National Park Service
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Northeast Region
Philadelphia, Pennsylvania

Classification and Mapping of Vegetation and Fire Fuel Models at Delaware Water Gap National Recreation Area: Volume 1 of 2

Technical Report NPS/NER/NRTR—2007/076

ON THE COVER
Hickory - Eastern Red-cedar Rocky Woodland, near Milford, Pennsylvania, in the Delaware Water Gap National Recreation Area.
Photograph by: Gregory Podniesinski.

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Executive Summary

Vegetation classification and mapping of vegetation associations, fire behavior fuel models, and canopy cover classes were conducted at the Delaware Water Gap National Recreation Area, creating current digital geospatial databases for the park.

Sixty-nine vegetation associations that occur within the park were identified and described in detail. This wide diversity of vegetation associations is a result of several factors, including differing bedrock geology, variable topographic features, and lengthy land use history. A map showing the locations of vegetation associations in the park was created following the USGS/NPS Vegetation Mapping Program protocols (The Nature Conservancy and Environmental Systems Research Institute 1994a, b, c). These vegetation associations were also crosswalked to the National Vegetation Classification System, as well as the Pennsylvania and New Jersey state classifications, in order to provide a regional and global context for the parks' vegetation. A dichotomous field key was developed for these vegetation associations to assist with field recognition and classification.

The five spatial data inputs required by the FARSITE fire growth simulation model were also developed for the Delaware Water Gap. These data are essential for fire and resource managers to adequate plan for and manage prescribed and wildland fires. Three data layers (elevation, slope, and aspect) were derived using spatial tools in ArcGIS from the existing digital elevation model created by North Carolina State University. The fire behavior fuel model data layer maps 12 fuel models that provide information on fire behavior. The original Anderson (1982) fuel model descriptions, as well as descriptions of the fuels within the park and the relationships between vegetation associations and fire fuel models, are included in this report. A canopy cover data layer was also created for the Delaware Water Gap National Recreation Area using the four cover classes required by the FARSITE program (Finney 1998). In addition, areas of the park with large concentrations of dead or dying trees were identified. These areas, predominantly dead or dying standing eastern hemlocks (*Tsuga canadensis*), pose an increased fire risk.

Keywords: vegetation association, vegetation classification, vegetation mapping, fire behavior fuel model, canopy cover class, FARSITE, Delaware Water Gap National Recreation Area.

Introduction

General Background

One of the goals of the National Park Service's (NPS) Inventory and Monitoring Program and Fire Management Program is to provide current and accurate information for effective, long-term management of the natural resources held in trust (NPS 2003a, b). The Inventory and Monitoring Program recommends that 12 basic natural resource inventories be developed for each park that contains significant natural resources. These park inventories provide crucial baseline information for the proper stewardship of natural and cultural resources. A map of each park's vegetation, based on aerial photography less than five years old, is one of the 12 inventories recommended by the program (NPS 2003a). In addition, the Fire Management Program's Wildland Fire Strategic Plan identifies mapping fire fuel models in collaboration with the Inventory and Monitoring Program's vegetation mapping projects as a core strategy to provide current and accurate data to fire and resource managers (NPS 2003b).

To ensure that vegetation mapping is standardized across the National Park Service (NPS), The Nature Conservancy (TNC), in conjunction with NatureServe, the Federal Geographic Data Committee (FGDC), and the Ecological Society of America Vegetation Subcommittee (ESAVS), developed a protocol for creating vegetation maps in national parks. This protocol was adopted by the United States Geological Survey (USGS)/NPS Vegetation Mapping Program as the standard (TNC and Environmental Systems Research Institute [ESRI] 1994a,b,c) and has been implemented at the Delaware Water Gap National Recreation Area (DEWA) by the Pennsylvania Natural Heritage Program (PANHP).

The goal of the vegetation mapping effort at the Delaware Water Gap National Recreation Area was to produce an up-to-date digital geospatial vegetation database for the park and to provide a vascular plant species list, a dichotomous key for vegetation associations, and descriptions of the vegetation associations in the park. Baseline information on plant community composition and rarity is critical to developing desired conditions and park management goals relating to native plant communities, nonnative plant and insect species, and effects of deer browse and other disturbances. The identification and description of plant communities also provide habitat information important to understanding associated organisms, including animals, protozoans, bacteria, and fungi. A map of vegetation associations may allow inferences about the location and abundance of species that are associated with each community.

This report also describes the park's vegetation in the context of a national and regional vegetation classification. The Nature Conservancy, in conjunction with NatureServe, the Federal Geographic Data Committee, and the Ecological Society of America Vegetation Subcommittee, developed the National Vegetation Classification System (NVCS) in order to standardize vegetation classification and facilitate the comparison of vegetation types throughout the United States and internationally. The NVCS is a systematic approach to classifying existing natural vegetation using physiognomics and floristics. This classification system has a hierarchical structure (Grossman et al. 1998).

The basic unit of vegetation classification in the NVCS is the association. An association is defined as a plant community type that is relatively homogeneous in composition and structure and occurs in a uniform habitat. For example, Northeastern Dry Oak - Hickory Forest is a common forest type on well-drained, acidic midslopes in the northeastern United States. Associations are also assigned global rarity ranks that indicate their conservation status and relative risk of extirpation (Grossman et al. 1998). Associations from the NVCS are often equivalent to communities in state-specific vegetation classifications, such as the Terrestrial and Palustrine Plant Communities of Pennsylvania (Fike 1999) or the Draft New Jersey Ecological Community Crosswalk (Walz et al. 2006). Therefore, NVCS associations can usually be crosswalked with communities in these state classifications.

Several associations that share one or more dominant or characteristic species can be grouped to form an alliance. Alliances are generally more wide-ranging geographically than associations, covering multiple habitats and broader species composition. For example, the Northeastern Dry Oak - Hickory Forest association mentioned previously is grouped with other similar oak-dominated forest associations into the White Oak - (Northern Red Oak, Hickory species) Forest Alliance. An association with unique species composition or environmental niche can be assigned to its own alliance, such that the alliance only contains one association instead of multiple associations.

One level above alliance is the formation, representing vegetation types that share a common physiognomy within broadly defined environmental factors (Grossman et al. 1998). For example, Lowland or submontane cold-deciduous forest is a common formation that encompasses numerous forest types in the northeastern and midwestern United States, including the White Oak - (Northern Red Oak, Hickory species) Forest Alliance mentioned above.

One of the core strategies identified in the Wildland Fire Strategic Plan is to implement a collaborative vegetation and fuels mapping program between the National Park Service Fire Management Program and the Inventory and Monitoring Program (NPS 2003b). The mission statement of the National Park Service Fire Management Program is to protect lives, property, and resources while restoring and maintaining healthy ecosystems. One of the guiding principles of the NPS Fire Management Program is to provide current and accurate data for fire and resource managers. Spatial databases of fire behavior fuel models, forest condition, and canopy closure are examples of the types of data that are essential for fire and resource managers to adequately protect park and adjacent landowners' resources.

FARSITE is a fire growth simulation model that can be used in fire management and preparedness planning (Finney 1998). It incorporates spatial information on fuels, fire behavior, topography, weather, and wind to predict fire spread under various scenarios. In order for FARSITE to model fire spread in a specific park five spatial data inputs are required: elevation, slope, aspect, fire fuel model, and canopy cover. For the Delaware Water Gap National Recreation Area the first three data layers (elevation, slope, and aspect) can be derived from the existing digital elevation model developed by North Carolina State University for the park in 2005. The two remaining data layers (fire behavior fuel model and canopy cover) have been developed by the Pennsylvania Natural Heritage Program and are presented as part of this report.

The fire behavior fuel models described by Anderson (1982) are the most commonly used standard fuel model inputs for FARSITE. Anderson (1982) described 13 fuel models that are classified into four groups—grasses, brush, timber, and slash. These fuel models are tools to realistically estimate fire behavior. Each fuel model represents certain fire behavior that is related to fuel load, fuel depth, ratio of surface area to volume for fuel particle size classes, and fuel moisture. These variables are critical to predicting whether a fire will ignite in a given vegetation type and to describing its rate of spread and intensity under varying environmental conditions. The 13 fuel models were created for severe conditions when wildfires pose the greatest risk to natural resources (Anderson 1982). Fire resource managers for the Delaware Water Gap National Recreation Area requested that Anderson fuel models be used in the fuel model mapping at this park. The canopy cover map created for the Delaware Water Gap National Recreation Area uses four cover classes that are standard to the FARSITE program (Finney 1998).

Park-specific Information

The Delaware Water Gap National Recreation Area was established in 1965 with the intent of providing recreational opportunities in conjunction with the proposed Tocks Island Dam Project and the resulting reservoir (Albert 2002). Authorized by Congress in 1962, the Tocks Island Dam Project had a footprint of approximately 9,300 ha (23,000 ac), with the proposed impoundment stretching 59.5 km (37 mi) upstream and the tail waters reaching above Port Jervis, New York. The creation of the Delaware Water Gap National Recreation Area added another 19,000 ha (47,000ac) to the project area. Opposition to the dam began to grow during the late 1960s and gained momentum during the early 1970s due to private property, and later, environmental issues. Finally, in 1975, the Delaware River Basin Commission (DRBC) voted to stop the dam project with New York, New Jersey, and Delaware voting against the project; only Pennsylvania voted for the project, while the federal government abstained. Subsequently, in 1978, the reach of the river originally proposed for the reservoir was declared by Congress as part of the National Wild and Scenic Rivers System. While the dam project was inactive, it was not formally de-authorized until 1992 (Albert 2002).

Delaware Water Gap National Recreation Area now covers 27,945 ha (69,052 ac) and includes the area authorized for the recreation area in 1965 as well as the area acquired for the now-defunct Tocks Island Dam Project. The park stretches from its southern terminus at the Delaware Water Gap to the town of Milford, Pennsylvania at the northern terminus, a distance of approximately 55 km (34 mi). The majority of the land parcels within the park boundary are owned by the federal government, covering 23,715 ha (58,601 ac) or 84.9% of park. Approximately 2,620 ha (6,474 ac; 9.4% of park) is owned by the Commonwealth of Pennsylvania or the state of New Jersey, and includes Worthington State Forest, Delaware River Joint Toll Bridge Commission property, Walpack Wildlife Management Area, and other miscellaneous land. An additional 310 ha (766 ac; 1.1% of park) is owned by various county, town, and borough governments, typically as watershed lands, roads, rights-of-way, and parks. At present, there are also 1,300 ha (3,212 ac; 4.7% of park) of private property inholdings within the park, including a mix of residences, small businesses, and communication towers. Approximately five million people visit the park each year to enjoy hiking trails, canoeing, fishing, scenic drives, and other activities.

Project Area

Location and Regional Setting

The Delaware Water Gap National Recreation Area is located along the Delaware River and includes portions of Pike, Monroe, and Northampton counties in Pennsylvania, and Sussex and Warren counties in New Jersey (Figure 1). The park covers portions of eleven 1:24,000 USGS topographic quadrangle maps: Portland, Stroudsburg, East Stroudsburg, Bushkill, Flatbrookville, Lake Maskenozha, Culvers Gap, Milford, Edgemere, Newton West, and Port Jervis South (Figure 2).

The park occurs primarily within two sections of two physiographic provinces, the Low Glaciated Plateau Section of the Appalachian Plateau Province and the Appalachian Mountain Section of the Ridge and Valley Province. The extreme southern end of the park (south of the Kittatinny Ridge) lies in a third section, the Great Valley Section of the Ridge and Valley Province (Epstein 2001b) (Figure 3).

The Low Glaciated Plateau Section of the Appalachian Plateau Province is restricted to the western portion of the park, west of the Delaware River Valley. This section extends from approximately Bushkill to Milford within the park (total area approximately 6,000 ha). The east edge of the Glaciated Low Plateau Section is characterized by steep shale and siltstone slopes and cliffs which have been over-steepened by glacial scouring and erosion during the last Pleistocene glaciation (Epstein 2001a; Witte 2001a, 2001b). The terrain of the Low Glaciated Plateau generally consists of relatively straight valleys separated by irregular intervening ridges with moderate and variable relief and numerous small water bodies (Briggs 1999).

The Appalachian Mountain Section of the Ridge and Valley Province is the largest section within the park, covering approximately 21,000 ha (52,000 ac). This section includes the Kittatinny Ridge and extends to the south and east to the western edge of Minisink Valley (more or less the historical floodplain of the Delaware River). This area also includes several smaller ridges to the northwest of the Kittatinny Ridge. The Great Valley Section of the Ridge and Valley Province is limited to a small area of rolling hills south of the Delaware Water Gap on both sides of the Delaware River and is bounded on the north by the Kittatinny Ridge (Epstein 2001a).

Park Environmental Attributes

The vegetation of the region is generally classified as Appalachian Oak Forest, typically dominated by white oak (*Quercus alba*) and northern red oak (*Quercus rubra*), with sugar maple (*Acer saccharum*), sweet birch (Betula lenta), bitternut hickory (*Carya cordiformis*), American beech (*Fagus grandifolia*), and tuliptree (*Liriodendron tulipifera*) as associates (Braun 1950). Many environmental factors, such as geology, topography, soils, hydrology, and fire, affect the types and distribution of vegetation within Delaware Water Gap National Recreation Area.

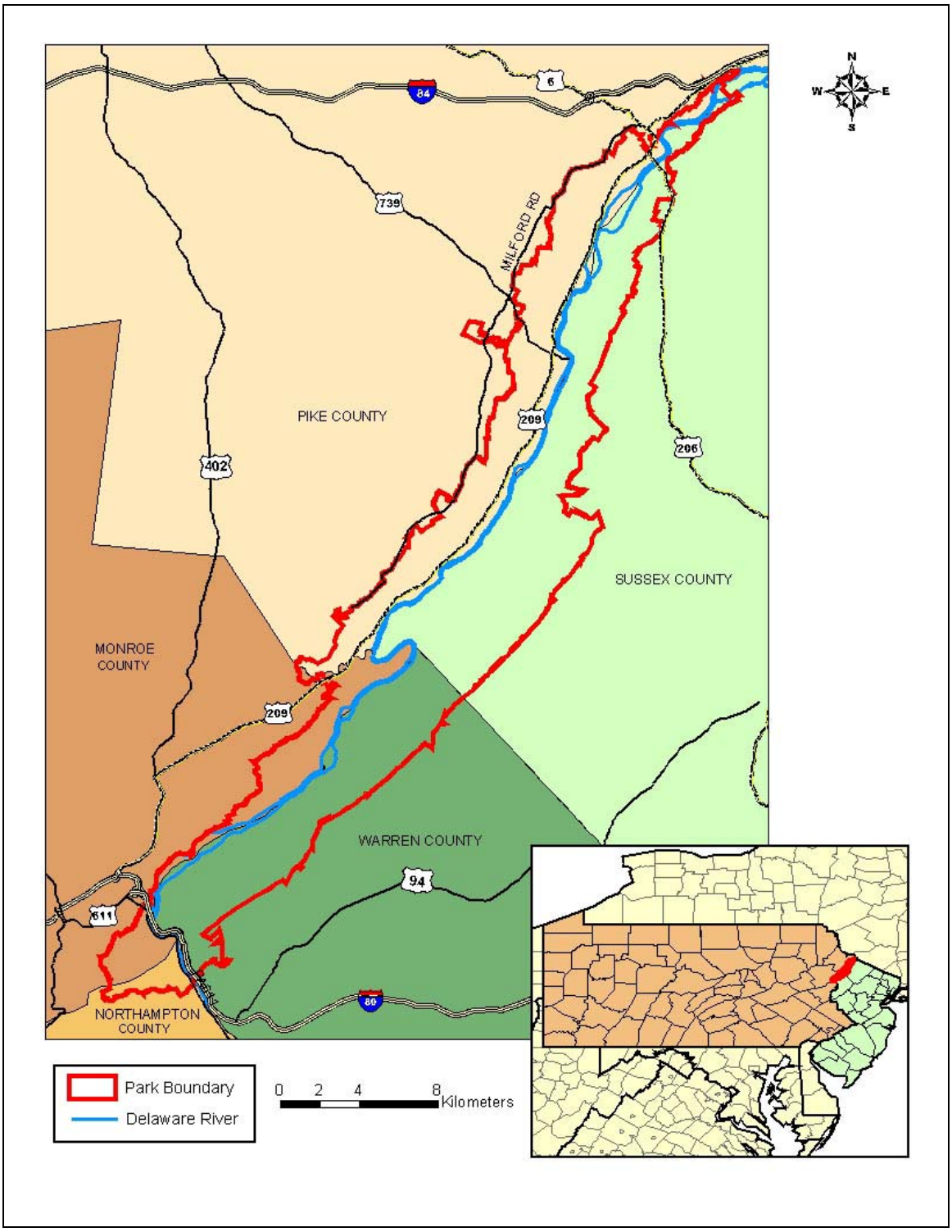

Figure 1. Location of Delaware Water Gap National Recreation Area in Northampton, Monroe, and Pike counties, Pennsylvania, and Warren and Sussex counties, New Jersey.

Figure 2. Location of Delaware Water Gap National Recreation Area on eleven 1:24,000 USGS topographic quadrangle maps.

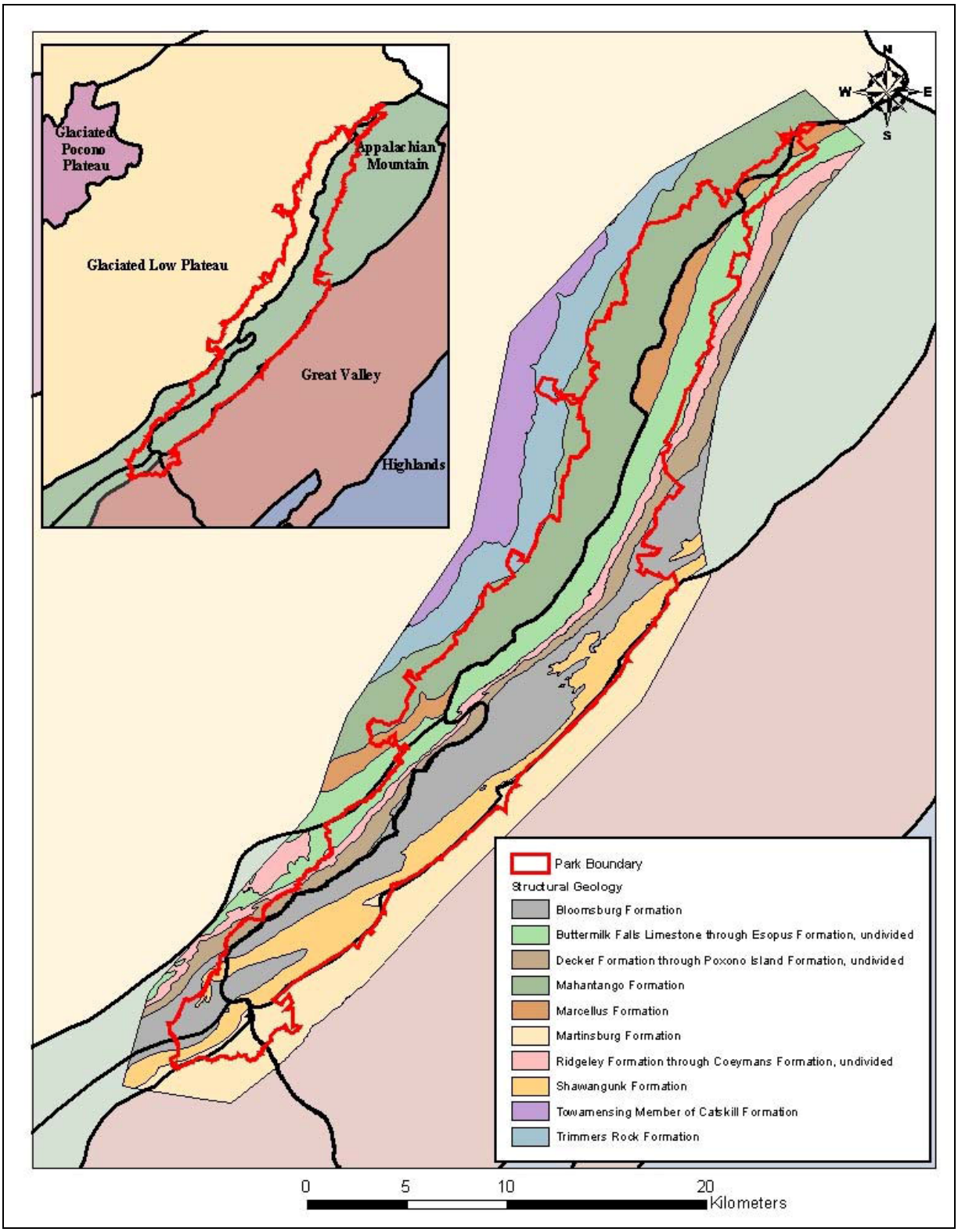

Figure 3. Physiographic province sections and structural geology of Delaware Water Gap National Recreation Area.

Geology

The structural geology of the park differs greatly among the sections of the physiographic provinces (Epstein 2001b) (Figure 3). The bedrock of the Low Glaciated Plateau Section of the Appalachian Plateau Province dips gently to the northwest with occasional gentle folds. The bedrock consists of Middle and Upper Devonian age strata, including the Marcellus Formation (shale and shaly limestone), the Mahantango Formation (siltstone and silty shale), and the Trimmers Rock Formation (siltstone, shale, and fine-grained sandstone). The Marcellus Formation is limited to a narrow band near Bushkill Creek. The Mahantango Formation is the dominant formation within the Low Glaciated Plateau Section of the park and forms the rolling uplands as well as the steep cliffs and escarpments along the western edge of the Delaware River valley. The Trimmers Rock Formation is limited to the extreme western portion of the park and includes the upper portion of Dingmans Creek near Fulmers Falls.

Within the park, the Appalachian Mountain Section of the Ridge and Valley Province consists of strongly folded Ordivician, Silurian, and Devonian age strata. The Ordivician stratum consists of slate and sandstone of the Martinsburg formation. This stratum is limited to the southwestern portion of the park near the Delaware Water Gap where it forms the lowest portion of the southeast facing slope of Kittatinny Mountain. Directly above and to the northwest of the Martinsburg Formation lies the Silurian Shawangunk Formation consisting of (from oldest to youngest): the Minsi Member (quartzite, conglomerate quartzite, and conglomerate), the Lizard Creek Member (thin to thick interbedded quartzite and argillite shale), and the Tammany Member (conglomerate and quartzite). The weather-resistant quartzite beds of the Shawangunk Formation form the ridge and cliffs associated with the Kittatiny Ridge and the Delaware Water Gap. Northwest of the Shawangunk Formation lies the Silurian Bloomsburg Red Beds which lie in the center of the Dunnfield Syncline (along Dunnfield Creek) near the Delaware Water Gap and along the northwest facing slope of most of the Kittatinny Ridge.

Northeast of the Walpack Ridge, the Bloomsburg Red Beds Formation extend from the toeslope of the Flat Brook floodplain to just below the summit of the Kittatinny Ridge (capped by the Shawangunk Formation). The Bloomsburg Red Beds Formation varies in composition from relatively weather-resistant silica-cemented sandstone and sandstone conglomerate to more easily weathered clayey sandstone, siltstone, and shale. Adjacent to the Bloomsburg Red Beds to the northwest are a series of Upper Silurian Formations, mapped as one unit (Decker, Bossardville Limestone, and Poxono Island Formations), which consists of limestone, dolomite, calcareous sandstones and shales, and sandstone, siltstone and sandstone conglomerate. South of Walpack Bend, these formations form the southeast facing slope of the Delaware River valley (including The Hogback) until approximately Shawnee-on-Delaware. North of Walpack Bend these formations trend to the northeast, forming the bottom of the Flat Brook valley and low rolling hills at the foot of the Kittatiny Ridge.

Parallel and to the northeast of the Upper Silurian Formations lie Lower Devonian bedrock consisting of six formations (Ridgely, Shriver Chert, Port Ewen Shale, Minisink Limestone, New Scotland, and Coeymans formations), mapped as one unit (Ridgeley through Coeysmans Formations), in Figure 3. This unit is characterized by numerous alternating beds of limestone, calcareous shale, calcareous sandstone, and sandstone conglomerate. This unit extends approximately from north of Depue Island to the northeast through the ridge of the Hogback at

Walpack Bend, eventually exiting the park near Peters Valley. The topography associated with the formation is low ridges and rolling hills. North of Walpack Bend this formation forms the northwest slope of the Flat Brook valley. The furthest western unit of the the Appalachian Mountain Section of the Ridge and Valley Province consists of Lower to Middle Devonian bedrock of the Esopus (silty shale and siltstone), Schoharie (calcareous siltstone), and Buttermilk Falls (limestone) Formations. The Buttermilk Falls formation is of particular interest as it appears to be associated with several rare calcareous plant communities within the park (Arnot and Montague Fens, Montague Calcareous Riverside Seep, and Calcareous Riverside Outcrop). Northwest of this unit is the transition to the Low Glaciated Plateau Section of the Appalachian Plateau Province, as indicated by the Devonian Age Marcellus Formation as discussed above.

The Great Valley Section of the Ridge and Valley Province occurs at the extreme southern tip of the park, south of Kittatinny Ridge and the Delaware Water Gap. The only geologic unit within the park portion of the Great Valley Section is the Ordivician Age Martinsburg Shale which occurs as relatively flat to gently rolling terrain.

Topography

Topography varies widely within the park. This is illustrated most dramatically at the Delaware Water Gap where the Delaware River (elevation 90 m [300 ft]) cuts through the Kittatinny Ridge creating spectacular views from Mt. Tammany (470 m [1,549 ft]) and Mt. Minsi (445 m [1,461 ft]). The elevation of the Delaware River floodplain decreases as the river runs through the park, from approximately 120 m (400 ft) at Mashipacong Island at the park's northern boundary to approximately 90 m (300 ft) at Arrow Island just south of the Delaware Water Gap. The height of the Kittatinny Ridge varies between 425 m and 487 m (1,400–1,600 ft) with one of the highest points occurring north of Crater Lake at 490 m (1,606 ft). The Hogback and Walpack Ridge run through the central portion of the park with height varying from 210 m to 365 m (700–1,200 ft). The plateau of the Low Glaciated Plateau sits at approximately 245 m to 290 m (800–950 ft), although elevation along the plateau can vary from 210 m to 320 m (700–1,055 ft). The northeast portion of the park in New Jersey gently rises from the Delaware River floodplain at 120 m to approximately 245 m (400–800 ft) at the park's eastern boundary. The valleys surrounding Flat Brook and Bushkill Creek occur at approximately 245 m (400 ft) in elevation.

Soils

Soils in the park vary by topographic position. Typical floodplain soils are fine sandy loams, including Delaware, Pope, Colonie, Barbour, Wallpack, Wyalusing, Philo, and Udifluvent soil series. Lower slopes and valleys tend to contain silt loams and sandy loams, typically Alden silt loam, Chenango gravelly fine sandy loam, Lordstown-Wallpack complex, Scio silt loam, Venango silt loam, Wallpack silt loam, Wellsboro silt loam, and Wyoming gravelly sandy loam. The soils of the Kittatiny Ridge tend to be complexes of rocky loams, silt loams, and sandy loams. Arnot, Benson, DeKalb, Hazen, Hoosic, Lackawanna, Lordstown, Manlius, Mardin, Morris, Nassau, Oquaga, and Otisville are typical soil series found in soil complexes on the ridge. Wetlands that occur at high elevations on the ridge tend to contain Alden mucky silt loam or Catden mucky peat. Soils typical of the Low Glaciated Plateau are rocky loams or soil complexes, primarily Arnot, Manlius, and Mardin, and less commonly, Oquaga, Lordstown,

Benson, Lackawanna, Edgemere, and Shohola series. Wetlands on the Low Glaciated Plateau tend to contain Paupack mucky peat.

Hydrology

The Delaware River, one of the last large free-flowing rivers left in the eastern United States, is the major hydrologic feature around which the park is centered. Nearly 70 km (42 mi) of the 530 km (330 mi) long Delaware River occurs within the park. Several major tributaries and smaller streams flow through the park into the Delaware River. In New Jersey, the Flat Brook is a significant major tributary, running through a valley between the Walpack Ridge and the Kittatiny Ridge from the eastern park boundary to the Delaware River. Buttermilk Falls Brook and Fuller Brook drain from the Kittatiny Ridge into the Flat Brook. Several small tributaries drain directly into the Delaware River from park land in New Jersey; however, Shimer's Brook and White Brook are the only two named streams. Van Campen Brook and Dunnfield Creek are two other major tributaries that originate on top of the Kittatiny Ridge and drain into the Delaware River.

In Pennsylvania, many of the tributaries flow off of the Glaciated Low Plateau through steep ravines that are often dominated by eastern hemlocks (*Tsuga canadensis*) and contain waterfalls of various heights. The larger and most visited of these streams are Raymondskill Creek, Adams Creek, Dingmans Creek, and Toms Creek. Smaller tributaries that flow from the Glaciated Low Plateau into the Delaware River include Conashaugh Creek, Dry Brook, Hornbecks Creek, Spackmans Creek, Alicia's Creek, Broadhead-Heller Creek, Mill Creek, Denmark Creek, VanCampen Creek, and Randall Creek. The Big Bushkill Creek, a major Pennsylvania tributary, is joined by Little Bushkill Creek before it enters the Delaware River just upstream of the Hogback. Three additional tributaries, Broadhead Creek, Cherry Creek, and Caledonia Creek, enter the Delaware River just upstream from the Delaware Water Gap.

Numerous ponds and small lakes are scattered throughout the park, many of which are recreational attractions. The waterbodies on the top of Kittatiny Ridge are either depressions carved by glacial activity, such as Sunfish Pond and Crater Lake, or impoundments created by damming a stream, such as Catfish Pond and Blue Mountain Lake. Most other waterbodies that do not occur on Kittatiny Ridge are impoundments created either by man, such as Egypt Mills Pond and Hidden Lake, or by beaver. Some smaller ponds lie in naturally occurring depressions.

Fire

Historically, fire has been an important influence on the Appalachian forests of the eastern United States. Low-intensity fires were ignited by lightning, as well as by Native Americans and Europeans settlers, who used fire to aid in hunting, to clear land, to maintain open grasslands and woodlands, and to encourage the growth of forage or food plants (Day 1953; Waldrop and Van Lear 1989; Delcourt and Delcourt 1998). The majority of the hardwood forests in the Delaware Water Gap National Recreation Area are adapted to this natural fire regime of frequent, low-intensity, low-severity surface fires that are generally non-lethal to the canopy trees but lethal to the understory vegetation. This fire regime is classified as Natural Fire Regime 1B (Heinselman 1981) or Historic Natural Fire Regime I (Schmidt et al. 2002) and has a return interval of more than 25 years, on average 35 years, between fires (Heinselman 1981; Schmidt et al. 2002). This

historic fire regime is not necessarily representative of the current condition of the park's vegetation.

During the industrial revolution around the turn of the 20th century, high-intensity, catastrophic fires became much more common due to intensive timber harvesting and steam locomotives. The destruction caused by these fires led to the fire suppression and control strategies enforced throughout the 20th century (Waldrop and Van Lear 1989; Shumway et al. 2001; Schuler and McClain 2003). Due to this fire suppression the historic fire regime has been altered. Schmidt et al. (2002) classified the forests in the region around the Delaware Water Gap National Recreation Area as Current Condition Class 2 to 3, indicating that historic fire regimes have been moderately to severely altered, posing a risk to the native ecosystems, and requiring varied levels of restoration treatments. Restoration and maintenance methods could include prescribed fire and hand or mechanical treatments. In general, in the Delaware Water Gap region, fires under "normal" non-drought conditions were determined to be of relatively low risk to homes and other flammable structures for most, but not all, of the fuel models represented (Schmidt et al. 2002).

Materials and Methods

Planning and Scoping

Several steps were taken to prepare for the vegetation classification and mapping of fire fuel models and vegetation at Delaware Water Gap National Recreation Area. Two planning and review meetings were held on June 4, 2001 and January 9, 2003 with ecologists from the Pennsylvania Natural Heritage Program and National Park Service (NPS) scientists, resource managers, fire specialists, and GIS specialists. The project timeline, mapping product specifications, access issues, natural resource management needs, available applicable GIS layers, and applicable previous and current research conducted at the park were discussed. A third meeting was held on April 25, 2003 with National Park Service Fire Management Program specialists to discuss the desired specifications for the fire fuel model mapping products.

Preliminary Data Collection and Review of Existing Information

Previous studies conducted at Delaware Water Gap National Recreation Area were obtained from the park's natural resource manager and reviewed for information pertinent to the park's vegetation. These reports included previous vegetation cover type mapping and rare species surveys (Myers and Irish 1981; Radis 1986). In addition, shapefiles containing digital information on bedrock geology, soils, streams, waterbodies, wetlands, agricultural fields, roads and trails, park boundaries, and parcel ownership were obtained from the park's GIS specialist.

Aerial Photography Acquisition and Processing

Color infrared, stereo pair 1:12,000 scale aerial photography for a digital orthophoto mosaic of Delaware Water Gap National Recreation Area was acquired from overflights on March 28, April 7, and April 11, 2002, during leaf-off conditions, by Kucera International. The photography, a total of 1,047 air photos that cover the park as well as a relatively large buffer area outside the park, was delivered to the National Park Service, quality checked, accepted as provided, and sent to North Carolina State University (NCSU). Upon receipt at NCSU, the air photos were counted to make sure that none were missing, scanned, and placed in the air photo archive maintained at NCSU for the NPS Northeast Region Inventory & Monitoring Program. Associated data and information provided by Kucera International, also stored in the air photo archive, included the airborne global positioning system and inertial mapping unit (GPS/IMU) data files, the camera calibration certificate for the camera, and the hardcopy flight report for the photography that crosswalks the airborne GPS/IMU data to the photo frame numbers.

The digital aerial photo mosaic was produced from the 151 color infrared air photos that cover the area within the park boundary, scanned at 600 dpi with 24-bit color depth. The scanned images of the air photos were imported into ERDAS Imagine (.img) format where a photo block was created using airborne GPS and IMU data that Kucera International supplied with the aerial photography. The photo block was manipulated until it could be triangulated with a root mean square error of less than 1. At this point, single frame orthophotos (one for each air photo) were generated within Imagine, the orthophotos were mosaicked in Imagine using an algorithm that

contained color balancing and cutline information. Finally, the mosaic (.img image) was compressed using MrSID software with a 20:1 compression ratio.

A metadata record for the mosaic was prepared according to current Federal Geographic Data Committee standards (FGDC 1998a). Metadata were produced in notepad and parsed using the U.S. Geological Survey (USGS) metadata compiler program (MP) to locate errors and omissions (USGS 2004). After all errors and omissions were corrected MP was used to generate final TXT, HTML, and XML versions of the metadata record, which are stored in the air photo archive. Key information for the Delaware Water Gap National Recreation Area photo mosaic is summarized in Table 1.

Photointerpretation

After receiving the digital orthophoto mosaic and hard copy photographs from North Carolina State University, ecologists at the Pennsylvania Natural Heritage Program developed a vegetation cover type map that identified broad vegetation types. The vegetation cover types were differentiated based on vegetation structure, leaf phenology, and hydrologic regime because these characteristics can be easily identified on aerial photography. This map was developed as a guide over which the vegetation sampling efforts would be distributed.

The vegetation cover type map was created through aerial photograph interpretation. Aerial photograph interpretation is the act of examining aerial photographs in order to identify objects, in this case, vegetation types (Avery 1978). The diapositive photographs (color infrared, stereo pair, hard copy photographs) were examined through a mirror stereoscope type F-71 which provides the viewer with a three-dimensional view of the photographs. The digital orthophoto mosaic was also examined onscreen in ArcView 3.2 (ESRI 1992–2000a). In addition, digital topographic quad maps were examined in ArcView 3.2. Using information gathered from the diapositives, the mosaic, and the topographic maps, polygons representing different vegetation cover types and land uses were identified. These polygons were digitized onscreen using ArcView 3.2.

Polygons that represented vegetation were attributed with vegetation cover types (Table 2). Nine polygons were labeled as a mosaic of two vegetation cover types, Deciduous Forest and Talus or Scree (i.e., Deciduous Forest / Talus or Scree). These polygons were labeled as mosaics because both types were present in the polygon, but clear boundaries between the two types could not be delineated. Polygons that represented sparse vegetation over naturally occurring geologic features were labeled by substrate type, including Cliff, Cobble Bar, Ridgetop Bedrock Outcrop, and Talus or Scree. These vegetation cover types are not modified Anderson level II categories (see following paragraph) because they could represent sparse vegetation associations that are important to the park.

Polygons that represented other land uses, such as buildings and roads, were attributed with map labels modified from the Anderson level II categories (Anderson et al. 1976). Please note that the Anderson land use and land cover classification (1976) is unrelated to the Anderson fire behavior fuel models (1982) also used in this report. Table 3 lists the modified Anderson level II categories used in the cover type map and shows the relationship between these map labels and the Anderson level I and level II classifications. The Anderson classification was modified in

Table 1. Summary of key information for the Delaware Water Gap National Recreation Area photo mosaic.

Title of metadata record:	Delaware Water Gap National Recreation Area Color Infrared Orthorectified Photomosaic - Spring (leaf-off) (dewa_spring.img and dewa_spring.sid)
Publication date of mosaic (from metadata):	March 1, 2003
Date aerial photography was acquired:	March 28, April 7, and April 11, 2002
Vendor that provided aerial photography:	Kucera International
Scale of photography:	1:12,000
Type of photography:	Color infrared, stereo pairs
Number of air photos in mosaic:	151
Archive location of air photos, airborne GPS/IMU files and camera calibration certificate	North Carolina State University, Center for Earth Observation
Scanning specifications:	600 dpi, 24-bit color depth
Horizontal positional accuracy of mosaics: Accuracy Standard	2.448 meters, meets Class 1 National Map
Number of ground control points upon which estimated accuracy is based:	41
Method of calculating positional accuracy:	Root mean square error (RMSE)
Archive location of mosaics and metadata:	North Carolina State University, Center for Earth Observation
Format(s) of archived mosaics:	.img (uncompressed); MrSID (20:1 compression)

Table 2. Number of polygons, mapped hectares within the park boundary, and number of plots sampled in vegetation cover types and Anderson level II categories (modified) at Delaware Water Gap National Recreation Area.

Vegetation Cover Type	Number of Polygons	Mapped Hectares within the Park Boundary	Number of Plots Sampled
Cliff	112	134.05	8
Cobble Bar	2	0.62	2
Deciduous Forest	1,163	12,072.77	67
Deciduous Forest / Talus or Scree	9	31.45	1
Deciduous Plantation	4	10.58	0
Deciduous Shrubland	169	534.82	7
Deciduous Woodland	63	131.45	5
Evergreen Forest	330	2,079.50	20
Evergreen Plantation	51	158.34	2
Evergreen Woodland	120	201.37	5
Grassland	229	520.18	11
Mixed Evergreen - Deciduous Forest	838	5,946.35	43
Mixed Evergreen - Deciduous Shrubland	164	583.53	11
Mixed Evergreen - Deciduous Woodland	127	330.95	6
Ridgetop Bedrock Outcrop	86	61.21	5
Saturated Herbaceous Vegetation	45	86.06	13
Seasonally Flooded Deciduous Forest	23	57.98	2
Seasonally Flooded Mixed Evergreen - Deciduous Forest	4	6.33	1
Seasonally Flooded Mixed Evergreen - Deciduous Shrubland	11	31.16	3
Semipermanently Flooded Deciduous Shrubland	10	20.05	3
Semipermanently Flooded Herbaceous Vegetation	20	26.04	5
Talus or Scree	28	28.19	0
Temporarily Flooded Deciduous Forest	150	882.03	13
Temporarily Flooded Deciduous Shrubland	16	58.12	7
Temporarily Flooded Deciduous Woodland	30	98.35	2
Temporarily Flooded Herbaceous Vegetation	54	65.72	7
Temporarily Flooded Mixed Evergreen - Deciduous Forest	24	194.00	2
Anderson level II category (modified)			
Built-up Land	131	351.97	0
Cropland	205	1,449.10	0
Pond	246	294.46	0
Right-of-way	22	56.94	0
River	12	1,184.97	0
Shale Pit	10	12.73	0
Transportation Corridor	12	130.98	0
Total	4,520	27,832.33	251

Table 3. Relationship between Anderson level II category (modified) map labels and the Anderson level I and II classifications.

Anderson level II (modified) map label	Anderson level I	Anderson level II	Anderson level II number
Built-up Land	Urban or Built-up Land	Residential	11
		Commercial and Services	12
		Industrial	13
		Industrial and Commercial Complexes	15
		Mixed Urban or Built-up Land	16
		Other Urban or Built-up Land	17
Cropland	Agricultural Land	Cropland and Pasture	21
Pond	Water	Lakes	52
		Reservoirs	53
Right-of-way	Urban or Built-up Land	Transportation, Communications, and Utilities	14
River	Water	Streams and Canals	51
Shale Pit	Barren Land	Strip Mines, Quarries, and Gravel Pits	75
Transportation Corridor	Urban or Built-up Land	Transportation, Communications, and Utilities	14

order to provide more specific information to the park and to avoid photo interpretation of human uses of various building types. For example, instead of Transportation, Communications, and Utilities, the map label Transportation Corridor was used for all roads and highways, while Right-of-way was used to label utility and communication corridors. Also, the use of specific buildings within the park was not distinguished by Residential, Commercial, Industrial, etc, but rather labeled with the generic map unit, Built-up Land. Given the focus on vegetation and fire fuel model mapping in this project, it was inappropriate to spend additional time mapping building uses and testing the accuracy of such map attributes.

To determine which vegetation cover types or modified Anderson level II categories should be assigned to each polygon, an aerial photography interpretation key (Appendix A) was used. The resulting vegetation cover type map (Figure 4) identified 4,520 map polygons, each labeled with a vegetation cover type or a modified Anderson level II category (Table 2). This vegetation cover type map was used to guide vegetation plot sampling in the park.

Field Data Collection and Classification

All vegetation plot sampling followed the USGS/NPS Vegetation Mapping Program protocols (TNC and ESRI 1994b). The Delaware Water Gap National Recreation Area is considered a large park (278 km^2 [107 mi^2]) for which the gradient directed transect sampling (gradsect) approach should be used. The gradsect approach is a variant of a stratified random sampling strategy that intends to efficiently describe the full range of vegetation by sampling along the full range of environmental variability (Gillison and Brewer 1985; Austin and Adomeit 1991). Gradsects are areas of the park selected for sampling that contain the strongest environmental gradients and that are reasonably accessible. This strategy optimizes the amount of data collected relative to the time and effort spent during vegetation sampling. The total area of the gradsects should include at least 15% of the park area (TNC and ESRI 1994b).

In order to select gradsect areas several environmental gradients and factors were examined, including elevation, slope, aspect, and geology. Due to the orientation of the Delaware Water Gap National Recreation Area around the Delaware River these factors form strong environmental gradients from the river to the ridgetops in both Pennsylvania and New Jersey. Thirteen potential gradsects, stretching from rivershore to the park boundary, were identified. These gradsects were distributed along the length of the park and on both sides of the river in order to capture environmental gradients between the southern and northern ends of the park, as well as the eastern and western sides of the river. For each of these potential gradsects, land ownership, accessibility, bedrock geology, and diversity of vegetation cover types were then assessed. Seven gradsects that contained publicall owned land, reasonable access, and representative diversity of bedrock geology and vegetation cover types were selected for sampling (Figure 5). Three gradsects were located in Pennsylvania and four occurred in New Jersey. These gradsects encompassed 5,377 ha (13,281 ac) in total, covering 19% of the park area.

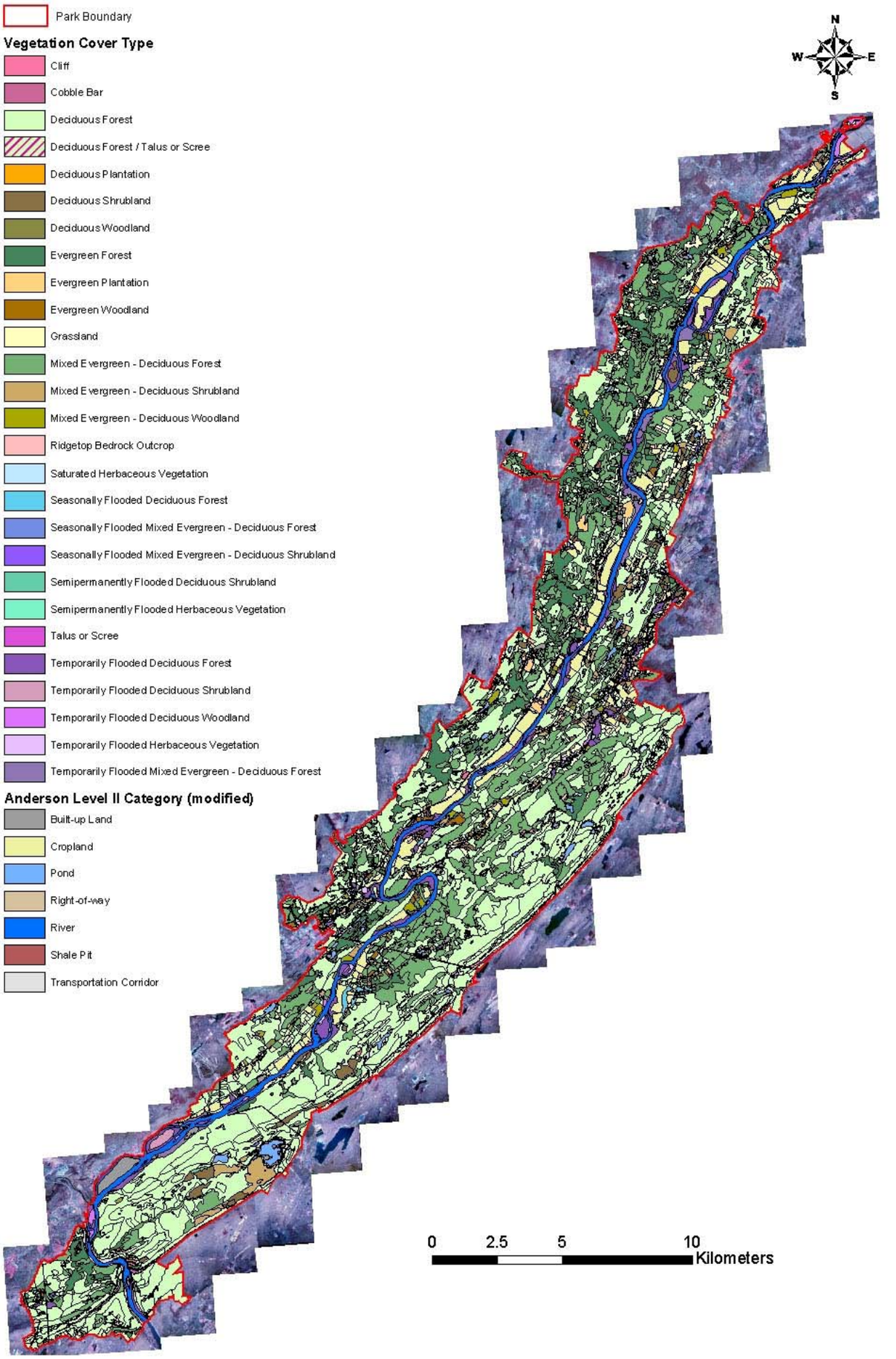

Figure 4. Vegetation cover types and Anderson level II categories (modified) delineated in the Delaware Water Gap National Recreation Area in order to guide vegetation plot sampling.

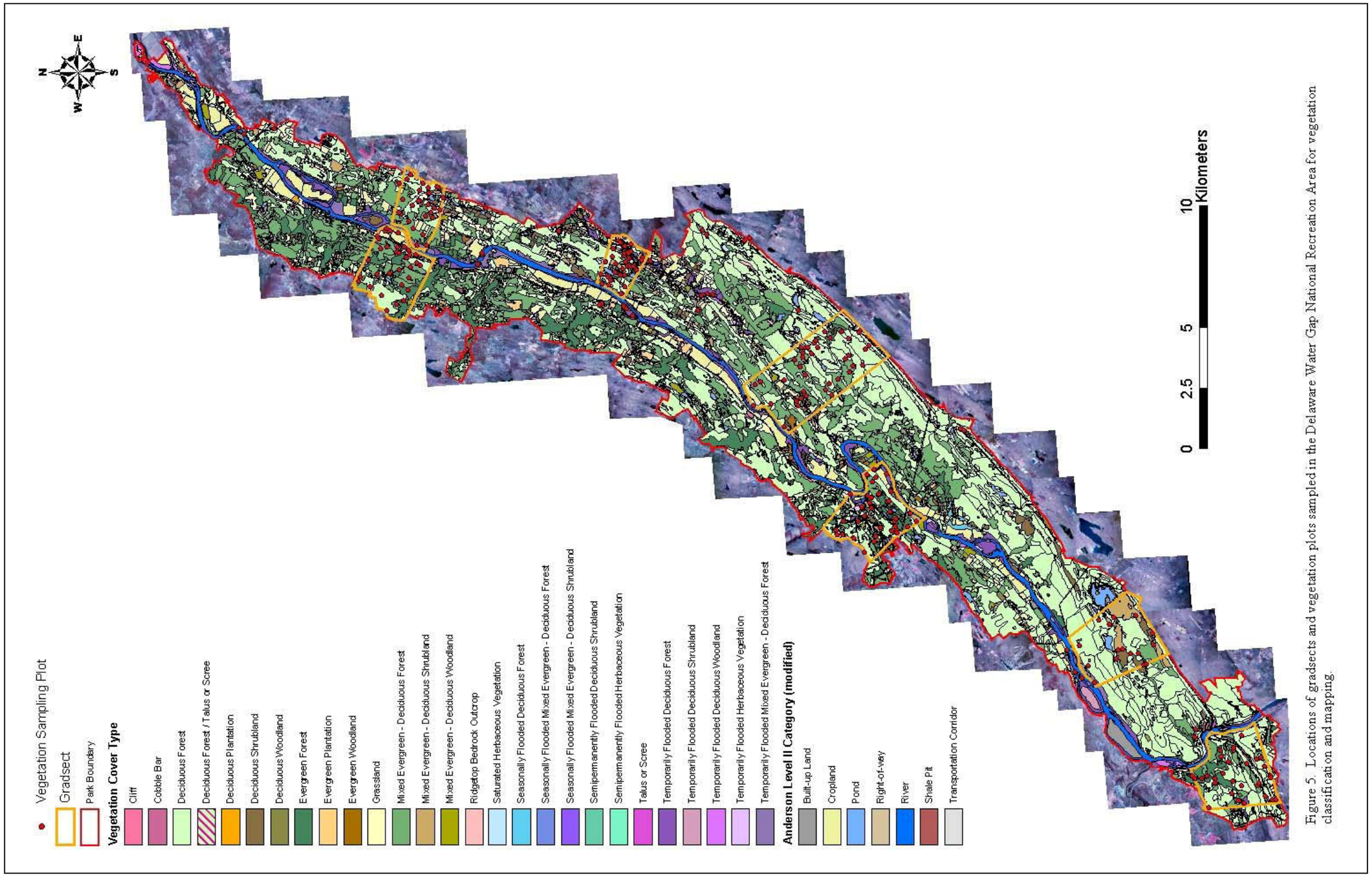

Figure 5. Locations of gradsects and vegetation plots sampled in the Delaware Water Gap National Recreation Area for vegetation classification and mapping.

To determine the number of plots that should have been sampled in each gradsect the vegetation cover type map was used as a guide. The number of vegetation cover types and the number of polygons per cover type in each gradsect was examined. The USGS/NPS Vegetation Mapping Protocol suggests that each vegetation association should have been sampled at least three times in order to capture the naturally occurring variation within the park (TNC and ESRI 1994b). Therefore, in each gradsect, at least three polygons of each vegetation cover type were selected for sampling. For vegetation cover types with less than three polygons, each polygon was selected for sampling. For cover types with numerous polygons, or for types that covered large areas, polygons were selected that represented different aerial photograph signatures and environmental settings in order to capture the natural range of variability of the vegetation. Polygons that represented modified Anderson level II categories were not sampled.

In addition to the gradsect sampling, vegetation cover types not adequately sampled by the gradsect method were targeted. Temporarily flooded and semipermanently flooded vegetation cover types on Delaware River islands and shoreline were accessed by canoe and sampled over a three-day period. Rare wetland and ridgetop communities identified in previous surveys were visited and sampled during six additional days. Towards the end of the second field season of plot sampling the distribution of vegetation cover types sampled was compared to the distribution of all vegetation cover types in the park. Cover types that were underrepresented by the plot sampling were targeted for additional field visits. During these field visits it was determined that most of the vegetation encountered were already adequately sampled; however, some additional plots were sampled in vegetation that differed from previously sampled plots.

Field Survey

Within each polygon selected for sampling a plot was established in an area that was most representative of the existing vegetation association (Mueller-Dombois and Ellenberg 1974). All vegetation data were collected following NatureServe's accepted natural heritage sampling protocols (Strakosch-Walz 2000), with 20-m × 20-m plots in forests and woodlands, 10-m × 10-m plots in shrublands, and 5-m × 5-m plots in herbaceous vegetation. The plot sampling data form used in this project is shown in Appendix B. The vegetation was visually divided into eight strata: emergent trees (variable height), tree canopy (variable height), tree subcanopy (>5m in height), tall shrub (2–5m), short shrub (<2m), herbaceous, non-vascular, and vines. The percent cover was estimated for each species in each stratum using modified Braun - Blanquet cover classes (Strakosch-Walz 2000). Specimens of species that were not identifiable in the field were collected for later identification. The diameter at breast height (dbh 1.3 m) was measured with a Biltmore stick or a diameter tape for all trees larger than 10 cm in diameter that were rooted in the plot. The diameters were recorded by species and strata.

In addition to floristic information, other environmental variables recorded at each plot included slope, aspect, topographic position, hydrologic regime, soil stoniness, average soil texture, and soil drainage. Any unvegetated area of the plot was characterized by the exposed substrate. Notes were taken on the plot representativeness of the surrounding vegetation and any other significant environmental information, such as landscape context, herbivory, stand health, recent disturbance, or evidence of historic disturbance. The vegetation profile and topographic position were sketched in cross-section to represent the location and setting of the plot.

The vegetation in each plot was assigned one of the Anderson (1982) fire fuel models and justification for the assignment was written on the field form. Canopy cover in the plot was assigned to one of four canopy cover classes (1=1–20%; 2=21–50%; 3=51–80%; 4=81–100%) required by the FARSITE software. In forest stands with sufficient ladder fuels to ignite a crown fire, the average crown height, average height to live crown, and average crown width were measured with a Biltmore stick or meter tape and recorded. However, only one of the 251 plots contained forest with sufficient ladder fuels to ignite a crown fire.

A digital photograph of each plot was also taken. The location of each plot was recorded with one of the following global positioning system (GPS) units: Garmin III+ in conjunction with CSI MBX-3 2 channel Automatic Differential Beacon Receiver, or Trimble Pocket Pathfinder in conjunction with Beacon-on-a-Belt and a Compaq Ipaq Pocket PC interface. The datum on the GPS unit was set to North American 1983 (Conus) and the coordinate system was set to Universal Trans-Mercator (UTM) zone 18.

Plot sampling was conducted from May through September in 2003 and 2004. In total, 251 plots were sampled throughout the park (Figure 5). The distribution of plots by vegetation cover type is shown in Table 2. No polygons labeled Talus or Scree were sampled because the majority of these polygons are inacessable and/or dangerous. However, sandstone talus included in this type was sampled in a mosaic polygon, Deciduous Forest / Talus or Scree. No polygons labeled Deciduous Plantation were sampled; however, these larch (*Larix* sp.) plantations were captured in some of the Mixed Evergreen - Deciduous Plantation polygons that were sampled.

Vegetation Classification and Characterization

Data from the 251 vegetation plots were entered into the NatureServe PLOTS 2.0 Database System on a Microsoft Access platform during winter 2003–2004 and winter 2004–2005. In the PLOTS 2.0 database, species were assigned standardized codes based on the *PLANTS Database, Version 3.5* developed by the Natural Resource Conservation Service in cooperation with the Biota of North America Program (USDA, NRCS 2004). For this report, some common names listed in the PLANTS Database were changed to reflect the common names typically used by ecologists and resource managers in this region. The common and scientific names of plants observed during the vegetation plot sampling are listed in Appendix C. Some tree and shrub seedlings and immature herbaceous plants could only be identified to the genus level and are therefore listed in the appendix as such. Environmental variables and species percent cover data were exported from the PLOTS database into Excel in order to be manipulated into a format compatible with PC-ORD version 4.0 Multivariate Analysis software (McCune and Mefford 1999).

The vegetation plot data were analyzed using several multivariate statistical techniques available in the PC-ORD software. In general, the analyses were designed to progressively fragment the dataset into more workable subsets using cluster analysis, two-way indicator species analysis, and non-metric multidimensional ordination analysis. Different techniques were employed to provide multiple lines of evidence from which to interpret the results. For a detailed discussion of the statistical techniques used in this study, please refer to McCune and Grace (2002). The data analysis and interpretation process was iterative in order to identify and analyze increasingly finer groups until vegetation associations were characterized.

Cluster analyses were performed using the percent cover of species data. This agglomerative analysis produces a hierarchical classification of the plots based on the similarity in their species composition. Euclidean distance measure and Ward's group linkage method were used in this analysis. Two-way indicator species analyses (TWINSPAN) were also performed using the percent cover of species data. This divisive analysis successively divides the plots into groups that are similar in species composition (Hill and Gauch 1979). Non-metric multidimensional ordination analyses (NMS) were performed using both the percent cover of species and the environmental variables from the plots. NMS is an ordination technique well suited to non-normal data sets (Kruskgal and Wish 1978). In this analysis Sorensen distance measure, a random starting configuration, and a stability criterion of 0.005 were employed. Forty runs were performed with the real data, with a maximum of 400 iterations.

The results of the classification analyses were then evaluated and compared to the Terrestrial and Palustrine Plant Communities of Pennsylvania (Fike 1999), Draft New Jersey Ecological Community Crosswalk (Walz et al. 2006), vegetation classifications at other national parks, and the ecologists' field experiences at the Delaware Water Gap National Recreation Area. Based on this evaluation, preliminary vegetation associations were identified. Compositional statistics were calculated to evaluate the consistency of associations and to assist in naming and describing the community types. Total and relatve cover, total and relative frequency, and relative importance value of each species were calculated by association. To compute total and relative cover the cover classes used in the field were converted to the midpoints of their respective percent ranges. Relative importance value of each species was calculated by averaging the relative cover and the relative frequency of that species.

After local, park-specific descriptions had been developed for the preliminary vegetation associations, based on the analyses described above, these associations were then crosswalked to the National Vegetation Classification System (NVCS). The NVCS was developed by ecologists of the Natural Heritage Program network and The Nature Conservancy after many years of literature review, data collection, and data anlysis. This collaborative effort culminated in the publication of *International Classification of Ecological Communities: Terrestrial Vegetation of the United States* (Grossman et al. 1998). The International Classification of Ecological Communities, now known as the International Vegetation Classification, of which the NVCS is a subset, has been revised and refined since 1998 and is now managed by NatureServe in continued collaboration with the network of Natural Heritage Programs. The classification is housed in the Biotics database and is updated regularly. The upper levels of the NVCS were adopted as a standard by the Federal Geographic Data Committee to support the production of uniform statistics on vegetation at the national level (FGDC 1996). The Vegetation Mapping Program of the National Park Service adopted the alliance level and, where possible, the association level, as the mapping unit for national parks.

The crosswalk to the NVCS for each association was determined through qualitative comparison of the preliminary park-specific local vegetation associations to existing associations in the National Vegetation Classification System by searching for alliances sharing similar dominant species, as well as physiognomy and environmental setting. Total floristic composition was used to determine the appropriate association within the alliance. Global information on the associations from the NVCS was then appended to the local descriptions to provide resource managers with a broader context for the vegetation in the park.

Each preliminary vegetation association was assigned a common name based on the Terrestrial and Palustrine Plant Communities of Pennsylvania (Fike 1999) or Draft New Jersey Ecological Community Crosswalk (Walz et al. 2006). If no appropriate name existed in Fike (1999) or Walz et al. (2006), the National Vegetation Classification System common name was used, or a park-specific common name was created in the case of successional and cultural vegetation types not easily handled by Fike (1999), Walz et al. (2006), or the NVCS.

A park-specific dichotomous key was created for the vegetation associations to guide accuracy assessment and for use by park natural resource managers and others (Appendix D). A dichotomous key is a tool for identifying unknown entities—in this case, vegetation associations. It is structured by a series of couplets, two statements that describe different, mutually exclusive characteristics of the associations. Choosing the statement that best fits the association in question leads the user to the correct association. The dichotomous key should be used in conjunction with the detailed vegetation association descriptions to confirm that the association selected with the key is appropriate.

Map Preparation

Following the vegetation data analysis, the vegetation cover-type map was edited and refined to develop a preliminary association-level vegetation map. Using ArcView 3.2, polygon boundaries were revised onscreen based on the plot data, field observations, classification analyses, aerial photography signatures, and topographic maps. Each polygon was assigned the name of a preliminary vegetation association based on the five information sources listed above. A mirror stereoscope type F-71 and a Bausch and Lomb zoom stereoscope were used to interpret the aerial photography signatures. An aerial photograph interpretation key for the vegetation associations and Anderson level II categories (modified) is located in Appendix A. Numerous polygons were labeled as mosaics of two associations because both types were present in the polygons, but clear boundaries between the two associations could not be delineated (i.e., Calcareous Riverside Outcrop / Calcareous Riverside Seep). These mosaics are not unique associations themselves, but rather indicate that two associations occur and intergrade within the polygon. Polygons labeled with Anderson level II categories (modified) retained their attributes in the vegetation association map. The only exceptions were the polygons labeled Right-of-way, which were assigned the names of preliminary vegetation associations in the association map.

In addition to preliminary vegetation association names, each polygon was assigned a fire behavior fuel model and a canopy cover class. Fuel model and canopy cover class were assigned based on the plot data, field observations, aerial photography signatures, topographic maps, and preliminary vegetation associations. The Anderson fire fuel behavior models that were most appropriate for the vegetation in the park were used. Park-specific descriptions of the fire fuel models, the relationship between the fuel models and the vegetation associations, and the original fuel model descriptions from Anderson (1982) are provided in Appendix E. The standard canopy cover classes defined by the FARSITE model were used to create the canopy cover class map. Canopy cover is defined as the horizontal percentages of the ground surface that is covered by tree crowns (Finney 1998). The cover classes are: Class 1: 1–20% of horizontal area covered by tree canopy; Class 2: 21–50% of horizontal area covered by tree canopy; Class 3: 51–80% of horizontal area covered by tree canopy; and Class 4: 81–100% of horizontal area covered by tree canopy.

Accuracy Assessment

Two sources of potential error in the vegetation map include: 1) horizontal positional accuracy, in which a location on the photomosaic does not accurately align with the same location on the ground due to errors in orthorectification or triangulation; and 2) thematic accuracy, in which the vegetation type assigned to a particular location on the map does not correctly represent the vegetation at the same location in the park due to mapping error. The USGS/NPS Vegetation Mapping Program protocols (TNC and ESRI 1994c) were followed to assess the positional accuracy of the digital photo mosaic and the thematic accuracy of the vegetation association, fire behavior fuel model, and canopy cover class maps.

Positional Accuracy Assessment

Well-defined positional accuracy ground control points, spaced throughout all quadrants of the mosaic, were placed on the final mosaic in ArcMap. Ground control points and zoomed-in screenshots of each point were plotted on hard copy maps with the mosaic as a background. These maps and plots were used to locate the ground control points in the field. For each plotted ground control point, field staff noted any alterations to the location in the field, and then recorded the coordinates with a real-time differentially corrected Garmin III+ in conjunction with CSI MBX-3 2 channel Automatic Differential Beacon Receiver. Mapped ground control points that were physically inaccessible were also noted. The field crew correctly located and collected accuracy assessment data at 42 ground control points. Prior to calculating accuracy, one ground control point was identified as an outlier with SAS's JMP program and removed. The field-collected "true" or "reference" GPS coordinates for the remaining 41 points were compared to the coordinates obtained from the mosaic viewed in ArcMap. Both pairs of coordinates for each point were entered into a spreadsheet in order to calculate horizontal accuracy (in meters). The accuracy calculation formula is based on root mean square error (FGDC 1998b; Minnesota Governor's Council on Geographic Information and Minnesota Land Management Information Center 1999). Figure 6 shows the distribution of the 41 ground control points within the park and surrounding area.

Thematic Accuracy Assessment

The thematic accuracies of the preliminary vegetation association map, the fire behavior fuel model map, and the canopy cover class map were assessed by the Pennsylvania Natural Heritage Program. A stratified random sampling approach was used, distributing the sampling effort across the preliminary vegetation association map. Since the vegetation association map contained many more types to be assessed than the fire fuel model or the canopy cover class map, one set of random sampling points could be used to assess the accuracy of all three maps. This combined sampling strategy was inherently more efficient and resulted in adequate sampling of the vegetation map and over sampling of the fire fuel model and canopy cover class map.

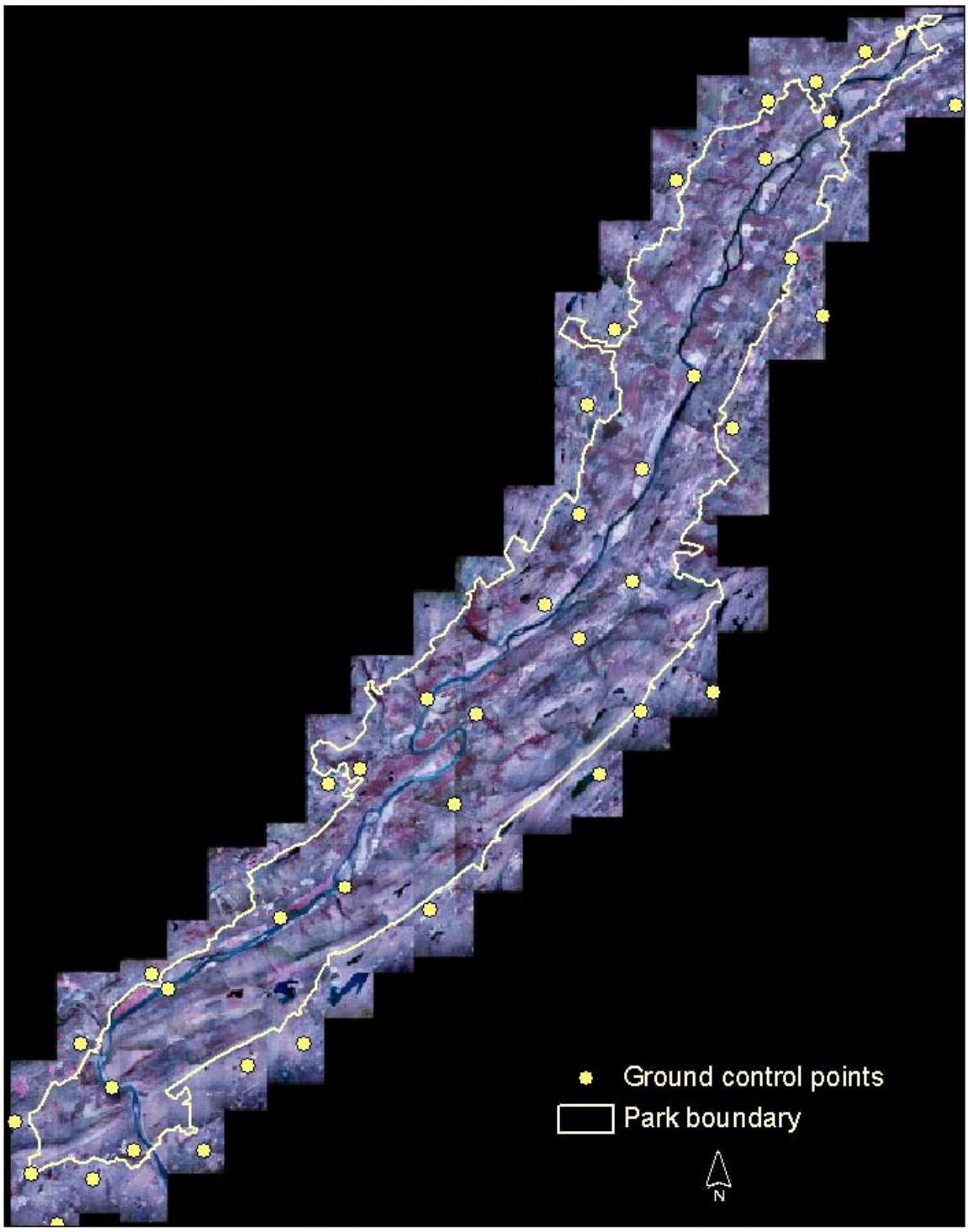

Figure 6. Ground control points used to calculate horizontal positional accuracy of the Delaware Water Gap National Recreation Area mosaic.

In this stratified random sampling design, the sampling effort was distributed across the preliminary vegetation associations (Table 4). Polygons labeled with modified Anderson level II categories were not included in the thematic accuracy assessment sampling. Two associations, Calcareous Seep and Water-willow Emergent Bed, were excluded from the accuracy assessment because they could not be mapped due to small patch size and the timing of the aerial photography, respectively.

The names of vegetation associations listed in Table 4 are from the preliminary classification determined before thematic accuracy assessment. Numerous changes were made to the classification after accuracy assessment; therefore, the preliminary association names in Table 4 do not fully match the final association descriptions presented in this report. For the thematic accuracy assessment sampling strategy, polygons labeled as a mosaic of two vegetation associations were lumped with the least abundant of the component associations. Since mosaics are not unique associations themselves, they should not be sampled separately in the accuracy assessment. Lumping the mosaics with the least abundant association favored additional sampling in less abundant associations; thus, increasing the sampling power.

In the stratified random sampling approach, the number of samples per association varied according to the rarity of the vegetation association, both in terms of number of polygons and polygon size. The following rules were used to determine the number of points assigned to each association (TNC and ESRI 1994c):

Scenario A: The class is abundant. It covers more than 50 hectares in total area and consists of at least 30 polygons. In this case, it is recommended that 30 polygons be selected at random from the set of the association's polygons. One sampling point will be assigned to each of the 30 selected polygons.

Scenario B: The association is relatively abundant. It covers more than 50 hectares in total area but consists of fewer than 30 polygons. In this case, it is recommended that 20 polygons be selected at random from the set of the association's polygons, and that one sampling point be assigned to each of the 20 selected polygons. If the association contains less than 20 polygons, some polygons will contain multiple sampling points. The number of sampling points assigned to each polygon is determined by the relative area of that polygon compared with the other polygon in that association.

Scenario C: The association is relatively rare. It covers less than 50 hectares in total area but consists of more than 30 polygons. In this case, it is recommended that 20 polygons be selected at random from the set of the association's polygons. One sampling point will be assigned to each of the 20 selected polygons.

Scenario D: The class is rare. It has 5–30 polygons and covers less than 50 hectares. In this case, it is recommended that five polygons be selected at random from the set of the association's polygons. One sampling point will be assigned to each of the five selected polygons.

Scenario E: The association is very rare. It has fewer than five polygons and occupies less than 50 hectares of the total area. In this case, it is recommended that one sampling point be assigned to each polygon.

Table 4. Thematic accuracy assessment (AA) sampling strategy for Delaware Water Gap National Recreation Area.

Preliminary Vegetation Association[1]	Number of Polygons	Mapped Hectares within Park Boundary	Number of AA Points Sampled[1]
Acidic Seep	1	0.09	1
Alder Wetland	2	2.21	2
Bear Oak - Wavy Hairgrass Shrubland	18	15.21	5
Bear Oak - Wavy Hairgrass Shrubland / Dry Oak - Heath Woodland	2	8.82	
Big Bluestem - Indian Grass River Grassland	5	2.43	5
Bitternut Hickory Lowland Forest	3	15.64	3
Bottomland Mixed Hardwood Palustrine Forest	25	99.84	20
Bottomland Mixed Hardwood Palustrine Forest / Silky Dogwood - Swamp Rose Wetland	3	6.55	
Bottomland Oak Palustrine Forest	9	49.98	5
Buttonbush Wetland	4	7.12	4
Calcareous Fen	3	3.61	3
Calcareous Riverside Outcrop / Calcareous Riverside Seep	4	2.90	4
Conifer Plantation	202	463.61	30
Dry Eastern Hemlock - Oak Forest	91	831.61	30
Dry Eastern White Pine - Oak Forest	250	1,659.59	30
Dry Hickory Ridgetop Forest	13	144.89	20
Dry Oak - Heath Forest	222	4,015.13	30
Dry Oak - Heath Woodland	43	159.20	30
Dry Oak - Mixed Hardwood Forest	215	2,877.19	30
Eastern Hemlock - Mixed Hardwood Palustrine Forest	4	20.56	4
Eastern Hemlock - Northern Hardwood Forest	161	1,166.83	30
Eastern Hemlock Forest	66	1,315.10	30
Eastern Red-cedar (Pitch Pine) - Prickly Pear Shale Woodland	81	68.30	30
Eastern Red-cedar Forest	16	23.37	5
Eastern White Pine - Successional Hardwood Forest	69	614.23	30
Eastern White Pine Forest	99	375.52	30
Hickory - Eastern red-cedar Rocky Woodland	22	15.16	5
Hickory - Eastern red-cedar Rocky Woodland / Dry Oak - Heath Woodland	1	18.29	
Hickory - Eastern red-cedar Rocky Woodland / Sandstone Talus	1	4.02	
Highbush Blueberry - Steeplebush Wetland	16	14.51	5
Japanese Knotweed Herbaceous Vegetation	11	6.29	5
Reed Canarygrass Riverine Grassland / Japanese Knotweed Herbaceous Vegetation	1	0.64	
Leatherleaf Peatland	1	0.62	3
Leatherleaf Peatland / Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland	2	6.99	
Little Bluestem Grassland	10	10.80	5
Marl Fen	1	0.19	1
Mixed Forb Marsh	29	52.14	30
Mixed Forb Marsh / Wet Meadow	1	1.91	
Pond / Mixed Forb Marsh	1	0.45	
Cattail Marsh	1	0.55	
Northeastern Modified Successional Forest	486	1,998.80	30
Northern Red Oak - Mixed Hardwood Forest	79	871.24	30
Oak Talus Forest	45	390.28	30
Dry Oak - Heath Forest / Oak Talus Forest	8	167.39	
Dry Oak - Mixed Hardwood Forest / Oak Talus Forest	3	144.16	
Old Field	253	543.29	30
Modified Successional Forest / Old Field	1	1.83	
Successional Shrubland / Old Field	1	0.52	

Table 4. Thematic accuracy assessment (AA) sampling strategy for Delaware Water Gap National Recreation Area (continued).

Preliminary Vegetation Association[1]	Number of Polygons	Mapped Hectares within Park Boundary	Number of AA Points Sampled[1]
Pitch Pine - Mixed Hardwood Rocky Summit	62	32.41	30
Dry Oak - Mixed Hardwood Forest / Pitch Pine - Mixed Hardwood Rocky Summit	1	19.74	
Dry Oak - Heath Forest / Pitch Pine - Mixed Hardwood Rocky Summit	4	43.15	
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland	8	21.81	5
Red Maple - Highbush Blueberry Palustrine Forest	29	34.63	5
Red Maple - Sweet Birch Hardwood Forest	146	1,556.53	30
Red Maple Palustrine Forest	54	115.80	30
Reed Canarygrass Riverine Grassland	12	28.56	5
Riverine Scour Vegetation	30	20.91	20
Riverine Scour Vegetation / Modified Successional Forest	1	7.16	
Sandstone Talus	26	18.62	30
Oak Talus Forest / Sandstone Talus	7	40.67	
Shale Scree Slope	13	16.60	5
Shale Scree Slope / Eastern Red-cedar (Pitch Pine) - Prickly Pear Shale Woodland	1	1.32	
Silky Dogwood Successional Palustrine Shrubland	28	47.36	30
Silky Dogwood Successional Palustrine Shrubland / Wet Meadow	7	15.08	
Silver Maple Floodplain Forest	76	538.84	30
Sparsely Vegetated Cliff	14	19.15	30
Hickory - Eastern Red-cedar Rocky Woodland / Sparsely Vegetated Cliff	24	36.64	
Oak Talus Forest / Sparsely Vegetated Cliff	1	0.60	
Successional Eastern Red-cedar (Eastern White Pine) Woodland	133	216.02	30
Successional Bear Oak - Heath Shrubland	30	285.18	30
Successional Bear Oak - Heath Shrubland / Dry Oak - Heath Woodland	1	10.24	
Successional Mixed Hardwood Forest	43	250.23	30
Successional Shrubland	364	904.45	30
Modified Successional Forest / Successional Shrubland	12	51.17	
Sugar Maple - American Beech - Sweet Birch Forest	113	1,632.95	30
Sugar Maple - American Basswood Forest	7	66.56	20
Sugar Maple Floodplain Forest	14	128.17	20
Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland	12	7.56	5
Sycamore - Mixed Hardwood Floodplain Forest	30	65.78	30
Sycamore - Mixed Hardwood Riverine Shrubland	13	10.04	5
Sycamore - Mixed Hardwood Riverine Shrubland / Riverine Scour Vegetation	1	4.14	
Sycamore Floodplain Forest	5	9.77	5
Tuliptree - Beech - Maple Forest	12	156.26	20
Tussock Sedge Marsh	15	10.57	5
Silky Dogwood Successional Palustrine Shrubland / Tussock Sedge Marsh	1	0.93	
Red Maple Palustrine Forest / Tussock Sedge Marsh	1	0.47	
Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop	27	6.75	5
Wet Meadow	49	60.76	30
Wet Meadow / Old Field Vegetation	1	1.98	
Old Field Vegetation / Wet Meadow	5	19.78	
Successional Shrubland / Wet Meadow	1	2.13	
Total	4,013	24,695.11	1,130

[1] Names of vegetation associations listed in the table are from the preliminary classification determined before thematic accuracy assessment. Numerous changes were made to the classification after accuracy assessment, therefore the preliminary association names in this table do not fully match the final association descriptions presented in this report.

2 Number of points determined by USGS/NPS Vegetation Mapping Program protocol (The Nature Conservancy and Environmental Systems Research Institute 1994c).

In order to randomly select the polygons in Scenarios A, B, C, and D, the Create Random Selection tool in Hawth's Analysis Tools was used in ArcGIS (Beyer 2004; ESRI 1999–2000b). For all of the scenarios, the Generate Random Points tool in Hawth's Analysis Tools was used to randomly determine the location of the sampling points in the polygon. If the randomly selected polygon or point fell on inaccessible privately owned lands the point was reassigned to a randomly selected polygon of the same association that fell on publicly owned land. The resulting 1,130 thematic accuracy assessment sampling points are shown in Figure 7.

These sampling points were also used to assess the thematic accuracy of the fire behavior fuel model map and the canopy cover class map. Because the vegetation association map contained many more types than either the fuel model or the cover class maps, the sampling design for the vegetation association map was also sufficient for the fire behavior fuel model map and the canopy cover class map. Even though the sampling design was created for the vegetation association map, the design distributed the sampling points across the fuel model and cover class map units proportionally to the number of polygons and the total mapped hectares of the units (Tables 5 and 6). For the fire behavior fuel models, five of the 12 models were oversampled, while seven of the 12 models were undersampled, according to the USGS/NPS Vegetation Mapping Program protocol (TNC and ESRI 1994c). For the canopy cover class map, all four classes were oversampled, yielding approximately 3–15 times the number of points recommended by the USGS/NPS Vegetation Mapping Program protocol (TNC and ESRI 1994c).

From July through September 2005 and April through July 2006, each accuracy assessment point was located in the field using one of the following GPS units: Trimble Pocket Pathfinder attached to a Beacon-on-a-Belt with a Compaq Ipaq Pocket PC interface, or Garmin GPS map 76 WAAS enabled. The datum on the GPS units was set to North America 1983 (Conus) and the coordinate system was set to Universal Trans-Mercator (UTM) zone 18. At the accuracy assessment point, the vegetation association at that location was determined using the dichotomous key and the detailed vegetation descriptions. The fire behavior fuel model appropriate for the area's vegetation was recorded. The percent canopy cover and the canopy cover class of the area were also noted. The minimum area of observation around the sampling point was a circle with a radius of 50 m. The accuracy assessment data form used in this study is shown in Appendix F.

Data from the 1,130 accuracy assessment points were entered into the NatureServe PLOTS 2.0 Database System on a Microsoft Access platform from November 2005 through July 2006. In the PLOTS database, species were assigned standardized codes based on the *PLANTS Database, Version 3.5* (USDA, NRCS 2004). For this report, some common names listed in the PLANTS Database were changed to reflect the common names typically used by ecologists and resource managers in this region. The common and scientific names of plants observed during thematic accuracy assessment sampling are listed in Appendix C. Some tree and shrub seedlings and immature herbaceous plants could only be identified to the genus level and are therefore listed in the appendix as such.

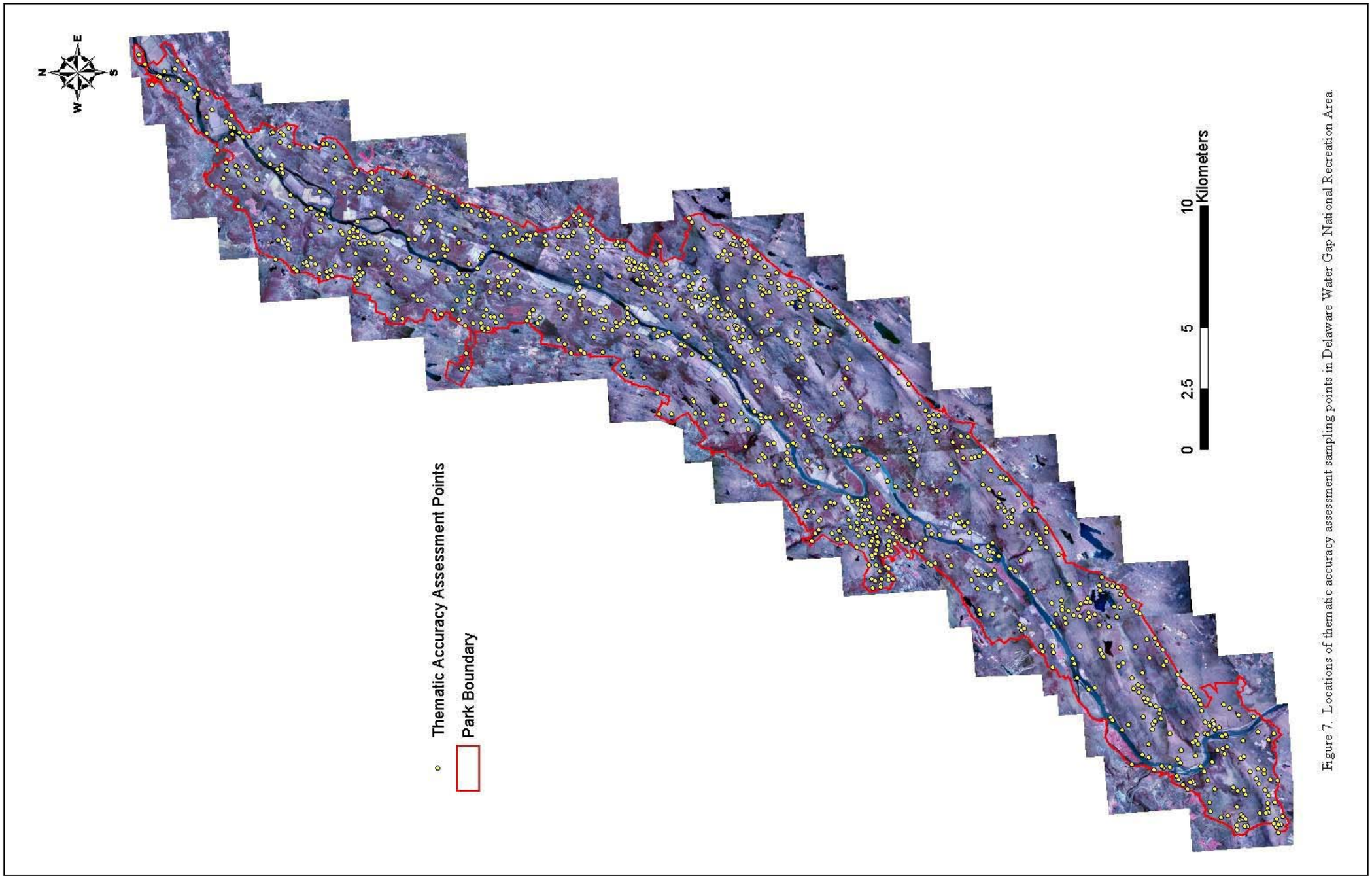

Figure 7. Locations of thematic accuracy assessment sampling points in Delaware Water Gap National Recreation Area.

Table 5. Distribution of thematic accuracy assessment sampling points across fire behavior fuel models in Delaware Water Gap National Recreation Area.

Fire Behavior Fuel Model	Number of Polygons	Mapped Hectares within Park Boundary	Number of Points Recommended by Protocol[1]	Number of AA Points Sampled
0	1,090	4,127.77	30	383
1	141	152.62	30	23
1/3	669	1,474.60	30	81
3	48	144.12	30	20
4	82	496.05	30	10
5	113	317.44	30	12
6	306	3,757.91	30	77
6/7	63	1,498.89	30	17
7	76	462.13	30	24
8	64	383.36	30	26
8/9	1,661	14,355.15	30	402
9	266	748.08	30	55
Total	4,579	27,918	360	1,130

[1] The Nature Conservancy and Environmental Systems Research Institute. 1994 (c). NBS/NPS Vegetation Mapping Program: Accuracy Assessment Procedures. 71pp. Report to the National Biological Survey and the National Park Service. Arlington, VA and Redlands, CA. <http://biology.usgs.gov/npsveg/standards.html > Last accessed 17 March 2005.

Table 6. Distribution of thematic accuracy assessment sampling points across canopy cover class map units in Delaware Water Gap National Recreation Area.

Canopy Cover Class	Number of Polygons	Mapped Hectares within Park Boundary	Number of Points Recommended by Protocol[1]	Number of AA Points Sampled
1	1,632	5,120.25	30	344
2	289	802.16	30	94
3	948	4,787.12	30	237
4	1,710	17,208.58	30	455
Total	4,579	27,918	120	1,130

[1] The Nature Conservancy and Environmental Systems Research Institute. 1994 (c). NBS/NPS Vegetation Mapping Program: Accuracy Assessment Procedures. 71 pp. Report to the National Biological Survey and the National Park Service. Arlington, VA and Redlands, CA. <http://biology.usgs.gov/npsveg/standards.html > Last accessed 17 March 2005.

The thematic accuracy of the vegetation association map was then tabulated using a contingency matrix that compared the mapped vegetation associations with the actual vegetation associations observed in the field. Contingency matrices were also tabulated for the fire fuel model and the canopy cover class maps. Overall percent accuracy and Kappa indices were calculated for the three maps (TNC and ESRI 1994c). Overall percent accuracy was calculated by dividing the number of correctly classified accuracy assessment points by the total number of accuracy assessment points. The Kappa index is the preferred method of reporting overall thematic accuracy because it takes into account that a certain number of correct classifications will occur by chance (Foody 1992). The USGS/NPS vegetation mapping protocol requires that the Kappa index of vegetation associations maps exceed 80% (TNC and ESRI 1994c).

Producer's accuracy and user's accuracy were also calculated in the contingency matrix. The producer's and user's accuracies for the vegetation association map should exceeded 80%, according to the USGS/NPS Vegetation Mapping Protocol (TNC and ESRI 1994c). These statistics are not independent, such that one incorrect observation point influences both the producer's and the user's accuracy.
Producer's accuracy represents the percentage of a given association that is correctly identified on the map. In other words, from the perspective of the map, what are the chances that this mapped association correctly matches the vegetation on the ground? Producer's accuracy is calculated by dividing the number of correct observation points in one mapped association class by the total number of observation points in that mapped association class. Error of omission is calculated as 1 - producer's accuracy. This error indicates the percentage of observation points that should have been mapped a given association, but were omitted.

User's accuracy represents the probability that a given location on the ground is classified correctly on the map. In other words, from the perspective of the real world vegetation, what are the chances this association on the ground correctly matches the mapped association? User's accuracy is calculated by dividing the number of correct observation points in one observed association by the total number of points at which that association was observed. Error of commission is calculated as 1 - user's accuracy. This error indicates the percentage of the observation points for a given association that were shown on the map as other associations.

Results

Vegetation Classification and Characterization

The vegetation associations of the Delaware Water Gap National Recreation Area were classified using iterative Cluster, TWINSPAN, and NMS analyses. Due to the large size of the dataset, it is impractical to include graphical representations of these analyses in this report. The results of these classification analyses were evaluated against each other and compared to the Terrestrial and Palustrine Plant Communities of Pennsylvania (Fike 1999), Draft New Jersey Ecological Community Crosswalk (Walz et al. 2006), National Vegetation Classification System, vegetation classifications at other Pennsylvania national parks, and the ecologists' field experiences at the Delaware Water Gap National Recreation Area. Based on this evaluation, preliminary vegetation associations were identified and a preliminary vegetation association map was created. These preliminary vegetation associations are listed in Table 4.

Thematic accuracy assessment was then conducted on this preliminary vegetation association map. Based on the data collected during accuracy assessment, the following revisions were made:

- Eastern Red-cedar (Pitch Pine) - Prickly Pear Shale Woodland and Hickory - Eastern Red-cedar Rocky Woodland were determined to be the same association and were lumped into the Hickory - Eastern Red-cedar Rocky Woodland association.
- Dry Oak - Heath Woodland and Dry Oak - Heath Forest were combined into the Dry Oak - Heath Forest association in order to maintain consistency with the other terrestrial forest associations that occur both as forests and woodland.
- Leatherleaf Peatland was split into two associations, Leatherleaf Peatland and Highbush Blueberry - Leatherleaf Wetland to more accurately capture the variation in these unique wetlands.
- Successional Eastern Red-cedar (Eastern White Pine) Woodland was split into two associations to better represent the different successional trajectories based on species dominance. Examples of this preliminary association that were dominated by eastern red-cedar were combined with the Eastern Red-cedar Forest association. Examples of this preliminary association that were dominated by eastern white pine were considered a different association, Successional Eastern White Pine Woodland.
- Successional Mixed Hardwood Forest was eliminated because only two of the 30 thematic accuracy assessment points proved to be correct. The polygons in the preliminary association map labeled as Successional Mixed Hardwood Forest were assigned to other associations, often Northeastern Modified Successional Forest.
- Six additional associations identified during the accuracy assessment were not captured in the preliminary classification. These additional associations were Black Walnut Bottomland Forest, Boulder Vernal Pool Sparse Vegetation, Eastern Woodland Vernal Pool Sparse Vegetation, Cattail Marsh, Hairyfruit Sedge Wetland, and Wooded Successional Old Field.
- Some association names were altered in order to better represent the concept of the association.

The resulting final classification described 69 vegetation associations in the Delaware Water Gap National Recreation Area.

Vegetation Association Descriptions

Detailed local descriptions for 69 vegetation associations were written based on plot data, compositional statistics, photographs of each plot, thematic accuracy assessment data, the ecologists' field observations at the Delaware Water Gap National Recreation Area, and the other research cited in the local descriptions. These vegetation associations were then crosswalked to the National Vegetation Classification System which contains range-wide global descriptions for each association. Since the local expression of an association can differ in various locations throughout its range, the local description provides information on the park-specific expression of the type. The global description provides the broader concept of the association and may include plant species that do not occur in the park, but are typical of the association elsewhere in its range.

One association, Wooded Successional Old Field, is a park-specific local vegetation type that is not represented in the NVCS and therefore is not attributed with a global description. Detailed local and global descriptions of the vegetation associations are contained in Appendix G in Volume 2 of this report; where representative photographs of each vegetation association from the Delaware Water Gap National Recreation Area are provided after each description.

Each association is also crosswalked to the state classifications for Pennsylvania and New Jersey (Fike 1999; Walz et al. 2006). The state conservation rank (S Rank), global conservation rank (G Rank), and classification confidence for state and global classifications are included in the descriptions. Classification confidence refers to the certainty that the association is accurately described, and that the association is distinct from other similar associations. Definitions of the conservation ranks and classification confidence codes are shown in Appendix H.

A dichotomous key was also developed for the vegetation associations of the Delaware Water Gap National Recreation Area (Appendix D). The dichotomous key should be used in conjunction with the detailed vegetation association descriptions to confirm that the association selected with the key is appropriate. This key and the detailed vegetation association descriptions were used in the thematic accuracy assessment and may be used by park resource managers and others to identify vegetation associations in the park

Vegetation Map Production

Based on the accuracy assessment sampling data and the final classification of 69 vegetation associations, the association level map was revised again to correct errors and create more accurate vegetation association polygon boundaries. In this final revision, accuracy assessment data, plot data, field observations, aerial photography signatures, and topographic maps were used to revise polygon boundaries and attributes. Two associations, Calcareous Seep and Water-willow Emergent Bed, were not mapped because they could not be identified on the spring 2002 aerial photography. The Calcareous Seep occurred under forest canopy and was too small in size to be identified through photointerpretation. The Water-willow Emergent Beds were not visible on the photography due to the higher water levels in the Delaware River in April 2002.

The resulting final vegetation association map is shown in Figure 8 and a summary of the vegetation association distribution and abundance is provided in Table 7. In the final map, several polygons were labeled as mosaics of two separate associations. These polygons were labeled as mosaics because both types were present in the polygons and clear boundaries between the two associations could not be delineated. Polygons that were attributed with modified Anderson level II categories retained their attributes in the final map. An aerial photograph interpretation key for the vegetation associations and Anderson level II categories (modified) is located in Appendix A.

Production of FARSITE Data Layers

The fire behavior fuel model map and the canopy cover class map were also revised based on the accuracy assessment data. The ArcView shapefile containing the fire behavior fuel model and the canopy cover class data was then converted into two raster files with 30 meter grid cell size. The Feature to Raster Conversion Tool in the ArcToolbox function of ArcGIS 9 was used to convert the shapefile into raster files. A cell size of 30 meter was selected so that these ratser files will be compatible with the FARSITE simulation model.

The final fire behavior fuel model map is shown in Figure 9. The fuel models associated with ericaceous shrubs (6, 6/7, and 7) that create more intense fires are shown in red and orange. Table 8 provides a summary of the percent of the park covered by each fuel model. The final canopy cover class map is shown in Figure 10. Table 9 provides a summary of the percent of the park covered by each canopy cover class.

In addition to the fire fuel model mapping, the National Park Service fire specialists requested that areas with large concentrations of dead or dying trees be identified. These areas are predominantly dead or dying standing eastern hemlocks (*Tsuga canadensis*) that have suffered mortality as a result of the hemlock woolly adelgid (*Adelges tsugae*). These dead or dying trees pose an increased fire risk. As the dead trees fall and become large downed debris, they potentially could act as Anderson Fuel Model 13, which is currently not mapped within the park. Figure 11 shows the areas that were identified as containing large concentrations of dead or dying trees. These areas cover 1,023.57 hectares, or 3.7% of the total park area (Table 10). The most common associations in these areas are Eastern Hemlock Forest, Dry Eastern Hemlock - Oak Forest, Eastern Hemlock - Mixed Hardwood Palustrine Forest, and Eastern Hemlock - Northern Hardwood Forest. The two deciduous forest associations (Dry Oak - Mixed Hardwood Forest and Red Maple - Sweet Birch Hardwood Forest) were identified in areas that were formerly mixed eastern hemlock-deciduous forests, but in which nearly all of the eastern hemlocks have died. Conifer Plantation, Dry Eastern White Pine - Oak Forest, and Eastern White Pine Forest also contained very rare isolated areas with large concentrations of dead or dying trees (Table 10).

In addition, FARSITE requires data layers of elevation, slope, and aspect, in 30 meter grid format. These data layers were created from a digital elevation model with a 10 meter cell size. The digital elevation model of the Delaware Water Gap National Recreation Area and environs was originally created by North Carolina State University for the National Park Service. To create the 30 meter elevation data layer, the Aggregation tool was used in ArcToolbox's Spatial Analyst Tools. The mean aggregation technique was employed with a cell factor of 3. To create

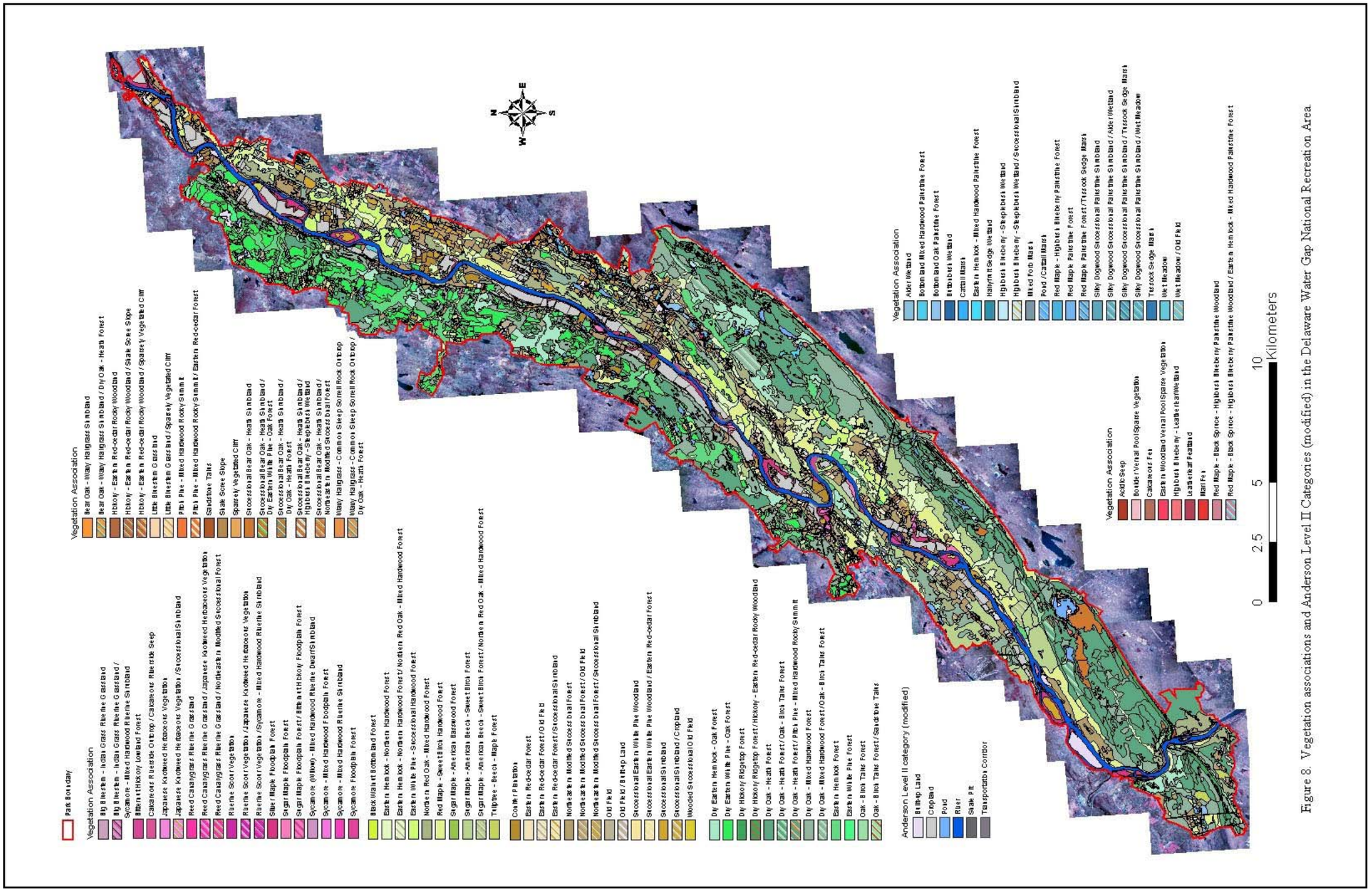

Figure 8. Vegetation associations and Anderson Level II Categories (modified) in the Delaware Water Gap National Recreation Area.

Table 7. Number of polygons and hectares for mapped vegetation associations and Anderson level II categories (modified) in Delaware Water Gap National Recreation Area. Two of the park's associations, Calcareous Seep and Water-willow Emergent Bed, are not listed in this table because they could not be identified on the spring 2002 aerial photography, and thus were not mapped.

Vegetation association or Anderson level II category (modified)	Number of Polygons	Total Mapped Hectares
Acidic Seep	1	0.09
Alder Wetland	2	2.01
Bear Oak - Wavy Hairgrass Shrubland	22	19.28
Bear Oak - Wavy Hairgrass Shrubland / Dry Oak - Heath Forest	2	5.82
Big Bluestem - Indiangrass Riverine Grassland	3	2.78
Big Bluestem - Indiangrass Riverine Grassland / Sycamore - Mixed Hardwood Riverine Shrubland	2	1.65
Bitternut Hickory Lowland Forest	5	24.56
Black Walnut Bottomland Forest	16	34.77
Bottomland Mixed Hardwood Palustrine Forest	20	68.89
Bottomland Oak Palustrine Forest	11	56.21
Boulder Vernal Pool Sparse Vegetation	6	1.50
Built-up Land	136	369.55
Buttonbush Wetland	4	7.12
Calcareous Fen	3	3.53
Calcareous Riverside Outcrop / Calcareous Riverside Seep	4	3.75
Cattail Marsh	2	1.20
Conifer Plantation	206	470.96
Cropland	159	1,268.52
Dry Eastern Hemlock - Oak Forest	107	1,075.41
Dry Eastern White Pine - Oak Forest	252	1,668.61
Dry Hickory Ridgetop Forest	19	152.82
Dry Hickory Ridgetop Forest / Hickory - Eastern Red-cedar Rocky Woodland	1	1.76
Dry Oak - Heath Forest	273	4,416.70
Dry Oak - Heath Forest / Oak - Birch Talus Forest	6	149.94
Dry Oak - Heath Forest / Pitch Pine - Mixed Hardwood Rocky Summit	3	12.59
Dry Oak - Mixed Hardwood Forest	246	2,915.93
Dry Oak - Mixed Hardwood Forest / Oak - Birch Talus Forest	2	118.96
Eastern Hemlock - Mixed Hardwood Palustrine Forest	6	29.82
Eastern Hemlock - Northern Hardwood Forest	149	1,102.80
Eastern Hemlock - Northern Hardwood Forest / Northern Red Oak - Mixed Hardwood Forest	1	12.34
Eastern Hemlock Forest	53	1,013.15
Eastern Red-cedar Forest	36	46.69
Eastern Red-cedar Forest / Old Field	19	31.77
Eastern Red-cedar Forest / Successional Shrubland	14	36.28
Eastern White Pine - Successional Hardwood Forest	76	683.56
Eastern White Pine Forest	98	310.33
Eastern Woodland Vernal Pool Sparse Vegetation	63	7.99
Hairyfruit Sedge Wetland	3	3.91
Hickory - Eastern Red-cedar Rocky Woodland	84	64.86
Hickory - Eastern Red-cedar Rocky Woodland / Shale Scree Slope	1	1.32
Hickory - Eastern Red-cedar Rocky Woodland / Sparsely Vegetated Cliff	29	55.48

Table 7. Number of polygons and hectares for mapped vegetation associations and Anderson level II categories (modified) in Delaware Water Gap National Recreation Area. Two of the park's associations, Calcareous Seep and Water-willow Emergent Bed, are not listed in this table because they could not be identified on the spring 2002 aerial photography, and thus were not mapped (continued).

Vegetation association or Anderson level II category (modified)	Number of Polygons	Total Mapped Hectares
Highbush Blueberry - Leatherleaf Wetland	4	9.31
Highbush Blueberry - Steeplebush Wetland	18	19.01
Highbush Blueberry - Steeplebush Wetland / Successional Shrubland	1	1.98
Japanese Knotweed Herbaceous Vegetation	10	4.26
Japanese Knotweed Herbaceous Vegetation / Successional Shrubland	1	1.98
Leatherleaf Peatland	2	0.82
Little Bluestem Grassland	9	10.28
Little Bluestem Grassland / Sparsely Vegetated Cliff	1	0.34
Marl Fen	1	0.19
Mixed Forb Marsh	14	23.33
Northeastern Modified Successional Forest	523	2,139.29
Northeastern Modified Successional Forest / Old Field	1	1.83
Northeastern Modified Successional Forest / Successional Shrubland	12	49.39
Northern Red Oak - Mixed Hardwood Forest	100	1,076.61
Oak - Birch Talus Forest	42	385.30
Oak - Birch Talus Forest / Sandstone Talus	6	25.97
Old Field	246	532.88
Old Field / Built-up Land	1	0.33
Pitch Pine - Mixed Hardwood Rocky Summit	57	28.55
Pitch Pine - Mixed Hardwood Rocky Summit / Eastern Red-cedar Forest	1	0.55
Pond	207	266.37
Pond / Cattail Marsh	1	3.07
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland	7	14.35
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland / Eastern Hemlock - Mixed Hardwood Palustrine Forest	1	3.33
Red Maple - Highbush Blueberry Palustrine Forest	39	49.70
Red Maple - Sweet Birch Hardwood Forest	145	1,535.43
Red Maple Palustrine Forest	48	129.40
Red Maple Palustrine Forest / Tussock Sedge Marsh	1	0.47
Reed Canarygrass Riverine Grassland	10	23.00
Reed Canarygrass Riverine Grassland / Japanese Knotweed Herbaceous Vegetation	1	0.64
Reed Canarygrass Riverine Grassland / Northeastern Modified Successional Forest	1	7.16
River	13	1,178.72
Riverine Scour Vegetation	23	15.46
Riverine Scour Vegetation / Japanese Knotweed Herbaceous Vegetation	2	6.03
Riverine Scour Vegetation / Sycamore - Mixed Hardwood Riverine Shrubland	2	5.96
Sandstone Talus	26	18.57
Shale Pit	11	12.19
Shale Scree Slope	21	20.93
Silky Dogwood Successional Palustrine Shrubland	31	50.98
Silky Dogwood Successional Palustrine Shrubland / Alder Wetland	1	6.37
Silky Dogwood Successional Palustrine Shrubland / Tussock Sedge Marsh	1	0.93
Silky Dogwood Successional Palustrine Shrubland / Wet Meadow	4	5.07

Table 7. Number of polygons and hectares for mapped vegetation associations and Anderson level II categories (modified) in Delaware Water Gap National Recreation Area. Two of the park's associations, Calcareous Seep and Water-willow Emergent Bed, are not listed in this table because they could not be identified on the spring 2002 aerial photography, and thus were not mapped (continued).

Vegetation association or Anderson level II category (modified)	Number of Polygons	Total Mapped Hectares
Silver Maple Floodplain Forest	70	509.10
Sparsely Vegetated Cliff	15	18.36
Successional Bear Oak - Heath Shrubland	20	216.69
Successional Bear Oak - Heath Shrubland / Dry Eastern White Pine - Oak Forest	1	0.81
Successional Bear Oak - Heath Shrubland / Dry Oak - Heath Forest	1	1.23
Successional Bear Oak - Heath Shrubland / Highbush Blueberry - Steeplebush Wetland	1	2.15
Successional Bear Oak - Heath Shrubland / Northeastern Modified Successional Forest	1	2.06
Successional Eastern White Pine Woodland	73	108.16
Successional Eastern White Pine Woodland / Eastern Red-cedar Forest	1	4.12
Successional Shrubland	356	858.84
Successional Shrubland / Cropland	1	6.69
Sugar Maple - American Basswood Forest	5	17.10
Sugar Maple - American Beech - Sweet Birch Forest	120	1,706.72
Sugar Maple - American Beech - Sweet Birch Forest / Northern Red Oak Mixed Hardwood Forest	1	42.50
Sugar Maple Floodplain Forest	16	71.35
Sugar Maple Floodplain Forest / Bitternut Hickory Floodplain Forest	1	8.90
Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland	9	4.43
Sycamore - Mixed Hardwood Floodplain Forest	27	55.08
Sycamore - Mixed Hardwood Riverine Shrubland	20	15.16
Sycamore Floodplain Forest	11	26.43
Transportation Corridor	10	128.89
Tuliptree - Beech - Maple Forest	9	66.05
Tussock Sedge Marsh	20	19.75
Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop	28	9.62
Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop / Dry Oak - Heath Forest	1	0.36
Wet Meadow	53	64.64
Wet Meadow / Old Field	2	5.37
Wooded Successional Old Field	23	52.46
Total	4,687	27,944.52

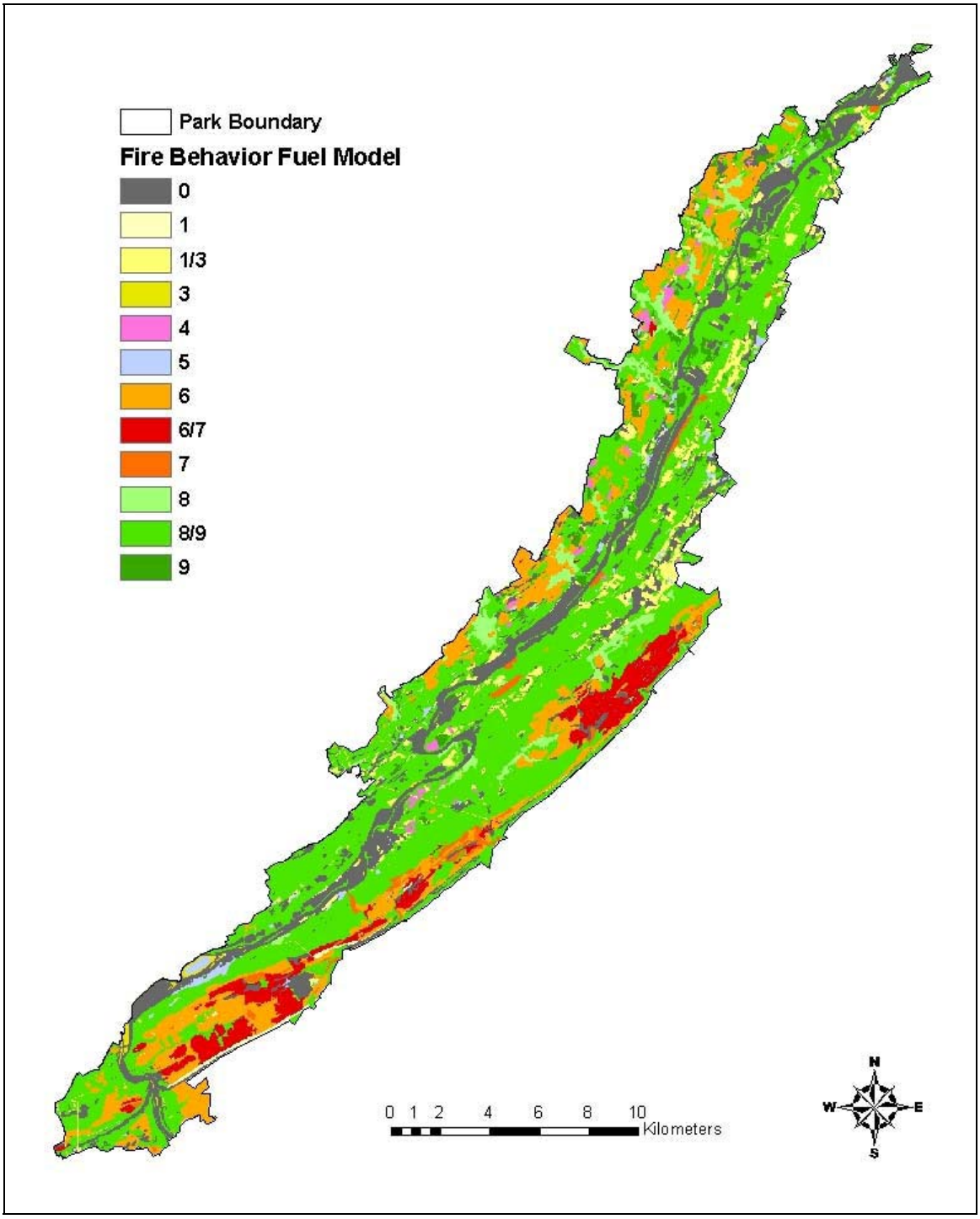

Figure 9. Fire behavior fuel models for Delaware Water Gap National Recreation Area.

Table 8. Summary of the fire behavior fuel model map of Delaware Water Gap National Recreation Area.

Mapped Fuel Model	Total Hectares	Total Acres	Percent of Park
0	4,520.00	11,164.40	16.17%
1	160.02	395.26	0.57%
1/3	1,512.67	3,736.29	5.41%
3	85.95	212.30	0.31%
4	244.45	603.78	0.87%
5	301.33	744.28	1.08%
6	4,015.36	9,917.94	14.37%
6/7	1,462.36	3,612.02	5.23%
7	413.92	1,022.38	1.48%
8	1,036.20	2,559.40	3.71%
8/9	13,553.25	33,476.54	48.50%
9	639.02	1,578.37	2.29%
Total	27,944.52	69,022.96	100.00%

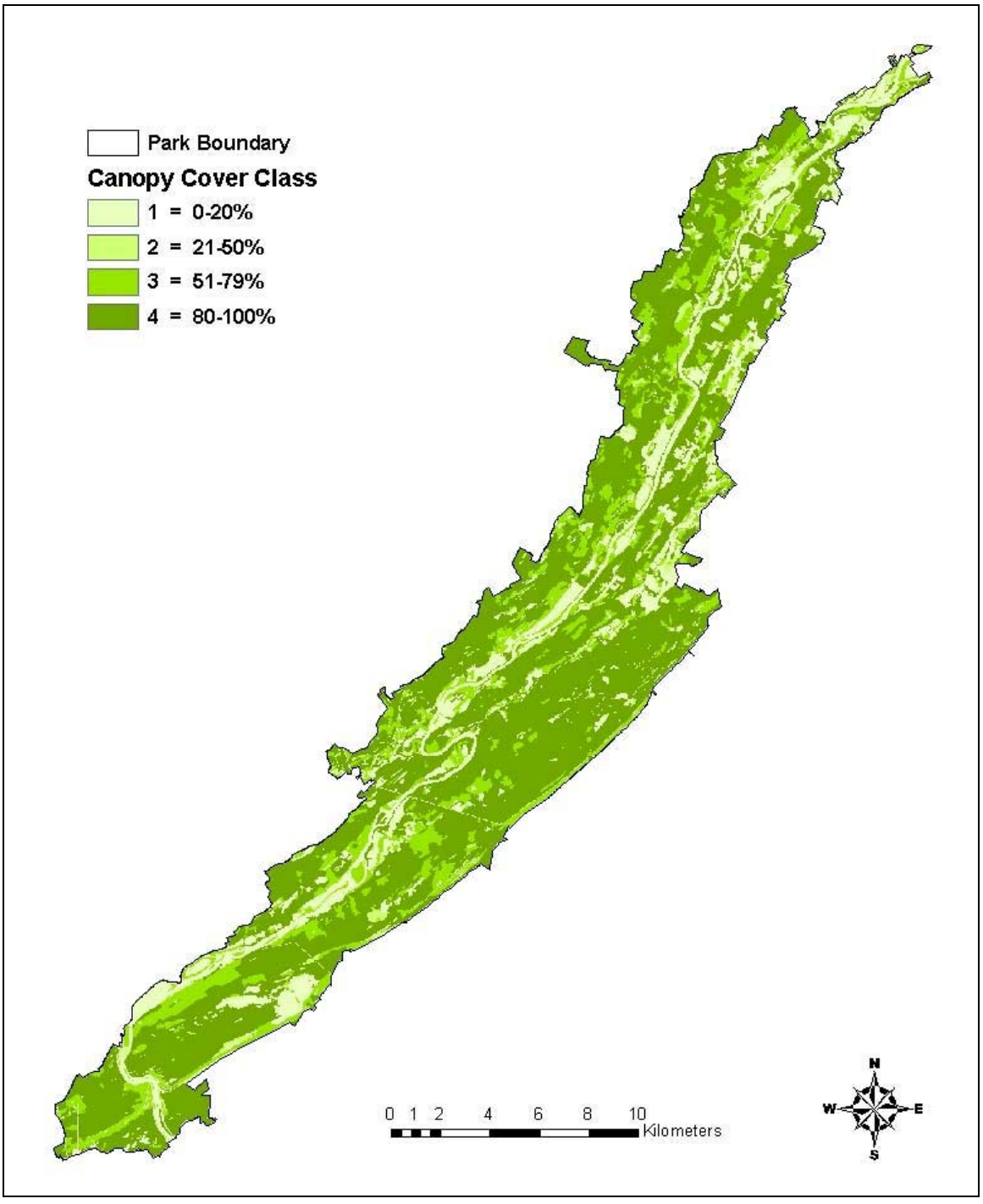

Figure 10. Canopy cover classes in Delaware Water Gap National Recreation Area.Table 9. Summary of the canopy cover class map of Delaware Water Gap National Recreation Area.

Table 9. Summary of the canopy cover class map of Delaware Water Gap National Recreation Area.

Mapped Canopy Cover Class	Total Hectares	Total Acres	Percent of Park
1	5,286.82	13,058.45	18.92%
2	583.39	1,440.98	2.09%
3	4,766.34	11,772.85	17.06%
4	17,307.97	42,750.68	61.94%
Total	27,944.52	69,022.96	100.00%

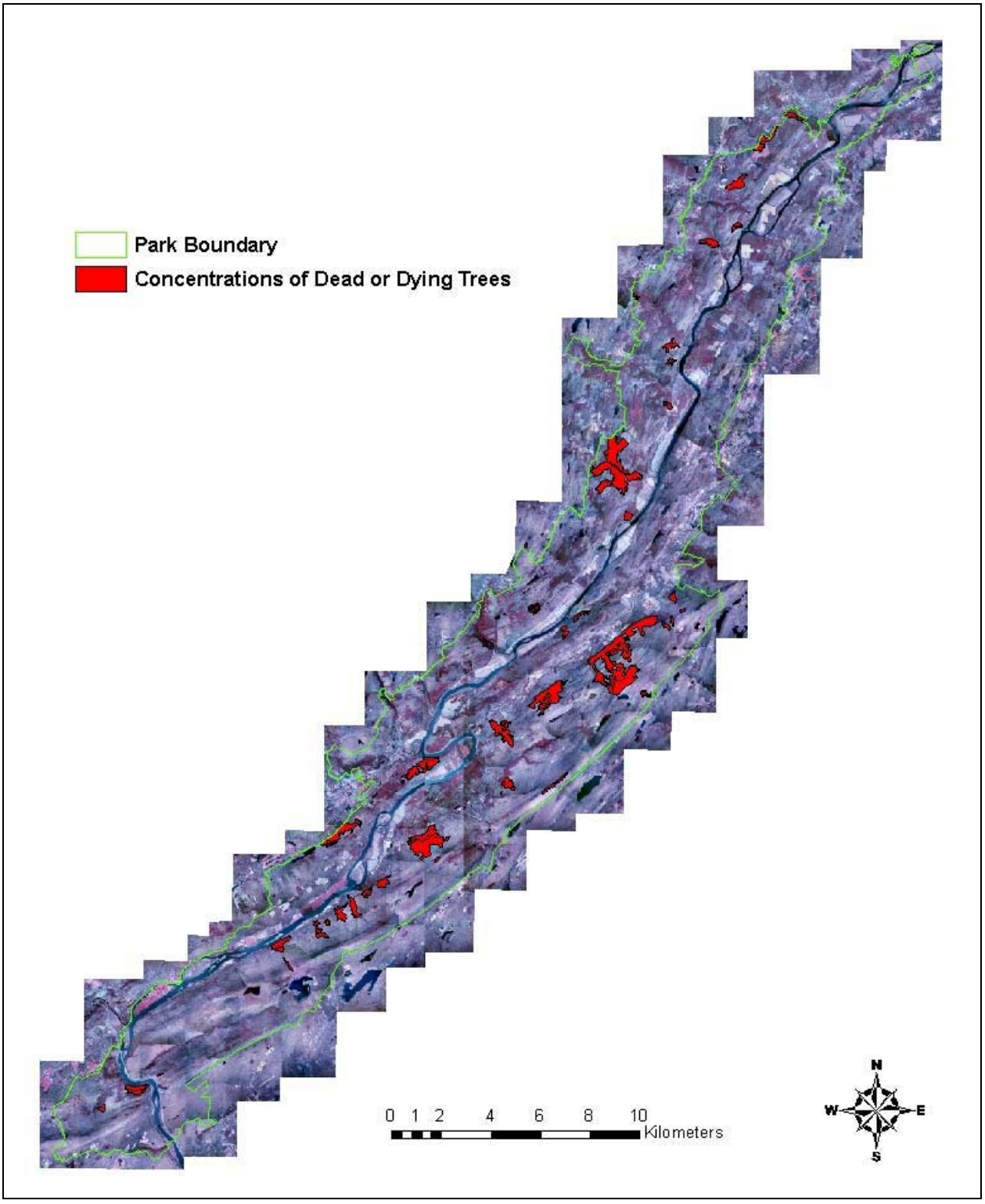

Figure 11. Areas of Delaware Water Gap National Recreation Area characterized by large concentrations of dead or dying trees, typically eastern hemlocks (*Tsuga canadensis*).

Table 10. Summary information for the areas of Delaware Water Gap National Recreation Area containing large concentrations of dead or dying trees, typically eastern hemlocks (*Tsuga canadensis*).

Vegetation Association	Number of Polygons	Total Mapped Hectares	Total Mapped Acres
Conifer Plantation	1	1.66	4.10
Dry Eastern Hemlock - Oak Forest	21	455.01	1,123.87
Dry Eastern White Pine - Oak Forest	2	11.28	27.86
Dry Oak - Mixed Hardwood Forest	3	17.65	43.60
Eastern Hemlock - Mixed Hardwood Palustrine Forest	1	2.71	6.69
Eastern Hemlock - Northern Hardwood Forest	22	308.65	762.37
Eastern Hemlock Forest	9	217.45	537.10
Eastern White Pine Forest	1	5.76	14.23
Red Maple - Sweet Birch Hardwood Forest	1	3.41	8.42
Total	61	1,023.57	2,528.22

the slope data layer, the Slope function in Spatial Analyst's Surface Analysis tool was employed. The output cell size was specified at 30 and degrees was selected as the output measurement. To create the aspect data layer, the Aspect function in Spatial Analyst's Surface Analysis tool was employed, with the cell size specified as 30.

Accuracy Assessment

Positional Accuracy

The horizontal positional accuracy of the mosaic is 2.448 meters which meets Class 1 National Map Accuracy Standards (FGDC 1998b). A copy of the spreadsheet containing the x and y coordinates for each ground control point and the accuracy calculation formula is included in the air photo archive.

Thematic Accuracy

Thematic accuracy assessment for the vegetation association map was calculated with a contingency matrix (Table 11). The final vegetation association classification was used in the contingency table to simplify the record keeping of correct and incorrect sampling points. Errors of omission were calculated for 59 of the 60 mapped vegetation associations. The error of omission could not be calculated for Successional Mixed Hardwood Forest because this type was eliminated in the final classification. Errors of commission were calculated for 60 of the 67 vegetation associations observed during accuracy assessment. The remaining seven vegetation associations were new to the classification and were not included in the preliminary vegetation association map. Therefore, the errors of commission could not be calculated for these associations. One Anderson level II category (modified) was also observed during the accuracy assessment due to errors in mapping.

Based on the contingency matrix (Table 11), the Kappa index for the preliminary vegetation association map was 55.0% ± 2.5%, with the overall percent accuracy calculated as 56.1%. This falls below the USGS/NPS vegetation mapping protocol requirement of 80%. The errors of omission for 11 of the 59 mapped vegetation associations exceeded the USGS/NPS vegetation mapping protocol requirement of 80%, with six associations attaining 100% correct. Twenty-two of the 59 vegetation associations had errors of omission below 50%. The errors of commission for 22 of the 60 vegetation associations observed during the accuracy assessment exceeded the USGS/NPS vegetation mapping protocol requirement of 80%, with 11 vegetation associations attaining 100% correct. Nineteen of the 60 vegetation associations had errors of commission below 50%.

The contingency matrix (Table 11) identifies some common trends in photointerpretation and mapping errors. First, in mixed coniferous - deciduous forest stands, the conifer species were often identified correctly; however, the associated hardwoods were occasionally incorrectly identified. For example, 13 of the 31 accuracy assessment points that were mapped as Eastern Hemlock - Northern Hardwood Forest were actually Dry Eastern Hemlock - Oak Forest. Second, percent cover of conifer trees was often over estimated during aerial photointrepretation. Since the bright pink conifers are obvious on the aerial photography, polygons were often considered to contain more cover of conifers relative to their deciduous associates.

Table 11. Contingency matrix and calculated errors for the thematic accuracy assessment of the vegetation association map of Delaware Water Gap National Recreation Area. The cells highlighted in green show the number of sampling points that were correct. Errors of commission and omission could not be calculated for the associations highlighted in orange because either the association was not included in the preliminary association map, or the association was removed from the final classification. The one modified Anderson level II category that was observed during accuracy assessment is highlighted in blue.

	Mapped Vegetation Association																																
Accuracy Assessment Observation	Acidic Seep	Alder Wetland	Bear Oak - Wavy Hairgrass Shrubland	Big Bluestem - Indiangrass Riverine Grassland	Bitternut Hickory Lowland Forest	Bottomland Hardwood Palustrine Forest	Bottomland Oak Palustrine Forest	Buttonbush Wetland	Calcareous Fen	Calcareous Riverside Outcrop / Calcareous Riverside Seep	Conifer Plantation	Dry Eastern Hemlock - Oak Forest	Dry Eastern White Pine - Oak Forest	Dry Hickory Ridgetop Forest	Dry Oak - Heath Forest	Dry Oak - Mixed Hardwood Forest	Eastern Hemlock - Mixed Hardwood Palustrine Forest	Eastern Hemlock - Northern Hardwood Forest	Eastern Hemlock Forest	Eastern Red-cedar Forest	Eastern White Pine - Successional Hardwood Forest	Eastern White Pine Forest	Hickory - Eastern Red-cedar Rocky Woodland	Highbush Blueberry - Steeplebush Wetland	Japanese Knotweed Herbaceous Vegetation	Leatherleaf Peatland	Little Bluestem Grassland	Marl Fen	Mixed Forb Marsh	Northeastern Modified Successional Forest	Northern Red Oak - Mixed Hardwood Forest
Acidic Seep	1																																
Alder Wetland		2																															
Bear Oak - Wavy Hairgrass Shrubland			1												1								3				1						
Big Bluestem - Indiangrass Riverine Grassland				3																											1		
Bitternut Hickory Lowland Forest					2																												
Black Walnut Bottomland Forest						1																											
Bottomland Hardwood Palustrine Forest						7	1																										1
Bottomland Oak Palustrine Forest						2	2																										
Boulder Vernal Pool Sparse Vegetation																														4			
Buttonbush Wetland								4																									
Calcareous Fen									3																								
Calcareous Riverside Outcrop										2																							
Calcareous Riverside Seep										1																							
Cattail Marsh																														1			
Conifer Plantation											27		1									4	1										
Dry Eastern Hemlock - Oak Forest												12			1			13	11														
Dry Eastern White Pine - Oak Forest												1	20					1				2	5								1		
Dry Hickory Ridgetop Forest			1											13	3									2									
Dry Oak - Heath Forest												4	1	2	42	3																	
Dry Oak - Mixed Hardwood Forest												8	1	4	10	23		1															4
Eastern Hemlock - Mixed Hardwood Palustrine Forest																	2	2															
Eastern Hemlock - Northern Hardwood Forest												1					1	11	2														
Eastern Hemlock Forest																			14		1	1											
Eastern Red-cedar Forest																				12												1	
Eastern White Pine - Successional Hardwood Forest											1	1	6					1	1		17	1										1	
Eastern White Pine Forest											1		1						2	1		19											
Eastern Woodland Vernal Pool Sparse Vegetation																																	
Hairyfruit Sedge Wetland																																	
Hickory - Eastern Red-cedar Rocky Woodland			1																				35										
Highbush Blueberry - Leatherleaf Wetland																											1						
Highbush Blueberry - Steeplebrush Wetland																								2						2			
Japanese Knotweed Herbaceous Vegetation																									2								
Leatherleaf Peatland																										1							
Little Bluestem Grassland																											2						
Marl Fen																												1					
Mixed Forb Marsh																								1					9				
Northeastern Modified Successional Forest						1					1				1			1		3	4		1							20	2		
Northern Red Oak - Mixed Hardwood Forest												2				4		1													1	11	
Oak Talus Forest														1	1																	1	
Old Field																											1				1		
Pitch Pine - Mixed Hardwood Rocky Summit																															1		
Pond																													3				
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland																																	
Red Maple - Highbush Blueberry Palustrine Forest						2																		1									
Red Maple - Sweet Birch Hardwood Forest															2																1	3	
Red Maple Palustrine Forest						2																1									1	3	
Reed Canarygrass Riverine Grassland																																	
Riverine Scour Vegetation				1						1																1							
Sandstone Talus																																	
Shale Scree Slope																							8										
Silky Dogwood Successional Palustrine Shrubland																														1			
Silver Maple Floodplain Forest																														1			
Sparsely Vegetated Cliff																																	
Successional Bear Oak - Heath Shrubland			1												2																		
Successional Eastern White Pine Woodland																															1		
Successional Shrubland						1									1								1										
Sugar Maple - American Basswood Forest																																	
Sugar Maple - American Beech - Sweet Birch Forest							1									1						1										4	
Sugar Maple Floodplain Forest						2																										1	
Sycamore - Mixed Hardwood Floodplain Forest						1	1																										
Sycamore - Mixed Hardwood Riverine Shrubland																																	
Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland				1																													
Sycamore Floodplain Forest																									2								
Tuliptree - Beech - Maple Forest					1																												
Tussock Sedge Marsh																								1					4				
Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop			1																														
Wet Meadow																													4				
Wooded Successional Old Field																																	
Total	1	2	5	5	3	19	5	4	3	4	30	29	30	20	64	31	3	31	30	16	30	30	50	5	5	2	4	1	29	30	30		
Producer's Accuracy (Percent Correct)	100.00%	100.00%	20.00%	60.00%	66.67%	36.84%	40.00%	100.00%	100.00%	75.00%	90.00%	41.38%	66.67%	65.00%	65.63%	74.19%	66.67%	35.48%	46.67%	75.00%	56.67%	63.33%	70.00%	40.00%	40.00%	50.00%	50.00%	100.00%	31.03%	66.67%	36.67%		
Error of Commission (1 - Producer's Accuracy)	0.00%	0.00%	80.00%	40.00%	33.33%	63.16%	60.00%	0.00%	0.00%	25.00%	10.00%	58.62%	33.33%	35.00%	34.38%	25.81%	33.33%	64.52%	53.33%	25.00%	43.33%	36.67%	30.00%	60.00%	60.00%	50.00%	50.00%	0.00%	68.97%	33.33%	63.33%		

Table 11 Contingency matrix and calculated errors for the thematic accuracy assessment of the vegetation association map of Delaware Water Gap National Recreation Area. The cells highlighted in green show the number of sampling points that were correct. Errors of commission and omission could not be calculated for the associations highlighted in orange because either the association was not included in the preliminary association map, or the association was removed from the final classification. The one modified Anderson level II category that was observed during accuracy assessment is highlighted in blue (continued).

	Mapped Vegetation Association																															
Accuracy Assessment Observation	Oak Talus Forest	Old Field	Pitch Pine - Mixed Hardwood Rocky Summit	Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland	Red Maple - Highbush Blueberry Palustrine Forest	Red Maple - Sweet Birch Hardwood Forest	Red Maple Palustrine Forest	Reed Canarygrass Riverine Grassland	Riverine Scour Vegetation	Sandstone Talus	Shale Scree Slope	Silky Dogwood Successional Palustrine Shrubland	Silver Maple Floodplain Forest	Sparsely Vegetated Cliff	Successional Bear Oak - Heath Shrubland	Successional Eastern White Pine Woodland	Successional Mixed Hardwood Forest	Successional Shrubland	Sugar Maple - American Basswood Forest	Sugar Maple - American Beech - Sweet Birch Forest	Sugar Maple Floodplain Forest	Sycamore - Mixed Hardwood Floodplain Forest	Sycamore - Mixed Hardwood Riverine Shrubland	Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland	Sycamore Floodplain Forest	Tuliptree - Beech - Maple Forest	Tussock Sedge Marsh	Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop	Wet Meadow	Grand Total	User's Accuracy (Percent Correct)	Error of Commission (1 - User's Accuracy)
Acidic Seep																														1	100.00%	0.00%
Alder Wetland																													1	3	66.67%	33.33%
Bear Oak - Wavy Hairgrass Shrubland			1												1															8	12.50%	87.50%
Big Bluestem - Indiangrass Riverine Grassland																														3	100.00%	0.00%
Butternut Hickory Lowland Forest													2								1									5	40.00%	60.00%
Black Walnut Bottomland Forest		2																	1		1									6	N/A	N/A
Bottomland Hardwood Palustrine Forest						1						1	1																1	13	53.85%	46.15%
Bottomland Oak Palustrine Forest							1					2																		7	28.57%	71.43%
Boulder Vernal Pool Sparse Vegetation																														4	N/A	N/A
Buttonbush Wetland																														4	100.00%	0.00%
Calcareous Fen																														3	100.00%	0.00%
Calcareous Riverside Outcrop																														2	100.00%	0.00%
Calcareous Riverside Seep																														1	100.00%	0.00%
Cattail Marsh																														1	N/A	N/A
Conifer Plantation																														33	81.82%	18.18%
Dry Eastern Hemlock - Oak Forest	2																			1										43	27.91%	72.09%
Dry Eastern White Pine - Oak Forest						1																								31	64.52%	35.48%
Dry Hickory Ridgetop Forest	2		1												1															23	56.52%	43.48%
Dry Oak - Heath Forest	3		4			1									7		1			1										69	60.87%	39.13%
Dry Oak - Mixed Hardwood Forest						3									3		2			4						2				65	35.38%	64.62%
Eastern Hemlock - Mixed Hardwood Palustrine Forest				1																1										6	33.33%	66.67%
Eastern Hemlock - Northern Hardwood Forest																				1										16	68.75%	31.25%
Eastern Hemlock Forest																														16	87.50%	12.50%
Eastern Red-cedar Forest																														13	92.31%	7.69%
Eastern White Pine - Successional Hardwood Forest																														29	58.62%	41.38%
Eastern White Pine Forest																1		1												26	73.08%	26.92%
Eastern Woodland Vernal Pool Sparse Vegetation							1																							1	N/A	N/A
Hairyfruit Sedge Wetland									1																				2	3	N/A	N/A
Hickory - Eastern Red-cedar Rocky Woodland											1																			37	94.59%	5.41%
Highbush Blueberry - Leatherleaf Wetland				2																										3	N/A	N/A
Highbush Blueberry - Steeplebush Wetland							2					1			2														1	10	20.00%	80.00%
Japanese Knotweed Herbaceous Vegetation								1	2																					5	40.00%	60.00%
Leatherleaf Peatland																														1	100.00%	0.00%
Little Bluestem Grassland														2																4	50.00%	50.00%
Marl Fen																														1	100.00%	0.00%
Mixed Forb Marsh																														10	90.00%	10.00%
Northeastern Modified Successional Forest		1				6	2						1		1		13	6		1	3								1	69	28.99%	71.01%
Northern Red Oak - Mixed Hardwood Forest	4					3	1						2				1		7	8	3					4				52	21.15%	78.85%
Oak Talus Forest	18																													21	85.71%	14.29%
Old Field		21						1										2										1		27	77.78%	22.22%
Pitch Pine - Mixed Hardwood Rocky Summit			22											1																24	91.67%	8.33%
Pond							1																						1	3	N/A	N/A
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland				2																										2	100.00%	0.00%
Red Maple - Highbush Blueberry Palustrine Forest				1	4		7																							15	26.67%	73.33%
Red Maple - Sweet Birch Hardwood Forest	1					6											6			2						3				24	25.00%	75.00%
Red Maple Palustrine Forest							12					1					2										1			23	52.17%	47.83%
Reed Canarygrass Riverine Grassland								2	2																				2	6	33.33%	66.67%
Riverine Scour Vegetation									9													1	1							14	64.29%	35.71%
Sandstone Talus										27																				27	100.00%	0.00%
Shale Scree Slope											4																			12	33.33%	66.67%
Silky Dogwood Successional Palustrine Shrubland					1							20										1								23	86.96%	13.04%
Silver Maple Floodplain Forest													20				1				2	2								26	76.92%	23.08%
Sparsely Vegetated Cliff														9														1		10	90.00%	10.00%
Successional Bear Oak - Heath Shrubland			1											1	14															19	73.68%	26.32%
Successional Eastern White Pine Woodland		1														16														18	88.89%	11.11%
Successional Shrubland		6										3				1		21											1	35	60.00%	40.00%
Sugar Maple - American Basswood Forest																			7											7	100.00%	0.00%
Sugar Maple - American Beech - Sweet Birch Forest						8	2										2		5	10	2					3				39	25.64%	74.36%
Sugar Maple Floodplain Forest												1	3				1				7	1								16	43.75%	56.25%
Sycamore - Mixed Hardwood Floodplain Forest																					1	20			3					26	76.92%	23.08%
Sycamore - Mixed Hardwood Riverine Shrubland									5														4	4						13	30.77%	69.23%
Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland																								1						2	50.00%	50.00%
Sycamore Floodplain Forest													1									5			2					10	20.00%	80.00%
Tuliptree - Beech - Maple Forest	1					1	1													1						8				13	61.54%	38.46%
Tussock Sedge Marsh																											3		2	10	30.00%	70.00%
Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop														1	1													3		6	50.00%	50.00%
Wet Meadow								1	1			1															1		19	27	70.37%	29.63%
Wooded Successional Old Field		1														1	1													3	N/A	N/A
Total	31	32	29	6	5	30	30	5	20	27	5	30	30	14	30	19	30	30	20	30	20	30	5	5	5	20	5	5	31	1130		
Producer's Accuracy (Percent Correct)	58.06%	65.63%	75.86%	33.33%	80.00%	20.00%	40.00%	40.00%	45.00%	100.00%	80.00%	66.67%	66.67%	64.29%	46.67%	84.21%	N/A	70.00%	35.00%	33.33%	35.00%	66.67%	80.00%	20.00%	40.00%	40.00%	60.00%	60.00%	61.29%			
Error of Omission (1 - Producer's Accuracy)	41.94%	34.38%	24.14%	66.67%	20.00%	80.00%	60.00%	60.00%	55.00%	0.00%	20.00%	33.33%	33.33%	35.71%	53.33%	15.79%	N/A	30.00%	65.00%	66.67%	65.00%	33.33%	20.00%	80.00%	60.00%	60.00%	40.00%	40.00%	38.71%			

Total Points Correct	634
Overall Accuracy	56.1%
Kappa Index	55.0%
90% Confidence Interval	2.5%

For example, 11 of the 30 accuracy assessment points that were mapped as Eastern Hemlock Forest were actually Dry Eastern Hemlock - Oak Forest. Third, mapping errors tended to occur between associations within the same vegetation cover type or ecological group. Within palustrine herbaceous vegetation occurrences of Wet Meadow and Tussock Sedge Marsh were often incorrrectly mapped as Mixed Forb Marsh. The most widespread example of this type of error was within the mesic terrestrial hardwood forests. Deciduous tree species can be very difficult to distinguish from each other in aerial photointerpretation. Thus, types such as Red Maple - Sweet Birch Hardwood Forest, Sugar Maple - American Beech - Sweet Birch Forest, and Northern Red Oak - Mixed Hardwood Forest that occur in similar mesic environmental settings were often incorrectly mapped as another mesic terrestrial hardwood forest type.

There are several reasons that the vegetation on the ground at an accuracy assessment sampling point is different than the mapped vegetation type. The inaccuracy can be attributed to one or more of the following reasons:

- The polygon is attributed with the incorrect association because of aerial photointerpretation error.
- The polygon boundary was incorrectly drawn due to aerial photointerpretation error.
- The sampling area around the point is an inclusion - a small patch of one association embedded within another association.
- The vegetation key is incorrect or incomplete leading to the misclassification of the sampling area.
- The classification is incorrect or incomplete and does not include the vegetation in the sampling area.

To address these multiple sources of error, revisions were made to several project products based on the thematic accuracy assessment data. Revisions were made to the classification itself (see Vegetation Classification and Charaterization section), the vegetation key (see Appendix D), and the preliminary vegetation association map (see Vegetation Map Production section). Because the vegetation association map was revised after thematic accuracy asssement, the accuracy of the final vegetation association map (Figure 8) is greater than that reported above for the preliminary vegetation association map. However, re-assessing the thematic accuracy of the final vegetation association map would require another round of intensive field sampling. The costs of a second round of sampling do not seem justified simply to quantify the level of increased accuracy in the final map.

The thematic accuracy of the fire behavior fuel model map was also calculated with a contingency table (Table 12). The Kappa index for the fuel model map was 68.1% ± 2.3%, with the overall percent accuracy calculated as 76.4%. This falls below the USGS/NPS vegetation mapping protocol requirement of 80%. The errors of omission for three of the 12 mapped fuel models exceeded the USGS/NPS vegetation mapping protocol requirement of 80%, while five fuel models had errors of omission below 50%. The errors of commission for only one of the 12 fuel models observed during the accuracy assessment exceeded the USGS/NPS vegetation mapping protocol requirement of 80%. Five fuel models had errors of commission below 50%.

Table 12. Contingency matrix and calculated errors for the thematic accuracy assessment of the fire behavior fuel model map of Delaware Water Gap National Recreation Area. The cells highlighted in green show the number of sampling points that were correct.

Accuracy Assessment Observation	Mapped Fire Behavior Fuel Model												Total	Error of Commission (Percent Correct)
	0	1	1/3	3	4	5	6	6/7	7	8	8/9	9		
0	323	1	5	8		1		1		8	30		377	86.21%
1	17	15	11	1			8				3		55	47.27%
1/3	5	4	45	2		3					1		60	75.00%
3	2		2	9		1							14	78.57%
4					1				1			5	7	14.29%
5	4		6			5					1		16	31.25%
6	9	1	1				39	6			13		69	65.22%
6/7	2	1					2	2	6		1		14	14.29%
7	1						3	7	7		1		19	73.68%
8		1	2		1					11	9	1	25	44.00%
8/9	21		8		5	2	24		10	7	337	8	422	79.86%
9			1		3		1				6	41	52	78.85%
Total	383	23	81	20	10	12	77	17	24	26	402	55	1130	
Error of Ommission (Percent Correct)	84.20%	65.22%	73.42%	45.00%	10.00%	41.67%	50.65%	93.75%	29.17%	42.31%	83.83%	74.55%		

Total Points Correct	863
Overall Accuracy	76.4%
Kappa Index	68.1%
90% Confidence Interval for Kappa Index	2.3%

For the canopy cover class map, a contingency table (Table 13) calculated the Kappa index as 59.9%±2.4%, with the overall percent accuracy calculated as 71.9%. This falls below the USGS/NPS vegetation mapping protocol requirement of 80%. The errors of omission for one of the four mapped cover classes exceeded the USGS/NPS vegetation mapping protocol requirement of 80%; however, all four fuel models had errors of omission above 50%. The errors of commission for two of the four cover classes observed during the accuracy assessment exceeded the USGS/NPS vegetation mapping protocol requirement of 80%. One of the cover classes had an error of commission below 50%, while the error of commission for the remaining cover class was just above 50%.

Project Deliverables

Final products of the vegetation mapping project are shown in Table 14. All products will be delivered to the National Park Service by the Pennsylvania Natural Heritage Program with this report.

Table 13. Contingency matrix and calculated errors for the thematic accuracy assessment of the canopy cover class map of Delaware Water Gap National Recreation Area. The cells highlighted in green show the number of sampling points that were correct.

Accuracy Assessment Observation	Mapped Canopy Cover Class				Total	Error of Commission (Percent Correct)
	1	2	3	4		
1	267	19	6	0	292	91.44%
2	58	48	25	2	133	36.09%
3	17	23	119	74	233	51.07%
4	2	4	87	379	472	80.30%
Total	344	94	237	455	1,130	91.44%
Error of Omission (Percent Correct)	77.62%	51.06%	50.21%	83.30%		

Total Points Correct	813
Overall Accuracy	71.9%
Kappa Index	59.9%
90% Confidence Interval for Kappa Index	2.4%

Table 14. Summary of products resulting from the vegetation classification and mapping of vegetation and fire fuel models at Delaware Water Gap National Recreation Area.

Product	FGCD-complaint spatial metadata
Aerial photos, including flight line map and photoindex	Yes
Photomosaic as paper copy and in digital format	Yes
Annotated field forms with vegetation plot sampling data	Not applicable
Vegetation plot sampling data in the PLOTS 2.0 database	Not applicable
Differentially corrected GPS locations of vegetation plots	Yes
Annotated field forms with thematic accuracy assessment Data	Not applicable
Thematic accuracy assessment data in the PLOTS 2.0 Database	Not applicable
Differentially corrected GPS locations of thematic accuracy assessment sampling points	Yes
Digital photos representative of all vegetation types	Not applicable
Final map of vegetation associations as paper copy and in digital format	Yes
Final map of fire behavior fuel models as paper copy and in digital format	Yes
Final map of canopy cover class as paper copy and in digital format	Yes
Final map of large concentration of dead or dying trees as paper copy and in digital format	Yes
Digital raster data of elevation in 30-m grid cells	Yes
Digital raster data of slope in 30-m grid cells	Yes
Digital raster data of aspect in 30-m grid cells	Yes
Final report as paper copy and in digital format	Not applicable

Discussion

Vegetation Classification and Characterization

This study of the Delaware Water Gap National Recreation Area identified and characterized 69 vegetation associations in detail. This wide diversity of vegetation associations is a result of several factors. First, the bedrock geology differs on the two sides of the Delaware River, primarily sandstones in New Jersey and shales and siltstones in Pennsylvania, with a band of limestone and other calcareous bedrock running through the center of much of the park. The calcareous rock underlying the Hogback and Walpack Ridge gives rise to base cation-rich soils and groundwater, which in turn provides the edaphic conditions for some of the park's most diverse forests and wetland systems. Second, topography and geomorphic features vary greatly across the park, including steep sandstone boulder slopes, cliffs, rocky summits, high elevation wetland depressions associated with Kittatinny Ridge, steep shale cliffs, and rolling uplands along the western edge of the park, as well as large and small river fluvial landform features associated with the Delaware River and Flat Brook, respectively. The broad valleys of the Delaware River and the Flat Brook within the Delaware Water Gap National Recreation Area stand in contrast to most of the other large parks in the Eastern Rivers and Mountains Network, where the rivers typically have narrow floodplains bounded by steep slopes and cliffs. Third, the varied land use history in the park has created a legacy of cultural landscapes and vegetation in varied stages of succession.

The composition and structure of the associations are strongly influenced by the varied environmental settings within the park, including geology, topography, hydrology, and land use history. Based on these environmental factors, the associations fall into ecological groups depicted by different hues in Figure 8.

Eight associations, Dry Eastern Hemlock - Oak Forest, Dry Eastern White Pine - Oak Forest, Dry Hickory Ridgetop Forest, Dry Oak - Heath Forest, Dry Oak - Mixed Hardwood Forest, Eastern Hemlock Forest, Eastern White Pine Forest, and Oak - Birch Talus Forest, are considered the park's xeric terrestrial forests. These vegetation types are associated with the thin, rocky soils and xeric conditions found on the upper elevations of the Kittatinny Ridge and the Low Glaciated Plateau. Dry Oak - Heath Forest is the matrix forest for the upper elevations of the Kittatinny Ridge and contains well-developed layers of volatile ericaceous shrubs. Dry Eastern White Pine - Oak Forest is the matrix forest on the Low Glaciated Plateau in Pennsylvania, often interspersed with patches of Eastern White Pine Forest. Dry Eastern Hemlock - Oak Forest is at the greatest risk of eastern hemlock mortality (*Tsuga canadensis*) as a result of the xeric setting. Significant eastern hemlock mortality has already occurred in many stands of Dry Eastern Hemlock - Oak Forest within the park, converting the stands to Dry Oak - Mixed Hardwood Forest. Eastern Hemlock Forest, the dominant vegetation in stream ravines in the Pennsylvania portion of the park, is also at risk of significant eastern hemlock mortality. The potential deleterious effects of eastern hemlock mortality is greatest in the Eastern Hemlock Forest, since the majority of the canopy and subcanopy could be killed, resulting in significant effects on stream temperature, wildlife habitat, pathways for invasive species, and vegetation community structure and composition. Dry Hickory Ridgetop Forest contains a more diverse graminoid and herbaceous layer than the other xeric terrestrial forests and is most common on

the crest of the southeastern facing slope of the Kittatinny Ridge. Dry Oak - Mixed Hardwood Forest is an extremely common forest type that is found throughout the park in moderately xeric settings. Oak - Birch Talus Forest is typical on the steep southeast facing slope of the Kittatinny Ridge where chestnut oak (*Quercus prinus*) and sweet birch (*Betula lenta*) occur over large sandstone boulders.

Interspersed with the xeric terrestrial forests are nine additional associations, Sandstone Talus, Shale Scree Slope, Sparsely Vegetated Cliff, Hickory Eastern Red-cedar Rocky Woodland, Pitch Pine - Mixed Hardwood Rocky Summit, Wavy Hairgrass - Common Sheep Sorrel Rock Outcrop, Bear Oak - Wavy Hairgrass Shrubland, Successional Bear Oak - Heath Shrubland, and Little Bluestem Grassland, that are strongly influenced by exposed bedrock, xeric conditions, thin soils, and fire. Sandstone Talus describes the very steep, southeast-facing, coarse sandstone boulderfields of the Kittatinny Ridge, in which lichens are often the dominant vegetation. Shale Scree Slope describes the very steep, southeast-facing, fine, gravelly shale and siltstone scree typical of the eastern edge of the Glaciated Low Plateau in Pennsylvania. These scree slopes often support weedy native and nonnative invasive species. Sparsely Vegetated Cliff includes the near-vertical, southeast-facing outcrops of sandstone, shale, and siltstone that often occur directly below the Hickory - Eastern Red-cedar Rocky Woodland. Pitch Pine - Mixed Hardwood Rocky Summit is restricted to isolated bedrock outcrops along the Kittatinny Ridge ridgetop on which stunted pitch pine (*Pinus rigida*), chestnut oak, and sweet birch persist in the crevices of the rock. Other ridgetop bedrock outcrops that lack trees are instead dominated by graminoids, especially wavy hairgrass (*Deschampsia flexuosa*), and are classified as Wavy Hairgrass - Common Sheep Sorrel Rock Outcrops. Bear Oak - Wavy Hairgrass Shrubland is characterized by dense patches of bear oak (*Quercus ilicifolia*) and intervening patches of wavy hairgrass. This volatile association is restricted to extremely thin soils over acidic bedrock where tree growth is limited. Successional Bear Oak - Heath Shrubland is typically created by catastrophic fires that remove the tree canopy and encourage dense regrowth of ericaceous shrubs (*Kalmia* spp., *Vaccinium* spp., and *Gaylussacia* spp.). These later two associations are prone to more intense fire behavior characterized by fuel models 6, 6/7, and 7. Little Bluestem Grassland typically occurs in these xeric terrestrial settings, however, most examples of this association within the park were likely planted in abandoned openings or rights-of-way.

In more mesic, mid- to lower-elevation settings, the common forest associations are Eastern Hemlock - Northern Hardwood Forest, Eastern White Pine - Successional Hardwood Forest, Northern Red Oak - Mixed Hardwood Forest, Red Maple - Sweet Birch Hardwood Forest, Sugar Maple - American Beech - Sweet Birch Forest, Sugar Maple - American Basswood Forest, Tuliptree - Beech - Maple Forest, and Black Walnut Bottomland Forest, and Bitternut Hickory Lowland Forest. Eastern Hemlock - Northern Hardwood Forest occurs in ravines and north-facing lower slopes in which eastern hemlock is co-dominant with maples (*Acer* spp.) and birches (*Betula* spp.). More mature examples of Eastern White Pine - Successional Hardwood Forest occur on the ridgetop of the Walpack Ridge; however, this association typically is composed of large old eastern white pines (*Pinus strobus*) over a younger layer of native hardwood trees. Northern Red Oak - Mixed Hardwood Forest is a very common forest type throughout the park in mesic settings. When oak-dominated forests are high-graded or otherwise disturbed the resulting forest can be strongly dominated by red maple (*Acer rubrum*) and/or sweet birch. This creates the low diversity Red Maple - Sweet Birch Hardwood Forest that is often bounded by old stone walls. The composition of Sugar Maple - American Beech - Sweet

Birch Forest varies from a pure sugar maple (*Acer saccharum*) canopy to a mixture of sugar maple, American beech (*Fagus grandifolia*), and sweet birch. This common association is usually found over calcareous bedrock. Sugar Maple - American Basswood Forest is restricted to steep slopes over calcareous bedrock and is distinguished from the previous association by the presence of American basswood (*Tilia americana*) and a rich diverse herbaceous layer. Tuliptree - Beech - Maple Forest occurs occasionally on mesic toeslopes, along sloping upland drainages, and in areas where past disturbance has opened the forest canopy. Along mesic drainage swales and floodplains of smaller streams, Black Walnut Bottomland Forest can occur where black walnut (*Juglans nigra*) dominates the canopy, typically over a dense carpet of the invasives species Japanese stiltgrass (*Microstegium vimineum*).

The park contains a diversity of palustrine associations, ranging from forest to sparse vegetation and from very common to globally rare. The five palustrine forest associations, Eastern Hemlock - Mixed Hardwood Palustrine Forest, Red Maple - Highbush Blueberry Palustrine Forest, Red Maple Palustrine Forest, Bottomland Oak Palustrine Forest, and Bottomland Hardwood Palustrine Forest, occur on low terrace floodplains of small creeks, broad flat areas with diffuse drainage, poorly drained or saturated soils, or in small upland depressions and impounded drainages. Eastern Hemlock - Mixed Hardwood Palustrine Forest is restricted to the broad areas around higher elevation drainages, typically on the Kittatinny Ridge, where eastern hemlock mixes with red maple, yellow birch (*Betula alleghaniensis*), and blackgum (*Nyssa sylvatica*). The Red Maple - Highbush Blueberry Palustrine Forest and Red Maple Palustrine Forest both contain canopies strongly dominated by red maple. However, the former also contains a well-developed shrub layer of highbush blueberry (*Vaccinium corymobsum*), while the understory of the latter is typically dominated by other hardwood shrubs, ferns, or sedges (*Carex* spp.). Red Maple Palustrine Forest is the most common palustrine forest type in the park. Bottomland Oak Palustrine Forest is characterized by the dominance of pin oak (*Quercus palustris*) or swamp white oak (*Quercus bicolor*). The species composition of Bottomland Hardwood Palustrine Forest can be highly variable and is often weedy due to previous or existing adjacent land uses.

The Alder Wetland and Buttonbush Wetland occur sporadically throughout the park in a variety of palustrine settings, dominated by alders (*Alnus* spp.) and common buttonbush (*Cephalanthus occidentalis*), respectively. Although only a few examples of these two shrub wetlands occur in the park, these associations are very common in Pennsylvania and New Jersey. The Highbush Blueberry - Steeplebush Wetland, a common palustrine shrubland in the park, can be variable in species composition and environmental setting, but contains highbush blueberry or steeplebush (*Spiraea* spp.) as a dominant shrub. Silky Dogwood Successional Palustrine Shrubland, the most common palustrine shrubland in the park, occurs predominantly in the floodplain of the Flat Brook in open areas that were formerly pastured or or in agriculture, typically in association with Wet Meadow vegetation.

Three of the palustrine herbaceous communities, Cattail Marsh, Hairyfruit Sedge Wetland, and Tussock Sedge Marsh, are characterized by their dominant species, which cover 25–90% of the wetland. The dominant species are cattail (*Typha* spp.), hairyfruit sedge (*Carex trichocarpa*), and tussock sedge (*Carex stricta*), respectively. Wet Meadow and Mixed Forb Marsh have much more variable species composition, although the hydrology differs between these two associations. Wet Meadows, often found in drained lakebeds, are typically flooded early in the

growing season, but are only saturated or drier late in the growing season. Mixed Forb Marshes typically hold standing water year-round.

Nine of the park's palustrine associations are notably unique. Within the park, Leatherleaf Peatland and Highbush Blueberry - Leatherleaf Wetland occur only in small depressions on the ridgetop of the Kittatinny Ridge in New Jersey. Outside the park in the glaciated portion of northeastern Pennsylvania and New York these two associations can be associated with large bog complexes. These vegetation types provide habitat for several state-listed rare plant species, including red spruce (*Picea rubens*, S1 in New Jersey), bunchberry (*Cornus canadensis*, S2 in New Jersey), and small cranberry (*Vaccinium oxycoccos*, S2 in New Jersey), as well as unusual plants typically associated with bogs. Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland also is restricted to depressions on the ridgetop of the Kittatinny Ridge in New Jersey and contains some of the "bog"-associated species from the previous two vegetation types, including leatherleaf (*Chamaedaphne calyculata*) and roundleaf sundew (*Drosera rotundifolia*). Three of the park's unique palustrine associations are restricted to areas of groundwater seepage that occur over calcareous bedrock. Only two locations of the Calcareous Seep have been documented in the park; however, since this association occurs in very small patches (approximately 0.1 ha in size), other examples could occur within the park. Calcareous Fen has the most occurrences (3) and is the largest patch community of the three calcareous associations, with one example reaching nearly 3 ha (7 ac) in size. Both fen associations contain an interesting diversity of calciphilic plant species and several state-listed rare plant species. Marl Fen is distinguished from the Calcareous Fen by the active precipitation of marl deposits. Only one example of the Marl Fen occurs within the park. Acidic Seep, a globally rare association that occurs at one location in the park, is associated with groundwater seepage over acidic bedrock at the toeslope of the Kittatinny Ridge. Although this association potentially could occur at other locations along the toeslope of the ridge, no additional occurrences have been located to date. Two of the park's unique palustrine associations are vernal pools, small depressions that hold standing water for part of the growing season and are dry for the remainder of the growing season. Eastern Woodland Vernal Pool Sparse Vegetation is relatively common in the park and provides important breeding habitat for amphibians. Boulder Vernal Pool Sparse Vegetation, boulder lined depressions on the ridgetop of Kittatinny Ridge, have not been intensively studied. The nonvascular vegetation and the fauna associated with these pools should be inventoried, since these unique habitats may support rare or interesting species.

The riparian areas surrounding the Delaware River and its major tributaries support a variety of forest, shrubland, and herbaceous associations. Of the five riparian forest associations, Silver Maple Floodplain Forest is the most common forest along the floodplain of the Delaware River. The second most common floodplain forest, Sycamore - Mixed Hardwood Floodplain Forest, contains sycamore (*Platanus occidentalis*) mixed with maples (*Acer* spp.), ashes (*Fraxinus* spp.), and river birch (*Betula nigra*). This type can occur both on the Delaware River and its major tributaries. Sycamore Floodplain Forest, whose canopy is dominated almost exclusively by sycamore, occurs on lower terraces of the tributaries that have finer textured substrate and higher flood frequency. Sugar Maple Floodplain Forest, typically a monoculture of sugar maple, is common on the high terraces of the Delaware River and the areas surrounding the Flat Brook. Although Bitternut Hickory Lowland Forest is only mapped in six locations within the park, this association likely occurs as small patches within the Silver Maple Floodplain Forest and other riparian forests. On low cobble bars and island heads, frequent flooding maintains the Sycamore

- Mixed Hardwood Riverine Shrubland and Sycamore (Willow) - Mixed Hardwood Dwarf Shrubland, as tall and short shrublands, respectively.

Three of the park's riparian associations are notably unique. Big Bluestem - Indiangrass Riverine Grassland, tall prairie-like vegetation, occurs in five locations on the river and is known to contain eastern sand cherry (*Prunus pumila* var. *depressa*), listed as S1 in Pennsylvania and S2 in New Jersey. The Calcareous Riverside Seep and the Calcareous Riverside Outcrop occur in mosaic together in three locations along the New Jersey shore of the Delaware River on sloping calcareous bedrock outcrops. The rock outcrops and the seeps which flow through fractures in the rock support approximately 25 of New Jersey's state-listed plant species.

The remaining four herbaceous riparian associations are extremely common, both in the park and the surrounding states. Water-willow Emergent Beds occur at the heads of islands and along shorelines where American water-willow (*Justicia americana*) forms extensive beds in the shallow water. On low cobble and gravel flats just above the low water line, Riverine Scour Vegetation typically occurs. This association is extremely variable in species composition due to frequent scour by water and ice, influxes of seed sources, and variable water levels. Reed Canarygrass Riverine Grassland is common on the Flat Brook and the Delaware River, where large patches of dense reed canarygrass (*Phalaris arundinacea*) cover low sandy areas of the floodplain. Japanese Knotweed Herbaceous Vegetation was described as an association to characterize the large patches of the invasive exotic species Japanese knotweed (*Polygonum cuspidatum*) that have colonized the islands and shoreline of the Delaware River. These knotweed stands are more common in the lower half of the park and have replaced the diverse native floodplain associations with a monoculture of Japanese knotweed.

Land use history is the most influential factor in determining the current species composition and vegetation structure in seven of the park's associations. Fields that are no longer plowed, planted, or grazed have developed into Old Fields, dominated by a variety of grasses, goldenrods (*Solidago* spp.), and other forbs. In order to prevent woody species from colonizing fields, they must be mowed at least biannually to impede the natural succession to Successional Shrubland. Although a few of the typical colonizing shrubs are native species, invasive exotic shrub species autumn-olive (*Elaeagnus umbellata*), mutliflora rose (*Rosa multiflora*), and bush honeysuckles (*Lonicera* spp.) can be abundant in the Successional Shrublands. When scattered deciduous trees cover greater than 25% of the Old Field or Successional Shrubland, the field is classified as a Wooded Successional Old Field. Often, eastern red-cedar (*Juniperus virginiana*) and eastern white pine trees become established in these abandoned fields. The associations Eastern Red-cedar Forest and Successional Eastern White Pine Woodland describe these situations. Numerous Conifer Plantations also occur in the park, in which native or nonnative pines (*Pinus* spp.), spruce (*Picea* spp.), or larch (*Larix* spp.) has been planted. Northeastern Modified Successional Forest occurs on former agricultural land and other disturbed or degraded sites in which early successional and weedy tree species have established. This association also often contains abundant invasive shrubs and herb species, as well as thick vines that twine through the canopy and groundstory.

Associations of Special Concern

Thirty of the 69 vegetation associations identified in Delaware Water Gap National Recreation Area have state conservation ranks of S1, S2, or S3, or global conservation ranks of G1, G2, or G3, indicating that they are vulnerable, imperiled, or critically imperiled. These associations, listed in Table 15, approximately in descending order of rareity, should be conservation and protection priorities for the park. Threats to these sites should be carefully evaluated and mitigated or abated. Some of the associations listed in Table 15 have high S ranks for the state of New Jersey, but low global ranks and Pennsylvania S ranks. The Kittatinny Ridge is the only portion of the Appalachian Mountain Section of the Ridge and Valley Province that falls within New Jersey; therefore, associations that are common in the Ridge and Valley and Appalachian Plateau only occur in New Jersey on the Kittatinny Ridge, creating a high S rank. Sugar Maple - American Beech - Sweet Birch Forest and Eastern Hemlock - Northern Hardwood Forest are two examples of relatively common forests types that are rare in New Jersey.

The Acidic Seep and small patch associations restricted to calcareous bedrock have very high global and state conservation ranks, indicating that there are very few examples of these associations known in North America. The ridgetop of the Kittatinny Ridge contains numerous rare associations, including the bog-like wetlands, rock outcrop communities, and fire-adapted shrublands. The sparsely vegetated associations characterized by talus, cliffs, and scree also have high state conservation ranks. Other noteworthy rare types include the two vernal pool associations and Big Bluestem - Indiangrass River Grassland.

Relationship to Cowardin Wetland Classification

The palustrine and riparian vegetation associations identified in this study can be crosswalked to the Cowardin classification system. The Cowardin classification system was used for the National Wetland Inventory mapping efforts. The palustrine and riparian associations fall into two systems (Palustrine and Riverine) that belong in the highest level of the Cowardin classification hierarchy. In the Cowardin classification, the Riparian system is limited to non-tidal wetlands contained within a river channel that have less than 30% total cover of any vegetation, including trees, shrubs, persistent emergents, emergent mosses, or lichens. The Palustrine system is defined as all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens (greater than 30% cover of vegetation). Below the system level, the vegetation associations can be keyed to a subclass, the lowest level of the classification hierarchy (Cowardin et al. 1979). The awkward classification of some associations stems from site to site variation in species composition and the differences in how the authors have defined their classification terms.

Table 15. State and global conservation ranks for rare associations in Delaware Water Gap National Recreation Area, listed approximately in descending order of rariety. See Appendix H for explanations of conservation rank codes. Note that GNR and SNR indicate that the association has not yet been ranked, and therefore conveys no information about rareity.

Vegetation Association	Global Rank	New Jersey State Rank	Pennsylvania State Rank
Acidic Seep	G1	S1	n/a
Calcareous Fen	G1G2	S1S2	S1
Calcareous Riverside Outcrop	G2	S1	n/a
Calcareous Riverside Seep	GNR	S1	n/a
Calcareous Seep	GNR	S1S2	S2
Marl Fen	G2	S2	n/a
Leatherleaf Peatland	G5	S1	S2
Pitch Pine - Mixed Hardwood Rocky Summit	GNR	S1	S2S3
Hickory - Eastern Red-cedar Rocky Woodland	G2G3	S1S2	S2
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland	GNR	S1?	S3
Eastern Hemlock - Mixed Hardwood Palustrine Forest	G4?	S1S2	S3S4
Wavy Hairgrass - Common Sheep Sorrel Rock Outcrop	GNR	S1S2?	S2
Highbush Blueberry - Leatherleaf Wetland	G3G5	S1S3	S4
Boulder Vernal Pool Sparse Vegetation	GNR	SNR	S1?
Successional Bear Oak - Heath Shrubland	G4G5	S2?	S2
Bear Oak - Wavy Hairgrass Shrubland	GNR	S2?	S3
Big Bluestem - Indiangrass River Grassland	GNR	S2?	S3
Hairyfruit Sedge Wetland	GNR	S2?	S3
Eastern Woodland Vernal Pool Sparse Vegetation	GNR	SNR	S3
Sandstone Talus	G3?	S3?	S3
Oak - Birch Talus Forest	G3G4	S3?	S3
Shale Scree Slope	GNR	n/a	S3
Sparsely Vegetated Cliff	G4	S3?	S3
Sugar Maple - American Basswood Forest	G4?	S2	S4
Sugar Maple - American Beech - Sweet Birch Forest	G5	S1S3	S4
Dry Hickory Ridgetop Forest	G4?	S2S3	S4
Eastern Hemlock - Northern Hardwood Forest	G4?	S3	S4
Bottomland Oak Palustrine Forest	GNR	SNR	S3
Bitternut Hickory Lowland Forest	GNR	SNR	S3?
Highbush Blueberry - Steeplebush Wetland	GNR	S3?	S5

Twenty-three vegetation associations considered palustrine in the vegetation mapping project fall into subclasses under Cowardin's Palustrine system (Table 16). The associations considered riparian in the vegetation mapping project fall into two different Cowardin systems, Palustrine and Riverine. Ten riparian associations are classified as Palustrine in the Cowardin system, and 4 riparian associations are classified in Cowardin's riparian system (Table 16) (Cowardin et al. 1979).

Relationship between Vegetation Associations and Fire Behavior Fuel Models

Fire behavior is influence by edaphic and climatic factors; however, vegetation structure and composition has a profound inpact on the fire behavior. Vegetation associations, defined by vegetation structure and composition, are often strongly correlated with specific fire behavior fuel models. For more specific details on the correlations between vegetation associations and Anderson fire behavior fuel models refer to Appendix E.

Approximately half (35) of the vegetation associations mapped in the Delaware Water Gap corresponded to only one Anderson fire behavior fuel model. The single fuel model that was most frequently attributed to the vegetation associations was fuel model 0, attributed to nearly all of the palustrine and riparian associations. An additional one third (22) of the vegetation associations corresponded to two or three fuel models. Eight fuel models were attributed to Northeastern Modified Successional Forest; the largest number of fuel models attributed to a single association. Multiple fuel models can correspond to a single association because of variation in species composition and vegetation structure encompassed in the association. For example, the fuel model for a stand of Dry Oak - Heath Forest is dependent on which species of ericaceous shrub are dominant. Since Northeastern Modified Successional Forest is the most variable association in species composition and structure, it follows that numerous fuel models could be attributed to it.

Vegetation Association Map Production

The final vegetation association map for Delaware Water Gap National Recreation Area depicts 67 of the 69 vegetation associations classified and characterized in this study. Two associations, Calcareous Seep and Water-willow Emergent Bed, were not mapped because they could not be identified on the spring 2002 aerial photography. The Calcareous Seep occurred under forest canopy and was too small in size to be identified through photointerpretation. The Water-willow Emergent Beds were not visible on the photography due to the higher water levels in the Delaware River in April 2002. Six modified Anderson level II categories were also mapped.

The Kappa index and errors of commission and omission reported for the vegetation association map and many vegetation associations fall below the USGS/NPS vegetation mapping protocol requirement of 80%. However, this low level of accuracy is typical for vegetation mapping efforts of large parks. A vegetation map of the Catskill Park in New York reported 28% accuracy for map units analogous to associations, 46% accuracy for map units analogous to alliances, and 90% accuracy for map units analogous to vegetation cover types (Driese et al. 2004). A vegetation association map of the Shenandoah National Park created through remote sensing and the USGS/NPS vegetation mapping protocols achieved 56–67% accuracy

Table 16. Crosswalk between the vegetation associations classified in this report and the Cowardin wetland classification system (Cowardin et al. 1979).

Cowardin Code	Cowardin Classification	Association
PRB2	Palustrine, Rock Bottom, Rubble	Boulder Vernal Pool Sparse Vegetation
PEM1	Palustrine, Emergent, Persistent	Acidic Seep Big Bluestem - Indiangrass Riverine Grassland Calcareous Fen Calcareous Riverside Seep Cattail Marsh Eastern Woodland Vernal Pool Sparse Vegetation Calcareous Seep Hairyfruit Sedge Wetland Mixed Forb Marsh Reed Canarygrass Riverine Grassland Tussock Sedge Marsh Wet Meadow
PSS1	Palustrine, Scrub-Shrub, Broad-Leaved Deciduous	Alder Wetland Buttonbush Wetland Highbush Blueberry - Steeplebush Wetland Marl Fen Highbush Blueberry - Leatherleaf Wetland Silky Dogwood Successional Palustrine Shrubland Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland Sycamore - Mixed Hardwood Riverine Shrubland
PSS3	Palustrine, Scrub-Shrub, Broad - Leaved Evergreen	Leatherleaf Peatland
PFO1	Palustrine, Forested, Broad - Leaved Deciduous	Black Walnut Bottomland Forest Bottomland Hardwood Palustrine Forest Bottomland Oak Palustrine Forest Red Maple Palustrine Forest Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland Red Maple - Highbush Blueberry Palustrine Forest Silver Maple Floodplain Forest Sugar Maple Floodplain Forest Sycamore - Mixed Hardwood Floodplain Forest Sycamore Floodplain Forest
PFO7	Palustrine, Forested, Evergreen	Eastern Hemlock - Mixed Hardwood Palustrine Forest
R3AB3	Riverine, Upper Perennial, Aquatic Bed, Rooted Vascular	Water-willow Emergent Bed Riverine Scour Vegetation Japanese Knotweed Herbaceous Vegetation
R3RS1	Riverine, Upper Perennial, Rocky Shore, Bedrock	Calcareous Riverside Outcrop

(Young 2006), similar to that reported here for the Delaware Water Gap National Recreation Area.

Errors in the association map were caused by several factors. The largest source of error was the difficulty in distinguishing deciduous hardwood tree species on the 1:12,000 aerial photography. Although the photography was flown in spring leaf-off conditions, none of the hardwood species were in spring anthesis at the time; therefore, hardwood species could only be distinguished by crown architechture and assumptions about correlated edaphic factors. At 1:12,000 scale, the subtleties of crown architechture cannot be consistently distinguished. Although smaller scale photography would not have been economically feasible for such a large park, the use of photography that captured either spring anthesis or fall senescence would have been more informative and would likely have led to a more accurate map. Another common error was the over estimation of conifer cover on aerial photography. Since the bright pink conifers are obvious on the aerial photography, polygons were often considered to contain more cover of conifers relative to their deciduous associates. In addition, the park's landscape has changed since photography was flown in 2002. For example, three major flood events have significantly altered much of the riparian areas in the past three years. Also, natural succession continues to alter the vegetation, creating Successional Shrublands in the unmanaged Old Fields. Corresponding changes in the vegetation result in errors in the map since the polygons were based on 2002 vegetation photograph signatures.

Fire Behavior Fuel Model and Canopy Cover Class Map Production

The completed fire behavior fuel model map indicates that the fuel model that covers the most area within the park is fuel model 8/9. Nearly half of the park's area is attributed to this fuel model that describes fire behavior in deciduous leaf litter. Due to the abundance of riparian, palustrine, and rock-dominated vegetation types in the park, the second most common fuel model in the park is 0. These areas of the park are unlikely to burn, and pose little fire risk. The greatest fire risk is posed by fuel models 6, 6/7, and 7, those associated with the volatile ericaceous shrubs, such as huckleberries (*Gaylussacia* spp.), blueberries (*Vaccinium* spp.), and laurel (*Kalmia* spp.), as well as bear oak. These fuel models cover nearly 6,000 ha (14,500 ac), approximately 20% of the park's area, primarily on the Kittatinny Ridge and the Low Glaciated Plateau.

The completed canopy cover class map indicates that nearly two-thirds of the park (62%) supports closed canopy forest (cover class 4). The majority of the remaining third of the park is either open canopied forest (cover class 3) or non-forested (cover class 1). Very little of the park area (2%) is sparsely forested (cover class 2).

Although the overall accuracy of the fire behavior fuel model map and the canopy cover class map were similar (76.4% and 71.9%, respectively), the Kappa indexes for these two maps (68.1 and 59.9%, respectively) were strongly influenced by the number of map classes being evaluated. The Kappa index takes into account the probability of the map and observation being correct by chance. Since the canopy cover class map only included four classes, the probability of being correct by chance was much higher than in the fire fuel model map that contained 12 map classes. In addition, the errors of commission and omission for the canopy cover classes 1

and 4 were much higher than the errors for cover classes 2 and 3, since discerning the extremes of a continuum is easier than distinguishing arbitrary breaks in the middle of a continuum.

Recommendations for Future Projects

The fire behavior fuel model map produced by this project will be very useful in the planning and management of wildland and prescribed fires. However, the original 13 Anderson fuel models are not necessarily the most appropriate description of vegetation fuels in the northeastern United States. An ongoing study, conducted by the USDA Forest Service Northeastern Research Station and funded by the Joint Fire Sciences Program, seeks to update the Anderson fuel models to be more appropriate for mixed oaks forests in the region. Through computer simulations and intensely monitored prescribed fires in Connecticut, New Jersey, Pennsylvania, Virginia, and West Virginia, the appropriateness of Anderson fuel models 6, 8, and 9 will be evaluated. Since no existing fuel models accurately depict ericaceous shrubs such as mountain laurel (*Kalmia latifolia*), blueberries, and huckleberries, the behavior of these fuels will be studied (Brose 2003). The estimated completion date for this project is fall 2008. Once the new or revised fuel models have been developed, the fire fuel model map of the Delaware Water Gap National Recreation Area should be revised to incorporate these updated fuel models. Minimal additional field work or data collection should be needed for this revision, given the large amounts of data collected both in this study and the Brose (2003) study. An updated map would provide more accurate information on fire behavior and would make the planning and management of wildland and prescribed fires safer and more effective.

Another information gap identified by this project is the assignment of global conservation ranks (G Ranks) and the updating of state conservation ranks (S Ranks) for the associations of special concern. Table 15 shows that for nearly half (14 of 30) of the park's associations of special concern, the G Rank is unknown. G Ranks provide critical information on the rarity of the assocation and indicate whether the association is known from no other locations in the world, or whether it is very common in other parts of North America. Such information could affect the management decisions made about these areas within the park and is therefore critical.

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Appendix A. Aerial photograph interpretation keys to vegetation cover types, vegetation associations, and Anderson level II categories (modified) at Delaware Water Gap National Recreation Area.

AERIAL PHOTOGRAPH INTERPRETATION KEY TO VEGETATION COVER TYPES AND ANDERSON LEVEL II CATEGORIES (MODIFIED) AT DELAWARE WATER GAP NATIONAL RECREATION AREA for Spring 2002 Color Infrared Aerial Photography

1. Individual tree crowns visible as gray, black, or pink signatures of varying architecture. Trees cover greater than 25% of area. (If buildings, structures, parking lots, and roads are present see couplet 11 below).

    2. Signatures of at least 25% of the trees are pink and conical, indicating evergreen trees.

        3. Signatures of at least 75% of the trees are pink and conical, creating a near continuous pink canopy or an open canopy of conical pink crowns.

            4. Tree crowns occur in visible rows or organized patterns. Stand usually has distinct, linear edges

                Evergreen Plantation

            4. Tree crowns do not occur in visible rows or organized patterns. Stand does not usually have distinct, linear edges.

                5. Tree crowns cover 25–60% of the area, such that individual trees or clumps of trees are visible in a matrix of white to light gray herbaceous vegetation. Gray shrubs may also be present.

                    Evergreen Woodland

                5. Tree crowns cover greater than 60% of the area, creating a near continuous canopy.

                    Evergreen Forest

        3. Signatures of 25–75% of the trees are pink and conical. The canopy contains light to dark gray deciduous tree crowns interspersed with pink, conical evergreen tree crowns.

            6. Tree crowns cover 25–60% of the area, such that individual trees or clumps of trees are visible in a matrix of white to light gray herbaceous vegetation. Gray shrubs may also be present.

                Mixed Evergreen - Deciduous Woodland

            6. Tree crowns cover greater than 60% of the area, creating a near continuous canopy.

                7. Signature under canopy is black, indicating standing water. Forest occurs in a swale, depression, or low topgraphic position.

                    Seasonally Flooded Mixed Evergreen - Deciduous Forest

7. Signature under canopy is white, light gray or pink, indicating leaf litter or vegetation. Forest occurs in terrestrial setting or adjacent to a river or stream.

    8. Forest occurs in a terrestrial setting, not adjacent to a major blue-gray curvilinear drainage feature.

        Mixed Evergreen - Deciduous Forest

    8. Forest is adjacent to dark blue-gray curvilinear feature of the Delaware River or its major tributaries.

        Temporarily Flooded Mixed Evergreen - Deciduous Forest

2. Signatures of trees are light to dark gray or black, indicating cold-deciduous trees. Less than 25% of the trees are pink and conical.

    9. Tree crowns occur in visible rows or organized patterns. Stand usually has distinct, linear edges.

        Deciduous Plantation

    9. Tree crowns do not occur in visible rows or organized patterns. Stand does not usually have distinct, linear edges.

        10. Tree crowns cover 60% or less of the area, such that individual trees or clumps of trees are visible in a matrix of white to light gray herbaceous vegetation. Gray shrubs may also be present.

            11. Individual gray or black tree crowns form an open canopy over bright white to light pink herbaceous vegetation. Woodland occurs on island or shoreline adjacent to dark blue-gray curvilinear feature of the Delaware River or its major tributaries.

                Temporarily Flooded Deciduous Woodland

            11. Individual gray or black tree crowns form an open canopy over light pink, gray, or white herbaceous vegetation. Rounded gray clumps of shrubs may also be present. Dark curvilinear drainage features are not present.

                Deciduous Woodland

        10. Tree crowns cover greater than 60% of the area, creating a near continuous canopy.

            12. Signature under canopy is black, indicating standing water. Forest occurs in a swale, depression, or low topgraphic position.

                Seasonally Flooded Deciduous Forest

            12. Signature under canopy is white, light gray or pink, indicating leaf litter or vegetation. Forest occurs in terrestrial setting or adjacent to a river or stream.

13. Forest occurs immediately adjacent to the dark blue gray curvilinear signature of a creek, tributary, or the Delaware River.

Temporarily Flooded Deciduous Forest

13. Forest does not occur immediately adjacent to the dark blue gray curvilinear signature of a creek, tributary, or the Delaware River.

Deciduous Forest

1. Individual tree crowns cover less than 25% of the area.

14. Signature is primarily white, gray, or pink ranging from uniform to mottled, representing shrub or herbaceous vegetation. Buildings, structures, parking lots, and roads are absent. Signature is not uniform dark blue gray with occasional white speckles, indicating open water. Signature is not extremely steeply sloping or isolated outcrops of white to blue gray, representing bare rock.

15. Shrubs cover greater than 25% of the area, appearing as round gray circles, or short, thin, pink cones. Shrubs are scattered or in clumps within a matrix of white, light gray, or pink herbaceous vegetation. Areas of dense deciduous shrub cover will have a bumpy gray signature.

16. At least 25% of the shrubs occur as short, thin, pink cones, with the remaining shrubs appear as round gray circles.

17. Shrubland occurs in a depression, or adjacent to dark gray curvilinear drainage features. Signature around shrubs is black (standing water) or bright dappled white (hummocks of herbaceous vegetation).

Seasonally Flooded Mixed Evergreen - Deciduous Shrubland

17. Shrubs occur in a matrix that is somewhat uniform or mottled white, light pink, or bright pink, representing terrestrial herbaceous vegetation. Dark gray curvilinear drainage features and the black signature of standing water are absent.

Mixed Evergreen - Deciduous Shrubland

16. Less than 25% of the shrubs occur as short, thin, pink cones. The vast majority of the shrubs appear as round gray circles.

18. Shrubland occurs in a basin, depression, or topographically low area. Signature shows uniformly bumpy blue gray shrubs over dark blue gray or black standing water. Dark blue gray curvilinear features of the Delaware River or its tributaries are generally absent.

Semipermanently Flooded Deciduous Shrubland

18. Dark blue gray or black signature of standing water does not appear interspersed with the rounded gray shrub features. Dark blue gray curvilinear drainage features may be present, though rounded gray shrub features generally appear in a matrix of dappled or mottled white, light pink, or bright pink vegetation or light blue gray cobbles.

    19. Shrubland occur on islands or shorelines in or adjacent to the dark blue gray curvilinear features of the Delaware River or its major tributaries.
    Temporarily Flooded Deciduous Shrubland

    19. Shrubland does not occur on islands or shorelines in or adjacent to the dark blue gray curvilinear features of the Delaware River or its major tributaries.
    Deciduous Shrubland

15. Shrubs cover 25% or less of the area. Signature is almost entirely white, light gray, and/or light to bright pink herbaceous vegetation, ranging from uniform to mottled.

    20. Signature is bright dappled white of herbaceous vegetation interspersed with black areas of open water. Dark gray linear drainage features can be present.

        21. Signature is bright dappled white and dappled, indicating saturated soil and dense hummocky herbaceous vegetation. Black areas of open water may be interspersed with the bright white vegetation. Dark gray linear drainage features are present.
        Saturated Herbaceous Vegetation

        21. Signature is primarily black open water with scattered white dapples of emergent vegetation. Or signature is light gray, indicating continuous, but not dense, herbaceous vegetation over standing water. Signature occurs adjacent to lakes, ponds, and Delaware River islands.
        Semipermanently Flooded Herbaceous Vegetation

    20. Signature is primarily white, pink, or gray. Black areas of open water are absent. Dark blue gray curvilinear features of the Delaware River or its major tributaries may or may not be present. Polygons may or may not have linear edges and regular shapes.

        22. Signature tends to be bright to light pink, white, and/or light to dark gray, often in wide linear bands of color. Parallel mow or till lines are often prominent. Polygons tend to have linear edges and regular shapes.
        Cropland

        22. Signature tends to be white, light pink, and/or blue gray, and does not occur in wide linear bands of color. Parallel mow or till lines are absent. Polygons may or may not have linear edges and regular shapes.

23. Occurs on edges of islands or shorelines adjacent to the dark blue gray curvilinear features of the Delaware River or its major tributaries.

Temporarily Flooded Herbaceous Vegetation

23. Does not occur adjacent to the dark blue gray curvilinear features of the Delaware River or its major tributaries. Round gray circles or bright pink cones of deciduous or evergreen shrubs may be widely scattered in the matrix of white or pink herbaceous vegetation. Polygons may have linear edges and regular shapes.

Grassland

14. Signature is not uniform to mottled white, gray, or pink, representing shrub or herbaceous vegetation. Buildings, structures, parking lots, and roads are present; OR signature is uniform dark blue gray with occasional white speckles, indicating open water; OR signature is extremely steeply sloping or isolated outcrops of white to blue gray, representing bare rock.

24. Buildings, structures, parking lots and roads are present, often surrounded by frequently mowed turf grass that has a light to bright pink signature.

25. Polygon is long, thin, straight or curvilinear feature with hard edges.

26. Evenly spaced metal structures connected by occasionally visible wires may be present. Color and texture of signature is variable. Polygon continues its linear path despite changes in topography or vegetation.

Right-of-way

26. Roads and highways have a linear uniform light gray to blue-gray signature often with visible lane lines and automobiles.

Transportation Corridor

25. Polygon is typically square or rectangular-like. Buildings, structures, and parking lots are visible, often surrounded by frequently mowed turf grass that has a light, bright pink signature.

Built-up Land

24. Signature is uniform dark blue gray with occasional white speckles, indicating open water; OR signature is extremely steeply sloping or isolated outcrops of white to blue gray, representing bare rock. Buildings, structures, parking lots and roads surrounded by bright pink mowed turf grass are absent.

27. Signature is uniform black to dark blue gray with occasional white speckles, indicating open water.

28. Feature is curvilinear dark blue gray with occasional white speckles.

River

28. Feature is small, somewhat circular or ovular black features isolated within other vegetation types.

Pond

27. Signature is extremely steeply sloping or isolated outcrops of white to blue gray, representing bare rock.

29. When viewed through a stereoscope, feature has a vertical or near vertical slope. Signature is white to light blue gray.

30. Feature tends to occur in the upper portion of steep slopes. Polygon may contain bright pink cones of evergreen shrubs or trees.

Cliff

30. Feature tends to occur on toe slopes or the lower portion of steep slopes. Signature has bright white coarse bouldery texture of talus or light blue gray fine texture of scree.

Talus or Scree

29. When viewed through a stereoscope, feature is flat, gently sloping, or convex.

31. Feature occurs on the edges of islands or shoreline in the Delaware River.

Cobble Bar

31. Feature tends of occur on ridgetops or other terrestrial settings. Feature does not occur on the edges of islands or shoreline in the Delaware River

32. Feature is flat to sloping. Signature is even textured, medium blue gray.

Shale Pit

32. Feature is convex to sloping. Signature is mottled white and light blue gray with a coarse bouldery texture.

Ridgetop Bedrock Outcrop

AERIAL PHOTOGRAPH INTERPRETATION KEY TO VEGETATION ASSOCIATIONS AND ANDERSON LEVEL II CATEGORIES (MODIFIED) AT DELAWARE WATER GAP NATIONAL RECREATION AREA for Spring 2002 Color Infrared Aerial Photography

Important Notes: a) Vegetation associations marked with asterisks (*) are difficult to distinguish from similar types by aerial photography signature alone. Additional information sources are needed for accurate identification.

b) Two associations were excluded from this key because they cannot be identified on the spring 2002 aerial photography and were not depicted on the vegetation association map. These associations are: Calcareous Seep and Water-willow Emergent Bed.

c) This key is intended for use with the 1:12,000 color infrared aerial photography flown of the Delaware Water Gap National Recreation Area in Spring of 2002. Use of this key with other photography is not advised.

d) Success in aerial photography interpretation involves one part ecological understanding, one part on-the-ground experience in the area, and one part luck. Please refer to the thematic accuracy assessment results section of this report as a disclaimer for the accuracy of this key.

1. Buildings, structures, parking lots and roads are present, often surrounded by frequently mowed turf grass that has a light to bright pink signature.

    2. Roads and highways have a linear uniform light gray to blue-gray signature often with visible lane lines and automobiles.

Transportation Corridor

    2. Polygon is typically square or angular. Buildings, structures, and parking lots are visible, often surrounded by frequently mowed turf grass that has a bright pink signature.

Built-up Land

1. Buildings, structures, parking lots and roads are absent. Signature can be varying shades and textures of white, pink, gray, blue, or black.

    3. Signature is uniformly dark blue gray to black, with occasional white speckles representing open water.

        4. Feature is curvilinear dark blue gray with occasional white speckles.

River

        4. Feature is small, somewhat circular or ovular black features isolated within other vegetation types.

            5. Feature is a very small (generally <0.5 ha in area), naturally occurring depression that holds standing water for only part of the year.

6. Substrate is coarse sandstone boulders (boulders may not be visible with high water in late winter-early spring).

Boulder Vernal Pool Sparse Vegetation*

6. Substrate is black leaf litter and soil.

Eastern Woodland Vernal Pool Sparse Vegetation*

5. Feature can be small or large (0.01–50 ha), naturally occurring or man-made depression that holds standing water year round.

Pond*

3. Signature can be varying shades and textures of white, pink, gray or blue, but is not uniformly dark blue-gray to black representing open water.

7. Signature is extremely steeply sloping or isolated outcrops, varying from white to blue-gray, representing bare rock.

8. When viewed through a stereoscope, feature has a vertical or near vertical slope. Signature is white to light blue-gray.

9. Feature tends to occur in the upper portion of steep slopes. Polygon may contain trees or shrubs visible as gray, black, or pink signatures of varying architecture.

10. Trees visible as gray, black, or pink signatures of varying architecture are sparse or absent.

Sparsely Vegetated Cliff

10. Trees visible as gray, black, or pink signatures of varying architecture are regularly scattered, covering >25% of the area. Feature tends to occur at the crest or top of extremely steep, typically south-east facing slopes.

Hickory - Eastern Red-cedar Rocky Woodland

9. Feature tends to occur on toeslopes or the lower portion of steep slopes. Signature has bright white coarse bouldery texture of talus or light blue-gray fine texture of scree.

11. Signature is light blue-gray to white with a coarsely bumpy texture. Feature tends to occur on the lower half of the steep southeast facing slope of the Kittatinny Ridge.

Sandstone Talus

11. Signature is light blue-gray to white with a smooth, fine-grained texture. Parallel vertical lines where scree is eroding may be visible. Feature tends to occur on the lower half of the steep southeast-facing slopes on the eastern edge of the Low Glaciated Plateau.

Shale Scree Slope

8. When viewed through a stereoscope, feature is flat, gently sloping, or convex.

12. Feature occurs on the edges of islands or shoreline in the Delaware River.

13. Thin linear feature with white signature that occurs on the New Jersey shoreline of the Delaware River, typically gently sloping to the northwest or southwest.

Calcareous Riverside Outcrop*

13. Feature can have variable size and shape, often with a blue gray or white signature and an irregular, fine bumpy texture. White or pink herbaceous vegetation may be present.

Riverine Scour Vegetation*

(Note: this signature may also be Reed Canary Grass Riverine Grassland, Hairfruit Sedge Wetland, or Japanese Knotweed Herbaceous Vegetation)

12. Feature tends to occur on ridgetops or other terrestrial settings. Feature does not occur on the edges of islands or the shoreline of the Delaware River

14. Feature is flat to sloping. Signature is even textured, smooth, medium blue gray.

Shale Pit

14. Feature is convex to sloping. Signature is mottled white and light blue gray with a coarse bouldery texture.

15. Rock outcrop contains trees visible as gray, black, or pink signatures of varying architecture are regularly scattered, covering >25% of the area.

Pitch Pine - Mixed Hardwood Rocky Summit

15. Trees visible as gray, black, or pink signatures of varying architecture are sparse or absent. Pink or white herbaceous vegetation may be present.

Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop

7. Signature can be varying shades and textures of white, pink, or gray, but is not extremely steeply sloping or isolated outcrops of white to blue-gray, representing bare rock.

16. Individual tree crowns, visible as gray, black, or pink signatures of varying architecture, cover greater than 25% of area

    17. Within the canopy and subcanopy combined, pink, conical-shaped conifers have relative cover of 75% or greater.

        CONIFEROUS FOREST/WOODLAND GROUP

    17. Within the canopy and subcanopy combined, pink, conical-shaped conifers have relative cover less than 75%.

        18. Within the canopy and subcanopy combined, pink, conical-shaped conifers have relative cover between 25–75%.

            MIXED FOREST/WOODLAND GROUP

        18. Within the canopy and subcanopy combined, pink, conical-shaped conifers have relative cover less than 25%

            19. Vegetation tends to occur in flat or low areas adjacent to rivers, streams, or other waterbodies. The ground under the canopy may (or may not) be black, indicating stand water.

            RIPARIAN OR PALUSTRINE DECIDUOUS FOREST/WOODLAND GROUP

            19. Vegetation tends to occur in terrestrial environments, not necessarily adjacent to rivers, streams, or other waterbodies. The ground under the canopy is not black, but may be white, gray or pink.

                TERRESTRIAL DECIDUOUS FOREST/WOODLAND GROUP

16. Individual tree crowns, visible as gray, black, or pink signatures of varying architecture, do not cover greater than 25% of the area.

    20. Shrubs, visible as rounded gray circles or small pink cones, cover greater than 25% of the area.

        SHRUB GROUP

    20. Shrubs, visible as rounded gray circles or small pink cones, do not cover greater than 25% of the area. Area is dominated by herbaceous or graminoid species that have a pink or white signature.

        HERBACEOUS GROUP

CONIFEROUS FOREST/WOODLAND GROUP

1. The majority of the conical pink crowns are deep reddish-pink with the thin, cylindrical or tear-drop shape of eastern red-cedar (*Juniperus virginiana*).

Eastern Red-cedar Forest

1. The majority of the pink conical crowns have signatures other than the deep reddish-pink, thin, cylindrical or tear-drop shape of eastern red-cedar (*Juniperus virginiana*).

2. Crown are tightly packed and regularly spaced, typically in a rectangular polygon with hard edges. Crowns are often small and obscurely starred-shaped.

Conifer Plantation

2. Crown do not appear tightly packed, regularly spaced, or in a rectangular polygon with hard edges.

3. The majority of the canopy is composed of bright pink, star-shaped conical crowns of eastern white pine (*Pinus strobus*).

4. Canopy cover exceeds 60%. Association often occurs on the Low Glaciated Plateau in Pennsylvania in the park.

Eastern White Pine Forest

4. Canopy cover varies between 25% and 60%. The white or light pink signature of herbaceous vegetation or the rounded gray signature of shrubs are visible in between the scattered pines. Association often occurs in fields.

Successional Eastern White Pine Woodland

3. The majority of the canopy is composed of the medium pink, rough-textured, conical crowns of eastern hemlock (*Tsuga canadensis*). Often occurs in ravines and north-facing slopes. Dead or declining eastern hemlocks will have a bluish hue and standing dead trees may be visible.

Eastern Hemlock Forest

MIXED FOREST/WOODLAND GROUP

1. Forest or woodland is composed of deep reddish-pink with the thin, cylindrical or tear-drop shape of eastern red-cedar (*Juniperus virginiana*) and a mixture of gray to black deciduous crowns. Canopy can be patchy, discontinuous, of varied height, or of small diameter trees. The bumpy gray of pink signature of shrubs or the white or light pink signature of herbaceous vegetation may be present under or in between the canopy. Gray vines may be visible, covering the trees or shrubs.

Northeastern Modified Successional Forest

1. Forest is not as described above.

2. Association occurs in an ovular depression on a ridgetop in New Jersey. Thin pink conical crowns and wispy gray crown are visible above a dense, bumpy gray and pink shrub layer that covers the depression.

Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland

2. Association does not occur in an ovular depression on a ridgetop in New Jersey and does not fit description above.

3. Pink or gray conical crowns are regularly spaced, often interspersed with rounded gray crowns of varying architecture. Conical crowns are often small and obscurely starred-shaped. Stand typically occurs in a rectangular polygon with hard edges.

Conifer Plantation

3. Conical crowns are not regularly spaced, and do not occur in a rectangular polygon with hard edges.

4. The majority of the conical crowns are the bright pink, star-shaped crowns of eastern white pine (*Pinus strobus*).

5. Forest occurs on dry sites. The deciduous crowns tend to be darker gray with the craggy, irregular architechture of oaks (*Quercus* spp.). Dense clumps of short, thin, bright pink, eastern white pine (*Pinus strobus*) regeneration may be common beneath the canopy in some parts.

Dry Eastern White Pine - Oak Forest

5. Forest occurs on dry-mesic to mesic sites. The deciduous crowns tend to be lighter gray to white, with more regular architecture. These crowns often appear rounded or ovular, as is typical of maples (*Acer* spp.), birches (*Betula* spp.), and other hardwoods. Often, the large, bright pink, star-shaped eastern white pine (*Pinus strobus*) crowns are taller than the remainder of the gray deciduous canopy.

Eastern White Pine - Successional Hardwood Forest

4. The majority of the conical crowns are the medium pink, rough-textured crowns of eastern hemlock (*Tsuga canadensis*). Dead or declining eastern hemlocks will have a bluish hue and standing dead trees may be visible

    6. The ground under the canopy appears black, indicating standing water. Vegetation occurs in a depression, flat area, or swale around a small creek or drainage.

        Eastern Hemlock - Mixed Hardwood Palustrine Forest

    6. The ground under the canopy has a white, gray or pink signature of leaf litter or ericaceous shrubs. Vegetation occurs in a variety of environmental settings.

        7. Forest occurs on dry sites. The deciduous crowns tend to be darker gray with the craggy, irregular architechture of oaks (*Quercus* spp.). The bluish hue of dead or declining eastern hemlocks (*Tsuga canadensis*) may be common.

            Dry Eastern Hemlock - Oak Forest

        7. Forest occurs on dry-mesic to mesic sites. The deciduous crowns tend to be lighter gray to white, with more regular architecture. These crowns often appear rounded or ovular, as is typical of maples (*Acer* spp.), birches (*Betula* spp.), and other hardwoods.

            Eastern Hemlock - Northern Hardwood Forest

RIPARIAN OR PALUSTRINE DECIDUOUS FOREST/WOODLAND GROUP

1. The stout branches and trunks of some individual trees are bright white and distinctly visible, indicating sycamore (*Platanus occidentalis*). Sycamores cover >25% of the area.

    2. The majority of the crowns have stout branches and trunks that are bright white and distinctly visible. Sycamore (*Platanus occidentalis*) constitutes 50% or greater relative cover of the canopy.

        Sycamore Floodplain Forest

    2. Sycamores (*Platanus occidentalis*) with stout branches and trunks that are bright white and distinctly visible cover between 25 and 50% of the area.

        Sycamore - Mixed Hardwood Floodplain Forest

1. Most tree trunks and individual branches are not bright white and distinctly visible. Tree crowns tend to be floating gray or white globes or craggy gray forms. Sycamores cover <25% of the area.

    2. Forest is dominated by rounded whitish gray floating globes or ovals with somewhat regular architecture, indicating dominance of maples (*Acer* spp.).

        3. Association occurs in an ovular depression on a ridgetop in New Jersey. Wispy gray ovular crown are visible above a dense, bumpy gray and pink shrub layer that covers the depression. Scattered thin pink conical crowns may be present.

            Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland

        3. Association does not occur in an ovular depression on a ridgetop in New Jersey and does not fit description above.

            4. At least 25% of the trees have the characteristic silver maple (*Acer saccharinum*) signature: multiple dark gray trunks originating from a single stump with rounded gray deliquescent crowns. The overall architecture is somewhat similar to broccoli. This association is very common on the floodplain and islands of the Delaware River.

                Silver Maple Floodplain Forest

            4. Trees with broccoli-esque architecture are not common. Crowns are excurrent, rounded whitish gray floating globes or ovals with somewhat regular architecture.

                5. The majority of the crowns are spherical with regular, whitish, fine branching, typical of sugar maples (*Acer saccharum*). This association is common on the floodplain the Delaware River and its major tributaries. The ground under the canopy typically has a white or gray signature of leaf or herbaceous litter.

                    Sugar Maple Floodplain Forest

5. The majority of crowns are whitish gray with more open, inverse conical or vase-shaped architecture, typical of red maples (*Acer rubrum*). Associations are common in depressions or flat areas surrounding small drainages. The ground underneath the canopy may be black, indicating standing water.

    6. Bumpy, rounded, white or gray signature of highbush blueberry (*Vaccinium corymbosum*) is visible under the canopy, and cover at least 25% of the area.
    Red Maple - Highbush Blueberry Palustrine Forest*

    6. Bumpy, rounded, white or gray shrubs are uncommon.
    Red Maple Palustrine Forest*

2. Tree architecture can be variable. The majority of the trees do not have rounded whitish gray floating globes or ovals with somewhat regular architecture, indicating dominance of maples (*Acer* spp.).

    7. Open canopy of the dark gray excurrent crowns of black walnut (*Juglans nigra*) over a continuous whitish pink herbaceous layer. Shrubs and subcanopy trees are sparse to absent. Association typically occurs on the floodplain of the Delaware River, its major tributaries, or in smaller drainages and swales.
    Black Walnut Bottomland Forest*

    7. Forest is not as described above.

        8. Crowns tend to be gray with the craggy, irregular architecture of oaks (*Quercus* spp.). Pin oak (*Quercus palustris*) and/or swamp white oak (*Quercus bicolor*) compose 25–75% relative cover in the canopy.
        Bottomland Oak Palustrine Forest*

        8. Crowns with darker gray, craggy, irregular architechture of oaks (*Quercus* spp.) are uncommon.

            9. Forest occurs on the floodplain of the Delaware River or its major tributaries. Many trees have somewhat open architechture with stout whitish branches typical of bitternut hickory (*Carya cordiformis*).
            Bitternut Hickory Lowland Forest*

            9. Forest occurs low flat areas surrounding drainages or streams. The signature of the canopy trees does not match the species described in any of the preceeding couplets. The groundstory is typically weedy, with a heterogeneous, patchy, pink and white signature that contains both shrubs and herbs.
            Bottomland Mixed Hardwood Palustrine Forest*

DECIDUOUS TERRESTRIAL FOREST SUBGROUP

1. Crowns are tightly packed, regularly spaced, extremely thin, rounded, blue-gray cones, characteristic of larches (*Larix* spp.). Trees typically in a rectangular polygon with hard edge.

Conifer Plantation

1. Vegetation is not as described above.

    2. In general, forests occur on dry sites, mid- to upper slopes, and ridgetops. In general, forests tend to be dominated by trees with darker gray signatures and the craggy, irregular architecture characteristic of oaks (*Quercus* spp.) or the thick-branched, rounded architecture of hickories (*Carya* spp.). A well-developed ericaceous shrub layer may be visible as blue-gray or pink bumpy texture under the canopy.

        3. Well-developed tall and/or short ericaceous shrub layers (40–95% absolute cover) are visible as blue-gray or pink bumpy texture under the canopy.

            4. Canopy is composed of the wispy, white crowns of young, small-diameter trees such as aspen (*Populus* spp.) and birch (*Betula* spp.), with scattered large individuals of pink conical-crowned pitch pine (*Pinus rigida*) and gray craggy oaks (*Quercus spp.*).

Successional Heath Shrubland

            4. Canopy is composed of established, larger-diameter oaks (*Quercus* spp.) and hickories (*Carya* spp.).

Dry Oak Heath Forest

        3. The tall and/or short ericaceous shrub layers, visible as blue-gray or pink bumpy texture under the canopy, cover less than 40% of the area. Groundstory is typically bright white or gray.

            5. Boulders, appearing as bright white sharp-edge bumps interspersed with black shadows, cover the majority of the ground under the canopy.

Oak - Birch Talus Forest

            5. The ground is evenly-textured bright white or gray, without significant cover of boulders as described above.

                6. The forest has an open canopy of thick-branched, rounded hickories (*Carya* spp.) over bright white graminoid-dominated groundstory. This association is very common on the crest of the south-east facing slope of the Kittatinny Ridge and occassional on isolated ridgetops.

Dry Hickory Ridgetop Forest*

6. The forest is dominated by craggy, irregular architecture characteristic of oaks (*Quercus* spp.). These associations are very common throughout the park.

    7. In general, this forest type occurs on drier site and is dominated by a drier suite of species - chestnut oak (*Quercus prinus*), white oak (*Q. alba*), pitch pine (*Pinus rigidia*), and ericaceous shrubs species (*Kalmia* spp., *Gaylussacia* spp., *Vaccinium* spp.).

        Dry Oak - Mixed Hardwood Forest*

    7. In general, this forest type occurs on more mesic sites and is dominated by a more mesic suite of species - northern red oak (*Quercus rubra*), maples (*Acer* spp.), birches (*Betula* spp.), American hornbeam (*Carpinus caroliniana*), northern spicebush (*Lindera benzoin*), and Japanese barberry (*Berberis thunbergii*).

        Northern Red Oak - Mixed Hardwood Forest*

2. In general, forests occur on dry-mesic to mesic sites, mid- to lower slopes, and low elevations. The canopy crowns tend to be lighter gray to white, with more regular architecture. These crowns often appear rounded, ovular, or vase-shaped, as is typical of maples (*Acer* spp.), birches (*Betula* spp.), tuliptree (*Liriodendron tulipifera*) and other hardwoods.

    8. The woodland or forest signature is either: a) predominantly a white or pink herbaceous/graminoid dominated-groundstory with scattered open-grown deciduous canopy trees that cover >25% of the field; or b) weedy-looking open to closed canopy deciduous forest over a heterogeneous, bumpy gray or pink shrub layer, often with gray vines covering the trees and shrubs.

        9. Woodland signature is predominantly a white or pink herbaceous/graminoid dominated-groundstory with scattered open-grown deciduous canopy trees that cover >25% of the field.

            Wooded Successional Old Field

        9. Forest or woodland contains a weedy-looking open to closed canopy over a heterogeneous, bumpy gray or pink shrub layer (characteristic of invasive shrubs), often with gray vines covering the trees and shrubs.

            Northeastern Modified Successional Forest

    8. Forest is typically a closed canopy deciduous forest with a consistent white or gray signature of leaf litter under the somewhat homogeneous canopy. Forest is not as described above.

        10. Oaks species (*Quercus* spp.) with darker gray signatures and craggy, irregular architecture OR tuliptree (*Liriodendron tulipifera*) with a white signature and vase-shaped or inverted-triangular-shaped architecture constitute at least 25% relative cover in the canopy.

11. Oaks species (*Quercus* spp.) with darker gray signatures and craggy, irregular architecture constitute at least 25% relative cover in the canopy).
Northern Red Oak - Mixed Hardwood Forest*

11. Tuliptree (*Liriodendron tulipifera*) with a white signature and vase-shaped or inverted-triangular-shaped architecture constitute at least 25% relative cover in the canopy.
Tuliptree - Beech - Maple Forest*

10. The canopy crowns tend to be lighter gray to white, with more regular architecture. These crowns often appear rounded or ovular, as is typical of maples (*Acer* spp.) and birches (*Betula* spp.). Oaks species (*Quercus* spp.) with darker gray signatures and craggy, irregular architecture AND tuliptree (*Liriodendron tulipifera*) with a white signature and vase-shaped or inverted-triangular-shaped architecture EACH constitute at least 25% relative cover in the canopy.

12. The majority of crowns are whitish gray with the open, inverse conical or vase-shaped architecture, typical of red maples (*Acer rubrum*), OR with the rounded, dense, somewhat irregular architechture of sweet birch (Betula *lenta*). In general, forest is not restricted to calcareous bedrock. The forest canopy may be very homogeneous, as the vast majority of the trees are the same age, and the same species.
Red Maple - Sweet Birch Hardwood Forest*

12. The majority of the canopy crowns are spherical with regular, whitish, fine branching, typical of sugar maples (*Acer saccharum*). Forest is often associated with calcareous bedrock.

13. Forest is uncommon and occurs on a mesic slope over calcareous bedrock. Basswood (*Tilia americana*) constitutes at least 25% relative cover in the canopy.
Sugar Maple - American Basswood Forest*

13. Forest is very common on mesic sites, often but not always, over calcareous bedrock. Basswood (*Tilia americana*) constitutes less than 25% relative cover in the canopy.
Sugar Maple - American Beech - Sweet Birch Forest*

HERBACEOUS GROUP

1. Riparian vegetation that occurs in the floodplain of the Delaware River on islands, shorelines, gravel/cobble bars, or riverbeds.

    2. Signature is an extremely thin band of white limestone outcrop along the New Jersey shoreline of the Delaware River, typically with a north-northwest exposure.
    Calcareous Riverside Outcrop / Calcareous Riverside Seep

    2. Signature is not an extremely thin band of north-northwest facing, white limestone outcrop along the New Jersey shoreline of the Delaware River. Signature can be of variable texture, typically blue-gray, light pink or white.

        3. Signature is distinctive, either: a) light gray, fine-textured clumps or blobs with rounded edges, characteristic of Japanese knotweed (*Polygonum cuspidatum*), or b) relative uniform light blue-gray, characteristic of prairie grasses.

            4. Signature is light gray, fine-textured clumps or blobs with rounded edges, characteristic of Japanese knotweed (*Polygonum cuspidatum*). Patches of bright white non-knotweed vegetation may be interspersed with the gray clumps.
            Japanese Knotweed Herbaceous Vegetation

            4. Signature is relative uniform light blue-gray, characteristic of prairie grass species such as big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*) and little bluestem (*Schizachyrium scoparium*).
            Big Bluestem - Indiangrass Riverine Grassland

        3. Signature is not as described above. Signature can be of variable texture, but is typically white, less often, blue-gray or light pink.

            5. Feature typically occurs at a low level, just above the water level. Variable signature is often bright white, often patchy, with an irregular texture, however, it also can be can be dark blue-gray or light pink.
            Riverine Scour Vegetation*

            5. Feature usually occurs slightly higher above the water level (approximately 1–5 meters). Signature is nearly always bright white and continuous, with a regular texture.

                6. Vegetation dominated by reed canary grass (*Phalaris arundinacea*). Very common on the Delaware River floodplain.
                Reed Canarygrass Riverine Grassland*

                6. Vegetation dominated by hairyfruit sedge (*Carex trichocarpa*). Rare on the Delaware River floodplain. Occasional on the Flatbrook floodplain.
                Hairyfruit Sedge Wetland*

1. Palustrine or terrestrial vegetation that is not directly associated with the Delaware River. Palustrine vegetation associated with creeks and tributaries to the Delaware River is included here.

    7. Palustrine vegetation occurs in depressions, low-lying areas, and adjacent to creeks, streams, and ponds. Black standing water or drainage rivulets may be visible.

        9. Association is a rare, small patch community directly associated with groundwater seepage, often over calcareous bedrock.

            10. Wetland occurs over calcareous bedrock and is not associated with the southeastern toeslope of the Kittatinny Ridge.

                Calcareous Fen*

            10. Wetland occurs over acidic sandstone, siltstone, shale or slate bedrock at the southeastern toeslope of the Kittatinny Ridge.

                Acidic Seep*

        9. Association is common and not limited to areas with groundwater seepage. Vegetation is typically flooded at least in the early portion of the growing season, such that black standing water is visible, or signature is speckled black and white.

            11. Vegetation occurs adjacent to creeks and tributaries, particularly the Flat Brook.

                12. Vegetation dominated by reed canary grass (*Phalaris arundinacea*).

                Reed Canarygrass Riverine Grassland*

                12. Vegetation dominated by hairyfruit sedge (*Carex trichocarpa*).

                Hairyfruit Sedge Wetland*

            11. Vegetation is not associated with creeks and tributaries.

                15. Wetland contains standing water for most or all of the year and is often associated with impounded drainages, ponded areas near streams, or saturated areas surrounding drainages.

                    16. The speckled black and white signature of emergent vegetation in standing water is prominent. The black signature of standing water is prominent in at least part of the area.

                        17. The white signature of tussock-forming sedges has a consistent, regular, speckled apparence.

                        Tussock Sedge Marsh*

17. The white signature of herbaceous vegetation is typically diffuse, heterogeneous, patchy, or variable.

Mixed Forb Marsh*

16. The signature is predominantly bright white, occasionally mottled. The black and white speckles and solid black signature of standing water is limited.

18. Association is not common in the park. Signature tends to have a slight bluish-gray tinge consistently throughout the white herbaceous vegetation.

Cattail Marsh*

18. Association is very common in the park. Signature is variable, however, it is often bright white, mottled with gray or black only in topographically low points. Drainages and swales may be visible.

Wet Meadow*

7. Terrestrial vegetation that is not restricted to depressions, low-lying areas, and areas adjacent to creeks, streams, and ponds. Black standing water or drainage rivulets are not present.

19. Vegetation occurs on smooth medium blue-gray bedrock outcrops on which white vegetation covers less than 50% of the area.

Wavy Hairgrass - Common Sheep Sorrel Rock Outcrop

19. Vegetation is uniform to mottled, light blue-gray, white, or pink. Smooth medium blue-gray bedrock outcrops are not visible.

20. Vegetation is typically light blue-gray, rarely white, with occasional tinges of pink.

Little Bluestem Grassland*

20. Vegetation is typically bright white or pink, often with mottles of both colors.

Old Field*

SHRUB GROUP

1. Vegetation occurs adjacent to the water of the Delaware River on islands, shorelines, or gravel/cobble bars.

    2. Short rounded gray shrubs less than 2 m in height are scattered over dark blue-gray cobbles, or white or pink herbaceous vegetation. This association is often inundated by the river on the photography, such that only the wispy whitish gray short shrubs are visible above the water.

        Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland

    2. Tall ovular gray shrubs 2–5 m in height occur over light blue-gray, white or pink herbaceous vegetation and cobbles.

        Sycamore - Mixed Hardwood Riverine Shrubland

1. Vegetation occur in a variety of palustrine or terrestrial settings, not adjacent to the water of the Delaware River on islands, shorelines, or gravel/cobble bars.

    3. Palustrine vegetation that tends to occur in depressions, or flat or low areas adjacent to streams, drainages, or ponds. The ground under the shrubs may (or may not) be black, indicating stand water.

        4. The low, bumpy, deep, rose-pink signature, characteristic of leatherleaf (*Chamaedaphne calyculata*) is prominent. Association occurs in an ovular depression on a ridgetop in New Jersey.

            5. Signature is near continuous, low, bumpy, deep, rose-pink color, characteristic of leatherleaf (*Chamaedaphne calyculata*). Taller, light gray rounded bumps, characteristic of highbush blueberry (*Vaccinium corymbosum*) are sparse or absent.

                Leatherleaf Peatland

            5. Taller, light gray rounded bumps, characteristic of highbush blueberry (*Vaccinium corymbosum*) cover 50% or more of the wetland, interspersed with the low, bumpy, deep, rose-pink color, characteristic of leatherleaf (*Chamaedaphne calyculata*).

                Highbush Blueberry - Leatherleaf Wetland

        4. The low, bumpy, deep, rose-pink signature, characteristic of leatherleaf (*Chamaedaphne calyculata*) is not obvious. Association does not necessarily occur in an ovular depression on a ridgetop in New Jersey.

            6. Signature shows light gray shrubs floating over dark blue gray or black standing water

7. Shrub signature tends to be more diffuse, characteristic of common buttonbush (*Cephalanthus occidentalis*).

Buttonbush Wetland*

7. Shrub signature tends to be more compact or rounded, characteristic of alders (*Alnus* spp.) or highbush blueberry (*Vaccinium corymbosum*).

8. Shrubland is dominated by alders (*Alnus* spp.).

Alder Wetland*

8. Shrubland is dominated by highbush blueberry (*Vaccinium corymbosum*).

Highbush Blueberry - Steeplebush Wetland*

6. Light gray rounded shrubs occur over a matrix of bright white (less commonly light pink) herbaceous vegetation. Dark blue gray or black standing water is not prominent.

9. Association is rare and occurs over calcareous bedrock.

10. Wetland contains active precipitation of marl deposits and the alga Chara (*Chara* spp.).

Marl Fen*

10. Wetland does not contain active precipitation of marl deposits or the alga Chara (*Chara* spp.).

Calcareous Fen*

9. Association is common and does not necessarily occur over calcareous bedrock.

11. Association is extremely common along the Flat Brook. Both gray shrubs and white herbaceous vegetation often have a pinkish tinge, and vegetation has weedy appearance.

Silky Dogwood Successional Palustrine Shrubland*

11. Association is found throughout the park in depressions and adjacent to drainages, ponds, or wetlands. Shrubs generally do not have a pinkish tinge and the vegetation does not appear as weedy.

Highbush Blueberry - Steeplebush Wetland*

3. Terrestrial vegetation that typically does not occur in depressions, or flat or low areas adjacent to streams, drainages, or ponds. The ground under the canopy is not black, but may be white, gray or pink

    12. Shrubland typically occurs at mid to low elevations on former agricultural land. Shrubs appear as rounded gray circles or bumpy clumps, or as short thin pink tear drops. The shrubs appear in a matrix of white or pink herbaceous vegetation.
    Successional Shrubland

    12. Shrubland is restricted to rocky soil at high elevations of the Kittatinny Ridge or the plateau in Pennsylvania. Associations typically occur above 200 meters elevation in New Jersey and above 150 meters in elevation in Pennsylvania.

        13. Shrubland occurs on cliffs, the crests of cliffs, or steeply sloping bedrock outcrops. Aspect is generally to south to southeast with a slope greater than 25% (often greater than 50%).
        Hickory - Eastern Red-cedar Rocky Woodland

        13. Shrubland occurs at high elevations, but not on cliffs or steep rocky slopes. Slope is generally less than 25%.

            14. Dense bumpy shrub layer is nearly continuous, containing dark gray and occasionally bright pink shrubs. Established canopy trees may be widely scattered throughout. The bright white signature of graminoids is rare.
            Successional Bear Oak - Heath Shrubland

            14. Dense clumps of dark gray, rounded shrubs and interspersed with the bright white signature of short graminoids. Bright pink shrubs are rare.
            Bear Oak - Wavy Hairgrass Shrubland

Appendix B. Vegetation plot sampling form.

Form 3: Quantitative Community Characterization Winter, 2002

Delaware Water Gap National Recreation Area Vegetation Mapping and Fire Fuel Modeling

A. General Information

Plot Number:_____. Site name:_____

Quad name(s):_____ Quad code(s): _____ County name(s):_____

Town:_____ State: _____ Image annotations:_____

Easting: _ _ _ _ _ _ E Northing: _ _ _ _ _ _ _ N EPE/APE: _____ DOP:_____ Map Datum: _____ Zone:_____

Survey date:_____.__.___ Surveyors:_____

B. Environmental Description

Representative sketch of stand and landscape position

Image Annotation: _____

Slope: _____

Aspect:_____

Elevation: _____

Stoniness:
__Stone free <0.1%
__Moderately stony 0.1-1%
__Stony 3-15%
__Very stony 15-50%
__Exceedingly stony 50-90%
__Stone piles >90%

Topographic position:
___ Interfluve (ridgetop) ___ Low slope
___ High Slope ___ Toe slope
___ High level ___ Low level
___ Midslope ___ Channel wall
___ Backslope ___ Channel bed
___ Step in slope ___ Basin Floor
___ Other: _____

Hydrologic regime:
___Permanently flooded ___Saturated
___Intermittently exposed ___Temporarily flooded
___ Semi-permanently flooded ___Intermittently flooded
___ Seasonally flooded ___ Artificially flooded

Average texture:
___ sand ___ clay loam
___ sandy loam ___ clay
___ loam ___ peat
___ silt loam ___ muck
___ other:_____

Fire Fuel Modeling:
Average Crown height: _____
Average Height to live crown: _____
Average Crown width: _____

Canopy Cover Class:
___ 1. 1-20% ___ 3. 50-80%
___ 2. 21-50% ___ 4. 81-100%

Downed Woody Debris Photo series:
_____

Anderson FBPS: _____

Justification and Notes:

Image Annotation:
_____

Soil drainage:
___ Rapidly drained
___ Well drained
___ Moderately well drained
___ Somewhat poorly drained
___ Poorly Drained
___ Very poorly drained

Unvegetated surface:
___% Bedrock ___ % Litter, duff
___% Large rocks (> 10 cm) ___% Wood (> 1 cm)
___% Small rocks (0.2-10 cm) ___% Water
___% Sand (0.1-2 mm) ___% Bare soil
___ % Other: _____

Soil profile description: note depth, texture, and color of each horizon. Note significant changes such as depth to mottling, depth to water table, root penetration depth

Horizon	Depth	Texture	Color	pH	Comments

Plot representativeness: Note homogeneity of vegetation and stand health

Environmental Comments: Note surrounding vegetation, landscape context, and other environmental factors.

C. Vegetation

Cowardin System: _____Terrestrial _____ Palustrine _____ Estuarine Plot number:_____ Plot dimensions:_____

Leaf Type	Leaf Phenology	Physiognomic Type			height	% cover
___ Broad-leaf	___ Deciduous	___ Forest	___ Woodland	T1 Emergent tree		
___ Semi-broad-leaf	___ Semi-deciduous	___ Sparse Woodland	___ Scrub Thicket	T2 Tree canopy		
___ Semi-needle-leaf	___ Semi-evergreen	___ Shrubland	___ Sparse Woodland	T3 Tree sub-canopy		
___ Needle-leaf	___ Evergreen	___ Dwarf Shrubland	___ Dwarf Scrub Thicket	S1 Tall shrub		
___ Broad-leaf herbaceous	___ Perennial	___ Sparse Dwarf Shrubland	___ Herbaceous	S2 Short shrub		
___ Graminoid	___ Annual	___ Non-Vascular	___ Sparsely Vegetated	H Herbaceous		
___ Pteridophyte				N Non-vascular		
R = 1 or few (+) = occasional 1 = <5% 2- = 5-12% 2+ = 13-25% 3 = 26-50% 4 = 51-75% 5 = 76+%				E Epiphyte		
				V Vine/liana		

Species / percent cover: starting with uppermost stratum, list all species and % cover for each in the stratum. For forests and woodlands, list on a separate line below each tree species the DBH of all trees above 10 cm diameter. Separate the measurements with a comma and note whether in cm or inches.

Appendix C. Plants observed in Delaware Water Gap National Recreation Area during vegetation plot and thematic accuracy assessment sampling.

Plants Observed in Delaware Water Gap National Recreation Area During Vegetation Plot and Thematic Accuracy Assessment Sampling

Nomenclature follows the PLANTS Database, Version 3.5 developed by the Natural Resource Conservation Service in cooperation with the Biota of North America Program (United States Department of Agriculture, National Resources Conservation Service 2004). For this report, some common names listed in the PLANTS Database were changed to reflect the common names typically used by ecologists and resource managers in this region. A table of observed vascular plants is shown first, followed by a table of observed non-vascular plants.

VASCULAR PLANTS

Family	Scientific Name	Common Name
Acanthaceae	*Justicia americana*	American water-willow
Aceraceae	*Acer ×freemanii*	Freeman maple
	Acer negundo	boxelder
	Acer pensylvanicum	striped maple
	Acer platanoides	Norway maple
	Acer rubrum	red maple
	Acer saccharinum	silver maple
	Acer saccharum	sugar maple
Alismataceae	*Alisma subcordatum*	American water plantain
	Sagittaria latifolia	broadleaf arrowhead
Amaranthaceae	*Amaranthus* sp.	pigweed
Anacardiaceae	*Rhus aromatica*	fragrant sumac
	Rhus copallina	dwarf sumac
	Rhus glabra	smooth sumac
	Rhus hirta	staghorn sumac
	Toxicodendron radicans	eastern poison ivy
	Toxicodendron vernix	poison sumac
Annonaceae	*Asimina triloba*	pawpaw
Apiaceae	*Angelica atropurpurea*	purplestem angelica
	Cicuta bulbifera	bulblet-bearing water hemlock
	Cicuta maculata	spotted water hemlock
	Cryptotaenia canadensis	Canadian honewort
	Daucus carota	Queen Anne's lace
	Hydrocotyle americana	American marshpennywort
	Osmorhiza claytonii	Clayton's sweetroot
	Osmorhiza longistylis	longstyle sweetroot
	Sium suave	hemlock waterparsnip
	Zizia aurea	golden zizia
Apocynaceae	*Apocynum androsaemifolium*	spreading dogbane
	Apocynum cannabinum	Indian-hemp
	Vinca minor	common periwinkle
Aquifoliaceae	*Ilex montana*	mountain holly
	Ilex verticillata	common winterberry
	Nemopanthus mucronatus	catberry
Araceae	*Arisaema dracontium*	green dragon
	Arisaema triphyllum	Jack in the pulpit

Family	Scientific Name	Common Name
Araceae (cont.)	*Calla palustris*	water arum
	Symplocarpus foetidus	skunk-cabbage
Araliaceae	*Aralia hispida*	bristly sarsaparilla
	Aralia nudicaulis	wild sarsaparilla
	Panax quinquefolius	American ginseng
	Panax trifolius	dwarf ginseng
Aristolochiaceae	*Asarum canadense*	Canadian wild ginger
Asclepiadaceae	*Asclepias incarnata*	swamp milkweed
	Asclepias syriaca	common milkweed
Aspleniaceae	*Asplenium platyneuron*	ebony spleenwort
	Asplenium rhizophyllum	walking fern
	Asplenium trichomanes	maidenhair spleenwort
Asteraceae	*Achillea millefolium*	common yarrow
	Ageratina altissima var. *altissima*	white snakeroot
	Ambrosia artemisiifolia	annual ragweed
	Ambrosia trifida	great ragweed
	Anaphalis margaritacea	western pearly everlasting
	Antennaria neglecta	field pussytoes
	Antennaria plantaginifolia	woman's tobacco
	Artemisia vulgaris	common wormwood
	Bidens bipinnata	Spanish needles
	Bidens cernua	nodding beggartick
	Bidens connata	purplestem beggarticks
	Bidens coronata	crowned beggarticks
	Bidens frondosa	devil's beggartick
	Centaurea biebersteinii	spotted knapweed
	Cirsium arvense	Canada thistle
	Cirsium discolor	field thistle
	Cirsium muticum	swamp thistle
	Cirsium vulgare	bull thistle
	Erechtites hieraciifolia	American burnweed
	Erigeron annuus	eastern daisy fleabane
	Erigeron philadelphicus	Philadelphia fleabane
	Erigeron strigosus	prairie fleabane
	Eupatorium fistulosum	trumpetweed
	Eupatorium maculatum	spotted joepyeweed
	Eupatorium perfoliatum	common boneset
	Eurybia divaricata	white wood aster
	Euthamia graminifolia	flat-top goldentop
	Galinsoga quadriradiata	shaggy-soldier
	Gnaphalium uliginosum	marsh cudweed
	Helenium autumnale	common sneezeweed
	Helianthus decapetalus	thinleaf sunflower
	Helianthus divaricatus	woodland sunflower
	Helianthus tuberosus	Jerusalem artichoke
	Hieracium aurantiacum	orange hawkweed
	Hieracium caespitosum	meadow hawkweed
	Hieracium pilosella	mouseear hawkweed
	Hieracium venosum	rattlesnakeweed
	Krigia biflora	twoflower dwarfdandelion
	Krigia virginica	Virginia dwarfdandelion

Family	Scientific Name	Common Name
Asteraceae (cont.)	*Lactuca* sp.	lettuce
	Leucanthemum vulgare	ox-eye daisy
	Mikania scandens	climbing hempvine
	Oclemena acuminata	whorled wood aster
	Packera aurea	golden ragwort
	Prenanthes alba	white rattlesnakeroot
	Prenanthes serpentaria	cankerweed
	Prenanthes trifoliolata	gall of the earth
	Rudbeckia hirta	blackeyed Susan
	Rudbeckia hirta var. *pulcherrima*	blackeyed Susan
	Senecio viscosus	sticky ragwort
	Solidago arguta	Atlantic goldenrod
	Solidago bicolor	white goldenrod
	Solidago caesia	wreath goldenrod
	Solidago canadensis	Canada goldenrod
	Solidago canadensis var. *scabra*	Canada goldenrod
	Solidago flexicaulis	zigzag goldenrod
	Solidago gigantea	giant goldenrod
	Solidago juncea	early goldenrod
	Solidago nemoralis	gray goldenrod
	Solidago odora	anisescented goldenrod
	Solidago patula	roundleaf goldenrod
	Solidago puberula	downy goldenrod
	Solidago rugosa	wrinkleleaf goldenrod
	Solidago ulmifolia	elmleaf goldenrod
	Symphyotrichum dumosum var. *dumosum*	rice button aster
	Symphyotrichum ericoides var. *ericoides*	white heath aster
	Symphyotrichum lateriflorum	calico aster
	Symphyotrichum lateriflorum var. *lateriflorum*	calico aster
	Symphyotrichum novae-angliae	New England aster
	Symphyotrichum patens var. *patens*	late purple aster
	Symphyotrichum prenanthoides	crookedstem aster
	Symphyotrichum puniceum var. *puniceum*	purplestem aster
	Symphyotrichum undulatum	waxyleaf aster
	Tanacetum vulgare	common tansy
	Taraxacum officinale	common dandelion
	Tussilago farfara	coltsfoot
	Verbesina alternifolia	wingstem
	Vernonia noveboracensis	New York ironweed
	Xanthium strumarium	rough cockleburr
	Xanthium strumarium var. *glabratum*	rough cockleburr
Balsaminaceae	*Impatiens capensis*	jewelweed
	Impatiens pallida	pale touch-me-not
Berberidaceae	*Berberis thunbergii*	Japanese barberry
	Berberis vulgaris	common barberry
	Caulophyllum thalictroides	blue cohosh
	Podophyllum peltatum	mayapple
	Alnus incana	gray alder
	Alnus serrulata	smooth alder
	Betula alleghaniensis	yellow birch
	Betula lenta	sweet birch

Family	Scientific Name	Common Name
Betulaceae (cont.)	*Betula nigra*	river birch
	Betula papyrifera	paper birch
	Betula populifolia	gray birch
	Carpinus caroliniana	American hornbeam
	Ostrya virginiana	eastern hop-hornbeam
Bignoniaceae	*Catalpa bignonioides*	southern catalpa
	Catalpa speciosa	northern catalpa
Blechnaceae	*Woodwardia areolata*	netted chainfern
	Woodwardia virginica	Virginia chainfern
Boraginaceae	*Echium vulgare*	common vipersbugloss
	Hackelia virginiana	beggarslice
	Lithospermum officinale	European stoneseed
	Myosotis laxa	bay forget-me-not
	Myosotis scorpioides	true forget-me-not
Brassicaceae	*Alliaria petiolata*	garlic mustard
	Arabis glabra	tower rockcress
	Arabis laevigata	smooth rockcress
	Arabis lyrata	lyrate rockcress
	Barbarea vulgaris	garden yellowrocket
	Brassica nigra	black mustard
	Brassica rapa	field mustard
	Cardamine parviflora	sand bittercress
	Cardamine pensylvanica	Pennsylvania bittercress
	Coincya monensis	star-mustard
	Erysimum cheiranthoides	wormseed wallflower
	Hesperis matronalis	dames rocket
	Lepidium virginicum	Virginia pepperweed
	Raphanus raphanistrum	wild radish
	Rorippa islandica	northern marsh yellowcress
	Rorippa nasturtium-aquaticum	watercress
	Rorippa sylvestris	creeping yellowcress
	Thlaspi arvense	field pennycress
Cactaceae	*Opuntia humifusa*	eastern prickly-pear
Callitrichaceae	*Callitriche sp.*	water-starwort
Campanulaceae	*Campanula aparinoides*	marsh bellflower
	Campanula rotundifolia	bluebell bellflower
	Lobelia cardinalis	cardinalflower
	Lobelia inflata	Indian-tobacco
	Lobelia kalmii	Ontario lobelia
	Lobelia siphilitica	great blue lobelia
	Lobelia spicata	palespike lobelia
	Triodanis perfoliata var. *biflora*	clasping Venus' looking-glass
	Triodanis perfoliata var. *perfoliata*	clasping Venus' looking-glass
Caprifoliaceae	*Diervilla lonicera*	northern bush honeysuckle
	Lonicera japonica	Japanese honeysuckle
	Lonicera maackii	Amur honeysuckle
	Lonicera morrowii	Morrow's honeysuckle
	Lonicera tatarica	Tatarian honeysuckle
	Sambucus nigra ssp. *canadensis*	common elderberry
	Sambucus racemosa var. *racemosa*	red elderberry
	Triosteum aurantiacum	orangefruit horse-gentian

Family	Scientific Name	Common Name
Caprifoliaceae (cont.)	*Viburnum acerifolium*	mapleleaf viburnum
	Viburnum dentatum	southern arrowwood
	Viburnum dentatum var. *lucidum*	southern arrowwood
	Viburnum lentago	nannyberry
	Viburnum prunifolium	blackhaw
	Viburnum rafinesquianum	downy arrowwood
Caryophyllaceae	*Cerastium arvense*	field chickweed
	Cerastium biebersteinii	Boreal chickweed
	Cerastium fontanum ssp. *vulgare*	big chickweed
	Dianthus armeria	Deptford pink
	Lychnis flos-cuculi	ragged robin
	Minuartia michauxii var. *michauxii*	Michaux's stitchwort
	Paronychia canadensis	smooth forked nailwort
	Saponaria officinalis	bouncingbet
	Silene latifolia	bladder campion
	Silene nivea	evening campion
	Stellaria alsine	bog chickweed
	Stellaria graminea	grasslike starwort
	Stellaria media	common chickweed
	Stellaria pubera	star chickweed
Celastraceae	*Celastrus orbiculatus*	oriental bittersweet
	Euonymus alata	winged burning bush
	Euonymus fortunei	winter creeper
Chenopodiaceae	*Chenopodium album*	lambsquarters
Cistaceae	*Helianthemum* sp.	frostweed
	Lechea intermedia	largepod pinweed
Clethraceae	*Clethra alnifolia*	coastal sweetpepperbush
Clusiaceae	*Hypericum ascyron*	great St. Johnswort
	Hypericum canadense	lesser Canadian St. Johnswort
	Hypericum gentianoides	orangegrass
	Hypericum mutilum	dwarf St. Johnswort
	Hypericum perforatum	common St. Johnswort
	Hypericum punctatum	spotted St. Johnswort
	Triadenum virginicum	Virginia marsh St. Johnswort
Commelinaceae	*Commelina communis*	Asiatic dayflower
Convolvulaceae	*Calystegia sepium*	hedge false bindweed
	Calystegia sepium ssp. *sepium*	hedge false bindweed
	Convolvulus arvensis	field bindweed
	Ipomoea coccinea	redstar
Cornaceae	*Cornus alternifolia*	alternateleaf dogwood
	Cornus amomum	silky dogwood
	Cornus florida	flowering dogwood
	Cornus racemosa	gray dogwood
Crassulaceae	*Penthorum sedoides*	ditch stonecrop
Cucurbitaceae	*Echinocystis lobata*	wild cucumber
	Sicyos angulatus	oneseed burr cucumber
Cupressaceae	*Juniperus virginiana*	eastern red-cedar
Cuscutaceae	*Cuscuta gronovii*	scaldweed
Cyperaceae	*Bulbostylis capillaris*	densetuft hairsedge
	Carex albicans	whitetinge sedge
	Carex albicans var. *emmonsii*	Emmons' sedge

Family	Scientific Name	Common Name
Cyperaceae (cont.)	*Carex albursina*	white bear sedge
	Carex amphibola	eastern narrowleaf sedge
	Carex amplifolia	bigleaf sedge
	Carex annectens	yellowfruit sedge
	Carex appalachica	Appalachian sedge
	Carex argyrantha	hay sedge
	Carex atlantica ssp. *atlantica*	prickly bog sedge
	Carex atlantica ssp. *capillacea*	prickly bog sedge
	Carex baileyi	Bailey's sedge
	Carex bebbii	Bebb's sedge
	Carex blanda	eastern woodland sedge
	Carex bromoides	bromelike sedge
	Carex canescens	silvery sedge
	Carex cephalophora	oval-leaf sedge
	Carex communis	fibrousroot sedge
	Carex comosa	longhair sedge
	Carex crinita	fringed sedge
	Carex cristatella	crested sedge
	Carex cryptolepis	northeastern sedge
	Carex davisii	Davis' sedge
	Carex debilis	white edge sedge
	Carex digitalis	slender woodland sedge
	Carex disperma	softleaf sedge
	Carex folliculata	northern long sedge
	Carex glaucodea	blue sedge
	Carex gracillima	graceful sedge
	Carex granularis	limestone meadow sedge
	Carex gravida	heavy sedge
	Carex gynandra	nodding sedge
	Carex hirsutella	fuzzy wuzzy sedge
	Carex hystericina	bottlebrush sedge
	Carex interior	inland sedge
	Carex intumescens	greater bladder sedge
	Carex lacustris	hairy sedge
	Carex laxiculmis	spreading sedge
	Carex laxiflora	broad looseflower sedge
	Carex leptalea	bristlystalked sedge
	Carex leptonervia	nerveless woodland sedge
	Carex livida	livid sedge
	Carex lupulina	hop sedge
	Carex lurida	shallow sedge
	Carex molesta	troublesome sedge
	Carex muehlenbergii	Muhlenberg's sedge
	Carex pellita	woolly sedge
	Carex pensylvanica	Pennsylvania sedge
	Carex plantaginea	plantainleaf sedge
	Carex prasina	drooping sedge
	Carex projecta	necklace sedge
	Carex radiata	eastern star sedge
	Carex retroflexa	reflexed sedge
	Carex rosea	rosy sedge

Family	Scientific Name	Common Name
Cyperaceae (cont.)	*Carex scabrata*	eastern rough sedge
	Carex scoparia	broom sedge
	Carex seorsa	weak stellate sedge
	Carex sparganioides	burr reed sedge
	Carex sprengelii	Sprengel's sedge
	Carex squarrosa	squarrose sedge
	Carex sterilis	dioecious sedge
	Carex stipata	owlfruit sedge
	Carex striata	Walter's sedge
	Carex stricta	tussock sedge
	Carex swanii	Swan's sedge
	Carex tetanica	rigid sedge
	Carex tonsa	shaved sedge
	Carex torta	twisted sedge
	Carex tribuloides	blunt broom sedge
	Carex trichocarpa	hairyfruit sedge
	Carex trisperma	threeseeded sedge
	Carex umbellata	parasol sedge
	Carex vesicaria	blister sedge
	Carex virescens	ribbed sedge
	Carex vulpinoidea	fox sedge
	Cyperus esculentus	chufa flatsedge
	Cyperus lupulinus	Great Plains flatsedge
	Cyperus lupulinus ssp. *lupulinus*	Great Plains flatsedge
	Cyperus squarrosus	bearded flatsedge
	Cyperus strigosus	strawcolored flatsedge
	Dulichium arundinaceum	threeway sedge
	Eleocharis acicularis	needle spikerush
	Eleocharis ovata	ovate spikerush
	Eleocharis palustris	common spikerush
	Eleocharis tenuis	slender spikerush
	Rhynchospora alba	white beaksedge
	Rhynchospora capillacea	needle beaksedge
	Schoenoplectus pungens	common threesquare
	Schoenoplectus pungens var. *pungens*	common threesquare
	Scirpus atrovirens	green bulrush
	Scirpus cyperinus	woolgrass
	Scirpus expansus	woodland bulrush
	Scirpus lineatus	drooping bulrush
	Scirpus microcarpus	panicled bulrush
	Trichophorum planifolium	bashful bulrush
Dennstaedtiaceae	*Dennstaedtia punctilobula*	eastern hayscented fern
	Pteridium aquilinum	western brackenfern
Dioscoreaceae	*Dioscorea quaternata*	fourleaf yam
	Dioscorea villosa	wild yam
Droseraceae	*Drosera intermedia*	spoonleaf sundew
	Drosera rotundifolia	roundleaf sundew
Dryopteridaceae	*Athyrium filix-femina*	common ladyfern
	Cystopteris fragilis	brittle bladderfern
	Cystopteris tenuis	upland brittle bladderfern
	Deparia acrostichoides	silver false spleenwort

Family	Scientific Name	Common Name
Dryopteridaceae (cont.)	*Dryopteris carthusiana*	spinulose woodfern
	Dryopteris cristata	crested woodfern
	Dryopteris intermedia	intermediate woodfern
	Dryopteris marginalis	marginal woodfern
	Gymnocarpium dryopteris	western oakfern
	Matteuccia struthiopteris	ostrich fern
	Onoclea sensibilis	sensitive fern
	Polystichum acrostichoides	Christmas fern
	Woodsia ilvensis	rusty woodsia
	Woodsia obtusa	bluntlobe cliff fern
Elaeagnaceae	*Elaeagnus umbellata*	autumn-olive
Equisetaceae	*Equisetum arvense*	field horsetail
	Equisetum fluviatile	water horsetail
Ericaceae	*Chamaedaphne calyculata*	leatherleaf
	Epigaea repens	trailing arbutus
	Gaultheria procumbens	eastern teaberry
	Gaylussacia baccata	black huckleberry
	Gaylussacia frondosa	blue huckleberry
	Kalmia angustifolia	sheep laurel
	Kalmia latifolia	mountain laurel
	Lyonia ligustrina	maleberry
	Rhododendron maximum	great laurel
	Rhododendron periclymenoides	pink azalea
	Rhododendron viscosum	swamp azalea
	Vaccinium angustifolium	lowbush blueberry
	Vaccinium corymbosum	highbush blueberry
	Vaccinium macrocarpon	cranberry
	Vaccinium pallidum	Blue Ridge blueberry
	Vaccinium stamineum	deerberry
Euphorbiaceae	*Acalypha rhomboidea*	Virginia threeseed mercury
	Chamaesyce maculata	spotted sandmat
	Chamaesyce nutans	eyebane
	Euphorbia corollata	flowering spurge
	Euphorbia cyparissias	cypress spurge
Fabaceae	*Amorpha fruticosa*	desert false indigo
	Amphicarpaea bracteata	American hogpeanut
	Apios americana	groundnut
	Baptisia tinctoria	yellow wild indigo
	Cercis canadensis	eastern redbud
	Coronilla varia	purple crownvetch
	Desmodium ciliare	hairy small-leaf tick-trefoil
	Desmodium nudiflorum	nakedflower tick-trefoil
	Desmodium paniculatum	panicledleaf tick-trefoil
	Gleditsia triacanthos	honeylocust
	Lathyrus latifolius	perennial pea
	Lespedeza violacea	violet lespedeza
	Lespedeza hirta	hairy lespedeza
	Lespedeza procumbens	trailing lespedeza
	Lespedeza virginica	slender lespedeza
	Medicago lupulina	black medick
	Melilotus alba	white sweetclover

Family	Scientific Name	Common Name
Fabaceae (cont.)	*Robinia pseudoacacia*	black locust
	Stylosanthes biflora	sidebeak pencilflower
	Tephrosia virginiana	Virginia tephrosia
	Trifolium aureum	golden clover
	Trifolium dubium	suckling clover
	Trifolium hybridum	alsike clover
	Trifolium pratense	red clover
	Trifolium repens	white clover
	Vicia tetrasperma	lentil vetch
	Wisteria sinensis	Chinese wisteria
Fagaceae	*Castanea dentata*	American chestnut
	Fagus grandifolia	American beech
	Quercus alba	white oak
	Quercus bicolor	swamp white oak
	Quercus coccinea	scarlet oak
	Quercus ilicifolia	bear oak
	Quercus muehlenbergii	chinkapin oak
	Quercus palustris	pin oak
	Quercus prinoides	dwarf chinkapin oak
	Quercus prinus	chestnut oak
	Quercus rubra	northern red oak
	Quercus velutina	black oak
Fumariaceae	*Corydalis flavula*	yellow fumewort
	Corydalis sempervirens	rock harlequin
	Dicentra canadensis	squirrel corn
	Dicentra cucullaria	dutchman's breeches
Geraniaceae	*Geranium maculatum*	spotted geranium
	Geranium robertianum	Robert geranium
Grossulariaceae	*Ribes rotundifolium*	Appalachian gooseberry
Hamamelidaceae	*Hamamelis virginiana*	American witch-hazel
Hydrangeaceae	*Philadelphus coronarius*	sweet mock orange
Hydrocharitaceae	*Elodea* sp.	waterweed
Hydrophyllaceae	*Hydrophyllum virginianum*	Shawnee salad
Iridaceae	*Hypoxis hirsuta*	common goldstar
	Iris pseudacorus	paleyellow iris
	Iris versicolor	harlequin blueflag
	Sisyrinchium montanum	strict blue-eyed grass
Isoetaceae	*Isoetes* sp.	quillwort
Juglandaceae	*Carya alba*	mockernut hickory
	Carya cordiformis	bitternut hickory
	Carya glabra	pignut hickory
	Carya ovalis	red hickory
	Carya ovata	shagbark hickory
	Juglans cinerea	butternut
	Juglans nigra	black walnut
Juncaceae	*Juncus brachycephalus*	smallhead rush
	Juncus canadensis	Canadian rush
	Juncus dudleyi	Dudley's rush
	Juncus effusus	common rush
	Juncus nodosus	knotted rush
	Juncus subcaudatus	woodland rush

Family	Scientific Name	Common Name
Juncaceae (cont.)	*Juncus tenuis*	poverty rush
	Luzula acuminata	hairy woodrush
	Luzula multiflora	common woodrush
Lamiaceae	*Clinopodium vulgare*	wild basil
	Collinsonia canadensis	richweed
	Cunila origanoides	common dittany
	Galeopsis tetrahit	brittlestem hempnettle
	Glechoma hederacea	ground ivy
	Hedeoma pulegioides	American false pennyroyal
	Lamium amplexicaule	henbit deadnettle
	Lamium purpureum	purple deadnettle
	Lycopus americanus	American water horehound
	Lycopus uniflorus	northern bugleweed
	Mentha ×piperita	peppermint
	Mentha arvensis	wild mint
	Monarda clinopodia	white bergamot
	Monarda fistulosa	wild bergamot
	Prunella vulgaris	common selfheal
	Pycnanthemum incanum	hoary mountainmint
	Pycnanthemum muticum	clustered mountainmint
	Pycnanthemum tenuifolium	narrowleaf mountainmint
	Pycnanthemum verticillatum	whorled mountainmint
	Pycnanthemum virginianum	Virginia mountainmint
	Scutellaria galericulata	marsh skullcap
	Scutellaria incana	hoary skullcap
	Scutellaria lateriflora	blue skullcap
	Teucrium canadense	Canada germander
	Trichostema dichotomum	forked bluecurls
Lauraceae	*Lindera benzoin*	northern spicebush
	Sassafras albidum	sassafras
Lemnaceae	*Lemna minor*	common duckweed
Liliaceae	*Allium tricoccum*	wild leek
	Allium vineale	wild garlic
	Convallaria majalis	European lily of the valley
	Erythronium americanum	dogtooth violet
	Hemerocallis fulva	orange daylily
	Lilium canadense	Canada lily
	Lilium superbum	turk's-cap lily
	Maianthemum canadense	Canada mayflower
	Maianthemum racemosum	feathery false lily of the valley
	Maianthemum racemosum ssp. *racemosum*	feathery false lily of the valley
	Medeola virginiana	Indian cucumber
	Narcissus pseudonarcissus	daffodil
	Ornithogalum umbellatum	sleepydick
	Polygonatum biflorum	smooth Solomon's seal
	Polygonatum pubescens	hairy Solomon's seal
	Scilla sp.	scilla
	Streptopus lanceolatus var. *roseus*	twistedstalk
	Trillium erectum	red trillium
	Uvularia perfoliata	perfoliate bellwort
	Uvularia sessilifolia	sessileleaf bellwort

Family	Scientific Name	Common Name
Liliaceae (cont.)	*Veratrum viride*	green false hellebore
Limnanthaceae	*Floerkea proserpinacoides*	false mermaidweed
Linaceae	*Linum striatum*	ridged yellow flax
Lycopodiaceae	*Huperzia lucidula*	shining clubmoss
	Lycopodium clavatum	running clubmoss
	Lycopodium complanatum	groundcedar
	Lycopodium digitatum	fan clubmoss
	Lycopodium obscurum	rare clubmoss
Lythraceae	*Decodon verticillatus*	swamp loosestrife
	Lythrum salicaria	purple loosestrife
Magnoliaceae	*Liriodendron tulipifera*	tuliptree
Malvaceae	*Abutilon theophrasti*	velvetleaf
Menispermaceae	*Menispermum canadense*	common moonseed
Molluginaceae	*Mollugo verticillata*	green carpetweed
Monotropaceae	*Monotropa uniflora*	Indianpipe
Myricaceae	*Comptonia peregrina*	sweet fern
	Morella pensylvanica	northern bayberry
Nymphaeaceae	*Nuphar lutea ssp. pumila*	yellow pond-lily
Nyssaceae	*Nyssa sylvatica*	blackgum
Oleaceae	*Forsythia viridissima*	greenstem forsythia
	Fraxinus americana	white ash
	Fraxinus nigra	black ash
	Fraxinus pennsylvanica	green ash
	Ligustrum vulgare	European privet
	Syringa vulgaris	common lilac
Onagraceae	*Circaea lutetiana*	broadleaf enchanter's nightshade
	Circaea lutetiana ssp. *canadensis*	broadleaf enchanter's nightshade
	Epilobium ciliatum ssp. *glandulosum*	fringed willowherb
	Epilobium coloratum	purpleleaf willowherb
	Epilobium leptophyllum	bog willowherb
	Epilobium strictum	downy willowherb
	Ludwigia alternifolia	seedbox
	Ludwigia palustris	marsh seedbox
	Oenothera fruticosa	narrowleaf evening-primrose
	Oenothera perennis	little evening-primrose
Ophioglossaceae	*Botrychium dissectum*	cutleaf grapefern
	Botrychium virginianum	rattlesnake fern
Orchidaceae	*Cypripedium acaule*	moccasin flower
	Epipactis helleborine	broadleaf helleborine
	Goodyera pubescens	downy rattlesnake plantain
	Spiranthes sp.	ladies'-tresses
Orobanchaceae	*Conopholis americana*	American squawroot
	Epifagus virginiana	beechdrops
Osmundaceae	*Osmunda cinnamomea*	cinnamon fern
	Osmunda claytoniana	interrupted fern
	Osmunda regalis	royal fern
Oxalidaceae	*Oxalis stricta*	common yellow oxalis
	Oxalis violacea	violet woodsorrel
Papaveraceae	*Sanguinaria canadensis*	bloodroot
Phytolaccaceae	*Phytolacca americana*	American pokeweed
Pinaceae	*Larix kaempferi*	Japanese larch

Family	Scientific Name	Common Name
Pinaceae (cont.)	*Picea abies*	Norway spruce
	Picea glauca	white spruce
	Picea mariana	black spruce
	Picea pungens	blue spruce
	Pinus nigra	Austrian pine
	Pinus pungens	Table Mountain pine
	Pinus resinosa	red pine
	Pinus rigida	pitch pine
	Pinus strobus	eastern white pine
	Pinus sylvestris	Scotch pine
	Pinus virginiana	Virginia pine
	Tsuga canadensis	eastern hemlock
Plantaginaceae	*Plantago lanceolata*	narrowleaf plantain
	Plantago major	common plantain
	Plantago virginica	Virginia plantain
Platanaceae	*Platanus occidentalis*	sycamore
Poaceae	*Agrostis gigantea*	redtop
	Agrostis perennans	upland bentgrass
	Agrostis scabra	rough bentgrass
	Agrostis stolonifera	creeping bentgrass
	Andropogon gerardii	big bluestem
	Andropogon virginicus	broomsedge bluestem
	Anthoxanthum odoratum	sweet vernalgrass
	Arrhenatherum elatius	tall oatgrass
	Brachyelytrum erectum	bearded shorthusk
	Bromus inermis	smooth brome
	Bromus kalmii	arctic brome
	Calamagrostis canadensis	bluejoint
	Cinna arundinacea	sweet woodreed
	Cinna latifolia	drooping woodreed
	Dactylis glomerata	orchard grass
	Danthonia spicata	poverty oatgrass
	Deschampsia caespitosa	tufted hairgrass
	Deschampsia flexuosa	wavy hairgrass
	Dichanthelium acuminatum var. *acuminatum*	tapered rosette grass
	Dichanthelium boscii	Bosc's panicgrass
	Dichanthelium clandestinum	deertongue
	Dichanthelium commutatum	variable panicgrass
	Dichanthelium depauperatum	starved panicgrass
	Dichanthelium dichotomum	cypress panicgrass
	Dichanthelium dichotomum var. *dichotomum*	cypress panicgrass
	Dichanthelium linearifolium	slimleaf panicgrass
	Dichanthelium sphaerocarpon var. *sphaerocarpon*	roundseed panicgrass
	Digitaria ischaemum	smooth crabgrass
	Digitaria sanguinalis	hairy crabgrass
	Echinochloa crus-galli	barnyardgrass
	Echinochloa muricata	rough barnyardgrass
	Elymus hystrix	eastern bottlebrush grass
	Elymus repens	quackgrass
	Elymus riparius	riverbank wildrye
	Elymus villosus	hairy wildrye

Family	Scientific Name	Common Name
Poaceae (cont.)	*Elymus virginicus*	Virginia wildrye
	Eragrostis spectabilis	purple lovegrass
	Festuca rubra	red fescue
	Festuca subverticillata	nodding fescue
	Glyceria canadensis	rattlesnake mannagrass
	Glyceria grandis	American mannagrass
	Glyceria striata	fowl mannagrass
	Leersia oryzoides	rice cutgrass
	Leersia virginica	whitegrass
	Lolium pratense	meadow ryegrass
	Microstegium vimineum	Japanese stiltgrass
	Muhlenbergia frondosa	wirestem muhly
	Muhlenbergia glomerata	spiked muhly
	Muhlenbergia mexicana	Mexican muhly
	Muhlenbergia sobolifera	rock muhly
	Muhlenbergia sylvatica	woodland muhly
	Panicum capillare	witchgrass
	Panicum rigidulum	redtop panicgrass
	Panicum virgatum	switchgrass
	Paspalum setaceum	thin paspalum
	Phalaris arundinacea	reed canarygrass
	Phleum pratense	timothy
	Phragmites australis	common reed
	Poa alsodes	grove bluegrass
	Poa compressa	Canada bluegrass
	Poa cuspidata	early bluegrass
	Poa nemoralis	wood bluegrass
	Poa palustris	fowl bluegrass
	Poa pratensis	Kentucky bluegrass
	Poa trivialis	rough bluegrass
	Schizachyrium scoparium	little bluestem
	Setaria faberi	Japanese bristlegrass
	Setaria parviflora	marsh bristlegrass
	Setaria viridis	green bristlegrass
	Sorghastrum nutans	Indiangrass
	Spartina pectinata	prairie cordgrass
	Sphenopholis intermedia	slender wedgescale
	Sporobolus sp.	dropseed
	Tridens flavus	purpletop tridens
Polemoniaceae	*Phlox subulata*	moss phlox
Polygalaceae	*Polygala paucifolia*	gaywings
	Polygala verticillata	whorled milkwort
Polygonaceae	*Polygonum amphibium*	water knotweed
	Polygonum amphibium var. *emersum*	longroot smartweed
	Polygonum arifolium	halberdleaf tearthumb
	Polygonum caespitosum	oriental ladysthumb
	Polygonum caespitosum var. *longisetum*	oriental ladysthumb
	Polygonum convolvulus	black bindweed
	Polygonum cuspidatum	Japanese knotweed
	Polygonum hydropiper	marshpepper knotweed
	Polygonum hydropiperoides	swamp smartweed

Family	Scientific Name	Common Name
Polygonaceae (cont.)	*Polygonum lapathifolium*	curlytop knotweed
	Polygonum pensylvanicum	Pennsylvania smartweed
	Polygonum persicaria	spotted ladysthumb
	Polygonum sagittatum	arrowleaf tearthumb
	Polygonum scandens	climbing false buckwheat
	Polygonum tenue	pleatleaf knotweed
	Polygonum virginianum	jumpseed
	Rumex acetosella	common sheep sorrel
	Rumex crispus	curly dock
	Rumex hastatulus	heartwing sorrel
	Rumex obtusifolius	bitter dock
Polypodiaceae	*Polypodium virginianum*	rock polypody
Pontederiaceae	*Pontederia cordata*	pickerelweed
Portulacaceae	*Claytonia virginica*	Virginia springbeauty
	Claytonia virginica var. *hammondiae*	Hammond's claytonia
Primulaceae	*Lysimachia ciliata*	fringed loosestrife
	Lysimachia hybrida	lowland yellow loosestrife
	Lysimachia nummularia	creeping Jenny
	Lysimachia quadrifolia	whorled yellow loosestrife
	Lysimachia terrestris	earth loosestrife
	Lysimachia vulgaris	garden yellow loosestrife
	Trientalis borealis	starflower
Pteridaceae	*Adiantum pedatum*	northern maidenhair
Pteridaceae	*Cheilanthes lanosa*	hairy lipfern
Pyrolaceae	*Chimaphila maculata*	striped prince's pine
	Chimaphila umbellata	pipsissewa
	Pyrola elliptica	waxflower shinleaf
Ranunculaceae	*Actaea pachypoda*	white baneberry
	Actaea rubra	red baneberry
	Anemone canadensis	Canadian anemone
	Aquilegia canadensis	red columbine
	Cimicifuga racemosa	black bugbane
	Clematis virginiana	devil's darning needles
	Coptis trifolia	threeleaf goldthread
	Hepatica nobilis	hepatica
	Hepatica nobilis var. *acuta*	sharplobe hepatica
	Hepatica nobilis var. *obtusa*	roundlobe hepatica
	Ranunculus abortivus	littleleaf buttercup
	Ranunculus acris	tall buttercup
	Ranunculus pensylvanicus	Pennsylvania buttercup
	Ranunculus recurvatus	blisterwort
	Ranunculus sceleratus	cursed buttercup
	Thalictrum dioicum	early meadow-rue
	Thalictrum pubescens	king of the meadow
	Thalictrum thalictroides	rue anemone
Rhamnaceae	*Rhamnus alnifolia*	alderleaf buckthorn
	Rhamnus cathartica	common buckthorn
Rosaceae	*Agrimonia gryposepala*	tall hairy agrimony
	Agrimonia pubescens	soft agrimony
	Agrimonia striata	roadside agrimony
	Amelanchier arborea	common serviceberry

Family	Scientific Name	Common Name
Rosaceae (cont.)	*Crataegus* sp.	hawthorn
	Dasiphora floribunda	shrubby cinquefoil
	Duchesnea indica	Indian strawberry
	Fragaria vesca	woodland strawberry
	Fragaria virginiana	Virginia strawberry
	Geum canadense	white avens
	Geum laciniatum	rough avens
	Geum rivale	purple avens
	Geum vernum	spring avens
	Malus sylvestris	European crabapple
	Photinia melanocarpa	black chokeberry
	Photinia pyrifolia	red chokeberry
	Physocarpus opulifolius	common ninebark
	Potentilla argentea	silver cinquefoil
	Potentilla canadensis	dwarf cinquefoil
	Potentilla recta	sulphur cinquefoil
	Potentilla simplex	common cinquefoil
	Prunus avium	sweet cherry
	Prunus pumila	sandcherry
	Prunus pumila var. *depressa*	eastern sandcherry
	Prunus pumila var. *susquehanae*	Susquehanna sandcherry
	Prunus serotina	black cherry
	Prunus virginiana	choke cherry
	Rosa blanda	smooth rose
	Rosa carolina	Carolina rose
	Rosa multiflora	multiflora rose
	Rosa palustris	swamp rose
	Rubus allegheniensis	Allegheny blackberry
	Rubus flagellaris	northern dewberry
	Rubus hispidus	bristly dewberry
	Rubus idaeus	American red raspberry
	Rubus occidentalis	black raspberry
	Rubus odoratus	purpleflowering raspberry
	Rubus phoenicolasius	wine raspberry
	Rubus pubescens	dwarf red blackberry
	Sorbus americana	American mountain ash
	Spiraea alba	white meadowsweet
	Spiraea alba var. *latifolia*	white meadowsweet
	Spiraea tomentosa	steeplebush
	Waldsteinia fragarioides	Appalachian barren strawberry
Rubiaceae	*Cephalanthus occidentalis*	common buttonbush
	Galium aparine	cleavers
	Galium asprellum	rough bedstraw
	Galium boreale	northern bedstraw
	Galium circaezans	licorice bedstraw
	Galium concinnum	shining bedstraw
	Galium lanceolatum	lanceleaf wild licorice
	Galium mollugo	false baby's breath
	Galium obtusum	bluntleaf bedstraw
	Galium palustre	common marsh bedstraw
	Galium pilosum	hairy bedstraw

Family	Scientific Name	Common Name
Rubiaceae (cont.)	*Galium tinctorium*	stiff marsh bedstraw
	Galium trifidum	threepetal bedstraw
	Galium triflorum	fragrant bedstraw
	Galium verum	yellow spring bedstraw
	Houstonia caerulea	azure bluet
	Houstonia serpyllifolia	thymeleaf bluet
	Mitchella repens	partridgeberry
Rutaceae	*Zanthoxylum americanum*	common pricklyash
Salicaceae	*Populus deltoides*	eastern cottonwood
	Populus grandidentata	bigtooth aspen
	Populus tremuloides	quaking aspen
	Salix bebbiana	Bebb willow
	Salix candida	sageleaf willow
	Salix discolor	pussy willow
	Salix eriocephala	Missouri River willow
	Salix fragilis	crack willow
	Salix nigra	black willow
	Salix sericea	silky willow
Santalaceae	*Comandra umbellata*	bastard toadflax
Sapindaceae	*Koelreuteria paniculata*	goldenrain tree
Sarraceniaceae	*Sarracenia purpurea*	purple pitcherplant
Saxifragaceae	*Chrysosplenium americanum*	American golden saxifrage
	Heuchera americana	American alumroot
	Heuchera americana var. *americana*	American alumroot
	Mitella diphylla	twoleaf miterwort
	Parnassia glauca	fen grass of Parnassus
	Saxifraga pensylvanica	eastern swamp saxifrage
	Saxifraga virginiensis	early saxifrage
	Tiarella cordifolia	heartleaf foamflower
Scrophulariaceae	*Agalinis tenuifolia*	slenderleaf false foxglove
	Chelone glabra	white turtlehead
	Digitalis lutea	straw foxglove
	Digitalis purpurea	purple foxglove
	Euphrasia stricta	drug eyebright
	Linaria vulgaris	butter and eggs
	Melampyrum lineare	narrowleaf cowwheat
	Mimulus ringens	Allegheny monkeyflower
	Paulownia tomentosa	princesstree
	Penstemon digitalis	talus slope penstemon
	Verbascum thapsus	common mullein
	Veronica arvensis	corn speedwell
	Veronica officinalis	common gypsyweed
	Veronica peregrina	neckweed
	Veronica serpyllifolia	thymeleaf speedwell
Simaroubaceae	*Ailanthus altissima*	tree of heaven
Smilacaceae	*Smilax glauca*	cat greenbrier
	Smilax herbacea	smooth carrionflower
	Smilax rotundifolia	roundleaf greenbrier
Solanaceae	*Datura stramonium*	jimsonweed
	Physalis alkekengi	strawberry groundcherry
	Solanum carolinense	Carolina horsenettle

Family	Scientific Name	Common Name
Solanaceae (cont.)	*Solanum dulcamara*	climbing nightshade
	Solanum nigrum	black nightshade
Sparganiaceae	*Sparganium americanum*	American bur-reed
	Sparganium androcladum	branched bur-reed
Staphyleaceae	*Staphylea trifolia*	American bladdernut
Thelypteridaceae	*Phegopteris connectilis*	long beechfern
	Thelypteris noveboracensis	New York fern
	Thelypteris palustris	eastern marsh fern
	Thelypteris palustris var. *pubescens*	eastern marsh fern
	Thelypteris simulata	bog fern
Thuidiaceae	*Thuidium delicatulum*	delicate thuidium moss
Tiliaceae	*Tilia americana*	American basswood
Typhaceae	*Typha angustifolia*	narrowleaf cattail
	Typha latifolia	broadleaf cattail
Ulmaceae	*Celtis occidentalis*	common hackberry
	Ulmus americana	American elm
	Ulmus rubra	slippery elm
Urticaceae	*Boehmeria cylindrica*	smallspike false nettle
	Laportea canadensis	Canadian woodnettle
	Pilea pumila	Canadian clearweed
	Urtica dioica	stinging nettle
	Urtica dioica ssp. *gracilis*	California nettle
Verbenaceae	*Phryma leptostachya*	American lopseed
	Verbena hastata	swamp verbena
	Verbena urticifolia	white vervain
Violaceae	*Viola blanda*	sweet white violet
	Viola conspersa	American dog violet
	Viola cucullata	marsh blue violet
	Viola macloskeyi	small white violet
	Viola macloskeyi ssp. *pallens*	smooth white violet
	Viola palmata	early blue violet
	Viola pubescens	downy yellow violet
	Viola sagittata	arrowleaf violet
	Viola sagittata var. *ovata*	arrowleaf violet
	Viola sororia	common blue violet
	Viola striata	striped cream violet
Vitaceae	*Parthenocissus quinquefolia*	Virginia creeper
	Vitis aestivalis	summer grape
	Vitis labrusca	fox grape
	Vitis riparia	riverbank grape
	Vitis vulpina	frost grape

NON-VASCULAR PLANTS

Family	Scientific Name	Common Name
Amblystegiaceae	*Campylium stellatum*	star campylium moss
Aulacomniaceae	*Aulacomnium palustre*	aulacomnium moss
Dicranaceae	*Dicranum* sp.	dicranum moss
Fontinalaceae	*Fontinalis antipyretica*	antifever fontinalis moss
Lepidoziaceae	*Bazzania* sp.	liverwort
Leucobryaceae	*Leucobryum* sp.	leucobryum moss
Polytrichaceae	*Polytrichum* sp.	polytrichum moss
Selaginellaceae	*Selaginella apoda*	meadow spikemoss
	Selaginella rupestris	northern selaginella
Sphagnaceae	*Sphagnum capillifolium*	sphagnum

Appendix D. Dichotomous field key to the vegetation associations of Delaware Water Gap National Recreation Area.

KEY TO VEGETATION ASSOCIATIONS IN DELAWARE WATER GAP NATIONAL RECREATION AREA

1. Area is predominantly bare rock outcrops, boulders, talus, scree, cobbles, gravel, sand, or bare leaf litter with scattered vegetation covering less than 25% of total area. These areas are often on extremely steep slopes, cliffs, ridgetops, or along the Delaware River shoreline.
SPARSE VEGETATION GROUP

1. Area is not predominantly bare rock outcrops, boulders, talus or scree. Vegetation covers 25% or more of the area.

    2. Association is dominated by herbaceous or graminoid species. Woody species cover less than 25% of the area. (Small patch herbaceous seeps or vernal pools that may occur under closed or partially closed forest canopy are included here).
HERBACEOUS GROUP

    2. Woody species (shrubs or trees) cover at least 25% of the area.

        3. Shrubs (woody species 5 meters tall or less) cover at least 25% of the area. Trees (woody species greater than 5 meters tall) cover less than 25% of the area.
SHRUB GROUP

        3. Trees (woody species greater than 5 meters tall) cover at least 25% of the area.

            4. Trees (woody species greater than 5 meters tall) cover 25–60% of the area.
WOODLAND GROUP

            4. Trees (woody species greater than 5 meters tall) greater than 60% of the area.
FOREST GROUP

SPARSE VEGETATION GROUP

1. Sparse vegetation occurs on cobble, gravel, or sand bars adjacent to the Delaware River.
Riverine Scour Vegetation

1. Sparse vegetation does not occur on cobble, gravel, or sand bars adjacent to the Delaware River.

    2. Ground is concave, a shallow basin or depression that holds standing water for at least part of the year. The bottom of the shallow basin may be lined with leaf litter or large boulders.

        3. The bottom of the depression is lined with leaf litter.
Eastern Woodland Vernal Pool Sparse Vegetation

        3. The bottom of the depression is lined with large boulders. These depression occur on the top of Kittantinny Ridge.
Boulder Vernal Pool Sparse Vegetation

    2. Either, the ground is convex and occurs on ridgetop or the crests of steep slopes with a substrate of large rock outcrops; OR the ground is steeply sloping with a substrate of loose weathered shale scree, rock cliffs, or large talus boulders. The area does NOT hold standing water for part of the year.

        4. Area is steeply sloping, at upper, middle or lower slope topographic positions. Substrate is composed of loose weathered shale scree, rock cliffs, or large talus boulders.

            5. Sparse variable vegetation established in crevices of steep, often southeast-facing sandstone or shale cliffs. Substrate not talus boulders, shale scree, or ridgetop rock outcrops.
Sparsely Vegetated Cliff

            5. Substrate is talus boulders or shale scree.

                6. Sparse variable vegetation established in crevices between large boulders that cover the ground (i.e., boulderfields). Occurs on very steep, typically southeast-facing lower slopes of the Kittatiny Ridge.
Sandstone Talus

                6. Association occurs on very steep, southeast-facing lower slopes covered in gravelly shale scree along the eastern edge of the plateau in Pennsylvania. Vegetation is variable and can be absent or sparse.
Shale Scree Slope

4. Area occurs on ridgetop or the crests of steep slopes. Substrate is large rock outcrops. Substrate is not loose weathered shale scree, rock cliffs, or large talus boulders.

    7. Trees and shrubs cover less than 10% of the area. Prominent vegetation includes herbaceous and graminoid species growing in crevices and in thin soil over bedrock. Characteristic species include wavy hairgrass (*Deschampsia flexuosa*), common sheep sorrel (*Rumex acetosella*), eastern hayscented fern (*Dennstaedtia punctilobula*), poverty oatgrass (*Danthonia spicata*), little bluestem (*Schizachyrium scoparium*), and tapered rosette grass (*Dichanthelium acuminatum* var. *acuminatum*).

        Wavy Hairgrass - Common Sheep Sorrel Rock Outcrop

    7. Trees and shrubs cover 10–25% of the area.

        8. Association occurs on rocky summits and ridgetops, often with northern or western aspect. Slope generally less than 25 %.

            Pitch Pine - Mixed Hardwood Rocky Summit

        8. Association occurs among rock outcrops on upper slopes, on the tops of cliffs along Kittatinny Ridge, or along narrow shelves on very steep southeast-facing cliffs in Pennsylvania. Aspect is generally to south to southeast with a slope greater than 25% (often greater than 50%).

            Hickory - Eastern Red-cedar Rocky Woodland

HERBACEOUS GROUP

1. Riparian vegetation that occurs in the floodplain of the Delaware River on islands, shorelines, gravel/cobble bars, or riverbeds. Vegetation structure and composition are influenced by river flooding and scour.

    2. Association is dominated (relative cover >50%) by either American water-willow (*Justicia americana*) or Japanese knotweed (*Polygonum cuspidatum*).

        3. Association is dominated by American water-willow (*Justicia americana*), forming emergent beds at the heads of islands or adjacent to bars and shorelines.
        Water-willow Emergent Bed

        3. Association is dominated by Japanese knotweed (*Polygonum cuspidatum*), establishing on islands and shorelines.
        Japanese Knotweed Herbaceous Vegetation

    2. Association is not dominated (relative cover <50%) of American water-willow (*Justicia americana*) or Japanese knotweed (*Polygonum cuspidatum*).

        4. Vegetation established on limestone outcrops or large fractured limestone cobbles along the New Jersey shoreline of the Delaware River.

            5. Association is characterized by open, sparsely vegetated sections of smooth Onondaga limestone outcrops with north-northwest exposure. Typical vegetation is a mixture of riparian species, xeric-loving crevice plants, and rare calciphiles.
            Calcareous Riverside Outcrop

            5. Association occurs on alluvial deposits combined with fractured limestone substrate. Seeps occur where groundwater flows out and over the cobbled substrate. Vegetation can be dense, robust, and diverse, supporting many grasses, sedges and rare calciphiles.
            Calcareous Riverside Seep

        4. Vegetation not associated with limestone outcrops or large fractured limestone cobbles along the New Jersey shoreline of the Delaware River.

            6. Vegetation dominated by reed canarygrass (*Phalaris arundinacea*) or hairyfruit sedge (*Carex trichocarpa*).

                7. Vegetation dominated by reed canarygrass (*Phalaris arundinacea*) that has greater than 50% cover.
                Reed Canarygrass Riverine Grassland

7. Vegetation dominated by hairyfruit sedge (*Carex trichocarpa*) that has greater than 50% cover.

Hairyfruit Sedge Wetland

6. Reed canarygrass (*Phalaris arundinacea*) and hairyfruit sedge (*Carex trichocarpa*) are absent or constitute less than 50% relative cover.

8. Vegetation resembles tall prairie-like grassland (in summer and early fall) dominated by big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*) and little bluestem (*Schizachyrium scoparium*). Association occurs on sand/gravel deposits along shorelines and on islands.

Big Bluestem - Indiangrass Riverine Grassland

8. Variable vegetation in and directly adjacent to the active channel that is underwater for a significant portion of the year and is exposed during periods of low water (typically mid summer to early fall except during flood events). Frequent scour causes variation in species composition that is characteristic of this community. Cobbles and sand on island heads, bars, spits, low terraces, and shorelines support this vegetation type.

Riverine Scour Vegetation

1. Palustrine or terrestrial vegetation that is not directly associated with the Delaware River. Palustrine vegetation associated with creeks and tributaries to the Delaware River is included here.

9. Palustrine vegetation with standing water, saturated soil, or groundwater seepage for at least a portion of the growing season.

10. Association occurs as a small patch community directly associated with groundwater seepage, often over calcareous bedrock.

11. Wetland occurs over calcareous bedrock and may contain calciphilic plant species.

12. Typical species include New York ironweed (*Vernonia noveboracensis*), eastern marsh fern (*Thelypteris palustris*), violets (*Viola* spp.), golden ragwort (*Packera aurea*), skunk-cabbage (*Symplocarpus foetidus*), Jack in the pulpit (*Arisaema triphyllum*), American marshpennywort (*Hydrocotyle americana*), thoroughwort (*Eupatorium* spp.), touch-me-not (*Impatiens* spp.), whorled mountainmint (*Pycnanthemum verticillatum*), American hogpeanut (*Amphicarpaea bracteata*), twoleaf miterwort (*Mitella diphylla*), white turtlehead (*Chelone glabra*), white edge sedge (*Carex debilis*), Japanese stiltgrass (*Microstegium vimineum*), and rice cutgrass (*Leersia oryzoides*). Does not contain the characteristic fen indicators listed below for Calcareous Fen.

Calcareous Seep

12. Wetland contains some of the following characteristic fen indicator species: fen grass-of-Parnassus (*Parnassia glauca*), Ontario lobelia (*Lobelia kalmii*), downy willowherb (*Epilobium strictum*), rigid sedge (*Carex tetanica*), smallhead rush (*Juncus brachycephalus*), and purple avens (*Geum rivale*). Common species include golden ragwort (*Packera aurea*), eastern marsh fern (*Thelypteris palustris*), narrowleaf mountainmint (*Pycnanthemum tenuifolium*), sensitive fern (*Onoclea sensibilis*), woodland rush (*Juncus subcaudatus*), wrinkleleaf goldenrod, (*Solidago rugosa*), tussock sedge (*Carex stricta*), crested woodfern (*Dryopteris cristata*), and Dudley's rush (*Juncus dudleyi*).

Calcareous Fen

11. Wetland occurs on acidic sandstone, siltstone, shale or slate bedrock. Characteristic vegetation includes tufted hairgrass (*Deschampsia cespitosa*), downy goldenrod (*Solidago puberula*), Boreal chickweed (*Cerastium biebersteinii*), and Hammond's claytonia (*Claytonia virginica* var. *hammondiae*).

Acidic Seep

10. Association not limited to areas with groundwater seepage. Vegetation is typically flooded at least in the early portion of the growing season.

13. Vegetation occurs adjacent to creeks and tributaries. Vegetation dominated by reed canarygrass (*Phalaris arundinacea*) or hairyfruit sedge (*Carex trichocarpa*).

14. Vegetation dominated by reed canary grass (*Phalaris arundinacea*) that has greater than 50% cover.

Reed Canarygrass Riverine Grassland

14. Vegetation dominated by hairyfruit sedge (*Carex trichocarpa*) that has greater than 50% cover.

Hairyfruit Sedge Wetland

13. Vegetation is not associated with creeks and tributaries. Reed canarygrass (*Phalaris arundinacea*) and hairyfruit sedge (*Carex trichocarpa*) are absent or constitute less than 50% relative cover.

    15. Wetland contains standing water for most or all of the year and is often associated with impounded drainages, ponded areas near streams, or saturated areas surrounding drainages.

        16. Dominant species is tussock sedge (*Carex stricta*) covering 30-75% of the area.

            Tussock Sedge Marsh

        16. Tussock sedge (*Carex stricta*) covers less than 30% of the wetland. Vegetation is dominated species that are tolerant of standing water, although species composition is variable.

            17. Cattails (*Typha* spp.) are the clear dominant in the wetland, covering greater than 50% relative cover.

                Cattail Marsh

            17. Cattails (*Typha* spp.) are not the clear dominant. Species composition can be variable. Common species include: needle spikerush (*Eleocharis acicularis*), swamp verbena (*Verbena hastata*), nodding beggartick (*Bidens cernua*), rice cutgrass (*Leersia oryzoides*), marshpepper knotweed (*Polygonum hydropiper*), arrowleaf tearthumb (*Polygonum sagittatum*), field horsetail (*Equisetum arvense*), New England aster (*Aster novae-angliae*), owlfruit sedge (*Carex stipata*), and/or marsh seedbox (*Ludwigia palustris*).

                Mixed Forb Marsh

    15. Wetland is typically flooded in early growing season and is dry or saturated the rest of the year.

        18. Vegetation is typically thick (>75% absolute cover). Typical species include a diverse mix of hydrophilic graminoids such as sedges (*Carex* spp.), bulrushes (*Scirpus* spp.), rushes (*Juncus* spp.), rice cutgrass (*Leersia oryzoides*), and rough bentgrass (*Agrostis scabra*). Associated herbs include arrowleaf tearthumb (*Polygonum sagittatum*), eastern marsh fern (*Thelypteris palustris*), and giant goldenrod (*Solidago gigantea*).

            Wet Meadow

        18. Vegetation is typically sparse (0–50% absolute cover) and occurs in a small depression that is seasonally flooded and lined with leaf litter.

            Eastern Woodland Vernal Pool Sparse Vegetation

9. Terrestrial vegetation with no standing water, saturated soils, or groundwater seepage.

    19. Vegetation occurs on bedrock outcrops or thin soils and covers less than 50% of the area. Wavy hairgrass (*Deschampsia flexuosa*), common sheep sorrel (*Rumex acetosella*), and poverty oatgrass (*Danthonia spicata*) are characteristic species.
    Wavy Hairgrass - Common Sheep Sorrel Rock Outcrop

    19. Vegetation is dense (>80% cover), not dominated by wavy hairgrass (*Deschampsia flexuosa*), and is not associated with bedrock outcrops.

        20. Little bluestem (*Schizachyrium scoparium*) covers greater than 50% of the area.
        Little Bluestem Grassland

        20. Little bluestem (*Schizachyrium scoparium*) covers less than 50% of the area. Characteristically dominant species are wrinkleleaf goldenrod (*Solidago rugosa*) and sweet vernalgrass (*Anthoxanthm odoratum*) with numerous other graminoid and herbaceous associates.
        Old Field

SHRUB GROUP

1. Riparian vegetation that occurs in the floodplain of the Delaware River on islands, shorelines, gravel/cobble bars, or riverbeds. Vegetation structure and composition are influenced by river flooding and scour.

    2. Vegetation is characterized by a moderately dense to dense short shrub layer less than 2 m in height. Characteristic species include willows (*Salix nigra, Salix eriocephala, Salix sericea*) and sycamore (*Platanus occidentalis*). Tall shrubs (2–5 m in height) cover less than 25% of the area.

        Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland

    2. Vegetation is characterized by a moderately dense to dense tall shrub layer of shrubs 2–5 m in height that cover greater than 25% of the area. Dominant species is typically sycamore (*Platanus occidentalis*), with associates river birch (*Betula nigra*), black willow (*Salix nigra*), and silver maple (*Acer saccharinum*).

        Sycamore - Mixed Hardwood Riverine Shrubland

1. Palustrine or terrestrial vegetation that is not directly associated with the Delaware River. Palustrine vegetation associated with creeks and tributaries to the Delaware River is included here.

    3. Palustrine vegetation with standing water, saturated soil or groundwater seepage for at least a portion of the growing season.

        4. Association is dominated or co-dominated by thick layer of leatherleaf (*Chamaedaphne calyculata*) that covers 50% or more of the wetland.

            5. Cover of highbush blueberry (*Vaccinium corymbosum*) and other tall shrubs is <50% of the wetland. A stunted dense layer of leatherleaf (*Chamaedaphne calyculata*) is prominent. Common “bog” plants such as purple pitcherplant (*Sarracenia purpurea*), roundleaf sundew (*Drosera rotundifolia*), swamp loosestrife (*Decodon verticillatus*), and white beaksedge (*Rhynchospora alba*) are typically growing on a thick sphagnum moss (*Sphagnum* sp.) mat.

                Leatherleaf Peatland

            5. Highbush blueberry (*Vaccinium corymbosum*) and other tall shrubs cover 50% or more of the wetland. A stunted dense layer of leatherleaf (*Chamaedaphne calyculata*) is prominent under the tall shrubs. The “bog” plants listed above are not common.

                Highbush Blueberry - Leatherleaf Wetland

        4. Leatherleaf (*Chamaedaphne calyculata*) is absent or a minor component of the wetland (cover < 50%).

6. Association occurs as a small patch community that contains calciphilic plants and is directly associated with groundwater seepage from calcareous bedrock. Shrubby cinquefoil (*Dasiphora floribunda*) and poison sumac (*Toxicodendron vernix*) are often present and may be abundant.

    7. Wetland contains active precipitation of marl deposits and the alga Chara (*Chara* spp.).

        Marl Fen

    7. Wetland does not contain active precipitation of marl deposits or the alga Chara (*Chara* spp.).

        Calcareous Fen

6. Association not limited to areas with groundwater seepage and does not contain calciphilic plants. Shrubby cinquefoil (*Dasiphora floribunda*) and poison sumac (*Toxicodendron vernix*) are absent. Area contains standing water in at least the early portion of the growing season or is associated with floodplains of creeks and drainages.

    8. Wetland is dominated by common buttonbush (*Cephalanthus occidentalis*) or alders (*Alnus* spp.).

        9. Vegetation is dominated by common buttonbush (*Cephalanthus occidentalis*). Wetland experiences prolonged or semi-permanent flooding and contains sparse herbaceous vegetation.

            Buttonbush Wetland

        9. Vegetation is dominated by smooth alder (*Alnus serrulata*) or mountain alder (*Alnus incana*). Tussock sedge (*Carex stricta*) is typically dominant (>50% cover) in the herbaceous layer.

            Alder Wetland

    8. Wetland is dominated by silky dogwood (*Cornus amomum*), multiflora rose (*Rosa multiflora*), highbush blueberry (*Vaccinium corymbosum*), and/or steeplebush (*Spiraea tomentosa*).

        10. Vegetation is dominated by silky dogwood (*Cornus amomum*), crack willow (*Salix fragilis*), Morrow's honeysuckle (*Lonicera morrowii*), and/or multiflora rose (*Rosa multiflora*) within a matrix of graminoids similar to those in a Wet Meadow or Reed Canarygrass Riverine Grassland. Wetland typically occurs on the floodplain of a creek or near a drainageway.

            Silky Dogwood Successional Palustrine Shrubland

10. Vegetation is dominated by highbush blueberry (*Vaccinium corymbosum*) and/or steeplebush (*Spiraea tomentosa*). Wetland occurs in a small upland depression or a basin surrounding a small streams.

Highbush Blueberry - Steeplebush Wetland

3. Terrestrial vegetation with no standing water, saturated soils, or groundwater seepage.

11. Shrubland typically occurs at mid to low elevations on former agricultural land. Characteristic shrubs are autumn-olive (*Elaeagnus umbellata*), gray dogwood (*Cornus racemosa*), multiflora rose (*Rosa multiflora*), eastern red cedar (*Juniperus virginiana*), eastern white pine (*Pinus strobus*), flowering dogwood (*Cornus florida*), Morrow's honeysuckle (*Lonicera morrowii*), smooth sumac (*Rhus glabra*), blackhaw (*Viburnum prunifolium*), and raspberries (*Rubus allegheniensis, Rubus phoenicolasius, Rubus occidentalis*). Herbaceous vegetation is typical of Old Field Vegetation.

Successional Shrubland

11. Shrubland is restricted to rocky soil at high elevations of the Kittatinny Ridge or the plateau in Pennsylvania. Associations typically occur above 200 meters elevation in New Jersey and above 150 meters in elevation in Pennsylvania. In general, the influential factors in vegetation structure and composition are harsh edaphic conditions and fire regimes. Characteristic shrubs include bear oak (*Quercus ilicifolia*), lowbush blueberry (*Vaccinium angustifolium*), Blue Ridge blueberry (*Vaccinium pallidum*), deerberry (*Vaccinium stamineum*), black huckleberry (*Gaylussacia baccata*), sheep laurel (*Kalmia angustifolium*), mountain laurel (*Kalmia latifolia*) and eastern red cedar (*Juniperus virginiana*).

12. Shrubland occurs on cliffs, the crests of cliffs, bouldery outcrops, or steeply sloping bedrock outcrops. Bare rock can cover a significant portion of the area. Scattered stunted trees of eastern red-cedar (*Juniperus virginiana*), pignut hickory (*Carya glabra*), or pitch pine (*Pinus rigida*) are present.

13. Vegetation occurs on cliffs, the crests of cliffs, or steeply sloping bedrock outcrops. Aspect is generally to south to southeast with a slope greater than 25% (often greater than 50%). The sparse stunted shrubland is characterized by eastern red-cedar (*Juniperus virginiana*), pignut hickory (*Carya glabra*), and chestnut oak (*Quercus prinus*).

Hickory - Eastern Red-cedar Rocky Woodland

13. Vegetation occurs on bouldery ridgetop outcrops or steeply sloping bedrock outcrops. Aspect is variable. The sparse stunted trees are typically pitch pine (*Pinus rigida*) with occasional hardwood associates.

Pitch Pine - Mixed Hardwood Rocky Summit

12. Shrubland occurs at high elevations, but not on cliffs, bouldery outcrops or steep rocky slopes. Bare rock outcrops may be scattered, but do not cover a significant portion of the area. Trees are rare or absent.

    14. In general, ericaceous shrub layer covers 80–100% of the area, while grasses and forbs cover <5% of the area. Huckleberry (*Gaylussacia baccata*) and blueberries (*Vaccinium* spp.) are typically the dominant heath species, with bear oak (*Quercus ilicifolia*) as a common tall shrub associate. Association is created and maintained by fire.

        Successional Bear Oak - Heath Shrubland

    14. In general, ericaceous shrubs and bear oak (*Quercus ilicifolia*) cover 25–75% of the area, interspersed with graminoids that cover 40–70% of the area. Bear oak (*Quercus ilicifolia*) is often the dominant shrub species, with heath species such as black huckleberry (*Gaylussacia baccata*) and blueberries (*Vaccinium* spp.) as associates. Common graminoids include wavy hairgrass (*Deschampsia flexuosa*), Pennsylvania sedge (*Carex pensylvanica*), and little bluestem (*Schizachyrium scoparium*). Association is influenced by thin soils over acidic bedrock, with fire as a secondary influence.

        Bear Oak - Wavy Hairgrass Shrubland

WOODLAND GROUP

1. Riparian or palustrine vegetation that contains saturated soil for at least part of the growing season or that occurs in the floodplain of the Delaware River, its major tributaries, or smaller drainages.

    2. Canopy is dominated by silver maple (*Acer saccharinum*) or black walnut (*Juglans nigra*).

        3. Canopy is dominated by silver maple (*Acer saccharinum*), often with a dense layer of reed canarygrass (*Phalaris arundinacea*) beneath.

            Silver Maple Floodplain Forest

        3. Canopy is dominated by black walnut (*Juglans nigra*), often with a dense layer of Japanese stilt grass (*Microstegium vimineum*) beneath.

            Black Walnut Bottomland Forest

    2. Canopy is dominated by red maple (*Acer rubrum*).

        4. Palustrine woodland that occurs above 150 meters elevation in New Jersey (currently only known from NJ). Open canopy is dominated by red maple (*Acer rubrum*) and blackgum (*Nyssa sylvatica*), over a thick tall shub layer of highbush blueberry (*Vaccinium corymbosum*) or great laurel (*Rhododendron maximum*). Associates distinctive to this association include yellow birch (*Betula alleghaniensis*), eastern hemlock (*Tsuga canadensis*), pitch pine (*Prinus rigida*), and black spruce (*Picea mariana*) in the canopy; and catberry (*Nemopanthus murcronatus*), and leatherleaf (*Chamaedaphne calyculata*) in the shrub layer. Common groundstory species include prickly bog sedge (*Carex atlantica* ssp. *capillacea*), northern long sedge (*Carex folliculata*), roundleaf sundew (*Drosera rotundifolia*), water arum (*Calla palustre*), threeleaf goldthread (*Coptis trifolia*).

            Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland

        4. Palustrine woodland does not contain the distinctive associates listed above.

            5. Woodland contains highbush blueberry (*Vaccinium corymbosum*) in the tall shrub layer (15–50% absolute cover). This association is often semi-permenantly or permenantly flooded.

                Red Maple - Highbush Blueberry Palustrine Forest

            5. Highbush blueberry (*Vaccinium corymbosum*) is sparse or absent (<15% absolute cover). Red maple (*Acer rubrum*) is the canopy dominant (25–95% relative cover) with a variety of associates. This association can be temporarily to permenantly flooded.

                Red Maple Palustrine Forest

1. Terrestrial forests that do not regularly experience saturated soils during the growing season or occur on the floodplain of river, creeks, or drainages.

    6. Vegetation is restricted to rocky and thin soils, often above 200 meters elevation in New Jersey and above 150 meters in elevation in Pennsylvania. Also includes rocky summits, rock outcrops, scree slopes, and talus slopes. In general, the influential factors in vegetation structure and composition are harsh edaphic conditions and fire regimes.

        7. Woodland occurs on very steep, often southeast-facing cliffs or scree, on gently to steeply sloping large bedrock outcrops, or on rocky summits.

            8. Woodland occurs on steep shale scree, typically at mid- to lower slopes in Pennsylvania. Typical trees include eastern white pine (*Pinus strobus*), gray birch (*Betula populifolia*), and tree of heaven (*Ailanthus altissima*).

                Shale Scree Slope

            8. Woodland occurs on cliffs, gently to steeply sloping large bedrock outcrops, or rocky summits in Pennsylvania or New Jersey.

                9. Woodland occurs among rock outcrops on upper slopes or on the crests of cliffs along Kittatinny Ridge. Aspect is generally to south to southeast with a slope greater than 25% (often greater than 50%). Characteristic trees include pignut hickory (*Carya glabra*), eastern red-cedar (*Juniperus virginiana*), pitch pine (*Pinus rigida*), and chestnut oak (*Quercus prinus*).

                    Hickory - Eastern Red-cedar Rocky Woodland

                9. Woodland occurs on gently to moderately steep sloping (slope <25%) rock outcrops and rocky summits. Characteristic trees include pitch pine (*Pinus rigida*), pignut hickory (*Carya glabra*), chestnut oak (*Quercus prinus*), and sweet birch (*Betula lenta*).

                    Pitch Pine - Mixed Hardwood Rocky Summit

        7. Woodland does not occur on very steep, often southeast-facing cliffs or scree, on gently to steeply sloping large bedrock outcrops, or on rocky summits.

            10. Woodland contains a thick layer of shrubs (often ericaceous) that cover greater than 40% of the area. Typical shrub species include lowbush blueberry (*Vaccinium angustifolium*), Blue Ridge blueberry (*Vaccinium pallidum*), deerberry (*Vaccinium stamineum*), black huckleberry (*Gaylussacia baccata*), sheep laurel (*Kalmia angustifolium*), mountain laurel (*Kalmia latifolia*), and bear oak (*Quercus ilicifolia*).

11. Open canopy consists of scattered established trees with diameters at breast height typically >20 cm. Tyipcal tree species are: oaks (*Quercus prinus, Quercus coccinea, Quercus rubra, Quercus alba, Quercus velutina*), blackgum (*Nyssa sylvatica*), eastern white pine (*Pinus strobus*), sweet birch (*Betula lenta*), pignut hickory (*Carya glabra*) and/or pitch pine (*Pinus rigida*).

Dry Oak - Heath Forest

11. Open canopy consists of newly established trees with diameters at breast height typically <20 cm. Common species include quaking aspen (*Populus tremuloides*), bigtooth aspen (*Populus grandidentata*), gray birch (*Betula populifolia*), sweet birch (*Betula lenta*), and black cherry (*Prunus serotina*).

Successional Heath Shrubland

10. Woodland does not contain a thick layer of typically ericaceous shrubs that cover greater than 40% of the area.

12. Ridgetop woodland is dominated or co-dominated by hickories (*Carya* spp.) that cover >25% of the canopy. Frequent on upper slopes of the southeast face of Kittatiny Ridge. Occasional as small patch in other sections of the Ridge.

Dry Hickory Ridgetop Forest

12. Woodland dominated by oaks (*Quercus* spp.) and/or pines (*Pinus* spp.).

13. Eastern white pine (*Pinus strobus*) and/or pitch pine (*Pinus rigida*) constitute greater than 25% relative cover in the canopy and subcanopy combined. Dry oaks (*Quercus prinus*, *Quercus rubra*, *Quercus velutina*, *Quercus alba*, *Quercus coccinea*) are the canopy associates. The stands often contain a thick layer of regenerating pine in the tall shrub layer.

Dry Eastern White Pine - Oak Forest

13. Eastern white pine (*Pinus strobus*) and/or pitch pine (*Pinus rigida*) constitute less than 25% relative cover in the canopy and subcanopy combined.

14. Woodland occurs on coarse, bouldery sandstone talus, either on the rocky steep southeast-facing slope of the Kittatiny Ridge or on occasional boulderfields in other sections of the park. Chestnut oak (*Quercus prinus*) and sweet birch (*Betula lenta*) are common canopy components.

Oak Talus Forest

14. Woodland occurs on coarse, bouldery sandstone talus. Canopy is dominated by dry oaks (*Quercus prinus, Quercus alba, Quercus coccinea, Quercus velutina*) with hickories (*Carya* spp.) and sweet birch (*Betula lenta*) as associates. The herbaceous layer is often dominated by graminoids.

Dry Oak - Mixed Hardwood Forest

6. Vegetation is not restricted to rocky sites with thin soils. In general, current vegetation structure and composition are most influenced by past land management and land use history (for former shale quarry sites, see rocky couplet above).

15. Woodland dominated by conifers such as eastern red-cedar (*Juniperus virginiana*), pine (*Pinus* spp.) or spruce (*Picea* spp.).

16. Open woodland dominated by young eastern red-cedar (*Juniperus virginiana*) with diameters at breast height typically <20 cm. Groundstory vegetation is typically dense and characteristic of Old Field Vegetation and.shrubs are often characterisitic of Successional Shrublands.

Eastern Red-cedar Forest

16. Woodland dominated by pine (*Pinus* spp.) or spruce (*Picea* spp.).

17. Open woodland dominated by young eastern white pine (*Pinus strobus*) with diameters at breast height typically <20 cm. Groundstory vegetation is typically dense and characteristic of Old Field Vegetation and.shrubs are often characterisitic of Successional Shrublands.

Successional Eastern White Pine Woodland

17. Woodland is dominated by scattered established eastern eastern white pine (*Pinus strobus*), red pine (*Pinus resinosa*), Scotch pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), blue spruce (*Picea pungens*) or larch (*Larix* sp.) with diameters at breast height typically >20 cm. Conifers appear planted in a pattern (typically in rows). Adventitious hardwoods may be present. The herbaceous layer is usually sparse with low diversity.

Conifer Plantation

15. Woodland dominated by hardwoods (eastern red-cedar [*Juniperus virginiana*] may be co-dominant in some stands).

18. Groundstory vegetation is typically dense and characteristic of Old Field Vegetation and.shrubs are often characterisitic of Successional Shrublands. Woodland is composed of scattered open-grown trees, of variable species composition.

Wooded Successional Old Field

18. Groundstory vegetation is not characteristic of Old Field Vegetation and shrubs are not characterisitic of Successional Shrublands. Woodland is characterized by early successional, weedy species such as black walnut (*Juglans nigra*), white ash (*Fraxinus americana*), black locust (*Robinia pseudoacacia*), eastern red-cedar (*Juniperus virginiana*), bigtooth aspen (*Populus grandidentata*), black walnut (*Juglans nigra*), black cherry (*Prunus serotina*), red maple (*Acer rubrum*) and eastern white pine (*Pinus strobus*). Invasive shrub and herb species are characteristic and abundant

    19. Black walnut (*Juglans nigra*) is the clear canopy dominant, often with a dense layer of Japanese stilt grass (*Microstegium vimineum*) beneath.

        Black Walnut Bottomland Forest

    19. Black walnut (*Juglans nigra*) is not the clear canopy dominant, although it can be an associate. White ash (*Fraxinus americana*), black locust (*Robinia pseudoacacia*), eastern red-cedar (*Juniperus virginiana*), bigtooth aspen (*Populus grandidentata*), and black cherry (*Prunus serotina*) are common canopy dominants. Invasive shrub and herb species are characteristic and abundant.

        Northeastern Modified Successional Forest

FOREST GROUP

1. Riparian or palustrine vegetation that contains saturated soil for at least part of the growing season OR that occurs in the alluvial or glacial floodplain terraces of the Delaware River Valley. Please note that some terrestrial forest associations can also occur on these floodplain terraces (see couplet 12 below).

    2. Forest is dominated by silver, sugar, or red maple (*Acer* spp.) that constitute at least 25% relative cover of the canopy. Numerous species may be present as associates, but each of the following species do not constitute more than 25% relative cover of the canopy: sycamore (*Platanus occidentalis*), bitternut hickory (*Carya cordiformis*), river birch (*Betula nigra*), eastern hemlock (*Tsuga canadensis*), oaks (*Quercus palustris*, *Quercus bicolor*), ashes (*Fraxinus nigra, Fraxinus americana, Fraxinus pennsylvanica*), American elm (*Ulmus americana*), and American hornbeam (*Carpinus caroliniana*). If maples constitute 25–50% relative cover, and one of the above species constitutes greater than 25% relative cover, see couplet 6 below.

        3. Forest is dominated by silver maple (*Acer saccharinum*) or sugar maple (*Acer saccharum*). Forest typically occurs on the floodplain of the Delaware River or its major tributaries.

            4. Silver maple (*Acer saccharinum*) constitutes at least 25% relative cover of the canopy; frequently relative cover exceeds 50%. Sugar maple (*Acer saccharum*) can be absent or co-dominant.

                Silver Maple Floodplain Forest

            4. Silver maple (*Acer saccharinum*) and sycamore (*Platanus occidentalis*) are absent or are occasional canopy associates (<25% relative cover). Sugar maple (*Acer saccharum*) constitutes at least 25% relative cover of the canopy and is prominent in the subcanopy; frequently relative cover exceeds 50%. [If sycamore canopy cover exceeds 25% relative cover, see couplet 10 below].

                Sugar Maple Floodplain Forest

        3. Forest is dominated by red maple (*Acer rubrum*) and typically occurs around smaller drainages, in depressions, and near groundwater seepage.

            5. Forest contains red maple (*Acer rubrum*) in the canopy (>50% relative cover) and highbush blueberry (*Vaccinium corymbosum*) in the tall shrub layer (15–50% absolute cover). This association is often semi-permenantly or permenantly flooded.

                Red Maple - Highbush Blueberry Palustrine Forest

5. Highbush blueberry (*Vaccinium corymbosum*) is sparse or absent (<15% absolute cover). Red maple (*Acer rubrum*) is the canopy dominant (25–95% relative cover) with a variety of associates. This association can be temporarily to permenantly flooded.

Red Maple Palustrine Forest

2. Forest is not dominated by silver, sugar, or red maple (*Acer* spp.). Canopy is dominated by one or more of the following species that can constitute more than 25% relative cover of the canopy: sycamore (*Platanus occidentalis*), bitternut hickory (*Carya cordiformis*), river birch (*Betula nigra*), eastern hemlock (*Tsuga canadensis*), oaks (*Quercus palustris, Quercus bicolor*), ashes (*Fraxinus nigra, Fraxinus americana, Fraxinus pennsylvanica*), American elm (*Ulmus americana*), and American hornbeam (*Carpinus caroliniana*). Maples may constitute 25–50% relative cover, if one of the above species constitutes grater than 25% relative cover.

6. Eastern hemlock (*Tsuga canadensis*) composes 25% or greater in the canopy and subcanopy combined. Common canopy associates include red maple (*Acer rubrum*), yellow birch (*Betula alleghaniensis*), and/or blackgum (*Nyssa sylvatica*). Forest occurs along small creeks and drainages.

Eastern Hemlock - Mixed Hardwood Palustrine Forest

6. Eastern hemlock (*Tsuga canadensis*) composes less than 25% in the canopy and subcanopy combined. Canopy dominants are bitternut hickory (*Carya cordiformis*), black walnut (*Juglans nigra*), sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), oaks (*Quercus palustris, Quercus bicolor*), ashes (*Fraxinus nigra, Fraxinus americana, Fraxinus pennsylvanica*), American elm (*Ulmus americana*), and/or American hornbeam (*Carpinus caroliniana*).

7. Canopy dominants are bitternut hickory (*Carya cordiformis*) or black walnut (*Juglans nigra*).

8. Bitternut hickory (*Carya cordiformis*) constitutes at least 25% relative cover of the canopy; frequently relative cover exceeds 50%. Forest occurs on the floodplain of the Delaware River or its major tributaries.

Bitternut Hickory Lowland Forest

8. Black walnut (*Juglans nigra*) is the clear canopy dominant; frequently relative cover exceeds 50%. Forest can occur on the floodplain of the Delaware River, its major tributaries, or in smaller drainages and swales.

Black Walnut Bottomland Forest

7. Canopy dominants are sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), oaks (*Quercus palustris, Quercus bicolor*), ashes (*Fraxinus nigra, Fraxinus americana, Fraxinus pennsylvanica*), American elm (*Ulmus americana*), and/or American hornbeam (*Carpinus caroliniana*).

9. Forest is dominated by pin oak (*Quercus palustris*) and/or swamp white oak (*Quercus bicolor*) with 25–75% relative cover in the canopy. Common canopy associates include red maple (*Acer rubrum*), American hornbeam (*Carpinus caroliniana*), ashes (*Fraxinus americana, Fraxinus nigra, Fraxinus pennsylvanica*), and American elm (*Ulmus americana*).

Bottomland Oak Palustrine Forest

9. Mesic oaks (*Quercus palustris, Quercus bicolor*) have relative cover less than 25% in the canopy. Canopy dominants are sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), ashes (*Fraxinus nigra, Fraxinus americana, Fraxinus pennsylvanica*), American elm (*Ulmus americana*), and/or American hornbeam (*Carpinus caroliniana*).

10. Sycamore (*Platanus occidentalis*) constitutes at least 25% relative cover in the canopy.

11. Sycamore (*Platanus occidentalis*) constitutes 50% or greater relative cover of the canopy, usually with ash (*Fraxinus* spp.) as an associate.

Sycamore Floodplain Forest

11. Sycamore (*Platanus occidentalis*) constitutes less than 50% relative cover of the canopy, and co-occurs with sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), white ash (*Fraxinus americana*) and/or river birch (*Betula nigra*).

Sycamore - Mixed Hardwood Floodplain Forest

10. Forest is typically weedy. None of the following species show clear dominance (>25% relative canopy cover): sycamore (*Platanus occidentalis*), eastern hemlock (*Tsuga canadensis*), mesic oaks (*Quercus palustris, Quercus bicolor*), red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), sugar maple (*Acer saccharum*), or bitternut hickory (*Carya cordiformis*), though these species may be present as associates. Canopy can be dominated by one or more of the following: black ash (*Fraxinus nigra*), American elm (*Ulmus americana*), white ash (*Fraxinus americana*), green ash (*Fraxinus pennsylvanica*), American hornbeam (*Carpinus caroliniana*), and/or river birch (*Betula nigra*).

Bottomland Mixed Hardwood Palustrine Forest

1. Terrestrial forests that do not regularly experience saturated soils during the growing season.

12. Within the canopy and subcanopy combined, conifers have relative cover of 75% or greater.

CONIFEROUS TERRESTRIAL FOREST SUBGROUP

12. Within the canopy and subcanopy combined, conifers have relative cover less than 75%.

13. Within the canopy and subcanopy combined, conifers have relative cover between 25–75%.

MIXED TERRESTRIAL FOREST SUBGROUP

13. Within the canopy and subcanopy combined, conifers have relative cover less than 25%.

DECIDUOUS TERRESTRIAL FOREST SUBGROUP

CONIFEROUS TERRESTRIAL FOREST SUBGROUP

[Note: Due to hemlock decline, observed foliar cover in hemlocks may be lower than the percentages listed in the key.]

1. Successional forest dominated by eastern red-cedar (*Juniperus virginiana*), with some of the following associates: white ash (*Fraxinus americana*), black locust (*Robinia pseudoacacia*), bigtooth aspen (*Populus grandidentata*), black walnut (*Juglans nigra*), black cherry (*Prunus serotina*), red maple (*Acer rubrum*) and eastern white pine (*Pinus strobus*).

   Eastern Red-cedar Forest

1. Forest not dominated by eastern red-cedar (*Juniperus virginiana*) with early successional and weedy associates.

   2. Relative cover of pines (*Pinus* spp.) or spruces (*Picea* spp.) in the canopy and subcanopy combined is greater than the relative cover of eastern hemlock (*Tsuga canadensis*) in the canopy and subcanopy combined. Eastern red-cedar (*Juniperus virginiana*) may be common in the subcanopy.

      3. Forest is dominated by eastern white pine (*Pinus strobus*), red pine (*Pinus resinosa*), Scotch pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), blue spruce (*Picea pungens*) or larch (*Larix* sp.). Adventitious hardwoods may be present as associates. Common species include: white ash (*Fraxinus americana*), flowering dogwood (*Cornus florida*), red maple (*Acer rubrum*), black cherry (*Prunus serotina*), American beech (*Fagus grandifolia*), American hornbeam (*Carpinus caroliniana*), sweet birch (*Betula lenta*), oaks (*Quercus* spp.) and hickories (*Carya* spp.). Eastern red-cedar (*Juniperus virginiana*) may be common in the subcanopy. Canopy conifer trees are even-aged and often regularly spaced.

         Conifer Plantation

      3. Forest is dominated by eastern white pine (*Pinus strobus*), with associates pitch pine (*Pinus rigida*), eastern hemlock (*Tsuga canadensis*), sweet birch (*Betula lenta*), mockernut hickory (*Carya alba*), black oak (*Quercus velutina*), northern red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), and red maple (*Acer rubrum*). Canopy trees are not even-aged or regularly spaced.

         Eastern White Pine Forest

   2. Relative cover of eastern hemlock (*Tsuga canadensis*) in the canopy and subcanopy combined is greater than the relative cover of pines (*Pinus* spp.) or spruces (*Picea* spp.) in the canopy and subcanopy combined.

      Eastern Hemlock Forest

MIXED TERRESTRIAL FOREST SUBGROUP

[Note: Due to hemlock decline, observed foliar cover in hemlocks may be lower than the percentages listed in the key.]

1. Successional forest dominated by eastern red-cedar (*Juniperus virginiana*) or eastern white pine (*Pinus strobus*), with early successional, weedy associates such as white ash (*Fraxinus americana*), black locust (*Robinia pseudoacacia*), bigtooth aspen (*Populus grandidentata*), black walnut (*Juglans nigra*), black cherry (*Prunus serotina*), and red maple (*Acer rubrum*). Abundant invasive herb, shrub and vine species are characteristic.

   Northeastern Modified Successional Forest

1. Forest is not as described above.

   2. Relative cover of pines (*Pinus* spp.) or spruces (*Picea* spp.) in the canopy and subcanopy combined is greater than the relative cover of eastern hemlock (*Tsuga canadensis*) in the canopy and subcanopy combined. Eastern red-cedar (*Juniperus virginiana*) may be common in the subcanopy.

      3. Forest is dominated by eastern white pine (*Pinus strobus*), red pine (*Pinus resinosa*), Scotch pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), blue spruce (*Picea pungens*) or larch (*Larix* sp.). Adventitious hardwoods are present as associates in the canopy or subcanopy. Common species include: white ash (*Fraxinus americana*), flowering dogwood (*Cornus florida*), red maple (*Acer rubrum*), black cherry (*Prunus serotina*), American beech (*Fagus grandifolia*), American hornbeam (*Carpinus caroliniana*), sweet birch (*Betula lenta*), oaks (*Quercus* spp.) and hickories (*Carya* spp.). Eastern red-cedar (*Juniperus virginiana*) may be common in the subcanopy. Canopy trees are even-aged and often regularly spaced.

         Conifer Plantation

      3. Forest is dominated by eastern white pine (*Pinus strobus*), with hardwood associates typical of dry oak forests or northern hardwood forests. Canopy trees are not even-aged or regularly spaced.

         4. Forest occurs on dry sites. Canopy is composed of eastern white pine (*Pinus strobus*), pitch pine (*Pinus rigida*), dry oaks (*Quercus prinus, Quercus rubra, Quercus velutina, Quercus alba, Quercus coccinea*), eastern hemlock (*Tsuga canadensis*) and eastern red-cedar (*Juniperus virginiana*) as associates. Common shrubs include bear oak (*Quercus ilcifolia*), mountain laurel (*Kalmia latifolia*), black huckleberry (*Gaylussacia baccata*), lowbush blueberry (*Vaccinium angustifolium*), Blue Ridge blueberry (*Vaccinium pallidum*), deerberry (*Vaccinium stamineum*), and eastern teaberry (*Gaultheria procumbens*). Dense eastern white pine regeneration may be present in shrub layer. The herbaceous layer is typically very sparse (<5% cover).

            Dry Eastern White Pine - Oak Forest

4. Forest occurs on dry-mesic to mesic sites. Canopy is composed of eastern white pine (*Pinus strobus*), red maple (*Acer rubrum*), sweet birch (*Betula lenta*), and mesic oaks (*Quercus rubra, Quercus palustris*), with associates eastern-red cedar (*Juniperus virginiana*), eastern hemlock (*Tsuga canadensis*), black cherry (*Prunus serotina*), American beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), bigtooth aspen (*Populus grandidentata*), sugar maple (*Acer saccharum*), bitternut hickory (*Carya cordiformis*) and yellow birch (*Betula alleghaniensis*). Common shrubs include northern spicebush (*Lindera benzoin*), common winterberry (*Ilex verticillata*), blackhaw (*Viburnum prunifolium*), southern arrowwood (*Viburnum dentatum*), Japanese barberry (*Berberis thunbergii*), mapleleaf viburnum (*Viburnum acerifolium*), and raspberries (*Rubus* spp.). Ericaceous shrubs (*Kalmia* spp., *Gaylussacia* spp., *Vaccinium* spp.) may be occasional in this type. The herbaceous layer is usually sparse to moderately dense.

Eastern White Pine - Successional Hardwood Forest

2. Relative cover of eastern hemlock (*Tsuga canadensis*) in the canopy and subcanopy combined is greater than the relative cover of pines (*Pinus* spp.) or spruces (*Picea* spp.) in the canopy and subcanopy combined.

5. Canopy is composed of eastern hemlock (*Tsuga canadensis*), dry oaks (*Quercus prinus, Quercus rubra, Quercus velutina, Quercus alba*), red maple (*Acer rubrum*), sweet birch (*Betula lenta*), hickories (*Carya glabra, Carya alba*), blackgum (*Nyssa sylvatica*), and common serviceberry (*Amelanchier arborea*). Common shrubs include: great laurel (*Rhododendron maximum*), mountain laurel (*Kalmia latifolia*), American witch-hazel (*Hamamelis virginiana*), Blue Ridge blueberry (*Vaccinium pallidum*), lowbush blueberry (*Vaccinium angustifolium*), black huckleberry (*Gaylussacia baccata*). The herb layer is also characteristically sparse (0–10% cover).

Dry Eastern Hemlock - Oak Forest

5. Canopy is composed of eastern hemlock (*Tsuga canadensis*) with mesic associates such as sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), sweet birch (*Betula lenta*), yellow birch (*Betula alleghaniensis*), tuliptree (*Liriodendron tulipifera*), and American beech (*Fagus grandifolia*). Oaks (*Quercus rubra*, Q*uercus alba, Quercus prinus*) may be present but are not co-dominant as in the Dry Eastern Hemlock - Oak Forest.

Eastern Hemlock - Northern Hardwood Forest

DECIDUOUS TERRESTRIAL FOREST SUBGROUP

1. In general, forests occur on dry sites, mid- to upper slopes, and ridgetops. In general, forests are dominated by dry oaks (*Quercus prinus, Quercus alba, Quercus coccinea, Quercus velutina, Quercus rubra*) and/or hickories (*Carya glabra, Carya alba, Carya ovalis*). Common associates include red maple (*Acer rubrum*), sweet birch (*Betula lenta*), blackgym (*Nyssa sylvatica*), eastern white pine (*Pinus strobus*), pitch pine (*Pinus rigida*), and eastern hemlock (*Tsuga canadensis*). Characteristic shrubs are ericaceous species (*Gaylussacia baccata, Vaccinium* spp.*, Kalmia* spp.*).*

    2. Forests contains dense tall and/or short shrub layer (40–95% absolute cover) dominated by ericaceous species (*Gaylussacia baccata, Vaccinium* spp., *Kalmia* spp.).

        3. Canopy is composed of young quaking aspen (*Populus tremuloides*), bigtooth aspen (*Populus grandidentata*), gray birch (*Betula populifolia*) and sweet birch (*Betula lenta*). Scattered individuals of pitch pine (*Pinus rigida*), scarlet oak (*Quercus coccinea*) and chestnut oak (*Quercus prinus*) may be also present.

            Successional Heath Shrubland

        3. Canopy is composed of established chestnut oak (*Quercus prinus*), northern red oak (*Quercus rubra*) and/or white oak (*Quercus alba*). Other common canopy associates include scarlet oak (*Quercus coccinea*), sweet birch (*Betula lenta*), red maple (*Acer rubrum*), pignut hickoty (*Carya glabra*), black oak (*Quercus velutina*), pitch pine (*Pinus rigida*), blackgum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), eastern white pine (*Pinus strobus*) and eastern hemlock (*Tsuga canadensis*).

            Dry Oak - Heath Forest

    2. Ericaceous shrubs (*Gaylussacia baccata, Vaccinium* spp., *Kalmia* spp.) cover less than 40% of the forest floor.

        4. The relative cover of hickories (*Carya* spp.) in the canopy and subcanopy combined exceeds the relative cover of oaks (*Quercus* spp.).

            Dry Hickory Ridgetop Forest

        4. The relative cover of oaks (*Quercus* spp.) in the canopy and subcanopy combined exceeds the relative cover of hickories (*Carya* spp.).

            5. Forest occurs on the rocky steep sandstone talus boulderfields. The open forest canopy is dominated by chestnut oak (*Quercus prinus*) and/or sweet birch (*Betula lenta*), with associates pignut hickory (*Carya glabra*), mockernut hickory (*Carya alba*), blackgum (*Nyssa sylvatica*), black oak (*Quercus velutina*), white oak (*Quercus alba*), red maple (*Acer ruburm*), eastern white pine (*Pinus strobus*) and pitch pine (*Pinus rigida*).

                Oak - Birch Talus Forest

            5. Forest does not occur on the rocky steep sandstone talus boulderfields.

6. Chestnut oak (*Quercus prinus*) and/or white oak (*Quercus alba*) are dominant with associates other oaks (*Quercus velutina, Quercus coccinea, Quercus rubra*), red maple (*Acer rubrum*), sweet birch (*Betula lenta*), hickories (*Carya glabra, Carya alba, Carya ovalis*), eastern hemlock (*Tsuga canadensis*), blackgum (*Nyssa sylvatica*), eastern white pine (*Pinus strobus*), pitch pine (*Pinus rigidia*), and rarely sugar maple (*Acer saccharum*). Patches of ericaceous shrubs species (*Kalmia* spp., *Gaylussacia baccata*, *Vaccinium* spp.) are typical. Common groundstory species are wavy hairgrass (*Deschampsia flexuosa*), Swan's sedge (*Carex swanii*), partridgeberry (*Mitchella repens*), striped prince's pine (*Chimaphila maculata*), Pennsylvania sedge (*Carex pensylvanica*), marginal woodfern (*Dryopteris marginalis*), wild sarsaparilla (*Aralia nudicaulis*), and starflower (*Trientalis borealis*).

Dry Oak - Mixed Hardwood Forest

6. Northern red oak (*Quercus rubra*) is often the most prominent oak species with associates of other oak species (*Quercus velutina, Quercus alba, Quercus coccinea, Quercus prinus*), hickories (*Carya glabra, Carya cordiformis, Carya ovata*), red maple (*Acer rubrum*), sweet birch (*Betula lenta*), sugar maple (*Acer saccharum*), tuliptree (*Liriodendron tulipifera*) and white ash (*Fraxinus amercana*). Common shrubs include American hornbeam (*Carpinus caroliniana*), northern spicebush (*Lindera benzoin*), and Japanese barberry (*Berberis thunbergii*). Characteristic herbs include Christmas fern (*Polystichum acrostichoides*), garlic mustard (*Alliaria petiolata*), and mayapple (*Podophyllum peltatum*).

Northern Red Oak - Mixed Hardwood Forest

1. In general, forests occur on dry-mesic to mesic sites, mid- to lower slopes, and low elevations. In general, forests are dominated by maples (*Acer* spp.), birches (*Betula* spp.), tuliptree (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), northern red oak (*Quercus rubra*), bitternut hickory (*Carya cordiformis*), and/or American basswood (*Tilia americana*). Also included here are young hardwood forests in which diameter at breast height of canopy trees does not exceed 25 cm for most trees, and forests dominated by early successional or weedy trees with abundant invasive species. Characteristic shrubs are northern spicebush (*Lindera benzoin*), American witch-hazel (*Hamamelis virginiana*), American hornbeam (*Carpinus caroliniana*), common winterberry (*Ilex verticillata*) and raspberries (*Rubus* spp.).

    7. Successional forest dominated by early successional, weedy species such as white ash (*Fraxinus americana*), black locust (*Robinia pseudoacacia*), bigtooth aspen (*Populus grandidentata*), black walnut (*Juglans nigra*), black cherry (*Prunus serotina*), red maple (*Acer rubrum*), eastern red-cedar (*Juniperus virginiana*) and eastern white pine (*Pinus strobus*). Abundant invasive herb, shrub and vine species are characteristic.

    Northeastern Modified Successional Forest

    7. Forest is not dominated by early successional, weedy tree species, invasive herb, shrub and vine species.

8. Oaks species (most commonly *Quercus rubra*, also *Quercus velutina* and *Quercus alba*) constitute at least 25% relative cover in the canopy. Common associates include red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), sweet birch (*Betula lenta*), and hickories (*Carya glabra, Carya cordiformis*).

Northern Red Oak - Mixed Hardwood Forest

8. Oaks species (*Quercus* spp.) constitute less than 25% relative cover in the canopy.

    9. Tuliptree (*Liriodendron tulipifera*) constitutes at least 25% relative cover in the canopy. Common associates include red maple (*Acer rubrum*), white ash (*Fraxinus americana*), sweet birch (*Betula lenta*), yellow birch (*Betula alleghaniensis*), and American beech (*Fagus grandifolia*).

Tuliptree - Beech - Maple Forest

    9. Tuliptree (*Liriodendron tulipifera*) constitutes less than 25% relative cover in the canopy.

        10. Sweet birch (*Betula lenta*) and/or red maple (*Acer rubrum*) constitute at least 50% relative cover in the canopy and subcanopy. Sugar maple (*Acer saccharum*) is not a significant component of the canopy or subcanopy. In general, forest is not restricted to calcareous bedrock. Current species composition and forest structure is generally influenced significantly by previous silvicultural or agricultural activities.

Red Maple - Sweet Birch Hardwood Forest

        10. Sweet birch (*Betula lenta*) and/or red maple (*Acer rubrum*) constitute less than 50% relative cover in the canopy. Sugar maple (*Acer saccharum*) is a significant component of the canopy or subcanopy. In general, forest tends to occur over calcareous bedrock and is less disturbed than Red Maple - Sweet Birch Hardwood Forest.

            11. American basswood (*Tilia americana*) constitutes at least 25% relative cover in the canopy, with associates sugar maple (*Acer saccharum*), sweet birch (*Betula lenta*), yellow birch (*Betula alleghaniensis*), oaks (*Quercus* spp.), eastern hemlock (*Tsuga canadensis*), and white ash (*Fraxinus americana*). Forest often on steep slopes with diverse, rich herbaceous layer containing bloodroot (*Sanguinaria canadensis*), blue cohosh (*Caulophyllum thalictroides*), dogtooth violet (*Erythronium americanum*), Virginia springbeauty (*Claytonia virginica*), northern maidenhair fern (*Adiantum pedatum*) and Canadian wild ginger (*Asarum canadense*).

Sugar Maple - American Basswood Forest

11. American basswood (*Tilia americana*) constitutes less than 25% relative cover in the canopy. Canopy dominants include sugar maple (*Acer saccharum*) and sweet birch (*Betula lenta*), with associates northern red oak (*Quercus rubra*), American beech (*Fagus grandifolia*), pignut hickory (*Carya glabra*), red maple (*Acer rubrum*), eastern hemlock (*Tsuga canadensis*), and white ash (*Fraxinus americana*).

Sugar Maple - American Beech - Sweet Birch Forest

Appendix E. Anderson fire behavior fuel model descriptions.

FIRE BEHAVIOR FUEL MODEL DESCRIPTIONS

The Anderson fire behavior fuel models were created primarily for flammable vegetation in the western and southeastern United States (Anderson 1982). As originally described, these fuel models are not necessarily directly applicable to vegetation in the northeastern states. The local descriptions shown below attempt to link and apply vegetation within the Delaware Water Gap National Recreation Area to the most appropriate Anderson fuel model. Due to variation in vegetation structure, species composition, and environmental setting, vegetation associations may be correlated with more than one fire behavior fuel model. Anderson descriptions were copied verbatim from Anderson (1982). In a few cases, there are minor contradictions between the original Anderson descriptions and the local descriptions, caused by applying western fuel models to northeastern vegetation.

Fuel Model 0

Local Description: Fire will not carry through the area due to one or more of the following reasons: a) the ground is saturated or is submerged under standing water; b) leaf litter and groundstory vegetation are discontinuous (typically <40% cover), separated by expanses of bare rock, gravel, sand, mineral soil, or other substrates that will not burn; c) there are no ladder fuels to carry a ground fire into the canopy or shrub layers.
Correlated Vegetation Associations: Alder Wetland, Bottomland Hardwood Palustrine Forest, Bottomland Oak Palustrine Forest, Buttonbush Wetland, Cattail Marsh, Eastern Hemlock - Mixed Hardwood Palustrine Forest, Hairyfruit Sedge Wetland, Highbush Blueberry - Steeplebush Wetland, Mixed Forb Marsh, Red Maple - Highbush Blueberry Palustrine Forest, Red Maple Palustrine Forest, Silky Dogwood Successional Palustrine Shrubland, Tussock Sedge Marsh, Acidic Seep, Boulder Vernal Pool Sparse Vegetation, Calcareous Fen, Eastern Woodland Vernal Pool Sparse Vegetation, Calcareous Seep, Highbush Blueberry - Leatherleaf Wetland, Leatherleaf Peatland, Marl Fen, Red Maple - Highbush Blueberry Palutrine Woodland, Water-willow Emergent Bed, Riverine Scour Vegetation, Pitch Pine - Mixed Hardwood Rocky Summit, Sandstone Talus, Shale Scree Slope, Sparsely Vegetated Cliff, Oak Talus Forest.
Anderson Description: Fuel Model 0 is not described in Anderson (1982). It is used in this project as a map unit to denote areas of the park that have a very low probability of carrying fire.

Fuel Model 1

Local Description: Fire is carried by short grasses that are generally below knee-level in height, such as wavy hairgrass (*Deschampsia flexuosa*), sweet vernalgrass (*Anthoxanthum odoratum*), sedges (*Carex* spp.), poverty oatgrass (*Danthonia spicata*), and Canada bluegrass (*Poa compressa*). These short graminoids cover >60% of the area, while shrubs have <60% cover.
Correlated Vegetation Associations: Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop, Hickory - Eastern Red-cedar Rocky Woodland, Dry Hickory Ridgetop Forest, Dry Oak - Mixed Hardwood Forest
Anderson Description: Fire spread is governed by the fine, very porous, and continuous herbaceous fuels that have cured or are nearly cured. Fires are surface fires that move rapidly through the cured grass and associated material. Very little shrub or timber is present, generally less than one third of the area. Grasslands and savanna are represented along with stubble, grass-tundra, and grass-shrub combinations that met the above area constraint. Annual and perennial grasses are included in this fuel model.

Fuel Model 2

Local Description: This fire behavior fuel model is not currently applicable to fuels in the Delaware Water Gap National Recreation Area.
Correlated Vegetation Associations: None.
Anderson Description: Fire spread is primarily through the fine herbaceous fuels, either curing or dead. These are surface fires where the herbaceous material, in addition to litter and dead-down stemwood from the open shrub or timber overstory, contribute to the fire intensity. Open shrub lands and pine stands or scrub oak stands that cover one-third to two-thirds of the area may generally fit this model; such stands may include clumps of fuels that generate higher intensities and that may produce firebrands. Some pinyon-juniper may be in this model.

Fuel Model 3

Local Description: Fire is carried by tall grasses that are generally above knee-level in height, such as big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*) and little bluestem (*Schizachyrium scoparium*). Tall grasses cover greater than 60% of the area while shrubs cover less than 60% of the area. Although the fire behavior in dense stands of Japanese knotweed (*Polygonum cuspidatum*) has not been studied in detail, this fuel model is likely the closest approximation.
Correlated Vegetation Associations: Big Bluestem - Indiangrass Riverine Grassland, Japanese Knotweed Herbaceous Vegetation
Anderson Description: Fires in this fuel are the most intense of the grass group and display high rates of spread under the influence of wind. Wind may drive fire into the upper heights of the grass and across standing water. Stands are tall, averaging about 3 feet (1 m), but considerable variation may occur. Approximately one-third of more of the stand is considered dead or cured and maintains the fire. Wild or cultivated grains that have not been harvested can be considered similar to tall prairie and marshland grasses.

Fuel Model 1/3

Local Description: Fire behavior varies in different seasons. Early in the year, the area is dominated by short grasses below knee-level in height. The fire behavior is most similar to fuel model 1 during this time. Late in the year, the area is dominated by graminods or forbs that area taller that knee-height. Fire behavior is most similar to fuel model 3 at this time. Graminoid and/or forb vegetation is dominant throughout the year, covering >60% of the area. Shrubs cover less than 60% of the area.
Correlated Vegetation Associations: Old Field, Little Bluestem Grassland, Successional Shrubland with scattered shrubs (<60% cover), Wooded Successional Old Field (shrubs <60% cover), Successional Eastern White Pine Woodland (shrubs <60% cover), Eastern Red-cedar Forest (open canopy of <60% cover interspersed with old field vegetation).
Anderson Description: This combined fuel model is not described in Anderson (1982). It is used in this project as a map unit to indicate seasonal variation in fire behavior in some graminoid- or forb-dominated areas.

Fuel Model 4

Local Description: Fire is carried by dense tall shrubs or small trees with flammable foliage, heavy loading of dead woody material, and/or dead fine woody material in the crowns. Eastern red-cedar (*Juniperus virginiana*) and eastern white pine (*Pinus strobus*) are the two species in the park that fit this fuel model. Woody plants are at approximately 2–5 meters in height and cover >60% of the area.
Correlated Vegetation Associations: Successional Shrubland (>60% cover of eastern red-cedar or eastern white pine shrubs), Dry Eastern White Pine - Oak Forest (>60% cover white pine regeneration), Eastern White Pine Forest (>60% cover white pine regeneration)
Anderson Description: Fires intensity and fast-spreading fires involve the foliage and live and dead fine woody material in the crowns of a nearly continuous secondary overstory. Stands of mature shrubs, 6 or more feet tall, such as California mixed chaparral, the high pocosins along the east coast, the pine barrens of New Jersey, or the closed jack pine stands of the north-central States are typical candidates. Besides flammable foliage, dead woody material in the stands significantly contributes to the fire intensity. Height of stands qualifying for this model depends on local conditions. A deep litter layer may also hamper suppression efforts.

Fuel Model 5

Local Description: Fire is carried by dense deciduous hardwood shrub species that do not support volatile foliage and that cover >60% of the area. Shrubs are typically less than 2 meters in height and common species include: autumn-olive (*Elaeagnus umbellata*), gray dogwood (*Cornus racemosa*), multiflora rose (*Rosa multiflora*), Morrow's honeysuckle (*Lonicera morrowii*), Japanese barberry (*Berberis thunbergii*), and raspberries (*Rubus* spp.). Short grasses and forbs typically carry the fire in between the dense clumps of shrubs.
Correlated Vegetation Associations: Successional Shrubland (>60% hardwood shrub cover), Northeastern Modified Successional Forest (>60% hardwood shrub cover)
Anderson Description: Fire is generally carried in the surface fuels that are made up of litter cast by the shrubs and the grasses or forbs in the understory. The fires are generally not very intense because surface fuel loads are light, the shrubs are young with little dead material, and the foliage contains little volatile material. Usually shrubs are short and almost totally cover the area. Young, green stands with no dead wood would qualify: laurel, vine maple, alder, or even chaparral, manzanita, or chamise. As the shrub fuel moisture drops, consider using a Fuel Model 6.

Fuel Model 6

Local Description: Fire is carried by moderately dense to dense short shrubs that support volatile foliage and have low fuel moisture content. Typical species include blueberries (*Vaccinium* spp.), huckleberries (*Gaylussacia* spp.), eastern teaberry (*Gaultheria procumbens*), sheep laurel (*Kalmia angustifolia*), and trailing arbutus (*Epigea repens*). These shrubs are less than 1 meter in height and cover >40% of the area. When these shrubs species have high live fuel moisture content, the fuel behavior may be driven by the deciduous leaf litter and more closely resemble fuel model 8/9.
Correlated Vegetation Associations: Dry Oak - Heath Forest (with *Vaccinium* spp., *Gaylussacia* spp.), Successional Bear Oak - Heath Shrubland, Dry Eastern White Pine - Oak Forest (>40% cover of *Vaccinium* spp., *Gaylussacia* spp.)

Anderson Description: Fires carry through the shrub layer where the foliage is more flammable than fuel model 5, but this requires moderate winds, greater than 8 mi/h (13 km/h) at midflame height. Fire will drop to the ground at low wind speeds or at openings in the stand. The shrubs are older, but not as tall as shrub types of model 4, nor do they contain as much fuel as model 4. A broad range of shrub considered include intermediate stands of chamise, chaparral, oak brush, low pocosin, Alaskan spruce taiga, and shrub tundra. Even hardwood slash that has cured can be considered. Pinyon-juniper shrublands may be represented but may over predict rate of spread except at high winds, like 20 mi/h (32 km/h) at the 20-foot level.

Fuel Model 7

Local Description: Fire is carried by dense tall shrubs that support volatile foliage and have low fuel moisture content. Common species include mountain laurel (*Kalmia latifolia*), great laurel (*Rhododendron maximum*), and bear oak (Quercus ilicifolia). Shrubs are approximately 1–3 meters in height and cover >60% of the area. When these shrubs species have high live fuel moisture content, the fuel behavior may be driven by the deciduous leaf litter and more closely resemble fuel model 8/9.
Correlated Vegetation Associations: Dry Oak - Heath Forest (with *Kalmia latifolia*), Dry Oak - Mixed Hardwood Forest (with *Rhododendron maximum*), Bear Oak - Wavy Hairgrass Shrubland
Anderson Description: Fires burn through the surface and shrub strata with equal ease and can occur at higher dead fuel moisture contents because of the flammability of live foliage and other live material. Stands of shrubs are generally between 2 and 6 feet (0.6 and 1.8 m) high. Palmetto-gallberry understory-pine overstory sites are typical and low pocosins may be represented. Black spruce-shrub combinations in Alaska may also be represented.

Fuel Model 6/7

Local Description: Fire is carried by both short and tall shrubs with volatile foliage and low fuel moisture content. Short and tall shrub layers each cover between 40–60 % of the area. Species are typical of those described in fuel models 6 and 7. When these shrubs species have high live fuel moisture content, the fuel behavior may be driven by the deciduous leaf litter and more closely resemble fuel model 8/9.
Correlated Vegetation Associations: Dry Oak - Heath Forest (with well-developed low and tall heath layers)
Anderson Description: This combined fuel model is not described in Anderson (1982). It is used in this project as a map unit to indicate vegetation with well-developed low and tall heath layers.

Fuel Model 8

Local Description: Fire is carried by continuous needle litter shed from short-needle evergreen trees such as eastern hemlock (*Tsuga canadensis*), larch (*Larix* spp.), and eastern red-cedar (*Juniperus virginiana*). Deciduous leaf litter is minimal in these coniferous stands. This fuel model also applies to the leaf litter of deciduous hardwood forests in the spring and summer when leaves have been compacted by the previous winter's snow. Due to seasonal variation in the litter's fire behavior, all deciduous hardwood forests have been mapped as fuel model 8/9.
Correlated Vegetation Associations: Eastern Hemlock Forest, Conifer Plantation (dominated by *Larix* spp.), Eastern Red-cedar Forest

Anderson Description: Slow-burning ground fires with low flame lengths are generally the case, although the fire may encounter an occasional "jackpot" or heavy fuel concentration that can flare up. Only under severe weather conditions involving high temperatures, low humidities, and high winds do the fuels pose fire hazards. Closed canopy stands of short-needle conifers or hardwoods that have leafed out support fire in the compact litter layer. This layer is mainly needles, leaves, and occasionally twigs because little undergrowth is present in the stand. Representative conifer types are white pine, and lodgepole pine, spruce, fir, and larch.

Fuel Model 9

Local Description: Fire is carried by continuous needle litter shed from long-needle evergreen trees such as pines (*Pinus* spp.) and spruce (*Picea* spp.). Deciduous leaf litter is minimal in these coniferous stands. This fuel model also applies to the leaf litter of deciduous hardwood forests in the fall and early winter when leaves have not yet been compacted by snow. Due to seasonal variation in the litter's fire behavior, all deciduous hardwood forests have been mapped as fuel model 8/9.
Correlated Vegetation Associations: Eastern White Pine Forest, Conifer Plantation (dominated by *Pinus* spp. or *Picea* spp.)
Anderson Description: Fires run through the surface litter faster than model 8 and have longer flame height. Both long-needle conifer stands and hardwood stands, especially the oak-hickory types, are typical. Fall fires in hardwoods are predictable, but high winds will actually cause higher rates of spread than predicted because of spotting caused by rolling and blowing leaves. Closed stands of long-needled pine like ponderosa, Jeffrey, and red pines, or southern pine plantations are grouped in this model. Concentrations of dead-down woody material will contribute to possible torching out of trees, spotting, and crowning.

Fuel Model 8/9

Local Description: This fuel model encompasses the seasonal variation in fire behavior of deciduous hardwood forest leaf litter. In spring and summer, leaf litter is typically compact and therefore creates slow-burning ground fires with low flame lengths. In fall and early winter, loose leaf litter and blowing leaves create faster-burning fires with longer flame lengths, higher rates of spread, and higher incidences of spotting. Mixed coniferous-deciduous forests are also included here.
Correlated Vegetation Associations: Dry Eastern Hemlock - Oak Forest, Dry Eastern White Pine - Oak Forest, Dry Hickory Ridgetop Forest, Dry Oak - Mixed Hardwood Forest, Eastern Hemlock - Northern Hardwood Forest, Eastern White Pine - Successional Hardwood Forest, Northern Red Oak - Mixed Hardwood Forest, Red Maple - Sweet Birch Hardwood Forest, Sugar Maple - American Beech - Sweet Birch Forest, Sugar Maple - American Basswood Forest, Tuliptree - Beech - Maple Forest, Northeastern Modified Successional Forest.
Anderson Description: This combined fuel model is not described in Anderson (1982). It is used in this project as a map unit to encompass the seasonal variation in fire behavior of deciduous hardwood forest leaf litter.

Fuel Model 10

Local Description: Fire is carried by leaf or needle litter interspersed with significant amounts of dead, downed coarse woody debris. The debris could have been caused by intense storm or fire events, insect-related mortality, or silvicultural prescriptions. This fuel model is not

currently mapped in the park. In the future, it may be applicable to stands of eastern hemlock (*Tsuga canadensis*) that experience significant mortality and tree fall due to hemlock woolly adelgid infestation.

Correlated Vegetation Associations: Currently, none. This fuel model could apply to numerous terrestrial forest types affected by storm fire, insects, or silviculture.

Anderson Description: The fires burn in the surface and ground fuels with greater fire intensity than the other timber litter models. Dead-down fuels include greater quantities of 3-inch (7.6-cm) or larger limb wood resulting from over-maturity or natural events that create a large load of dead material on the forest floor. Crowning out, spotting, and torching of individual trees are more frequent in this fuel situation, leading to potential fire control difficulties. Any forest type may be considered if heavy down material is present; examples are insect- or disease-ridden stands, wind-thrown stands, over-mature situations with deadfall, and aged light thinning or partial-cut slash.

Fuel Model 11

Local Description: This fire behavior fuel model is not currently applicable to fuels in the Delaware Water Gap National Recreation Area. In the future, these slash models could be appropriate for forested areas in the park that experience widespread mortality of eastern hemlocks (*Tsuga canadensis*).

Correlated Vegetation Associations: None.

Anderson Description: Fires are fairly active in the slash and herbaceous material intermixed with the slash. The spacing of the rather light fuel load, shading from overstory, or the aging of the fine fuels can contribute to limiting the fire potential. Light partial cuts or thinning operations in mixed conifer stands, hardwood stands, and southern pine harvests are considered. Clear-cut operations generally produce more slash than represented here. The less-than-3-inch (7.6-cm) material load is less than 12 tons per acre (5.4 t/ha). The greater-than-3-inch (7.6-cm) is represented by not more than 10 pieces, 4 inches (10.2 cm) in diameter, along a 50-foot (15-m) transect.

Fuel Model 12

Local Description: This fire behavior fuel model is not currently applicable to fuels in the Delaware Water Gap National Recreation Area. In the future, these slash models could be appropriate for forested areas in the park that experience widespread mortality of eastern hemlocks (*Tsuga canadensis*).

Correlated Vegetation Associations: None.

Anderson Description: Rapidly spreading fires with high intensities capable of generating firebrands can occur. When fire starts, it is generally sustained until a fuel break or change in fuels is encountered. The visual impression is dominated by slash and much of it is less than 3 inches (7.6 cm) in diameter. The fuels total less than 35 tons per acre (15.6 t/ha) and seem well distributed. Heavily thinned conifer stands, clear-cuts, and medium or heavy partial cuts are represented. The material larger than 3 inches (7.6 cm) is represented by encountering 11 pieces, 6 inches (15.2 cm) in diameter, along a 50-foot (15-m) transect.

Fuel Model 13

Local Description: This fire behavior fuel model is not currently applicable to fuels in the Delaware Water Gap National Recreation Area. In the future, these slash models could be appropriate for forested areas in the park that experience widespread mortality of eastern hemlocks (*Tsuga canadensis*).

Correlated Vegetation Associations: None.

Anderson Description: Fire is generally carried across the area by a continuous layer of slash. Large quantities of material larger than 3 inches (7.6 cm) are present. Fires spread quickly through the fine fuels and intensity builds up more slowly as the large fuels start burning. Active flaming is sustained for long periods and a wide variety of firebrands can be generated. These contribute to spotting problems as the weather conditions become more severe. Clear-cuts and heavy partial-cuts in mature and over-mature stands are depicted where the slash load is dominated by the greater-than-3-inch (7.6-cm) diameter material. The total load may exceed 200 tons per acre (89.2 t/ha) but fuel less than 3 inches (7.6-cm) is generally only 10 percent of the total load. Situations where the slash still has "red" needles attached but the total load is lighter, more like model 12, can be represented because of the earlier high intensity and quicker area involvement.

Fire Behavior Fuel Models Typical for Vegetation Associations and Anderson Level II Categories (modified) in Delaware Water Gap National Recreation Area. The characteristic fuel models that are typical and common for each association are indicated by an "X". Fuel models that are uncommon, but occasionally occuring, for each association are marked with a "u".

	Fire Behavior Fuel Model											
Vegetation Association	0	1	1/3	3	4	5	6	6/7	7	8	8/9	9
Acidic Seep	X											
Alder Wetland	X											
Bear Oak - Wavy Hairgrass Shrubland	u	u							X			
Big Bluestem - Indiangrass Riverine Grassland	u			X								
Bitternut Hickory Lowland Forest	X										X	
Black Walnut Bottomland Forest	u										X	
Bottomland Mixed Hardwood Palustrine Forest	X											
Bottomland Oak Palustrine Forest	X											
Boulder Vernal Pool Sparse Vegetation	X											
Buttonbush Wetland	X											
Calcareous Fen	X											
Calcareous Riverside Outcrop / Calcareous Riverside Seep	X											
Cattail Marsh	X											
Conifer Plantation					u					X	X	X
Dry Eastern Hemlock - Oak Forest	u						u	u	u		X	
Dry Eastern White Pine - Oak Forest					X		X	u			X	
Dry Hickory Ridgetop Forest	u	X									X	
Dry Oak - Heath Forest							X	X	X			
Dry Oak - Mixed Hardwood Forest		u			u				u		X	
Eastern Hemlock - Mixed Hardwood Palustrine Forest	X											
Eastern Hemlock - Northern Hardwood Forest									u		X	
Eastern Hemlock Forest												
Eastern Red-cedar Forest			X		u	u				X		
Eastern White Pine - Successional Hardwood Forest					u				u		X	u
Eastern White Pine Forest					u							X
Eastern Woodland Vernal Pool Sparse Vegetation	X											
Hairyfruit Sedge Wetland	X											
Hickory - Eastern Red-cedar Rocky Woodland	X	X										
Highbush Blueberry - Leatherleaf Wetland	X											
Highbush Blueberry - Steeplebush Wetland	X											
Japanese Knotweed Herbaceous Vegetation				X								
Leatherleaf Peatland	X											
Little Bluestem Grassland			X									
Marl Fen	X											
Mixed Forb Mar	X											
Northeastern Modified Successional Forest	u	u	u	u	u	u		u			X	
Northern Red Oak - Mixed Hardwood Forest									u		X	

Vegetation Association	Fire Behavior Fuel Model											
	0	1	1/3	3	4	5	6	6/7	7	8	8/9	9
Oak - Birch Talus Forest	X								u		X	
Old Field			X									
Pitch Pine - Mixed Hardwood Rocky Summit	X	u					u					
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland	X											
Red Maple - Highbush Blueberry Palustrine Forest	X											
Red Maple - Sweet Birch Hardwood Forest											X	
Red Maple Palustrine Forest	X											
Reed Canarygrass Riverine Grassland	X		u									
Riverine Scour Vegetation	X	u		u								
Sandstone Talus	X											
Shale Scree Slope	X											
Silky Dogwood Successional Palustrine Shrubland	X											
Silver Maple Floodplain Forest	X			X							X	
Sparsely Vegetated Cliff	X											
Successional Bear Oak - Heath Shrubland							X	X	u			
Successional Eastern White Pine Woodland		u	X		u						u	
Successional Shrubland	u	u	X		u	X						
Sugar Maple - American Basswood Forest											X	
Sugar Maple - American Beech - Sweet Birch Forest									u		X	
Sugar Maple Floodplain Forest	X										X	
Sycamore - Mixed Hardwood Floodplain Forest	X										u	
Sycamore - Mixed Hardwood Riverine Shrubland	X											
Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland	X											
Sycamore Floodplain Forest	X			u							u	
Tuliptree - Beech - Maple Forest						u					X	
Tussock Sedge Marsh	X											
Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop	X	X										
Wet Meadow	X											
Wooded Successional Old Field			X			u						
Anderson Level II Category (modified)												
Built-up Land	X	u	u								u	
Cropland	X		X									
Pond	X											
River	X											
Shale Pit	X											
Transportation Corridor	X											

Appendix F. Accuracy assessment data form.

Accuracy Assessment Form for USGS-NPS Vegetation Mapping Program

AA Point: _____ Park: DEWA Date: _____ Observers: _____

GPS Unit: _____ Projection: UTM Map datum: NAD83 Zone: 18

Easting __ __ __ __ __ __ E Northing __ __ __ __ __ __ __ N PDOP: _____ EPE: _____

Offset: YES / NO Easting Offset: + / - _____ m Northing Offset: + / - _____ m

Topographic Description: _____ Elevation: _____ m Aspect: ____

Vegetation Association at Point: _____

Veg Assoc 2 w/in 50m of point: _____

Veg Assoc 3 w/in 50m of point: _____

Major Species by Strata:
T1: _____
T2: _____
T3: _____
S1: _____
S2: _____
H: _____
V: _____

Rationale for Classification: _____

Fire Fuel Model: _____ Percent Cover of Canopy: _____ Canopy Cover Class: 1 2 3 4

Comments:

Appendix G. Local and global descriptions of vegetation associations in Delaware Water Gap National Recreation Area.

The local and global descriptions of the 69 vegetation associations in Delaware Water Gap National Recreation Area are contained in Volume 2, the companion document to this volume.

Appendix H. Definitions of global and state conservation ranks and Anderson classification confidence.

Global Rank Codes and Definitions

Global ranks (i.e., range-wide conservation status ranks) are assigned at NatureServe's Headquarters or by a designated lead office in the Heritage/Conservation Data Center Network.

GX - Presumed Extinct - Believed to be extinct throughout its range. Not located despite intensive searches of historic sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.

GH - Possibly Extinct - Known from only historical occurrences. Still some hope of rediscovery.

G1 - Critically Imperiled - Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or stream miles (<10).

G2 - Imperiled - Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or stream miles (10 to 50).

G3 - Vulnerable - Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.

G4 - Apparently Secure - Uncommon but not rare, and usually widespread. Possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.

G5 - Secure - Common, typically widespread and abundant. Typically with considerably more than 100 occurrences and more than 10,000 individuals.

GNA - Rank not applicable - Common cultural, ruderal, planted, modified, managed, invasive, and/or non-natural type. Has little or no conservation value.

GNR - Not Ranked - A rank has not yet been determined for this element, therefore its rarity is currently unspecified. As the NVCS is further revised with additional information, the SNR will be changed to a numeric rank based on available data.

G#G# - Rank Range - The actual rank of the element is within the range specified by the numbers, however the exact status of the rariety of the element is uncertain. For example, G2G3 indicates that the rank may be either G2 or G3.

State Rank Codes and Definitions

State ranks are assigned by the Pennsylvania Natural Heritage Program and the New Jersey Natural Heritage Program and apply to an element only as it exists in each state, regardless of its range-wide status.

SX - Extirpated - Element is believed to be extirpated from the state.

SH - Historical - Element occurred historically in the state (with expectation that it may be rediscovered), perhaps having not been verified in the past 20 years, and suspected to be still extant. Naturally, an Element would become SH without such a 20-year delay if the only known occurrences in a state were destroyed or if it had been extensively and unsuccessfully looked for. Upon verification of an extant occurrence, SH-ranked Elements would typically receive an S1 rank. The SH rank should be reserved for Elements for which some effort has been made to relocate occurrences, rather than simply ranking all Elements not known from verified extant occurrences with this rank.

S1 - Critically Imperiled - Critically imperiled in the state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state. Typically 5 or fewer occurrences or very few remaining individuals or acres.

S2 - Imperiled - Imperiled in the state because of rarity or because of some factor(s) making it very vulnerable to extirpation from the state. Typically 6 to 20 occurrences or few remaining individuals or acres.

S3 - Vulnerable - Vulnerable in the state either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences.

S4 - Apparently Secure - Uncommon but not rare, and usually widespread in the state. Usually more than 100 occurrences.

S5 - Secure - Demonstrably widespread, abundant, and secure in the state, and essentially ineradicable under present conditions.

SNA - Rank not applicable - Common cultural, ruderal, planted, modified, managed, invasive, and/or non-natural type. Has little or no conservation value.

SNR - Not Ranked - A rank has not yet been determined for this element, therefore its rarity is currently unspecified. As the state vegetation classifications are further revised by additional information, the SNR will be changed to a numeric rank based on available data.

S#S# - Rank Range - The actual rank of the element is within the range specified by the numbers, however the exact status of the rariety of the element is uncertain. For example, S1S3 indicates that the rank may be either S1, S2, or S3.

Other Rank Qualifiers

? - Inexact or Uncertain - Denotes inexact or uncertain numeric rank. The ? qualifies the character immediately preceding it in the rank.

Association Classification Confidence

Confidence refers to the certainty that the classification is correct, that the association is accurately described, and that the association is distinct from other similar associations. Confidence for the global NVCS association descriptions was attributed by NatureServe. Confidence for the state association crosswalks was attributed by the Pennsylvania Natural Heritage Program and the New Jersey Natural Heritage Program.

1 - Strong - Classification is based on quantitative analysis of verifiable, high-quality field data (species lists and associated environmental information) from plots that are published in full or are archived in a publicly accessible database. A sufficient number of high-quality plots covering the expected geographic distribution and habitat variability of the vegetation type, as well as plots from related types across the region, have been used in the analysis.

2 - Moderate - Classification is based either on quantitative analysis of a limited data set of high-quality, published/accessible plots and/or plots from only part of the geographic range, or on a more qualitative assessment of published/accessible field data of sufficient quantity and quality.

3 - Weak - Classification is based on limited, or unpublished/inaccessible plot data or insufficient analysis, anecdotal information, or community descriptions that are not accompanied by plot data. These types have often been identified by local experts. Although there is a high level of confidence that these types represent recognized vegetation entities, it is not known whether they would meet national standards for floristic types in concept or in classification approach if sufficient data were available.

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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