



Vegetation and Soil Monitoring Protocol for the Eastern Rivers and Mountains Network, Version 3

Natural Resource Report NPS/ERMN/NRR—2014/758



ON THE COVER

View of the New River from Long Point in the New River Gorge National River.

Photo Credit: S. Perles.

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Stephanie Perles¹, James Finley², Douglas Manning¹, Matthew Marshall¹

¹National Park Service

Eastern Rivers and Mountains Network

420 Forest Resources Building

University Park, Pennsylvania 16802

²Pennsylvania State University

School of Forest Resources

332 Forest Resources Building

University Park, Pennsylvania 16802

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Protocol Revision History

The Vegetation and Soil Monitoring Protocol consists of a narrative (this report) and Standard Operating Procedures (SOPs) that outline specific data collection details of the monitoring protocol. The latest versions of the SOPs and additional supporting information can be accessed online at the National Park Service's Eastern Rivers and Mountains Network website (<http://science.nature.nps.gov/im/units/ermn/monitor/vegetation.cfm>). The narrative and each SOP have respective revision history logs to document changes in the protocol. The following revision history log is for the narrative.

Version numbers will be incremented by a whole number (e.g., Version 1.3 to 2.0) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.3 to Version 1.4) when there are minor modifications that do not affect requirements or procedures included in the protocol. Rows are added to the log as needed for each change or set of changes tied to an updated version number.

Version #	Date	Revised By	Changes	Justification
1.0	2008	Stephanie Perles	Creation of original ERMN I&M Vegetation and Soil Monitoring protocol	
2.0	2009	Stephanie Perles	Revision of introduction and objectives to be consistent with other network protocols	Consistency within network
3.0	2013	Stephanie Perles	Revision of Sampling Design section	Include information gained from power analysis and changes to sampling design that had occurred

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Executive Summary

The Vegetation and Soil Monitoring Protocol consists of a narrative (this report) and Standard Operating Procedures (SOPs) that outline specific data collection details of the monitoring protocol. The latest versions of the SOPs and additional supporting information can be accessed online at the National Park Service's Eastern Rivers and Mountains Network website (<http://science.nature.nps.gov/im/units/ermn/monitor/vegetation.cfm>).

This protocol outlines the justification, objectives, and procedures developed for long-term monitoring of vegetation and soil throughout the National Parks Service's (NPS) Eastern Rivers and Mountains Network (ERMN) within the Inventory and Monitoring Program. Included in this protocol are: (1) background, rationale, and objectives for monitoring of vegetation and soil, (2) sampling design, (3) field methods, (4) data management, analysis, and reporting, (5) personnel requirements and training, and (6) operational requirements.

Monitoring of vegetation and associated components provides information on several high-priority vital signs in the ERMN parks. The Forest, Woodland, Shrubland, and Riparian Vegetation vital sign was ranked as the highest priority in the vital signs selection process. This protocol primarily details how the Vegetation vital sign will be monitored. However, the protocol will also collect information on two other vital signs: Soil Function and Dynamics; and Status and Trends of Invasive/Exotic Plants, Animals, and Diseases.

This protocol draws on the U.S. Forest Service Forest Inventory and Analysis program and the vegetation monitoring protocols of four other Inventory and Monitoring programs in the eastern United States. The overall goal of this protocol is to monitor indicators of ecological integrity to provide information on the condition of the parks' vegetation and how this condition is changing over time. The locations of the permanent vegetation monitoring plots are determined in each ERMN park through a random, spatially balanced sampling design. Plots are sampled on a four-year panel design, in which one panel containing one-fourth of a park's total plots is sampled each year. In the field, data are collected on vegetation composition, structure, tree vigor, forest pests and pathogens, tree regeneration, shrubs, groundstory diversity, herbaceous plants sensitive to browse, coarse woody debris, and soils. The field methods and data handling procedures are described in detail in standard operating procedures that can be accessed online at the National Park Service's Eastern Rivers and Mountains Network website (<http://science.nature.nps.gov/im/units/ermn/monitor/vegetation.cfm>).

Background and Objectives

Background and History

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS) mission to manage park resources “unimpaired for the enjoyment of future generations.” Park managers are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions and working with other agencies and the public for the long-term protection of park ecosystems. The overall purpose of natural resource monitoring in parks is to develop scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems (Fancy et al. 2009). Use of monitoring information will increase confidence in manager's decisions and improve their ability to manage park resources, and will allow managers to confront and mitigate threats to the park and operate more effectively in legal and political arenas.

The NPS has initiated a long-term ecological monitoring program, known as “Vital Signs Monitoring,” to provide the minimum infrastructure to allow more than 270 national park system units to identify and implement long-term monitoring of their highest-priority measurements of resource condition (Fancy et al. 2009). The term “vital signs” refers to a relatively small set of information-rich attributes that are used to track the overall condition or “health” of park natural resources and to provide early warning of situations that require intervention. We define vital signs as a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values (Fancy et al. 2009). The broad-based, scientifically sound information obtained through this systems-based monitoring program will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

NPS Vital Signs Monitoring is implemented programmatically through 32 ecoregional “networks” or groupings of parks linked by geography and shared natural resource characteristics. The network approach, through shared funding and professional staff, also facilitates collaboration, information sharing, and economies of scale.

To be relevant to current management issues and anticipate future issues, monitoring programs must be scientifically credible and produce quality data that is readily accessible and explicitly linked to management decision-making processes. To meet those criteria, explicitly stated goals and objectives are critical. The NPS established (Fancy et al. 2009) programmatic goals for all 32 networks as they plan, design, and implement integrated natural resource monitoring. These goals are to:

1. Determine the status and trends of selected indicators of park ecosystem conditions to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources;

2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management;
3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments;
4. Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment; and
5. Provide a means of measuring progress towards performance goals.

The complex task of developing a monitoring program requires a front-end investment in planning and design to ensure that monitoring will meet the critical information needs of each park and produce scientifically credible data that are accessible to managers and other researchers in a timely manner. To that end, each network follows an explicit program development and implementation strategy (Fancy et al. 2009) that includes a peer-reviewed monitoring plan (Marshall and Piekielek 2007) and a series of detailed, peer-reviewed monitoring protocols that describe how data are to be collected, managed, analyzed, and reported (Oakley et al. 2003).

This protocol outlines the justification and procedures for long-term monitoring of vegetation and soils within the Eastern Rivers and Mountains Network (ERMN). The ERMN includes nine parks in New York, New Jersey, Pennsylvania, and West Virginia (Figure 1) which together encompass nearly 91,000 ha of land area and over 600 stream and river miles and within the parks' authorized boundaries. The network includes four smaller parks in central and southwestern Pennsylvania that have a primary cultural or historical focus. These cultural parks are Allegheny Portage Railroad National Historic Site (ALPO), Johnstown Flood National Memorial (JOFL), Fort Necessity National Battlefield (FONE), and Friendship Hill National Historic Site (FRHI). The remaining five larger parks preserve segments of large rivers and generally extend to the ridgetops surrounding the river section. These river parks are Upper Delaware Scenic and Recreational River (UPDE), Delaware Water Gap National Recreation Area (DEWA), New River Gorge National River (NERI), Gauley River National Recreation Area (GARI), and Bluestone National Scenic River (BLUE).

In addition to vegetation and soils, the ERMN is also developing monitoring protocols for streamside birds (Marshall et al. 2012), benthic macroinvertebrates (Tzilkowski et al. 2009), invasive species early detection (Keefer et al. 2010), surface water quality and flow, riparian plant communities, weather and climate, and air quality (Marshall and Piekielek 2007).

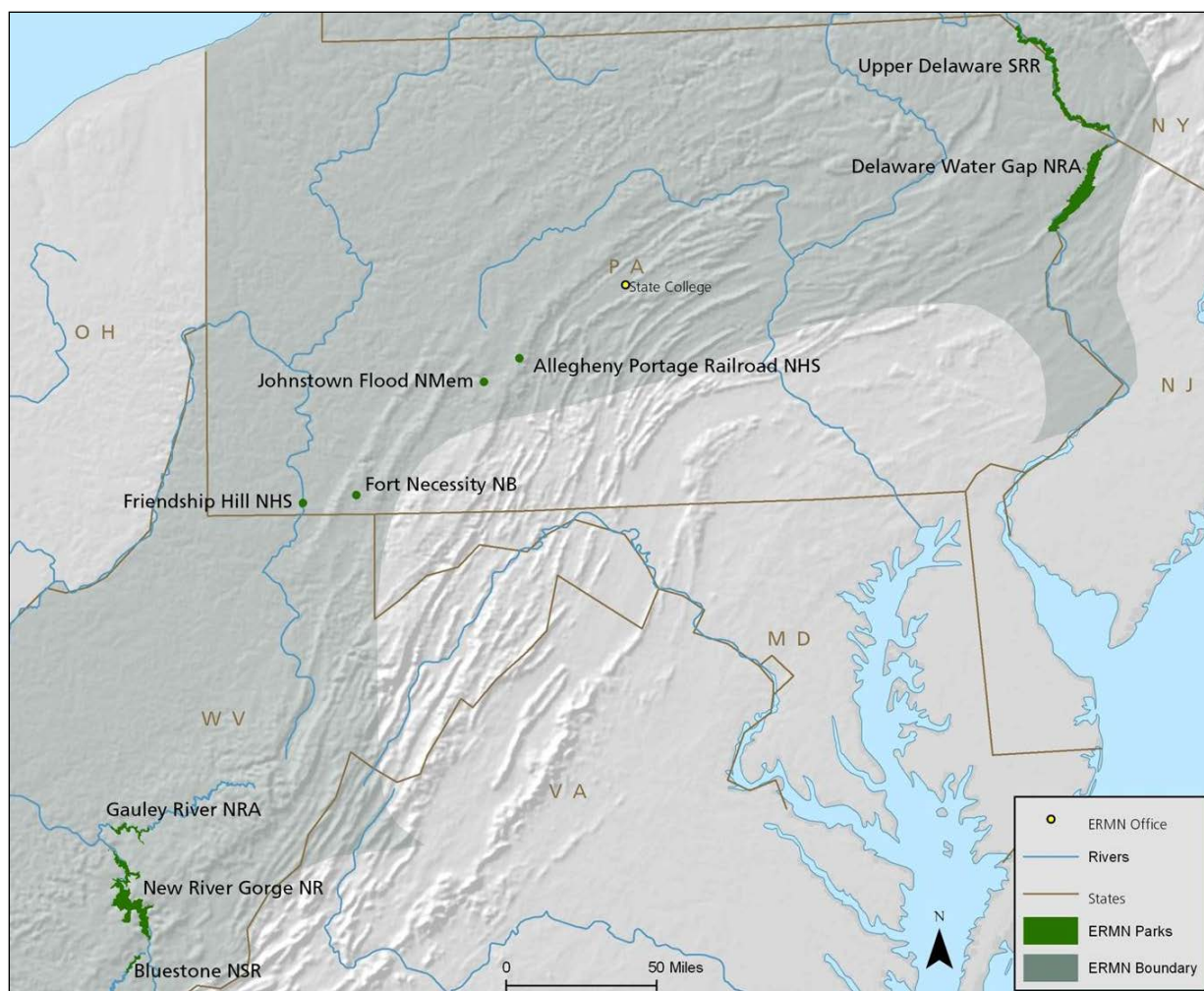


Figure 1. Locations of parks in the Eastern Rivers and Mountains Network.

Rationale for Monitoring this Resource

Long-term monitoring of vegetation and soils was identified among the highest priority vital signs during the ERMN prioritization process (Marshall and Piekielek 2007). The vital sign process highlighted the importance of plant species diversity and functional plant communities as natural resources critical to the parks. These vegetation communities can also serve as an integrated measure of terrestrial ecosystem health by expressing information about climate, soils, and disturbance. Further, vegetation itself serves as a base for other trophic components such as wildlife. Because of this interwoven relationship between vegetation and both biotic and abiotic components, this protocol incorporates the Network's monitoring plans for Forest, Woodland, Shrubland, and Riparian Vegetation as well as those of related vital signs: Status and Trends of Invasive/Exotic Plants, Animals and Diseases; and Soil Function and Dynamics.

The network spans a large geographic area, and the vegetation within the parks varies with latitude, elevation, geology, and topographic position. However, all of the parks occur in either or both of the Appalachian Plateau and the Ridge and Valley Physiographic Provinces (Fenneman 1938), providing

a unifying regional tie among the parks. Some of the major vegetation types in the ERMN include: mixed mesophytic forest on mesic sites in West Virginia, oak-hickory forests on drier ridgetops throughout the network, Allegheny hardwood forest in Pennsylvania, hemlock ravines in DEWA and NERI, as well as plantations and successional habitats found in several of the historic parks (Perles et al. 2006a, b, c; Perles et al. 2007a, b; Vanderhorst et al. 2007; Vanderhorst et al. 2008).

Numerous ecological and anthropogenic forces affect the parks' vegetation. The effects of and interactions among these forces are discussed in detail in the Terrestrial Ecosystem conceptual model developed for ERMN (Rentch 2006), and are briefly summarized here. Ecological factors such as geology, soil nutrient availability, weather, and disturbance patterns directly influence the structure, composition, and dynamics of the vegetation. Some anthropogenic stressors are easily identified, such as visitor overuse or loss and fragmentation of habitat due to development inside and outside of the parks. Many changes in forest vegetation over time are often linked to several interacting ecological and anthropogenic factors. Exotic species, white-tailed deer (*Odocoileus virginianus*), acid and nutrient deposition, climate change, and altered disturbance regimes are also some important factors affecting the parks' vegetation.

The introduction and spread of exotic insects, diseases, and plants is a serious threat to the parks' vegetation. Some prominent exotic forest pests already established in or near some ERMN parks include hemlock woolly adelgid (*Adelges tsugae*), emerald ash borer (*Agrilus planipennis*), gypsy moth (*Lymantria dispar*), beech scale insect (*Cryptococcus fagisuga*, inciting agent of beech bark disease), and elongate hemlock scale (*Fiorinia externa*). Between 1996 and 2001, intense mortality-causing insect and pest activity was recorded by the United States Forest Service (USFS) Forest Health Protection's aerial surveys in parts of the Allegheny Mountains and the Northern Ridge and Valley in West Virginia. Also during this time period, intense defoliation-causing agent activity occurred in the Northern Ridge and Valley and Northern Unglaciaded Allegheny Plateau in Pennsylvania where gypsy moth activity was relatively high (Coulston et al. 2005). Other pathogens and insects such as sudden oak death (*Phytophthora ramorum*), Asian longhorned beetle (*Anoplophora glabripennis*), and Sirex woodwasp (*Sirex noctilio*) may pose significant future threats to the ERMN parks (Keefer et al 2010).

Earthworms are another group of exotic pests that could adversely impact the parks' vegetation. Earthworms are native to North America south of the extent of the Wisconsin glacialiation (Hendrix and Bohlen 2002), and thus native earthworms are likely to occur in all ERMN parks except DEWA and UPDE. However, introduction of exotic earthworms can have profound effects on the soil and vegetation, including alteration of soil mineral horizons, elimination of the soil organic horizon, changes to the rate at which leaf litter is cycled, alteration of the soil microbial and fungal communities, significant reductions in herbaceous plant diversity and cover, shifts in herbaceous species composition, reduction in tree seedling density, and introduction of pathogens (Proulx 2003; Hale et al. 2006). The most dramatic effects of exotic earthworms have been recorded in ecosystems previously devoid of earthworms (such as DEWA and UPDE). In areas inhabited by native earthworms, exotic earthworms have successfully invaded only after soil or vegetation disturbance (Hendrix and Bohlen 2002).

Invasive exotic plants also threaten the vegetation in ERMN parks. These nonnative species are often competitive with native plant species or dramatically change the vegetation structure of a site, often affecting wildlife habitat. Invasive plants can also disrupt ecosystem-level processes by altering resource utilization, trophic structures, and disturbance regimes. These disruptions may result in altered fire regimes, nutrient cycling, or soil development (Vitousek 1990; Mack et al. 2000; Pimentel et al. 2000). Since invasive plants are inherently difficult to control, the management of these species and the effects on vegetation can challenge park resource managers.

Changes in land use and land management over the previous decades have led to expanded native white-tailed deer populations (Latham et al. 2005). The effects of selective browsing by deer on forest ecosystems include reduced species richness, altered species composition towards dominance of non-preferred and browse-resilient species, competitive exclusion of native species, regional biotic homogenization, reduction in plant growth rates, and reduced survival of tree seedlings and saplings (Russell et al. 2001; Horsley et al. 2003; Rooney et al. 2004; Kirschbaum and Anacker 2005; Latham et al. 2005). In particular, browse pressure from deer has reduced the abundance, growth, and/or fecundity of many native plant species in the lily (Liliaceae), arum (Araceae), and orchid (Orchidaceae) families (Anderson 1994; Augustine and Frelich 1998; Ruhren and Handel 2003; Kirschbaum and Anacker 2005). Conversely, the spread of less-palatable species such as hay-scented fern (*Dennstedtia punctilobula*) and striped maple (*Acer pensylvanicum*) can interfere with desirable tree species regeneration and herbaceous species diversity (Latham et al. 2005).

Acid deposition in the Appalachian Mountains is primarily a result of emissions from electrical power generation and heavy manufacturing in the Midwest. Acid deposition can have significant effects on soils including depletion of base cations such as calcium and magnesium, mobilization of aluminum and manganese, and the accumulation of sulfur and nitrogen in soils (Driscoll et al. 2001). The reduction in basic cations and the toxicity of mobile Al and Mn have been linked to the decline in sugar maple (*Acer saccharum*) in Pennsylvania (Drohan and Sharpe 1997; Kogelmann and Sharpe 2006). In addition, the long-term effects of excess nitrogen deposition and mobility in forested systems are also a concern (Aber et al. 2003). Compared to the other northeastern states, Pennsylvania experiences a relatively high rate of nitrogen deposition. Excess nitrogen deposition can lead to reductions in surface water quality through increased nitrate leaching. Soil data also show decreasing ratios of soil carbon to nitrogen with increased nitrogen deposition (Aber et al. 2003).

Many temporal changes in vegetation can be linked to interacting ecological and anthropogenic factors. For example, the decreased prominence of oaks (*Quercus* spp.) and the increased prominence of red maple (*Acer rubrum*) in Pennsylvania and West Virginia over the last century can be attributed to fire suppression, differential white-tailed deer browsing, and the ability of red maple to thrive after disturbances (Abrams 1998). It is also unclear how global climate change will affect the composition of the region's forest. One U.S. Forest Service model predicts large shifts in suitable potential habitat for many of our parks' common tree species under the various climate change scenarios (Iverson et al. 1999).

Depending on the successional stage, disturbance history, and the site it occupies, there are certain parameters within which a terrestrial vegetation ecosystem can be described as "healthy" (Tierney

and Faber-Langendoen 2007b). By measuring taxonomic, structural, and demographic features, an assessment can be made as to whether or not the ecosystem's parameters fall within expected or accepted norms and ranges of variability. These measures serve as indicators of ecological integrity that can be explicitly linked to park management. Thus, this protocol will provide park managers with comprehensive long-term data about the condition of the parks' vegetation resources and how this condition is changing over time.

The concept of "ecological integrity" is increasingly being used as a measuring tool to assess the state of ecosystems and the effectiveness of land management actions upon those ecosystems (Karr 1993; Woodley 1993). Building upon the related concepts of biological integrity and ecological health, ecological integrity is a broader and more useful conceptual endpoint for ecological assessment and reporting (Czech 2004). "Integrity" is defined as the quality of being unimpaired, sound, whole, or complete. To have integrity, an ecosystem should be relatively unimpaired and complete across a range of characteristics and scales (DeLeo and Levin 1997). "Ecological integrity" has been defined as a measure of the composition, structure, and function of an ecosystem in relation to the system's natural or historical range of variation and the perturbations imposed upon it by natural or anthropogenic agents of change (Karr and Dudley 1981). "An ecological system ... has integrity ... when its dominant ecological characteristics (e.g., elements of composition, structure, function, and ecological processes) occur within their natural ranges of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human disruptions" (Parrish et al. 2003).

Measurable Objectives

Monitoring objectives were established to meet the overarching vital signs programmatic goals and the rationale for monitoring the resource described above, while clearly articulating what will be measured and the desired outcome of the protocol. The monitoring objectives are coupled with sampling (or statistical) objectives and, in time, with park management objectives (Elzinga et al. 1998) in an iterative process. In this way, monitoring will not be a stand alone activity, but instead an adaptive component of a larger process of natural resource management and decision making (Nichols and Williams 2006, Lovett et al. 2007). These objectives may also be refined at the park-specific level to fully integrate with management goals, available management actions, and resource conditions.

The purpose of the vegetation and soils protocol is to measure indicators of ecological integrity to provide information on the condition of the parks' vegetation and how this condition is changing over time. Towards this end, we will monitor status and trends in the structure, function, and dynamics of the vegetation in ERMN parks in order to inform management decisions affecting those systems.

Specifically, the primary monitoring objective is to document trends in:

- Proportion of monitoring plots in four successional stages;
- Relative density of key tree species (e.g. oaks and maples) among forest strata (i.e. canopy, saplings, seedlings);

- Growth and mortality rates of key tree species (e.g. hemlocks and ash);
- Density of snags;
- Tree regeneration stocking index;
- Coarse woody debris volume;
- Proportion of species richness and cover held by native and nonnative understory species;
- Proportion of monitoring plots that contain invasive plant species, and average number of invasive species per monitoring plot;
- Number of plants for select indicator species most palatable to white-tailed deer; and
- Basic soil chemistry, with a focus on Ca:Al and C:N ratios.

These monitoring objectives are driven by three broad questions that guide the monitoring program:

- How are vegetation composition, structure, and demography changing over time in relation to weather, climate, landscape dynamics, invasive species, deer browse, and natural processes such as gap formation and succession?
- How are soil and soil fertility changing in relation to acid and nutrient deposition?
- How do park and network status and trends compare to regional trends, historical data, and desired future conditions and/or management objectives?

Sampling Design

Sampling Design Rationale

The ERMN Vegetation Monitoring Program is designed to monitor ecological integrity of the parks' vegetation in a standardized and cost-efficient manner. This protocol must contribute to statistical inferences of status and trends within and across parks with sufficient power to detect change. The use of permanent plots increases power to detect trends over time. The protocol will also facilitate comparison of ERMN data with other NPS networks and regional data such as that from the United States Forest Service (USFS) Forest Inventory and Analysis (FIA) Program.

The USFS FIA Program has been monitoring forest resources on a regional basis across the United States since the 1930s. Beginning in the 1990s, a Forest Health Monitoring (FHM) component was developed by several federal agencies, and later incorporated into the ground survey component of the FIA program. FIA protocols have undergone extensive development by the USFS with academic and other government agency partners (USFS 2007). The FIA program developed a substantial and ongoing database that can be used to assess regional trends in forest resource capacity and health across the region and the country (<http://fia.fs.fed.us/>). Adopting the widely used FIA protocols allows us to take advantage of data collected from forests within or near the ERMN parks. For these reasons, ERMN has chosen to use FIA protocols as a starting point for its vegetation monitoring protocol. However, the FIA protocols have been adjusted to fit ERMN parks and objectives and to be cost-effective. Thus, while FIA is the basis of the ERMN protocol, not all of the data collected on FIA plots will be collected on ERMN plots.

In addition, at least four other I&M networks in the eastern U.S. (Northeast Temperate Network, Mid-Atlantic Network, National Capital Region, and Great Lakes Network) are using the FIA protocols as a basis for their vegetation monitoring protocols (Sanders et al. 2008; Schmit et al. 2009; Tierney et al. 2012, Comiskey et al. 2009). Therefore, the ERMN chose this model to maximize benefits of data sharing. The ERMN protocol has drawn heavily from protocols developed in these other networks and has benefited from their experiences implementing those protocols.

Site Selection

Plot locations for vegetation monitoring have been selected from a regular grid of potential plot locations in each ERMN park using a generalized random-tessellation stratified (GRTS) design (McDonald 2004; Stevens and Olsen 2004). In brief, the GRTS technique uses reverse hierarchical ordering to map two-dimensional space (e.g. locations of plots in a park) into one-dimensional space, by giving each plot an ordered spatial address. Then, restricted randomization is used to order the addresses into a random, spatially-balanced list of plots (McDonald 2004; Stevens and Olsen 2004). This sampling design differs from the hexagonal sampling framework employed by the USFS FIA Program (Brand et al 2000).

There are three main advantages to a GRTS design. First, the sample points generated by GRTS are spatially balanced, wherein there is generally uniform dispersion of sampling sites over the area of interest. Second, the GRTS design allows for flexible sample size, such that sites can be added to or excluded from the sampling plan, while still maintaining the spatial balance and without

compromising the integrity of the overall design. This allows potential sites to be rejected if they are determined inappropriate or additional sites to be added or removed if funding is increased or decreased, or our objectives shift. The third asset of the GRTS method is that it is a probabilistic sampling design, whereby sampling points are randomly chosen from among those in a systematic grid, eliminating site selection bias, and allowing inference to the entire sampling frame. This also provides additional flexibility for post-stratification of plots based on ecological system, vegetation association, or other criteria, as needed (Stevens and Olsen 2004).

Vegetation types and land area of ERMN parks vary considerably. To provide park resource managers with park-specific information about trends in vegetation condition, a separate sampling design was developed for each park. Sample size varied by park to ensure statistical inferences can be made for smaller ERMN parks, while allocating sufficient resources to larger parks.

One park, the Upper Delaware Scenic and Recreational River, was not included in the vegetation and soil monitoring program due to its limited area of publicly owned land. The authorized boundary of UPDE encompasses approximately 26,000 ha, however, only about 12 ha are owned by the National Park Service. Furthermore, only 5% of the land within the authorized boundary (approximately 1,225 ha in total) is held by public entities (i.e. federal government, Commonwealth of Pennsylvania, State of New York, or Sullivan County Parks). Establishing plots on private lands involves risk of lost investment because the National Park Service will have little control over the land use. In addition, data collected from plots on select publicly or privately owned parcels will not necessarily be representative of the park as a whole, making it difficult to draw inferences and guide management decisions (Urquhart et al. 1998).

For the eight other network parks, some areas within the parks were excluded from the vegetation monitoring program, specifically:

- non-vegetated land, including transportation corridor, built-up land, river, pond, etc;
- intensively managed lands, such as agricultural fields, regularly mowed grasslands, areas maintained as non-forest in perpetuity for cultural or historic purposes;
- slopes $\geq 30^\circ$ (equivalent to $\geq 58\%$ slope)¹ as calculated from digital elevation models within the parks.

The remaining area is considered the sampling universe. Privately-owned lands within the parks' authorized boundary are included in the sampling universe; however, no sampling occurs on private land. Therefore, private lands are not part of the area of inference until they are acquired by the park

¹ For the safety of the field crew and to avoid severe disturbance to the soil and vegetation on steep slopes during plot installation and data collection, plots that occurred on very steep slopes could not be included in the sampling design. Steep slopes, including vertical cliffs, are prevalent in the three West Virginia parks. Thirty degrees (58%) was selected as the steep slope cut-off because it provided for crew safety, while removing a reasonable number of points from the regular grid of points. Reducing the steep slope cut-off to 25 degrees removed a significantly larger number of points from the regular grid of points. The decision to use 30 degrees as the cut-off was made in consultation with park resource managers, ecologists who have worked in the West Virginia parks, and other NPS I&M networks.

and plots are established there. The monitoring data cannot be used to make inferences to areas of the park outside the area of inference. The sampling universe will not change over time, but the area of inference will expand to include newly-acquired lands as they are sampled. The area and percentage of the park encompassed by the sampling universe and area of inference are shown in Table 1 and in Appendix A.

Table 1. Information on the regular grid of sample points created for each park's sampling design.

	DEWA	ALPO	JOFL ²	FONE ³	FRHI	GARI	NERI	BLUE
Total Park Area (ha)	27,944	518	76	373	280	4,557	29,203	1,755
Sampling Universe^a (ha)	24,121	471	25	320	231	3,527	21,231	996
Percent of Park Area in Sampling Universe	86.3%	90.9%	33.3%	85.8%	82.6%	77.4%	72.7%	56.7%
Area of Inference^b 2013 (ha)	23,354	471	25	320	231	1,430	17,347	988
Percent of Park Area in Area of Inference 2013	83.6%	90.9%	33.3%	85.8%	82.6%	31.4%	59.4%	56.3%
Distance between Points (meters)	750	250	100	250	250	250	750	250
Number of Points in Park Boundary	499	90	79	58	43	730	523	281
Number of Points on Private Land (Dormant until Acquired)	19	0	3	0	0	452	127	1
Number of Points on Non-vegetated / Managed Land Removed	55	10	55	11	6	12	11	12
Number of Points on $\geq 30^\circ$ Slopes Removed	13	0	0	0	0	37	78	113
Number of Points Entered into GRTS	412	80	24	47	37	229	307	155
Number of Points Selected from GRTS	150	30	15	30	30	100	150	80

^a Sampling universe includes the area within the parks' authorized boundary excluding steep slopes and intensively-managed or unvegetated land

^b Area of inference include the publically-owned lands within the sampling universe

² In JOFL, points located on the historic lakebed, the dam, and the mowed area around the visitor center were removed because this area will be maintained as open to preserve the viewshed and facilitate historical interpretation. Through consultation with the park's natural resource manager (Kathy Penrod, personal communication, April 2007), it was decided that the only areas of the park that should be monitored are the picnic area, the woodlot south of the road across from the picnic area, the wooded area southeast of the lakebed, and the shrubby field south of the visitor center. Points were left in these areas and from these remaining points the GRTS selection was drawn.

³ In FONE, points located in the hayfields on the Rush property were removed since these fields are regularly mowed. The remainder of the points on the Rush property were included in the sampling design, since permission to conduct vegetation monitoring on the Rush property was granted by Mrs. Rush in 2008 (Marie Rush, personal communication, March 2008). In addition, points located in the Great Meadow were removed because this area will be maintained as open to retain its historical character and viewsheds.

To determine the monitoring plot locations, a regular triangular grid of points covering the extent of a park's authorized boundary was created using Hawth's Tools' Regular Point Generation Tool (Beyer 2004) in ArcGIS 9.1 (ESRI 1999–2005). Each point indicates the location for the center of a potential monitoring plot; the distance between points varied by park as a function of park size (Table 1). From this regular grid, points were removed if they did not occur within the sampling universe. The number of points removed by each of the criteria is shown in Table 1. The remaining points and their coordinates were entered into the GRTS software. The number of points selected from GRTS (Table 1) was determined by overestimating the projected number of plots that could be sampled, based on park size and the estimated capacity of a summer field crew (for additional discussion on sample size see "Recommended number of sampling sites" below). Thus, the number of points selected from GRTS includes 50%–100% more plots than will likely be sampled.

The GRTS program generates an ordered list of potential plot sampling locations. Plots will be assigned to sampling panels (see Sample Frequency and Replication section below) in the order they occur on the list. In New River Gorge National River, for example, the first 25 plots on the list will be assigned to panel 1, the second 25 plots on the list will be assigned to panel 2, and so forth. Plot locations may be rejected if they are deemed unsuitable by the field crew (see the Site Selection and Plot Establishment SOP on ERMN website for rejection criteria and procedures), in which case the next location on the list is chosen.

After all of the plots were established, we realized that the sampling plan did not include a method for incorporating plots on newly-acquired land parcels which were privately-held in 2007 when the original ordered list was created. To rectify this oversight, a new "inholding" GRTS sample was created for the parks with private inholdings (DEWA, GARI, NERI, and BLUE). From the original grid of points, all points on land privately owned in 2007 were selected. Points on steep slopes and unvegetated or intensively managed lands were removed. The remaining points were submitted to the GRTS program and a randomly ordered list of all of the points was returned. We calculated the sampling density from the original GRTS sample and determined the number of plots needed on private land to maintain the same sampling density (Table 2). The specified number of plots was divided into four panels and then plots were selected from the ordered GRTS list. Every four years, before beginning a new sampling cycle (re-sampling panel 1), a review of the land ownership should be conducted to determine if any of the selected plots are publically owned.

The sampling universe for vegetation and soil monitoring includes all the area within each park boundary that is vegetated, not intensively managed (as defined above), and has a slope of less than 30°. Thus, terrestrial, palustrine, and riparian vegetation types, regardless of whether they are dominated by trees, shrubs, herbaceous, or graminoid plants, are included. Successional vegetation developing in abandoned agricultural fields or other previously disturbed areas is also included. Submerged aquatic vegetation is not included in this sampling design due to the spatial and temporal variability of those vegetation types and the difficulty in mapping and locating them (in rivers and ponds). With the exception of JOFL, the majority of the vegetation in all of the ERMN parks is terrestrial forest or woodland (Table 3).

Table 2. Information on the sampling design for the parks' private inholding.

	DEWA	GARI	NERI	BLUE
Sampling Density Original GRTS (2007 area of inference / number of plots installed)	229.0	35.8	166.6	24.7
Sampleable Private Land Area (ha)	767	2,097	4,233	8
Number of Plots Needed on Private Land to Maintain Sampling Density	3	59	25	0
Number of Plots Needed on Private Land per Panel		15	6	

Table 3. Area (in hectares) of vegetation types and land uses in ERMN parks. These figures were derived from vegetation maps produced by the Pennsylvania and West Virginia Natural Heritage Programs (Perles et al. 2006a, b, c; Perles et al. 2007a, b; Vanderhorst et al. 2007; Vanderhorst et al. 2008; Vanderhorst et al. 2010).

Vegetation Type	UPDE	DEWA	JOFL	ALPO	FONE	FRHI	GARI	NERI	BLUE
Terrestrial Forest / Woodland	19,509.74	21,544.57	26.95	430.20	275.61	191.80	3,929.25	24,277.47	1,486.08
Riparian Forest / Woodland	397.73	193.48				31.73	36.27	319.59	146.16
Palustrine Forest / Woodland	50.92	861.27					1.22		
Terrestrial Shrubland	50.28	1,103.65			64.06	5.88			
Riparian Shrubland	28.92	29.18		0.44					
Palustrine Shrubland	3.76	103.60							
Terrestrial Herbaceous / Graminoid	147.76	558.15		35.55					
Riparian Herbaceous / Graminoid	402.43	55.92		3.17			64.19	308.54	
Palustrine Herbaceous / Graminoid	22.07	124.63		0.98	16.36	2.07	0.03	63.95	
Terrestrial Sparse Vegetation		142.47					8.70	7.04	
Land Use									
Not Vegetated (Developed Land / Roads / Open Water)	4,598.00	1,959.12	12.64	48.00	17.18	23.92	515.60	4,226.13	122.44
Managed Grassland / Agriculture	939.80	1,268.52	36.06			24.93			
Total Area of Vegetation in Park (Vegetation Type Area – Land Use Area)	20,613.61	24,716.92	26.95	470.34	356.03	231.48	4,039.66	24,976.59	1,632.24
Total Park Area	26,151.41	27,944.56	75.65	518.34	373.21	280.33	4,555.26	29,202.72	1,754.68
Percent of Park Currently in Terrestrial Forest or Woodland	74.6%	77.1%	35.6%	83.0%	73.8%	68.4%	86.3%	83.1%	84.7%

Stratification based on ecosystems, vegetation associations, landscape features, or geology has not been incorporated into this monitoring program. Stratification on a dynamic variable such as vegetation type has been problematic. As the plots' vegetation changes over time, the original strata assignment is compromised, resulting in analytical errors (Diefenbach and Mahan 2002). Further, a sampling design with strata based on vegetation types prevents inferences about those vegetation types not sampled. An alternative to stratification by vegetation type is stratification based on a more permanent landscape feature such as elevation, slope, aspect, or geology. In the smaller ERMN parks, this sort of stratification is unnecessary because the landscapes are somewhat homogeneous. In the larger, more diverse ERMN parks, stratification on landscape features would create numerous strata, so many that it would be difficult to attain a sample size in each strata that would provide sufficient statistical power to detect trends over time. However, preliminary analyses have shown that, during analysis, post-stratification into domains by vegetation type (e.g. xeric, mesic, successional, and riparian) reduces plot-to-plot variability, increases the detectable level of change (see Detectable Levels of Change section below), and provides relevant results to resource managers.

Sample Frequency and Replication

Vegetation monitoring will occur annually but each plot will not be measured every year. Yearly plot measurements can affect soil compaction and understory trampling which would bias the monitoring data (Urquhart et al. 1998). Additionally, yearly changes in trees and soil are likely sufficiently small as to warrant a longer sampling return interval. Therefore, plots are sampled on a four-year simple panel design, in which one panel containing one-fourth of a park's total plots is sampled each year (Table 4a). On the fifth year, the vegetation in the first panel of plots is re-sampled. Sampling will take place during summer months (May–September) when foliage and understory plants are fully developed. A four-year rotation is a good balance between sampling too frequently, where plot trampling can occur, and sampling too intermittently, which reduces the ability to detect change over a given time period. Sampling at four-year intervals will allow time for some change to occur, yet provide relatively frequent feedback to park natural resource managers. This design will provide information on trends in the key parameters after five years; however, our confidence in the estimates of these trends may be low. Our ability to detect trends will increase with subsequent revisits (Urquhart et al. 1998).

An alternative design is a connected panel (Table 4b) in which some plots are visited every year (common panel) in addition to the plots that are revisited once every fifth year. This connectivity can provide increased power to detect trends by allowing for the estimation of site-by-year variance earlier in the sampling design (Urquhart et al. 1998, Urquhart and Kincaid 1999). However, based on power analyses of ERMN data collected 2007–2011, the connected panel design did not provide sufficient additional power over the simple panel design to justify the additional sampling cost (Perles et al. 2012); therefore, the ERMN will employ a simple panel design.

Table 4. Schematic for (a) simple panel and (b) connected panel designs.

(a)

	Year											
Panel	1	2	3	4	5	6	7	8	9	10	11	12
1	X				X				X			
2		X				X				X		
3			X				X				X	
4				X				X				X

(b)

	Year											
Panel	1	2	3	4	5	6	7	8	9	10	11	12
1	X				X				X			
2		X				X				X		
3			X				X				X	
4				X				X				X
Common	X	X	X	X	X	X	X	X	X	X	X	X

Each year, three plots from the panel are selected to be resampled as a quality control measure. The three plots are resampled within a few weeks of the original sampling; however, crew members switch roles for the resampling, such that the original data recorder is responsible for taking measurements during the revisit. If possible, a different botanist samples the quadrats during the revisits.

Recommended Number of Sampling Sites

Several factors should be considered in determining the total number of sites sampled in each park. The primary driver of sample size should be the power to detect change over time in the key parameters that provide information towards the program's objectives. Two factors that influence our ability to detect change over time are alpha and beta (Irwin 2008). Alpha is the probability of detecting a "false change," or falsely detecting a change when it did not occur. Beta is the probability of "missed change," or wrongly concluding no change occurred when it actually did. Power is equal to $1 - \beta$. The NPS I&M Program is typically more concerned about "missed change" than "false change" and therefore may specify a beta smaller than the alpha; common accepted values of alpha and beta range from 0.01 to 0.2 (Irwin 2008).

Other important factors affecting sample size are budgetary and logistical constraints such as length of growing season and availability of qualified crew members. The ERMN Vegetation Monitoring Program budget currently contains sufficient funds for one crew of three people over 15 weeks. Based on the preliminary experiences of other NPS networks that have implemented vegetation monitoring programs, ERMN estimated that our crew could realistically sample between 300 and 400 plots over a four-year cycle. Thus, we divided a projected 350 total plots among the network's parks to ensure a minimum sample size for statistical inference in the smaller ERMN parks, while allocating sufficient resources to the larger parks. The distribution of plots by park is shown in Table 5. By 2013, there were 362 plots installed in ERMN parks.

Table 5. The number of new monitoring plots established by year in ERMN parks.

Year	NERI ^a	DEWA	JOFL ^b	ALPO ^b	FONE	FRHI	GARI	BLUE	Total
2007	20	26	1	3	5	5	12	12	84
2008	29	26	3	6	5	5	9	9	92
2009	25	25	3	6	5	5	9	9	87
2010	26	25	3	6	5	5	10	10	90
2011	2	0	2	3	0	0	0	0	7
2012	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0
Total	102	102	12	24	20	20	40	40	362
Percent of Total Plots	29%	28%	3%	7%	6%	6%	11%	11%	

^a New plots were installed in 2011 from the “inholding” sample described in the Site Selection section above. No plots in the “inholding” panel 2 or 3 (2012 or 2013) occurred on public land.

^b Logistical issues prevented a full panel of plots from being established in ALPO and JOFL in 2007, so additional plots were added in 2011 to complete the panel.

Detectable Levels of Change

Realistic and appropriate values for alpha and beta will be determined as more data is collected. However, this monitoring program should ideally be able to detect a 20 percent change in key parameters over five or ten years (i.e, two or three plot revisits), with a power of 0.80 and an alpha of 0.1. A power analysis can be used to determine the sample size needed to detect a set level of change in a parameter at a particular power and alpha level. However, the vegetation and soil monitoring program collects numerous measurements. The sampling design may provide an adequate sample size for some measurements, but may not be adequate for others. Additionally, as the monitoring is expected to continue indefinitely, more data will be added and the power to detect change will increase. Even if adequate power is not attained after the first cycle of panels, adequate power may be achieved after several repetitions (Urquhart et al. 1998).

Based on power analyses of ERMN data collected on 30 key forest health variables between 2007 and 2011 (Perles et al. 2012), the program’s sampling design at the two largest network parks (NERI and DEWA) is likely overly intensive for detecting a 5% trend · year⁻¹ for all the studied variables, is appropriate for detecting a 1% trend · year⁻¹ in most variables, and is insufficient for detecting a 1% trend · year⁻¹ for a few variables. In the smaller parks, the small sample sizes currently employed are sufficient to detect small trends (1%·year⁻¹) in some important variables (e.g., live tree basal area); however, for some variables (e.g., coarse woody debris volume), only larger trends (5% · year⁻¹) are able to be detected. These power estimates are “best case scenarios” since the estimates of coherent temporal variation and estimates of trend variation were likely underestimated based on only four to five years of data. Although the power analyses were potentially overly-optimistic, they suggest that the current sampling design is meeting the program’s objectives (Perles et al. 2012).

Post-stratification of plots into vegetation domains (e.g. xeric, mesic, successional, riparian, etc.) during analysis can increase detectable levels of change by reducing plot-to-plot variability. Given the wide diversity of vegetation types present in the parks, post-stratification also provides park

managers with management-relevant information since different trends in the same forest health variable may be occurring in the different forest types. Power analyses of ERMN data suggest that in the four larger ERMN parks, there are sufficient samples to post-stratify plots by vegetation domains and retain adequate power (Perles et al. 2012).

Field Methods

Field methods for ERMN vegetation monitoring use FIA protocols as a starting point; however, the ERMN has tailored FIA protocols to fit the network's objectives and to be cost-effective. The ERMN has collaborated with several other NPS Vital Signs Networks in the eastern U.S., building primarily on standards and protocols developed by the National Capital Region Network and the Northeast Temperate Network (Schmit et al. 2009; Tierney et al. 2012).

Standard operating procedures (SOPs, on the ERMN website) provide detailed instructions for the ERMN vegetation monitoring protocol. The SOPs include instructions on field season preparation, necessary equipment, field work schedule, plot establishment, data collection, data management, and analysis. It is essential for successful long-term monitoring to establish standard methods such as these and to carefully follow them. Changes to established protocols should be clearly justified, documented, and dated to ensure their use in subsequent years.

Plot Design

The ERMN will monitor an extensive network of permanent plots, measuring a suite of site, stand, tree, understory, and soil variables. The plot design includes several imbedded sampling units (Figure 2). Tree, stand, and site measurements are collected within fixed-area, circular plots, 15 m in radius. This plot area (707 m^2) is nearly equivalent to the combined total area of the four standard FIA subplots (673 m^2) where that program collects tree data (USFS 2007).

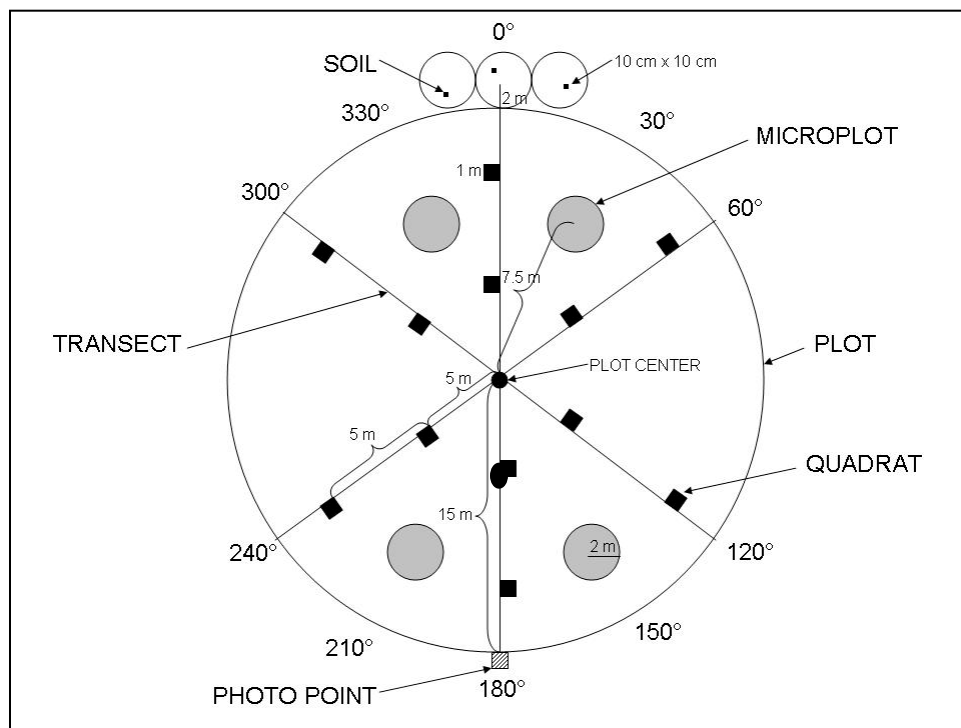


Figure 2. Plot design for ERMN Vegetation Monitoring protocol.

Tree regeneration and shrub measurements are collected on four 2-m radius circular microplots embedded within each plot. This number of microplots was determined statistically optimal for assessing tree regeneration by the FIA Pennsylvania Regeneration Study (McWilliams et al. 2001; McWilliams et al. 2005).

Data on coarse woody debris are collected using line intersect sampling (Van Wagner 1964) along six 15-m transects. Total transect length in this protocol (90 m) is nearly equivalent to the total transect length for coarse woody debris used in the FIA plot design (88 m total, from four sets of three transects, with each transect 7.3 m in length) (USFS 2007). The recommended length, number, and configuration of coarse woody debris transects has been debated in the literature, and is ultimately dependent on the amount of coarse woody debris present, the distribution of the debris, the logistical cost of sampling, and the desired precision of measurement (Pickford and Hazard 1978; Nemec and Davis 2002; Woodall and Monleon 2008).

With the arrangement of the six transects shown in Figure 2, pieces of coarse woody debris are more likely to intersect multiple transects than in the traditional 3-transect design used by FIA and several other NPS I&M Networks. The ERMN coarse woody debris SOP requires recording the intersection of a piece of coarse woody debris with multiple transects. Thus, data from the multiple intersections could be removed from the analysis at some future time. However, Woodall and Monleon (2008) demonstrated that the line intercept sampling estimator is unbiased regardless of the shape in which any cluster of transects is arranged. This means that each intersection of a transect with a piece of coarse woody debris should be counted, regardless of whether the piece has intersected a transect elsewhere in the plot (Woodall and Monleon 2008).

Data on understory plant composition and the diversity of understory species are monitored using twelve 1-m² quadrats set along the six transects. A photograph of the plot is taken from the plot's southern edge to document change in vegetation structure over time. Six additional photographs are taken from plot center aimed at the pins marking the ends of each of the transects. Three soil samples are collected from sampling frames located adjacent to the plot's northern edge.

Details for Taking Measurements

Detailed instructions on data collection and definitions for all data fields are provided in the Standard Operating Procedures available on the ERMN website (<http://science.nature.nps.gov/im/units/ermn/monitor/vegetation.cfm>). However, general types of data that will be collected are described briefly here.

The crew collects basic information describing the site (e.g., slope, aspect, elevation, and terrain position) within each plot. Stand structure and disturbance are qualitatively assessed using visual inspection. Each tree ≥ 10 -cm diameter-at-breast-height (DBH) on the plot is scribed and its species, DBH, status (live/dead), crown position, dieback, and vigor class are recorded. The presence of selected pests, pathogens, damages, and defects are also recorded for each tree. These data will yield information on tree growth, mortality, and condition, as well as stand structure and composition. Tree seedlings are quantified by species and size class on the microplots to assess advanced regeneration and deer browsing. Percent cover and number of individuals of shrub species are also collected on

the microplots. Vegetation within the microplots is also characterized by percent cover class within the following groups: nonvascular, herbaceous, vine, graminoid, and fern.

On the transects, the diameter at the point of intersection and the decay class is measured and recorded for each piece of coarse woody debris >7.5 cm in diameter and >1 m in length. Intersections of one piece of coarse woody debris on more than one transect is noted. The percent cover of all herbaceous, graminoid, and vine species on 1-m² quadrats is recorded to provide information on understory species composition, presence of exotic species, and biotic homogenization.

The number, height, and reproductive activity of specific herbaceous species sensitive to deer browse are also recorded. Table 6 lists the indicator species selected based on research that suggests or recommends the species is an appropriate indicator of deer browse. The list includes numerous genera to account for the floristic diversity among the parks and the vegetation diversity within the larger parks. Fairybells (*Prosartes* spp.) was fairly common in NERI during the first year of data

Table 6. Species that will be monitored as potential indicators of deer browse, along with citations for research that suggests or recommends that the species is an appropriate indicator of deer browse.

Scientific Name	Literature
<i>Actaea</i> spp. (<i>A. pachypoda</i> , <i>A. podocarpa</i> , <i>A. rubra</i>)	Webster and Parker 2000
<i>Actaea racemosa</i> (formerly <i>Cimicifuga racemosa</i>)	(Browse preference is debated) Heckel et al. 2010 Rawinski 2008
<i>Arisaema triphyllum</i>	Webster and Parker 2000 Ruhren and Handel 2000 Fletcher et al. 2001 Diefenbach and Fritsky 2007 Heckel et al. 2010
<i>Maianthemum canadense</i>	Rooney 1997 Kirschbaum and Anacker 2005 Diefenbach and Fritsky 2007
<i>Maianthemum</i> spp. (<i>M. racemosum</i> , <i>M. stellatum</i>)	Fletcher et al. 2001 Augustine and deCalesta 2003 Webster et al. 2005
<i>Medeola virginiana</i>	Webster et al. 2005 Diefenbach and Fritsky 2007
<i>Osmorhiza</i> spp. (<i>O. claytonia</i> , <i>O. longistylis</i>)	Webster and Parker 2000 Heckel et al. 2010
<i>Podophyllum peltatum</i>	(Browse preference is debated) Heckel et al. 2010
<i>Polygonatum</i> spp. (<i>P. biflorum</i> , <i>P. pubescens</i>)	Fletcher et al. 2001 Augustine and deCalesta 2003 Webster et al. 2005
<i>Prosartes</i> spp. (<i>P. lanuginosa</i> , <i>P. maculata</i>)	
<i>Trillium</i> spp. (numerous)	Anderson 1994 Augustine and Frelich 1998 Kirschbaum and Anacker 2005' Heckel et al. 2010
<i>Uvularia</i> spp. (<i>U. grandiflora</i> , <i>U. perfoliata</i> , <i>U. puberula</i> , <i>U. sessilifolia</i>)	Fletcher et al. 2001 Webster et al. 2005

collection using this protocol and was added to the list of potential indicator species. The reproductive activity of these plants is recorded because several studies found that reproductive activity is a more suitable indicator of deer browse than frequency or plant height (Ruhren and Handel 2000; Fletcher et al. 2001). For example, the ratio of flowering to non-flowering Canada mayflower (*Maianthemum canadense*) may be a suitable indicator of forest conditions (Diefenbach and Fritsky 2007). However, on state forest lands in Pennsylvania, mean height of Indian cucumber (*Medeola virginiana*) was the most precise deer browse indicator in a study that also evaluated Canada mayflower, Jack-in-the-pulpit (*Arisaema triphyllum*), and trilliums (*Trillium* spp.) (Diefenbach and Fritsky 2007).

Monitoring the effects of deer herbivory on a landscape scale (as is proposed in the larger parks) may be difficult (Russell et al. 2001; Kirschbaum and Anacker 2005). In a large landscape, deer density can vary by season, year, and site, depending on the distribution and abundance of preferable food sources. It is unclear whether this variability will mask trends in deer browse indicator plants over time. In addition, confounding environmental factors may affect both deer density and plant survival, further increasing the observed variability (Russell et al. 2001; Kirschbaum and Anacker 2005).

Three separate soil samples are collected adjacent to the plot. Each sample is collected by genetic horizons (e.g., O, A, and/or B), storing soil from each horizon separately. These samples are chemically analyzed to provide information on the effects of atmospheric deposition and the ability of these soils to support forested ecosystems. Although a suite of chemical analyses will be conducted, calcium to aluminum ratios and carbon to nitrogen ratios are the focus of the soil monitoring effort.

Data Handling, Analysis, and Reporting

Metadata Procedures

Any dataset compiled by the ERMN must be accompanied by metadata. This includes both spatial and non-spatial datasets. For metadata associated with geospatial data, we abide by Executive Order 12906, which mandates that every federal agency document all new geospatial data it collects or produces using the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM; www.fgdc.gov/metadata/constan.html). All GIS data layers will be documented with applicable FGDC and NPS metadata standards. The Network will also generate FGDC-style metadata for non-spatial datasets that meet this standard, without the geospatial-specific elements.

Overview of Database Design

The vast majority of data collected by the ERMN Vegetation Monitoring Program will be stored in the Vegetation and Soil Monitoring Database. This database is compliant with the Natural Resources Database Template (NRDT) and is similar to vegetation monitoring databases developed in other I&M networks in the eastern U.S. The ERMN Vegetation Monitoring Database was developed in Microsoft Access 2003.

The Master Plant List in the Vegetation and Soil Monitoring Database was created from the PLANTS Database, as downloaded from the USDA PLANTS website in April 2007 (USDA, NRCS 2007). The PLANTS Database was developed by the Natural Resource Conservation Service in cooperation with the Biota of North America Program. Nomenclature in the Master Plant List follows the PLANTS Database; however, some common names in the Master Plant List have been changed to reflect the common names typically used by ecologists and resource managers in this region.

Data Entry, Verification, and Editing

Accurate collection and stewardship of data are critical to the success of the vegetation monitoring program. Ensuring data quality must be a priority during crew training, and throughout the data collection, entry, verification, and validation process.

Data will be entered into the ERMN Vegetation Monitoring Database in two ways. First, field crews may enter data directly into a field copy of the database running on a rugged tablet computer. The database incorporates many functions and utilities to help reduce data entry errors and promote data integrity. Entering data in this manner eliminates the need to transfer data from paper field forms into a project database, and thus reduces data entry errors. Alternatively, field crews may record data on paper field forms (Appendix B) and enter data into the project database at a later time.

Regardless of the data collection method, a crew member must review all paper data sheets or all sections of the field database before the crew leaves each plot. The crew leader is responsible for ensuring that all datasets undergo complete quality assurance and quality control procedures. A detailed description of the data quality assurance and quality control procedures is provided in the Data Quality Assurance and Quality Control SOP on the ERMN website.

Recommendations for Routine Data Summaries and Analysis

Data from the ERMN Vegetation Monitoring Program will be analyzed in three ways:

1. Annual summaries on the status of the vegetation in each park;
2. Analysis of changes in key parameters over time, typically summarized every four years; and
3. Evaluations of relationships between environmental parameters and the vegetation structure, demography, and species composition.

After each field season, data will be analyzed to produce annual summaries on the status of vegetation by park. Some parameters that will be summarized annually are listed in Table 7. These annual summaries will provide park managers and the Network with current status information relevant to policy and management decisions. Other analytical approaches may be utilized to assess the status of vegetation structure, demography, and species composition.

The ERMN will also analyze temporal change for parameters listed in Table 7. These analyses will typically take place every four years, after the plots in all four panels are revisited. After two or more complete sampling cycles, analyses can evaluate trends in the data. These analyses can use general or mixed linear models to partition spatial and temporal variability and assess temporal change, as is done by the USFS FIA program (Woodall and Williams 2005). Other possible analytical tools include paired *t*-tests, repeated measures ANOVA, Kolmogorov-Smirnov two-sample test, and calculating instantaneous rate of change.

The ERMN also plans to collect and analyze covariate data on environmental parameters associated with vegetation. Data collected for other ERMN Vital Signs, such as Air Quality, Weather and Climate, and Landscape Dynamics, will provide information on climate variables, air pollution concentration, deposition rates, and land use change. It is our hope that these variables will help account for the relationship between certain response variables (such as tree growth or mortality rate) and key ecosystem drivers and stressors.

Furthermore, the ERMN is collaborating with other NPS I&M networks to determine appropriate regional analyses that can be conducted with the vegetation monitoring data from our networks. In the future, the ERMN plans to work with other regional partners, such as the US Forest Service FIA program and the Northeastern Soil Monitoring Network, on regional data analyses. Contributing towards regional analyses will provide context for conditions and trends observed in ERMN parks and strengthen our understanding of regional trends.

Recommended Reporting Schedule and Format

Two types of reports will be produced for the ERMN Vegetation Monitoring Program. Annual summary reports that provide information on the status of vegetation will be produced each year. Park superintendents and resource managers are the primary audience for the annual summary reports. These summaries will document the efforts of the Vegetation Monitoring Program and convey findings of the previous field season.

Table 7. Some parameters that will be analyzed annually to provide information on the status of vegetation in the parks.

Type of Vegetation Data	Parameter
Trees	Total Live Basal Area Total Live Density Relative Live Basal Area for select species Relative Live Density for select species Species Richness, Shannon Index, Berger-Parker Index Histograms of Diameter class distribution Snag Basal Area Snag Density Ratio of Number Snags : Number Live Trees Mortality Rate (by Park and by Species) Recruitment Rate (by Park and by Species) Growth Rate (by Species and by Size Class within Parks)
Tree Regeneration	Stocking Index (McWilliams et al. 2001, 2005) Total Sapling Basal Area Relative Sapling Basal Area for select species Total Sapling Density Relative Sapling Density for select species Histograms of seedling frequency by height Species Richness Oak Sustainability Index (Woodall et al 2008)
Shrubs	Average Percent Cover by species or species groups Species Richness
Coarse Woody Debris	Volume
Herbaceous Plants	Species Richness, Shannon Index, Berger-Parker Index Proportion of Total Cover in Rhizomatous Ferns Proportion of Total Cover in Invasive Exotic Species Proportion of Total Cover in Native Species Proportion of Total Cover in Non-Native Species Proportion of Total Species Richness in Invasive Species Proportion of Total Species Richness in Native Species Proportion of Total Species Richness in Non-Native Species
Deer Browse Indicator Species	Frequency by Species Ratio of Number of Reproducing : Nonproducing Individuals Total Number of Individuals Average Height
All Species within Plot	Jaccard's Similarity Index Floristic Quality Index Frequency of Select Invasive Exotics

In addition to annual summary reports, detailed reports in which data are analyzed and synthesized will be produced on a periodic basis, typically every four years, after the completion of each sampling cycle. These reports will follow a format appropriate for a scientific journal and will contain in-depth analyses. Further, these comprehensive reports will place the observed results in both a regional and historical context by relating them to published literature, discussing the significance of the results relative to changing environmental factors, and providing management recommendations based on these findings. The target audience will be park natural resource managers, the ERMN, and other I&M networks. Outside of the park service, the target audience can include state departments of natural resources, the U.S. Forest Service, and the broader scientific community.

Data Archival Procedures

During the field season, data collected on the field computer in the field database must be backed up to an external hard disk daily and to the network server or Google Drive weekly. The field computer and the hard disk shall be stored separately.

If data are recorded on paper data sheets, a photocopy of the original paper data sheets shall be produced on acid-free paper within one week of data collection. These copies shall be delivered to the Network Data Manager and housed in a separate building from the original data sheets. Alternatively, paper data sheets can be scanned into an electronic Adobe file (.pdf) and stored on an external hard disk and/or ERMN computer.

The ERMN has entered into a long-term agreement with North Carolina State University to serve as our primary digital archive. This archive, along with a variety of ERMN and I&M national program resources, comprise the various repositories that store and safeguard ERMN products for future use.

Personnel Requirements and Training

Roles, Responsibilities, and Qualifications

The following personnel will be involved in the Vegetation Monitoring Program:

Plant Ecologist

The ERMN Plant Ecologist functions as the Vegetation Monitoring Program Manager and is responsible for coordinating all aspects of the project, including field work, data management, and analysis/reporting. This person functions as a liaison between the ERMN I&M Program and the vegetation field crew collecting data in Network parks. Specific responsibilities of the plant ecologist include:

- develop an annual field schedule
- acquire the appropriate permits
- establish and refine annual and seasonal budgets
- hire seasonal field crew
- prepare, repair, and/or purchase equipment
- prepare database for the field season (review species lists, add crew members names, etc.)
- contact local experts in botany, soils, and entomology to establish working relationships prior to the field season
- arrange and/or conduct field crew training
- oversee field crew during field season, providing logistic and administrative support
- ensure plot work meets quality standards
- ensure adequate numbers of plots are established and/or measured each season at each park
- ensure effective communication between park staff, field crew, and other ERMN staff
- review and revise monitoring protocol and standard operating procedures as needed
- ensure proper data QA/QC and data archival procedures are followed
- data analysis and report writing.

Vegetation Crew Leader

The ERMN Vegetation Monitoring Crew Leader will be responsible for managing the vegetation field crew. S/he will work closely with the Plant Ecologist to ensure that all training and permits requirements are met and that project supplies and equipment are in order. The crew leader should be skilled in botany, with a strong knowledge of the flora of Pennsylvania and West Virginia. In addition to the responsibilities of a crew member, the Vegetation Crew Leader will perform the following tasks:

- coordinate directly with park resource managers when conducting field work in each park
- ensure that all field crew members are trained in proper data collection procedures
- identify plants accurately and/or process unknown plants for later identification
- conduct data verification if data from paper field sheets were entered into database
- ensure that all data undergoes the proper QA/QC procedures.

Field Crew Members

The field crew members will be responsible for data collection in the field and data entry into the project database. Crew members may be graduate or undergraduate students who have strong interest or experience in forest ecology and/or natural resources. Crew members must be able to identify common trees and shrubs of Pennsylvania and West Virginia. Between the crew leader and the two crew members, the crew should ideally have knowledge or expertise in all of the following areas: forest pests and pathogens; forest soils; and identification of herbaceous and graminoid plants. Specific tasks that the crew members will be responsible for include:

- complete mandatory training
- collect field data accurately as described in the Standard Operating Procedures
- identify plants accurately and/or process unknown plants for later identification
- ensure plot work meets the desired standards of quality
- enter data accurately into the project database either in the field or from paper data sheets
- complete timesheets and expense reimbursement forms accurately and in a timely manner
- ensure all necessary equipment is assembled, clean, and functional prior to each trip.

ERMN Data Manager

The Data Manager will be responsible for providing database training to the crew leader and field crews. S/he will also ensure that all individuals involved in the project are aware of their data management responsibilities. The Data Manager will be responsible for providing any database assistance and GIS support as needed. Specific tasks that the data manager will be responsible for include:

- create, update, and maintain the structure and functionality of the Vegetation Monitoring Database
- ensure that the Vegetation Monitoring Database is compliant with the NRDT
- provide database and GIS training and support
- coordinate data archival procedures.

ERMN Network Coordinator

The Network Coordinator will be responsible for overseeing and coordinating the development and implementation of the Vegetation Monitoring Program and the other vital sign protocols. S/he will ensure that the Vegetation Monitoring Program is aligned with and contributing towards network goals. The Network Coordinator will also provide support in budget, personal, and logistical matters.

Training Procedures

Prior to each field season, the ERMN must ensure that all field personnel fully understand the protocol by conducting in-situ training sessions. Training will occur in mid-May and last at least one week. Field crew training should involve careful review and discussion of all standard operating procedures, in addition to field sessions in which training plots are established and measured. Specific topics covered during training are detailed in the Field Season Preparation SOP (on ERMN website).

Operational Requirements

Annual Workload and Field Schedule

Plot sampling will begin in late May and extend through the end of August. Since the growing season is longer in West Virginia, the West Virginia parks should be sampled at the beginning and the end of the field season. Sampling will most likely follow this schedule:

- Late May–Early June: NERI
- June–Early July: DEWA
- July: ALPO, JOFL, FONE and FRHI
- August: GARI, BLUE, and NERI.

The fall and winter months are used for data entry and QA/QC, data analysis, and report writing. Preparations for the upcoming field season will occur in late winter and early spring.

Facility and Equipment Needs

The logistical and equipment needs of the vegetation monitoring crew are detailed in the Field Season Preparation SOP (on the ERMN website). Ideally, the crew will stay in park housing while they are conducting field work. The Plant Ecologist and Vegetation Crew Leader should coordinate housing and transportation needs with park staff. The crew will have a dedicated vehicle for the summer, but may need occasional transportation assistance from park staff to reach certain plots.

Startup Costs and Budget Considerations

This protocol was developed through a Cooperative Agreement with The Pennsylvania State University's Department of Ecosystem Science and Management. The budget for the first year of protocol development through this agreement was approximately \$102,000, including expenses for the first year of data collection.

Future costs associated with the annual field sampling portion of the vegetation monitoring protocol are detailed in Table 8. This estimate includes salary for the field crew leader and two crew members, transportation, housing, travel costs, and supplies which are used every year, such as rebar, caps, spikes, soil bags, etc. Additional future costs for this program include salary and benefits for a GS 11/12 Plant Ecologist, estimated to be \$69,500 annually.

Soil sample analysis is also a significant expense for the program. However, the exact cost will depend on number of samples collected, temporal frequency of sample collection, and specific analyses that are conducted. Soil samples collected in 2007 will be analyzed at the University of Maine Analytical Lab and Soil Testing Service at a cost of \$35/sample, or \$15,365 total.

Table 8. Estimated yearly costs for one field crew to implement data collection portion of the ERMN vegetation monitoring protocol.

Expense Type	Estimated Yearly Costs
Salary (including fringe)	
Field Crew Members (2)	\$16,500.00
Field Crew Leader	\$9,500.00
Logistics	
Fleet Vehicle	\$4,000.00
Housing and Travel Expenses	\$6,000.00
Supplies	\$1,000.00
Total	\$37,000.00

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Appendix A. Sampling Universes in ERMN Parks.

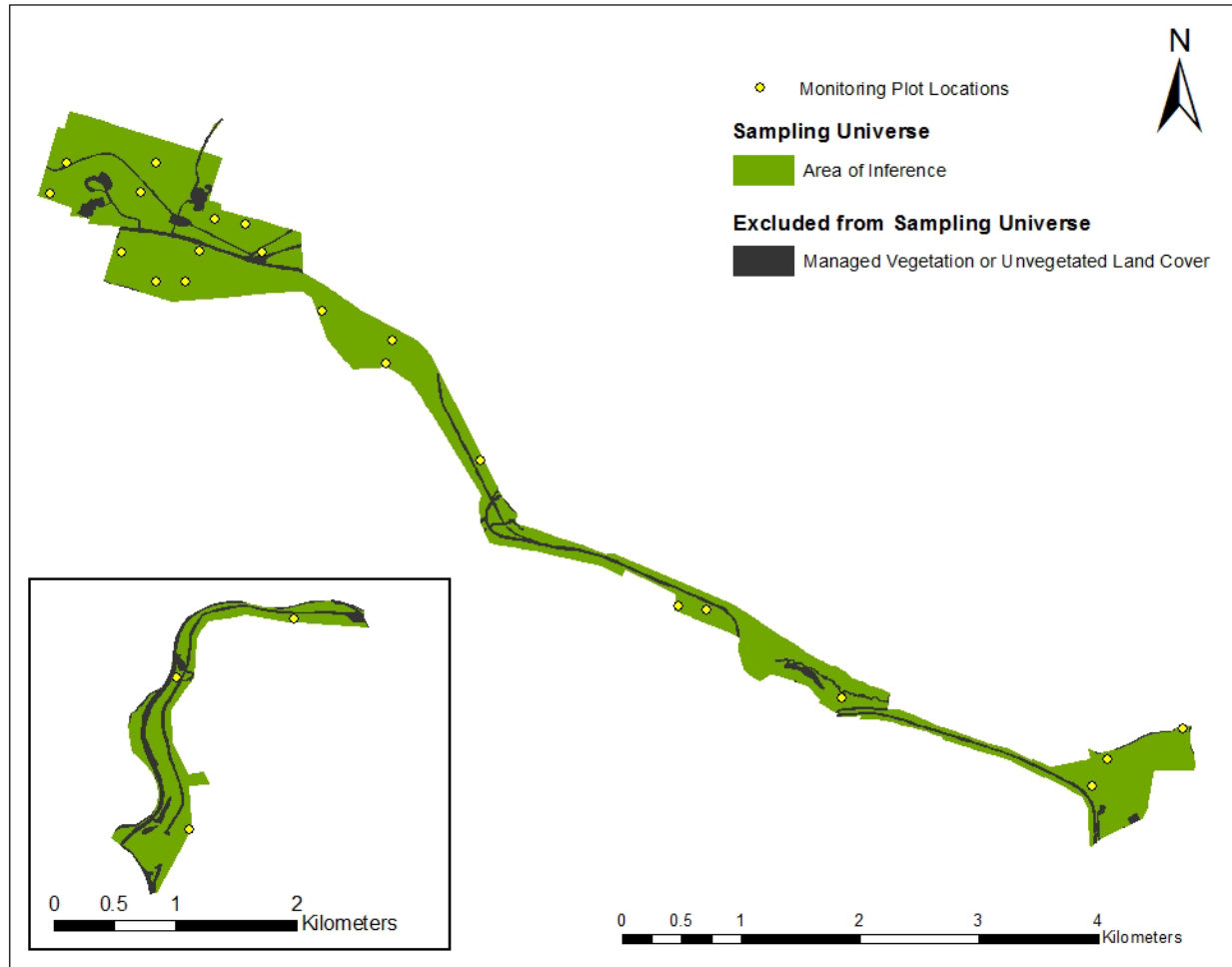


Figure A1. Sampling universe (91% of park area), area of inference (91% of park area) and plot locations for Allegheny Portage Railroad National Historic Site. Sampling universe includes the area within the parks' authorized boundary excluding steep slopes greater than 30° and intensively-managed or unvegetated land. Area of inference includes the publically-owned lands within the sampling universe. Inferences derived from the monitoring data cannot be applied to areas of the park outside the area of inference. In ALPO, excluded areas are primarily developed land, transportation corridors, and the historic trace. Before sampling began in 2007, the park's natural and cultural resource managers reviewed every potential plot location and requested that two plots be excluded from the monitoring due to their proximity to significant cultural resources or safety hazards.

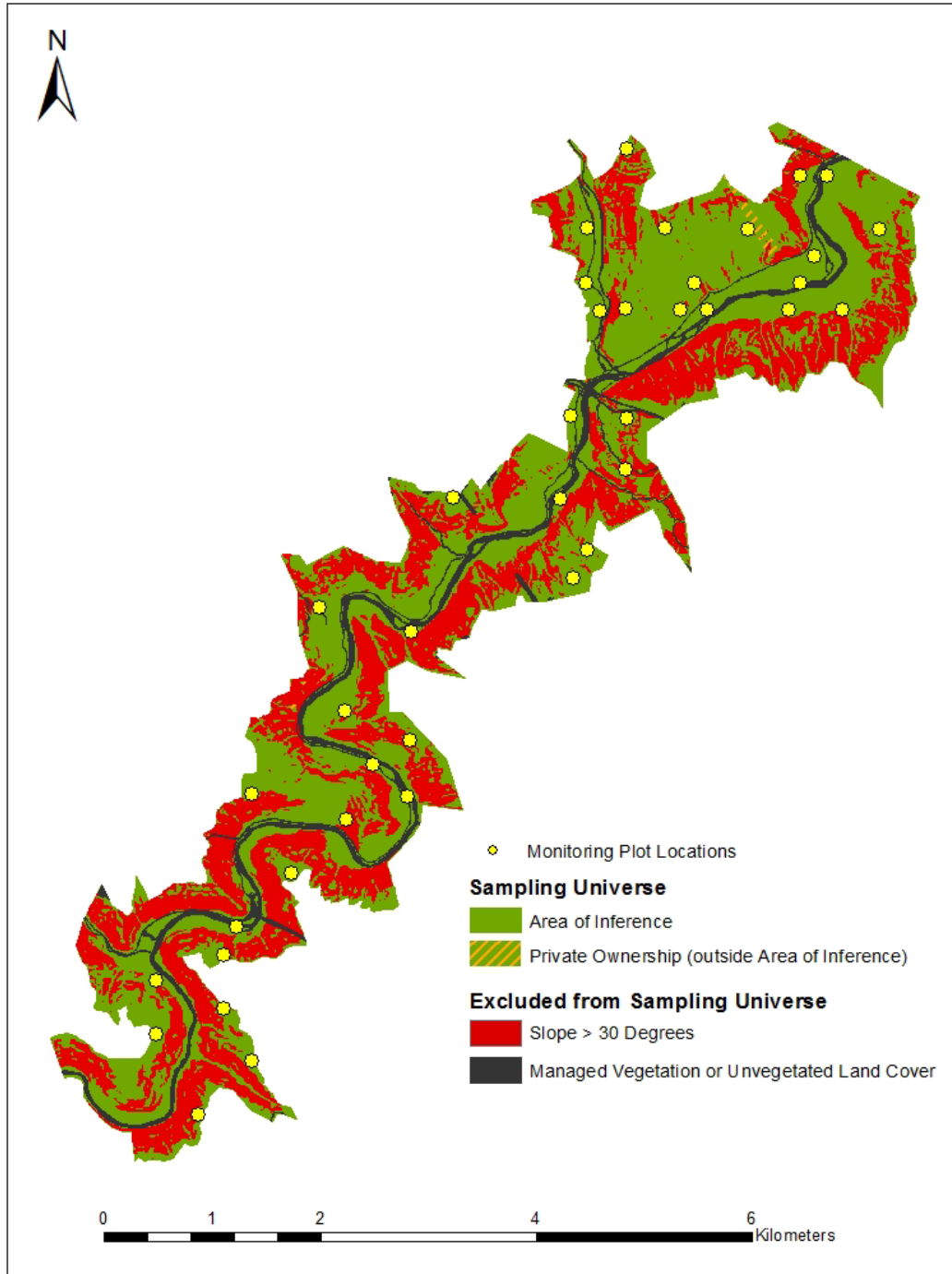


Figure A2. Sampling universe (57% of park area), area of inference (56% of park area) and plot locations for Bluestone National Scenic River. Sampling universe includes the area within the parks' authorized boundary excluding steep slopes greater than 30° and intensively-managed or unvegetated land. Area of inference includes the publically-owned lands within the sampling universe. Inferences derived from the monitoring data cannot be applied to areas of the park outside the area of inference. In BLUE, excluded areas are primarily slopes steeper than 30°. Reducing the steep slope cut-off to 25° would have removed significantly more plots from the grid of potential plots in BLUE.

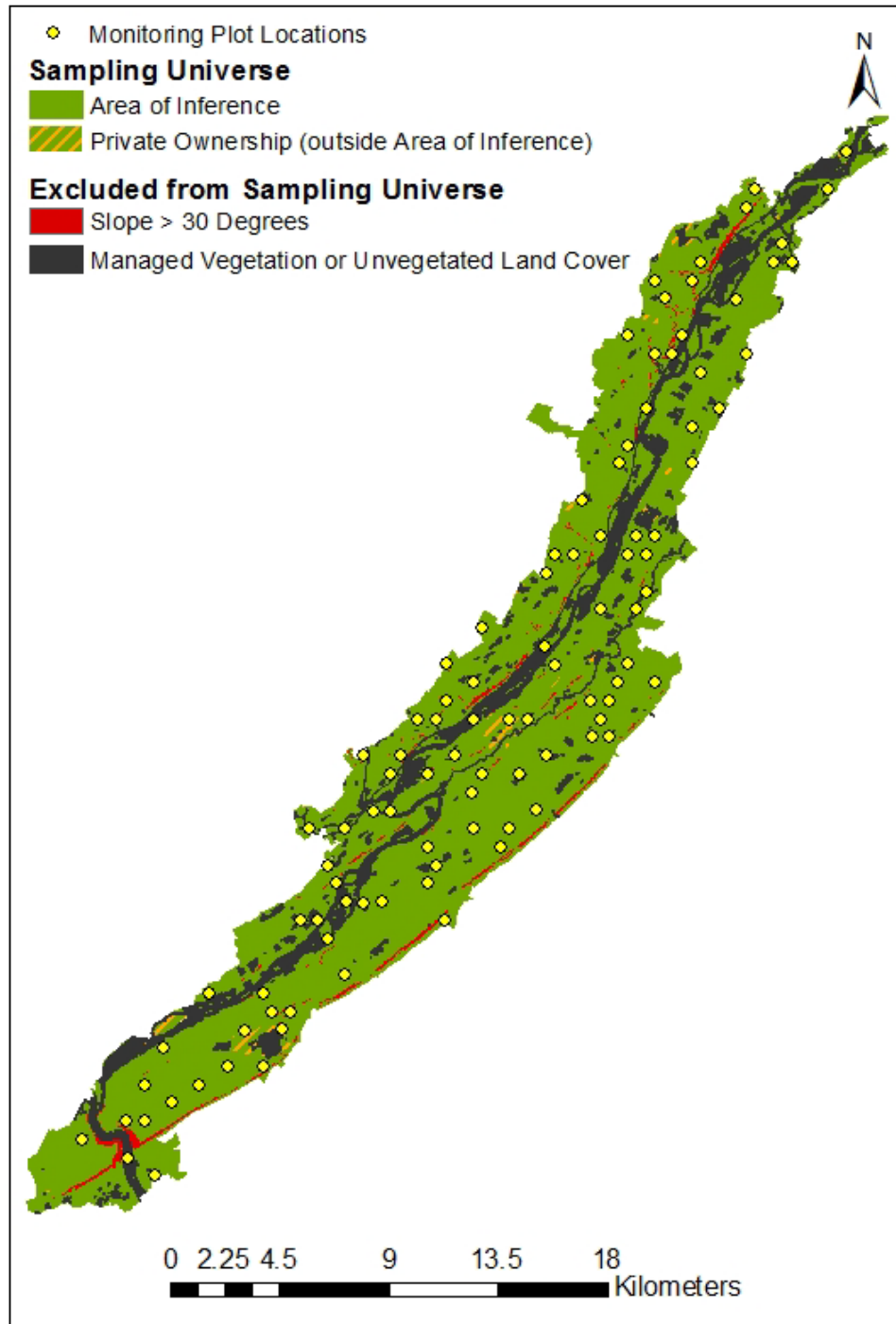


Figure A3. Sampling universe (86% of park area), area of inference (84% of park area) and plot locations for Delaware Water Gap National Recreation Area. Sampling universe includes the area within the parks' authorized boundary excluding steep slopes greater than 30° and intensively-managed or unvegetated land. Area of inference includes the publically-owned lands within the sampling universe. Inferences derived from the monitoring data cannot be applied to areas of the park outside the area of inference. In DEWA, excluded areas are primarily agriculture, developed land, privately-owned land, open water, transportation corridors, and steep slopes.



Figure A4. Sampling universe (86% of park area), area of inference (86% of park area) and plot locations for Fort Necessity National Battlefield. Sampling universe includes the area within the parks' authorized boundary excluding steep slopes greater than 30° and intensively-managed or unvegetated land. Area of inference includes the publically-owned lands within the sampling universe. Inferences derived from the monitoring data cannot be applied to areas of the park outside the area of inference. In FONE, potential plots were excluded from the Great Meadow since that area will be maintained as open to retain its historical character and viewsheds. In addition, potential plots located in the hayfields on the Rush property were also excluded since these fields are regularly mowed.



Figure A5. Sampling universe (83% of park area), area of inference (83% of park area) and plot locations for Friendship Hill National Historic Site. Sampling universe includes the area within the parks' authorized boundary excluding steep slopes greater than 30° and intensively-managed or unvegetated land. Area of inference includes the publically-owned lands within the sampling universe. Inferences derived from the monitoring data cannot be applied to areas of the park outside the area of inference. In FRHI, excluded areas are primarily managed fields, developed land, and rights-of-way.

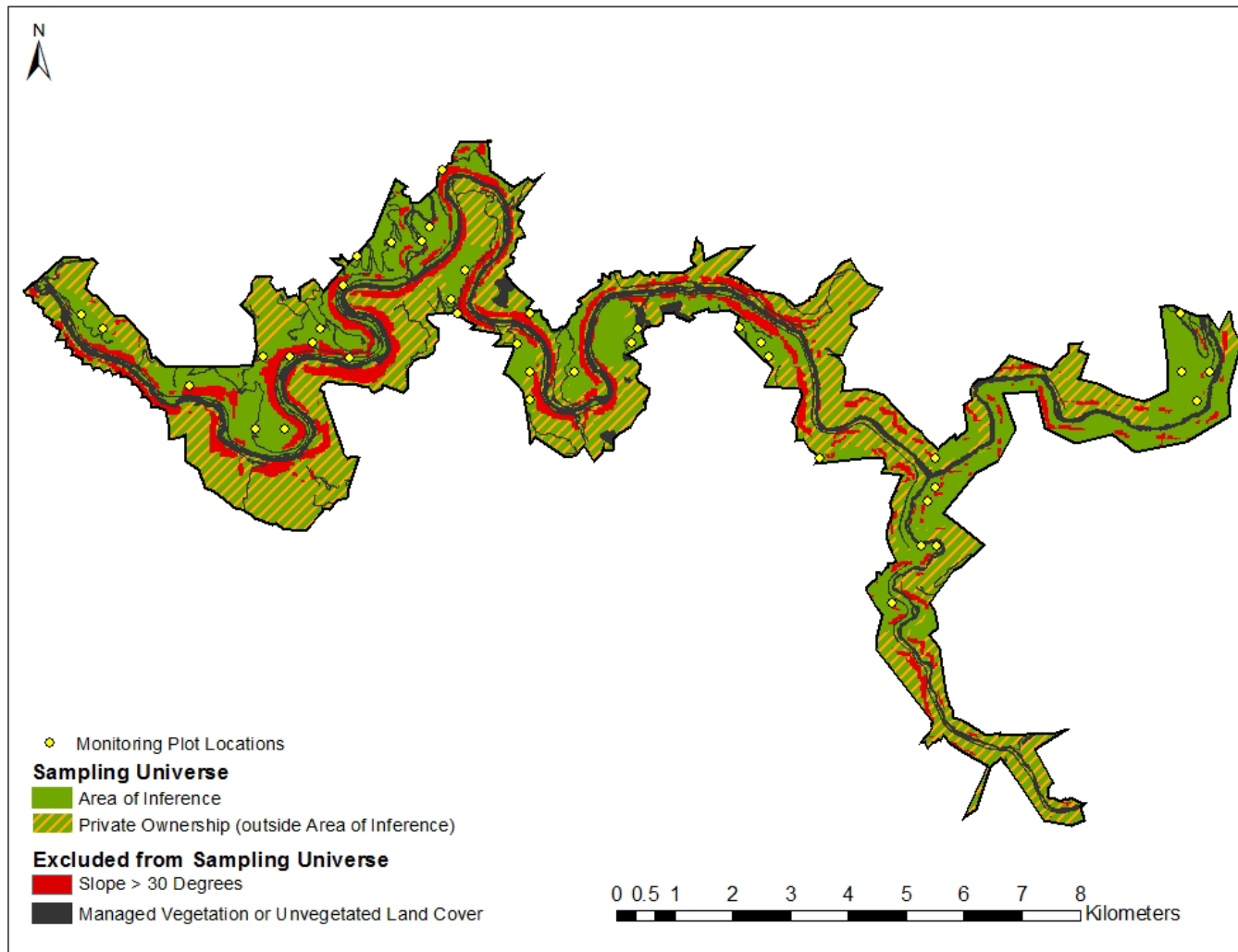


Figure A6. Sampling universe (77% of park area), area of inference (31% of park area) and plot locations for Gauley River National Recreation Area. Sampling universe includes the area within the parks' authorized boundary excluding steep slopes greater than 30° and intensively-managed or unvegetated land. Area of inference includes the publically-owned lands within the sampling universe. Inferences derived from the monitoring data cannot be applied to areas of the park outside the area of inference. In GARI, excluded areas are primarily privately-owned land, along with some steep slopes.

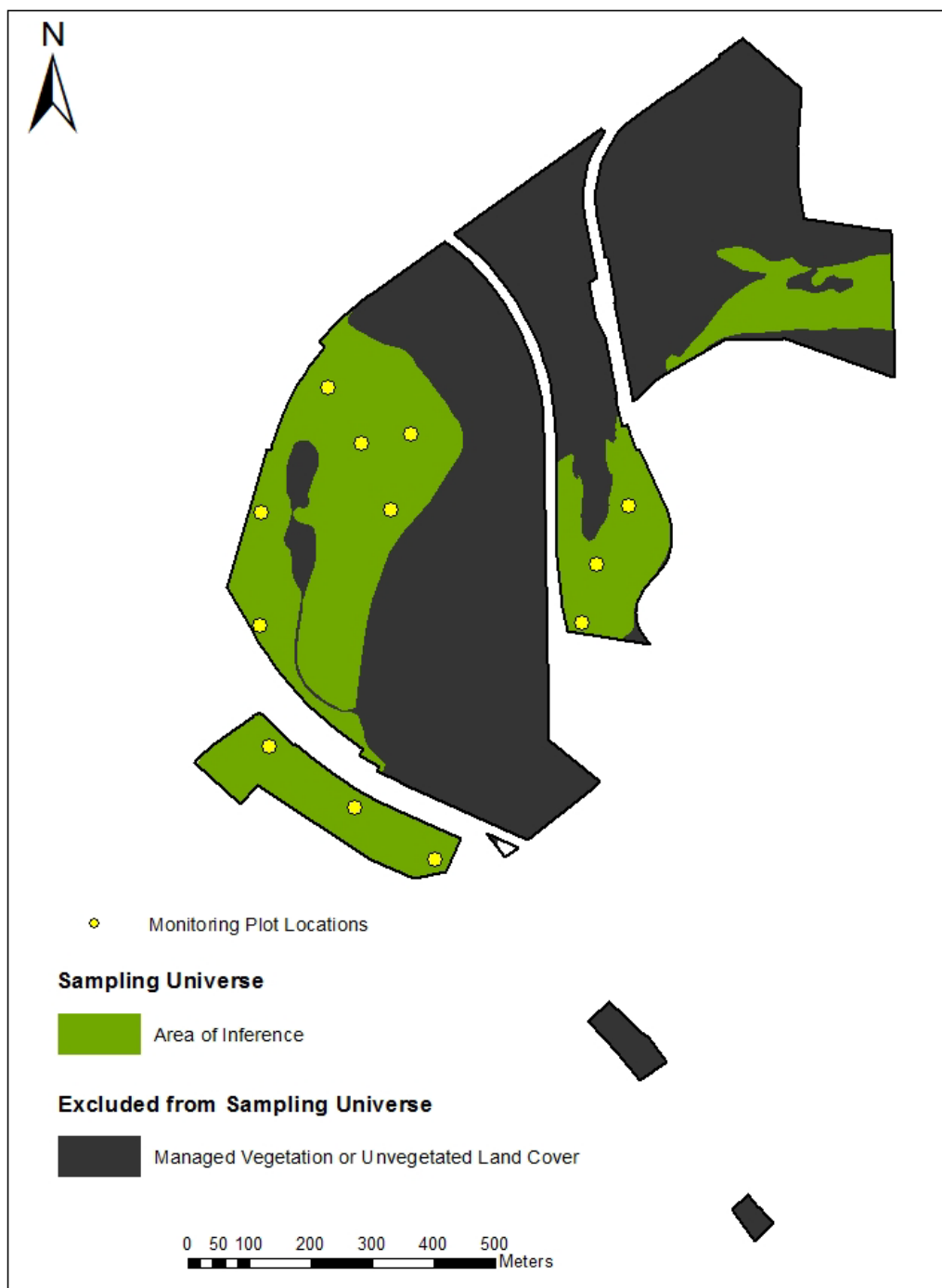


Figure A7. Sampling universe (33% of park area), area of inference (33% of park area) and plot locations for Gauley River National Recreation Area. Sampling universe includes the area within the parks' authorized boundary excluding steep slopes greater than 30° and intensively-managed or unvegetated land. Area of inference includes the publically-owned lands within the sampling universe. Potential plots located on the historic lakebed, the dam, and the mowed area around the visitor center were excluded because these areas will be maintained as open to preserve the viewshed and facilitate historical interpretation. Through consultation with the park's natural resource manager (Kathy Penrod, personal communication, April 2007), the sampling universe shown above was identified. Inferences derived from the monitoring data cannot be applied to areas of the park outside the area of inference.

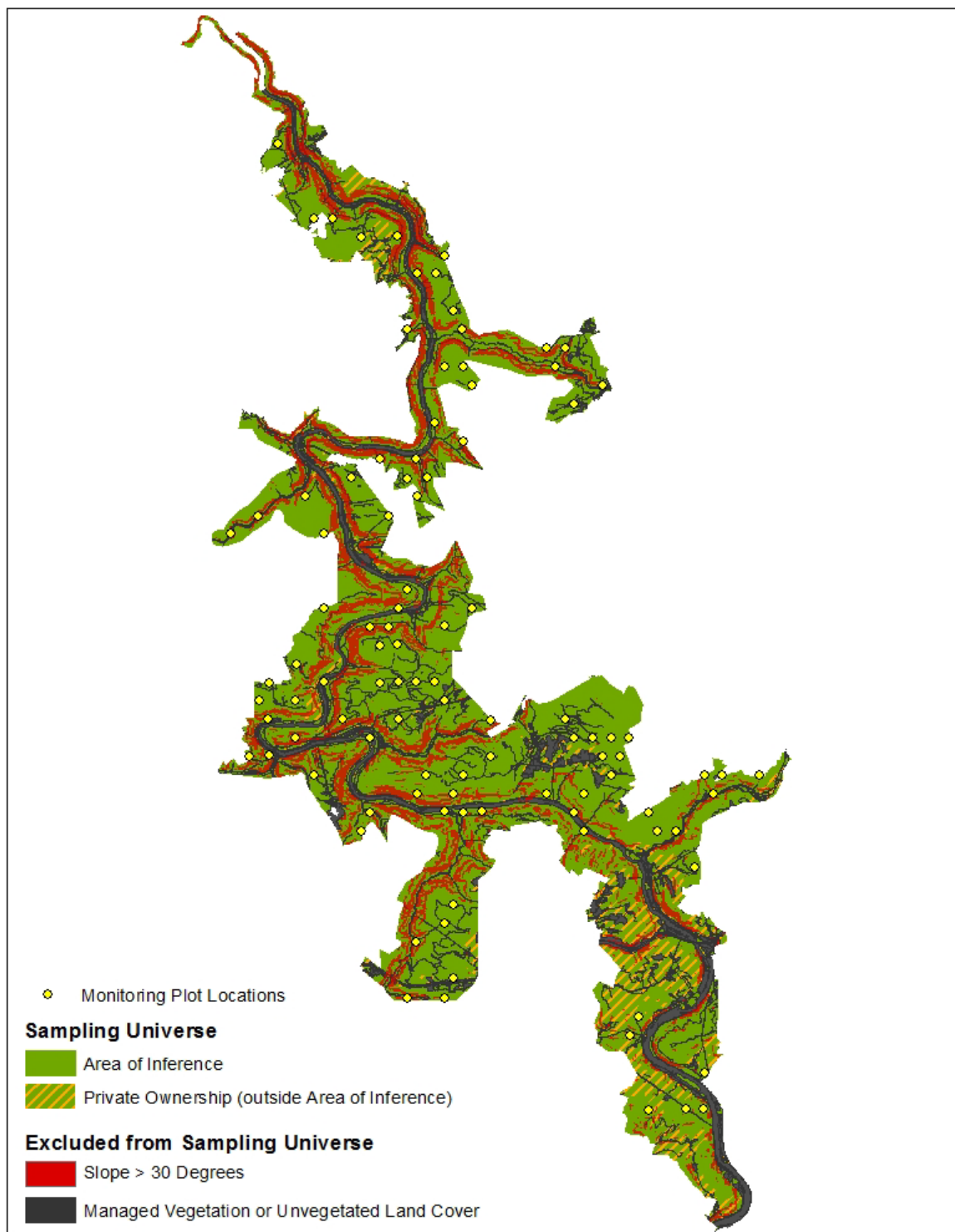


Figure A8. Sampling universe (73% of park area), area of inference (59% of park area) and plot locations for New River Gorge National River. Sampling universe includes the area within the parks' authorized boundary excluding steep slopes greater than 30° and intensively-managed or unvegetated land. Area of inference includes the publically-owned lands within the sampling universe. Inferences derived from the monitoring data cannot be applied to areas of the park outside the area of inference. In NERI, excluded areas are primarily privately-owned land and steep slopes.

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Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

<http://www.nature.nps.gov/>

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