Professional Land Surveyors of Ohio

2009
ANNUAL CONFERENCE

OSIP Specification, Equipment and Technology

Bob Brinkman, CP, PLS, Project Director
Woolpert, Inc

The Ohio State Imagery Program Specification, Equipment & Technology

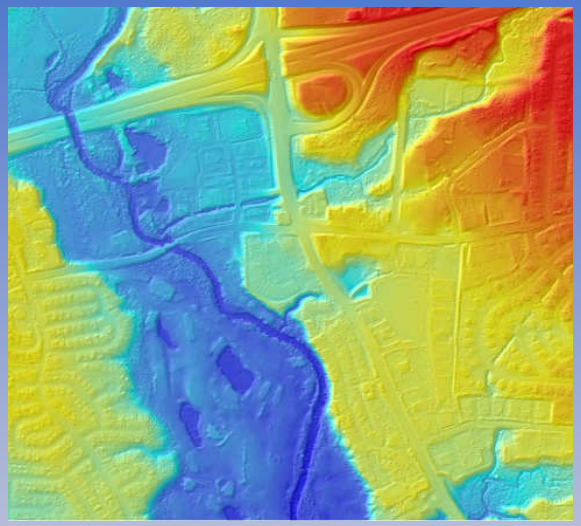
Presented by:

Bob Brinkman, Project Director

Woolpert, Inc.

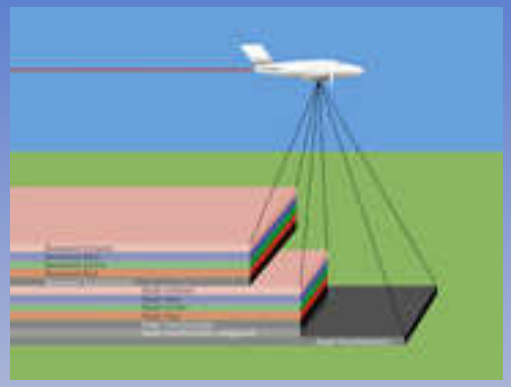
The Ohio Statewide Imagery Program

Equipment & Technology



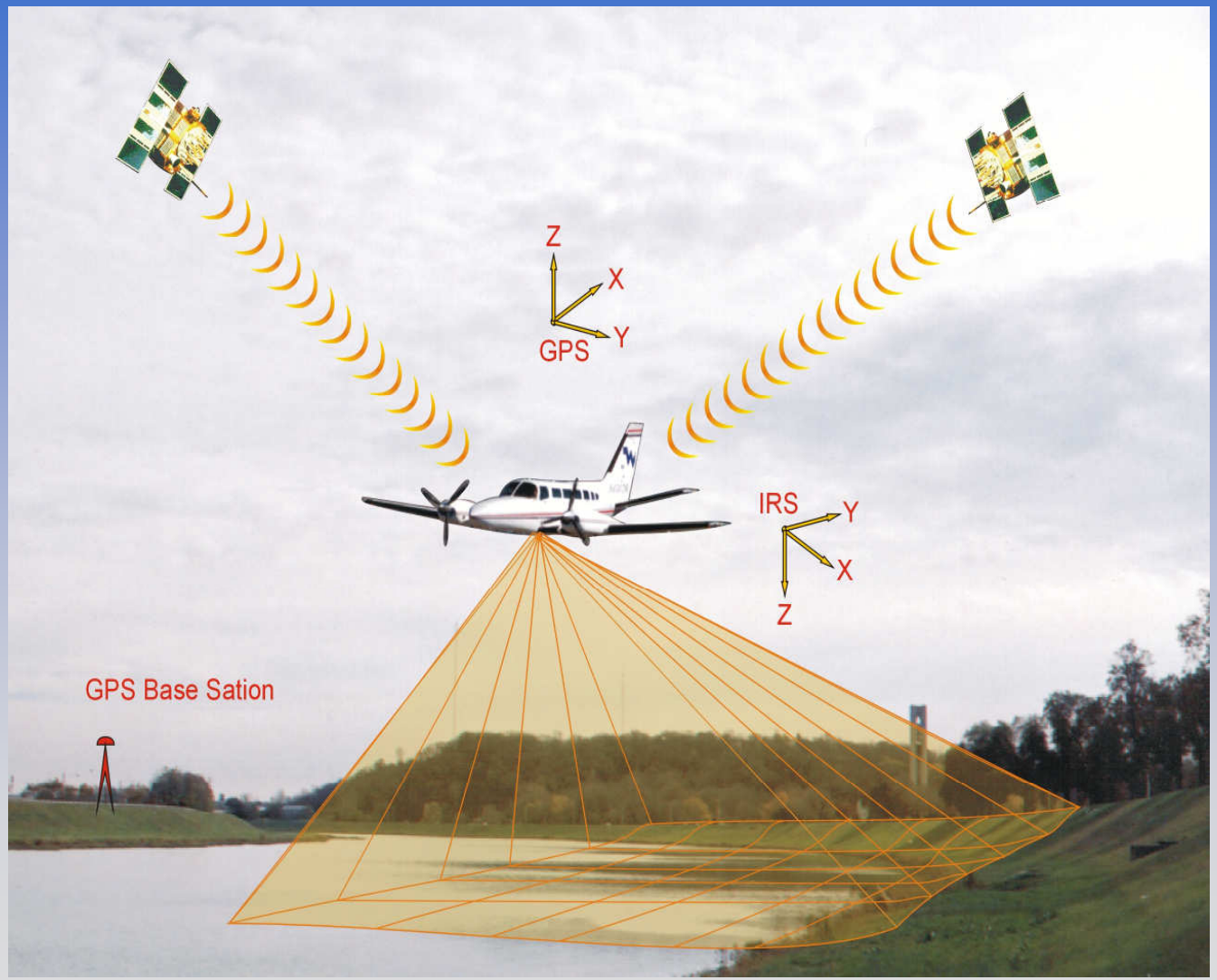
Program Technology/Equipment

Leica ADS40 Multi-Spectral Camera Sensors



Leica ALS50 LiDAR Sensors

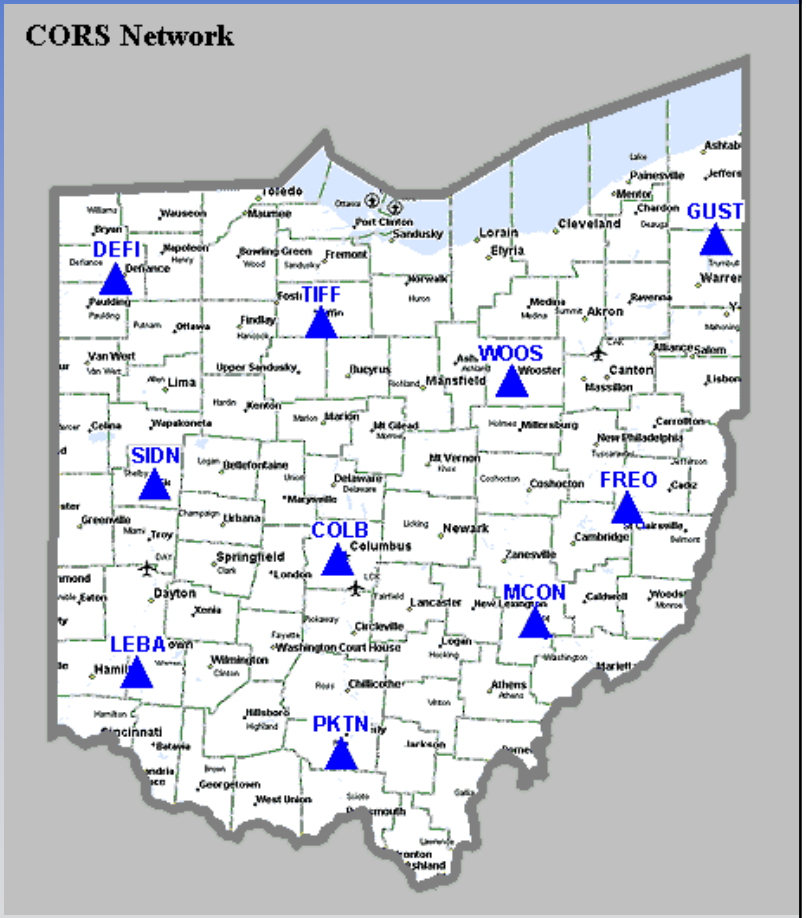
Airborne Imagery & LiDAR Acquisition



The Ohio Statewide Imagery Program
Ground Control

Airborne GPS established utilizing the State's:

- Continuously Operating Reference Stations (CORS)
- Trimble Virtual Reference Station (VRS)

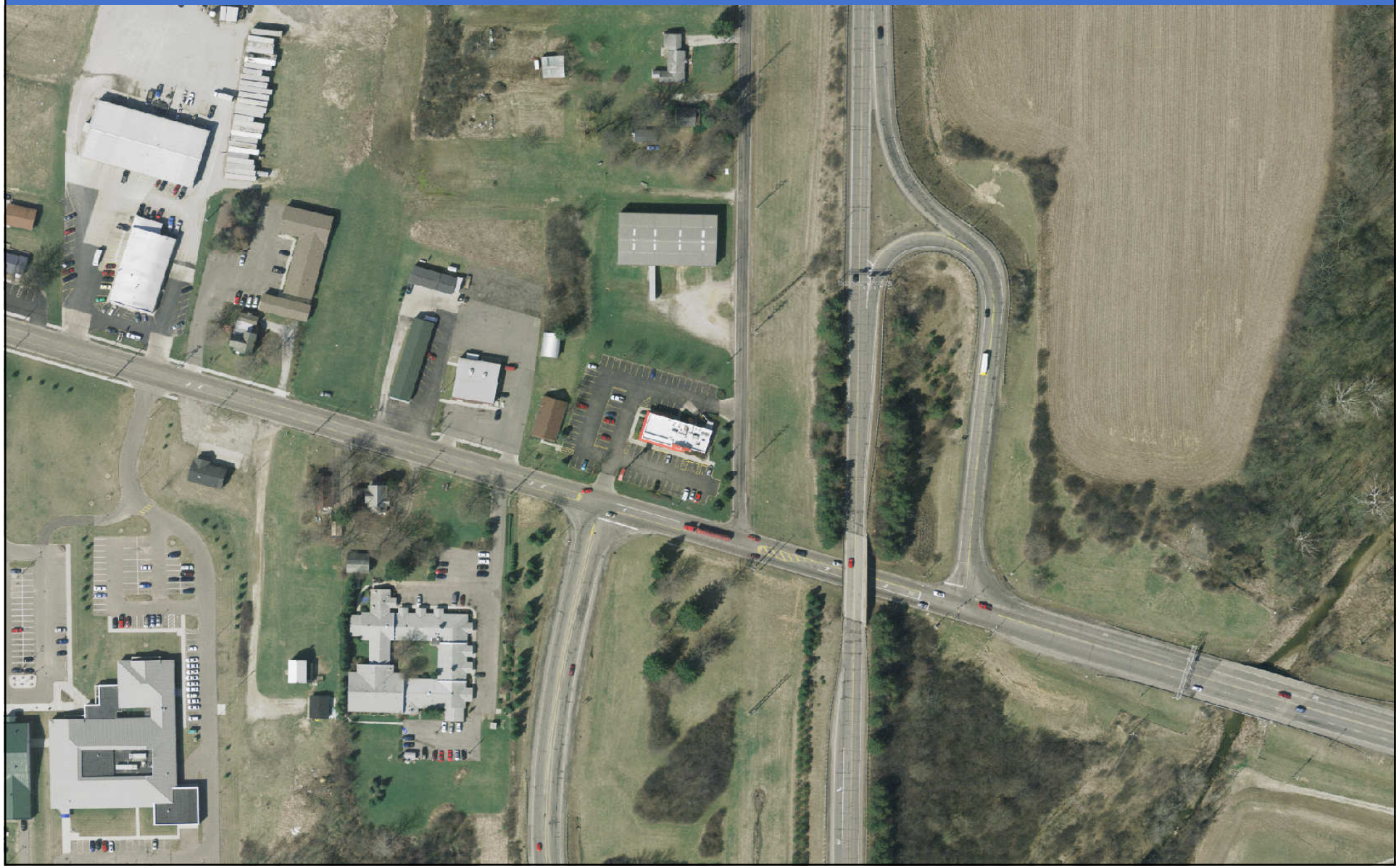


Datum & Coordinate System

- **Vertical**
  - NAVD88
  - US Survey Feet
- **Horizontal**
  - Ohio State Plane Coordinate System
  - North and South Zones
  - NAD83 (2005)
  - US Survey Feet

Color Digital Orthoimagery

1.0-foot resolution – 9600’ AGL



Color Digital Orthoimagery

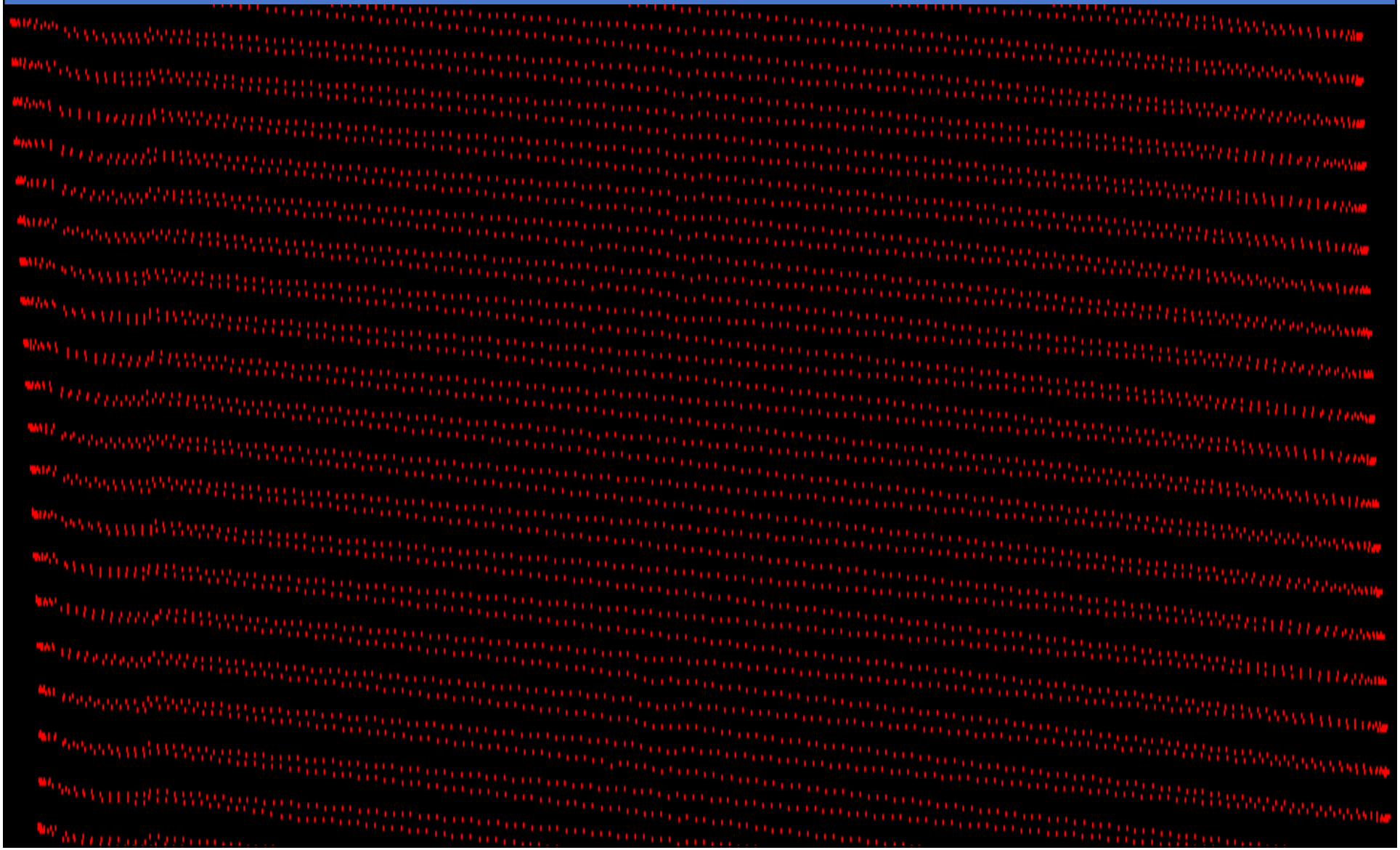
0.5-foot resolution – 4800’ AGL

Color Infrared Digital Orthoimagery

3.0-foot resolution – 28800’ AGL

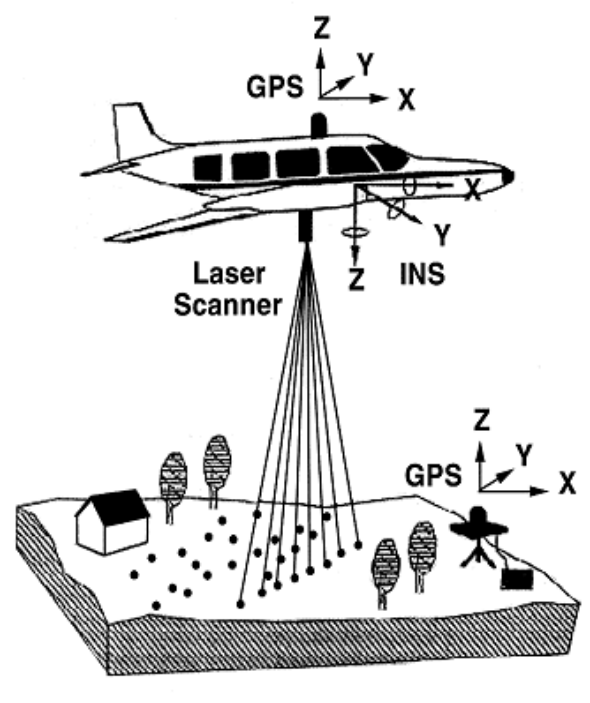
Airborne LiDAR

6.5-foot average resolution – 8100’ AGL



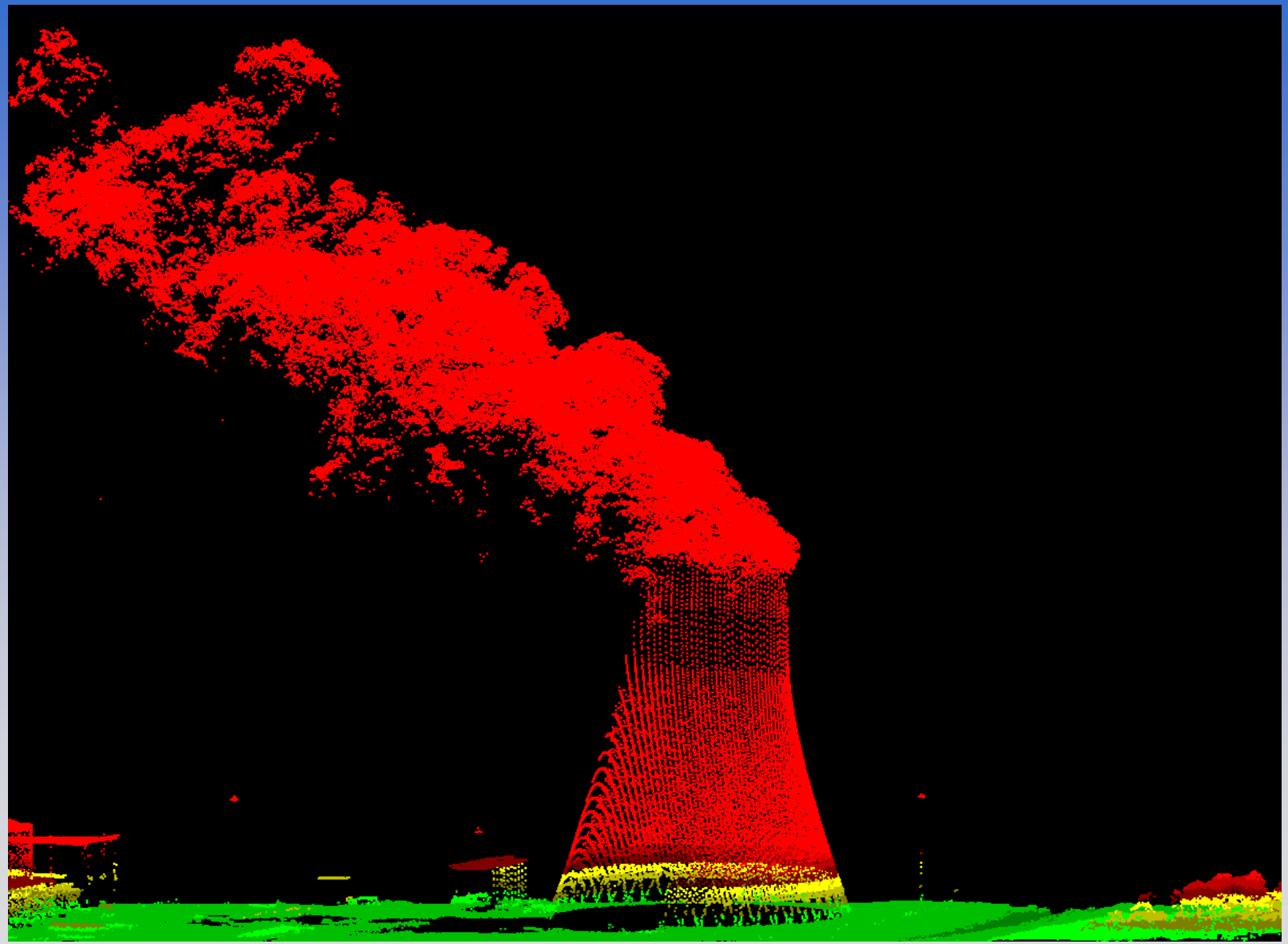
LIDAR Laser Sensor

- **"First returns"** provide Digital Surface Models (DSMs)
  - Roof tops
  - Tree tops
  - Open Earth



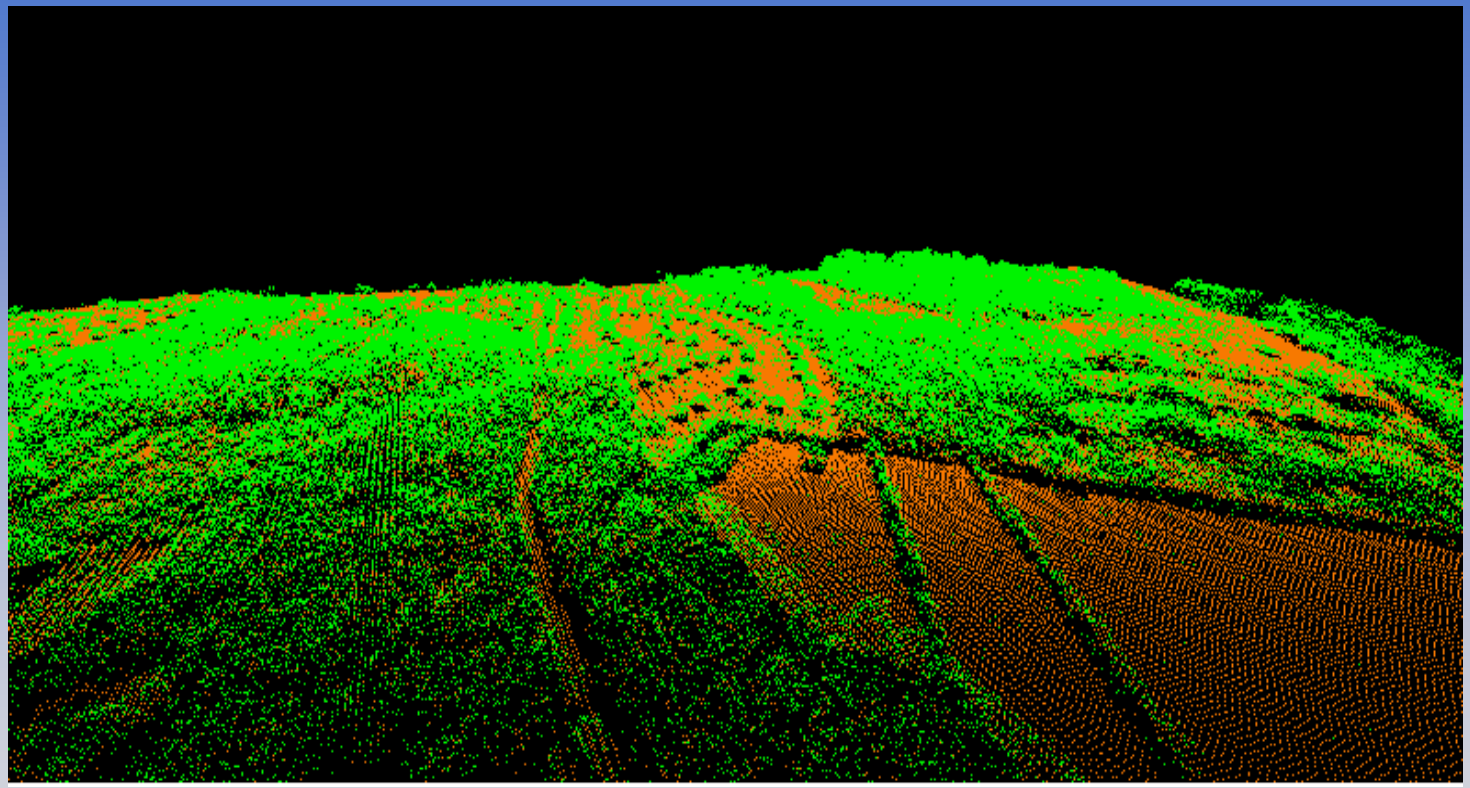
- **"Last returns"** can provide Digital Elevation Models (DEMs) of the "bare earth" if fully processed to remove buildings and vegetation that were not penetrated by the LIDAR pulses

Point Cloud



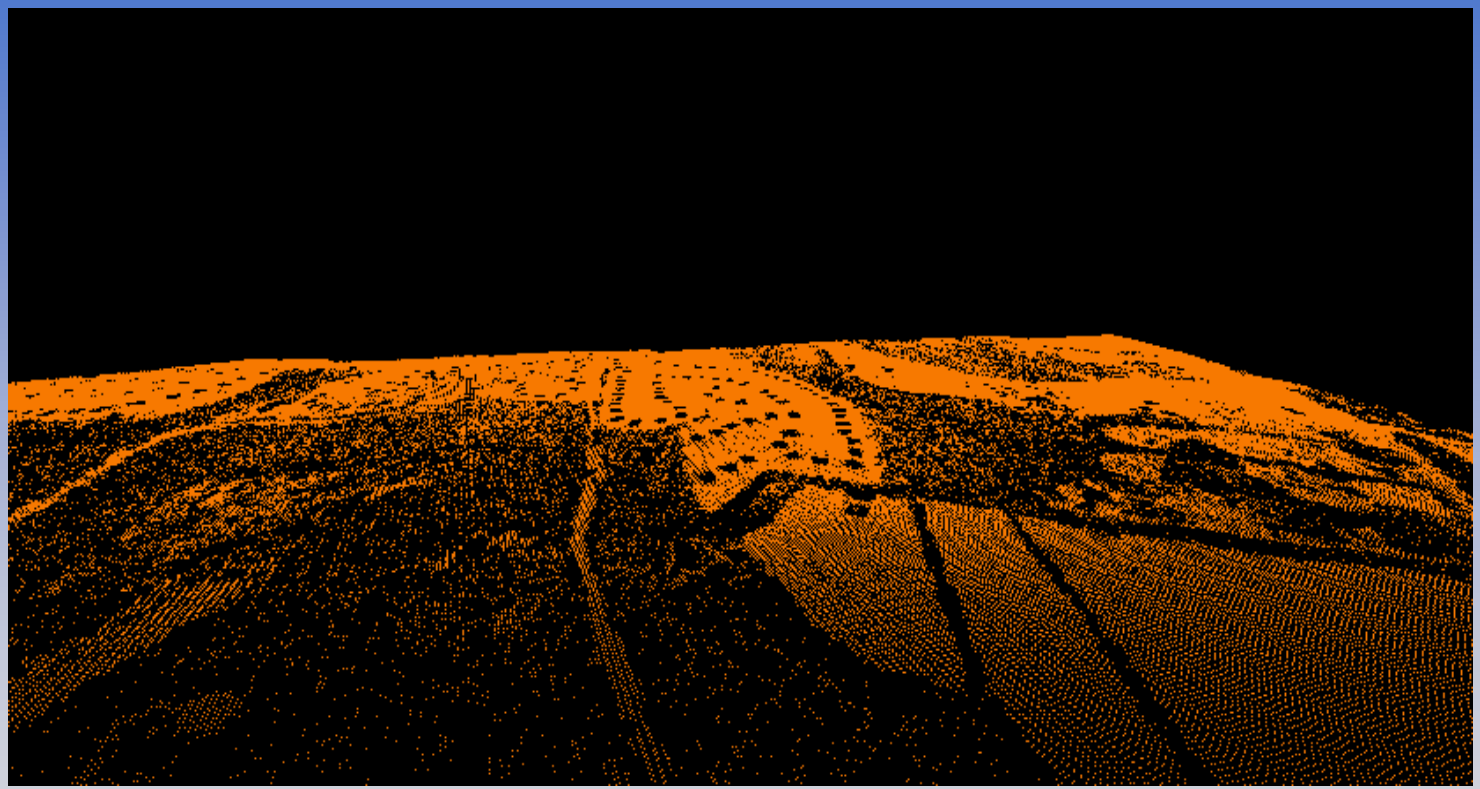
Point Cloud

Classify "Above Ground" Features



Green Above Ground Features

Bare-Earth Surface



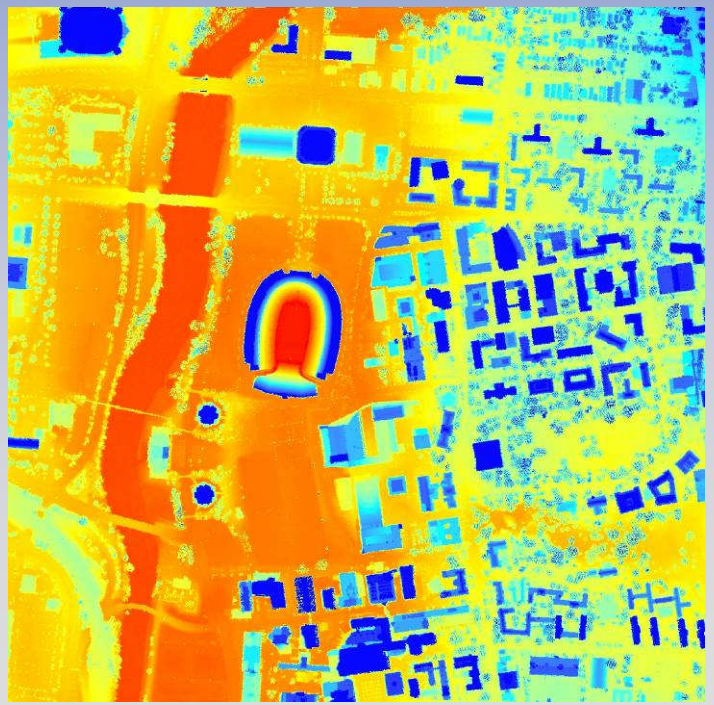
Orange Depicts Ground or “Bare-Earth Surface”

LiDAR Intensity Imagery

- Measurement of energy return
- Strength of return is mapped to pixel value
- Interpolated from random points
- Orthometrically correct
- Ability to interpret linear features, especially man-made
- Quality dependant on acquisition parameters

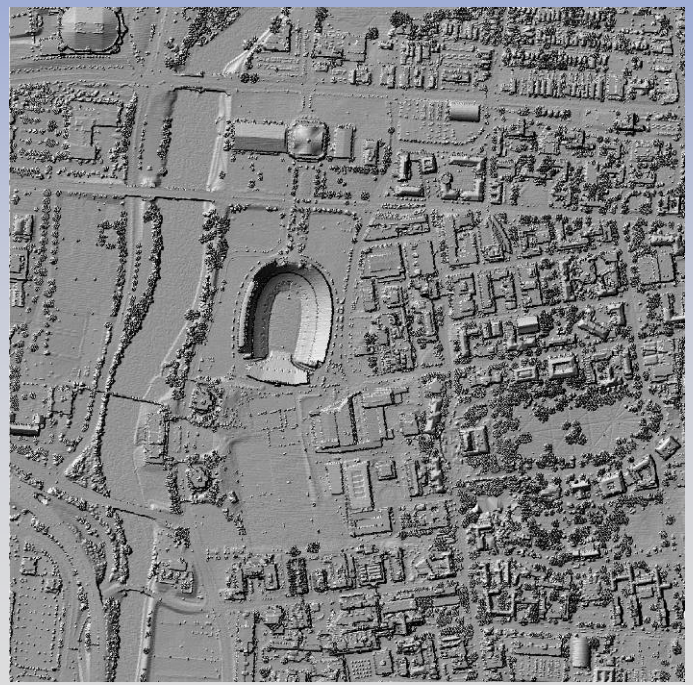
LiDAR Acquisition

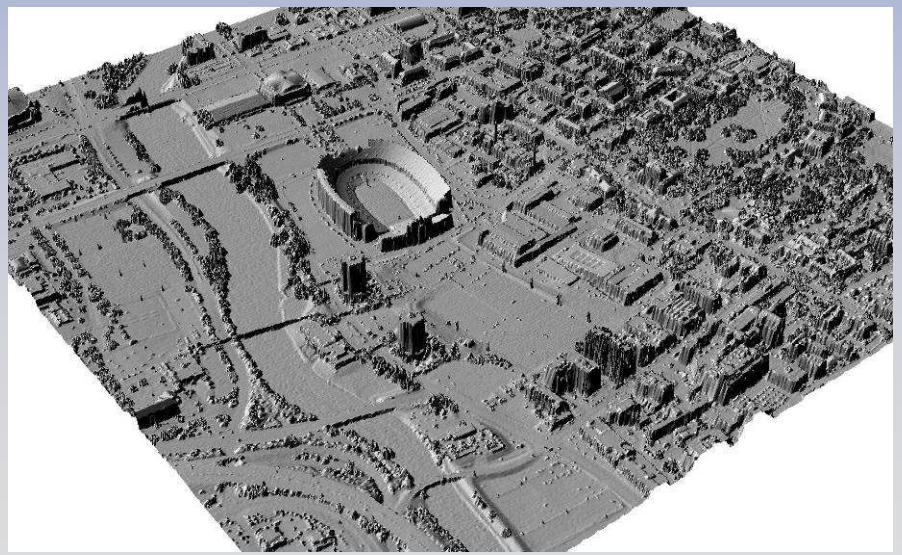
- Obtained LiDAR at an <u>average</u> of a 6.5-foot post spacing
- Bare-Earth Surface DEM/non-Ground LiDAR
- DEM was used for ortho rectification
- Bare-Earth Surface DEM is suitable to “support” the generation 2-foot contours (Quality Control Report generally found data to be accurate between 0.3’ and 1.00’)



LiDAR Generated Delivery Products

- Bare-Earth Surface DEM in ArcGrid (binary) Format
- Bare-Earth Surface DEM in ArcGrid (ASCII) Format
- Classified LiDAR Data in LAS Binary File Format





LAS Binary File Format

Classified LiDAR Data in LAS Binary File Format

- The LAS file format is a public file format for the interchange of LIDAR data between vendors and customers.

- Alternative to proprietary systems or a generic ASCII files
  - Proprietary formats cannot be easily taken from one system to another.
  - ASCII represent poor performance very large file sizes

- With other formats information specific to the LIDAR data is lost. The LAS file format is a binary file format that maintains information specific to the LIDAR nature of the data while not being overly complex.

LAS Format

POINT DATA RECORD FORMAT 0:

Item	Format	Size	Required
X	long	4 bytes	*
Y	long	4 bytes	*
Z	long	4 bytes	*
Intensity	unsigned short	2 bytes	
Return Number	3 bits (bits 0, 1, 2)	3 bits	*
Number of Returns (given pulse)	3 bits (bits 3, 4, 5)	3 bits	*
Scan Direction Flag	1 bit (bit 6)	1 bit	*
Edge of Flight Line	1 bit (bit 7)	1 bit	*
(1.1) Classification	unsigned char	1 byte	*
(1.1) `Scan Angle Rank (-90 to +90) – Left side	char	1 byte	*
(1.1) User Data	unsigned char	1 byte	
(1.1) Point Source ID	unsigned short	2 bytes	*

LAS Format

Classification Bit Field Encoding

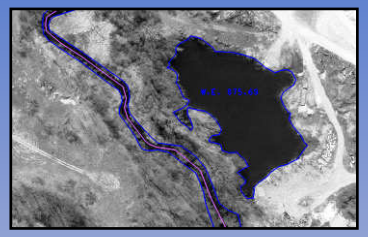
Bits	*Field Name*	*Description*
0:4	Classification	Standard ASPRS classification as defined in the following classification table.
5	Synthetic	If set then this point was created by a technique other than LIDAR collection such as digitized from a photogrammetric stereo model.
6	Key-point	If set, this point is considered to be a model key-point and thus generally should not be withheld in a thinning algorithm.
7	Withheld	If set, this point should not be included in processing (synonymous with Deleted).

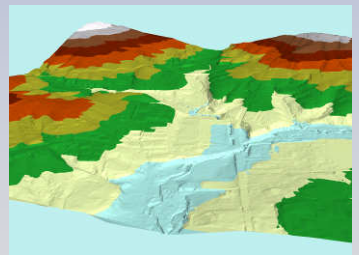
ASPRS Standard LIDAR Point Classes

Classification Value (bits 0:4)	*Meaning*
0	Created, never classified
1	Unclassified[1]
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water
10	*Reserved for ASPRS Definition*
11	*Reserved for ASPRS Definition*
12	Overlap Points[2]
13-31	*Reserved for ASPRS Definition*

What was NOT included in the Statewide LiDAR deliverables

- DEM did not contain 3-D Breaklines
  - Define sharp changes of elevation
  - Cliffs, Escarpments, Banks, Levies
  - Edges of Rivers, Lakes, Streams, Ponds, Ditches
  - Edges of Roads, Trails, Parking areas
- Contours
  - Bare-Earth DEM suitable to “support” generation of 2-ft contours





Note: Counties that choose to upgrade to 0.5-foot resolution ortho-photography also had/have an option to obtain 3D Breaklines & Contours

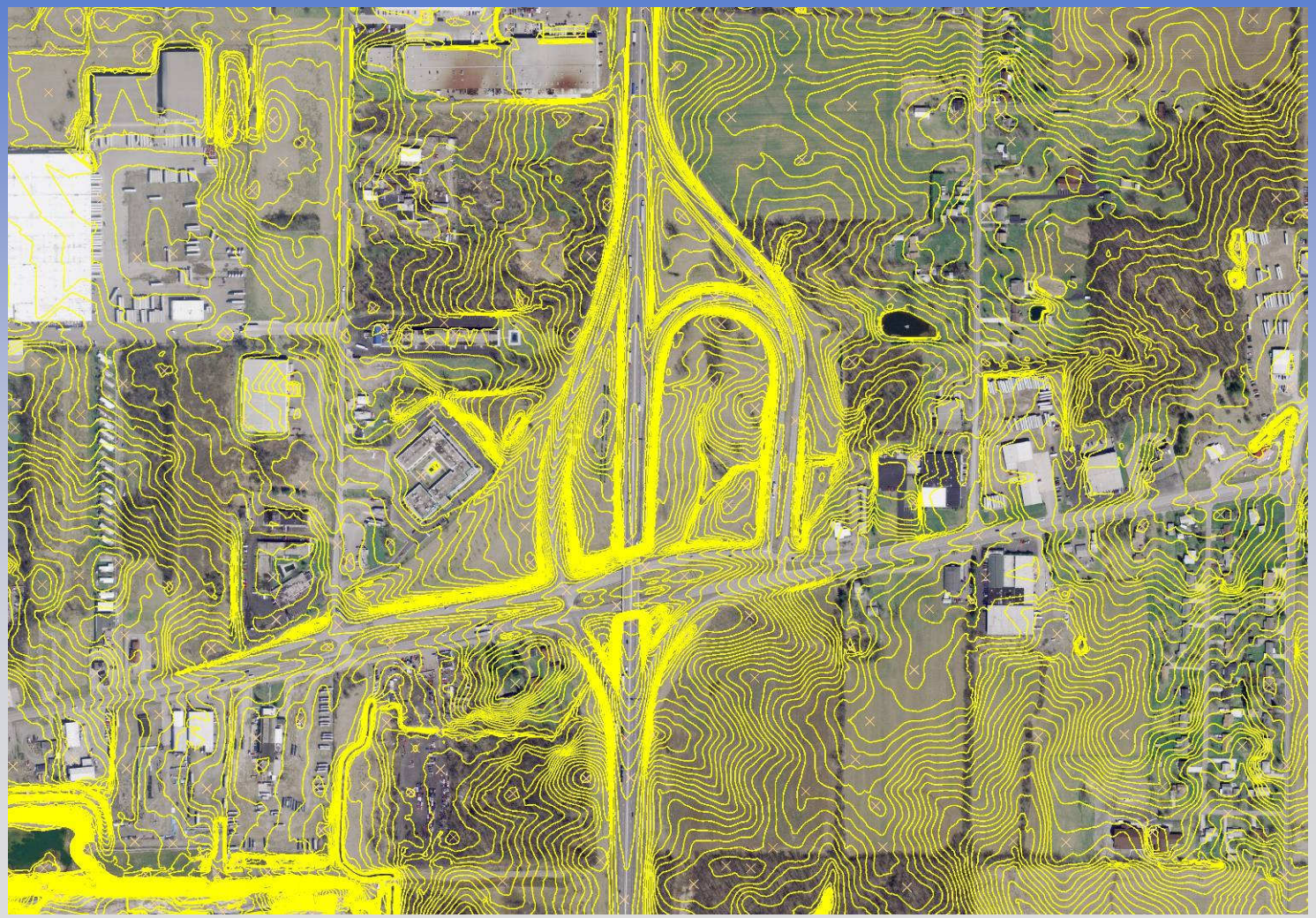
Adding Breaklines to LiDAR?

- Accuracy
  - Hydro-enforcement
  - Define Vertical Edges
- Aesthetics
  - Smooth contours
  - Cartographic contours
- Efficiency
  - Less dense LiDAR

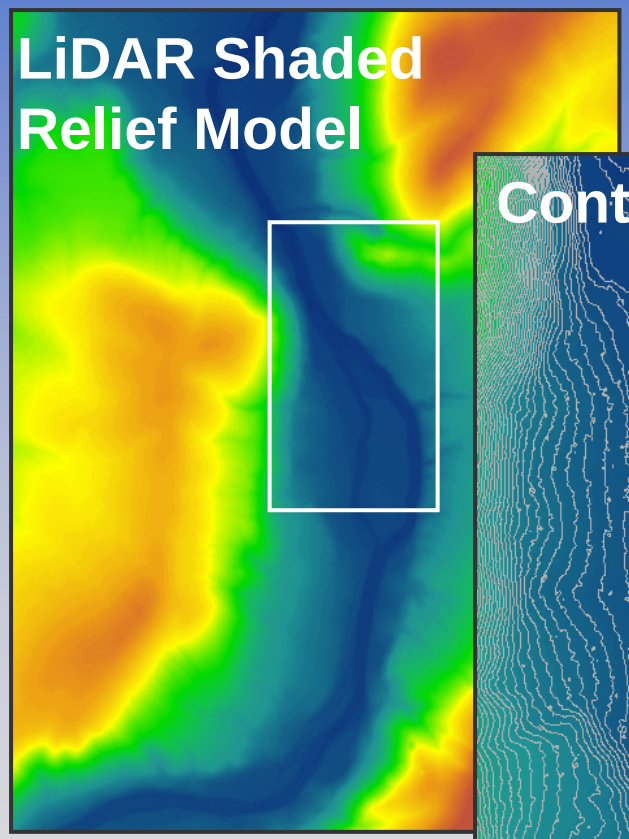
Digital Orthophotography & Contours

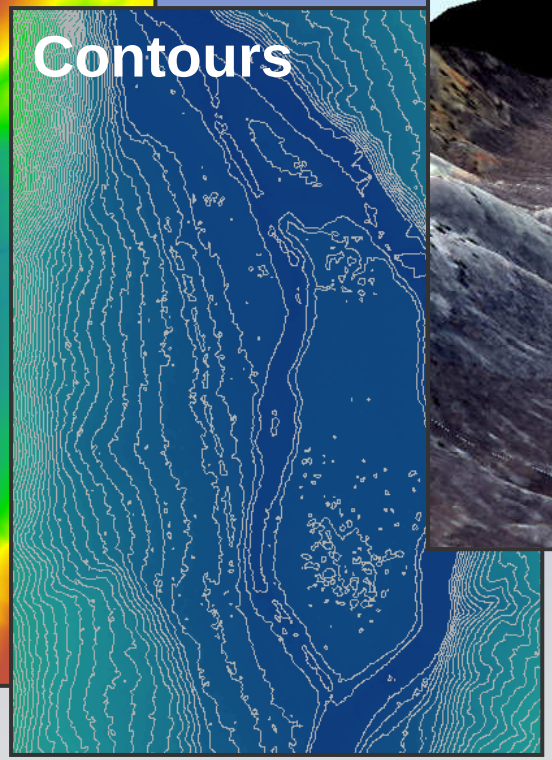
City of Lima, Ohio – Interstate 75

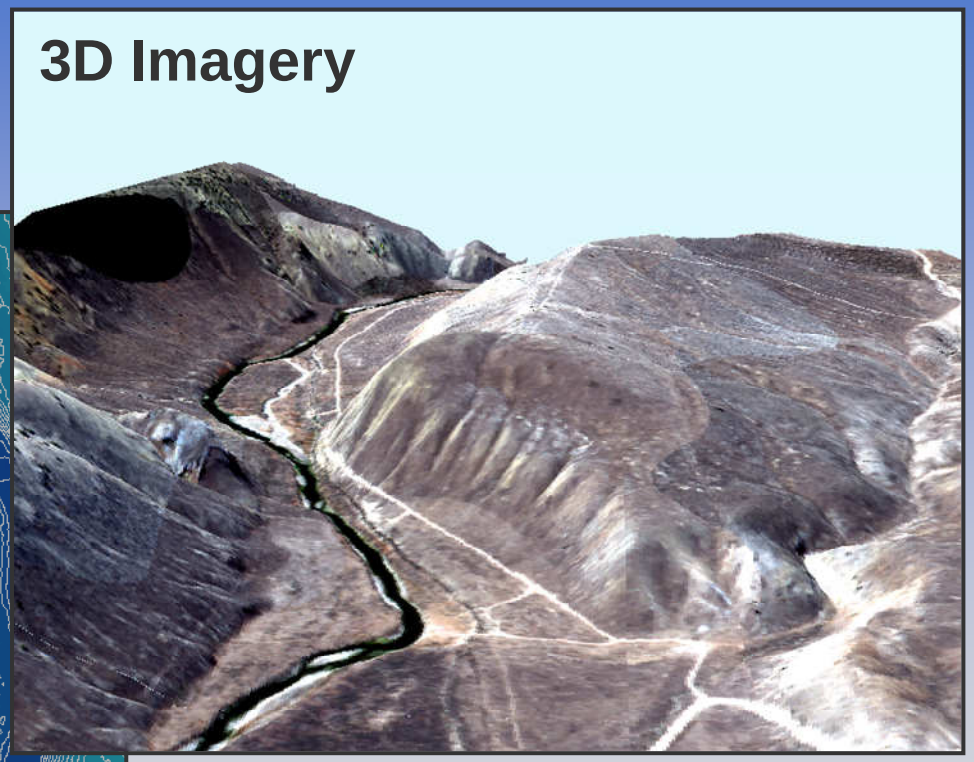
2-Foot Contours created from 3D breaklines and LiDAR Mass Points



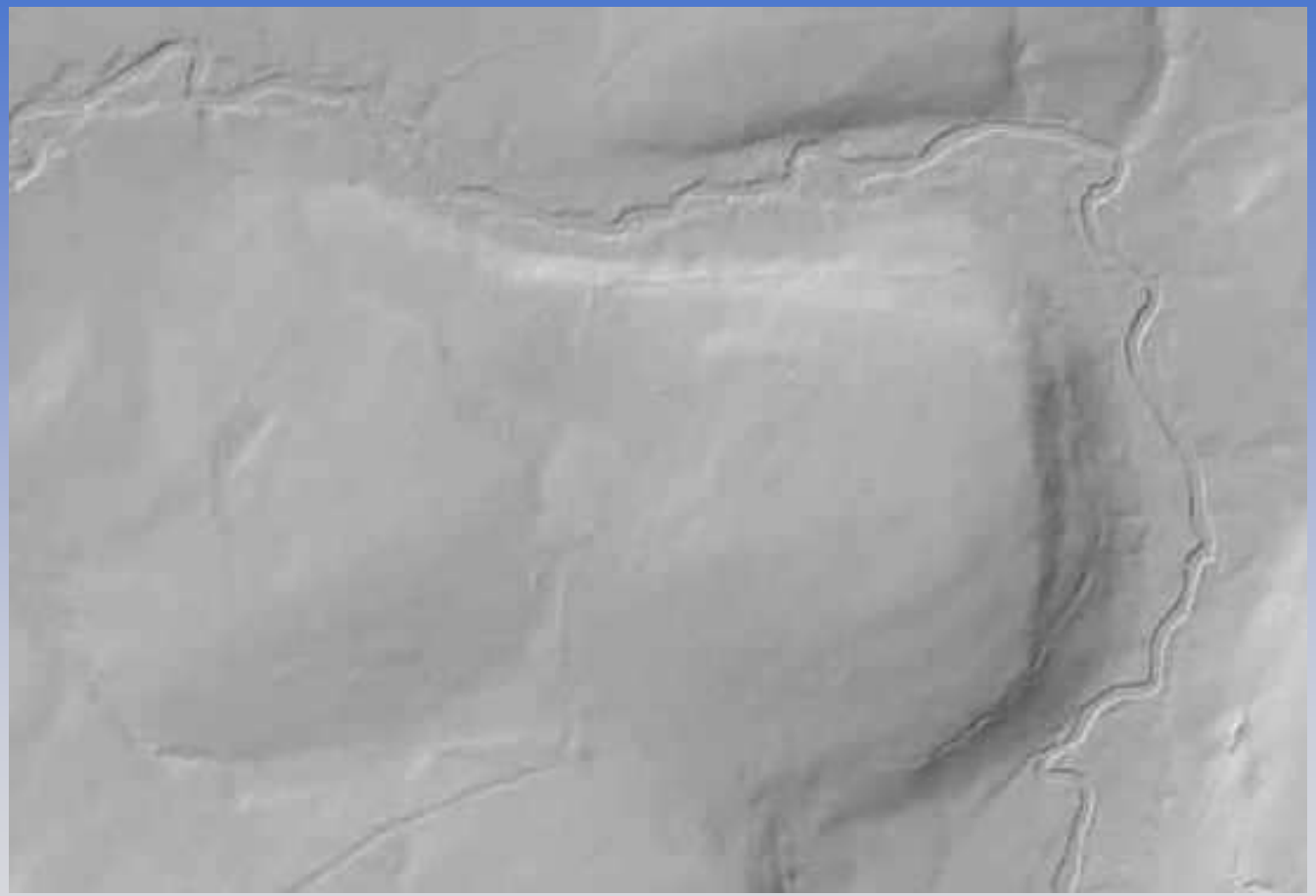
Light Detection And Ranging (LiDAR) Derived Elevation Models



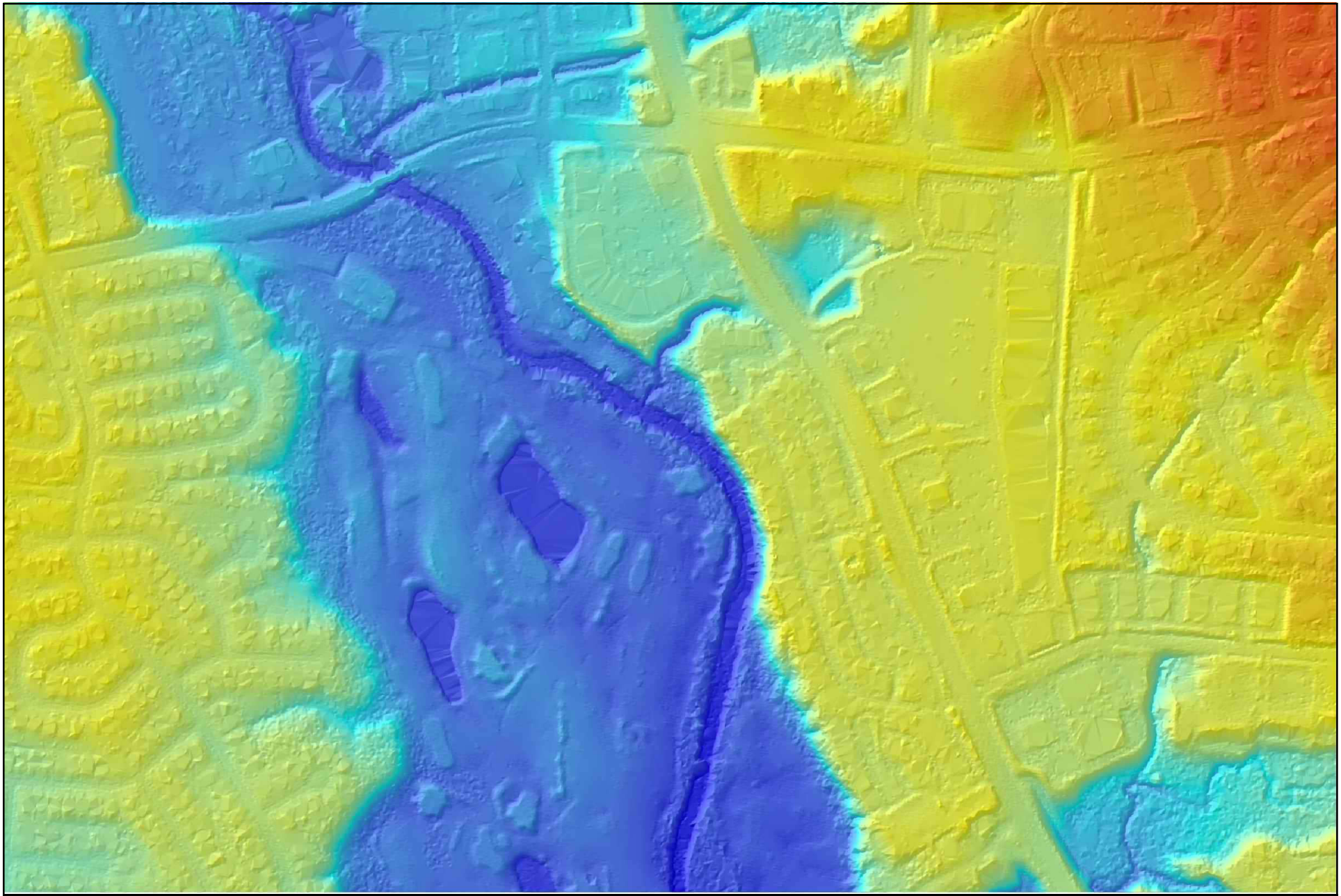


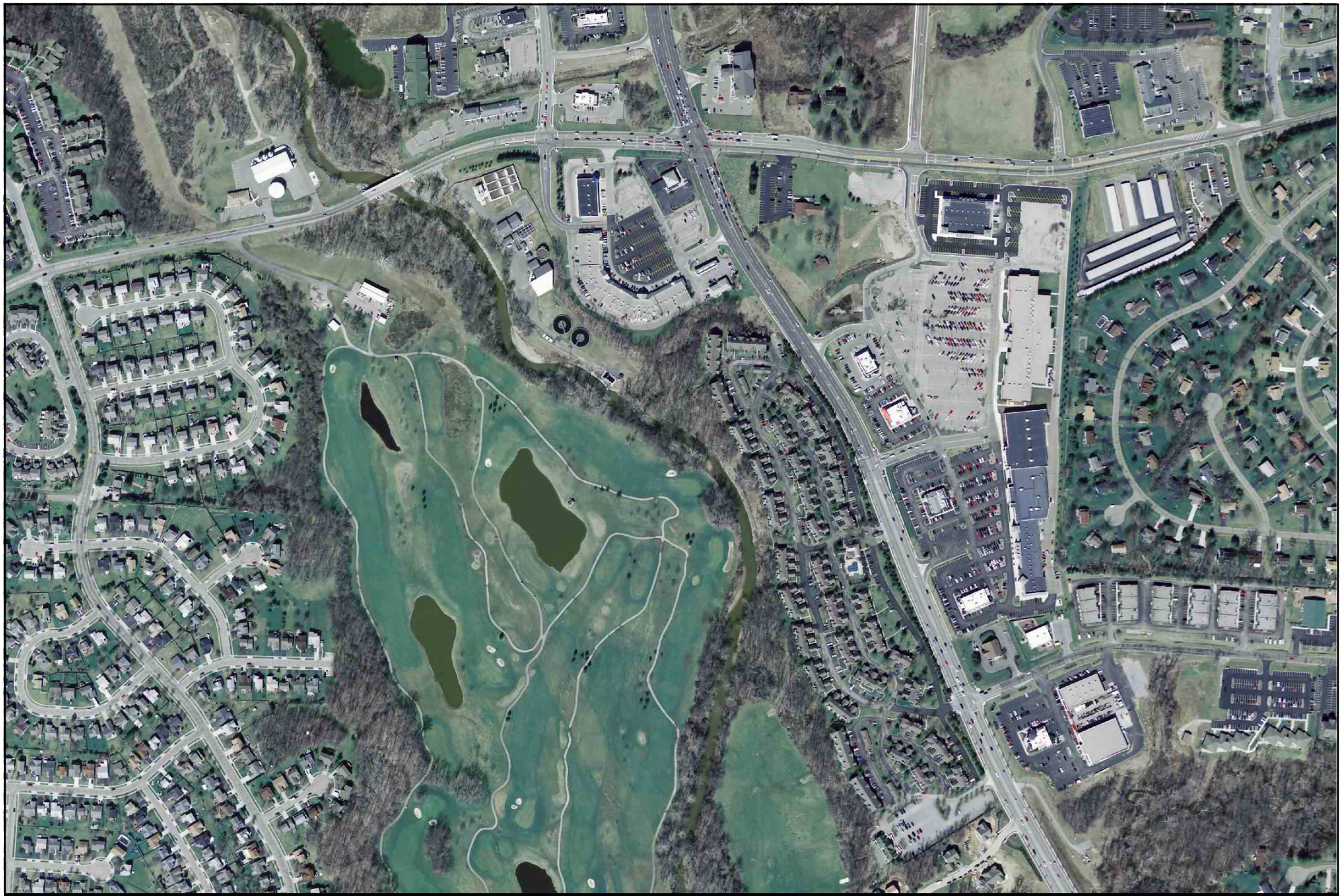


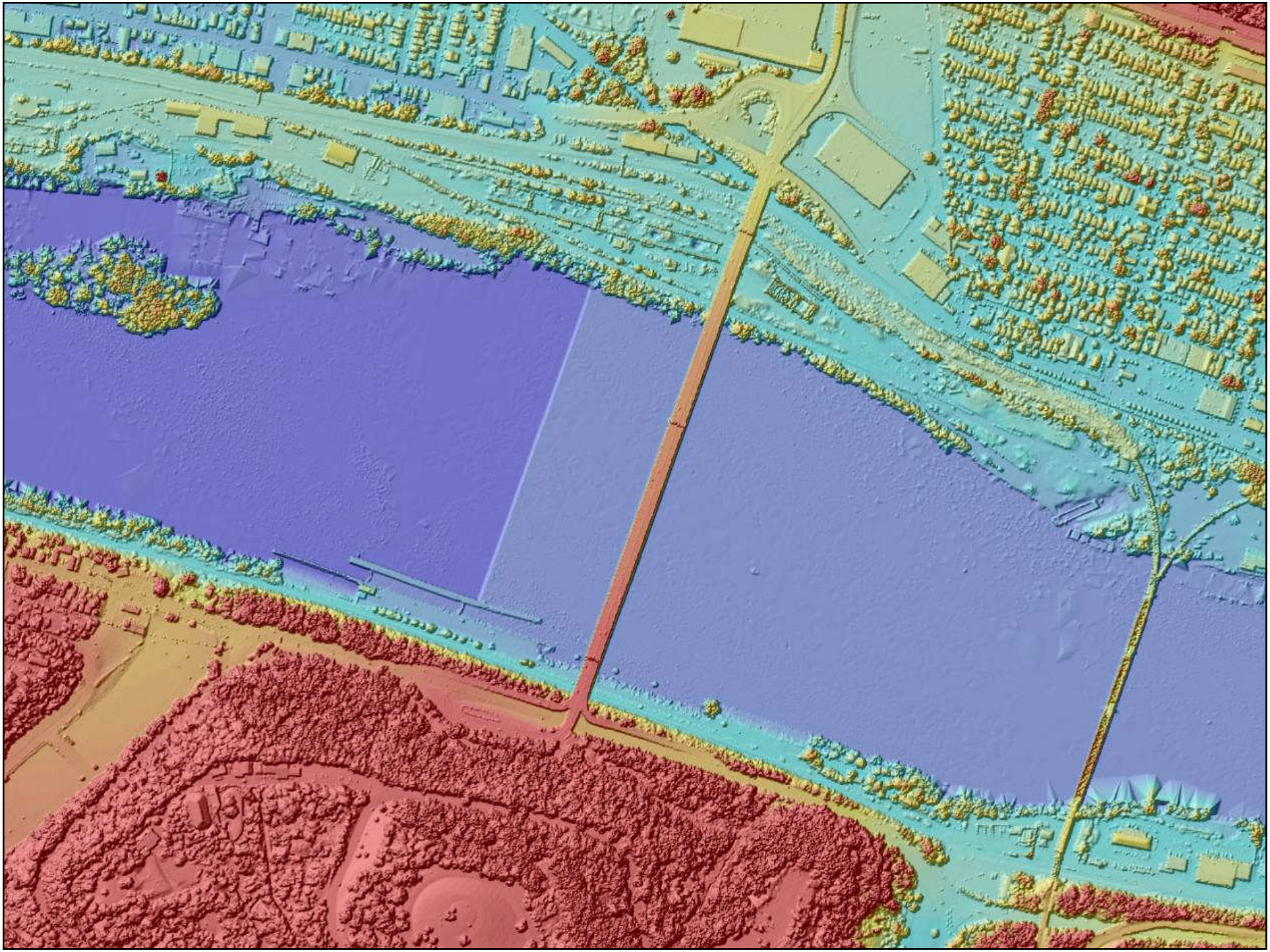
Shaded Relief of Bare-Earth Surface "Hillshade"



Sun azimuth: 315 degree from north
Sun angle: 20 degree







LiDAR for Predictive Flood Modeling

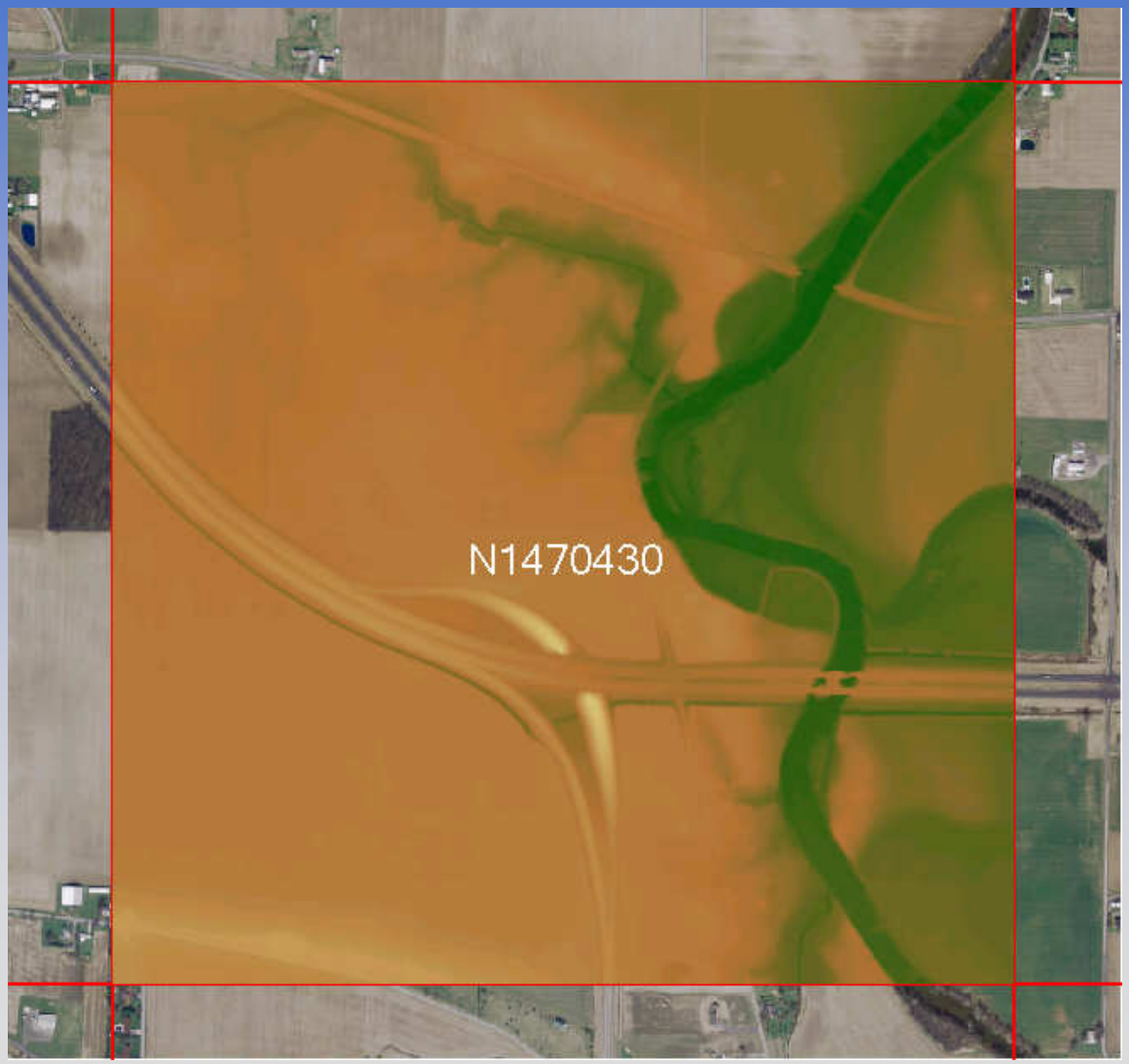
Bluffton, Ohio

During the Flood (August 21, 2007)

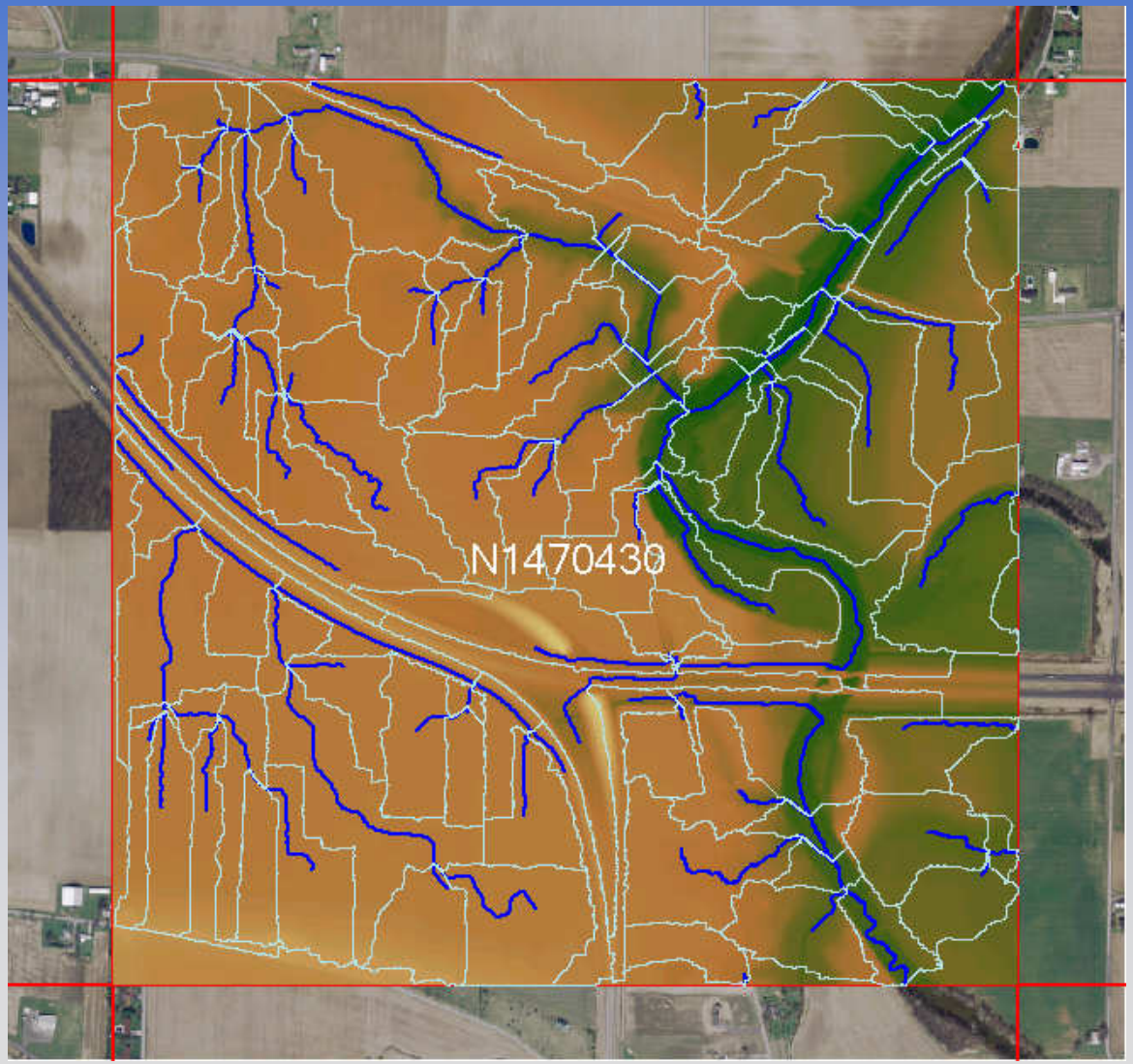
Images courtesy of the Allen County Engineer's Office

Watershed Analysis

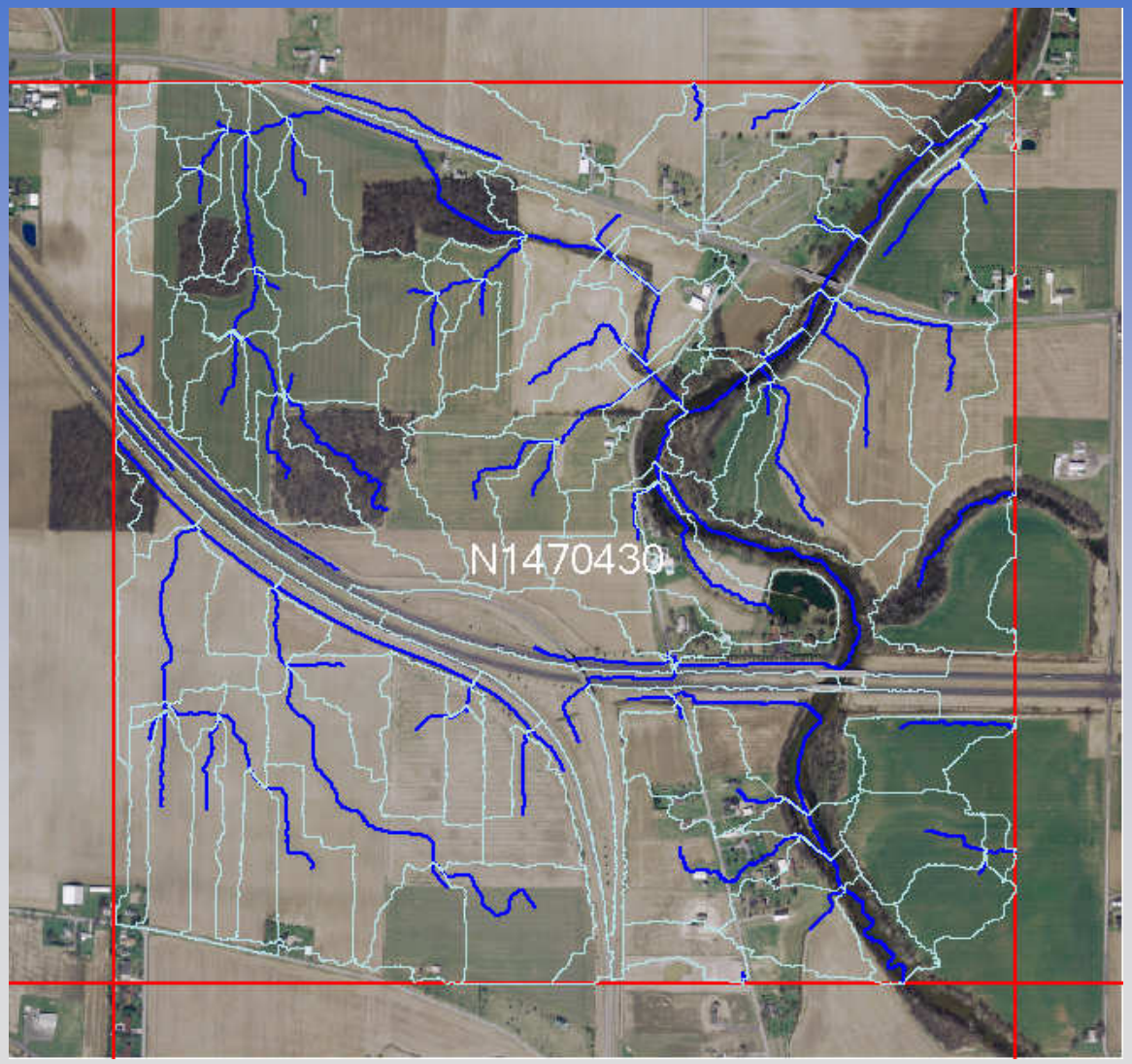
Watershed Analysis



Watershed Analysis



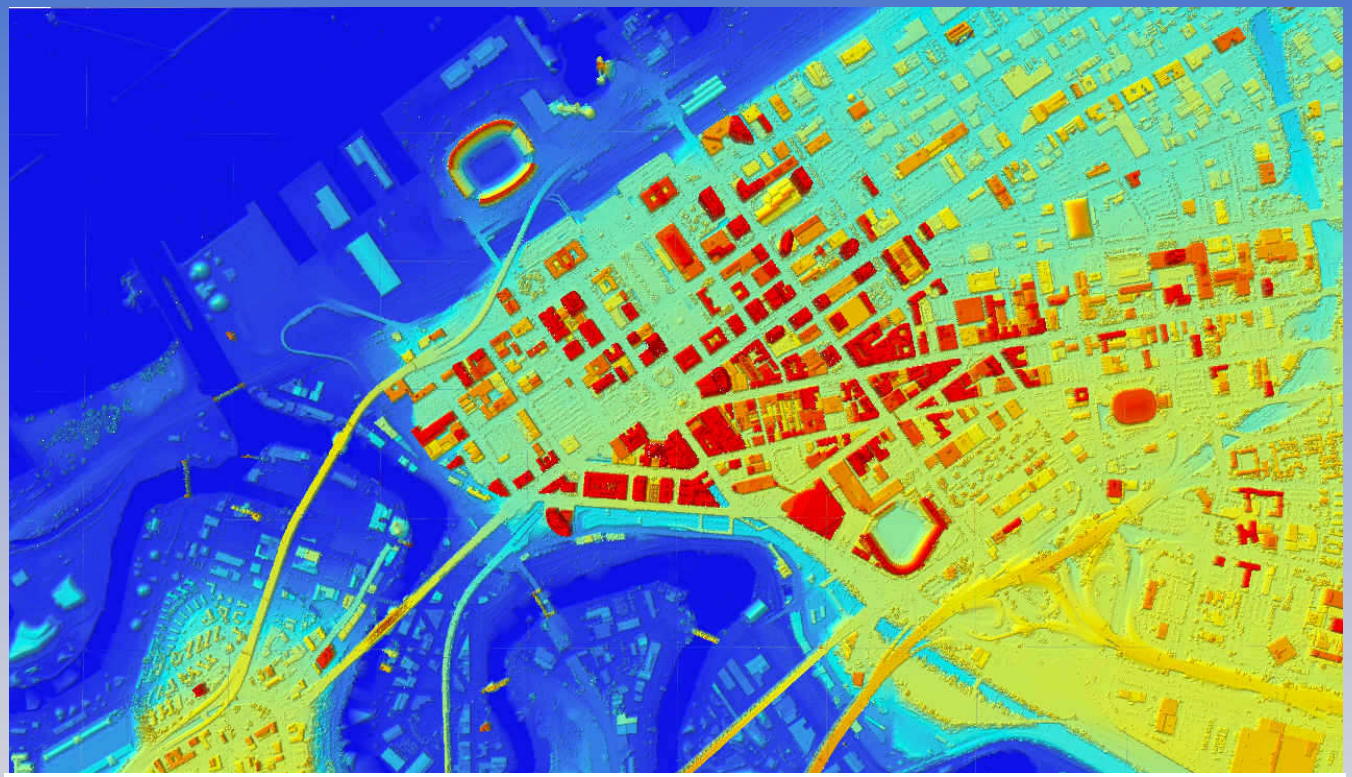
Watershed Analysis

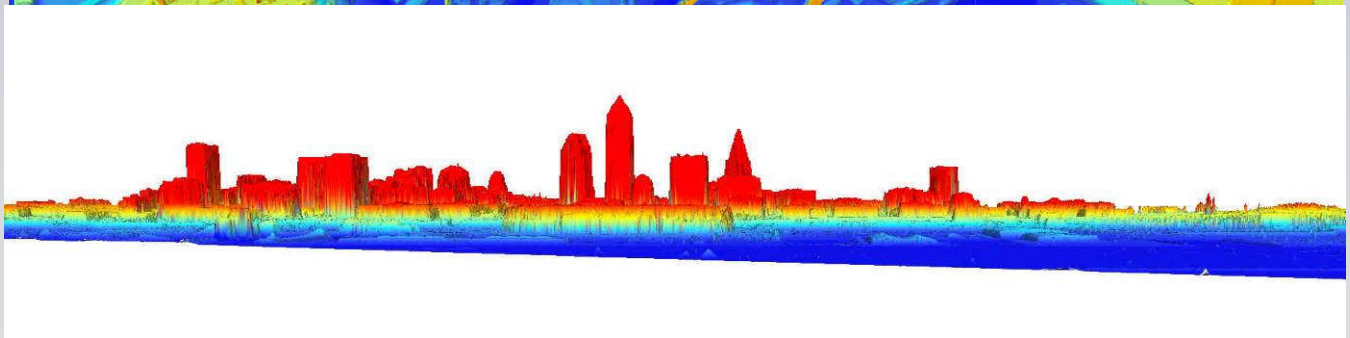


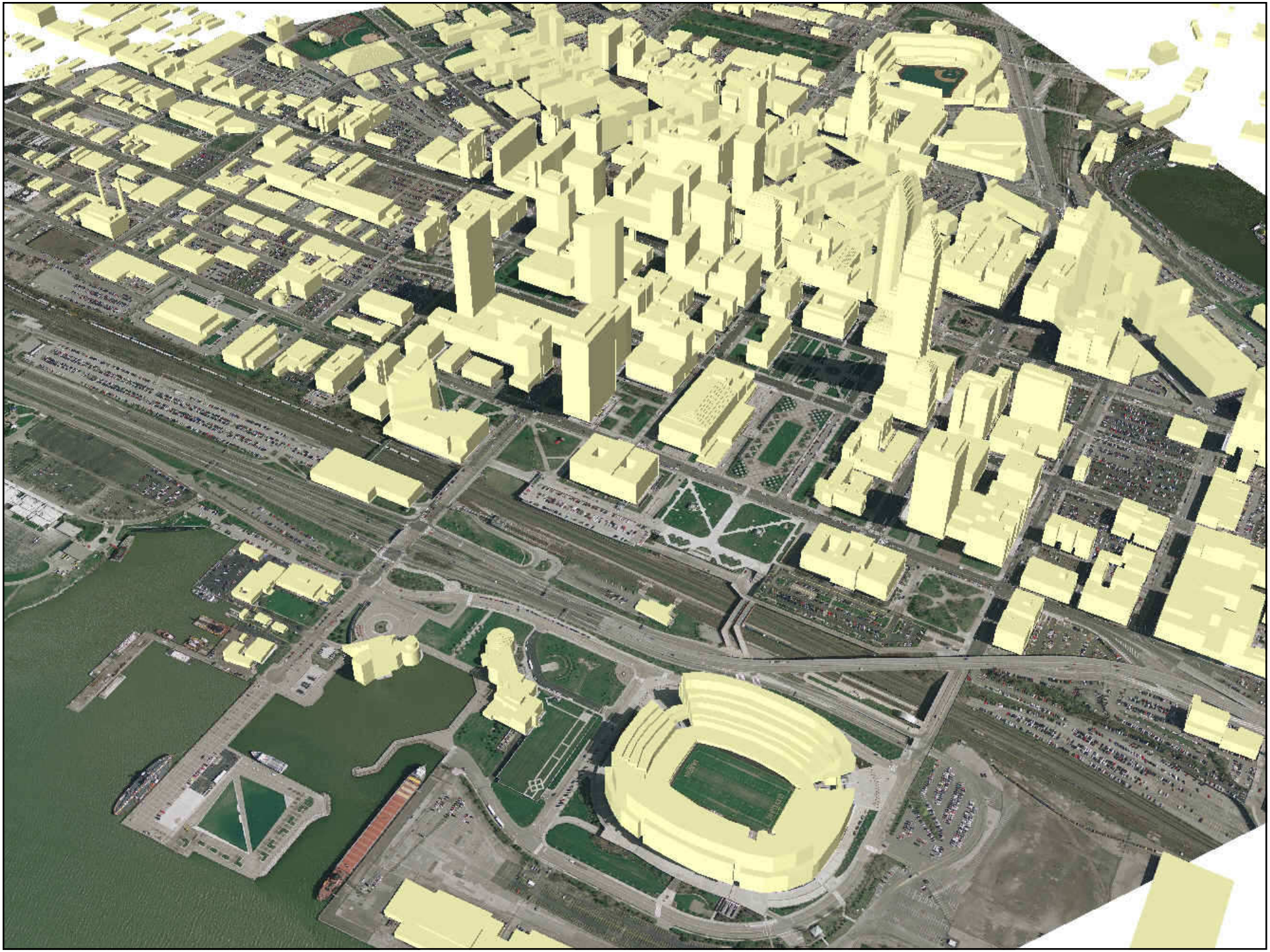
LiDAR Shaded Relief Model

City of Cleveland, Ohio

Blue shading = low elevations; Red shading = high elevations

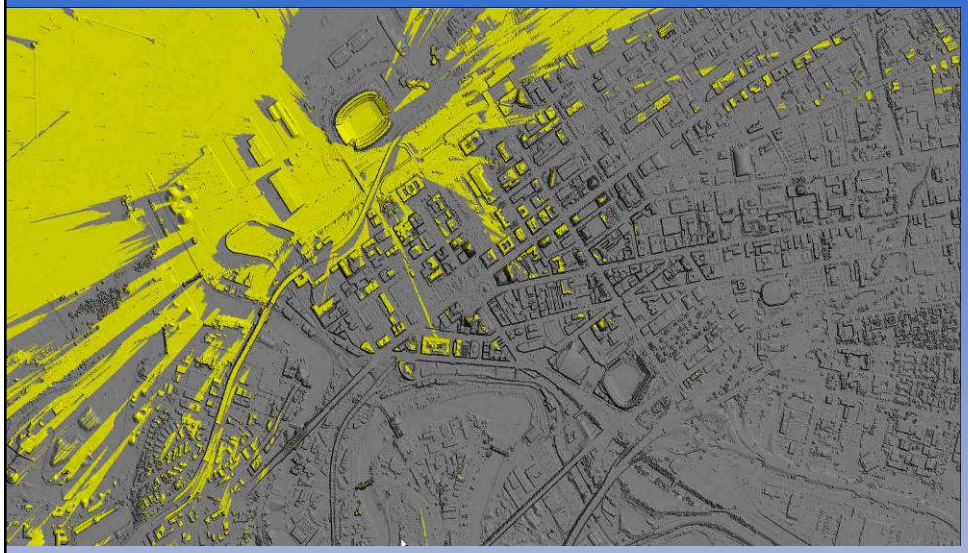


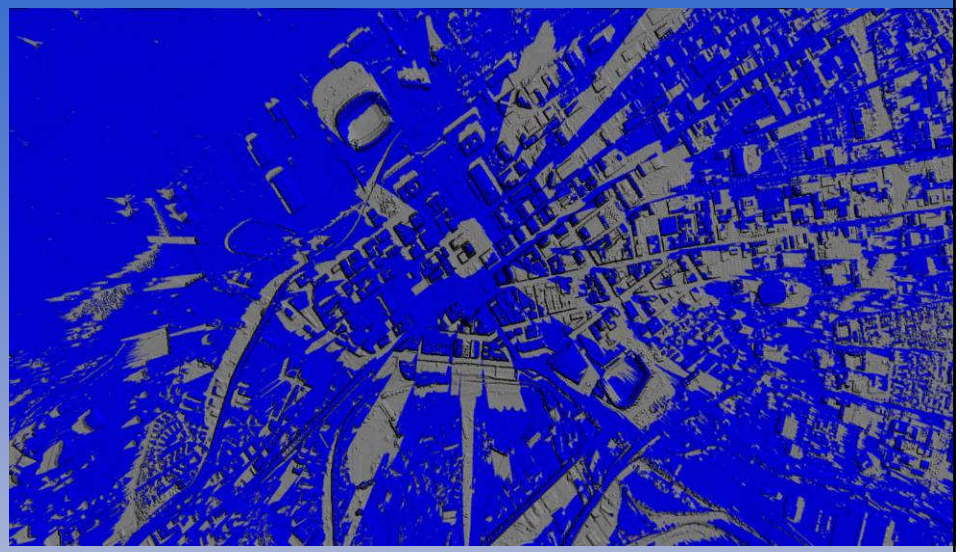




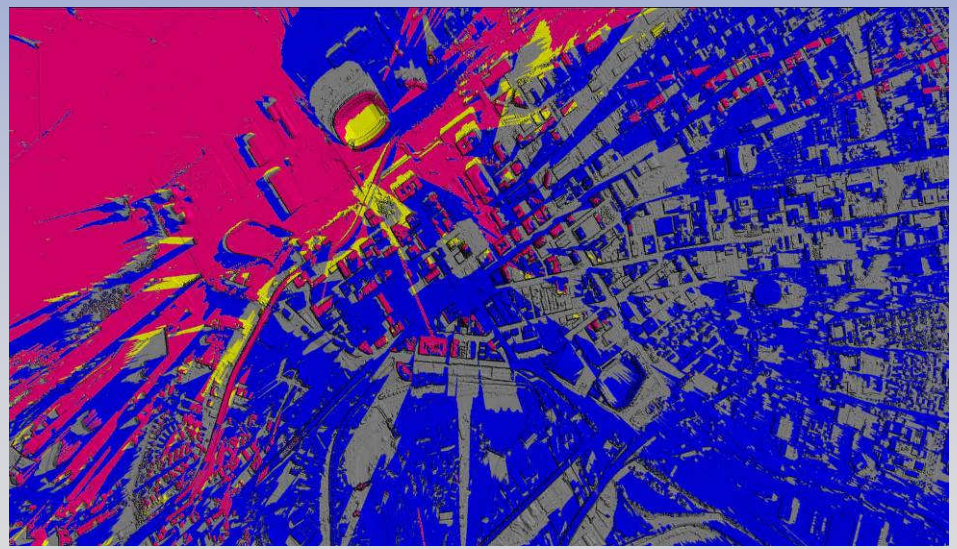
LiDAR for Predictive Line-of-Sight Modeling

Cleveland, Ohio





Yellow: visible from Brown's Stadium



Blue: visible from Key Bank Building

Pink: visible from Brown's Stadium and Key Bank Building

LiDAR for Archeological Identification/Discovery

Licking County, Ohio

Shaded Relief Color Coded Model

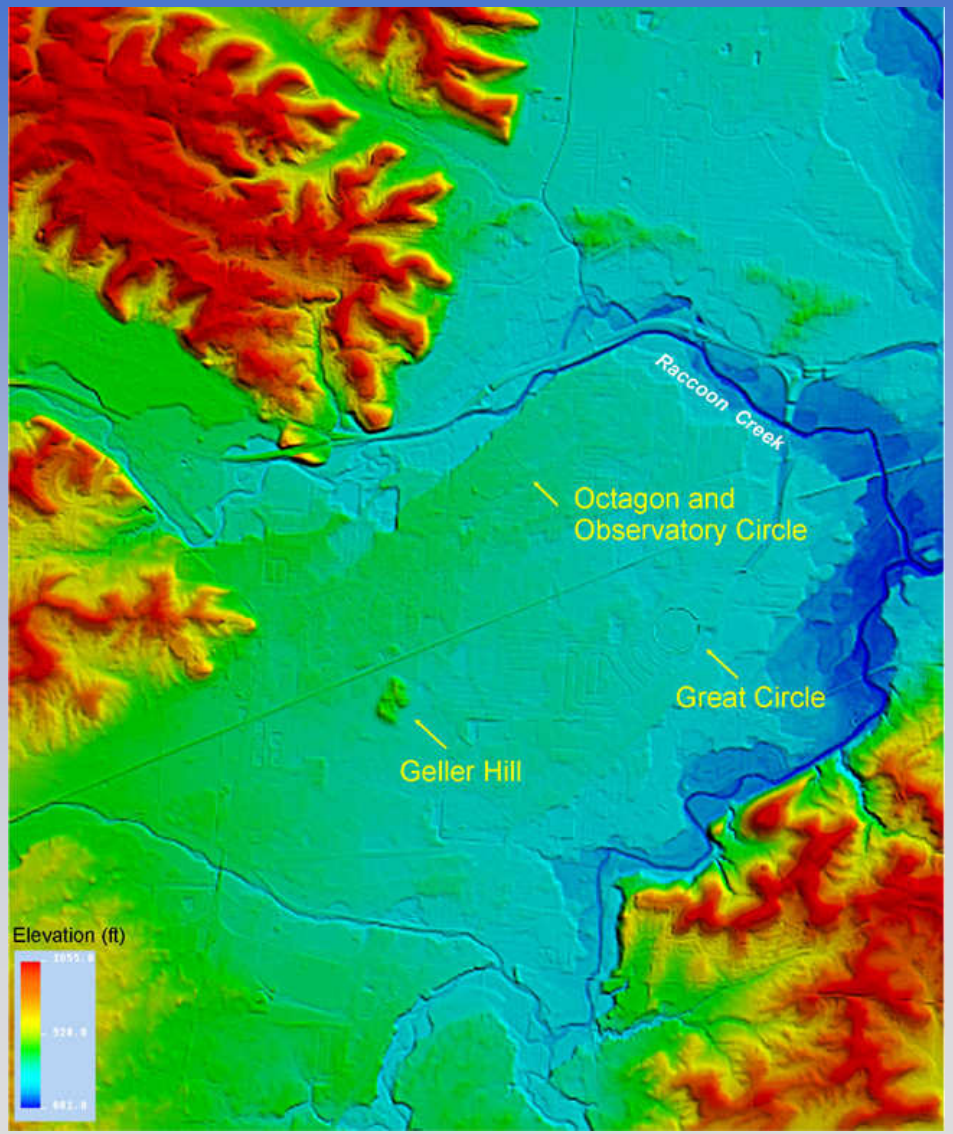


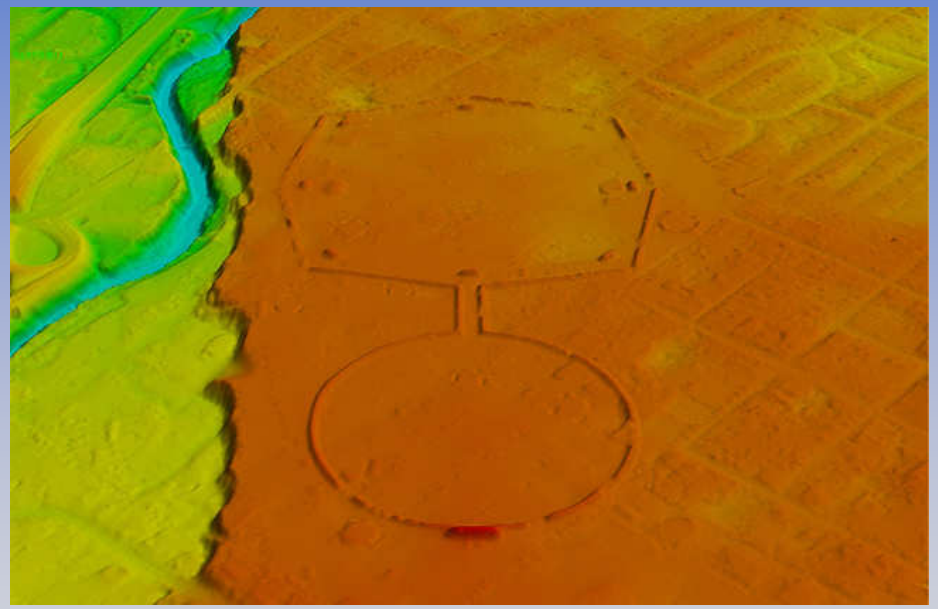
Image courtesy of the Ohio Archeological Council

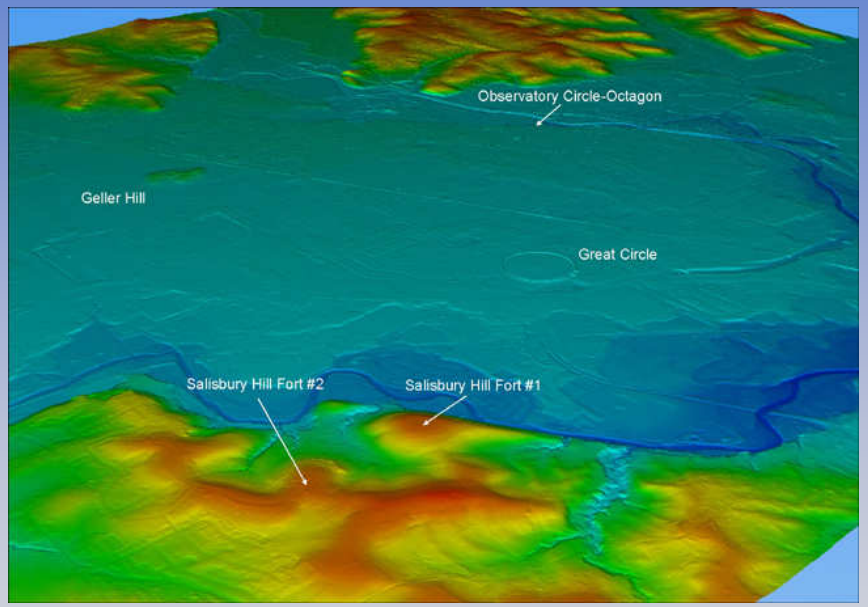
LiDAR for Archeological Identification/Discovery

Licking County, Ohio

Octagon and Observatory Circle Indian Mounds

Shaded Relief Color Coded Model

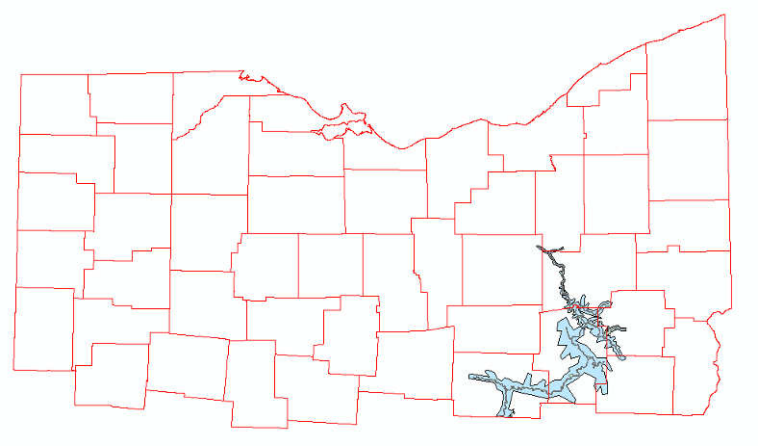


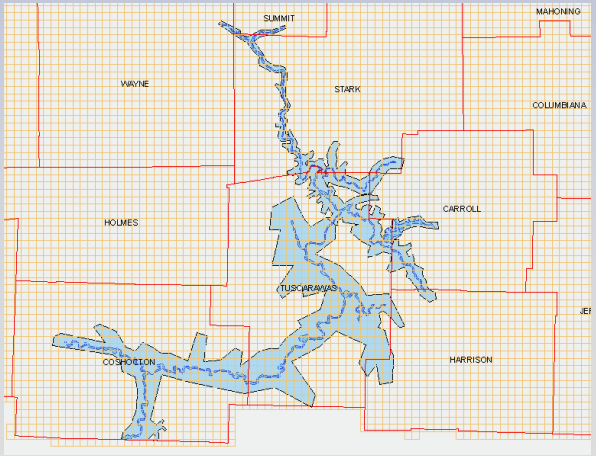


Images courtesy of the Ohio Archeological Council
http://ohioarchaeology.org/
Click on 'Current Research in 2008'
Click on 'LiDAR Analysis of Prehistoric Earthworks'

Tuscarawas and Muskingum Rivers

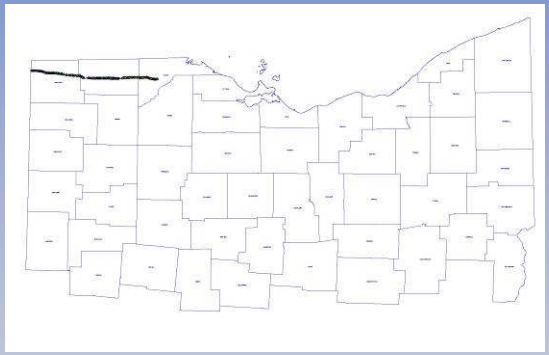
- Huntington COE
- Flood Control Projects – Bolivar Dam, Dover Dam, Mohawk Dam, Beach City Dam, and Zoar Levy
- H & H modeling - Dam failure, Down stream impact, emergency response/operations
- Environmental Study – Stream Bank Erosion
- Deliverables – DTM, Hydro, Bridges
- Cost: $65K ($150K) – Savings: ~$85K
- Schedule: 3 months (9 months) – Savings: 6 months





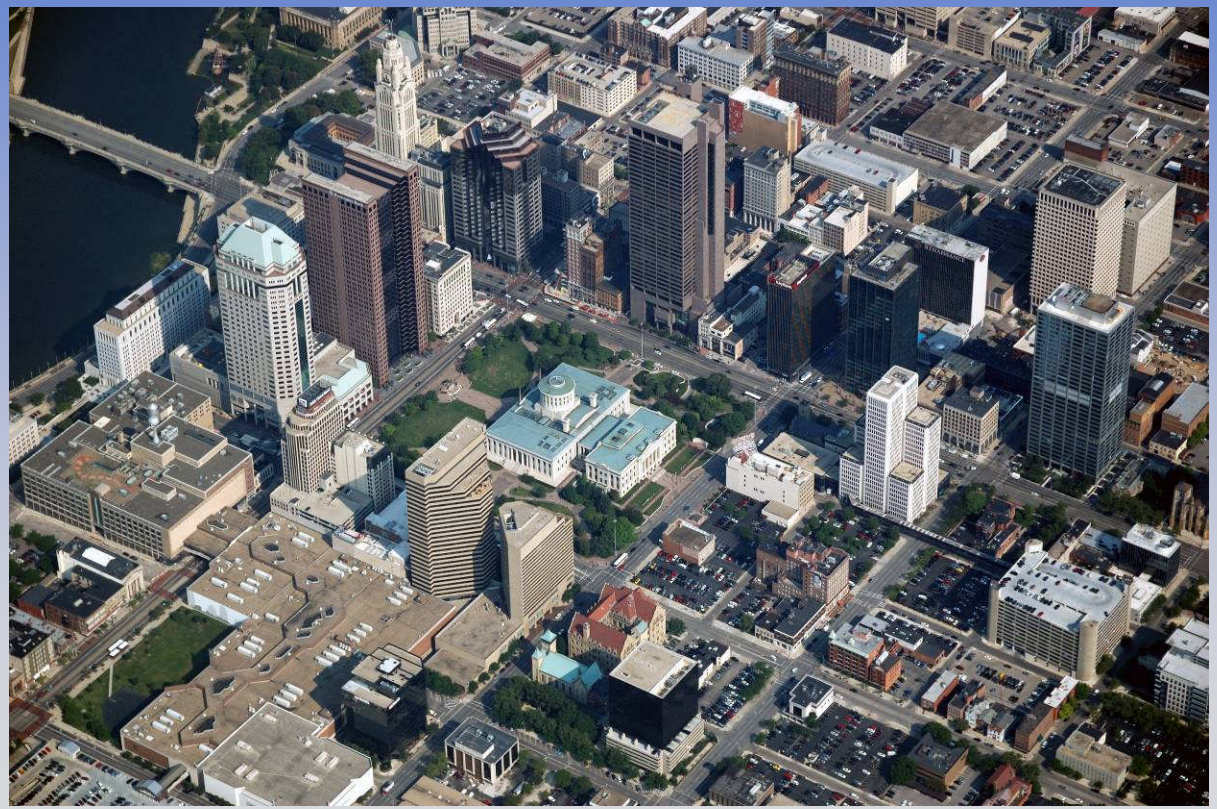
GIS Application and Return-on-Investment

- Ohio Turnpike – utilizing the homogenous Statewide dataset to create a seamless GIS data program



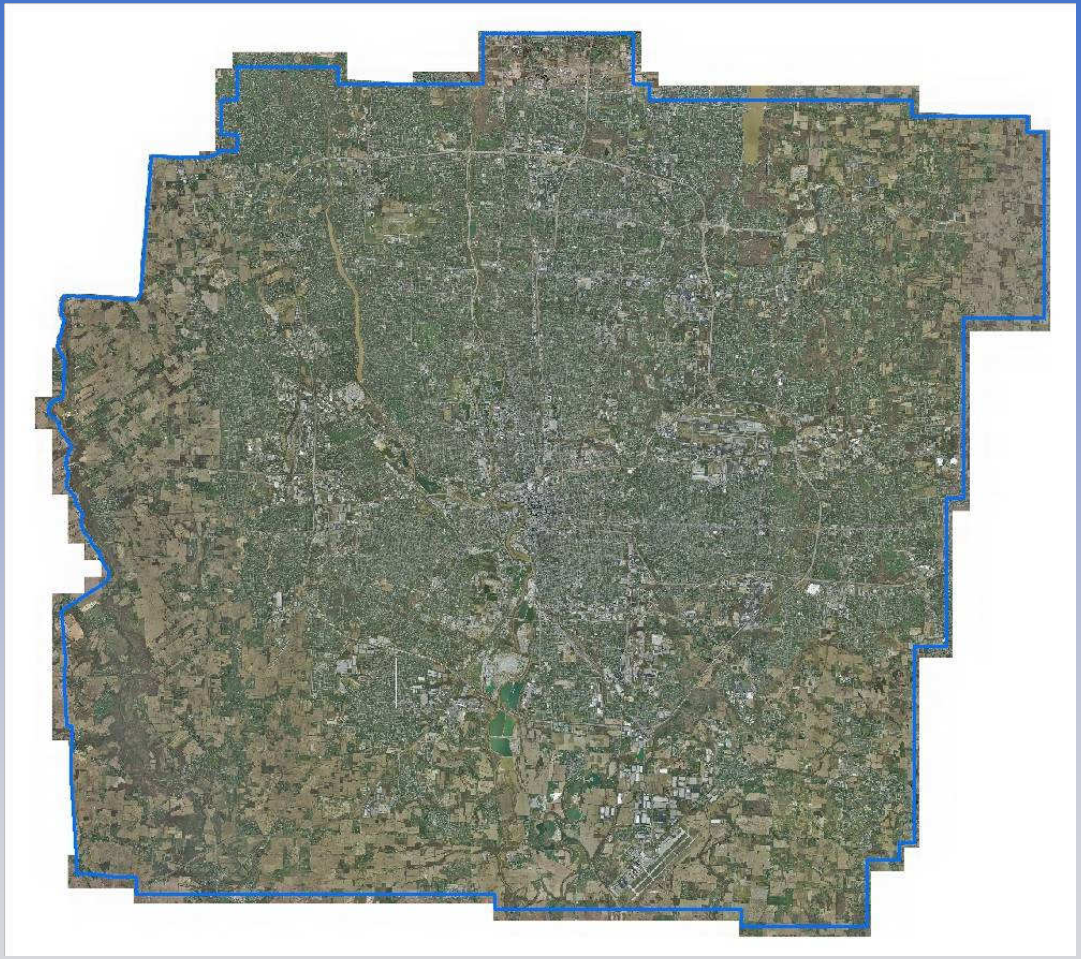
- Benefit to the Turnpike/State of Ohio: Shortened Timeframe and Cost Savings
- Estimated cost savings with the State Program: ~45%
- Estimated time savings, 8-10 months

Fusing LiDAR and Ortho-Imagery to Determine Impervious Surfaces



City of Columbus

Service Area



- Service Area: ~600 Square Miles in Size
- Covers the entire land area of Franklin County, plus portions of Delaware, Fairfield, Licking and Union Counties

Columbus Impervious Surface Program

Columbus, Ohio

Process – Semi-Automated Feature Extraction

- Remote Sensing Techniques and Software
  - Utilize Ortho-Imagery
    - Color Ortho-Imagery (0.5-foot pixel resolution)
    - Color Infra-red Ortho-Imagery (0.5-foot pixel resolution)
  - Utilize LiDAR Elevation & Intensity

Color Ortho Analysis

Color Infra-red Ortho Analysis

Leica ADS40-II
12-bit Images (4096 unique values)

Spectral bands

- **Panchromatic 465–680nm**
- **Blue 428–492nm**
- **Green 533–587nm**
- **Red 608–662nm**
- **Near-infrared 833–887nm**

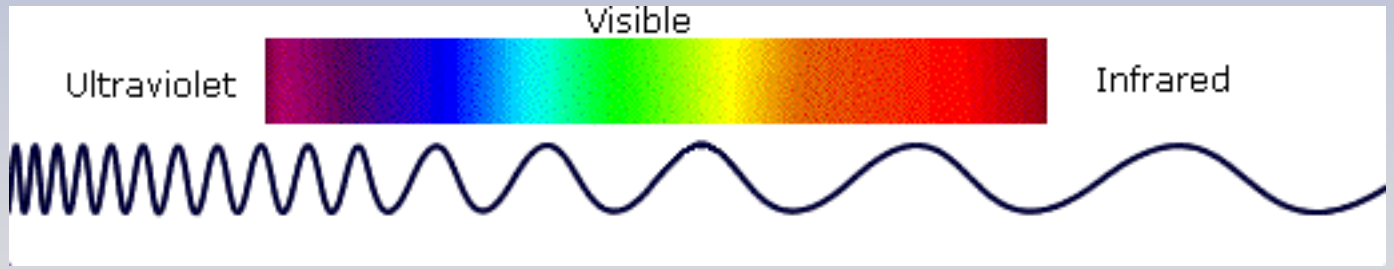
Color Ortho Analysis

Color Infra-red Ortho Analysis

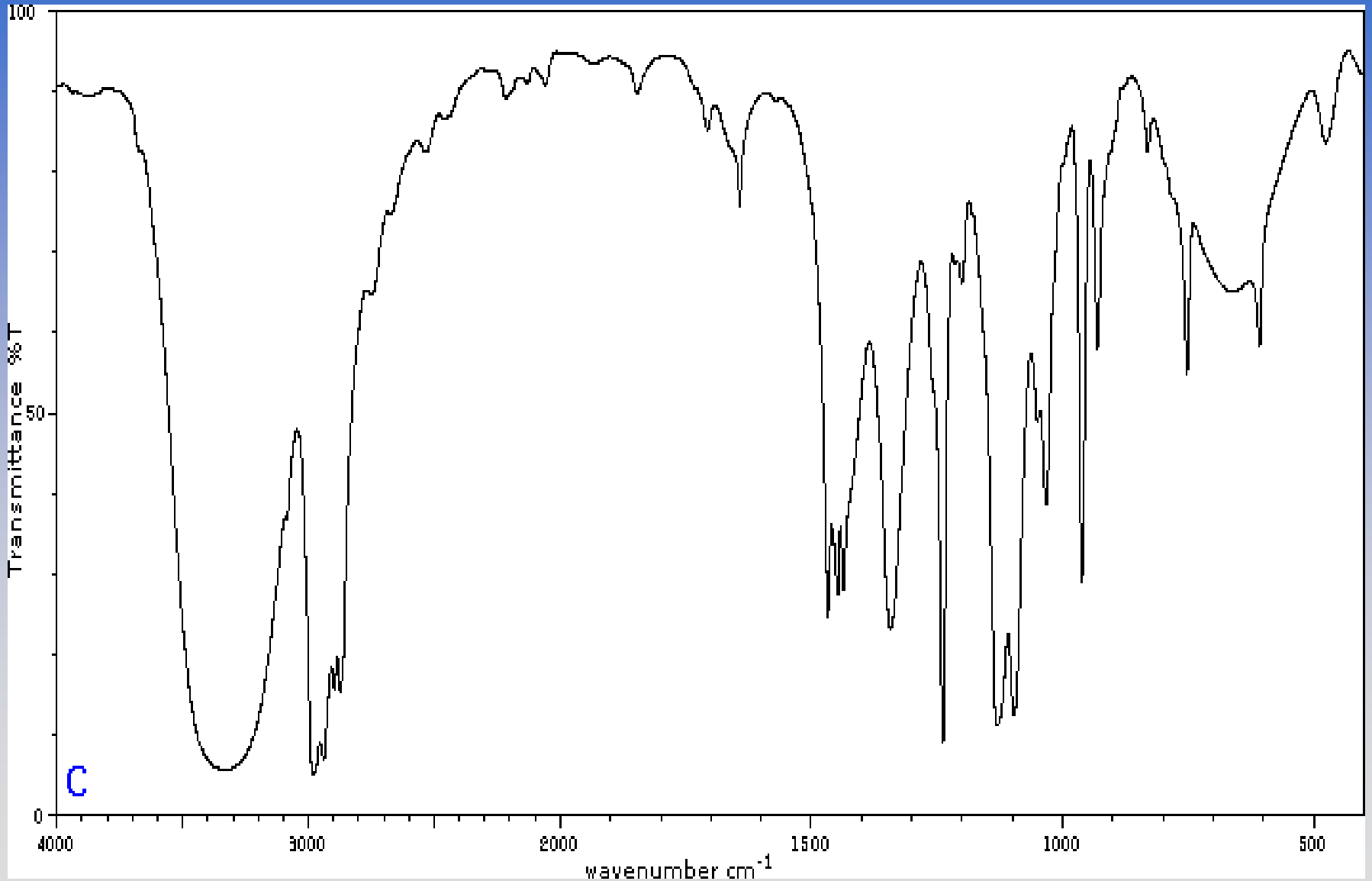
Leica ALS50
8-bit (Intensity)

Spectral bands

- **Near-infrared 1064 nm**



Spectral Signature



Columbus Impervious Surface Program

Columbus, Ohio

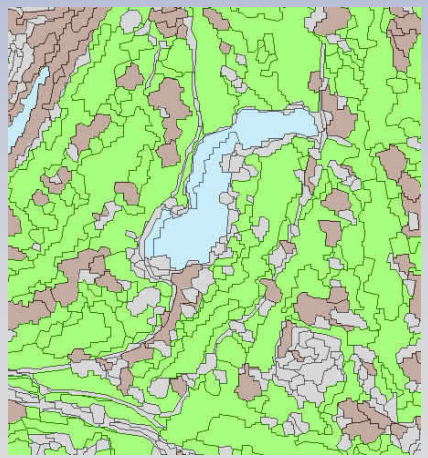
Existing Impervious Data:

- Comprised of photogrammetrically derived line-work
- Updated using heads-up digitizing on ortho-photography
- Files provided in AutoCAD Format

Columbus Impervious Surface Program

Columbus, Ohio

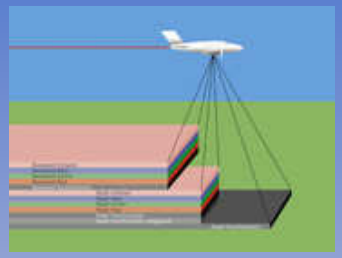
Process – Semi-Automated Feature Extraction



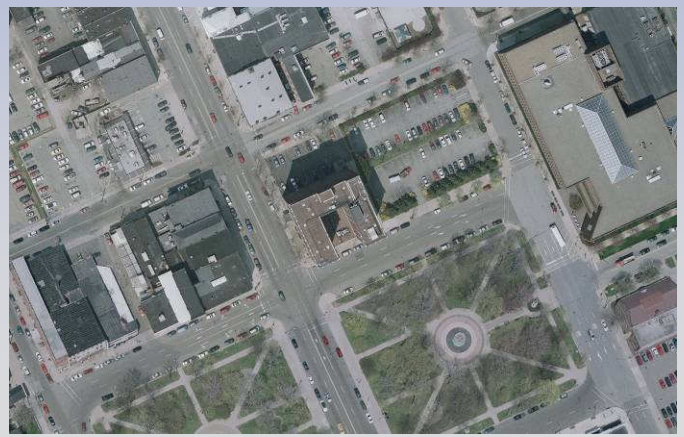
Columbus Impervious Surface Program

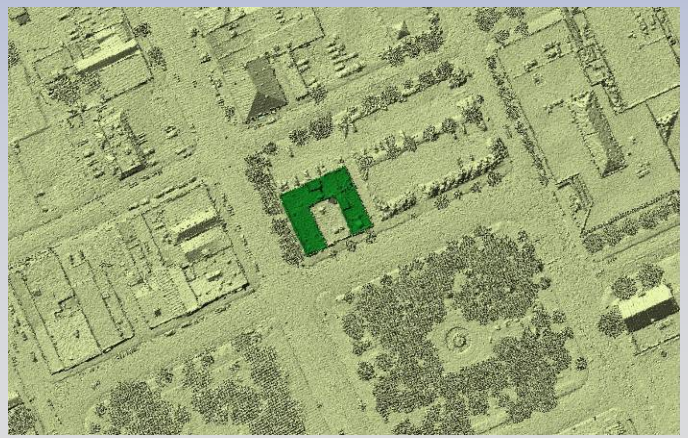
Columbus, Ohio

Why implement the semi-automated impervious surface program?



- Provides a higher accuracy
  - Delineates and identifies smaller areas more accurately
  - Large reduction in potential human error
  - Offers a more consistent and fair approach
- Provides a more cost effective approach
  - Traditional heads-up digitizing = substantially higher cost
  - Provides opportunity to perform delineation on a yearly basis
- Provides a shorter completion timeframe
  - Traditional heads-up digitizing = much longer timeframe
  - Provides opportunity to perform delineation on a yearly basis



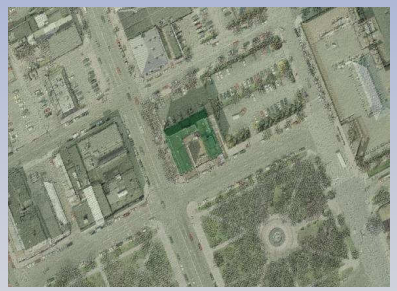


Columbus Impervious Surface Program

Columbus, Ohio

How is the automated impervious surface delineation implemented?

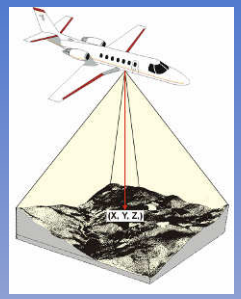
- Utilize digital orthophotography dataset
  - Color 1”=100’ scale orthos with 0.5-foot pixel resolution
  - Color 1”=100’ scale infra-red orthos with 0.5-foot pixel resolution
- Utilize Existing OSIP LiDAR dataset
  - 2-meter point density over the entire service area
  - Elevation model, intensity imagery, patterning
- Utilize existing parcel dataset
  - Use existing parcel datasets in the service area to identify commercial properties
- Utilize existing impervious surface areas as quality assurance
  - Investment from previous datasets is not lost
- Utilize ESRI software to incorporate datasets
  - Using all datasets above provides the impervious delineation
  - Impervious surfaces are compatible with the City’s existing software



Columbus Impervious Surface Program

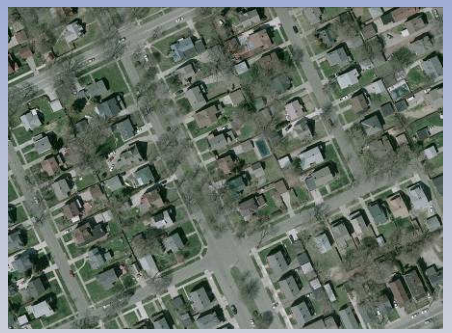
Columbus, Ohio

Process – Semi-Automated Feature Extraction

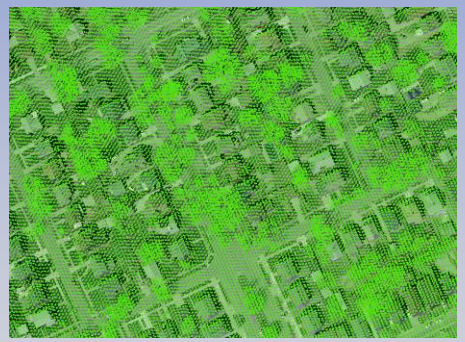


- Remote Sensing Techniques and Software
  - Utilize LiDAR – OSIP 2-meter Data
    - Elevation Data
    - Intensity Data

Existing Pan/Color/IR Imagery



LiDAR Point Cloud



LiDAR Intensity

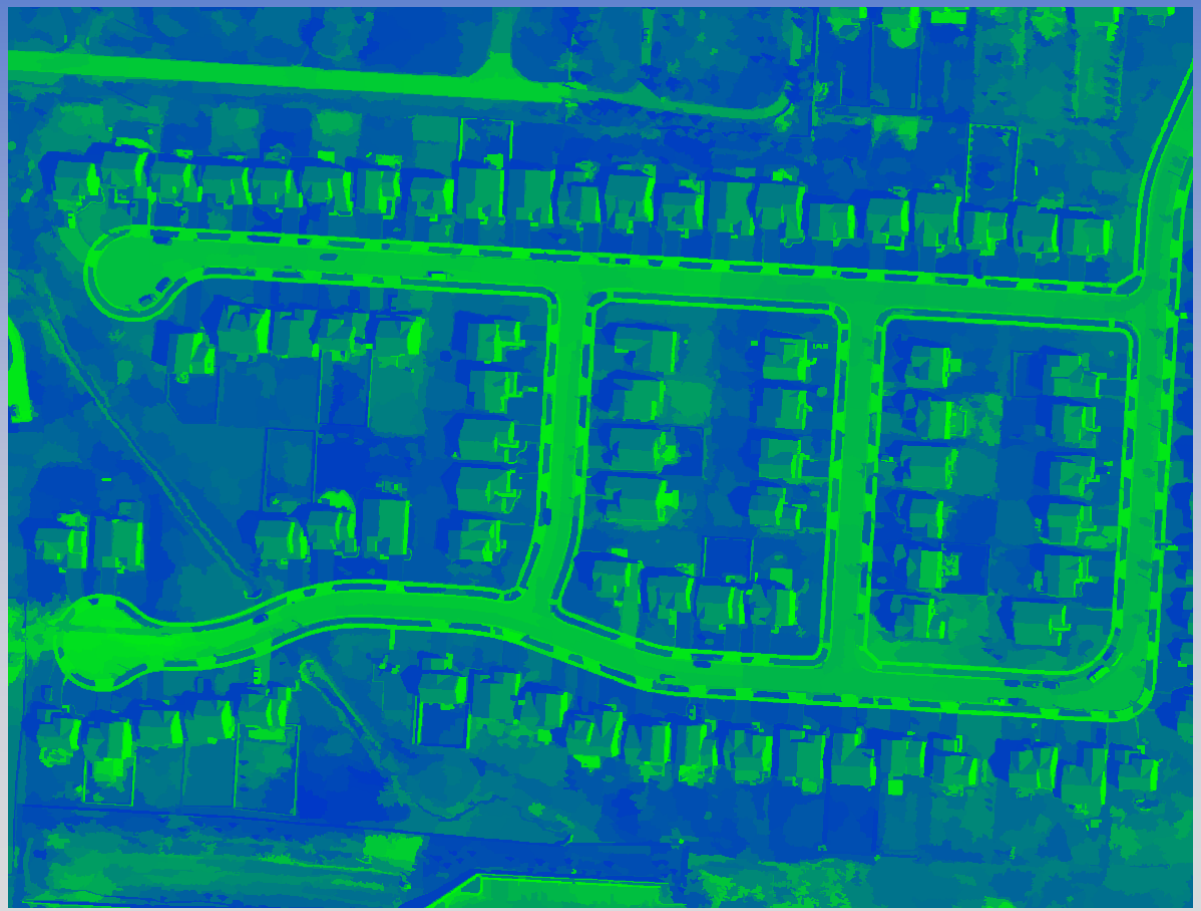
LiDAR allows for the delineation of impervious surfaces obscured by foliage (tree canopy), areas of shadow (around buildings) and buildings/structures (elevation and intensity).

Columbus Impervious Surface Program

Implement Automated Impervious Area Process

Impervious Surface Process

Definians* eCognition *software

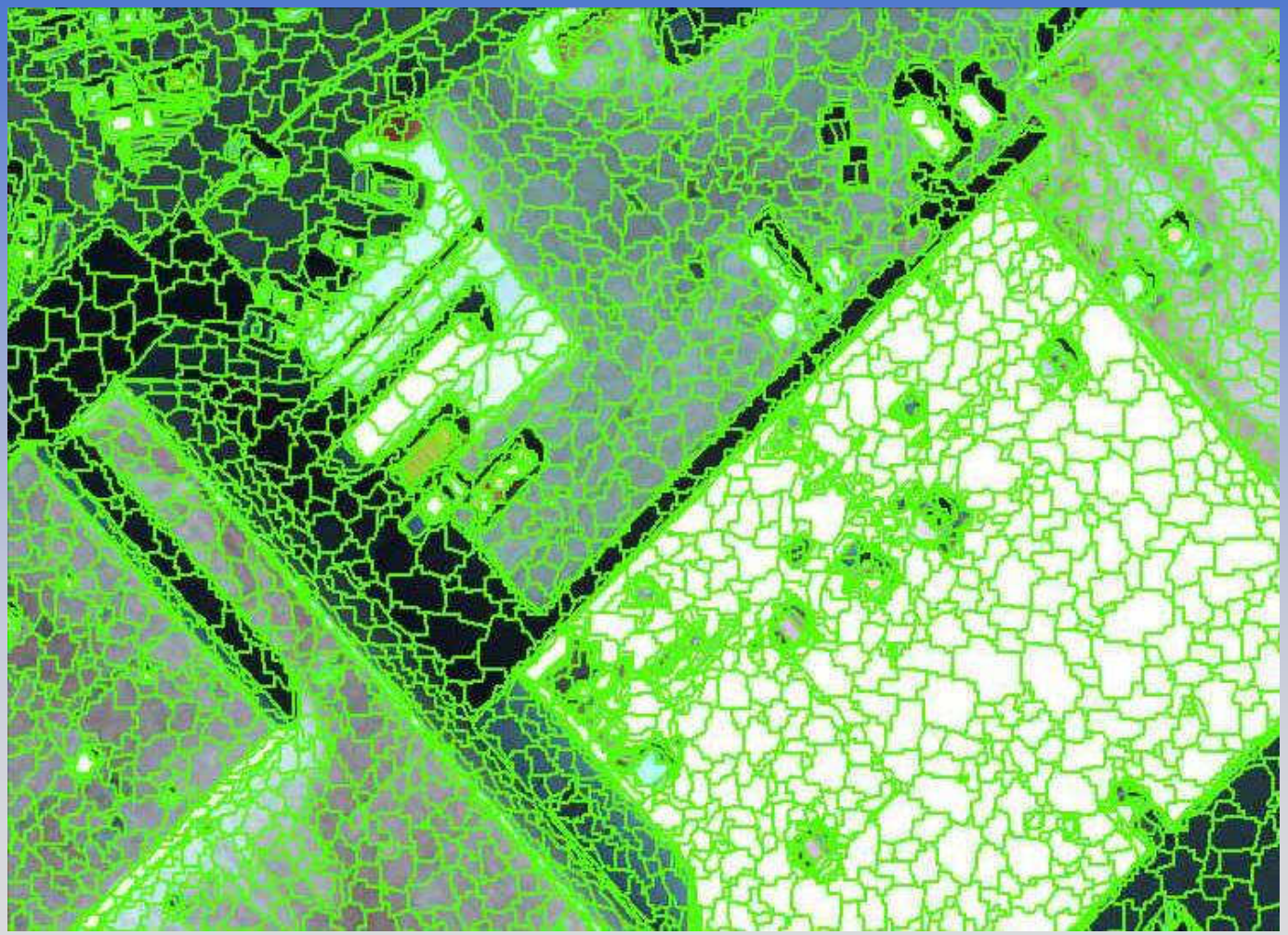


1) **Combine Ortho and LiDAR**
2) **Perform Segmentation**
3) **Perform Analysis**

Columbus Impervious Surface Program

Eastland Mall

Natural Color Orthophoto Overlaid with Polygon Segmentation
Based upon groupings of pixel values

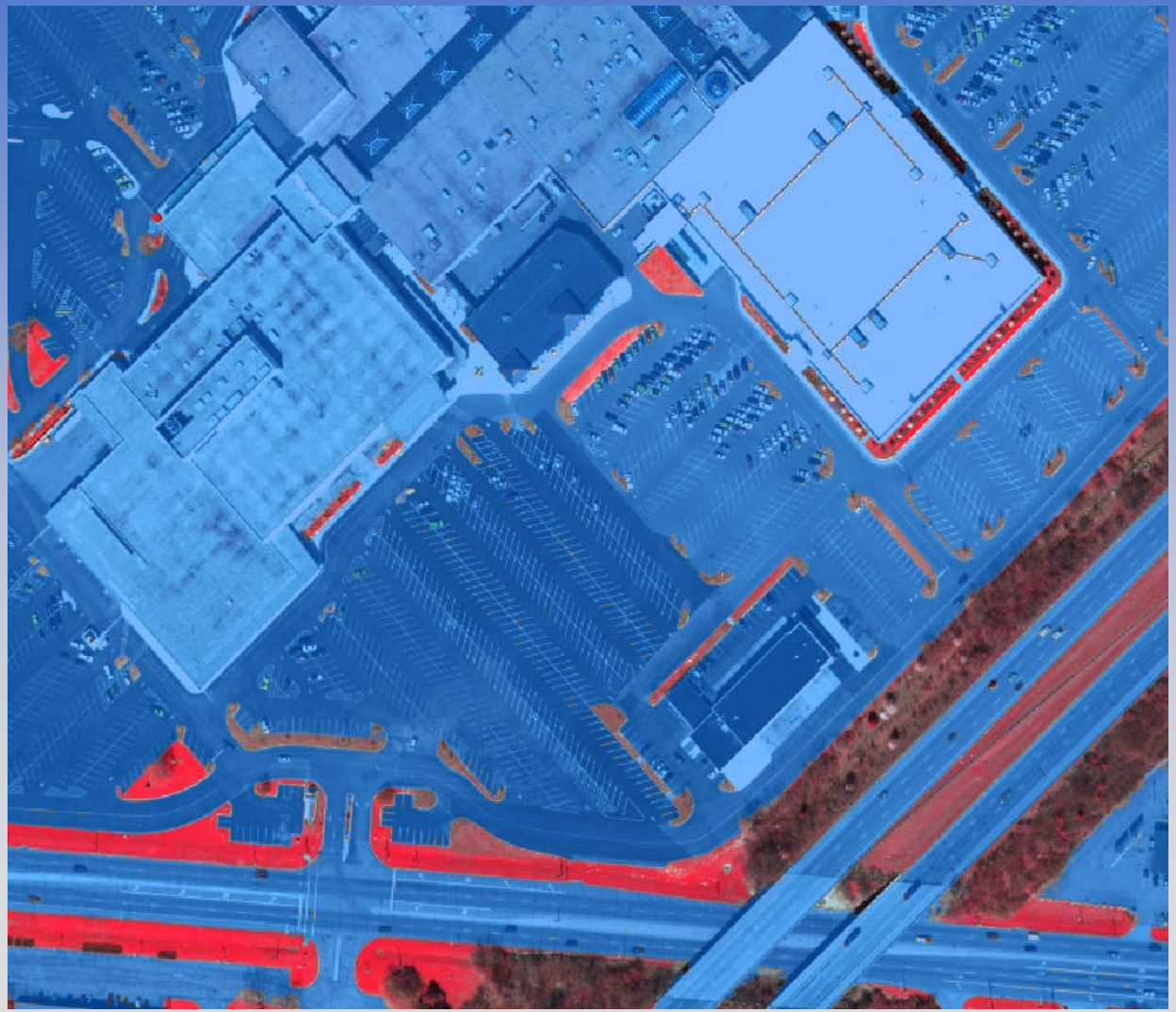


Columbus Impervious Surface Program

Eastland Mall

Color Infra-red Orthophoto Overlaid with Automated Impervious Surface (Blue Hue)

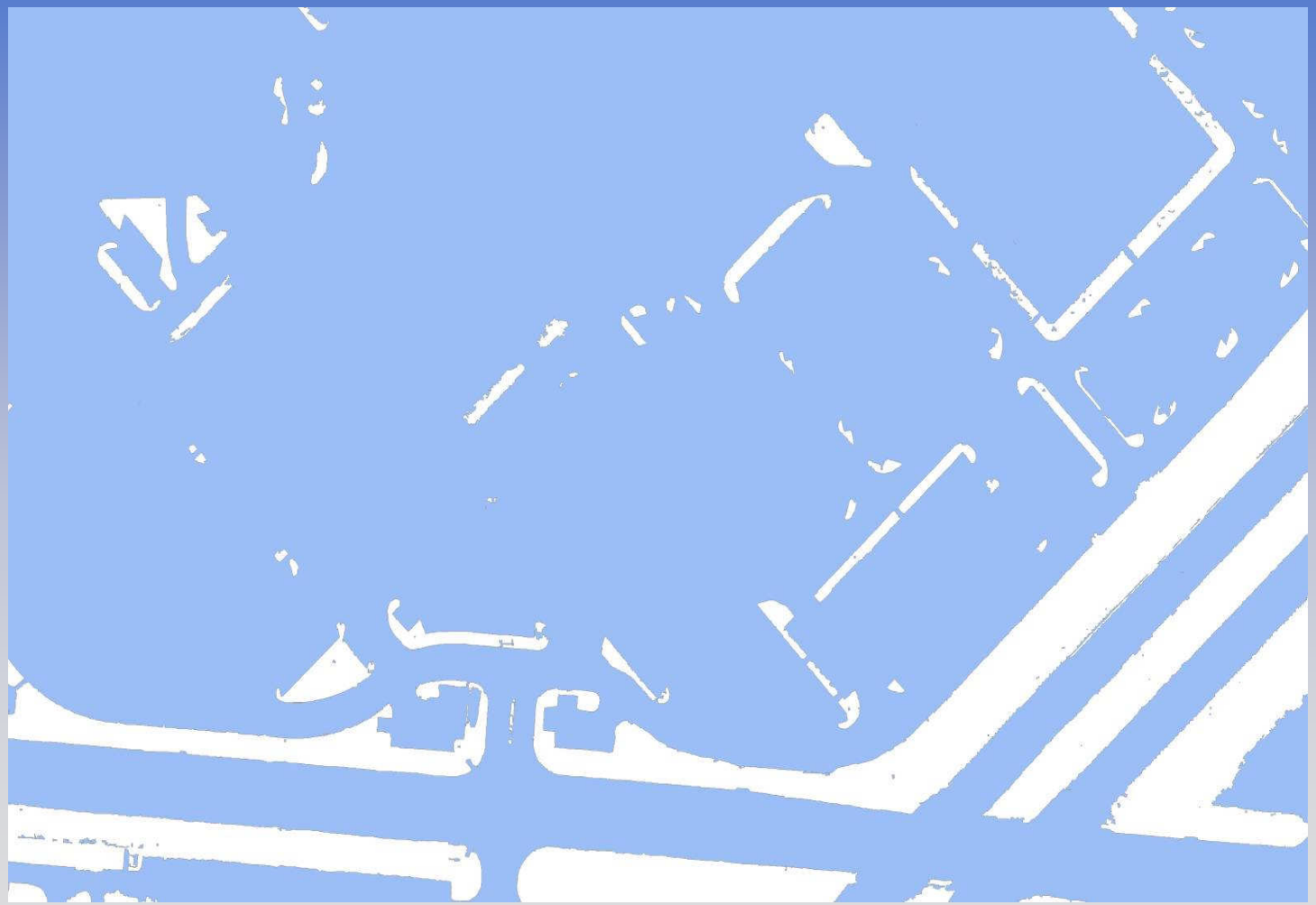
Zoomed-In View



Columbus Impervious Surface Program

Eastland Mall

Automated Impervious Surface Delineation - Polygon
Impervious Shapefile



Columbus Impervious Surface Program

Lessons Learned

Lessons Learned

- **Shadows are a potential issue**
- **Can be refined using denser LiDAR**

Columbus Impervious Surface Program

Lessons Learned

Lessons Learned

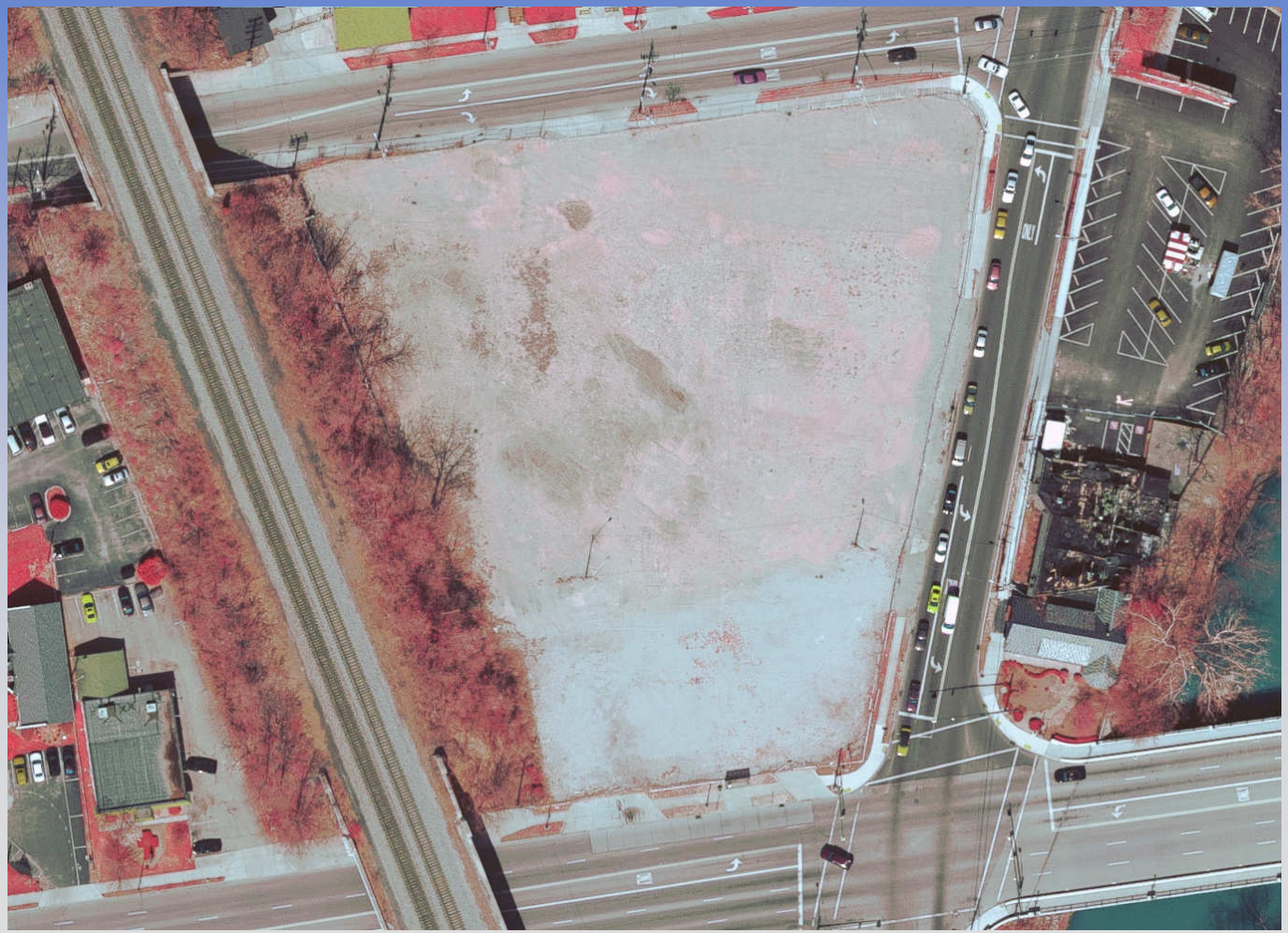
- **Vegetation (trees) covering impervious areas are a potential issue**
- **Can be refined using denser LiDAR**

Columbus Impervious Surface Program

Lessons Learned

Lessons Learned

- **Some surface areas identified as impervious, may not be impervious (i.e. compacted soil/stone, exposed clays).**

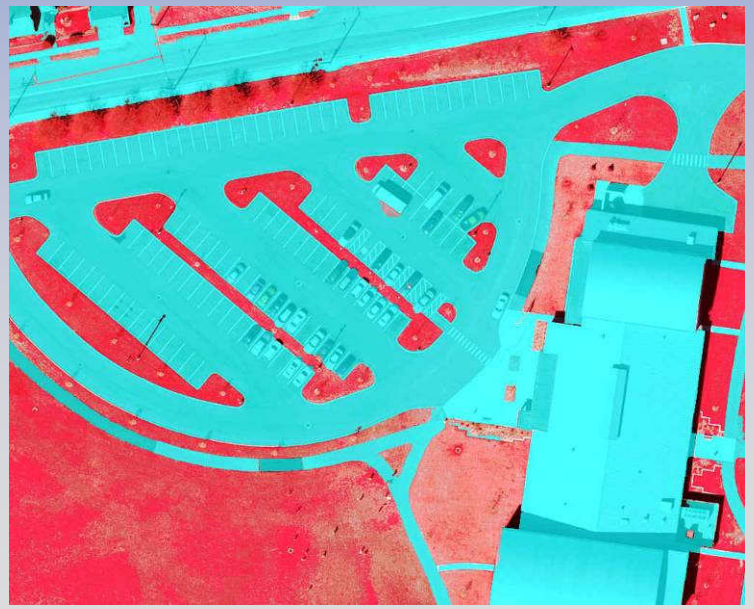


Columbus Impervious Surface Program

Project Status

PROJECT STATUS

- All input data (orthos/LiDAR) completed
- Project area segmentation completed
- Project area impervious surface completed
- Extraction of impervious surfaces for commercial parcels completed
- QC of commercial parcel impervious surfaces competed
- Projected completed and delivered to Columbus: January, 2009

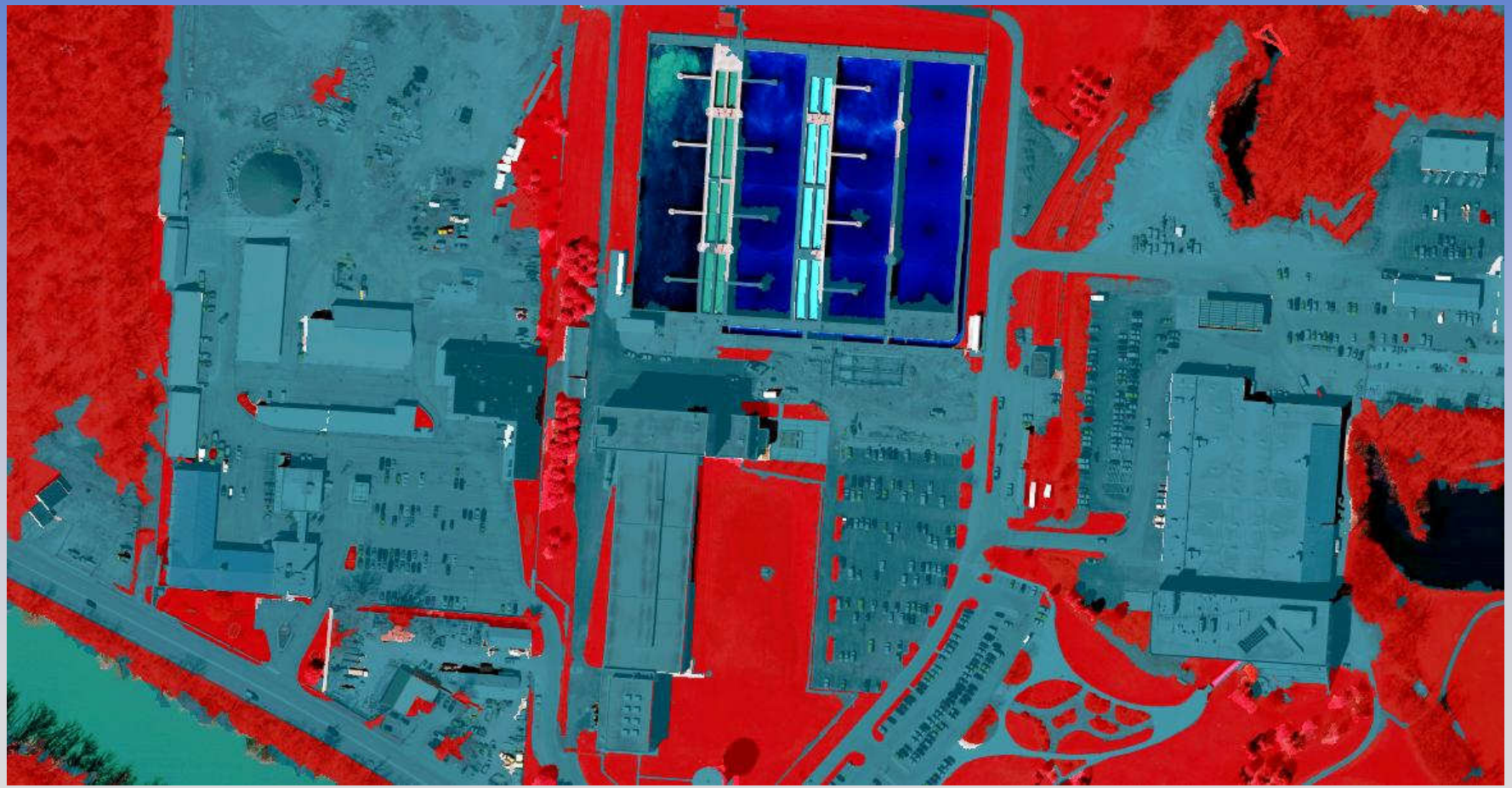


Columbus Impervious Surface Program

Implement Automated Impervious Area Process

Sample Final Datasets

Impervious Surfaces Shown in Blue/Gray



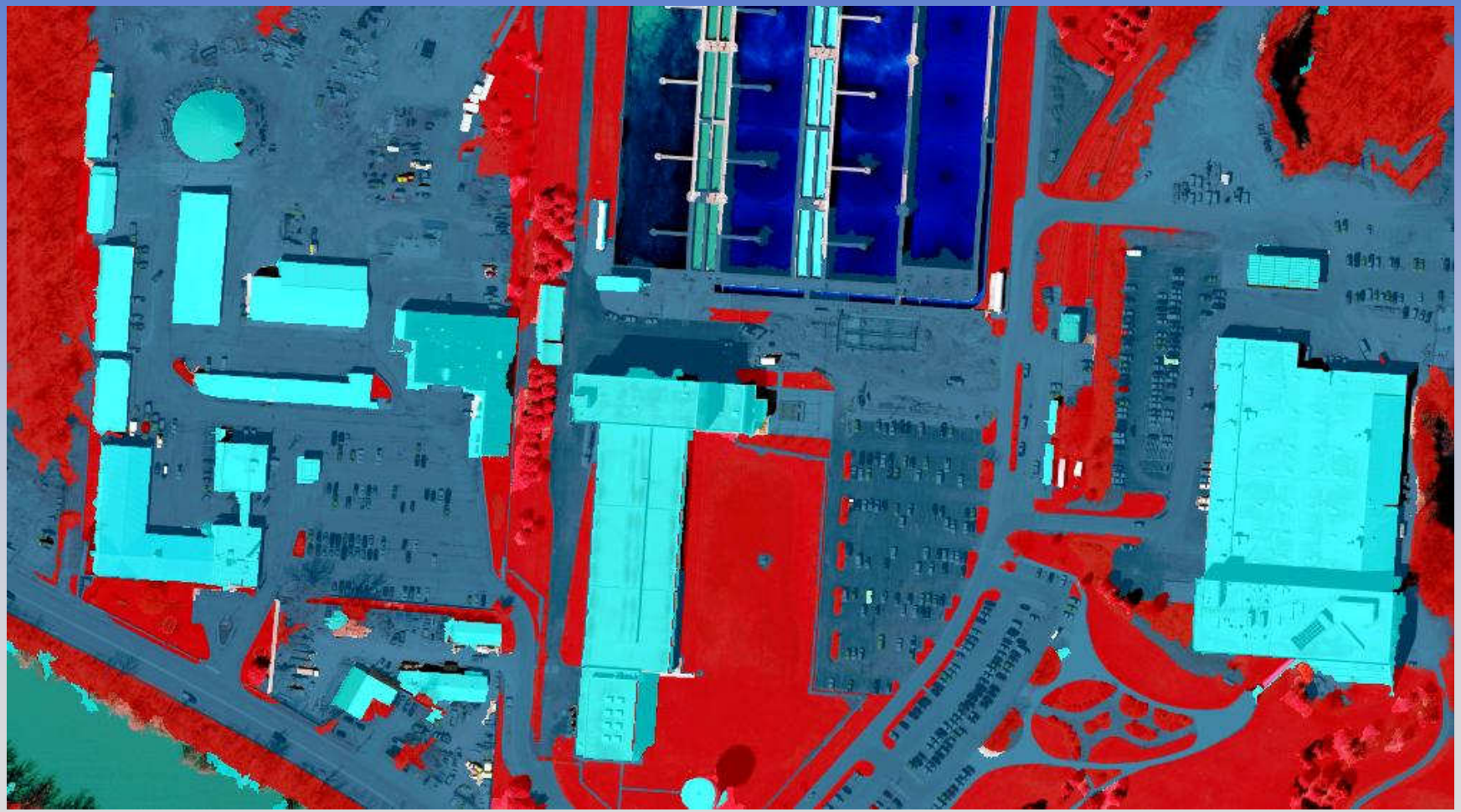
Columbus Impervious Surface Program

Implement Automated Impervious Area Process

Sample Final Datasets

Impervious Surface Shown in Blue/Gray

Building Classification Shown in Light Blue



Columbus Impervious Surface Program

Implement Automated Impervious Area Process

Benefits

- **Release technicians to perform other tasks**
- **Opportunity to maintain a more up-to-date and accurate database**
- **Opportunity to offer a more fair assessment of impervious surfaces**
- **Greatly reduced time frame of maintaining impervious surface database**
- **Greatly reduced costs associated with maintaining an impervious surface database (using traditional methods)**
- **Reduce human error (using computer software and geo-spatial datasets)**
- **Track growth through change detection of impervious surfaces (where is population growth occurring?)**

Columbus Impervious Surface Program

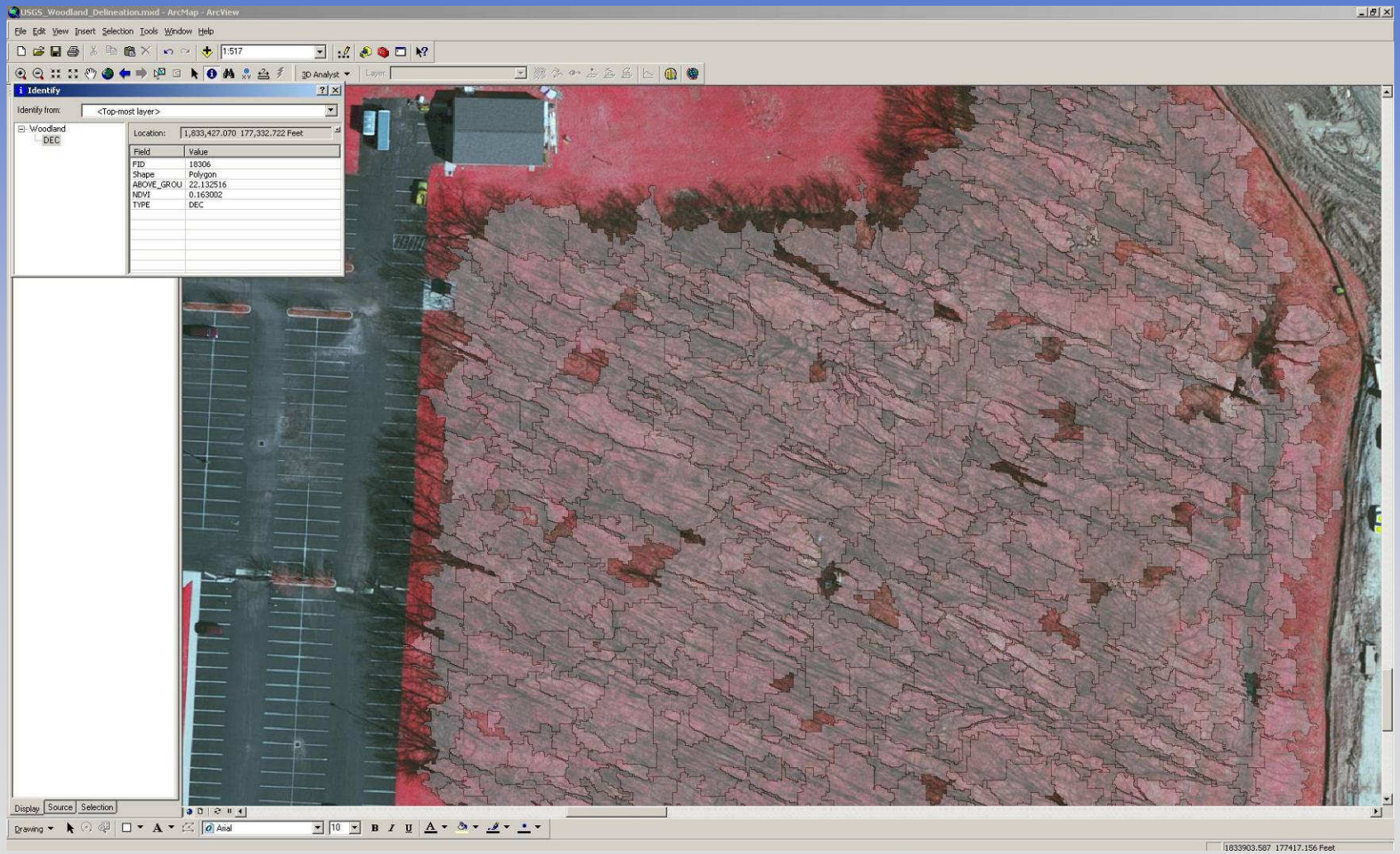
Implement Automated Impervious Area Process

ODOT EXAMPLES

Columbus Impervious Surface Program

Implement Automated Impervious Area Process

Beyond Impervious Surface Delineation (Other Uses)
Vegetation Analysis (NDVI)



The Ohio Statewide Imagery Program

Questions?

http://ogrip.oit.ohio.gov