OSM call for Applied Science Projects ï final report in response to solicitation (RFP61014)

A natural areas inventory report

and

A method for identifying critical wildlife habitats and outstanding natural areas by assessing vegetation through spatial analysis utilizing remote sensing and aerial survey data in combination with existing GIS coverages of ecological data.

Addresses Scope/special interest topics:

3.1.7 Vegetation Assessment

3.1.8 Wildlife conservation

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Natural Areas Inventory report

Introduction/Justification

This project will demonstrate a method for identifying critical wildlife habitats and significant natural areas by assessing vegetation through spatial analysis utilizing remote sensing and aerial survey data in combination with existing GIS coverages of ecological data. This will also enable quick assembly of relevant information including historic and recent records of rare species occurrences where habitat has been altered and is deemed unsuitable. Through the use of a tablet computer and mobile GIS during aerial surveys and ground-truthing, information will be entered into the Biotics (natural heritage information) database more directly than previously possible, and accordingly made available to permit reviewers in a timelier manner. This method should result in more precise ecological data than is currently available in Kentucky, which will aid permit reviewers in identifying those areas most likely to harbor rare species and critical habitats. Information resulting from these data will be used for the development of habitat models for federally listed species, such as Indiana bats. The proposed method will reduce time and moneys spent on surveys, while aiding in the identification and protection of critical natural resources

Study area

The study area includes three counties in Kentucky located within two different physiographic regions (Figure 1). Carter County is located in the Eastern Kentucky Coalfields, and characterized by the rugged topography of the Appalachian Plateaus. Important ecological features include habitat for endangered Indiana and gray bats, as well as extensive forest tracts that are habitat for many interior forest species, i.e. Cerulean warbler and black bear. Muhlenberg and McLean County are located within the western Kentucky coalfields in the Shawnee Hills, an area of rolling topography that has been intensively mined and is highly agricultural, but still contains important wildlife habitats, particularly associated with wetlands. All three counties contain known occurrences of rare species and natural communities, and encompass a wide geographic spread ensuring that the proposed methodology was tested in a variety of environments and will be applicable in a wide range of areas and ecological regions.

Methods

a) Preliminary data analysis/remote imagery analysis

An ArcView project was created in which currently available data for rare species and communities from the Kentucky Natural Heritage Program have been combined for preliminary landscape analysis (appendix I). These data include location information for rare species and wildlife habitats from the Biotics database. Biotics is a customized information management system designed to support the Natural Heritage methodology used by NatureServe and the network of Natural Heritage Programs and Conservation Data Centers. The Biotics database of the Kentucky Natural Heritage Program is the most comprehensive database for rare species and natural community information in Kentucky and contains data that have been collected by heritage biologists, as well as qualified biologists of numerous research institutions and other state and federal agencies over the past 30 years. Biotics is an Oracle database with an integrated GIS component.

Other relevant data sources consulted include vegetation data from the Kentucky GAP project (Kentucky Gap Analysis 2002), topography (Figures 2 and 3), geology (Figures 4, 5, and 6), soils, and physiographic regions (Figure 7). Large forest blocks (Evans et al. 2002) (Figures 8 and 9) were examined on aerial photos, but only included in a detailed natural areas inventory if aerial photo analysis indicated the possible presence of high quality communities, especially mature forest stands (refer to Imagery Interpretation, p. 8, in the 2nd half of this document for more info).

Current imagery, including National Agricultural Imagery Program (NAIP) (USDA FSA, 2004) color aerial photos and 1 m satellite imagery (Kentucky Office of Geographic Information. 1992-1999) was carefully analyzed to check the status of known occurrences and to identify new Potential Natural Areas (PNAs). Older aerial photos on file in county Property Value Administrator (PVA) and/or Natural Resources Conservation Service (NRCS) offices, were also analyzed for PNAs, because they tend to be of better quality than the more current photos and allow for identification of some natural features that do not show up on more current photos. They were also used to determine past land use of PNAs. PNAs identified included tracts of mature or old-growth forest, forested or open wetlands, such as bottomland hardwood forests, wet meadows or seeps, intact watersheds, natural openings and grasslands, rock outcrops and other unusual natural communities that are characterized by high biodiversity and provide habitat for wildlife including rare species, particularly in the vicinity of known occurrences.

b) Aerial surveys

While imagery interpretation is an efficient way to generate a preliminary list of PNAs, many important details needed for vegetation assessment can only be identified through aerial surveys and a mobile GIS.

All PNAs generated from analysis of the data sources discussed above were digitized as polygons into a shapefile in ArcView (Figures10 and 11). These sites, as well as known location of rare species occurrences and critical wildlife habitats, were surveyed by helicopter in March 2007. For the aerial surveys, the data were imported into XMap 4.5 and a flightplan was designed (Figures 12, 13, and 14)**.** This program is a powerful and scalable mapping software that was used in connection with DeLorme data and imagery sets. The mapping program was connected to a GPS allowing for easy tracking during the flight, and accurate location data recording. During aerial surveys of each PNA, data regarding ecological condition, structure, and composition were recorded. Any disturbance such as mining, logging, conversion to agriculture, grazing, changes in hydrology or water quality, development, roads, power lines, and presence of exotic species was noted.

PNAs that had been impacted so severely that natural area quality was much reduced were eliminated from the study. PNAs that had been misidentified based on earlier imagery interpretation were also eliminated from the study.

c) Ground Truthing

PNAs not eliminated during aerial surveys were ground checked by a qualified biologist. The time frame of this study allowed only for select site visits. PNAs for ground truthing were carefully chosen to include examples of a variety of vegetation types. During the site visits, detailed data regarding composition, structure, and signs of anthropogenic or natural disturbance was recorded.

Qualitative data for all sites that were ranked as ecologically significant, based on the standard ranking criteria developed by NatureServe (NatureServe, 2006), were transferred into the Biotics database and will be included in the data package provide to the permitting branch of the Department of Natural Resources. Information on eliminated sites is kept at the natural heritage program.

Results

Carter County

Carter County is located at the western edge of the Appalachian Plateaus which is characterized by hilly terrain (Figure 2). Its north western section is influenced by the calcareous substrates of the Knobs region (Figure 7). Prior to European settlement, the county was primarily forested (Figure 1B). Today, large tracts of forest persist, but much fragmentation and clearing has occurred, especially within the few larger floodplains, due to farming and mining (Figure 1A). Remote imagery analysis resulted in 38 PNAs (Figure 10, Table 1). They included numerous larger intact forest tracts (Figure 8), possible native grassland remnants in the eastern part of the county, and limestone cliff sections and riparian habitats associated with Tygarts Creek and its tributaries.

During aerial surveys in spring of 2007 13 PNAs were eliminated. Ground surveys were conducted of 13 PNAs. Three PNAs were determined to be significant in the county (Table 1, Figure 15). As a result of previous and current surveys 67 occurrences of 16 rare species and 2 natural communities are known from Carter County.

McLean County

McLean County, in the Shawnee Hills ecological region, used to have extensive, primarily forested wetlands (Figure 1B), but is now highly agricultural, and the hydrology of large parts has been drastically altered. Mining has also impacted large tracts, primarily in the southeastern section of the county. Only scattered remnants of lowland forest remain. (Figure 1A).

Remote imagery analysis resulted in 24 PNAs (Table 3, Figure 11). Large Forest Block data indicated that no larger tracts of forest remain in the county (Figure 9). Most PNAs (16) were small tracts of bottomland forest, flatwoods and other wetlands. These areas were targeted for further surveys because they could contain high quality remnants of natural communities, as well as rare plant and animals associated with aquatic and wetland habitats. PNAs also included six upland forest tracts. These small tracts were included because they represent the last remnants of upland forest habitat in the county. Eleven PNAs were eliminated during helicopter surveys. Primary reasons were recent logging and mining activities, altered hydrology, and land clearing.

Ground surveys were conducted of five PNAs. Of these, four were eliminated, three having been logged since the helicopter survey in spring and one because low ecological quality was not apparent during aerial surveys. As a result of the surveys, one PNA was determined to be county notable, but this site is currently in the process of being logged. As a result of previous and current surveys 21 occurrences of 18 rare species and two natural communities are known from McLean County (Figure 16).

Muhlenberg County

Muhlenberg County also used to be primarily forest covered, including a mix of upland forest primarily in the southern part of the county, and lowland forest in the northern half, and along stream corridors (Figure 1B). While much of the forest remains (Figure 9), fragmentation is high, primarily through agricultural and mining impacts. Muhlenberg County is one of the most extensively mined counties in Kentucky (Figure 1A), and much of the central section has been converted to artificial grasslands, plantations and impoundments. The hydrology of large parts has been drastically altered for agricultural use, flood control and mining. Remote imagery interpretation resulted in 57 PNAs, including upland and lowland forest tracts, open wetlands and a few possible native grassland patches.

Twenty-three PNAs were eliminated during helicopter surveys leaving 34 PNAs needing ground truthing (Table 2). Primary reasons for elimination were recent logging and mining activities, altered hydrology, and land clearing. 16 PNAs were visited on the ground. Of these, 12 were eliminated, either because logging occurred since the helicopter survey in spring, or because low ecological quality was not apparent during aerial surveys. Four PNAs were determined to be notable in the county. As a result of previous and current surveys, 61 occurrences of 44 rare species and 2 natural communities are known from Muhlenberg County (Figure 17).

A method for identifying critical wildlife habitats and outstanding natural areas by assessing vegetation through spatial analysis utilizing remote sensing and aerial survey data in combination with existing GIS coverages of ecological data.

Introduction

Natural resources agencies and organizations as well as private companies that extract and/or manage natural resources have much control over the welfare of rare species and natural areas. While they are faced with complex federal and state regulations, they also benefit from a growing body of knowledge regarding rare species and natural areas and increasingly sophisticated planning tools that enable proactive land-use planning.
The method for natural area inventory described below is an economically feasible way of identifying important elements of biodiversity within a larger survey area in a timely manner. Access to this data can reduce the potential of conflict; it helps streamline the permitting process, while avoiding impacting natural resources.

Remote Imagery Interpretation

Identification of natural areas and rare species occurrences used to be a matter of biologists combing the landscapes on foot, using limited resources, such as topographic maps and soil surveys, and sometimes aerial photos to guide them. New species occurrences or outstanding natural communities were often discovered by chance. Today, due to the availability of a wide range of aerial imagery, Geological Information System (GIS) coverages of abiotic and biotic land characteristics, and improved GPS technology, remote imagery analysis can significantly reduce this process while increasing the likelihood of identifying significant natural areas within a survey site. This process, however, still requires an intimate understanding of the landscapes and species involved, as well as of the limitations of the imagery used. After assembling applicable GIS coverages, a shapefile is created for digitizing potential natural area (PNA) polygons. Features that may be targeted include tracts of mature or old-growth forest, forested or open wetlands, such as bottomland hardwood forests, wet meadows, or seeps, intact watersheds, natural openings and grasslands, rock outcrops and other unusual natural communities that are characterized by high or unique biodiversity and might provide habitat for rare species. These features can be identified by creating overlays of different coverages, and careful imagery interpretation.

The following section includes descriptions of a variety of available coverages and an evaluation of their utility for natural area identification. While all of these are specifically for Kentucky, similar versions of most are available in other states as well. However, at this time, Kentucky is fortunate to have one of the most complete and detailed statewide GIS databases in the eastern United States, and not all of the GIS coverages discussed below are available in other states.

Natural heritage data:

Natural heritage data are maintained by natural heritage programs within each state. NatureServe, the umbrella organization for natural heritage programs in this country, has developed Biotics, the current data tracking system for natural heritage data. Biotics is a customized information management system designed to support the Natural Heritage methodology used by NatureServe and the network of Natural Heritage Programs and Conservation Data Centers. Biotics provides the most reliable natural heritage information available in most states. Biotics data can usually be provided by natural heritage programs with a GIS coverage containing point, line and polygon records.

Natural heritage data can be very useful, if used in connection with other coverages, for developing search criteria of suitable habitat of rare species or ecological communities as part of predictive modeling. However, due to the complexness of this relational data system, information has to be analyzed very carefully. Quality and completeness of natural heritage data will vary from state to state, and negative information is usually not included in the data base. Natural heritage biologists can be a valuable resource for interpreting existing heritage data, and making recommendations for target species and communities.

Topographic maps: These provide very important data for predicting PNAs, including information on slope, aspect, hydrology, land cover (i.e open vs. forested) and land use (i.e. mined areas, development). Overlaying clear topographic maps with other coverages is especially useful for identifying PNAs and analyzing natural are quality (Figure 18, 19, 20, 21, 23).

Aerial black and white photos: High quality black-and-white leaf-on photos are useful for PNA identification because they depict several features that are not identifiable on other imagery, especially information on forest quality, such as crown size, forest structure, canopy closure, and they allow for easy distinction between evergreen and deciduous trees (Figures 18, 22). In Kentucky, these aerial photos are usually older, and are therefore not reliable indicators for current conditions. However, they are useful for preliminary PNA identification and provide important information regarding past land use. Leaf-off aerial photos (Kentucky Office of Geographic Information 1992-1999) are equally important for different reasons. While forest age and characteristics are often difficult to judge, other features stand out better than on leaf-on photos. These include different types of disturbance, such as roads and mining (Figure 21C), but also natural features such as cliff-lines and rock outcrops (Figure 22), wetlands, and small scale natural communities, such as bogs, glades and woodlands (Figure 18). They are also very useful for distinguishing evergreen from deciduous trees (Figure 1).

Leaf-on color photos (1 m resolution 2004 National Agricultural Imagery Program): These are the most current aerial photos available that provide information regarding current land use and conditions. However, resolution and clarity are not as good as that of some older photos, which limits their use for analyzing forest quality and composition. Many important features are difficult to pick out on these images, including roads, woodlands and glades, as well as stands of evergreen trees (Figures 18 and 22). On the other hand, NAIP imagery is the only imagery that shows crown size (Figures 22 and 24) and due to the contrast in color, allows for fairly easy distinction between native warm-season grasslands and cool-season dominated areas (Figure 25). Logging operations generally also show up well on leaf-on photos (Figure 26). In Kentucky 1 ft resolution color aerial photo imagery is available for select areas in the state (primarily urban areas).

Geology: A statewide GIS coverage of the generalized geology is available in Kentucky, and of some use, such as to identify limestone and sandstone outcrops that are associated with potential habitat of several rare species (Figures 4 and 5). However, imagery of scanned geological quad maps are significantly more detailed (a digitized version of the geological quad maps is scheduled for publication in summer 2007) and yields information not only regarding the underlying geology, but also land use, especially mining (Figure 6).

Soils: Soil data can be a useful component for remotely identifying potential locations of natural communities. However, digitized soil maps are not yet available for many areas at a scale useful for natural areas inventory. County soil surveys are often a more reliable source for soil information than generalized digitized versions. Also, another advantage of the printed versions is that metadata are readily available. Most county soil surveys focused their effort on agricultural areas. Soil data for undeveloped areas, where natural area remnants are more likely to occur, are often less detailed and precise.

Large Forest Blocks: The Kentucky Large Forest Block Project was initiated to address a lack of information on the location and quantity of large tracts of forest remaining in Kentucky. Large forest blocks were identified using GIS modeling techniques. A minimum accepted size for a forest block was defined as 1,000 acres. Statewide road data were utilized to identify roadless areas that met the acreage requirements. An overlay analysis was performed using the roadless layer and GAP Analysis Program land cover data to identify large roadless areas that were forested. Because of the ecological significance of large forest blocks, they were included as PNAs in this study. Large forest blocks provide critical habitat for many interior species, and a natural buffer for exotic species (for examples see Figures 4 and 5).

GAP and KLS vegetation map: As part of the Gap project (Kentucky GAP analysis program, 2002) and Kentucky Landscape Snapshot (Lambert et al. 2002), vegetation maps were produced that show existing natural and semi-natural vegetation of terrestrial ecosystems throughout the state as a tool for conservation planning and biodiversity protection. Kentucky Gap is using two primary sources for modeling purposes. The first is the spectral classification derived from the Thematic Mapper data. The second source is digital elevation models, which provide information on topographic variables that influence the distribution of vegetation. From the digital elevation model information regarding slope, aspect, and concavity-convexity was derived. However, vegetation maps derived solely from remotely sensed data can have serious drawbacks since frequently spectral variations in the data do not correspond to different vegetation types directly. In most instances, additional information needs to be included before a reliable vegetation map can be produced.

We found that these coverages are only of limited utility for natural area identification, due to their low resolution and large pixel size (30m x 30m). Consequently, small communities, such as bogs or glades do not show up, and native warm season grasslands, for example, are not distinguishable from cool season exotics. The Gap vegetation coverage was designed for analysis on a regional rather than local scale and should be used with caution.

Examples of Remote Imagery Identification

The following section demonstrates with examples how imagery interpretation can be used to identify different types of natural areas and evaluate natural area quality.

Forests

Analysis of significant forest tracts should involve three major factors: forest quality, size and landscape context. These are the factors that NatureServe uses to rank natural areas. Forest quality is primarily determined by a combination of forest maturity, structural and species diversity, lack of disturbance and of exotic species. Aerial photos, in Kentucky especially the 2004 NAIP color imagery, can be helpful for identifying large crowns and intact canopy cover (Figures 19, 22, and 27) and logging operations (Figure 26). Other features are often more easily identifiable on black and white leaf-off photos. These include trails and roads, drill sites, and mining scars, pipeline and powerline corridors, plantation type plantings, as well as signs of livestock grazing. They are also useful to distinguish evergreen from deciduous trees (Figures 18 and 22). Because forest quality is strongly influenced by historical land use, analysis of historic photos, and older topographic maps is advisable (Figure 20). While mined areas are often evident from the air (Figures 21A, B, and C) this is not always the case (Figure 21D). It is therefore critical to consult GIS coverages that provide data for past and present mining activities. Some past mining activities are only evident during a ground visit.

Many forest types are strongly linked to specific landscape positions and other physiognomic characteristics. It is often possible to predict the occurrence and distribution of forest types through the interpretation of remote imagery overlaid with clear topographic maps and other appropriate GIS coverages (Figure 28)

Larger, contiguous forest blocks are ecologically significant, because they offer habitat to species associated with forest interiors, and they have a higher resilience to exotic species. They are also important for the protection of aquatic resources. Aerial photos can easily be used to identify larger forested areas, and in Kentucky, the large forest block coverage produced by the Kentucky Large Forest Block Project is a useful resource. It is important to consider how much contiguous forest occurs within the survey area, and which rare or sensitive species depend on larger forest blocks in this area, to determine the relative importance of a forest block within a given region (Figures 8, 9, and 20).

These questions can be answered by analyzing natural heritage data and overlaying the large forest block coverage with NAIP imagery. However, significant looking tracts should be surveyed by helicopter to check for recent disturbances, especially those causing fragmentation.

Landscape context is another important factor influencing the ecological significance of a forest tract. Forested tracts imbedded in a forested matrix are less susceptible to invasion by exotic species and loss of biodiversity than forest tracts surrounded by agricultural or developed areas, and especially down-slope or downstream from such areas. Isolated forest stands are also more susceptible to wind-throw and loss of species than forest tracts surrounded by forest (Figure 27). But even stands that appear intact can be severely impacted by exotic species (Figure 29). It is therefore imperative that all sites not eliminated during aerial surveys are visited on the ground to confirm ecological intactness.

Within a given survey area, special attention should be paid to potentially occurring rare forest types. In Kentucky, examples include bottomland hardwood forest (Figure 19 and 31) and Cumberland Highlands forest (Figure 32). Any occurrence of a globally rare forest type should be considered significant.

While remote imagery analysis is very useful for creating a preliminary list of PNAs, additional critical features can only be identified during aerial surveys, especially during the spring. These include signs of recent logging, species composition (Figure 33), bole size, and presence of certain exotics (Figure 30).

Grasslands

Most of the original prairie in Kentucky and surrounding states has been converted to agriculture. Existing remnants are usually small, widely scattered, and often do not stand out on aerial photos. For these reasons, it can be very challenging to identify native grassland remnants remotely. During spring, after cool season grasses turn green, the color contrast to the still dormant warm season grasses serves as a useful tool for detecting native grasslands (Figure 25). While it is impossible to judge quality remotely, several factors can be used to quantify it to some degree. Native grassland patches can occur in most regions. However, high quality remnants are usually located within the historic range of native prairie. Historic land use is another factor influencing grassland quality. Analysis of historic photos can reveal if an area has been extensively grazed or used agriculturally. While some grazed areas can be dominated by prairie vegetation, diversity is nearly always low. However, high quality sites can sometimes look like regular hayfields or pasture, and low quality sites might look promising from the air (Figure 34A). To make a determination on quality, a site visit is usually required. Historic photos can also reveal if an area has been continuously open, or has been cleared fairly recently, in which case diversity would likely be low.

Glades/woodlands

Glades and dry woodlands are somewhat easier to locate, because they are bound to specific site conditions. They are usually located on south and southwest facing slopes, associated with natural rock outcrops, thin soil, and often characterized by the presence of scattered evergreens.

These features are fairly easily distinguishable on leaf-off black and white aerial photos. If much canopy is present, as is the case in some woodlands, they might be impossible to see on color, leaf-on photos. Aerial photos should be over-laid with clear topographic maps to identify likely occurrences. Another character to look for is an irregular shape, which distinguish natural, minimally disturbed from anthropogenic openings (Figures 34b and c). Aerial photos can also reveal serious erosion problems and the presence of trails which can greatly impact diversity (Figure 35). Not all glades, however, share the characteristics described above. Flat rock glades are located on level ground, and are characterized by extensive bare rock outcrops that usually show up as bright white or light colored areas (Figure 36). It is important to keep in mind that many degraded glades look intact from the air, and that ground surveys are required to determine ecological quality.

Woodlands are among the most difficult natural communities to identify remotely. Even though woodland canopy closure, by definition, is significantly lower than that of forests (50-75% vs. 75-100%), this difference is often not apparent remotely. Instead, some dry woodlands can easier be identified on black and white photos, due to the frequent presence of evergreens (Figure 18).

Natural mesic woodlands are difficult to distinguish from anthropogenic communities. Bluegrass Savanna woodlands, in central Kentucky, for example, are virtually indistinguishable from thinned forests (Figure 24).

Wetlands

In Kentucky the majority of wetlands were located in the Jackson Purchase and Shawnee Hills regions. Since European settlement about 90% have been cleared, drained, converted to agricultural uses or destroyed by mining. Intact wetlands are characterized by undisturbed hydrology, lack of trails, grazing and exotics, and good water quality. Forested wetlands should have mature trees, a high structural and species diversity, and an intact understory and herb layer.

Especially significant are those stands that are also large in size and unfragmented. Most wetlands are easy to identify by overlaying aerial photos with clear topographic maps (Figures 19, 37).

Many features indicating disturbance in hydrology can be seen on topographic or geological maps. These include mining, dams, drainage ditches, and ponded areas (Figure 6). Other features such as recent clearing or logging, and to some extend water quality, if extensive sedimentation or discoloration occurs can be picked out on colored aerial photos. Some infestations of exotic plants can also be detected remotely (Figure 37). Smaller wetlands, such as seeps and marshes are more difficult to detect. Potential locations can be selected on topographic maps (Figures 23,and 38), and followed up by flying in spring. It is important to remember that some wetlands are seasonal (i.e. sinkhole ponds) and easily overlooked when dry, while others, such as seeps, are often impossible to detect from the air after trees leaf out.

Aerial surveys

While imagery interpretation is an efficient way to generate a preliminary list of PNAs, many important details for vegetation assessment can only be generated through the use of a helicopter and a mobile GIS.

All PNAs generated from analysis of the data sources discussed above should be digitized as polygons into a shapefile in ArcView. These sites, as well as any known location of rare species occurrences and critical wildlife habitats, should be surveyed by helicopter. For the aerial surveys, the data are imported into XMap 4.5 or similar program. This program is a powerful and scalable mapping software that can be used in connection with DeLorme data and imagery sets. In XMap a flight plan can be developed for a time efficient route (Figures 12, 13, and 14). The mapping program can be connected to a Delorme GPS, allowing for easy tracking during the flight, and accurate location data recording.

During aerial surveys of each PNA, data regarding ecological intactness, structure, and composition should be recorded. Note any indication of disturbance such as mining, logging, conversion to agriculture, grazing, changes in hydrology or water quality, development, roads, power lines, and presence of exotic species. Photographs should also be taken of each site. Before surveying new sites, it is always a good idea to fly over examples of known high quality sites to help calibrate the surveyors and help develop search images.

Spring is usually the best season for conducting aerial surveys because many important natural features are easiest identifiable early in the year. Trees are starting to leaf out, often allowing identification to genus, sometimes species, but, because leaves havenât matured, it is still possible to collect data on stand maturity and structure, as well as disturbance (Figures 27 and 33). Certain small scale natural communities can also be picked out easiest during spring. These include seeps and bogs, seasonal ponds and springs, as well as small glades and rock outcrops which will later in the season be hidden by canopy.

Also, some exotic species such as bush honeysuckle (*Lonicera makii*) show up well during early spring flights, because they green up before most native species (Figure 30). Cool season grasses are greening up, whereas warms season grasses are still dormant resulting in a stark color contrast which aids in the identification of native grasslands.

However, the best time for identifying native grasslands is late summer or fall when many prairie forbs flower.

Aerial surveys are also an efficient way to survey communities that are difficult to access, such as wetlands (Figures 31 and 37) and to identify disturbances in hydrology (Figure 21C).

Ground surveys

Remote imagery interpretation and aerial surveys help to shorten the natural area inventory process, especially by assisting in identifying impacted sites, but remaining sites usually have to be ground-truthed to determine natural area quality, because many impacts are not apparent remotely. Also, development and other means of destruction of natural areas, such as mining and logging, occur at a rapid pace in some areas. Consequently, available imagery might not reflect recent impacts.

Data collected during ground surveys should include information regarding composition, vegetation structure, any signs of impacts and disturbances, as well as landowner information and indications of possible future impacts to a site. These data should be entered into a geo-spatial database, so that the information will be available for landscape-wide planning for natural resource protection. Data regarding rare species and high quality natural communities should be forwarded to the appropriate natural heritage program where they will be entered into the Biotics database.

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U.S. Geological Survey Geologic Quadrangle Map Series. The product of joint project of the U.S. Geological Survey and Kentucky Geological Survey from 1960-1978. Scale 1:24,000 7.5 minute Quadrangles.

Appendix I

Report of Endangered, Threatened, and Special Concern Plants, Animals, and Natural Communities for Carter, McLean, and Muhlenberg Counties, Kentucky

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Kentucky State Nature Preserves Commission
Key for County List Report

Within a county, elements are arranged first by taxonomic complexity (plants first, natural communities last), and second by scientific name. A key to status, ranks, and count data fields follows.

STATUS

KSNPC: Kentucky State Nature Preserves Commission status:
N or blank = none   E = endangered   T = threatened   S = special concern   H = historic   X = extirpated

USESA: U.S. Fish and Wildlife Service status:
blank = none   C = candidate   LT = listed as threatened   LE = listed as endangered
SOMC = Species of Management Concern

RANKS

GRANK: Estimate of element abundance on a global scale:

G1 = Critically imperiled	GU = Unrankable
G2 = Imperiled	G#? = Inexact rank (e.g. G2?)
G3 = Vulnerable	G#Q = Questionable taxonomy
G4 = Apparently secure	G#T# = Infraspecific taxa (Subspecies and variety abundances are coded with a 'T' suffix; the 'G' portion of the rank then refers to the entire species)
G5 = Secure	
GH = Historic, possibly extinct	GNR = Unranked
GX = Presumed extinct	GNA = Not applicable

SRANK: Estimate of element abundance in Kentucky:

S1 = Critically imperiled	SU = Unrankable	Migratory species may have separate ranks for different population segments (e.g. S1B, S2N, S4M):
S2 = Imperiled	S#? = Inexact rank (e.g. G2?)	
S3 = Vulnerable	S#Q = Questionable taxonomy	S#B = Rank of breeding population
S4 = Apparently secure	S#T# = Infraspecific taxa	S#N = Rank of non-breeding population
S5 = Secure	SNR = Unranked	S#M = Rank of transient population
SH = Historic, possibly extirpated	SNA = Not applicable	
SX = Presumed extirpated		

COUNT DATA FIELDS

OF OCCURRENCES: Number of occurrences of a particular element from a county. Column headings are as follows:
E - currently reported from the county
H - reported from the county but not seen for at least 20 years
F - reported from county & cannot be relocated but for which further inventory is needed
X - known to have extirpated from the county
U - reported from a county but cannot be mapped to a quadrangle or exact location.

The data from which the county report is generated is continually updated. The date on which the report was created is in the report footer. Contact KSNPC for a current copy of the report.

Please note that the quantity and quality of data collected by the Kentucky Natural Heritage Program are dependent on the research and observations of many individuals and organizations. In most cases, this information is not the result of comprehensive or site-specific field surveys; many natural areas in Kentucky have never been thoroughly surveyed, and new species of plants and animals are still being discovered. For these reasons, the Kentucky Natural Heritage Program cannot provide a definitive statement on the presence, absence, or condition of biological elements in any part of Kentucky. Heritage reports summarize the existing information known to the Kentucky Natural Heritage Program at the time of the request regarding the biological elements or locations in question. They should never be regarded as final statements on the elements or areas being considered, nor should they be substituted for on-site surveys required for environmental assessments.

KSNPC appreciates the submission of any endangered species data for Kentucky from field observations. For information on data reporting or other data services provided by KSNPC, please contact the Data Manager at:

Kentucky State Nature Preserves Commission
801 Schenkel Lane
Frankfort, KY 40601
(502) 573-2886 (phone)
(502) 573-2355 (fax)
email: naturepreserves@ky.gov
internet: www.naturepreserves.ky.gov

County	Taxonomic Group	Scientific name	Common name	Statuses	Ranks	# of Occurrences E	H	F	X	U
Carter	Vascular Plants	*Acer spicatum*	Mountain Maple	E /	G5 / S1S2	1	0	0	0	0
Carter	Vascular Plants	*Calopogon tuberosus*	Grass Pink	E /	G5 / S1	0	1	0	0	0
Carter	Vascular Plants	*Carex rugosperma*	Umbel-like Sedge	T /	G5 / S2?	1	0	0	0	0
Carter	Vascular Plants	*Castilleja coccinea*	Scarlet Indian Paintbrush	E /	G5 / S1	0	0	1	0	0
Carter	Vascular Plants	*Cypripedium kentuckiense*	Kentucky Lady's-slipper	E / SOMC	G3 / S1S2	0	1	0	0	0
Carter	Vascular Plants	*Cypripedium parviflorum*	Small Yellow Lady's-slipper	T /	G5 / S2	1	0	0	0	0
Carter	Vascular Plants	*Dodecatheon frenchii*	French's Shooting Star	S /	G3 / S3	1	0	0	0	0
Carter	Vascular Plants	*Erythronium rostratum*	Yellow Troutlily	S /	G5 / S2S3	1	0	0	0	0
Carter	Vascular Plants	*Juglans cinerea*	White Walnut	S / SOMC	G3G4 / S3	2	0	0	0	0
Carter	Vascular Plants	*Lathyrus palustris*	Vetchling Peavine	T /	G5 / S2	1	0	0	0	0
Carter	Vascular Plants	*Lilium philadelphicum*	Wood Lily	T /	G5 / S2S3	1	0	0	0	0
Carter	Vascular Plants	*Lonicera dioica var. orientalis*	Wild Honeysuckle	E /	G5TNRQ / S1	1	0	0	0	0
Carter	Vascular Plants	*Maianthemum stellatum*	Starflower False Solomon's-seal	E /	G5 / S1	1	0	0	0	0
Carter	Vascular Plants	*Najas gracillima*	Thread-like Naiad	S /	G5? / S2S3	0	1	0	0	0
Carter	Vascular Plants	*Paxistima canbyi*	Canby's Mountain-lover	T / SOMC	G2 / S2	5	0	1	0	0
Carter	Vascular Plants	*Spiranthes ochroleuca*	Yellow Nodding Ladies'-tresses	T /	G4 / S2?	0	1	0	0	0
Carter	Vascular Plants	*Taxus canadensis*	Canadian Yew	T /	G5 / S2S3	2	0	0	0	0
Carter	Vascular Plants	*Thaspium pinnatifidum*	Cutleaf Meadow-parsnip	T / SOMC	G2G3 / S2S3	4	1	0	0	0
Carter	Vascular Plants	*Toxicodendron vernix*	Poison Sumac	E /	G5 / S1	1	0	0	0	0
Carter	Vascular Plants	*Viola walteri*	Walter's Violet	T /	G4G5 / S2	6	0	0	0	0
Carter	Terrestrial Snails	*Glyphyalinia raderi*	Maryland Glyph	S / SOMC	G2 / S1	0	0	0	0	1
Carter	Freshwater Mussels	*Cyprogenia stegaria*	Fanshell	E / LE	G1 / S1	0	1	0	0	0
Carter	Freshwater Mussels	*Epioblasma triquetra*	Snuffbox	E / SOMC	G3 / S1	2	2	0	0	0
Carter	Freshwater Mussels	*Lasmigona compressa*	Creek Heelsplitter	E /	G5 / S1	4	2	0	0	0
Carter	Freshwater Mussels	*Simpsonaias ambigua*	Salamander Mussel	T / SOMC	G3 / S2S3	0	4	1	0	0
Carter	Freshwater Mussels	*Villosa lienosa*	Little Spectaclecase	S /	G5 / S3S4	1	3	0	0	0
Carter	Insects	*Calopteryx dimidiata*	Sparkling Jewelwing	E /	G5 / S1	1	0	0	0	0

County	Taxonomic Group	Scientific name	Common name	Statuses	Ranks	# of Occurrences E	H	F	X	U
Carter	Insects	*Manophylax butleri*	A Limnephilid Caddisfly	S /	G2 / S2	1	0	0	0	0
Carter	Insects	*Ophiogomphus howei*	Pygmy Snaketail	T / SOMC	G3 / S1S2	1	1	0	0	0
Carter	Other Invertebrates	*Hesperonemastoma inops*	A Cave Obligate Harvestman	S /	G1G2 / S1S2	0	1	0	0	0
Carter	Other Invertebrates	*Macrocheles stygius*	A Cave Obligate Mite	T /	G1G2 / S1S2	0	1	0	0	0
Carter	Other Invertebrates	*Pseudotremia carterensis*	A Cave Obligate Milliped	S /	G2G3 / S1S2	0	3	0	0	0
Carter	Fishes	*Ichthyomyzon fossor*	Northern Brook Lamprey	T /	G4 / S2	2	2	0	0	0
Carter	Fishes	*Lampetra appendix*	American Brook Lamprey	T /	G4 / S2	0	1	0	0	0
Carter	Fishes	*Percopsis omiscomaycus*	Trout-perch	S / SOMC	G5 / S3	13	3	0	0	0
Carter	Amphibians	*Cryptobranchus alleganiensis alleganiensis*	Eastern Hellbender	S / SOMC	G3G4T3T4 / S3	0	1	0	0	0
Carter	Breeding Birds	*Ammodramus henslowii*	Henslow's Sparrow	S / SOMC	G4 / S3B	1	0	0	0	0
Carter	Breeding Birds	*Pooecetes gramineus*	Vesper Sparrow	E /	G5 / S1B	0	1	0	0	0
Carter	Mammals	*Corynorhinus rafinesquii*	Rafinesque's Big-eared Bat	S / SOMC	G3G4 / S3	1	0	0	0	0
Carter	Mammals	*Mustela nivalis*	Least Weasel	S /	G5 / S2S3	1	0	0	0	0
Carter	Mammals	*Myotis grisescens*	Gray Myotis	T / LE	G3 / S2	1	1	0	0	0
Carter	Mammals	*Myotis leibii*	Eastern Small-footed Myotis	T / SOMC	G3 / S2	1	0	0	0	0
Carter	Mammals	*Myotis sodalis*	Indiana Bat	E / LE	G2 / S1S2	6	0	0	0	0
Carter	Communities	*Pine savanna-woodland*		/	GNR / S1	1	0	0	0	0
Carter	Communities	*Virginia pine forest*		/	GNR / S5	1	0	0	0	0
Carter County Total:						**67**	**32**	**3**	**0**	**1**

County	Taxonomic Group	Scientific name	Common name	Statuses	Ranks	# of Occurrences E	H	F	X	U
Mclean	Vascular Plants	*Amsonia tabernaemontana var. gattingeri*	Eastern Blue-star	E /	G5T3Q / S2?	0	0	1	0	0
Mclean	Vascular Plants	*Carya aquatica*	Water Hickory	T /	G5 / S2S3	1	0	0	0	0
Mclean	Vascular Plants	*Chelone obliqua var. speciosa*	Rose Turtlehead	S /	G4T3 / S3	0	1	0	0	0
Mclean	Vascular Plants	*Limnobium spongia*	American Frog's-bit	T /	G4 / S2S3	0	1	0	0	0
Mclean	Vascular Plants	*Maianthemum stellatum*	Starflower False Solomon's-seal	E /	G5 / S1	0	1	0	0	0
Mclean	Vascular Plants	*Muhlenbergia glabrifloris*	Hair Grass	S /	G4? / S2S3	0	1	0	0	0
Mclean	Vascular Plants	*Ptilimnium costatum*	Eastern Mock Bishop's-weed	H /	G3G4 / SH	0	2	0	0	0
Mclean	Vascular Plants	*Ptilimnium nuttallii*	Nuttall's Mock Bishop's-weed	E /	G5? / S1S2	1	0	0	0	0
Mclean	Vascular Plants	*Trepocarpus aethusae*	Trepocarpus	S /	G4G5 / S3	2	0	0	0	0
Mclean	Freshwater Mussels	*Lampsilis ovata*	Pocketbook	E /	G5 / S1	0	1	0	0	0
Mclean	Freshwater Mussels	*Villosa lienosa*	Little Spectaclecase	S /	G5 / S3S4	0	1	0	0	0
Mclean	Fishes	*Erimyzon sucetta*	Lake Chubsucker	T /	G5 / S2	0	1	0	0	0
Mclean	Fishes	*Hybopsis amnis*	Pallid Shiner	E / SOMC	G4 / S1	0	1	0	0	0
Mclean	Amphibians	*Hyla avivoca*	Bird-voiced Treefrog	S /	G5 / S3	1	0	0	0	0
Mclean	Reptiles	*Clonophis kirtlandii*	Kirtland's Snake	T / SOMC	G2 / S2	1	0	0	0	0
Mclean	Reptiles	*Nerodia erythrogaster neglecta*	Copperbelly Water Snake	S / SOMC	G5T2T3 / S3	5	0	0	0	0
Mclean	Reptiles	*Thamnophis sauritus sauritus*	Eastern Ribbon Snake	S /	G5T5 / S3	2	0	0	0	0
Mclean	Breeding Birds	*Botaurus lentiginosus*	American Bittern	H /	G4 / SHB	0	1	0	0	0
Mclean	Breeding Birds	*Circus cyaneus*	Northern Harrier	T /	G5 / S1S2B,S4N	2	0	0	0	0
Mclean	Breeding Birds	*Corvus ossifragus*	Fish Crow	S /	G5 / S3B	1	0	0	0	0
Mclean	Mammals	*Nycticeius humeralis*	Evening Bat	S /	G5 / S3	0	1	0	0	0
Mclean	Communities	*Bottomland hardwood forest*		/	GNR / S2	2	0	0	1	0
Mclean	Communities	*Xerohydric flatwoods*		/	GNR / S1S2	0	0	0	1	0
Mclean County Total:						**18**	**12**	**1**	**2**	**0**

County	Taxonomic Group	Scientific name	Common name	Statuses	Ranks	# of Occurrences E	H	F	X	U
Muhlenberg	Vascular Plants	*Amsonia tabernaemontana var. gattingeri*	Eastern Blue-star	E /	G5T3Q / S2?	1	0	0	0	0
Muhlenberg	Vascular Plants	*Carya aquatica*	Water Hickory	T /	G5 / S2S3	1	1	0	0	0
Muhlenberg	Vascular Plants	*Chelone obliqua var. speciosa*	Rose Turtlehead	S /	G4T3 / S3	1	0	0	0	0
Muhlenberg	Vascular Plants	*Didiplis diandra*	Water-purslane	S /	G5 / S2S3	1	0	0	0	0
Muhlenberg	Vascular Plants	*Dodecatheon frenchii*	French's Shooting Star	S /	G3 / S3	1	0	0	0	0
Muhlenberg	Vascular Plants	*Muhlenbergia glabrifloris*	Hair Grass	S /	G4? / S2S3	1	0	0	0	0
Muhlenberg	Vascular Plants	*Trepocarpus aethusae*	Trepocarpus	S /	G4G5 / S3	1	0	0	0	0
Muhlenberg	Vascular Plants	*Trifolium reflexum*	Buffalo Clover	E /	G3G4 / S1S2	0	1	0	0	0
Muhlenberg	Vascular Plants	*Zizaniopsis miliacea*	Southern Wild Rice	T /	G5 / S1S2	2	1	0	0	0
Muhlenberg	Freshwater Mussels	*Cyprogenia stegaria*	Fanshell	E / LE	G1 / S1	2	1	0	0	0
Muhlenberg	Freshwater Mussels	*Epioblasma obliquata obliquata*	Catspaw	E / LE	G1T1 / S1	0	1	0	0	0
Muhlenberg	Freshwater Mussels	*Lampsilis ovata*	Pocketbook	E /	G5 / S1	0	1	0	0	0
Muhlenberg	Freshwater Mussels	*Pleurobema rubrum*	Pyramid Pigtoe	E / SOMC	G2 / S1	2	1	0	0	0
Muhlenberg	Freshwater Mussels	*Toxolasma lividus*	Purple Lilliput	E / SOMC	G2 / S1	0	1	0	0	0
Muhlenberg	Freshwater Mussels	*Villosa lienosa*	Little Spectaclecase	S /	G5 / S3S4	2	2	1	0	0
Muhlenberg	Crustaceans	*Orconectes ronaldi*	A Crayfish	N /	G3 / S2S3	1	0	0	0	0
Muhlenberg	Insects	*Poanes viator*	Broad-winged Skipper	T /	G5 / S1S2	1	0	0	0	0
Muhlenberg	Insects	*Stylurus notatus*	Elusive Clubtail	E / SOMC	G3 / S1	0	0	0	0	1
Muhlenberg	Fishes	*Erimyzon sucetta*	Lake Chubsucker	T /	G5 / S2	0	2	0	0	0
Muhlenberg	Fishes	*Hybopsis amnis*	Pallid Shiner	E / SOMC	G4 / S1	0	1	0	0	0
Muhlenberg	Fishes	*Ichthyomyzon castaneus*	Chestnut Lamprey	S /	G4 / S2	0	1	0	0	0
Muhlenberg	Fishes	*Lepomis miniatus*	Redspotted Sunfish	T /	G5 / S2	5	0	0	0	0
Muhlenberg	Amphibians	*Cryptobranchus alleganiensis alleganiensis*	Eastern Hellbender	S / SOMC	G3G4T3T4 / S3	1	0	0	0	0
Muhlenberg	Amphibians	*Hyla avivoca*	Bird-voiced Treefrog	S /	G5 / S3	2	0	0	0	0
Muhlenberg	Amphibians	*Hyla cinerea*	Green Treefrog	S /	G5 / S3	1	0	0	0	0
Muhlenberg	Reptiles	*Nerodia erythrogaster neglecta*	Copperbelly Water Snake	S / SOMC	G5T2T3 / S3	5	1	0	1	0
Muhlenberg	Reptiles	*Thamnophis sauritus sauritus*	Eastern Ribbon Snake	S /	G5T5 / S3	4	0	0	0	0

County	Taxonomic Group	Scientific name	Common name	Statuses	Ranks	# of Occurrences E	H	F	X	U
Muhlenberg	Breeding Birds	*Ammodramus henslowii*	Henslow's Sparrow	S / SOMC	G4 / S3B	3	0	0	0	0
Muhlenberg	Breeding Birds	*Ardea alba*	Great Egret	E /	G5 / S1B	1	0	0	0	0
Muhlenberg	Breeding Birds	*Asio flammeus*	Short-eared Owl	E /	G5 / S1B,S2N	1	0	0	0	0
Muhlenberg	Breeding Birds	*Asio otus*	Long-eared Owl	E /	G5 / S1B,S1S2N	1	0	0	0	0
Muhlenberg	Breeding Birds	*Botaurus lentiginosus*	American Bittern	H /	G4 / SHB	0	1	0	0	0
Muhlenberg	Breeding Birds	*Chondestes grammacus*	Lark Sparrow	T /	G5 / S2S3B	1	0	0	1	0
Muhlenberg	Breeding Birds	*Circus cyaneus*	Northern Harrier	T /	G5 / S1S2B,S4N	2	0	0	0	0
Muhlenberg	Breeding Birds	*Cistothorus platensis*	Sedge Wren	S /	G5 / S3B	1	0	0	0	0
Muhlenberg	Breeding Birds	*Gallinula chloropus*	Common Moorhen	T /	G5 / S1S2B	1	0	0	0	0
Muhlenberg	Breeding Birds	*Haliaeetus leucocephalus*	Bald Eagle	T / Delisted	G5 / S2B,S2S3N	1	0	0	0	0
Muhlenberg	Breeding Birds	*Ixobrychus exilis*	Least Bittern	T /	G5 / S1S2B	1	0	0	0	0
Muhlenberg	Breeding Birds	*Pandion haliaetus*	Osprey	T /	G5 / S2B	2	0	0	0	0
Muhlenberg	Breeding Birds	*Riparia riparia*	Bank Swallow	S /	G5 / S3B	1	0	0	0	0
Muhlenberg	Breeding Birds	*Vireo bellii*	Bell's Vireo	S / SOMC	G5 / S2S3B	4	0	0	0	0
Muhlenberg	Mammals	*Myotis austroriparius*	Southeastern Myotis	E / SOMC	G3G4 / S1S2	1	0	0	0	0
Muhlenberg	Mammals	*Myotis grisescens*	Gray Myotis	T / LE	G3 / S2	1	0	0	0	0
Muhlenberg	Mammals	*Nycticeius humeralis*	Evening Bat	S /	G5 / S3	1	0	0	0	0
Muhlenberg	Communities	*Bottomland hardwood forest*		/	GNR / S2	2	0	0	0	0
Muhlenberg	Communities	*Cypress swamp*		/	GNR / S3	1	0	0	0	0
Muhlenberg County Total:						**61**	**16**	**1**	**2**	**1**

Appendix II

Figure 1A. Current land cover types of Kentucky.

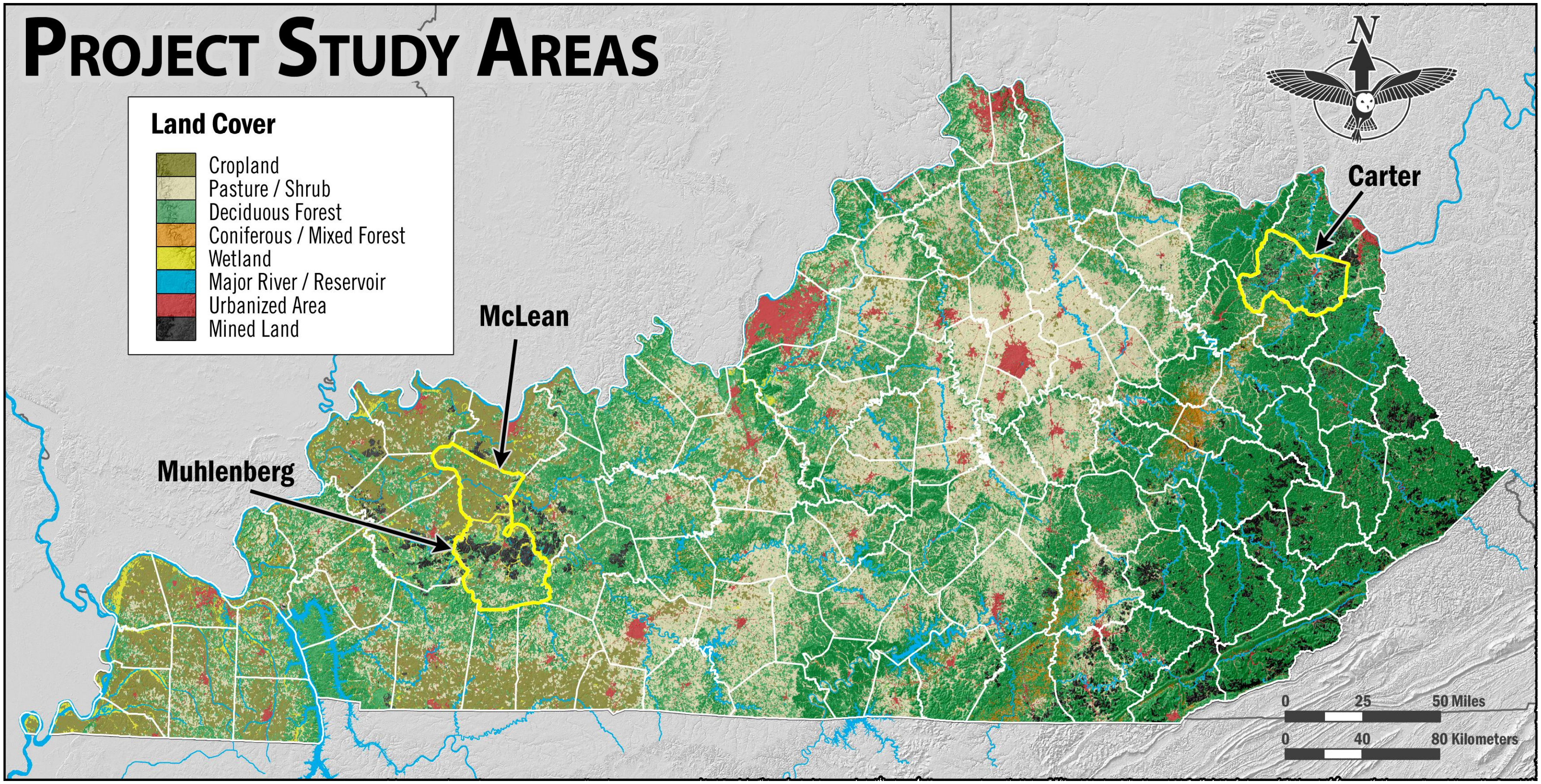

Figure 1B. Prehistoric land cover types of Kentucky.

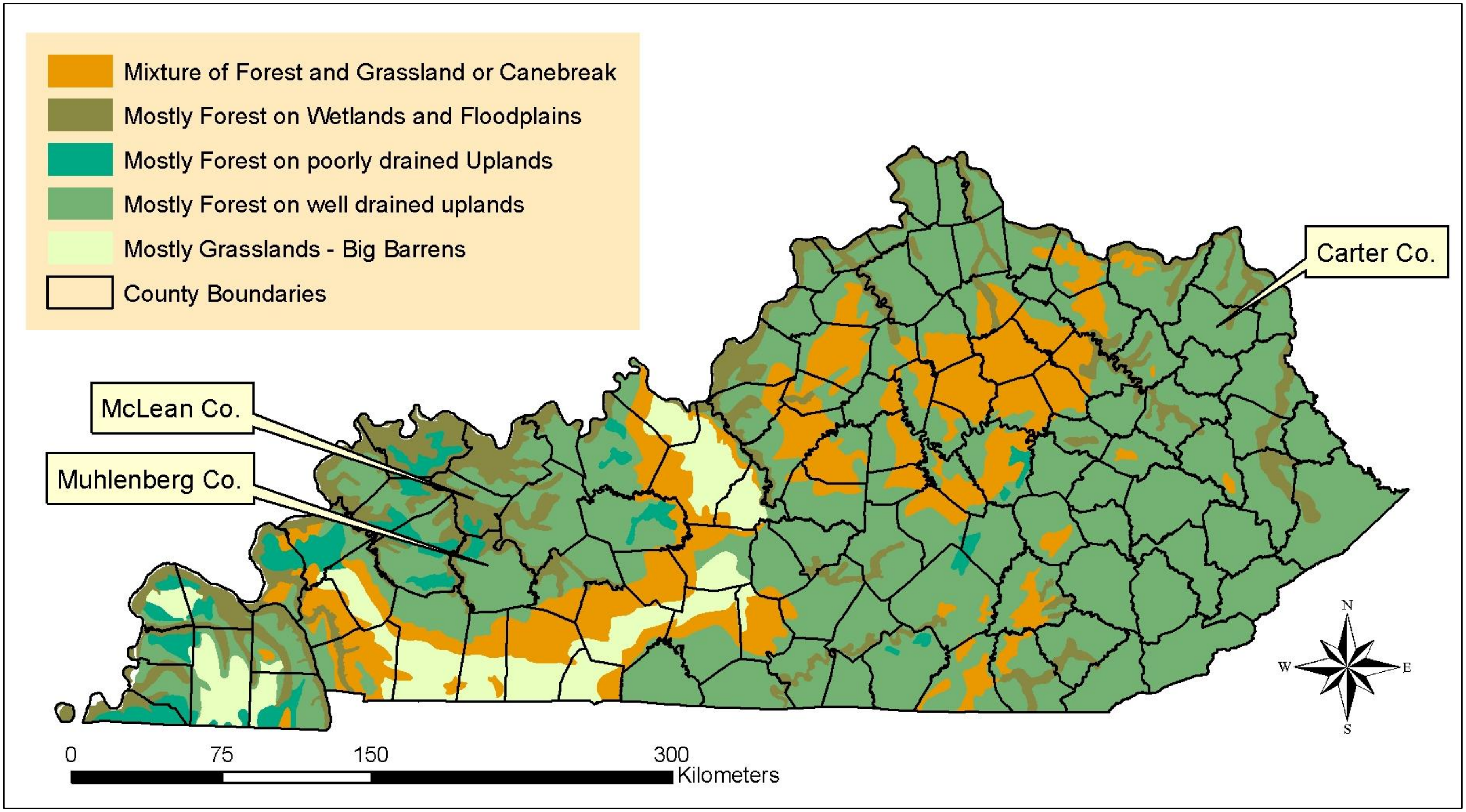

Figure 2. Topographic relief of Carter County, Kentucky.

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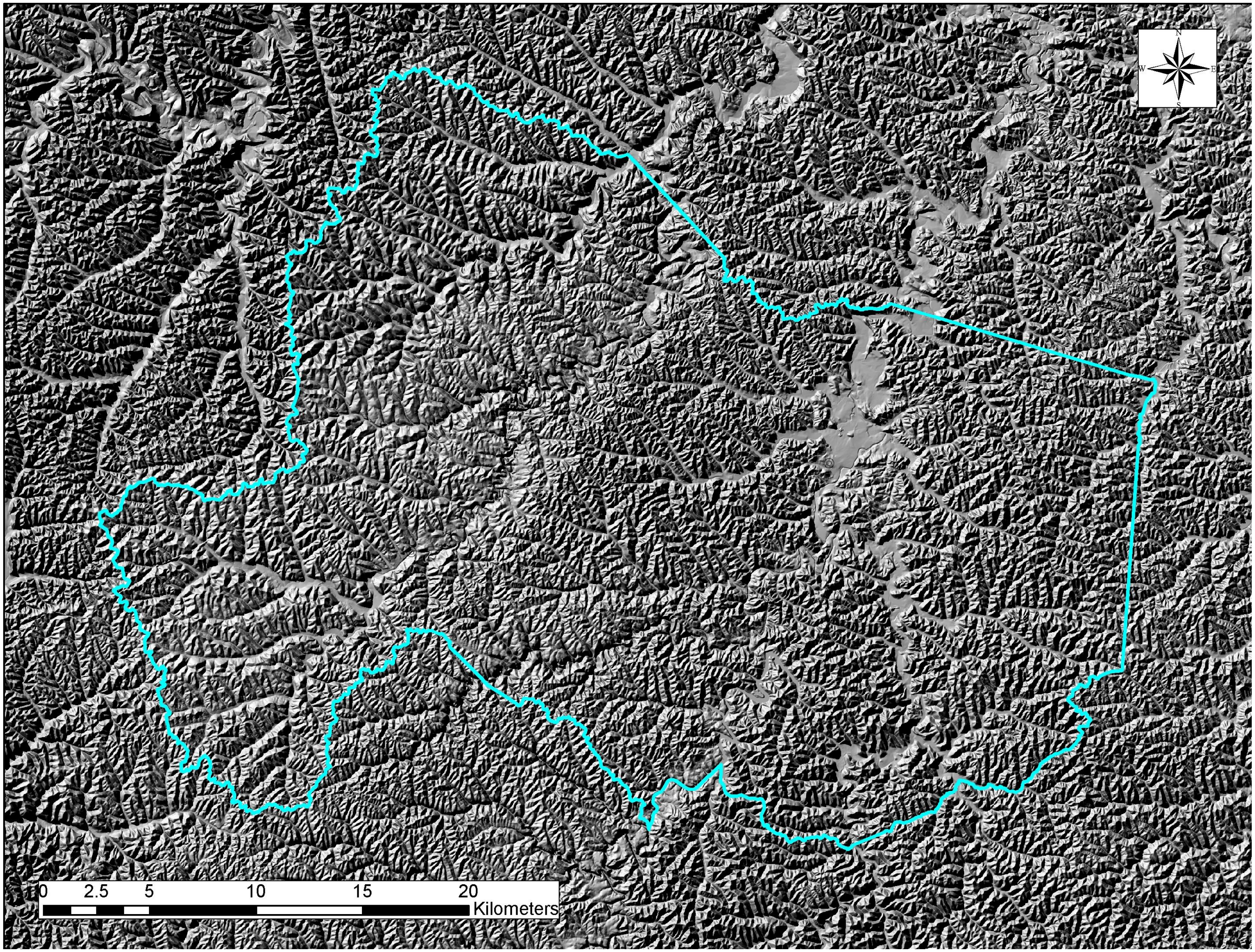
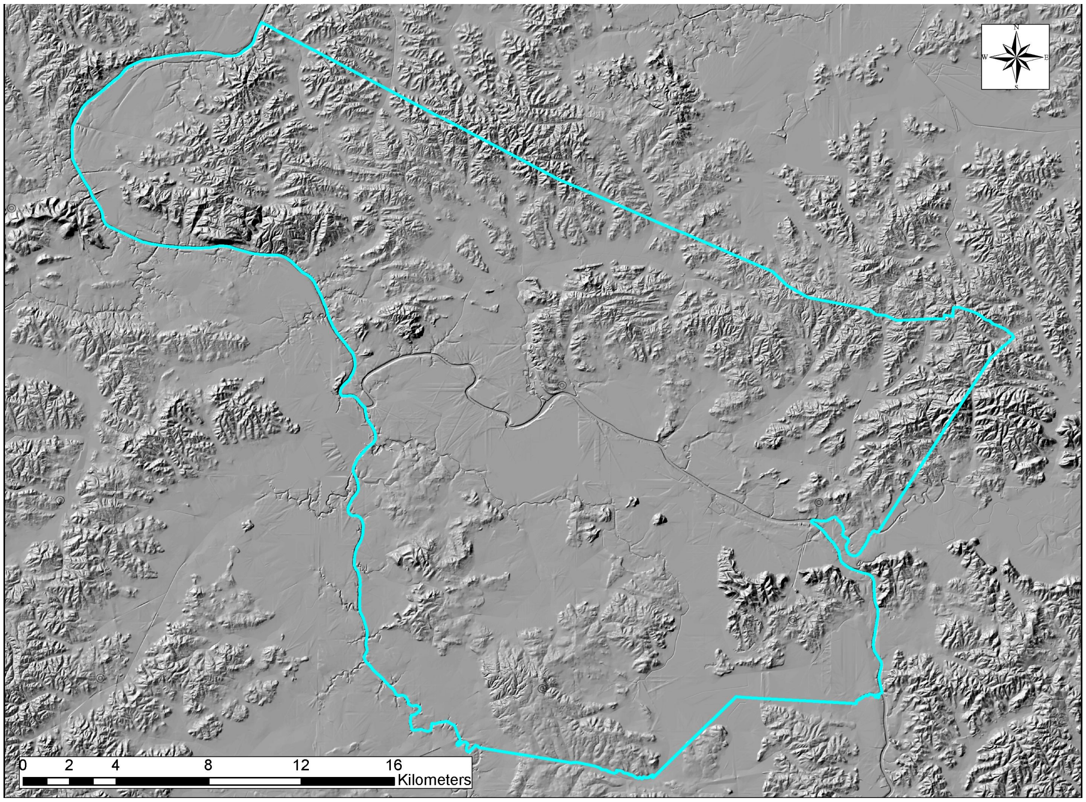


Figure 3. Topographic relief of McLean (top) and Muhlenberg (bottom), Counties KY.



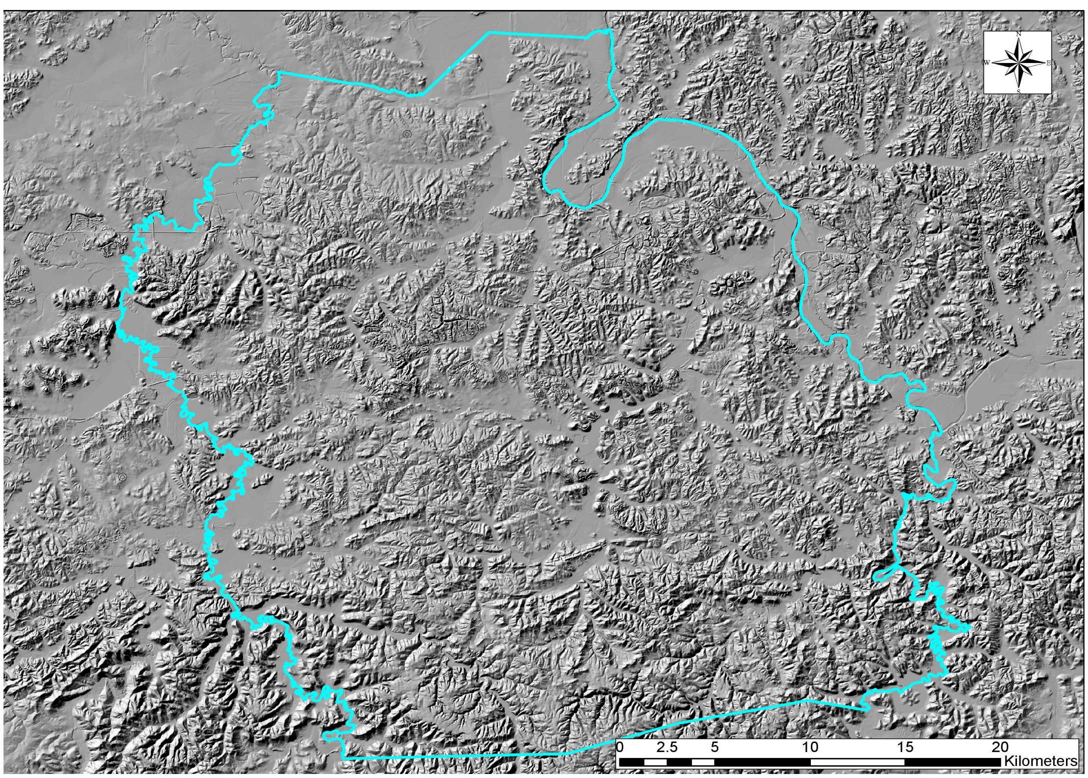


Figure 4. Generalized geology of Carter County, Kentucky.

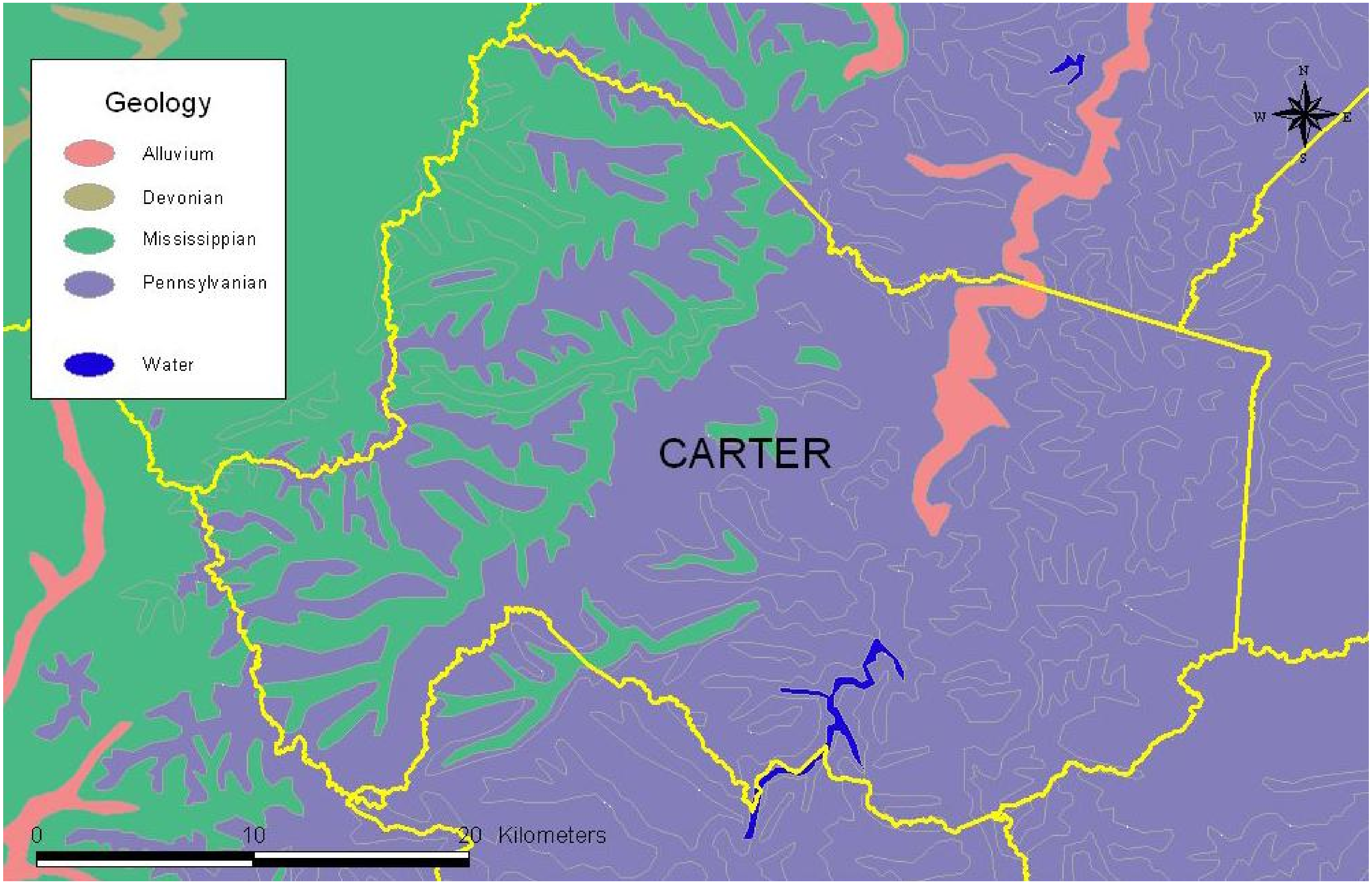


Figure 5. Generalized gology of McLean and Muhlenberg Counties, Kentucky.

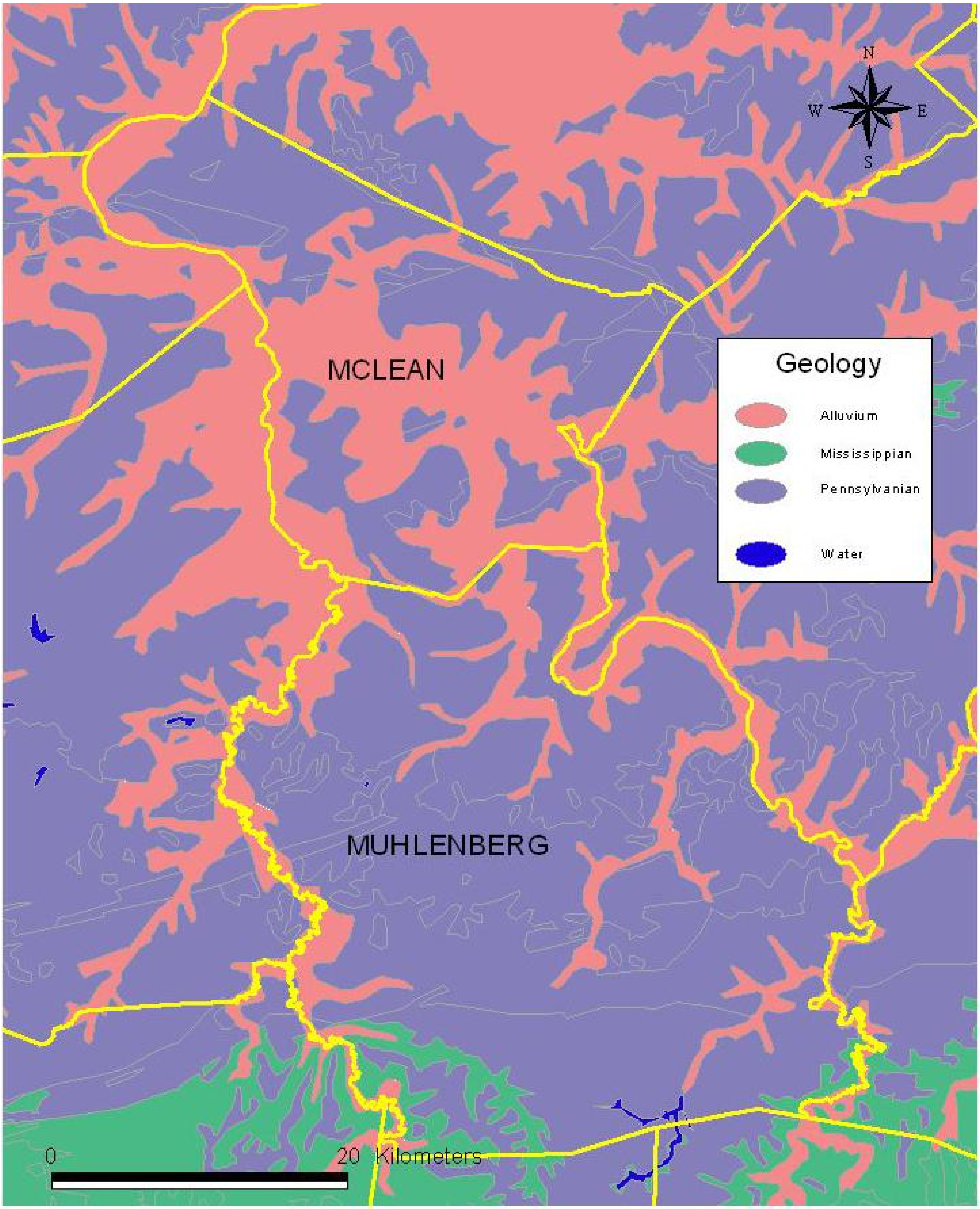


Figure 6. For Kentucky, images of seamless geological maps are now available. These provide not only information regarding the underlaying geology, but also landuse history, especially mining, as this example from eastern Muhlenberg County, KY, shows.

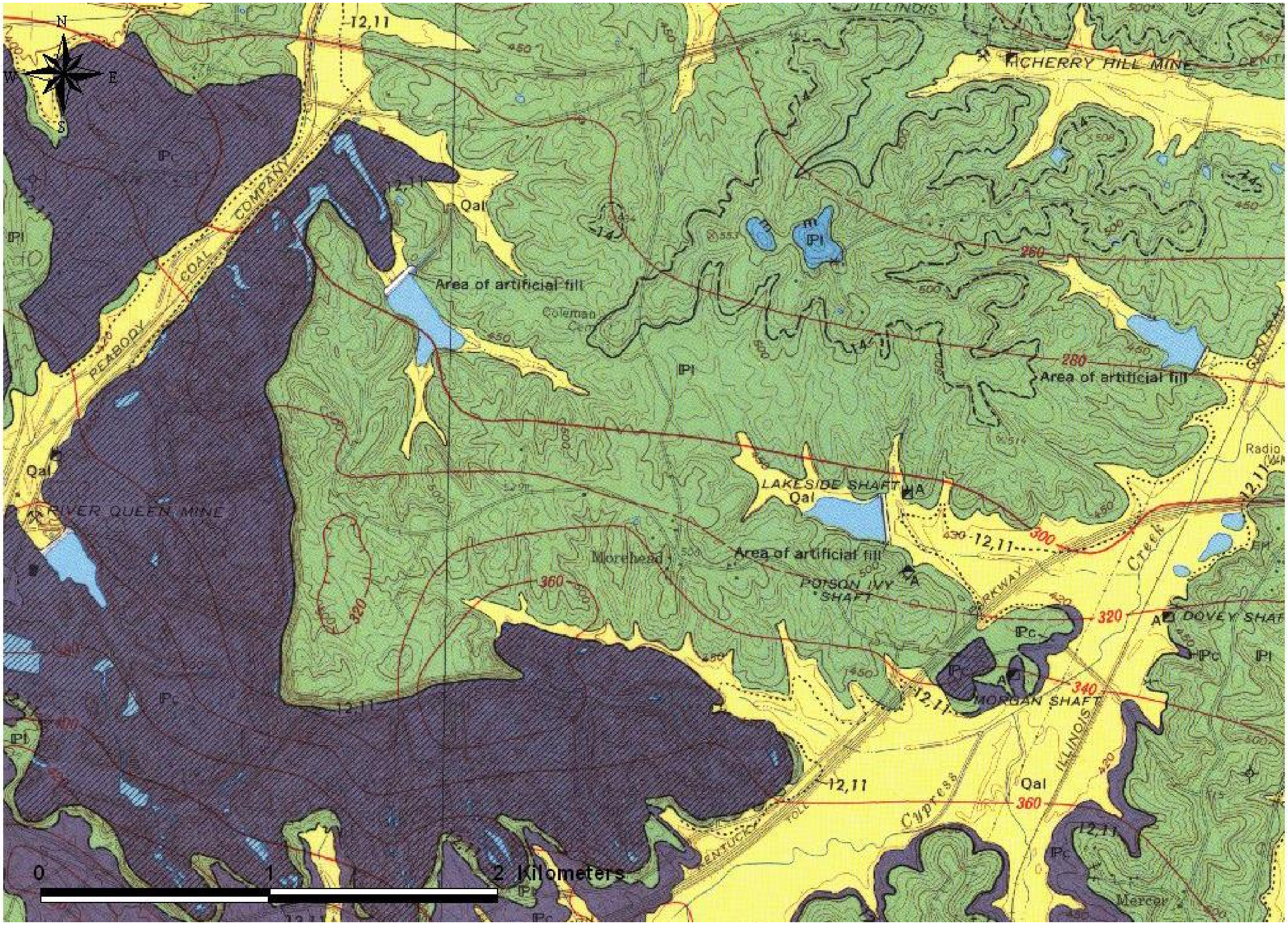


Figure 7. Physiographic provinces of Kentucky.

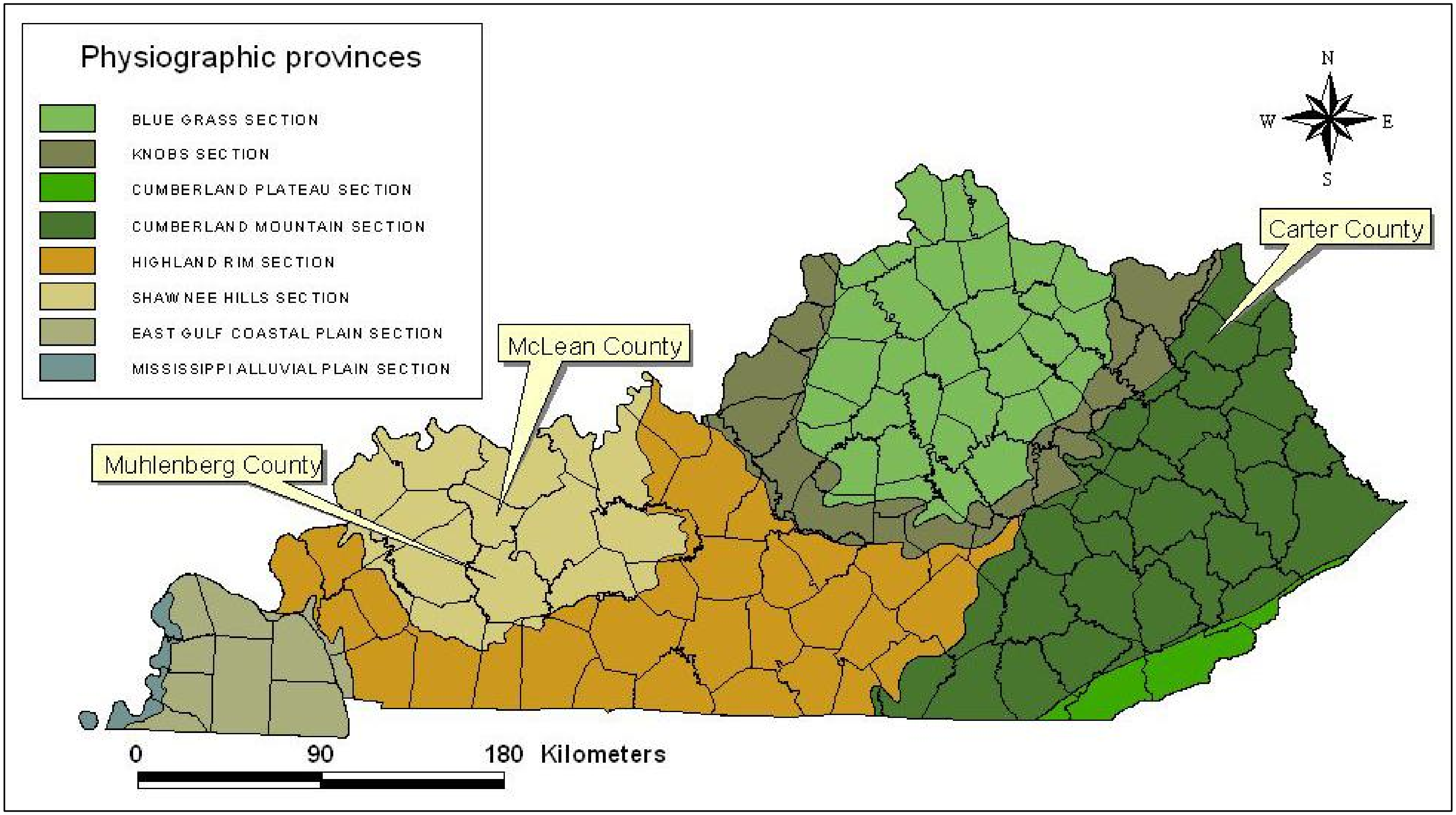


Figure 8. Large forest block analysis of Carter County, Ky. Large forest blocks were checked against aerial photos to determine their validity. Forest blocks that had been cleared, mined, otherwise fragmented or simply been misidentified by the computer model were eliminated from the study.

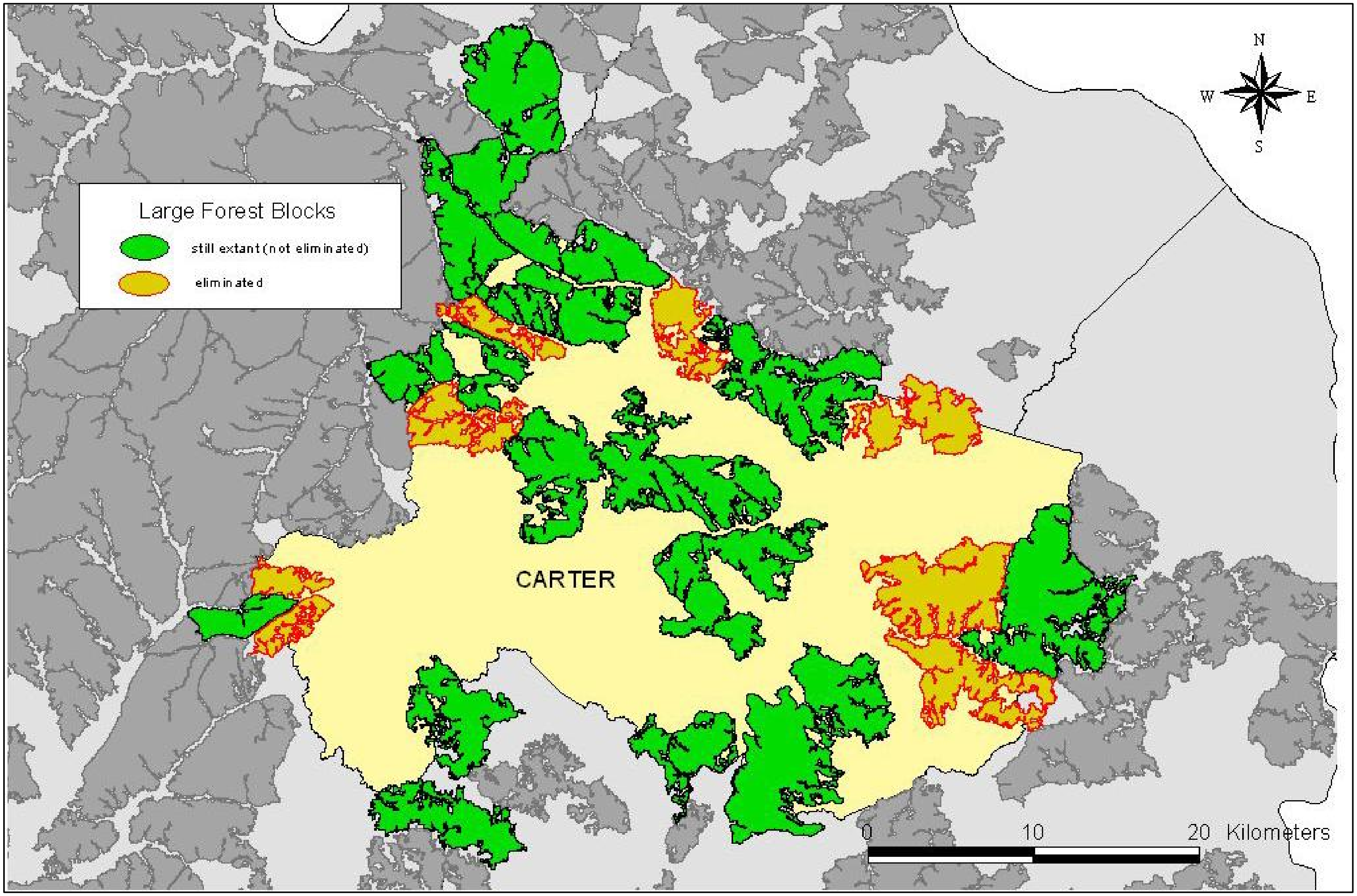


Figure 9. Large forest block analysis of McLean and Muhlenberg Counties, KY. Large forest blocks were checked against aerial photos to determine their validity. Forest blocks that had been cleared, mined, otherwise fragmented or simply been misidentified by the computer model were eliminated from the study.

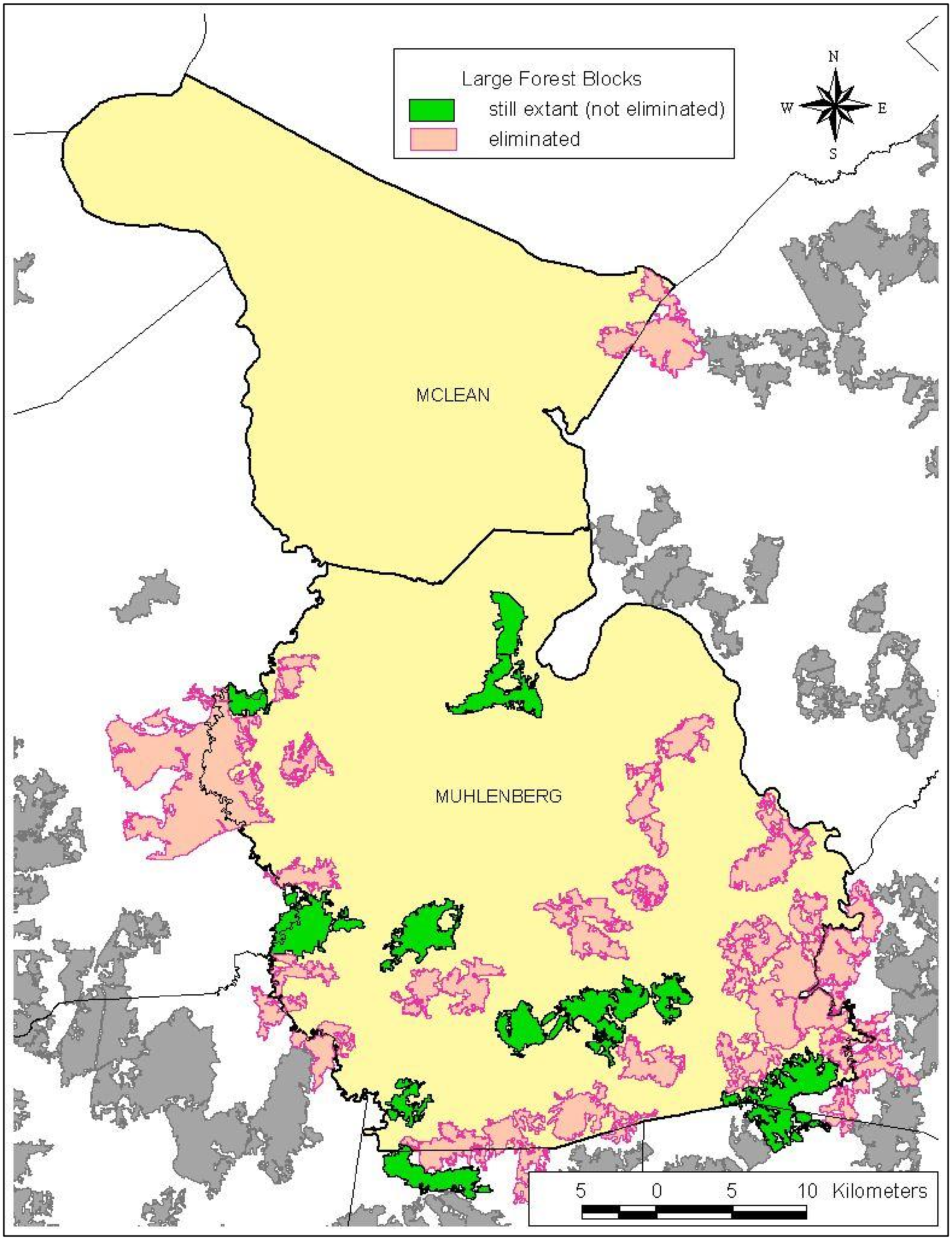


Figure 10. Preflight map showing potential natural areas, natural heritage data, and large forest blocks in Carter County, KY.

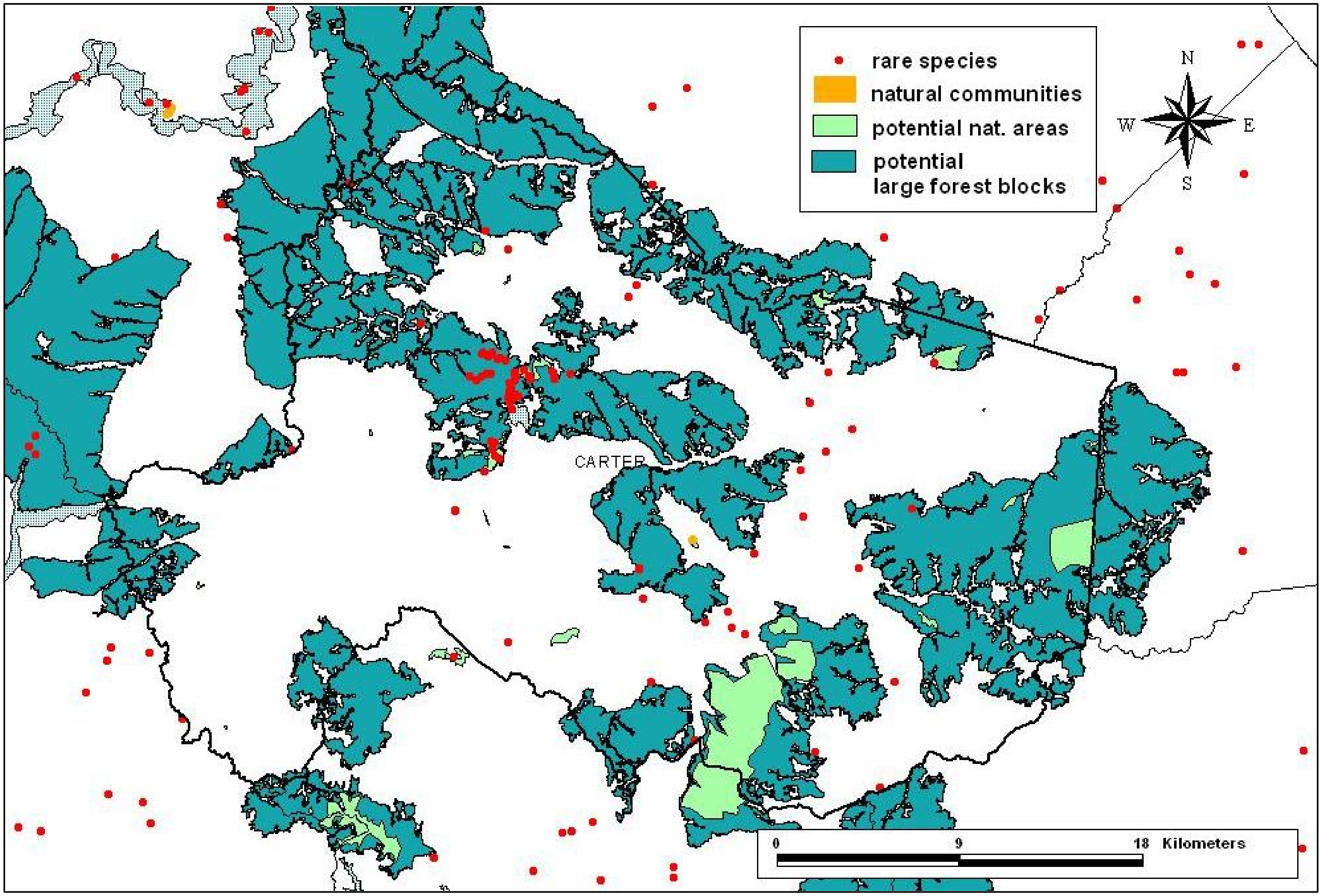


Figure 11. Preflight map showing potential natural areas, natural heritage data and large forest blocks in McLean and Muhlenberg County, KY.

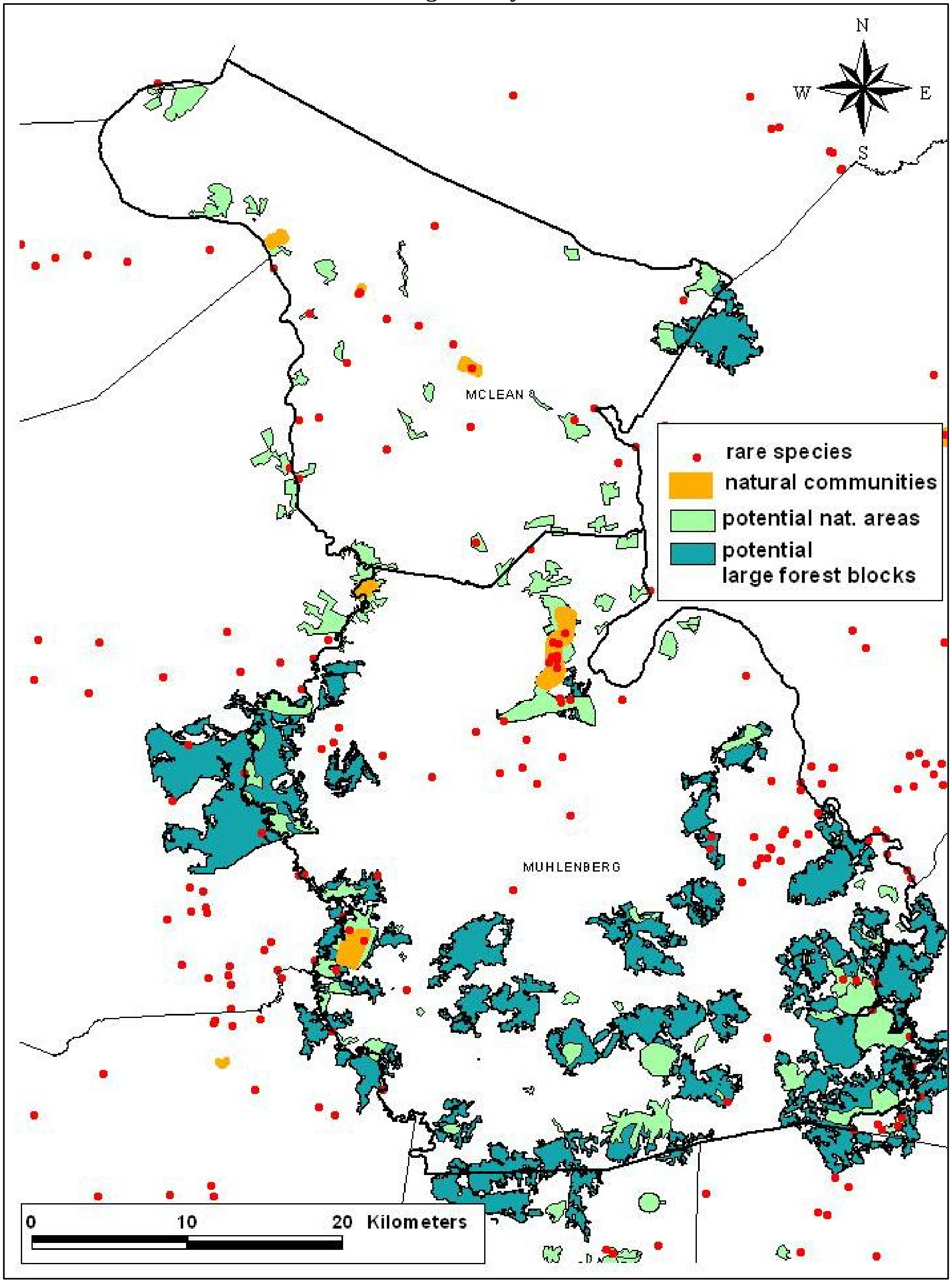


Figure 12. Flightplan for Carter County, Kentucky. PNAs shown as blue shapes.

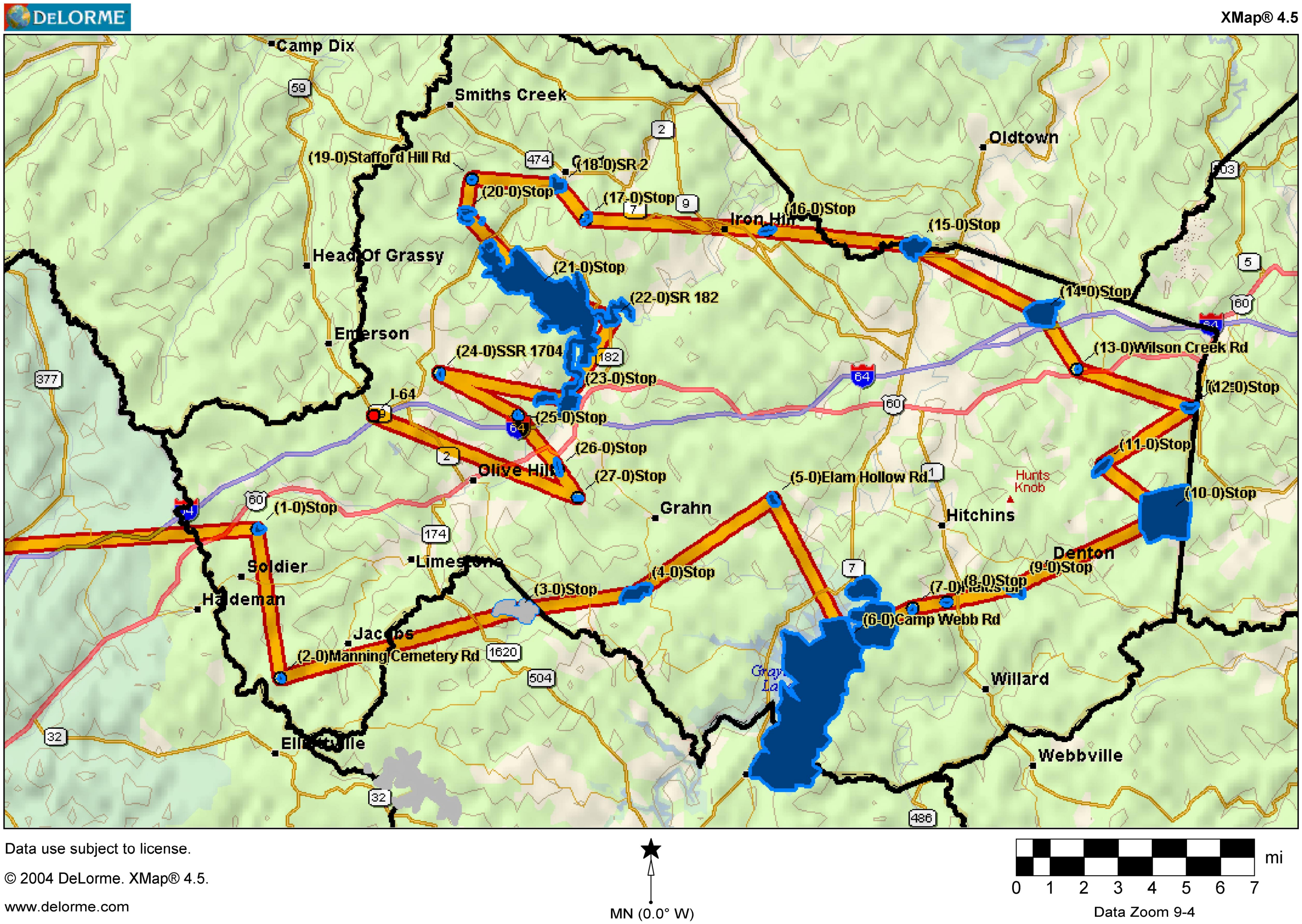


Figure 13. Flightplan for McLean County, Kentucky. PNAs shown as blue shapes.

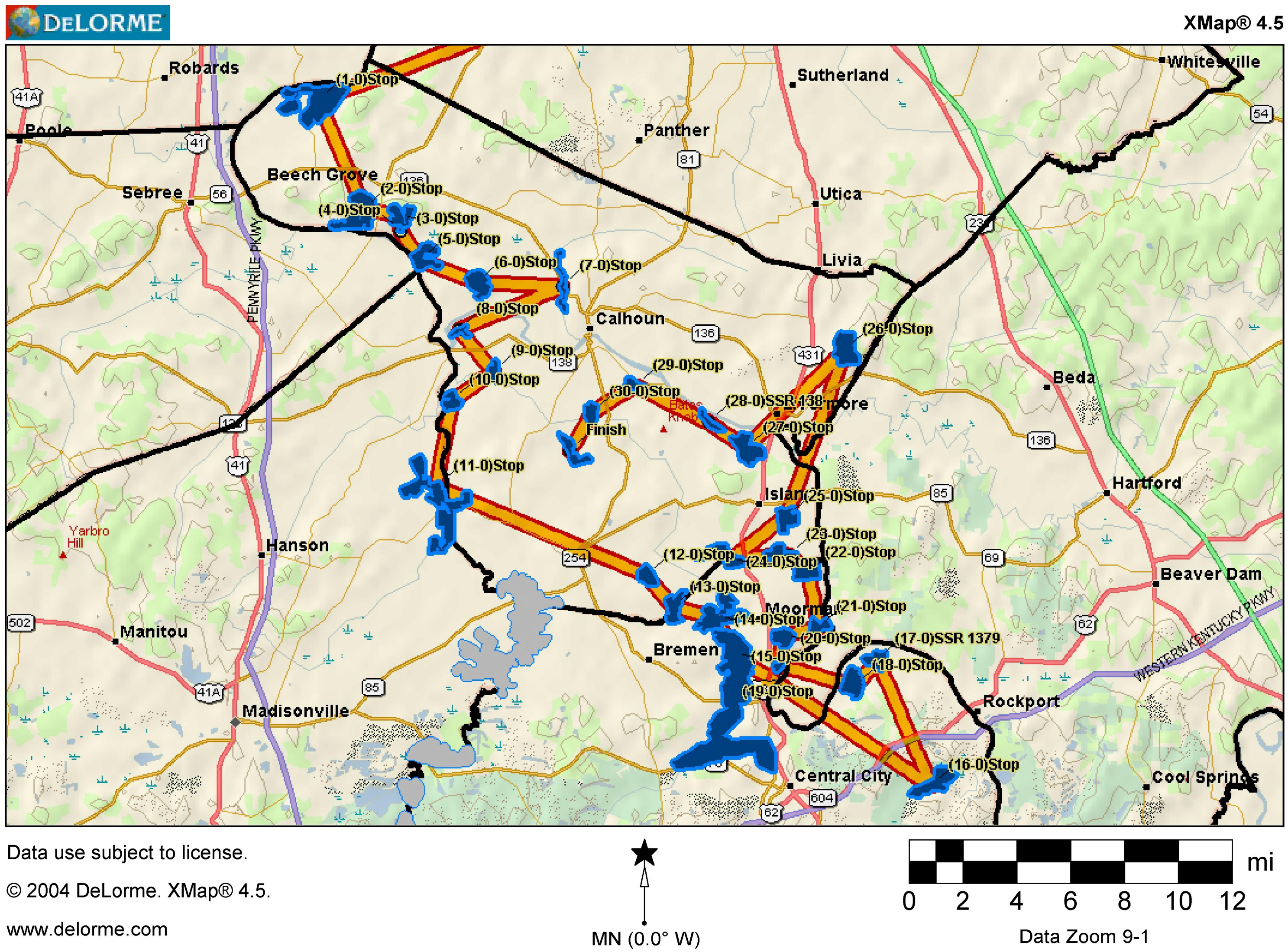


Figure 14. Flightplan for Muhlenberg County, Kentucky. PNAs shown as blue shapes.

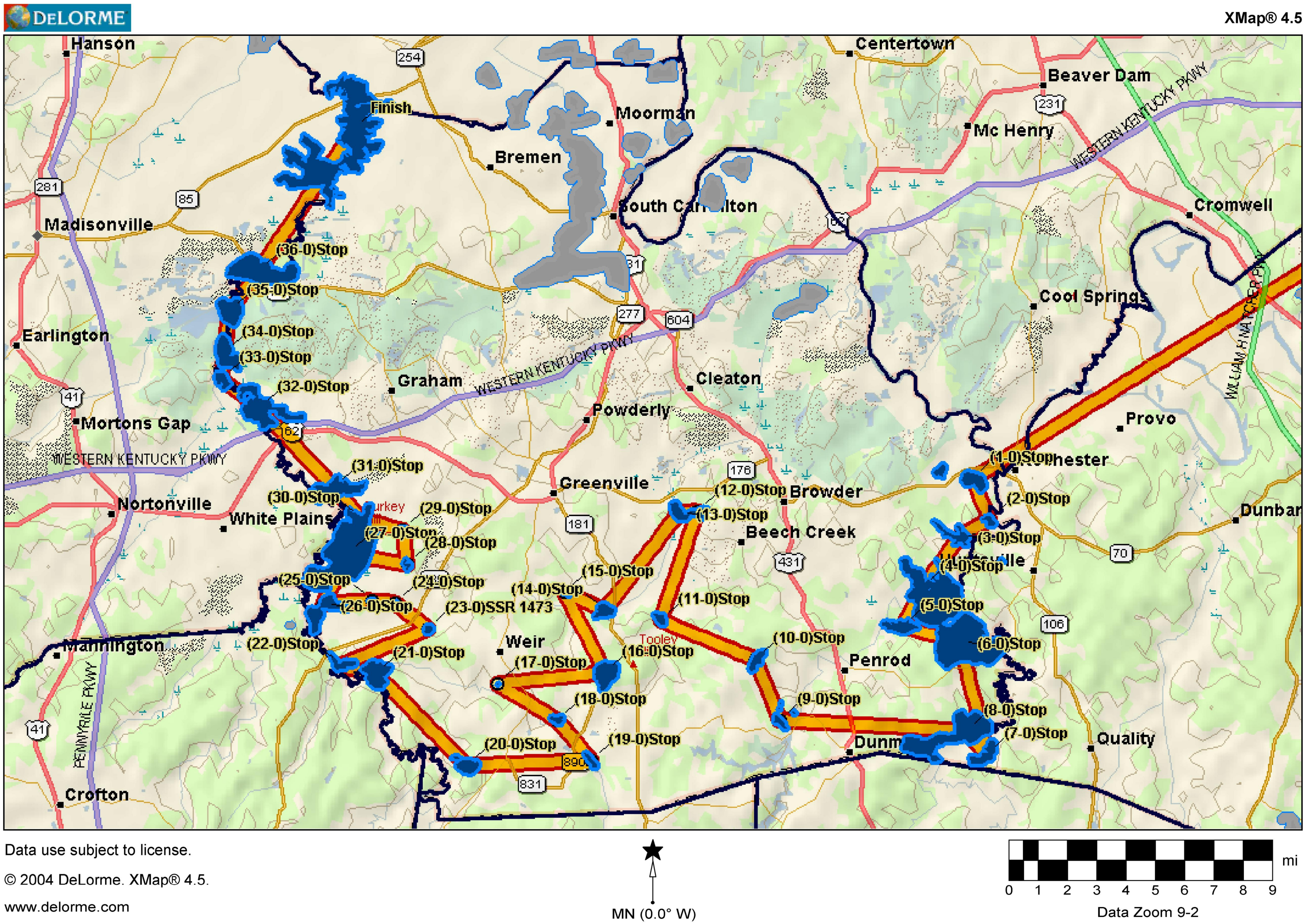


Figure 15. Preliminary results of natural areas inventory of Carter County, Kentucky. Also showing natural heritage data and large forest blocks.

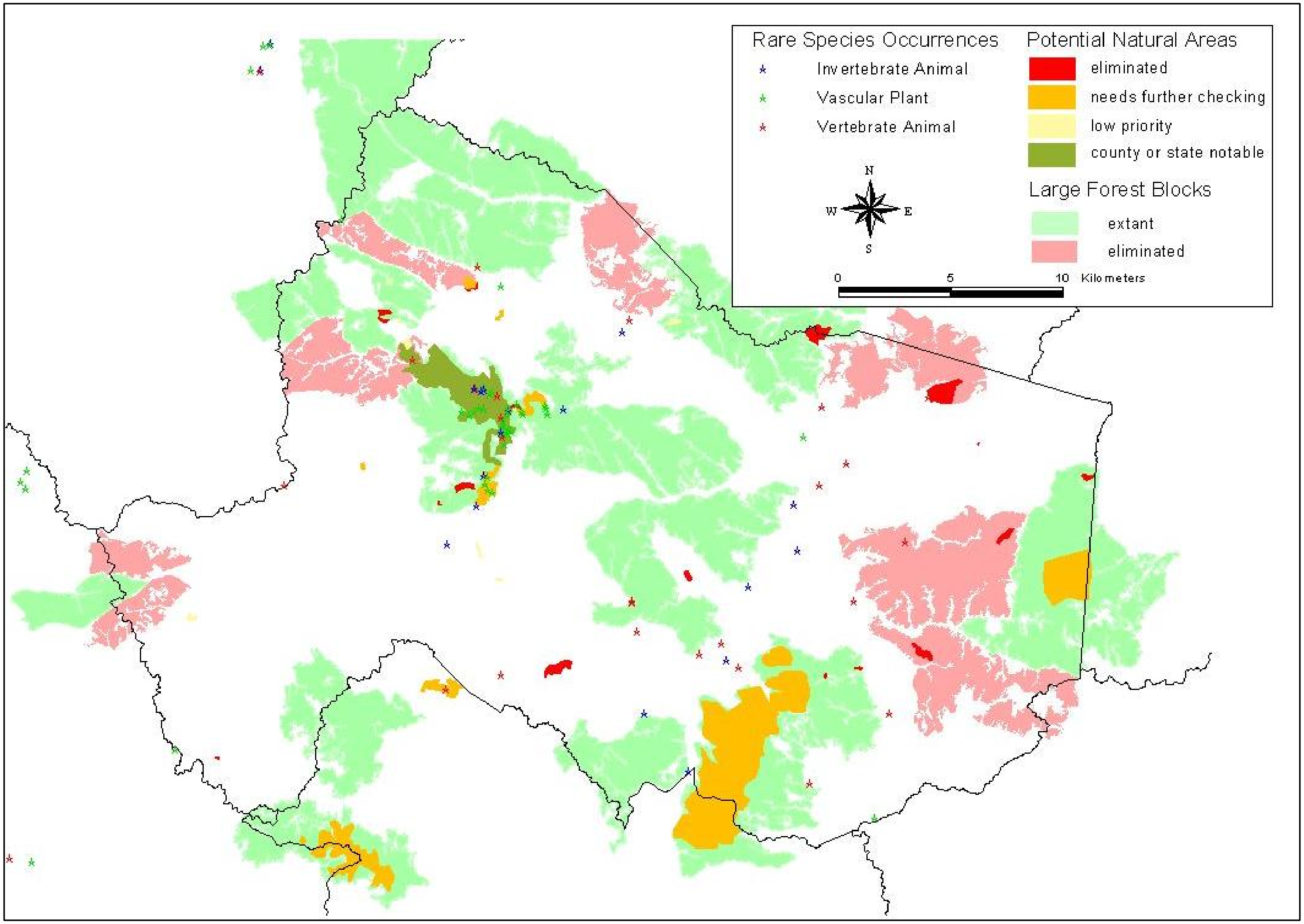


Figure 16. Preliminary results of natural area inventory of McLean County, Kentucky also showing natural heritage data and large forest blocks.

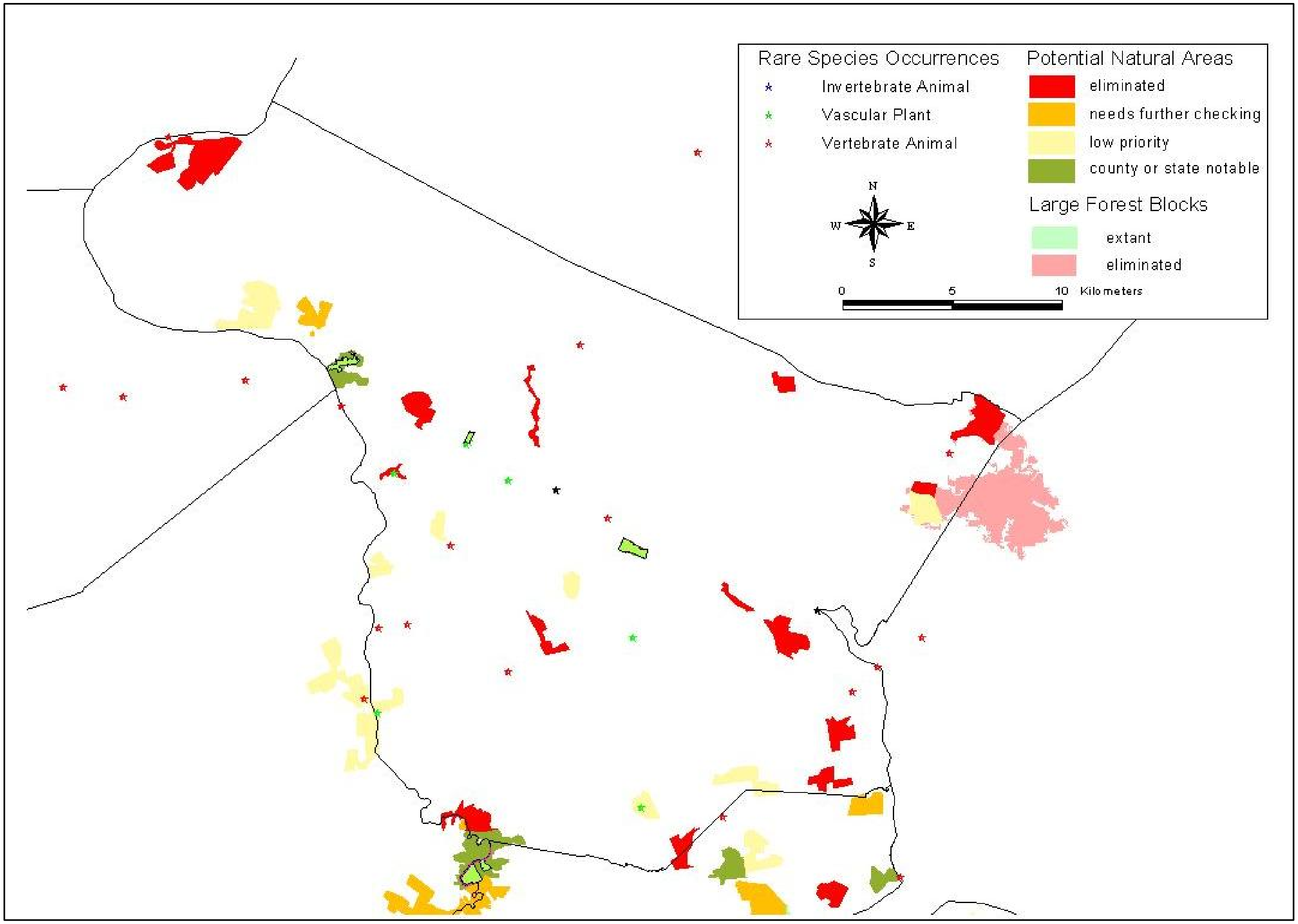


Figure 17. Preliminary results of natural areas inventory of Muhlenberg County, Kentucky. Also showing natural heritage data a

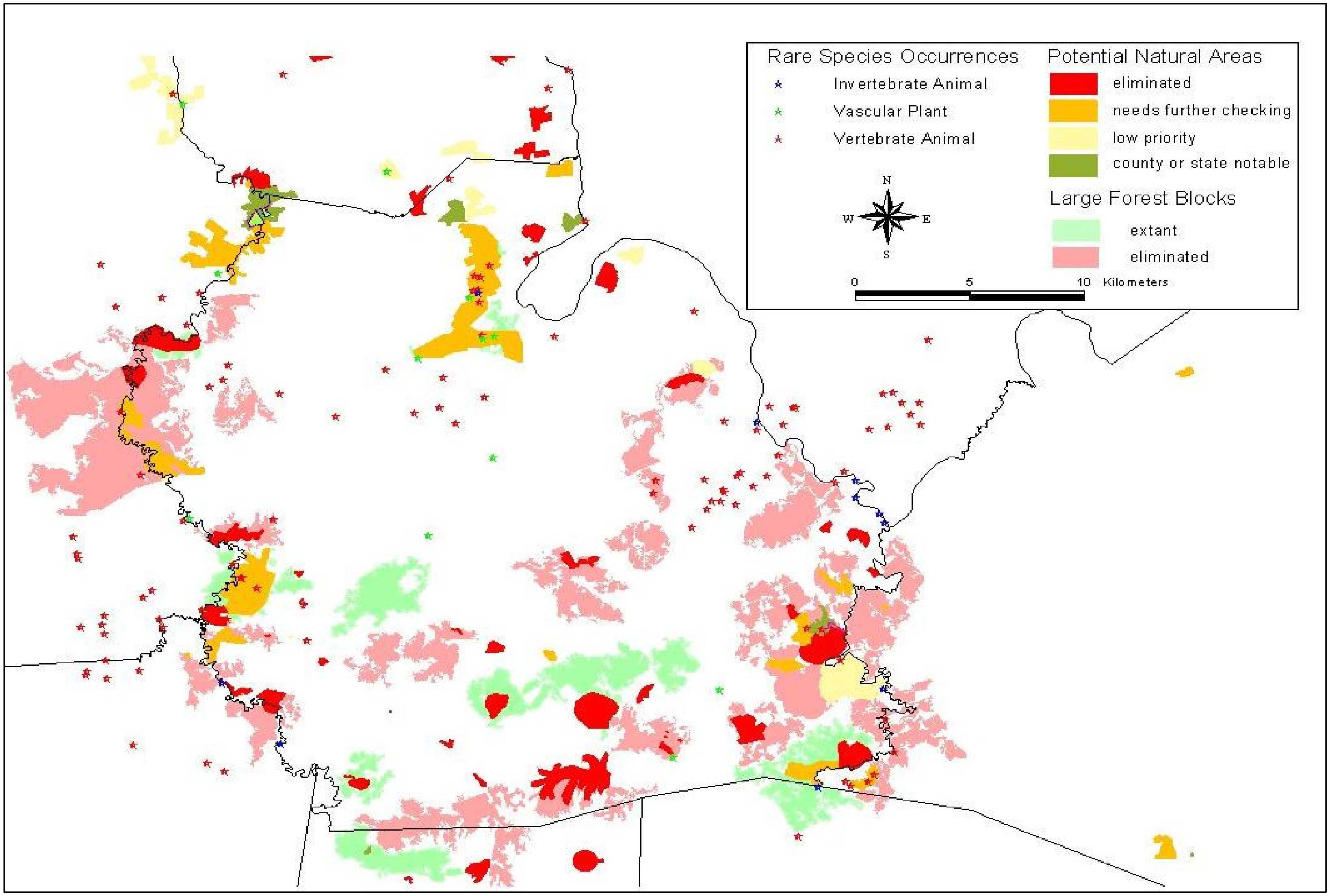
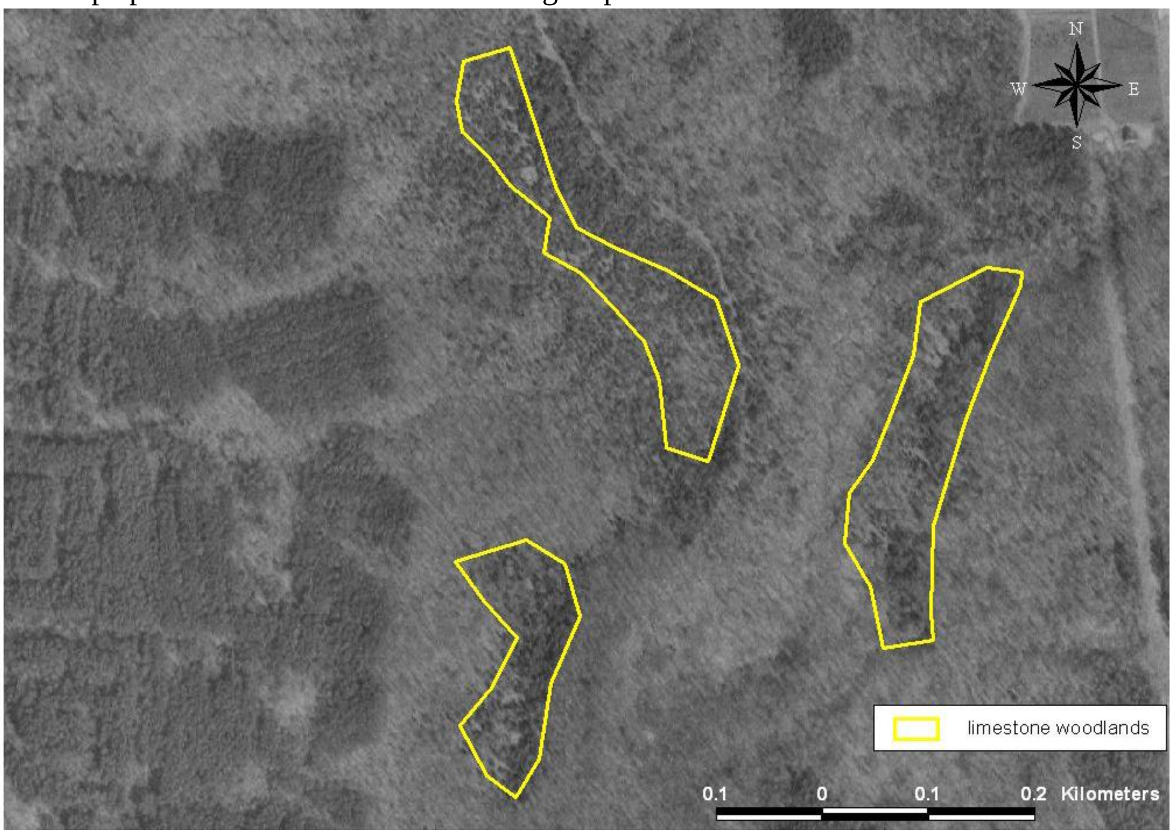


Figure 18. Limestone woodlands in Christian County, KY. They are only visible on the leaf-off black and white photo, but not on the 2004 NAIP color image. Note also loblolly pine plantations visible only on the leaf-off black and white photo (far left). Layering clear topographic maps over remote images reveals the woodlandsôcharacteristic landscape position on south and west facing slopes.



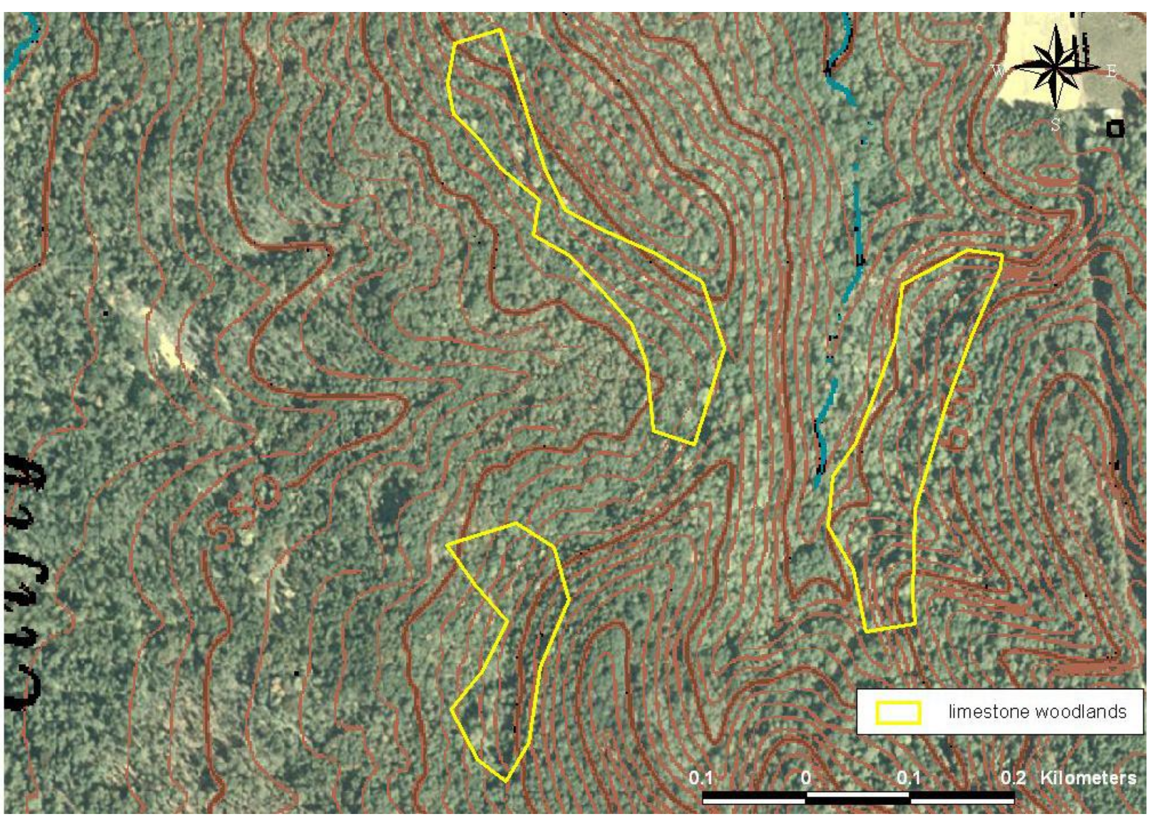


Figure 19. In this example a clear topographic map was used in conjunction with 2004 NAIP imagery to help identify flatwood and bottomland forest types of varyimg maturity along the Pond River in Muhlenberg County, Kentucky..

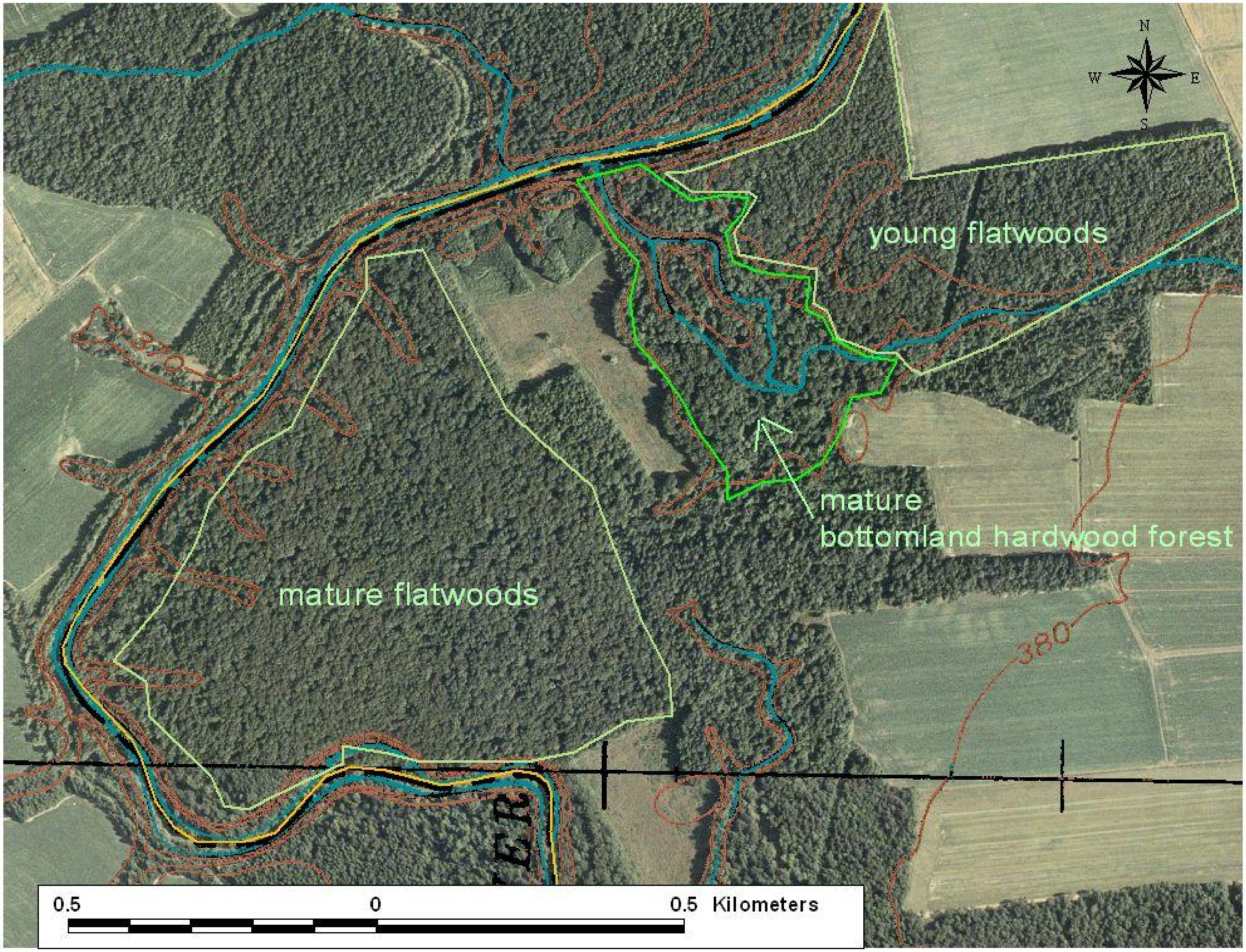


Figure 20. Overlaying older topographic maps with current aerial photos serves as a tool for analyzing changes in forest cover. This image of a section of the Pond River corridor in north-western Muhlenberg County shows a reduction in forest cover by about 80% within the past four decades based on a 1963 topographic map and 2004 NAIP imagery.

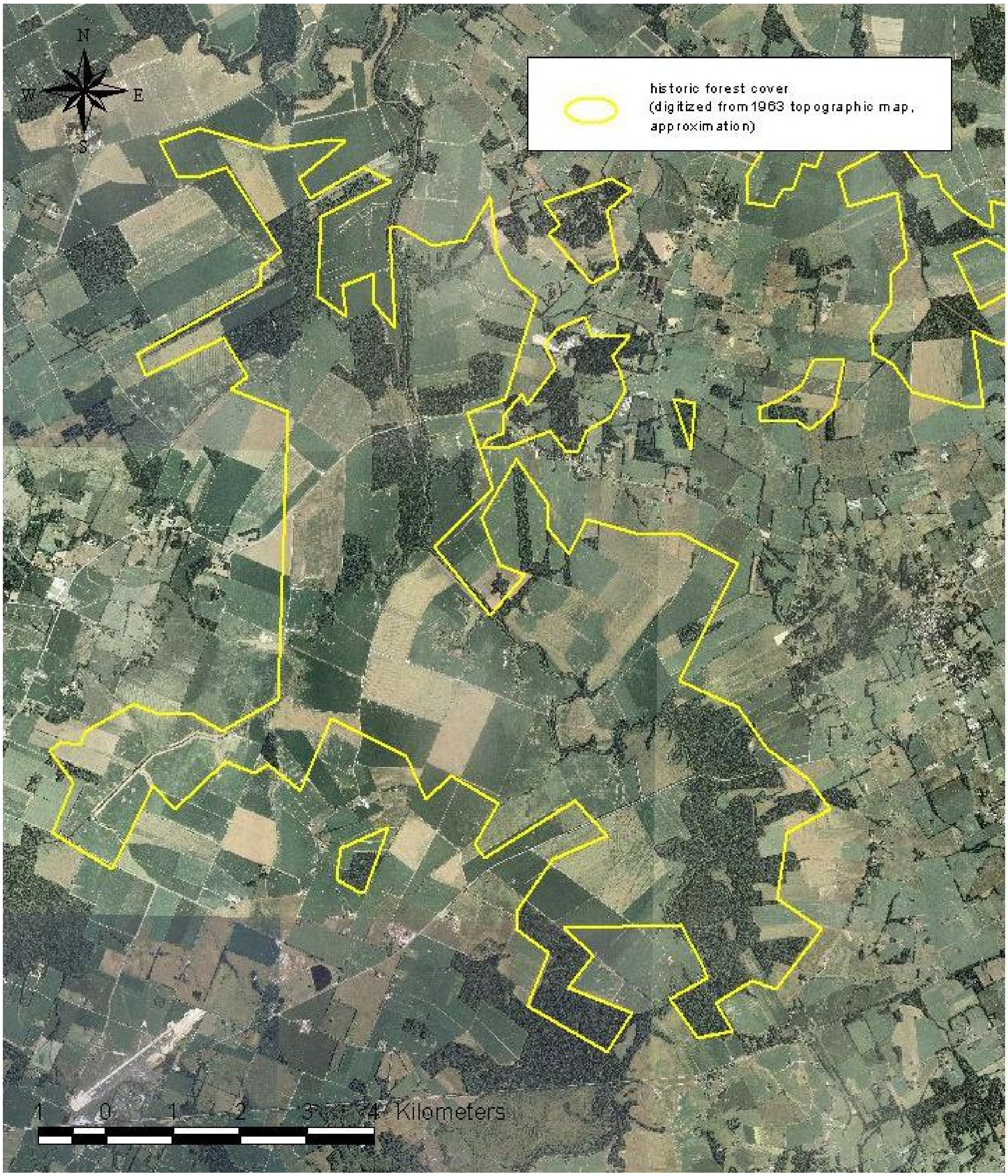


Figure 21. Even though recent or ongoing mining activities are often visible on aerial photos, surface scars and alterations caused by mining can be obstructed by maturing forest, as in this example of a 2004 NAIP image in Carter County where mined areas where revealed on topographic maps.

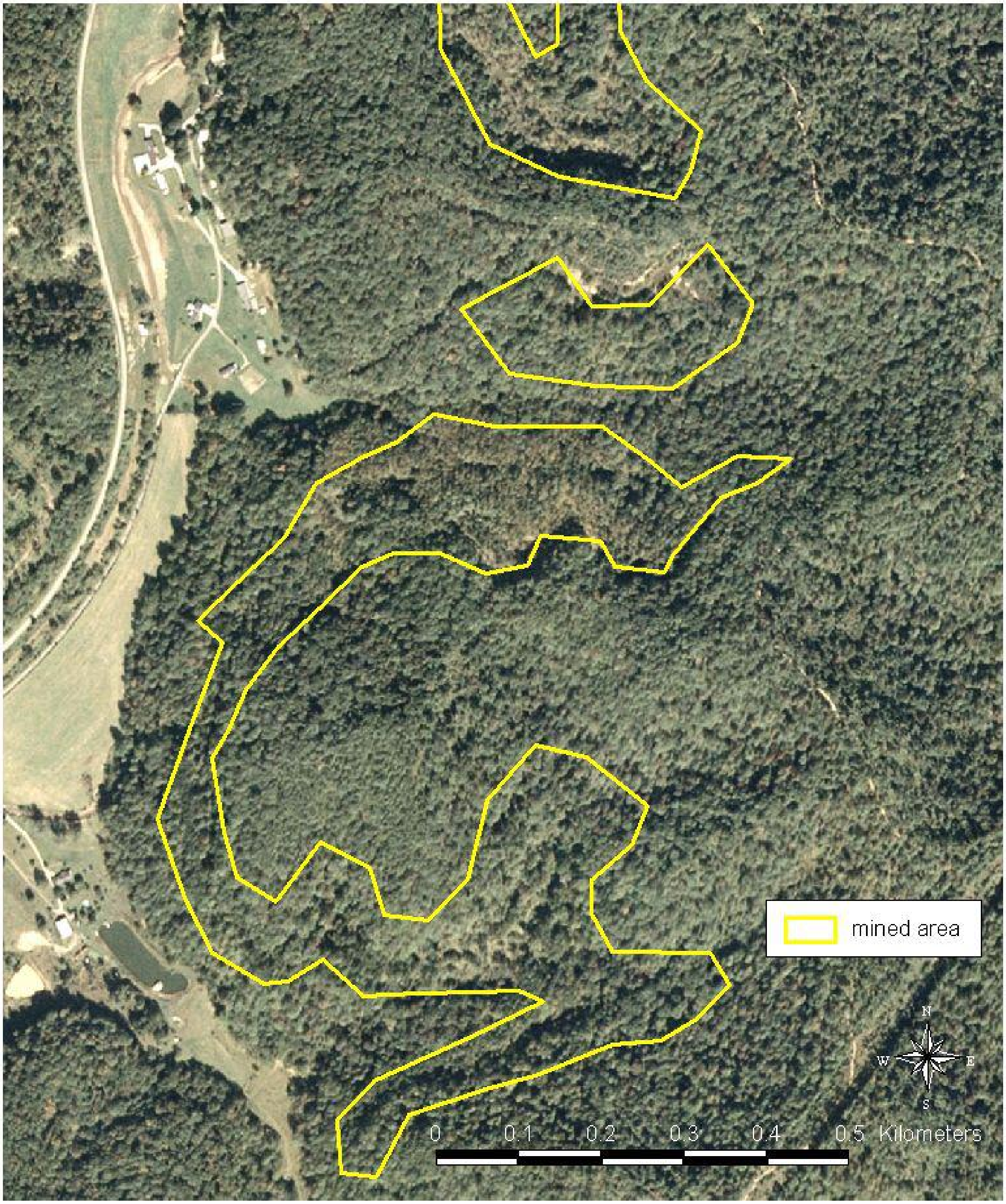


Figure 21B. Most active and abandoned or reclaimed surface mines and related ground disturbances can be detected on 2004 NAIP imagery, as in this example from eastern Muhlenberg County.

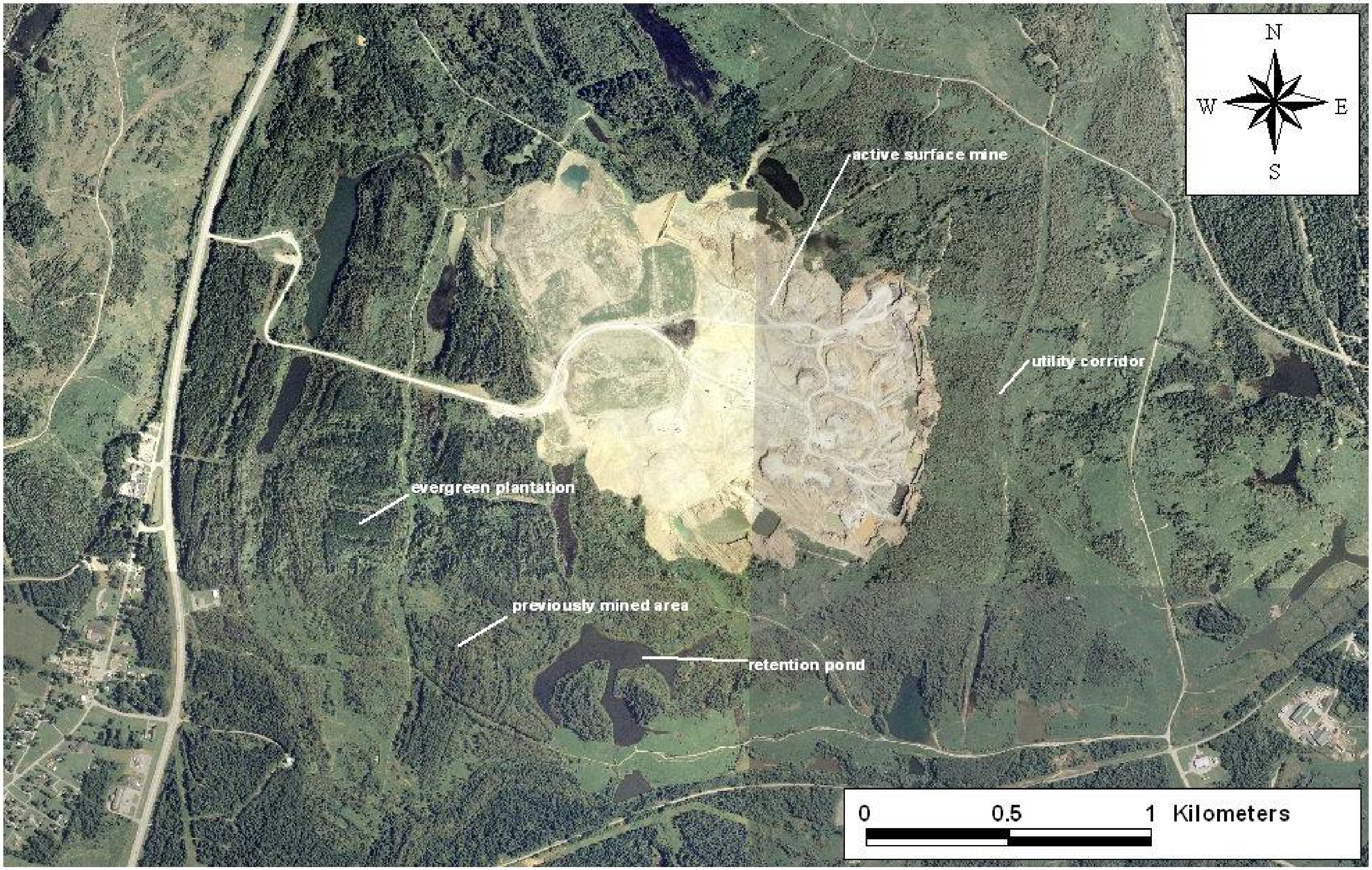


Figure 21C. Examples of aerial views of acid mine drainage in Muhlenberg County, Kentucky.

Figure 21D. Some mining activities, such as contour mining in heavily forested areas are easier to detect on leaf off black and white photos than on NAIP imagery (example from eastern Carter County).

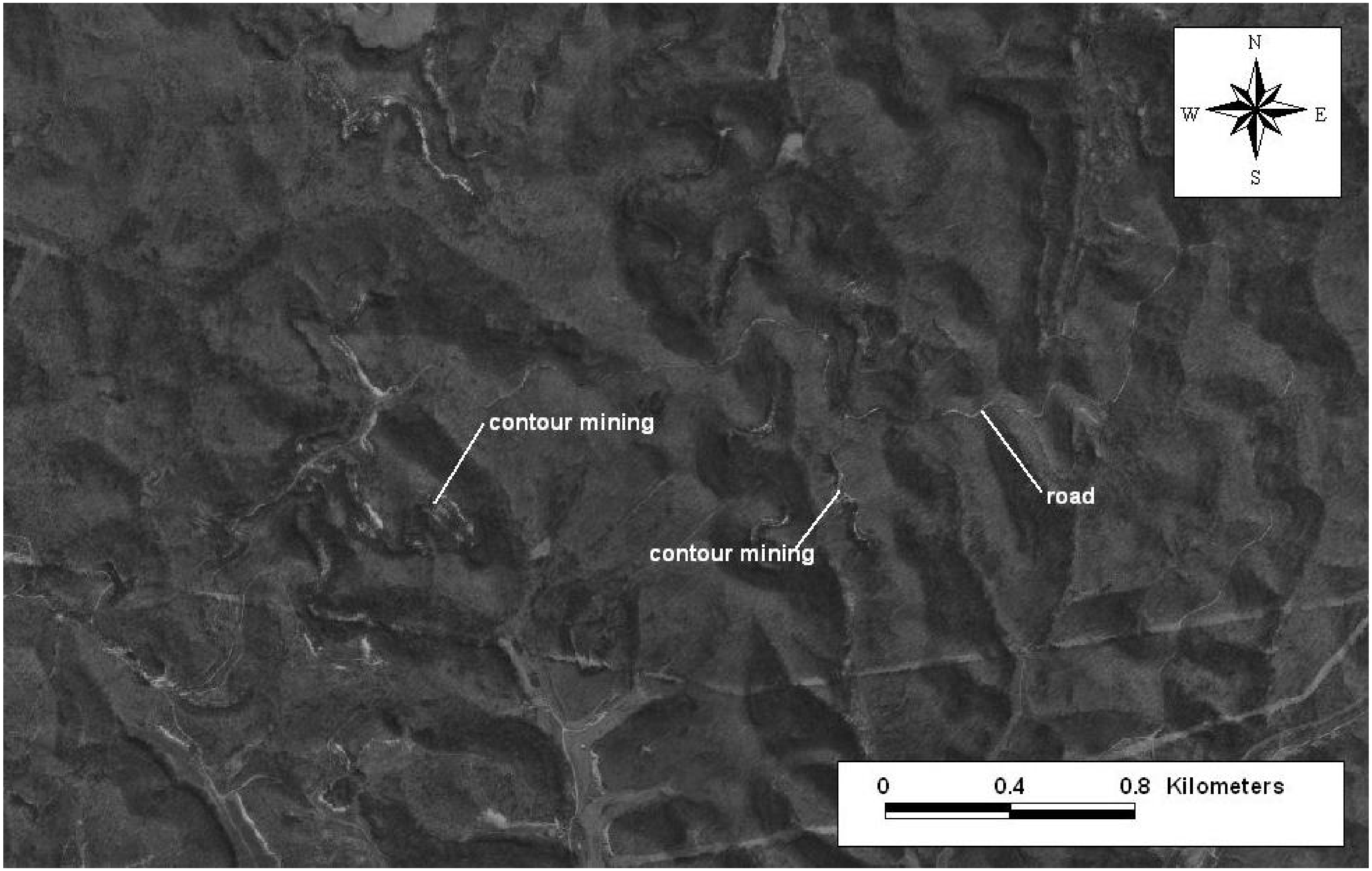
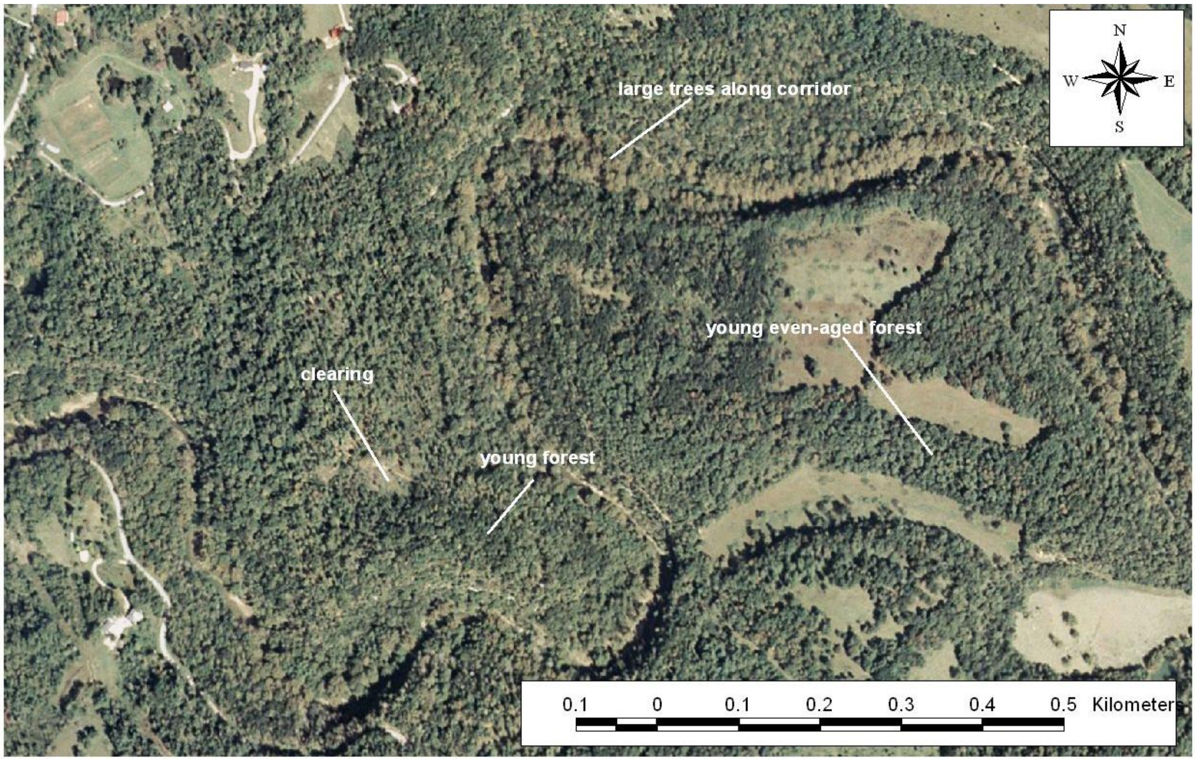


Figure 22. Features that can be easier identified with leaf-on aerial photos include approximate stand age and crown size, whereas the contrast between evergreens and deciduous trees is much less apparent, and clifflines and rock outcrops are more difficult to identify than on leaf-off images (Carter Caves State Park, Carter Co., Kentucky).



Features that can be easily identified on black and white leaf-off photos include rock outcrops and cliffs, as well as road and stream corridors. Stands of evergreens are also easily distinguishable from deciduous trees.

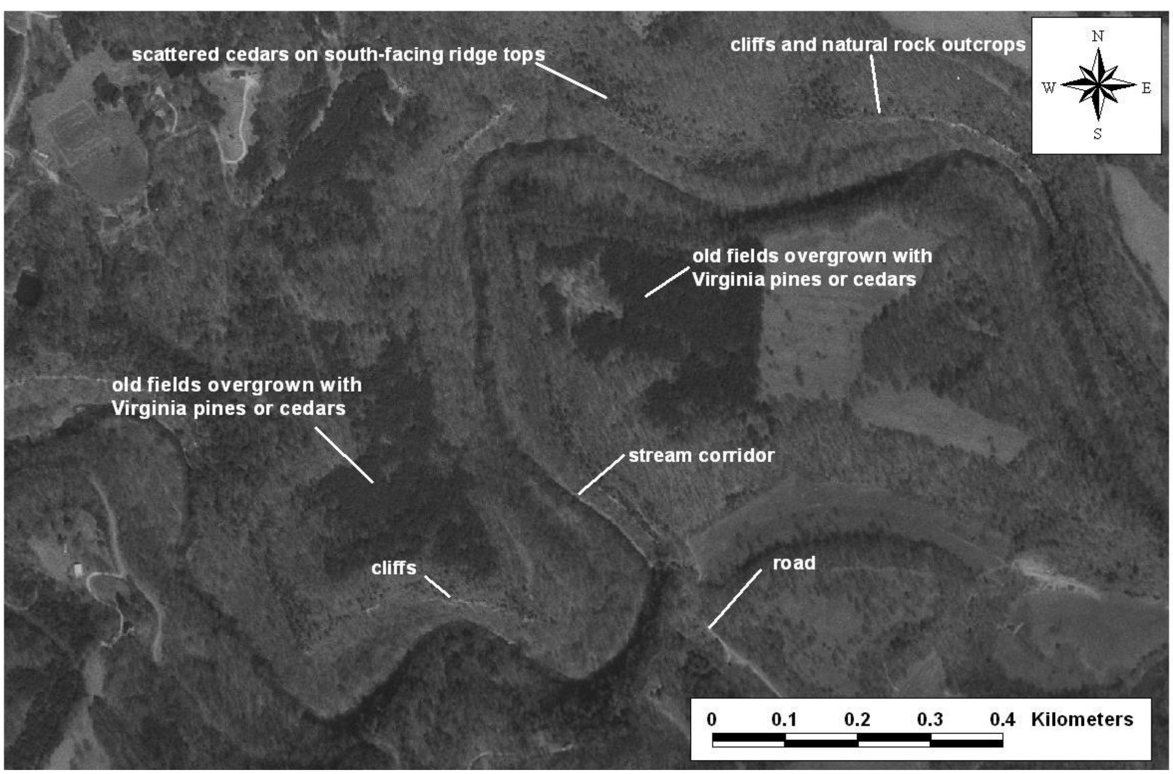


Figure 23. Isolated wetlands such as this sinkhole pond can be identified through viewing a combination of aerial photos and clear topographic maps. This inconspicuous looking wetland is a natural heritage site that supports several rare species.

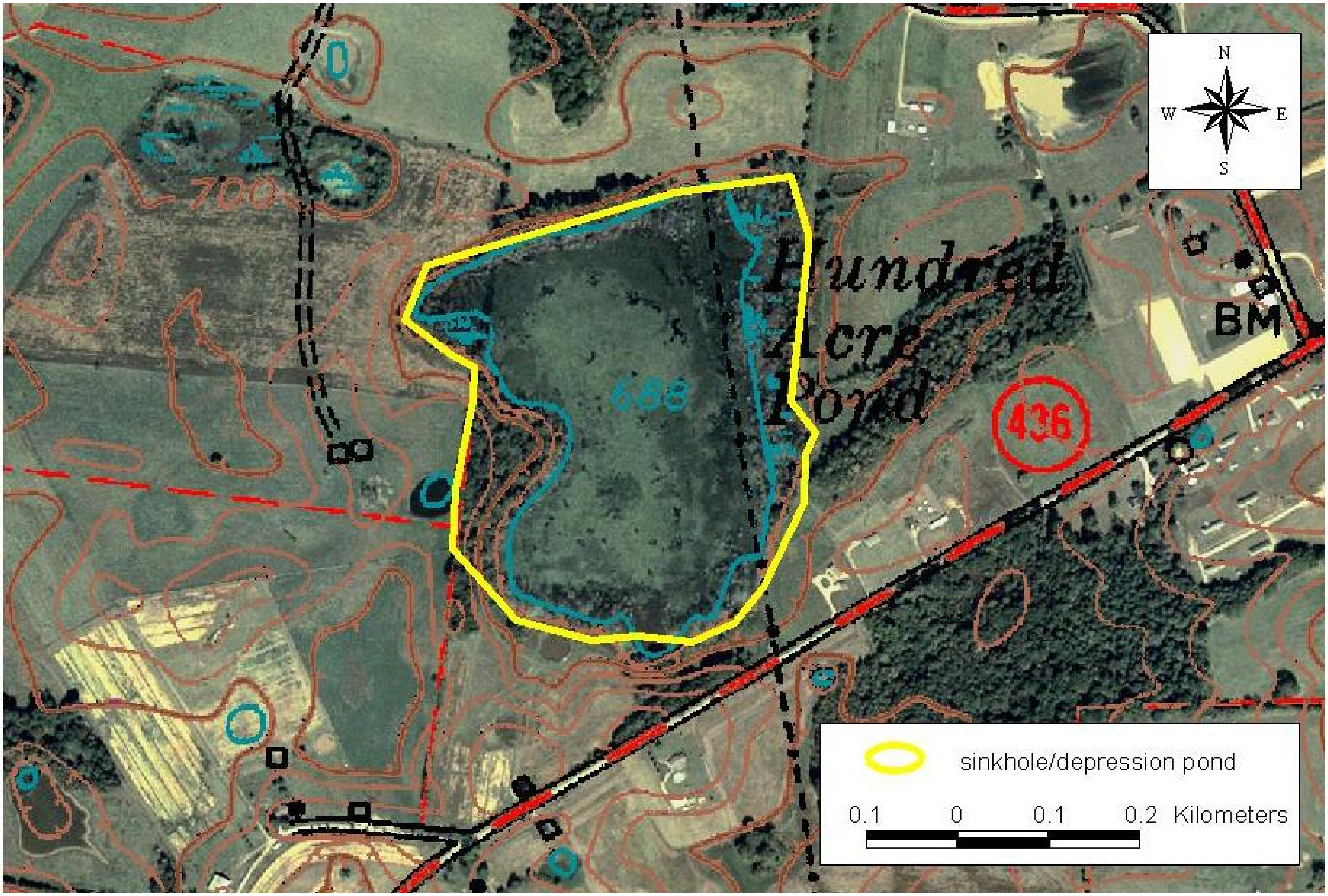


Figure 24. NAIP 2004 image and ground photo of Griffith Woods, a Bluegrass Savanna-woodland remnant, which is a globally rare community type. It is characterized by mature blue-ash, Chinquepin oak, bur oak and shell bark hickory, but the understory is dominated by exotic cool season grasses and shrubs.

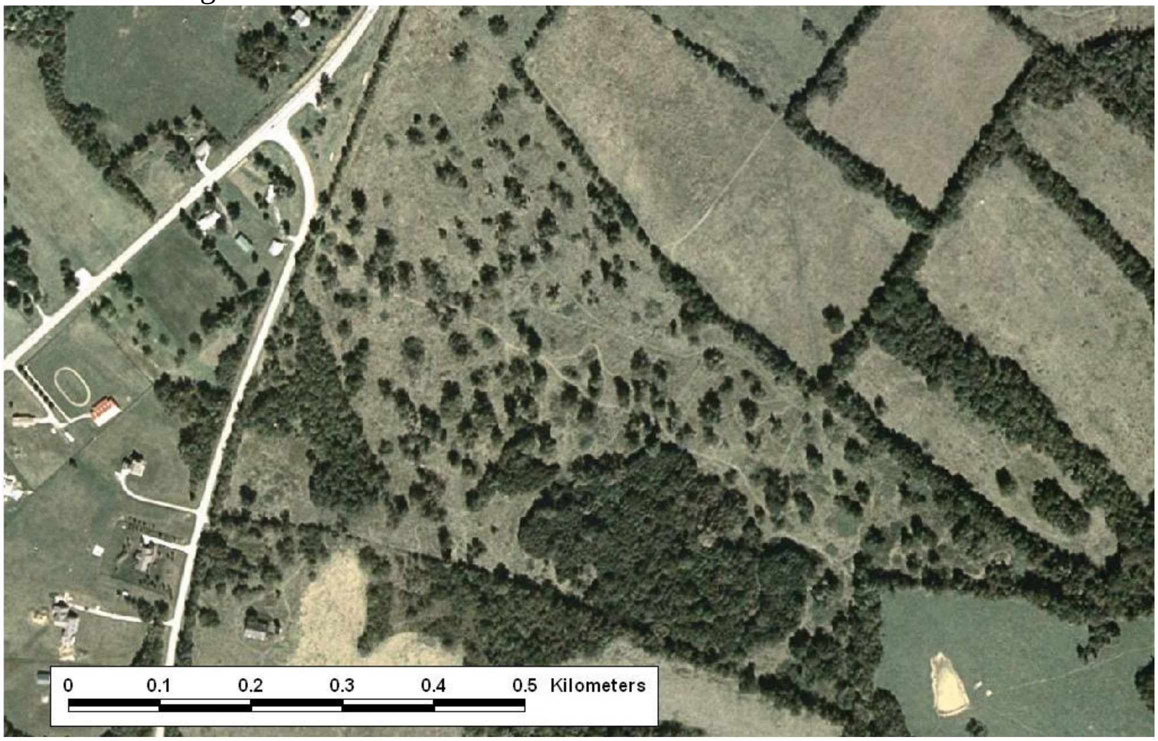


Figure 25. Due to the sometimes stark color contrast between warm and cool season grasses, 2004 NAIP imagery, especially taken in spring, is very useful for identifying potential native grassland remnants. Even sites that look highly abused, if located within the known historic prairie range, can yield high quality grassland remnants. This example of an eroding pasture in Nelson County, contains a high quality tallgrass prairie remnant.

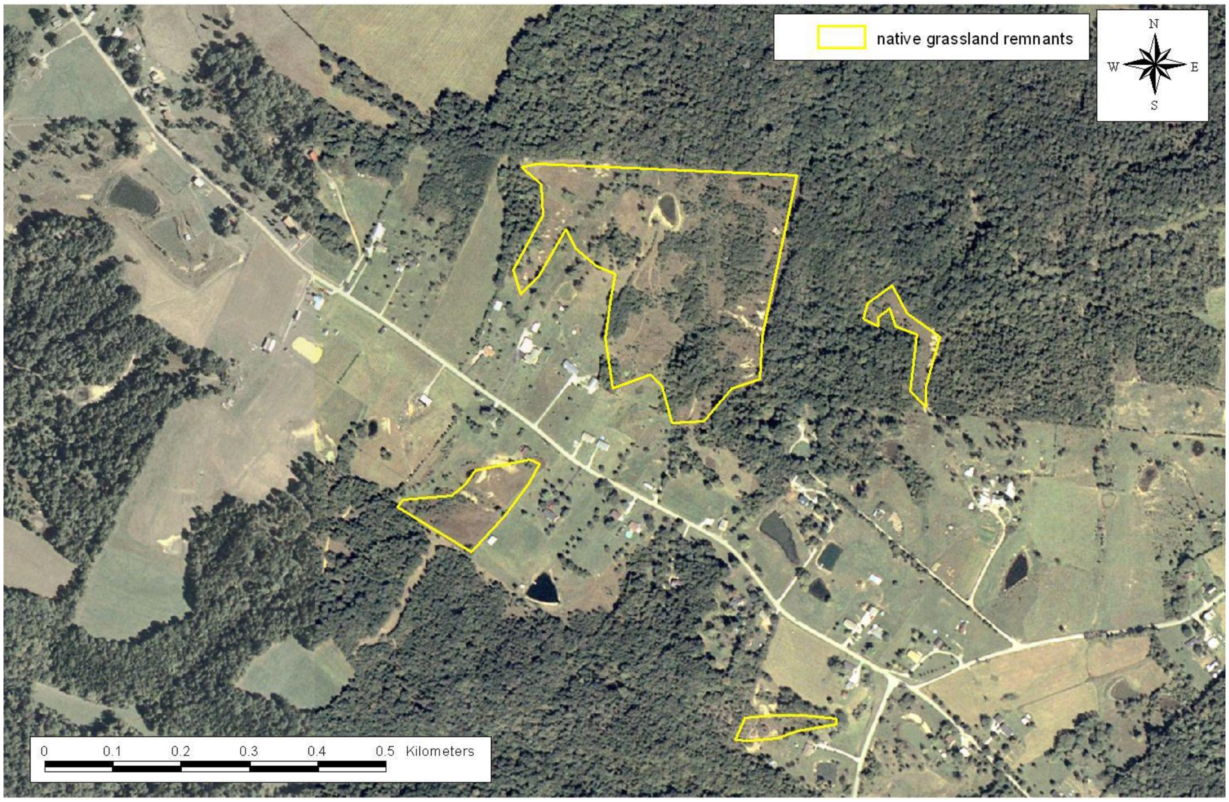
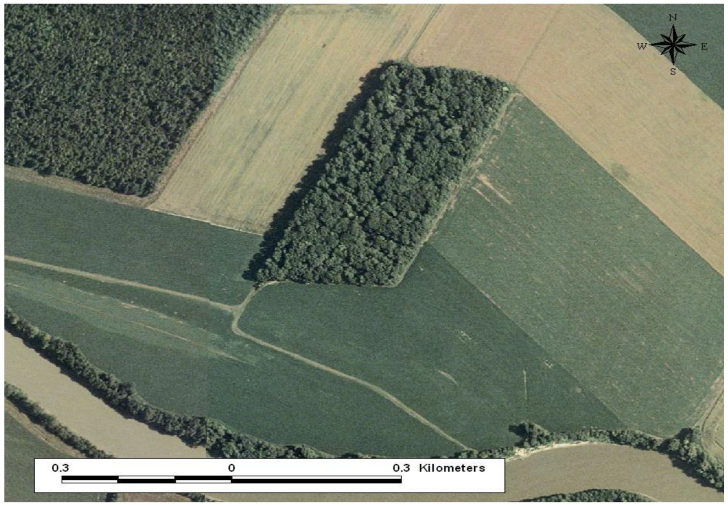


Figure 26. Various types of logging activities are often easily detectable on 2004 NAIP imagery. While clearcutting can also be seen on leaf-off black and white photos, selective logging operations are usually not distinguishable. Example from eastern Carter County, KY.

Figure 27. Floydôs Woods McLean Co.
An old-growth bottomland hardwood forest. The large crown size contrasts starkly to the crowns of nearby younger stands. Unfortunately, due to its small size and poor landscape context, this site has limited natural area value. It lacks the diversity of larger stands, is susceptible to windfall, and not sustainable in the long term.



2004 NAIP image

2007 aerial photo

Figure 28. Example of natural community mapping for Cumberland Falls State Nature Preserve, based on aerial photos overlain with clear topographic maps. This kind of mapping requires an intimate knowledge of the landscape under consideration and the communities involved and ideally should be accompanied by ground surveys.

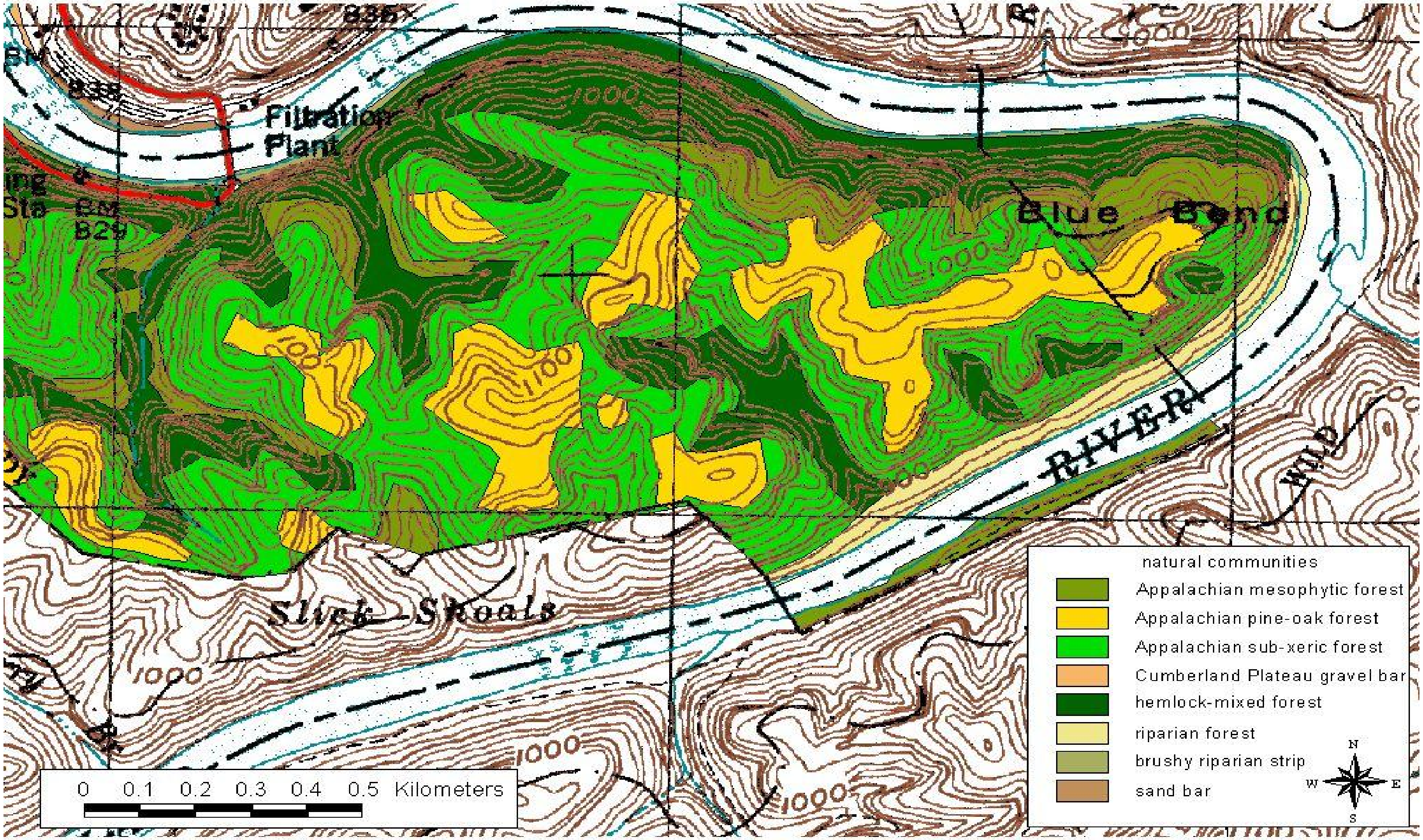


Figure 29. Invasions by exotic plants can not usually be depicted on remote imagery. While the forest within the stream corridor appears intact and fairly well buffered on this 2004 NAIP image, a ground survey showed that an extensive area downstream of the KY 182 bridge is riddled with exotics, especially climbing Euonymus (*Euonymus fortunei*), and garlic mustard (*Alliaria petiolata*).

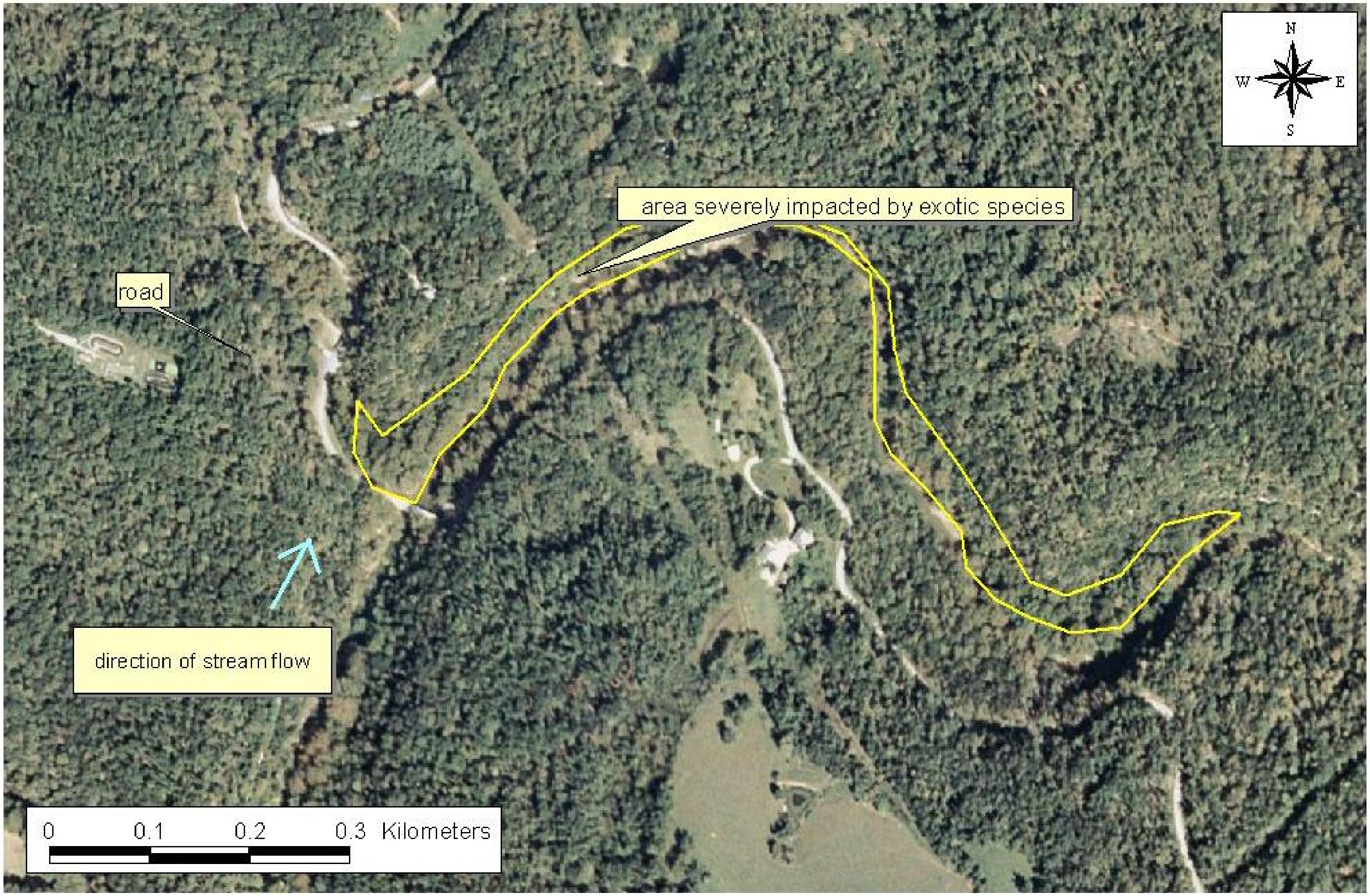


Figure 30. Some exotic plant problems can be detected during aerial surveys in spring before most trees leaf out. This example shows extensive infestation by bush honeysuckle (*Lonicera makii*) which leafs out early. (Mesic calcareous forest near Frankfort, Kentucky)

Figure 31. On this photo (March 2007 aerial survey), distinct wetland zones are visible. Bottomland hardwood forest (at the lower right) grades into currently flooded swamp forest, which transitions into an open cypress swamp. Areas of giant reed *Phragmites australis* infestation are clearly visible in this zone.

Maturing bottomland hardwood forest in McLean county, Kentucky.

Figure 32. Cumberland Highlands forest, a rare forest type in Kentucky, is restricted to elevations above approximately 3,400ft. Digital elevation models in connection with aerial photos can be used to predict occurrences of this forest type. Dominant species include *Betula lutea, Fagus grandifolia, Acer saccharum, Tilia heterophylla* and *Prunus serotina*. The understory is typically very rich and diverse.

Figure 33. If aerial surveys are conducted in spring, some information regarding composition can be collected. In this image, for example, trees with green spring foliage are mostly maples and tulip poplars, where the latter can be identified by their characteristic conic shape. Young foliage of oaks appears orange and brownish, whereas the trees that have not leafed out are probably predominantly hickories.

Figure 34a. This 2004 NAIP image shows what could be interpreted to be a native grassland remnant in Carter County, KY. Inspection on the ground, however, revealed that, while native grasses occur, diversity is low, and the only warm season grass present is broomsedge (Andropogon virginicus), which is not an indicator of native prairie remnants. Carter County does not fall within the historic range of prairie which probably explains the lack of higher quality grasslands.

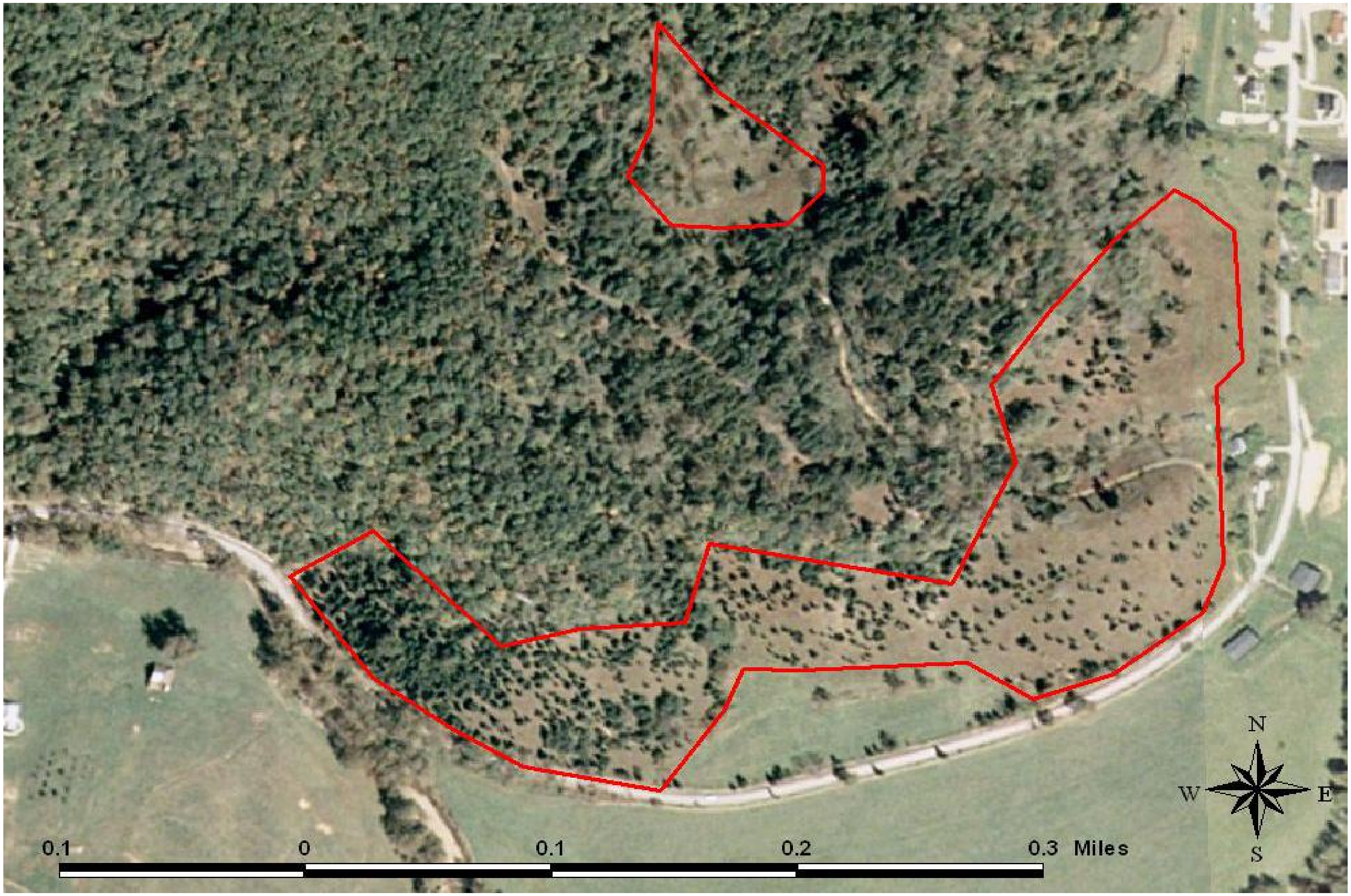


Figure 34b. Intact limestone slope glade as seen on leaf-off black and white photo with clear topographic overlay (Thompson Creek Glade State Nature Preserve, KY). Note the characteristic irregular shape, the south and westerly aspect, and presence of cedars appearing dark in contrast to the surrounding hardwood trees, and the light patches indicating erosion or rock outcrops.

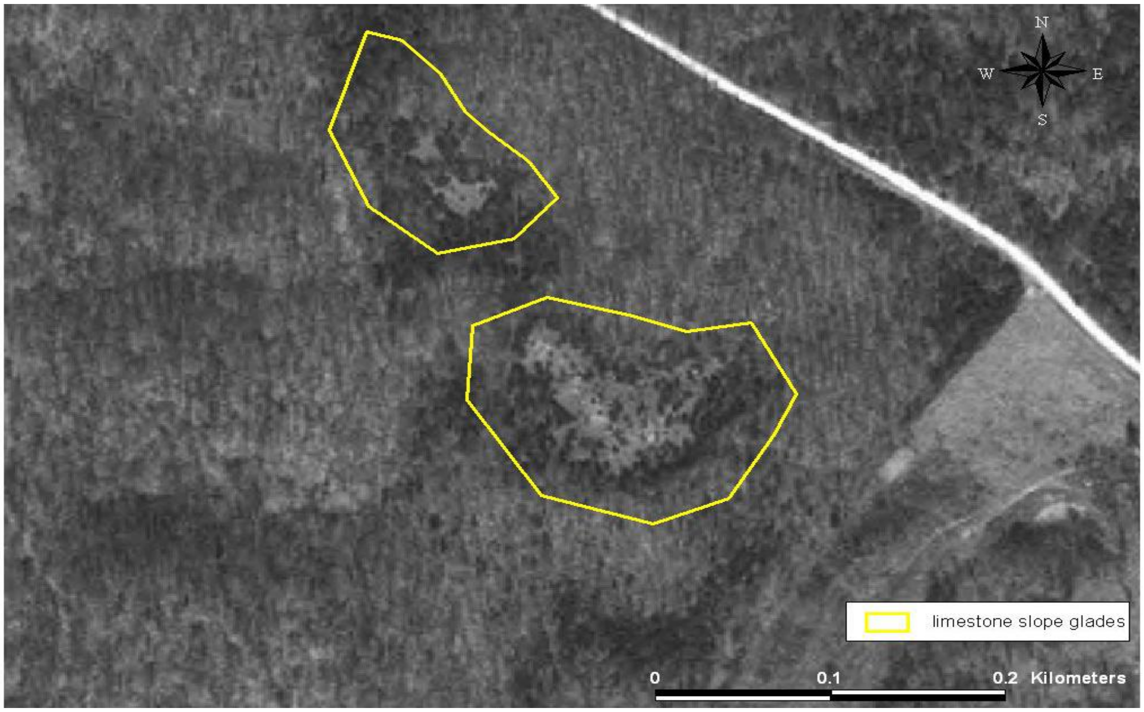


Figure 34c. Intact limestone slope glade viewed from helicopter. Irregular shape, patches of warm season grasses, and scattered cedars are evident.

Figure 35. Glades can often be detected from the air due to the presence of rock outcrops and are associated with irregular shaped canopy openings, and evergreens, especially red cedars. However, quality assessment requires site visits. This promising looking glade in McLean County turned out to be of very low diversity and was eliminated from the study.

Figure 36. Flatrock glades, as seen on black and white leaf-off photo (Flat Rock Glades State Nature Preserve, KY) and from the helicopter (below).

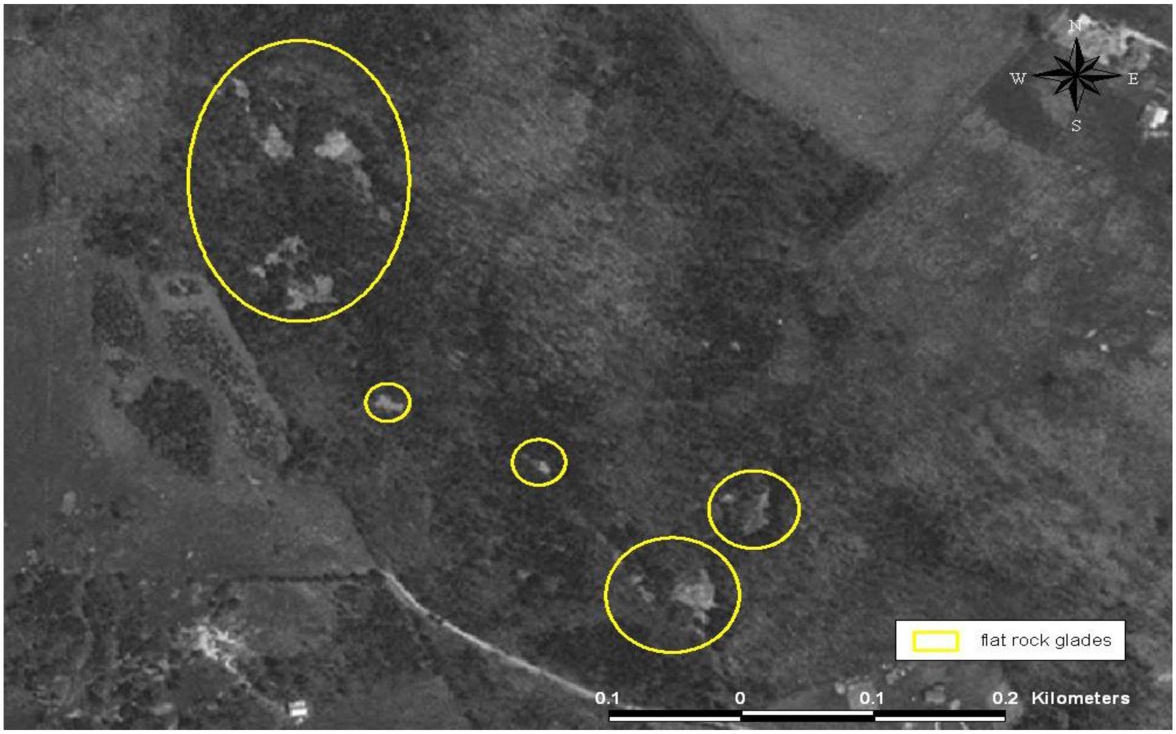
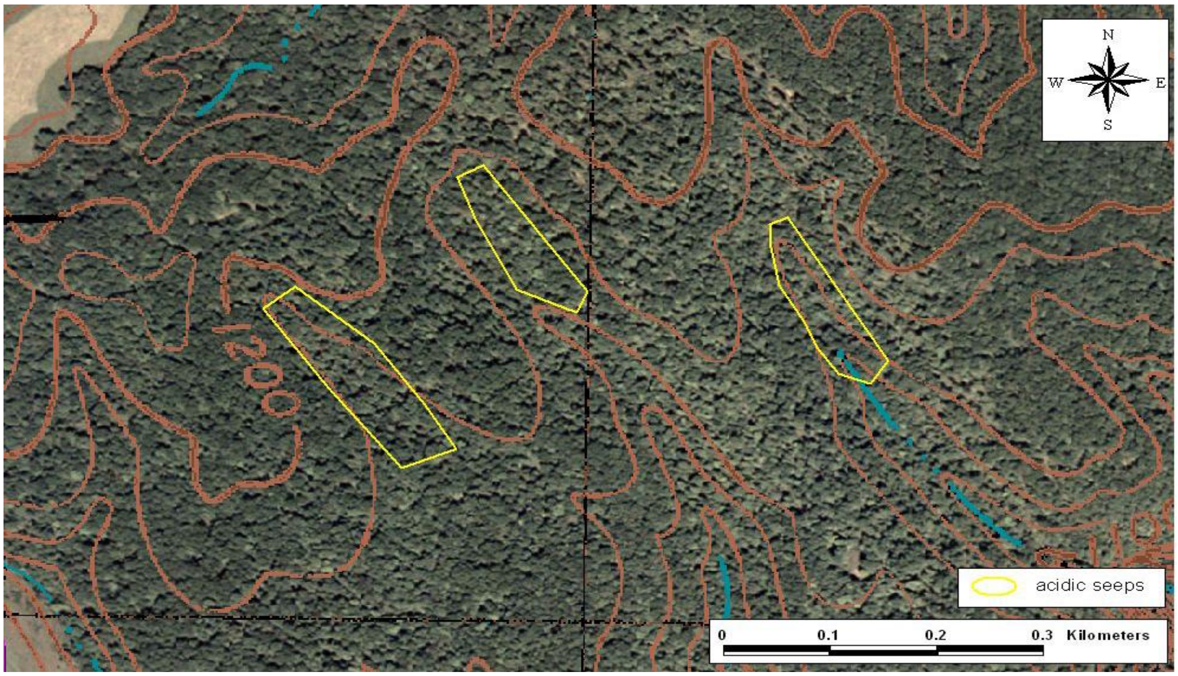


Figure 37.This 2007 photo taken during aerial surveys shows a cypress swamp in northern Muhlenberg County. Locals call these open wetlands ñcypress scattersò.

This 2004 NAIP image shows an open cypress swamp similar to the one in the photo above, but the brownish color indicates heavy infestation with reed, *Phragmites australis.*

Figure 38. Acid seeps are one type of small natural communities that is impossible to identify on aerial photos, as this example demonstrates. This series of seeps, which supports several rare species, was found during aerial survey in the spring before leaves would obscure patches of *Osmunda* ferns. Previous to flying, likely locations were chosen based on topographic characteristics (streamheads with gentle slope on broad forested ridges).



Appendix III

Table 1. Natural area inventory data for Carter County, Kentucky.

NAME	PNA #	VEGETATION TYPE	P_STATUS	GENERAL COMMENTS	FLIGHT COMMENTS	FIELD COMMEMTS	ACRES
Upper Tygart Hills	1	Upland Grassland	low priority NFC		MH/BDY: 3/20/07; very small native patch grassland	landowner declined access	12.953
Greenbrier	2	Upland Grassland	Eliminated		MH/BDY: 3/20/07; eliminate	old field natives but boring	4.528
Big Sinking Creek	3	Upland Forest	Eliminated		MH/BDY: 3/20/07; natural shrubland?; nice hemlock, cedar but small pna	MH/BY: a nice mix of spring wildflowers and other natives but mined spoil and logging disturbance present; 4/13/07	133.587
	4	Upland Woodland	Eliminated		MH/BDY: 3/20/07; known site lots of pine-does not look like savann	grown up and scrubby, lost savanna character	27.293
Grayson Lake WMA	5	Upland Forest	NFC		MH/BDY: 3/20/07;large forest block		751.375
Grayson Lake WMA	5	Upland Forest	NFC		MH/BDY: 3/20/07; large forest block		4953.533
Grayson Lake WMA	5	Upland Forest	NFC		MH/BDY: 3/20/07; large forest block		233.732
Fields Branch Grassland_2	6	Upland Grassland	Eliminated	low priority based on field checks of similar sites in area	MH/BDY: 3/20/07;eliminate		5.518
Fields Branch Grassland	7	Upland Grassland	Eliminated	low priority based on field checks of similar sits in area	MH/BDY: 3/20/07;eliminate		8.012
	8	Upland Forest	Eliminated		MH/BDY: 3/20/07; mature second growth; nothing special	partially logged, past mining in part of site	74.412
The Pigeon Roost	9	Upland Forest	NFC		MH/BDY: 3/20/07; keep; big trees in ravine		1143.146
	10	Upland Forest	Eliminated		MH/BDY: 3/20/07; eliminate; mature second growth but small		49.332
Rush Woods	11	Upland Forest	Eliminated		MH/BDY: 3/20/07; eliminate; big trees but small		24.520
Wilson Creek Grassland	12	Upland Grassland	Eliminated		MH/BDY: 3/20/07;eliminate; no native grasses		1.570
Wilson Creek Woods	13	Upland Forest	Eliminated		MH/BDY: 3/20/07;eliminate; logged around entire perimeter		289.713
Little Sandy Woods	14	Upland Forest	Eliminated		MH/BDY: 3/20/07;eliminate; some big trees though		163.518
Burnett Cementary	15	Upland Grassland	Eliminated	low priority based on ground checks of similar sites nearby	MH/BDY: 3/20/07;keep native grasses ??		12.678
Barnes Top	16	Upland Grassland	NFC		MH/BDY: 3/20/07; looks really good; slope prairie with rocky woods above		6.675
Barnes Top	16	Upland Grassland	NFC		MH/BDY: 3/20/07; looks really good; slope prairie with rocky woods above		3.639
Buffalo Hills	17	Upland Grassland	Eliminated	native grassland?	MH/BDY: 3/20/07; looks really good; keep; western part looks best	mostly used for pasture; dominated by native weedy grasses but not natural; eliminate	20.121
Buffalo Hills	17	Upland Woodland	NFC		MH/BDY: 3/29/07; looks really good; keep; western part looks best	landowner has been burning property; mesic woods and dry woodlands hold alot of native species; needs a revisit; visited 5/4/07	40.118

Pipeline	18	Upland Grassland	Eliminated	low priority based on ground checks of similar sites nearby	MH/BDY: 3/20/07; looks good	landowner declined permission	4.731
McGlone Prairie	19	Upland Grassland	Eliminated	low priority based on ground checks of similar sits nearby	MH/BDY: 3/20/07; eliminate		36.525
	20	Upland Grassland	Eliminated	low priority based on ground checks of similar sites nearby	no comment		1.106
Carter Caves (State Preserv	21	Upland Forest	State Significant		MH/BDY: 3/20/07; LFB, state forest, park and preserve; many rare species protected		2156.049
	22	Riparian	County Notable	riparian corridor and cliffs, numerous rare species occurrences	3/29/07; beaver dams; dead tree swamp; nfc	visited 8/1/07; nice bottomland with shrub swamps!; NFC	267.630
	22	Upland Forest	Eliminated		no comment	MH/BDY: Eunymous fortunei a serious problem here; is the dominant herb layer through much of this area	17.255
Tygart's Bends	22	Riparian	NFC		no comment		132.066
Tygart's Creek	23	Upland Forest	NFC		MH/BDY: 3/20/07;keeper; stream and cliffs with hemlok?; trees mature		203.481
	24	Upland Forest	Eliminated		no comment	MH/BDY: current logging eliminate	11.020
	24	Upland Forest	Eliminated		no comment	MH/BDY: weedy species; next to logged area; might be logged in near future; second grwoth mature woods	44.327
	25	Upland Woodland	NFC	delete this? Why was this chosen for NAI?	no comment		6.475
	26	Upland Grassland	Eliminated	low priority based on ground checks of similar sites nearby	MH/BDY: 3/20/07; keep; color looks good; w/ lots pine		5.053
powerline	27	Upland Grassland	Eliminated	low priority based on ground surveys of similar sites nearby	MH/BDY: 3/20/07; best part near north of pna; only keep for species		5.179
powerline	28	Upland Grassland	Eliminated	low priority based on ground checks of similar sites nearby	MH/BDY: 3/20/07; not as good; tall grass		1.223
Tiereny Ridge	29	Upland Woodland	State Significant	high quality calcareous woodland; five listed species; known site for rare plts	no comment	BDY/MH visited 5/3/2007: nice ridge woodland with 5 listed plant populations	0.893
	30	Upland Grassland	low priority NFC	grassland and slope glade?	MH/BDY: 3/29/07; grassland and slope glade?		31.315

Table 2. Natural area inventory data for Muhlenberg County, Kentucky.

NAME	PNA #	VEGETATION TYPE	PNA STATUS	GENERAL COMMENTS	FLIGHT COMMENTS	FIELD COMMEMTS	ACRES
Jarrels Bottoms	1	Wetland	Eliminated	LJM: PNA01; swamp; bdy: includes BHF ranked A quality; but small crowns?; 2004 Aerial Imagery	ME/BDY: 3/29/07; this part logged		320.117
Turkey Hill Bottoms	1	Bottomland Forest	NFC	LJM: PNA01; swamp; bdy: includes BHF ranked A quality; but small crowns?; 2004 Aerial Imagery	ME/BDY: 3/29/07; good chunk of wet woods; nfc; ditches present		1678.895
Green River Bottoms	2	Bottomland Forest	Eliminated	LJM: PNA02	ME/BDY: 3/29/07; young and thinned; eliminate		348.623
Green River Bottoms	2	Bottomland Forest	low priority NFC	mature bhf; bdy:uneven, logged?	ME/BDY: 3/29/07; mostly very young		195.078
Cypress Creek	3	Wetland	NFC	LJM: pna03; large wetland, young woods, shrub swamp	ME/BDY: 3/29/07; many large patches of Phragmites throughout		3707.222
Boggess Hollow Woods	4	Upland Forest	Eliminated	LJM: PNA04; recent photo shows impact	no comment		958.676
Sulpher Spring Creek	5	Upland Forest	Eliminated	LJM: PNA05	no comment	LJM: cut (logged)	1532.349
Pryor Creek Woods	6	Upland Grassland	Eliminated	prairie remnant; LJM: PNA06 in part	3/29/07; eliminate		61.459
Rocky Creek Woods	7	Upland Forest	Eliminated	LJM: PNA07	no comment	LJM: cut (logged)	981.550
Dunmor Woods	8	Upland Forest	Eliminated	LJM: PNA08; recent photo shows impact; BDY: not sure if this polygon is in the right location	no comment	no comment	532.569
Jockys Branch, Mud River Flats	9	Bottomland Forest	Eliminated	larger bottomland forest; LJM pna8?; bdy: extended pna to include jockys branch; rcovering bottomland and steep topography for county; forsts are sttill young	3/29/07; keeper; young; good size	visited 9/2007; MH: young and low diversity; creek corridor witrh invasives	588.945
Jockys Branch, Mud River Flats	9	Bottomland Forest	NFC	larger bottomland forest; LJM pna8?; bdy: extended pna to include jockys branch; rcovering bottomland and steep topography for county; forsts are sttill young	3/29/07; keeper; young; good size		491.569
Mud River Hills	10	Upland Forest	low priority NFC	bdy: a large entact chunck of forest with upland and lowland communities; some glady-grassy openings throughout; woods looks to be cut over 15-20 yrs ago?	3/29/07; current logging; decent looking woods; lowlands cleared; upland woods decent; low priority		1622.602
	11	Bottomland Forest	NFC	bottomland forest	3/29/07; nfc; dead tree swamp interesting; woods young		199.317
Rocky Creek Bottoms	12	Bottomland Forest	County Notable	bottomland swamp: western poly	3/29/07; beaver dams; dead tree swamp; nfc	visited 8/1/07; nice bottomland with shrub swamps!; NFC	217.941
Rocky Creek Bottoms	12	Wetland	Eliminated	bottomland swamp: northern poly	3/29/07; beaver dams; dead tree swamp; nfc	visited 8/1/07; nice, young areas of bottomland forest but cows and microstegium too plentiful in this small area	83.995
Rocky Creek Bottoms	12	Wetland	NFC	bottomland swamp: cenral poly	3/29/07; beaver dams; dead tree swamp; nfc		321.643
	13	Wetland	NFC	bottomland swamp	3/29/07; keeper; ok marsh w/ nuphar		171.085
	14	Wetland	Eliminated	small swamp	ME/BDY: 3/29/07; nothing of interest; small timber;3/29/07		51.248
	15	Bottomland Forest	Eliminated	bottomland forest; bdy: looks partly logged	ME/BDY: 3/29/07; logged		199.199
	16	Bottomland Forest	Eliminated	bottomland forest; too small	no comment		59.547
	17	Wetland	Eliminated	swamp; bdy: but channelized	MH/BDY: 3/20/07; young; looks to be poor quality		226.555
	17	Wetland	low priority NFC	swamp; bdy: but channelized	MH/BDY: 3/20/07; more mature best part		204.572

Table 3. Natural area inventory data for McLean County, Kentucky.

NAME	PNA #	VEGETATION TYPE	P_STATUS	GENERAL COMMENTS	FLIGHT COMMENTS	FIELD COMMEMTS	ACRES
Cypress Flatwoods	1	Bottomland Forest	low priority NFC	young flatwoods	ME/BDY: 3/29/07; some big trees near the center of the pna; thinned and logged on eastern and western		352.074
	2	Bottomland Forest	Eliminated	young flatwoods	ME/BDY: 3/29/07; young; keep	young and low diversity, eliminate	219.804
Island Flatwoods	3	Bottomland Forest	Eliminated	young flatwoods	ME/BDY: 3/29/07; eliminate half is currently being logged		257.234
Livermore Flats	4	Bottomland Forest	Eliminated	young flatwoods	ME/BDY: 3/29/07; northern end higher priority	visited 8/16/07; visited lowlands north of state route 138 and the western part along state route 2110; of medium quality; landscape too fragmented; eliminate	434.778
Highland Slough	5	Wetland	Eliminated	slough	ME/BDY: 3/29/07; keep for aquatic plants; not defensible as a natural area	visited 8/16/2007; weedy marsh species present; eliminate	87.842
Nall Woods	6	Bottomland Forest	Eliminated	BDY: known site: Nall woods; BHF	ME/BDY: 3/29/07; good flatwoods; nfc!! average	visited 8/16/07; currently being logged; eliminate	136.699
Vicker Bridge Bottoms	7	Bottomland Forest	low priority NFC	MH: bottomland forest; BDY: very young	ME/BDY: 3/29/07; low priority; small trees; natural pond w/ cypress		139.294
Coffman Bridge Bottoms	8	Bottomland Forest	Eliminated	MH: bottomland forest; BDY: very young	ME/BDY: 3/29/07; eliminate		186.838
Shrubby Bottom	9	Wetland	low priority NFC	shrub swamp?	ME/BDY: 3/29/07; low priority nfc; young		189.032
	10	Bottomland Forest	low priority NFC	bottomland forest	ME/BDY: 3/29/07; thin cronwns; low priority nfc		158.415
Gravel Ford Bridge Bottoms	11	Bottomland Forest	low priority NFC	bottomland forest	ME/BDY: 3/29/07; low priority nfc; young		120.104
Mt. Vernon Woods	12	Upland Forest	Eliminated	upland forest/cliffs	ME/BDY: 3/29/07; recently logged; eliminate		332.612
Big Yellow Forest	13	Bottomland Forest	County Notable	bottomland forest?; BDY; flatwoods? and some parts look mature	ME/BDY: 3/29/07; keeper; some more mature areas with very young; nfc	mature forest, B quality, but currently being cut	339.103
Denhart Woods	14	Upland Forest	Eliminated	large forest block w/ glady slope	ME/BDY: 3/29/07; logged, eliminate		233.380
Denhart Prairie Patch	15	Upland Grassland	Eliminated	native grasses?	ME/BDY: 3/29/07; eliminate		3.329
Trailer Woods	16	Upland Forest	low priority NFC	upland forest; BDY: w/ glade	ME/BDY: 3/29/07; keeper; lots of deer blinds; low priority nfc		700.801
Abe's Bottoms	17	Bottomland Forest	Eliminated	bottomland forest?; BDY: very young	ME/BDY: 3/29/07; eliminate; logged and thin		1059.329
Long Falls	18	Bottomland Forest	Eliminated	bottomland forest	ME/BDY: 3/29/07; eliminate		144.327
Lonely Woods	19	Upland Forest	Eliminated	BDY: nothing of interest, very young, small	young		140.745
Big Stillhouse Woods	20	Upland Forest	Eliminated	large forest block; disturbance and not continous but crowns in some areas look rel. large: extended polygon	ME/BDY: 3/29/07; this part logged; eliminate		110.134
Big Stillhouse Woods	20	Upland Forest	low priority NFC	large forest block; disturbance and not continous but crowns in some areas look rel. large: extended polygon	ME/BDY: 3/29/07; OK		341.398
	21	Upland Forest	Eliminated	large forest block; BDY: but crowns small and recently logged	logged		552.403
Eagle Creek Pond	22	Wetland	Eliminated	small wetland with natural pond?	ME/BDY: 3/29/07; eliminate; backed up; no phragmites though		55.098