OBJECT-ORIENTED IMAGE ANALYSIS FOR SINKHOLE INVENTORY

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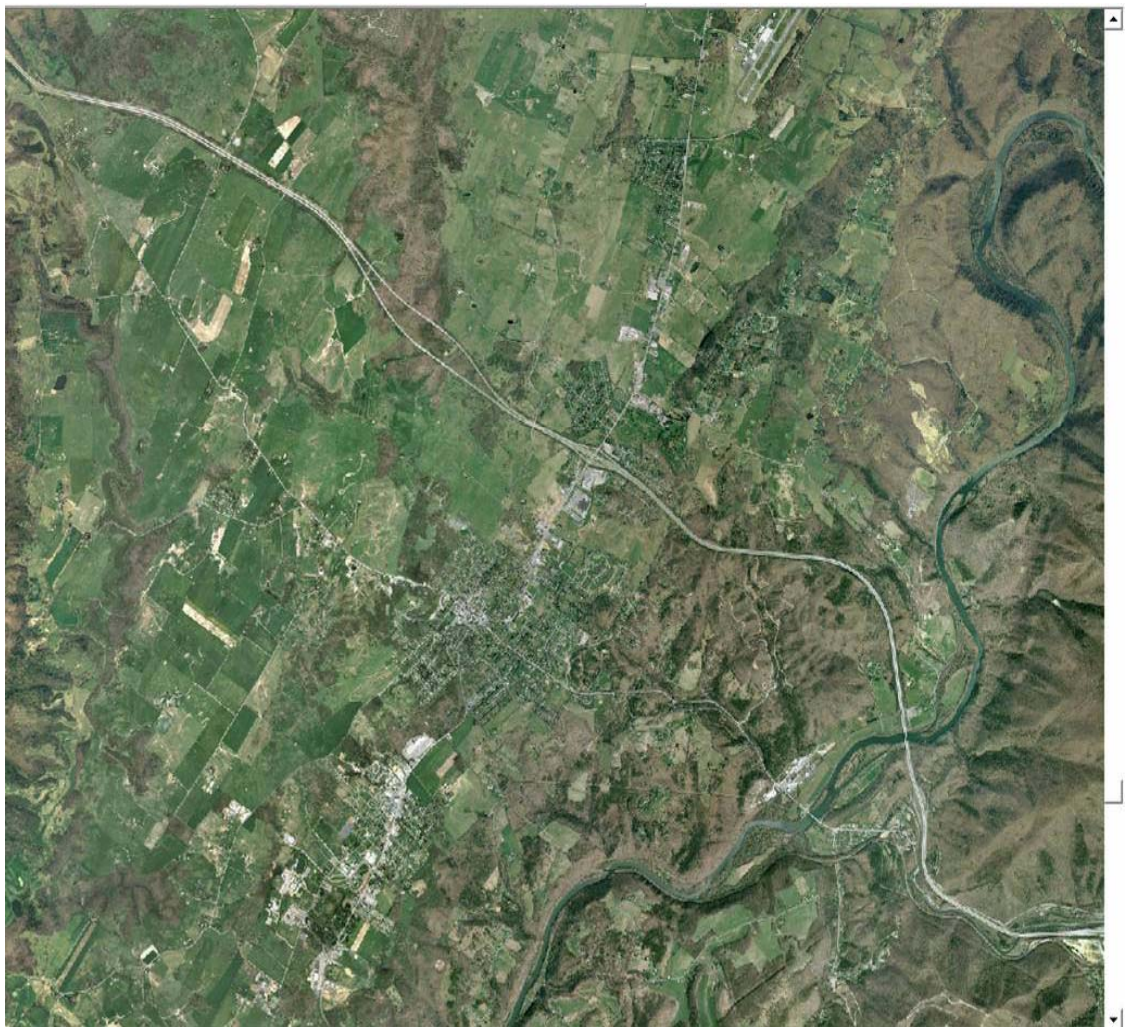
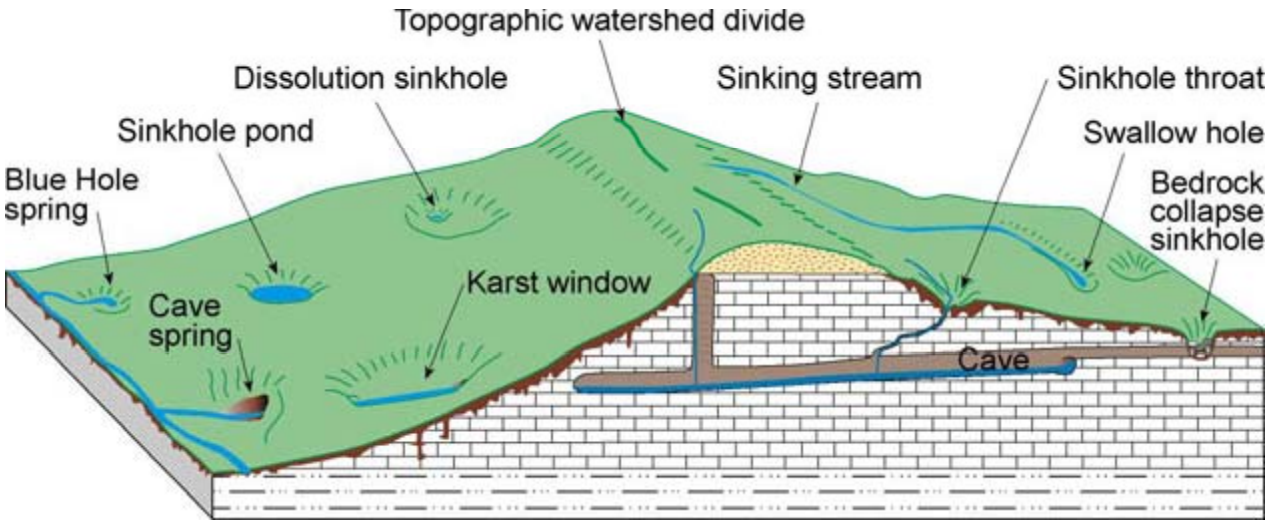
Rationale

- 40% of US groundwater for drinking comes from karst aquifers
- population pressure extend into karst areas
- aquifer drawdown/sinkholes
- changes in runoff morphology (Impervious surface, building footprints)
- well developed carbonate regions
- manual methodology time-consuming/Interpretive
- WV has no statewide sinkhole inventory



Karst Features



Sinkhole Plain

Surface Karst

Sinkholes

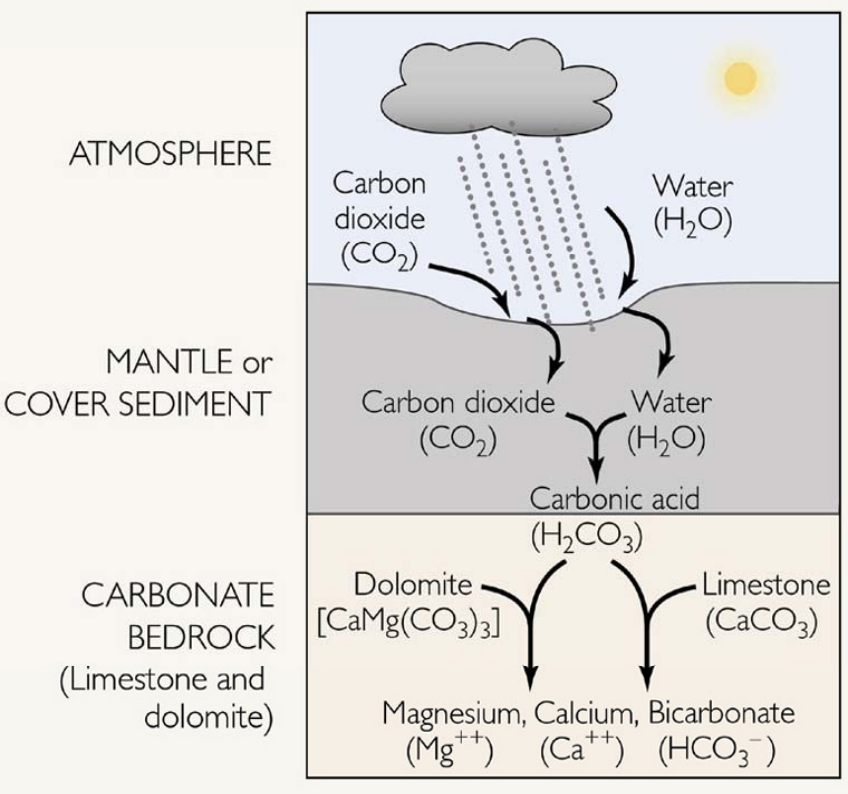
- The flow of surface and subsurface water affects how, where, and when sinkholes develop. Thus, formation of sinkholes is sensitive to changes in hydraulic and mechanical stresses that may occur naturally or as the result of human activity

- Urbanization creates impervious surface which redirects channel morphology and increases water velocities, increasing hydraulic gradients and potential energy

- New sinkholes have been correlated to land-use practices (Newton, 1986). Induced sinkholes are conceptually divided into two types: those resulting from ground-water pumping (Sinclair, 1982) and those related to construction and development practices.

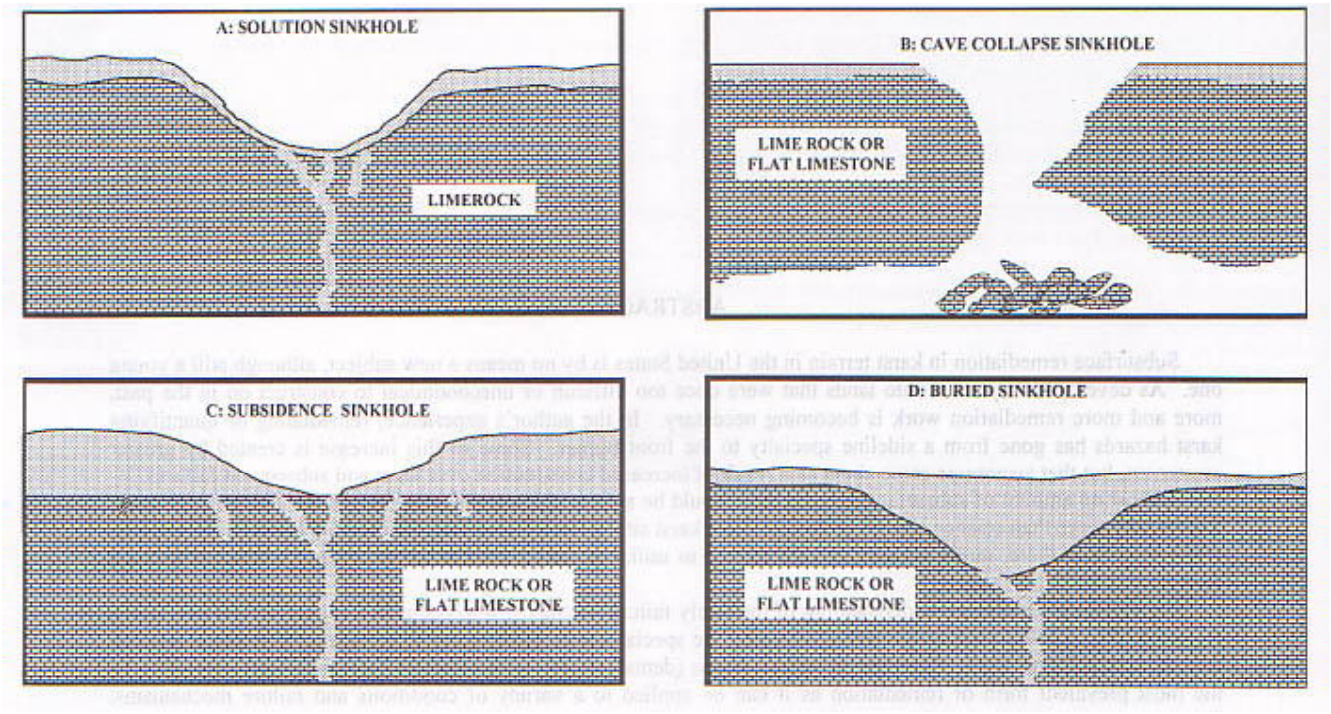
Sinkholes

- Two types of sinkholes caused by dissolution: cover-subsidence and cover-collapse sinkholes. They develop from dissolution and "suffosion."



Disolution by Carbonic Acid (USGS Circular 1182)

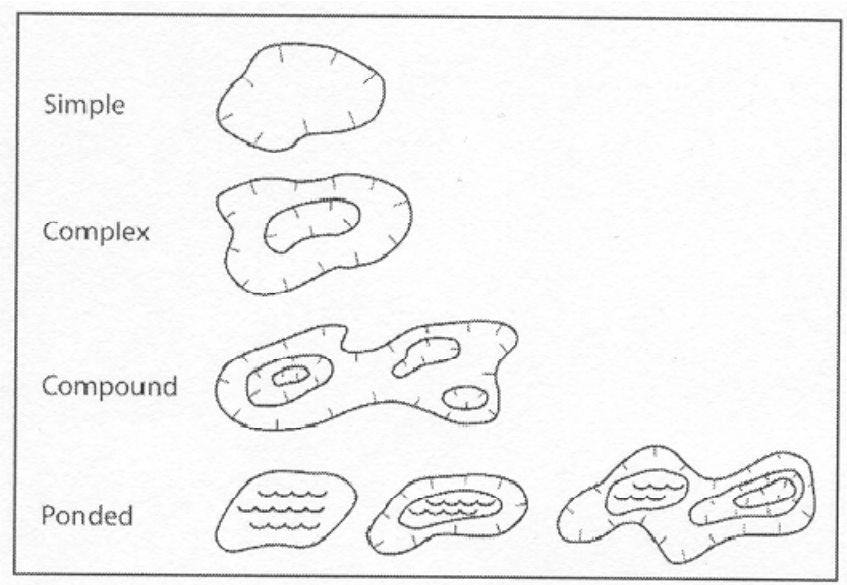
SINKHOLE TYPES IN STUDY AREA



(Modified from Beck, 1991)

MORPHOLOGY OF SINKHOLES IN LEWISBURG QUARTERQUAD

- 4 types: simple, complex, ponded, and compound
- Simple sinks have 1 depression contour; complex sinkholes have several concentric contours
- Compound sinks are large, irregularly-shaped depression contours with 2 or more nested contours
- Ponded sinks can be any of the other three types but are water-filled

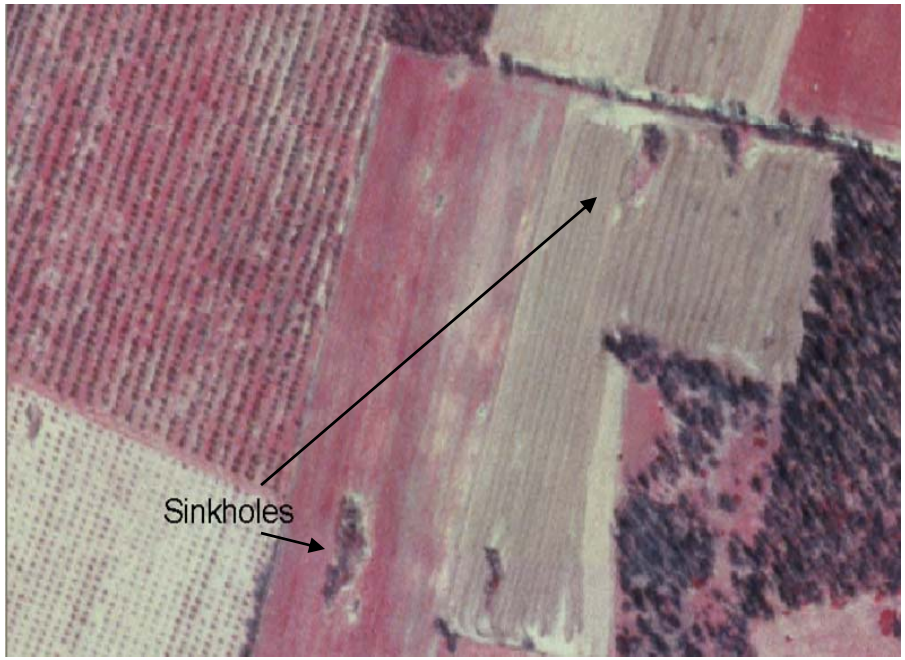


Adapted from Angel *et al*., 2004

Mapping Subsidence

- Grid overlays
- Tonal changes
- CIR shows zones of moisture
- Shape/stereopairs

Aerials: 1:12,000 USGS DOQQ

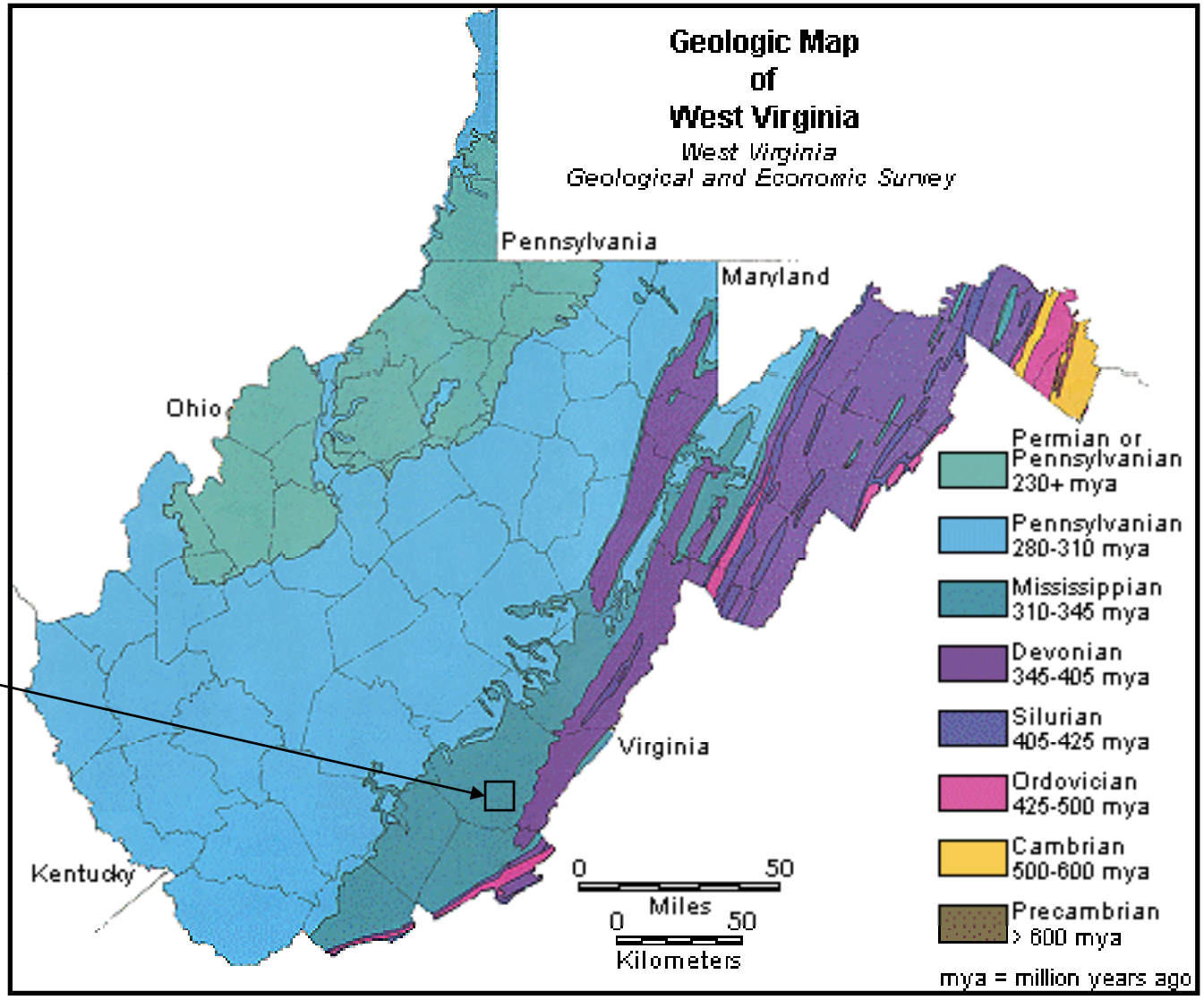


Source: Lewisburg NW DOQQ 1996; WVDEP

Objective

- Examine the feasibility and accuracy of using high-resolution digital aerial imagery within an image-object analysis platform (Definiens Professional™) for land cover quantification and classification resulting in faster and less expensive automated sinkhole inventory

Study Area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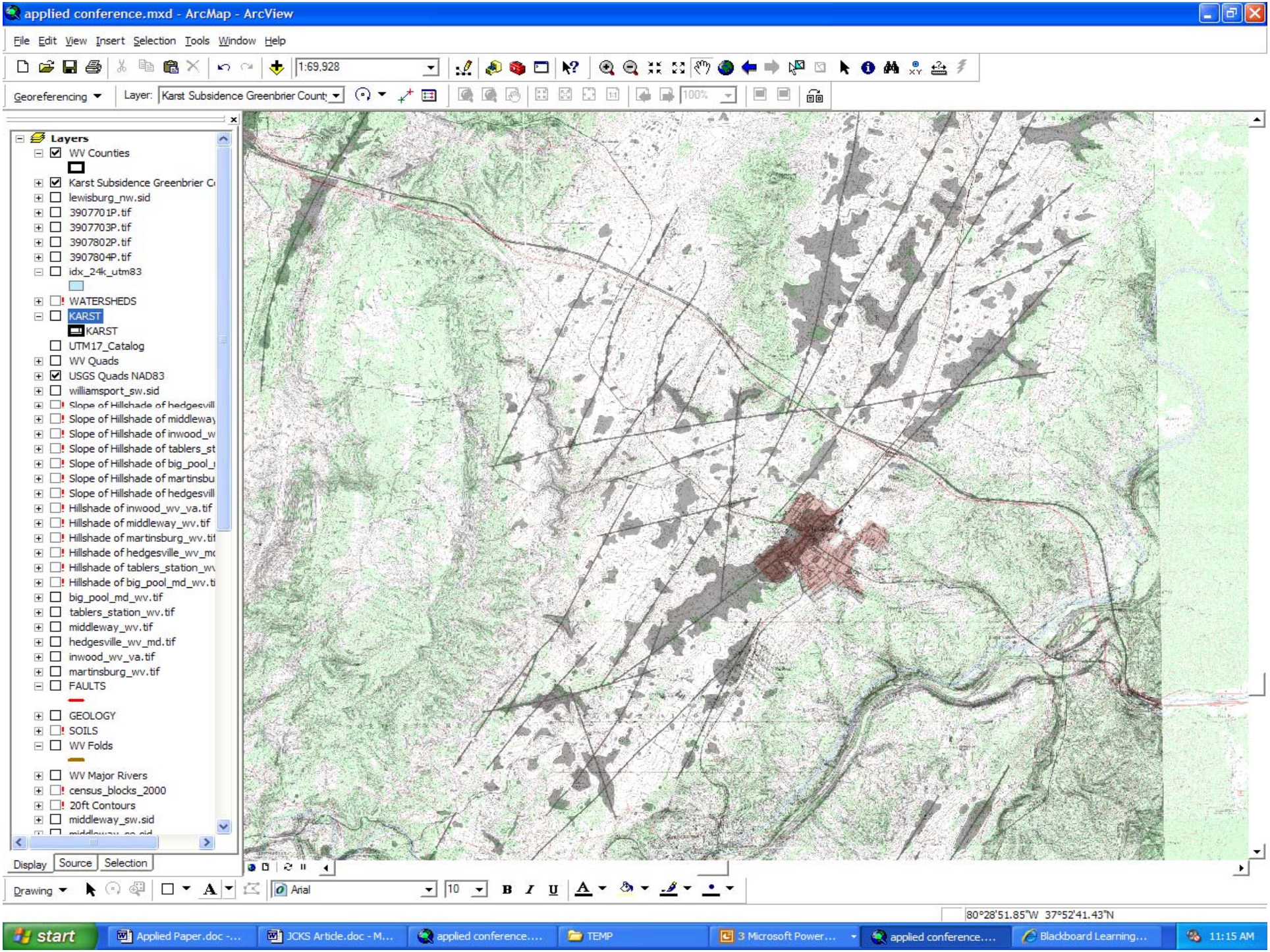
Kilometers
Permian or Pennsylvanian 230+ mya
Pennsylvanian 280-310 mya
Mississippian 310-345 mya
Devonian 345-405 mya
Silurian 405-425 mya
Ordovician 425-500 mya
Cambrian 500-600 mya
Precambrian > 600 mya
mya = million years ago

Karst in West Virginia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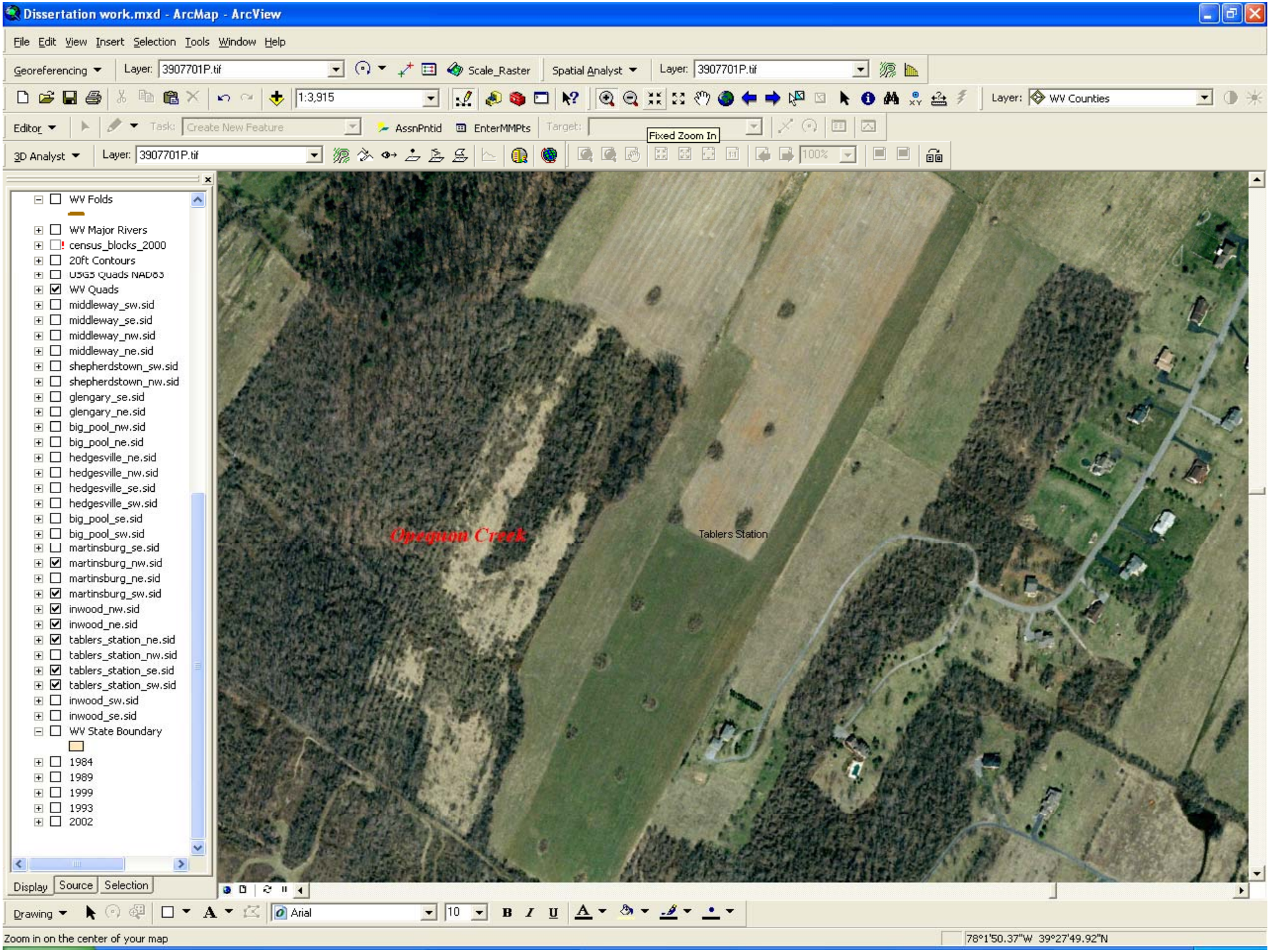
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STUDY AREA & DATA SET

Karst topography of study area

Aerial of study area

- 42 km² area where Miss. age rocks come to surface in Greenbrier County (Lewisburg NW QQ)
- Site has experience increased growth in outlying areas in recent years; increase in sinkholes
- Hundreds of depression contours on Lewisburg quad
- Digital aerial coverage acquired at 1:4800 scale from WVGS
- Ortho-rectified to <9.8’ horizontal error at 95% confidence level and brought into Defeniens™ Professional as TIFF file

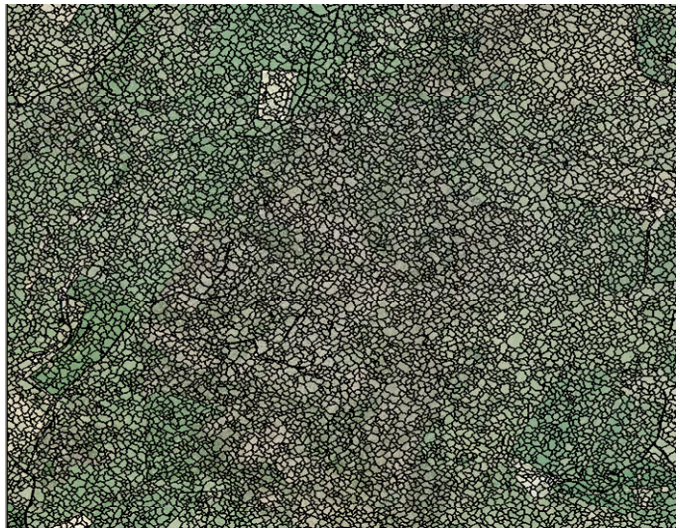
Object-Oriented Analysis

- Object-oriented image processing techniques are becoming more popular for the analysis of landscapes as data sets become less expensive(Blaschke *et al*., 2000)
- Recognize homogenous regions; distinguish landscape similarities as the human eye does
- Since sinkholes are easily recognizable objects in landscape, object-oriented image analysis offers potential
- While alternative methods exist (LIDAR, ALSM), cost-prohibitive for municipalities and communities

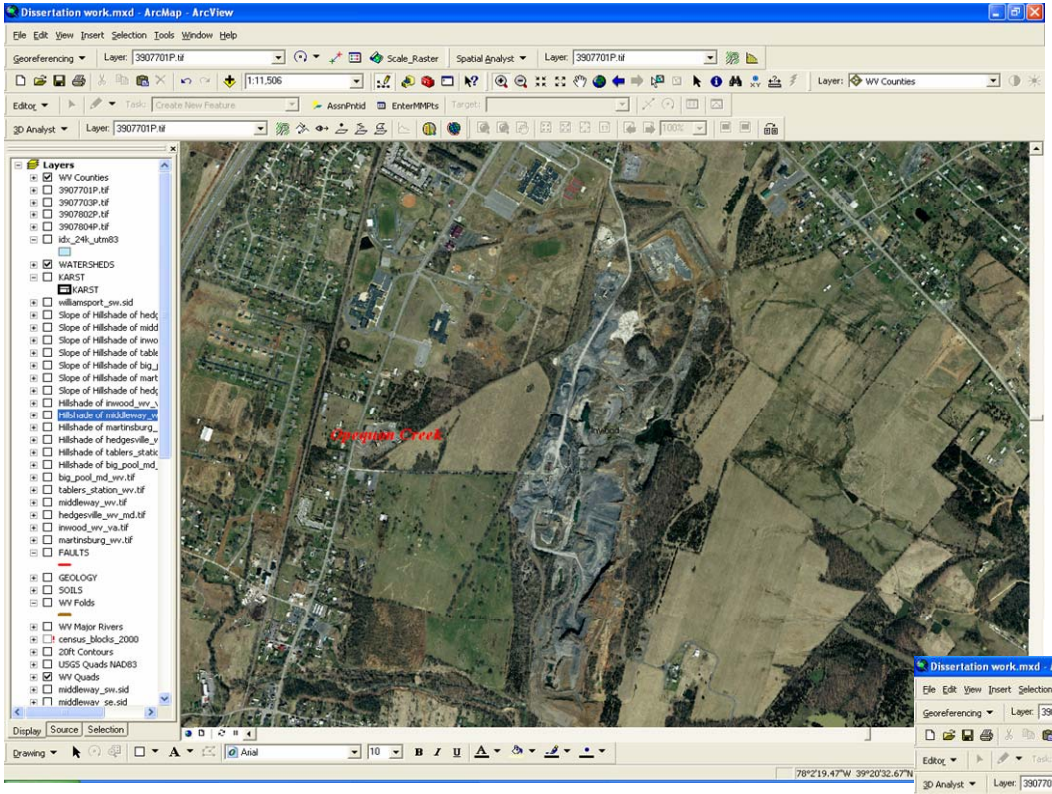
MULTI-RESOLUTION SEGMENTATION

- Image segmentation is the most important step in object-oriented analysis
- Poor segmentation results in an inaccurate classification
- Large (80), medium (25) and small (3) scale parameters were examined for suitability. Used a medium scale parameter of 45
- Color parameter (.1); Shape (.9); Compactness & Smoothness (.5)

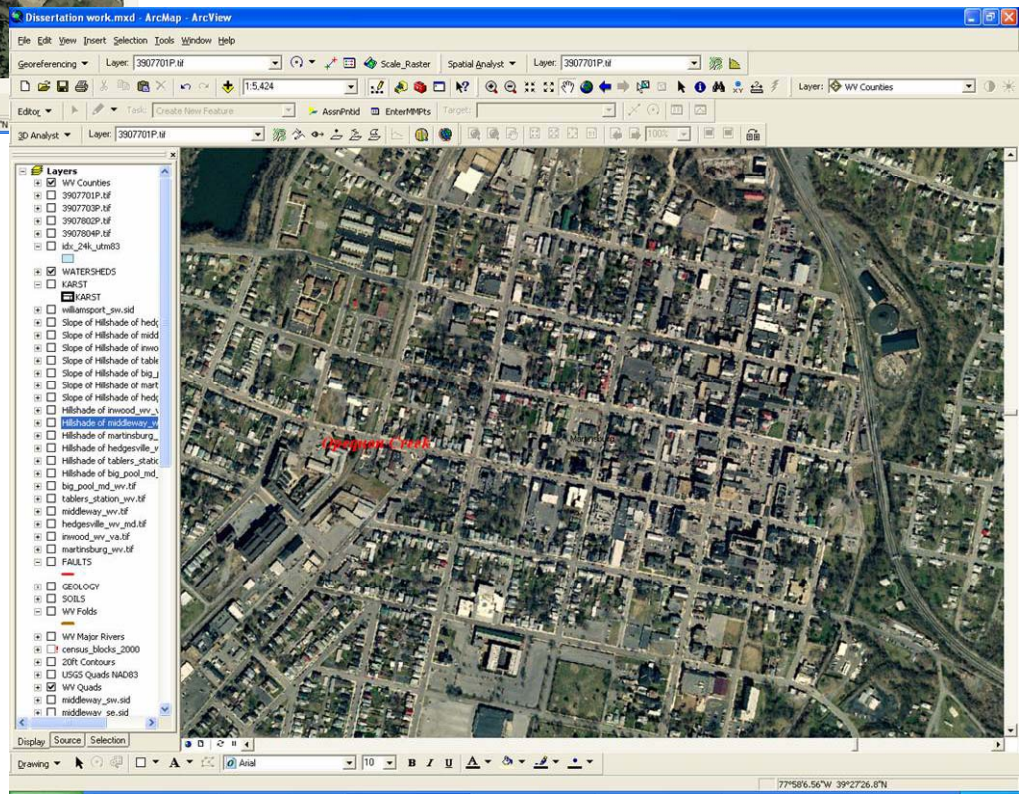
Scale Parameter (80)

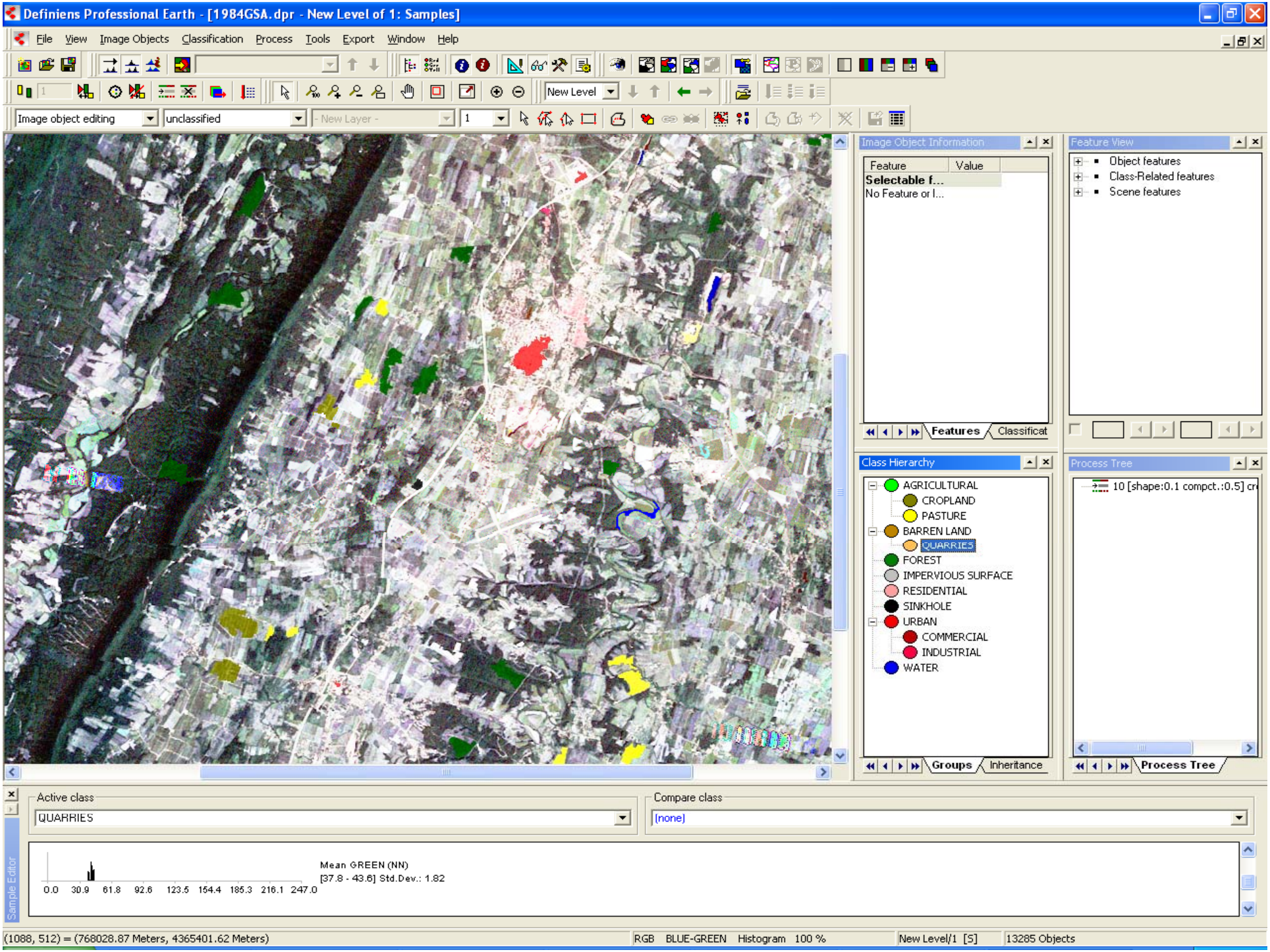


Scale Parameter (20)



Sampling Land Use/Land Cover Supervised Classification

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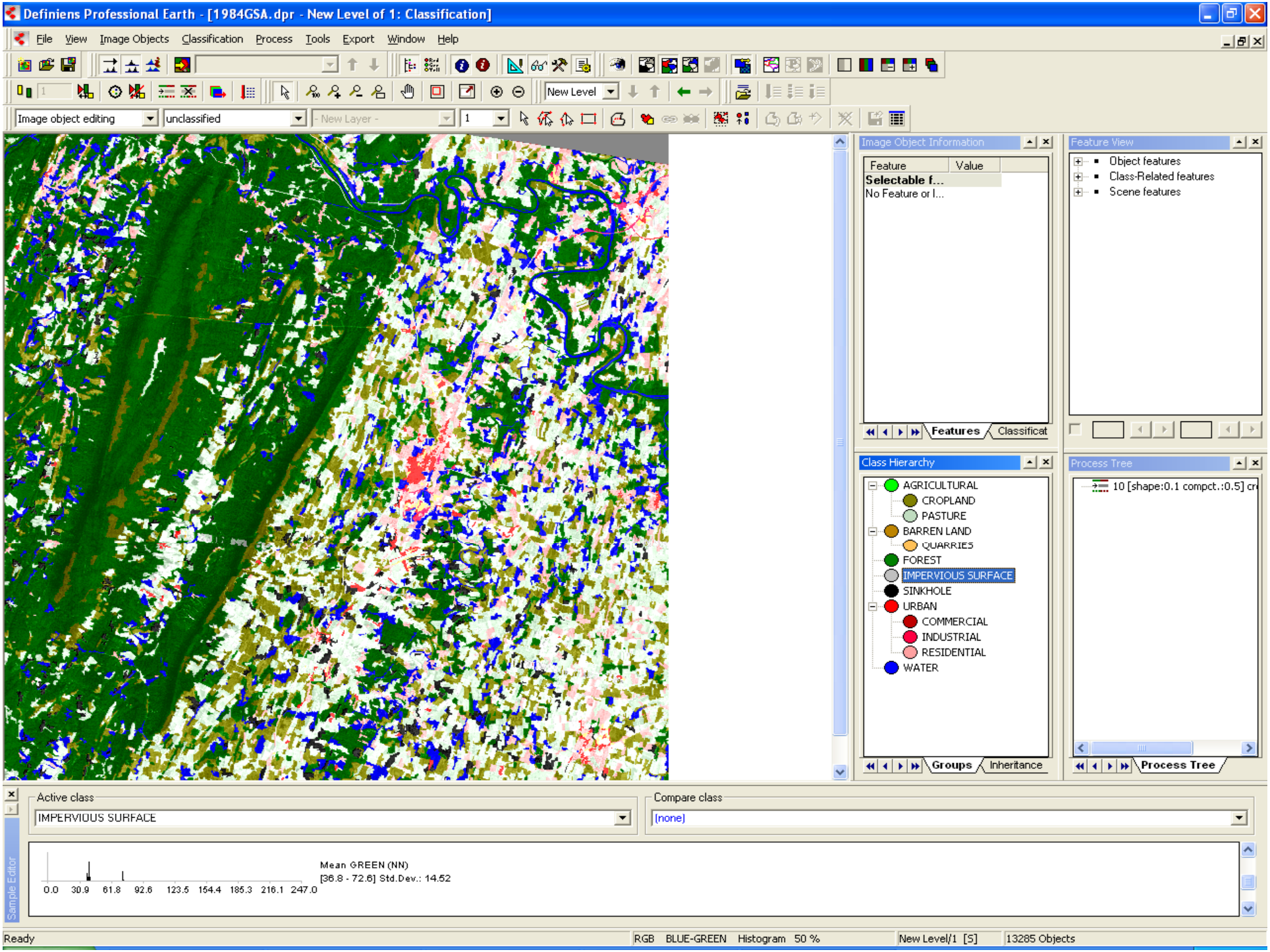
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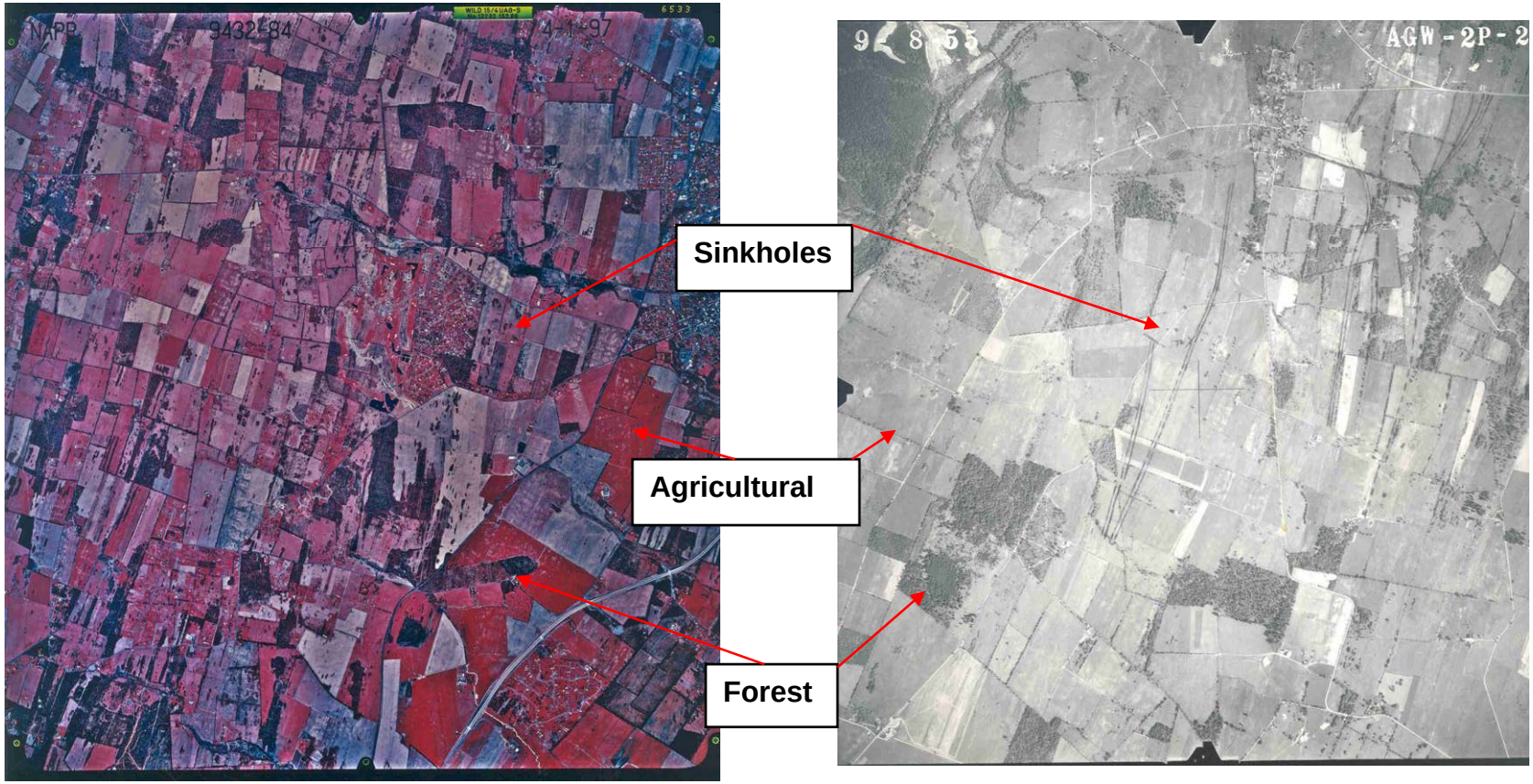
GRID COUNT OF SINKHOLES IN MIDDLEWAY NW QUARTER QUADRANGLE

↑N

1	8	23	7	0	14
10	11	9	1	0	20
13	12	5	2	0	11
8	16	9	2	1	10
9	7	11	1	11	4
5	5	16	6	5	15
5	8	8	15	9	12

0 1.5 3 6 Kilometers

Hard Copy Interpretation



GRID COUNTS VS. OBJECT-ORIENTED ANALYSIS

	Sinkhole Totals
Aerial Photo Grid Count	362
Topographic Grid Count	345
Object-Oriented Analysis	382
Accuracy of Aerial Photo vs. Topographic Count	95%
Accuracy of Image-Object Classification vs. Topographic Count	89%

CONCLUSION

- Results suggest that automated image-object analysis shows promise for being useful in spatial and contextual examinations of landscapes, especially sinkhole inventory
- More attainable financially for small organizations and municipalities than laser swath mapping or light detection and ranging methods
- Majority of the sinkholes incorrectly classified were agricultural objects of similar size, shape, and color, suggesting that the algorithm may have had some problems differentiating between objects with similar contextual information
- Difference may be attributable to the minimum mapping unit (40 foot contour interval) of the topographic quadrangle that failed to capture smaller features
- Aerial photograph grid count errors probably attributable to interpretation errors by analyst