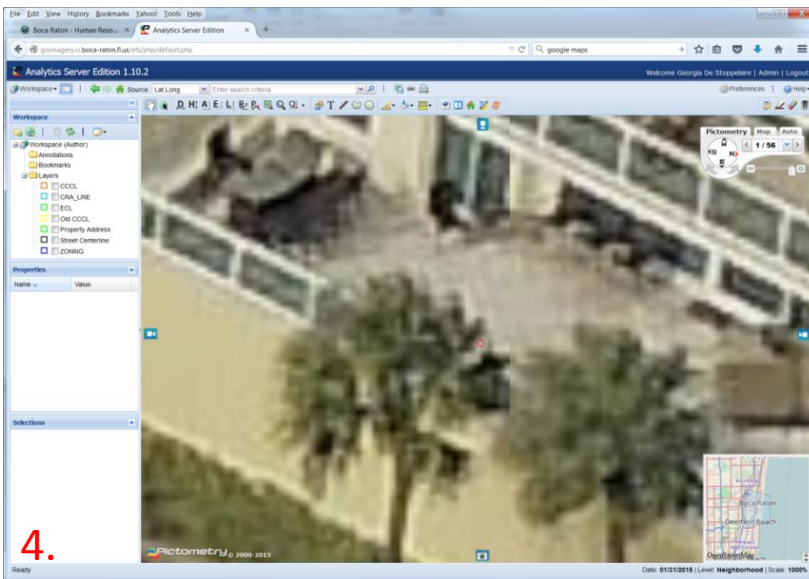


Navigate to location...

- 1 m (mosaic)
- 9 in
- 3 in

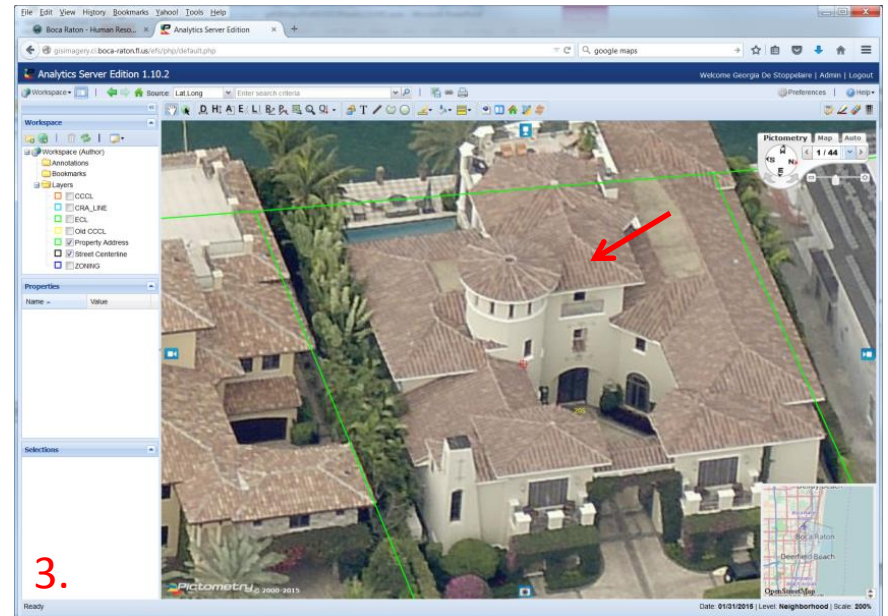
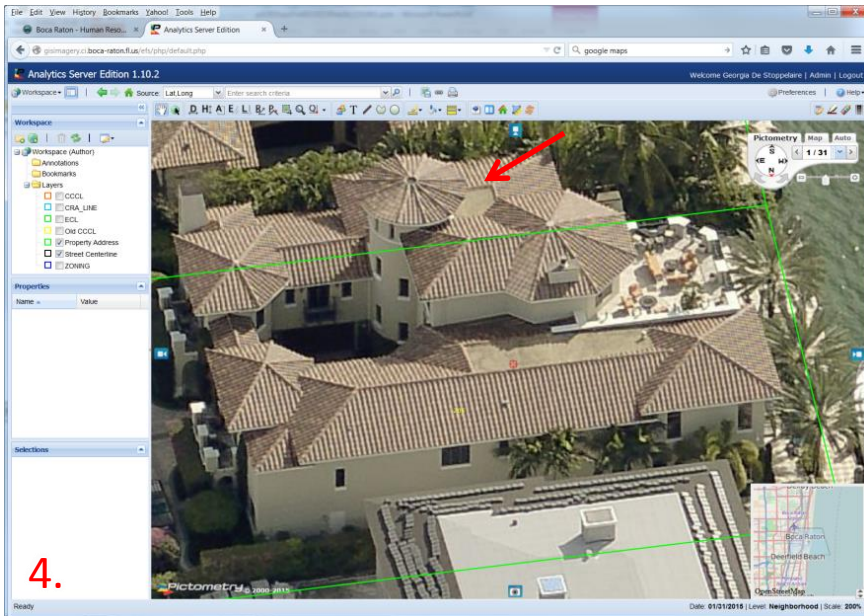
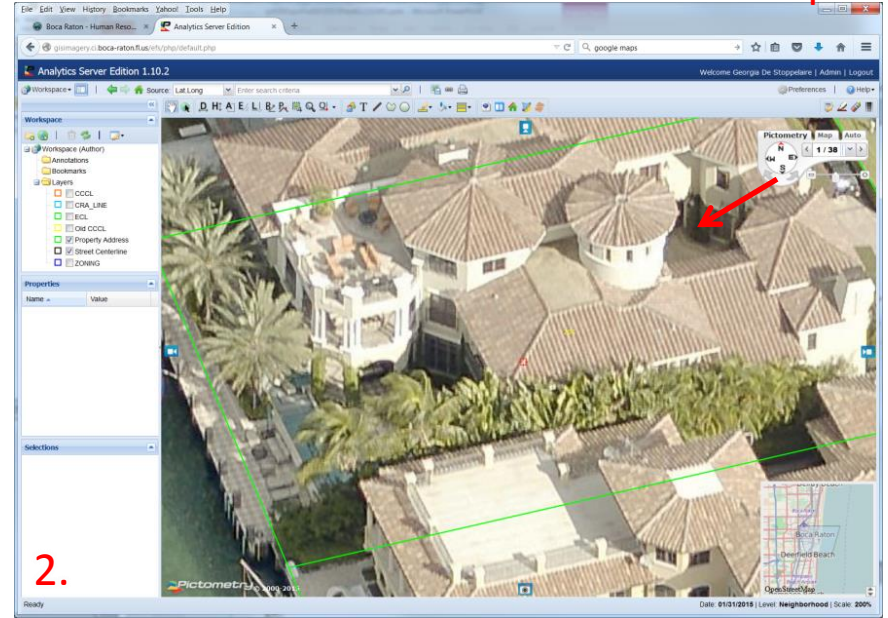
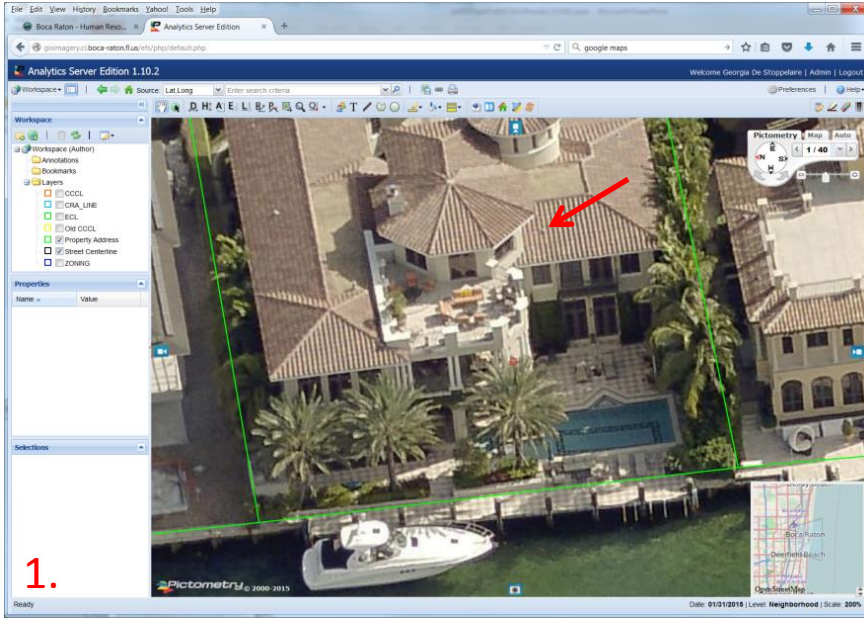


Count stories...

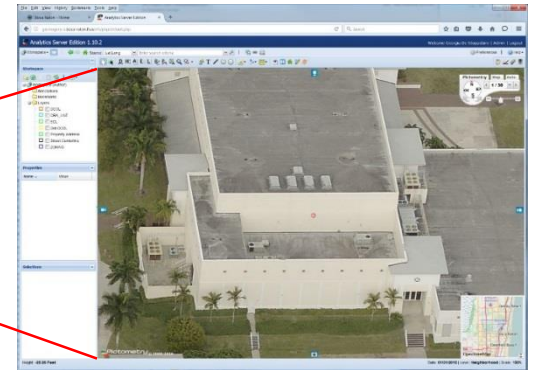
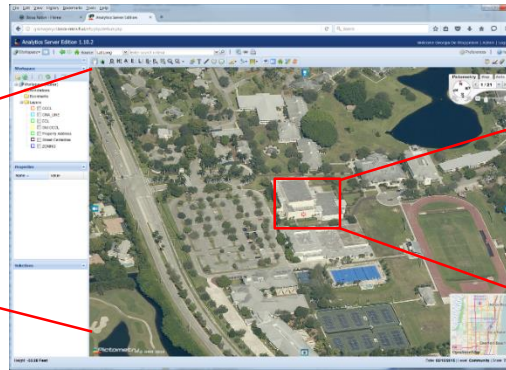
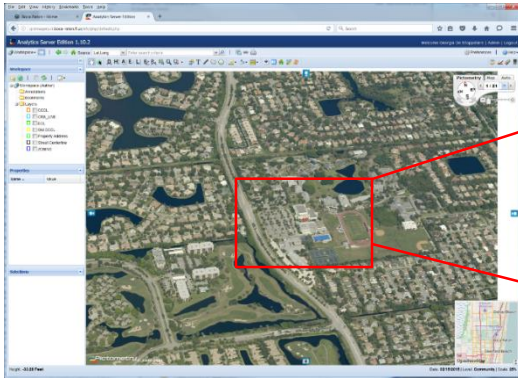


Residential – 3 floors, or 35 ft, or taller

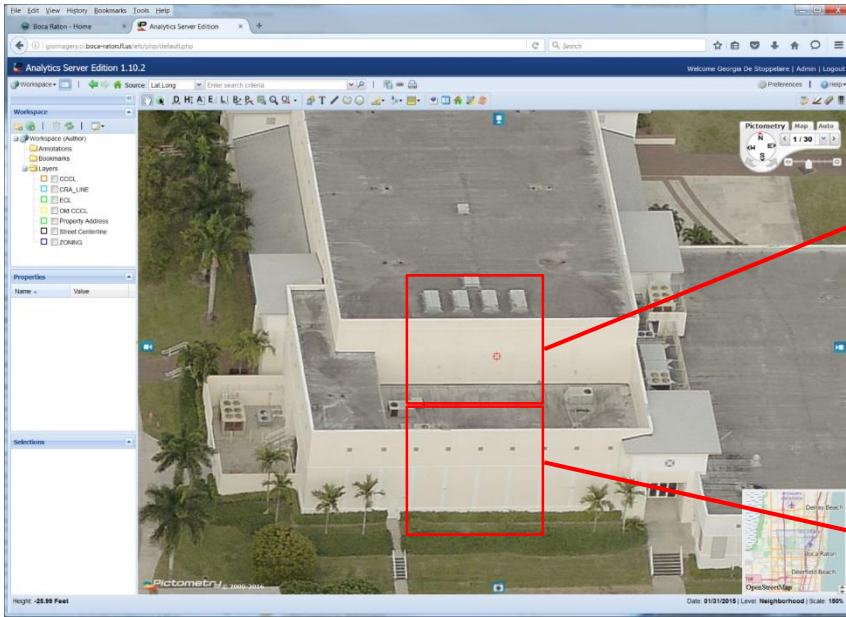
• steeples



Navigate to location...



Measure height...

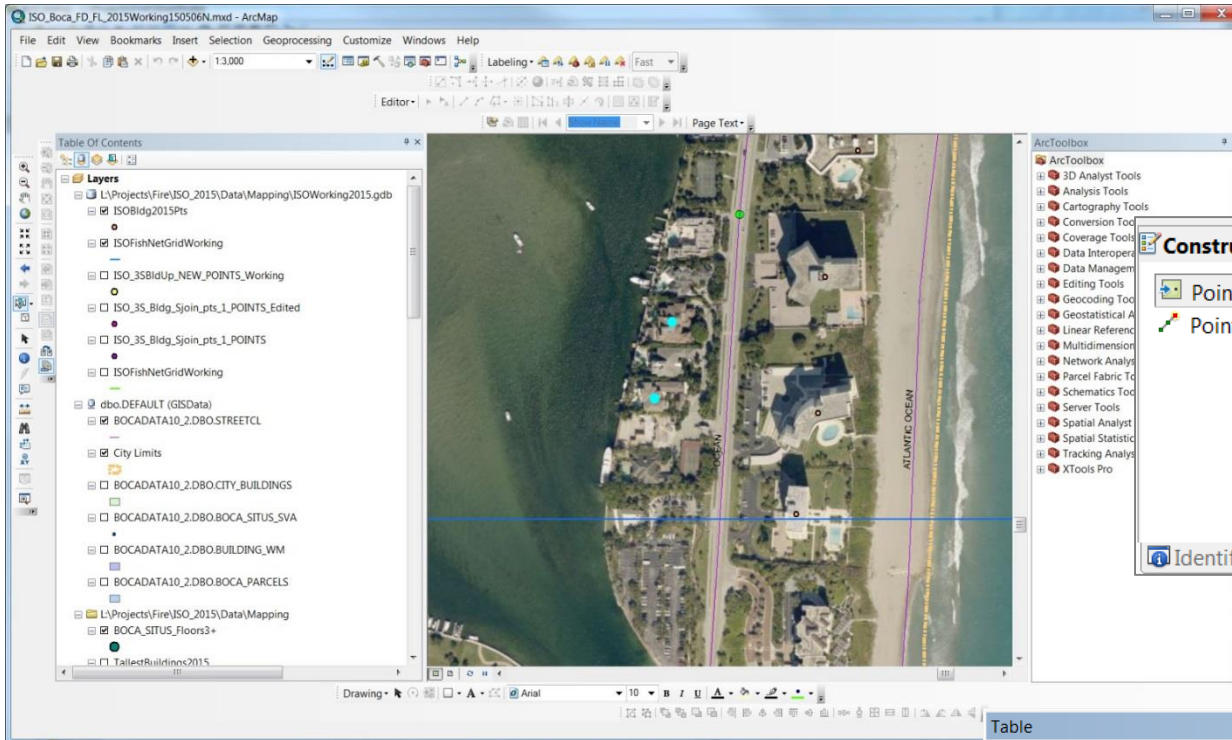


- 26 + 33.25 = 59.25 ft

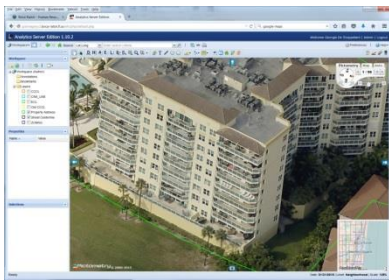
Create a point...

ArcMap

- Edit session
- Add point



Record data...

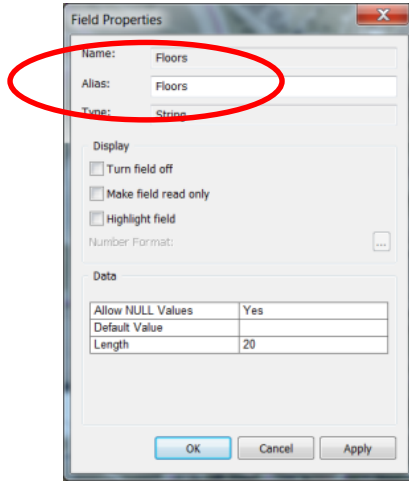


OBJECTID_12 *	Shape *	Story	Floors	Num_Floors	HeightFt
837	Point	GT 3	14	14	<Null>
840	Point	GT 3	21	21	<Null>
15	Point	<Null>	22	<Null>	<Null>
16	Point	<Null>	22	<Null>	<Null>
849	Point	GT 3	3	3	<Null>
850	Point	GT 3	3	3	<Null>
851	Point	GT 3	3	3	<Null>
17	Point	<Null>	5	5	<Null>
18	Point	<Null>	5	5	<Null>
841	Point	GT 3	5	5	<Null>
203	Point	GT 3	7	7	<Null>
842	Point	GT 3	7	7	<Null>

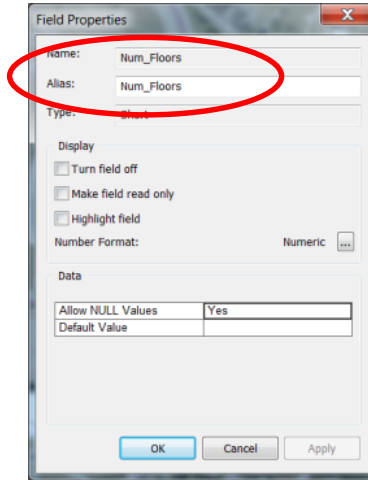
(12 out of 555 Selected)

- One point per building
- Number of floors, or measured height

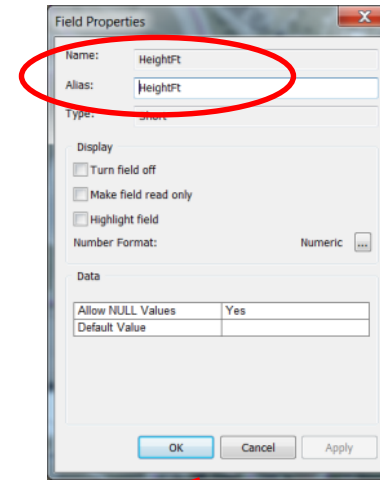
Recording data...



Field Properties dialog for the 'Floors' field. The 'Name' and 'Alias' fields are circled in red. The 'Type' is 'Short Integer'. The 'Display' section has 'Turn field off', 'Make field read only', and 'Highlight field' all unchecked. The 'Number Format' is 'Numeric'. The 'Data' section shows 'Allow NULL Values' as 'Yes', 'Default Value' as an empty field, and 'Length' as '20'.



Field Properties dialog for the 'Num_Floors' field. The 'Name' and 'Alias' fields are circled in red. The 'Type' is 'Short Integer'. The 'Display' section has 'Turn field off', 'Make field read only', and 'Highlight field' all unchecked. The 'Number Format' is 'Numeric'. The 'Data' section shows 'Allow NULL Values' as 'Yes', 'Default Value' as an empty field, and 'Length' as an empty field.



Field Properties dialog for the 'HeightFt' field. The 'Name' and 'Alias' fields are circled in red. The 'Type' is 'Short Integer'. The 'Display' section has 'Turn field off', 'Make field read only', and 'Highlight field' all unchecked. The 'Number Format' is 'Numeric'. The 'Data' section shows 'Allow NULL Values' as 'Yes', 'Default Value' as an empty field, and 'Length' as an empty field.

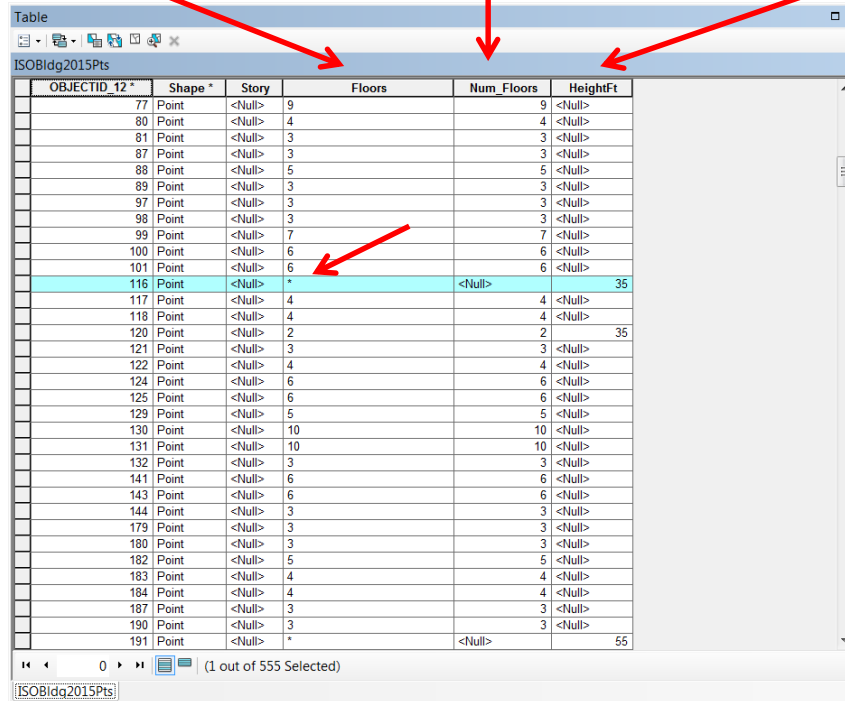


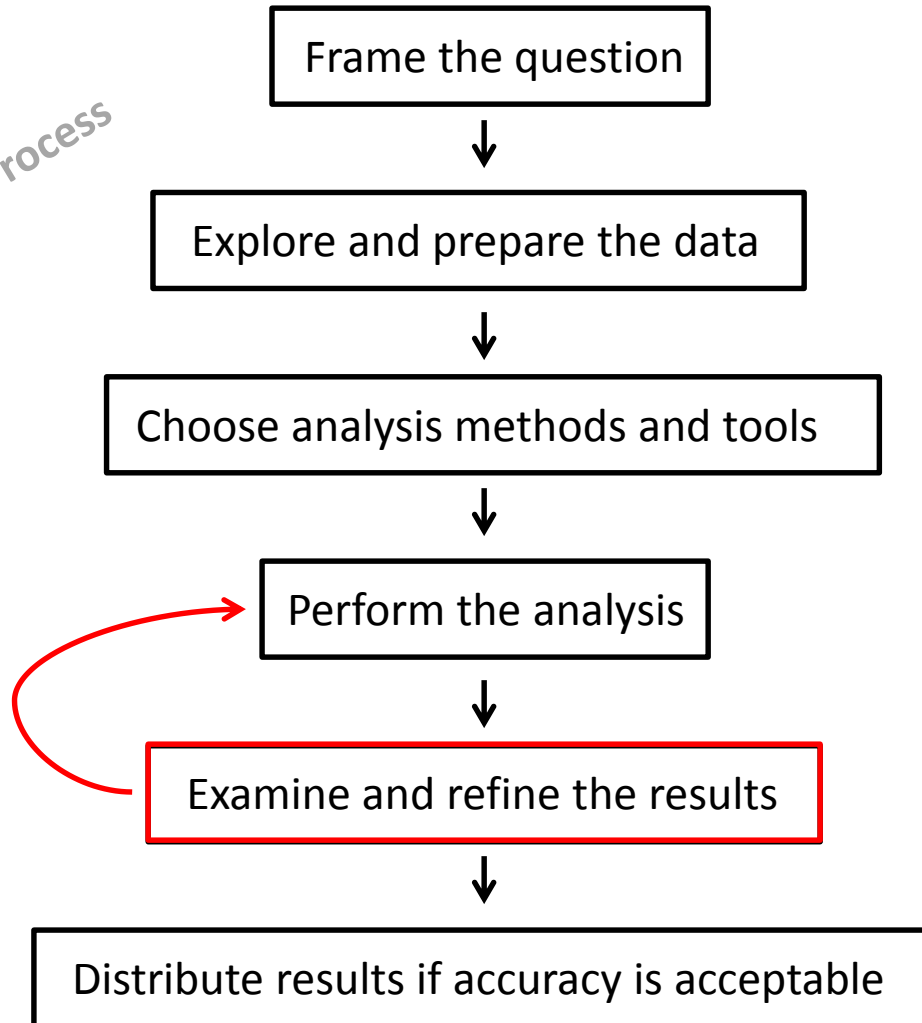
Table view showing data for ISOBldg2015Pts. The table has columns: OBJECTID, Shape, Story, Floors, Num_Floors, and HeightFt. A red arrow points to the asterisk in the Story column of row 116.

OBJECTID	Shape	Story	Floors	Num_Floors	HeightFt
77	Point	<Null>	9		9
80	Point	<Null>	4		4
81	Point	<Null>	3		3
87	Point	<Null>	3		3
88	Point	<Null>	5		5
89	Point	<Null>	3		3
97	Point	<Null>	3		3
98	Point	<Null>	3		3
99	Point	<Null>	7		7
100	Point	<Null>	6		6
101	Point	<Null>	6		6
116	Point	*		<Null>	35
117	Point	<Null>	4		4
118	Point	<Null>	4		4
120	Point	<Null>	2		2
121	Point	<Null>	3		3
122	Point	<Null>	4		4
124	Point	<Null>	6		6
125	Point	<Null>	6		6
129	Point	<Null>	5		5
130	Point	<Null>	10		10
131	Point	<Null>	10		10
132	Point	<Null>	3		3
141	Point	<Null>	6		6
143	Point	<Null>	6		6
144	Point	<Null>	3		3
179	Point	<Null>	3		3
180	Point	<Null>	3		3
182	Point	<Null>	5		5
183	Point	<Null>	4		4
184	Point	<Null>	4		4
187	Point	<Null>	3		3
190	Point	<Null>	3		3
191	Point	<Null>	*	<Null>	55

- Add fields to record data
- '*' = "not stories"; marker
 - need to measure height

Steps in the Analysis Process

Based on Esri's
Five-Step GIS Analysis Process



Source: Esri Training Matters, 2009

<http://blogs.esri.com/esri/esrtrainingmatters/2009/10/08/use-the-five-step-gis-analysis-process/>

Verify the data...

- Examine the data
 - Visual analysis
 - (QA) check all points 2x during data collection
 - Check records via random sampling
 - points 20+



- Clean up tables for delivery
 - Copy layer
 - Edit to remove unnecessary attributes
 - Standardized data
 - Field Calculator
- Compare table attributes from the data-collected vs. final data layers
 - Number of records must match

Table

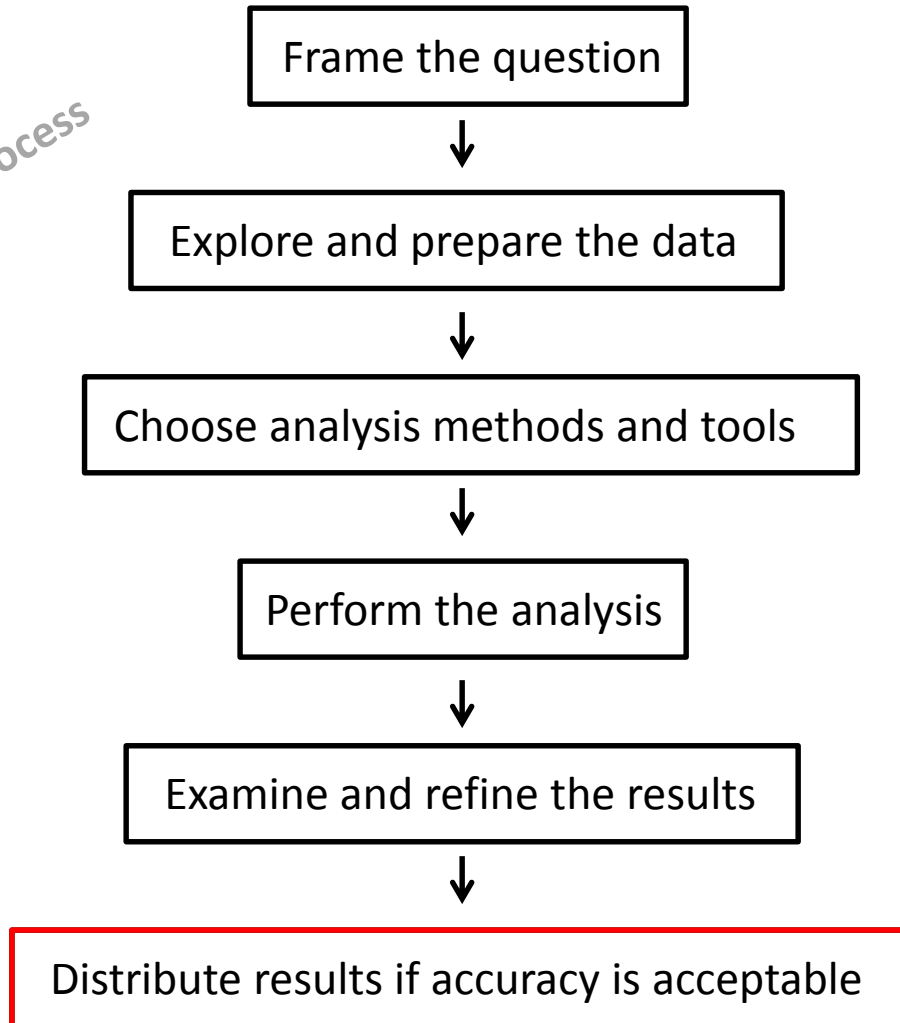
ISOBldg2015Pts

OBJECTID_12 *	Shape *	Story	Floors	Num_Floors	HeightFt
116	Point	<Null>	*	<Null>	35
191	Point	<Null>	*	<Null>	55
201	Point	GT 3	*	<Null>	40
1092	Point	<Null>	*	<Null>	35
1093	Point	<Null>	*	<Null>	35
1094	Point	<Null>	*	<Null>	35
1095	Point	<Null>	*	<Null>	35
1117	Point	<Null>	*	<Null>	35
1128	Point	<Null>	*	<Null>	35
1152	Point	<Null>	*	<Null>	35
1156	Point	<Null>	*	<Null>	35
60	Point	<Null>	10	10	<Null>
130	Point	<Null>	10	10	<Null>
131	Point	<Null>	10	10	<Null>
276	Point	GT 3	10	10	<Null>
281	Point	GT 3	10	10	<Null>
332	Point	GT 3	10	10	<Null>
559	Point	GT 3	10	10	<Null>
795	Point	GT 3	10	10	<Null>
811	Point	GT 3	10	10	<Null>
1157	Point	<Null>	10	10	<Null>
14	Point	<Null>	12	12	<Null>
230	Point	GT 3	12	12	<Null>
556	Point	GT 3	12	12	<Null>

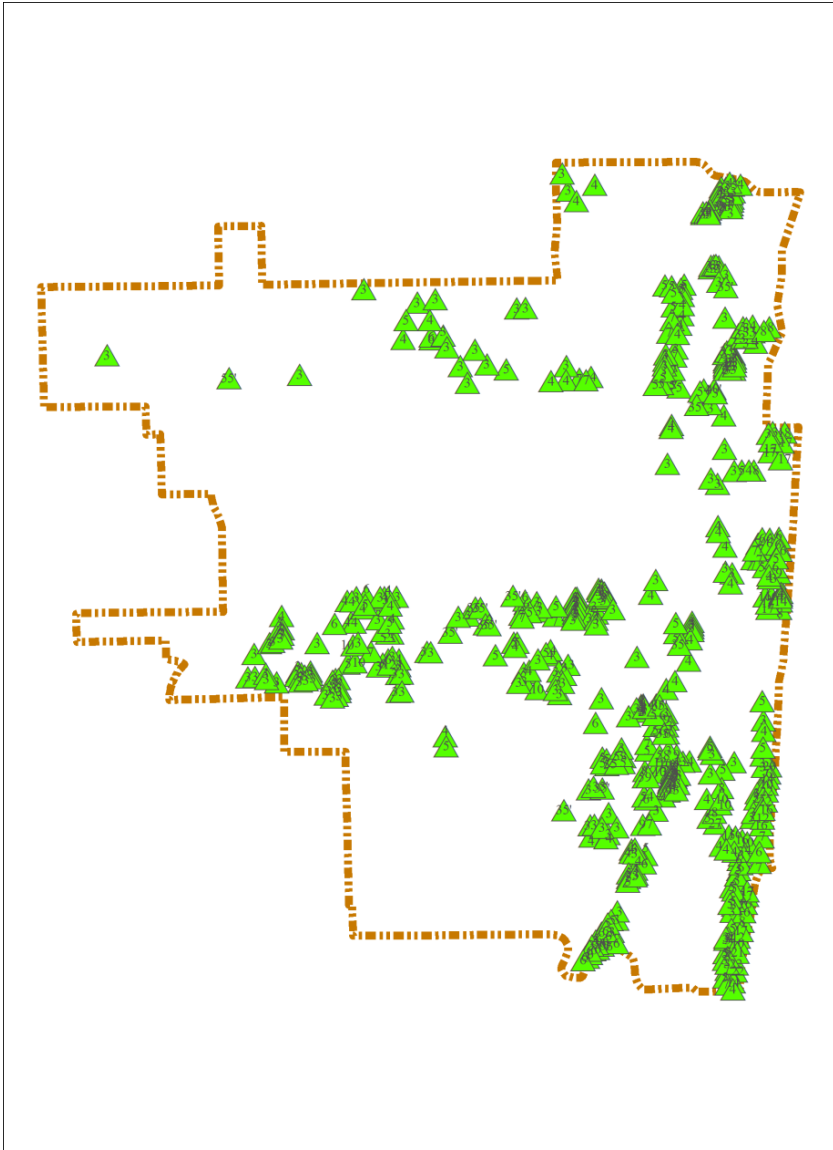
ISOBldg2015Pts (0 out of 555 Selected)

Steps in the Analysis Process

Based on Esri's
Five-Step GIS Analysis Process



Results



All buildings three or more stories in height, or 35 ft or taller [in a data layer]

(...with the actual number of stories and/or height in feet denoted.)

Final product:

- Data layer (feature class; shape file)
- Removed unnecessary attributes
- Only attributes of 'Floors' and 'HeightFt'

A screenshot of a data table window titled 'BocaRatonTallBldgsISO2015'. The table has five columns: FID, Shape, OBJECTID_1, Floors, and HeightFt. Red arrows point to the 'Floors' and 'HeightFt' columns. The table contains 10 rows of data. At the bottom, it shows '(0 out of 555 Selected)' and the table name 'BocaRatonTallBldgsISO2015' in a text box.

FID	Shape *	OBJECTID_1	Floors	HeightFt
91	Point	187	3	0
92	Point	190	3	0
93	Point	191	*	55
94	Point	194	3	0
95	Point	196	3	0
96	Point	197	3	0
97	Point	198	7	0
98	Point	199	5	0
99	Point	200	5	0
100	Point	201	*	40

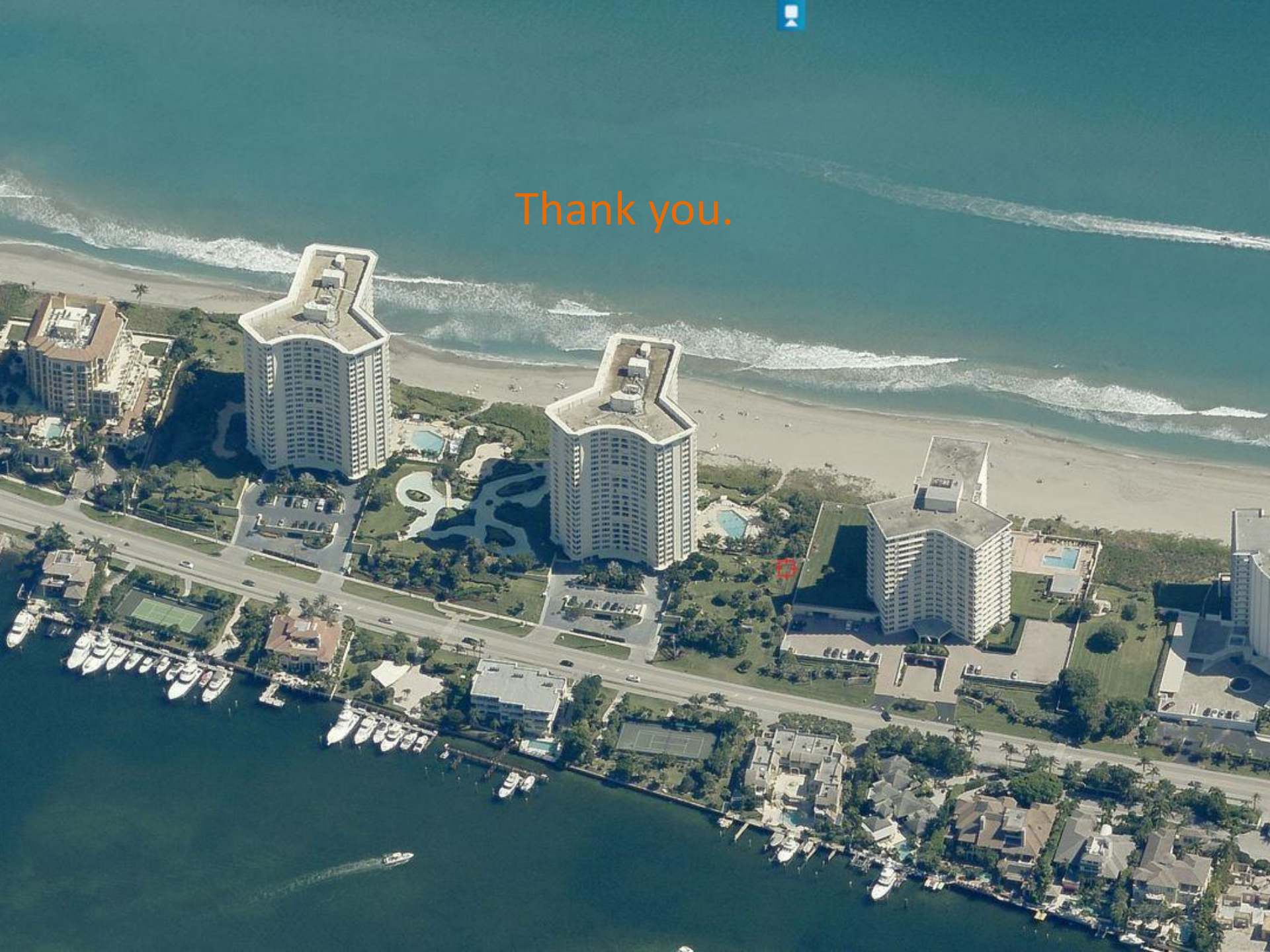
Discussion

- Using ArcGIS and 4-way, 360-degree high resolution aerial imagery
 - Develop a quick process
 - Reduce cost of field data collection
 - Repeatable
 - Customer satisfaction (i.e., Fire Dept., Insurance Services Office (ISO))
- Category definition/descriptions
 - Specifics of 'height'; types of buildings to include
- Building must be manually analyzed
 - Visual analysis
 - Requires many views of sides of buildings
 - Multiple measurements
- Digital data in geospatial format
 - Resource for other projects

Conclusion

- Successfully produced geospatial data with high relative accuracy for building heights using GIS and remote sensing technologies
- Oblique and four-way views of orthogonal high resolution imagery holds promise for practical application in other GIS projects

Thank you.



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Summary Absolute Horizontal Accuracies	6

Glossary

DEM	Digital Elevation Model
FOV	Field Of View
GPS	Global Positioning System
GSD	Ground Sample Distance (a.k.a. Pixel size)
GSE	Ground Surface Error
IMU	Inertial Measurement Unit
SBET	Smoothed Best Estimate Trajectory
PDOP	Positional Dilution of Precision
USGS	United States Geological Survey

Introduction

This paper will outline the procedures used, and the results of, absolute horizontal accuracy testing of individual orthogonal frame imagery captured and processed utilizing Pictometry's patented system.

Problem Statement

The goal of this testing is to generate values suitable to use in the "produced to meet" accuracy statement as defined in the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014).

Conclusion

Based on testing in accordance with the procedures outlined in ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014), the absolute horizontal accuracy of Pictometry's individual orthogonal frame imagery has the following "produced to meet" horizontal accuracies at the 95% confidence interval utilizing a DEM accurate to 1 meter:

3 inch [7.5 cm] GSD = 2.9 feet [88 cm]
 4 inch [10 cm] GSD = 3.5 feet [106 cm]
 6 inch [15 cm] GSD = 4.4 feet [134 cm]

Glossary

DEM	Digital Elevation Model
FOV	Field Of View
GPS	Global Positioning System
GSD	Ground Sample Distance (a.k.a. Pixel size)
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IMU	Inertial Measurement Unit
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Relative Measurement Accuracies in Oblique and Orthogonal Imagery	6
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Relative Measurement Accuracies	10

Glossary

DEM	Digital Elevation Model
FOV	Field Of View
GPS	Global Positioning System
GSD	Ground Sample Distance (a.k.a. Pixel size)
GSE	Ground Surface Error
IMU	Inertial Measurement Unit
SBET	Smoothed Best Estimate Trajectory
PDOP	Positional Dilution of Precision
USGS	United States Geological Survey

Introduction

This paper will outline the procedures used, and the results of, the relative measurement accuracy calculations performed for individually captured orthogonal and oblique imagery frames.

Problem Statement

The goal of this paper is to provide a quantitative analysis of the relative measurement accuracies that can be obtained within individually captured orthogonal and oblique imagery frames.

Conclusion

It can be conservatively stated that the relative measurement accuracies which can be achieved when carefully measuring well-defined features within Pictometry's individually captured orthogonal and oblique frame imagery can be expressed in a simplified format as follows:

$\pm (1.4 \times \text{GSD} + 0.3\% \text{ of distance measured})$

Conclusion

It can be conservatively stated that the relative measurement accuracies which can be achieved when carefully measuring well-defined features within Pictometry's individually captured orthogonal and oblique frame imagery can be expressed in a simplified format as follows:

$\pm (1.4 \times \text{GSD} + 0.3\% \text{ of distance measured})$