Digital Vegetation Database and Map for Obed Wild and Scenic River



Final Report

By

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Digital Vegetation Database and Map for Obed Wild and Scenic River

Summary

This report describes the vegetation mapping procedures employed by the Center for Remote Sensing and Mapping Science (CRMS), Department of Geography, University of Georgia, for the Obed Wild and Scenic River (OBRI) in the Appalachian Highlands Inventory and Monitoring Network (APHN) of the National Park Service under Cooperative Agreement No. H5028 01 0651, entitled, "Digital Vegetation Databases and Maps for National Park Service Units in the Appalachian Highlands and Cumberland/ Piedmont Networks". OBRI encompasses 5073 acres (2054 hectares) in central Tennessee in the Cumberland Plateau region. The centerpiece of the park is the Obed Wild and Scenic River which offers high quality white water kayaking and canoeing, hiking and world class rock climbing in a rich historical context.

Using the National Vegetation Classification System (NVCS) developed by NatureServe, with additional classes and modifiers developed by CRMS, the vegetation communities for OBRI were manually interpreted from 1:12,000 scale stereo color infrared aerial photographs acquired by the U.S. Forest Service in November, 2002. Although the legislated area of OBRI is 5073 acres, additional areas were mapped, including 250 acres included in the Southeast Regional Office (SERO) map and the area designated as Obed gorge area (8927 ac). Finally, a buffer area, extending 400 m outside of the park (13958 ac) was mapped using a more general classification system. Consequently, the total area mapped for OBRI, including the park and buffer was 22,885 acres (9265 ha).

Using a minimum mapping unit of 0.5 hectares (MMU = 0.5 ha), polygons representing areas of relatively uniform vegetation were delineated and annotated on clear plastic overlays registered to the aerial photographs. Polygons were labeled according to the dominant vegetation community. Where the polygons were not uniform, second and third vegetation classes were added. Further, a number of modifier codes were employed to indicate important aspects of the polygon that could be interpreted from the photograph (for example, burn condition). The polygons on the plastic overlays were then corrected using photogrammetric procedures and converted to vector format for use in creating a geographic information system (GIS) database for the park. In addition, high resolution color orthophotographs were created from the original aerial photographs for use in the GIS. Upon completion of the GIS database (including vegetation, orthophotos and updated roads and hydrology layers), both hardcopy and softcopy maps were produced for delivery.

Metadata for the database includes a description of the vegetation classification system used for the park, summary statistics and documentation of the sources, procedures and spatial accuracies of the data. At the time of this writing, the accuracy assessment of the vegetation mapping is underway but has not yet been completed for this park. Thus, those procedures and results will be provided in a separate report.

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Digital Vegetation Database and Map for Obed Wild and Scenic River

Introduction

As part of the USGS/BRD-NPS Vegetation Mapping Program, the Center for Remote Sensing and Mapping Science (CRMS), Department of Geography, University of Georgia, was requested to provide detailed vegetation maps of the parks in the Appalachian Highlands Inventory and Monitoring Network (APHN) of the National Park Service. This report describes the procedures and results of the vegetation mapping activities for Obed Wild and Scenic River (OBRI) undertaken by the CRMS under Cooperative Agreement No. H5028 01 0651, entitled, “Digital Vegetation Databases and Maps for National Park Service Units in the Appalachian Highlands and Cumberland/Piedmont Networks”. OBRI encompasses 5073 acres (2054 hectares) in central Tennessee in the Cumberland Plateau region. The centerpiece of the park is the Obed Wild and Scenic River which offers high quality white water kayaking and canoeing, hiking and world class rock climbing in a rich historical context.

Using the National Vegetation Classification System (NVCS) developed by Natureserve and adopted as a standard by the Federal Geographic Data Committee, with additional classes and modifiers defined by CRMS, vegetation associations and communities for OBRI were interpreted using manual methods from 1:12,000-scale stereo color infrared aerial photographs acquired by the U.S. Forest Service in November, 2002 (FGDC, 2008). For this project, vegetation associations, which include both understory and herb layers in their descriptions, were interpreted from the aerial photographs by inferring the community based on the overstory/canopy characteristics, supplemented with field work. Although the legislated area of OBRI is 5073 acres, additional areas were mapped, including 250 acres included in the Southeast Regional Office (SERO) map and the area designated as Obed gorge area (8927 ac) (Fig. 2). Finally, a buffer area, extending 400 m outside of the park (13958 ac) was mapped using a more general classification system. Consequently, the total area mapped for OBRI, including the park and buffer was 22,885 acres (9265 ha).

Using a minimum mapping unit of 0.5 hectares (MMU = 0.5 ha), polygons representing areas of relatively uniform vegetation communities were delineated and annotated on clear plastic overlays registered to the aerial photographs. Polygons were labeled with CEGL codes according to the dominant vegetation community. Where the polygons were not uniform, second and third vegetation classes were added. Further, a number of modifier codes were employed to indicate important aspects of the polygon that could be interpreted from the photograph (for example, burn condition).

The polygons on the plastic overlays were then scanned and corrected using photogrammetric procedures and converted to vector format for use in creating a

geographic information system (GIS) database for the park. In addition, high resolution color orthophotographs were created from the original aerial photographs for use in the GIS. Upon completion of the GIS database (including vegetation, orthophotos and updated roads and hydrology layers), both hardcopy and softcopy maps were produced for delivery.

Metadata for each database includes a description of the vegetation classification system used for each park, summary statistics and documentation of the sources, procedures and spatial accuracies of the data. At the time of this writing, the accuracy assessment of the vegetation mapping is underway but has not yet been completed for this park. Thus, those procedures and results will be provided in a separate report.

The Center for Remote Sensing and Mapping Science (CRMS), Department of Geography at The University of Georgia (www.crms.uga.edu), has been involved in vegetation mapping and database development in national parks of the southeastern United States for the past 10 years (Welch et al. 1995, 1999, 2002a, 2002b; Welch and Remillard 1996). As a remote sensing and mapping facility, the CRMS is unique in its combination of expertise in both technical and biological aspects of vegetation mapping projects. Scientists at the CRMS specialize in image processing, photogrammetry, GIS, air photo interpretation and field surveying, as well as botany, biology and ecology. This allows a close link between the three major components of a vegetation mapping/database project: 1) photogrammetric rectification; 2) vegetation interpretation, classification and field verification; and 3) GIS database construction.

In addition to in-house cross training of technical and biological skills, the CRMS has developed a strong working relationship with NatureServe, a non-profit conservation organization that developed the U.S. National Vegetation Classification System (NVCS) and is a primary partner in the USGS-NPS National Vegetation Mapping Program (www.natureserve.org). Collaboration between the CRMS and the NatureServe-Durham, North Carolina Office has resulted in the development of a detailed classification system for southeastern park lands that maximizes the information on vegetation communities that can be gleaned from large-scale color infrared aerial photographs, while remaining compatible with the U.S. National Vegetation Classification System (Anderson et al. 1998, Jackson et al. 2002).

Objectives

The objectives of this report are to:

1. describe the mapping procedures employed to map the vegetation communities of Obed Wild and Scenic River (OBRI);
2. demonstrate how digital photogrammetry, photointerpretation, GIS and Global Positioning Systems (GPS)-assisted field techniques were refined, adapted and integrated to permit the construction of geocoded vegetation databases from large-scale aerial photographs;
3. discuss the NVCS in general and its adaptation for use in parks in the Appalachian Highlands I&M Network; and
4. provide classification systems, summary statistics and vegetation maps for the park.

Digital data in the form of ArcGIS geodatabases, shapefiles, orthophotos and metadata are provided on the accompanying DVDs. Most of the techniques described below were first developed and refined during the mapping of Great Smoky Mountains National Park, which is considered to be one of the most difficult terrain areas to map in the United States (Jordan, 2002; Welch et al., 2004).

Study Area

The Obed Wild and Scenic River encompasses 5073 acres (2054 hectares) in central Tennessee in the Cumberland Plateau region. The centerpiece of the park is the Obed National Wild and Scenic River which offers high quality white water kayaking and canoeing, hiking and world class rock climbing in a rich historical context (Figure 1). The Obed is one of only nine Wild and Scenic Rivers authorized in the Southeastern United States. The Obed River and its tributaries flow over 45 miles through some of the most rugged, and undeveloped terrain in eastern Tennessee. It offers a vast array of both cultural and natural resources. A complex network of streams drain park and adjacent lands supporting diverse flora and fauna as well as providing numerous recreational opportunities (Walker et al, undated).

Although the legislated area of OBRI is 5073 acres, additional areas were mapped, including 250 acres included in the Southeast Regional Office (SERO) map and the area designated as OBRI Managed Area (8927 ac). Finally, a buffer area, extending 400 m outside of the park (13958 ac) was mapped using a more general classification system. Consequently, the total area mapped for OBRI, including the park, Obed gorge area and buffer was 22,885 acres (9265 ha) (Figure 2).

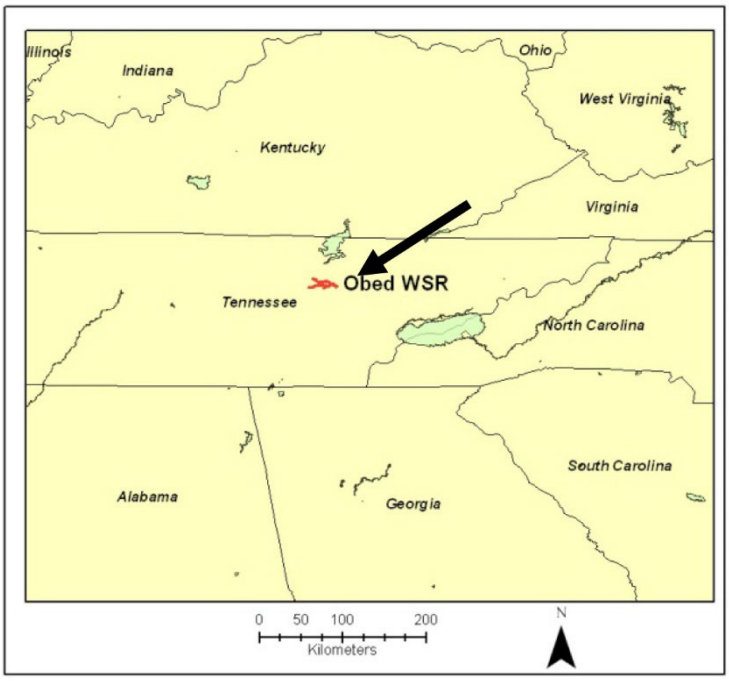


Figure 1. Obed Wild and Scenic River is located on the Cumberland Plateau in central Tennessee.

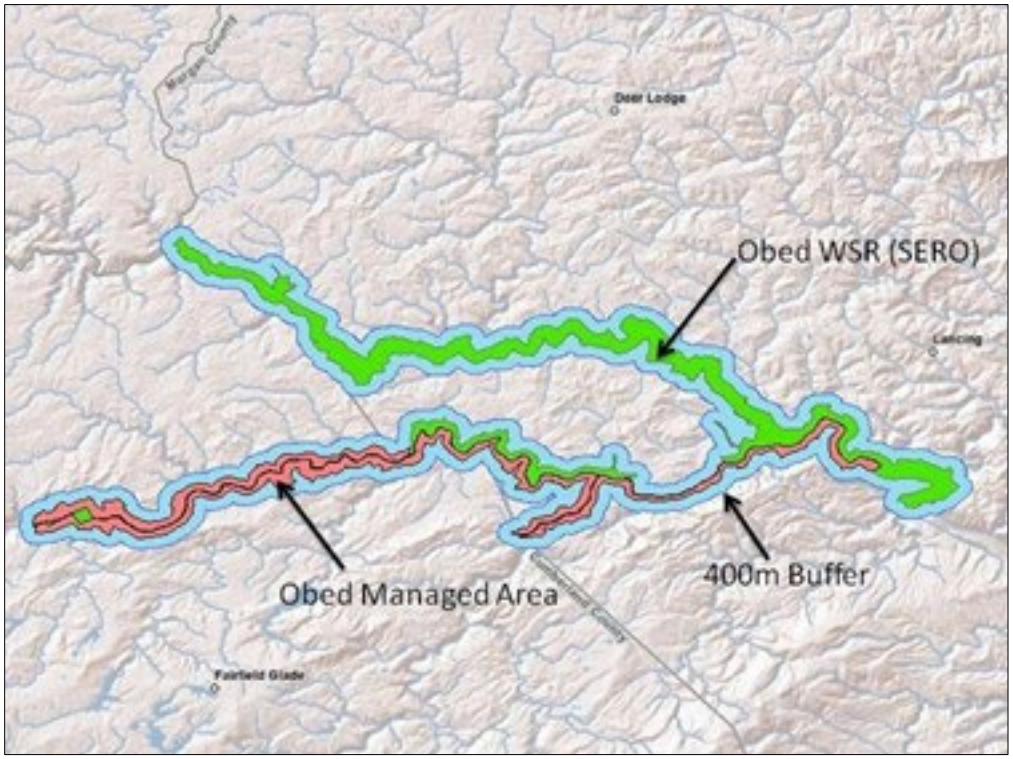


Figure 2. Locations and extents of the various areas mapped for OBRI, including the Legislated Boundary (green), the Obed gorge area (red) and the Buffer Area (blue).

Requirements

The primary requirement for the project was to produce a vegetation database and associated maps in vector format that contained polygons for vegetation associations and communities plotted to within approximately ±5 to 10 m of their true ground locations. To accomplish this, vegetation was mapped using color infrared aerial photographs of 1:12,000 scale in film transparency format recorded with a standard photogrammetric mapping camera (f = 15 cm) on November 2, 2002 by the U. S. Forest Service. The fall photos were acquired when the leaves were still on the trees (leaf-on) and displayed a color diversity that allowed the vegetation communities/species to be identified (Figure 3). Vegetation associations, which include both understory and herb layers in their descriptions, were interpreted from the aerial photographs by inferring the community based on the overstory/canopy characteristics. Relief displacements were a major consideration in the mountainous areas and required photogrammetric correction methods in order to ensure geometric accuracy (Jordan, 2004). Using ground control obtained from USGS Digital Orthophoto Quarter-Quads (DOQQ) and the National Elevation Dataset (NED), polygons were plotted to within approximately ± 5 m of their true ground locations, thus meeting National Map Accuracy Standards for 1:15,000 scale maps and exceeding the requirements for 1:24,000 scale maps.



Figure 3: A portion of a 1:12,000 scale color infrared aerial photograph of the Obed River recorded on November 2, 2002 and used for photo interpretation of vegetation detail.

In general, the mapping tasks are divided into four major categories of operations:

1. Collection and integration of collateral datasets;
2. Photogrammetry, which includes the initial scanning and orthorectifying of the CIR photographs and subsequent rectification of the interpreted overlays;
3. Photointerpretation and ground truthing, which includes delineation and attribution of polygons representing vegetation classes on aerial photographs; and
4. Geographic information systems (GIS), which includes converting the photointerpretation to vectors, editing and attributing the vegetation polygons and creating the final GIS database and hardcopy maps.

Final products include the following:

1. Overstory vegetation maps in digital format attributed according to the National Vegetation Classification System (NVCS);

2. Generalized vegetation classes for a buffer area extending 400 m outside of the park boundary;
3. Digital orthophotos created from the CIR aerial photographs;
4. Updated roads and hydrology line work within park boundaries;
5. Hard and softcopy maps of the final database; and
6. Metadata in the National Park Service format for the vegetation map and orthophotos.

As most national parks are located in natural areas with typically dense forest cover, steep slopes, absence of ground control and high relief, the construction of a vegetation database accurate in both the spatial and thematic context necessitated a combination of softcopy photogrammetry, manual photo interpretation and GIS procedures organized in parallel as shown in Figure 4. These are discussed below.

Collateral Datasets

A base GIS dataset was compiled for the park that consisted of a combination of publicly available data layers (http://seamless.usgs.gov) and those provided by the park resource managers (Table 1). Basic layers included existing roads and trails, hydrology, boundaries, digital raster graphics (DRGs), digital orthophoto quarter quads (DOQQs), digital elevation models (DEMs), and any available additional ancillary data layers, such as geology, soils, and historical vegetation maps. All data layers were cast on the Universal Transverse Mercator (UTM) coordinate system, North American Datum of 1983 (NAD83), in the UTM Zone 16. Roads, trails and streams within the park boundaries were updated to correspond to the DOQQs wherever they were visible. These updated data layers are included in the individual park geodatabases.

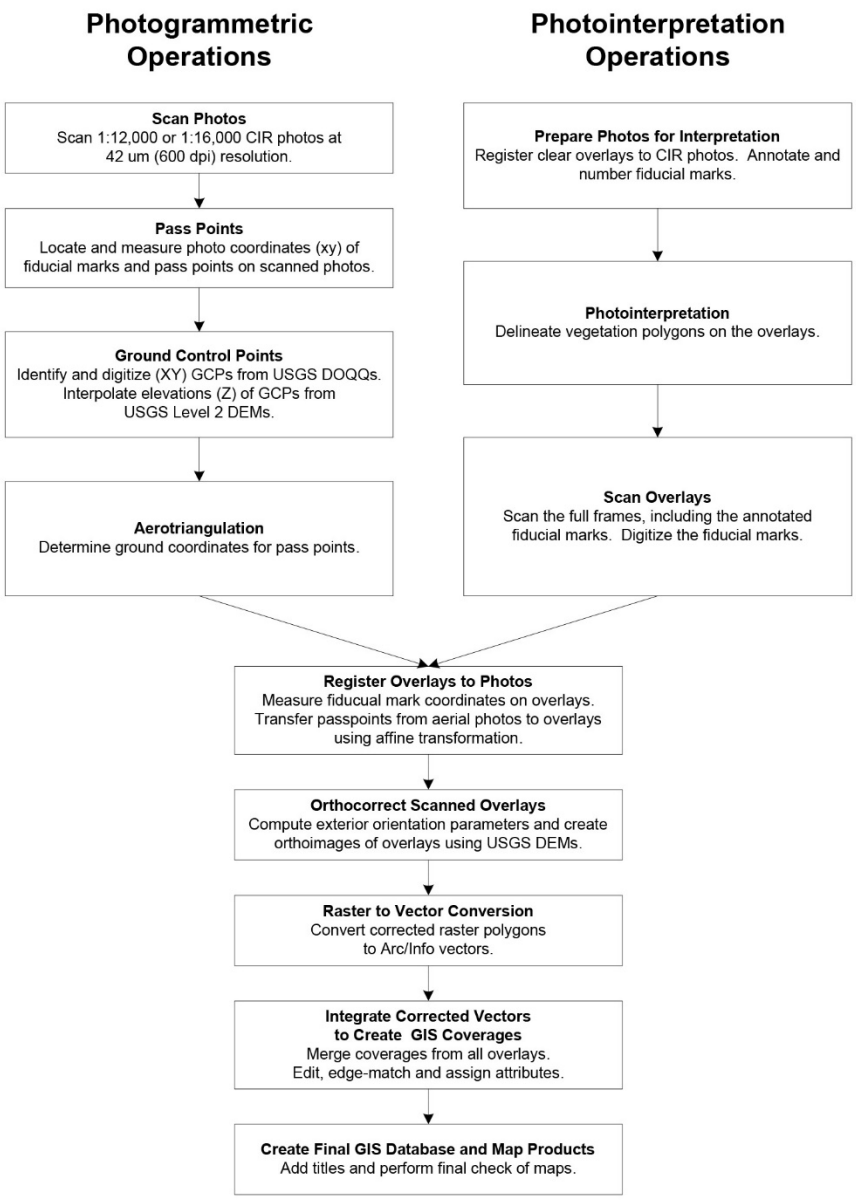


Figure 4: Generalized diagram showing photogrammetric, photointerpretation and GIS operations used to map vegetation from aerial photographs by the CRMS. Photos of OBRI were at 1:12,000 scale.

Table 1: Specifications of data sources available for map/database development of the Obed Wild and Scenic River vegetation database.

Data Source	***Format and Type of Data***	***Flying Height (FH) and/or Scale***	***Resolution***	***Comments***
USFS Color Infrared (CIR) Air Photos October/ November 2000-2002	23 x 23 cm Analog film transparencies	FH =1800 m 1:12,000	~ 0.5 m	Fall leaf-on conditions are ideal for mapping overstory forest communities.
USGS Digital Raster Graphics Topographic Maps	Digital scanned topo maps	1:24,000	2.33 m	Last updated 1970's. A good base map but missing some more recent cultural features.
USGS DOQQs Pan (1993) and CIR (1999)	Digital Orthophotos	FH = 6000 m 1:40,000	1 m	USGS DOQQs have a planimetric accuracy of approximately ± 3 m RMS. Winter photographs.
USGS Level 2 DEMs	Digital Elevation Models	1:24,000	30 m post spacing	USGS Level 2 DEMs have a vertical accuracy of approximately ± 3-5 m RMSE.
NPS best-available park boundaries	Digital vector data (shape files)	1:24,000	N/A	We used the most current boundary files available from the NPS at the time of map compilation.
USGS DLG Census TIGER Line Files National Hydrology Dataset (NHD)	Digital vector data (shape files) roads, trails, hydrology, political boundaries	1:24,000	N/A	We used the best vector datasets available. Usually provided by NPS or retrieved from the USGS Seamless database.

Photogrammetric Operations

The main objective of the photogrammetric procedure was to create a set of color infrared orthophotos from the same aerial photographs that were being used for the vegetation mapping. To accomplish this, we first had to densify the sparse ground control in the Park by means of aerotriangulation, a photogrammetric operation whereby a relatively small number of ground control points (GCPs) are used to mathematically compute the ground coordinates of a much larger number of identified pass points (Jordan, 2002). In this way, an adequate control network is generated for the orthophoto rectification process. These control points were also used to rectify the interpretation overlays.

Scanning

The CIR aerial photographs in transparency format were scanned at 600 dpi (42 µm) using an Epson Expression 10000XL flatbed scanner. This scanner is capable of scanning materials up to 11x17" in size at optical resolutions up to 1200 dpi and is equipped with a backlight attachment for scanning transparent materials. The 600 dpi scanning resolution was selected to balance the resolution requirements for the orthophotos with data storage and processing considerations. The photographs were laid on the scanning surface and, to reduce distortions, a heavy piece of clear glass was placed on top to ensure flatness of the film during scanning. Each photo was then scanned using Adobe Photoshop and saved as a 24-bit color TIFF file. During scanning, care was taken to scan the full frame of the photograph, including the corner fiducial marks and marginal data. File names for the scanned photographs were assigned according to the flight line and frame number. For example, photo 13 from flight line 2 was named 2-13.tif. Photos from each park were stored in separate folders on the CRMS Data server. All photos from each flight line were scanned. For original photos of 1:12,000-scale, the resulting pixel size was approximately 0.5 m. After the photos were scanned, the original film transparencies were turned over to the photointerpreters while the photogrammetric operations continued using the digital data.

Ground Control and Pass Point Measurement

These digital photos were then displayed on the computer monitor and with the aid of the *R-WEL*, *Inc*. Desktop Mapping System (DMS) software package, the image (x,y) coordinates of pass points and GCPs were measured in the softcopy (computer, heads-up digitizing) environment. This was a painstaking and time-consuming task. Pass points per photo were selected and measured on adjacent photographs. In some parks, there were enough cultural features so that features such as driveways, road intersections, parking lots, or sidewalks could be used as pass points. In other cases, it was necessary to use hay bales, bare spots in a field, creeks, rocks or trees as pass points (Figure 5).

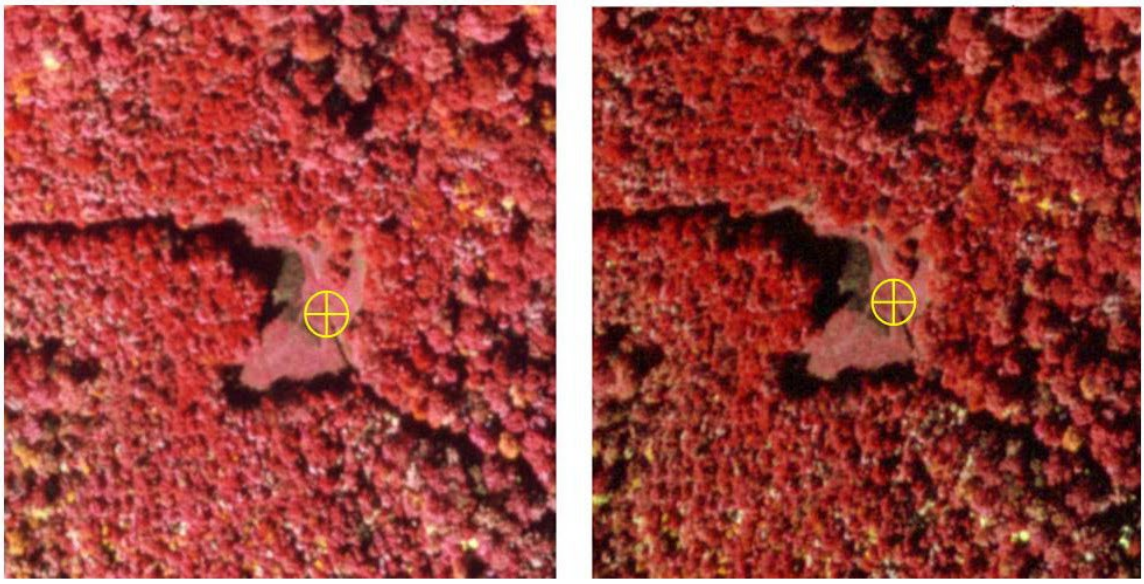


Figure 5: Well-defined natural and manmade features were used as pass points in overlapping images (yellow cross in circle symbols in the photos above). At least nine pass points per photo were identified with six being in the stereo overlap area between adjacent photos.

Ground control points were, for the most part, well-defined man-made and natural features (e.g., road intersections, parking lots, rock outcrops and forks in stream channels) identified on both the scanned color infrared transparencies and USGS Digital Orthophoto Quarter Quads (DOQQs) produced from 1:40,000-scale panchromatic or color infrared (CIR) aerial photographs recorded in 1993 or 1998. The Universal Transverse Mercator (UTM) grid coordinates (X,Y tied to the North American Datum of 1983 or NAD 83) of these GCPs were measured directly from the DOQQs (accurate to within $\pm$ 3 m). Elevations for the GCPs were derived using CRMS custom software to interpolate the Z-coordinates to within $\pm$ 3 to $\pm$ 5 m from USGS Level 2 Digital Elevation Models (DEMs) with 30-m post spacing (Figure 6). Thus, in this project, no ground survey work was required (or performed) to obtain the GCPs needed as a framework for the aerotriangulation process.

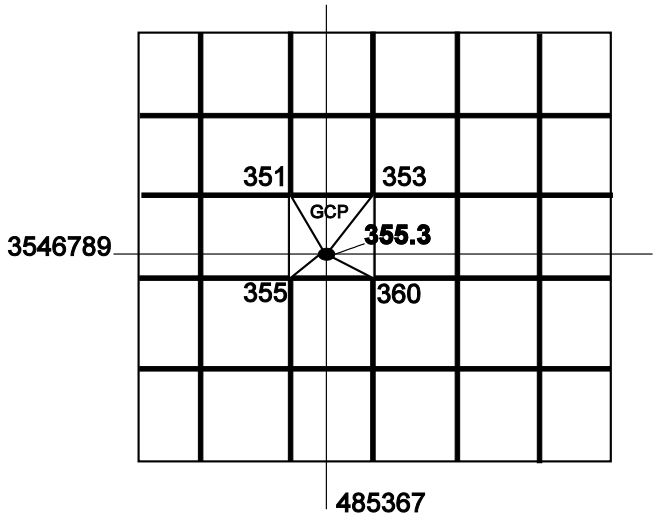


Figure 6: The elevations of ground control points (GCPs) were determined from the 30-m digital elevation model (DEM) using a bilinear interpolation algorithm.

Aerotriangulation

Analytical aerotriangulation was undertaken on a flight line by flight line basis and then all of the flight lines for the park were merged for the final run. The Aerosys software package, in conjunction with the DMS software, was employed for the aerotriangulation process. Output from the aerotriangulation was a set of X, Y and Z coordinates in the UTM coordinate system for the nine or more pass points identified by CRMS personnel on each photo. Typical root-mean-square error (RMSE) values for these coordinates averaged $\pm$5 m for the XY vectors and $\pm$ 6 m for elevations (Z).

Nine pass points per photo are measured and transferred to adjacent photos in the flight line. In addition, a number of ground control points are measured on the DOQQ and each photo (Figure 7). In the aerotriangulation process, the individual photos are joined numerically, related to the ground coordinate system using the GCPs and then the ground coordinates of the pass points are calculated. This dense network of GCPs can then be used to orient and orthorectify the CIR aerial photographs and to generate orthophotomosaics (Figure 8). After the orthophotomosaic is generated, the seamlines between adjacent photos are examined for misalignment. Terrain features that are well aligned between individual photographs indicate a good overall solution. The orthophotos and mosaics, in turn, are employed as a base reference layer in the editing and attributing operations required to build the vector database.

A critical use of the aerotriangulated GCPs is in the rectification of the vector overlays generated as part of the photointerpretation procedure described below. A well-aligned orthophoto mosaic provides the geometry and foundation necessary for the rectified vegetation linework of individual photographs to be edgematched correctly during the editing process.

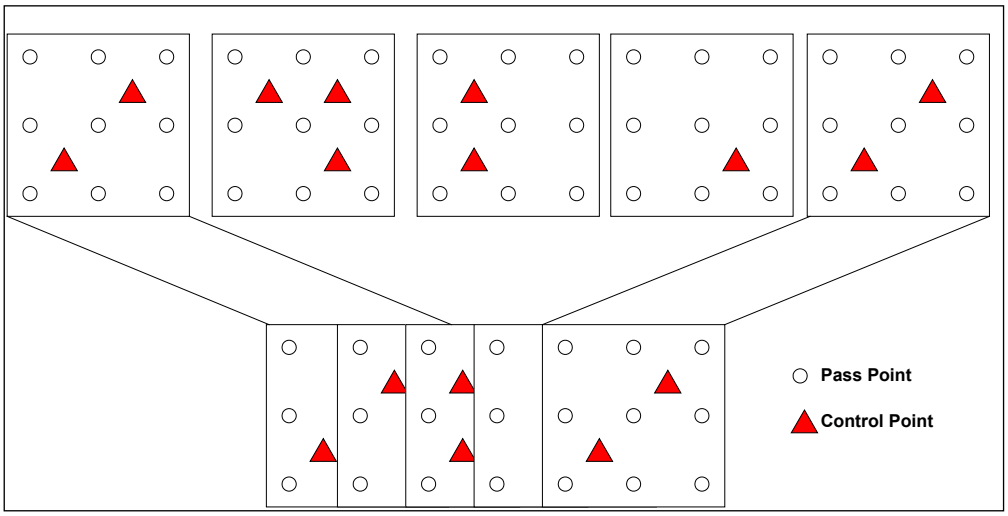


Figure 7: Nine pass points per photo and additional GCPs are measured and transferred to adjacent photos in the flight line.



Figure 8: A mosaic of orthorectified 1:12,000-scale photographs of OBRI was created for quality assurance and checking and to provide an image backdrop for the GIS database. The ground pixel dimension is 0.75m.

Photointerpretation and Ground Truthing Operations

The steps of the photointerpretation process listed in Figure 4 proceeded in parallel with the photogrammetric operations. Overstory vegetation was interpreted from the 1:12,000-scale leaf-on color infrared aerial photographs in 9 x 9 inch film transparency format.

Although it might appear desirable to scan the color infrared transparencies at high resolution and undertake the vegetation classification as an on-screen interpretation and digitizing procedure, this has proved to be exceedingly time consuming, cumbersome and expensive compared to more traditional approaches (Welch et al. 1995 and 1999; Rutchey and Vilchek 1999). More importantly, photointerpreters must view the vegetation and the terrain in stereo and in color within the context of a relatively large area of the landscape in order to identify the vegetation communities. This is most easily done using a stereoscope to view the analog air photos so that the vegetation patterns can be assessed in relation to the terrain. Recognizing the need to augment manual procedures with automated techniques, the steps described below integrate conventional photointerpretation procedures with digital processing technology in an attempt to streamline the database and map compilation process.

At the beginning of the mapping project, the photointerpreters, in conjunction with NatureServe and NPS plant specialists and resource managers, conducted field investigations to collect data on the vegetation communities and correlate signatures evident on the aerial photographs with ground observations. Photointerpreters learned about management concerns and impacts to the vegetation communities and their distributions such as damage by exotic insects, fire, wind, excessive park use, etc. Information on land use history before and after the creation of the park, invasive plant species and ongoing park vegetation management practices also was critical to understanding past, present and future vegetation conditions.

All of these factors must be taken into consideration during the photo-interpretation process to ensure a meaningful vegetation classification system is used for the park and to accurately identify and portray the vegetation communities. At OBRI, a total of four 2-4 day field trips were conducted, including an initial reconnaissance field visit to explore representative habitats, rare and important communities and managed, disturbed or invaded areas, as well as revisits to plots previously surveyed by NatureServe. Additional field visits were conducted during the interpretation process to verify initial interpretations, identify communities with unusual signatures and answer any questions.

Field sampling consisted of field data collection at numerous points along and off trails within the parks that were representative of both typical vegetation communities and unique or highly damaged areas (Figure 9). Points were selected to fall within areas identified on the aerial photographs as being unique or representative of typical areas. Additional points were selected as appropriate

during the field survey whenever a new community was encountered. Methods and information collected resembled NatureServe's "Quick Plot" surveys. The percent cover of dominant overstory and understory species was recorded for an area approximately 15 to 20 m around each point, along with any additional overstory/understory species identified and characteristics of the herb layer such as rich, sparse, dominant species, etc. Site conditions were noted by recording relative slope, aspect and canopy openness. Notes on presence of exotics, evidence of past or present human influence (e.g., agriculture, grazing, logging, mowing, exotic vegetation removal, old homesites), damage by insects, wild hogs, blow down or fire also were recorded. Each point was geolocated by marking a waypoint with a Global Positioning System (GPS) handheld receiver such as a Garmin V or Garmin Geko. These units are Wide Area Augmentation System (WAAS)-enabled and typical horizontal positional accuracies were +/- 3 to 5 m. The Estimated Positional Error (EPE) was noted for each field waypoint collected, especially when error approached or exceeded +/- 10 m. The elevation of each field waypoint also was recorded, albeit vertical accuracy is generally more than two times lower than horizontal accuracy. As a back-up to the use of GPS for geolocation, field crews also carried paper field maps with the UTM grid coordinates, elevations, roads and rivers superimposed on an image background, usually a USGS DOQQ (Figure 10). The maps were useful in planning the field route, marking notes and augmenting the GPS digital display.

At each field point, the primary association type was determined based on NatureServe definitions of associations in the National Vegetation Classification System (NVCS) used in the USGS/NPS National Vegetation Mapping Program (i.e., NVCS Community Element Global (CEGL) code numbers) (Anderson et al. 1998, Grossman et al. 1998 and 1994). Since CRMS interpreters were usually accompanied by NatureServe botanists to assist with species identification and coordinate classification, interpretation and accuracy assessment efforts, CRMS and NatureServe personnel would discuss and agree on the association designation before moving on. If the field point was located in a mixed area indicative of an ecotone or an area of successional recovery, both the dominant and secondary (and sometimes tertiary) associations also were determined. If there was no good match to an NVCS CEGL, careful notes were taken to allow later assignment of the appropriate CEGL or CRMS-created class (e.g., a managed, damaged, human influence or successional class). Spreadsheets containing these field points and observations are included in the Appendix of this document and in digital form on the accompanying CD.



Figure 9: Conducting a field survey of the vegetation prior to beginning detailed photo interpretation. During this field survey, the vegetation communities are explored to correlate the community with its appearance on the aerial photograph.

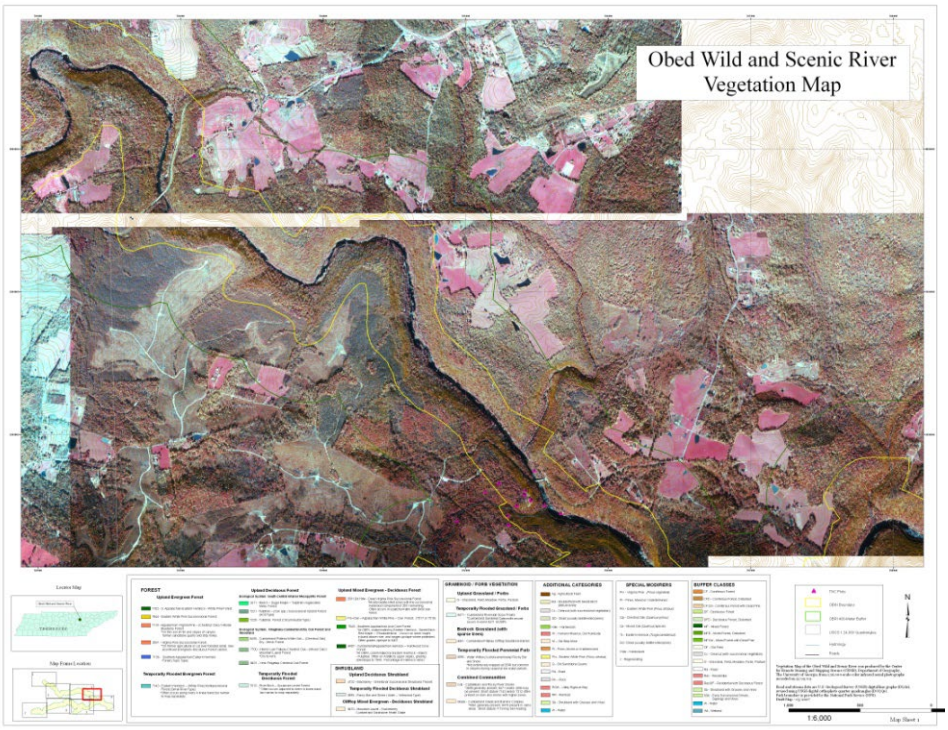


Figure 10: Field map for OBRI used for field data collection with UTM grid, false color infrared orthophotos, 10m topographic contours, roads and rivers.

NatureServe developed a classification field key based on field plot surveys for OBRI before the CRMS-NatureServe field work was conducted. During the subsequent field work, the key was jointly used, informally tested and then modified, if necessary. Although this process tended to require considerable additional time that was outside of the scope of CRMS mapping tasks, its importance was recognized after NatureServe conducted some of the first accuracy assessments of CRMS vegetation databases. For the accuracy assessment to work properly, it is imperative that NVCS classes in the NatureServe field key match the classes used by CRMS for interpretation, that the definitions of the classes are not modified after the interpretation is completed and that CRMS and NatureServe botanists agree on the classes the keys "key-out" to.

During a full field day, the UTM coordinates and field data were typically collected at approximately 10 to 15 locations. Digital camera images were taken at most field points to document the vegetation and site conditions. Digital ground photos were tied to geographic locations with the aid of a Garmin hand-held GPS receiver. The GPS coordinates of each photo location was recorded along with the frame number, location, date and time of each image as notes in the field notebook (Figure 11). These images were stored with the field notes and GPS locations to provide a pictorial record of field observations.



Figure 11: Ground digital image of overstory and understory vegetation along the Obed River.

A compilation of all field information was used by CRMS photointerpreters to connect the NVCS association-level classes identified in the field with photo signatures for vegetation patches identified on the color infrared aerial photographs. The locations of CRMS field points were transferred from the GPS units to ArcMap and superimposed on orthorectified images of OBRI. Information from the field points on overstory, understory and herbaceous strata, environmental site conditions and any notes on human influence or disturbance were used to delineate areas of homogeneous vegetation communities into areas (i.e., vegetation polygons) and label (i.e., attribute) polygons with the appropriate NVCS association class (i.e., CEGL).

The term, *association*, is defined by Grossman et al. (1998) as a "plant community type of definite floristic composition, uniform habitat conditions and uniform physiognomy". Vegetation classification studies by NatureServe were conducted prior to CRMS photointerpretation in most parks to create a list of typical NVCS associations and provide a comprehensive description of species found in one or several strata of vegetation: tree canopy, sub-canopy, tall shrub, short shrub, herbaceous, bryophytes, vine/liana and epiphyte. The combination of vegetation in all of these strata present determines the community type and NVCS association CEGL. Additional information on global and local site conditions also are included in NatureServe park classification descriptions. This information was extremely helpful to CRMS interpreters and photointerpretation proceeded most smoothly when classification studies by NatureServe were completed prior to photointerpretation. Close cooperation between CRMS and NatureServe personnel in conducting field work and throughout the photointerpretation process was essential because in some cases CRMS interpreters found vegetation signatures on the aerial photographs that did not fit in the existing NVCS associations listed for the park. Since NatureServe plots are dispersed throughout the parks and the intensity of field work that is required for each plot may limit the number of plots that can practically be surveyed, there were times when additional existing NVCS classes and even new vegetation classes to the NVCS classification system were identified by the photointerpreters. Careful consideration was given to these perceived "new" classes and in some cases additional NatureServe plots were established to document the vegetation in the field. It was more common that NatureServe definitions of NVCS associations would be modified to reflect the particular dominance or mix of species in particular parks.

It should also be noted that the term "overstory vegetation" refers to vegetation communities that are named and referenced by vegetation in their tallest stratum, plus abundant and/or indicator species in lower strata. Photointerpreters can see the tallest strata on color infrared photos and may or may not be able to see through this layer to shorter sub-canopy or understory layers. Sometimes a community can be determined solely by its location (e.g., along a ridge or on the south slope) and the uppermost stratum. In other cases, a lower stratum (or strata) must be seen because this stratum determines the community type. If supplemental air photos that were taken in leaf-off conditions were available at

no cost for a park, such as USGS Digital Ortho Quarter Quads acquired in the winter months, then these photos were used to identify the type and density of the understory strata. This information, combined with species and abundances identified from field work, was used to separate NVCS classes with similar overstory components but difference sub-canopy understory or herbaceous components. If it was not possible to determine the association-level class due to similar overstory characteristics and lack of information on sub-canopy vegetation, then a more general class, perhaps at the alliance level, was assigned to the polygon.

The vegetation classification system used for OBRI is provided in the Appendix of this report. The NVCS association-level classes listed as CEGL numbers and class names are fully described in separate documents produced by NatureServe and provided to the NPS on a park-by-park basis. Each of the parks in the Appalachian Highlands Network that were mapped by CRMS includes NVCS CEGLs with additional classes. Figure 12 and Figure 13 show the structure of this classification system for OBRI. Modifiers to the NVCS classes, for example, can indicate variations of a particular NVCS class that are characteristic of the park being mapped and not well represented by the NVCS. The modifiers were added to the classification system to provide specific information about 1) successional stages of vegetation communities; 2) damage conditions; 3) types of management practices (e.g., mowing or planting); and 4) land uses not covered by the NVCS, such as Human Influence, Residential, Commercial/Industrial, Agriculture and Roads (Figure 14). This classification schema was employed in other NPS vegetation mapping projects such as Everglades National Park and Great Smoky Mountains National Park with considerable success (Madden et al. 1999, Jackson et al. 2002, Madden et al. 2004).

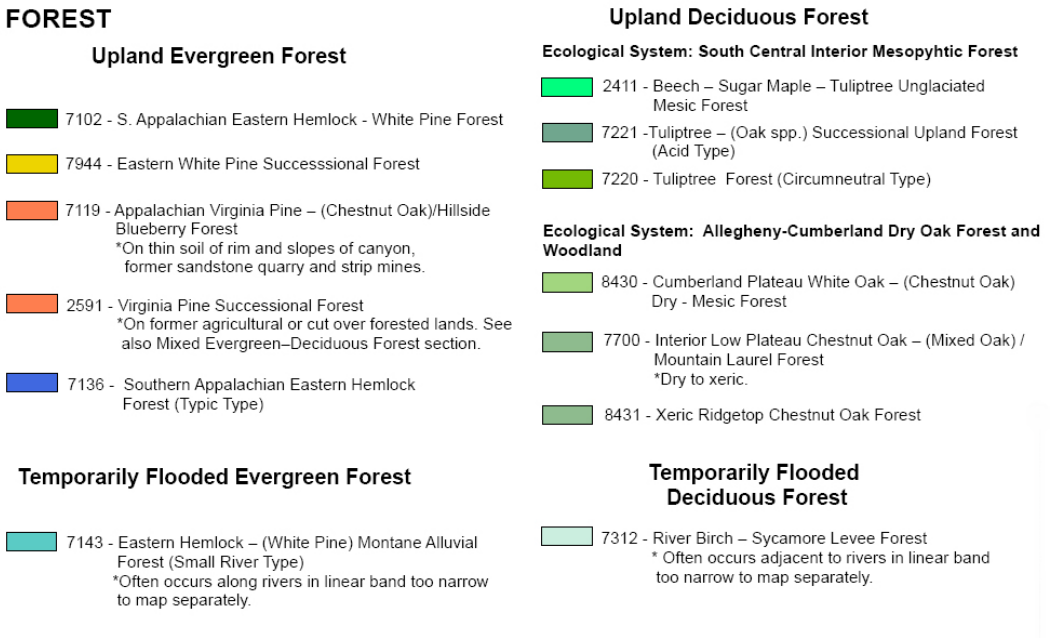


Figure 12: CRMS Vegetation Classification System for OBRI that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 1 – Forest Classes).

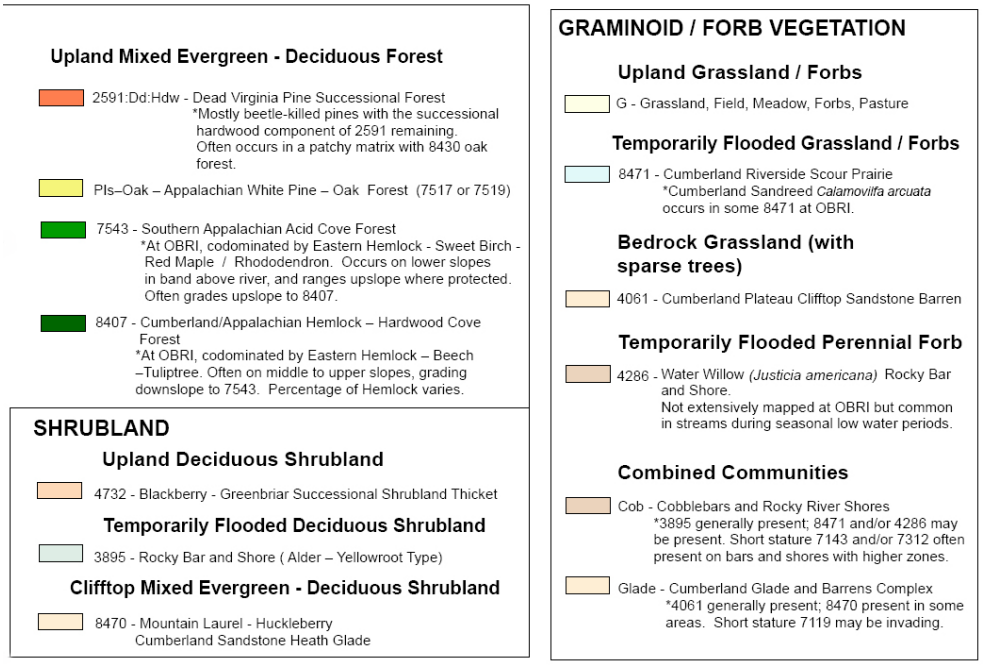


Figure 13: CRMS Vegetation Classification System for OBRI that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 2- Forest Classes (continued), Shrubland and Graminoid/Forb Vegetation Classes).

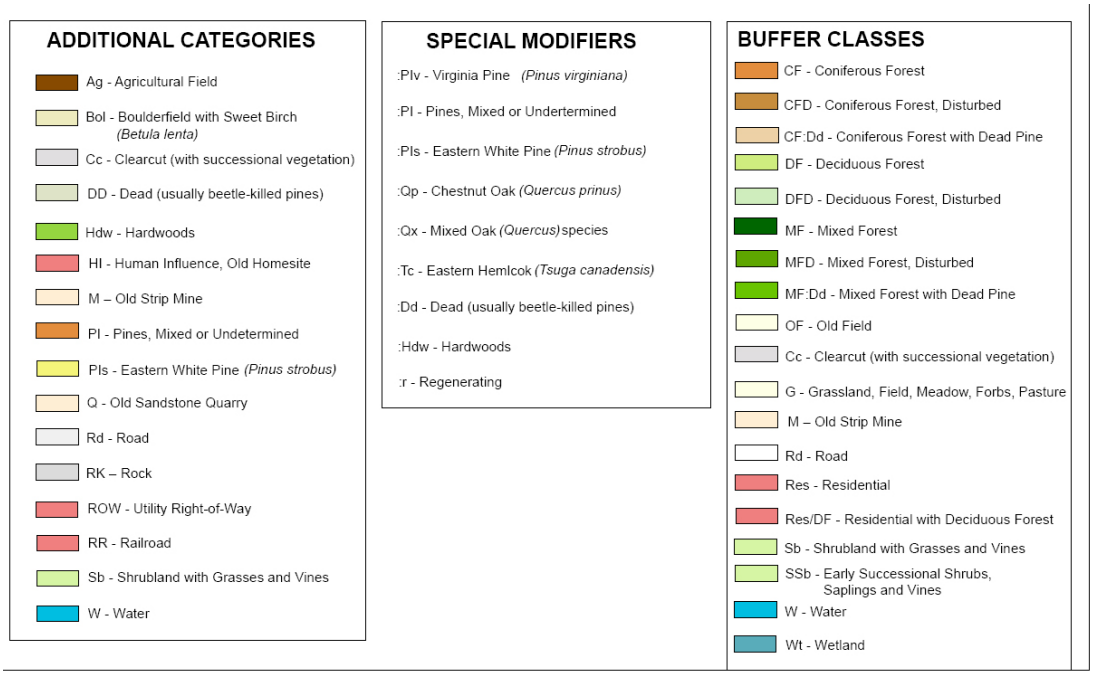


Figure 14: CRMS Vegetation Classification System for OBRI that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 3 – Additional Categories, Special Modifiers and Buffer Classes).

The NVCS is best suited to large parks that are relatively undisturbed and have remained so for long enough for vegetation communities to develop in accordance with the environmental and climatic conditions of the site. Areas that are regularly or extensively disturbed by logging, fire, wind damage, exotic insects, exotic vegetation and human activities are not easily classified with the NVCS. For this reason, the CRMS augmented the NVCS classes developed for OBRI by NatureServe to include additional disturbed, managed, successional and modified classes, along with numerical and alpha modifiers to provide detailed information to users of the vegetation databases and maps.

Once the overstory community classification systems were established for each park, the photointerpretation proceeded by taping transparent plastic overlays to the film transparencies and transferring the photo numbers and fiducial marks to the overlays by means of a Rapidograph technical pen. The film transparencies, with plastic overlays, were then placed on a high intensity light table and the polygons corresponding to the vegetation classes outlined on the overlay using the Rapidograph pen while viewing the photographs through a stereoscope. This is a simple, fast, inexpensive and flexible method of creating a vegetation overlay that can be scanned to create a raster file.

In order to accommodate the complex vegetation patterns often found in National Park units and generally maintain a minimum mapping unit of 0.5 ha, a three-tiered scheme was developed for attributing vegetation polygons, similar to that developed for an earlier project in the Everglades of south Florida (Madden et al.

1999). The three-tiered scheme allowed photointerpreters to annotate each polygon in the database with a primary or dominant vegetation class accounting for more than 50 percent of the vegetation in the polygon. Where appropriate, secondary and tertiary vegetation classes are added to describe mixed-plant communities within the polygon. Secondary and tertiary classes were especially useful for describing ecotones, and for polygons with a patchwork of communities below the minimum mapping unit size.

GIS Operations

Creating the Map Database

Following recommendations by Welch and Jordan (1996), the interpreted overlays were scanned using the Epson 10000xl scanner at a resolution of 127 µm (200 dpi) using Adobe Photoshop. All annotated point, line, polygon and attribute information on the overlay was thus converted to raster format and saved as a black-and-white, 8-bit TIFF file (Figure 15). The parameters derived from the differential rectification of the scanned 1:12,000-scale photos (described above) were then applied to the scanned overlay files via registration with the transferred fiducial marks and the scanned overlays were orthorectified in the same manner as the original aerial photographs. Figure 16 illustrates the magnitude of polygon displacement in a mountainous area, as well as distortion in polygon shape and size, due to variable relief displacements across the photograph. The image on the left (Figure 16a) represents an uncorrected overlay with a superimposed 1-cm grid. After differential rectification to correct for relief displacement (Figure 16b), the grid appears to be distorted but, in fact, the lines on the overlay are in their correct planimetric locations as a result of the rectification process. Figure 17 shows the entire overlay after correction. The wavy edges of the overlay are an artifact of the process resulting from the corrections for relief displacements which are greatest along the edge of the photograph.

After differential rectification of the scanned raster overlay files, the files were converted to vector format with the software package Feature Analyst (VLS-Inc.) and saved in ArcView shapefile format – one file per overlay. The resulting vector files were then edited, edgematched and merged into a single ArcView shapefile to produce a seamless vegetation map corresponding to the area covered by the park (Figure 18 and Figure 19).

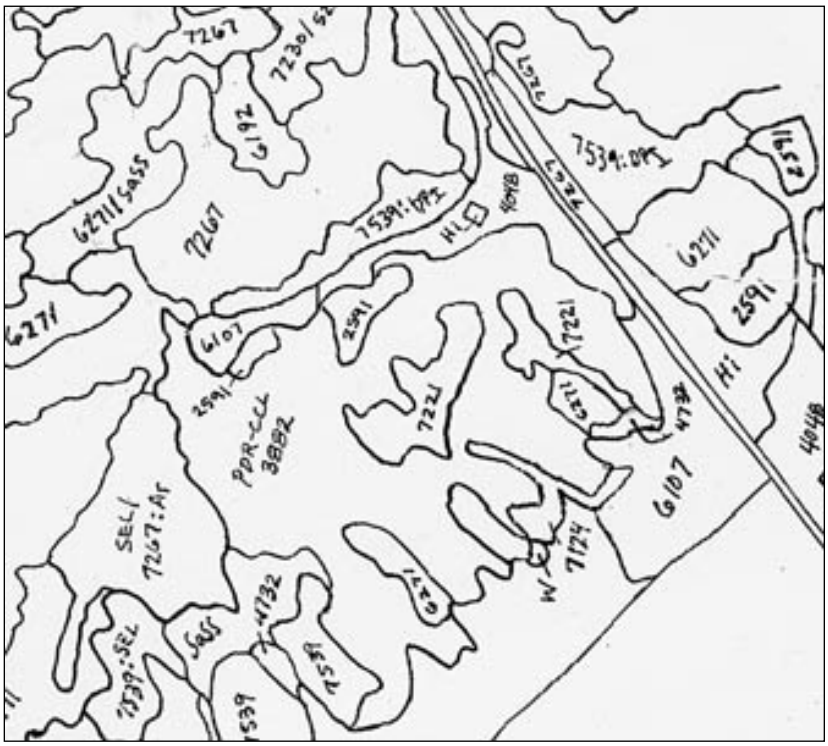


Figure 15: Sample scanned overlay showing vegetation polygons and CEGL code values.

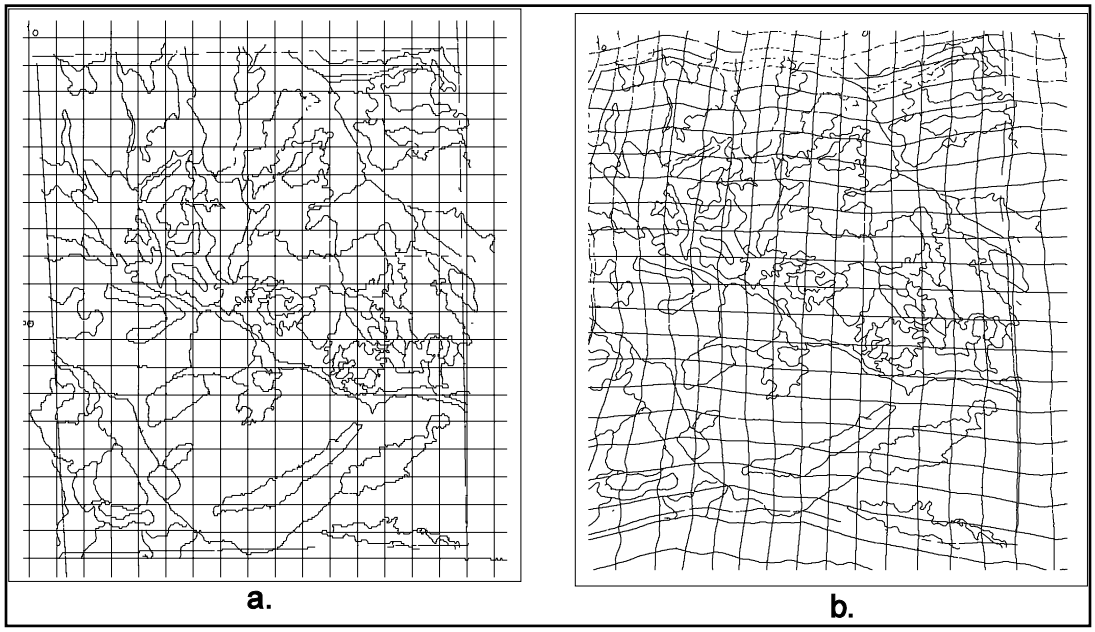


Figure 16: (a) Original photo overlay depicting vegetation polygons and a 1-cm grid before corrections for relief displacement. (b) Overlay and grid after orthorectification showing the extreme corrections required to accommodate the large range of relief in the area.



Figure 17: Full overlay that has been orthorectifed and is ready for raster-to-vector conversion. The uneven edges are a result of the differential rectification process that removes the relief displacements from the photos.

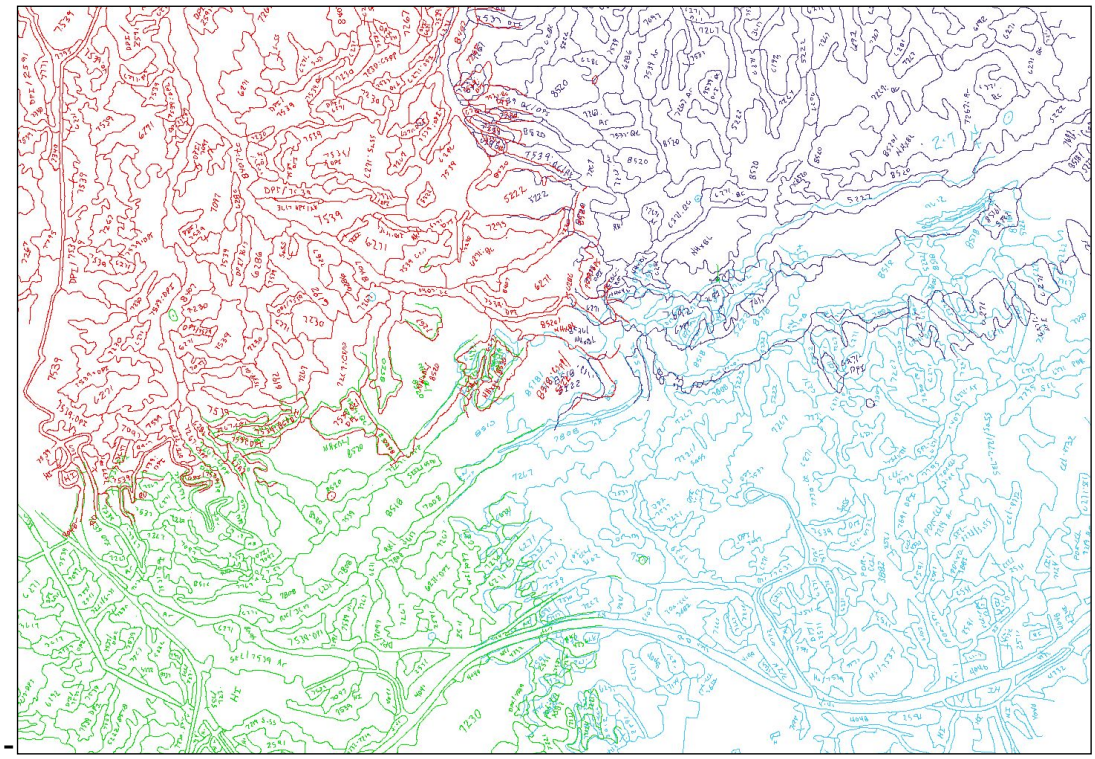


Figure 18: Individual (unedited) vector files from four adjacent photos.

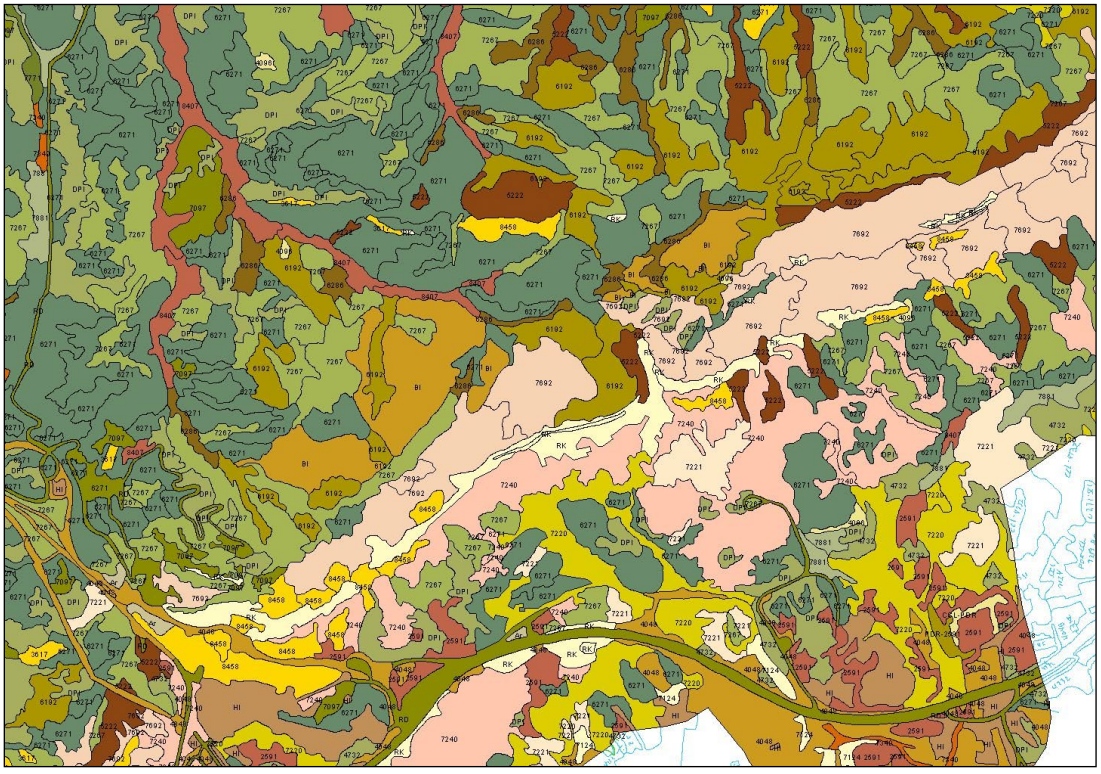


Figure 19: Section of the vegetation database that has been edited, edge matched and attributed.

Experience in the Great Smoky Mountains National Park has shown that a typical coverage for the area corresponding to a USGS 1:24,000-scale map can contain over 4,500 polygons that must be attributed with a dominant vegetation class, and possibly secondary and tertiary vegetation classes. Depending upon the complexity of the map, more than 700 man-hours can be required to produce a single quad-sized vegetation map from the 1:12,000-scale photos, including quality control checks of labels/line work within and between adjacent maps. Although limited funds available for the project precluded a thorough check of thematic classification accuracy, maps were taken into the field as they were completed to assess the general agreement between map information and observations on the ground. A more thorough accuracy assessment of the vegetation will be performed as a separate project.

Quality Assurance/Quality Assessment

The final step before creating the actual map layouts was to perform quality assurance/quality assessment (QA/QC) inspections of the data. In this process, both the orthophotos and vegetation maps were checked to make sure that they fit the underlying DOQQs properly. In ArcMap, the DOQQ, orthophoto and vegetation layers were loaded and displayed in register with one another. The 'Effects' toolbar provides a *swipe* feature which allows one layer to be rolled back to see the underlying layers. By rolling the topmost layer back and forth, any misregistration between layers can be detected by visual inspection. This procedure was applied to both the orthophotos and the vegetation layer. Data mismatches of this sort resulted primarily from errors in aerotriangulation and ground control, orthophoto generation and edge matching operations. It was also possible that the photo interpreter did not delineate or attribute the feature correctly. When such a misregistration was found, the cause was determined and the data were corrected.

Final Products

GIS Databases

Final products included a seamless park-wide GIS database in ArcGIS geodatabase and ArcView shapefile formats of detailed overstory vegetation communities, along with vegetation statistics, large scale hardcopy maps and orthophoto images. More generalized vegetation/land use/land cover classes are provided for a 400-m buffer surrounding the park boundaries. Each map sheet contains a color-coded legend and brief description of all vegetation classes found in OBRI. Applications of the park map/database products include: 1) vegetation assessment for general resource management tasks; 2) utilization of the overstory vegetation structure for classifying fuels and the associated risk of forest fire; 3) habitat assessment; and 4) provision of baseline data for future studies of vegetation or habitat change.

The vegetation databases provide a basis for park-wide resource management decisions. Basic information that is required by all managers includes a spatial inventory of existing vegetation communities and summary statistics indicating the total area covered by each community. These data can be quickly tallied in a GIS environment once the database has been developed. Comprehensive lists of all overstory and buffer vegetation classes as well as special modifiers are provided in this document and also within the database and metadata for each park. A summary of the respective areas of each dominant vegetation class within OBRI is also provided.

Detailed information at the association-level is often needed to address management problems that target individual species. For example, the overstory vegetation database can be queried to locate pure stands of Virginia Pine *(Pinus virginiana)* that might be susceptible to southern pine beetle infestation. The maps and databases also facilitate monitoring of important habitats such as Cobble Bars and Glades which contain rare and endangered plant species (NPS-APHN, 2009).

Other management questions may require a broader perspective. Given the complexity of vegetation diversity in the APHN parks, the vegetation maps will assist park managers with assessing general trends in vegetation patterns when posed with management questions on a Park-wide level.

Map Products

Large scale final map products were created within ArcMap and designed to show both the orthophoto coverage and the vegetation maps. For the vegetation maps, colors were assigned and the polygons labeled with the dominant vegetation and modifier and, where present, the second vegetation and modifier. Additional planimetric map data included roads, trails, hydrology, boundaries and a UTM coordinate grid. Legends are designed to provide full definitions of the vegetation and buffer classes and modifiers, as well as information about the park, map projection, data sources and authorship (Figure 18). All maps for OBRI are projected to the Universal Transverse Mercator Coordinate System, North American Datum of 1983, Zone 16.

Large-format (3x4 ft) hardcopy maps were provided to the NPS as data were delivered while softcopy versions in Adobe Acrobat (PDF) format are provided on the accompanying DVDs. Final databases compiled and organized into ArcGIS Geodatabases and ArcView shapefiles, along with metadata complying with NPS and FGDC Standard version FGDC-STD-001-1998. These files also are included on the accompanying DVDs.

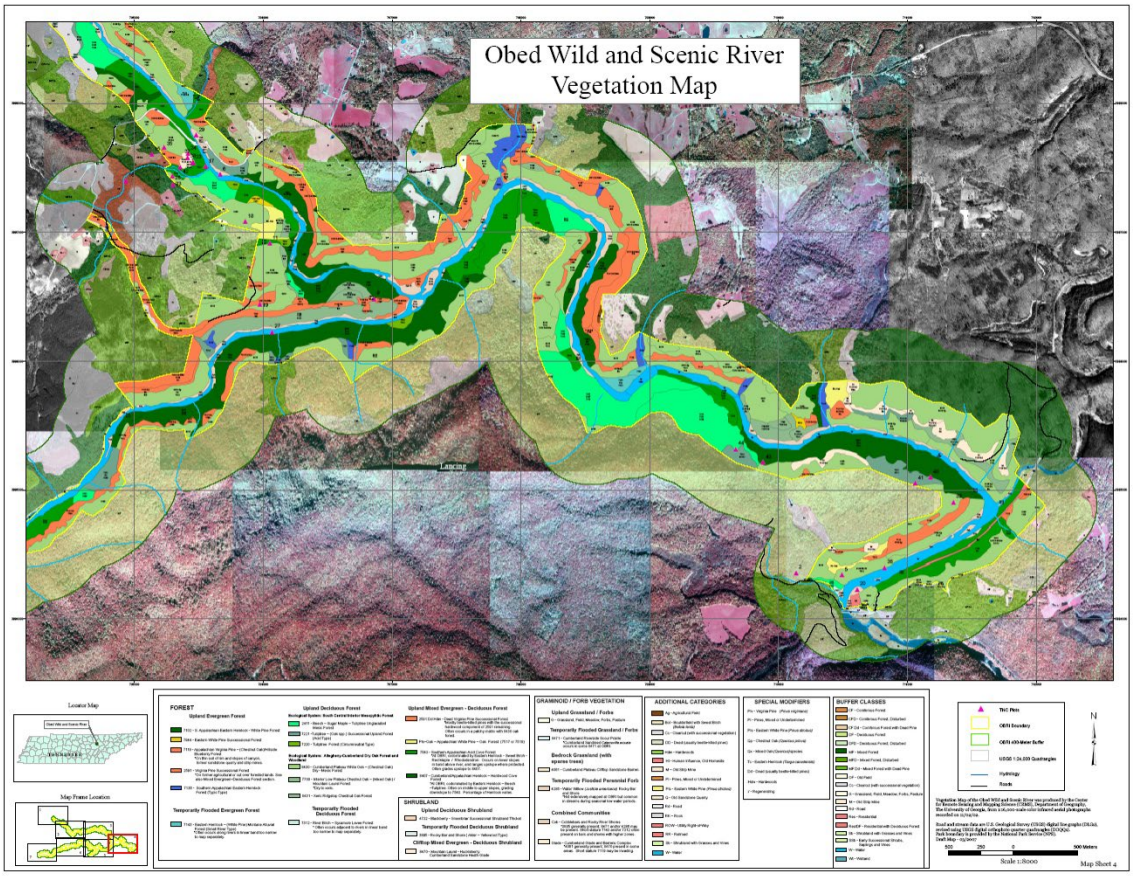


Figure 20: Final map product for Section 4 of OBRI. Copies of all 7 map sections are provided in the Appendix.

Summary and Conclusion

Vegetation in the Obed Wild and Scenic River (OBRI) in the Appalachian Highlands Inventory and Monitoring Network (APHN) was mapped by the Center for Remote Sensing and Mapping Science (CRMS), Department of Geography, University of Georgia under Cooperative Agreement No. H5028 01 0651, entitled, “Digital Vegetation Databases and Maps for National Park Service Units in the Appalachian Highlands and Cumberland/Piedmont Networks”. Vegetation mapping of the park was accomplished using a set of procedures and methods originally developed by the CRMS for the Great Smoky Mountains National Park Vegetation Mapping Project. In this process, color infrared aerial photographs were acquired in the fall of 2002, timed to coincide with the peak color change of the trees. The mapping included three primary areas of activity: photogrammetry, photointerpretation and field survey, and GIS database development and map creation.

Photogrammetric operations involved scanning the aerial photographs, the extension of ground control using analytical aerotriangulation and softcopy

photogrammetric techniques, production of digital orthophotographs from the color infrared aerial photographs, and ortho-correction of the interpreted overlays in preparation for GIS database compilation. Photointerpretation was performed using manual methods on mylar overlays while viewing the aerial photographs in stereo on a light table. Although time-consuming, this method is superior to automated methods because it permits a much wider range of vegetation classes to be detected and delineated while drawing on the botanical and site specific knowledge of the photo interpreter, in addition to collateral datasets such as NatureServe plot data, field survey notes from site visits, and maps showing topography and geology. Using a minimum mapping unit of 0.5 ha, polygons delineating areas of a single vegetation community were drawn on the mylar overlays and assigned a numeric CEGL code corresponding to the appropriate National Vegetation Classification System (NVCS) class. Where a NVCS CEGL code did not fit the interpretation, an alpha code or modifier (e.g., HI = Human Influence) was employed as a descriptor.

Upon completion of the photointerpretation, the overlays are scanned and orthocorrected using the photogrammetric parameters determined previously and transferred fiducial marks as registration points. The lines drawn on the rectified overlays representing vegetation polygons are converted from raster to vector format using Feature Analyst Extension for ArcGIS and then edited, edge matched and, finally, assigned attributes to create the preliminary vegetation GIS database. After final checking by the photo interpreters, the database is finalized and hardcopy and softcopy map products created for delivery to NPS.

For the Obed National Wild and Scenic River, a total of 21 unique vegetation classes were found over a total park and Obed gorge area of 3614 ha (8,926.6 acres). The average size of vegetation polygons is 2.4 ha (~6 acres). The NVCS system was found to work best in areas where the vegetation had been relatively undisturbed but did not truly account for the successional or managed vegetation classes found in many of the parks in this project. For this reason, it was important for the photointerpreters and the NatureServe field botanists to work together to develop keys and to refine the classes to best fit the situation on the ground. This cooperation not only creates a better set of vegetation classes but it also prevents serious errors from occurring in subsequent operations such as accuracy assessment surveys.

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References

Anderson, M., P. Bourgeron, M.T. Bryer, R. Crawford, L. Engleking, D. Faber-Landerdoen, M. Gallyoun, K. Goodin, D. H. Grossman, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, L. Sneddon and A.S. Weakley, 1998. International Classification of Ecological Communities: Terrestrial Vegetation of the United States. Vol. II. The National Vegetation Classification System: List of Types. The Nature Conservancy, Arlington Virginia, 502 p.

Federal Geographic Data Subcommittee (FGDC), 2008. National Vegetation Classification Standard, Version 2. FGDC-STD-005-2008 (Version 2), February, 119 pp. http://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation/NVCS_V2_FINAL_2008-02.pdf/. Accessed June 24, 2008.

Grossman, D., K. L. Goodin, X. Li, D. Faber-Langendoen and M. Anderson, 1994. *USGS-NPS Vegetation Mapping Program: Standardized National Vegetation Classification System*, Prepared for United States Department of Interior National Biological Service and National Park Service by The Nature Conservancy and Environmental Systems Research Institute, Arlington, Virginia and Redlands, California, respectively, http://biology.usgs.gov/npsveg/classification/index.html, Accessed April 27, 2004.

Grossman, D.H., D. Faber-Langendoen, A. S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K.D. Patterson, M. Payne, M. Reid and L Sneddon, 1998. *International Classification of Ecological Communities: Terrestrial Vegetation of the United States. Volume I. The National Vegetation Classification System: Development, Status and Applications*. The Nature Conservancy, Arlington, Virginia, 126 p.

Jackson, P., R. White and M. Madden, 2002. *Mapping Vegetation Classification System for Great Smoky Mountains National Park.* Center for Remote Sensing and Mapping Science, Department of Geography, The University of Georgia, 7 p.

Jordan. T.R., 2004. Control Extension and Orthorectification Procedures for Compiling Vegetation Databases of National Parks in the Southeastern United States, In, M.O. Altan, Ed., *International Archives of Photogrammetry and Remote Sensing*, Vol. 35, Part 4B: 657-662.

Jordan, T. R., 2002. Softcopy Photogrammetric Techniques for Mapping Mountainous Terrain: Great Smoky Mountains National Park. Doctoral Dissertation, The University of Georgia, 193 pp.

Madden, M., 2003. Visualization and analysis of vegetation patterns in National Parks of the Southeastern United States. In, J. Schiewe, M. Hahn, M. Madden and M. Sester, Eds., Proceedings of Challenges in Geospatial Analysis, Integration and Visualization II, International Society for Photogrammetry and Remote Sensing Commission IV Joint Workshop, Stuttgart, Germany: 143-146, online at http://www.iuw.uni-vechta.de/personal/geoinf/jochen/papers/38.pdf.

Madden, M. and Giraldo, M., 2005. Landscape modeling and geovisualization. (Non Peer-reviewed Invited Paper), In, S. Nayak, Ed., Geospatial Today, 3(7):14-20.

Madden, M., D. Jones and L. Vilchek, 1999. Photointerpretation key for the Everglades Vegetation Classification System. *Photogrammetric Engineering and Remote Sensing*, 65(2): 171-177.

Madden, M. and T. Jordan, 2005. Geovisualization of vegetation patterns in national parks of the southeastern United States, In, E. Stefanakis, M.P. Peterson, C. Armenakis and V. Delis (Eds.), Proceedings of the First International Workshop on Geographic Hypermedia: Geographic Hypermedia: Concepts and Systems, April 4-5, 2005, Denver, CO, CD-ROM publication, 7 pages.

Madden, M. and T. Jordan, 2004. Database development and analysis for decision makers in National Parks of the Southeast, In, Proceedings of the American Society for Photogrammetry and Remote Sensing Fall Conference, September 12-16, 2004, Kansas City, MO, CD-ROM publication, 10 pages.

Madden, M., T.R. Jordan and J. Dolezal, 2006. Geovisualization of vegetation patterns in National Parks of the Southeast, In, E. Stefanakis, M.P. Peterson, C. Armenakis, V. Delis (Eds.), Geographic Hypermedia: Concepts and Systems, Springer-Verlag, New York: 329-344.

Madden, M. and R. Welch, 2004. Fire fuel modeling in National Parks of the Southeast. In, Proceedings of the Annual American Society for Photogrammetry and Remote Sensing, May 23-28, Denver, Colorado, CD-ROM publication, 4 pages.

Madden, M., R. Welch, T. Jordan, P. Jackson, R. Seavey and J. Seavey, 2004. Digital Vegetation Maps for the Great Smoky Mountains National Park, Final Report to the U.S. Dept. of Interior, National Park Service, Cooperative Agreement Number 1443-CA-5460-98-019, Center for Remote Sensing and Mapping Science, The University of Georgia, Athens, Georgia, 112 pages.

NPS. 2004. “Assessing the risk of foliar injury from ozone on vegetation in parks in the Cumberland/Piedmont Network,” October 2004, http://www2.nature.nps.gov/air/Pubs/pdf/03Risk/cupnO3RiskOct04.pdf

NPS-APHN, 2009. Nature & Science, Appalachian Highlands Network, National Park Service, http://science.nature.nps.gov/im/units/aphn/, accessed August 1, 2009.

Rutchey, K and L. Vilchek, 1999. Air photointerpretation and satellite imagery analysis techniques for mapping cattail coverage in a northern Everglades impoundment. *Photogrammetric Engineering and Remote Sensing*, 65(2): 185-191.

Welch, R., Madden, M. and R. Doren, 1999. Mapping the Everglades. Photogrammetric Engineering and Remote Sensing, 65(2): 163-170.

Welch, R., M. Madden and T.R. Jordan, 2002. Photogrammetric and GIS techniques for the development of vegetation databases of mountainous areas: Great Smoky Mountains National Park, *ISPRS Journal of Photogrammetry and Remote Sensing*, 57(1-2): 53-68.

Welch, R., and T.R. Jordan, 1996. Digital Orthophoto Production in a Desktop Environment, *GIM Magazine*, Vol. 10, No. 7 (July), pp. 26-27.

Welch, R., M. Remillard and R. Doren, 1995. GIS database development for South Florida's National Parks and Preserves. *Photogrammetric Engineering and Remote Sensing*, 61(11): 1371-1381.

Appendix A – Maps and Statistics for Obed Wild and Scenic River (OBRI)

Table A-1. OBRI Vegetation Class Descriptions

Table A-2. OBRI Vegetation Statistics

Table A-3. OBRI Buffer Vegetation Statistics

Figure A-1. OBRI Index Map

Figure A-2. OBRI Map Sheet 1

Figure A-3. OBRI Map Sheet 2

Figure A-4. OBRI Map Sheet 3

Figure A-5. OBRI Map Sheet 4

Figure A-6. OBRI Map Sheet 5

Figure A-7. OBRI Map Sheet 6

Figure A-8. OBRI Map Sheet 7

Table A-1: OBRI Vegetation Class Descriptions

FOREST

Needle-Leaved Upland Evergreen Forest

7102 – Southern Appalachian Eastern Hemlock-Eastern White Pine/ Great Rhododendron Forest

7994 – Eastern White Pine Successional Forest

7119 – Virginia Pine – (Shortleaf Pine) – (Chestnut Oak)/ *Vaccinium* spp. Forest, on thin soil of rim and steep slopes of canyon, and on former sandstone quarries. Virginia Pines at OBRI are often dead (Dd), mostly beetle killed, sometimes with a Chestnut Oak component remaining. 7119 is regenerating.

2591 – Virginia Pine Successional Forest, with early successional hardwoods (Red Maple, Sweetgum, Tuliptree), on former agricultural or cut over forested lands which were usually 8430 at OBRI; on deeper soils than 7119.

2591:Dd:Hdw – See Mixed Needle-Leaved Evergreen –Deciduous Forest section.

7136 – Southern Appalachian Eastern Hemlock/ Great Rhododendron Forest

Temporarily Flooded Temperate Needle-Leaved Evergreen Forest

7143 – Eastern Hemlock – (Eastern White Pine) Temporarily Flooded Alluvial Forest

Upland Deciduous Forest

2411 – Beech – Sugar Maple – Tuliptree Unglaciated Mesic Forest

7221 – Tuliptree – Mixed Oak Successional Upland Forest (Acid Type)

7220—Tuliptree / (Redbud) Successional Upland Forest (Circumneutral Type)

8430 – White Oak – (Chestnut Oak) / Oakleaf Hydrangea – *Viburnum* sp. Dry-Mesic Forest (*Viburnum* sp. = *Viburnum dentatum* at OBRI). On cut over and dry sites Chestnut Oak is often dominant and attributed 8430:Qp.

7233 – White Oak (Northern Red Oak - Sugar Maple – Beech) Mesic Forest. Not found; reported to be present.

7700 – Chestnut Oak – (Oak spp.) / Mountain Laurel- (*Vaccinium arboreum*) Dry-Xeric Forest, on shallow soils of steep canyon walls, generally associated with sandstone cliffs at OBRI. May be difficult to distinguish from, and may grade into, 8430:Qp. Virginia Pine usually present and often beetle-killed.

8431 – Chestnut Oak - (Scarlet Oak) / *Vaccinium arboreum-Vaccinium pallidum* Xeric Ridgetop Forest

Temporarily Flooded Deciduous Forest

7312 – River Birch – Sycamore / Smooth Alder Levee (Floodplain) Forest. Tuliptree, Sweetgum, Red Maple, Elm spp. Also common in canopy at OBRI.

Mixed Needle-Leaved Evergreen – Deciduous Forest

8427 – Shortleaf Pine – White Oak- (Mixed Mesic Oak) / *Vaccinium* sp. Forest

2591 – See Needle-Leafed Upland Evergreen Forest section.

2591:Dd:Hdw – 2591 Forest, now with dead (Dd) Virginia Pines, mostly beetle-killed; and with the successional hardwood component (Hdw) of 2591 remaining (Red Maple, Sweetgum, Tuliptree). Often occurs in a patchy matrix with cut over 8430 oak forest at OBRI.

7543 – Tuliptree – Sweet Birch – Eastern Hemlock/ Great Rhododendron Acid Cove Forest. At OBRI, occurs in a linear band (:b) on protected slopes along streams in canyon; sometimes ranges high up convex, straight, and moderately concave slopes when facing north. On deep, protected slopes in OBRI canyons 7543 often grades upslope to 8407.

8407 – Eastern Hemlock – (Beech – Basswood) – Umbrella Magnolia Cove Forest. Tuliptree and Sweet Birch also dominate canopy at OBRI. On deep, protected canyon slopes, grades downslope to 7543. Percentage of Hemlock varies.

SHRUBLAND

Deciduous Shrubland

4732 – Blackberry – Greenbriar Successional Shrubland Thicket

Temporarily Flooded Deciduous Shrubland

3895 – Smooth Alder – Yellowroot Rocky Bar and Shore

Mixed Evergreen – Deciduous Shrubland

8470 -- Mountain Laurel – Huckleberry Cumberland Sandstone Heath Glade

GRASSLAND

Temperate Grassland

4048 – *Fescue* spp. Herbaceous, Cultivated Meadow

Temporarily Flooded Grassland

8471 – (Carolina Willow – Smooth Azelea) – Big Bluestem – (Tall Blue Wild Indigo – Rand's Goldenrod) Cumberland Riverside Scour Prairie. Look for Cumberland Sandreed (*Calamovilfa arcuata*) in 8471at OBRI.

Bedrock Grassland (with sparse trees)

4061—Little Bluestem – Silky Oatgrass – *Liatris* sp. Cumberland Sandstone Glade and Barrens. Also found but too narrow to map on bands of sandstone banks bordering streams in the canyons. Also colonizing old sandstone quarries (Q).

Temporarily Flooded Perennial Forb

4286 – Water-willow (*Justicia americana*) Rocky Bar and Shore. Not extensively mapped at OBRI but common in streams during seasonal low water periods.

Combined Communities

Cob – Cobblebars and Rocky River Shores. 3895 generally present; 8471 and/or 4286 may be present. Short stature 7143 and/or 7312 often present on bars and shores with higher zones.

Glade – Cumberland Glade and Barrens Complex. 4061 generally present; 8470 present in some areas; with scattered Virginia Pines or short stature 7119; short stature 7994 may be invading some areas.

Q – Former sandstone quarries at rim of canyon; 4061 is colonizing bedrock where debris is collecting to form soil.

ADDITIONAL CATEGORIES

Ag	Agricultural Field
Bol	Boulderfield with Sweet Birch (*Betula lenta*)
Cc	Clearcut
Dd	Dead (usually beetle-killed White Pines or Virginia Pines)
Hb	Herbaceous vegetation
HI	Human Influence, old homesite
Jv	Eastern Red Cedar (*Juniperus virginiana*)
Q	Quarry
Rd	Roadway
RK	Rock
ROW	Utility Right of Way
RR	Railroad
Sb	Shrubs, Saplings, Vines
W	Water

SPECIAL MODIFIERS

:Cx	Mixed Hickory (*Carya*)species
:PI	Pines, mixed or undetermined
:PIs	Eastern White Pine (*Pinus strobus*)
:Qp	Chestnut Oak (*Quercus prinus*)
:Qx	Mixed Oak (*Quercus*) species
:Tc	Eastern Hemlock (*Tsuga canadensis*)
:b	Occurs in linear band along stream
:Dd	Dead (usually beetle-killed pines)
:Hdw	Hardwoods
:r	Regenerating

BUFFER CLASSES

CF	Coniferous Forest
CFD	Coniferous Forest – Disturbed
CF:Dd	Coniferous Forest with Dead Pine
DF	Deciduous Forest
DFD	Deciduous Forest – Disturbed
MF	Mixed Forest
MFD	Mixed Forest – Disturbed
MF:Dd	Mixed Forest with Dead Pine
OF	Old Field
Cc	Clearcut (with successional vegetation)
G	Grassland, Field, Meadow, Forbs, Pasture
M	Old Strip Mine
Rd	Road
Res	Residential
Res/DF	Residential with Deciduous Forest
Sb	Shrubland with Grasses and Vines
SSb	Early Successional Shrubs, Saplings and Vines
W	Water
Wt	Wetland

Table A-2: OBRI Vegetation Statistics

DominantVeg	Description	FREQ	Area (m^2)	Area (ha)
2411	Beech - Maple - Tuliptree Unglaciated Mesic Forest	44	2246911.41	224.69
2591	Virginia Pine Successional Forest with early successional hardwoods. On former agricultural (or cut-over forested lands which were usually 8430) at OBRI. See also 2591:Dd:Hdw.	141	2853576.17	285.36
3895	Smooth Alder - Yellowroot Rocky Bar and Shore	8	28892.59	2.89
4061	Cumberland Plateau Sandstone Barrens	1	508.25	0.05
4286	Water Willow (*Justicia americana*) Rocky Bar and Shore. Common during seasonal low water periods.	1	2322.86	0.23
4732	Blackberry - Greenbriar Successional Shrubland Thicket	1	4035.52	0.40
7102	S. Appalachian Eastern Hemlock - Eastern White Pine / Rhododendron Forest	103	2282004.95	228.20
7119	Virginia Pine - (Chestnut Oak) / Vaccinium spp. Forest. On thin soil of rim and steep slopes of canyon, and on former sandstone quarries.	202	3882460.48	388.25
7136	S. Appalachian Eastern Hemlock / Rhododendron Forest	56	603384.01	60.34
7143	Eastern Hemlock - (Eastern White Pine) Temporarily Flooded Forest	55	701781.71	70.18
7220	Tuliptree / (Redbud) Successional Forest (Circumneutral Type)	18	372144.37	37.21
7221	Tuliptree - Mixed Oak Successional Forest (Acid Type)	23	439401.06	43.94
7312	River Birch - Sycamore / Smooth Alder Levee (Floodplain) Forest. Tuliptree, Sweetgum, Red Maple, Elm spp. also common in canopy at OBRI.	34	261179.16	26.12
7543	Tuliptree - Sweet Birch - Eastern Hamlock / Rhododendron Acid Cove Forest. Occurs in a linear band (B) at OBRI on protected slopes, above streams in canyons; sometimes ranges high up slopes when facing north. Often grades upslope to 8407.	61	2303661.33	230.37

DominantVeg	Description	FREQ	Area (m^2)	Area (ha)
7700	Chestnut Oak - (Oak spp.) / Mountain Laurel Dry / Xeric Forest. On shallow soil of steep canyon walls, Virginia Pine often present and beetle-killed.	27	641951.72	64.20
7944	Eastern White Pine Successsional Forest	35	436494.61	43.65
8407	Eastern Hemlock - (Beach - Basswood) - Umbrella Magnolia Cove Forest. Tuliptree and Sweet Birch also dominate canopy at OBRI. Often grades downslope to 7543. Percentage of Hemlock varies.	44	2321501.48	232.15
8430	White Oak - (Chestnut Oak) / Oakleaf Hydrangea - Viburnum sp. Dry - Mesic Forest. On cut-over and dry sites, Chestnut Oak is often dominant and attributed 8430:Qp.	365	12660511.83	1266.05
8431	Chestnut Oak - (Scarlet Oak) / Vaccinium spp. Xeric Ridgetop Forest	2	29179.60	2.92
8470	Mountain Laurel - Huckleberry Cumberland Sandstone Heath Glade	2	13451.16	1.35
8471	Cumberland Riverside Scour Prairie	14	17996.18	1.80
Ag	Agriculture	9	35884.20	3.59
Bol	Boulderfield with Sweet Birch (*Betuta lenta*)	2	4169.56	0.42
Cc	Clearcut (with successional vegetation)	24	504785.70	50.48
Cob	Cobblebars and Rocky River Shores. 3895 generally present; 8471 and/or 4286 may be present. Short stature 7143 and/or 7312 often present on bars and shores with higher elevation zones.	103	463667.08	46.37
Dd	Dead	3	34355.56	3.44
G	Grassland, Old field, Meadow, Forbs	21	98140.55	9.81
Glade	Cumberland Glade and Barren Complex. 4061 and/or 8470. Virginia Pines and White Pines invading some areas.	2	8864.67	0.89
HI	Human Influence	8	13339.99	1.33
Hdw	Hardwoods	1	30203.36	3.02
M	Abandoned Strip Mines	11	133039.84	13.30
PI	Pine	5	86397.00	8.64
PIs-Oak	S. Appalachian Eastern White Pine-Oak Forest	22	470581.15	47.06

DominantVeg	Description	FREQ	Area (m^2)	Area (ha)
Q	Former sandstone querry at rim of canyon; 4061 colonizing debris pockets on bedrock.	1	11814.37	1.18
RK	Road	7	21243.45	2.12
ROW	Rock	3	5341.77	0.53
RR	Utility Right-of-Way	1	15839.14	1.58
Rd	Railroad	16	66010.32	6.60
Sb	Shrubland, grasses, vines	1	3630.34	0.36
W	Water	21	2030059.53	203.01
TOTAL		1498	36140718.06	3614.07

Table A-3: OBRI Buffer Vegetation Statistics

Buffer Code	Description	FREQ	Area (m^2)	Area (ha)
CF	Coniferous Forest	32	943780.00	94.38
CF:Dd	Coniferous Forest with Dead Pine	39	1597465.13	159.75
CFD	Coniferous Forest, Disturbed	4	53510.05	5.35
Cc	Clearcut (with successional vegetation)	56	4033919.55	403.39
DF	Deciduous Forest	75	11432541.70	1143.25
DFD	Deciduous Forest, Disturbed	17	597233.10	59.72
G	Grassland, Fields, Meadow, Forbs, Pasture	93	2635828.71	263.58
M	Abandoned Strip Mines	2	85424.45	8.54
MF	Mixed Forest	81	11314693.72	1131.47
MF:Dd	Mixed Forest with Dead Pine	95	17862438.91	1786.24
MFD	Mixed Forest, Disturbed	60	3370983.65	337.10
OF	Old Field	42	744120.16	74.41
Rd	Road	70	460818.53	46.08
Res	Residential	46	402096.85	40.21
Res/DF	Residential with Deciduous Forest	16	102348.26	10.23
SSb	Early Successional Shrubs, Saplings, and Vines	26	606360.48	60.64
Sb	Shrubland with Grasses and Vines	7	53995.47	5.40
W	Water	74	205478.12	20.55
Wt	Wetland	1	5491.51	0.55
TOTAL		**836**	**56508528**	**5651**

Table A-4: Field Notes

SeqNum	UTM_X	UTM_Y	Date	CEGL	Comments
1	691137	4001353	Nov-04	7944/7221	Dense; previously logged;50% canopy cover; pine beetle kill;look on photo to see if dead pine or oak/maple/sassafrass are dominant
2	710137	3994151	Nov-04	8427	
3	696987	3999205	Nov-04	8430	
4	691180	4001127	Nov-04	7143	Similar to CEGL 7102; Tsuga canadensis; White Pine; different than 7102 because of location
5	710493	3994135	Nov-04	8430	
6	705666	3997243	Nov-04	8471	
7	697236	3995748	Nov-04	7143	
8	697152	3995778	Nov-04	8430	
9	706861	3996276	Nov-04	Sandstone Glade	
10	696781	3999631	Nov-04	8430	Dark
11	706053	3996706	Nov-04	8407	
12	698154	3999338	Nov-04	7143/8407	Photo is reddish/orange
13	698395	3999606	Nov-04	8427	
14	685632	3992935	Nov-04	7220	
15	705136	3997397	Nov-04	2591	
16	704935	3997192	Nov-04	4732/4048	
17	705554	3997303	Nov-04	Riverine Shrubland	
18	705861	3996877	Nov-04	8430	
19	705975	3996231	Nov-04	8430	
20	710610	3994022	Nov-04	8471	
21	685727	3992865	Nov-04	7701	
22	684649	3992728	Nov-04	7143	
23	705458	3997333	Nov-04	8470	

SeqNum	UTM_X	UTM_Y	Date	CEGL	Comments
24	705417	3997405	Nov-04	8470	
25	698336	3999547	Nov-04	7143	No floodplain; steep slopes
26	701689	3994809	Nov-04		
27	706069	3996020	Nov-04	8431	
28	705295	3997227	Nov-04	8407	
29	705481	3997545	Nov-04	8471	
30	703093	3999746	Nov-04	4048	
31	705547	3997803	Nov-04	7543?	Dark; Moist
32	705480	3998188	Nov-04	8431/8430	Red oak dominant
33	705311	3997363	Nov-04		Out of park? Walked Point Trail and bushwhacked to the top; private meadow beyond tree line
34	705865	3997078	Nov-04	8430	Same as NS Plot 18
35	706872	3996484	Nov-04		End of High Point Trail; Very beautiful
36	702903	3999987	Nov-04	Riverine Shrubland?	On W. side of Clear Creek; Mesic; hemlock, magnolia, holly, Liriodendron, 1 pine, I big hickory, 1 big sweet gum
37	702939	4000096	Nov-04	7543	Boulders; Little White Pine; Kalmia in understory; between creek and road; dark and dense
38	702935	4000258	Nov-04		Juniper; VA pine; willow?;grasses; flagging for a transect; very beautiful
39	702808	3999753	Nov-04	8430	steep; xeric; more open; old road bed from highway to river
40	702850	3999906	Nov-04		large, flat, slow moving water; thick, duffy bank; upslope is steep; has old road bed parallel to river; photo shows road bed cutting perpendicular to river - wrong photo?
41	702805	3999946	Nov-04	hemlock/silverbell association from Smokies?	thick understory; silverbell is indicative of rich sites
42	710569	3993973	Nov-04	8471	Same as NS Plot 20; evidence of flooding 15 ft above head
43	710608	3994006	Nov-04	Temporarily Flooded Grassland	Cobble bar; large drainage area; Sycamore, Black Gum; Va Pine away from river

SeqNum	UTM_X	UTM_Y	Date	CEGL	Comments
44	710595	3994010	Nov-04		White Oak; Chestnut Oak
45	691163	4001089	Nov-04	7143	Black cherry; Shagbark Hickory; Cornus florida; Fraxinus penn.; White Pine; Native Bamboo
46			Nov-04	7543	App. Acidic cove; hemlock; lirio; betula; tsuga. Rhody
47	696781	3999631	Nov-04	8430	Same as NS Plot 10
48	698377	3999546	Nov-04	7143	80% canopy cover
49	698156	3999549	Nov-04	7143/8407	
50	702846	3999577	Nov-04		Water willow; rocky shoals; rover birch; temporarily flooded river birch levee
51	705452	3997580	Nov-04		Dead pine and white pine. Va pine at overlook. Hemlock, birch, maple
52	705379	3997451	Nov-04	7543	steep slopes with maple, tripetal magnolia
53	705505	3997682	Nov-04		River; cobblebar; white pine and oak
54	705530	3999763	Nov-04	8430	White Oak; Chestnut Oak; red oak; red maple;
55	705497	3997992	Nov-04	7543	
56	705514	3998026	Nov-04	7543	
57	705449	3998192	Nov-04	8431	Chestnut, white oak, scarlett; red maple; sourwood; red maple
58	705448	3998197	Nov-04	8430	
59	705310	3997307	Nov-04		Same as Plot 33
60	705305	3997147	Nov-04		Same as Plot 33
61	705607	3997212	Nov-04		White oak, hemlock, pine
62	705603	3997219	Nov-04		Same as Plot 61
63	705651	3997217	Nov-04		hemlock; no subcanopy; no herb; open
64	705864	3997086	Nov-04		white oak, white pine, red maple, ilex
65	706877	3996472	Nov-04		Same as Plot 35;Va pine w/red maple, vaccinium
66	702904	4000023	Nov-04		Mag amcro, hemlock, lirio, white pine, sweetgum, red maple
67	702931	4000062	Nov-04	7543	Hemlock; rhodo; kalmia; white pine
68	702929	4000263	Nov-04	Temporarily Flooded Cobblebar	mixed grass and forbs; red cedar shrubs; white pine

SeqNum	UTM_X	UTM_Y	Date	CEGL	Comments
69	702772	3999766	Nov-04	7543	on edge of 8430
70	702812	3999730	Nov-04	7543	same plot as 69
71	702831	3999916	Nov-04	7543	same as plot 40
72	702797	3999965	Nov-04	silverbell - hemlock	same as plot 41
73	3999881	698351	Apr-05	8430	white oaks- shaggy barks, rounded leaf lobes. Red oaks- pointy leaf lobes. 8430 can be mix or can be single or few or all spp frm description.
74	3999922	698358	Apr-05	7119	Virginia pine, shortleaf pine, 3rd pine. Whatever exists under dead pine is secondary class. Here, Chestnut oak. Lots of dead trees. Few oaks in understory. Sparse understory. Remember to look at elevation. Cedar here is "kind of goofy" (Carl).
75	3999970	698381	Apr-05	7119Dd	Was Va pine, now with hickory, post oak. On top of slope. Flat, grassy ground cover. More moist than pt 31.
76	3999924	698431	Apr-05	8430	Oak mix. Acidic soils (sandstone). 4392 right above here - big rocks, little veg. May not see it from photo.
77	3999919	698432	Apr-05	7102	White pine/hemlock. Lower down, more mesic, white oaks becoming more numerous. Still steep slope to river. Red maple - furrowed bark, opposite branching. Sugar maple - bark is flaky, peely higher up.
78	3997663	705232	Apr-05	7100 or 7944	Beginning of Point Trail. Strange classification. E hemlock, white pine, white oak, black oak, red maple, cherry, chestnut oak, scarlett oak. Not typical oak type. Will receive new classification list from Carl. Cut over area - lots of stumps. Understory - holly, few baby pine, even fewer dogwood. This goes from parking lot to boardwalk.
79	3997583	705414	Apr-05	4061	perennial grassland. Flat rock w/ perennial grasses, short stubby va pine, on overlook boardwalk. This is a composite area, with a few different classifications. Holly on top of rocks too. Other classes in this area: 8470, 7119, 4061, 4343

SeqNum	UTM_X	UTM_Y	Date	CEGL	Comments
80	3997550	705461	Apr-05	8407	Right below the lookout, red maple and hemlock, sweet birch, Va pine. Trees start growth belos cliff, and grow up to cliff. Goes from west of overlook around to rocks at this point.
81	3997583	705376	Apr-05		End of glade and of boardwalk.
82	3997596	705367	Apr-05		Waterfall on trail from lookout to Lilly Bridge? Hemlock rhody?
83	3997506	705356	Apr-05	8407	Across stream and downriver. Sweet birch, tulip poplar, hemlock, rhody,
84	3997432	705287	Apr-05	8407	NS plot 28. near boundary. Hemlock hardwood cove. Also on lower slope below cliff opposite pt 45 - betula, magnolia; protected slope facing north.
85	3997373	705301	Apr-05	8430?	hilltop; dry; not very many trees. Logged? Pine beetle kill. Midstory is mostly dead oaks. Same veg up to park boundary.
86	3988230	747580	Apr-05		
87	3994411	710820	Apr-05	7312	River birch/sycamore community. Followed nature trail off of Cumberland Trail. Right by river. From river inland about 300 feet, then oak with some pine. Lots of paw paw in understory. Flat, sandy. Directly across river, same classification, then upslope is oak with hemlock and pine. Top looks like 8430.
88	3994933	711483	Apr-05	7143	Change from oak to hemlock cove type. Along Cumberland Trail (due south). Above trail is oak, dead pine, drier stuff. Here, little understory, but a lot of hemlock, mixed with oak, a few junipers, and dead pine. (Hemlock/oak, but NOT cove, according to Phyllis)
89	3994936	711477	Apr-05	8521	on dry hilltop. Scarlett oak, black oak, white oak. Holly and few maple in midstory. Flat. Few large dead trees. Little to no ground veg. Leaf litter is 100%. NO PINE.

SeqNum	UTM_X	UTM_Y	Date	CEGL	Comments
90	3995073	711149	Apr-05	7221	Tulip poplar successional!! Identified on photos by large cream colored crowns. Intersection of old raod bed and Cumberland Trail. Flat ridge top. Dry. 100% leaf litter. Mostly oak: blak oak, red oak, princess tree. Below this point, large hemlock crossing old road bed, going towards river (hemlock acid cove).
91	3995067	711146	Apr-05	2411	Beech maple unglaciated. Beech, maple, red oak, sugar maple. Common in protected areas. N facing slope. Up trail and uphill side of pt 51. Richer site, indicated by foamflower, blue cohosh, bloodroot. This will go down to hemlock cove. Neighbor of tulip poplar successional. Only a few red oak, other than that no oak. Trillium. very little hemlock.
92	3995062	711047	Apr-05	7221	on ridgetop. On old rail path. Next to larger pond. Same classification as tulip poplar, even though up higher and a little more open canopy.
93	3995207	709884	Apr-05	8407	next to creek. On Cumberland Trail. Hemlock dominated. True acid cove. Cooler. Darker. Not as much under or midstory. Still quite dry. On slope. Basswood, beech, sugar maple, rhodo, No pine, No oak. Yellow violet associated with hemlock.
94	3995321	709667	Apr-05	7143	Alley Ford, off of Cumberland Trail. River birch community is in water right now. (Cobblestone and river birch). Flat area above river is where this point is taken. Flooded alluvial plain with white pine in description, not here. Hemlock, birch, red maple, sugar maple, beech, sweetgum, lots of leatherwood. Open, duffy, sandy, really very beautiful. golden ragwort-typical of temporarily flooded areas. W. side of Obed River. Across river - rocky, lots of dead pine, gaging station with a road next to it, ehrlichea(?) in bloom.
95			Apr-05	4392	Right above pt 33. Drier. Cumberland plateau. Rock vegetation. Acidic soils (sandstone)

SeqNum	UTM_X	UTM_Y	Date	CEGL	Comments
96			Apr-05		Below pt 33 at river is water willow veg type (not true willow). Forms beds in shoals. Likes to be covered with flowing water. Rocky on shoals with 2 or 3 inches of water. This is typical right along river's edge.
97			Apr-05		From Barnett Bridge - next to river mockernut hickory w/yellow buds, hemlock, dogwood, VA pine, white pine
98			Apr-05		Clear Creek from Barnett Bridge, facing west. Can see shrubland in river.
99			Apr-05		Clear Creek, from Barnett Bridge, facing east.
100			Apr-05		Looking from overlook. Lots of dead pine, hemlock, oaks. Looking north: lots of dead pine, hemlock, oak, looking across river (south facing slope). Looking south: (north facing slope) hemlock/pine on bottom of slopes, oaks.
101			Apr-05	8407	From overlook, looking at N. facing slope. Tulip poplar, hemlock, pine, birch, white pine; ridgetop is 8430
102	3999654	698581	August-05	8430	Va pine recently dead. Look for thick white pine patch next to bend in road on photo.
103	3999635	698567	August-05	8407	DEAD HEMLOCK not pine. 7543 beneath this, next to river.
104	3999583	698714	August-05	8430s	Looks like dead things on photo, but really just a weird signature. Trees have structure and leaves.
105	3999593	698711	August-05	8430s	Large dead Va pine - down and standing. Obvious beetle kill.
106	4000378	703322	August-05	8430Th	Entrance to road off of highway. SE mini cove. Just below ridge. Oak with hemlock.
107	3999522	702648	August-05		
108	3999511	702661	August-05		
109	3999579	702645	August-05	8430	Even oak canopy.
110	3999710	702698	August-05	8430	Tall standing dead Va pine and down va pine. Grapes. Bberry, thick floor cover. Lots of light.
111	3999706	702700	August-05	8430Qr	Photo has larger, brighter crowns. NOT a part of 7119. Downslope and to right - hemlock, Downslope and to left - big N Red and White oaks. At border of hemlock community.

SeqNum	UTM_X	UTM_Y	Date	CEGL	Comments
112	3999842	702735	August-05	8430	In draw. All same as previous point except for addition of hickory. In ravine/draw. Near telephone lines.
113	3999906	702715	August-05	7119	On edge of White Pine.W. Pine has strong seedbank. Hemlock will not make it to overstory,
114	3999907	702752	August-05	7102	Edge of hemlock, edge of dead pine, edge of cliff.
115	3999902	702750	August-05	7944	To E, below old road bed, very big White pine, with oak and tulip poplar. Point taken on edge of elevated road area. 315 deleted. Same coordinates as 314.
116	4000181	702814	August-05	7944	White pine, hemlock. Near big free standing rocks. Poor dry soils. Point taken near split in old road bed.
117	3999598	703062	August-05	8430Ps	Oak with white pine. Depression in photo with smaller trees above and larger pines are all around.
118	4000327	702667	August-05	8430s	Very old oak overstory. Va Pine was knocked down by wind. No dead pine standing. 319and 320 deleted. Same coordinates as 318.
119	4000323	702451	August-05	7221	Meadowy, open, on periphery of dead stuff. Lots of ticks. Out of park? Near Darnell Smith's farm. Lots of ticks.
120	4000312	702450	August-05	7944Dd	Dead white pine with white pine seedlings that are about 3 years old.
121	4000236	702364	August-05		
122	4000048	702267	August-05		325 deleted. Same as 324.
123	3999964	702299	August-05		327, 328, 329 deleted. Same coordinates as 326.
124	3999874	702198	August-05		
125	3998172	716783	August-05	Glade complex	Same disturbance (beetle kill) but different patterns. Red maple and white pine in understory - neither should be here. 7944 on photo should be part of the complex, is NOT successional white pine.
126	3997565	705447	August-05	8430	Little area between river and park boundary (between trail and park boundary). Has red maple. May affect CIR on photo.
127	3997381	705276	August-05		
128	3997123	705714	August-05		

SeqNum	UTM_X	UTM_Y	Date	CEGL	Comments
129	3996708	706040	August-05	8430s	White pine was closed canopy and large. Even oak canopy; mature. But pine will still take over. Hilltop.
130	3996710	706047	August-05	8431	Scarlett oak/White pine mix. On ridgetop of Point Trail.
131	3997856	704801	August-05	7119	Along road edge. Access Road - Park ranger told us that this area is pretty trashed from human use/disturbance (4-wheelers).
132	3997941	704751	August-05	8430s	Less white pine was here to begin with; evident from number of stems. Shady. White pine will make it to canopy, but will comprise maybe up to 10% of canopy. Very thick herbaceous cover - little bare soil.
133	3997839	705096	August-05	8430	Va pine dying. Some alive, some dead. Va pine will not come back. Dark. Dense shrub cover. No pine seedlings.
134	3997827	705094	August-05		small stemmed coppiced tress. Small circle of trees that were logged. White oak, hickory, Red maple, tulip poplar, N Red Oak.
135	3997741	705202	August-05	8431	Bare soil. Tulip poplar, scarlett oak were as tall as Va pine. Even sized oak canopy. Med-sparse shrub layer. Next to coppiced area.
136	3994055	688828	August-05	7701	At end of Genesis (?) Rd in WMA. Next to Obed River, where bridge washed out. Both sides of Obed are Sycamore/Beech floodplain.
137	3994006	688672	August-05	8430	IN middle of the road, a few yards up from the river. Upslope I s8430, downslope is 7701 and 7221.
138	3994003	688671	August-05	7220	Look for white trees (tulip poplar) in photo. Also some birch, red maple, dogwood. Across the small levee, western white pine seedlings. Can see tall pines across the river.
139	3994076	688642	August-05	8430	More dry. Moist 8430 with red oak and a lot of white oak on bottom of slope. Bottom of slope may also contain 7221 w/8430 as a secondary veg.
140	3997118	705750	August-05	8430	A lot of N red oak along the Point trail. May influence photo signature.

SeqNum	UTM_X	UTM_Y	Date	CEGL	Comments
141	4002128	691369	August-05	8430s	moderate bare soil. Lots of herbs, High light level. Was Va pine.
142	4002105	691390	August-05	8430s	Was Va pine. Lots of large dead Va pine. Little bare soil. Lots of herbs and shrubs. Lots of light.

Digital Vegetation Maps of the Obed Wild and Scenic River

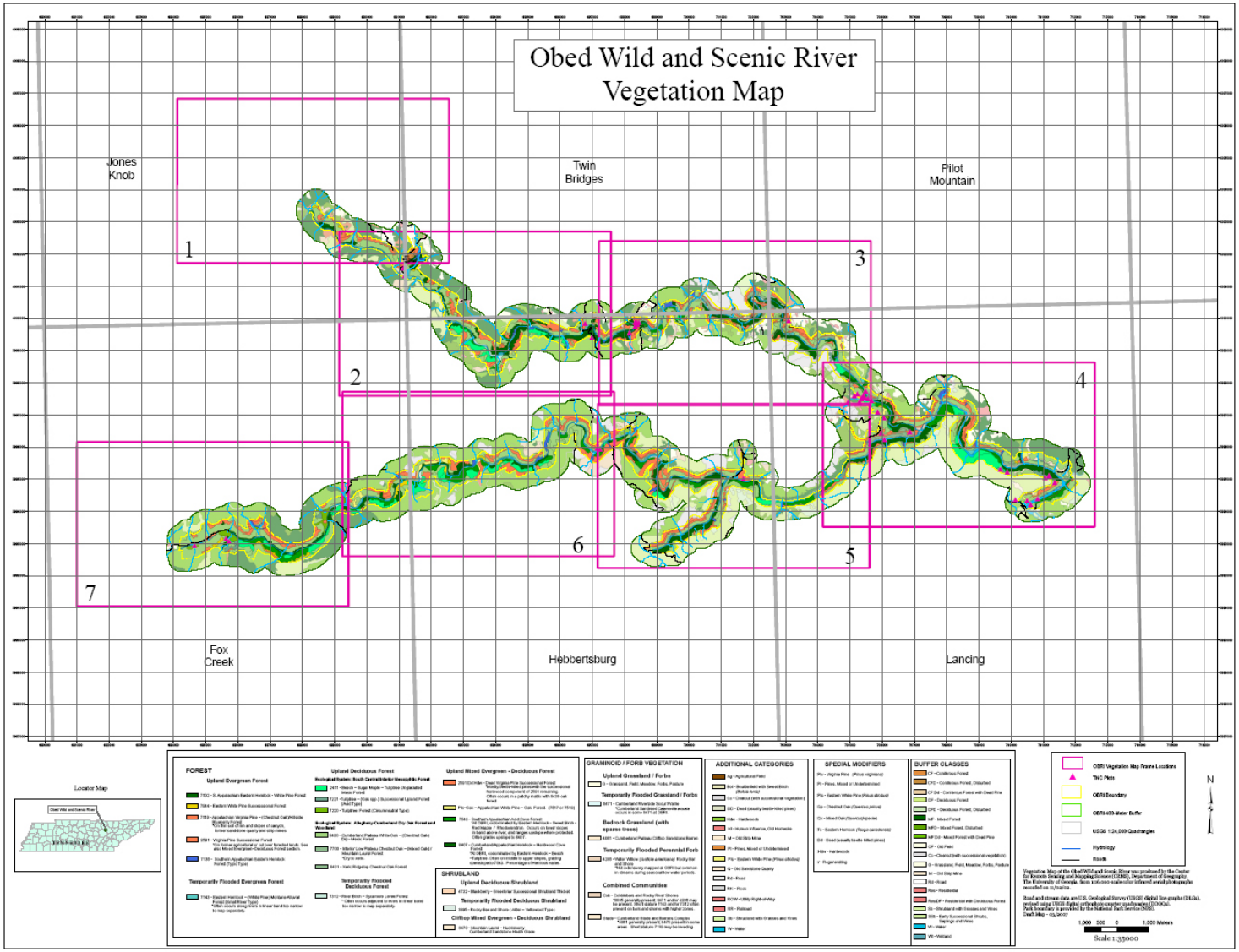


Figure A-1. OBRI Index Map

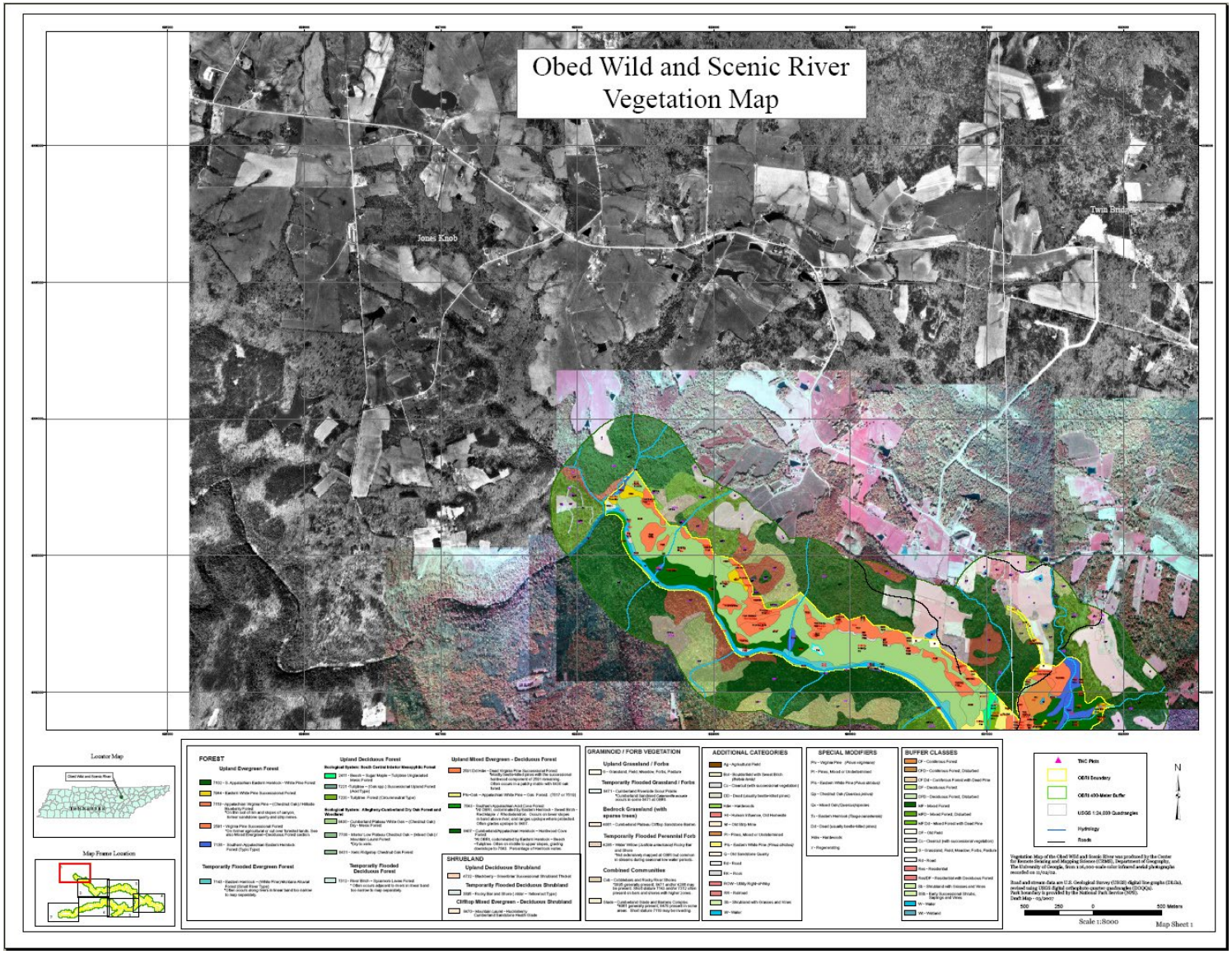


Figure A-2. OBRI Map Sheet 1

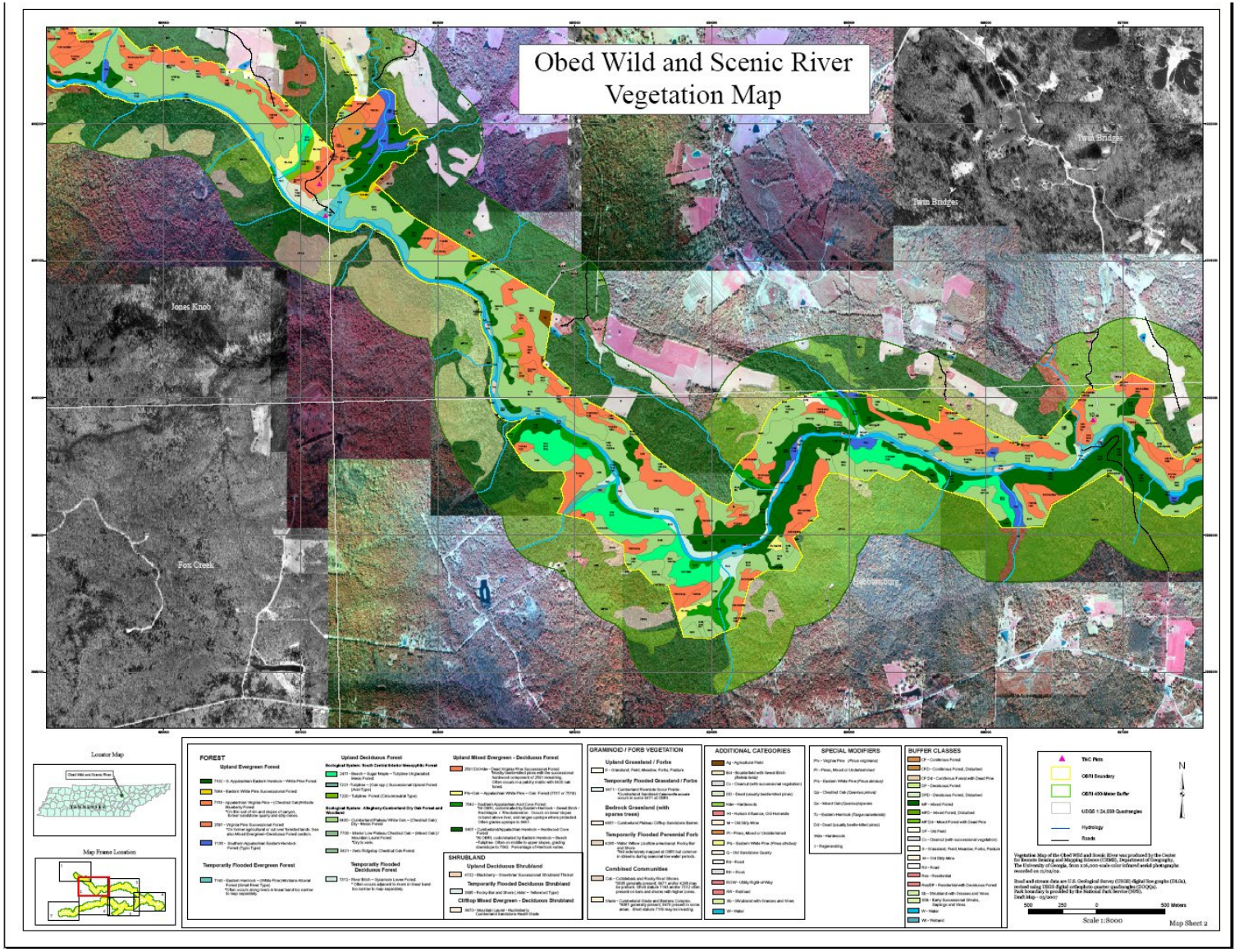


Figure A-3. OBRI Map Sheet 2

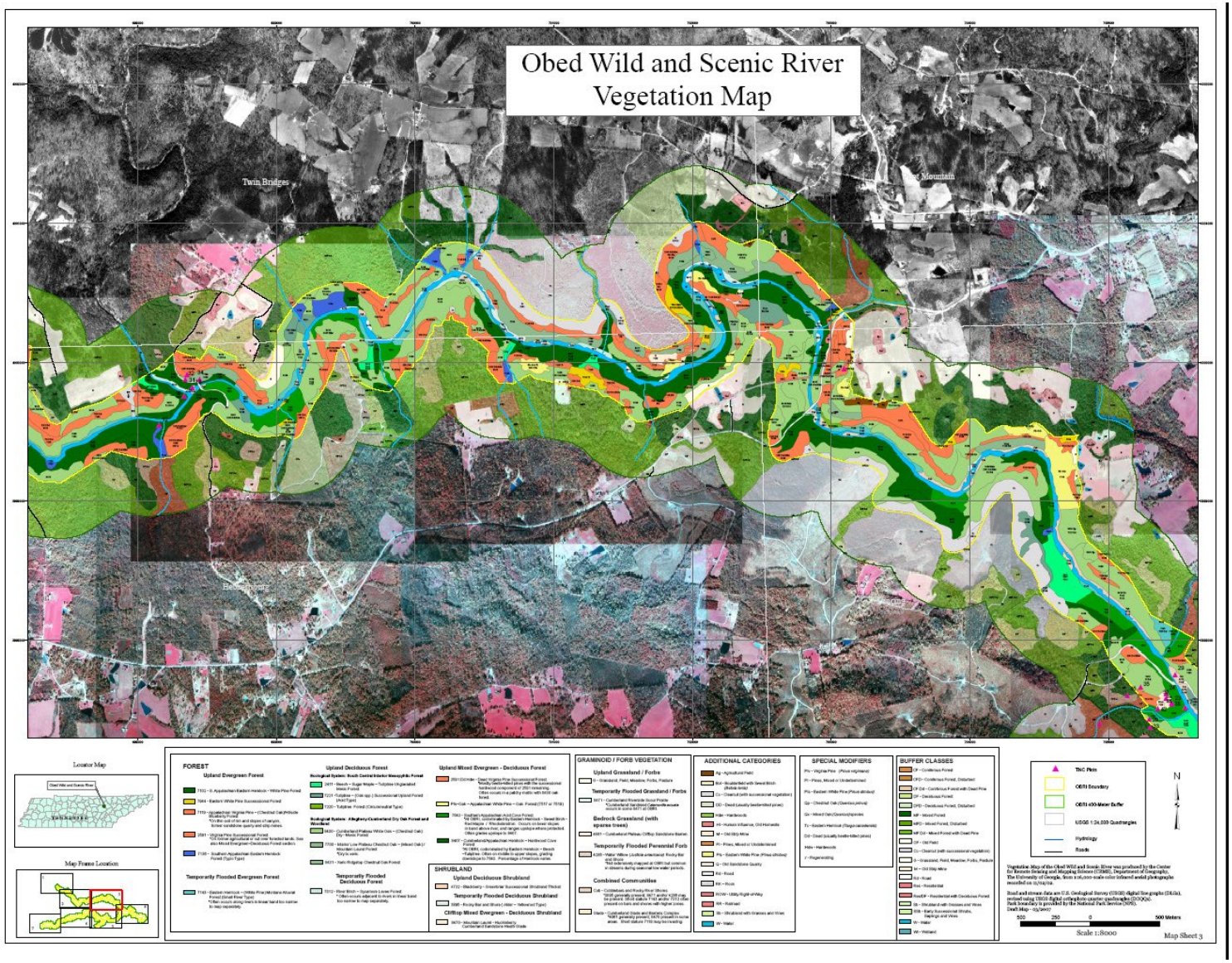


Figure A-4. OBRI Map Sheet 3

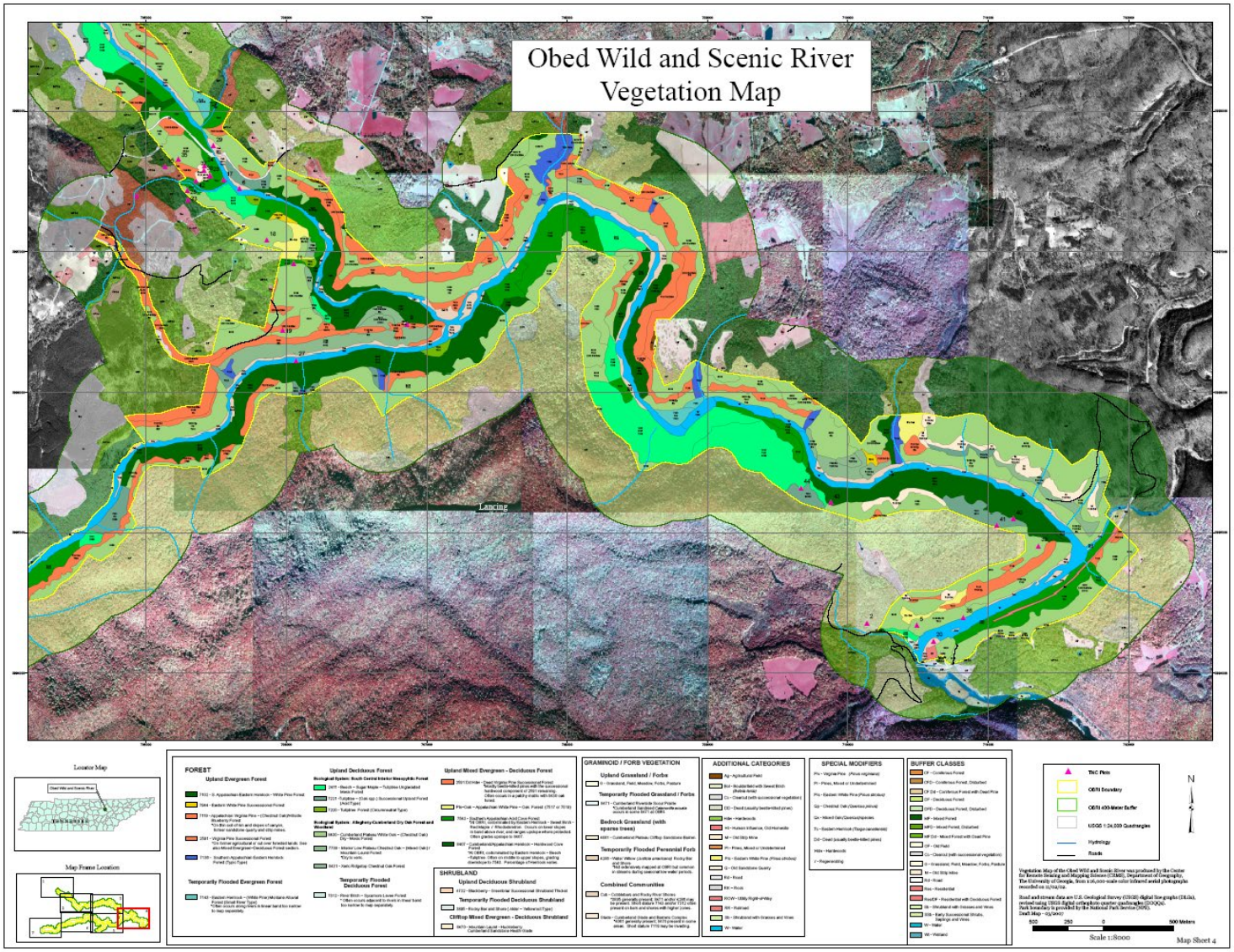


Figure A-5. OBRI Map Sheet 4

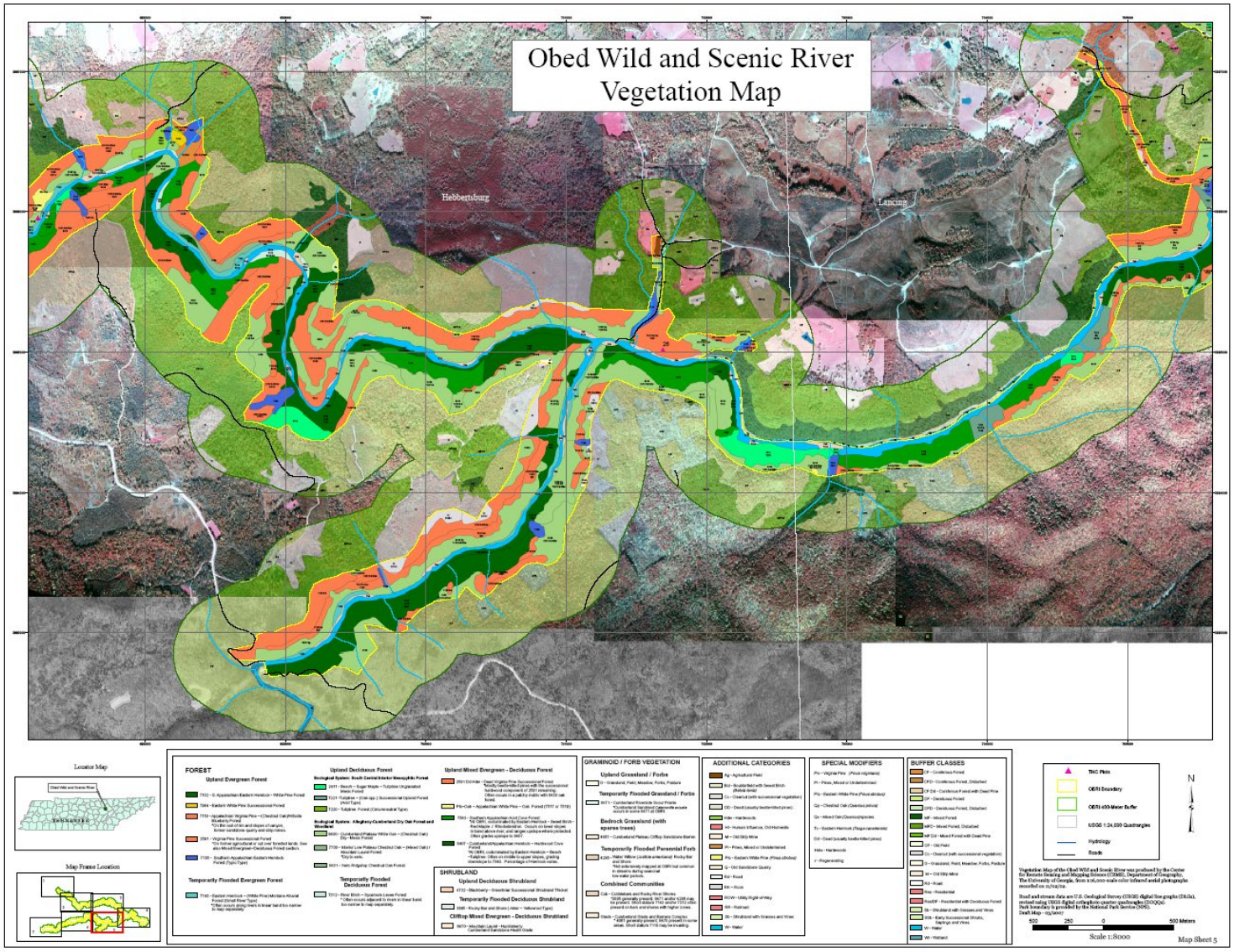


Figure A-6. OBRI Map Sheet 5

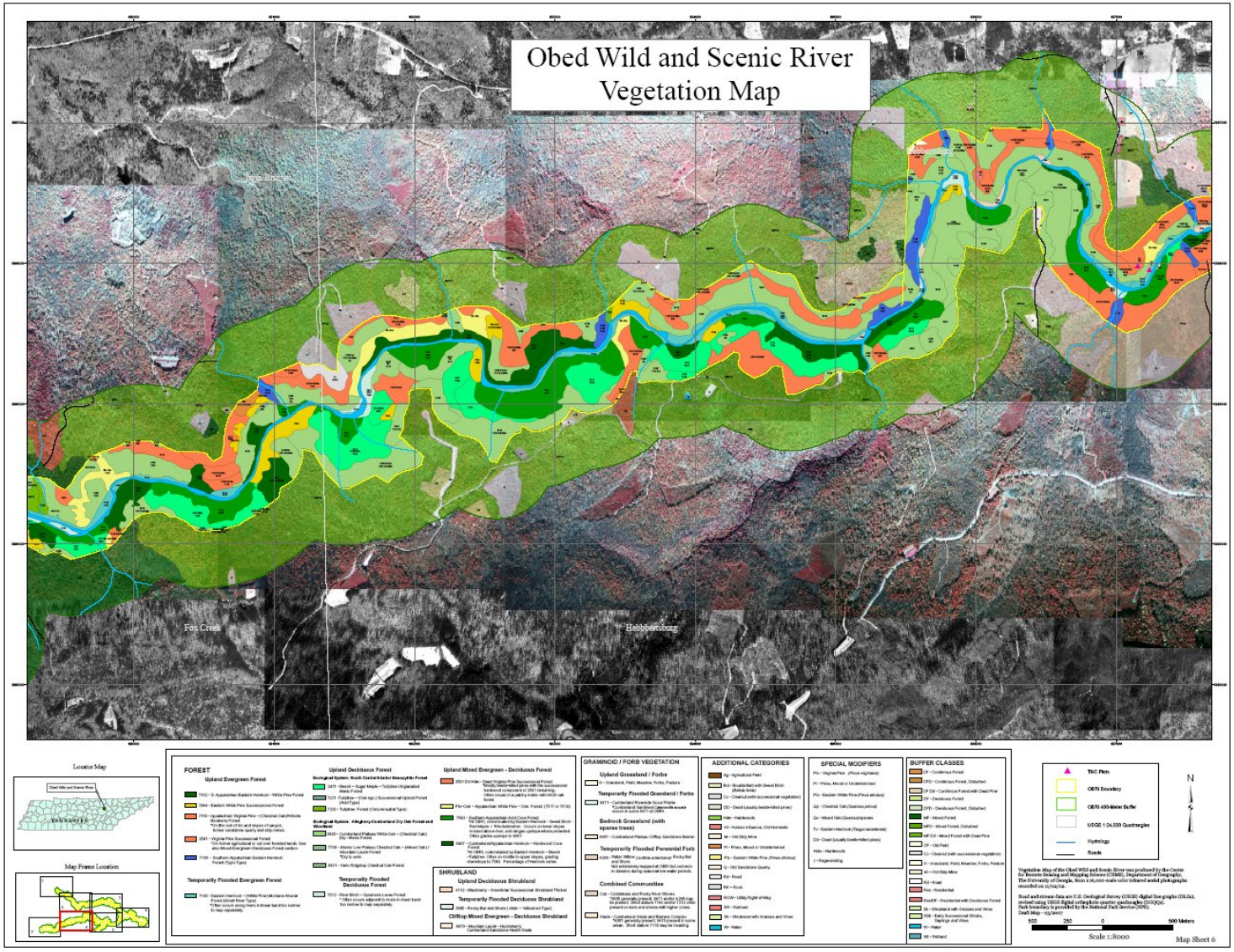


Figure A-7. OBRI Map Sheet 6

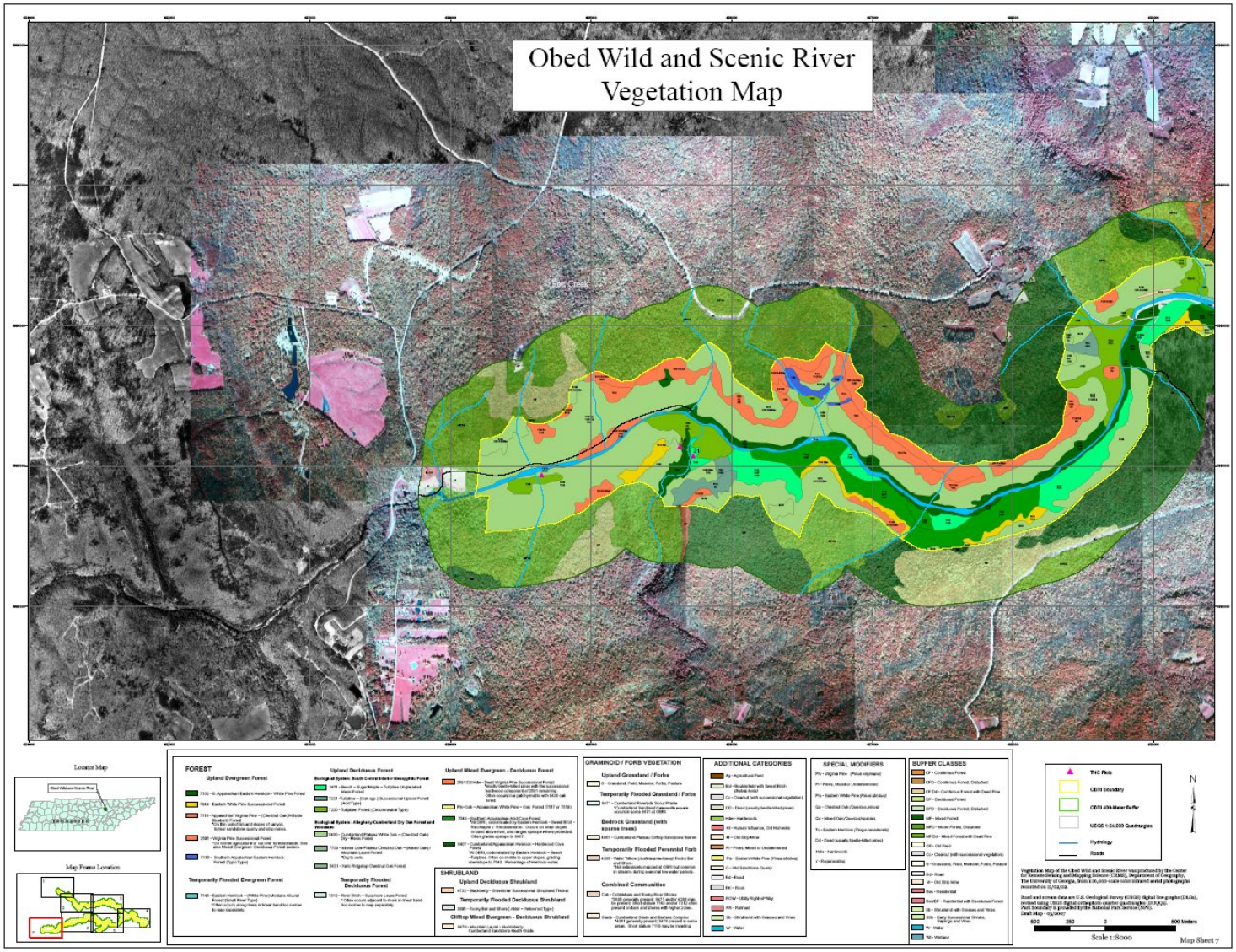


Figure A-8. OBRI Map Sheet 7