USING NAIP AERIALS TO ASSESS IMPERVIOUS SURFACE AREA

Presented by INCOG

July 19, 2023

Embassy Suites – Will Rogers Airport, Oklahoma City

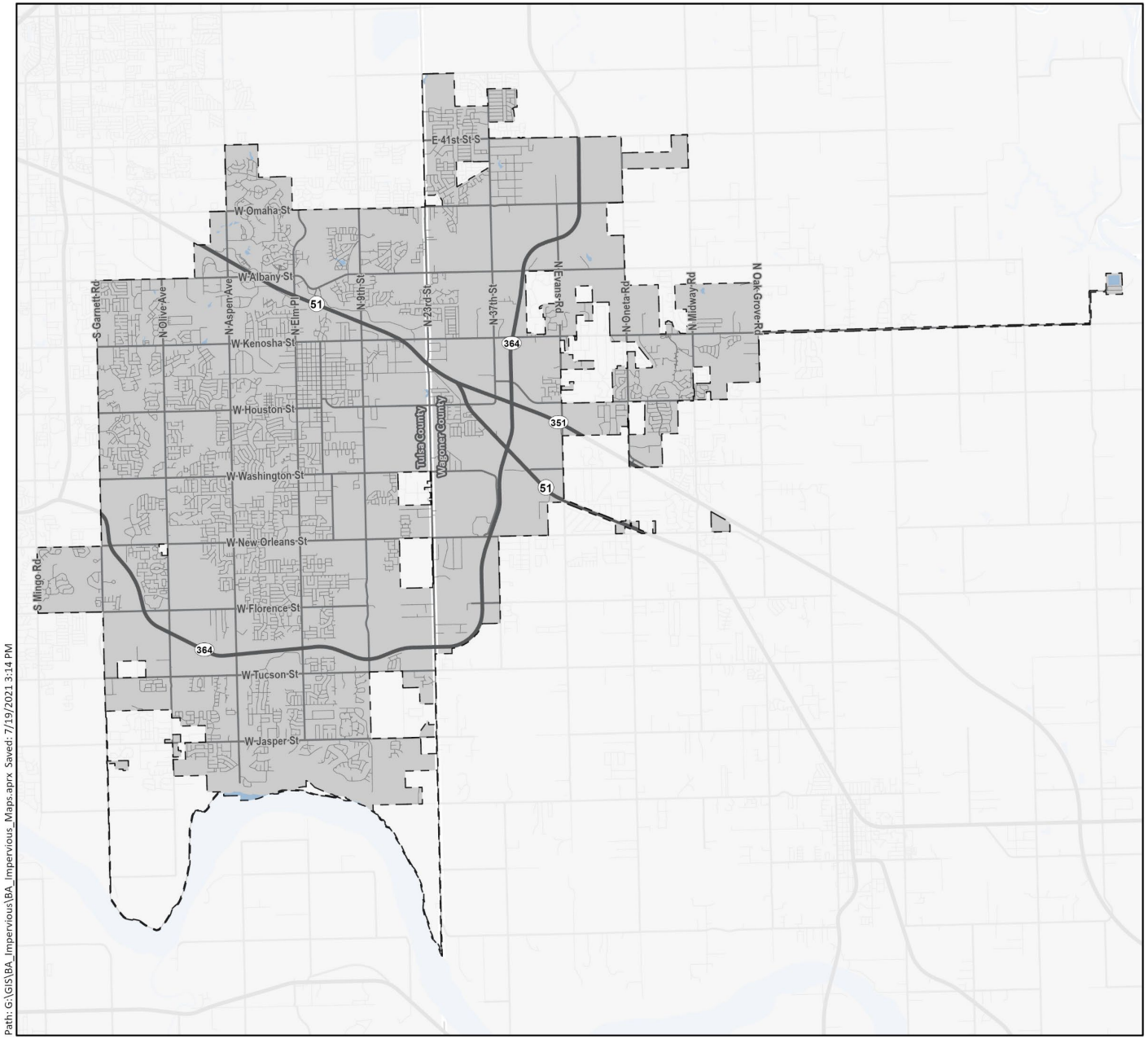
PROJECT SUMMARY

- INCOG received an EPA Water Quality Management Planning Grant in 2018 to estimate impervious surface area for large areas using image classification
- The city of Broken Arrow was selected as the trial city for this analysis
- Knowing the amount of impervious surface area is useful in determining runoff from rainfall and snow melt, stream loading, peaking potential, stormwater collection system sizing, identifying problem areas, and percent of impervious area in a watershed
- Use of National Agriculture Imagery Program (NAIP) aerials and Arc GIS Desktop software
- Issues and difficulties encountered and how to work around them

BROKEN ARROW, OK

- Fourth largest city in Oklahoma
- 2020 census population of 113,540
- Land area in Tulsa and Wagoner Counties
- Land area of 61.63 square miles
- Land use practices range from agricultural to heavy industrial

Broken Arrow Corporate Limits



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Legend

Broken Arrow Corporate Limits

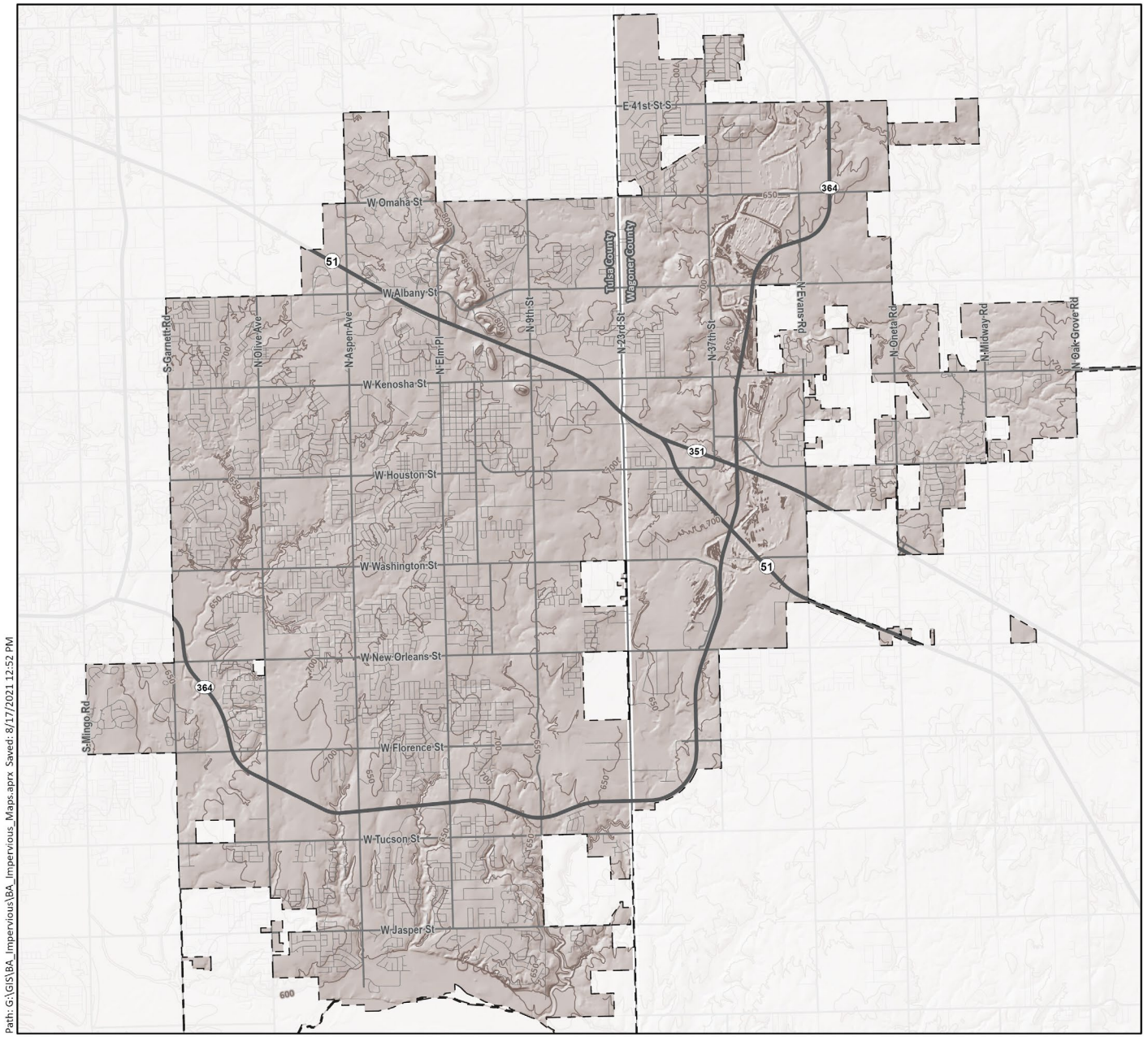
N

0 0.5 1 2 3 Miles

Location Map

INCOG

Broken Arrow Topography



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Legend

- Contour Line
- Broken Arrow Corporate Limits

N

0 0.5 1 2 Miles

Location Map

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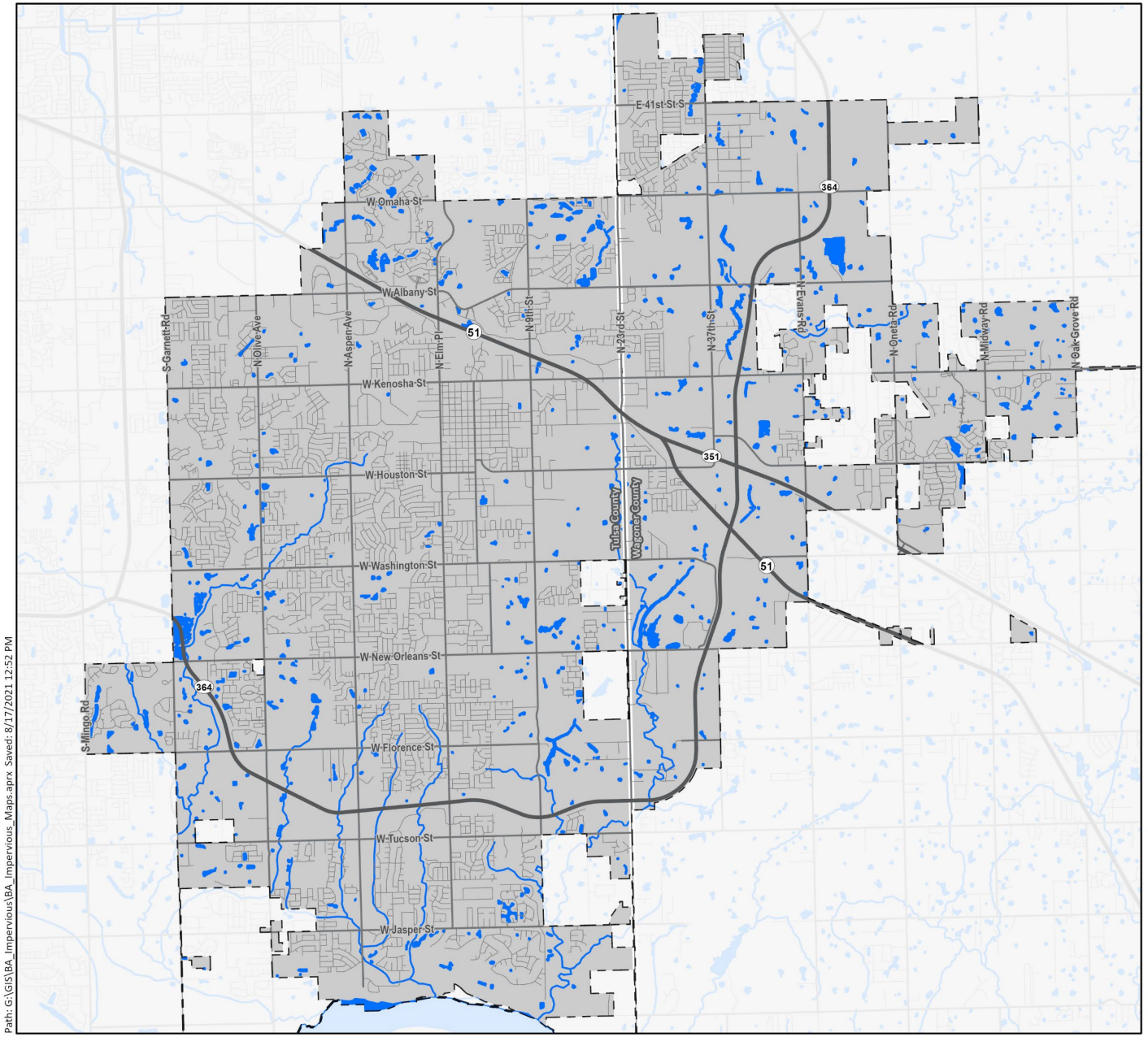
Broken Arrow Water Bodies



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Legend

- Stream
- Water Body (Lake/Pond)
- Broken Arrow Corporate Limits

N

0 0.5 1 2 Miles

Location Map

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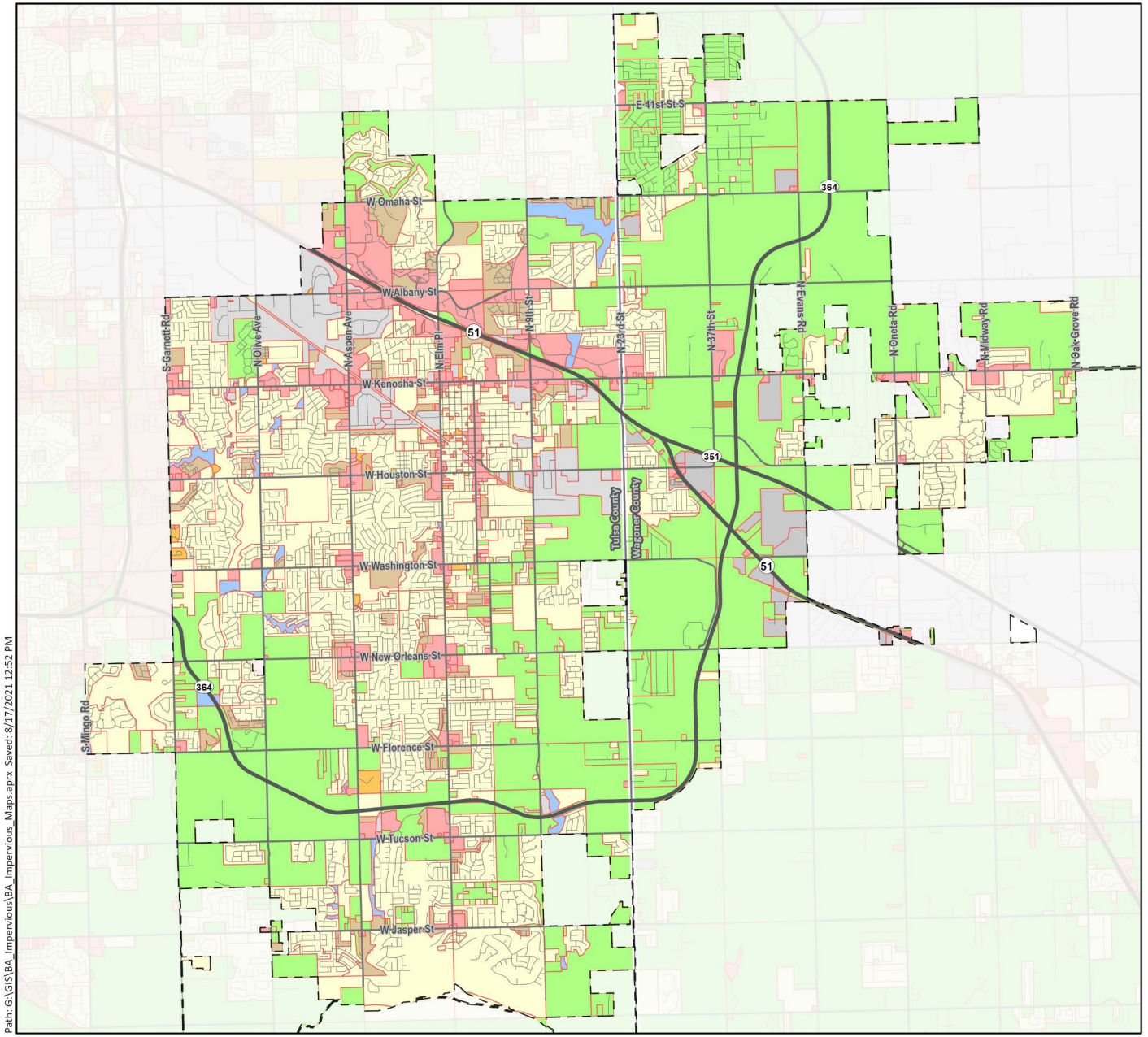
Broken Arrow Zoning



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Legend

- Broken Arrow Corporate Limits

Broken Arrow Zoning

- Agriculture
- Industrial
- Commercial
- Office
- Residential Single-Family
- Residential Multi-Family
- Flood District
- Corridor

N

0 0.5 1 2 Miles

Location Map

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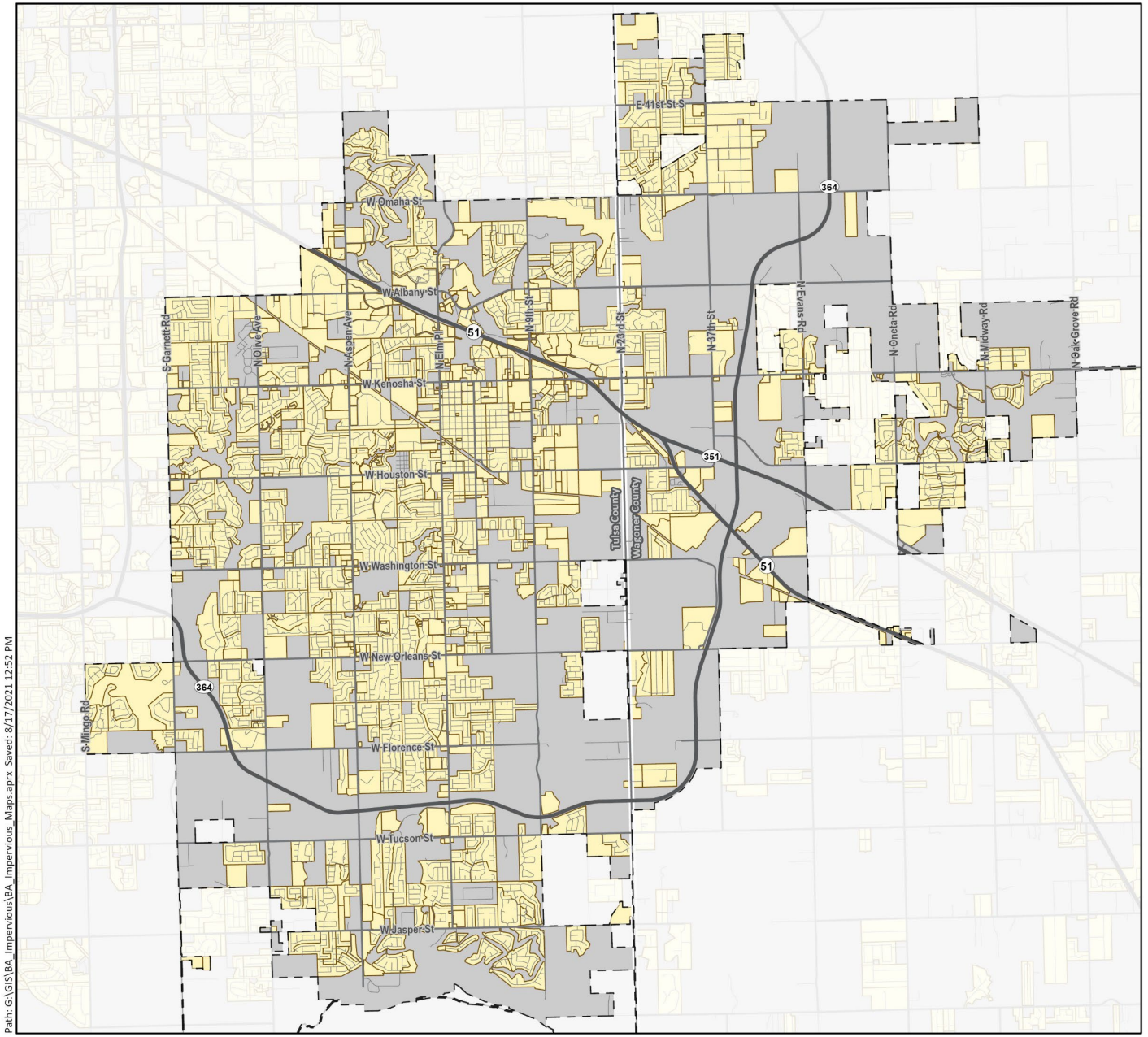
Broken Arrow Subdivisions



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Legend

- Broken Arrow Subdivisions
- Broken Arrow Corporate Limits

N

0 0.5 1 2 Miles

Location Map

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NAIP AERIALS

- NAIP aerials are published nationwide and taken during the growing season (leaf-on)
- Relatively good resolution (1 meter or better) compared to Satellite imagery (e.g. Landsat imagery ranges from 15 to 60 meter + resolution)
- Often available in four bands
- The first three bands contain red, green, and blue (RGB) values
- The fourth band is Near Infrared
- These were used to calculate the mean values among the pixels within training samples

Broken Arrow NAIP Aerial - Natural Color

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Legend

Broken Arrow Corporate Limits

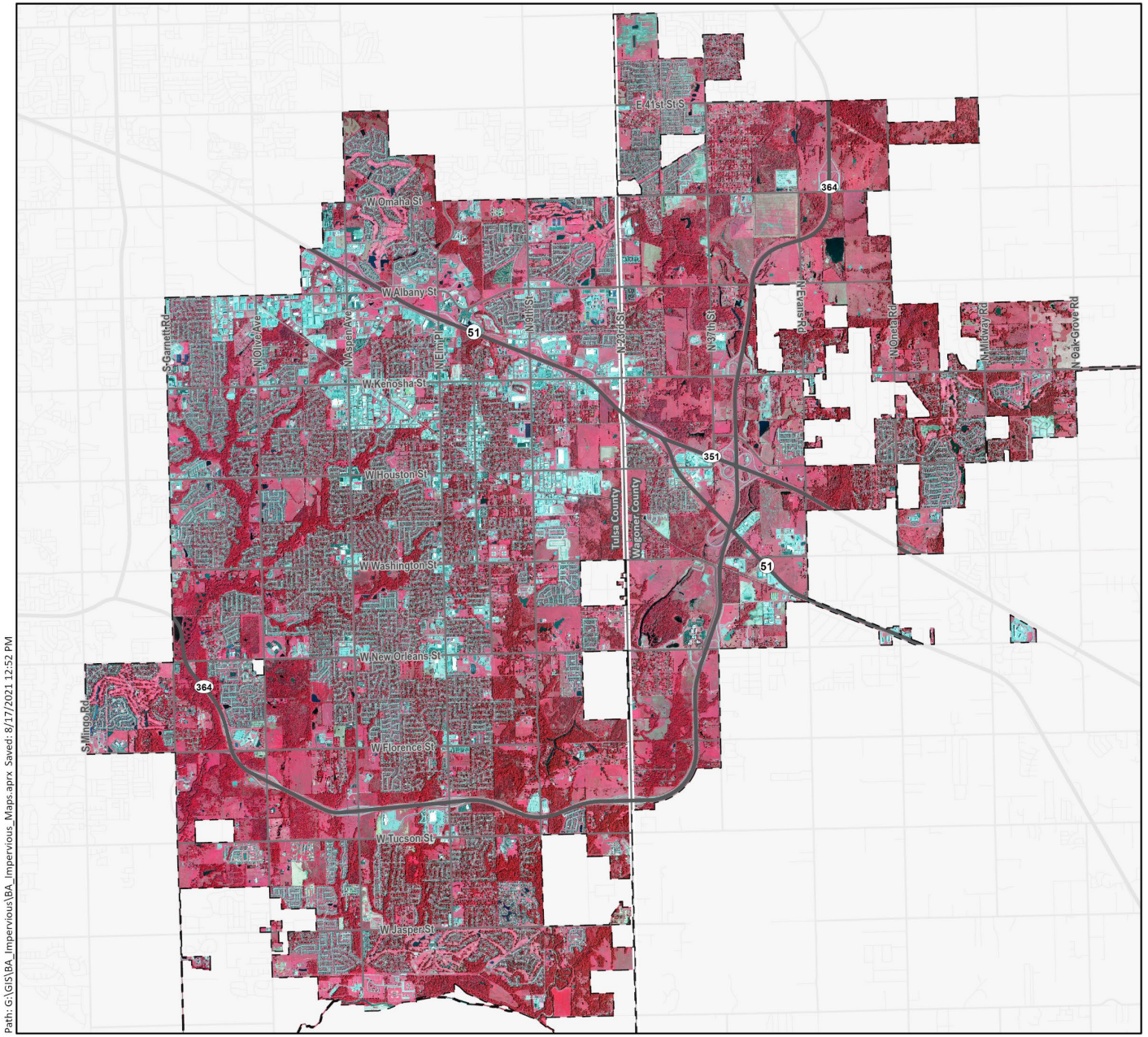
N

0 0.5 1 2 Miles

Location Map

INCOG

Broken Arrow NAIP Aerial - Color Infrared



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Legend

Broken Arrow Corporate Limits

N

0 0.5 1 2 Miles

Location Map

INCOG

GETTING STARTED

- Open ArcGIS Desktop and save a map document (.MXD file) in the working directory
- Locate and save additional shapefiles and features you will use
- To reduce file size, you can clip the NAIP aerials using raster clip (Toolboxes: Data Management Tools>Raster>Raster Processing>Clip)

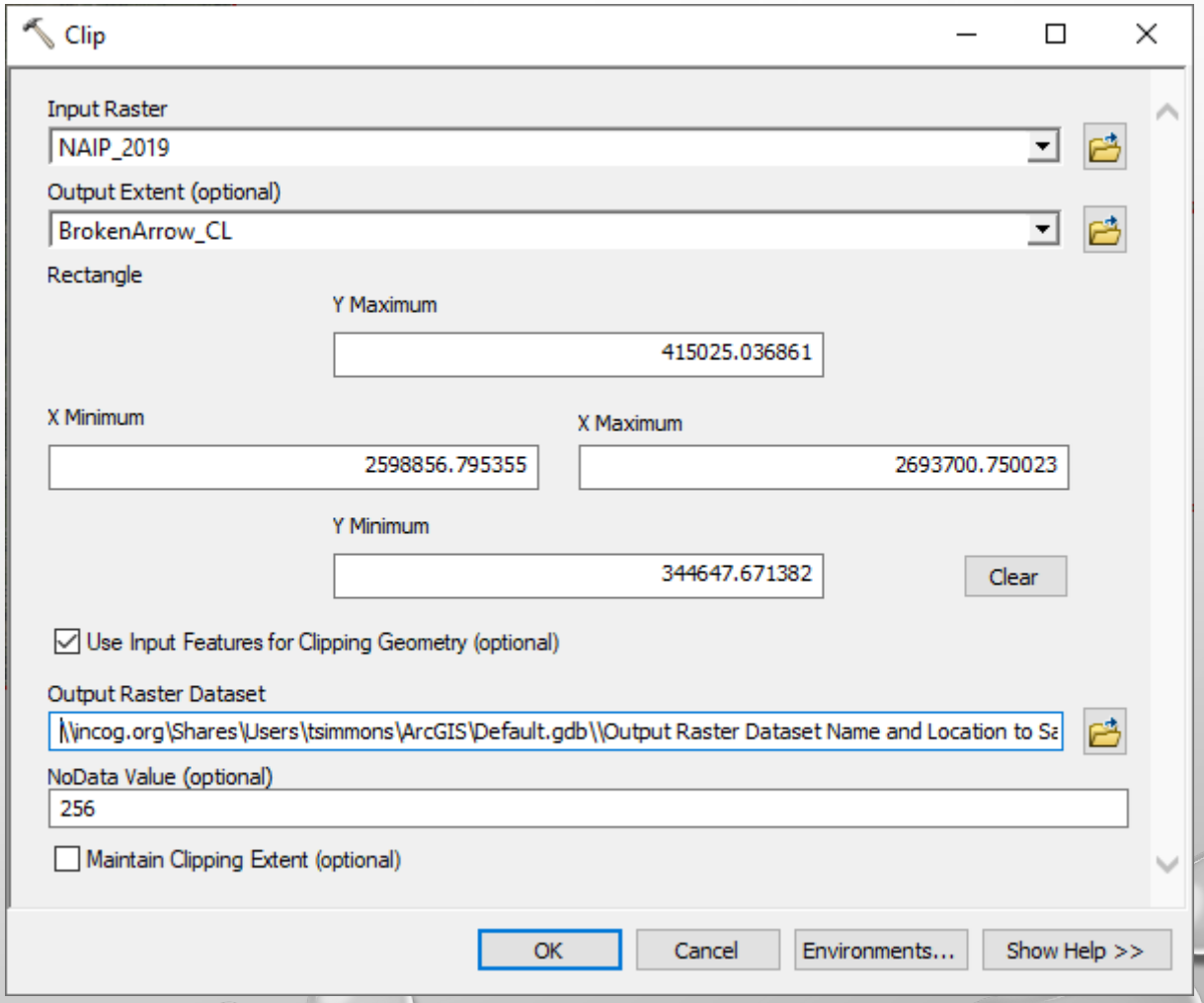


IMAGE CLASSIFICATION AND TRAINING SAMPLE MANAGER

- Activate Image Classification toolbar
- Activate Training Sample Manager. This is used to draw polygons to identify classes and calculate their signatures. These identify homogenous land cover/uses (i.e., classes).
- Classes can be merged and renamed to form a single class and colors can be changed to reflect the land cover that correlates to that class.

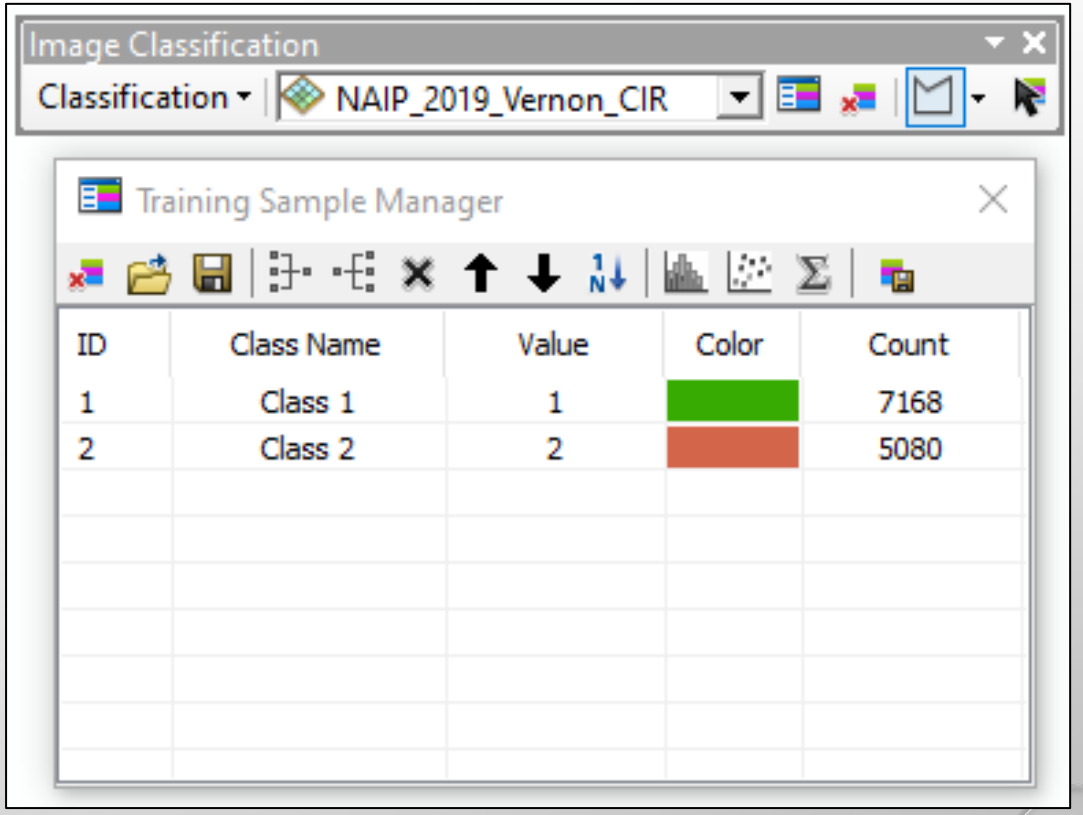
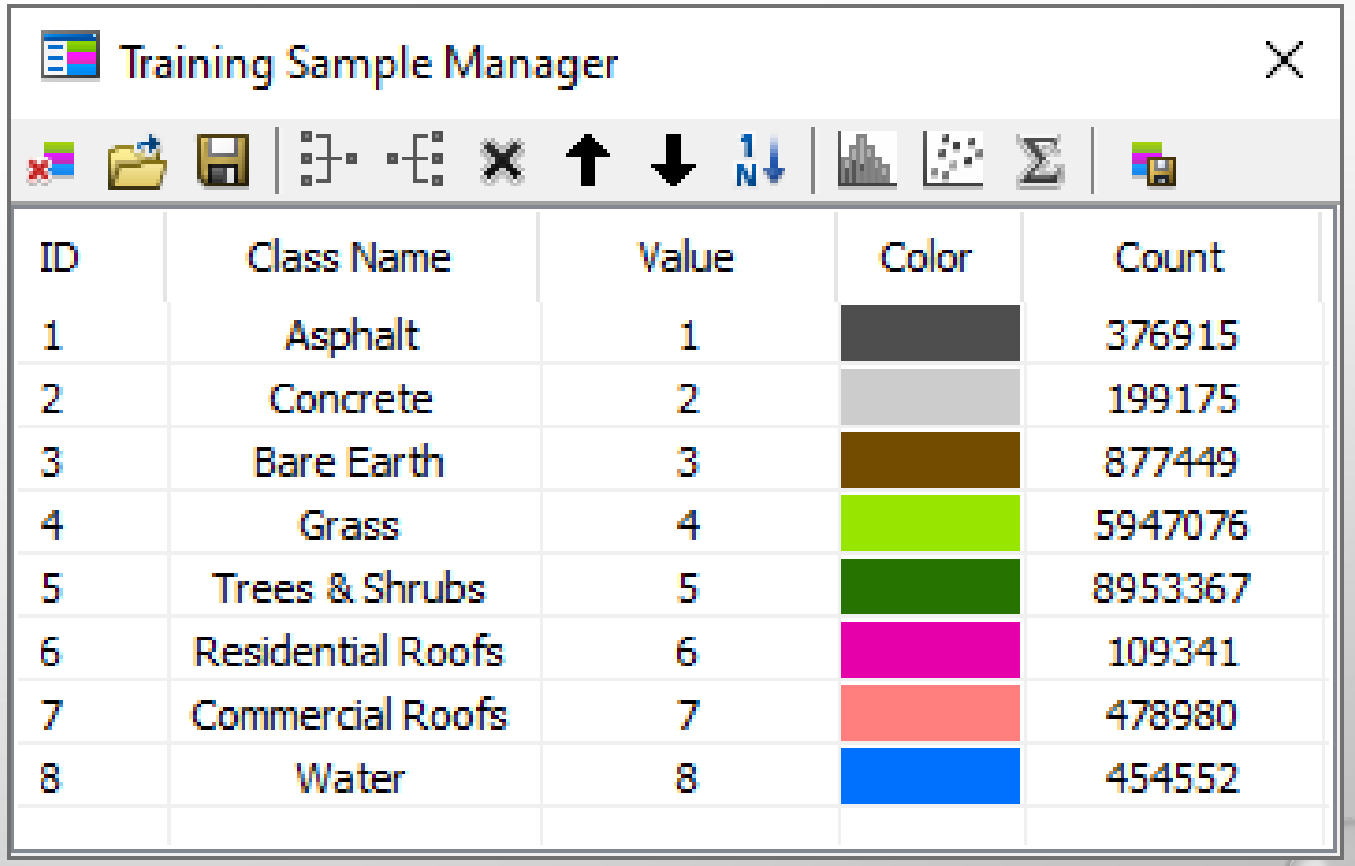


IMAGE CLASSIFICATION AND TRAINING SAMPLE MANAGER

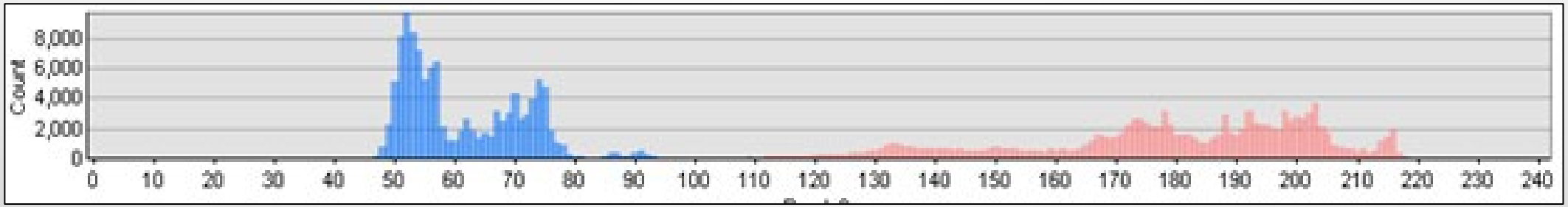
- Initial classes identified were asphalt, concrete, bare earth, grass-maintained, grass un-maintained, trees & shrubs, residential roofs (asphalt shingles), commercial roofs, and water.
- It was difficult to discern between grass-maintained and grass un-maintained, so they were merged into grass.



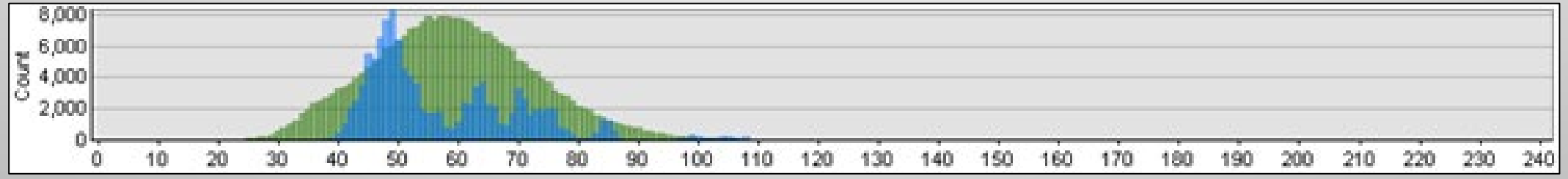
ID	Class Name	Value	Color	Count
1	Asphalt	1		376915
2	Concrete	2		199175
3	Bare Earth	3		877449
4	Grass	4		5947076
5	Trees & Shrubs	5		8953367
6	Residential Roofs	6		109341
7	Commercial Roofs	7		478980
8	Water	8		454552

EVALUATING TRAINING SAMPLES

Training samples were compared to each other using the evaluation tools found in the Training Sample Manager, namely the Histogram, Scatterplot, and Statistics tools to determine whether there is enough separation between the classes.



Histogram showing distinction between spectral characteristics of water (blue) and commercial roofs (pink)

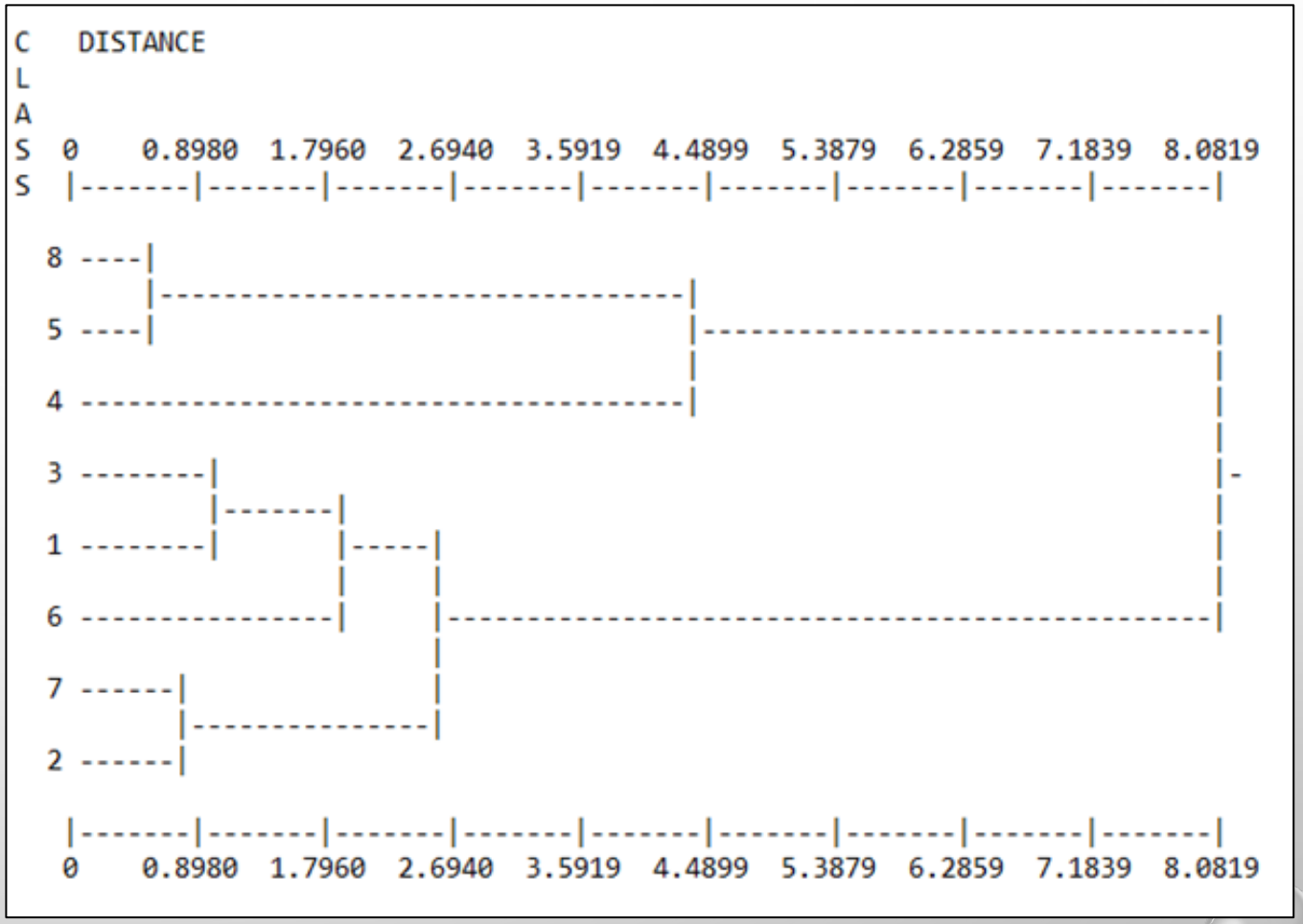


Histogram showing overlap between spectral characteristics of water (blue) and trees & shrubs (green)

SIGNATURE FILES

- When all training samples have been created and evaluated, a signature file can be created. The signature file is used by the Maximum Likelihood Classification tool to automatically assign each pixel in the NAIP aerial to one of the classes identified using the Training Sample Manager.

- Before classification is executed, further evaluation of the signature file can be performed using the Dendrogram tool. This tree diagram shows the separation of the training sample classes.



Dendrogram showing classes with similar characteristics for the natural color aerial.

DENDROGRAM ANALYSIS

- The dendrogram for this project revealed that the classes identified for water and trees & shrubs (Classes 8 & 5) shared many similarities, as did bare earth and asphalt (Classes 3 & 1), and commercial roofs and concrete (Classes 7 & 2).
- Using a GIS waterbody feature map to identify water instead of relying on image classification would solve the overlap issue for water and trees & shrubs, enabling those classes to be merged. Water, trees, and shrubs represent land areas that are pervious.
- Merging commercial roofs with concrete would resolve the overlap present with those two classes since they are both impervious.
- Bare earth and asphalt present a problem as those two classes fall within pervious and impervious, respectively.

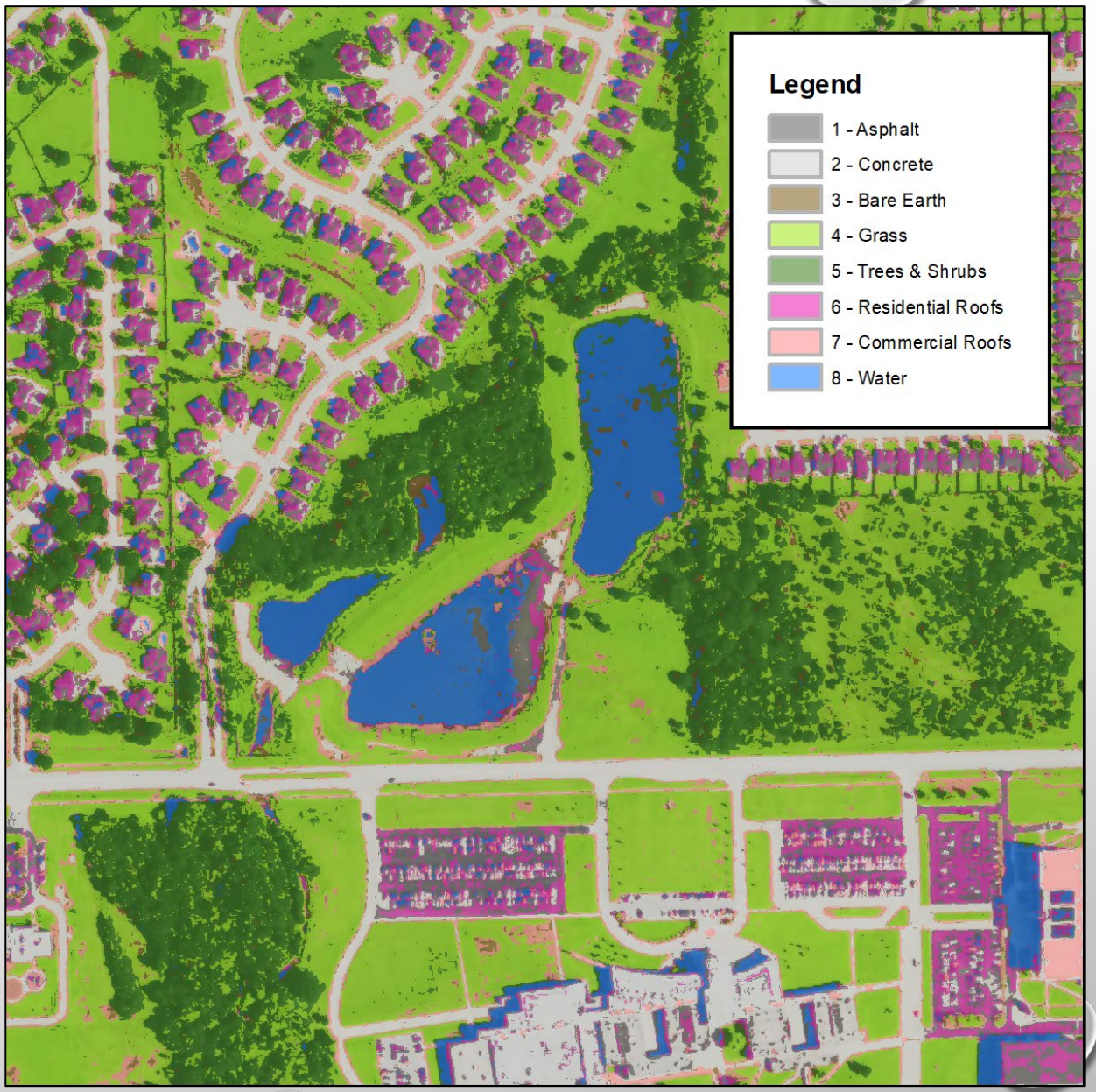
CLASSIFIED RASTER

- Once the signature file has been evaluated and any necessary edits have been made, the Maximum Likelihood Classification tool can be executed to create a classified raster.
- The Maximum Likelihood Classification tool assigns each pixel in the NAIP aerial to one of the training sample classes identified using the Training Sample Manager.
- Examining the resulting classified raster may reveal areas that were misclassified by the tool.
- These can be cleaned up using some post-processing tools, such as filtering, smoothing, or removing small, isolated regions.

OBSERVATIONS REGARDING MAPS ON NEXT SLIDE

- Initially, the analysis was run with the natural color NAIP aerial and later with the infrared NAIP aerial using all 8 land cover classes.
- Different land cover types are distinguishable from each other, but there were misclassifications.
- Some parking lots along the lower part of the image were misclassified as residential roofs.
- The areas surrounding streets were misclassified as bare earth, for the natural color aerial, and as commercial roof for the infrared aerial.
- In the natural color aerial, water is shown to be prevalent among the trees, and for both aerials, shadows are being classified as water.
- The roof of the building at the bottom of the image is mostly classified as commercial roof in the natural color aerial, but almost entirely as concrete in the infrared aerial.

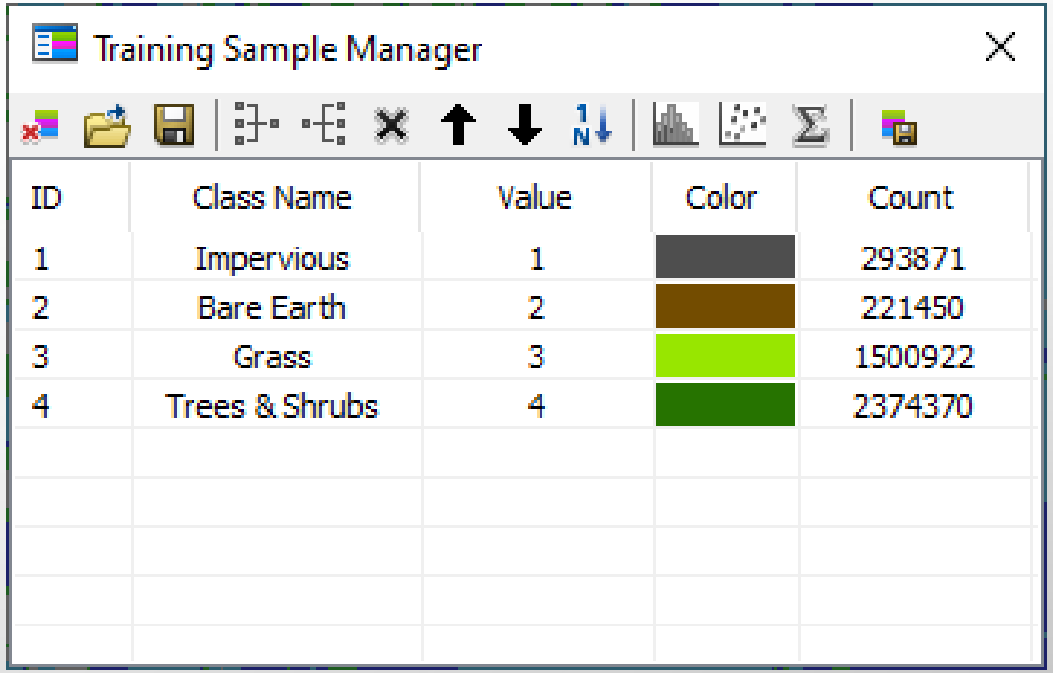
Classified raster using the natural color NAIP



Classified raster using the infrared NAIP

MISCLASSIFICATION ADJUSTMENTS

- Due to the misclassifications of the first run, a new training sample was created from the original to improve the classifications.
- Classes 8 and 5 (water and trees & shrubs) were merged since their spectral characteristics were so similar and a GIS waterbody feature was available.
- It was also decided to disregard the distinction between the various types of impervious surfaces and merge them all into one impervious category.
- Classes 1 (asphalt), 2 (concrete), 6 (residential roofs), and 7 (commercial roofs) were merged to form a single impervious class.



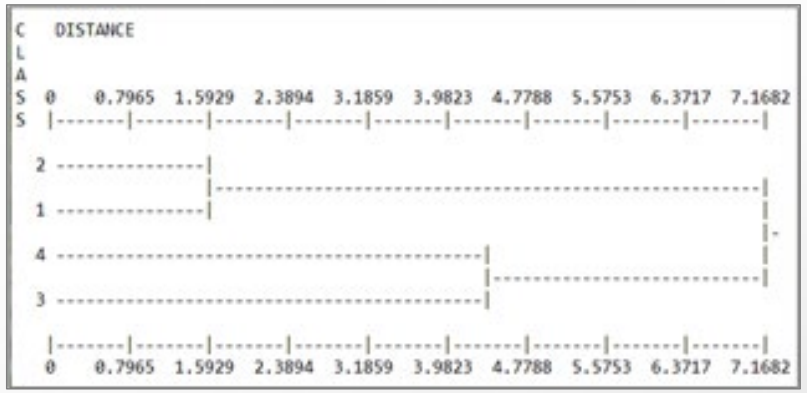
ID	Class Name	Value	Color	Count
1	Impervious	1		293871
2	Bare Earth	2		221450
3	Grass	3		1500922
4	Trees & Shrubs	4		2374370

Training Sample Manager with 4 classes

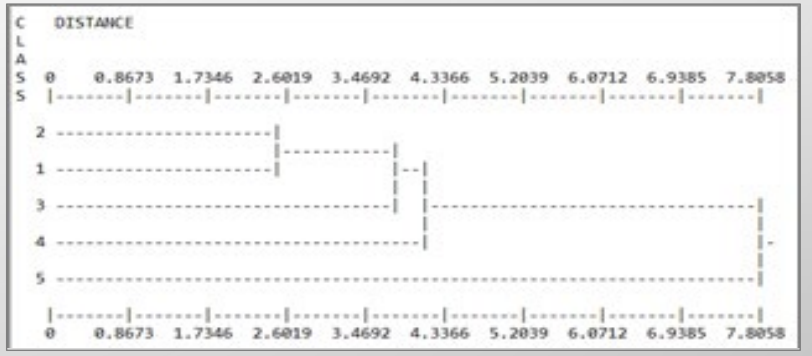
MISCLASSIFICATION ADJUSTMENTS

- The dendrogram tree diagrams for each of the signature files created from the new merged classes reveals that classes 1 and 2 (impervious and bare earth) have similar spectral characteristics, particularly for the natural color aerial. However, those two classes represent impervious and pervious land covers, so they were not merged.

- The Maximum Likelihood Classification tool was then run again using the two new signature files created from the merged training samples. The results are shown on the next slide.



Dendrogram showing merged classes with similar characteristics for the natural color aerial



Dendrogram showing merged classes with similar characteristics for the infrared aerial

The analysis is now classifying impervious surfaces around the edge of streets and along roof lines as bare earth for the natural color aerial. The same is true for the infrared aerial, at least around the edges of streets.

Grass and trees & shrubs appear to have been classified well for both aerials. Unfortunately, the analysis is classifying many building shadows as trees.

Natural color

Infrared

REVIEW AT THIS POINT

- Overall, the analysis using the infrared aerial appears to do a better job at distinguishing impervious from pervious surfaces.
- However, bare earth presented a problem both with the natural color aerial and with the infrared aerial.
- To improve upon it, some post-classification processing was employed, namely the majority filter and boundary clean tools were used to further refine the images.
- Although subtle, the post processing improved the classification by removing isolated pixels and smoothing the edges.

- The figures below show the results of the post-classification processing.

CONVERT CLASSIFIED RASTER TO VECTOR

- To perform any area calculations, such as acres of impervious surface per land cover class, it is necessary to convert the post-processed classified raster to a vector.
- This is accomplished by using the Raster to Polygon tool found in the From Raster toolset located in the Conversion toolbox.
- Once the land cover is in a vector format (polygon), it can be analyzed further by splitting it up based on any level of geography, such as watershed, and calculating area totals, such as acres, for the different land cover classes within the geography.
- This is also the point at which building footprints and waterbodies could be inserted to represent those land covers more accurately and to arrive at better area calculations.

LESSONS LEARNED

- Certain land cover/uses are hard to distinguish from one another both at the human level (i.e., visually from aerials) and for the computer in terms of spectral characteristics.
- In terms of visual characteristics, asphalt varied in color from light grey on old, weathered surfaces to dark grey or black for new surfaces.
- Grass varied in color from light green to dark green depending upon soil moisture level, nutrient availability, grass height, and age.
- Trees and shrubs were generally dark green.
- Another limitation to using the NAIP aerial is the fact that tree canopy can obscure features, such as roadways and rooftops, resulting in areas being misclassified as pervious when in fact they are impervious.

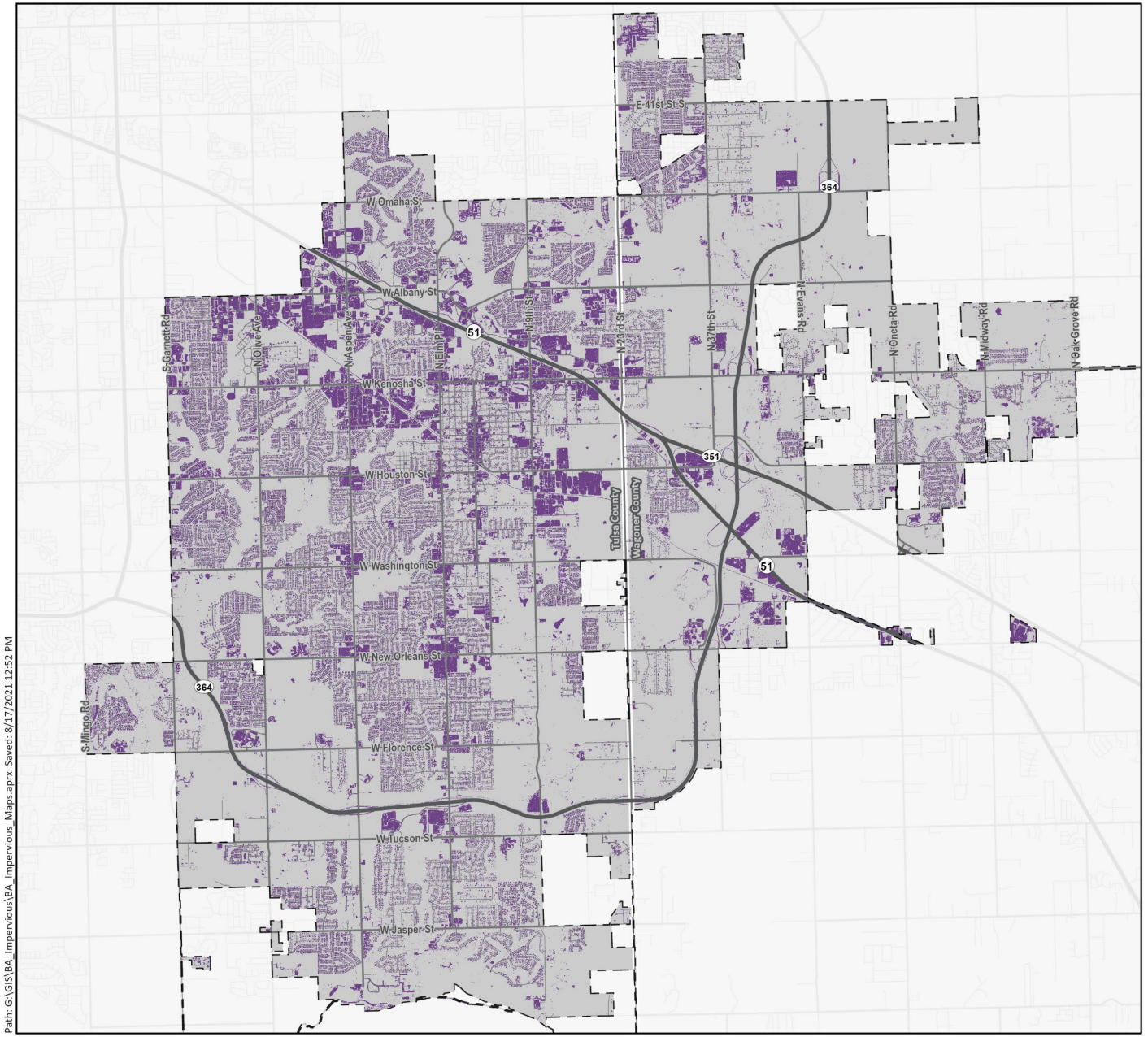
LESSONS LEARNED

- Residential roofs (asphalt shingles) varied in color from light grey (almost white) to various shades of brown.
- Commercial roofs were generally light grey to nearly white.
- Metal roofs showed the most variation. They are available in almost any color of paint.
- Water varied from light green to dark green and almost looked black at times.
- In addition to the range of colors, the appearance of a surface can vary according to the angle of the sun, light intensity, cloud cover, and level of shade.

ORIGINAL INTENT OF THE STUDY

- The original intent of this study was to explore the practicality of using NAIP aerial imagery to determine the imperious surface area of a large area of land.
- Along the way we explored the possibility of looking at subclasses of pervious and impervious surfaces.
- By combining all of the impervious surface area classes into a single class and all of the pervious areas into another class, we can produce a map showing pervious verses impervious surfaces with just two classes.
- Once we have differentiated between pervious and impervious surface areas, we can begin to analyze this on a basin level.

Broken Arrow Impervious Surface



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Legend

- Impervious Surface
- Broken Arrow Corporate Limits

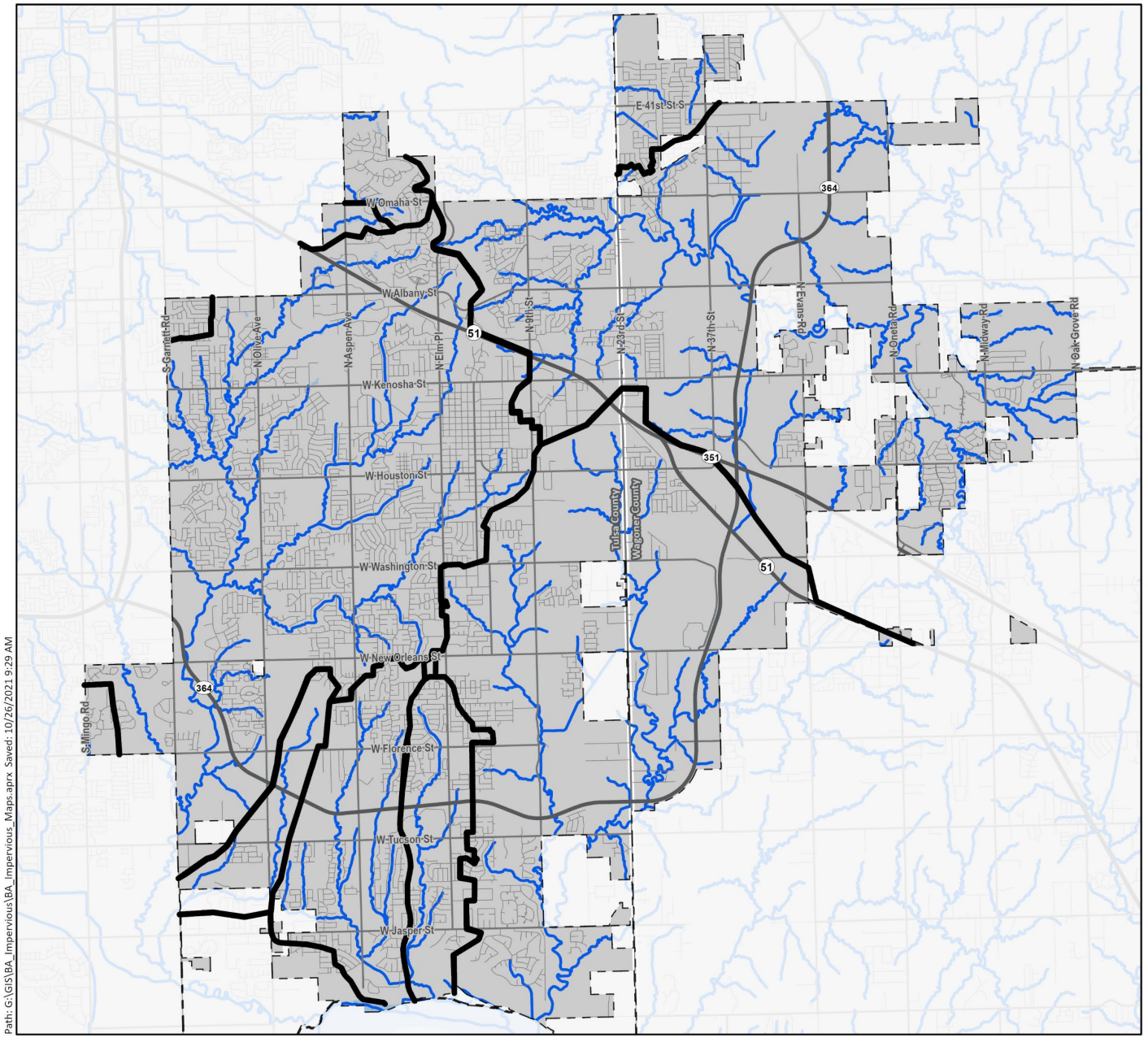
N

0 0.5 1 2 Miles

Location Map

INCOG

Streams by Drainage Basin



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Legend

- Stream
- Drainage Basin Boundary
- Broken Arrow Corporate Limits

N

0 0.5 1 2 Miles

Location Map

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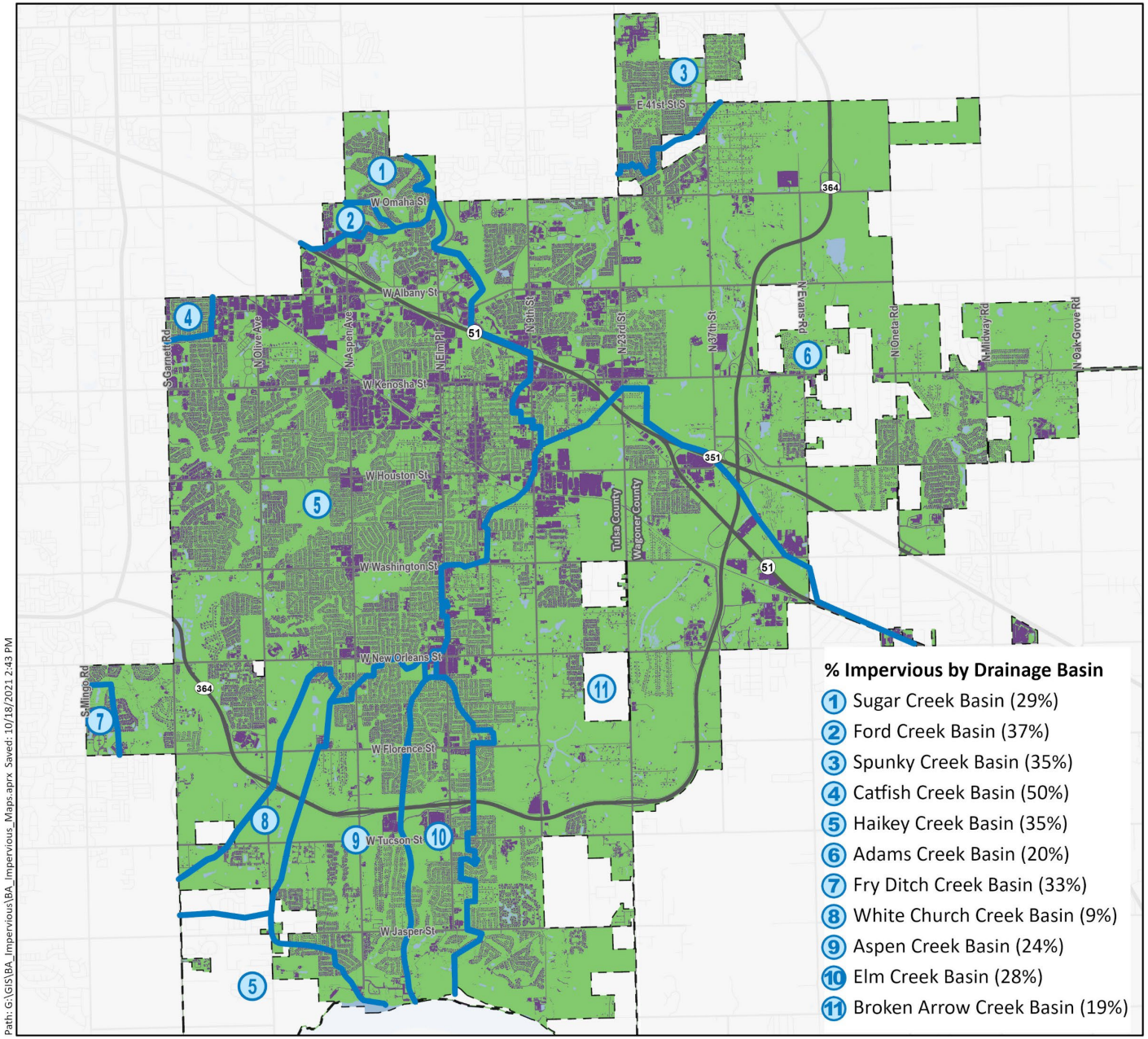
Percent Impervious Surface by Drainage Basin



% Impervious by Drainage Basin

1. Sugar Creek Basin (29%)
2. Ford Creek Basin (37%)
3. Spunky Creek Basin (35%)
4. Catfish Creek Basin (50%)
5. Haikey Creek Basin (35%)
6. Adams Creek Basin (20%)
7. Fry Ditch Creek Basin (33%)
8. White Church Creek Basin (9%)
9. Aspen Creek Basin (24%)
10. Elm Creek Basin (28%)
11. Broken Arrow Creek Basin (19%)

Legend

- Drainage Basin Boundary
- Broken Arrow Corporate Limits

Broken Arrow Land Cover

- Pervious Surface (73%)
- Impervious Surface (25%)
- Water (2%)

N

0 0.5 1 2 Miles

Location Map

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Thank You

For additional information, review the final project report and/or contact:

Ty Simmons
tsimmons@incog.org
Vernon Seaman
vseaman@incog.org

Olive Creek