



Land Cover Monitoring Protocol for the Heartland Inventory and Monitoring Network

Natural Resource Report NPS/HLTN/NRR—2014/754



ON THE COVER

Herbert Hoover birthplace cottage at Herbert Hoover NHS, prescribed fire at Tallgrass Prairie NPres, aquatic invertebrate monitoring at George Washington Carver NM, the Mississippi River at Effigy Mounds NM.

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Natural Resource Report NPS/HLTN/NRR—2014/754

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Executive Summary

This is the first edition of a Land Cover Monitoring Protocol for the Heartland Inventory and Monitoring Network. A fundamental concern of the Heartland Network (HTLN) is whether the species, communities and ecological processes comprising the natural resources of small and/or highly fragmented parks are sustainable in the face of habitat loss in areas adjacent to the park and climate change. Potential impacts from adjacent land-use change on park natural resources include reduced water and air quality, increased invasive plant occurrence, altered animal populations associated with neighboring habitat loss, and diminished quality of the park's scenic viewshed. HTLN parks are bordered by adjacent land uses ranging from cattle grazing of native rangeland, to cultivated agricultural fields, to rapid urban development. A key aspect of measuring the effects of isolation and fragmentation is documenting past and current land cover and analyzing rates of land cover change. The purpose of this monitoring protocol is to determine long-term trends in land cover change inside and adjacent to HTLN parks and to determine the rate and distribution of urban expansion around HTLN parks. This land cover protocol demonstrates how to acquire data, process data, assess accuracy, analyze data, and report the data.

Acknowledgments

The National Park Service's Inventory and Monitoring Program provided funding for land cover monitoring protocol development and continues to fund monitoring across Heartland Inventory and Monitoring Network parks. This protocol was written in conjunction with the University of Arkansas at Monticello, Spatial Analysis Laboratory (SAL). We especially like to thank N. Riggan of SAL. Mike Story and Miguel Villarreal conducted the peer-review of this document for which we are grateful. We would also like to thank M. DeBacker for his continued work and support associated with this protocol. Numerous NPS staff and volunteers have contributed to the development of this protocol. Therefore, the list of authors simply reflects those who put down on paper the work of this larger group.

List of Acronyms

AA: Accuracy Assessment

AOI: Area of Interest

BUFF: Buffalo National River

DEM: Digital Elevation Model

DN: Digital Number

DNR: Department of Natural Resources

DOQ: Digital Ortho-Quad

EFMO: Effigy Mounds National Monument

EMR: Electromagnetic Radiation

GCP: Ground Control Point

GDB: Geodatabase

GIS: Geographic Information System

GPS: Global Positioning System

GWCA: George Washington Carver
National Monument

HEHO: Herbert Hoover National Historic
Site

HOME: Homestead National Monument of
America

HOCU: Hopewell Culture National Historic
Park

HOSP: Hot Springs National Park

HRG: High Resolution Geometric

HTLN: Heartland Network

I&M: Inventory and Monitoring

IAP: Individual Acquisition Plan

LC: Land cover

LIBO: Lincoln Boyhood National Memorial

MDB: Microsoft Access database

MSU: Missouri State University

NAD83: North American Datum 1983

NED: National Elevation Dataset

NPS: National Park Service

NRCS: Natural Resources Conservation
Service

NRDT: Natural Resource Database
Template

OZAR: Ozark National Scenic Riverways

PERI: Pea Ridge National Military Park

PIPE: Pipestone National Monument

RAM: Random access memory

RMS: Root Mean Square

RS: Remote sensing

SBAS: Satellite-Based Augmentation
System

SOP: Standard Operating Procedure

SOW: Statement of Work

SPOT: Satellite Pour l'Observation de la
Terre

SRP: Stratified random points

SWIR: Short-Wave Infrared

USGS: United States Geological Survey

UTM: Universal Transverse Mercator

WICR: Wilson's Creek National Battlefield

XML: Extensible Markup Language

Background and Objectives

Background

The Heartland Inventory and Monitoring Network (HTLN) is part of the nationwide Inventory & Monitoring (I&M) program of the National Park Service (NPS). The HTLN serves 15 National Park Service (NPS) units in eight Midwestern states. The network covers a large geographic region from Ohio to Kansas and Minnesota to Arkansas with park sizes ranging from 65 ha (160 ac) to 38,757 ha (95,730 ac). These parks contain a wide variety of natural and cultural resources including sites focused on commemorating civil war battlefields, Native American heritage, westward expansion, and our U.S. Presidents. Multiple ecosystems are represented across the parks including rivers, lakes, springs, prairies, wetlands, and forests. The Network is charged with creating inventories of its species and natural features as well as monitoring trends and issues. Critical inventories help park managers understand the natural resources in their care while monitoring programs help them understand meaningful change in natural systems and to respond accordingly.

An underlying theme of the Heartland Network is the question of whether the species, communities and ecological processes comprising the natural resources of small and/or highly fragmented parks are sustainable in the face of adjacent habitat loss and climate change. Potential impacts from adjacent land-use change on park natural resources include reduced water and air quality, increased invasive plant occurrence, altered animal populations associated with neighboring habitat loss, and diminished quality of viewshed. HTLN parks are bordered by adjacent land uses ranging from cattle grazing of native rangeland, to cultivated agricultural fields, to rapid urban development. A key aspect of measuring the effects of isolation and fragmentation is documenting past and current land cover and analyzing rates of land cover change.

Land cover (LC) is a distinct concept applied to the classification of the earth's land surface (Estes et al. 1982). Land cover is defined as visible features on the landscape. For this classification we are only considering land cover, because seldom can we see land use. The classification of LC is the assignment of classes to a geographic area based upon similar characteristics of LC. Numerous uses exist for digital LC classification maps. For example, LC classification maps provide insight into a region's soils and geology (Ustin et al. 1999, Gupta 2003). Land cover classification maps are used extensively in conservation planning (Turner et al. 2003, Kerr and Ostrovsky 2003), informing land development decisions in metropolitan areas (Ridd 1995, Weber and Puissant 2003), planning and implementing large-scale inventories of natural resources (Anderson 1982, Volgelmann et al. 1998), and monitoring change in ecosystem/landscape condition over time (Frohn 1998, Lambin 1996, Weng 2002). Land cover data, particularly when used in conjunction with other data such as terrain maps and Digital Elevation Models (DEMs), can be useful in identifying areas more or less suited to specific land management practices and thereby aid in the assessment of appropriate practices for use in a specific area to attain certain goals (Bonner et al. 1982).

A discussion on the how and why certain methods were chosen over others can be found in Appendix A. The appendix contains a summary of R. Weih and N. Riggan's Hot Springs National Park case study and the HTLN's Hopewell Culture National Historic Park case study.

Measurable Objectives

1. Determine long-term trends in land cover change inside and adjacent to HTLN parks.
2. Determine the rate and distribution of urban encroachment within the study area of HTLN parks.
3. Determine long-term trends in land cover within watershed boundaries for parks that are National or Scenic Rivers.

Study Area

The study area of interest for this protocol will be referenced as “local scale”. Local scale implies a courser resolution than park scale, but a finer resolution than the regional scale information provided by NPScape (<http://science.nature.nps.gov/im/monitor/npscape>). The local scale information provides a bridge between the park vegetation maps and the regional NPScape datasets.

LC monitoring is conducted at 12 parks within the HTLN. These parks are Buffalo National River (BUFF), Effigy Mounds National Monument (EFMO), Hopewell Culture National Historic Park (HOCU), George Washington Carver National Monument (GWCA), Herbert Hoover National Historic Site (HEHO), Homestead National Monument of America (HOME), Hot Springs National Park (HOSP), Lincoln Boyhood National Memorial (LIBO), Ozark National Scenic Riverways (OZAR), Pea Ridge National Military Park (PERI), Pipestone National Monument (PIPE), and Wilson’s Creek National Battlefield (WICR). The study areas vary between the park units. For the two river parks (BUFF & OZAR) a modified watershed boundary is sampled. For the remaining ten parks, the study area is a 10km buffer around the park merged with the 10 digit hydrologic unit(s). Detailed information and maps of the study areas can be found in SOP 1.

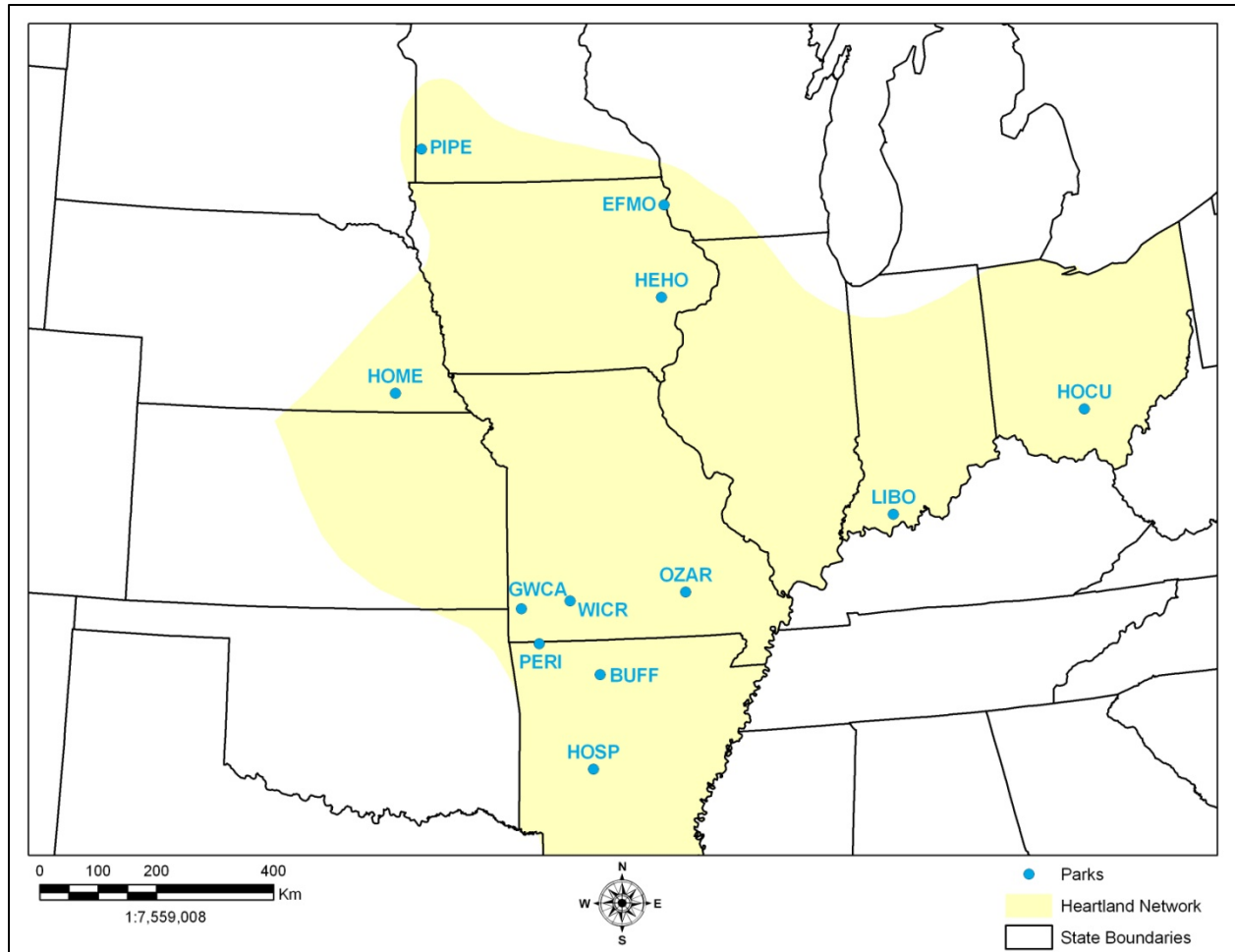


Figure 1. Map that represents where LC monitoring takes place within the HTLN.

Methods

Data Acquisition

Imagery Requirements

The most important component of a land cover remote sensing classification is the acquisition of imagery. When researching what imagery to use for this protocol, we developed a list of requirements and factors for the imagery to meet. The first factor was to find an imagery source that would be available and consistent for all twelve parks. It is also important that imagery spatial and spectral resolutions stay consistent for change detection analysis (Lu et al. 2004). Secondly the imagery needs to accommodate the size and shape of HLTN parks, which range from relatively small size (~80 hectares), to narrow and linear (less than a kilometer wide) to as large as a watershed. A third factor was finding imagery that contained a short-wave infrared band (SWIR). This SWIR band would help in classifying vegetation types, especially evergreen forest on a leaf-on image scene. Finally the imagery had to be affordable and constant over the long-term. Townsend et al. (2009) states that high resolution imagery ($\leq 4\text{m}$) are expensive, cover relatively small areas, and are more susceptible to effects of geometry. Landsat imagery covers a large area, but complete coverage is currently no longer reliable due to a failure with the

scan-line corrector in 2003 (Townsend et al. 2009). SPOT satellite imagery or similar imagery products with a 10m resolution will meet all of the factors listed above. SPOT 10m imagery is multispectral with a SWIR band. It covers a large enough area (60km) to cut down on geometry effects. SPOT imagery has been a reliable source since 1986 and with the launches of SPOT 6 and 7 in 2012-2013 there will be continuity until 2023. SPOT imagery is also an affordable product, and can also be found on the USGS EarthExplorer website (<http://earthexplorer.usgs.gov/>) as part of the North American Data Buy (Figure 3).

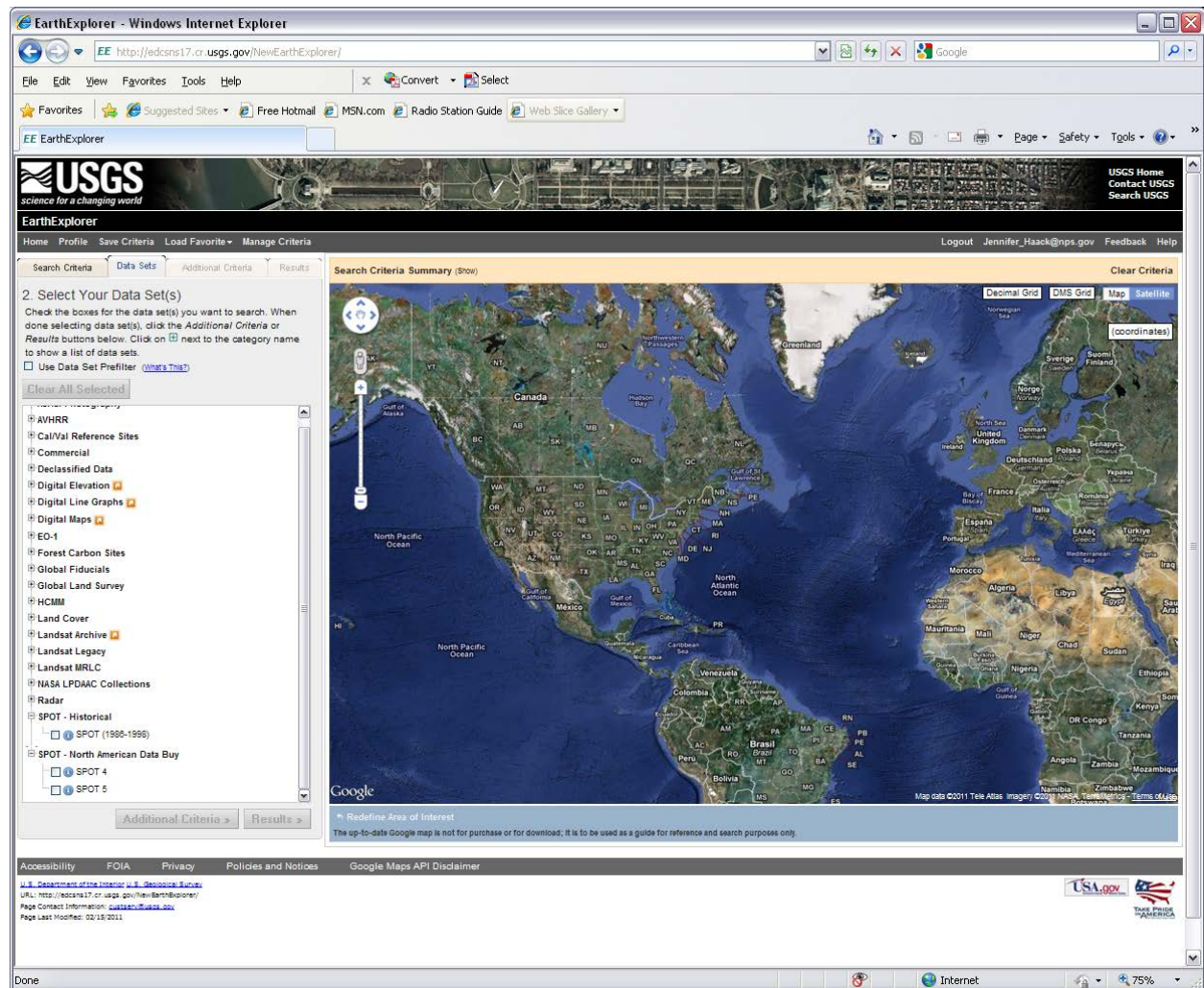


Figure 2. USGS EarthExplorer website.

In addition to the SPOT imagery, two other raster sources are needed to complete a classification. One is orthorectified aerial imagery. The aerial imagery acquired should have a resolution of 2 meters or less. This will be used to photo interpret accuracy assessment points. Aerial imagery should have a date as close to the SPOT imagery date as possible. The second raster data source is a DEM. The DEM will be used for orthorectification or atmospheric corrections of imagery if needed, and can also be used during classification.

SPOT Satellite Imagery

SPOT (Satellite Pour l'Observation de la Terre) is a high-resolution, optical imaging earth observation satellite system operating from space. It is controlled by SPOT Image based in Toulouse, France. SPOT 5 satellite imagery was used in this protocol and the satellite was launched on May 3, 2002. SPOT 5 has two High Resolution Geometric (HRG) instruments that offer a spatial resolution of 2.5 to 5 meters in panchromatic mode and 10 meters in multispectral mode. The SPOT multispectral imagery bands are B1 (0.50 - 0.59 μm - green), B2 (0.61 - 0.68 μm - red), B3 (0.78 - 0.89 μm - Near Infrared), and B4 (1.58 - 1.75 μm - Short-wave Infrared). The Short-wave Infrared band, originally a 20 meter resolution, is resampled to a 10-meter spatial resolution to match Bands 1-3 by the vender. The SPOT imagery has a radiometric resolution of 8-bits. The HRG sensor on SPOT 5 has rotating optics to facilitate off-nadir image acquisition (+/- 27 degrees). This feature provides a greater opportunity to collect cloud- free images over a given location. For land cover classifications it is recommended that the incidence angle be less than 12 degrees, if possible. Table 1 shows the different levels in which SPOT imagery can be purchased. Level-1B preprocessing includes both radiometric and geometric corrections. These corrections compensate for effects due to the viewing conditions and the satellite/Earth system. Geometric corrections are done to compensate for systematic effects, including: panoramic for distortion, Earth's rotation and curvature, and variations in the satellite's orbital altitude relative to the reference ellipsoid. Geometric corrections fully compensate panoramic distortion. The following radiometric corrections are done at Level-1B; the gains applied to each spectral band during scene acquisition, CCD detector dark current values, CCD detector normalization coefficients, absolute calibration coefficients, pixel count histograms, spectral profiles of the scene's spectral bands, and dynamic range enhancement (method and threshold values). The DIMAP format is a public format for describing geographic data. The DIMAP format is used for SPOT products and was introduced with the launch of SPOT 5.

Table 1. SPOT Processing Levels

Level 1A	Radiometrically Corrected by compensating for variations caused by detector sensitivity. Not Geometrically Corrected Commonly used with mapping applications and for geometric processing. Accurate within 50 meters.
Level 1B	Same Radiometric Correction. Geometrically Corrected by compensating for systematic effects. Commonly used for geometric measurements, photo-interpretation, and thematic studies. Accurate within 50 meters.
Level 2A	Same Radiometric Correction Geometrically Corrected to match a standard map projection (UTM WGS 84). Commonly used to combine different kinds of geographic information and apply color processing. Accurate within 50 meters.
Level 2B	Georeferenced Commonly used as digital maps. Generally accurate within 30 meters.
Level 3	Georeferenced Commonly used to map relief. Generally accurate within 30 meters.

Orthorectified Aerial Images

Digital Ortho-Quads (DOQs) are spatially planimetric (flat-map) digital aerial photograph images with high spatial resolutions. Spatial resolutions are generally two meters or better. These images usually can be acquired through various federal, state, or local web portals at little or no cost. The date of acquisition for these images varies from state to state and the images are usually flown in the winter (leaf-off).

Digital Elevation Model (DEM)

A DEM is required to orthorectify the SPOT satellite imagery. It is best to use the highest spatial resolution DEM obtainable for the area being orthorectified. All of the United States has at least a 30-meter DEM available from the USGS National Elevation Dataset (NED), with some areas having a finer spatial resolution. The state of Arkansas has a 5-meter DEM available. The USGS DEMs are digital files consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. Digital elevation models are gridded data representing real world elevations on the Earth's surface. Because DEMs provide real world elevations, scientists and decision makers have used DEMs in many disciplines for topographic surface modeling.

Training Data for Classification

Training data is location information used to develop classification training signatures. The training dataset documents the land cover classes present at specific locations. These training data points should mostly be on the ground “field-collected” locations that are documented with a GPS (Global Positioning System) unit. However, some training data points can be collected by

photo interpretation from good quality imagery, for example DOQs that are different from the imagery to be classified. Timing is important when capturing training data. This is true for both the field collected and photo interpreted points. Training data should be collected as close as possible to the dates of the classification imagery. The similar dates are important due to the changes that can occur on the land in a relatively short amount of time, such as road and urban development or natural disasters such as tornados, fires or ice storms.

Image Preparation

Before classification of the imagery can take place, the imagery must be processed for spatial location and atmospheric interference if needed.

Orthorectification

For a digital image to be useful in Geographic Information System (GIS) or Remote Sensing (RS) applications, the image needs to be referenced to a ground coordinate system. This is accomplished using a process called rectification. When an image is rectified, every pixel in the image is translated to its true ground location via comparison to a dataset that is referenced to real world coordinates. A warping polynomial is then defined and applied to the image. The most common method of achieving this is by obtaining ground control points (GCPs).

Ground control points, by definition, are positions with a known location that are identifiable in both referenced and unreferenced datasets (Gibson and Power 2000). These positions can be extracted from referenced GIS layers, images, or obtained from Global Positioning System (GPS) locations. Most remote sensing software today allows a user to view both datasets at the same time to locate and input GCPs for a quick way to reference the image.

DOQs are spatially referenced aerial photographs with a spatial resolution of one meter. They are commonly used for visualization, delineating boundaries of tree stands, properties, streets, and rivers, as well as referencing other datasets. Such applications are possible because DOQs are planimetric (flat-map) images with high spatial resolutions. Ground control points can be located within the image with relative ease. Road intersections are often the most visible features found in both DOQs and satellite images and are commonly used in rectification.

Rectification requires a projection and resampling technique. These are defined by the specific requirements of the application. Making the correct choices at this point is essential for accurate spatial referencing of image data. The projection of the unreferenced imagery will be the same as the referenced dataset, so a dataset with the appropriate projection must be used. The concept of projections is based on the understanding that the earth is an imperfect spheroid that cannot be represented on a flat map the same way throughout the world (Burrough and McDonnell 1998). A projection consists of geometric shapes specific to the region of interest that specify certain mathematical properties when the projection is calculated. The most commonly used projection is the Universal Transverse Mercator (UTM) (Burrough and McDonnell 1998). The UTM employs the Clarke 1866 spheroid to represent North America. For this protocol all data will be in UTM NAD83. The UTM Zone depends on the location of the Park (see SOP 4).

Orthorectification is a form of rectification that accounts for variations in scale influenced by differences in elevation in the image. Orthorectification is preferable to rectification if an image covers large areas, or if the landscape is more topographically diverse (like mountains). When

elevation differences occurs, areas of the image closest to the sensor will have a significantly different scale than areas that are more distant from the sensor. This scale variation can lead to errors in position locations in the image. When elevation values are taken into account in the rectification process (orthorectification), the scale variation is removed and the image becomes planimetric (a flat map) (Gibson 2000).

Atmospheric Correction

The electromagnetic radiation (EMR) signals collected by satellites are modified by scattering and absorption of gases and aerosols while traveling through the atmosphere from the Earth's surface to the sensor. When and how to correct for atmospheric effects depends on; the remote sensing and atmospheric data available, the information desired, and the analytical methods used to extract information from the imagery. The total signal (DN) at the sensor consists of four components: path radiance, reflected radiation from the viewed pixel, scattered radiation from the neighborhood, and terrain radiation reflected to the pixel as shown in Figure 3. The atmospheric conditions (water vapor content, aerosol type, visibility) for a scene can be estimated. Then, the surface reflectance spectrum of a target in the scene can be viewed as a function of the selected atmospheric parameters.

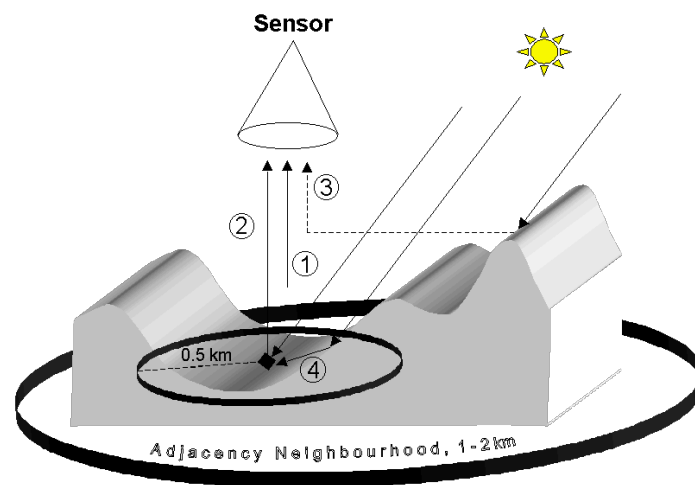


Figure 3. Four components of a signal (ATCOR3 Manual)

- Component 1: path radiance: radiation scattered by the atmosphere (photons without ground contact).
- Component 2: reflected radiation from the viewed pixel.
- Component 3: adjacency radiation: ground reflected from the neighborhood and scattered into the view direction.
- Component 4: terrain radiation reflected to the pixel (from opposite hills, according to the terrain view factor).

Only component 2 contains information from the viewed pixel.

In the spectral region 0.4 – 2.5 μm satellite images that map the earth's landscape are affected by the atmosphere and solar zenith angle as previously discussed. The imagery contains information about the solar radiance reflected at the ground, atmospheric absorption, and scattering by the atmosphere. The scattering process changes the direction of incident light.

Two of the most common uses of satellite images are for land cover (LC) classification and LC change detection. When doing a LC classification using imagery two questions arise concerning atmospheric correction.

1. When is atmospheric correction necessary prior to image classification?
2. If atmospheric correction is necessary which method do you use?

The interaction of solar radiation with the atmosphere has been characterized by Chandrasekhar (1960). A number of methods have been developed to correct atmospheric effects in satellite images based on radiative transfer theory (Hann et al. 1991, Vermote et al. 1997). However, these corrections require accurate measures of atmosphere optical properties at the time of image acquisition, which are frequently unavailable or questionable. Consequently many remote sensing image atmospheric corrections use information obtained from the image to correct the image. The ATCOR3 software uses this method along with the Absolute Calibration Gains for the SPOT imagery. This information is found in the VOL_LIST.PDF (Figure 4) file under the Absolute calibration gains heading in the report.

Work Order

: TS5- (S070207204051360)

Volume

: NETWORK CSP0005805

Scene ID

: 5 592-280/7 07/02/03 17:04:24 1 J

Product Code

: SPOT_SCENE

Date

: 2007-02-07 20:56:04



Scene Extract Parameters

Scene ID

5 592-280/7 07/02/03 17:04:24 1 J

K-J identification

592-280

Date

2007-02-03 17:04:24.1

Instrument

HRG 1

Shift Along Track

7 4200

Preprocessing level

1B

Spectral mode

J

Number of spectral bands

4

Spectral band indicator

HI1

HI2

HI3

HI4

Gain number

8

8

7

5

Absolute calibration gains

3.162396

3.803701

3.071707

10.741221

(W/m2/sr/μm)

Orientation angle

14.026538 degree

Incidence angle

L3.384224 degree

Sun angles (degree)

Azimut: 155.938311 Elevation: 35.315020

Number of lines

3082

Number of pixels per line

3013

Figure 4. SPOT Leaf-on Scene Parameters in VOL_LIST.PDF file

For many applications that involve image classification and change detection, atmospheric correction is not necessary. An example in which atmospheric correction would not be required would be a classification of single scene (geographic location) or multiple dates of imagery of

the same scene that are placed in a single dataset and classified. This method is valid as long as the training data sets are derived from the image being classified. If this is true, than atmospheric correction has little effect on classification accuracy (Foody et al. 1996, Fraser et al. 1977, Kawata et al. 1990). Atmospheric correction is also unnecessary for change detection if the change detection is based on post classification (Singh 1989).

Based on the literature and non-scientific investigations done by Weih (2008) of the example datasets used in developing this protocol, atmospheric correction benefits are small compared to the time, data, and assumptions required to perform atmospheric correction. This statement is only true if the classification is using a single scene or multiple dates of the same scene (geographic location) and the change detection is based on post classification. If the classification is based on multi scenes (different geographic locations) then atmospheric correction is recommended, unless each scene is treated as a separate classification. Since some Park classifications might involve multiple scenes the method for atmospheric correction is included in this protocol.

Supervised Image Classification

Supervised classification according to Campbell (2002) is the process of using areas of known identity to classify an area of unknown identity. For this protocol areas of known identity are referred to as training classes. The classification types used for this protocol are a modified Anderson classification (see SOP 3).

The process of supervised image classification involves several steps. These include creating training classes, running the supervised classification, assessing the accuracy of the classification and, when the classification is of acceptable accuracy, spatially cleaning the dataset to create the final classification product (see figure 5).

The development of training classes is recursive. Training classes are adapted, based on the accuracy assessment of classification outputs. Training classes are created by selecting pixel signatures representing known land cover types from the satellite image. The success and accuracy of the signature sets depends directly on the cognitive skills of the analyst. Training classes are used to create a supervised classification dataset by way of pattern matching of spectral values. A minimum of 5 – 10 trainings areas containing at least 100 pixels should be created for each training class; this helps guarantee the spectral properties of the classes are represented within the training dataset (Campbell 2002).

The classification is assessed for accuracy by using an error matrix that is described in the following section Accuracy Assessment. If accuracy is lower than 80 percent, training classes are modified according to the analyst's review of the classification dataset. If the accuracy assessment is equal to or better than 80 percent, then the classification is "spatially cleaned". What is meant by "spatial cleaning" is de-speckling or recoding of individual imagery pixels. The final classification becomes the baseline for future land cover change analysis.

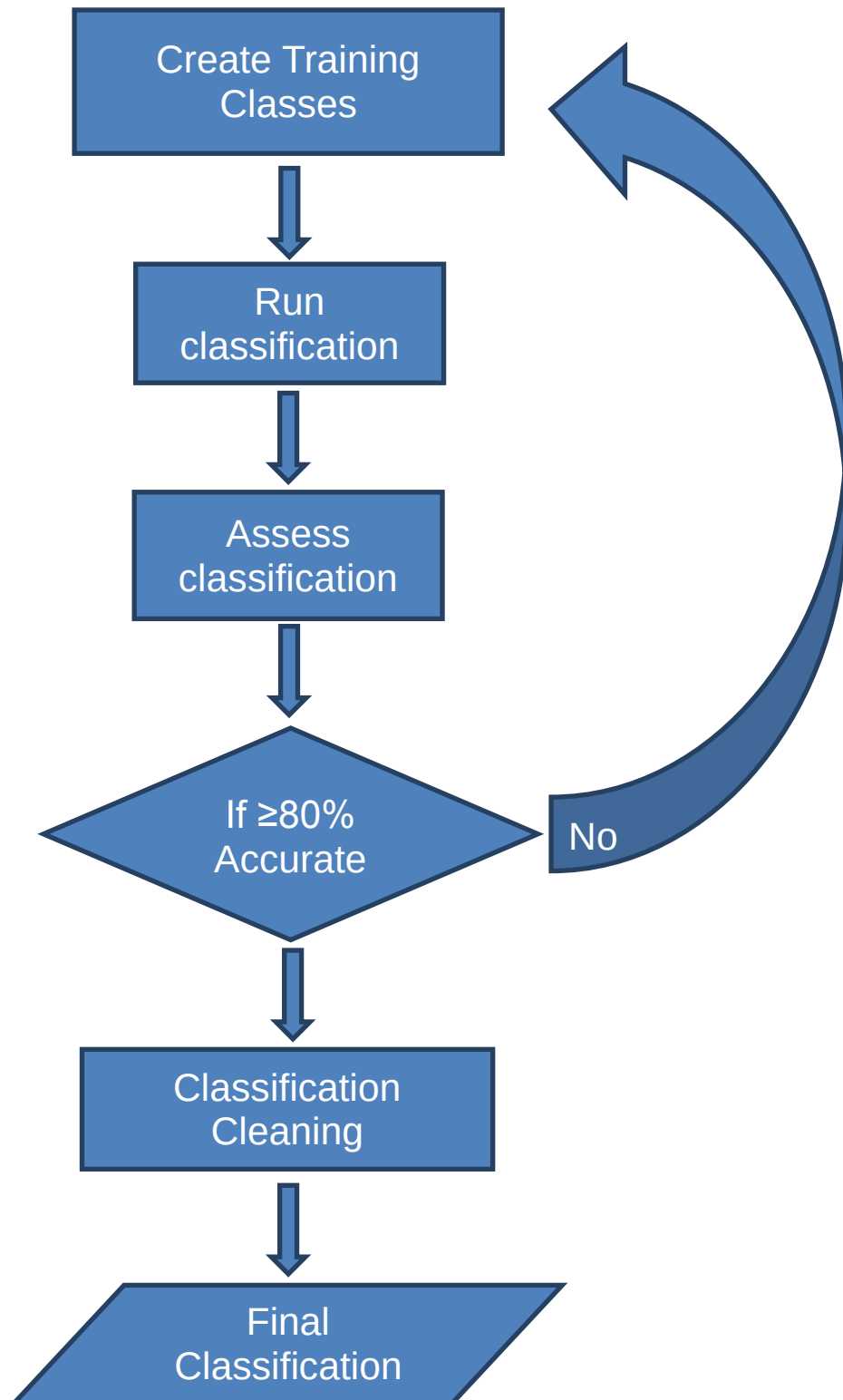


Figure 5. Flow chart of classification process steps.

Sampling Design and Accuracy Assessment

For accuracy assessment points, the method used will be a stratified random sampling design. A stratified random design is based on sampling points that are randomly distributed and proportional to the area of individual land cover classes. A stratified random sampling design is necessary to capture smaller or rare classes that would not be represented in a random sample. The stratified random points used for an accuracy assessment are derived from the classification, and interpreted from a high resolution image that is different from the imagery used for classification.

Why is the accuracy of the classifications important? Accuracy assessments (AA) can increase quality by identifying errors to correct. AA are also used to compare different methods, models, interpreters, etc used for classifications. Finally, if a classification will be used for the purpose of making decisions then it is essential to know the quality of the data (Congalton and Green 1999).

When evaluating an image classification, there are two forms of accuracy that can be considered. The first is non-site-specific accuracy, which looks at the overall agreement between the classified image and the reference data without examination of the agreement between them at specific locations (Campbell 2007). For example, non-site-specific accuracy would involve the examination of the percent Evergreen Forest in the classified image and comparing it to the percent Evergreen Forest in the reference data. Relying solely on non-site-specific accuracy to evaluate a classification can hide errors resulting from disagreement in the placement of classes between the classified image and the reference data.

The second form of accuracy is site-specific accuracy, which is the examination of the agreement between classes at specific locations on the classified image and in the reference data (Campbell 2007). This examination is done by means of an error matrix (also known as a confusion matrix or contingency table) to compare, for specific locations, what an area is in the reference data versus how that area has been classified. The error matrix helps to identify instances of classification error for specific classes. There are two main types of classification errors: errors of omission and errors of commission. Errors of omission are instances where a site has been excluded from a class that it belongs to. Errors of commission are instances where a site is included in an incorrect class. Campbell (2007) noted that these errors tend to balance each other out, as an error of omission for one class will also be tabulated in the error matrix as an error of commission in another class. Given the characteristics of these errors, it is best to examine them on a class-by-class basis before assuming the errors in one class reflect the errors found in all classes.

For site-specific accuracy assessment using the error matrix, there are three primary measures of classification accuracy: overall classification accuracy, producer's accuracy, and user's accuracy. Overall classification accuracy is the measure of how much area was correctly classified out of the entire area classified. From the error matrix, overall classification accuracy is the sum of the diagonals divided by the total (Congalton and Green 1999).

Producer's accuracy is calculated for each class and gives an indication of how well a particular class has been classified by the producer of that classification. This accuracy is most often used

by the producer as a means to assess how the classification was performed. From the error matrix, the producer's accuracy for each class is the result of dividing the correctly classified pixels by the number of reference data pixels in that class (as determined by the column total).

User's accuracy is also calculated for each class and gives an indication of how accurate the areas assigned to a given class on the image classification actually belong to that class 'on the ground'. This accuracy is of greater importance to the users of the classification because it indicates how true the classified image is to the actual situation on the ground. User's accuracy provides a measure for the map user of the probability that the pixels on the classification map are the same as the reference data (Stehman and Czaplewski 1998). From the error matrix, the user's accuracy for each class is the result of dividing correctly classified pixels in a given class by the total number of pixels in that class on the classified image (as determined by the row total). Figure 6 shows an example of the error matrix calculations.

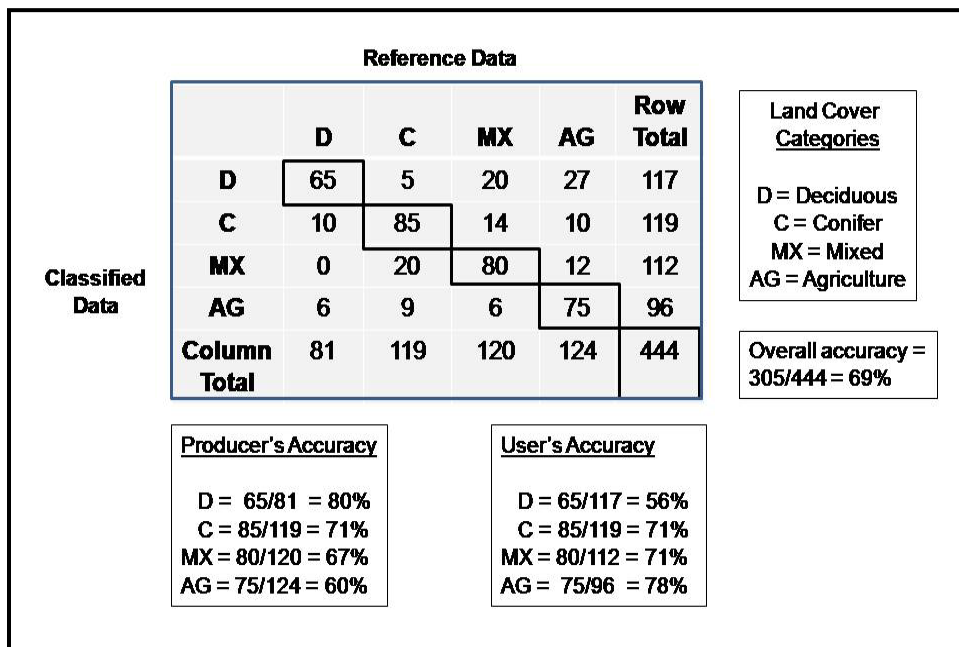


Figure 6. Hypothetical Error Matrix.

A Kappa analysis should also be computed. Kappa measures the difference between the observed agreement (error matrix's overall accuracy) and agreement that could be produced by chance (Congalton and Green 1999, Campbell 2002). Kappa is estimated by KHAT ($\hat{K}$). The KHAT value is a measure of how well the classification and the reference imagery agree with each other (Congalton and Green 1999).

Analysis and Results

The two main products created from a classification are map outputs and tabular results. For this protocol, the map output is a representation of land cover types based on medium to high multispectral satellite imagery. After classifications are produced for a different time period per park, change detection analysis shall be completed.

Map Output

The map output should show the full extent of the classified area, park boundary, and land cover legend. Colors chosen for land cover classes should include a diversity of colors and shades. See Figure 7 for examples of color and shade choices.

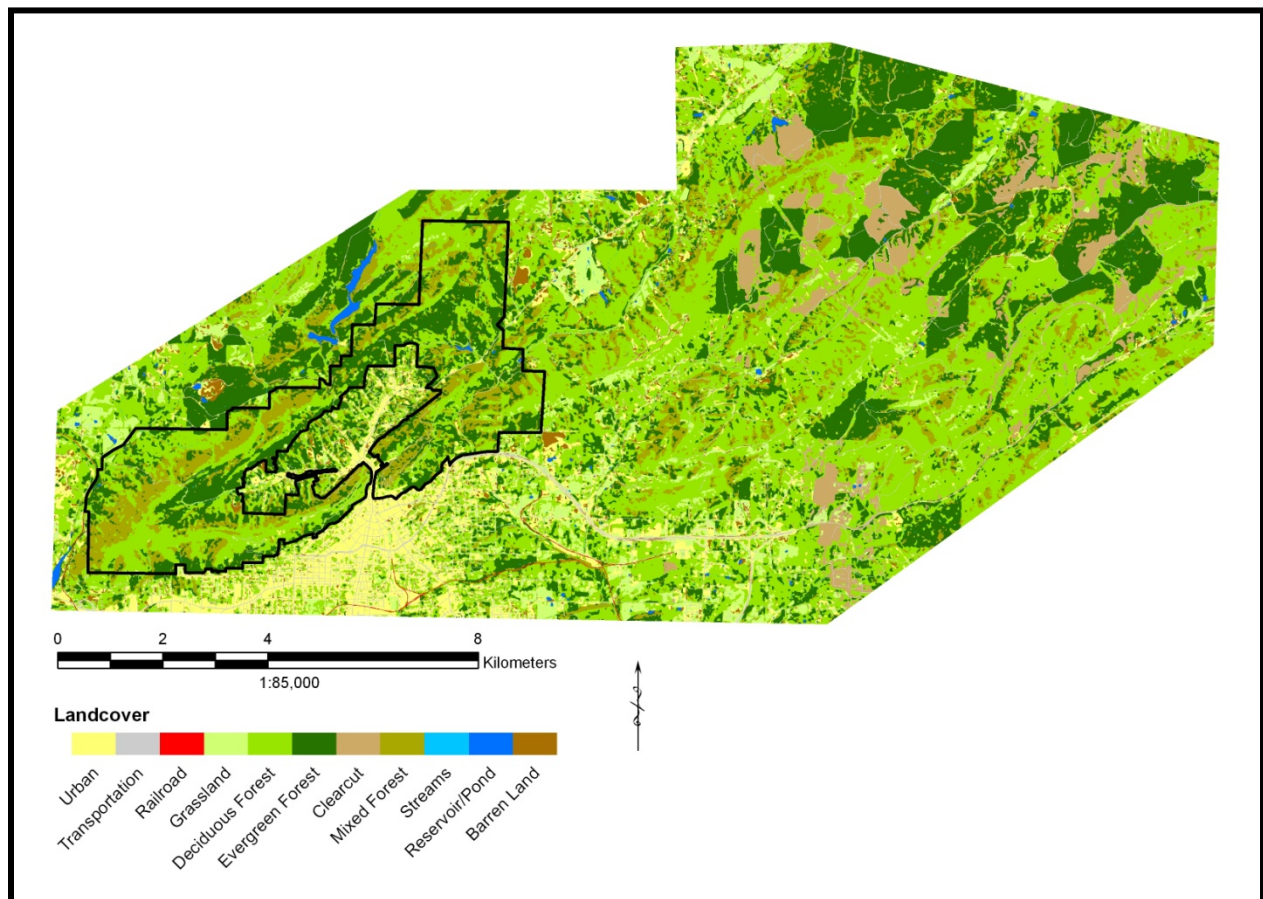


Figure 7. Example of map output results.

Tabular Results

The table results should show the total area of each land cover class within the area of interest (AOI) as well as total area of all classes combined. For an example of this see Table 2. The table should list the area in both acres and hectares to the nearest hundredth. Classification results can also be displayed graphically as shown in Figure 8.

Table 2. Example of land cover class area results in table form.

Land Cover	Acres	Hectares
Urban/Build-up	2850.68	1153.01
Transportation	1312.94	531.32
Railroad	41.72	16.88
Grassland	2323.81	940.29
Deciduous Forest	17750.48	7183.02
Evergreen Forest	9805.38	3967.61
Clearcut/Young Plantation	1810.93	732.9
Mixed Forest	4825.61	1952.62
Streams	85.52	34.45
Reservoirs/Ponds	181.55	73.43
Barren Land	667.2	269.83
Total	41655.82	16855.36

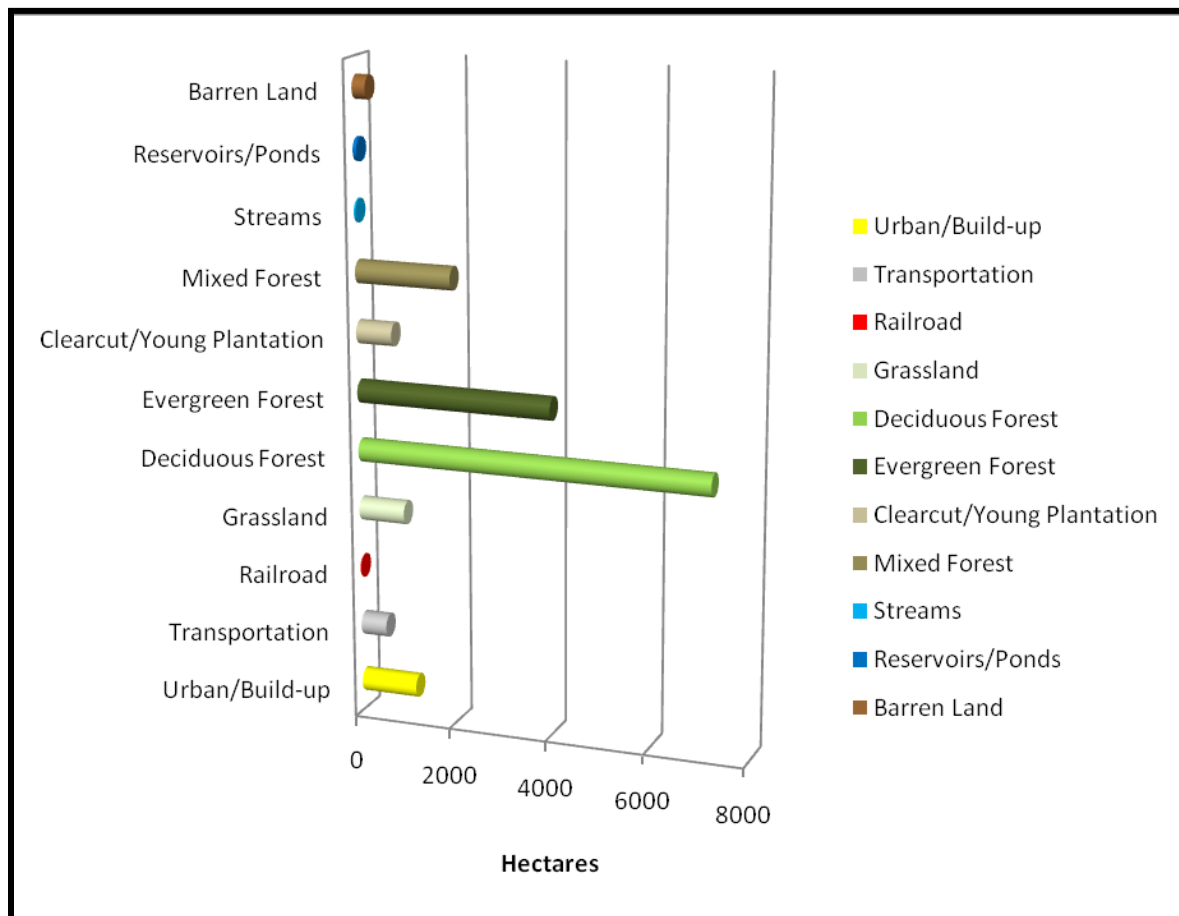


Figure 8. Land cover class results graph.

Change Analysis

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh 1989). Once more than one time period has been classified and finalized on the ~10 year resample schedule, a change comparison should be completed. After every new classification is complete it should be compared to the original or base classification processed for this protocol for change. When more than 2 processing cycles have passed the latest classification should always be compared to the one previous for change as well. According to Coppin et al. (2004) it takes at least a few decades of correct monitoring to comprehend landscape changes. When conducting change detection analysis it is essential to have accurate spatial registration of the multi-date imagery (Singh 1989, Coppin et al. 2004, and Lu et al. 2004). There are multiple methods of processing change detection. For this protocol we will use the post-classification method. Advantages of post-classification are the reduction of impacts such as atmospheric and environmental differences between the multi-date imagery (Singh 1989, Mas 1999, Coppin et al. 2004, and Lu et al. 2004). Post-classification also allows the calculation of class change matrices. A draw back to the post-classification system is errors generated during each stage of the classifications are multiplied (Singh 1989 and Townsend et al. 2009). Townsend et al. (2009) gave an example of this, an 83% accurate classification is compared to an 87% one which yields a 72% accurate change detection map. There are other methods for change analysis; however since the goal of HTLN monitoring protocol is to see what land cover classes are being converted to different cover classes, post-classification change analysis is the method used to get that type of information. If one only needed to know that a change took place and not what it was or if only looking at change in one class, then a different method other than post-classification should be used. For a good breakdown of the different types of change detection possible, see Townsend et al. 2009, SOP 8.

Data Management

Effective data management allows the project leader to store and retrieve large quantities of data securely and efficiently. Data management typically becomes an issue when sample sizes are in the range of 10^4 to 10^5 or greater. Natural resource monitoring databases will frequently exceed these values. Database design should accommodate these sample sizes while meeting project requirements.

Overview of Database Design

There are two databases that are used for the land cover monitoring project. One is a MS Access database (MDB) that houses all the non-spatial data and information for the project. The other database is an ESRI ArcGIS file geodatabase (GDB) that stores all the spatial data for the project.

Monitoring databases share many similarities with data warehouses. They emphasize events that are stored in one or more core tables. These event tables, in turn, are linked to parameter tables that provide the information necessary to understand the events. The NPS Inventory and Monitoring Program developed the natural resource database template (NRDT) as a proof-of-concept database model for managing long-term ecological monitoring data (<http://science.nature.nps.gov/im/apps/template>). The NRDT is an event-based design that standardizes the relationship between location, time and event data. The template promotes the integration of inventory and monitoring datasets. It also improves development efficiency by encouraging the reuse of design features.

Non-Spatial Database

Stored inside the MDB are all the non-spatial data, which is information on training data and accuracy assessment sampling, imagery purchases, classification results, and classification definitions (Figure 9).

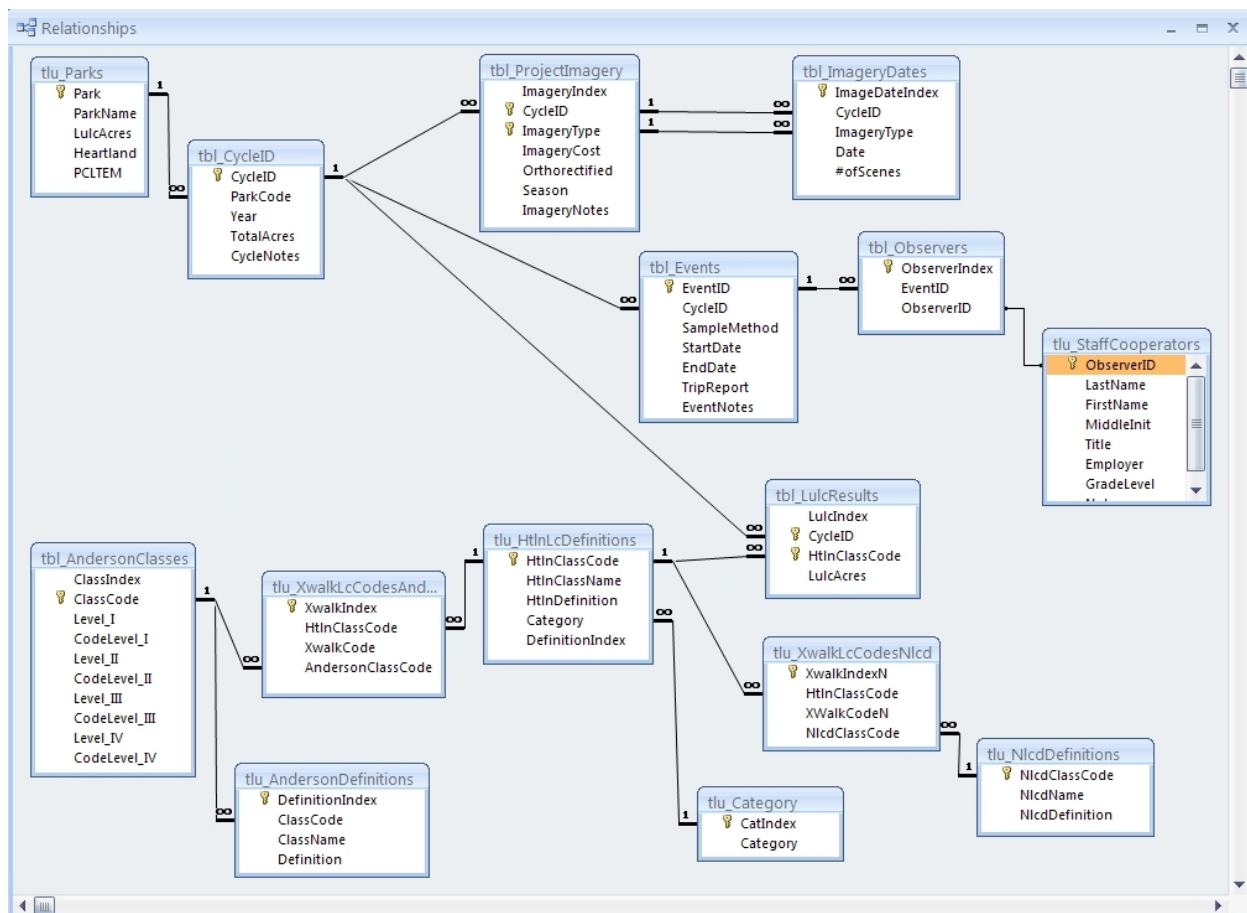


Figure 9. Table relationships in the land cover non-spatial database.

Spatial Geodatabase

The GDB houses spatial data associated with the land cover project. All spatial data is stored in the following coordinate system and projection: UTM (Universal Transverse Mercator) NAD (North American Datum) 1983. The data that is stored in the GDB is all AOI, all training data, accuracy assessment points, the finalized land cover classifications, and change analysis outputs. AOIs are the land cover study areas that are in polygon form.

Metadata Procedures

Metadata will be generated using ESRI ArcGIS metadata. The generated metadata file will be stored in XML format and uploaded to the NPS IRMA Portal that is located at <https://irma.nps.gov>.

Data Archival Procedures

Archival procedures must be completed and are jointly accomplished by the project manager and data manager. Data archival procedures follow established network procedures that can be found in SOP 9.

Personnel Requirements and Training

Roles and Responsibilities

The network GIS specialist serves as the project manager, image analyst and normally as the crew leader for land cover monitoring field work. The data management aspect of the monitoring effort is the shared responsibility of the project manager and the data manager. The project manager oversees data collection, data entry, data verification and validation, as well as data summary, analysis, and reporting. The project manager designs the database and oversees data security, archiving, and dissemination, with help from the data manager. The project manager, in collaboration with the data manager, also develops data entry forms and other database features to assure data quality and to automate report generation. The data manager is responsible for following appropriate data handling procedures.

Qualifications and Training

Qualifications

Field observers must also be skilled with GPS navigation and data collection, as well as a working knowledge of the land cover classes and definitions. Observers should be well-organized and work well as team members.

Image analyst must have working knowledge of the following software: ESRI ArcGIS and ERDAS IMAGINE. The image analyst must keep all digital data well organized and documented.

Training

Before field work begins, every crew member shall be trained by the GIS specialist to use the GPS unit and will learn the land cover classes and definitions. If it has been awhile since the image analyst has processed imagery, he or she should work through the software tutorials that pertain to the work being done. Enough time should be allowed before work begins to review the software tutorials.

Operational Requirements

Annual Workload

The field work requires a 2 person crew. Depending on what study area is being sampled, field work may take from 1 to 5 weeks to complete. The image processing work is also study area dependent, and may take from 2 to 12 months. Data management, analysis, and reporting needs will take 4 weeks.

Hardware Needs

Equipment requirements for field work are a GPS unit, external antenna, digital camera, compass, rangefinder, clipboard, data sheets, pencils, map, and laptop. The laptop is used to download a copy of the GPS data, and digital photos after each field day.

Software Needs

The office equipment need is a personnel computer with enough RAM and hard drive space for image processing. The computer must be loaded with the following software: ArcGIS, ERDAS IMAGINE, and MS Access.

Budget Considerations

Personnel expenses for field work are based on a crew of two, one GIS specialist and one biological science technician. Data management needs requires staff time of biological science technicians, project manager, and data manager. Administrative requirements, such as the purchasing of project imagery, utilize the time of the GIS specialist, network coordinator and the parks administrative clerk. Startup costs include the purchase of equipment and supplies as well as maintenance or replacement of equipment shared among multiple projects (e.g., GPS units, cameras, vehicles).

Table 3. Estimated annual budget for land cover monitoring.

Category	Annual Cost
Staff salary	\$40250.00
Imagery	\$10000.00*
Field work travel	\$1000.00
Computer hardware and software	\$2250.00
Vehicle lease	\$500.00
Supplies	\$500.00
Administrative Support and Overhead	\$2160.00
TOTAL	\$56660.00

*Cost estimate could vary from \$5,000 to \$70,000 depending on AOI.

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Standard Operating Procedures

Land Cover Monitoring Protocol Heartland I&M Network and Prairie Cluster Prototype Monitoring Program

Standard Operation Procedure 1: Study Areas and Revisit Schedule

Version 1.00 (02/17/2012)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP identifies where land cover monitoring will take place in HTLN. It also documents the land cover area of interest (AOI) and revisit schedule.

I. Study Areas

There are twelve HTLN parks where land cover monitoring takes place. These parks are Buffalo National River (BUFF), Effigy Mounds National Monument (EFMO), Hopewell Culture National Historic Park (HOCU), George Washington Carver National Monument (GWCA), Herbert Hoover National Historic Site (HEHO), Homestead National Monument of America (HOME), Hot Springs National Park (HOSP), Lincoln Boyhood National Memorial (LIBO), Ozark National Scenic Riverways (OZAR), Pea Ridge National Military Park (PERI), Pipestone National Monument (PIPE), and Wilson's Creek National Battlefield (WICR). The park land cover sampling order can be found in table 1.1. Sampling order does not preclude more than one park being completed at the same time. The AOI for individual parks are shown in Figures 1.2 – 1.13.



Figure 1.1. A map of the twelve parks where HTLN land cover monitoring occurs.

Table 1.1. Sampling order of land cover monitoring at HTLN parks.

Sampling Order	Park	AOI Area (acres)
1	HOCU	374,335
2	HOSP	367,624
3	LIBO	169,052
4	BUFF	870,490
5	OZAR	1,857,480
6	PERI	346,163
7	WICR	157,376
8	GWCA	188,691
9	EFMO	314,435
10	PIPE	167,196
11	HOME	155,232
12	HEHO	147,922

BUFF Area of Interest

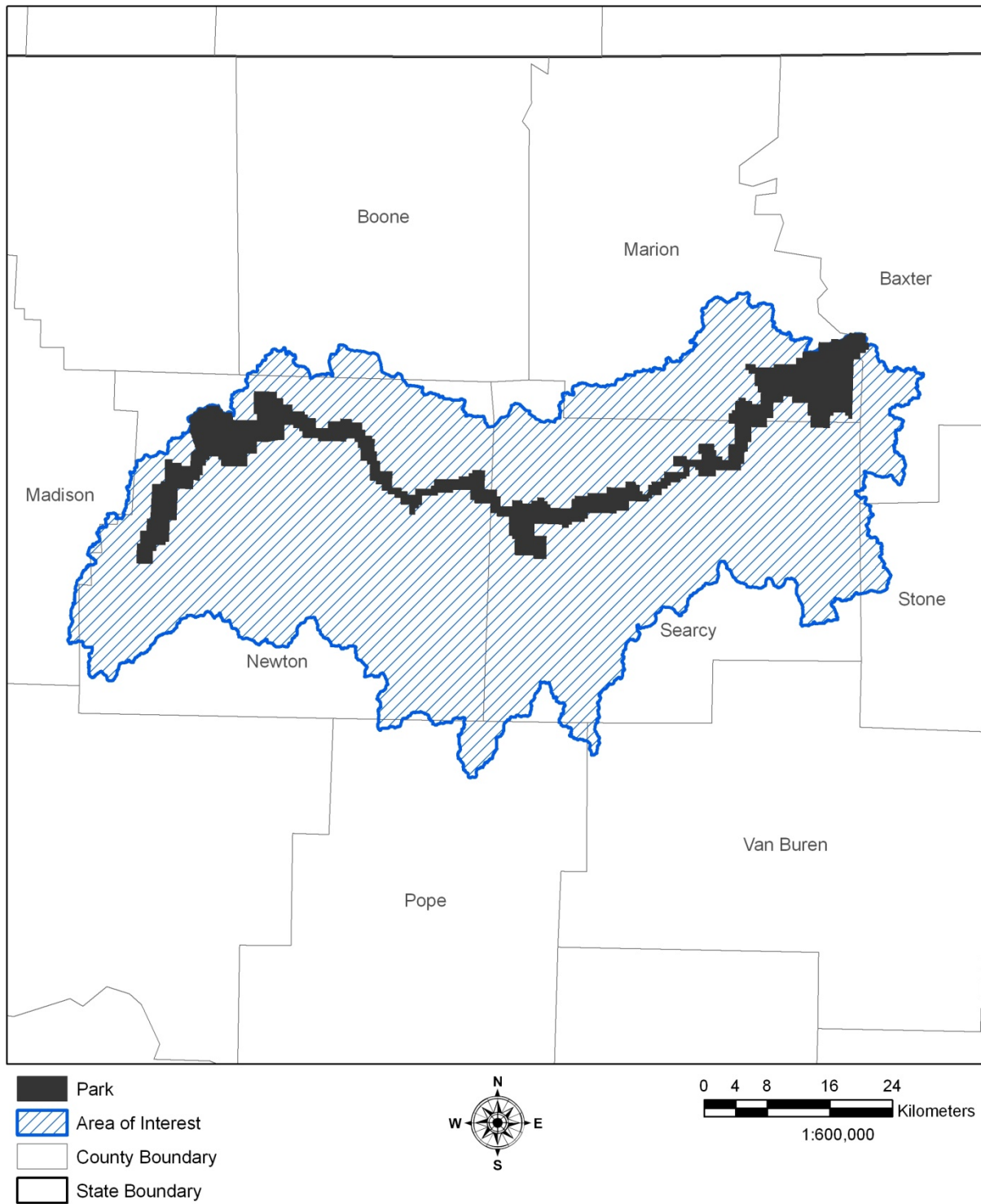


Figure 1.2. Land cover monitoring AOI for Buffalo NR.

EFMO Area of Interest

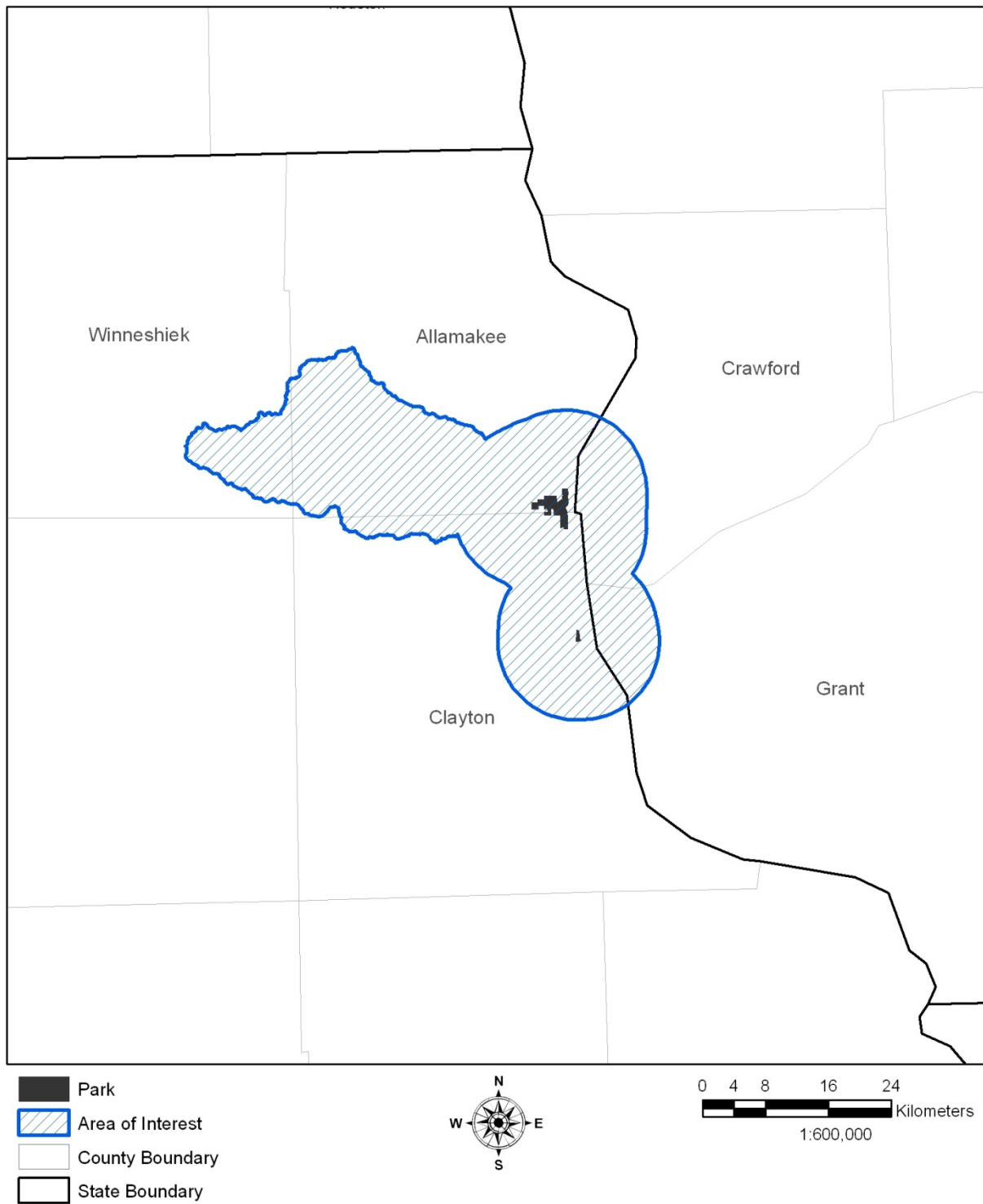


Figure 1.3. Land cover monitoring AOI for Effigy Mounds NM.

GWCA Area of Interest

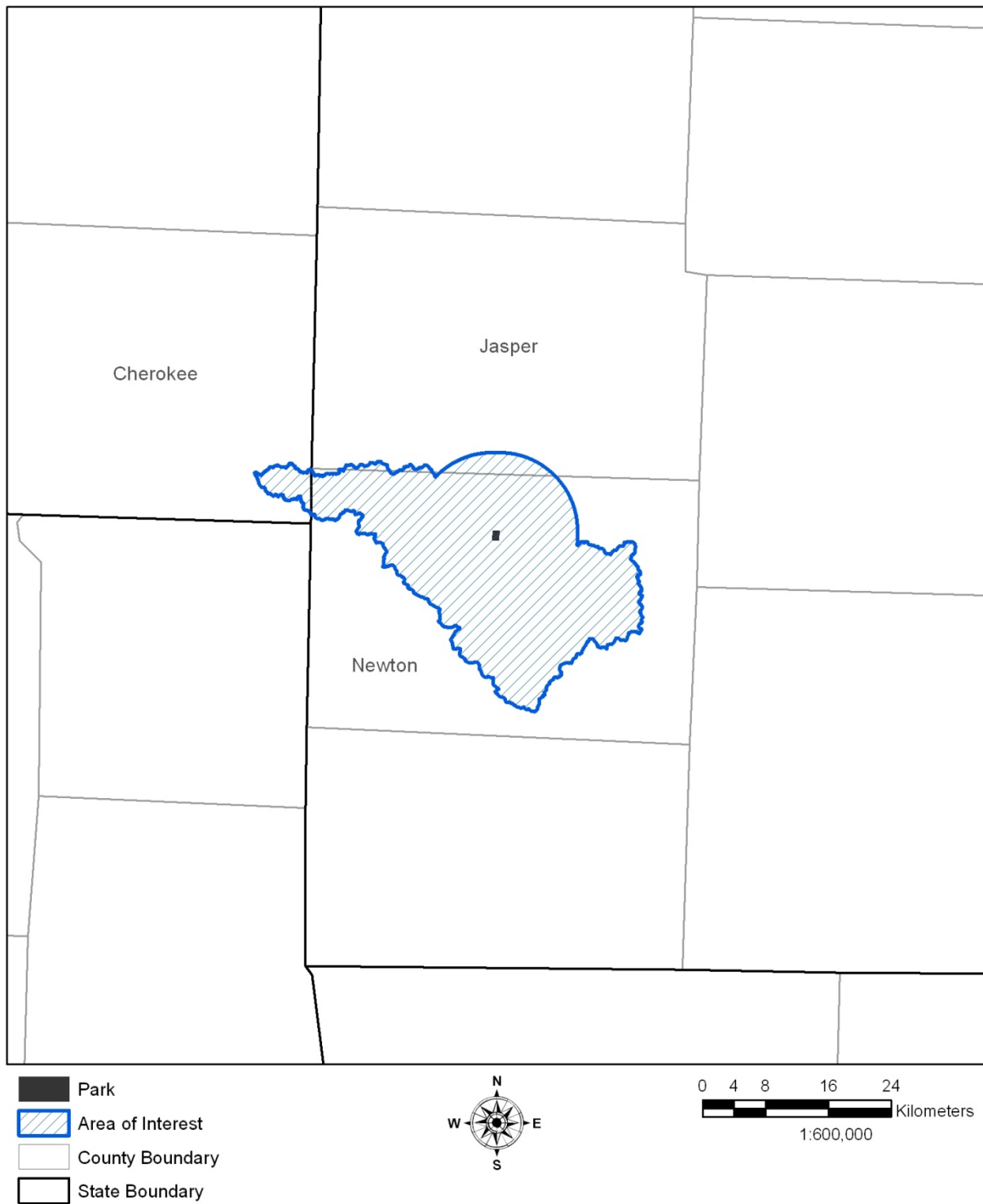


Figure 1.4. Land cover monitoring AOI for George Washington Carver NM.

HEHO Area of Interest

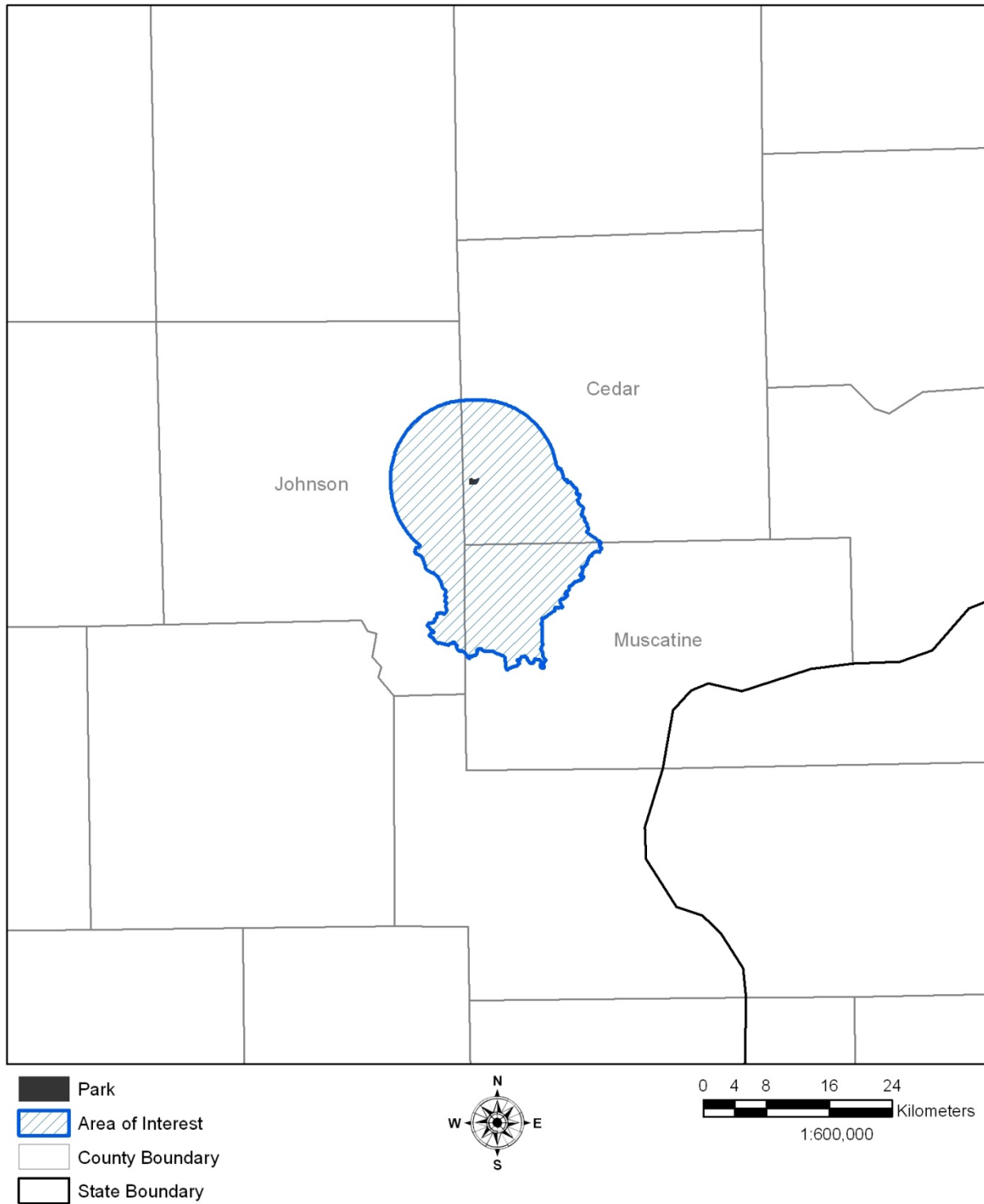


Figure 1.5. Land cover monitoring AOI for Herbert Hoover NHS.

HOME Area of Interest

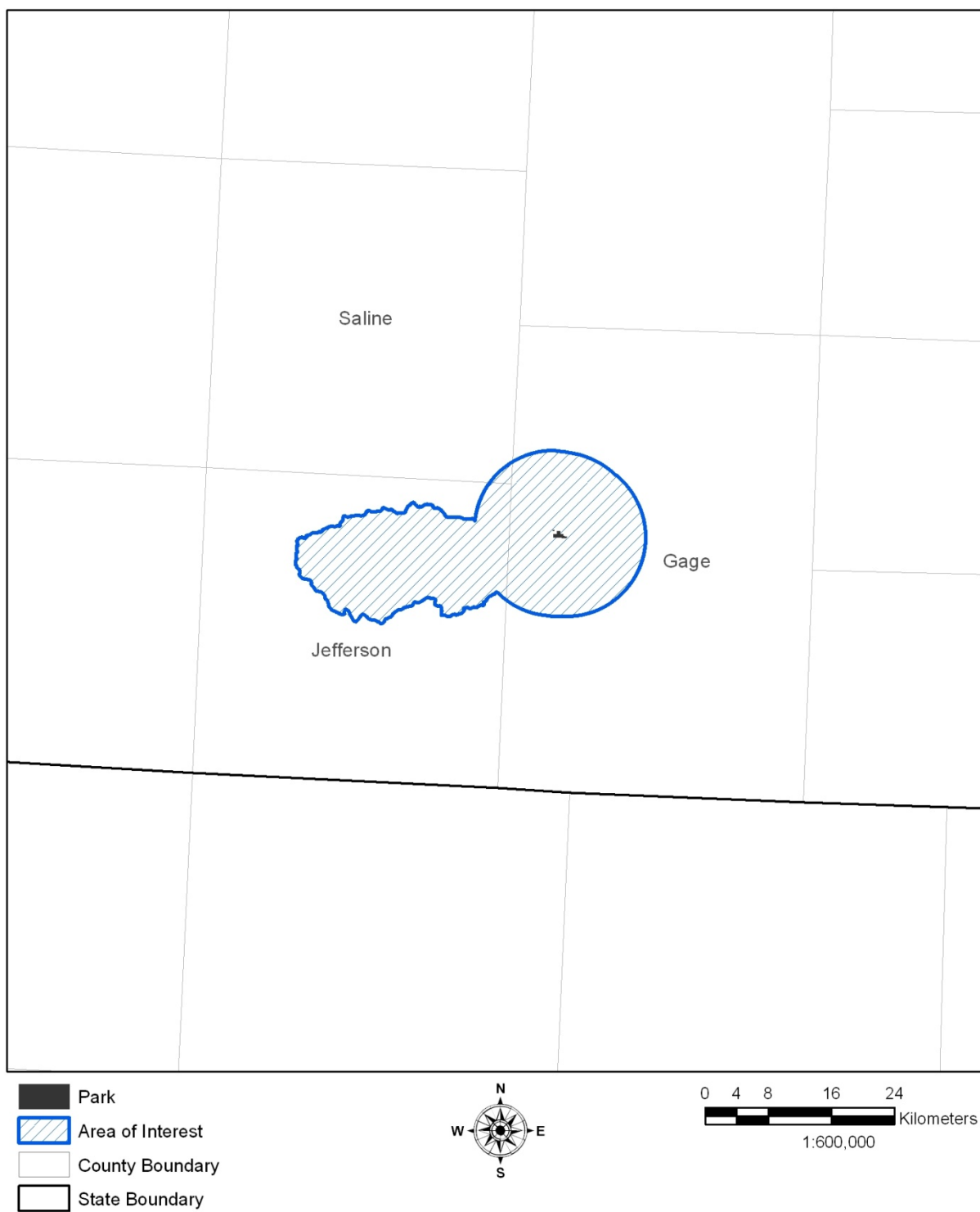


Figure 1.6. Land cover monitoring AOI for Homestead NM of America.

HOCU Area of Interest

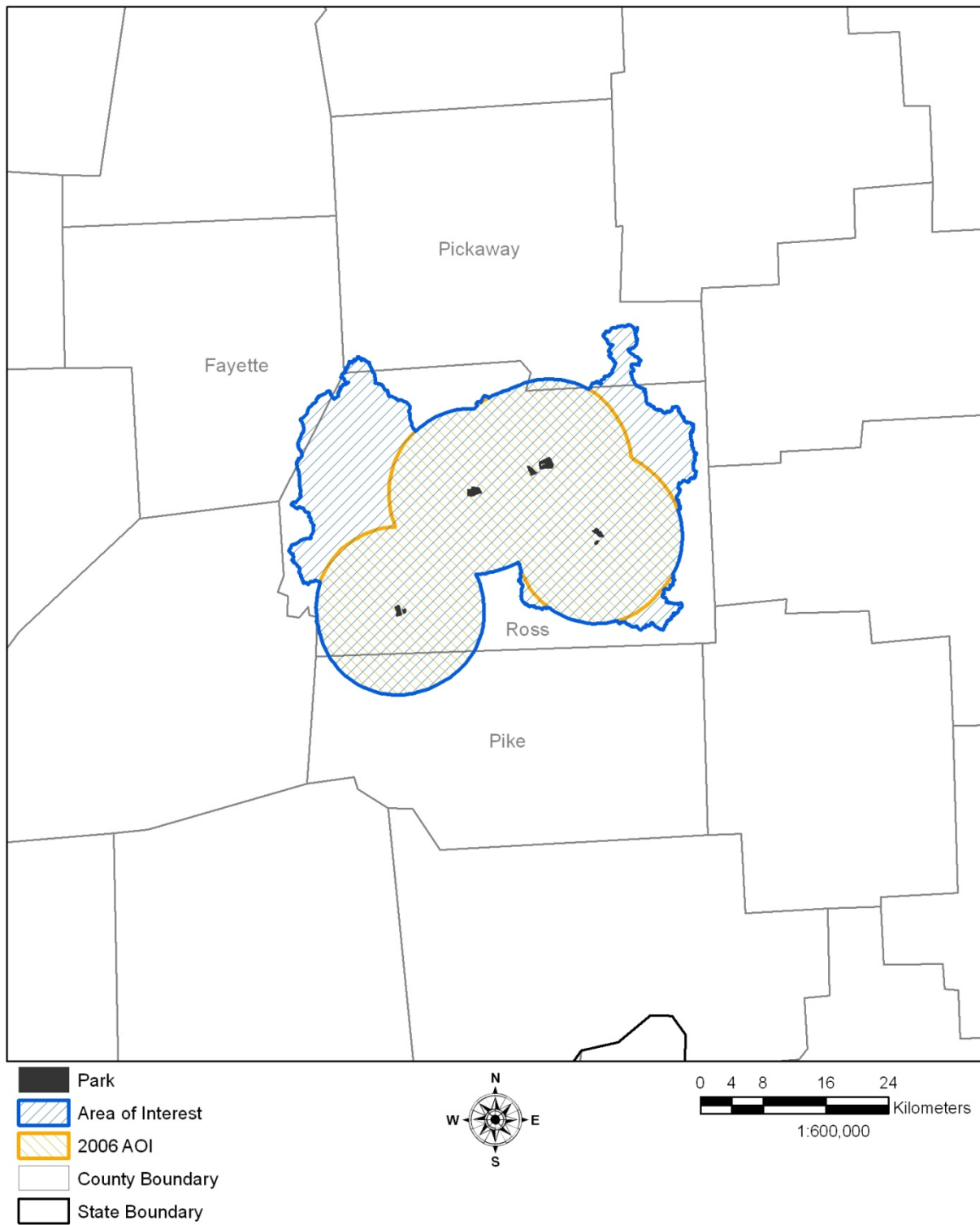


Figure 1.7. Land cover monitoring AOI for Hopewell Culture NHP.

HOSP Area of Interest

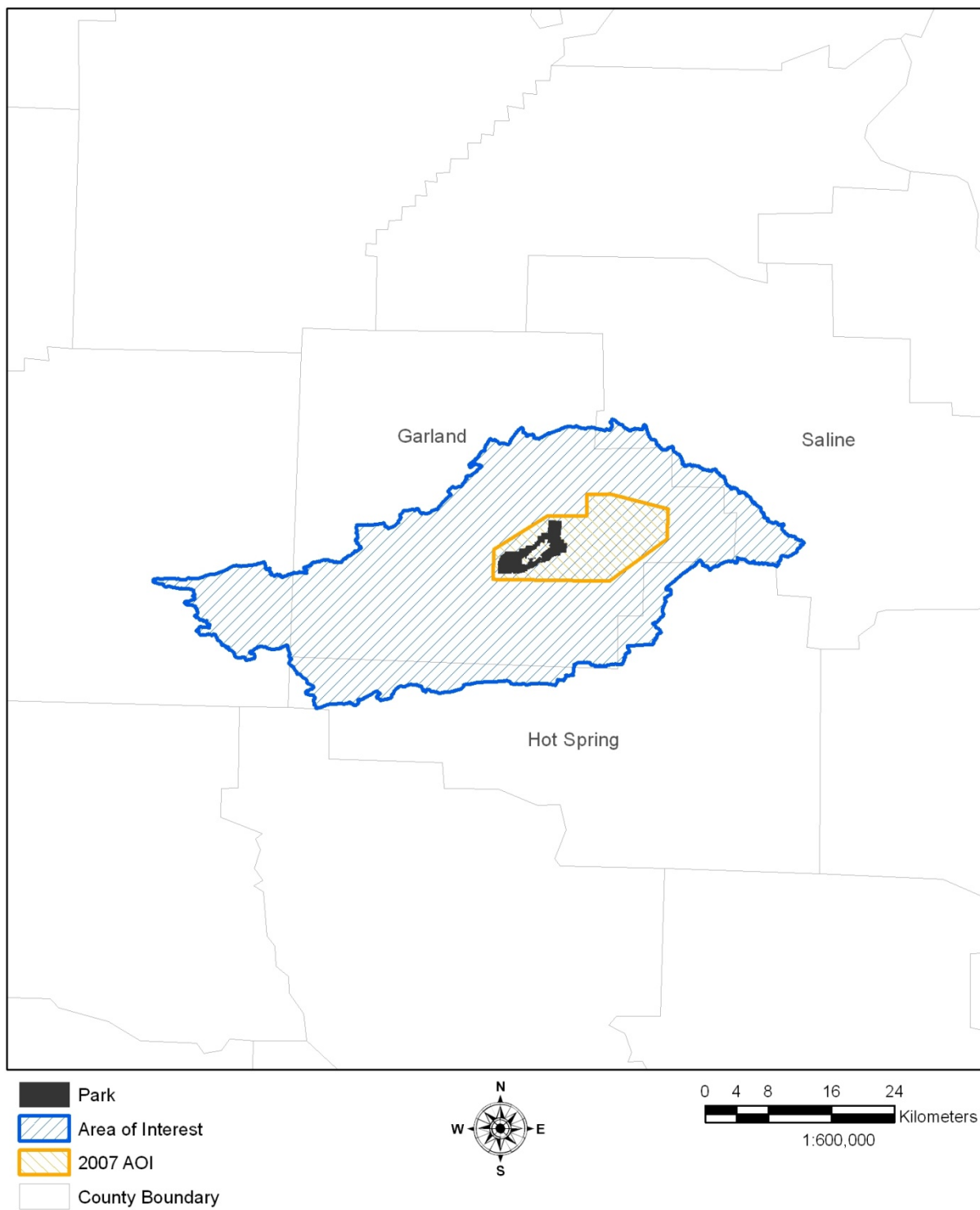


Figure 1.8. Land cover monitoring AOI for Hot Springs NP.

LIBO Area of Interest

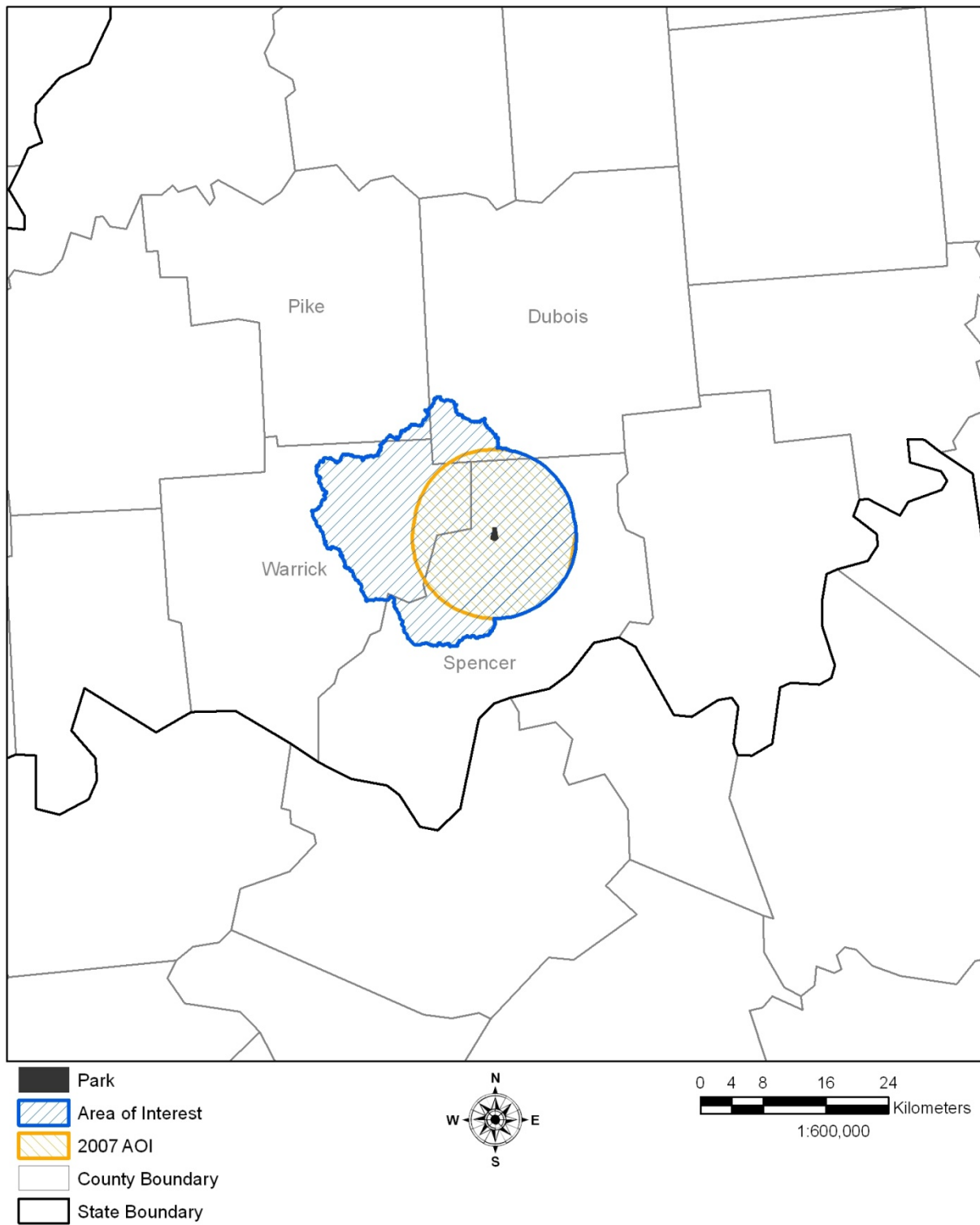


Figure 1.9. Land cover monitoring AOI for Lincoln Boyhood N MEM.

OZAR Area of Interest

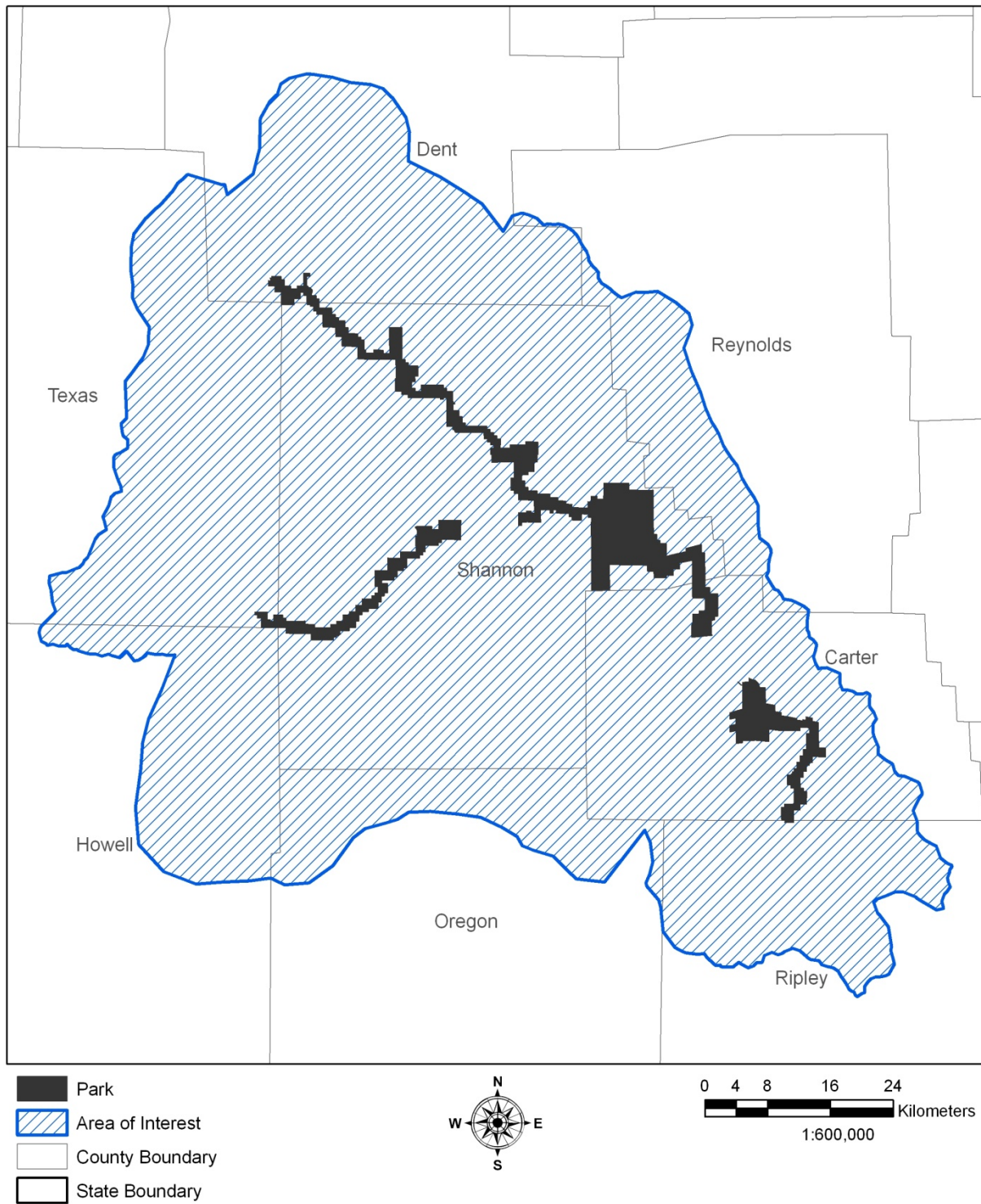


Figure 1.10. Land cover monitoring AOI for Ozark NSR.

PERI Area of Interest

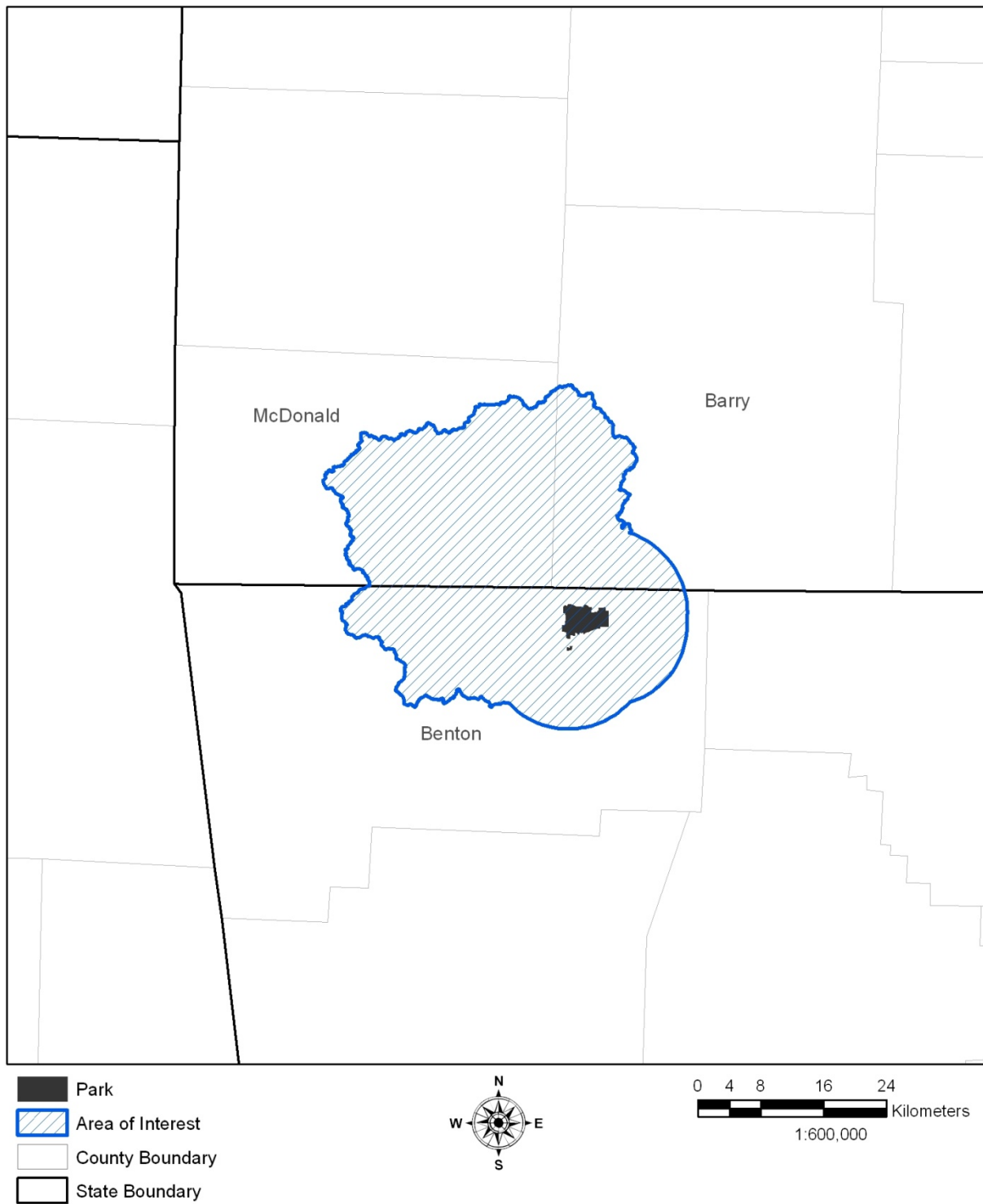


Figure 1.11. Land cover monitoring AOI for Pea Ridge NMP.

PIPE Area of Interest

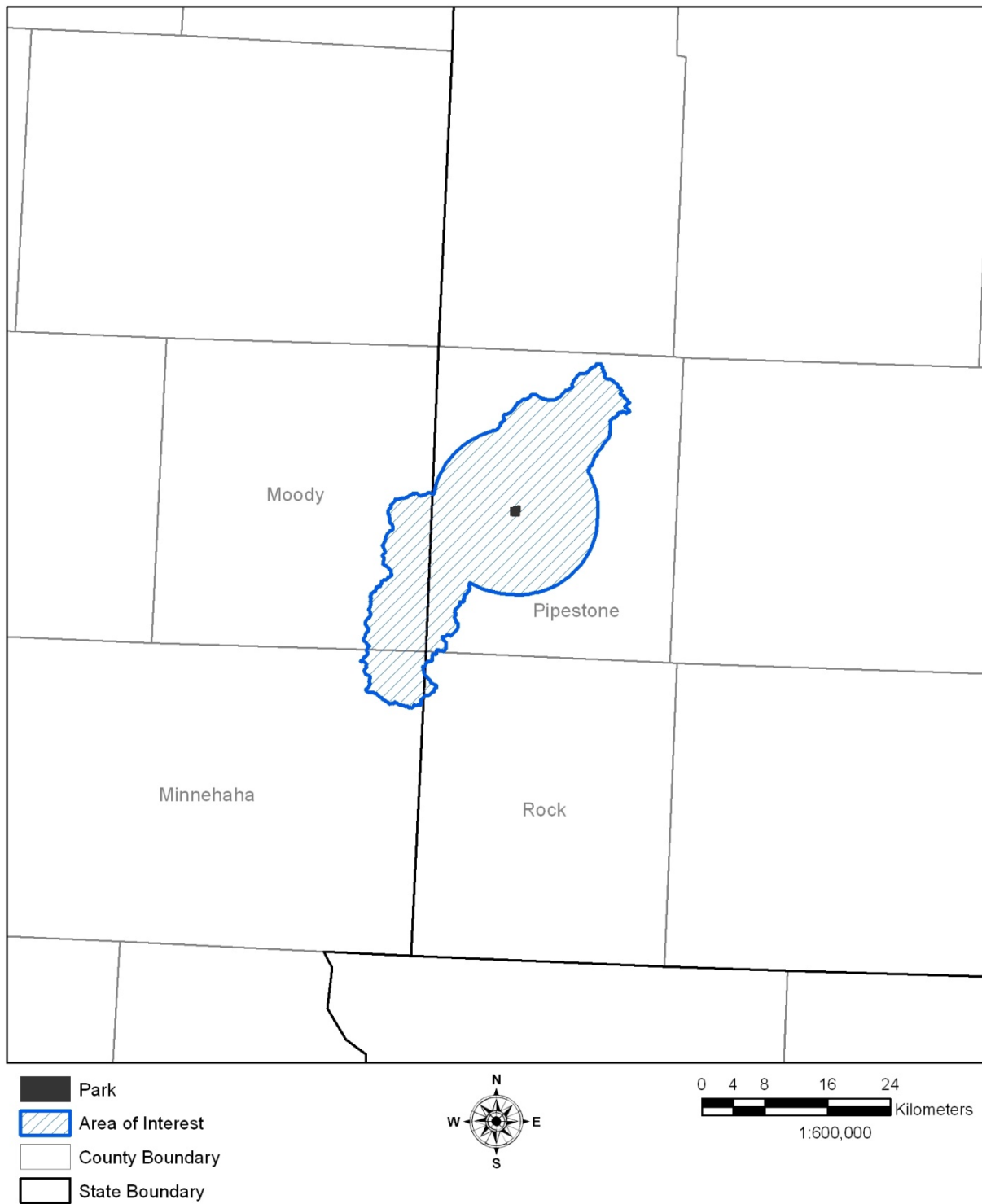


Figure 1.12. Land cover monitoring AOI for Pipestone NM.

WICR Area of Interest

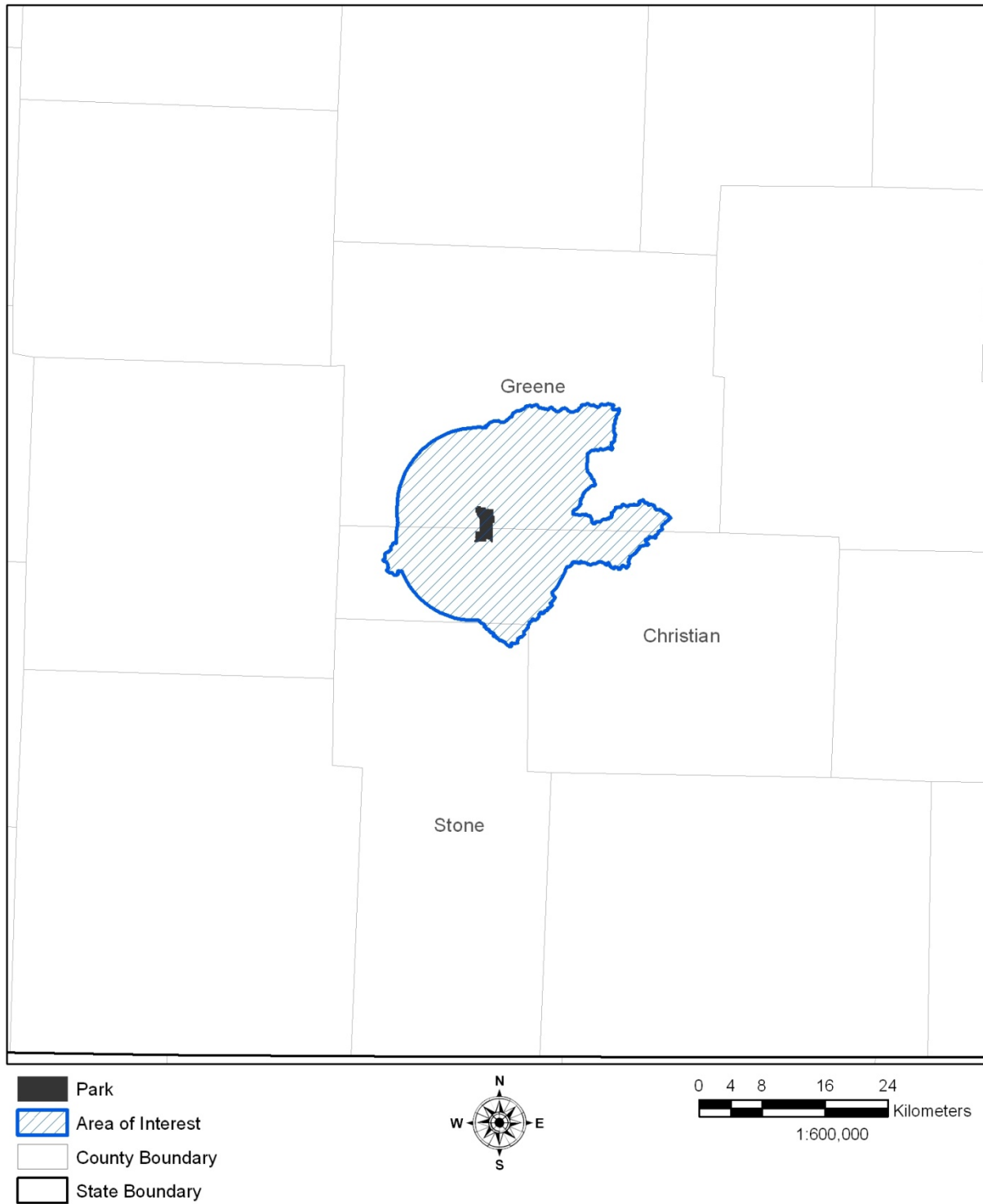


Figure 1.13. Land cover monitoring AOI for Wilson's Creek NB.

Land Cover Monitoring Protocol
Heartland I&M Network and Prairie Cluster Prototype Monitoring Program

Standard Operation Procedure 2: Project Preparations

Version 1.00 (03/31/2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP provides information on what must be completed before land cover monitoring can proceed at a park. Initially imagery for the AOI must be acquired, along with any other ancillary data (spatial layers, reports, or maps) that will help with land cover classification. This SOP also describes the field and office equipment needed to complete the project.

I. Acquiring Imagery

Imagery that covers the AOI(s) for a certain time period will need to be acquired. In most cases this will mean putting together a purchasing contract for image(s). However, before purchasing imagery check on the USGS EarthExplorer website (<http://earthexplorer.usgs.gov/>) to see if there is any imagery that could be used for the land cover monitoring. Listed below are the imagery specifications that are needed for this study:

- At least 10 meter pixel resolution
- Multispectral imagery bands: Green, Red, Near Infrared, and Short-wave Infrared
- Incidence angle of +/- 7.5
- Imagery scene(s) must cover entire AOI
- Imagery scene(s) must be obtained for 2 time periods: leaf-on and leaf-off
- Less than 10% cloud cover
- Less than 10% ice/snow cover
- Imagery scene(s) orthorectified to UTM NAD83, zone 14, 15, 16 or 17 (depending on park location) north

Items that will need to be turned into the contracting officers for imagery purchases are individual acquisition plan (IAP), statement of work (SOW), and cost estimate.

II. Acquiring Ancillary Data

Before any field work or classification is started, data mining for newer or improved spatial base layers, reports, or maps should occur. For spatial layers search GIS clearinghouses, such as, NRCS, USGS, NPS, DNR, state and university GIS webportals. Examples of spatial layers that should be searched for are roads, trails, finer resolution elevation, wetlands, and boundaries, to name a few. Along with spatial layers search for any maps or reports that could help with decisions in land cover classifications.

III. Equipment Needed

Field Equipment

The following list is what will be needed to complete field work associated with the project's accuracy assessment.

- Laptop with Trimble Pathfinder Office and ERSI ArcGIS software loaded
- GPS unit
- GPS antenna
- Compass
- Rangefinder
- Camera
- Meter tape
- Datasheets (blank)
- Clipboard
- Pencils
- Electrical adapter for the car
- Maps of the area
- Document of classification descriptions
- Notebook

Office Equipment

The only thing needed to complete office work is a computer that can handle processing remote sensing data. Specification for computers change frequently, so please refer to the current software recommendations. To complete this project the computer must have the following software loaded: ERDAS IMAGINE and ESRI ArcGIS.

Land Cover Monitoring Protocol
Heartland I&M Network and Prairie Cluster Prototype Monitoring Program

Standard Operation Procedure 3: Land Cover Classes and Descriptions

Version 1.00 (03/31/2011)

Revision History Log:

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This SOP details the land cover classes and definitions used for this protocol. The classes are a modified Anderson classification. Within the Access database (SOP 9) is a cross-walk table from these HTLN classes to either original Anderson classes or NLCD (National Land Cover Database) 2006 classes. The cross-walk table will help when comparing the HTLN classifications to other national and regional classifications.

I. Classes

Table 3.1. List of land cover classes

Level 1	Level 2
Barren	Barren
Cropland	Cropland
Forest	Deciduous Forest
	Disturbed Successional Forest
	Evergreen Forest
	Mixed Forest
Grassland	Grassland
Urban/Built-up	Urban/Built-up
	Railroad
	Transportation
Water	Ponds/Reservoirs
	Streams
Wetland	Forested Wetland
	Non-Forested Wetland

II. Definitions

Table 3.2. List of land cover classes with their definition

Code	HTLN Class Name	HTLN Definition
B	Barren	Land that supports very little vegetation, and is not part of the Urban/Built up class. Examples are gravel bars, beaches, bare exposed rock, sand dunes, gravel pits, quarries, strip mines, and wasteland.
C	Cropland	Cultivated land for the purpose of row or close grown crops. Examples are corn, soybean, rice, cotton, small grains, sunflowers, and truck crops.
F	Forest	Land dominated by trees of any type.
FD	Deciduous Forest	Land that is dominated by types of deciduous trees. The deciduous trees must cover 75% or greater area.
FDS	Disturbed Successional Forest	Forest land that has been disturbed by natural or human means. Examples are forest clearcuts, tree plantations, wind damage, fire, etc.
FE	Evergreen Forest	Land that is dominated by types of evergreen trees. The evergreen trees must cover 75% or greater area.
FM	Mixed Forest	Land that is covered with trees of both deciduous and evergreen types. Neither deciduous or evergreen trees cover 75% or more of the total area.
G	Grassland	Land that is dominated by the presence of grasses, grass-like, or forb vegetation. Examples are pastures, hayland, lawn, grass road right-of-ways, rangeland, prairies, cropland that has been left fallow for a number of years, etc.
U	Urban/Built-up	Any structure or surface that was built by humans that is not part of the natural system. This class includes, but is not limited to the following: buildings, houses, farmsteads, barns, roads, railroad, parking lots, dams, electrical substations, industrial areas, poultry facilities, and other impervious surfaces.
URR	Railroad	This is a subcategory of the urban/built up class. It pertains to railroads.
UT	Transportation	This is a subcategory of the urban/built up class. It pertains to road or pathway made by humans. Examples are highways, streets, gravel roads, impervious walkways, etc.
W	Water	Land covered with permanent open water. This class includes: rivers/streams, ponds, lakes, reservoirs, bayous, etc.
WP	Ponds/Reservoirs	This is a subcategory of the water class. It pertains to permanent ponds, lakes, and reservoirs.
WS	Streams	This is a subcategory of the water class. It pertains to permanent rivers and streams.
WtF	Forested Wetland	Wetland dominated by forest.
WtNF	Non-Forested Wetland	Wetland dominated by any vegetation class except forest.

Land Cover Monitoring Protocol
Heartland I&M Network and Prairie Cluster Prototype Monitoring Program

Standard Operation Procedure 4: Collecting Training Data

Version 1.00 (03/31/2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP describes the procedures for collecting land cover training data for use in creating signature sets. This data can either be collected in the field with GPS units or in the office by photo interpretation. For specifics on how to use the HTLN GPS units, please see the document: Heartland Network Operational Plan for GPS.

I. Collecting Training Data in the Field

GPS Unit Settings

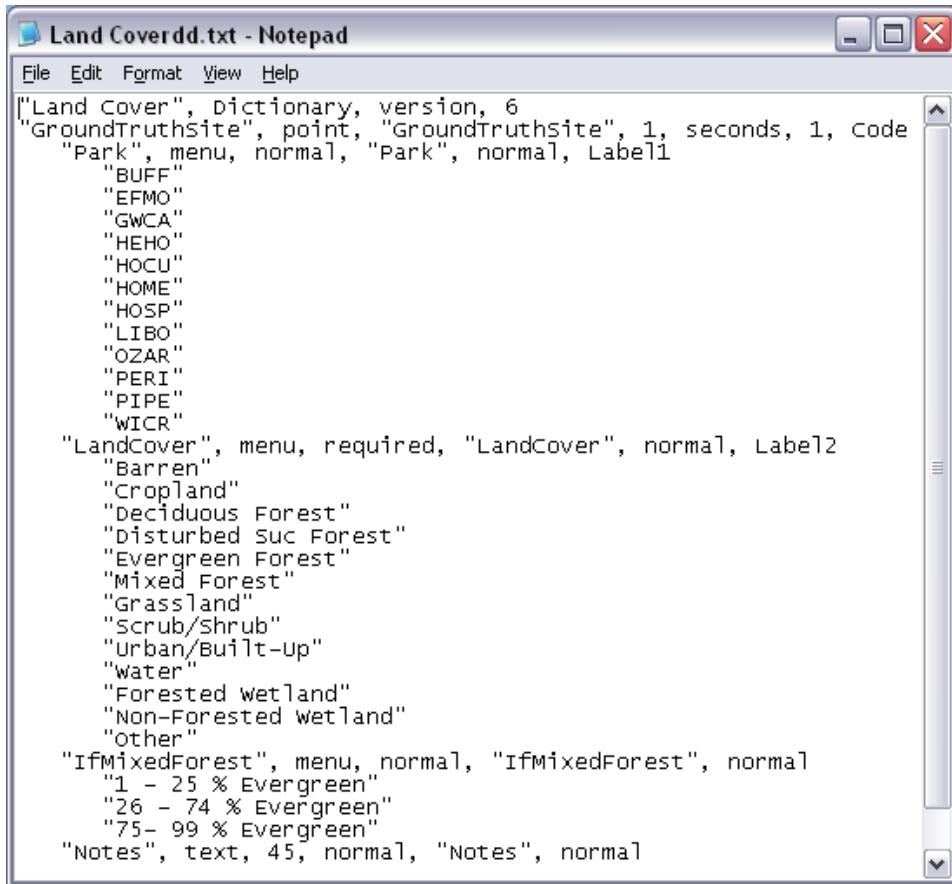
The following settings should be applied to the GPS unit:

- System: UTM
- Datum: NAD 1983 (conus) CORS96
- Zone (is park dependent):
 - o Zone 14N : HOME and PIPE
 - o Zone 15N: BUFF, EFMO, GWCA, HEHO, HOSP, OZAR, PERI and WICR
 - o Zone 16N: LIBO
 - o Zone 17N: HOCU
- Altitude Measure: Height Above Ellipsoid (HAE)
- Units: Meters
- Antenna Height: Is dependent on who is collecting data or which vehicle the antenna is placed on. No matter if the antenna is internal or external the measurement should be set for the collection person. Measure the distance from the bottom of the antenna to the ground with a meter tape and enter the measurement in the GPS antenna height settings.
- PDOP: If settable should not be greater than 6.0 (the lower the number the more accurate the location)
- GPS Correction: Set to integrated SBAS (real-time setting)
- Satellite Elevation: Minimum of 15 degrees.

Data Loaded on GPS Unit

The following files should be loaded onto the GPS unit before site collection begins. The first bullet is for collection purposes. The remaining is for navigation purposes.

- Land cover data dictionary: HtlcLC.ddf
- Background file that has a base image, roads, AOI boundary, and park boundary
- AOI boundary, park boundary, and roads import files



```
Land Coverdd.txt - Notepad
File Edit Format View Help
["Land Cover", Dictionary, version, 6
"GroundTruthSite", point, "GroundTruthSite", 1, seconds, 1, Code
"Park", menu, normal, "Park", normal, Label1
"BUFF"
"EFMO"
"GWCA"
"HEHO"
"HOCU"
"HOME"
"HOSP"
"LIBO"
"OZAR"
"PERI"
"PIPE"
"WICR"
"LandCover", menu, required, "LandCover", normal, Label2
"Barren"
"Cropland"
"Deciduous Forest"
"Disturbed Suc Forest"
"Evergreen Forest"
"Mixed Forest"
"Grassland"
"Scrub/shrub"
"Urban/Built-up"
"Water"
"Forested Wetland"
"Non-Forested Wetland"
"Other"
"IfMixedForest", menu, normal, "IfMixedForest", normal
"1 - 25 % Evergreen"
"26 - 74 % Evergreen"
"75- 99 % Evergreen"
"Notes", text, 45, normal, "Notes", normal
```

Figure 4.1. Text output of the GPS data dictionary used for collecting training data.

GPS Data Collection

To start data collection first you must name the GPS rover file. For data management reasons, name the GPS rover file being collected with the park code, the year of collection and 'lc' (ex: bufflc2009 or peri2013lc). In the rover file name, do not include spaces. All points that are collected for a park can be saved within the same rover file unless more than 5 days has elapsed since the start of data collection. If this has occurred, create a new rover file with the same name, but with a B, C, 2, 3, etc. at the end.

Sites will only be collected as point features. If the point is being collected with GPS positions, a minimum of **50** positions should be collected at a **1 second** interval. While the positions are being acquired hold the antenna still. If the antenna is moved or shifted during collection, which decreases accuracy, please recollect the point. However, sites can also be collected by heads-up

digitizing on the map screen of the GPS unit. Both methods can be used in the same data file with the same data dictionary.

Once the site data has been collected, return the GPS unit to the GIS specialist for data processing.

GPS Unit Notes

When not using the GPS unit for more than 5 minutes, turn the unit off to save battery power. Make sure to close all software programs first before turning the GPS unit off. When the GPS is not being used, place the unit in an area out of harm's way and not in direct sunlight. Each GPS unit has a different battery life, look up what the life is for the unit you take out.

There may be times when the GPS unit will not give you a reading. The first thing to do is check the GPS plan to see if it is just a bad time of day, due to the arrangement of the GPS satellites. If it is one of these times, the only thing to do is be patient and wait, this should correct itself in less than an hour. It is wise to check the GPS plan before leaving for the field, so this does not cause delays. Another reason for no GPS reading is the GPS receiver is being blocked. Make sure your hand or other equipment is not blocking the receiver. At other times a tree or hill can block part of the horizon making it impossible for the GPS satellites signal to reach you. If you are collecting data, you will need to offset to collect your data. Go to an area where a GPS signal can be collect and offset back to the site by using a compass and rangefinder/meter tape. However, if you are navigating also go to where a signal can be received and then guide the other members of your crew to the site location.

Please be familiar with the Heartland Network Operational Plan for GPS before going into the field. There should be a copy in each HLTN vehicle, to use as reference when needed. Finally, make sure to take all parts and hard case associated with each GPS unit when visiting a park and do not mix parts between units. Even though parts can look alike, at times they have different voltages that will cause harm when used with the wrong GPS unit.

II. Collecting Training Data in the Office

Photo Interpretation Data

If you don't believe you acquired enough training data with the field methods, then additional sites can be collected in the office by using photo interpretation. Photo interpretation is accomplished by heads-up digitizing points with an additional image that is not the satellite image being classified. The additional image is usually a DOQ with a high spatial resolution and was captured close to the same time as the satellite image being classified.

Land Cover Monitoring Protocol
Heartland I&M Network and Prairie Cluster Prototype Monitoring Program

Standard Operation Procedure 5: Image Preparation

Version 1.00 (03/31/2011)

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This SOP contains instructions for preparing the imagery before the classification process commences. Specifically this SOP outlines how to orthorectify, correct for atmosphere, layer stack, and clip image bands to just the area of interest (AOI).

I. Orthorectification

In most cases when imagery is purchased, the company will orthorectify the imagery for a fee. Normally this option is the quickest and cheaper way to get the orthorectified product you need to run the classifications. However, in cases where it is too expensive for the imagery to come orthorectified or the imagery was acquired from a clearinghouse as raw imagery, then Appendix B details how to complete the orthorectification in-house.

II. Atmospheric Correction

If the imagery that is being processed is hazy and contains multiple scenes of imagery then an atmospheric correction should be done. The software used for this step is the Atmospheric and Topographic Correction (ATCOR3), which is an ERDAS Imagine module add-on. The imagery must be orthorectified first before being processed for atmospheric correction.

Procedures

1. Open an ERDAS Imagine session. Under Toolboxes click on ATCOR, from which you'll select **ATCOR3 Derive Terrain Files**.
2. Once you clicked on **ATCOR3 Derive Terrain Files** you will get the Generate Terrain Files window from DEM. This is used to create the necessary datasets (Slope, Aspect, Skyview, and Shadow) required by ATCOR3 from the DEM. In addition to the DEM file and DEM pixel size, required inputs are the zenith and azimuth sun angles. You can calculate the zenith and sun angles by specifying the image acquisition date, time, and location, but a more accurate method for SPOT imagery is to use the angles that are listed in the VOL_LIST.PDF file under the Sun angles (degree) heading in the report (Figure 5.1) for the image you are doing the atmospheric

correction. The azimuth angle is read directly from the report (155.938311), but the zenith angle must be calculated from the Elevation angle using the following equation.

Zenith angle (54.68498) = 90^0 – Elevation (35.315020)

You specify the location where you want to store the Slope, Aspect, Skyview, and Shadow data files, which will be used later for the Atmospheric/Topographic correction.

- **Slope** – slope in degrees: 0^0 to 90^0 , coded as 0-90
- **Aspect** – aspect of DEM from 0^0 to 360^0 , coded clockwise as 0-360 with the value 361 as flat
- **Skyview** – result of ray tracing program, values stored between 0-255, 100^0 = 255 (full horizon) and 0^0 =0 (no view of sky)
- **Shadow** – cast shadow, values are 1 = Shadow 0 = No shadow

Scene Extract Parameters				
Scene ID	5 592-280/7 07/02/03 17:04:24 1 J			
K-J identification	592-280			
Date	2007-02-03 17:04:24.1			
Instrument	HRG 1			
Shift Along Track	7 4200			
Preprocessing level	1B			
Spectral mode	J			
Number of spectral bands	4			
Spectral band indicator	HI1	HI2	HI3	HI4
Gain number	8	8	7	5
Absolute calibration gains (W/m2/sr/μm)	3.162396	3.803701	3.071707	10.741221
Orientation angle	14.026538 degree			
Incidence angle	15.384224 degree			
Sun angles (degree)	Azimut: 155.938311 Elevation: 35.315020			
Number of lines	3082			
Number of pixels per line	3013			
Location in the full scene				
Top left corner	Pixel: 1387 Line: 2155			
Bottom right corner	Pixel: 4399 Line: 5236			
Scene Center Location				
Latitude	N34° 31' 31"			
Longitude	W93° 1' 31"			
Pixels number	2995			
Line number	3011			

Figure 5.1. Sun angles for SPOT Leaf-off Scene Parameters in VOL_LIST.PDF file

3. Click **OK** in the Generate Terrain Files window and the process should start. It will take some time to create the four files (Slope, Aspect, Skyview, and Shadow). Click **OK** when the process is done. This processes generates four files that are necessary for the Atmospheric/Topographic correction of the SPOT image. Figure 5.2 shows the four files that are created.

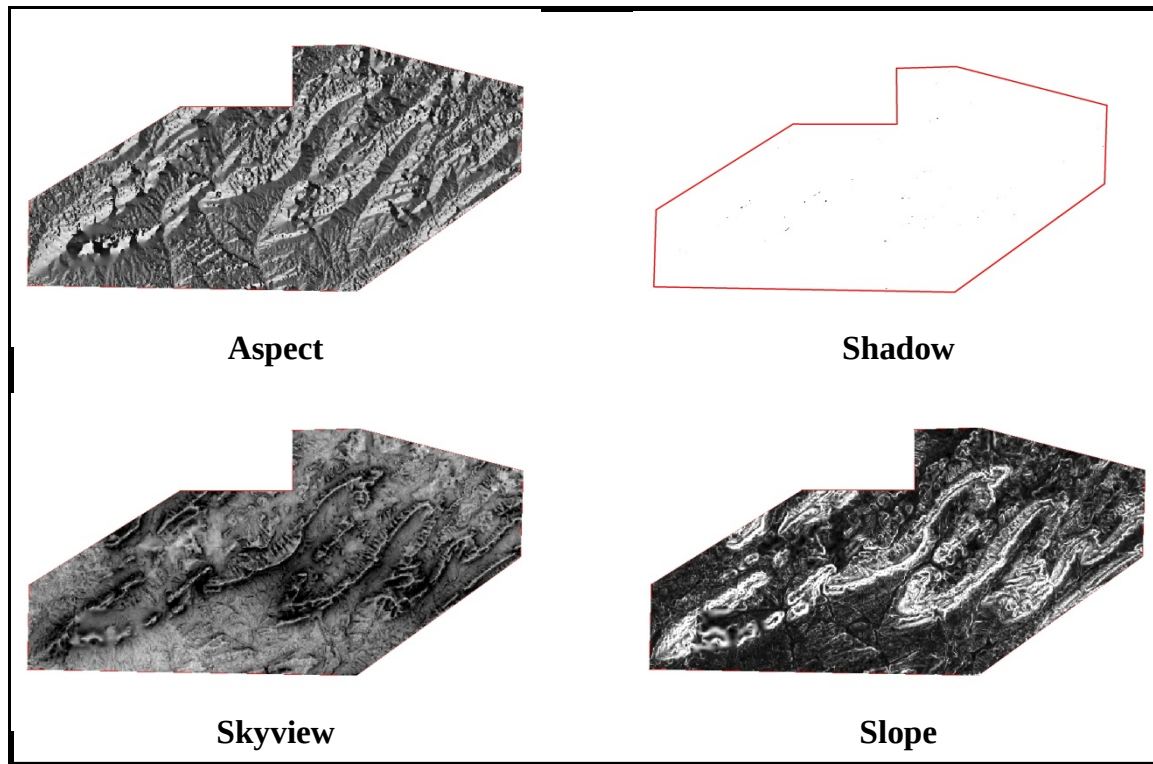


Figure 5.2. Slope, Aspect, Skyview, and Shadow data sets created from the DEM.

4. Click ATCOR3 Workstation to start ATCOR. Create a new ATCOR3 project and specify the location and name of the new project.

5. Once the ATCOR3 Workstation Main Menu window opens you need to specify the input SPOT image and output image along with setting three groups of parameters. The first group of parameters you will set is the acquisition date. Click the **Set** button next to Acquisition Date and the Acquisition Date window will open. Fill in the Day, Month, and Year when the image was taken in the Acquisition Date window. The second group of parameters you will set is the acquisition input layers. Click the **Set** Button next to input layers and the Layer Number window will open. The Layer Band Assignment is 3 (file, green) for 1, 2 (file, red) for 2, 1 (file, NIR) for 3, and 4 (file, MIR) for 4. These assignments are based on file Band assignments of the input image (example SPOT image) as shown below (Figure 5.3):

Band 1 - (0.78 - 0.89 μm – Near Infrared)
 Band 2 - (0.61 - 0.68 μm - red)
 Band 3 - (0.50 - 0.59 μm - green)
 Band 4 - (1.58 - 1.75 μm – Mid Infrared)

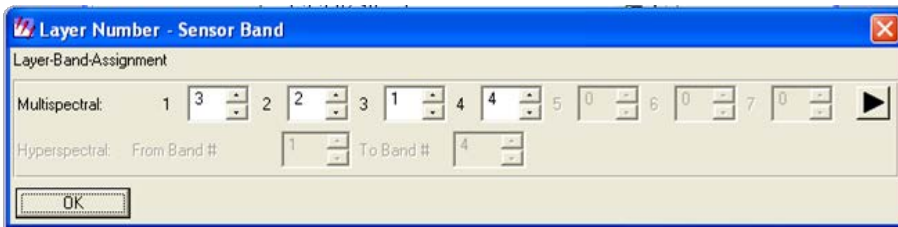


Figure 5.3. ATCOR3 Layer Number Window.

The last group of parameters you will set is the scale factors. Click the **Set** Button next to scale factors and the Output Scale Factors window will open (Figure 5.4). For SPOT data the defaults are accepted for the Factor for Temperature and Offset for Temperature. These defaults don't apply to SPOT imagery because SPOT imagery does not have a thermal band. We set the Factor for Reflectance to 1.00 as shown in Figure 5.4. This is used to scale the output reflectance image. We are not going to scale the output image.

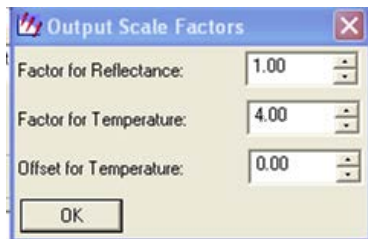


Figure 5.4. ATCOR3 Output Scale Factors Window

6. Now that the three groups of parameters are set, you need to provide ATCOR3 with information on the geometry when the image was taken. Enter the solar zenith (54.68498) and azimuth (155.938311) angles as done previously from the VOL_LIST.PDF file (Figure 5.1). Click the **Set** Button next to Elevation Files and enter the locations and file names of the Slope, Aspect, Skyview, and Shadow file. For the sensor choose SPOT-5 MS (multi-spectral).

7. For a SPOT 5 image building a calibration file to use in the atmospheric/topographic correction. The following information is from the ATCOR manual concerning SPOT 5. If you are using SPOT 1-4 imagery you will not be building a calibration file.

Spot-5

Exception: for the SPOT cameras the calibration coefficient $A(i)$ is specified in the metadata file as:

$$DN(i) = A(i) \times L(i)$$

and the $A(i)$ coefficients (with unit $[m^2 \text{ sr micron } W^{-1}]$) enter the ATCOR calibration file and $c0(i) = 0$.

ATCOR converts the $A(i)$ internally as

$$c1(i) = 0.1 / A(i)$$

to obtain the required unit [mW cm⁻² sr⁻¹ micron⁻¹].

Please use the values given in the “metadata.dim” file for SPOT-5 imagery, not the values of the “vol_dir.pdf”. The values of “vol_dir.pdf” should be used for SPOT 1-4!

The calibration file can be built in any text editor, for example Windows Notepad. The absolute calibration gains for SPOT 5 example leaf-off image text file is shown below.

```

4  c0    A    c0[mW/cm2 sr micron], A[m2 sr micron/W]
1  0.00  3.162396
2  0.00  3.803701
3  0.00  3.071707
4  0.00  10.741221

```

You obtain the above information from the VOL_LIST.PDF file under the Absolute calibration gains heading in the report (Figure 5.5) for the image you are doing the atmospheric correction.

Scene Extract Parameters				
Scene ID	5 592-280/7 07/02/03 17:04:24 1 J			
K-J identification	592-280			
Date	2007-02-03 17:04:24.1			
Instrument	HRG 1			
Shift Along Track	7 4200			
Preprocessing level	1B			
Spectral mode	J			
Number of spectral bands	4			
Spectral band indicator	HI1	HI2	HI3	HI4
Gain number	8	8	7	5
Absolute calibration gains (W/m2/sr/μm)	3.162396	3.803701	3.071707	10.741221
Orientation angle	14.026538 degree			
Incidence angle	L3.384224 degree			
Sun angles (degree)	Azimut: 155.938311 Elevation: 35.315020			
Number of lines	3082			
Number of pixels per line	3013			
Location in the full scene				
Top left corner	Pixel: 1387 Line: 2155			
Bottom right corner	Pixel: 4399 Line: 5236			
Scene Center Location				
Latitude	N34° 31' 31"			
Longitude	W93° 1' 31"			
Pixels number	2995			
Line number	3011			

Figure 5.5. Absolute calibration gains for SPOT Leaf-off Scene Parameters in VOL_LIST.PDF file

8. Select the **Atmospheric Selections** Tab in the ATCOR3 Workstation Main Menu window to set the Scene Visibility value in Km and the Model for Solar Region. Scene Visibility can be obtained from weather station information. You can obtain this information from <http://www.wunderground.com/history/> web site. The Model for Solar Region for SPOT imagery (tiltable sensor) you specify the amount of tilt which can be obtained from the Incident

Angle in the VOL_LIST.PDF file. Also, you may need to set the atmosphere type in the Model for Solar Region. After entering this data click the **Specifications** Tab and then click **Run Correction** and the process starts running. After clicking **Run Correction**, the Constant Atmosphere Module window appears.

9. For the question perform Haze Removal before correction choose **No**. and then click the **Atmosphere Correction** button to start the process. The Haze removal is an independent process of ATCOR3 and can be used without atmospheric correction. In this Protocol we are doing atmospheric correction. The bi-directional reference distribution function (BRDF) Correction menu pops up. The BRDF takes into account surface types that exhibit anisotropic reflectance behavior, the reflectance depends on viewing and illumination geometry. For SPOT imagery we chose an Empirical BRDF correction and Model 1 with the default Threshold angle and Lower boundary values if the off-nadir angle (incident angle) is less than 20° and Model 3 for angles $> 20^{\circ}$. See the VOL_LIST.PDF file report to get the incident angle of the image.

10. Click **OK** and the model continues to run with no further questions being asked.

Figure 5.6 compares the before and after atmospheric correction images.

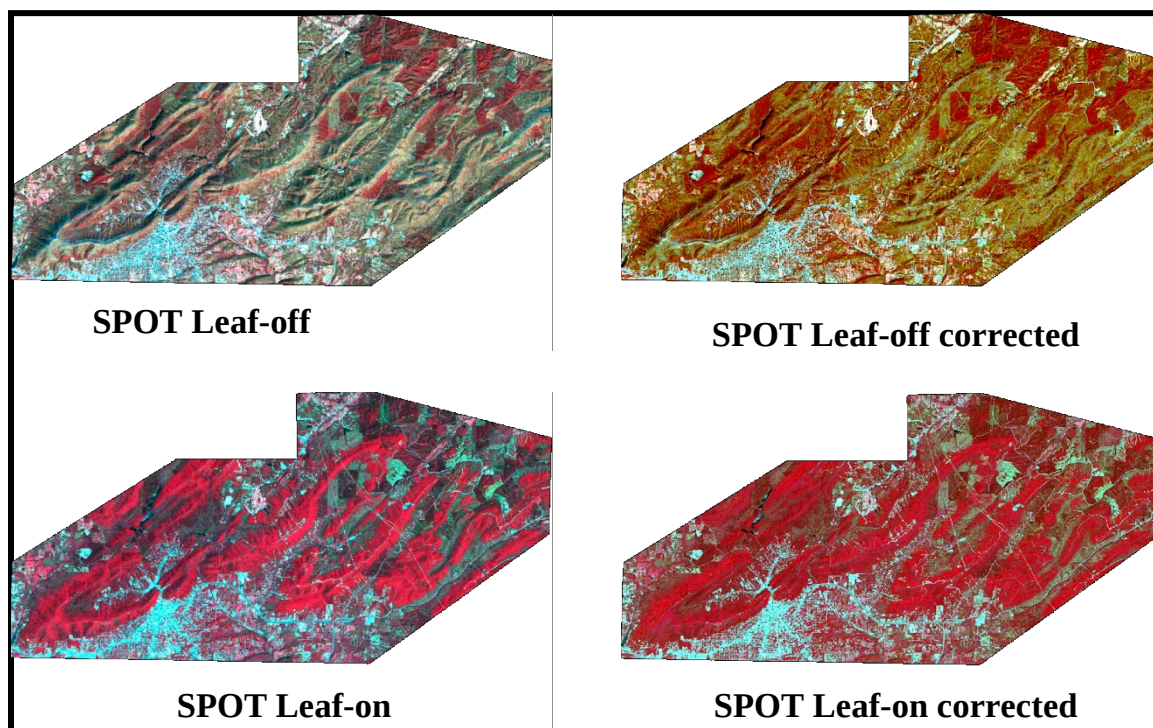


Figure 5.6. Comparison of atmospheric correction before and after SPOT Imagery 321 (RGB).

As previous discussed in this section of the SOP, atmospheric correction should be applied if the classification is based on multi scenes (different geographic locations).

III. Layer Stack

Layer stack is the process of taking multiple bands of imagery from different image scenes and combining them into one multi-band image. For this protocol this method will be used when a leaf-on and leaf-off image has been acquired. The images should be layer stacked so one 8 band image can be classified instead of two 4 band images.

Procedures

1. Open the software ERDAS Imagine.
2. Under the Raster menu, select Spectral – Layer Stack
3. In the Input File browse to the images you want to stack and add all bands (depending on how many images are being stacked, determines the amount of times this step will need to be done). Remember to document the order of the image bands as they are entered into the Add window. That way when metadata is created later, the fact that band 1 equals the green leaf-on band, band 8 equals the SWIR leaf-off band, and so forth will be preserved.
4. Also in the Layer Stack window select Union, Unsigned 8 bit, and an Output File name.
5. Click OK

IV. Clip to AOI

Classification of imagery can be a time consuming process. Therefore, to make those steps as efficient as possible, use the AOI to subset the imagery. This clips out parts of the imagery not in the study area to speed up processing.

Procedures

1. Open the software ERDAS IMAGINE.
2. Under the Raster menu, select Subset & Chip – Create Subset Image.
3. The Subset window has now opened. Set the following choices:
 - Input File – is the image you want to subset
 - Output File – is the name and location you want to save the file as
 - Data Type Output – Unsigned 8 bit, continuous
 - Select Layers – set range for all layers in the image you are subsetting
 - AOI button – choose the .aoi for the study area to be processed
4. Click OK

Land Cover Monitoring Protocol
Heartland I&M Network and Prairie Cluster Prototype Monitoring Program

Standard Operation Procedure 6: Supervised Image Classification

Version 1.00 (03/31/2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

I. Land Cover Classes

Below is a list of possible classes that each classification could have. Due to the fact that the parks being classified are scattered throughout the Midwest in seven different states, each park may not have the entire list of classes present, but a sub-sample of the following list. A current class list along with class definitions can be found in the land cover MS Access Database under reports: HtlnLcDefinitions and also in SOP 3.

- Urban/Built-up
- Cropland
- Grassland
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Disturbed Successional Forest
- Water
- Barren
- Wetland Forested
- Wetland Non-Forested

II. Classification Processing

Townsend (et al, 2009) states:

Numerous software packages and classification algorithms exist that may be used to accurately classify satellite imagery into land cover maps. No single method is necessarily more correct than any other, and the person processing the imagery should have the freedom to select the

method that is most appropriate to a particular application. It is important that a single method not be set in stone because classification methods are constantly being revised.

Below is an example of how to process a supervised classification. The software used for the following steps is ERDAS Imagine.

Procedures

1. First create signatures under the signature editor window (Figure 6.1). This is done by creating .aoi polygons that capture pixel values representing land cover types. The .aoi's are used to import the spectral values into a signature training set.

Class #	Signature Name	Color	Red	Green	Blue	Value	Order	Count	Prob.	P	I	H	A	FS
1	Bright Evergreen Forest		0.441	0.999	0.451	304	304	303	1.000	✓	✓	✓	✓	
2	Medium Evergreen Forest		0.000	1.000	0.000	1	305	289	1.000	✓	✓	✓	✓	
3	Dark Evergreen Forest		0.498	1.000	0.000	2	306	206	1.000	✓	✓	✓	✓	
4	Sunny Deciduous Forest		0.290	0.710	0.314	3	307	312	1.000	✓	✓	✓	✓	
5	Medium Deciduous Forest		0.000	0.392	0.000	4	308	570	1.000	✓	✓	✓	✓	
6	Dark Deciduous Forest		0.049	0.271	0.055	5	309	438	1.000	✓	✓	✓	✓	
7	Lawn		1.000	0.647	0.000	6	310	397	1.000	✓	✓	✓	✓	
8	Red Spring Crop		1.000	1.000	0.000	7	311	598	1.000	✓	✓	✓	✓	
9	Green Spring Crop		1.000	0.843	0.000	8	312	559	1.000	✓	✓	✓	✓	
10	Grass		0.627	0.322	0.176	9	313	580	1.000	✓	✓	✓	✓	
11	Water		0.000	0.000	1.000	10	314	353	1.000	✓	✓	✓	✓	
12	Barren		0.000	1.000	1.000	11	315	71	1.000	✓	✓	✓	✓	
13	Light Urban		0.827	0.827	0.827	12	316	305	1.000	✓	✓	✓	✓	
14	Dark Urban		0.570	0.570	0.550	13	317	233	1.000	✓	✓	✓	✓	

Figure 6.1. The signature editor window in ERDAS Imagine.

2. Once all the signatures are collected, a supervised classification can be processed. In the supervised classification window (Figure 6.2), enter the image to be classified, the signatures, and the output classification name. The decision rule choices are modified based on the individual image to obtain the best possible classification.

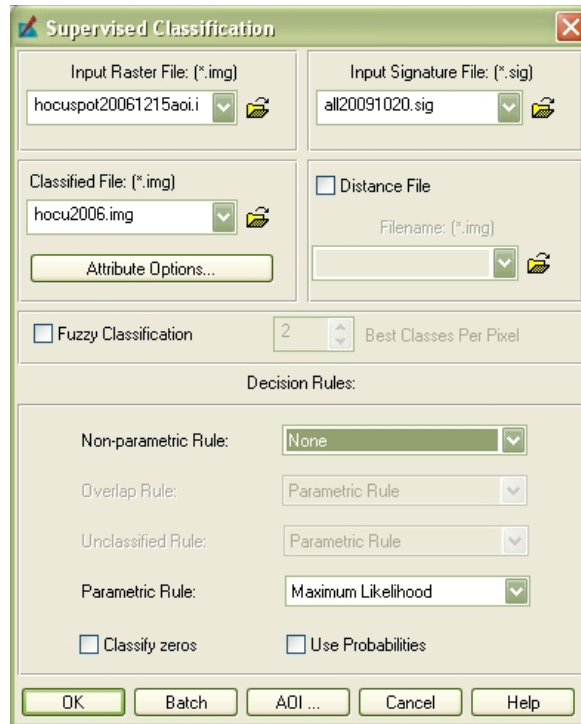


Figure 6.2. The supervised classification window in ERDAS Imagine.

3. After a classification is created, visually inspect the output, as a preliminary assessment. If the classification is of poor quality after the preliminary assessment, rerun steps 1 and 2. However, if the classification is acceptable, then calculate an error matrix. For steps on how to calculate an error matrix, see SOP 7 Accuracy Assessment.
4. If error matrix has an overall accuracy of 80%, then proceed to step 5, if under 80% then repeat steps 1 – 3.
5. Next recode the classification to combine different field attributes that represent the same class. For example, sunny deciduous forest and dark deciduous forest classes are both deciduous forest (Figure 6.3), but were broken apart for signature reasons during classification. They were recoded to deciduous forest. The classification is also recoded to despeckle pixels representing noise in the classification output.

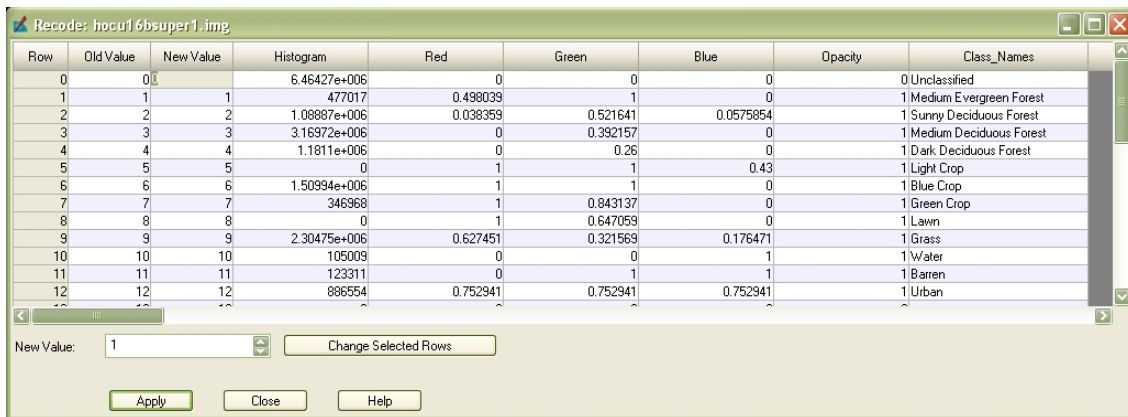


Figure 6.3. An example of the recode window in ERDAS Imagine.

- Once recoding is completed, rerun the error matrix from step 3, for the final accuracy assessment.

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Standard Operation Procedure 7: Accuracy Assessment

Version 1.00 (10/17/2012)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP will describe the procedures for completing an accuracy assessment (AA) on the processed classification. Software used for this procedure was ArcGIS® and Microsoft Excel.

I. Reference Data

Stratified random points (SRP) will need to be created to assess the accuracy of the classification. The number of random points that will be created is the number of land cover classes multiplied by 50 (Congalton and Green 1999). Next determine the relative area proportions of each land cover class. The number of random points per class to generate will be proportional to the total area of the class within the classification.

Once the SRPs are generated proceed to photo interpretation. Overlay SRPs on high resolution imagery that is close in date to the imagery used to run the classification. Identify the class each SRP belongs to and save that within the SRP layer.

II. Accuracy Assessment Procedure

1. Before initiating AA, the classification raster output from SOP 6 is converted to a vector shapefile. In order to perform the AA, the spatial join tool should be used to create a point shapefile that has an attribute table containing both the class codes from the SRP, as well as the class codes from the LC classification shapefile. To perform the join open **ARC Toolbox> Analysis Tools> Overlay> Spatial Join**. Add the SRP file as the Target Features parameter, the classification shapefile as the Join Features parameter, and assign the output file a name and location (Figure 7.1). Leave the other fields as defaults. The Attribute Table of the new output shapefile should look similar to Figure 7.2.

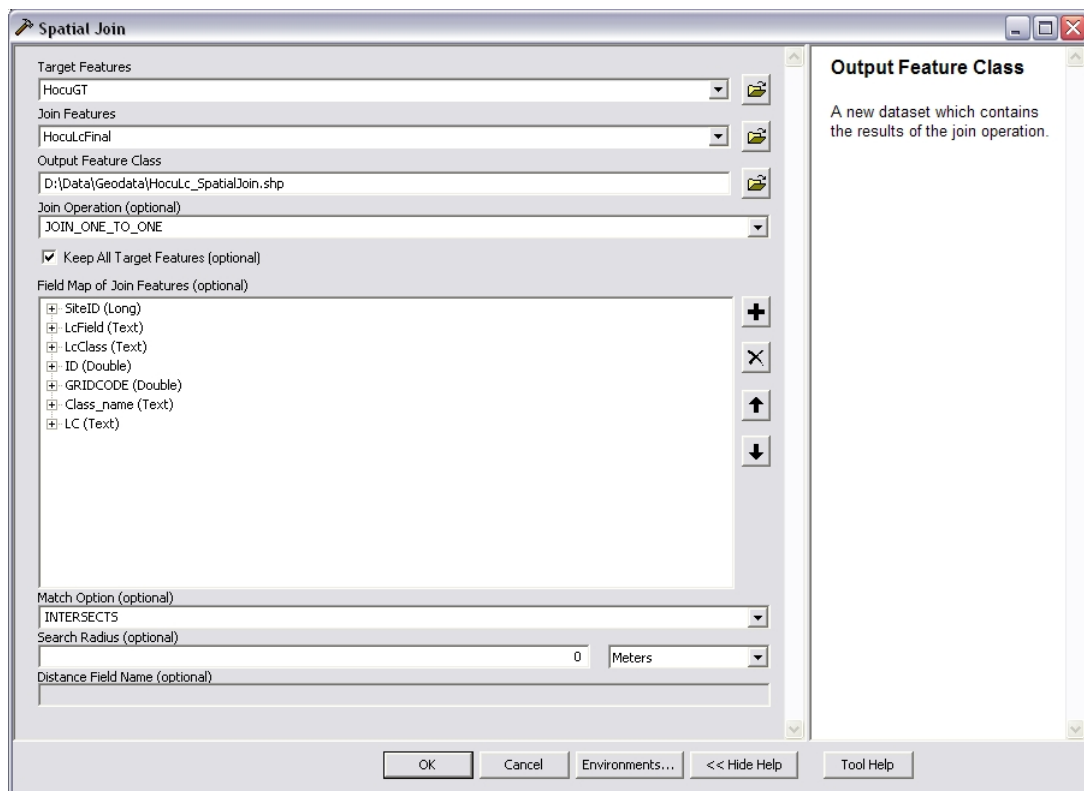


Figure 7.1. Spatial Join Tool window.

FID	Shape	SiteID	LcField	LcClass
0	Point	1	W	W
1	Point	2	C	C
2	Point	3	C	G
3	Point	4	B	B
4	Point	5	FD	G
5	Point	6	FE	FE
6	Point	7	FD	FD
7	Point	8	G	G
8	Point	9	G	G
9	Point	10	U	U
10	Point	11	U	U
11	Point	12	W	W
12	Point	13	C	C
13	Point	14	G	G
14	Point	15	FD	FD
15	Point	16	G	C
16	Point	17	C	C
17	Point	18	B	B
18	Point	19	U	B
19	Point	20	FD	FD

Record: 0 Show: All Selected Records: 20

Figure 7.2. Attribute table for the spatially joined data.

2. Now a decision needs to be made on how you are going to compare the SRP data to the classification or vice versa. If you compare the classification to the SRP, then you will fill in the rows of the error matrix. Otherwise, fill in the columns. For this protocol, we compared the classification with the SRP data. Using the Select by Attributes tool, select in turn each of the different LC codes from the SRP for the classification, in this case the LC field; this will highlight the points having that value (Figure 7.3).

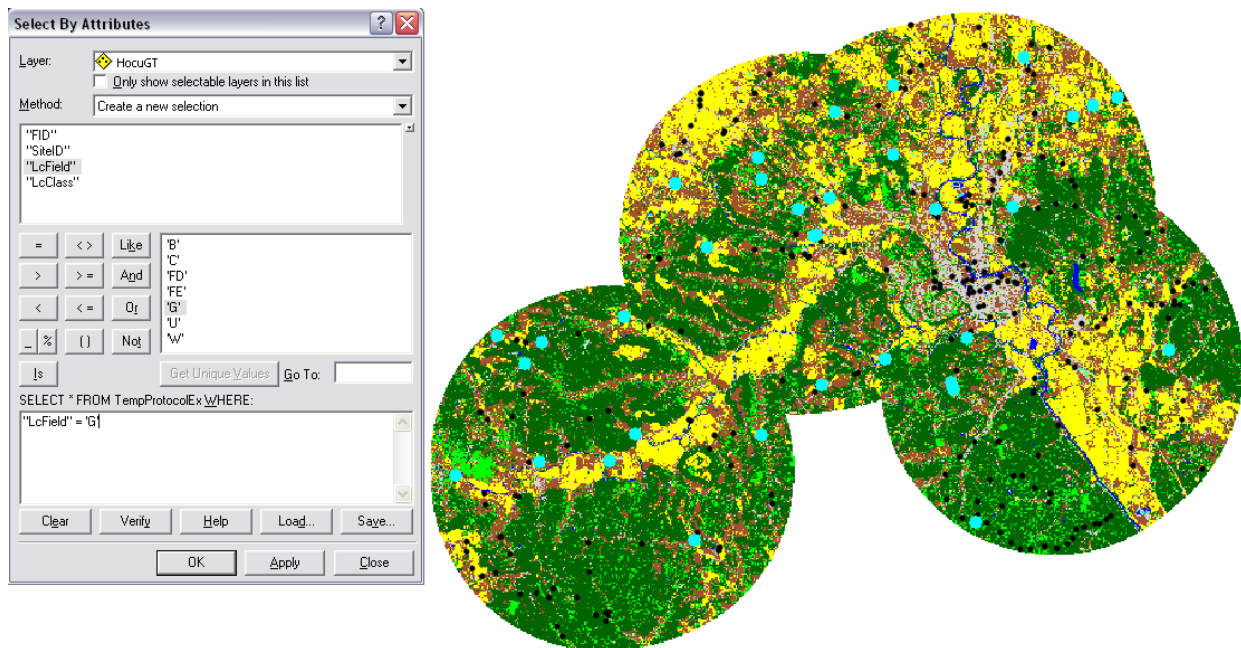


Figure 7.3. Sites with the LC code for grassland highlighted.

3. Open the Attribute Table and choose to Show only the selected data, and output the Attribute Table. After outputting the Attribute Table for each of the cover types, you can compare the two land cover codes manually and determine where the two are in agreement. It is now just a matter of counting up the number of times the two columns agree (a correct classification) and the number and type of cover classes for when they disagree. These values are entered into the error matrix and calculations for User's Accuracy, Producer's Accuracy, and Overall Accuracy are determined as previously discussed in this protocol (see pages 12-13).

4. Calculate the KHAT value with the below equation Congalton and Green 1999, Campbell 2002):

$$\text{KHAT} = \frac{\text{Observed-Expected}}{1-\text{Expected}}$$

The observed value is the overall accuracy value in decimal form from the error matrix (step 3). The expected value is calculated by summing the marginal products and dividing by the grand total of products (Campbell 2002). KHAT values can range from -1 to 1, with positive values expected since there should be a positive correlation between the classification and the imagery

used for the classification. When the KHAT value is greater than 0 this signifies that the produced classification is better than a random classification (Colgalton and Green 1999).

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Standard Operation Procedure 8: Change Analysis

Version 1.00 (10/17/2012)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP describes the procedures for completing post-classification change detection. For this SOP must already have two finalized classification for the same area from two different time periods.

I. Classification Specifications

The two different classifications being processed must:

1. Be spatially registered exactly to each other.
2. Have identical classification systems.
3. Have the same pixel resolution.
4. Be from two different time periods
5. If possible be from the same imagery sensor.
6. If possible be from the same time of year.

II. Post-Classification Change Detection

Once two classifications that are spatially registered are produced, change detection analysis can be processed using the following steps. For this protocol the most recent classification should be compared to the base classification and to the classification previous to the recent one.

1. Open the two classifications in ArcMap.
2. Select the Windows menu and click Image Analysis. This opens the Image Analysis window (Figure 8.1).

3. In the Image Analysis window, select the two images to process change detection on. Click the Difference button at the bottom of the window.
4. Once the difference is processed, select that layer and check mark the DRA choice make the different values easier to see.
5. Export and rename the difference layer.
6. If needed reclassify the difference layer values.
7. Produce a map that shows land cover change categories and no change areas (Figure 7.2).
8. Create a class change detection matrix (Table 7.1)

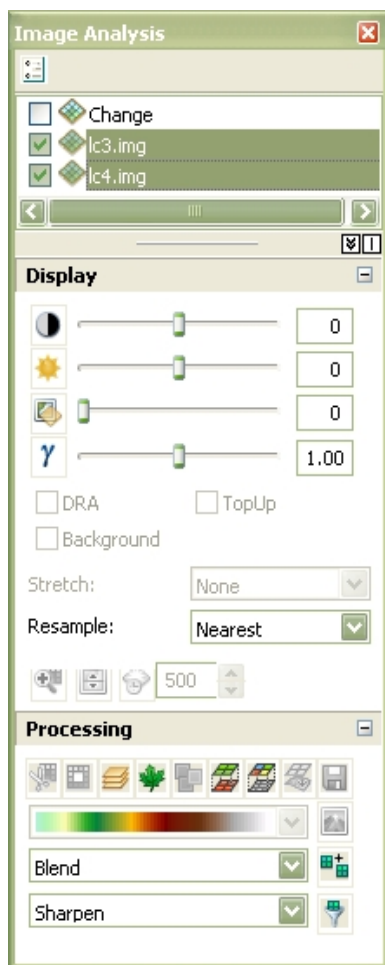


Figure 8.1. The Image Analysis window in ArcMap.



Figure 8.2. Example of a map output for change detection.

Table 8.1. Example of class change detection matrix

2003	2013			
	Grassland	Crop	Deciduous Forest	Evergreen Forest
	Grassland	13		
	Crop			
	Deciduous Forest	4		
	Evergreen Forest	10		

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Standard Operation Procedure 9: Data Management

Version 1.00 (03/31/2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP describes procedures for managing the database for Land Cover (LC) monitoring. There are two databases for LC monitoring. The first is a file GDB (LULCLC_FileGDBv1.2.gdb) that is used to house the spatial data, including AOIs, GT sites, and the final classification for the project. The GDB is a container for spatial data only and will not be discussed in this SOP. The second database is a MS Access file (LULCCA1.3.mdb) that contains project operations information and final result tallies of the final class areas. This document addresses procedures for data management of the LULCCA1.3.mdb.

I. Data Entry

The first item that needs to be entered is the LC cycle. The cycle is the park and the year of the classification that is used to organize all of the operations and data. See Figure 9.1.

LC event and observers (Figure 9.2) represent training data collections and the observers who acquired the data. Record this data as it becomes available in order to track the training data collection process.

Information on the imagery used in this protocol is recorded in LC imagery form (Figure 9.3). The image type, cost, season, and date must be entered in this form. This information should be entered as it becomes available.

The sum of the area for each class type is entered into the LC results form (Figure 9.4) for a given cycle. The percent of class total area is then calculated automatically. These results will then be used for LC reporting.

Also housed in the LULCCA1.3.mdb are the current LC classes along with the definitions for each (See Figure 9.5). This form feeds an auto-generated report that can be printed and taken into the field as reference.

LC Cycle

Cycle ID: OZARLULCCA2010

Park: OZAR

Year: 2010

Total Acres:

Cycle Notes: Field work at OZAR took 4 trips ranging from Sept 2010 to Feb 2011. A few icy roads were problematic.

Record: 1 of 5 | No Filter | Search

Figure 9.1. LC cycle form for the Access database.

LC Events and Observers

Event ID: BUFFLULCCA20080324

Cycle ID: BUFFLULCCA2008

Sample Method: Field

Start Date: 20080324

End Date: 20080325

Trip Report: ☒

Notes: 48 ground truth sites were collected in the North Eastern 1/3 of the study area. Pull-offs and roads down to BUFF entry sites provided the best places to sample.

subfrm_Observers

ObserverID	Name	Date
JLH		
MSW		
*		

Record: 1 of 10 | No Filter | Search

Figure 9.2. LC events and observers form for the Access database.

LC Imagery

Cycle ID: HOCULULCCA2008

Type: SPOT

Cost: \$10,550.00

Orthorectified: Imagery contractor

Season: Leaf-on & Leaf-off

Notes: Cost is for both leaf-on and leaf-off SPOT.

Imagery Dates

Date	#ofScenes
20060817	1
20061215	1
*	0

Record: 1 of 2

Figure 9.3. LC imagery form for the Access database.

LC Results

Cycle ID: HOSPLULCCA2007

Class Code: U

Acres: 2850.68

% of LULC: 6.84%

Record: 7 of 11

Figure 9.4. LC results form for the Access database.

The screenshot shows a Microsoft Access form titled "frm_HtlNcDefinitions". The form has a green header with the text "HTLN Land Cover Definitions". On the left, there is a list box labeled "Category" with the following items: Urban, Forest, Grassland, Crop, Water, Wetland, Barren (selected), and Grassland. To the right of the list box, there are two text boxes: "Class Code" with the value "B" and "Class Name" with the value "Barren". Below these, there is a text area labeled "Definition" containing the text: "Land that supports very little vegetation, and is not part of the Urban/Built up class. Examples are gravel bars, beaches, bare exposed rock, sand dunes, gravel pits, quarries, strip mines, and wasteland." At the bottom of the form, there is a status bar showing "Record: 1 of 16", a "No Filter" button, and a "Search" button.

Figure 9.5. LC definitions form for the Access database.

II. Version Control

Version control provides a logical organization for database archives, it helps prevent data overwrites and it ensures that only the most current copy of the database will be used in any analysis.

Versions of archived data sets are handled by adding a floating point number to the file name, with the first version being numbered 1.0. Each major version is assigned a sequentially higher whole number. Each minor version is assigned a sequentially higher .1 number. Major version changes include migrations across Access releases and complete rebuilds of front-ends and analysis tools. Minor version changes include bug fixes in front-end and analysis tools.

Prior to any major changes of a data set, a copy should be stored with the appropriate version number. This allows for the tracking of changes over time. Notify frequent users of database version updates, previous archives and their locations.

III. Backups

Secure data archiving is essential for protecting data files from corruption. HTLN maintains an SOP for backing up two program servers. One server is located at the Missouri State University (MSU) campus and the other at the visitor's center at Wilson's Creek National Battlefield (WICR). Both servers are Dell PowerEdges with minor differences in configuration. Backups are made daily to large external hard drives.

System backups should be stored off-site. Project files and databases should be exchanged between the two servers at least once per month. Files are exchanged using a portable hard drive. Files are synchronized between servers based on file size and most recent date modified. Server comparisons are made using Beyond Compare, Scooter Software, Inc. For greater security, files from MSU should be read-only at WICR and files from WICR should be read-only at MSU. In

addition, files from each location should be handled in separate directories on the transfer hard drive.

IV. Metadata

Up-to-date metadata are a requirement for Natural Resource Inventory and Monitoring databases and a requirement of federally funded databases in general. Fortunately, there are some excellent metadata tools that have been developed by Natural Resource WASO staff. “NPS Metadata Tools and Extractor” or the equivalent should be used to create LC metadata to meet FGDC requirements. Metadata for LC should be provided to the NPS Natural Resources GIS Data Store or any other NPS data clearinghouses designated to manage metadata.

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Standard Operation Procedure 10: Reporting and Presentation

Version 2.00 (July 2009)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	07/2009	D.G. Peitz K.M. James	Revise entire document	Reflect use of NRTR format	2.0

This SOP gives step-by-step instructions for reporting on land cover monitoring data collected by Heartland Inventory and Monitoring Network (HTLN). The SOP describes the procedure for formatting a report, the review process and distribution of completed reports. Efficient reporting on monitoring results is critical in assisting park Resource Managers in management decisions. Therefore, a reporting schedule is given with critical dates identified.

I. Report Format

Template

The report template for Natural Resource Technical Reports should be followed (<http://www.nature.nps.gov/publications/NRPM/index.cfm>). Natural resource reports are the designated medium for disseminating high priority, current natural resource management information with managerial application. The Natural Resource Technical Reports series is used to disseminate the peer-reviewed results of scientific studies in the physical, biological and social sciences for both the advancement of science and the achievement of the National Park Service's mission.

Style

Standards for scientific writing as recommended in the CBE Style Manual (CBE Style Manual Committee 1994) should be followed. Reports should be direct and concise. Refer also to Mack (1986), Day and Gastel (2006) and Strunk and White (2000) for guidelines on appropriate writing style.

II. Types of Reports and Review Process

Table 10.1. Summarizes the types of reports produced and the review process. Adapted from DeBacker et al. 2005.

Type of Report	Purpose of Report	Primary Audience	Review Process	Frequency
Comprehensive 4 - year Status Reports	Summarize monitoring data collected during a sampling year by HTLN and any observations made by park staff and volunteers during the previous three years, to provide an update on the status of plant communities. Document related data management activities and data summaries.	Park resource managers and external scientists	Internal peer review by HTLN staff	Every 4 th year
Executive Summary of Comprehensive 4 - year Status Reports	Same as Comprehensive 4 – year Status Reports but summarized to highlight key points for non-technical audiences.	Superintendents, interpreters and the general public	Internal peer review by HTLN staff	Simultaneous with Comprehensive 4 -year Status Reports
Comprehensive Trends and Analysis and Synthesis Reports	Describe and interpret trends in plant communities. Describe and interpret relationships among observed trends and park management, known stressors, climate, <i>etc.</i> Highlight resources of concern that may require management action.	Park resource managers and external scientists	Internal peer review by HTLN staff	Every 12 -16 years
Executive Summary of Comprehensive Trends and Analysis and Synthesis Reports	Same as Comprehensive Trends and Analysis and Synthesis Reports, but summarized to highlight findings and recommendations for non-technical audiences.	Superintendents, interpreters and the general public	Internal peer review by HTLN staff	Simultaneous with Comprehensive Trends Analysis and Synthesis Reports

III. Report Distribution

Following review, the comprehensive report for a park will be distributed to the resource management staff and the superintendent by the beginning of the next field season after data is collected by the HTLN. Reports can also be distributed to interested partners involved in conservation or restoration of plant communities. This determination is made by the park, the network, or the regional office. All data collected are public property and subject to requests under the Freedom of Information Act (FOIA). However, sensitive data, such as the location of rare species, must be withheld in some cases. Reports containing non-sensitive data will be made publicly available and disseminated through the network website: (<http://science.nature.nps.gov/im/units/htln/>).

IV. Literature Cited

- CBE Style Manual Committee. 1994. Scientific style and format: the CBE manual for authors, editors and publishers. Sixth edition. Council of Biology Editors, Cambridge University Press, New York, New York, USA.
- DeBacker, M.D., C.C Young (editor), P. Adams, L. Morrison, D. Peitz, G.A. Rowell, M. Williams and D. Bowles. 2005. Heartland Inventory and Monitoring Networks and Prairie Cluster Prototype Monitoring Program Vital Signs Monitoring Plan. National Park Service, Heartland Inventory and Monitoring Networks and Prairie Cluster Prototype Monitoring Program, Wilson's Creek National Battlefield, Republic, Missouri. 104 p. plus appendices.
- Day, R.A. 1983. How to write and publish a scientific paper. Second edition. ISI Press, Philadelphia, Pennsylvania, USA.
- Mack, R.N. 1986. Writing with precision, clarity and economy. *Bulletin of Ecological Society of America* 67:31-35.
- Strunk, W. Jr. and E.B. White. 1979. *The Elements of Style*. Third Edition. Macmillan, New York, New York, USA.

Land Cover Monitoring Protocol
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Standard Operation Procedure 11: Revising the Protocol

Version 1.0 (December 2004)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This Standard Operating Procedure explains how to make and track changes to the Land Cover Monitoring Protocol for the Heartland Inventory and Monitoring Network narrative and accompanying SOPs. Observers asked to edit the Protocol Narrative or any one of the SOPs need to follow this outlined procedure to eliminate confusion in how data are collected and analyzed. All observers should be familiar with this SOP to identify and use the most current methodologies.

I. Procedures:

1. The Land Cover Monitoring Protocol for the Heartland Inventory and Monitoring Network (HTLN) narrative and accompanying SOPs has attempted to incorporate the soundest methodologies for collecting and analyzing land cover data. However, all protocols regardless of how sound require editing as new and different information becomes available. Required edits should be made in a timely manner and appropriate reviews undertaken.
2. All edits require review for clarity and technical soundness. Small changes or additions to existing methods will be reviewed in-house by HTLN staff. However, if a complete change in methods is sought, an outside review is required. Regional and national staff of the National Park Service with familiarity in land cover research and data analysis will be utilized as reviewers. Also, experts in land cover research and statistical methodologies outside of the Park Service will be utilized in the review process.
3. Document edits and protocol versioning are tracked in the Revision History Log that accompanies the Protocol Narrative and each SOP. Log changes in the Protocol Narrative or SOP being edited only. Version numbers increase incrementally, major changes by whole numbers (i.e. version 1.0, version 2.0, etc.) and minor changes by tenths (e.g. version 1.1,

version 1.2, etc). Record the previous version number, date of revision, author of the revision and identify paragraphs and pages where changes are made and the reason for making the changes along with the new version number.

4. Inform the Data Manager about changes to the Protocol Narrative or SOP so the new version number can be incorporated in the Metadata of the project database. The database may have to be edited by the Data Manager to accompany changes in the Protocol Narrative and SOPs.
5. Post new versions on the internet and forward copies to all individuals with a previous version of the affected Protocol Narrative or SOP.

Appendix A

Pilot Study

Much testing and thought went into determining which LC classification method would work best for the HTLN. A pilot study was conducted by Robert Weih and Norman Riggan (University of Arkansas, Monticello). This study assessed different land cover classification methods at Hot Springs National Park (HOSP). A follow up pilot study was also conducted by the HTLN at Hopewell Culture National Historic Park (HOCU). The goal of the two pilot studies, along with outside information was to answer the following questions:

- What is an ideal image resolution for classifying at a landscape scale?
- Is there imagery that could be obtained consistently over the years to be used for change analysis?
- What classification methods produce an accuracy assessment greater than 80%?
- What imagery and methods would be affordable over the long term?

The HOSP study looked at an area of approximately 43,600 acres in and around HOSP. Three different classification methods were compared: unsupervised, supervised, and object-based. For the supervised and object-based classifications the same training datasets were used. Roads, railroads and streams were not classified, but GIS polygon layers of each were added to the final classifications of each method. The classifications were processed on the following imagery.

- A: a Principal component analysis (PCA) ran on a 1 meter DOQ merged with 10 meter leaf-on and leaf-off SPOT.
- B: a PCA ran on a 1 meter DOQ merged with 10 meter leaf-off SPOT.
- C: a PCA ran on 10 meter leaf-on/leaf-off SPOT.
- D: a 10 meter leaf-on SPOT.

All classification methods (object-based, supervised, and unsupervised) were applied to A - C above, and only object-based classification was processed on D. Table A (Riggan 2009) reports the User's Accuracies of the various trials. For more information on the HOSP study, please see Riggan (2009) and Riggan and Weih (2009).

Table A. Hot Springs case study classification comparison accuracies.

LC	Object-based				Supervised			Unsupervised		
	A	B	C	D	A	B	C	A	B	C
Urban	85.9	79.5	83.7	68.3	70.4	86.2	82.9	73.0	50.0	79.5
Road	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3
Railroad	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Grassland	83.8	90.6	75.6	75.0	86.5	78.6	86.1	75.0	11.1	92.0
Deciduous	87.2	85.8	70.5	59.2	76.6	78.5	73.9	69.4	40.7	60.3
Evergreen	85.7	86.8	55.3	57.1	79.7	75.3	74.3	61.7	41.5	44.2
Clearcut	50.0	73.7	43.3	54.2	22.2	25.4	35.1	21.3	100.0	58.3
Mixed Forest	55.8	28.4	12.8	17.1	36.4	33.3	23.3	0.0	2.5	6.7
Water	100.0	100.0	100.0	100.0	100.0	95.0	94.4	100.0	56.7	100.0
Barren	64.3	85.7	61.9	68.8	41.9	50.0	53.3	31.0	23.1	52.9
Overall Accuracy	82.0	78.2	66.1	58.9	66.9	71.8	64.4	64.4	41.5	60.1

The HOSP study was useful, but not conclusive. In the HOSP study the most accurate classification was the object-based produced from the PCA merged DOQ with the leaf-on/leaf-off SPOT. However, that method was the most expensive, with high resolution imagery from around the same time period as the SPOT imagery. A concern was that purchasing all the different imagery for the (A) object-based classification would not be possible for all 12 parks or sustainable over time for the change analysis cycles. Another unknown was whether the same resolution and band specification could be acquired over time for the change analysis. In order to learn more about what supervised classifications could produce on just SPOT imagery, a second pilot study was completed.

The HOCU pilot study compared supervised classifications on different types of imagery combinations. The imagery was SPOT leaf-on, SPOT leaf-off, SPOT leaf-on/leaf-off, DOQ resolution merged with SPOT leaf-on/leaf-off, PCA of SPOT leaf-on/leaf-off, and SPOT leaf-on/leaf-off with SPOT PCA leaf-on/leaf-off stacked together. Many different supervised rules and imagery combinations were tested. The resolution merged and PCA imagery generally produced less accurate results than the plain imagery bands. The supervised maximum likelihood classification ran on SPOT leaf-on/leaf-off produced a product that had an accuracy of 81.5.

Both pilot studies produced classifications that were 82% accurate, over the 80% threshold. However, the supervised classification process was both quicker and cheaper.

Appendix B

Orthorectification

In GIS, elevation values are stored in raster Digital Elevation Model (DEM). Every cell in the raster has an X- and Y-value representing its location on the earth, as well as a Z-value that represents its height above sea level. DEMs are a valuable input to many decision-making processes in the form of 3D surface visualization, viewshed analysis, and hydrologic analysis, as well as orthorectification (USGS 2005).

Error occurs during orthorectification for each GCP as well as for the process as a whole. This error is measured by Root Mean Square (RMS) error. RMS is defined as the distance between the input GCP coordinates and the retransformed coordinates (ERDAS 1999b). In other words, the application takes the point from the unreferenced image and transforms it using the current transformation matrix. The differences in the x and y direction between this calculated new point and the point from the referenced dataset are then found using the following equation (ERDAS 1999b):

$$\text{RMS error} = \sqrt{(x_r - x_i)^2 + (y_r - y_i)^2}$$

Where: x_i and y_i are the source coordinates

x_r and y_r are the retransformed coordinates

RMS results are given in the units of the referenced image. Error tolerance is defined by three attributes, the accuracy of the GCPs being used, the characteristics of the data, and the end use of the orthorectified image (Gibson and Power 2000). For this protocol the RMS error should range from 0.4 to 0.8 times the spatial resolution of the satellite imagery. The RMS error reports how well the new resample imagery fits the GCPs, it does not report the spatial accuracy of the image to the Earth's surface. Total error for a transformation matrix is calculated using the following equation (ERDAS 1999a):

$$T = \sqrt{\frac{1}{n} \sum_{i=1}^n XR_i^2 + YR_i^2}$$

Where: T = total RMS error

n = the number of GCPs

i = GCP number

XR_i = the X residual for GCP _{i}

YR_i = the Y residual for GCP _{i}

The next step after the polynomial equation has been defined is to resample the image. Resampling is the technique used for “transforming a raster image from one particular scale and projection to another” (Burrough and McDonnell 1998). Mathematical models are applied to every cell in the output image to calculate the cell value and placement. The three most common resampling techniques are; nearest neighbor, bilinear interpolation, and cubic convolution

(Burrough and McDonnell 1998; Gibson and Power 2000). Each of these methods has advantages and disadvantages over the others.

Nearest neighbor (Figure B.1) calculates a value for a new pixel based on the value of the cell nearest it when the new location is back-transformed to the old location (Gibson and Power 2000). This method is the closest to maintaining the original values of the image. It is important to use this technique when working with discrete or thematic values. Problems with this method include the fact that new images are not as smooth as desirable and some cell values may be lost or even duplicated (ERDAS 1999a). This is the recommended resample method for this land cover protocol.

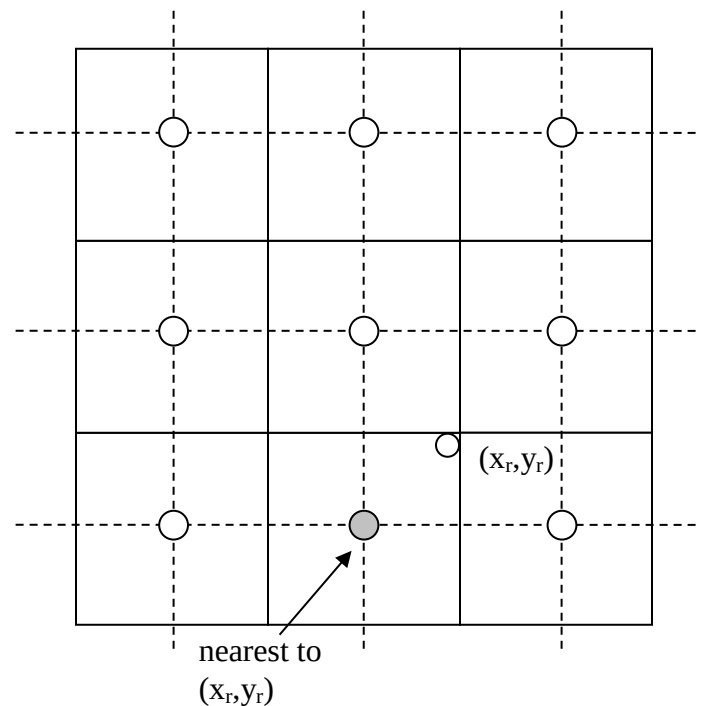


Figure B.1. In nearest neighbor resampling a back-transformed cell is assigned the value of the cell that is nearest to it.

Bilinear interpolation (Figure B.2) calculates the values of the new cells based on a mathematical model that takes into account the four nearest neighbors and weighted distances of a back-transformed cell (Gibson and Power 2000). This method is used most often when the cell size of data is changed and a user wants continuous data. It is more spatially accurate than Nearest Neighbor, and is smoother, making a more visually appealing image. The disadvantage of smoothing the data is that edges are not as contrasted and original values and extremes can be lost (ERDAS 1999a).

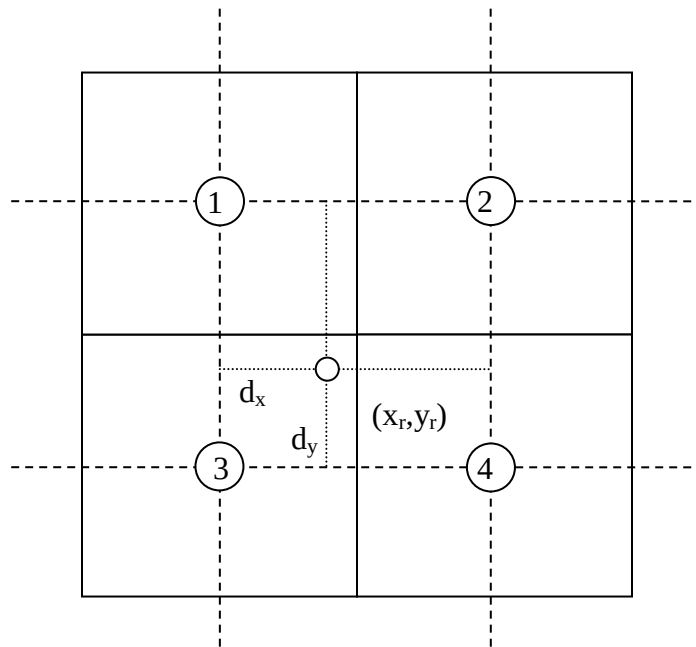


Figure B.2. Bilinear interpolation takes into account the four nearest cells as well as weighted distances of a back-transformed cell (d_x , d_y).

Cubic convolution (Figure B.3) is a complex and time consuming technique that takes into account 16 of the pixel's nearest neighbors and applies a cubic function to average the values and set a new value (Gibson and Power 2000). This method is the closest to maintaining the original mean and standard deviations of the data. It also can smooth and sharpen the image to improve its appearance. Similar to bilinear interpolation, it is used most often when cell sizes are being drastically changed. The disadvantages are also similar to Bilinear Interpolation, and data values can be altered (ERDAS 1999a)

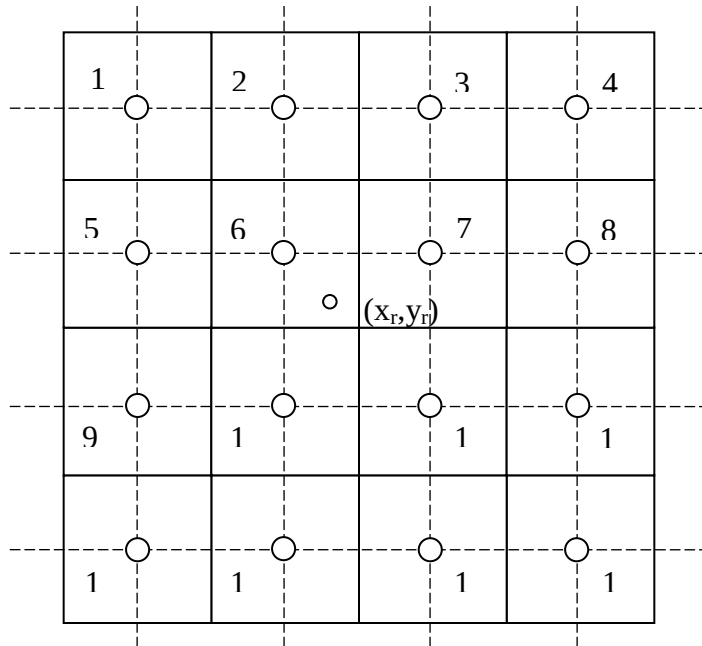


Figure B.3. In cubic convolution, the back-transformed cell is assigned a value based on the 16 cells.

Procedures:

The software used to complete this procedure is ERDAS Imagine.

1. Begin by opening an ERDAS Imagine session with two viewer windows. One for the image being rectified (source- SPOT imagery) and one for the image used in rectification (reference- DOQ imagery).
2. Import the source file as a SPOT DIMAP format (not as a TIFF) so that the metadata is imported with the image. Output file format will be IMAGINE (.img).
3. Open the SPOT source image in View #1.
4. Open the reference image (i.e. DOQs) in View #2.
5. Click on the **Control Points** under the Raster >> Multispectral menu. The **Set Geometric Model** window opens; select the correct model (Ex: SPOT).
6. Now the SPOT Model Properties window will appear. Make sure to check the box labeled Account for Earth's curvature. Increase the Number of Iterations to 30. For the Elevation Source chose the file which contains your DEM file for the study area. An important parameter to enter for the SPOT model is the incidence angle. This number is different for every SPOT image, and can be found in the VOL_LIST.PDF file under the Scene Extract Parameters heading in the report. An example of the report is shown in Figure B.4. Be careful to enter the incidence angle, not the orientation angle. Also, once the angle is entered in the SPOT Model Properties window, the Imagine software will display this value rounded to two decimal places. The full six decimal places are recorded; only the displayed value is different.

Work Order

: TS5- (S070207204051360)

Volume

: NETWORK CSP0005805

Scene ID

: 5 592-280/7 07/02/03 17:04:24 1 J

Product Code

: SPOT_SCENE

Date

: 2007-02-07 20:56:04



Scene Extract Parameters

Scene ID

5 592-280/7 07/02/03 17:04:24 1 J

K-J identification

592-280

Date

2007-02-03 17:04:24.1

Instrument

HRG 1

Shift Along Track

7 4200

Preprocessing level

1B

Spectral mode

J

Number of spectral bands

4

Spectral band indicator

HI1

HI2

HI3

HI4

Gain number

8

8

7

5

Absolute calibration gains (W/m2/sr/μm)

3.162396

3.803701

3.071707

10.741221

Orientation angle

14.026538 degree

Incidence angle

L3.384224 degree

Sun angles (degree)

Azimet: 155.938311

Elevation: 35.315020

Number of lines

3082

Number of pixels per line

3013

Figure B.4. SPOT Scene Parameters in VOL_LIST.PDF file.

- Next select a projection for the source image. Click the Projection tab in the upper left corner. Click the **Add/Change Projection...** button and a new window will open to choose a projection. Chose the category for Universal Transverse Mercator (UTM), Geodetic Reference System 1980, North American Datum 1983 for the Northern hemisphere, or “UTM GRS 1980 NAD83 North”. Within that category, chose the correct zone for the park being worked on.
- Select the reference source for Ground Control Points (GCPs). Now you are ready to select georeferencing points within the **Multipoint Geometric Correction** window.
- Selecting Ground Control Points (GCP): Orthorectification is a process to remove an image’s geometric errors, which can be caused by sensor angle, curvature of the earth, topography, or the sensor. By fitting the GCPs from the reference image with those of the source image, and by taking into account elevation changes using the DEM, the result is an image that is planimetric with uniform scale. Reliability is improved by selecting good GCP across the entire scene. The best points are those which are easily seen on both images, but also represent more permanent man-made or natural structures such as road intersections, buildings, or rock formations. Towers or other highly-elevated structures are not good GCP locations because their corners/points can change position depending on the viewing angle. Rivers and streams also are not good choices because they change over time. Also, shadows of features should be avoided since shadows are constantly changing based on the time of day and season.
- To select a ground control point, you first need to identify a suitable point in the source image. Here’s where the zoom window becomes very helpful. Notice that both the source and reference Viewers have a white box with short lines joining the edge on all sides. The box represents the area of your zoomed in Viewers; the lines extending outward are handles to assist in moving the box around the image. By clicking and dragging one of the handles, the box moves to a different area; by clicking and dragging a corner of the box, you can zoom in

and out (the box size will respond by increasing or decreasing in size). In this case, the source image is our lowest resolution (SPOT) and thus we will begin our search there for a GCP. Urban areas have many more road intersections and may provide a good starting point. Drag the box to a suitable location and adjust the zoom level so you can see enough detail to select points. The two viewers are not synchronized, so when you move the source zoom box, you will need to move the zoom box on the reference image to the same area. If you can find a good point on the lower-resolution image, that same point should stand out on the higher-resolution DOQ image. Once you have navigated to a location where you want to select a GCP, you need to select a GCP. Click the **Create GCP** tool .

11. The X Input and Y Input fields contain the coordinates of the SPOT image and the X Ref and Y Ref fields contain the DOQ image (UTM NAD83) coordinates. The Z Ref field contains the elevation of that location based on the DEM. It is recommended that you choose at least 30 GCPs to orthorectify the SPOT image that are distributed throughout the image as shown by the example in Figure B.5.

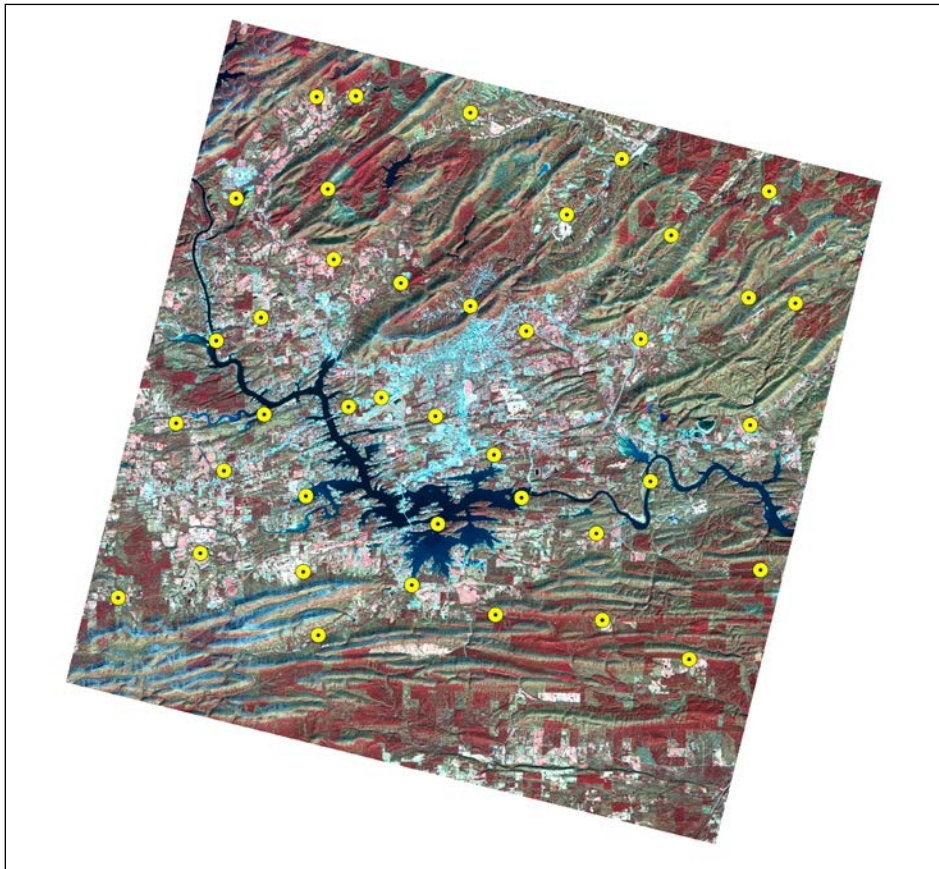


Figure B.5. Distribution of GCPs on a SPOT image.

12. After you have chosen more than four GCPs, the software can compute the Control Point Error or RMS for the orthorectification if you click the **Solve Geometric Model with Control Points** .
13. Figure B.6 shows a good control point location at the intersection of a road on a curve.

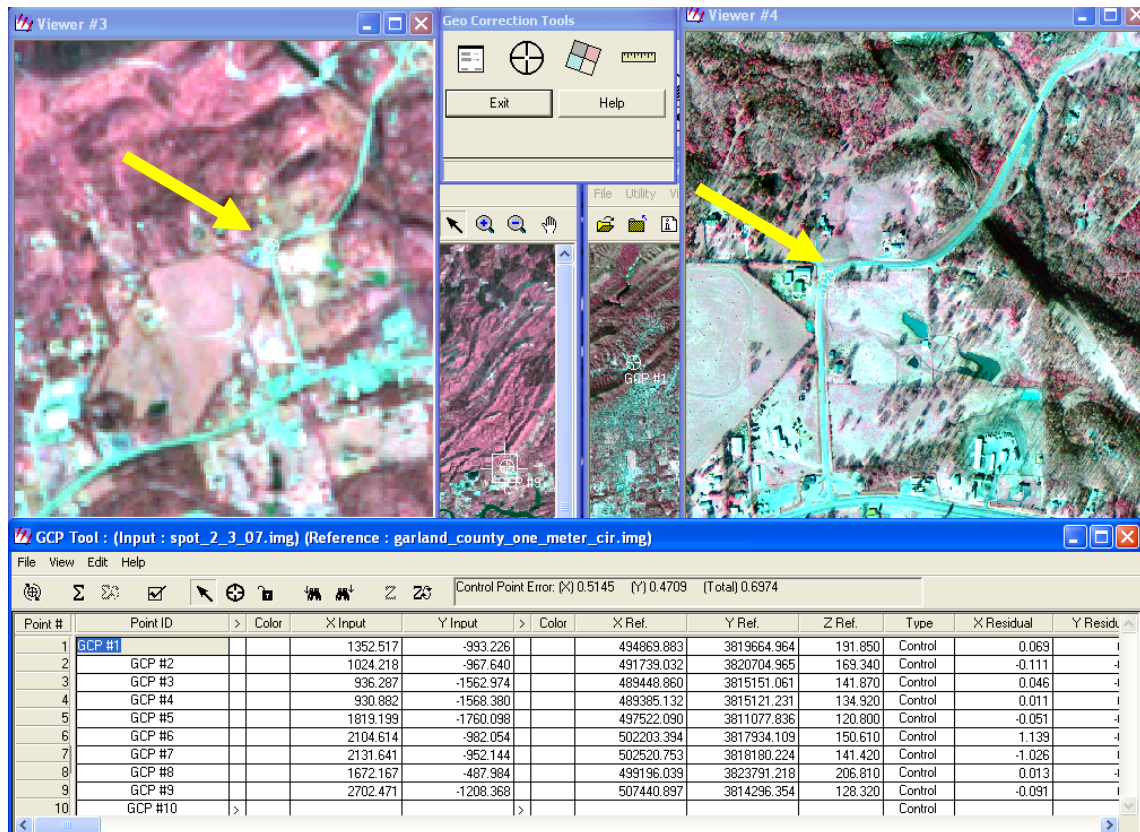


Figure B.6. Location of GCP #1.

14. Areas of high contrast also provide good locations for GCPs. The GCP location shown in Figure B.7 of a road intersection surrounded by forests provides an ideal GCP location. As previously discussed, you want to avoid control points near shadows or control points that could be elevated above the surface. Figure B.8 shows some examples of GCP locations that you want to avoid. The area in the circle could be an elevated freeway ramp and the area where the arrow is pointed shows the differences that could occur in shadows.

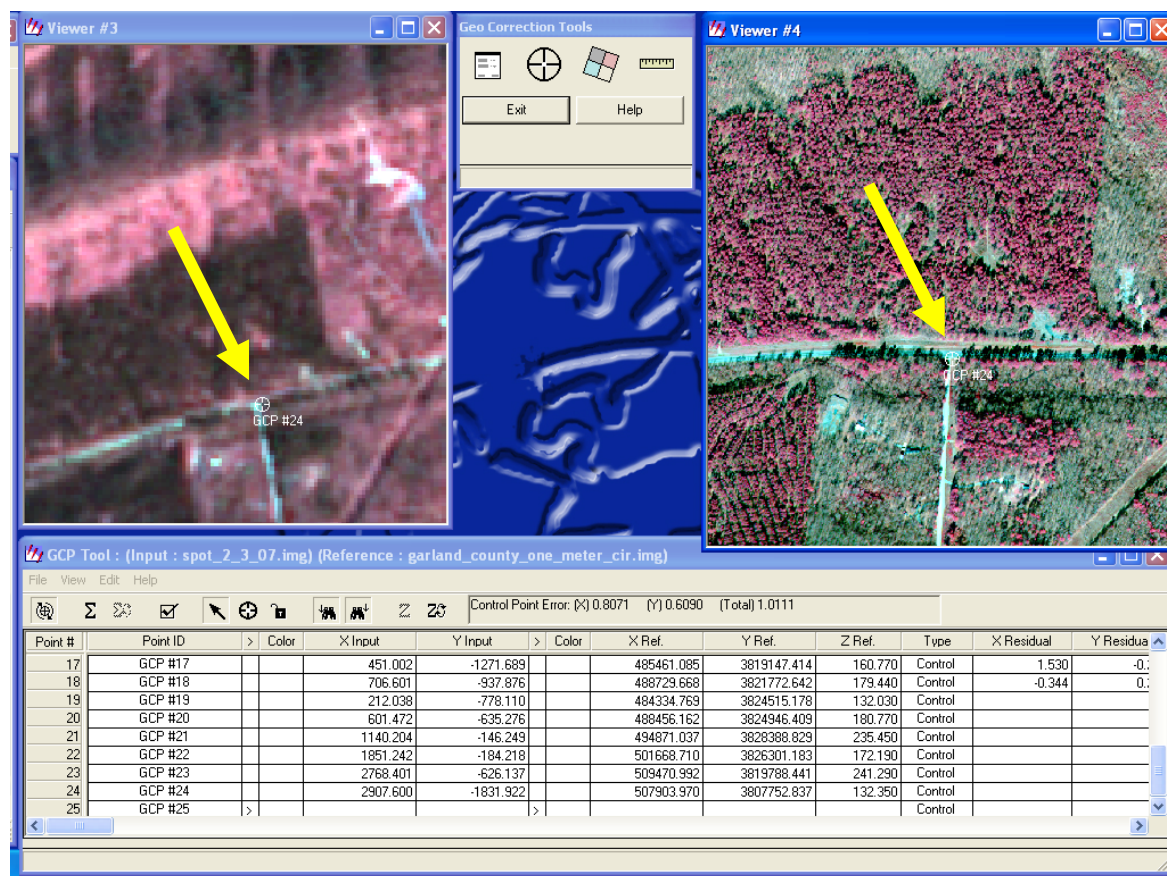


Figure B.7. An ideal GCP location.

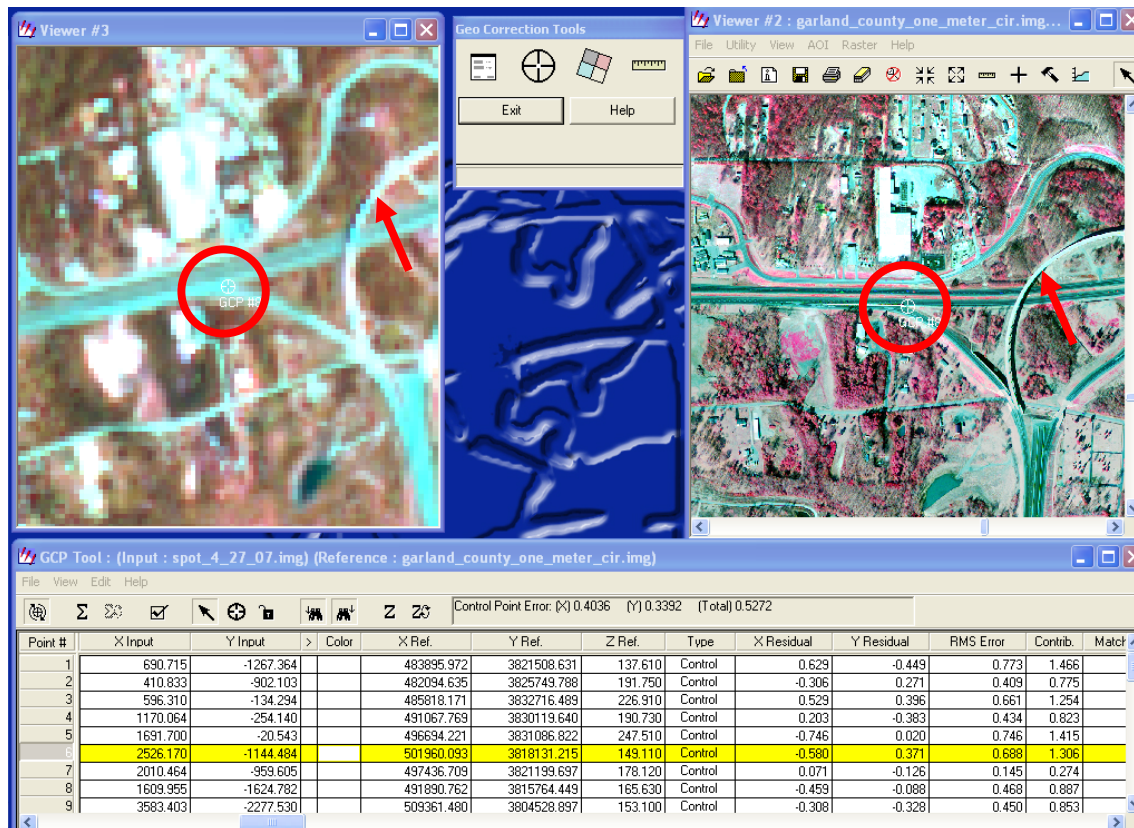


Figure B.8. Example of poor GCP locations.

15. Once 40 or more GCPs have been selected that are evenly distributed throughout the image it is time to examine all the GCPs that have a high individual RMS error. Your goal is to have 30+ GCPs evenly distributed throughout the image and with your total Control Point Error value between 0.4 to 0.8 image units (pixels). For SPOT imagery a pixel is 10 meters. You can select any control point by clicking on Point #. All the screens will zoom to the location of the control point selected and the record for that control will be highlighted in yellow as shown in Figure B.8. If it was determined that control point should be deleted, right click on the point number and click **Delete Selection** in the context menu. When selecting control points with high RMS values to delete, be sure to maintain a good distribution of control points throughout the image as previously shown in Figure B.5.
16. After you have checked your control points and you are satisfied with the total control point error you are ready to orthorectify the SPOT image. Click the **Display Resample Image Dialog** . This will display the Resample window.
17. The output file name and location must be specified. Click on the **folder** icon to set the output location and name. The resample method must be specified, select Nearest Neighbor. The output cell size is set to 10 map units. Since we are orthorectifying the image to DOQs that are in UTM NAD83 meters, the cell size shown represents 10 meters. This is the cell size of SPOT imagery as previously discussed. *Note: If you are going to merge the SPOT imagery with other aerial/satellite raster data that has a cell size (pixel size) less than 10 meters, the cell size should be set to the highest resolution pixel size of the merge data sets. For example, if the SPOT imagery was going to be combined with one-meter aerial photography you will set*

the cell size to one-meter. The SPOT imagery true resolution is still 10-meters, but the pixels are one-meter, but resampling to one-meter facilitates resolution scaling and partitioning during the merge process with other data. Check the Ignore Zero in Stats, this will facilitate viewing the orthorectified SPOT image later.

18. Click OK in the Resample window and the data will be orthorectified. After the SPOT imagery is orthorectified, open both the orthorectified SPOT imagery and the DOQ in the same viewer and visually examine the orthorectification. Compare how roads and other features register to each other. If you are satisfied then the process is done and you can exit ERDAS Imagine. If you are not satisfied, then you may need to select some more GCPs and resample the image.

After the SPOT image is orthorectified the final Band combinations of the output image are as follows:

Band 1 - (0.78 - 0.89 μm – Near Infrared)

Band 2 - (0.61 - 0.68 μm - red)

Band 3 - (0.50 - 0.59 μm - green)

Band 4 - (1.58 - 1.75 μm – Mid Infrared)

The Band combinations are changed with the SPOT DIMAP format.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

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